Planning for America's Water Infrastructure Needs

Consensus document from an interdisciplinary workshop at Stanford University

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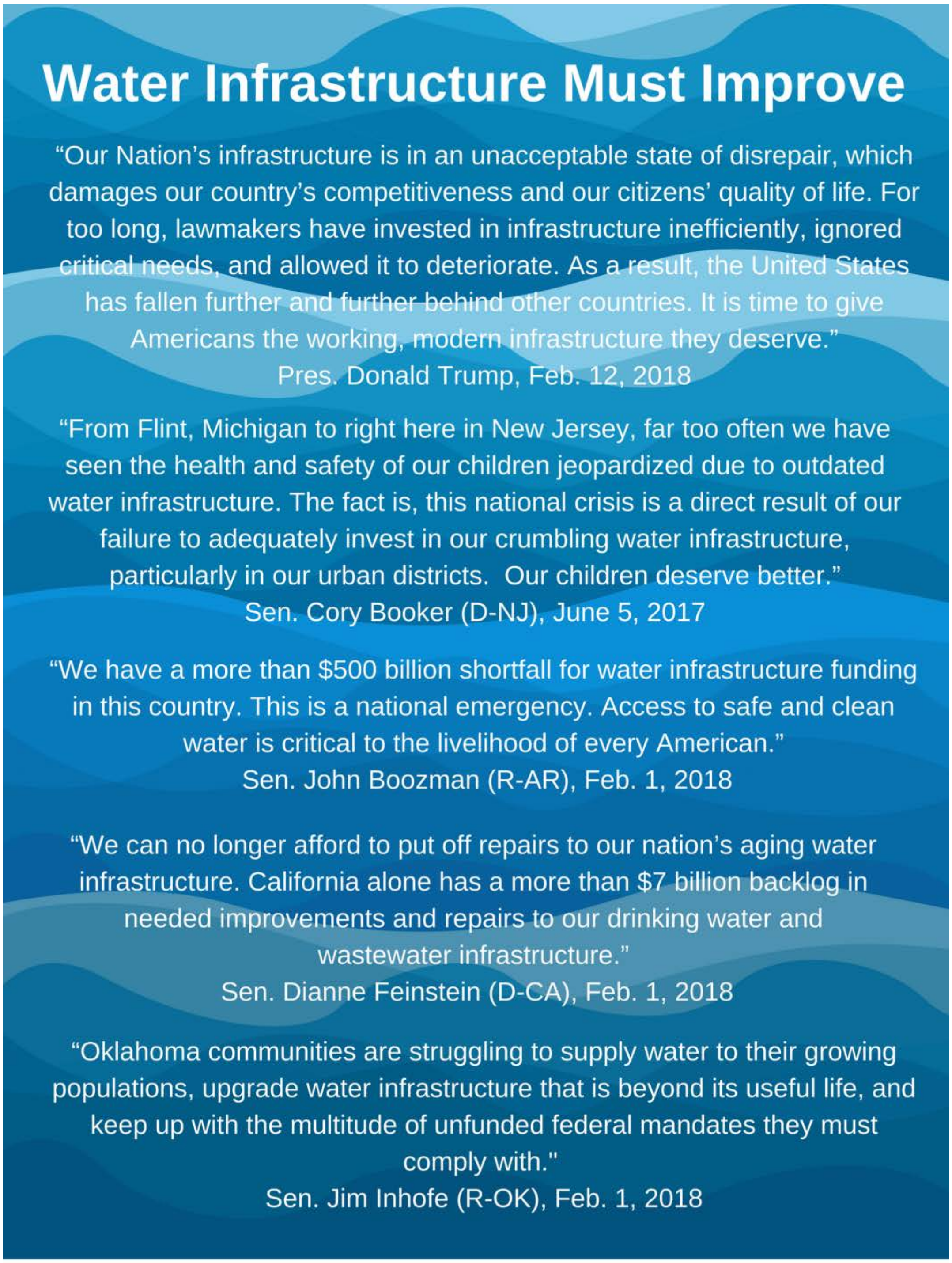
Water in the West



Sources for the Graphic: THE PRESIDENT OF THE U.S., FRAMEWORK FOR REBUILDING INFRASTRUCTURE IN AMERICA, H.R. DOC. NO. 115-95, at 1 (Feb. 12, 2018); Press Release, Sen. Cory Booker, Booker, Gottheimer Announce Legislation Ensuring Safe Drinking Water in Schools (June 5, 2017), https://www.booker.senate.gov/?p=press_release&id=611; Press Release, Sen. John Boozman, Boozman, Booker, Inhofe, and Feinstein Introduce Water Infrastructure Investment Reform Legislation (Feb. 1, 2018), https://www.boozman.senate.gov/public/index.cfm/press-releases?ID=5DEC61E7-6C6C-44B1-AFA6-09349661D012; Press Release, Sen. Dianne Feinstein, Senators Introduce Bipartisan Water Infrastructure Reform Legislation (Feb. 1, 2018), https://www.feinstein.senate.gov/public/index.cfm/press-releases?id=6646BCE2-B4AB-4263-B98A-CC9E4A366388 (containing Sen. Feinstein's and Sen. Inhofe's statement).

EXECUTIVE SUMMARY

One of the many challenges facing the United States today is the need for effective, reliable water infrastructure. The stakes are high: without water to drink, people die. Without waterways to navigate, commerce shrivels. Without mechanisms to constrain water, water-related natural disasters destroy communities. A modern water infrastructure system is therefore necessary to promote individual and social welfare. The question is how to develop it. Water managers—those who create and institute water policy at the federal, state, and local level—face a plethora of challenges, many of which are unique to their management area.

The "Planning for America's Water Infrastructure Needs" Conference in February 2018 discussed many of those needs. This paper is based on the ideas participants discussed at the conference, namely the five challenges that all water managers face and three particular water infrastructure issues: the opportunities afforded by considering water systems as "loops," the importance of resiliency in response to climate change, and the reforms in federal, state, and private funding mechanisms that can facilitate water infrastructure financing.

Water managers face five common challenges. The first is funding. Updating water infrastructure requires funding from a number of sources—federal, state, and local government, as well as private investors. The second is leadership. Leaders are necessary to gather stakeholders, set goals, and establish priorities. The third is modern and streamlined investment procedures that minimize cost and reduce delay. The fourth is education. Unless the public understands the importance of water infrastructure and its impact on their quality of life, voters will not provide the sustained support necessary for adequate funding over time. The final aspect is interconnectivity. Water systems are connected. Changes in one area affect another. Water managers must keep that connectivity in mind when setting policy.

Interconnectivity also matters in managing water systems as loops—as structures that affect each other. First, there is a localized water use loop. Utilizing decentralized infrastructure, it is possible to move away from a linear view of water supply—taking water from its source, piping it to consumers, and then disposing of the water—to a paradigm that collects water, stores it for use, uses it efficiently, and then recycles it. The result: augmented water supplies and a number of other benefits.

The second loop is that of water management. Water infrastructure projects exist within a system, whether at a regional level, watershed level, or multi-watershed level, with each level encompassing lower ones. Each project is connected to the system and, thus, each project is connected to all the others—like a loop. As a result, a project has effects across the system. Part of effective management is controlling those ripple effects to create an intelligent and coherent water system.

Effective management also creates an information-sharing process, such as a bottom-up/top-down propagation of water infrastructure solutions. There, data from infrastructure experiments at lower system levels make their way up the different management loops. Higher loop managers then send the solutions back down to other, lower loops. The transfer takes advantage of the interconnectivity of water systems and results in wider uptake of infrastructure solutions and better infrastructure overall.

Climate change provides an example of how the bottom-up/top-down model would work. Climate change poses the challenges of extremes and uncertainty. The changing climate increases the chance of extreme weather events. It is uncertain, however, what types of extreme weather event will occur and how extreme they will be. One response to climate change is to make infrastructure more resilient. Resilient infrastructure creates systems that can withstand most extreme events but are flexible enough to mitigate damage if there are project failures; the structures fail gracefully, not uncontrollably, thereby protecting the system from total failure.

Moreover, as different areas of water management develop infrastructure responses to climate change, they can take advantage of information sharing. The process can disseminate infrastructure solutions across all water systems. Sharing solutions increases the odds that water infrastructure weathers the challenges of climate change.

Finally, dealing with climate change, reforming water management, and rethinking water infrastructure all require funding from every level of government. That requires considering significant reforms to federal financing policies and procedures. Reform can include, for example, an increased focus on funding new projects and a streamlined project approval process.

Funding can also come from private investors. Public-private partnerships (P3s), which combine government and private investment, can fund numerous different projects. They are cooperative financing vehicles, the ultimate form of the vehicle depending on the need and the circumstance. As a result, there are a number of different ways to structure P3 financings so as to ensure the most effective financing vehicle possible.

There are many different reforms, challenges, and ideas that water managers must address to ensure that America has a 21st Century water infrastructure. The challenges range from the concrete and the specific—climate change or financing vehicles—to the broad and the abstract—rethinking water management and infrastructure investment concepts. There is much to do. The ideas this paper contains are just a start. The goal is to realize and to build upon them.

CONTENTS

RETHINKING WATER INFRASTRUCTURE: FIVE COMMON CHALLENGES*

Water is critical because it sustains all life, the environment, and the economy. It has shaped the nation, and the nation has, in turn, shaped water. Dams, canals, reservoirs, and aqueducts crisscross the U.S., transporting water from areas of plenty to areas of scarcity.

That water infrastructure needs modernization. The American Society of Civil Engineers gives U.S. water-related infrastructure grades ranging from D's to C+'s.[1] The issues are legion: inland waterways, on which $229 billion of cargo moves, use locks and dams "well beyond their 50-year design."[2] The average dam is 56 years old, and about 15,500 dams have "high-hazard potential."[3] Pipes carrying drinking water have up to a 100-year lifespan, but they must last the estimated 200 years it will take to replace them.[4]

Modernization is expensive, but the cost of not modernizing is higher. For example, last year, heavy rain filled the Oroville Dam in California to its brim.[5] Normally, the dam would release water through a spillway to regulate water levels. However, the main spillway suffered from erosion, thus reducing the amount of water it could contain.[6] Officials turned to an emergency spillway—for the first time in the dam's 48-year existence—only to find that it, too, was eroding.[7] The cost of the erosion was high: 200,000 people had to evacuate[8] as "millions of gallons of uncontrolled water" poured into the Feather River.[9] Officials are still calculating the repair costs; the current estimate is $875 million.[10] Proper investment and maintenance could have prevented the disaster for a lower cost than just reacting to the crisis.[11] Oroville, as the chart below shows, is just one example.

