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Improving the Federal Response to Western Drought: Five Areas for Reform

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Introduction

The American West is prone to drought. The prolonged dry periods that regularly hit the region have shaped the way states have developed their water supply infrastructure and the system of laws and institutions that govern water use. The latest drought—with acute water shortages in many states and record-high temperatures across the West—has tested these systems, exposing both strengths and weaknesses.

For more than a century the federal government, with its many agencies and programs, has been deeply involved in western water. It is the West's largest landowner, irrigation water supplier, hydropower generator, water information provider, and environmental regulator. It is also the West's most important partner in managing water. This partnership is complicated. Westerners are often resistant to too much federal involvement in planning and decision making, yet they regularly call for more federal support. And federal agencies often work at cross purposes.

Improving the federal role in western drought management is urgent. The West's population continues to grow, while its climate continues to warm. The latest drought has provided a window into an uncertain and challenging water future in the region. To meet this challenge—and to avoid unwanted economic, social, and environmental consequences—western states and the federal government will need to strengthen their complex, and sometimes reluctant, partnership in water management.

The various federal authorities are an asset that could be leveraged to resolve longstanding water conflicts that increase vulnerability to drought. The policies and actions of the many federal agencies involved in water resource management need to be coordinated and aligned, most usefully at the basin or watershed scale. To do so will require leadership and willingness to use "carrot and stick" approaches.

Moreover, to improve drought resilience, federal policies toward agricultural land and water management and headwater forests will need to change. Current federal irrigation efficiency programs do not improve system resilience and flexibility. These programs need to shift to meet basin-scale objectives that reduce net water use and return water to aquifers, streams, and wetlands. Additionally, the poor health of federal-owned headwater forests is due to historic management practices and drought stress. To protect the quality and supply of water from these

source areas, the federal government should accelerate efforts to reduce vulnerability to extreme wildfires.

Finally, all drought operations and planning in the West rely heavily upon water information and forecasts provided by multiple federal agencies. The federal government should preserve and enhance existing hydrologic and meteorologic data networks hit by budget cuts, and modernize the technology used for forecasting. This may require rebalancing budget allocations for research, observations, and forecasting.

This report begins with a spotlight on the current western drought, followed by a roadmap of the various federal roles that touch on western water management. It then identifies a suite of modest, pragmatic federal actions that can help western states prepare for droughts and water scarcity—and better manage drought emergencies when they do occur. These recommendations are based on analysis of public information and interviews with more than 40 individuals at the federal, state, and local levels.[1]

A Spotlight on Western Drought

In this report, we focus on the 11 westernmost states in the "lower 48." These states all lie entirely west of the 100th meridian, a traditional dividing line that reflects considerable differences in climate. On average, western states are much drier, and precipitation is also much more variable across years (Figure 1).

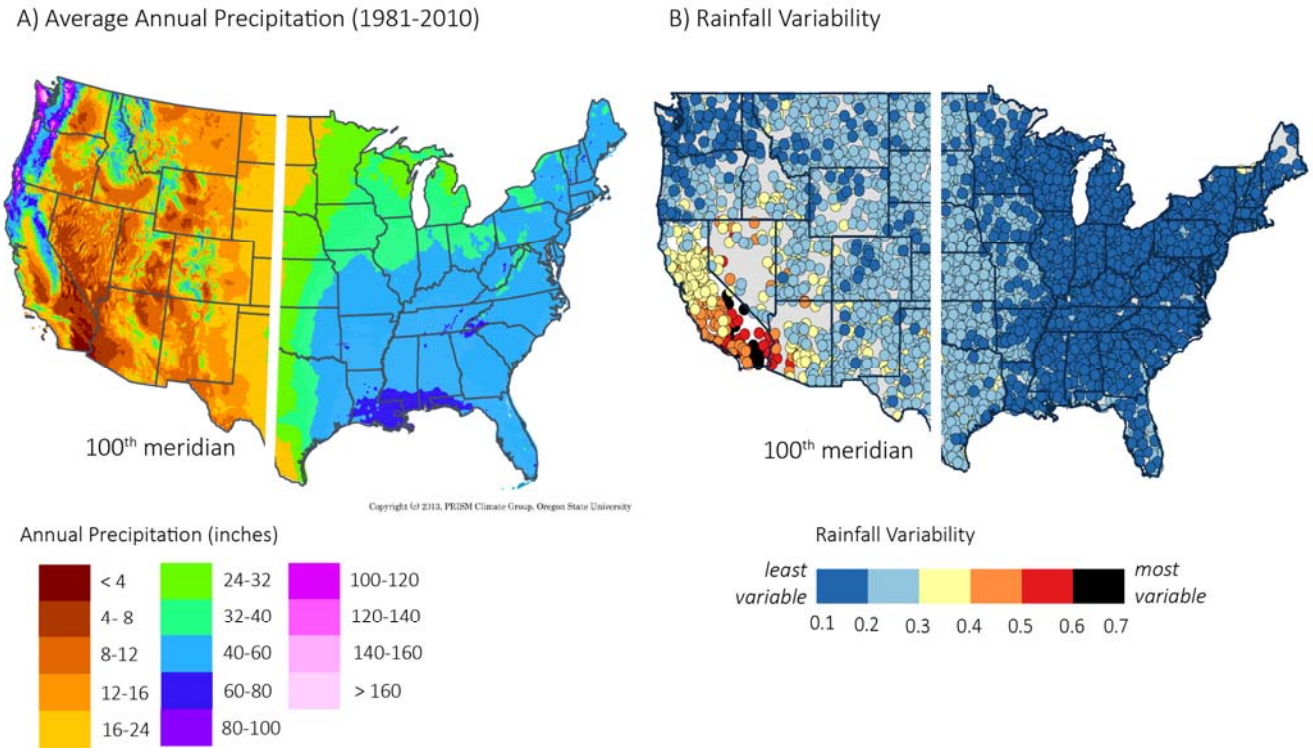
This climate presents unique challenges. In western states, agriculture accounts for most residential and business use of water (Figure 2a).[2] Farming occurs principally in areas with relatively low annual rainfall and a summer dry season ideal for growing crops, if the land can be irrigated.[3] In addition, many large urban areas are located far from their sources of supply. To meet agricultural and urban demands for reliable supplies, the region has invested in an extensive water storage and transport system. Despite these investments, the West is vulnerable to drought, with wide-ranging consequences for residents and ecosystems.

[1] The interviews took place in October and November 2015 and included experts in 7 federal agencies and 22 state and local agencies and nonprofit organizations in Arizona, California, Colorado, Nevada, and Washington, DC. This report does not directly consider tribal water supply issues or the federal government's trust responsibilities to the tribes.

[2] This total does not include water dedicated for environmental purposes (for instance, to maintain riverine and wetland habitat and to protect water quality). Such estimates are not consistently available across states. For an explanation of how water use is accounted for in California, including agricultural, urban, and environmental uses, see Mount et al. 2014.

[3] The exceptions are several states with a substantial proportion of harvested crop acreage planted to dryland crops (especially grains): Montana (84%), Washington (64%), Colorado (59%), and Oregon (57%) (author estimates using 2012 Census of Agriculture data, reported in US Department of Agriculture, 2015a). Throughout the 11-state region, irrigation is generally more intensive than in states further east, where rainfall provides a higher share of crop water needs. The average volume of irrigation water applied per acre ranges from a low of 2.2 acre-feet/acre (Washington) to 5.1 acre-feet/acre (Arizona). In comparison, the figure is 0.7 acre-feet/acre in Nebraska, a state where irrigation is an important farm input (author estimates using 2010 US Geological Survey data on irrigated acres and water used in irrigation, reported in Maupin et al. 2014).

Figure 1. Precipitation is Both Lower and More Variable in Western States



Source: Average precipitation: Oregon State University (2015). Rainfall variability: Dettinger (2011).

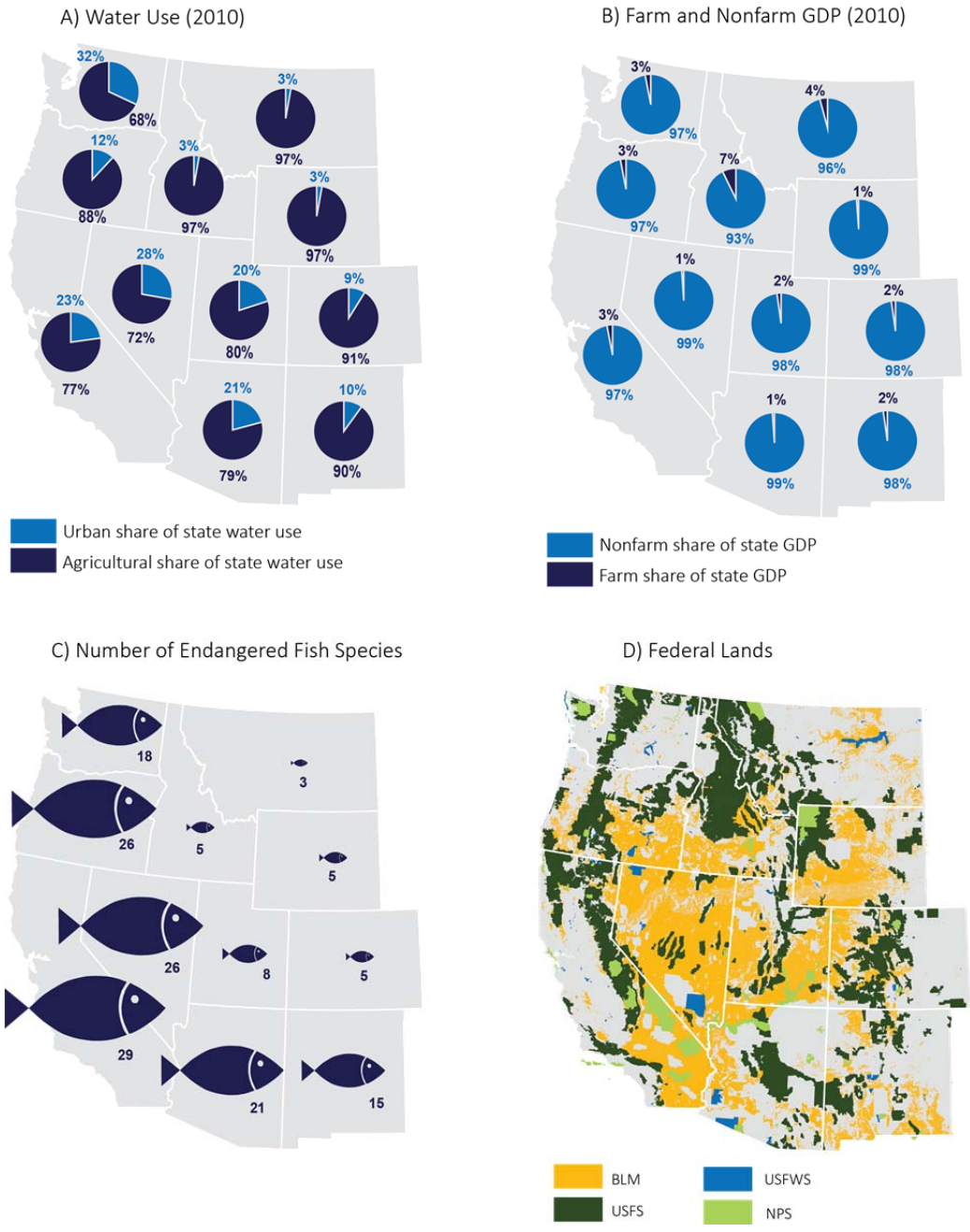
Notes: Dots in the rainfall variability panel represent the variation of total annual precipitation at weather stations for 1951–2008, as measured by the coefficient of variation. The larger the value, the greater the year-to-year variability.

