‘When The Well’s Dry’: Water and the Promise of Sustainability in the American Southwest

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ABSTRACT

The Colorado River has become part of a vast plumbing system. It is still a natural system, dependent upon weather patterns, geological processes and laws of physics. But it is also a cultural system, governed by dams, laws and political relationships. The river is neither natural nor unnatural, but both – separating the categories makes little sense. This article argues that it is more accurate to combine the categories of nature and culture, to see humans as inextricably and deeply entwined with the natural world, and to recognise all environmental issues as characterised by the contradictory relationships humans have developed with the world they inhabit.

KEYWORDS

American Southwest, Colorado River, water use, sustainability, environmental values

As with all cities, the history of Tucson in southern Arizona is one of increasing environmental domination. Water is the key factor: finding it, building reservoirs, canals and pipelines for it, pumping it from deep underground and, when all else fails, filing lawsuits over it. Without water, Tucson would be a mere cluster of houses secreted in the desert with no commercial agriculture to speak of and little if any mining. Without a source of water, Tucson’s golf courses, symbols of desert hubris, would shrivel up beneath the hot summer sun and blow away. Swimming pools would be useful only for skateboards and inline skates. Retired snowbirds who travel from northern climes to overwinter in the warmth of the Sonoran Desert would find more favourable places to alight. The US Air Force would certainly not have a base nearby.

Environment and History **15** (2009): 441–462.
doi: 10.3197/096734009X12532652871992

The Santa Cruz River used to flow year-round in the area, with periodic drought-induced interruptions. A small river, its flow was sufficient for the needs of a few thousand people, when combined with water from a handful of local springs. At one time the Santa Cruz and other smaller rivers supported riparian zones thick with cottonwood trees and willows. Water tables were high enough to sustain large mesquite forests, called *bosques* in Spanish. Beaver, muskrat, fish and turkey were well adapted for life in and along the desert's rivers. [1]

In the late-seventeenth century, Father Eusebio Francisco Kino, a Jesuit priest who established missions in northern Mexico, thought that upwards of 5,000 people could live in the Tucson area. Long before the Spanish arrived, the Hohokam practised irrigation and floodwater agriculture – for some 2,000 years – then abandoned the region for reasons that are still murky but probably had to do with increasing temperature and aridity or, more likely, devastating floods coupled with the increased salt content of their soils resulting from millennia of irrigation. Today in the Tucson area there are more than 830,000 people. The cottonwood forests and mesquite bosques are gone, victims of the demise of the basin's rivers. Overall biodiversity is in decline, while the replacement of native species with non-native species – some 380 alien species are well established in the Sonoran Desert – continues apace. [2]

In 2000 I moved from my home in Maine to Tucson to participate in an international research project studying the relationships between cultural values and environmental policies. Part of my research interest, part of what drew me away from Maine, was a desire to understand the problems of sustainable development in the southwest. How can a rapidly growing city such as Tucson survive in a desert environment? What factors will ultimately limit growth? Water, as many researchers have pointed out, is the essential resource. As I began my own research I was not surprised to learn that water consumption and use in the southwest is considerably higher than other areas. The national average in the United States is 40 gallons per person per day (1 US gallon equals 3.79 litres). This includes water for bathing, flushing toilets, running dishwashers, watering plants, drinking and so on. Desert life requires much more. People in Phoenix and Las Vegas use on average more than 300 gallons per person per day, with swimming pools, evaporative coolers, misters and flood-water irrigation of lawns accounting for part of the higher use. Tucson's averages are a little better, standing between 106 and 148 gallons per person per day, down from a high of about 205 gallons per person per day in the early 1970s. These figures demonstrate a commitment to water conservation, but they also indicate a problem looming in Tucson's future. If the city doubles in population over the next twenty-five years or so, as some projections have it, how can it continue to function with high rates of water consumption? Where will the water come from?[3]

GROUNDWATER

In southern Arizona the Santa Cruz River disappeared into the sand because of an increasing, and increasingly thirsty, human population. As luck may have it, beneath the Sonoran Desert lie huge aquifers, estimated to contain about 63 million acre-feet of water in the Tucson Basin and the nearby Avra Valley Basin (one acre-foot equals 325,851 gallons or 1,233 cubic metres). Extracting water from these aquifers began in the 1870s. Windmills provided the best pumping technology but could only raise water twenty-five feet or so and were often idled by lack of wind. In 1889, wood-burning steam engines provided the next technological improvement, capable of drawing 1,250 gallons a minute from forty feet below the surface. In 1914, gas and electric pumps were introduced, at a time when rivers in Tucson still had regular flows. By the 1940s, enough water had been pumped out of the aquifers – most of it for agriculture – to significantly lower the water table, in some places by as much as two hundred feet, which had the effect of removing what little surface flow remained in local rivers. Riparian zones that depended upon year-round water sources died. Dry washes remained behind, on the banks of which the City of Tucson eventually built wonderful narrow parks for runners, bicyclists and lovers of dry washes. Barring some radical change in climate, all future river flows will be sporadic flood events, dramatic, spectacular, short-lived, with the occasional kayaker playing (illegally) on the waves. There is one exception: a nine-mile stretch of the Santa Cruz has become perennial once again, flowing with effluent water discharged from a wastewater treatment plant at a level no kayaker would deign to boat. [4]

Water pumped out of the ground is insufficient to meet the projected needs of this rapidly growing desert city. Geological and hydrological reports indicate that much more water is being removed than is being naturally replenished, by a factor of two. Eventually, the aquifers will be pumped effectively dry, as is happening in the much larger Ogallala aquifer beneath Colorado, Kansas, Oklahoma, New Mexico and Texas. Since 1940, when pumping began in earnest, between 6 and 8 million acre-feet of the most easily accessible water in the aquifers has been removed. As the water table drops, it takes more energy to lift water from the depths. Pumping costs will in time escalate. In 1983, it cost approximately US$138.10 to pump a million gallons of water (about 3.068 acre-feet); in 2000, the average cost to pump a million gallons of water for both gas and electric wells was still fairly modest, US$162.05. (These figures are only a small portion of the overall costs needed to deliver water to consumers, which also include administrative, distribution and capital repayment costs.) In the early 1980s, several scholars argued that such energy costs, no matter how high, would not matter at all in two or three generations, when the groundwater may be gone, given the projected rates of consumption. By 2000, however, the City of Tucson, mostly through education and conservation programs, had slowed groundwater removal, but not enough to be sustainable.[5]

One effect of removing groundwater is subsidence: the earth above the aquifer compacts, sometimes a few inches, sometimes several feet. The ground no longer absorbs water easily. Cracks and fissures appear on the surface. So far more than 3,000 square miles of Arizona have subsided. As water is mined the overall elevation of Arizona is thus lowered. Projections of as much as twelve feet of subsidence have been made for areas around downtown Tucson. At the present rate at which water is sucked from the ground it may take fewer than twenty-five years for such remarkable drops of elevation to occur.[6]

The US Federal Government, the State of Arizona, Pima County and the City of Tucson are of course aware of the various problems, and have taken some steps to remedy them. In 1980 for example, under pressure from Interior Secretary Cecil Andrus, a comprehensive Arizona Groundwater Management Act was passed, which created the Arizona Department of Water Resources. The basic goal of the Department is to ensure that water for the State does not run out, which means that groundwater removal must at some point equal groundwater renewal. The critical areas are the population centres of Prescott, Phoenix and Tucson, the agricultural area of the Pinal water management district, which lies between Phoenix and Tucson, and a district called Santa Cruz, which encompasses the city of Nogales on the Mexican border. For Prescott, Phoenix and Tucson, the safe-yield goal is set for the year 2025, when supply should equal demand.[7]

