DE GRUYTER DOI 10.1515/cjpp-2013-0043 — Calif. J. Politics Policy 2014; aop

Andrew Fahlund, Min L. Janny Choy* and Leon Szeptycki

Water in the West

Keywords: climate change; ecosystem services; environmental flows; financing; green infrastructure; water; water-energy; water governance; water infrastructure; water management; water markets; water policy; western water; western history.

***Corresponding author: Min L. Janny Choy,** Water in the West, a joint program of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West, Stanford University, Stanford, CA, USA, e-mail: jannychoy@stanford.edu, website: www.waterinthewest.stanford.edu

Andrew Fahlund and Leon Szeptycki: Water in the West, a joint program of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West, Stanford University, Stanford, CA, USA

1 Introduction

> *"One cannot be pessimistic about the West. This is the native home of hope. When it fully learns that cooperation, not rugged individualism, is the quality that most characterizes and preserves it, then it will have achieved itself and outlived its origins. Then it has a chance to create a society to match its scenery."*
>
> — *Wallace Stegner*

The Western United States is a diverse region of the country, with little in common between places like Cody, Wyoming and Palo Alto, California. One condition common to the region – with the exception of a few coastal communities – is aridity. It seems odd to characterize an entire region by what it lacks, but water has always been the most consistent and frequently cited tie that binds the West.

Although a long history of papers, reports, and books have analyzed issues around western water,[1] the last official comprehensive examination of the subject was published 15 years ago. In 1996, Congress chartered the Western Water Policy Review Advisory Commission (Commission) to publish a report, *Water in the West:*

1 Marc Reisner, *Cadillac Desert*: The American West and Its Disappearing Water (1986); Stewart L. Udall, *Beyond the Mythic West* (1990); Wallace Stegner, *The American West as Living Space* (1987).

Challenge for the Next Century (1998 Report).[2] A central question the authors were tasked to answer was, "Are the current uses of water and water related resources sustainable and if not, what institutional changes will enhance sustainable management?" This effort was modeled after another comprehensive study of the nation's water resources from 1973. The Commission explained that they "opted to build from that study, focusing on the important, often unanticipated developments since." We have similarly elected to build from where the most recent effort left off. While not nearly as expansive or as well resourced,[3] this paper will give the reader some insights into how western water management is shaped and is shaping the region today and in the near future, with a particular focus on what has changed over the last 15 years.

1.1 The Setting

Water is scarce throughout most of the western United States. It is a vast area of mountain ranges, deserts, canyons, and grasslands with very little precipitation, except for pockets in the Pacific Northwest, Rockies, and Sierra Nevada. The West has typically been defined by the 100th Meridian. On average, the region west of this longitude – which runs down the center of the Great Plains – receives less than 20 inches of annual rainfall, whereas more than 20 inches of precipitation falls east of this line.

Another defining characteristic of the West is open space. While water is scarce, public lands are abundant.[4] Many western states have significant federal land ownership: for example, 81% of Nevada, 67% of Utah, 62% of Idaho, and 48% of California are federally owned and managed.[5] The abundance of public lands enables a wide range of activities, from energy development and agriculture

2 The mandate of the Commission was to focus principally on the role of federal government in western water management for the next 20 years. We do not limit ourselves to that narrow focus here. Western Water Policy Review Advisory Commission, *Water in the West: Challenge for the Next Century* (1998).

3 The 1973 National Water Commission Report took 5 years and cost $22M, and the 1998 Report took 2 years and cost $2.5M.

4 Ross W. Gorte, Carol Hardy Vincent, Laura A. Hanson, and Marc R. Rosenblum, "Federal Land Ownership: Overview and Data," Congressional Research Service (2012). NirajChokshi, "More Than Half of the West is Federally Owned. Now Some States Want That Land Back," Washington Post, October 15, 2013. Available at: http://www.washingtonpost.com/blogs/govbeat/wp/2013/10/15/almost-half-the-west-is-federally-owned-now-some-states-want-their-land-back/.

5 U.S. General Services Administration, Office of Governmentwide Policy, "Federal Real Property Profile, as of September 30, 2004," Table 16, pp. 18–19.

to tourism and conservation, but perhaps most significantly, it has uniquely enabled a system of large water developments throughout the West.

1.2 History of Water in the West

To understand the current trends affecting western water policy and management, it may be helpful to understand how we arrived here. Much of the current cultural and legal system of water allocation is a legacy of the 19th century while the infrastructure and institutions are products of the 20th century. A central question, of course, is how well this legal regime and infrastructure will fare in confronting the needs and issues of the 21st century.

In the East, through a common law system carried over from England and dating back to ancient Rome, property that abuts a water body carries with it a right to put that water to a reasonable use. This riparian system has worked well in areas with plentiful rainfall and a relatively consistent and abundant supply of water.[6] In the arid West, perennial streams are fewer and farther in between and their flows are variable and uncertain. The need to allocate a scarce and unpredictable resource gave rise to the prior appropriation system.

Emerging out of the western mining boom in the 1840s, this legal principle granted rights to water through a system of seniority that requires all users to put that water to beneficial use. Sometimes described as "first in time, first in right," the system allowed miners and later farmers and cities to divert water from its natural course provided they put that water to work. The initial water allocations were determined in the 19th century by who showed up first, dug irrigation ditches, and started withdrawing water. This system persists to this day, although now administrative and judicial programs in each state allocate new water rights and govern existing ones. Under this system, the rights of senior water users must be satisfied first, before junior users receive anything. Failure to put water to a beneficial use may jeopardize one's right to that water. This is sometimes described as "use it or lose it."

Most western states operate strictly under prior appropriation, although some treat groundwater separately.[7] Generally, holding a water right entitles an

6 Riparian states are not exempted from water scarcity, as shown in recent conflicts between Georgia, Florida, and Alabama. For a complete understanding of US water law, see Barton Thompson, Jr., John Leshy, and Robert Abrams, *Legal Control of Water Resources, Fifth Edition* (West Publishing, 2013).

7 Barton Thompson, Jr., John Leshy, and Robert Abrams, *Legal Control of Water Resources, Fifth Edition* (West Publishing, 2013).

individual to use water for a specified beneficial use, which historically meant irrigation, mining, domestic, or municipal use. The terms of the water rights also typically include a priority date, an allowable quantity, and a specified location for the withdrawal.

A great deal of our infrastructure was also built up during the era of western settlement, as were the laws governing use of that infrastructure. John Wesley Powell, early explorer and scholar of the West, recognized early on that continued westward expansion by American settlers would require irrigation of the land. Powell advocated for a cooperative water development approach that was basin-oriented.[8] He wrote several seminal papers that warned about the folly of westward expansion without a fundamental shift in our thinking, institutions, and investments concerning water.[9]

Powell's words were largely ignored. The linear grids of the flatter East were superimposed on the more topographically and hydrologically complex West. It became increasingly clear that Powell was right about irrigation. So called "reclamation projects" were at first privately funded enterprises that time and again failed due to a lack of money, technical expertise, and organization. Resounding and persistent calls for the federal government to intervene eventually succeeded with passage of the Reclamation Act in 1902. The U.S. Bureau of Reclamation (BOR) under the Department of the Interior quickly studied potential water development projects in each western state, with the first projects funded by the sale of federal lands. This launched the federal government into a seven-decade era of dominance in large water developments throughout the West.

The Dust Bowl and the Great Depression, under Franklin Roosevelt, further intensified federal involvement in the West, as job creation became a driving rationale for large water development projects. These large projects enabled the mass settlement of the West in the 1940s. Although the Reclamation Act originally focused on providing infrastructure for irrigating family farms of 160 acres or less, water and power from reclamation projects ultimately facilitated large-scale agriculture and development of mega cities such as Las Vegas, Phoenix, and Los Angeles. State water projects, most notably in California, further added to the storage and plumbing infrastructure of the West. This expansion and growth helped set the stage for today's conflicts between agricultural and urban uses.

By the 1960s, increasing public consciousness of pervasive and widespread water pollution and ecological damage gave birth to the modern environmental

8 For an overview, see National Public Radio, "The Vision of John Wesley Powell," August 26, 2003, available at: http://www.npr.org/programs/atc/features/2003/aug/water/part1.html.
9 John Wesley Powell, *Report on the Lands of the Arid Regions of the United States* (1878).

movement. Several high-profile fights took place over dam construction in the West, as environmental advocates began to utilize new tools and employ more sophisticated strategies.[10] What soon followed was the passage of a raft of federal legislation including the Wild and Scenic Rivers Act (1968), National Environmental Policy Act (1970), Clean Water Act (1972), and Endangered Species Act (ESA) (1973). These federal laws recognized the importance of the environment and its connection to human health, and they fundamentally changed the way water projects (and any actions with a federal nexus) are planned and implemented.

By the 1980s, the development boom had run out of steam and the consequences of its excesses began to take hold. Due in large part to dams and water withdrawals, populations of Pacific salmon and other aquatic species began to crash. There are now about thirty fish that are federally listed as threatened or endangered in California alone.[11] Mandated restrictions on water withdrawals to protect fish provoked an inevitable backlash. Building on the backlash against restrictions on logging prompted by the spotted owl listing, and on private property rights movements such as the sagebrush rebellion, ranchers and other western water users have condemned environmental restrictions on water use as an attack on the rural way of life in the West.

Subsequent years were marked by political and legal battles between these two sides, mostly resulting in stalemate. While the 1990s and early 2000s saw some examples of collaboration and environmental restoration, there were no major laws passed or protections granted to waters and lands (nor were any repealed).

Some suggest that we have entered into an era of "The New West." It is hard to guess how this new era will define itself, and it is debatable whether drawing a distinction around an era provides any real value or clarity,[12] but it is certain that today's West is different from even 15 years ago from a demographic, cultural, economic, and environmental point of view.

We see a New West characterized by denser (and growing) urban population centers, rising ecological and recreational values of rivers and streams, and a growing awareness of water scarcity. The population of the West has grown by

---

10 Daniel McCool, "River Republic: The Fall and Rise of America's Rivers" (Columbia University Press, 2012).

11 Department of Fish and Game, Natural Resources Agency, State of California, "State & Federally Listed Endangered & Threatened Animals of California," (2013). Available at: http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/TEAnimals.pdf.

12 Paul Robbins, Katharine Meehan, Hannah Gosnell, and Susan J. Gilbertz, "Writing the New West: A Critical Review," *Rural Sociology* 74, no. 3, (2009), 356–382. Richard White, *Its Your Misfortune and None of My Own: A New History of the American West*, (University of Oklahoma Press, 1991).

13.8%, or 8.7 million people, from 2000 to 2010.[13] Four out of the top five fastest-growing states in the US, ranked by percentage change in population (projected between 1995 and 2025) are in the West: California (56%), New Mexico (55%), Arizona (52%), and Nevada (51%).[14] There are many divides in this New West that continue to pull westerners further apart, such as cities/agriculture, coastal/inland, wealthy/poor. Cities have typically used 20% of total water available, while agriculture used 80%.[15] In light of growing populations, urban demand for water will only grow. At least some of this demand will be satisfied by water transfers from agriculture to cities, and many rural communities view the loss of this water as a threat to their economic viability and their culture. The need to leave water in rivers to restore threatened and endangered species only adds to the potential for conflict.

While conflict is a real issue in western water, it is not the whole story; there are signs of more resilient and cooperative approaches to water management in this new West. From southern California's shift to diversify its water supply with local and recycled sources, to climate change legislation on state and local levels, to a basin-wide study of the Colorado River to understand its current and future water demand and supply, efforts are being made at all levels to mitigate water and climate risks, often by working together. These are all promising signs that westerners are at the verge of creating a society to match its scenery, as Stegner had hoped for.