For example, California has experienced acute water scarcity over the past four years, with record-low snowpack and the lowest cumulative precipitation in recorded history.[4] This has resulted in severe shortages for agricultural, urban, and environmental uses; multiple emergency declarations from the state's governor; mandatory conservation in cities; the most extensive curtailments of water rights in state history; and record rates of groundwater pumping.

Over the past two years, these dry conditions have extended across other parts of the West. In 2015, the Columbia Basin and coastal Oregon and Washington—where precipitation is usually higher and more reliable—have seen significant drought, with dramatic reductions in runoff and

[4] See Hanak et al. (2015). California may be in the midst of a longer-term drought; only two of the last 10 years have had above-average precipitation.

Figure 2. Western State Characteristics Related to Water Management



Sources: Water use: Maupin, et al. (2014); GDP (Gross Domestic Product): US Bureau of Economic Analysis (2015); Endangered fish count: state websites; Federal lands: US Geological Survey (2015). For details, see technical appendix Tables A1-A4.

Notes: A) Water use estimates are for applied water, which excludes the portion of water that returns to rivers or groundwater basins after use. The total also excludes water for the energy sector, most of which is available for reuse. B) Farm GDP includes primary crop and livestock production and food and beverage processing. C) The total includes fish listed as threatened or endangered under the federal Endangered Species Act. Some states have additional listings under state laws. D) BLM: Bureau of Land Management, USFWS: US Fish and Wildlife, USFS: US Forest Service, NPS: National Park Service.

Figure 3. In 2015, Much of the West Was in Severe Drought

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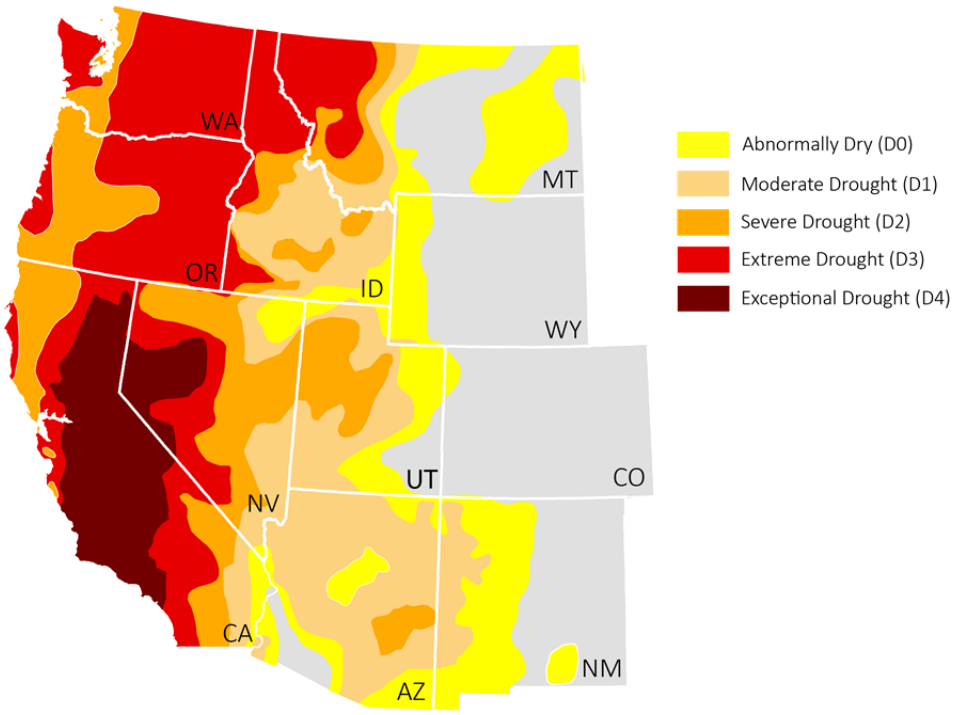

Source: US Drought Monitor, August 25, 2015.

Note: The August 25, 2015 Drought Monitor is a snapshot of conditions for that year's growing season.

record low snowpack (Figure 3). The Yakima Valley, one of the Columbia Basin's most productive agricultural watersheds, saw extensive curtailments in water deliveries to farms.[5]

Although spring rain and snow in 2015 reduced the worst effects of this latest drought for the Colorado River Basin—a major water source for seven states—this region is experiencing chronic drought. The past 15 years have been the driest in the basin's recorded history, and part of a well-documented long-term decline in precipitation and runoff. If current trajectories hold, the imbalance between water supply and demand will lead to significant cuts in deliveries across the basin (US Bureau of Reclamation 2012).

Warmth is a common feature of recent western droughts. Increases in air temperature magnify droughts in several ways. Greater warmth lengthens growing seasons and reduces soil moisture, lowering the amount of water that runs into rivers and streams while increasing water demand, particularly for agriculture. Higher temperatures also reduce the share of precipitation that falls as snow and shift the timing of snowmelt runoff to earlier in the year. Most western water management systems rely on snowpack for a significant amount of water storage, along with the predictable timing of its release as snowmelt in the spring and early summer when irrigation de-

[5] In July 2015, the flows in mountain tributaries in Yakima Basin were so low that some of the most senior water rights in Washington had to be curtailed. In all, 129 irrigators had to stop watering (Washington Department of Ecology 2015).

mands are high. This hydrology in turn determines the timing and amount of diversion for many water rights. During this latest drought, the combination of record-low snowpack and early snowmelt has significantly reduced water availability.

Vulnerability to drought varies across sectors, reflecting different degrees of preparedness and resilience. Recent drought impacts in California have been studied most extensively, and illustrate broader trends (Hanak, et al. 2015). The majority of western economic activity occurs in urbanized areas (Figure 2b). This sector has fared better than most, due to conservation efforts and system investments prior to the drought. Irrigated agriculture is more vulnerable, given the central importance of water as a production input. Farmers in California's Central Valley faced nearly 50 percent average cuts in surface water deliveries in 2015, but groundwater pumping, water trading, and high commodity prices have reduced the negative economic effects associated with land fallowing.[6]

Rural community drinking water systems and domestic wells have proven less resilient, causing concentrated hardship in economically disadvantaged communities—many of which are also experiencing drought-related job losses. Finally, the record-high temperatures and low precipitation have severely affected western rivers, wetlands, and forests. If drought continues, California may lose as many as 18 species of native fishes—including most salmon runs. Managed and natural wetlands are essential to migratory and resident waterbirds. These habitats have been greatly reduced, with likely impacts on the Pacific Flyway.[7] And drought has accelerated the decline of western forests' health, which increases risk of severe wildfires (van Mantgem, et al. 2009, Stephens, et al. 2014, Asner, et al. 2015).

Water scarcity and high temperatures are forcing western land and water managers to make some difficult decisions. Reductions in water use and tradeoffs between competing uses have been costly to manage and highly contentious, often leading to litigation and calls for controversial legislation. In California, dividing the limited water available in reservoirs between irrigators and environmental flows to rivers and wetlands has been at the center of debate over drought management. And in the Colorado Basin, there is a growing tension between maintaining agricultural production at current levels and meeting municipal demands. As the climate continues to warm, navigating these tradeoffs will become increasingly challenging. Reductions in snowpack and changes in snowmelt timing—as seen in this drought—are increasingly likely to affect both water and land management, two areas where the federal government plays a vital role.[8]

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[6] For details on farm economy impacts, see Howitt, et al. (2015). Groundwater pumping has played a critical role in reducing these impacts by making up for most of the losses in surface water. However, historic and current rates of groundwater pumping in some basins are unsustainable. This concern prompted the adoption of the 2014 Sustainable Groundwater Management Act, which will require the development and implementation of plans to bring basins into balance by 2040.

[7] For a general summary see Kay (2015). Federal and state wildlife refuges have seen dramatic water cutbacks, with many closed to waterfowl hunting this winter. Fall flooding of rice fields, which provides essential habitat for migratory waterbirds, declined from 300,000 acres to less than 100,000 acres in 2015. Farmers normally use flooding to break down rice straw (Sabalow 2015).

[8] Key references on the implications of climate change for western water management include Dalton, et al. (2013), Pierce, et al. (2013), Vano, et al. (2014), Dettinger, et al. (2015), and Diffenbaugh, et al. (2015).