But as the Department's reports make clear, increasing population and new industry may render this goal impossible to meet. After 2025, if the projected Tucson population of 1.25 million to 1.6 million continues to grow, all bets are off. Even if a balanced water budget is met by 2025, the results may be extreme, with trade-offs between human consumption and landscape. As one research report noted in 1988: 'the effects on individuals' lifestyles and on the total environment would be severe. Essentially, all greenery within the metropolitan area would disappear.'[8] The loss of greenery may be a dire prediction, offset by recent practices and ordinances requiring use of indigenous drought tolerant plants. Still, if greenery decreases because of water conservation measures, then the buildings and streets of Tucson would absorb even more energy from the sun, further raising the temperature of the city, which in many places is already two degrees Celsius higher than surrounding rural areas, as Andrew C. Comrie demonstrated in a recent article in the *Bulletin of the American Meteorological Society*. Coupled with global warming, Tucson could become hot indeed.[9]

For the Santa Cruz district to the south of Tucson, the goal is simply to keep water tables from dropping at all and to maintain the present safe-yield level. The Pinal water goals to the north are much more ambiguous, and resemble the disastrous use of the Ogallala aquifer. These goals are, as the management plan has it, 'to protect the agricultural economy as long as feasible, and preserve water supplies for future non-agricultural purposes'. To protect the agricultural economy means a planned depletion of Pinal groundwater, which since 1948 has meant pumping more than 43 million acre-feet from the underlying aquifer. The ultimate equation is quite simple: when the water is gone, commercial agriculture stops. In other words, grow crops until the aquifer runs dry. The little remaining protected water, for future, unspecified non-agricultural uses, lies between 1,000 and 1,200 feet below the surface.[10]

COLORADO RIVER WATER

Local residents refrain from addressing the threat to continued human habitation in the area because of the promise of renewable water brought in from the Colorado River. Farmers, politicians and Tucson's residents apparently believe that Colorado River water will keep underground sources from being depleted. Water from this distant source would allow Tucson to prosper, in part by stemming the flow of precious groundwater into Tucson's faucets, toilets and swimming pools. Tucson's alternative newspaper, *The Tucson Weekly*, is the single dissenting public voice, and frequently publishes informed diatribes against the use of Colorado River water and its presumed potential to alleviate local water problems.[11]

Transporting Colorado water to central and southern Arizona has not been easy. As a political problem, developing Colorado River water for use elsewhere had its origins in the early twentieth century. The first solution was to create the 1922 Colorado River Compact, which arbitrarily divided the Colorado River watershed into upper and lower basins. Arizona, California and Nevada make up the lower basin; Colorado, New Mexico, Utah and Wyoming make up the upper basin. Small portions of Arizona and New Mexico were placed in both basins (Figure 1).[12]

Geographically, the dividing line between the two basins is at Lee's Ferry, a wide shallow spot on the Colorado River where it is joined by the Paria River in northern Arizona before it enters the Grand Canyon. Named after John Doyle Lee, a Mormon who homesteaded the area at Brigham Young's suggestion, Lee's Ferry seems an appropriate historical site to divide western water, even if the geographical division is questionable.

John Lee, along with other Mormons and a group of Paiute Indians, had participated in the infamous 1857 Mountain Meadow massacre of 120 men, women and adolescent immigrants headed to California from Missouri and Arkansas. At the time, the US government had sent troops to Utah and Mormons were edgy about federal incursion into their lands. What triggered the killing, however, was trivial: a few taunts and slurs about Mormons, perhaps about their marriage practices (Lee had eighteen wives), tossed off by members of the immigrant wagon train passing through The State of Deseret, as the Mormons

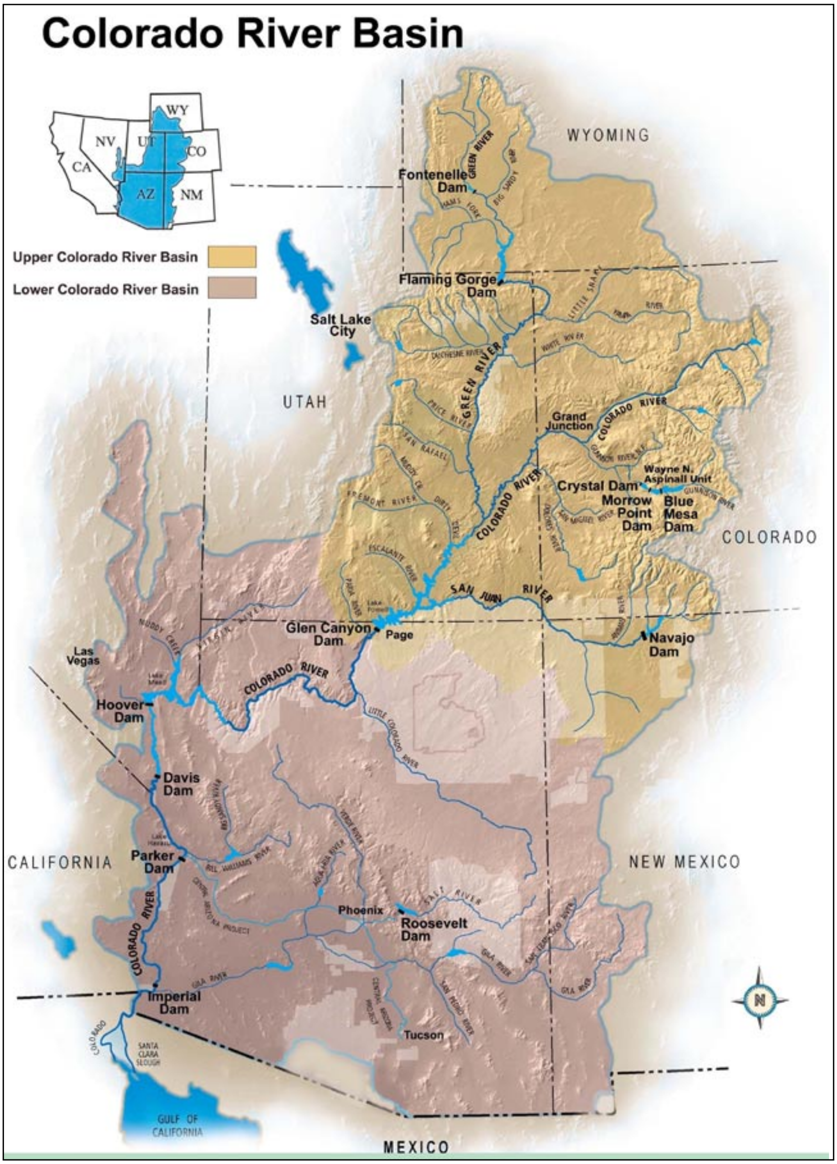

FIGURE 1. Map of the Upper and Lower Colorado River Basins.
Source: Glen Canyon Dam Adaptive Management Program, US Department of Interior www.gcdamp.gov

called their territory. Horrified by the killing, the Mormon leadership tried to hide the massacre, excommunicated Lee and others from the church, and suggested Lee move deep into the desert where he could nonetheless continue to serve the church from afar. Twenty years later, in 1877, Lee was captured and executed for his crime, the only one of his party to meet this fate, 'clearly a scapegoat for a wider guilt', as historian Donald Worster has noted.[13]

To divvy up western water at Lee's Ferry, where many of the contradictions of western life are so starkly apparent, is historically fitting. Increasing federal power in a region marked by a strong sense of individualism, religious nation-building in a country that insists on the separation of church and state, Indian-white conflict and cooperation, polygamous murderers hiding out in the desert – the stuff of western history and myth, played out within the vastness of the Colorado River drainage. Here, after the turn of the century, the wider guilt Worster speaks of took new forms, and new contradictions became apparent, with the Colorado River and Lee's Ferry playing increasingly central roles.