In this paper, we investigate some of the key issues that dominate today's conversations about western water and explore how some of these issues have emerged or evolved since the last comprehensive review of western water in 1998. In particular, we focus on water management and governance, preparing for a changing climate, ecosystem services, water markets and transfers, connections between water and energy, advances in knowledge and technology, and water infrastructure finance. While there are numerous other water issues to explore, we chose these because of the unique attention they have received and continue to gain in recent years.

13 The West includes Alaska, Ariz., Calif., Colo., Hawaii, Idaho, Mont., Nev., N.M., Ore., Utah, Wash., and Wyo. Source: U.S. Census Bureau, Census 2010; Census 2000; 1990 Census. www.census.gov.

14 See Paul Campbell, "Population Projections: States, 1995–2025," U.S. Census Bureau (1997), http://www.census.gov/prod/2/pop/p25/p25-1131.pdf. Note that census projections from prior to 2010 should be considered cautiously as the impact of the 2008 recession on population movements in the West could be substantial.

15 This is consumptive water use, which is the water removed from supplies that is not returned to water sources. For crops, plant transpiration and evaporation from the soil and foliage drive consumptive use.

2 Water Management and Governance

Because of its very nature, water has always been a difficult resource to manage. How do you draw boundaries around something that has no clear beginning or end? How do you manage something that is constantly moving and changing? How do you regulate something that does not have a clear owner? The complexities of water laws, policies, institutions, and investments are a reflection of the resource itself.

Look at a map of the western US and it becomes clear that the straight lines that form so many borders among the 17 states west of the 100th meridian defy the lines that matter most – its rivers and watersheds. Those borders complicate management of water as much as anything. Perhaps more than any other question affecting water in the West, the challenge of management and governance continues to perplex and confound policy makers and water professionals.

The US operates on a system of cooperative federalism, with responsibility and jurisdiction for water resources distributed and nested among federal, state, and local levels of government.[16] Traditionally, federal government maintains some authority over water quality and flood control, the states have retained primacy over water supply, while local agencies administer many of these programs and provide basic services to customers, including water supply and sewage.

At every level, jurisdiction over water resources is divided among numerous entities with responsibility for various and often overlapping pieces of the larger puzzle – sanitation, water delivery, flood management, fish and wildlife, recreation.[17] Long lamented, this balkanization has more recently been embraced for its checks and balances.[18]

What further complicates overlapping jurisdictions is that water moves – problems upstream tends to magnify as one moves downstream. This is true of both water quality (e.g., pollution) and quantity (e.g., excessive withdrawals). Benefits and costs are easily misaligned. Upstream communities incur the costs of maintaining clean water while downstream communities enjoy the benefits.

---

16 Andrea K. Gerlak, "Federalism and US Water Policy: Lessons for the Twenty-First Century," *The Journal of Federalism* 36 no. 2 (2005), 231–257.

17 In fact, there are estimated to be more than 52,000 community public water systems that are publicly owned, cooperatives, or privately owned that have a direct hand in some kind of traditional water management. See Environmental Protection Agency, "FACTOIDS: Drinking Water and Groundwater Statistics for 2009," Office of Water (2009). http://www.epa.gov/ogwdw/databases/pdfs/data_factoids_2009.pdf.

18 Martin Doyle, "American River Management," *Journal of the American Water Resources Association* 48, no. 4 (2012).

Commissioners of the 1998 report on *Water in the West* highlighted management and governance as one of its key concerns. The commissioners supported several fundamental goals of management and governance that work from the bottom up and the top down: 1) Improve decision making by coordinating at the basin level; 2) Develop measurable objectives for basin management; 3) Improve efficiency of agency activities through integration of programs and budgets; 4) Expand technical and financial support of watershed projects; and 5) Support basin trusts to maximize financial resources. There are certainly examples in the intervening years of improvements in each of these areas, although effective management and governance in western water is as elusive today as it was in Powell's time.

2.1 Today's Water Management and Governance

The past 15 years have been particularly marked by conflict over water in the West's largest and most storied river basins. Of course, the complexity and conflict that defines basins like the Colorado, Columbia, Sacramento-San Joaquin, Rio Grande and Missouri should not come as any great surprise. These rivers involve tremendous historic competition between upstream and downstream jurisdictions, competing industries, and competing demands served by major federal infrastructure projects. With the exception of the Sacramento-San Joaquin, each of these rivers is governed by complex interstate and even international agreements. And each is home to a complex and fragile ecosystem with species that have become endangered because of water use and infrastructure.

Competition between upstream and downstream states on the Missouri River led to litigation over the operation of a series of dams in Montana and the Dakotas that brought into conflict navigation, flood control, power production, and recreation as well as ecosystems protection.[19] While the litigation ostensibly centered on the fate of endangered fish and birds, the real dispute is on allocation of water between upstream and downstream states. Another focus of almost non-stop litigation has been the interaction between dams and salmon in the Columbia River basin, involving upstream and downstream states, tribes, environmental

19 South Dakota v. Ubbelohde, 330 F.3d 1014, 1020 (8th Cir. 2003); In re: Operation of the Missouri River System Litigation, No. 07-1149 (8th Cir. Feb. 8, 2008) (affirming lower court, upholding U.S. Army Corps operations along Missouri River.); for more information, see Karla Hauk: "Missouri River Case: A River Runs Through it, in re: Operation of the Missouri River System Litigation," *Great Plains Nat. Resources Journal* 61 (2005).

advocacy groups, and hydropower and navigation lobbies.[20] With billions of dollars spent in court and on mitigation, little has changed in the Columbia River basin.

One effort at a new governance structure that many believed showed promise at tackling large, interdisciplinary water management problems was the CALFED process. Established in 1994 as an effort to coordinate the efforts of state and federal agencies to maintain water supplies for cities and agriculture, improve water quality, and restore the Sacramento-San Joaquin Bay Delta ecosystem for endangered species, this 10-year cooperative effort culminated in a plan for coordination and action among 25 federal and state agency participants.[21] While these achievements were unprecedented and exhibited remarkable progress, many criticized the program for generating lots of process but yielding few results.[22] Since the demise of CALFED, additional efforts at coordination and collaboration have arisen to manage and govern the Delta, each with their own mixed result.[23] And of course, litigation remains a constant.

Given that it is the West's largest and most arid basin, it is ironic that the Colorado River arguably has seen greater degrees of cooperation and collaboration than others in the region. The cooperation could be driven by a pressing need: the basin is over-allocated, with less water than presumed in the Colorado River Compact.[24] In 2009, Congress passed the SECURE Water Act, which among other things directed the Bureau of Reclamation to conduct comprehensive studies to evaluate and define options for meeting future water demands in rivers basins in the West, including the Colorado.[25] While parties are still a long way

20 Michael Blumm, "The Real Story Behind the Columbia Basin Salmon Debacle: Dam Preservation under the Endangered Species Act," *Environmental Law* 41, Lewis & Clark Law School Legal Studies Research Paper No. 2011-16, July 12, 2011; see also The Oregonian, "Timeline, major players in the Northwest salmon lawsuit in the Columbia River basin," May 07, 2011. http://www.oregonlive.com/environment/index.ssf/2011/05/timeline_major_players_in_the.html.

21 CALFED Bay-Delta Program Archived Website, "Record of Decision and other Key Documents," http://calwater.ca.gov/calfed/library/Archive_ROD.html.

22 CALFED Bay-Delta Program Archived Website, "History of CALFED Bay-Delta Program," http://www.calwater.ca.gov/calfed/about/History/Detailed.html.

23 See the Bay Delta Stewardship Council http://deltacouncil.ca.gov/, and the Bay Delta Conservation Partnership http://baydeltaconservationplan.com/Home.aspx. For a comprehensive examination, see National Research Council, *Sustainable Water and Environmental Management in the California Bay-Delta* (Washington, D.C., The National Academies Press, 2012). http://www.nap.edu/catalog.php?record_id=13394.

24 U.S. Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study," 2012.

25 For a summary, see Bureau of Reclamation, "The Water Conservation Initiative and Implementation of the Secure Water Act," available here: http://www.usbr.gov/lc/region/programs/crbstudy/SWA.pdf.

from agreement about how to resolve long-term water needs and have not fully achieved inter-jurisdictional coordination of regulations, investments, and plans, they are certainly moving in a more positive direction than ever before.

It has been said in the financial world that there are institutions that are "too big to fail." Despite the many odds stacked against them, this may be an apt description of the major river systems of the western US. Perhaps this is why the largest and most contentious among them may be showing the greatest signs of cooperation. Dr. Brad Udall of the University of Colorado explained in a speech at a conference celebrating the 50th anniversary of the landmark Supreme Court decision regarding the California River, *Arizona v. California*, that while "the law of the river" may say that Arizona will go dry before California has to cut back in the slightest, "the reality of the public" will not tolerate such an extreme outcome.[26] If he is right, perhaps the backstop to governance in western water is common sense and fairness. The Colorado Basin states have made progress working towards a solution to their severe problems because they have to – they face a genuine shortfall in the face of acute demand that they cannot fail to address.

So where do we go from here? If we are still discussing the same issues that Powell raised in the 1800s, it either suggests we need to press harder for more concrete action, or that we need to change the conversation.

The 1998 Report stressed the need for a coordinating body for water, particularly among federal agencies, and recommended reconvening the Water Resources Council (1965–1981). While it has not been convened or funded since 1981, the Council remains authorized by law and was originally empanelled to coordinate the planning, investments, management, and regulation of water resources among federal agencies.[27] It also included provision for better coordinating federal activities with states, local agencies, and the private sector. Although President Obama has not heeded calls to reconstitute the Council, his Administration has convened an ad hoc interagency task force around water resource issues.[28] While it is difficult to see whether those efforts have translated to actions on the ground, they appear to be responding to this commonly cited need for federal coordination.

26 The "Law of the River" refers to the Colorado River Compact, signed by the seven states within the Colorado River basin: Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, and California. The compact grants senior water rights to California.

27 18 CFR Chapter VI – Water Resources Council.

28 The Water Resources Development Act of 2007 directed federal agencies to rewrite the Principles and Guidelines for Water Resource Development Projects, which governs water infrastructure evaluation and decision-making among several federal agencies.

A major theme dominating current discussions about water management and governance is the concept of integrated water resource management (IWRM). Integrated management is commonly thought of as coordinated planning, co-management of water quantity, quality, flood control, land use, and ecosystems, and sharing information across disciplines and agencies. Proponents say benefits include more efficient and cost effective management, reliable water supplies, adaptability in the face of climate change, and equity across sectors.

Several national forums have argued for variations of IWRM as a centerpiece to future water management.[29] Over the past several years, the Johnson Foundation has led an effort to convene diverse stakeholders to discuss challenges and solutions to sustainable management of the nation's water and have repeatedly identified integration as critical.[30]

Integrated water management has a particular resonance among western water managers given the interrelation of the resources they are entrusted with and the complexity of the institutions and legal structures they must navigate. For example, operating a reservoir requires balancing between storing as much water for consumptive use as possible, while leaving storage space available in the event of a flood. Water left instream may be beneficial to both wildlife and hydropower, but can place strains on irrigated agriculture and cities. Land use decisions affect flood control, water demand, and the health of freshwater ecosystems, but are often made by government entities that have no experience or responsibility for these resources. Integrating the management of groundwater and surface water, which were once treated as separate resources in most western states, has become the norm in recognition of their hydrologic connection and because of its importance in providing cheap, reliable water storage.[31]

29 The American Water Resources Association's 2011 National Water Vision explains, "Water resources cannot be managed sustainably without active and purposeful recognition of their many linkages and varied interconnections. This recognition, in fact, requires a holistic approach to water and the practice of integrated water resources management." US Water Alliance, a coalition of municipal water utilities, agricultural leaders, and environmental interests, has held a series of meetings promoting the idea of "One Water Management" and developing a network to share information and advance its agenda of "adaptive, integrative water management planning" http://www.uswateralliance.org/activities/one-water-networking/.