Federal Roles and Responsibilities

The federal role in western water and land management has been evolving (Figure 4).[9] From the mid-19th century to the 1930s, programs such as the Homestead Act encouraged the settlement of western lands by farmers, ranchers, miners, and loggers. In the late 19th century, agencies took on a greater role in forest and rangeland management and in providing water information such as stream gages. By the early 20th century, when it became clear that major investments in irrigation systems were necessary for western agriculture, the government began actively supporting water infrastructure development, with significant subsidies for the construction of dams and aqueducts. During the Great Depression it launched direct cash support to farmers and ranchers through crop price subsidies and other programs. And in the late 1960s, it enacted laws to protect water and air quality and native species—embarking on a new set of environmental stewardship responsibilities, including protection of endangered species (Figure 2c). Around this time, agencies also began funding urban and rural drinking water and wastewater infrastructure.[10]

Today, more than two dozen federal departments and agencies engage in some facet of western water resource management (Box 1). Their roles and responsibilities are broad, complex, and occasionally conflicting. These roles can be summarized as seven key federal functions that affect drought preparation and response (Table 1).

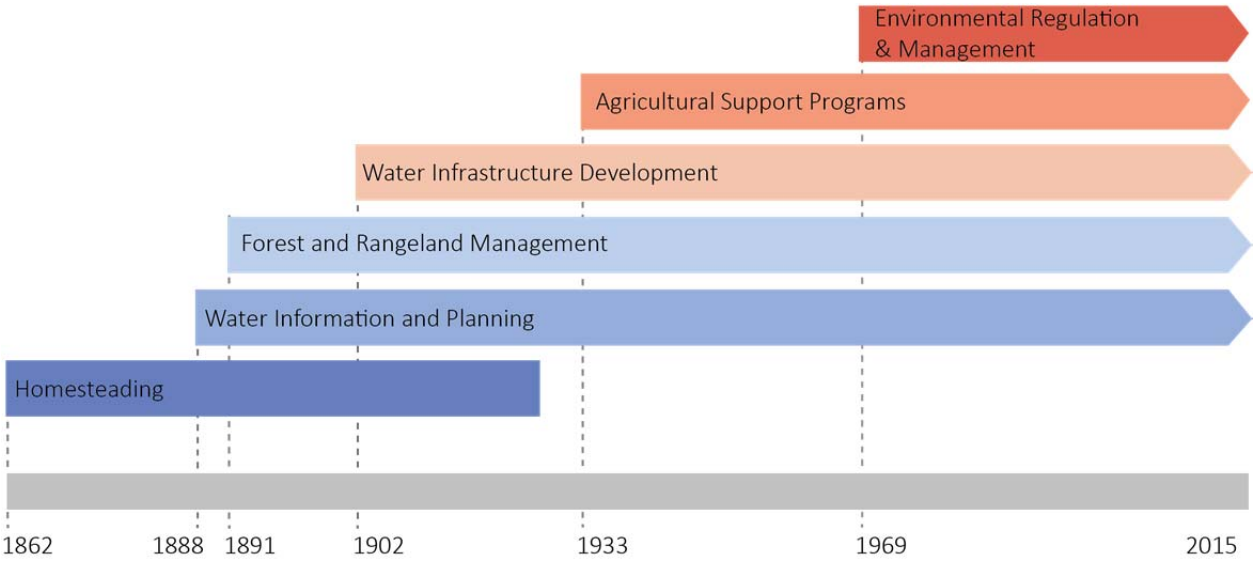
As the federal government's role has evolved, the use of its resources has shifted significantly. During much of the 20th century, it made substantial investments in large water supply and flood control infrastructure projects.[11] USBR and the Army Corps were primarily seen as infra-

[9] Key acts indicating start dates for each area in Figure 4 include the 1862 Homestead Act (homesteading), the 1888 law authorizing surveys of irrigated lands in the West (water information and planning), the Forest Reserve Act of 1891 (forest and rangeland management), the 1902 Reclamation Act (water infrastructure development), the Agricultural Adjustment Act of 1933 (agricultural support programs), and the 1969 National Environmental Policy Act (environmental regulation and management). In each of these areas, additional laws and programs expanded federal roles. For instance, the Federal Flood Control Act of 1928 significantly expanded flood infrastructure responsibilities, Public Law 74-86 of 1935 created the Soil Conservation Service that added on-farm technical funding for farmers and ranchers, the Organic Act of 1897, the Taylor Grazing Act of 1934, the Multiple Use Sustained Yield Act of 1960, the Federal Land Policy Management Act of 1976, and the National Forest Management Act of 1976 were important for forest and rangeland management, and the 1972 Clean Water Act, the 1973 Endangered Species Act, and the 1974 Safe Drinking Water Act expanded environmental regulatory mandates. In some cases, earlier laws and programs were also relevant (e.g., the Swampland Acts of 1849 and 1850 encouraged the draining of wetlands and were important in California farmland development).

[10] Throughout the history of western water development, the federal government has played a dominant role in negotiations over tribal water rights and in the development of infrastructure for farms and communities on tribal lands. This report does not focus specifically on these water management issues. However, most of our recommendations can be applied to improving drought resilience on tribal lands.

[11] Federal subsidies for the capital costs of USBR water infrastructure projects were substantial, particular for irrigators. In a review of 130 USBR projects, the Government Accountability Office (2014) found that 30 percent of construction costs on average were considered nonreimbursable and covered directly by the federal government. Unlike power and municipal customers, irrigation water customers are not required to pay interest on the reimbursable costs, repayment of which generally stretches over 40 years or more. Irrigators have also been relieved of roughly 60 percent of their share of construction cost reimbursements through direct government subsidies or cross-subsidies from other project beneficiaries.

Figure 4. The Federal Role in Western Water and Land Management Has Expanded over Time



Note: The timeline is illustrative and reflects the launch of major programs in each area (see note 9 for details).

structure agencies, designing and building most of the extensive network of large dams and aqueducts in use in the West today. Since the late 1970s, these agencies—and particularly USBR—have transitioned from constructing new facilities to managing existing infrastructure. The Army Corps now also has a major regulatory role in enforcing Section 404 of the Clean Water Act, which governs the discharge of dredged or fill materials into rivers, lakes, wetlands, and coastal waters. Today, the EPA disburses the most federal funding for new investments in water infrastructure. EPA contributions to state-run low-interest loan and grant programs for drinking water and wastewater projects totaled over $420 million in 2014 for the 11 western states, compared to just $66 million for water-related grants from USBR (Table 2).

Surprisingly, the USDA is now the dominant source of federal payments to state and local partners in the western water sphere. This includes grants and low-interest loans for water supply and quality infrastructure ($172 million in 2014), and agricultural stewardship grants of more

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Today, USBR projects supply irrigation water to roughly a third of all irrigated acreage in the 11 states in this study (authors' calculations using Table 2 from Podolak and Doyle 2014). In some states, Army Corp projects supply additional acreage. Federal subsidies to urban wastewater agencies were also substantial in the early years of the implementation of the Clean Water Act (1970s and 1980s), with cost shares of up to 75 percent for treatment plant upgrades. Federal cost shares are still substantial for flood investments (up to 65 percent for Army Corps projects and 100 percent for USBR projects), though funding is not available to support all eligible projects.

Box 1. Federal Agencies Involved in Western Water

- Federal Emergency Management Agency **(FEMA)**
- Federal Energy Regulatory Commission **(FERC)**
- National Aeronautics and Space Administration **(NASA)**
- US Army Corps of Engineers **("Army Corps")**
- US Department of Agriculture **(USDA)**
  - Farm Services Agency **(FSA)**
  - Risk Management Agency (**RMA**)
  - Rural Utilities Service **(RUS)**
  - US Forest Service **(USFS)**
- US Department of Commerce
  - National Oceanic and Atmospheric Administration **(NOAA)**
    - National Marine Fisheries Service **(NMFS)**
    - National Weather Service **(NWS)**
    - National Environmental Satellite, Data, and Information Service **(NESDIS)**
    - Office of Atmospheric and Oceanic Research **(OAR)**
- US Department of Energy **(DOE)**
- US Department of Health and Human Services **(HHS)**
- US Department of Housing and Urban Development **(HUD)**
- US Department of the Interior **(DOI)**
  - Bureau of Indian Affairs (**BIA**)
  - National Park Service **(NPS)**
  - US Bureau of Land Management **(BLM)**
  - US Bureau of Reclamation **(USBR)**
  - US Fish and Wildlife Service **(USFWS)**
  - US Geological Survey **(USGS)**
- US Department of Justice (**DOJ**)
- US Department of State (**DOS**)
- US Environmental Protection Agency **(EPA)**

than $830 million annually. The USDA is also the primary source of emergency drought relief. In total, USDA funding accounted for 63 percent of the more than $2.8 billion in federal water-related payments to the western states in 2014.

These numbers exclude spending on programs carried out directly by federal agencies—including forest management, data programs, and agency operational budgets more generally—all of which also matter for western drought preparation and response.[12] But they highlight the the fact that direct funding for new water infrastructure development is now quite limited, and focused mainly on drinking water and wastewater systems rather than water storage and conveyance projects. They also underscore the potential of aligning the federal support to agriculture—the dominant water-using sector—with the goal of building regional drought resilience. This is one of the priorities for reform highlighted in the next section.

[12] For instance, USBR's total federal budget for the 17 states in which it operates was just over $1 billion in 2014 (US Bureau of Reclamation 2015). Water users and other non-federal partners also contributed over $300 million to USBR operational expenses.

Table 1. Federal Roles in Water Resource and Ecosystem Management

Function	Roles and Responsibilities	Principal Agencies Involved
Interstate and International River Management	Negotiation of agreements and assistance with management of water resources shared among states and with Native American tribes and Canada and Mexico	DOI (Secretary's office plus USBR and BIA), DOJ, DOS
Water Infrastructure	Construction and operation of reservoirs and aqueducts that supply water, generate hydropower, support recreation, and reduce flood risk; financial support to municipal drinking water and wastewater systems	USBR, Army Corps, FERC, EPA, RUS, HHS, HUD, BIA
Agricultural Stewardship	Provision of matching grants to farmers and ranchers to improve water use efficiency and soil health, and to conserve wetlands and farmlands	USDA (NRCS, FSA)
Environmental Protection	Regulation of water and land management to improve water quality and ecosystem health and to protect native biodiversity	USFWS, NMFS, EPA, Army Corps, FERC
Forest and Rangeland Management	Management of federal forests and rangelands in upper watersheds for multiple objectives, including forest health and water supply and quality	USDA (USFS, NRCS, FSA), NPS, BLM
Water Information and Forecasting	Generation of water information and weather and climate forecasting used in all facets of water management	NOAA (NWS, NESDIS, OAR), USGS, NASA, DOE, NRCS, USBR, Army Corps
Emergency Drought Relief [a]	Provision of emergency financial support, principally to affected farms and rural communities	USDA (FSA, RMA), FEMA

[a] The federal government has two distinct processes for providing emergency drought funding. State governors can request disaster assistance from the secretary of USDA. Such declarations are relatively common, and they trigger USDA emergency assistance, including low-interest loans, livestock forage assistance, etc. In an unrelated process, state governors can request the president to declare a drought disaster under the Stafford Act, which governs major disaster and emergency declarations and results in FEMA involvement and emergency financial assistance. This authority is rarely used in the continental US (the last time was for New Jersey in 1980; more recent drought declarations have been issued for US territories, e.g., Micronesia in 2007).