Those who controlled water in the arid West controlled the West's destiny. States, fearing for their futures, began to fight for a share of Colorado water. The architects of the Colorado River Compact were determined to devise a rational and federally mandated plan to provide water for western development, and to allocate water among squabbling states for all future uses. In 1928, after six years of stalemate and consequent Congressional intervention, six of the states signed the compact. That same year the Boulder Canyon Project Act apportioned Colorado River water to the lower basin states. Nevada was allocated 300,000 acre-feet; California 4.4 million acre-feet; and Arizona 2.8 million acre-feet. Believing its water needs were being slighted, the State of Arizona – the lone, petulant holdout – refused to sign the compact until 1944, the same year that the Mexican Water Treaty committed the United States to deliver 1.5 million acre-feet of Colorado River water to Mexico.[14]

Under the terms of the compact, each basin got 7.5 million acre-feet per year to apportion among its member states, based on vastly over-inflated flow estimates, some as high as 22 million acre-feet per year. The compact used a 16.8 million acre-feet per year figure, calculated from measurements taken at Lee's Ferry, but, as later researchers discovered, this estimate was derived from an unusually wet ten-year period between 1914 and 1923. A more accurate flow estimate, calculated from tree-ring data over a four hundred year span, puts the long-term yearly average at 13.5 million acre-feet per year. But the initial Lee's Ferry estimate would nonetheless hold, over-committing available water based on inaccurate flow estimates and defining future relationships between states. The result was a political tradition in the arid West that ignored empirical constraints.[15]

With the Colorado River Compact finally in place, the second political solution to bring Colorado River water to central and southern Arizona was the creation of the Central Arizona Project (CAP), wedded for a time to the ill-fated dams proposed for the Grand Canyon. The Grand Canyon dams were to produce hydroelectricity, the sale of which would pay for a scheme to add water to the Colorado River. This water would come from the Pacific Northwest, from the Columbia River, which carries ten times as much water as the Colorado. After over-committing the water nature provided, the solution was not to scale back growth in the arid West, nor was it to forge a human relationship to the Colorado River that was proportional to its size. The solution was to construct a system to transport Columbia River water to the Colorado River, and thereby increase the size of the Colorado to bring it in line with inaccurate flow measurements: Nature-by-design, or by government fiat.[16]

Environmental groups rallied to defeat the proposed dams in the Grand Canyon, but the Central Arizona Project continued to receive strong political support. Secretary of the Interior Steward Udall and his brother Arizona Representative Morris Udall – grandsons of John Doyle Lee – were key political figures in keeping the Central Arizona Project going, as was Arizona Senator Carl Hayden, for whom the project was a long-term goal. It was finally authorised in conjunction with many other water projects under the Colorado River Basin Project Act and signed into law by President Lyndon Johnson in 1968. After five more years of political haggling, construction began. The economic benefits of hydroelectric dams within the Grand Canyon, the environmental costs of filling the Grand Canyon, and the engineering problems with transporting Columbia River water to the Colorado were no longer under consideration. In this instance, values associated with environmental preservation seemed to trump values associated with massive public works projects.[17]

CAP water was initially intended to expand Arizona agricultural lands, in the hope that even more desert with its long growing season could be converted into farmland. But by 1968 it had become water for agricultural salvage. So much water had been pumped out of the ground in central Arizona that no new agricultural lands could be developed. CAP water was needed to sustain the lands already under cultivation. Moreover, the authorisation act required that for every acre-foot of delivered CAP water, one less acre-foot of groundwater could be mined. There was a further problem. By the late 1970s it was clear that growing populations in Phoenix and Tucson would need CAP water for residential not agricultural purposes. As these cities expanded, they encroached upon former farmlands and converted them to suburbs; CAP water would eventually be used to irrigate suburban lawns. In addition, under the 1908 Supreme Court ruling Winters v. United States, Indian tribes on reservations were entitled to a share of water at levels sufficient to support their communities – but the percentages, a century later, have yet to be determined for many of them.[18]

The political problems were nearly intractable. California's congressional delegation stalled the Central Arizona Project as long as possible because in the interim southern California could use all of the water that would otherwise go to Phoenix and Tucson. To finally win Congressional authorisation of the project required, moreover, the so-called California Guarantee. This guarantee meant that California would receive all of its allocated water before Arizona could take any. If California insists on this provision during a prolonged drought, little if any Colorado River water will be pumped to Phoenix and Tucson. Still, political compromises in place, CAP construction began in 1973 with high hopes for the future growth of metropolitan Arizona.[19]

By 1977 the Central Arizona Project was well underway, yet increasingly excessive costs did not equal potential benefits and President Jimmy Carter, in an attempt to save more than US$9 billion in federal money, announced that the project, along with nineteen other similar water reclamation efforts, would be halted. Carter eventually changed his mind under intense pressure from western politicians who, as it turns out, were less fiscally and environmentally prescient than the former President. Many of them had staked their political careers on bringing federally funded water to arid western cities, and they did not appreciate efforts to undermine their desires. Table pounding in committee meetings substituted for rational environmental discourse, as western politicians gathered support for their water works, and prevailed. The Central Arizona Project would continue.[20]

While the political problems were difficult, the engineering problems were easier; they simply needed lots of money. Transporting Colorado River water meant lifting water 2,900 feet from Lake Havasu, constructing fourteen pumping stations, and digging 336 miles of canals and tunnels to reach the south side of Tucson. Much of the power for such heavy lifting comes from the coal-burning Navajo Generating Station near the town of Page in northern Arizona. The Bureau of Reclamation, which built the Central Arizona Project, bought nearly 25 per cent of the Navajo Station in order to have sufficient power to move Colorado River water south and east. Coal for the plant is strip-mined on Black Mesa, transported seventy-five miles to the generating plant, burned to produce steam to move turbines to produce electricity, in order to move relatively recent snowmelt several hundred miles from the Colorado River Drainage System deep into the Sonoran Desert where it rarely snows, so that the Arizona metropolises of Phoenix and Tucson will stop depleting their precious groundwater.[21]

Black Mesa sits on Navajo and Hopi reservations. The Peabody Western Coal Company leased rights to the coal from the Navajos and Hopis, and also negotiated an arrangement to use Navajo water to transport the coal by slurry to another power station, the Mojave Generating Station some 270 miles distant in Nevada. Richard White, in his analysis of the modern rise of the metropolitan West, describes the results: 'The lease provided the coal at prices well under its market value, and it virtually gave away the precious water. Another Interior Department agency, the Bureau of Indian Affairs, had a trust obligation to protect Navajo and Hopi interests, but it approved the contracts. This was how growth worked. Indian energy and water subsidised Phoenix's [and Tucson's] energy and water. The Indians lost; Peabody Coal and the metropolitan West won.'[22]

By the standards of western water projects, where the North American term 'boondoggle' is too often appropriate, the Central Arizona Project is on the large side.[23] Begun in 1973 and substantially completed in 1993, it has the capacity to bring about 1.5 million acre-feet of water each year into central and southern Arizona. Construction costs were US$4.7 billion. Marc Reisner, whose book *Cadillac Desert* details the sorry history of water allocation in the West, provides an apt characterisation of the project: 'as incongruous a spectacle as any on earth: a man-made river flowing uphill in a place of almost no rain'.[24]