30 The Johnson Foundation Freshwater Summit, "Charting New Waters,"(2010). http://www.johnsonfdn.org/aboutus/chartingnewwaters.

31 One notable exception is California where regulation and management of surface water and groundwater remain separate and distinct. See Barbara Tellman, "Why has Integrated Management Succeeded in Some States but not in Others?" *Journal of Contemporary Water Research and Education* (2011).

Perhaps the most tangible attempt to realize this vision of integration is California's Integrated Regional Water Management Planning program (IRWMP).[32] The program, administered by the Department of Water Resources and the State Water Resources Control Board, has been used to bring together the dozens of water agencies and stakeholders in hydrologic regions throughout the state to coordinate plans and prioritize water projects and investments to meet a wide array of regional objectives. The program uses access to state bond funding as an incentive for participation. Unfortunately, the prospect of continued water bond funding in California is unclear and it is uncertain whether this incentive is actually affecting the state's most difficult water management challenges.

There is really no beginning or end to the conversation about water management and governance in the western US, but based on trends, we expect that ever pressing needs will keep the discussion alive for years to come. Effective governance is necessary for functioning markets that not only improve economic efficiency but avoid impacts to rural communities and the environment. With climate change, the agreements struck between the states over the past several decades will almost inevitably need to be revisited, whether amicably or through the courts. And the need and desire to replace aging infrastructure, possibly with new technologies, will present opportunities for cooperative financing, coordinated management, and new governing regulations. Over the past 15 years, we have made some progress in better integrating water management decisions, but have not found ways to employ these lessons more broadly, or apply them to the region's most important water management problems.

3 Preparing for a Changing Climate

It is safe to say that almost every report, article, or document written about western water now devotes at least some of its attention to the present and future challenges of a changing climate. Given this overwhelming level of attention, it is startling to think that just 15 years ago, it was little more than a footnote.

32 Department of Water Resources, State of California." Integrated Regional Water Management Grants" http://www.water.ca.gov/irwm/grants/index.cfm. Similar state efforts are underway in Oregon and Colorado.

When the Commissioners of *Water in the West* (1998 Report) were making recommendations about the future of western water, they paid little attention to climate change. Among the report's more than 400 pages, only three paragraphs even mention it. The report summed up climate change and its role in the future of the American West by saying, "in the years to come, the West's water supplies may also be influenced by human-induced climate change."[33,34] Times have changed indeed.

In the past 15 years, confidence of climate change models and predictions have improved by leaps and bounds, and our understanding of current and future impacts is much clearer.[35] That increased understanding has underscored the risks for western water supplies, and solidified.[36] Climate change has come to dominate the attention of the water sector in the West.

The climate of the West has always been characterized by extreme variability. The region has seen some incredible extremes and the so-called "normal" water year is ever elusive. Tree rings and other paleoclimatic data present a picture of the climate of western North America frequented by droughts and punctuated by catastrophic floods. Numerous droughts, greater than any witnessed by European settlers, plagued the Colorado River basin between 750 and 1500.[37] At the other end of the spectrum, recent studies in the Central Valley of California show a regular incidence of "biblical" floods that filled the Central Valley every 200 years.[38] The region is no stranger to climatic extremes, but all of the models of climate change predict with a great degree of confidence that those extremes will become even greater and more frequent because of greenhouse gas pollution.

33 Western Water Policy Review Advisory Commission, *Water in the West: Challenge for the Next Century*, pp 2-1, 2-3 (1998).

34 Dr. Kathleen Miller prepared an excellent accompanying report for the Commission that describes the possibility of reduced water availability and increased flooding, but her analysis and recommendations were scantily mentioned in the main text. Kathleen Miller, "Climate Variability, Climate Change, and Western Water," Western Water Policy Review Advisory Commission, National Technical Information Service, Springfield, VA (1997).

35 Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2013: The Physical Science Basis," http://www.ipcc.ch/report/ar5/wg1/#.UmlyWaWo4pE.

36 Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2013: The Physical Science Basis," http://www.ipcc.ch/report/ar5/wg1/#.UmlyWaWo4pE.

37 David M. Meko, Connie A. Woodhouse, Christopher A. Baisan, Troy Knight, Jeffrey J. Lukas, Malcolm K. Hughes, and Matthew W. Salzer, "Medieval Drought in the Upper Colorado River Basin," *Geophysical Research Letters* 34 (2007).

38 B. Lynn Ingram, "California Megaflood: Lessons from a Forgotten Catastrophe," *Scientific American*, (January 19, 2013).

A growing body of research and reports, such as the 2009 National Climate Assessment[39] and a 2011 report to Congress from the Bureau of Reclamation,[40] point to significant threats to water resources from climate change. These can be summarized by the following:

- Average temperatures are rising, thereby increasing evaporation and increasing the severity of recent droughts;
- A greater portion of winter precipitation is falling as rain in the mountains rather than snow, and snow is also melting earlier in the year, compromising reliance on surface water storage in the West;
- Across the West warming, drought, and resulting insects and disease, will increase wildfires and impacts to people and ecosystems;
- Extreme rainfall events are expected to increase in frequency and intensity;
- Coastal flooding and erosion is already occurring and is damaging some areas of the California coast during storms and extreme high tides;
- Wildlife adapted to historic temperature regimes and hydrology are vulnerable to changing conditions.

The West has witnessed a number of extreme weather events over the past 15 years, although none can be attributed specifically to climate change.[41] Nevertheless, because these droughts and floods resemble the kinds of events forecast in various climate change scenarios, they have left an impression on both water managers as well as the general public.

A landmark paper by Miley et al. (2008) in *Science*, entitled, "Stationarity is Dead," lays out the idea that the past is no longer a sufficient predictor of the future and that we need to adjust the way we plan for our water resources in the future. That presents a tremendous challenge. The West's dams, levees, and other infrastructure, once the envy of the water world, were built on past assumptions. Laws and policies on water rights, species recovery plans, and clean water permits are calibrated to data collected over the last century, for the most part. Land use decisions are dependent on that data and history as well. The realization that the

39 U.S. Global Change Research Program, "Global Climate Change Impacts in the United States: 2009 Report," http://nca2009.globalchange.gov/water-resources.

40 Department of the Interior, "SECURE Water Act – Reclamation Climate Change and Water 2011," U.S. Bureau of Reclamation. http://www.usbr.gov/climate/SECURE/.

41 Examples include flooding in California in 1997, Missouri River floods in 2010, drought in Texas and the Plains in the 2000s, drought in California 2008–2011, and drought in the Colorado River basin from 2000 to present. While Hurricane Katrina and Superstorm Sandy did not occur in the Western states, they had significant impacts on public perceptions of risk around weather events.

future will not conform to the past is now leading to a transformation in the water industry and a whole new way of thinking and working.[42]

Despite the consensus within the scientific community around anthropogenic climate change and its impacts on water resources in the West, public attitudes in the region have been decidedly mixed. Regardless of politics and views about the causes of climate change, water managers seem to be heeding the risks and orienting their planning to address it – even if they may call it by another name.

Federal, state and local water agencies have undertaken significant planning efforts to ensure that the West's water resources and communities are prepared for a changing climate. Beginning in 2009, federal agencies began working with stakeholders to develop a *National Action Plan* that provides an overview of the challenges a changing climate presents for the management of the nation's freshwater resources and describes actions that federal agencies will take to help freshwater resource managers ensure adequate water supplies and protect water quality and public health.[43] In February 2013, federal agencies released their first Climate Change Adaptation Plans to plan for and address the impacts of climate change on their programs and operations. As part of a new partnership among the National Oceanic and Atmospheric Administration and universities throughout the nation,[44] the Western Water Assessment was established at the University of Colorado, Boulder to evaluate and address societal vulnerabilities related to climate change and water resources and provide advice and direction to local decision-makers about how best to prepare.[45]

Federal agencies are not alone in their efforts to confront the challenges of a more volatile and uncertain climate. Over the past several years, the Western Governors' Association (WGA) has issued several reports describing vulnerability of states to a changing climate, as well as serving as a clearinghouse to share advice and best practices among them.[46] WGA's 2010 climate adaptation

42 L.D. Brekke, J.E. Kiang, J.R. Olsen, R.S. Pulwarty, D.A. Raff, D.P. Turnipseed, R.S. Webb, and K.D. White, "Climate Change and Water Resources Management: A Federal Perspective," *U.S. Geological Survey Circular* 1331, (2009), 65. http://pubs.usgs.gov/circ/1331/.

43 Interagency Climate Change Adaptation Task Force, "National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate," (2011). http://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_national_action_plan.pdf.

44 NOAA's Regional Integrated Sciences and Assessments (RISA) Program is a collaboration of 11 regional programs operating across the U.S.

45 Information about the Western Water Assessment is available at http://wwa.colorado.edu.

46 Western Governor's Association's work on climate change can be found here: http://www.westgov.org/initiatives/climate.

report emphasizes the need for states to coordinate with federal agencies on good science and best practices.

The front lines of water management remain at the local level – municipalities, counties, and utilities, as well as businesses and individuals. Numerous communities throughout the West such as Seattle, Boulder, and the state of California, have been identified as models of adaptation planning for the rest of the world.[47] Colorado and other states have modified drought mitigation and response plans to consider the impact of climate change. There have been a number of excellent publications that provide direction and guidance to planners in developing adaptation plans.[48] Adaptation planning has turned out to be a natural integrator of more traditional water management plans that until now were developed and functioned independently. Planners for land and water are finding opportunities to collaborate and pool resources around the need to plan for climate change.

There are certainly numerous jurisdictions that have yet to pick up this mantle but even water agencies in conservative parts of the region are finding ways to address the risks of climate volatility without wading into debates over the causes. The state of Oklahoma has an exceptional state water plan that gives careful consideration to a changing climate.[49] In early 2013, the Idaho legislature passed a state water plan despite its references to climate change and variability.[50]

Many best practices, legal reforms, and investment decisions that are recommended in the face of a changing climate are little more than restatements of past recommendations for sustainable water management. Nevertheless, the addition of climate change to the historic list of threats to western water management appears to be creating a new sense of urgency to implement old and new solutions.

47 See http://www.georgetownclimate.org/adaptation/state-and-local-plans?order=province&sort=desc and https://bouldercolorado.gov/pages/climate-adaptation; California has the first statewide climate adaptation program in the U.S. See California Natural Resources Agency, "2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order S-13-2008," State of California, (2009).

48 Ben Chou, "Ready or Not: An Evaluation of State Climate and Water Preparedness Planning," *Natural Resources Defense Council Issue Brief*, (April 2013). Fay Augustyn and Ben Chou, "Getting Climate Smart: A Water Preparedness Guide for State Action," *American Rivers and Natural Resources Defense Council* (2013).

49 Oklahoma Water Resources Board, "2012 Oklahoma Comprehensive Water Plan Update," (2011). Available at: http://www.owrb.ok.gov/supply/ocwp/ocwp.php.