Table 2. Federal Funding for State and Local Water and Drought Management, FY 2014

Programs	Funds designated for the 11 western states ($ millions)	Percentage of total
Water infrastructure	$1,103	39%
Water supply and quality:		
US Bureau of Reclamation [a]	$66	2%
Environmental Protection Agency [b]	$422	15%
HHS, Indian Health Services [d]	$37	1%
HUD, Community Development Block Grants [e]	$37	1%
USDA, Rural Utilities Services [c]	$172	6%
Flood management:		
Army Corps of Engineers [f]	$369	14%
Agricultural water and land stewardship	$834	30%
USDA, Farm Services Agency [g]	$283	10%
USDA, Natural Resources Conservation Service	$551	20%
Emergency response [h]	$873	31%
USDA, Farm Services Agency (feed subsidies)	$229	8%
USDA, Risk Management Agency (crop insurance) [i]	$523	19%
FEMA (fire management assistance grants)	$120	4%
Total	**$ 2,810**	100%
Total USDA:	**$ 1,759**	63%

Source: Authors' calculations using agency budgets. For details, see technical appendix Table A5

Notes: The table reports funds designated for the 11 western states shown in Figure 2. The amounts shown are generally obligations made in fiscal year (FY) 2014—definite, binding financial agreements for which payment might be made immediately, or in a later year. Where obligations were not available,

we used FY 2014 payments, which could reflect obligations made in prior years. In several cases, FY 2013 was the latest year available.

[a] USBR funding includes various grant programs (Water Smart, Title XVI, rural water supply, feasibility studies, and California Bay-Delta water conservation).

[b] EPA water infrastructure funding is for state revolving funds for drinking water and wastewater systems.

[c] Rural Utilities Services funding is for grants and low-interest loans to rural communities, including colonias and Native American tribes.

[d] Indian Health Services funding is from the Sanitation Facilities Construction Program. Additional funding for Native American tribes is available through Bureau of Indian Affairs programs, not shown here. BIA's nationwide budget for water resources was approximately $10.5 million in FY 2014.

[e] HUD Community Development Block Grants for water and sewer improvement projects are for FY 2013.

[f] Army Corps of Engineers funding is for flood management construction grants.

[g] Farm Services Agency funds are for the Conservation Reserve Program.

[h] The table includes funding triggered by drought emergency declarations and drought-related crop insurance. It excludes food and housing assistance programs that have been listed in some accounts of federal drought support, but that do not appear to be additional to existing social programs.

[i] Risk Management Agency crop insurance payments are for claims issued for drought, irrigation water supply unavailability, and heat. The federal subsidy averages about two-thirds of the premiums paid.

Five Areas for Reform

The interviews conducted for this study revealed widespread recognition that the federal government has been making efforts to improve and coordinate its response to drought and to focus expenditures in some key areas. However, the consensus view was that it could be a much more effective partner with western states. Here we examine five areas for improvement, building on efforts now underway and successful approaches that merit expansion.

Our recommendations promote increasing management flexibility to plan for and respond to water scarcity while meeting multiple, sometimes competing goals for supporting the health of the western economy and its natural environment. Most recommendations could be accomplished using existing agency authorities, but several require congressional action. Additionally, recognizing that new funding is likely to be difficult in the current fiscal environment, we emphasize better use of existing funds. Some actions can have near-term benefits. But most involve improving preparation for future drought and building long-term resilience.

1. Leverage Federal Authority

The Issue

One of the great challenges for building western drought resilience is making strategic decisions that involve tradeoffs in water uses. Across the West, longstanding, controversial water management issues have persisted. During drought, these conflicts escalate, often leading to litigation. The federal government has multiple roles (water supplier, regulator, agricultural sector supporter, largest landowner, etc.), giving it the opportunity to use its coordinated influence to resolve these issues. This influence can come in the form of both carrots and sticks: the ability to

convene multiple agencies and stakeholders to frame and resolve disputes, the provision of financial and technical support for innovation, and the threat of federal intervention if parties fail to come to a resolution.

Several recent examples illustrate how coordinated federal influence has helped address some critical problems. In the 1990s, the federal government was instrumental in negotiating mechanisms for improving flows for salmon in Columbia River tributaries, through water trading and purchases (Garrick, et al. 2008). In California, Department of the Interior involvement combined with potential regulatory consequences of failing to act brought about the 1994 Bay-Delta Accord and the CALFED program. This reduced conflicts (for a time) between agricultural, urban, and environmental uses of water in the Sacramento-San Joaquin Delta (Rieke 1996).

In the Colorado Basin, USBR and the Department of the Interior have played a central role in highlighting the imbalance between available supply and water use, and promoting basin planning efforts to address it. This resulted in a 2003 agreement among California agricultural and urban water users to reduce their Colorado River withdrawals, along with water trades and efficiency investments to stretch available supplies.[13] It also included the 2007 interim guidelines for managing shortages in the lower Colorado Basin—which facilitated new, more flexible mechanisms for storing and trading water (National Research Council 2007). The Departments of State and the Interior have also been instrumental in negotiations with Mexico to share shortages on the river and provide environmental flows for the Colorado River Delta.[14] And finally, the Departments of the Interior and Justice have been central to negotiated settlements of more than 30 Indian water rights claims (Thorson, et al. 2006).

These and other examples illustrate how the federal government can help tackle the thorniest water management problems, even though these agreements can take time and solutions will not always be enduring.[15]

Suggested Reforms

Use Federal Influence to Resolve Water Conflicts

To help state and local entities better prepare for drought and long-term water shortages, and to balance multiple economic and environmental objectives for water use, the federal government should expand efforts to support drought contingency planning in river basins. Multiple

[13] The Quantification Settlement Agreement (QSA) was signed by four Southern California water districts, the state of California, and US Department of the Interior. The agreement provided means for various water transfers to occur (most notably a 45-year transfer of water from the Imperial Valley to San Diego), while keeping intact California's basic Colorado River apportionment (4.4 million acre-feet annually). The QSA also committed the state of California to restoring the environmentally sensitive Salton Sea (California Department of Fish and Game 2010).

[14] In 2012, Minute 319 amended the 1944 Water Treaty to provide for sharing of surpluses and shortages on the Colorado River between Mexico and the United States. For instance, Mexico can now store some of its Colorado River water in Lake Mead, and the US can send less Colorado River water to Mexico during droughts. The amendment also provides for a pilot program of environmental flows to the Colorado River Delta (Buono 2012).

[15] Additional examples include the Yakima River Basin Integrated Water Resource Management Plan (US Bureau of Reclamation 2012), the Blackfoot River Recreation Management Plan (Montana Department of Fish, Wildlife, and Parks 2010), the Candidate Conservation Agreement for Arctic Grayling in the Upper Big Hole River, and the Truckee River Operating Agreement (US Bureau of Reclamation 2016). All had a combination of regulatory threat and effective federal engagement to reach agreement.

state and local interviewees supported this idea, despite mixed views about the federal role in western water. They noted that such efforts can be most effective if they: (1) involve the key parties in disputes, (2) have a limited window of time for action, (3) are seen as a viable alternative to litigation, (4) include federal support to accomplish goals, and (5) are backed by the potential for federally imposed regulatory solutions if parties fail to come to agreement.

Examples where the federal government could help move other parties to resolution include:

- **Balancing supply and demand on the Colorado River**. Although the government has been instrumental in drought contingency planning in the Colorado River Basin, it needs to further encourage the lower basin parties (Arizona, California, Nevada, and Mexico) to resolve shortage issues. It also needs to facilitate the implementation of conservation programs in the upper basin (Colorado, New Mexico, Utah, and Wyoming) that can make supplies available for the whole river system. Both are essential for building drought resilience along this major water source.
- **Managing California's Sacramento-San Joaquin Delta for co-equal goals.** The longstanding water supply and ecosystem conflicts of the Sacramento-San Joaquin Delta have become acute during the latest drought. The solutions are more political than technical, requiring negotiation among parties. Since the failure of the Bay-Delta Accord in the mid-2000s, the federal government—which operates the large Central Valley Project—has taken a back seat. The state of California has become the leader, enacting landmark legislation in 2009 that established water supply reliability and ecosystem health as "co-equal goals" for the Delta. Yet strong federal partnership is key to resolving this conflict, given the pervasive federal role in the Delta, including water supply, flood control, and environmental regulation (Hanak, et al. 2011, 2013).
- **Completing the agreements in the Klamath Basin.** The early 2000s drought in the Klamath Basin revealed weaknesses in federal management of water tradeoffs. In 2001 irrigation water was shut off to protect instream flows for listed species; in the following year environmental flows were relaxed to supply irrigators, culminating in a massive die-off of salmon.[16] Since that time, the Department of the Interior has played a key role in extensive negotiations between stakeholders, tribes, federal, state, and local agencies—resulting in the Klamath Basin Restoration Agreement and the Klamath Hydroelectric Settlement Agreement. The first of these expired at the end of 2015 because of a lack of congressional action (Houston 2016). The administration should focus on how to revive and ultimately implement these agreements.

We acknowledge that the complex and occasionally difficult relationship between the federal government and western states makes this recommendation challenging. Western states, and westerners in general, tend to resist what is perceived as federal intervention in authorities that reside with the states. Yet the federal government is deeply involved in western water management, and it has used its multiple authorities effectively in the past. Leadership, done well, can help break water policy logjams and improve drought resilience.

[16] For a brief history of the water conflicts in the Klamath River basin, see The Oregon Story (1997). For details on the Klamath restoration agreements, see Klamath Restoration Agreements.