The desert river that flows uphill made little economic sense, as Maurice Kelso, William Martin and Lawrence Mack pointed out in 1973 in their book *Water Supplies and Economic Growth in an Arid Environment*. But by 1993 it was an accomplished fact. The result, at least for Tucson, was not what anyone expected. In 1995 CAP water was banned for residential use by voter initiative because it tasted bad, had a foul smell, and contained high mineral levels that corroded old pipes. Nobody wanted to drink it. The water damaged dishwashers, water heaters, evaporative coolers and other water-dependent appliances. Fish in aquariums died. Houseplants wilted. Pipes sprung leaks. Tucsonans were unhappy. The City of Tucson in fact paid out US$1.9 million worth of CAP related claims to some 5,300 claimants, apparently a fraction of the damage done.[25]

This was an extraordinary and unforeseen turn of events. After billions of dollars, dozens of lawsuits, several decades of persistent political manoeuvring at state and federal levels, and twenty years' anticipation as canals were dug and pumping stations built, Tucsonans refused to drink Colorado River water. The completion of the project, however, had already triggered the 1994 organisation of the Central Arizona Water Conservation District, a state entity charged with operating CAP and repaying Arizona's obligation of US$1.8-2.3 billion of the costs associated with the project. Not wanting to drink the water, Tucsonans were nevertheless obligated to pay their share of the project's costs.

Too thick to drink, too thin to plough, as the old timers used to say about the Colorado River when it still ran red and muddy. One wonders what the new saying may be. Even at its source, high in the Colorado Rockies or in Wyoming's Wind River Mountains, you cannot drink the water neat: human use of the backcountry has resulted in a dramatic increase of water-borne giardia, a one-celled organism that produces what is described as explosive diarrhoea in those who have ingested it. And along its course, new contaminants threaten to work their way into the river. Outside of Moab, Utah, 13 million tons of tailings from a uranium mill were situated near enough to the Colorado River to allow radioactive material and other hazardous wastes such as arsenic, lead and mercury to drain into the river given a large enough flood. The federal government initially wanted to leave the pile of radioactive tailings where it was. In response to various lawsuits and other forms of political pressure from those downriver, the House and Senate both approved legislation to move the tailings away from the flood plain, signed into law by President Clinton on 30 October 2000.[26]

After Tucson voters expressed their displeasure over Colorado River water in the form of a Water Consumer Protection Act, the City of Tucson was required to use CAP water, which it had already contracted to buy, in only a few ways. The City could sell or exchange it for other water; allow its use for agriculture, mining, parks, golf courses and schools; use it to prevent land from subsiding; and inject it into wells, if it was properly treated and 'free from disinfection byproducts'. There was one possible exception: CAP water could be delivered as potable water only if it matched in quality the groundwater Tucsonans had grown accustomed to. No mention is made in the Act of possible radioactive contamination.[27]

One strategy Tucson has actively pursued is to refill aquifers by dumping CAP water back into the ground, along with effluent from wastewater that has been treated in sewage treatment plants. Other proposed solutions included inflatable dams that could be blown up during rainstorms, plugging riverbeds long enough for captured water to percolate into the ground, after which the dams would deflate. But the CAP and wastewater recharge solutions are the ones that have been implemented.[28]

In the Avra Valley west of Tucson a US$73 million project included the construction of large 'spreading basins' into which CAP water is pumped. This water, spread over three 20-acre basins, sinks into the ground, ridding itself of impurities as it goes, losing about one and one half per cent to evaporation before it settles into the earth. After about six months, some portion of this water reaches the underlying aquifers, where it blends with deeper, purer Pleistocene water, to be pumped out and used for municipal purposes. Blended water began to reach households in May of 2001; by 2007, blended water accounted for about half of Tucson's water use. The City anticipates that up to 60,000 acre-feet of CAP water will be recharged into aquifers each year. Some wells can then be shut off, allowing levels of aquifers to again rise (although it is unclear whether earth that has subsided from previous water withdrawals will readily absorb the recharged water). The overall costs of the project approach US$250 million.[29]

Undrinkable Colorado River water and a diminishing supply of pure groundwater: Mix them together and the problem appears to be solved, at least in the short run. Three main historical lessons seem clear enough. First, the City of Tucson is sustainable only if water is carried by canal nearly 350 miles from the northwest and dumped into basins where it will join underground aquifers after expected losses from evaporation. A perennially flowing river, however, is not enough to ensure a sustainable future for Tucson. A continuous supply of energy to pump Colorado River water into the Sonoran Desert is also needed. Yet Black Mesa will eventually be strip-mined bare, and new sources of cheap energy will be needed to move water such great distances.

The second historical lesson: The City of Tucson is sustainable only if all taxpayers in the United States underwrite the true costs of water in the desert, as they indeed have for the CAP project. In effect, all US taxpayers have allowed Tucson to grow, partly by directly funding the CAP project and partly by allowing federal agencies such as the Bureau of Indian Affairs to agree to contracts that benefit the metropolitan West at the expense of Indian communities who have had a much longer presence in the area. Whether the result is good, environmentally sound policy is open to debate. But once such a project is in place, it has long-term environmental and economic consequences, and new generations will be forced to confront and adapt to the decisions of earlier generations.

The third lesson: Tucson is sustainable only if population growth slows dramatically. If it does not, and in truth there is no sign that it will, all the existing groundwater in the region, and all the water Arizona can squeeze out of the Colorado River, will be insufficient.

CULTURE-NATURE

It is no longer possible to think of the natural world as distinct from the human world. Environmental historians have long known that natural environments, even those that appear to be unsullied by humans, are frequently creations of past human activity, at least in part. Before Europeans arrived in the Americas, for example, humans had already substantially altered ecosystems, sometimes dramatically, through hunting and fishing practices, farming techniques, widespread use of grassland and shrub-land fires, and their own social interactions. Contemporary ecologists who thought their studies were only about the natural world are beginning to recognise that human involvement must be factored into any adequate ecosystem analysis for both past and present environments. As a 1997 article in the journal *Science* noted, 'most aspects of the structure and functioning of the earth's ecosystems cannot be understood without accounting for the strong, often dominant influence of humanity'. This is certainly true of water in the West.[30]

John Wesley Powell, who first floated the length of the Colorado River in 1869, suggested to the 45th Congress in his 1878 *Report on the Lands of the Arid Region* that irrigation districts should be the organising feature of the arid West. Such districts, made up of property owned by nine or more persons, would be confined to lands that government surveyors deemed irrigable. Water, held in common, would be guaranteed for each property, which would not exceed more than 80 acres per individual. At all costs, water should be controlled by individual local farmers organised into collective water districts, which would build and maintain ditches and canals. Private entrepreneurs who would own, develop and market water would not be allowed to operate, nor would the federal government play a major role, except as scientific advisor. Powell based his suggestion on Mormon water apportionment policies, which allocated water held in common to the benefit of all landowners. Mormons borrowed the practice of collective water control from Hispanic farmers along the Rio Grande, who in turn had incorporated Indian irrigation techniques.[31]

Had Congress adopted Powell's suggestion, one wonders what kinds of regional identities would have resulted. Defining a state as a series of water districts, rather than by the straight-line triangular logic of the surveyor, may have produced collective identities that are more ecologically sensitive than those we see today. If state boundaries coincided with natural boundaries, then efforts to alter the courses of major rivers, to move water from one basin to another, and to support the rapid growth of desert cities, would have required a keener sense of natural processes, a more subtle connection between nature and culture. As it stands, the connection between nature and culture is still there, but it is blunt, unsubtle, manifest in large construction projects that link distant ecosystems and in political machinations that fund such projects.[32]