50 Idaho Water Resource Board, "State Water Plan," (2012). The document is available here: http://www.idwr.idaho.gov/waterboard/WaterPlanning/Statewaterplanning/State_Planning.htm.

4 Ecosystem Services and Green Infrastructure

The idea that natural ecosystems provide society with a diverse stream of benefits has been around for a long time,[51] however it was not until 2006 that the idea of "ecosystem services" was formalized with the publication of the United Nations Millennium Ecosystem Assessment.[52] Today there is fairly broad recognition of this concept and numerous efforts to incorporate the value of those natural assets into decision making of all sorts, from environmental regulation to public and private investments. As with climate change, the authors of the 1998 Report paid little attention to this issue compared to the attention it receives today.

The concept of ecosystem services is closely linked with the notion that water infrastructure need not be limited to just constructed and heavily engineered systems. The idea of natural or green infrastructure is to use natural assets such as forests, riparian areas, and wetlands, or mimic those natural systems through the use of bioswales, green roofs, and constructed wetlands, to achieve water management goals and objectives. In the West, ecosystem services and green infrastructure have been especially evident in the areas of forest planning, floodplain management, and urban design, although there are many other examples.

4.1 Forests

The most oft-cited example of the value of ecosystem services is New York City's City's decision to invest $1B to protect its watershed in lieu of spending $6–8 B to build new water treatment facilities.[53] This approach of large scale watershed protection and management is actually much more common in the western US where cities such as San Francisco, Portland, and Boise have relied on forested landscapes, mostly on federal lands, to maintain water quality and avoid the expense of building new infrastructure. A study of 27 US water supply systems

51 John Loomis, Paula Kent, Liz Strange, Kurt Fausch, and Alan Covich, "Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired river Basin: Results from a Contingent Valuation Survey," Ecological Economics, 33 (2000), 103–117. Joy B. Zedler and Suzanne Kercher, "Wetland Resources: Status, Trends, Ecosystem Services, and Restorability," *Annual Review of Environmental Resources* 30 (2005), 39–74.
52 United Nations Environment Programme, "Millennium Ecosystem Assessment." Learn more here: http://www.unep.org/maweb/en/index.aspx.
53 Graciela Chichilnisky and Geoffrey Heal, "Economic returns from the biosphere," *Nature* 391 (1998), 629–630.

demonstrated that greater forest cover correlates to lower water treatment costs: watersheds with 60% forest cover required an average of $297,110 (per 3785 m^3) in annual water system treatment cost, compared to $923,450 for watersheds with only 10% forest cover.[54] Another study found that every $1 invested in forest watershed protection saves between $7.50 and $200 in water treatment costs.[55] And none of these numbers reflect the value of ancillary benefits (e.g., recreation, wildlife) that these actions provide.

In 1997, then U.S. Forest Service Chief Mike Dombeck attempted to resurrect what was a long forgotten but fundamental pillar in the organic statute of his agency.

> *"No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the US…"*[56]

Chief Dombeck was fond of reminding the public that more than 66 million Americans derive their drinking water from Forest Service lands.[57] While many of his specific initiatives were slowed or halted by opponents in Congress, his reminder that water is central to the mission of the Forest Service has lasted. Water remained a top priority of the USFS under both the Bush and Obama Administrations and it has been similarly embraced by sister land management agencies such as the Bureau of Land Management. In 2012 the USFS adopted a new planning rule that for the first time directs staff to consider ecosystem services as well as multiple uses when making management decisions for public lands.[58]

It remains to be seen how the agency will implement this new rule, but at least one new program, Forests-to-Faucets, illustrates how the agency is partnering with the water industry to improve freshwater conditions in the West. Forests-to-Faucets brings together municipal utilities within each USFS region to cooperate on forest management and pool resources to meet mutual

54 Sandra L. Postel and Barton H. Thompson, Jr., "Watershed Protection: Capturing the Benefits of Nature's Water Supply Services," *Natural Resources Forum* 29 (2005), 98–108.
55 Walt V. Reid, "Capturing the Value of Ecosystem Services to Protect Biodiversity," in *Managing Human Dominated Ecosystems*, ed. V.C. Hollowell, ed. (Missouri Botanical Garden, St. Louis, 2001).
56 Forest Service Organic Administration Act of 1897, 16 U.S.C. Section 475.
57 James Sedell, Maitland Sharpe, DainaDravnieks Apple, Max Copenhagen, and Mike Furniss, "Water and the Forest Service," *U.S. Department of Agriculture, Forest Service, FS-660*, (2000).
58 U.S. Department of Agriculture, Forest Service, "2012 Planning Rule." Available at: http://www.fs.usda.gov/detail/planningrule/home/?cid=stelprdb5359471.

objectives.[59] Denver Water's 1.3 million customers receive most of their water from snowpack and streams that originate on National Forests. In 1996 and 2002, Denver Water experienced two severe fires in watersheds that supply the Front Range with water. In August of 2010, Denver Water formalized a partnership with the US Forest Service to reduce wildfire risk, restore areas recovering from past wildfires, and minimize erosion in the watersheds that are critical for Denver Water's water supplies and infrastructure.[60] Each agency is contributing up to $16.5 million over a 5-year period with an average cost of $27 to each Denver Water household.[61] In a more recent example of a watershed collaboration to improve water quality, Colorado Springs Utilities and the Forest Service initiated a 5-year partnership to help restore the areas burned by the devastating Waldo Canyon Fire in 2012 – the largest, most expensive and destructive fire in Colorado's history. Colorado Springs Utilities will invest approximately $6 million in support of watershed health, and the Forest Service will complete on-the-ground project work that complement the Utilities' investments.[62] Other partnerships like these are beginning to emerge throughout the West.

4.2 Floodplains

The pattern of precipitation in the West is expressed through extreme volatility, including catastrophic flooding.[63] While native systems are adapted to and indeed depend on this natural volatility, flooding can cause human loss exacerbated by extensive man-made impervious surfaces, which creates even flashier events and larger devastation to development in floodplains and flood-prone areas.

59 U.S. Department of Agriculture, Forest Service, "Forests to Faucets." Available at: http://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml.

60 Denver Water, "From Forests to Faucets: U.S. Forest Service and Denver Water Watershed Management Partnership." Available at: http://www.denverwater.org/supplyplanning/watersupply/partnershipUSFS/.

61 *Ibid*.

62 U.S. Department of Agriculture, Forest Service, "Innovative Partnership to Protect Colorado Springs Water Supply," 2013. Available at: http://blogs.usda.gov/2013/04/10/innovative-partnership-to-protect-colorado-springs-water-supply/.

63 Recent examples include the Colorado Front Range 2013 and the Missouri River 2010–2011: The Atlantic, "Historic Flooding Across Colorado," September 16, 2013. Available at: http://www.theatlantic.com/infocus/2013/09/historic-flooding-across-colorado/100591/. U.S. Department of Commerce, "The Missouri/Souris River Floods of May-August 2011," National Oceanic and Atmospheric Administration, National Weather Service (2012). Available at: http://www.nws.noaa.gov/os/assessments/pdfs/Missouri_floods11.pdf.

Perhaps the best known flood control system in the western US, if not the world, is the Los Angeles River. A project designed and constructed by the US Army Corps of Engineers, this concrete-lined trapezoidal channel, regularly seen during the car chases of numerous action movies, was once viewed as the only way to manage river flooding: get the water away from the city and downstream as quickly as possible. Today many view this hardened system as a poster child of what not to do. Over the past several years, communities have begun to embrace a more balanced approach to flood management.

From 1961 to 1997, Napa, California flooded on 19 separate occasions, resulting in over $542 million in damages.[64] In response, the US Army Corps proposed channelizing the river and building levees, much like they had done in Los Angeles, but instead a coalition of citizens and local businesses came together to propose an alternative "living river" design. This approach maintains and restores the connection of the river to its flood plain. It maintains channel features and forms a continuous riparian corridor along the river. Napa's approach provides flood protection equal to the Corps' 100-year flood design standards, but it does so while helping the community reinvigorate its downtown and enhance its economic base. While reliance upon traditional dams and levees remains a fundamental part of the region's flood control system, the lessons from Napa are being emulated by numerous other communities throughout the West.

Not only is the West seeing innovation in the form of floodplain restoration projects, but it is also seeing policy change that could have even broader implications for flood management in the region. In 2007 Congress mandated an update to the Principles and Guidelines for Water Resource Planning,[65] and the President's Council on Environmental Quality (CEQ) convened a multi-agency committee to comply. In 2013, CEQ published Principles and Standards that requires an ecosystem services approach for evaluating water resource and associated land use decisions.[66]

This mandate represents a rather sweeping change from the traditional cost benefit analysis used by many federal agencies. The US Army Corps of Engineers and the Bureau of Reclamation are currently grappling with how best to design

64 http://www.americanrivers.org/natural-security-case-studies-1/.

65 H.R. 1495 (110th): Water Resources Development Act of 2007. Also known as WRDA 2007, this bill mandated updating the 1981 Principles and Guidelines.

66 Council on Environmental Quality, "Principles and Requirements for Federal Investments in Water Resources," March 2013. Available at: http://www.whitehouse.gov/sites/default/files/final_principles_and_requirements_march_2013.pdf.

and implement a framework that will comply with this new mandate and serve their planning and decision-making needs.[67]

4.3 Urban Design

Cities are comprised primarily of what water managers call “impervious” surfaces. These are hardened surfaces such as roads, rooftops, and parking lots where rainfall is unable to soak into the ground. Rather than recharging local groundwater, rainfall on urban landscapes runs rapidly off of impervious surfaces, into storm drains, and then into local streams, causing unnaturally high peak flows and flooding. This urban stormwater also picks up pollutants such as heavy metals, fertilizer, pesticides, and oil and grease from our lawns, driveways, and roads as it makes its way to the nearest storm drain. In the mid 1990s, the idea that cities could better mimic the hydrology of natural landscapes and improve water quality through the use of bioswales, rain gardens, or green roofs began to take hold and the idea of green infrastructure was born.

Sometimes described as “low impact development” (LID), the concept has spread widely in the last decade.[68] Large and small cities from Portland to Los Angeles have turned to green infrastructure to address water pollution, flooding, and additional challenges around water scarcity and endangered species.[69]

Originally driven to comply with water quality requirements set by the Regional Water Resources Control Board, the city of Los Angeles has begun a comprehensive effort to integrate green infrastructure throughout the basin.[70]

67 A suggested framework has been provided by Leonard Shabman, “Towards Integrated Water Resources Management: A Conceptual Framework for U.S. Army Corps of Engineers Water and Related Land Resources Implementation Studies,” US Army Corps of Engineers, Institute for Water Resources Visiting Scholar Program, January 2012-VSP-01 (2012). Available at: http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/2012-VSP-01.pdf.

68 EPA defines LID as “an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product.” Available at: http://water.epa.gov/polwaste/green/.

69 City of Portland, “Portland’s Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits,” Bureau of Environmental Services, 2010. Available at: http://www.portlandoregon.gov/bes/article/298042.

70 US Environmental Protection Agency, “Green Infrastructure Opportunities and Barriers in the Greater Los Angeles Region: An Evaluation of State and Regional Regulatory Drivers that Influence the Costs and Benefits of Green Infrastructure,” Green Infrastructure Technical Assistance Program, Council for Watershed Health, Los Angeles, CA, 833-R-13-001 (2012).

An important secondary goal of this effort is stormwater capture and storage in groundwater aquifers to augment water supplies. Surrounding jurisdictions such as Orange County and San Bernardino also have begun to invest in green infrastructure projects that capture stormwater and use it to recharge local groundwater aquifers.[71] This has become a vital strategy for this arid region to meet its present and future water supply needs.