2. Coordinate Federal Actions More Effectively

The Issues

Coordinating the federal response to drought involves two fundamental obstacles. The first is organizational. The various agencies' regional offices have different geographical boundaries and headquarters (Figure 5). This complicates efforts to work with multiple agencies on basin-scale issues. In addition, decision making is centralized in some agencies, such as the Army Corps, but more distributed in others, such as the EPA and NRCS. (In the latter type of agency, decisions made by headquarters in Washington, DC do not necessarily filter out to implementation in the field quickly.) Our interviewees routinely noted this lack of alignment of jurisdictions and authorities as a significant impediment to effective implementation of federal drought efforts.

Second, there is an unresolved tension between the historic roles of the federal government as a promoter of irrigation water supply and agricultural development, and its expanded role of environmental stewardship, requiring both compliance with and implementation of environmental laws. Interviewees in and out of federal agencies described the approach used by various agencies—particularly USBR and to some extent USDA—of attempting to "wring as much water as possible from the system without breaking environmental laws." In this view, environmental stewardship is a constraint on historical missions and project operations rather than an equal priority to supplying water for economic uses (and not the "co-equal goals" concept adopted by California for the Bay-Delta in 2009).

This approach tends to steer agencies away from finding multi-benefit solutions to problems that could result in less water for economic uses. It also promotes operation of water systems to maximize yields, leaving limited flexibility if conditions change in unforeseen ways.[17] And it encourages the subsidization of irrigation efficiency investments, even when they have the net effect of promoting more water consumption (Box 2).

At the same time, some observers perceive federal fish and wildlife agencies as risk-averse and increasingly inflexible, making it difficult to develop creative solutions and to experiment with new approaches.

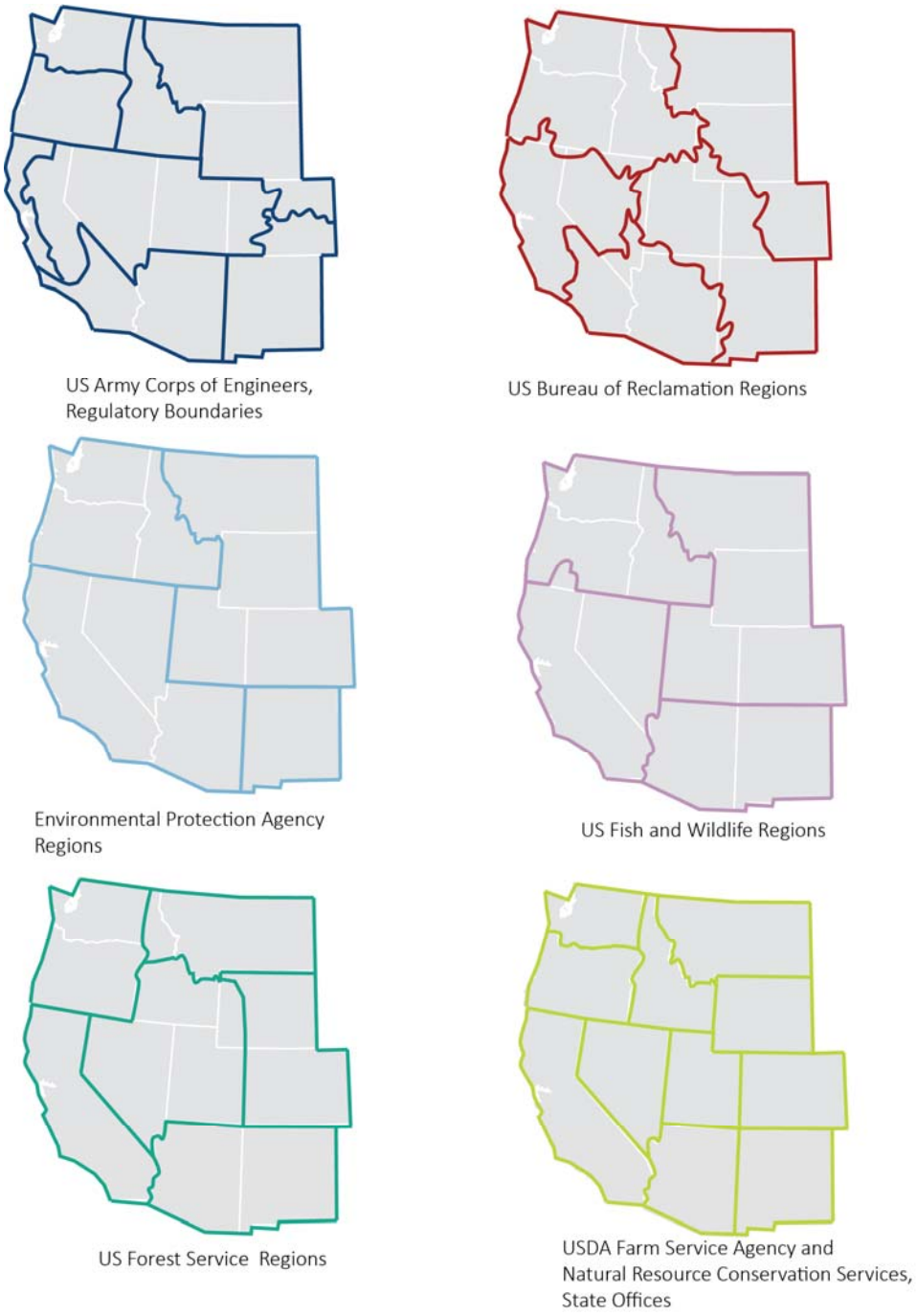
Institutional complexity and lack of clarity on how to meet both economic and environmental goals and statutory obligations make federal water management rigid, just the opposite of what is needed to respond and adapt to droughts. Left unaddressed, these challenges will impede federal efforts to help the West adapt to a changing climate and growing population.

During the latest drought, the federal government has made noteworthy attempts to improve agency coordination. Examples include the National Drought Resilience Partnership established by the White House, and various drought initiatives within the member agencies and departments.[18] Within the region, regulatory agencies report major improvements in coordination with

[17] An unfortunate outcome of this approach concerned the operation of Shasta Dam—the largest reservoir for California's Central Valley Project—in 2014 and 2015. Irrigation water releases early in the season did not adequately consider the effects of hotter temperatures on the availability of cold water supplies needed for salmon later in the season, resulting in more than 90 percent losses of young winter-run Chinook salmon in both years (Mount 2015, Sabalow 2015).

[18] The National Drought Resilience Partnership (2013) is a body established by the White House in 2013 to coordinate drought actions among federal agencies, including Homeland Security, Federal Emergency Management Agency, Environmental Protection Agency, Department of the Interior, Department

Figure 5. Regional Office Boundaries Vary Greatly across Federal Agencies



Source: Authors' illustration based on region maps from agency websites

Note: USDA's Farm Service Agency and Natural Resource Conservation Service both have state-level offices, as does the Bureau of Land Management.

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of Agriculture, Army Corps of Engineers, Department of Energy, and Department of Commerce. For examples of other agency initiatives see National Drought Resilience Partnership (2015).

Box 2. Irrigation Efficiency Does Not Always Make More Water Available

Western farmers use large volumes of water for irrigation (Figure 2a). Farmers have been adapting to increasing water scarcity through investments to improve irrigation efficiency, often with federal subsidies. Conversion from flood irrigation to drip or micro-spray reduces the amount of water applied to the land to grow a specific crop. This can improve water quality, by reducing discharges of farm chemicals into rivers and groundwater basins. However, these investments do not generally translate to increases in overall water availability (Ward and Pulido-Velazques 2008, Hanak, et al. 2009, Pfeiffer and Lin Lawell 2014). That is because much of the irrigation water not consumed by crops either returns to streams or percolates through the soil to recharge groundwater—in both cases making it available for reuse. Indeed, more efficient irrigation systems can *increase* the amount of water consumed, because they enable farmers to increase yields on existing acreage (e.g., by adding an extra cutting of alfalfa) or even to expand irrigated acreage. Unless the saved water is returned to the system, increases in irrigation efficiency can help individual farmers, but add stress on water availability in river basins.

their federal and state partners. In addition, the Council on Environmental Quality (CEQ) has become a point of contact for state and local agencies, often acting as an intermediary to help facilitate communication with federal agencies. Despite this progress, however, a perception remains that the federal response to drought is fragmented, with imprecise definition of authorities and poorly aligned—if not conflicting—missions.[19]

This perception is not new. Multiple attempts have been made over many decades to organize and integrate federal actions, since an integrated approach that encompasses all facets of water management is likely to be most effective and enduring (Cody and Carter 2009). Yet the resistance to integration is broad, both within agencies and among stakeholders who rely upon funding or services from single programs and agencies (Kenney 2008).

Suggested Reforms

Our two recommendations focus on drought resilience and response issues, rather than all facets of water management.

[19] As several interviewees pointed out, this perception is accentuated by the fact that many of the federal drought programs highlighted by the National Drought Resilience Partnership are simply a relabeling of existing programs, not new efforts.

Rebalance Priorities and Seek Consistency at the Proper Scale

Improving drought resilience and emergency response in the West requires matching problem-solving efforts to the scale of those problems. This scale will generally be either river basins—the large catchment areas that often cross state boundaries—or the smaller watersheds or subcatchment areas within these basins. For example, addressing the long-term imbalance between water supply and use in the Colorado Basin will require alignment of multiple agency actions at the scale of the entire river basin over a period of many years (Figure 6). To improve emergency supplies for disadvantaged rural and tribal communities, or return flows to rivers to protect water quality during drought, the appropriate scale may be the watershed, over short periods of time. Alignment and balance of agency priorities is essential in all cases, as are efforts to mesh federal actions with state and local priorities.