The Colorado River has become part of a huge, complex plumbing system. It is still a natural system, dependent upon weather patterns, geological processes and laws of physics. But it is also a cultural system, governed by dams, laws and political relationships. Its water has been diverted, stored and apportioned. Natural spring floods and low winter flows have been evened out, changing riverine ecology in the process. Artificial floods, intended to restore eroding sandbars in the Grand Canyon, have been tried as a substitute for natural floods, with encouraging results. Sixty non-native species of fish, introduced by federal, state and local agencies, are well adapted to life in the dam-controlled Colorado River basin environment, and in many instances they successfully outcompete the 32 species of native fish. The river has become an 'Organic Machine', to borrow the title of Richard White's book on the Columbia River: neither natural nor unnatural, but both – separating the categories makes little sense. It is more accurate to combine the categories of nature and culture, to see humans as inextricably and deeply entwined in the natural world, and to recognise all environmental issues as characterised by the contradictory relationships humans have developed with the world they inhabit. The question then becomes how best to effect the twining of nature and culture while bringing the contradictions into full view.[33]

The City of Tucson began the process of depleting its underground water sources in the late-nineteenth century. By the 1960s it became clear that the water would eventually run out, and plans were made to capture water from afar – lower quality water, unpalatable, not the pure Pleistocene water locals had grown accustomed to. At the time no one thought to ask whether Tucson residents would drink or use Colorado River water once it arrived in their taps, splashed into their bathtubs, and trickled into their washbasins. Still, not content to make use of the water resources at hand, Tucson, the State of Arizona, and the federal government ranged farther afield, and in a display of technological sophistication – or ecological arrogance, depending upon your point of view

– pumped water deep into the desert, whereupon local people turned their noses up at the expensive, noisome gift.

City dwellers typically do not live lives in intimate contact with the natural world. Many of their relationships with nature are mediated by technology, by regulations governing their activities, and by the form of the city itself. That form is not self-contained. The Santa Cruz River used to flow from Tucson north into the Gila River, which in turn, before development, flowed into the Colorado River, contributing during wet years as much as 1 million acre-feet to that river's flow. By lowering its water table and drying up the Santa Cruz, Tucson effectively detached itself from the Colorado River drainage. With the completion of the Central Arizona Project the direction of flow has been reversed and, for good or ill, Tucson is once again within the Colorado River system, but as a recipient of, rather than a contributor to, the Colorado River. Tucson is thus connected in a new way to the river's tributaries, watersheds and mountain sources, as well as to the states, Indian tribes and other water users who claim a portion of the river as their own. Tucson's residents, refusing to drink Colorado River water unless it is blended with the sweet, ancient water beneath them, are part of the river nonetheless, at least for the foreseeable future. What began in the nineteenth century as a simple need for water, satisfied by pumping it from below ground, has in the first decade of the twenty-first century become a cluster of needs, a web of connections, and the ecology of the Colorado River has become vastly more complex as a result.

The increasing ecological complexity of the river comes from the human side of things. Laws, political relationships, international treaties, technological improvements, science, commerce – their successes and their failures – are now part of the ecology of the Colorado River system. Nature and culture together, river and plumbing system as they articulate or fail to articulate, provide the bases for environmental change or stability. This is not to say that the ecosystems associated with the Colorado River drainage are in good shape. They are not. Many environments in the drainage have been seriously degraded by human activities. Native plant and animal species have become endangered, and non-native species have proved to be hardy invaders, often supplanting native species. Sediment flows which once formed a significant part of the riverine environments on the Colorado Plateau have been curtailed. Before the Hoover Dam was completed in 1935, 180 million tons of silt were carried each year by the Colorado River, a sediment load that was reduced to 13 million tons when the plug was in place. Sediment now accumulates behind dams, the effect of which will be the eventual failure of the dams unless massive dredging projects are undertaken (Where will the sediment be put? Who will fund such projects?). Accumulating sediment also displaces water, so that the reservoirs become less efficient over time. In Lake Mead, formed by the Hoover Dam, 137,000 acre-feet of water each year are lost to silt. In Lake Powell, formed by the Glen Canyon Dam, 70,000 acre-feet of water are displaced each year by accumulating sediment.[34]

But the basic problem is not simply about providing sufficient water for Tucson, or any other western city. It is not about improving water consumption habits, developing new technologies, or finding ways to make reservoirs and water transportation systems more efficient. The basic problem is much larger and in fact involves a set of nested problems. What needs to be better addressed are the social and environmental implications of removing water for desert use on all of the environments and communities affected by that removal. By taking a share of the Colorado River's flow, Tucson contributes to any number of environmental problems in other places. The Colorado River Delta in Mexico, for example, where habitat for migratory birds has shrunk, needs to be revitalised by regular and larger flows of Colorado River water and the sediment loads it once contained. In the Sea of Cortez fish such as the totoaba and a species of porpoise are endangered, in part because of Colorado River management practices. Further north and east, Black Mesa continues to be strip-mined to provide power to pump water to Tucson. Throughout the Colorado system water diversions have lowered water quality to such an extent that in many places water is too salty to meet the requirements of the Clean Water Act. Such examples could be extended. Yet as Colorado River water entered Tucson's municipal system for the second time, there was very little local public discussion of the sources and sustainability of CAP water itself, or with the effect that Tucson has on distant environments. Instead, public discussion invoked past problems – of taste, corrosion of pipes and damage to appliances – and celebrated efforts to overcome them. With mixed feelings, but also with general support, Tucsonans anticipated the future benefits of CAP water.[35]

PUBLIC DISCOURSE AND ENVIRONMENTAL VALUES

Missing in public discourse, however, was any sustained debate about the environmental values that informed the construction of the Central Arizona Project in the first place, or about the basis for the governmental decisions that at great expense moved water to Tucson. This is unfortunate because current residents of Tucson confront those values each time they turn on a water tap, jump into a swimming pool and irrigate their gardens.

Missing too was sustained discussion of the larger environmental responsibility Tucsonans share with all residents within the Colorado River plumbing system. This is also unfortunate, since Tucsonans are now as culpable for the effects of water storage, diversions and withdrawals as those in southern California, who take more than their allotted 4.4 million acre-feet each year, or those in Denver who benefit from seventeen transmountain water diversions that transport water between different hydrological systems, or those millions of persons who each year recreate on huge bodies of Colorado River water in its placid, domesticated, water-skiing, pleasure-boating form – on Lakes Havasu, Mead and Powell. Tucsonans share a wider guilt in the environmental effects of their water use, but there is no scapegoat, no single governmental body to blame. All users are implicated in the widespread environmental and social effects of the Colorado plumbing system, yet a collective sense of shared responsibility appears to be absent.