Numerous challenges with green infrastructure remain. Many strategies are still not well tested and their benefits not well quantified, making it challenging to rely upon them to meet regulatory requirements or planning goals. Many of the benefits of green infrastructure projects extend well beyond their immediate purposes, so those who pay the costs do not always enjoy the benefits. Without more integrated planning and management, that misalignment of benefits can diminish the incentive to invest in these projects.

The American Recovery and Reinvestment Act (ARRA) in 2009 included large sums of new federal funding for infrastructure projects. While the majority of that spending went to traditional infrastructure projects, at least some was dedicated to green infrastructure. The State Revolving Fund, which provides low interest loans to wastewater and drinking water utilities, included a set-aside requiring that 20% of that funding "go a green reserve."[72] That provision has remained part of the program, and has begun to spur innovation and demand for green infrastructure projects throughout the country. Local financing mechanisms such as Los Angeles' Proposition O have also set aside funding for green projects.[73]

No one predicted back in 1998 that green infrastructure or ecosystem services would be such an integral part of western water management today. There is a great deal of additional research and development that needs to take place before these concepts will become fully integrated into the mainstream, but every

71 For more information, see Groundwater Replenishment System, "Groundwater Recharge," available at: http://www.gwrsystem.com/the-process/water-delivery/groundwater-recharge.html Inland Empire. Utilities Agency, "Groundwater Recharge," available at: http://www.ieua.org/sustain/gw/recharge.html. Southern California Water Committee, Stormwater Task Force, "Stormwater Capture: Opportunities to Increase Water Supplies in Southern California," 2012. Available at: http://socalwater.org/images/SCWC_Stormwater_White_Paper__Case_Studies.Smaller.pdf.

72 For more information see U.S. Environmental Protection Agency, "Water: Clean Water State Revolving Fund: Green Project Reserve," available at: http://water.epa.gov/grants_funding/cwsrf/Green-Project-Reserve.cfm and American Rivers, "Putting Green to Work," 2010. Available at: http://www.americanrivers.org/initiative/stormwater-sewage/projects/funding-green-infrastructure-solutions/.

73 For details on LA's Prop O program, see "Proposition O Background," available at: http://www.lapropo.org/.

indication is that things are heading that way. One important opportunity that these approaches can provide is better cooperation and collaboration between cities and upstream rural communities. Eventually, many predict that robust markets will arise, providing an additional source of income to the rural West.

5 Water Markets

The notion of water markets sparks a more or less perpetual debate. Many see water markets as the ticket to a more rational and efficient allocation of water in the West. Most economists believe that more open markets would allow water to flow smoothly and efficiently to the uses with the greatest societal worth. Freer markets would also create incentives for less wasteful water use by making the economic value of the water a greater factor in decisions by users – a rancher who has the option of selling a portion of his water right is more likely to increase his irrigation efficiency. However, many resist turning over such a critical and public resource as water to a free market.[74]

Although the appropriative water rights system creates property rights to use water, it does not facilitate free and open transfer of those rights. Every western state subjects water rights transfers to considerable oversight, intended to protect other water rights holders, the environment, and local economies. The debate over specific water transfers, and water markets generally, can implicate the very culture of the West, and the conflict between the old and new West, because markets tend to shift water from agricultural uses to growing cities. The sale of water rights by a rancher to a distant city may yield profits for him, but that sale may bring bad economic news for his neighbors, local communities, and businesses. No water means no irrigation. No irrigation means no crops. No crops means no sales of fertilizer, seeds, and tractor parts. If enough ranchers sell their water, the economic scales can tip, and the local economy can crash. Indeed, perhaps the most famous water transaction in the West, the accumulation of Owens Valley water rights by Los Angeles, in fact did destroy an entire community.[75]

We have not resolved this debate in the last 15 years, although we certainly have water markets. In 1998, the Commission report recognized the challenge "to

74 For an extensive discussion of these issues, see T.L. Anderson, et al. "Tapping Water Markets," (2012).

75 Marc Reisner, Cadillac Desert: The American West and Its Disappearing Water, Chapter 5 (1986).

facilitate transfers on the one hand, recognizing the benefits they may produce, and to scrutinize transfers on the other hand, understanding their potential costs to society," but did not provide clear path for resolving these conflicting policy goals.[76] Not much has changed since then. In 2011, the Western Governors' Association (WGA) announced its official policy on water transfers, and recognized the same tension: "Western Governors believe states should identify and promote innovative ways to allow water transfers from agricultural to other uses (including urban, energy and environmental) while avoiding or mitigating damages to agricultural economies and communities."[77] Easier said than done, to be sure.

Western states have not developed any significant legal changes in the past 15 years that address this tension, and many water transfers indeed stir conflict. Despite the static legal landscape, water markets are playing an important role in water allocation in western states, particularly in regions experiencing the most acute shortages or during times of drought. Market participants are finding and using new tools to transfer water while protecting local communities.

Today, the modern administrative system of appropriative rights allows for water rights transfers, but only after jumping through a set of regulatory hoops. In every state, a party must obtain approval of the relevant state agency (or water court, in the case of Colorado) if they wish to change the beneficial use of their water right, the place of withdrawal, the place of use, or the location of return flows.

The state can only approve the transaction if it finds that the sale will result in no injury to other water rights holders, and in some states the proposed sale must also be consistent with the public interest. As a result of this oversight, even noncontroversial transactions can be time consuming and expensive.

Economists have argued that we need to reduce oversight of water transactions in order to allow markets to reallocate water to more valuable and efficient uses, but have been unable to put viable policy options on the table that would actually accomplish this goal. For example, the only suggestion made in the 1998 report that would really oil the wheels of the market was a relatively modest proposal to allow shortcut surrogates (such as irrigated acres) for actual measurements to reduce the amount of time and money spent on determining consumptive use. Western states are simply not ready to give up protections for water rights owners impacted by water markets. Furthermore, the level of scrutiny we

76 1998 Report, pages 6–27 to 6–28.

77 Western Governors Association Policy 11–7 (2011).

give such transactions is well in line with the overall level of government oversight of natural resources and environmental quality.

Despite the lack of major policy reforms, however, water markets are in fact playing an important role in reallocating water in the West. The degree, location, and timing of market activity tend to show that where circumstances put true pressure on water supplies, markets do function to reallocate water uses. A look at the last 15 years shows that while markets are not booming, they are certainly perking along quite nicely.

5.1 Current Status

In 2012, the Western Governors' Association published a report that provides a good, up-to-date review of the current status and importance of water markets in the West.[78] Over the last 25 years, western water markets have remained active, and it is fair to say that water transactions have become commonplace in several western states. The volume of water traded annually has varied from a low of just over 500,000 acre-feet (AF) (in 1988), to highs above 2.5 million AF (a peak reached in 1991, 1994, 2000, and 2005).[79] Volumes of water traded over that period have predictably been higher in more arid and populous states (California leads the way, with 13.3 million AF traded over this period, almost 5 million AF ahead of second place Arizona).[80] Region-wide, the primary buyers for water rights have been municipalities seeking new supply. Purchasers seeking water for energy extraction, agriculture production, and environmental uses have also driven some of the demand on the market.[81]

There are several insights that the overall numbers miss. First, water markets play a vital role for states that face the most critical water shortages. As part of a survey conducted for the WSWC report, New Mexico reported that water transfers are the only remaining method available for obtaining new supplies.[82] In Texas, the volume of water traded in 2011, the first year of the current drought, ballooned to 1.7 million AF, after averaging 150,000 acre-feet per year (AFY) from 2007 to 2009.[83] Similarly, droughts in the late 1980s and late 1990s

78 Western Governors Association, et al., "Water Transfers in the West," (2012).
79 *Ibid*., Figure 1, page 9.
80 *Ibid*., Figures 2 and 3, page 13.
81 *Ibid*., pp. 10–11.
82 *Ibid*., p. 13.
83 *Ibid*., Figure 1, p. 9.

sparked California's water markets (although over the last 10 years markets have remained at high and steady levels).[84] In California, water transfers are the most economical option for obtaining new water, cheaper than both building new storage and desalination.[85]

Second, water markets are at least in significant part driven by local infrastructure and conditions. In California, water markets are enabled by the state's unrivaled network of pipes, pumps, canals, and aqueducts. After growing significantly from 1980 to 2000, markets have remained relatively constant in California, in part because pumping limits imposed on the Bay-Delta system have made it harder to move water from north to south in the state.[86]

Finally, while there have not been any major policy innovations driving water markets in the last 15 years, buyers, sellers, and states have found ways to move water from agricultural to urban users while preserving rural economies. Two major water transfers in Southern California illustrate both the progress in developing water markets and the continuing controversy about their effects on rural irrigation districts.

San Diego, Los Angeles, and three large irrigation districts in Southern California all rely on water diverted from the Colorado River. All totaled, California has historically used approximately 5.2 million AFY of Colorado River water. This water supply is not so much stretched thin as stretched past the breaking point. California is under a mandate to reduce its use of Colorado River water from 5.2 to 4.4 million AFY by first 2015 and then 2025 to comply with the Colorado River Compact.[87] All the while, urban demand in Southern California has continued to grow. For decades, fingers have pointed at the large irrigation districts [Coachella Valley Water District, Palo Verde Irrigation District, and the Imperial Irrigation District (IID)], which use comparatively large amounts of water per acre, in part because of the area's salty soils, and in part because of outdated irrigation practices and infrastructure.

84 Ellen Hanak and Elizabeth Stryjewski, "California's Water Market by the Numbers: Update 2012," p. 19, figure 3 (2012).

85 Ellen Hanak, Jay Lund, Ariel Dinar, Brian Gray, Richard Howitt, Jeffrey Mount, Peter Moyle, and Barton "Buzz" Thompson, "California Water Myths," page 11 (2009).

86 Ellen Hanak and Elizabeth Stryjewski, "California's Water Market by the Numbers: Update 2012," (2012).

87 California Resources Agency, "California's Colorado River Water Use Plan (Draft)," Colorado River Board of California, May 2000. Department of the Interior, "Record of Decision: Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead," Bureau of Reclamation, 2007.

These exigencies have driven the parties to pull off two of the largest water transactions in history.[88,89] Both transactions allow farmers the flexibility of fallowing the least productive fields, freeing up water for urban growth and allowing farmers to focus on the most valuable crops. The Palo Verde deal includes funding for local economic stimulus; the IID includes devoting some conserved water to the restoration of the Salton Sea. Yet both transactions have also been bitterly criticized as condemning local communities to the same fate as the Owens River valley.

These two transactions exemplify the status of water markets today. Where the demand pressure is great enough, and the infrastructure allows it, we can implement impressively complicated water transfers. In the coming years, water markets can be improved through collecting and disseminating better data about transactions, establishing clearer rules about water conservation and water rights forfeiture, and expediting review for similar, recurring transactions.

5.2 Environmental Water Transfers

One market innovation that has taken hold in the last 15 years is that of water rights transactions designed to restore streams and other aquatic ecosystems. These water transfers, called environmental flow transactions, only began to become legally feasible in the late 1980s, make up a meaningful portion of the overall water market in some states. They have played an important role in the protection and restoration of key spawning tributaries for trout and salmon in the Columbia basin, wildlife refuges in California's Central Valley, and other aquatic ecosystems in the western United States. Transaction costs for these types of transfers remain unfortunately high, however, and their future depends on more sustainable and increased funding.