We suggest that federal efforts to manage drought be shifted from the centralized, Washington, DC-based approach currently used (e.g., Drought Resilience Partnership and coordination by CEQ) to a more distributed authority, where interagency teams with expertise in the basin or watershed address priority areas and actions. These federal drought response teams would work closely with their partner state agencies to set priorities, but would seek to rebalance federal policies at the watershed or basin scale. The teams need to be led by a high-level administrative appointee with significant coordination authority, who will serve as the principal point of contact for state and local agencies as well as stakeholder groups. A presidential memorandum may be sufficient to establish these teams, though congressional authorization may be needed to authorize them to streamline and coordinate permitting or, in some select cases, to waive National Environmental Policy Act (NEPA) review requirements.[20]

Perhaps most importantly, these interagency teams need consistent plans that, in consultation with state agencies, integrate federal priorities by aligning agency actions, including planning, operations, funding support, and regulation.[21] This strategy is not without precedent. During the 1980s and 1990s, the Department of the Interior took the lead in establishing interagency guidelines and coordination for negotiations over settlements of tribal water rights (Colby, et al. 2005). These efforts, typically led by a senior Department of the Interior official, unified federal efforts during settlement talks. Another example from the energy field is the interagency rapid response team for transmission, set up in 2009 to coordinate and expedite transmission permitting (Gray, et al. 2013).[22]

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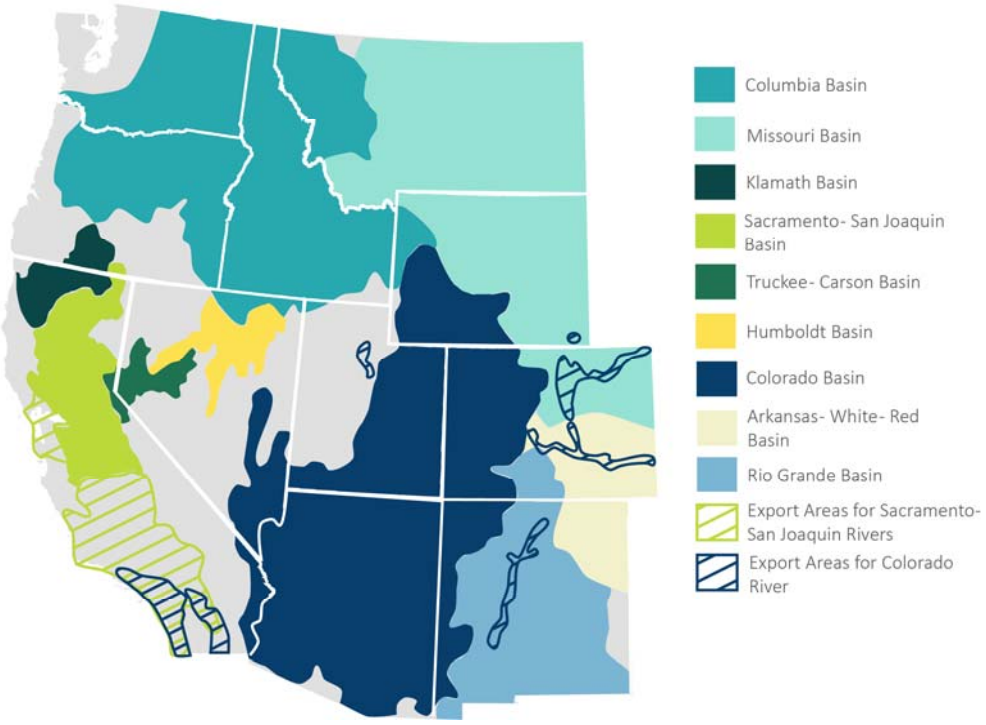
[20] Western states might also benefit from the formation of a congressional drought caucus to help coalesce calls for more federal attention.

[21] This includes alignment of agencies that do not always have similar priorities, policies, and jurisdictions. For example, supply enhancement and demand reduction in the Colorado Basin will require coordinated actions between the US Forest Service (the largest landowner in source areas), NRCS (since agricultural use accounts for 90 percent of upper basin water use), the National Park Service (a major land owner), USFWS (key regulator) and USBR (water master for the lower basin and manager of storage in the upper basin), working closely with state and local agencies. Although there has been frequent communication between federal agencies working in the basin, there is no coordinated federal plan that balances priorities and expenditures for water supply, ecosystem management, and other priorities.

[22] A more durable approach to federal agency consistency is that provided by the Coastal Zone Management Act of 1972. This law requires that federal agencies act, where practicable, in a manner consistent with state-approved (and federally sanctioned) Coastal Zone Management Plans. For a description of how this approach would work in watershed management, see Thompson (2012).

Figure 6. Major Western River Basins Are the Appropriate Scale for Aligning Many Federal Actions



Source: Authors' illustration based on western watershed maps.
Note: Export areas receive water from the Colorado and Sacramento-San Joaquin Rivers.

We recognize that implementing this recommendation will be difficult. Not all basins and watersheds have well-developed and cooperating stakeholder groups and local agencies necessary to make this work. Additionally, entrenched constituencies and some states may see alignment and consistency of federal policies as a threat to services they have traditionally received. Indeed, a shift in a policy that seeks to "wring as much water from the system as possible" to its logical alternative—working with states to manage and even reduce water demand—may get a hostile reception. Although current federal efforts to coordinate activities are yielding some benefit, they are likely to face limited success unless they address the fundamental problem of a lack of integration of federal activity at the proper scale.

Develop Drought Biodiversity Plans

To align economic and environmental objectives of water management during droughts more effectively, federal agencies need to improve their preparation with respect to ecosystems and the increasing water stress expected with a warming climate.[23] The severity of the latest drought,

[23] A broader challenge is how to manage native species biodiversity with a changing climate, which may limit the ability to sustain some species in the wild. This issue is discussed in Hanak, et al. (2011), chapter 5.

particularly in California, highlighted how poorly prepared federal and state agencies were for dealing with environmental drought emergencies, including the potential for multiple extinctions. Agencies had no contingency plans and were forced to take actions on an ad hoc basis. Federal fish and wildlife agencies should develop plans in partnership with key agencies like USBR, the Army Corps, NRCS, and state counterparts to sustain native biodiversity during drought (Hanak, et al. 2015). These plans should identify the most at-risk populations and the emergency measures needed to support them. These measures should include identification and protection of habitat in locations that are critical to survival of species during drought emergencies, prioritization of measures to save species such as changing dam release schedules and water purchases, and use of conservation hatcheries.[24] These plans should identify not only the emergency actions needed during drought, but also the management options to build resilience to drought during wet years. One urgent priority is a drought plan for West Coast salmon, given the combined risks from low flows and higher temperatures.

3. Change Agricultural Support Programs

The Issue

The federal government is deeply involved in supporting western farmers. It does this both through water and hydropower supply projects and the many programs under the Farm Bill, which range from crop subsidies, to crop insurance and emergency drought relief, to soil and water conservation programs. Given agriculture's large role in western water use, even minor changes in agricultural practices can have broad impacts on water supplies and ecosystem health.

The agricultural water and land stewardship programs run by the Natural Resources Conservation Service and the Farm Service Agency are singularly important. The NRCS provides farmers with technical and financial support to improve water use efficiency and to conserve soils, water, and wildlife habitat through on-farm investments. It also runs easement programs that pay farmers to permanently restore their fields to wetlands or to maintain agricultural production for 30 years on land that might otherwise be developed. The FSA's conservation reserve program is also a type of easement program that pays farmers to idle environmentally sensitive cropland and replace it with a cover crop for 10 to 15 years.

Because these programs are reasonably well funded ($834 million in 2014 in this region), they create a unique opportunity to improve drought resilience in ways that meet multiple federal, state, and local objectives, at scales that are likely to have broad impact. But several changes are needed to better align these programs with these broader goals, while still supporting the core client base—individual farmers. Some of these changes can be accomplished under existing statutes, with policy reorientation at the agency level. Others may need congressional authorization and should be considered for incorporation in the next Farm Bill (2019), if not sooner.

Suggested Reforms

Build Agricultural Drought Resilience at the Basin Scale

One way to align federal stewardship programs with broader basin goals is to shift their emphasis to partnering with water districts and other entities, such as producer associations, that use

[24] For a discussion of lessons from the Australian state of Victoria's planning efforts, see Mount et al. (2015).

watershed or basin goals to guide management. The Regional Conservation Partnership Program (RCPP), created under the 2014 Farm Bill, is a step in this direction; it encourages the NRCS to work with partners at the watershed scale.[25] The Conservation Reserve Enhancement Program (CREP) is another example; it enables states to partner with the FSA to achieve a specific conservation objective when land is idled under the conservation reserve program.

This partnership approach is important because it facilitates looking at the aggregate effects of stewardship investments on water resources in the area, and it can help implement programs that require the coordinated participation of numerous farmers and ranchers. Payments for temporary or permanent land retirement are a case in point. For instance, the CREP program might be used as a way to help fund the retirement of some agricultural water rights in basins where states are trying to reduce water use, either to meet interstate river-compact obligations (as in the upper Colorado Basin or on the Rio Grande), to reduce groundwater overdraft (as in California's San Joaquin Valley), or to increase environmental flows to protect endangered species (a concern in many watersheds). Similarly, the NRCS's wetlands easement program will be most ecologically valuable if used strategically to restore wetlands where they are most needed to support waterbirds and other wildlife.

To work well in meeting some basin objectives, easement programs will require more flexibility than they have today. For instance, in the upper Colorado Basin, some farmers have expressed an interest in rotational fallowing rather than permanent land retirement as a way to reduce water use. Instead of rigid rules that lands be held in the FSA's conservation reserve program for 10 to 15 years, the program could allow farmers within an area to jointly commit to a level of fallowing and then rotate the responsibilities among themselves (perhaps using a bidding process). This change would make it more attractive. NRCS's agricultural land easement program also needs more flexibility. In places like the San Joaquin Valley, where perennial crops now make up close to half of crop acreage, it could be valuable to offer easements that create incentives for some farmers to maintain their land in annual crops or alfalfa, which can be more easily fallowed during droughts. But currently, this easement program only restricts conversion of farmland to other uses, such as houses, and officials we spoke with expressed reluctance to offer this additional option.

Other sources of funding would also be appropriate in some of these cases. For instance, urban agencies in Colorado could support rotational fallowing as an alternative to the "buy and dry" approach of permanently fallowing farmland to acquiring irrigation water for municipal uses. And perennial crop farmers in California may have an incentive to compensate some neighbors for keeping acreage in field crops to provide flexibility for drought management. But with our recommended changes to increase program flexibility, the USDA payment programs can remain consistent with their objectives of protecting idled land with cover crops (the conservation reserve program) or maintaining land in farming (the agricultural land easement program) while supporting broader watershed goals.