* Many propositions and anecdotes presented here were referenced at the Conference. Footnotes are for instances where extra research was necessary and for data citations.

1 *Id.* at 6.

2 ASCE, INFRASTRUCTURE REPORT CARD: A COMPREHENSIVE ASSESSMENT OF AMERICA'S INFRASTRUCTURE 54-55 (2017).

3 *Id.* at 30-31.

4 *Id.* at 36-37.

5 Geoff McGhee, *Days that Nearly Brought Disaster to the Oroville Dam*, THE BILL LANE CENTER CTR. FOR THE AM. WEST: . . . & THE WEST BLOG (Feb. 14, 2017), https://west.stanford.edu/news/blogs/and-the-west-blog/2017/oroville-dam-graphic.

6 *Id.*

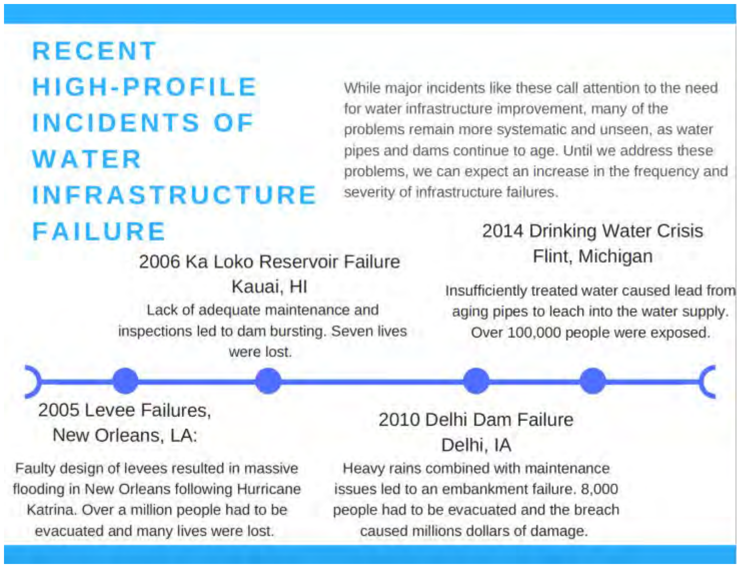
7 *Id.*

8 McGhee, *supra* note 5.

9 Rong-Gon Lin II et al., *Here's the Nightmare Scenario at Oroville Dam that Officials Are Fighting to Prevent*, L.A. TIMES (Feb. 13, 2017), http://www.latimes.com/local/lanow/la-me-ln-oroville-dam-how-20170213-story.html?utm_source=dlvr.it&utm_medium=twitter.

10 Ryan Sabalow & Dale Kasler, *One Year Later: The Crisis at Oroville Dam*, THE SACRAMENTO BEE (Feb. 7, 2017), http://www.sacbee.com/news/local/article198679674.html.

11 *See id.*



Sources for the Graphic: AM. SOC'Y OF CIVIL ENG'RS: HURRICANE KATRINA EXTERNAL REVIEW PANEL, THE NEW ORLEANS HURRICANE PROTECTION SYSTEM: WHAT WENT WRONG AND WHY v-vii, 33-35, 43, (2007); Dustin Goto & Amarjit Singh, *Ka Loko Dam Break*, 2 J. LEG. AFF. & DISP. RES. ENGINEERING CONSTRUCTION 198, 200-02 (2010); Christina Capecchi, *A Dam Gives Way in Iowa and Residents Tally Losses*, N.Y. TIMES (July 25, 2010), https://www.nytimes.com/2010/07/26/us/26iowa.html; Joe DiFazio, *Flint, Michigan, Water Crisis Update: Government Spends Thousands of Dollars Per Day For Bottled Water*, NEWSWEEK (Mar. 14, 2018), http://www.newsweek.com/flint-bottled-water-michigan-lead-flint-water-crisis-844547; *Case Study: Lake Delhi Dam (Iowa, 2010)*, ASS'N OF ST. DAM SAFETY OFFICIALS, http://damfailures.org/case-study/lake-delhi-dam-iowa-2010/ (last visited May 15, 2018).

Modernizing water infrastructure is clearly necessary and will return more than it costs. The issue is that the necessary modernization is not happening. That is not due to a lack of awareness; decision-makers are certainly aware of the need.[12] The problem is creating an environment where solutions can arise. Creating that environment requires overcoming five common challenges that confront all water managers: funding, leadership, investment policies, education, and interconnectedness. Water managers who neglect any of those challenges are likely to see their systems decline, and, depending on the age of their infrastructure and the needs of the communities they serve, may be courting disaster.

1. FUNDING

One thing all can agree on is that the funding shortfall in water infrastructure is immense—amounting to trillions of dollars[13]—and that it is likely impossible to raise the necessary funds from any one source.

That has always been true. Federal funding, for example, has never been sufficient. At its peak, federal funding constituted about 45% of total direct, governmental investment in water infrastructure.[14] Today, federal funding constitutes around 10-15% of total direct investment.[15] The trend is unlikely to change.[16] Despite the Trump Administration's focus on infrastructure

[12] *See, e.g.*, OFFICE OF MGMT. & BUDGET, AMERICA FIRST: A BUDGET BLUEPRINT TO MAKE AMERICA GREAT AGAIN 41 (2018) (saying that the budget provides "robust funding for critical drinking and wastewater infrastructure").
[13] *See* ASCE, *supra* note 2, 32, 37, 56.
[14] *See* CBO, PUBLIC SPENDING ON TRANSPORTATION AND WATER INFRASTRUCTURE, 1956-2014 tbls.W-2, W-6 (2015) [hereinafter PUBLIC SPENDING] (counting expenditures on water resources, water transportation, and water utilities; netting out federal grants).
[15] *Id.*
[16] *See id.*

investment,[17] its suggested level of funding is too low.[18] Similar problems plague state and local financing of water infrastructure.[19]

Gathering the necessary funds will therefore require combining different funding sources. The potential sources are federal, state, and local governments and the private sector. Combining them requires a number of changes. For example, private funding is already a funding source for renewable energy development and should be able to play the same role for water infrastructure.[20] Unlocking its potential requires reforms such as reducing regulatory barriers.[21] It also requires developing new financing vehicles that will be attractive to investors.[22]

Like federal funding, state and local investment in capital infrastructure is on the decline.[23] That funding decrease is partly an allocation issue; the aging infrastructure requires more funding to support operations and maintenance instead of capital investment.[24] But the total amount of funding must increase as well. That means higher taxes or water rates, which typically requires voter approval. And getting approval is difficult, though not impossible.[25]

To be sure, there are many management reforms that can stretch available resources; some of them are discussed in this paper. But no matter how much management is improved, more funding will be necessary, and the amount will not be small.

2. LEADERSHIP

Improving water infrastructure will also require effective leadership. Water projects involve numerous parties, usually including representatives from federal, state, and local governments. Each level of government may also have representatives from different agencies. Then there are non-governmental stakeholders. Indian Tribes, for example, may have an interest in the water.[26] Business interests, like agriculture, have expectations regarding water availability. Local communities—from growing cities to small rural towns—may have their culture and livelihood tied-up in the water. Leaders will have to bring those groups together, have to get their buy-in and cooperation, and have to convince them that water infrastructure is everyone's problem and everyone's responsibility.

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[17] *See generally* White House, Fact Sheet: 2018 Budget: Infrastructure Initiative 1-3 (2018), https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/fact_sheets/2018%20Budget%20Fact%20Sheet_Infrastructure%20Initiative.pdf.

[18] *See* Michael Widmann, *Trump's Infrastructure Plan: A Gift to the Private Sector*, DUKE NICHOLAS SCH. OF THE ENV'T: STAT. & ENV'T POL. BLOG (last visited May 15, 2018), http://sites.nicholas.duke.edu/statsreview/env-212-environmental-policy-blog-2017/trumps-infrastructure-plan-a-gift-to-the-private-sector/.

[19] Non-federal direct spending on water infrastructure is the balance left after subtracting federal spending. It has ranged from about 55-90% of total water infrastructure spending. *See* PUBLIC SPENDING, *supra* note 14, tbls.W-2, W-6.

[20] *See* KIM QUESNEL ET AL., TAPPING INTO ALTERNATIVE WAYS TO FUND INNOVATIVE AND MULTI-PURPOSE WATER PROJECTS: A FINANCING FRAMEWORK FROM THE ELECTRICITY SECTOR 17 fig.8, 31 (2016).

[21] *See id.* at 7 (listing some risks for private investors, including heavy regulation).

[22] *See infra* "Private Funding and P3s."

[23] *See* PUBLIC SPENDING, *supra* note 14, at exhibit 13.

[24] *See id.*

[25] *See California Proposition 1, Water Bond (2014)*, BALLOTPEDIA, https://ballotpedia.org/California_Proposition_1,_Water_Bond_(2014) (last visited May 15, 2018).

[26] *See, e.g.*, *Winters v. United States*, 207 U.S. 564, 576-77 (1908) (establishing federal reserved water rights for Indian tribes).

Second, leaders will have to make tough decisions about priorities. There are limited resources for seemingly unlimited water projects.[27] That necessarily means that some projects are not accomplished.

Leaders will also need to be flexible when setting priorities. Water needs and events that affect infrastructure are not static. They change, sometimes dramatically. For example, the Oroville Dam breakdown was due to heavy rain.[28] Such extreme events are more likely as climate change advances.[29] As events progress, leaders must be willing to change their focus to promote efficient water policies.

3. POLICIES AND PROCEDURES

Many water-related laws and regulations need to better reflect modern needs and priorities. For example, whether or not the federal government funds a project depends mainly on the project's contribution to national economic development.[30] A more comprehensive approach would consider many other factors as well.