88 The IID transaction was first proposed by San Diego in the early 1980s, and took almost 20 years to negotiate. Even after it was finalized in 2002, it was initially voted down by the IID board of directors. Only after the federal Department of Interior announced that it would reduce the district's allocation of Colorado River water did the board ultimately approve the deal.

89 The Metropolitan Water District (MWD) of Southern California negotiated long-term (35 year) purchases of water from the Palo Verde Irrigation District and IID. The Palo Verde deal involves the transfer of between 35 and 120 thousand AFY, and relies on voluntary fallowing by district farmers. The IID will transfer an average of 300 thousand AFY. This transaction also relies on rotational fallowing, but primarily in the short-term. The MWD is also paying the IID to install improved irrigation equipment and improve the efficiency of its practices.

In 1986, Oregon passed the first statute allowing private entities to purchase or receive as donations water rights that could then be dedicated for instream uses and held in trust by the state. Montana, Colorado, California, Washington, Wyoming, New Mexico and Utah have all also passed statutes creating some type of mechanism for dedicating existing diversionary rights for instream use to protect or restore environmental or recreational values. These statutes vary in their breadth and focus.

In several states, agencies and a variety of NGOs, including several "water trusts," have developed innovative transactions whereby willing sellers or donors can devote some or all of their water rights to the purpose of enhancing aquatic ecosystems.[90] These include permanent transfers of water rights, fixed term leases, irrigation efficiency projects where a portion of the conserved water is left in stream, short-term water transfers, irrigation forbearance agreements, and the use of water banks to allocate water for stream flow. These transactions have played a critical role, particularly where long-term streams of funding are available.

In California, environmental transactions made up 20% of the volume of water traded between 2003 and 2011. Most of these transactions were funded as part of the Central Valley Project Improvement Act's Water Acquisition Program or CalFed's Environmental Water Account. These project-funded transfers tend to be annual purchases of water allocated between streamflows and wildlife refuges. The volume of transactions is thus largely driven by amply funded mitigation programs for large projects.

The Columbia Basin has been the true nursery for environmental water transactions. As part of its compliance with the Endangered Species Act, the Bonneville Power Administration is required to provide funding to restore flow in priority tributaries. The resulting Columbia Basin Water Transaction Program (CBWTP) has disbursed an average of approximately $5 million a year in the Columbia Basin states for environmental water transactions since 2002.[91] A growing community of NGOs have used CBWTP grants to leverage additional funding from state and federal agencies and private donors. Through fiscal year 2011, the CBWTP has supported a total of 53 permanent water rights transfers and well over 200 leases, irrigation forbearance agreements, and other temporary transactions. Over the life of these transactions, these transfers represent a commitment of a total of 5.8 million acre-feet of water.

Although the last 15 years have seen enormous progress in environmental water transactions, this progress has not been spread across the West. Many

90 For example see www.thefreshwatertrust.org, www.washingtonwatertrust.org, www.coloradowatertrust.org, and www.scottwatertrust.org.

91 Administered by the National Fish and Wildlife Foundation.

states have very limited recognition of instream flow rights.[92] Outside the Columbia Basin states and California, flow transactions have been sparse.[93] Even California and the Columbia basin, which have witnessed the largest number of environmental water transfers, transaction costs can be very high.[94]

It will take time, hard work, and in some states new laws and policies to lower transaction costs, reduce approval time, and spread the use of environmental water transactions across a broader swath of the West. The most important factor in the future growth of voluntary water rights transfers for flow restoration, however, is sustainable funding.

6 Water-Energy Nexus

Within the last decade, a conversation has emerged that begins with two basic observations: it takes water to produce energy and it takes energy to move and treat water. This conversation has especially resonated in the western US, because the region is almost as well known for its rich and diverse energy resources as for its scarcity of water.[95]

The field of integrated water-energy studies was established in 1994,[96] but research and public discourse on this topic was still nascent in the late 1990s and garnered no mention in the 1998 Commission Report. It was not until the publication of several studies by the California Energy Commission and Sandia National Laboratory in the mid-2000s that this issue became prevalent in discussions about water and energy management.[97] While emerging, regulatory and operational innovation,

92 Idaho's program is limited to the use of water banks in one river basin. Wyoming law has barely recognized instream flow rights, and has seen only one transaction. New Mexico's program is limited to a water bank with the purpose of restoring endangered species and complying with interstate water compacts.

93 In Colorado, which fully recognizes instream flow rights, transactions have been severely limited by an exacting approval process that drives up transaction costs and uncertainty.

94 A recent study of transaction costs for the CBWTP showed that they varied widely and unpredictably, from lows of less than $200 an acre/foot to a high of $1500 an acre/foot.

95 While there have been a number of thoughtful publications on this subject, the most recent comprehensive review focused on the Western US is by Douglas S. Kenney and Robert Wilkinson, "The Water-Energy Nexus in the American West," *Edward Elgar Publishing* (2011).

96 Peter Gleick, "Water and Energy," *Annual Review of Energy and the Environment* 19 (1994), 267–299.

97 Gary Klein, Martha Krebs, Valerie Hall, Terry O'Brien, and B.B. Blevins, "California's Water-Energy Relationship," *California Energy Commission* (2005). Ron Pate, Mike Hightower, Chris Cameron, and Wayne Einfeld, "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources," Sandia National Laboratories Report, No. SAND 2007-1349C (2007).

as well as interdisciplinary research to explore the potential benefits of integrated water-energy resource management, are still largely a promise rather than reality.[98]

6.1 Energy Use in the Water Sector

Depending upon where you live, moving, treating, and heating water uses between 4 and 18% of regional electricity and as much of 30% of natural gas. In the western United States, one of the main energy demands of the water sector is transporting water long distances from its source to its end use. At 8.35 pounds per gallon, the weight of water requires a significant amount of energy to lift. For instance, to meet Southern California's demands, water is pumped through 3000 miles of pipelines, tunnels and canals,[99] and some of it is pumped more than 3000 feet in elevation over the Tehachapi mountain range.[100] This energy cost of transporting water is not limited to cities. Irrigation water in the Columbia River basin must be pumped several hundred feet up the canyon wall from behind Grand Coulee Dam to irrigate farmland through 5800 miles of canals, drains and waterways in the arid region of eastern Washington.[101] When energy was cheap and plentiful, these costs were easier to ignore, but with tightening supplies and increased concerns about carbon emissions, the energy intensity of transporting water long distances has become a significant question of energy as well as water management.

Of course, conveyance is not the only source of energy demand imbedded in water. Estimates from numerous studies suggest that water supply treatment consumes 0.8% of the nation's energy.[102] With calls for more advanced treatment

98 Water in the West, "Water and Energy Nexus: A Literature Review," Stanford University (2013).
99 Jennifer Stokes and Arpad Horvath, "Energy and Air Emission Effects of Water Supply." *Environmental Science & Technology* 43 no. 8 (2009), 2680–2687.
100 Gary Klein, Martha Krebs, Valerie Hall, Terry O'Brien, and B.B. Blevins, "California's Water-Energy Relationship," *California Energy Commission* (2005).
101 Gary Wolff, Ronnie Cohen, and Barry Nelson, "Energy Down the Drain: The Hidden Costs of California's Water Supply," *Natural Resources Defense Council* (2004).
102 Franklin Burton, "Water and Wastewater Industries: Characteristics and Energy Management Opportunities," *Electric Power Research Institute* (1996). B. Appelbaum, R. Goldstein, and W. Smith, "Water & Sustainability: U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century," *Electric Power Research Institute* (2002). Gary Klein, Martha Krebs, Valerie Hall, Terry O'Brien, and B.B. Blevins, "California's Water-Energy Relationship," *California Energy Commission* (2005). Bill Bennett, Laurie Park, and Robert Wilkinson, "Embedded Energy in Water Studies, Study 1: Statewide and Regional Water-Energy Relationship," *California Public Utilities Commission* (2010). Bill Bennett, Laurie Park, and Robert Wilkinson, "Embedded Energy in Water Studies, Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles," *California Public Utilities Commission* (2010).

of contaminants of emerging concern (e.g., pharmaceuticals and pesticides), the energy intensity of water treatment could increase. Cities throughout the West are reducing energy use through more water efficient infrastructure and calls for water conservation among end users, but because it has proven difficult to measure the amount of energy saved through water savings, utilities have not been sufficiently credited for their efforts.

In addition to energy savings linked to best management practices and system optimization, substantial amounts of energy could be extracted from wastewater itself. Many researchers are exploring emerging technologies for producing energy from wastewater processing.[103] The Inland Empire Utilities Agency in California already operates a wastewater treatment system with several anaerobic digesters that process 65 million gallons of wastewater into high-quality recycled water and biogas.[104]

Groundwater provides up to 30% of total water supply across the West. But groundwater pumping is energy intensive; one study done for the California Public Utilities Commission reported that the monthly electricity requirements of groundwater pumping in California exceed those of the state's water conveyance system at the peak of the summer.[105] Exacerbating the energy demands of groundwater pumping is the fact that as aquifer levels decline, more energy is needed to pump water from greater depths.[106]

Desalination, another alternative water source, is perennially debated, but it is still currently one of the most expensive water sources due to its energy demand.[107] Over time, new technologies, such as membrane filters that require less energy to push seawater through, have emerged to make desalination a bit more competitive. But in order for desalination to be a viable option, the price of water must be high enough. For the US, water pricing is subsidized by the government and does not reflect actual costs of supply, even as other utilities such as electricity have increased costs. Many have argued that because of the large

103 The National Science Foundation is funding an engineering research center, Reinventing the Nation's Urban Water Infrastructure (ReNUWIt) For more information see www.urbanwater.org.
104 Gary Klein, Martha Krebs, Valerie Hall, Terry O'Brien, and B.B. Blevins, "California's Water–Energy Relationship," *California Energy Commission* (2005).
105 Bill Bennett, Laurie Park, and Robert Wilkinson, "Embedded Energy in Water Studies, Study 1: Statewide and Regional Water-Energy Relationship," *California Public Utilities Commission* (2010).
106 Many groundwater aquifers are being depleted, e.g., Ogallala Great Plains Aquifer, Central Valley aquifers, Paso Robles aquifer.
107 Heather Cooley, Peter Gleick, and Gary Wolff, "Desalination, With a Grain of Salt: A California Perspective," *Pacific Institute* (2006). Gary Klein, Martha Krebs, Valerie Hall, Terry O'Brien, and B.B. Blevins, "California's Water–Energy Relationship." *California Energy Commission* (2005).

energy and environmental costs of desalination plants (i.e., brine disposal), other more cost-effective options should be pursued first, such as wastewater recycling and reuse, water transfers, and conservation and efficiency.[108]

The Congressional Research Service recently released two reports on the water and energy nexus highlighting the interest among federal decision-makers in this burgeoning topic.[109] California is continuing to lead the way to develop measures to lower the energy intensity of the state's water supplies driven by the state's climate change legislation – AB32, the Global Warming Solutions Act of 2006.[110] The California Public Utilities Commission is also examining the possibility of allowing for the investment of future energy-efficiency program dollars to reduce the energy embedded in the state's water supplies through projects to save water and energy in the water utility and end user sectors.[111]

6.2 Water Use in the Energy Sector

Energy production has been a major part of the western economy for the past 100 years – oil production in Texas and California, coal mining in Montana and Wyoming, hydropower in the Columbia and Colorado River basins, uranium mining in Arizona. Each of these processes requires a significant amount of water, putting those uses in competition with agriculture, cities, and the environment, among others.

While the connections are not new, the energy sector has changed and grown since the 1990s, particularly with new technologies in natural gas and renewable energy. These new areas of activity, along with the traditional ones, are placing greater burdens on the region's water supplies.