Thinking at the basin scale will also require changing irrigation efficiency grants to meet basin water-management goals. Improved on-farm efficiency—meaning reductions in the amount of water it takes to grow a specific crop—frequently does not translate into more water in the system, since newly available water is often used to increase overall crop production (Box 2). Moreover, on-farm "inefficiencies" are often vital to the recharge of groundwater as well as to

[25] In addition to facilitating broader planning on strategic use of NRCS funds, this program also authorizes some funding to support system-level investments (e.g., improvements at the level of an irrigation district), rather than strictly limiting payments to on-farm investments.

downstream users. Yet individual farmers have incentives to make these investments—especially when they are subsidized—because farmers reap individual benefits even if there are negative consequences for the basin and other water users.[26]

Improve Instream Flows and Wetlands

In keeping with the objective of considering environmental benefits alongside those of producers, USDA programs should also ensure that increased on-farm efficiency does not reduce—and ideally enhances—water to meet environmental needs.

To this end, NRCS and FSA programs should explicitly prioritize working with states, local water districts, and other federal agencies to help farmers return flows to wetlands and rivers to achieve multiple benefits. This can be accomplished in many ways. Beyond the permanent wetland easement program, solutions should include expanding work to improve temporary, strategic flows to meet wetland and instream habitat needs. This can also include dedicating water created through irrigation efficiency programs to meet environmental needs. Again, greater flexibility in reimbursements will be needed. Currently, contracts for conservation practices are limited to three years, and the assumption is that these practices are revenue-generating and self-sustaining. But investments with the primary objective of supporting aquatic habitat generally do not cover their full costs, and merit longer-term support. One extremely valuable NRCS program during the California drought has been payments to farmers to temporarily flood their fields to support habitat for the waterbirds of the Pacific Flyway. Yet this program is now running into time limits for some willing participants under NRCS program rules. Again, working with larger groups of producers, through irrigation districts or associations, can provide needed flexibility while supporting the program's client base.

Promote a Culture of Innovation

Many interviewees cited a field-level culture within NRCS that is resistant to piloting new approaches and technologies. The NRCS is not a research organization, but it can—and should—play a valuable role in testing innovations and learning through adaptive management. For example, many growers and water managers are interested in recharging overdrafted basins in California's Central Valley by deliberate winter and spring flooding of orchards that have drip and subsurface irrigation systems.[27] This deviates from the traditional NRCS policy that seeks to improve on-farm irrigation efficiency. So far, NRCS appears to oppose funding these efforts.

An additional constraint for experimentation is shortages in technical support staff. Budget cuts have reduced the number of technical staff, with most staff now committed to administering grants for adopting established technologies rather than fostering innovative programs. Experimentation and learning—including building relationships with new partners at the watershed scale—will require a commitment to building technical staff. Several creative efforts are under-

[26] In some western states, "use it or lose it" laws can be a disincentive to water conservation programs that make water available for transfer. This is something state laws will need to address, as California has done, for instance, by making water conservation a beneficial use—a policy that has encouraged temporary leasing of water rights for various purposes (Hanak and Stryjewski 2012).

[27] This would involve capturing flood flows currently not appropriated by other water users. To fully take advantage of this practice, the state will also need to expand rights to drought storage (Gray et al. 2015).

way in this regard, including partnerships with foundations and nonprofits to fund shared staff.[28] The numerous agricultural experiment stations located at land grant universities—also supported by USDA—are key providers of research and demonstration projects that can spur innovation, another potential opportunity NRCS could leverage.[29]

4. Improve Headwaters Management

The Issue

The federal government is the West's largest landowner, with title to over half the total land area (Figure 2d). The US Forest Service is also the principal owner and manager of the region's forested, mountainous upper watersheds—the source areas for most surface water runoff.

This close connection between western forests and water supply was recognized in the Organic Administration Act of 1897, which established protections for federal forested lands "for the purpose of securing favorable conditions of water flows." Forest conditions today, however, are often neglected when it comes to improving drought resilience and supplies. Yet studies have shown that healthy forests provide an array of services, including multiple water supply benefits (Postel and Thompson 2005). In particular, better water quality reduces treatment costs, and greater annual yields can be of high value during droughts (Bales, et al. 2011).

The current drought has brought one aspect of western forest management to the fore. Historic fire suppression policies—which sought to put out fires as quickly as possible to prevent property damage and loss of timber—have led to a build-up of vegetation throughout western forests, making them susceptible to infestation with insects, pathogens, and disease. The dry and warm conditions of this drought have stressed these overcrowded forests, leading to widespread tree death. These conditions—dense, dry, and dead—have made forests vulnerable to extreme wildfires (Williams, et al. 2013, Stephens, et al. 2014). The intensity of these fires can significantly alter forest composition and diminish many of the benefits derived from forests. Extreme fires have been common throughout the region during recent drought years, causing loss of life, property damage, poor air quality, lower-quality runoff, and loss of reservoir capacity (Hanak, et al. 2015, McCann and Mount 2015, US Department of Agriculture 2015b and 2015c).

The issue of restoring western forest health to protect water supplies has been widely debated for years. Many actions can be taken to improve forest conditions, such as stream and meadow restoration, improvement of roads, and better timber harvest practices. But the consensus view is that the highest and most urgent priority is to reduce forest density and the likelihood and consequences of extreme fires. In 2014, under the Federal Land Assistance, Management, and Enhancement Act of 2009, the Department of the Interior and USDA developed the Forests and Rangelands National Cohesive Wildland Fire Management Strategy (Wildland Fire Leadership Council 2014) that sets forth such a goal.[30] Ongoing revision of multiple national forest plans is

[28] An example of creative partnerships between the NRCS and nonprofit organizations is the Rangeland Watershed Initiative by Point Blue Conservation Science (2015).

[29] Gold, et al. (2013) recommend ways to strengthen USDA-funded research at these institutions in support of agricultural sustainability goals.

[30] See also the Western Watershed Enhancement Project, a joint effort by USBR and USFS to reduce fuel load above USBR reservoirs as insurance against the water-quality and capacity-reduction problems caused by wildland fires (US Department of Agriculture 2013).

seeking to effect change in forest management to meet these goals through a combination of mechanical thinning, prescribed fire, and managed wildfire.

Yet one of the largest barriers to achieving this goal is the cost of fire-fighting itself, and the way resources are allocated to the USFS. In 1996, fire suppression made up just 16 percent of the USFS budget; in 2014, 50 percent of the total budget and 56 percent of discretionary spending went to fire-fighting (US Department of Agriculture 2015d). This shift has drawn resources away from actions that would improve forest health and reduce the future costs of wildfire. Meanwhile, emphasis on fire suppression—rather than prevention—leads to continued build-up of fuels, increasing the likelihood and intensity of future fires.

Despite the general consensus of forest managers in favor of a shift to fire prevention and forest health and away from fire-fighting, there are multiple disincentives to change (North, et al. 2015). Fire suppression is still the default response, notably during drought, given fears of the potential for unmanageable fire and the associated risks for property. Local stakeholder pressure has at times made it difficult to initiate mechanical thinning and prescribed burn programs. And large areas of national forestlands are either physically inaccessible or hard to access for forest treatment due to permitting challenges, typically associated with endangered species.

Suggested Reforms

Restructure Funding for Wildfire Suppression

The budget that is allocated for fighting wildfires should be separated from other Forest Service activities, such as fire prevention and forest restoration. In 2015, administrative and congressional proposals were considered that would shift the responsibility for suppression of extreme wildfires to FEMA's emergency funding program, but this change was not included in the enacted FY 2016 budget.[31] Because the largest 1–2 percent of fires now consumes roughly 30 percent of the fire-fighting budget, this would free up as much as $320 million a year for forest health management and fire prevention actions (US Department of Agriculture 2015d). Achieving this funding reform should remain a priority.

Initiate Multiple Large-Scale Collaborative Projects to Restore Forest Health

There has been considerable progress in improving the pace of restoration of forested lands nationwide (US Forest Service 2015). Yet many interviewees felt that to date, most efforts at fire prevention and forest health have been small-scale demonstration projects. To improve public perception and demonstrate benefits—including the potential for boosting drought resilience for downstream users—the Forest Service needs to incorporate a series of large-scale projects into all of the emerging forest management plans. These projects should explore incentives for financial investments from beneficiaries to cover a portion of the costs.[32] In addition, partnerships should be formed to promote research and development of new wood energy and building industry products that can increase the value of harvests that reduce fuel loads.

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[31] This change would be considered budget neutral (Congressional Budget Office 2014).

[32] For instance, in a study of the northern Sierra Nevada watershed, Podolak, et al. (2015) found that a three-fold increase in the scale of national forestland restoration could generate up to a six percent increase in the mean annual streamflow for individual watersheds. The economic benefits from increased hydropower generation and water uses would be sufficient to cover between one-third and the full cost of thinning. Examples of existing programs where water users contribute to forest management include Denver, Phoenix, and the San Francisco.

5. Improve Water Data and Forecasting

The Issue

Drought requires making difficult decisions on how to allocate scarce water supplies. Managing water in the West relies on timely and useful information on water use, availability, and forecasting. The federal government is the largest provider of this information. Collection, integration, and dissemination of on-site water data (including rainfall, snowpack, soil moisture, and flows) are principally the responsibility of NOAA, the National Weather Service (NWS), and USGS, with extensive state, local, and private partnerships. NOAA and NASA provide satellite-based information necessary for weather forecasting and land- and water-use monitoring, primarily through the Landsat and NESDIS programs. The NWS provides near-term weather forecasts (10 days or less), and both monthly (subseasonal) and seasonal climate forecasts.

Water information and forecasts are essential to a diverse array of federal drought management activities. The National Integrated Drought Information System (NIDIS) is a multi-agency cooperative. NIDIS is best known for its drought monitor, which tracks drought conditions nationwide and is used to guide drought declarations that qualify for federal assistance.[33] NWS weather forecasts are used to populate runoff models developed by USBR, the Army Corps, and many state agencies to guide reservoir operations for water supply, hydropower, and flood control. In recent years, there has been considerable interest in using forecasts to inform more flexible reservoir operations, which could improve both supply and flood-control functions in a warming and more variable climate.[34] Weather and seasonal climate forecasts are also essential to many of USDA's activities, including farm support and fire management.