Rivers connect diverse environments. They also connect different polities, cultures and histories. But they flow, or fail to flow, based on any number of unpredictable natural and human-induced changes to the world. Technological fixes to the unpredictable flows of rivers bring with them their own set of contingencies, as do the demands of increasing human populations. For the Colorado River the result can best be characterised as a set of competing interests, worked out through compacts, laws, treaties and in courts – the so-called Law of the River. A set of common social or environmental values, by contrast, does not characterise uses of the river. One explanation for the split between local interests and a wider set of shared values is historical: current generations take for granted the plumbing system, unless it fails, and may not clearly understand the large-scale environmental consequences of the choices of their ancestors. Such choices and their consequences do not remain at the forefront of public discussion, despite the considerable efforts of environmental groups to keep them there. A second explanation for the lack of shared social and environmental values is geographical: local people tend to stay concerned with local environments and often do not extend their concerns to distant locales unless, again, the system fails. In this, Tucson is no different from other western cities. A third explanation is ideological. By casting arguments about the Colorado River as natural system *versus* a plumbing system, the debate about the future of the river and its many uses becomes polarised and the essential connection between nature and culture is obscured. Even at its most wild, the Colorado River is now a plumbing system. Even in its most domesticated form, the Colorado River is still part of the natural world.

THE WORTH OF WATER

People in Tucson will, more likely than not, adopt water conservation practices little by little. They will improve drip irrigation for their gardens, and place rain barrels beneath their waterspouts. Water systems that bring potable water to Tucson's households will be decoupled from water systems for golf courses and parks – a decoupling Tucson has already begun. Perhaps inflatable dams will be built, in effect creating riverine rain barrels, so that rainwater flushed off of Tucson's streets will be put to some purpose. Over time, as people conserve water and the population grows, the city may turn brown and dun coloured, as water-greedy green lawns, plants and trees are replaced with drought-resistant species, some of which are local, some of which hail from other parts of the planet. Rising energy cost may become the strongest water conservation factor, forcing people to deal more effectively with the essential aridity of the southwest simply because they cannot afford to do otherwise.

Major Powell, hero of western river runners who frequently cite his account of the Green and Colorado Rivers, would not have been surprised at the fate of the Colorado River. 'All the waters of all the arid lands', he predicted in his report to Congress, 'will eventually be taken from their natural channels' and used for agricultural and other human purposes. He would have been surprised, however, at the means to that fate. He believed the future of western development should not be in the hands of the federal government, but in private hands. Under his plan large rivers such as the Colorado may have become mere rivulets, when all of their tributaries were blocked with relatively small dams for local use. The opposite of Powell's vision is the contemporary reality. The results of western water policies are massive dams such as Hoover, Glen Canyon and Flaming Gorge; massive water projects such as the Central Arizona Project, the Central Utah Project and others, coordinated by federal agencies and funded by federal dollars; and the apparently unsustainable growth of cities such as Tucson, Phoenix and Las Vegas.

Yet it is not Powell and his vision for the arid West but an earlier American, Benjamin Franklin, who may have best characterised the difficulty with sustainability in a place of little rain, and where social and political trajectories appear to ignore that central fact: 'When the well's dry', he said in one of his famous aphorisms, 'we know the worth of water.'

NOTES

Acknowledgements: Research for this article was part of a larger effort to understand the relationships between values and environmental policies in India, China, Japan and the US, directed by the Carnegie Council on Ethics and International Affairs, with funding from the National Science Foundation (Grant No. NSF SES-0080846), the United States-Japan Foundation, and the Henry Luce Foundation, Inc. I would like to dedicate this article to Bill Cote, Mona Letourneau, Dan McCool, Fiona Smith, Greg Smoak and Richard White – scholars, companions and friends, with whom I have spent many pleasurable days boating on Western rivers.

[1] Despite human encroachment, the Sonoran Desert is still extraordinarily diverse, with a large variety of flowering trees and plants, hundreds of species of bees, butterflies, and moths, dozens of reptile species, some 86 species of mammals, and approximately 450 nesting and migrating bird species. See Steven J. Phillips and Patricia Wentworth Comus, eds., *A Natural History of the Sonora Desert* (Tucson: Arizona-Sonora Desert Museum Press, 2000). See also Gary Paul Nabhan's engaging book *The Desert Smells like Rain: A Naturalist in O'Odham Country* (San Francisco: North Point Press, 1982).

[2] On Father Kino, see Herbert E. Bolton, *Rim of Christendom: A biography of Eusebio Francisco Kino, Pacific coast pioneer* (New York: Macmillan, 1936; reprint, Tucson: University of Arizona Press, 1984). On the Hohokam, see Jefferson Reid and Stephanie Whittlesey, *The Archaeology of Ancient Arizona* (Tucson: University of Arizona Press, 1997). On the establishment of non-native species, see Phillips and Comus, eds., *A Natural History of the Sonoran Desert*.

[3] Participating groups in the international project included the Center for the Study of Developing Societies in India, the Lake Biwa Museum in Japan, the Research Center for Contemporary China, at Peking University, and the Bureau of Applied Research in Anthropology, at The University of Arizona. We wanted to know how local values entered the policymaking process, whether environmental concerns of local people were being adequately addressed by policymakers, and whether there were any commonalities across ten markedly different study sites in these four countries. See the project description at the website for the Carnegie Council on Ethics and International Affairs, *www.cceia.org*, and the volume that resulted, Joanne Bauer, ed., *Forging Environmentalism: Justice, Livelihood, and Contested Environments* (New York: M.E. Sharp, 2006). For an extended analysis of sustainability in Tucson, see in the same volume, David Jenkins, Joanne Bauer, Scott Brunton, Diane Austin and Thomas McGuire, 'Two Faces of American Environmentalism: The Quest for Justice in Southern Louisiana and Sustainability in the Sonoran Desert'. See also David Jenkins, 'Atlantic Salmon, Endangered Species, and the Failure of Environmental Policies', *Comparative Studies in Society and History* 45 (October 2003): 843–872, a study which originated in the larger project. For water use figures, see *Water in the West: Challenge for the Next Century,* Report of the Western Policy Review Advisory Commission (June 1998). On Tucson water consumption, see William E. Martin, Helen M. Ingram, Nancy K. Laney and Adrian H. Griffin, *Saving Water in a Desert City* (Washington, D.C.: Resources for the Future, 1984).

[4] An acre-foot is a measure invented by the US Geological Survey in the late-nineteenth century to describe the amount of water needed to irrigate an acre of land. If all of the water in the Tucson and Avra Basins was recoverable, it could, under the Geological Survey's definition, irrigate 63 million acres of farmland. On the history of water use in the area, see Joe Gelt, Jim Henderson, Kenneth Seasholes, Barbara Tellman and Gary Woodard, with Kyle Carpenter, Chris Hudson and Souad Sherif, 'Water in the Tucson Area: Seeking Sustainability', Water Resources Research Center Issue Paper No. 20, 1999; Joe Gelt, 'Water Conservation, Yesterday and Today: A Story of History, Culture and Politics', *Arroyo* 10 (December 1999); T. Lindsay Baker, Steven R. Rae, Joseph E. Minor and Seymour V. Connor, *Water for the Southwest: Historical Survey and Guide to Historic Sites* (New York: American Society of Civil Engineers, 1973).

[5] On the Ogallalla aquifer, see John Opie, *Ogallalla: Water for a Dry Land* (Lincoln: University of Nebraska Press, 1993). The 1983 data for the Tucson area are from William E. Martin, Helen M. Ingram, Dennis, C. Cory, and Mary G. Wallace, 'Toward sustaining a desert metropolis: water and land use in Tucson, Arizona', in Mohamed T. El-Ashry and Diana C. Gibbons, eds., *Water and Arid Lands of the Western United States*, (Cambridge: Cambridge University Press, 1988), 281–327. In 1983, the total cost (pumpage, administrative, distribution, capital repayment) to deliver water was approximately US$1,334.93 for a million gallons. Liz Greene, of Tucson Water, provided the 2000 pumpage data. On the projected electrical costs for Tucson Water, see David Modeer, 'Power, new sources boost water costs', *Arizona Daily Star* page B7, 23 February 2001. See also Martin, Ingram, Laney, and Griffin, *Saving Water in a Desert City.*

[6] R.T. Hanson and J.F. Benedict, *Simulation of Ground Water Flow and Potential Land Subsidence, Upper Santa Cruz Basin, Arizona* (Tucson: US Department of Interior, US Geological Survey, 1994). A basketball rim stands at ten feet. Perhaps, I thought when I read the geological reports, the City of Tucson could take advantage of the situation and build sunken basketball courts, a cooler place for kids to play hoops. Subsidence of course is not unique to Arizona. It has occurred in Mexico City, Beijing and Tokyo, among other places.