There must also be a streamlined approval process. Procedural labyrinths can thwart investment in, and development of, water infrastructure projects. Statutes can be part of the issue. The law requires time-consuming processes like permits,[31] environmental studies,[32] and biological studies[33] before a project can be approved. Statutory delays also arise due to federal funding mechanisms. The federal government operates via annual appropriations. Water projects, however, take years to finish. The mismatch increases the time and costs of water projects.[34]

Agency procedures may also add to delays. To take one example, projects sometimes require approval from numerous federal agencies.[35] The multitude of approvals creates delays. Remedying the situation requires two types of reform. One is streamlining and consolidating administrative processes to reduce project approval time. The second is updating and reforming those statutes that codify the procedural maze.[36]

4. EDUCATION

Two examples, both common when dealing with water infrastructure, highlight the importance of education. The first is political. As with almost any type of government spending, the public will ultimately bear the cost of most water infrastructure investment. That is not politically popular, especially since the public will not experience the infrastructure's benefits for

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[27] *Cf.* U.S. ARMY CORPS OF ENG'RS, NATIONAL REPORT: RESPONDING TO NATIONAL WATER RESOURCES CHALLENGES 49 (2010) [hereinafter NATIONAL REPORT] (discussing funding priority criteria).

[28] *Atmospheric Rivers and the Lake Oroville Dam Stress*, GLOBAL HYDROLOGY RES. CTR., https://ghrc.nsstc.nasa.gov/home/content/atmospheric-rivers-and-lake-oroville-dam-stress (last visited May 15, 2018).

[29] *See* NATIONAL REPORT, *supra* note 27, at 51.

[30] *See id.* at 13-14 (noting that the goal of national economic development has driven federal water policy for decades and there is increasing pressure to change that focus).

[31] *See, e.g.*, Clean Water Act § 404, 33 U.S.C. § 1344 (2017).

[32] *See, e.g.*, National Environmental Policy Act § 102, 42 U.S.C. § 4332.

[33] *See, e.g.*, Endangered Species Act § 7, 16 U.S.C. § 1536.

[34] *See* NATIONAL REPORT, *supra* note 27, at 47-48.

[35] *See, e.g.*, Clean Water Act § 404 (giving the Army Corps of Engineers and the E.P.A. jurisdiction over dredging permits).

[36] *Cf.* Strycker's Bay Neighborhood Council, Inc. v. Karlen, 444 U.S. 223, 227 (1980) (per curiam) (holding that the N.E.P.A. is purely procedural).

a number of years. Furthermore, the project's benefits may be "hidden" because they are intangible—the avoided cost of future infrastructure failure, for example. Because the benefits are intangible, the public appreciates them less and the projects are less likely to garner support. Education can help ameliorate those issues. By educating the public about the need for and benefits of water infrastructure, water managers can gain support for the funding they need.

The second example deals with data-gathering. Water managers need to continuously assimilate new research and new data, in a process analogous to continuing education requirements in other professions[37]. Like any continuing education program, the new information allows managers to refresh their knowledge of their water systems and how elements within the system interact. The result is more effective water infrastructure policy. For example, atmospheric rivers—"long, narrow bands of high water vapor that transport moisture"—caused the Oroville Dam crisis.[38] Further study of atmospheric rivers can help improve managers' responses in the future, in part by giving them new data.[39] Similarly, the current estimate is that climate change will reduce the flow of the Colorado River by 10-30%.[40] More accurate estimates will allow Colorado River managers to plan water management and investment policies more effectively.

The two examples, the Orville Dam and the Colorado River, are also important because they highlight the connection between educating and being educated. Investment in research and data gathering requires public funding.[41] However, the investment's benefit is hidden. Water managers must therefore educate the public on the need for better science. The need for "continuing education" therefore requires water managers to be educators. Then, as water managers assimilate new data on how water systems interact, they will be better able to educate the public about water infrastructure investment.[42] That education includes the need for research, thus starting the process again. The cycle helps generate support for water infrastructure modernization in increasingly potent ways.

5. INTERCONNECTEDNESS

Water infrastructure projects and policies do not exist in a vacuum. Funding and leadership must combine to develop infrastructure projects. Both challenges touch on education. Educating the public and knowing how a project works are aspects of leadership—the former is an example of managing stakeholders and the latter is an example of setting priorities. Moreover, since public support is part of project financing, education is integral in generating financing. And, of course, proper policies and procedures can drive funding, leadership, and education.

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[37] *See, e.g.*, *Minimum Continuing Legal Education*, STATE BAR OF CAL., http://www.calbar.ca.gov/Attorneys/MCLE-CLE (last visited May 15, 2018) ("A career in law can involve continuing education of all kinds. You may want to add or switch specialties, gain new skills or simply update yourself in your field.").

[38] *See Atmospheric Rivers and the Lake Oroville Dam Stress*, *supra* note 28.

[39] *See Atmospheric River Reconnaissance – 2018 Is Underway*, CTR. FOR WESTERN WEATHER & WATER EXTREMES: SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO (Feb. 8, 2018), http://cw3e.ucsd.edu/atmospheric-river-reconnaissance-2018-underway/ (describing the need for future research, current research, and the institution's partnership with the Army Corps in conducting that research).

[40] Douglas Kenney et al., *The Colorado River and the Inevitability of Institutional Change*, 32 PUB. LAND & RESOURCES L. REV. 103, 111 (2011).

[41] *See* NATIONAL REPORT, *supra* note 27, at 58-59 (discussing the difficulty in ensuring steady federal funding for research into water resources).

[42] *See id.* at 20.

A management mindset that focuses on interconnectivity is especially important. Water policy in one area affects other areas, and often in ways that are hard to predict. Watersheds do not respect political boundaries.[43] The Colorado River, for example, flows through seven U.S. states and Mexico.[44] Since the river is over-appropriated,[45] changes upriver—even small changes—can affect an immense number of parties.

Connections may not even be water-driven. Consider the climate. The climate is not a water infrastructure project, yet its impact on water resources is significant. Climate change may reduce the Colorado River's water supply.[46] Climate—atmospheric rivers—was the connection that exposed the Oroville Dam's compromised spillway.[47] Cultivating a mindset that recognizes the interconnectivity between water systems, funding, leadership, and education is part of establishing effective water infrastructure policies.

CONCLUSION

The state of America's water infrastructure is alarming. There needs to be a daunting amount of improvement. The issue is generating the impetus to do the work. That requires meeting five challenges that face water managers everywhere:

1) Funding to build water projects.
2) Leadership to bring stakeholders together and to establish clear investment priorities.
3) Policies and procedures that do not delay, and ultimately prevent, necessary projects.
4) Education to ensure public support and to understand the science justifying the investment.
5) Recognition of the interconnectivity of water and water systems.

Successful water infrastructure policy begins with addressing and managing those challenges. Doing so requires changing mindsets, pushing for reforms, and uniting local communities behind the importance of water infrastructure in maintaining America's quality of life.

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[43] *Cf.* NATIONAL REPORT, *supra* note 27, at 3 ("A national initiative is needed. Water planning may be more successful if [developed through a system] that permits government at all levels to integrate needs, stakeholder interest, policies and programs, and scalable information on many levels . . . .").
[44] Kenney et al., *supra* note 40, at 104.
[45] *Id.* at 109-11.
[46] *See id.* at 111-12.
[47] *Atmospheric Rivers and the Lake Oroville Dam Stress*, *supra* note 28.

LOOPING WATER: RETHINKING WATER INFRASTRUCTURE

Hydrologically, water travels in loops. Water comes down, goes back up, and comes down again. Loops are geographically wide: where water goes up is not where it will come down. They are also temporally wide: when water goes up and comes down varies.

In contrast, the current water supply infrastructure does not loop. It moves—like the pipes constituting it—linearly from supply to use to disposal. However, a linear supply concept only works if water is plentiful, which is increasingly not the case.[1] The result is strained water supply systems, and those strains will increase with population and economic growth. Linear water supply systems also have a difficult time handling the unpredictability of water's hydrological movement. Changes in rainfall, either geographically or temporally, create mismatches between water location and water demand.

The fix requires, in part, conceptualizing water supply infrastructure as a loop, like the natural water cycle loop. Two loop concepts are likely to be useful. The first is a water-use loop. Linear water supply systems implement an old mantra: "Supply, use, and dispose." A water use loop implements a "collect, store, use efficiently, and recycle," mantra. The goal: maximize water supply through recycling or storing water for future uses. As a result, the potential uses of each quantum of water multiplies; one drop of water turns into many drops of supply.

Creating a water use loop requires decentralized infrastructure that can adapt to the needs of a particular area and the vagaries of the water cycle. However, any change in water infrastructure implicates the interconnectivity of water systems. Any one project can cause impacts beyond its locale. Consider the Los Angeles Aqueduct's effect on Mono Lake. Los Angeles, in order to get a new supply of water, diverted water from four of the five streams feeding Mono Lake.[2] Because of the diversion, water flow into the lake dropped and the lake began drying up.[3] The drying lake threatened numerous species, as well as human health.[4] Los Angeles's diversions therefore impacted more than just the components of the Los Angeles Aqueduct; they affected Mono Lake, the environment in and around the lake, and the area's population. Effective water management would have created a plan to serve Los Angeles's need while preventing such impacts—something stakeholders from both areas do today.[5]

The Mono Lake story illustrates the second loop: that of a water system. In a water system, what happens at Point A affects things at Point B. Proper water infrastructure policy accounts for that loop by considering the effects of different projects on the system as a whole.