The dramatic rise in domestic production of natural gas in states such as Colorado, Utah, and Wyoming is the result of exploiting deep shale deposits that were not previously considered economically recoverable. Natural gas extraction

108 *Ibid*.

109 Claudia Copeland, "Energy-Water Nexus: The Water Sector's Energy Use," *Congressional Research Service* (2013). Nicole T. Carter, "Energy-Water Nexus: The Energy Sector's Water Use," *Congressional Research Service* (2013).

110 GEI, "Water-Energy Nexus Research: Recommendations for Future Opportunities," *GEI Consultants* (2013). Kelly Twomey Sanders and Michael E. Webber, "Evaluating the Energy Consumed for Water use in the United States." *Environmental Resources Letters* 7 no. 3 (2012).

111 Bill Bennett, Laurie Park, and Robert Wilkinson, "Embedded Energy in Water Studies, Study 1: Statewide and Regional Water-Energy Relationship," *California Public Utilities Commission* (2010). GEI, "Water-Energy Nexus Research: Recommendations for Future Opportunities," *GEI Consultants* (2013).

has changed dramatically with development of a new technology known as directional drilling, used in conjunction with hydraulic fracturing. Drilling and processing natural gas requires significant inputs of water and produces polluted water as a byproduct. Significant controversy has arisen from produced water, the use of hydraulic fracturing (or fracking) fluids, and limited water availability, leading to conflict around contamination of domestic wells and impacted streams, and sharp competition for scarce water supplies.[112] The U.S. Environmental Protection Agency is studying how to address impacts, but its hands are tied to a great extent, because the Energy Policy Act of 2005 excludes hydraulic fracturing (except diesel fuel) from regulation under the Safe Drinking Water Act.[113] There is also broad tension between the states and federal government about where authority lies for regulating natural gas development on public lands.

In addition to natural gas, the renewable energy field has grown tremendously since the late 1990s, spurred by federal government incentives and mandates as well as a growing demand among consumers. The federal government, led by the Bureau of Land Management (BLM), has conducted a large-scale study of the American West looking at the suitability of public lands for large-scale solar energy production. This is particularly important given the water intensity of solar thermal power plants, which use the sun to make steam and power a generator in much the same way as fossil fuels. To facilitate permitting while protecting sensitive places, the BLM also identified areas where development is not advised. This evaluation includes assessment of water resources.[114] Sandia National Laboratory, in cooperation with the Western Governors' Association, has been exploring the intersection of western water resources, energy generation potential, and transmission siting.[115] The result of this effort is similarly designed to help states and federal agencies plan for energy and water management.

In the plains states, production of ethanol has become another important nexus between water and energy. The demand for biofuels has risen sharply due

112 Robert W. Howarth, Anthony Ingraffea, and Terry Engelder, "Natural gas: Should fracking stop?" *Nature* 477 (2011), 271–275; Environmental Protection Agency, "EPA's Study on Hydraulic Fracturing and its Potential Impact on Drinking Water Resources," available at: http://www2.epa.gov/hfstudy.

113 Mary Tiemann and Adam Vann, "Hydraulic Fracturing and Safe Drinking Water Act Regulatory Issues," Congressional Research Service, 2013. http://www.fas.org/sgp/crs/misc/R41760.pdf.

114 U.S. Bureau of Land Management, "Solar Energy Development Programmatic EIS" http://solareis.anl.gov/documents/index.cfm.

115 Sandia National Laboratories, "Energy and Water in the Western and Texas Interconnects" http://energy.sandia.gov/?page_id=1741.

to federal mandates and production incentives. The water intensity of biofuels is significantly greater in areas requiring irrigation, raising questions about its future in the West.

Thermoelectric generation is particularly water intensive, but it varies depending upon the type of fuel and technology used. While only a fraction of the total water is used up in the process, the environmental and water supply impacts of both water withdrawals and the quality of returned water is of critical concern. Low water levels in rivers and reservoirs have caused power plants to reduce and halt production in places such as Texas and Arizona.[116] To address concerns, treated wastewater is increasingly used in power plants close to large population areas, such as the 3.3 gigawatt (GW) nuclear power plant in Palo Verde for Phoenix, Ariz. In some places, thermoelectric power plants are largely contributing to the overdraft of rapidly declining aquifers.[117] New technological innovations are leading to the development of dry and hybrid cooling technologies to achieve lower water intensities in power plant operations.[118]

Future energy supply choices are increasingly taking account of water resource constraints in the planning and investment decisions. While water may not be a determinative factor, decisions around everything from natural gas extraction to power plant siting are looking carefully at their water footprints.

7 Advances in Technology and Knowledge

Most water technology has changed little in the past century: it remains a system of pipes and valves, dams and levees, treatment plants and pumps. Household toilets use less water today, but the basic design is recognizable to what has been in use for more than 100 years.

116 U.S. GAO, "Energy-Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Trends in Power Plant Water Use," *U.S. Government Accountability Office* (2009). Kristen Averyt, Jeremy Fisher, Annette Huber-Lee, Aurana Lewis, Jordan MacKnick, Nadia Madden, John Rogers, and Stacy Tellinghuisen, "Freshwater use by U.S. Power Plants: Electricity's Thirst for a Precious Resource," *Union of Concerned Scientists* (2011). Heather Cooley, Julian Fulton, and Peter H. Gleick, "Water for Energy: Future Water Needs for Electricity in the Intermountain West," *Pacific Institute* (2011).

117 William M. Alley, "Tracking U.S. Groundwater: Reserves for the Future?" *Environment* 48 no. 3 (2010), 37–41.

118 Heather Cooley, Julian Fulton, and Peter H. Gleick, "Water for Energy: Future Water Needs for Electricity in the Intermountain West," *Pacific Institute* (2011).

Water technology stands in stark contrast to the extraordinary advances witnessed in computing, communications, and other areas of high tech. Since the mid to late 1990s, when the commission wrote the *Water in the West* report, we have witnessed the emergence of incredible new technologies such as faster and more powerful computers, the internet, geographic information systems (GIS), satellites, and remote sensing. While not created for water management, these advances have independently and synergistically revolutionized our analytic abilities, communications, mapping, data sharing, and monitoring in ways the commissioners could not have imagined within such a short span of time.

As a result of these advances, everything is becoming smaller, cheaper, faster, and more readily available. Computers now enable data collection, storage, and processing that allow water managers to model and operate complex systems. The internet enables sharing of data and information almost instantaneously. Mapping using GIS has changed natural resources management with its powerful graphic and analytical capacities abilities, from determining the least-impactful route for a natural gas pipeline in Colorado to tracking the movements of and dictating responses to large wildfires all over the West.

Emerging remote sensing technologies such as LiDAR, GRACE, and METRIC[119] allow for data collection about water resources to be accomplished from long distances using airplanes and satellites, helping to reduce costs and overcome problems presented by multiple jurisdictions or access to private property. For instance, the entire Lake Tahoe basin in the Sierra Nevada was flown by a plane using LiDAR.[120] The resulting map provides an understanding of the physical and man-made features of the landscape that is second only to a walk over each inch of the basin by foot. The data and maps are being used by planners and other decision-makers to help inform land management policies that influence water quality.

In addition to transformations from the high-tech sector, there are some exciting developments in the traditional water field as well. Advances in irrigation technology, leading to more targeted application from drip irrigation or

119 For more information on these technologies, see University of California, Irvine, "Remote Sensing of Groundwater Depletion using GRACE." http://www.ess.uci.edu/project/2012famiglietti and University of Idaho, "METRIC – Mapping EvapoTranspiration at High Resolution and Internalized Calibration." http://extension.uidaho.edu/kimberly/2013/05/metric-mapping-evapotranspiration-at-high-resolution-and-internalized-calibration/.

120 Open Topography, "Lake Tahoe Basin LiDAR Data Released," (2011). http://www.opentopography.org/index.php/news/detail/lake_tahoe_basin_lidar_data_released.

micro sprinklers, has reduced evapotranspiration and produced large water savings, particularly in the agriculture sector.[121] Because agriculture constitutes around 80–90% of the total water demand in the West, efficiency frees up water for other uses.[122]

Great strides in water efficiency also have been made in cities over the past decade.[123] Despite more people living in cities, per capita water use has been in decline due to efficiency stemming from advances in what might be called "low-tech" solutions. For instance, the city of Los Angeles uses the same amount of water today as it did in 1980s, while at the same time adding 1 million new residents.[124] Water districts all over the West have also increased funding for and demonstrated success with turf "buy-back" programs to incentive landscape conversions to less thirsty plants. Cities like Las Vegas, Phoenix and Tucson have, through necessity, wholly embraced the return to desert landscaping.[125]

Recycled water is the next cheapest option for "new" water supplies after efficiency. While water recycling and reuse were strategies encouraged by the 1998 report, they have become more widely implemented, particularly in water-scarce areas that are reliant on uncertain or shrinking water supplies. Over the past decade, southern California has become a leader in recycling water.[126] Orange County treated wastewater is recycled and injected into the local aquifer, to be pumped back up with

121 Glenn Schaible and Marcel Aillery, "Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emergy Demands," *U.S. Department of Agriculture, Economic Information Bulletin* no. 99, (2012), 67.

122 Whether this conserved water will be used for the expansion of croplands or transferred to meet growing demands for urban use or instream environmental flows is case specific. In west Kansas, it was found that a switch from flood to center pivot irrigation resulted in an average of 13% expansion in irrigated acreage. See http://www.agmanager.info/policy/water/Peterson-K_State_report_final.pdf.

123 An example is toilets, which encompassed nearly 30% of total indoor water use in a home. Toilets used up to 3.5 gallons per flush in the early 1990s, but that dropped to 1.6 gallons as mandated by the Energy Policy Act in 1992; now high efficiency models use 1.28 gallons.

124 Antonio Villaraigosa, "Securing L.A.'s Water Supply," 2008. http://mayor.lacity.org/stellent/groups/ElectedOfficials/@MYR_CH_Contributor/documents/Contributor_Web_Content/LACITY_004714.pdf.

125 About 70% of residential demand for water goes to outdoor irrigation in Las Vegas. Ellen Hanak and Matthew Davis, "Lawns and Water Demand in California," *Public Policy Institute of California* (2006). http://www.ppic.org/content/pubs/cep/ep_706ehep.pdf.

126 Most of the water for southern California is imported over long distances from the Sierra Nevada Mountains and the Colorado River. Because future imported supplies are likely to get cut through Bay Delta issues and Colorado River shortages, S. California has been trying to ease its dependence on imported water.

groundwater for drinking water. Direct potable reuse,[127] which would eliminate the aquifer injection, would be more efficient, but faces public perception challenges.

Exciting new wastewater treatment technologies are emerging due to energy, environmental, and human health concerns. From an energy standpoint, microbial fuel cells have been successfully demonstrated in the lab whereby bacteria breaking down sewage also generate electricity.[128] Effective scaling-up of these microbial processes will replace traditional steps in the wastewater treatment process and help to power wastewater treatment plants. To date, these new technologies have not advanced far from the lab; it will be a while before they can be used operationally in wastewater treatment plants.

One area that is likely to garner much more attention in the near future is the need to treat non-traditional water pollutants. Known as contaminants of emerging concern (CECs), these pollutants include pharmaceuticals, agricultural antibiotics, and some pesticides that have been linked to cancers and endocrine disruption. Traditional wastewater and water treatment plants are not designed to remove CECs so research is now focused on new approaches. Recognizing the need to address CECs, the new cutting edge Silicon Valley Advanced Water Purification Center will use UV disinfection and oxidation through hydrogen peroxide.