[7] See *Water Transfers in the West: Efficiency, Equity, and the Environment*, (Washington, D.C.: National Academy Press, 1992), especially chapter 9, 'Central Arizona: The Endless Search for New Supplies to Water the Desert'. See also *Third Management Plan for Tucson Active Management Area, 2000–2010* (Arizona Department of Water Resources, December 1999); *Third Management Plan for Pinal Active Management Area, 2000–2010* (Arizona Department of Water Resources, December 1999); *Third Management Plan for Phoenix Active Management Area, 2000–2010* (Arizona Department of Water Resources, December 1999); *Third Management Plan for Santa Cruz Active Management Area, 2000–2010* (Arizona Department of Water Resources, December 1999); *Third Management Plan for Prescott Active Management Area, 2000–2010* (Arizona Department of Water Resources, December 1999).

[8] Martin, Ingram, Cory and Wallace, 'Toward sustaining a desert metropolis', 311–12.

[9] Andrew C. Comrie, 'Mapping a Wind-Modified Urban Heat Island in Tucson, Arizona (with Comments on Integrating Research and Undergraduate Learning)', *Bulletin of the American Meteorological Society* 81 (October 2000): 1–15.

[10] *Third Management Plan for Pinal Active Management Area, 2000–2010*, 1-1, 1-2.

[11] On the history of Colorado River water, see Philip Fradkin, *A River No More: the Colorado River and the West* (New York: Knopf, 1981). On the current state of the river see Dale Pontius, with SWCA, Inc, Colorado River Basin Study, Report to the Western Water Policy Review', Advisory Committee, (August 1997). Joe Gelt provides an accessible summary, 'Sharing Colorado River Water: History, Pubic Policy and the Colorado River Compact', *Arroyo* 10 (August, 1997). On restoration, see Robert W. Adler, *Restoring Colorado River Ecosystems: A Troubled Sense of Immensity* (Washington: Island Press, 2007). See also David H. Getches and Charles J. Meyers, 'The River of Controversy: Persistent Issues', and Norris Hundley, Jr., 'The West Against Itself: The Colorado River – An Institutional History', both in *New Courses for the Colorado River: Major Issues for the Next Century*, Gary D. Weatherford and F. Lee Brown, eds. (Albuquerque: University of New Mexico Press, 1986). The *Tucson Weekly* consistently ridicules CAP water and its potential to alleviate local water problems. See 'Vote Yes on Prop 200', (November 2-8, 1995), Jim Wright, 'Pumping Money' (May 2-8, 1996), Vicki Hart, 'CAP is Still Crap', (October 23-29, 1997), Vicki Hart, 'Pumping Bile', and Jim Nintzel, 'Flow Chart', (August 19-25, 1999).

[12] *Colorado River Compact*, 1922, 45 Stat. 571. The text of the compact is available at http://www.lc.usbr.gov. See Norris Hundley, Jr., *Water and the West: the Colorado River Compact and the Politics of Water in the American West* (Berkeley: University of California Press, 1975).

[13] Donald Worster, *A River Running West: The Life of John Wesley Powell* (New York: Oxford University Press, 2001), 249. See also Juanita Brooks, *The Mountain Meadow Massacre* (Palo Alto: University of California Press, 1950), and *John Doyle Lee: Zealot, Pioneer, Builder, Scapegoat* (Glendale, California: A.H. Clark, 1962).

[14]*Boulder Canyon Project Act*, 45 Stat. 1057, 43 USC 617. California and Arizona had a long-running dispute over appropriate percentages of water, which was finally resolved in 1963 by the Supreme Court in *Arizona v. California*, 373 US 546 (March 9, 1964). Both the act and the judicial decision can be found at http://www.lc.usbr.gov. On the history of the Mexican treaty, see Norris Hundley, Jr., *Dividing the Waters: A Century of Controversy Between the United States and Mexico* (Berkeley: University of California Press, 1966).

[15] For a study of long-term flow measurements, see David Meko, Charles W. Stockton, and William R. Burgess, 'The Tree-Ring Record of Severe Sustained Drought', *Water Resources Bulletin* 31(1995): 789–801. See generally *Water in the West: Challenge for the Next Century*. See also Donald Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West* (New York City: Oxford University Press, 1985).

[16] For histories of CAP water see Ernest A. Engelbert, *The Origins and Policy Issues of the Pacific Southwest Water Plan* (Boulder: University of Colorado Press, 1965); Rich Johnson, *The Central Arizona Project, 1918–1968* (Tucson: University of Arizona Press, 1977); Robert Dean, '"Dam Building Still Had Some Magic Then": Stewart Udall, the Central Arizona Project, and the Evolution of the Pacific Southwest Water Plan, 1963–1968', *Pacific Historical Review* 66 (February 1997): 81–98.

[17] *Colorado River Basin Project Act*, Public Law 90-537, 82 Stat. 885. As Byron E. Pearson points out, the political circumstances were more complex than a simple story of triumphant environmental groups rallying public support to stop the proposed dams; see *Still the Wild River Runs: Congress, the Sierra Club, and the Fight to Save Grand Canyon* (Tucson: University of Arizona Press, 2002). See also Wendy Nelson Espeland, *The Struggle For Water: Politics, Rationality, and Identity in the American Southwest*, (Chicago: University of Chicago Press, 1998).

[18] On Indian water rights, see Daniel McCool, *Command of the Waters: Iron Triangles, the Federal Water Development Program, and Indian Water* (Berkeley: University of California Press, 1987), Thomas R. McGuire, William B. Lord and Mary G. Wallace, eds., *Indian Water in the New West* (Tucson: University of Arizona Press, 1993), Monroe B. Price and Gary D. Weatherford, 'Indian Water Rights in Theory and Practice: Navajo Experience in the Colorado River Basin', *Law and Contemporary Problems* 40 (1976): 108–131. On the Winters Doctrine see Norris Hundley, Jr., 'The "Winters" Decision and Indian Water Rights: A Mystery Reexamined', *Western Historical Quarterly* 13 (1982): 17–42, and John Shurts, *Indian Reserved Water Rights: The Winters Doctrine in Its Social and Legal Context, 1800s–1930s* (Norman: University of Oklahoma Press, 2000).

[19] Some people argue that it is highly improbable that California would insists on receiving all of its 4.4 million acre-feet at the expense of Arizona during a prolonged drought. Pat Mulroy, General Manager Southern Nevada Water Authority, noted in 1997: 'Do we really seriously believe that in a time of shortage, one city's needs will be met in its entirety while the needs of another city are completely ignored? … It is ludicrous to assume that the needs of Los Angeles and San Diego will be met while the needs of Phoenix, and Tucson, and Scottsdale are ignored. Politically, it will not happen.' 'The Colorado River Compact at 75: A Conversation About its Past and Future', 7–8. Convened by the Western Water Policy Commission of the Council of State Governments – WEST (August 22, 1997).