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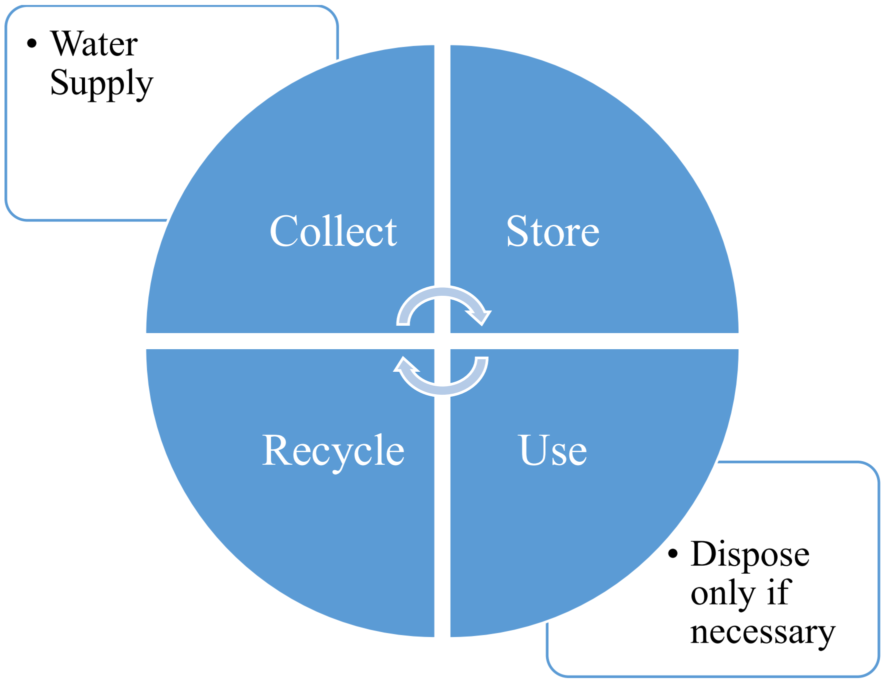
[1] *See* Vincent C. Tidwell et al., *Mapping Water Availability, Projected Use and Cost in the Western United States*, ENVTL. RES. LETTERS, June 2014, at 6-7 & fig.1 (showing the lack of available surface water in the U.S.).
[2] Nat'l Audubon Soc'y v. Super. Ct., 658 P.2d 709, 711 (Cal. 1983).
[3] *Id.* at 715.
[4] *Id.* at 715-16.
[5] *See* L.A. DEP'T OF WATER & POWER, 2017 ANNUAL OWENS VALLEY REPORT 1-1, 1-30 fig.1.13 (2017) (summarizing the agreement's goals and plan for water withdrawals).

1. THE WATER USE LOOP AND THE IMPORTANCE OF DECENTRALIZED SYSTEMS



Perhaps the greatest value of creating a water use loop that collects, stores, uses efficiently, and recycles water is in augmenting water supplies. Traditional centralized infrastructure is ill-suited to create such loops. The goal of traditional water infrastructure—built along the old linear concept—is to transport water many miles to consumers. As a result, traditional infrastructure is expensive, time-consuming to build, and inflexible.[6] Its high costs require significant benefits to justify its construction. Local recycling projects, though beneficial, usually risk not being beneficial enough to justify the cost of promoting them.[7] The San Jose Municipal Water System's purple pipe recycling infrastructure is illustrative of that. The system cost millions of dollars per mile of pipe,[8] yet produced lower quality, salty water.[9]

Decentralized systems, by contrast, typically lack the downsides of traditional infrastructure, largely because decentralized infrastructure operates on a smaller scale. Los Angeles, for instance, established stormwater reuse infrastructure to augment water supplies in neighborhoods.[10] Those projects use infiltration basins along sidewalks to collect stormwater.[11] Underground basins then store the water for use.[12]

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[6] *See* Heather N. Bischel et al., *Management Experiences and Trends for Water Reuse Implementation in Northern California*, 46 ENVTL. SCI. & TECH. 180, 185-86 (2012) (discussing the cost barriers to investing in pipes for recycled water).

[7] *Cf. id.* at 187 (noting that the structure of federal and state grant programs does not encourage small water recycling projects).

[8] *See id.* at 185; *see also* Richard G. Luthy, Urban Water Supply in the Arid West (2014), http://deltacouncil.ca.gov/sites/default/files/documents/files/Urban-Water-Supply-in-the-Arid-West-Increasing-Reliability-Richard-Luthy.pdf.

[9] *See* Luthy, *supra* note 8.

[10] For a short presentation on the idea, see Luthy, *supra* note 8.

[11] *Id.*

[12] *Id.*

Such decentralized infrastructure projects, products of a "collect, store, use efficiently, and recycle" mindset, pair well with other water management programs. Take demand-side management activities. Managing demand stretches existing water resources, and decentralized systems supplement the existing supply. Both therefore reduce pressures on existing water supply and thus help ensure a steady supply of water.

Decentralized water supply systems also can supply numerous co-benefits. For example, the stormwater capture system augments supply. It also helps prevent floods and provides non-water benefits: For example, the neighborhood drainage basins are usually bioswales—flowering gardens. The gardens improve air quality and community appearance and therefore increase property values.

Co-benefits are especially important because decentralized systems, while not as expensive as centralized projects, are not free. Because decentralized projects may be too small to qualify for federal or state funding,[13] financing comes from the voters. Co-benefits provide immediate, tangible benefits to the community. They therefore encourage local buy-in for the project.

2. WATER MANAGEMENT LOOPS

Water use loops are just part of the story. All water infrastructure exists within a system and each structure causes impacts throughout the system. Every water system is therefore a loop: every element of the system is connected, and a change in one affects everything else. There are three obvious, geographically-defined loops. They are, in order from the smallest to the largest area: regional loops, watershed loops, and multi-watershed loops. The smaller loops form the constituent elements of the larger loops.

Two concepts apply to every loop level, albeit to different degrees. The first is scalability. Larger loops should apply concepts that are effective at lower loops at an appropriate scale. The second concept is that of cooperation and coordination. Idiosyncrasies and experimentation among loops create an environment ripe for data gathering and sharing. Cooperation and coordination, mainly in the form of information sharing, create a "wisdom of the masses" approach to water infrastructure. The result is greater uptake of infrastructure solutions.

2.1 The First Loop: Local and Regional Management

Regional loops are the smallest loops and the loops with the greatest potential for scaling up the "collect, store, use efficiently, and recycle" mentality. It is easier, for example, to focus on recycling opportunities at a regional level. A regional recycling plan can, with relative ease, take used water from one locale, treat it, and use it elsewhere. For instance, farms could use disposed urban drinking water for irrigation.

Another example takes advantage of existing infrastructure. Regional water areas are likel to have significant unused water infrastructure capacity. Aquifer recharge ponds are a common example: most ponds' intake is only a fraction of their total capacity.[14] Regional water managers could build systems that take recycled water from across the region and put it in recharge ponds

[13] *See* Bischel et al., *supra* note 6, at 187.
[14] Jonathan L. Bradshaw & Richard G. Luthy, *Modeling and Optimization of Recycled Water Systems to Augment Urban Groundwater Recharge Through Underutilized Stormwater Spreading Basins*, 51 ENVTL. SCI. & TECH. 11809, 11811 (2017).

for future use.[15] The regional authority thus centrally implements a "collect, store, use efficiently, and recycle" mentality.

There are others ways regional water managers can create a more efficient water management plan. The possibilities are endless, and the role of creativity is large. The goal is to foster a regional water management system that connects decentralized systems to a central management plan that incorporates the water use loop mentality.

2.2 The Second Loop: The Watershed

Watersheds cover the area from where water first starts flowing to its final discharge into something like a sea or a reservoir.[16] They are therefore key loops. Changes or activity, such as weather activity, along a watershed alters water flow and thus water availability in the watershed. Effective management manages those ripple effects. The watershed manager must therefore understand each project's impact across the watershed.[17]

That raises a significant challenge, one of scope. Watersheds encompass numerous projects and activities, which can spawn a near-infinite number of ripple effects. Flexibility—the ability to change policies when necessary—is therefore necessary. There are at least two elements to flexibility. One is effective data gathering and forecasting. Managing infrastructure on a watershed level requires knowing what is happening and how it affects the system. Without proper data-gathering and analysis, a manager cannot evaluate a project's or activity's effect on the watershed. The need for accurate data and models requires investment in research. Developing flexibility requires that managers advocate for investment in research.

The second aspect of flexibility is nimble planning. Nimble planning requires managers to implement certain policies when a certain event occurs—a "trigger." An example of nimble planning is the Army Corps of Engineers' response to the 2011 Mississippi River flood. There, the Corps had a trigger—the river reaching a certain level.[18] Once the river reached the trigger point, the Corps breached a floodwall to allow water to enter a floodway.[19] The Corps' action prevented massive damage to downriver areas.[20]

Education also plays a significant role in watershed management. Watershed managers have access to a plethora of information from across the watershed, including regional and sub-regional water infrastructure solutions. The manager can provide other regions in the watershed with those solutions. The manager thus facilitates bottom-up/top-down water infrastructure development. Lower loops develop infrastructure solutions. The watershed manager learns of them, and then sends the solutions back down to other regions and localities that have not adopted them. The result is more efficient water systems.

The watershed manager's role is significant. The potential challenges and resulting solutions are infinite. The need for flexible management, education, and integration are constant.

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[15] *See id.* at 11810.
[16] *See What Is a Watershed?*, NAT'L OCEAN SERV., https://oceanservice.noaa.gov/facts/watershed.html (last visited May 15, 2018).
[17] That includes changes to water supply, but also changes to things like the environment. *See* Nat'l Audubon Soc'y v. Super. Ct., 658 P.2d 709, 715-16 (Cal. 1983) (discussing the impacts of the Los Angeles Aqudeuct on Mono Lake's environment).
[18] U.S. ARMY CORPS OF ENG'RS, ROOM FOR THE RIVER 12 (2012).
[19] *Id.* at 12-13.
[20] *See id.* at 13.

Without them, infrastructure development—though impacting the entire watershed—will be incomplete and inefficient.

2.3 The Final Loop: Management Across Watersheds

On one level, effective multi-watershed management is similar to effective watershed management. First, it should be flexible. Take California's Central Valley Flood Protection Plan, which covers two river basins[21] and displays characteristics of effective watershed loop management. The plan initially considered four different approaches to flood control before choosing one,[22] and state administrators update the plan over time as they get new information.[23]

Second, like the watershed manager, the multi-watershed manager must be an educator. However, the educator role figures more prominently for multi-watershed managers: first, because multi-watershed managers have access to so much data. Multi-watershed managers get regional and local data, *and* watershed data. The amount of information is immense and is something that other managers do not have and cannot easily obtain. The volume of information that a multi-watershed manager has means that the manager's power to inform lower-level managers is great.

