Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 161, Pages 66-80, August 2017

Model Water Transfer Mechanisms as a Drought Preparation System

*Mike Pease[1] and Tricia Snyder[1]

[1]*Central Washington University, Ellensburg, WA, USA*
**Corresponding Author*

Abstract: This article evaluates the suitability of two supply-side drought management tools, Emergency Water Banks and Strategic Water Reserves for multi-year severe drought periods. The limited sample-size related to the implementation of either makes direct comparison impossible, but through case studies some cursory evaluation as to their efficacy and their limitations is possible. These short-term tools take different approaches to increase the amount of water available for reallocation during drought. While neither are stand-alone solutions, and may not be suitable for continual use, both hold potential to provide short-term relief during periods of severe shortage. Both however, carry drawbacks that can undermine their efficacy, or preclude adequate support for their implementation.

Keywords: *drought, water allocation, climate adaptation, planning*

Recent International Panel on Climate Change (IPCC) models project an increase in extended drought in many semi-arid areas around the globe over the next fifty years (Wilder et al. 2010; IPCC 2014). For the Southwestern United States, IPCC models suggest a simultaneous increase of temperature of 2-5 degrees centigrade by 2100 and a decrease of precipitation of 5-8 percent (Wilder et al. 2010), an increase in actual evapotranspiration (Cowell and Urban 2011), and increasing weather and climatic variability (IPCC 2011; Stroup 2011; IPCC 2014). While water storage can mitigate the effects of short-term water shortages, few freshwater-scarce areas are equipped to deal with prolonged severe drought events. This problem is compounded in regions lacking full adjudications of water entitlements, meaning the temporal and volumetric extents of water rights are unclear. While drought coping mechanisms are not new (Whittlesey et al. 1986; Howe 2000; Steinemann and Cavalcanti 2006), the predicted climatic variability will make it increasingly important for water managers to create actionable plans for shortages in spite of the lack of clarity of water rights (Corbridge 1998; Stakhiv 2011; Stroup 2011). This article will evaluate the strengths and weaknesses of drought-period water transfer mechanisms to temporarily reallocate freshwater supplies from willing sellers when conditions reach critically low levels.

Climate Change and Drought Planning

For this article, drought plans on file with the National Drought Mitigation Center (2016) from 44 states were evaluated; of the 19 member states of the Western Governors Association, the portion of the country with the highest concentration of semi-arid areas, 18 states have created state-wide Drought Plans, but only six of these plans have been updated since 2010 (National Drought Mitigation Center 2016). Inspection of these plans (Table 1) reveals most western states (n=15) have quantifiable definitions of drought conditions, and most (n=12) have clearly stated drought actions. Few plans (n=10) contain what Rossi et al. (2008) labeled Drought Contingency Plans, specific actions and implementation strategies to mitigate drought, and even fewer states (n=12) discuss water reallocation as a strategy for dealing with water shortages. Review of the plans also showed a close balance between drought plans that are mitigation-based and response based. Drought plans in the United States have historically relied upon response-based measures (Wilhite et al. 2014). In part, this is due to the inherent nature of drought, including its multi-modal and diffuse spatial impacts, which makes adaptive measures difficult for policy-makers to identify (Wilhite et al. 2014). Mitigation measures exist for the impacts drought inflict on local and regional water supply systems (Rossi et al. 2005; 2008).

Reducing the impacts of drought can be separated into two categories: risk management and crisis management (Wilhite et al. 2014). Similar to other natural hazards, drought management policy has historically centered around crisis management or those tools put into action following the drought event (Wilhite et al. 2014). Crisis management is defined through its effort to recover the area affected; this is done through first assessing the impact, responding to those impacts, putting recovery efforts in place, and, finally, beginning reconstruction (Wilhite et al. 2014). In recent years, drought policy has moved towards more adaptive measures and began focusing on risk management (Hayes et al. 2004; Cooley et al. 2015), as well as crisis management (Wilhite et al. 2014). These tools are put into action when drought is not occurring and defined by efforts to protect vulnerable areas. Focus is placed on planning and reducing risks, rather than recovering from impacts (Wilhite et al. 2014). A key component of any risk management strategy is including early-warning indicators (Wilhite et al. 2014), which can often be achieved through the close monitoring of drought indices.