[20] Fradkin, *A River No More*, 3–14. Espeland, *The Struggle For Water*, 4–14.

[21] The Bureau of Reclamation owns 24.3% of the Navajo Generating Station; The Salt

River Project owns 21.7%; the Los Angeles Department of Water and Power owns 21.2%; the Arizona Public Service Company owns 14%; Nevada Power Co. owns 11.3%; and Tucson Gas and Electric owns 7.5%. For an analysis of the Ninth Circuit's decision concerning air pollution from the Navajo Generating Station, in *Central Arizona Water Conservation District v. EPA*, see R. Nicole Cordan, 'Lost in the Haze? Central Arizona Fulfills Congress's Promise to Protect Visibility in the National Parks', *Environmental Law* 24 (July 1994): 1371–1394.

[22] Richard White, *"It's Your Misfortune and None of My Own": A History of the American West* (Norman: University of Oklahoma Press, 1991), 558. See also Susanne Gordon, photographs by Alan Copeland, *Black Mesa: Angel of Death* (New York: Doubleday, 1973). Indians continue to lose. Peabody Coal pumps 4,000 acre-feet of groundwater each year to put in its pipeline. This is pristine water from the N-aquifer that locals use for drinking. See David Beckman, Michael Jasny, Lissa Wadewitz and Andrew Wetzler, 'Drawdone: Groundwater Mining on Black Mesa', (Natural Resources Defense Council, October 2000)

[23] The term 'boondoggle' refers to wasteful, government-sponsored projects of questionable value.

[24] Marc Reisner, *Cadillac Desert: the American West and its Disappearing Water* (New York: Viking, 1986), p. 304.

[25] Maurice M. Kelso, William E. Martin and Lawrence E. Mack, *Water Supplies and Economic Growth in an Arid Environment: An Arizona Case Study* (Tucson: University of Arizona Press, 1973). See the series on CAP water in the *Arizona Daily Star* (29 April–4 May, 2001).

[26] See various articles by Mary Manning, 'Suits filed against radioactive flows into Colorado River', *Las Vegas Sun* (October 23, 1998), 'Officials fear floods could cause radioactive contamination of water', *Las Vegas Sun* (July 30, 1999), 'So. California backs bill on radioactive water tailings', *Las Vegas Sun* (February 10, 1999). The law requiring the Department of Energy to clean up the tailings was part of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001, Public Law: 106-398. Energy Secretary Bill Richardson, in a Department of Energy press release, seemed to give more weight to scenic protection than to water purity: 'Radioactive waste sits at the gateway of two national parks, Arches and Canyonlands. This area is a geological wonderland, nestled in a valley with scenic red cliffs and surrounded by rugged, beautiful desert terrain. The Department of Energy has the expertise and experience to relocate the material in a secure, permanent location that is safely away from the Colorado River and the national parks.' *www.energy.gov/HQPress/releasses00/janpr/pr00009.htm* See the Department of Energy website devoted to the Moab tailings, *www.gjo.doe.gov/moab*, and The National Academy of Sciences June, 2002 report, 'Remedial Action at the Moab Site – Now and for the Long Term' (The National Academies, Committee on Long-Term Institutional Management of DOE Legacy Waste Sites: Phase 2).

[27] *Water Consumer Protection Act*, Public Initiative Petition 1994–2001.

[28] For an interesting and helpful assessment of sustainable water, see Jason I. Morrison, Sandra L. Postel and Peter H. Gleick, *The Sustainable Use of Water in the Lower Colorado River Basin*, Oakland, CA: Joint Report of the Pacific Institute for Studies in Development, Environment, and Security and the Global Water Project (November 1966). On the inflatable dam proposal, see 'Summary, Rillito Recharge Project: Artificial Groundwater Recharge Demonstration Project', and 'Final Report: Rillito Recharge

Project', US Department of the Interior, Bureau of Reclamation, in participation with the US Environmental Protection Agency, November 1996.

[29] For fairly hopeful newspaper accounts, see Maureen O'Connell, 'Blended water to flow here by spring', *Arizona Daily Star* (September 25, 2000), and Mitch Tobin, 'CAP water to be clean, leaders vow', *Arizona Daily Star* (March 2, 2001). See also the series on CAP water in the *Arizona Daily Star* (29 April – 4 May, 2001).

[30] The literature on the topic is expanding rapidly. See Daniel B. Botkin, *Discordant Harmonies: A New Ecology for the Twenty-First Century* (New York: Oxford University Press, 1990). For studies of human impacts on local ecosystems see Carole L. Crumbly, ed., *Historical Ecology: Cultural Knowledge and Changing Landscapes* (Santa Fe: School of American Research, 1994); Jeanne X. Kasperson, Roger E. Kasperson and B. L. Turner, eds., *Regions at Risk: Comparisons of Threatened Environments* (Tokyo, New York, Paris: United Nations University Press, 1995); Shepard Krech III, *The Ecological Indian: Myth and History* (New York: W.W. Norton, 1999); Mark. J. McDonnell and Steward T. A. Pickett, eds., *Humans as Components of Ecosystems: The Ecology of Subtle Human Effects and Populated Areas* (New York: Springer-Verlag, 1993); J. R. NcNeill, *Something New Under the Sun: An Environmental History of the Twentieth-Century World* (New York: W.W. Norton, 2000); Charles L. Redman, *Human Impacts on Ancient Environments* (Tucson: The University of Arizona Press, 1999); B. L. Turner II, William C. Clark, Robert W. Kates, Hohn F. Richards, Jessica T. Mathews and William B. Meyers, eds., *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years* (Cambridge: Cambridge University Press, 1990). The quote is from Peter M. Vitousek, Harold A. Mooney, Jane Lubchenco and Jerry M. Melillo, 'Human Dominations of Earth's Ecosystems', *Science* 227 (1997): 494–499.

[31] John Wesley Powell, 'Report on the Lands of the Arid Region', 45 Cong., 2d session, House Exec. Doc. 73. Worster, *A River Running West*, 354-60.

[32] For an example of a subtle and apparently sustainable system of allocating water, see J. Stephen Lansing, *Priests and Programmers: Technology of Power in the Engineered Landscape of Bali* (Princeton: Princeton University Press, 1991).

[33] On artificial floods, see W.K. Stevens, 'Grand Canyon roars again as ecologic clock is turned back', *The New York Times* (February 25, 1997); on introduced and native fish, see W. L. Minckley, 'Native fishes of the Grand Canyon: an obituary?' in *Colorado River Ecology and Dam Management* (Washington, D.C.: National Academy Press, 1977), 124–177; Richard White, *The Organic Machine: Making and Remaking the Columbia River* (Hill and Wang, 1996).

[34] On sediment flows see Fradkin, *A River No More*, 182.

[35] For a discussion of the Colorado River Delta, see Jennifer Pitt, Daniel F. Luecke, Michael J. Cohen, Edward P. Glenn and Carlos Valdés-Casillas, 'Two Nations, One River: Managing Ecosystem Conservation in the Colorado River Delta', *Natural Resources Journal* 40 (Fall 2000): 819–864; and Edward P. Glenn, Christopher Lee, Richard Felger and Scott Zengel, 'Effects of Water Management on the Wetlands of the Colorado River Delta, Mexico', *Conservation Biology* 10 (August 1996): 1175–1186. For a discussion of the disjunction between local concerns and wider environmental effects, see Evan R. Ward, 'Geo-environmental disconnection and the Colorado River Delta: Technology, culture, and the political ecology of Paradise', *Environment and History* 7 (2007): 219–246.