Third, multi-watershed managers, like watershed managers, have significant influence over lower loops. The federal government is a good example. As a multi-watershed manager, the federal government has significant leverage over managers of smaller water management loops due to its control over funding or permitting. The leverage the federal government has means it can encourage lower-loop managers to take up particular water infrastructure solutions.

The educational role multi-watershed managers play makes them important facilitators of bottom-up/top-down solution propagation. Water policy solutions are likely to arise at lower loops. There, the risks of innovation and the costs of development are typically the lowest. The lower loops thus generate data that moves up to higher loops. Regional and watershed managers, when they get the data, can send the information back down to smaller units. But the biggest payoff is when the data reaches the multi-watershed loop. At that level, it can spread widely—potentially into all watersheds. The multi-watershed manager must establish a system that facilitates the sharing and accepting of information. Doing so will help advance water infrastructure modernization across the country.[24]

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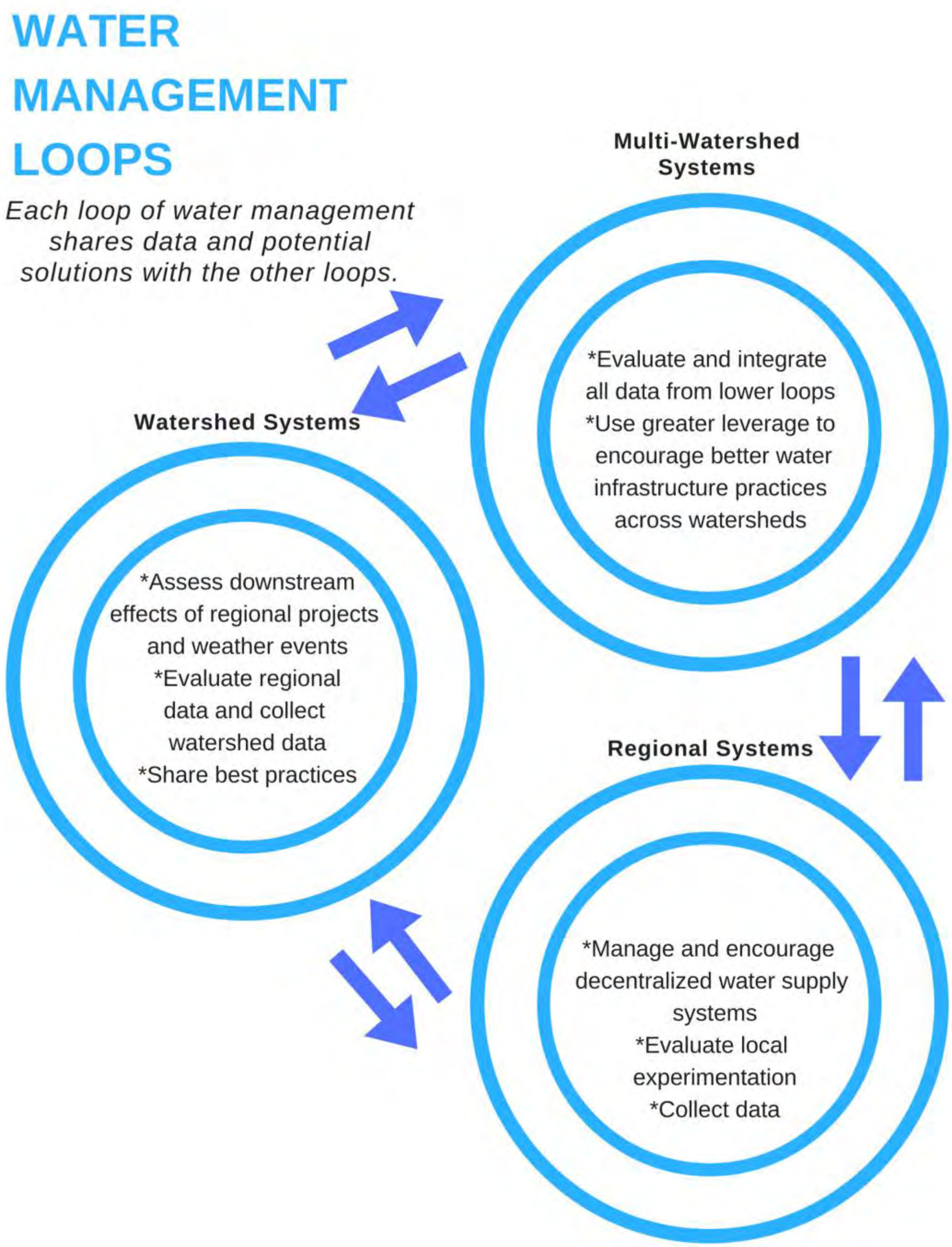
[21] *See* CAL. DEP'T OF NAT. RES., CENTRAL VALLEY FLOOD PROTECTION PLAN: 2017 UPDATE 1-2 (2017).

[22] *Cf. id.* at 1-5 (discussing the original 2012 plan).

[23] *See generally id.* at 1-1 (describing the report as the five year update to the 2012 plan).

[24] *See* U.S. ARMY CORPS OF ENG'RS, NATIONAL REPORT: RESPONDING TO NATIONAL WATER RESOURCES CHALLENGES 42-44 (2010) (discussing the need for such a system).



CONCLUSION

Water infrastructure, like the water cycle, should loop in two ways. The first is a water use loop. The goal of the loop is to augment and to stretch existing water supplies. The loop replaces the traditional "supply, use, dispose" approach with a "collect, store, use efficiently, and recycle" approach. Instead of sending water from its source to users to disposal, it seeks to maximize the use of every drop of water.

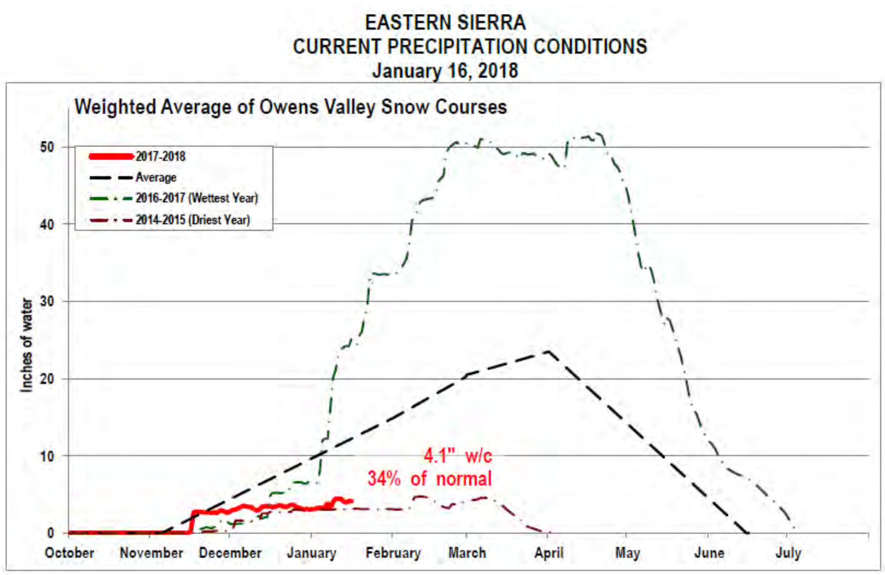
The second loop deals with centralized water management. Water systems are loops; actions in one area affect water supplies and quality elsewhere. Effective water management requires centralized direction to prevent or to minimize potentially deleterious ripple effects. There are logically three such loops: regional water loops, watershed loops, and multi-watershed loops. Water managers at each loop level should direct infrastructure projects in the context of the loop.

Water management loops are also responsible for establishing bottom-up/top-down solution propagation. Smaller management loops have more freedom to experiment and to discover innovative water infrastructure solutions. Information about those solutions should move up the loops. Higher loop managers then deliver the solutions down to different lower loops in their management areas. At the highest level—the multi-watershed level—the process transfers solutions across watersheds. The nation thus “crowd-sources” water infrastructure solutions. The net result is faster progress towards 21st century water infrastructure.

CLIMATE CHANGE: THE NEED FOR RESILIENCY

Climate change impacts water resources in two ways. The first are changes to the resource. For example, climate change will likely cause warmer temperatures, which can alter water availability.[1] The second is climate variability, especially uncertainty regarding extreme weather events. At least two aspects of extreme weather events will impact water infrastructure. The first is the occurrence of more extreme weather, such as natural disasters like hurricanes, floods, or droughts, as well more mundane, yet consequential events, like record-breaking temperatures on a particular day.[2] The second aspect is the level of extremity. Climate change will tend to make extremes more extreme. It is not just that more hurricanes will hit Houston, it is also that more hurricanes will be as bad as Harvey.[3]

Extremes *will* occur. The problem is uncertainty. Uncertainty regarding climate change comes in two types. One is uncertainty regarding the type of extreme event. Consider precipitation. There are two extremes: deluges or droughts. Climate change makes it more likely that one or the other will happen, though impossible to tell which. The other uncertainty is about how extreme an event will be. The following chart provides an example. It illustrates the rainfall during the wettest and driest years for the Eastern Sierra snowpack, one of Los Angeles's water sources, and compares them to the historic average. Those extreme events occurred in close proximity – the wettest year was only two years after the driest. There was no warning that two record-breaking climate events would occur one after the other.



Ted Bardacke, Director of Infrastructure, Mayor's Office, City of Los Angeles, Presentation at Planning for America's Water Infrastructure Needs: The 4th Straw; Building Los Angeles' New Water Infrastructure (Feb. 6, 2018).