Federal expenditures in this area can be put into three general categories: forecasting and related information services critical to water management (21 percent); support for observation systems, both sustained (38 percent) and experimental (18 percent); and support for research and new technology development, including applied (8 percent) and basic (16 percent) research programs that do not directly inform operations (Table 3).[35]

Multiple interviewees in federal, state, and local agencies noted three significant problems with current federal water information and forecasting programs. First, there has been a long-term decline in land- and sea-based on-site monitoring systems (gages, meteorological stations, buoys, weather radar, etc.) necessary for informing real-time water management and improving operational forecasts. Second, there is general concern that NOAA and NWS have been slow to modernize their forecast models and products and to operationalize new technology and information sources. The greatest need for drought management is improved water availability and use information, including surface and groundwater, and seasonal and subseasonal forecasting

[33] See US Drought Portal (National Drought Mitigation Center 2015). Figure 3 in the text provides a snapshot of a drought monitor map in late August 2015.

[34] The idea is to reduce the rigidities in current "rule curves" that guide the release of water from reservoirs to prevent downstream flooding. A pilot project on the Russian River in California is investigating the potential for this type of reoperation (Sonoma County Water Agency 2015). High-quality forecast models are critical to flexible operations of this type, because maintaining more water in reservoirs (which can provide significant water supply benefits during droughts) can have catastrophic consequences if it reduces the capacity to prevent flooding.

[35] These categories are based, in part, on those developed as part of the *National Plan for Civil Earth Observations* (Office of Science and Technology Policy 2014).

Table 3. Federal Spending on Water- and Weather-Related Forecasting, Observations, and Research, FY 2014 ($ millions)

	Descriptions	Forecasting and Related Services	Observations		Research		Total
Agencies			**Sus-tained**	**Experi-mental**	**Applied**	**Basic**	
DOE	Climate and earth system modeling					$298	$298
NASA	Satellites: Landsat, Suomi NPP, Aqua, etc.		$40	$1,054	$95	$636	$1,825
NOAA, NESDIS	Product development, readiness and application; satellite and product operations		$2,087				$2,087
NOAA, NWS	Weather and climate forecasting	$1,063					$1,063
NOAA, OAR	NIDIS, weather and air chemistry research, climate research				$247		$247
USDA, NRCS	Snow and soil surveys	$9	$80				$89
USGS	Water use, streamflow gages, groundwater studies, water quality	$162	$68		$109		$339
Total:		**$1,234**	**$2,275**	**$1,054**	**$451**	**$934**	**$5,948**
		21%	**38%**	**18%**	**8%**	**16%**	

Sources: Agency budgets: NASA. USDA, NOAA, DOE. For details, see technical appendix Table A6.

Notes: Percentages exceed 100 because of rounding. The table does not include monitoring and forecasting systems of agencies that operate water infrastructure projects (USBR and the Army Corps).

that allows for operations decisions months in advance. Third, end-user agencies, such as USBR and the Army Corps, need to continue upgrading their own information systems and forecasting models that guide operations.[36]

The need to modernize and integrate water information and forecasting has been a central concern of the Western States Water Council, which has called repeatedly for increased federal investments to fill key information and forecasting gaps (Western States Water Council 2012). The Western Governors Association has cited this issue as a top priority, developing a 2014

[36] This issue was highlighted during the past two years in California when two successive years' cohorts of winter run Chinook salmon—an endangered species—were killed due to poor management of cold water releases from Shasta Reservoir by USBR (Mount 2015, Sabalow 2015).

Memorandum of Understanding with NOAA to jointly seek improvements. Over the past three decades, the National Research Council (NRC) has conducted multiple reviews of the NWS. In 2012, two NRC reports (National Research Council 2012a, 2012b) described a comprehensive vision for a modern and more nimble NWS. The NWS responded to this review and developed a modernization plan entitled *Weather-Ready Nation Roadmap* (National Weather Service 2013).

One of the major challenges facing improvement of water information and forecasting is the diverse array of federal programs producing and using this information. It has proven difficult to create stable funding. Budgets for NOAA (Department of Commerce), USGS (Department of the Interior), NRCS (USDA), and NASA, for example, are managed by separate congressional committees, and each agency and committee has its own appropriation caps.[37] It has proven equally difficult to align actions, since each committee and agency has its own priorities.

Although it might be ideal to align actions, priorities, and funding for western water information and forecasting systems into a single entity, this is impractical at the current time. Instead, the following suggested reforms focus on urgent near-term needs for managing drought. These recommendations are essential for successfully accomplishing the four other reforms discussed in this report.

Suggested Reforms

Strengthen Data Collection Systems

The West poses unique challenges for collecting hydrological and meteorological information. The mountainous terrain, numerous small watersheds, and highly variable climate require dense monitoring information networks. Due to fiscal cutbacks, federal support for data collection systems has lagged, degrading their quality and usefulness. There is an increasing reliance on a fragile patchwork of partnerships with federal, state, and local agencies to keep these systems going. The relative cost of improvement is low compared to the value of the information for managing drought.[38] This is particularly the case for on-site, earth-based measurements. Thanks to advances in gaging technology, the costs continue to go down. And although satellite-based systems are improving, they have not—and are unlikely to ever—replace the need for basic on-the-ground measurements. To address this issue, Congress should consider a hydrological and meteorological network upgrade program—led jointly by DOI and USDA with extensive state agency and stakeholder input—that specifically targets new funds to restore and improve the quality of monitoring networks in the West.

[37] This problem was highlighted by the efforts of NASA to end its commitment to Landsat due to budget cuts. The satellite system is established technology (not a top NASA priority) that has been in use for more than 30 years, and it is the principal source of satellite-based information on land use and land cover changes and water use. The issue has been resolved in the short term, after a concerted effort by the Western States Water Council and Western Governors' Association, by establishing a joint management program between NASA, DOI, and NOAA (described in detail here: http://geo.arc.nasa.gov/sge/landsat/mgmtplan.html). However, budgets for this program remain at risk, with potentially high consequences for western water management.

[38] For example, snow monitoring support through the NRCS SNOTEL program is just $9 million per year, and USGS stream gaging investments amount to less than $65 million per year nationwide. Both programs depend heavily on partner funds to expand and maintain networks. The USGS maintains approximately 8,000 stream gages (about 10 percent less than they operated in 1970) and partners with over 800 federal, state, and private entities. In addition, NWS operates an extensive Cooperative Observer Program that links information from many privately maintained meteorological stations.

Modernize the National Weather Service

A number of interviewees pointed out that it has been difficult to improve the skill and utility of NWS forecasts, particularly in the subseasonal and seasonal range essential for drought planning and management. Many of the forecast models are decades old and in need of modernization. This stems in part from the limited available budget. However, observers also noted the great challenge of incorporating new technology into NWS operations. This problem, euphemistically referred to as the "valley of death" between research and operations, has been long recognized (National Research Council 2011, 2012b). Its root causes are many, but lie principally with the continued failure to link research efforts closely to specific NWS operational needs, and NWS institutional resistance to adopting new technology. This issue is addressed in the NWS Weather Ready Roadmap, but recommended reforms have yet to be implemented. The administration should identify approaches that would speed completion of elements of this plan that specifically address western drought information needs. (Most urgent is completion of the Roadmap's Science and Technology Plan.)

Reevaluate Funding Mechanisms

Improving gaging networks and modernizing the NWS will require new approaches to funding. The increased emphasis on partnerships with state and local agencies has helped, but maintaining stability in these resources is difficult. The administration should work with Congress to conduct a comprehensive reevaluation of funding within the three general areas: forecasting, observations, and research. Upgrading and modernization may be achieved by rebalancing the funding portfolio.

Improve Water Use Monitoring

One of the challenges western states face in managing water is estimating net use by agricultural users. As noted above, a portion of water applied through irrigation returns to the system, either as runoff from fields or through groundwater basin recharge. Managing water efficiently in these systems—including curtailment of water rights during droughts as well as water transfers that can reduce the costs of shortages—requires accurate knowledge about net water use. Space-based imaging of crops, such as in the Idaho Department of Water Resources' METRIC program, shows great promise in this regard.[39] Idaho's program uses Landsat imagery to calculate net use of water by crops, allowing for precise estimates of actual water use and facilitating more flexible water management. The federal government has been and should continue to be a supportive partner in these efforts. This includes developing user-friendly, accessible archives of Landsat imagery, together with tools—such as METRIC—to estimate net water use.

Conclusion

The federal government is directly or indirectly involved in all facets of western water management through its land and infrastructure ownership as well as its diverse authorities. As western states seek to adapt to a growing population and the prospect of more frequent and intense droughts, the federal government can and should be their foremost partner.

[39] METRIC is a joint effort between the Idaho Department of Water Resources and the University of Idaho that, with the use of Landsat imagery, is able to track net agricultural water use (evapotranspiration) to help guide local water management (Idaho Department of Water Resources 2015).

Improving the effectiveness of federal assistance in building drought resilience and responding to drought emergencies can be accomplished with modest changes in policy and funding. The federal government should leverage its many support programs and the prospect of regulatory action—its "carrot-and-stick" powers—to bring resolution to longstanding conflicts that are increasing regional and local vulnerability to drought.

To accomplish this, the multiple agencies working on water issues should align policy objectives—particularly economic support and environmental stewardship—and address problems at the proper scale, using local administrative teams. Given the scale of agricultural water use in the West and the size of existing federal farm programs, the greatest potential for lasting, regional change lies with aligning the activities of key USDA programs—run by the NRCS and the FSA—to watershed and river basin conservation objectives, including using farm efficiency and easement programs to return some water to rivers and wetlands.

As the West's largest landowner, the federal government must also recognize its role as steward of the region's headwaters. Management of forested lands—especially to reduce the impacts of severe wildfire—is essential for building drought resilience over the long term. Finally, the federal government is the most important provider of western water information. Modernizing water information and forecasting programs can reduce the economic cost, social disruption, and environmental impacts of drought.

Although these policy and funding changes are modest, institutional changes of this kind can be difficult, particularly if they challenge entrenched constituencies and bureaucracies. Yet without change in the way the federal government engages with the West on water, the lessons of the current drought will be lost, only to be learned all over again the next time drought strikes.

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