Many promising new technologies have emerged from the oil and gas industry to help groundwater managers better understand and quantify aquifers in less costly and intrusive ways. Traditional data collection required drilling new wells but new technologies such as large-scale airborne data collection allow us to map changes in the Earth's surface, better defining groundwater basins and deriving more accurate estimates of groundwater volumes. New geophysical techniques are also being used to capture spatial heterogeneity over the landscape to develop more effective plans and sampling strategies, and to site wells properly. For instance, real time kinematic (RTK) – GPS is currently being use to measure subsidence in the Kings River Conservation District in the Central Valley of California.[129] Nuclear magnetic resonance is another powerful technique used to better understand aquifer properties being applied in the Ogallala aquifer in Nebraska to develop an interactive surface and groundwater model.

---

127 Direct potable reuse (DPR) is defined as the process of treating wastewater to drinkable standards and returning it directly to the potable water distribution system. Singapore relies upon DPR for some of its supply. See https://www.watereuse.org/product/direct-potable-reuse-path-forward.

128 Xing Xie, Meng Ye, Po-Chun Hsu, Nian Liu, Craig S. Criddle, and Yi Cui, "Microbial Battery for Efficient Energy Recovery," *Proceedings of the National Academy of Sciences* 110 (2013), 40.

129 Water in the West, "Uncommon Dialogue: Advances in Technology in Support of California's Groundwater Management," April 20, 2012, Stanford University.

In general, additional funding for research into creating water technologies and innovations is needed. Water is priced so low that there is insufficient research capital available from either government or industry. To illustrate this problem, the Water Environment Research Foundation spends $11M per year on research while the Electric Power Research Institute spends well over $250M annually. For the same reason, there is little incentive to adopt expensive technologies that improve efficiency, whether through use, better information, or improved decision-making. Better technologies can only spread in conjunction with policies (or market pricing mechanisms) that drive efficiency.

Requirements for monitoring, data collection, and dissemination are needed. Better collaboration and cooperation should be facilitated. In addition, there must be greater incentives for risk adverse water managers to take risks with experimental technologies. Testing new technologies must take place at a scale sufficient to make them believable.

8 Water Infrastructure Financing

One question that never loses its relevance in the world of western water is how to pay for it. The earliest European settlement of the region involved mostly local financing of water resource projects, best exemplified by the efforts of the Mormon Church in Utah. Starting in the late 1840s, the Mormon Church built dams in the Wasatch Mountains for water storage and canals to convey the snowmelt to the lowlands. [130] This was followed by a period of rather intensive investment by the federal government in large water reclamation and flood control projects between 1930 and 1970. The passage of the federal Clean Water Act in 1972 prompted the federal government to make another significant contribution, this time to wastewater and drinking water treatment infrastructure. Since that time, federal investments in large water projects have waned and support for wastewater and drinking water utilities is becoming more limited.[131] Throughout, state funding for water projects for the most part was limited. Today, funding for western water has circled back and is now again primarily reliant upon local sources of funding for water management and infrastructure.

The time and cost of building water infrastructure projects has grown tremendously over time. The Hoover Dam, constructed in 1935, cost $49 million

130 Alan A. Lew, "Geography: USA," Chapter 9 – The Mountain West and Southwest, 2004. Available at: http://www.geog.nau.edu/courses/alew/gsp220/text/chapters/ch9.html.
131 U.S. Environmental Protection Agency, "How the Clean Water State Revolving Fund Program Works." http://water.epa.gov/grants_funding/cwsrf/basics.cfm.

(roughly $800M with inflation) and was completed in only 2 years, while just the environmental impact statement for a proposed water pipeline project in the Sacramento Delta cost more than $250 million and 6 years to complete.[132] The tremendous expense of new infrastructure has contributed to a decline in new projects, leading to deterioration in the condition of water infrastructure in the West and much of the country. The American Society of Civil Engineers has given the nation's water infrastructure a grade of D+.[133] The Environmental Protection Agency quantifies the investment gap in drinking and wastewater infrastructure at $540 billion nation wide.[134] Regionally, there are increasingly vocal calls for collaboration and leadership to address the problem.[135]

While the era of big federal western water infrastructure projects has passed, some high profile projects continue to be proposed, drawing controversy and questions about funding. As discussed above, water transfers require water infrastructure, and large pipelines facilitating interbasin transfers of water have been proposed for a number of places throughout the region: the Colorado River to St. George, Utah; Spring Valley, NV to Las Vegas, Nevada; the Sacramento River beneath the Delta; and the Flaming Gorge Reservoir to Colorado's Front Range. Fierce debates have raged about the costs and benefits of these projects and whether taxpayers should shoulder any of the burdens. New dam projects or dam enlargements continue to be proposed in places across the West, though at a far lower rate than in previous decades.[136] The state of Idaho is even considering

132 David Moore, "The Hoover Dam: A World Renowned Concrete Monument," (1999). http://www.romanconcrete.com/docs/hooverdam/hooverdam.htm.

133 American Society of Civil Engineers, "2013 Report Card on America's Infrastructure." http://www.infrastructurereportcard.org.

134 "State and local governments have spent $1.1 trillion since the 1960s on water and wastewater infrastructure, with an additional $140 billion federal investment, but EPA's 2002 analysis identifies a current need of $540 billion." Steve Allbee, EPA Gap Analysis Program Director, November 2010, from Western States Water Council Report, "Western Water Resources Infrastructure Strategies: Identifying, Prioritizing and Financing Needs" (2011).

135 Western States Water Council, "Western Water Resources Infrastructure Strategies: Identifying, Prioritizing, and Financing Needs," 2011. http://www.westgov.org/wswc/infrastructure%20report_final_lowresolution.pdf.

136 California Department of Water Resources, "Shasta Lake Water Resources Investigation." http://www.water.ca.gov/storage/shasta/ Kelly Zito, "Water Interests Argue New State Dam Proposals," September 29, 2009, San Francisco Chronicle. http://www.sfgate.com/green/article/Water-interests-argue-new-state-dam-proposals-3215200.php. Texas Water Development Board, "2012 State Water Plan" (2012), available at http://www.twdb.state.tx.us/waterplanning/swp/2012/index.asp. WendeeHotcamp, "Texas Thirst for Dams Bucks National Trend," August 4, 2011, Pacific Standard Magazine.http://www.psmag.com/environment/texas-thirst-for-dams-bucks-national-trend-34541/.

reconstruction of the Teton Dam, which famously and catastrophically failed in 1976.[137] More common are multi-dimensional projects involving enhancement of water supplies and ecological restoration. Efforts like the Yakima River project in Washington State enjoy diverse local political support and are often able to justify their substantial costs by touting non-market ecological restoration benefits. Nevertheless, they are confronting the stark realities of limited public funding to meet all of their goals.[138]

Unfortunately, aging infrastructure is occurring simultaneously with substantial resistance among the public to any increases in government spending and taxation, including water rates.[139] Numerous water utilities in Las Vegas, Denver, San Francisco, and Seattle have imposed significant rate increases over the past several years, driven at least in part by the success of their conservation programs. With consumers using less water, and the fixed costs of infrastructure remaining constant or rising, utilities must find ways to increase revenues to remain solvent.[140] With some utilities unable or afraid to propose rate increases, funding has become increasingly inadequate to meet basic operations, not to mention capital replacement. While most water infrastructure in the West is not as old as its eastern counterparts, this lack of investment is likely to catch up with the region in the next 20 years.

States like California and Texas continue to fund some water infrastructure projects through general obligation bonds and direct appropriations, but these efforts are becoming more and more difficult. Other states such as Wyoming are using revenues from more lucrative enterprises such as energy development to help support water projects.[141]

137 U.S. Bureau of Reclamation, "The Failure of Teton Dam," Pacific Northwest Region. http://www.usbr.gov/pn/about/Teton.html.

138 Steve Malloch and Michael Garrity, "Yakima River Basin Plan: Strange Bedfellows Take Risks and Find Common Ground," The Water Report, Issue 106, December 15, 2012. U.S. Geological Survey, "Yakima River Basin," USGS Washington Water Science Center. http://wa.water.usgs.gov/projects/yakimagw/.

139 In California, a $11.14 billion water bond was first proposed for state water supply and restoration efforts for the 2010 ballot, pushed back to the 2012 ballot, and ultimately removed. Proponents will try again in 2014. Association of California Water Agencies, "2014 Water Bond." More information at http://www.acwa.com/spotlight/2014-water-bond.

140 Alliance for Water Efficiency, "Conservation Oriented Rate Structures." Available at: http://www.allianceforwaterefficiency.org/1Column.aspx?id=712.

141 The Wyoming Water Development Commission and Program is funded by state mineral severance taxes. Sue Lowry, "Wyoming Water Development Program," presented to Western States Water Council on Infrastructure Needs and Strategies, November 14, 2012, Wyoming State Engineer's Office. Available online at: http://www.westernstateswater.org/wp-content/uploads/2012/11/Lowry.pdf.

With increasingly limited government funding for water infrastructure, some jurisdictions are increasingly turning toward the private sector for financing. Public private partnerships (P3s) are a way in which private capital and expertise is used to facilitate needed facility upgrades. While P3s may resolve the problem of ready access to capital, the jurisdiction must still pay back those loans, and that usually means raising rates. Privatization of water infrastructure remains relatively rare in the West, although cooperative arrangements are beginning to arise in some jurisdictions.[142] In one of the most prominent examples to date, the City of Stockton privatized their water systems (water, wastewater, and storm-water) in a $600M, 20-year deal in 2003 with a multinational company, but 4 years later, the city decided to withdraw from the contract because of numerous issues, the most prominent of which was strong public opposition to the privatization of a public good.[143]

Some say the West is not running out of water, just cheap water. As water becomes scarce and as the infrastructure necessary to acquire and deliver that water must be maintained and replaced, the cost of water will climb. Water managers will have to be thoughtful about the choices they make about which infrastructure to fund and consumers ultimately will have to pay more for the water that they use. This will present a growing economic and political challenge for the western region.

9 Conclusion

It has been said that the more things change, the more they stay the same. Those who follow discussions about western water have witnessed some significant changes over the past two decades, including the central importance of climate change. Still, subjects like governance and finance remind us that change is hard to achieve. While new inventions and policies regularly arise, promising new opportunities for more sustainable management of water, it is political will that

142 The city of Cle Elum, Washington, has had a public-private partnership with Veolia Water since 2003 for the operation of its wastewater treatment facility. City of Cle Elum, Washington, "Wastewater Treatment Plant." http://www.cityofcleelum.com/publicworks/wastewater.asp.

143 Craig Anthony, "Water Privatization Trends in the United States: Human Rights, National Security, and Public Stewardship," *William and Marry Environmental Law and Policy Review* 33 no. 3, (2009), 785. http://scholarship.law.wm.edu/cgi/viewcontent.cgi?article=1027&context=wmelpr. Angela Godwin, "Show Me the Money: Options for Meeting Water Infrastructure Funding Needs," Waterworld Magazine 28:10. Available at: http://www.waterworld.com/articles/print/volume-28/issue-10/editorial-features/show-me-the-money-options-infrastructure-funding.html.

is actually in the shortest supply. We have more than enough information, technology, and expertise to start implementing the recommendations in this paper. But we need the political leadership.

Undoubtedly, two decades from now, people will still be having conversations about many of the same issues we have touched upon in this paper. They will also be discussing subjects we have not even considered. But faced with the imperative that water is vital to all life on earth, there is no doubt that many more conversations will take place.