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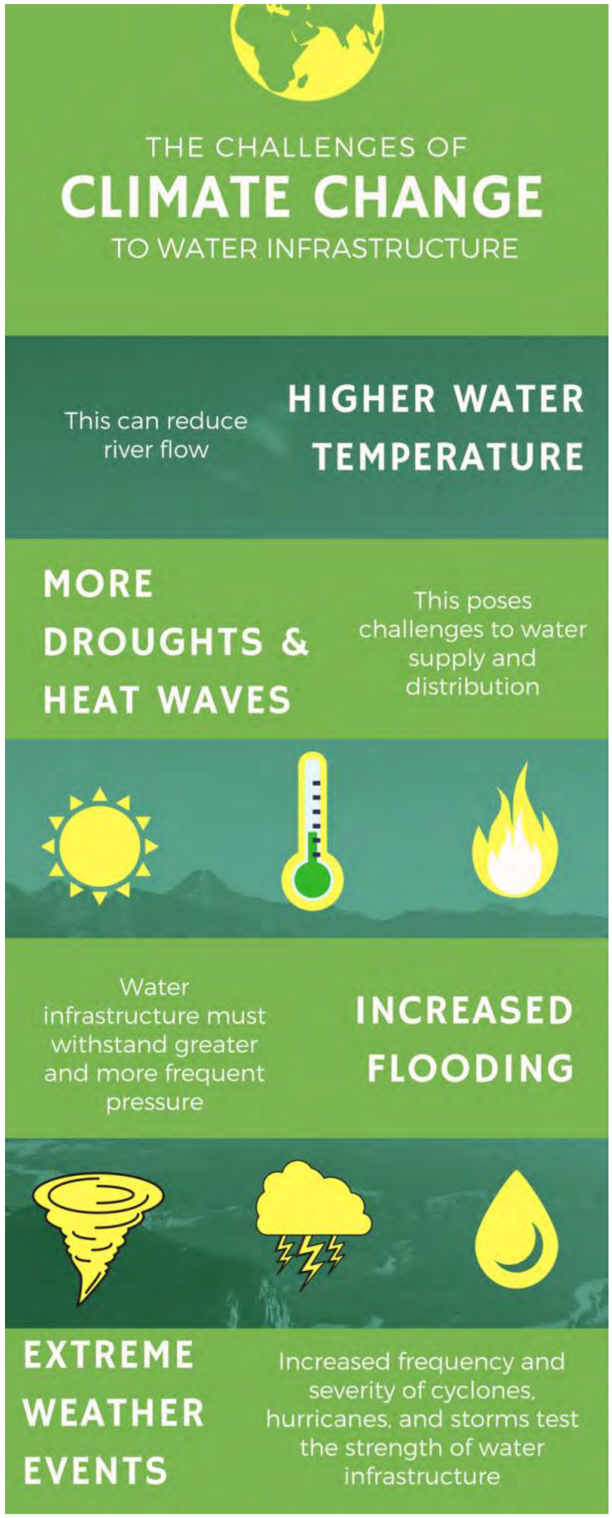
[1] *See* Douglas Kenney et al., *The Colorado River and the Inevitability of Institutional Change*, 32 PUB. LAND & RESOURCES L. REV. 103, 111 (2011) (estimating that climate change will reduce Colorado River flow by 10-30%).

[2] *See generally* Noah S. Diffenbaugh et al., *Unprecedented Climate Events: Historical Changes, Aspirational Targets, and National Commitments*, SCI. ADVANCES, Feb. 14, 2018, at 2 fig.1 (providing charts about the increase in extreme events that climate change will cause).

[3] *Cf.* Henry Fountain, *Scientists Link Hurricane Harvey's Record Rainfall to Climate Change*, N.Y. TIMES (Dec. 13, 2017) (discussing studies concluding that climate change has made storms of Hurricane Harvey's magnitude three times more likely) https://www.nytimes.com/2017/12/13/climate/hurricane-harvey-climate-change.html.

Climate change therefore poses two problems for water managers: extremes and uncertainty. Fortunately, managing extremes is part of handling uncertainty. The first response to uncertainty is to invest in research. Better science increases certainty. Research, however, takes time. Water managers need to act now even in the face of uncertainty. Thus the second response: flexibility. Flexible policies can respond to improvements in climate science and subsequent increases in certainty regarding extremes. Flexible infrastructure is infrastructure that prevents most failures, but also contains damage from failing structures.

Climate change also provides a chance to maximize the value of the bottom-up/top-down solution propagation of looping water management. The uncertainty surrounding climate change creates incentives for experimentation and data-gathering at different water management loops. It provides an opportunity to "crowd-source" solutions.



Sources for Graphic: Noah S. Diffenbaugh et al., *Unprecedented Climate Events: Historical Changes, Aspirational Targets, and National Commitments*, SCI. ADVANCES, Feb. 14, 2018, at 2 fig.1; Douglas Kenney et al., *The Colorado River and the Inevitability of Institutional Change*, 32 PUB. LAND & RESOURCES L. REV. 103, 111 (2011); *The Consequences of Climate Change*, NASA, https://climate.nasa.gov/effects/ (last visited May 15, 2018).

1. DEVELOPING POLICY IN LIGHT OF SCIENTIFIC UNCERTAINTY

Incorporating uncertainty into water infrastructure planning is a change from historic practice. Prior water infrastructure projects had four characteristics:

1. A focus on national economic development.
2. A planned life-cycle of 100 years or more.
3. High expectations for operational and functional reliability.
4. Large consequences of failure for public health and safety.

Each characteristic demanded certainty. The long life of a project made it hard to alter midstream. Policymakers and investors therefore needed to be certain of the project's benefit before investing. Similarly, the consequences of failure and consumer expectations regarding reliability required certainty. The projects had to work, and work well.

Climate change undermines the traditional paradigm. Uncertainty is, for now, the new norm. That does not mean that infrastructure projects should not be reliable. Nor does it mean that the public should accept the large consequences of infrastructure failure. It means that a key feature of water infrastructure should be resiliency. There are four characteristics of resiliency:

1. Proactivity: Policy changes based on better scientific predictions regarding climate change. The change requires a trigger point, which ensures that the information justifies altering investment priorities.
2. Mindfulness of cascading impacts: Decisions consider how a failure in one area might impact the rest of the system. Since water infrastructure systems depend on interdependent structures, proper design should ensure that a failure in one part does not bring down the whole.
3. Sustainability: The system is sustainable in terms of its environmental impact and its ability to withstand climate events.
4. Adaptiveness: The system adapts to extreme climate events.

Those four characteristics arise from, first, a focus on the water system, and, second, a need for risk-informed planning and design. The term "water system" is broad. It covers infrastructure (in order to consider cascading effects), the environment (to ensure that the project can adapt to climate change and that investment in it can change if necessary), and more. The goal is to consider each project in the context of the water system instead of in isolation.

The focus on the water system is important due to the need for risk-informed planning and design that finds its expression, in part, in resilient infrastructure systems. Resilient infrastructure systems incorporate risks in their designs. The goal is to create systems that adapt to changes and thereby prevent or mitigate damage. The idea of "failing gracefully" is an example of the concept. Take a particular structure. The advent of increasingly unpredictable and increasingly extreme climate events makes it possible that the structure will fail. "Failing gracefully" means that, in the event of failure, there are mechanisms that mitigate and contain the damage. Thus, if one structure fails—or is about to fail—the system remains intact. A structure may fail, but the system survives its loss.

Indeed, it is possible to combine the ideas of "failing gracefully" and trigger points, as the example below shows. In that case, the there was a trigger point that resulted in a planned "failure" of a levee to prevent unplanned failures that could threaten the entire system.

The 2011 Mississippi Valley Flood[4]

The 2011 Mississippi River flood was the largest recorded flood on the lower part of the river. The flood was so large that it exceeded the 60-foot level on levees near Cairo, Illinois. Downstream from Cairo was the Birds Point-New Cairo Floodway (BPNM). The BPNM's purpose was to "make room for the river" by directing floodwater into areas where it would do little harm, thus relieving pressure on the system. The "direction" took the form of an explosive breach of the levee.

The 2011 flood put the system to the test. By topping 60 feet at Cairo, the water levels reached the trigger point. Before breaching the levees to open the floodway, the Corps made one last calculation: the costs of the diversion—the evacuation of 230 residents, flood damage in the floodway, flooding of agricultural land, and damage to the levee—against the cost of not opening the floodway—downriver levees failing. The conclusion: open the floodway. The plan worked; the flood did not overtop downstream levees. The floodway prevented about $234 billion in damages.

The event highlights the value of resiliency. The flood's height meant that the system would not be able to contain it. Rather than letting the system fail unpredictably and disastrously, the Corps used the BPNM floodway to control the failure. By opening the floodway, the Corps isolated and minimized the damage. The planned breach of the levee (what people would traditionally consider a "failure") protected the system and headed off catastrophic, uncontrollable failures elsewhere.

The event also illustrates the importance of flexibility and trigger points. The Corps established a trigger point for the planned levee breach. It also embedded a balancing test to ensure that the value of the mitigation was worth the cost. It had room to maneuver even in cases calling for use of the floodway. At no point did inflexible rules force the Corps to act in a way that prevented crisis management of the system.

1.1 Resilient Infrastructure: Two Challenges

Part of developing a resilient water infrastructure policy—perhaps the most difficult part—is selling it to the public. The idea of mitigating damage, because it assumes damage will occur somewhere, is not something the public likes to hear.[5] Unfortunately, the public needs to hear it. The expense of creating resilient water infrastructure, as with any water infrastructure, requires managers to go to the voters.

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[4] For an in-depth discussion of the flood and the Army Corps of Engineers' response, see U.S. Army Corps of Engineers, *Room for the River* (2012). The case study here is taken from that publication and the Corps' post flood report, U.S. Army Corps of Engineers, *2011 Post-Flood Report* (2012).

[5] *Cf.* Missouri *ex rel.* Koster v. U.S. Army Corps of Eng'rs, No. 1:11CV00067 SNLJ, 2011 WL 1630339 (E.D. Mo. Apr. 29, 2011) (rejecting Missouri's motion for a preliminary injunction to enjoin the breach of the BPNM floodway).

Convincing voters to support resilient water infrastructure projects involves emphasizing at least two items. The first is the cost of *not* building resilient infrastructure. A cascading failure in water infrastructure is more expensive than building a system that mitigates the effects of extreme climate events. Flood control measures in the Mississippi River System are an example. Over time, the system has prevented $612 billion of damages.[6] That amounts to a $44 return on every $1 invested in flood control and protection.[7]

The second is the threat of extreme weather events. Voters need to know what may happen in the future. That justifies investment in science and modeling. The more certain the threat of extreme climate events, the more salient such events are for the public. The more salient weather extremity is, the more the public is likely to support resilient infrastructure projects.

Besides educating the public, developing resilient water infrastructure requires changes in policies and procedures underlying water infrastructure funding. Individual projects sit within a larger system. Those systems must be resilient, and that requires coordination among the different projects. Policies and procedures should acknowledge that need. Take the BPNM floodway. A single floodway, with a destructible cap, may not make sense to build in isolation. It makes a great deal of sense in the context of protecting the integrity of the Mississippi River and Tributary System.

2. WIDENING THE LOOP—CLIMATE EXTREMES AND INTEGRATING WATER POLICIES

The challenges of climate change require effective utilization of the widening loops of water management. Climate change presents an opportunity to utilize the bottom-up/top-down solution propagation system of water management loops. The water use loop, for example, responds to some of the issues climate change poses. By establishing a water supply loop, local areas can augment water supplies. As a result, their water supplies can withstand extreme climate events like a drought. As local solutions arise, they should move up the different water management loops. The higher loops of water management can then disseminate the solutions to other areas. In that way, national water infrastructure can better withstand climate change.

The bottom-up/top-down system is also useful for disseminating scientific data regarding climate change. Scientific research can come from many areas. It could come from multi-watershed managers like the federal government. It can also come from smaller loops. Certain regional or watershed loops may be more interested in a specific impact of climate change than other areas. California, for example, might worry most about droughts and research drought cycles. Managers on the Mississippi River may see flooding as their biggest concern. They therefore research flooding. Floridians may invest more in hurricane research. Sharing the data from those region-specific studies, which a bottom-up/top-down system does, provides water managers everywhere with more information, and thus more certainty. They are then better prepared to handle climate change.

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[6] ROOM FOR THE RIVER, *supra* note 4, at 23.
[7] *Id.*

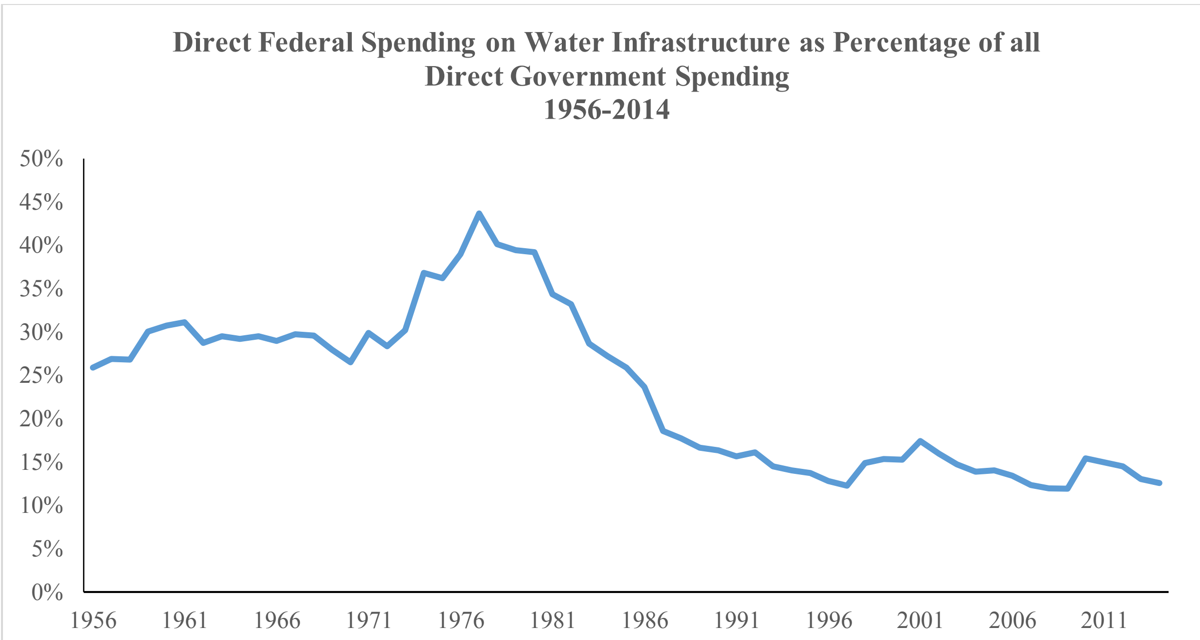
CONCLUSION

The problem of climate change is partly one of uncertainty. Extreme weather events, defined by both type of event and level of extremity, are inevitable. When, where, and to what extent extreme events will occur is the question. The response is to promote resiliency in water infrastructure. Resilient infrastructure both prevents failure and mitigates damage when failure inevitably occurs. It responds to the risks and uncertainty of climate change by accepting the reality of uncertainty and controlling it as much as possible.

Climate change is also a powerful reason to use the bottom-up/top-down propagation system incumbent in looped water management. Climate change is a phenomenon that affects all watersheds. Innovation and information creation will often occur at lower loops. It is important to move that data up the loops to the multi-watershed manager and then back down to other managers. Taking advantage of the opportunity to engage in a bottom-up/top-down system of reform will help promote resilient systems across the country and provide more information on climate change.

FINDING FUNDS: PROCEDURAL HURDLES AND FINANCING VEHICLES

Improving water infrastructure is not cheap. Depending on the type of infrastructure, modernization can cost trillions of dollars.[1] The question is where to obtain the financing. It is unlikely to come from one source. Consider the chart below, which shows federal spending on water infrastructure.



CBO, PUBLIC SPENDING ON TRANSPORTATION AND WATER INFRASTRUCTURE, 1956-2014 tbls.W-2, W-6 (2015) (covering expenditures on water infrastructure, water utilities, and water resources; total funding nets out federal grants to states and localities).

Currently, the federal government provides roughly between 10-15% of water infrastructure funds. Federal grants provide states with about a third of the funds they spend on infrastructure.[2] That is significant, and indicates that the federal government has an important role to play in water financing. That role may be enhanced by important reforms. But other sources of funding will also be necessary. State and local governments are one source. Private investment is another, assuming the existence of investment vehicles like private-public partnerships (P3s). Developing those financing sources is key to modernizing America's water infrastructure.

1. REFORMING FEDERAL FUNDING POLICIES AND PROCEDURES

Ideally, the federal government should be an investor in, and facilitator of, water infrastructure. Being an "investor" requires complicated substantive reform that likely requires national debate. For example, to be an "investor" means that the federal government should focus more on capital investment. "Facilitation" requires significant procedural reforms.

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[1] *See, e.g.*, ASCE, INFRASTRUCTURE REPORT CARD: A COMPREHENSIVE ASSESSMENT OF AMERICA'S INFRASTRUCTURE 2, 32, 37, 56 (2017).

[2] *See* CBO, PUBLIC SPENDING ON TRANSPORTATION AND WATER INFRASTRUCTURE, 1956-2014 23 (2015) [hereinafter PUBLIC SPENDING].

Acting as an "investor" would stretch federal water infrastructure financing.[3] In general, infrastructure funding goes to one of two places: to new projects or to maintenance and operation of existing structures.[4] The less the federal government spends on maintenance, the more it can spend on capital investment. Another issue is that federal management of water infrastructure discourages state and local investment. Because the federal government handles maintenance and will pay to rebuild infrastructure, states and localities may have an incentive to let infrastructure crumble.

Shifting operations and maintenance responsibilities to states and localities ameliorates disincentives and frees federal funds for infrastructure investment. The shift also better aligns the federal government's financing role with its job as a multi-watershed manager. Investors pick opportunities based on an evaluation of market data. Similarly, multi-watershed managers receive a plethora of data from the different watersheds in their loop.[5] Using that data, the manager, like an investor, places funds where they will provide the most "return."

Affecting the shift is easier said than done. To begin with, significant legislation is necessary. To illustrate, localities and individual users receive a significant federal subsidy for reclamation water and the attendant infrastructure; they typically pay 10-15% of all costs of the projects.[6] Historically, Congressional action has been necessary to shift operations and maintenance responsibility for reclamation projects to local users.[7]

Administrative changes could also help. For example, agencies set factors to determine investment priority. Agencies could prioritize projects that have local or private cost-sharing agreements and maintenance plans.[8] The net result is more local management of water infrastructure and more federal financing of water infrastructure.

Shifting federal funding priorities aside, there are also federal procedural reforms that could facilitate water projects. Getting federal approval for a water project can be onerous. The more onerous it is to get federal approval, the more expensive projects become and the less likely they are to happen. The reform: streamline the process. For any particular agency, that means reducing red tape.[9] Across agencies, reform should focus on increasing inter-agency cooperation because water infrastructure projects usually require multi-agency approval. Take dredging. Under the Clean Water Act, the Army Corps of Engineers and the E.P.A. must approve the dredging permit.[10] Other approvals may be necessary, perhaps from the Fish and Wildlife Service under the

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[3] *Cf.* PUBLIC SPENDING, *supra* note 2, tbls. W-2, W-6 (providing federal funding amounts and state funding amounts; federal financing representing a significantly smaller share).
[4] *See id.* at tbl. W-2 (illustrating the relationship).
[5] *See* discussion *supra* "The Final Loop: Management Across Watersheds."
[6] C.B.O., WATER USE CONFLICTS IN THE WEST: IMPLICATIONS OF REFORMING THE BUREAU OF RECLAMATION'S WATER SUPPLY POLICIES 13 (1997).
[7] *Cf.* BARTON H. THOMPSON, JR. ET AL., LEGAL CONTROL OF WATER RESOURCES 870-73 (5th ed. 2013) (discussing Congressional reforms to the Reclamation Act, including price reforms).
[8] *Cf.* U.S. ARMY CORPS OF ENG'RS, NATIONAL REPORT: RESPONDING TO NATIONAL WATER RESOURCES CHALLENGES 13 (2010) (discussing altering the factors that the Corps considers when determining what projects to finance).
[9] The Trump Administration has undertaken efforts to reduce red-tape. *See generally* Exec. Order No. 13807, 82 Fed. Reg. 40463 (Aug. 15, 2017) (attempting to establish more efficient agency approval procedures).
[10] *See* 33 U.S.C. §§ 1344(a), (d) (2017).

Endangered Species Act.[11] Where multi-agency approval is necessary, agencies should work together to streamline the permitting process.

But as easy as it is to call for streamlining, implementing a streamlined approval process is difficult. The Trump Administration is the latest to try. By executive order, if multiple agencies are involved in the permitting process, one agency must be the lead agency.[12] The lead agency shepherds the project "through the environmental review and authorization process."[13] The other agencies must "respond to all reasonable requests for information from the lead . . . agency in a timely manner."[14] Moreover, where an environmental impact statement (EIS) is necessary, the agencies must work together to produce one statement in a timely manner.[15] Once the lead agency issues the EIS, all involved agencies have ninety days to issue "all Federal authorization decisions."[16] The Executive Order is a step in the right direction, but additional steps are necessary.

2. STATE AND LOCAL FUNDING

State and local funding comprises the bulk of water infrastructure financing.[17] That should not change. To the extent that state and local administrative processes tie up projects, there should be reform to streamline the process.[18] State and local infrastructure investment, however, faces a particular challenge that federal financing does not: in many cases, voters must approve higher taxes to fund water projects. Unfortunately, that is not politically popular.

The solution, in large part, is leadership and public education. A key stumbling block for voters is temporal: infrastructure projects provide benefits far in the future but require immediate costs. People instinctively reject such arrangements. Political leaders thus must educate the public about the need for water infrastructure investment. One aspect to emphasize is project's co-benefits. Neighborhood drainage ditches, which utilize bioswales, are an example.[19] The bioswales beautify neighborhoods while serving important water management goals.[20] They provide immediate benefits and thus reduce the temporal mismatch. Another point leaders could discuss is how investment today—for example, investment in resilient infrastructure—avoids future cost. Political leaders can also discuss the costs arising from current practices. For example, Los Angeles' "Save the Drop" campaign promoted water conservation by emphasizing the impact that water waste had on city residents in the future and in the present.[21] The campaign resulted in a reduction in water consumption. Focusing on the cost of outdated infrastructure could likewise increase public support for infrastructure investment.

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[11] *See* 15 U.S.C. § 1539(a)(1) (allowing for incidental take permits). The first Supreme Court case addressing the scope of the Endangered Species Act, *T.V.A. v. Hill*, 437 U.S. 153 (1978), dealt with a dam whose construction threatened an endangered fish.
[12] Exec. Order No. 13807, 82 Fed. Reg. at 40466 (section 5 of the order).
[13] *Id.*
[14] *Id.*
[15] There are some listed exceptions to the timeliness requirement. *See id.*
[16] *Id.* The timeframe is subject to extension in certain cases. *Id.*
[17] *See* discussion *supra* "Funding."
[18] The reforms should be similar to the federal administrative reforms suggested above.
[19] *See* discussion *supra* "The Water Use Loop and the Importance of Decentralized Systems."
[20] *See id.* (providing some benefits).
[21] *See Mayor's Fund for Los Angeles: Save the Drop*, OMELET, https://www.omeletla.com/project/save-the-drop/ (last visited May 15, 2018).

There are endless permutations of public education campaigns. The important point is that, when done properly, they work. California voters, for example, passed a large bond initiative to provide financing for water infrastructure.[22] The question is not, therefore, *will* the public vote for water infrastructure funds. The question is *who* will convince them.

3. PRIVATE FUNDING AND P3S

The final source of funding is private investment. One model to tap into private funds is the P3 model.[23] P3s are cooperative agreements between governmental and private entities. P3s, however, are not free lunches. As with any partnership, there are risks involved, as the following chart shows.

Model	Risk
Government as Purchaser	Government funding is the source of the private entity's return. There are two risks: 1) The government fails to appropriate funds, thus causing the private entity to go bankrupt. 2) The private entity does not finish the project because government funding falls short or looks like it may do so.
Lender	The private borrower does not have enough at stake to ensure that the borrower completes the project.
Government as Operator/Shared Operator	The government takes on too much of the project's risk. The shift increases costs to the government and lowers the incentive the private entity has to perform.
Grantor-Prime	The government provides funds using wrong criteria.

Ultimately, the decision about what model to use, the four above or something else, and what risks to accept, is one for the government. Each model has its pros and cons. There are, however, idiosyncrasies to the P3 vehicle that transcend any particular model. Two are especially important. The first is that of bundling. The second is establishing effective individual P3 governance.

Bundling P3 projects under one financing and management program provides a number of benefits. For example, it provides private entities a way to invest in multiple projects to diversify their risk. Another benefit is a more efficient governance structure. First, housing multiple P3 projects under one umbrella makes information-sharing among the different projects easier. Solutions from one project can move to another. Second, housing numerous, similar projects under

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22 *California Proposition 1, Water Bond (2014)*, BALLOTPEDIA, https://ballotpedia.org/California_Proposition_1,_Water_Bond_(2014) (last visited May 15, 2018).

23 There is no requirement that the federal government be involved in P3 projects. However, this section will focus on federal P3 projects. Many of the concepts transfer to P3 projects that do not involve the federal government.

one governmental entity aids the entity in acquiring expertise in that particular type of project. The entity can then apply that expertise in the future.

Establishing effective P3 governance is also important. The first step is developing a process to identify worthy P3 projects. The second step is ensuring that funding for P3 financing exists throughout the life of the project.

The second governance consideration concerns the particulars of each P3 project—who will do what and when, who will have oversight over a particular project, and so on. To an extent, the answers to those questions are project specific. Yet as the government does more P3 projects, certain patterns and best practices are likely to emerge. Replicating the best practices will make P3 projects run more smoothly in the future. That, then, brings the concept back to bundling. Bundling similar P3 projects together under one agency allows the agency to see numerous variations of P3 governance. The large amount of information the agency gathers gives it the best chance to see and to develop a set of best practices.

Water infrastructure P3 policy is still developing. There are many areas that require the government to make significant policy decisions with no obviously right answers. All decisions, though, must keep in mind the goal of P3s: effectively tapping private funding for water infrastructure. For each P3 project that has, and will, happen, such as the Fargo-Moorhead P3 project, the government needs to determine what worked and what did not. That introspection will illuminate the path for future P3 financing.

Fargo-Moorhead Case Study

The Fargo-Moorhead Diversion Financing is a P3 project to build flood management infrastructure along the Red River. In order to develop the project, the federal government entered into an agreement with a number of local entities. The local entities included a Diversion Authority formed by an agreement between local cities, counties, and a water district. The federal government and the Diversion Authority split responsibility for developing the project between them. Construction on both projects would be concurrent.

The Diversion Authority used a P3 structure to build its part of the project. The P3 agreement established the structure of the project. The P3 contractor would build the Authority's portion of the project. The Authority would pay the contractor using local financing under the terms of the parties' contract. The private contractor was responsible for the project's plans and specifications. The Authority took on a supervisory role; it would review the outcomes and the objectives of the project.

In the end, the P3 has been a success so far. The financing mechanism saved an estimated $400 million and reduced project completion time by 50%. It also provided a number of lessons applicable to water infrastructure P3s:

1. Water infrastructure investment presents unique liability issues for private investors. One particular issue: federal law may not indemnify the P3 contractor from claims arising from potential flooding. In response, the Authority agreed to protect the private contractor from liability. Similar agreements may be necessary for future P3 projects.

2. Just as with federal funding and project approval in general, permitting procedures can hamper the development of a P3 project. Streamlining the permitting process can result in better, more efficient projects.

CONCLUSION

Funding for modernization of the nation's water infrastructure is essential and must come from a number of sources, including federal, state, and local governments and private parties. Governmental financing likely requires significant reforms. For example, the federal government should consider focusing more funding on investing in new water infrastructure projects than on managing those that exist. Shifting operations and maintenance responsibilities to states and localities frees federal funds for capital projects. The federal government should also rethink its approval processes. Reform, both substantive and procedural, that reduces project approval time reduces the costs of water infrastructure.

Then there are private investors. There are many ways private funds can play a role in updating water infrastructure. One promising vehicle is P3 financing. P3 financing, if done well, can provide significant benefits. It can reduce costs and project completion time. As the P3 projects go forward, the government must determine what works and what does not. Doing so can unlock the potential that the P3 model promises.

SUMMARY

Water is a valuable resource. People need water for work, play, and life. But water is only useful if people can access it. Access requires water infrastructure.

America's water infrastructure is, however, in a distressing state. Much of it is aged and in need of upgrading. Moreover, the theories and premises behind the last century's infrastructure investment are proving wrong and unworkable. Climate change is a paradigmatic example. At the start of the 20th century, water managers did not consider a scenario in which climate uncertainty and extreme weather events are the norm.

The upshot is that the system is in need of an overhaul. Infrastructure needs upgrading. Concepts underlying how and where the country invests in water infrastructure need revisiting and revising. Overhauls, however, are expensive. There is the cost of the brick-and-mortar infrastructure. Then there is the cost of aligning the policies, procedures, funding sources, and politics so as to create an environment where investment occurs.

Achieving the necessary overhaul is difficult, as is any policy that requires large expenditures of money and a change in attitudes. It is a challenge the country can meet. The American experience has been about taming water—from the mills of the East to the great dams and aqueducts of the West. The spirit that created that infrastructure still exists. It is a matter of turning it towards the problem at hand. And it is turning. Experiments in alternative water infrastructure schemes, from P3 projects to decentralized infrastructure systems, are occurring with increasing frequency. Those are all signs that the country is getting serious about investing in a modern infrastructure system.

We are therefore at the start of the process. There is much still to do. The contents of this paper, relative to the scope of the problem, are modest. It has provided ideas to consider, proposed possible solutions, and identified some unique challenges. Yet if there is one key idea, it is that of cooperation and collaboration. Both will be the hallmarks of a modern water infrastructure policy. Project financing requires cooperation between all the different potential sources of funding. Reforming policies and procedures requires cooperation and collaboration among agencies and within legislatures. Cooperation and collaboration are integral to modernizing America's water infrastructure. Here, at the start, is the time to cultivate both.