As part of its National Integrated Drought Information System, the National Oceanic Atmospheric Administration's NOAA Palmer Drought Severity tools can help determine when emergency drought management measurements should be implemented. The Palmer Drought Severity Index (PDSI) uses a series of algorithms to analyze an array of hydrologic supply and demand indicators (Dai et al. 2016), creating a local drought index (Table 2). Specifically, the PDSI accounts for current weather patterns and previous moisture levels to provide a quick-responding, broad assessment of drought conditions. The Standardized Precipitation Index (SPI) proposed by McKee et al. (1993) defines drought through probability and is based on long-term historical records at a specific temporal resolution (Vicente-Serrano et al. 2012). Drought is generally defined in one of four ways: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz 1985). Meteorological drought simply compares the actual amount of precipitation to the average amount for a given area; hydrological drought demonstrates a lack of precipitation and its effects on both surface and groundwater and is measured on a watershed scale (Wilhite and Glantz 1985). Agricultural drought is generally defined through meteorological and soil characteristics (Nam et al. 2012); socioeconomic drought draws on criterion from all three to highlight supply and demand measures (Wilhite and Glantz 1985). The PDSI data are updated weekly, providing a timely overview of hydrologic availability.

NOAA maintains a series of local drought observation tools. Under the National Integrated Drought Information System Act (NIDIS) NOAA was appropriated \$84 million dollars (USD) between FY 2007 and FY 2012 to carry-out the purposes of the act, which primarily focus on integrating "information on the key indicators of drought in order to make usable, reliable, and timely drought forecasts" (NIDIS PL 109-430, 2006). NOAA's considerable research into the linkages between oceanic temperatures and drought are ongoing (NOAA 2012), and may provide a robust predictive model in the future. NIDIS funds helped to create Regional Drought Early Warning Information Systems (DEWS) (National Integrated Drought Information System 2016).

This paper will evaluate two supply-side drought management tools, Emergency Water Banks and Strategic Water Reserves, as mechanisms to deal with multi-year droughts. The purpose is not to determine the suitable 'trigger' to identifying drought conditions that warrant action; that determination is best left to local water managers, since the implications of drought in a given watershed are a function of what Howe (1992) labeled, the "uniqueness of water supply system management", a complex calculus of water demand, storage, evapotranspiration rates,

Table 1. Identified state drought plans from National Drought Mitigation Center (2016) database.

State	Last Updated	Quantifiable Definition of Drought (Y/N)	Clearly Identified Drought Actions (Y/N)	Plan to Implement Drought Actions (Y/N)	Discussion of Water Reallocation Mechanisms (Y/N)	Response-based or Mitigation-based (RB/MB)
Alabama	2013	Y	Y	N	N	RB
Arizona	2004	Y	Y	Y	Y	MB
California	2010	Y	Y	Y	Y	MB
Colorado	2013	Y	Y	Y	Y	MB
Connecticut	2003	Y	Y	N	N	MB
Delaware	1982	Y	Y	Y	N	RB
Florida	2007	Y	Y	N	N	RB
Georgia	2015	N	Y	Y	N	RB
Hawaii	2005	Y	Y	Y	N	MB
Idaho	2001	Y	Y	N	Y	RB
Illinois	2011	N	N	N	N	MB
Indiana	2015	Y	Y	Y	N	RB
Iowa	1985	N	N	N	N	RB
Kansas	2012	Y	Y	N	N	RB
Kentucky	2008	Y	Y	Y	N	MB
Maryland	2000	Y	Y	Y	N	RB
Massachusetts	2013	Y	Y	Y	N	RB
Michigan	1988	N	N	N	N	RB
Minnesota	2009	Y	Y	N	N	RB
Missouri	2002	Y	Y	Y	N	RB
Montana	1995	Y	N	N	Y	MB
Nebraska	2000	N	Y	N	N	MB
Nevada	2012	Y	Y	Y	Y	RB
New Hampshire	1990	Y	Y	N	N	RB
New Jersey	1991	Y	Y	N	N	RB
New Mexico	2006	Y	Y	Y	Y	MB
New York	1988	Y	Y	N	N	RB
North Carolina	2005	N	Y	N	N	RB
North Dakota	1981	N	N	N	N	RB
Ohio	2009	N	Y	N	N	RB
Oklahoma	1997	Y	Y	Y	N	RB
Oregon	2016	N	Y	N	Y	RB
Pennsylvania	2010	Y	Y	N	N	RB
Rhode Island	2002	N	N	N	N	RB
South Carolina	2009	N	Y	N	N	RB
South Dakota	2015	Y	Y	Y	Y	MB
Tennessee	2010	N	Y	N	N	RB
Texas	2005	Y	Y	Y	Y	MB
Utah	1993	Y	N	N	Y	RB
Vermont	2005	N	N	N	N	RB
Virginia	2003	Y*	Y**	Y	N	RB
Washington	1992	Y	Y	Y	Y	RB
West Virginia	2002	Y	Y	N	N	RB
Wyoming	2003	Y	N	N	Y	RB

* Parameters differ by month.

** Mandatory restrictions only implemented in emergency phase.

Table 2. Palmer Drought Severity Index (PDSI) and Standardized Precipitation Index (SPI) categories comparison (Adopted from NOAA 2012; World Meteorological Organization 2012).

Palmer Index Score	Category	Standardized Precipitation Index Score	Category
4.0	Extremely Moist	2.0+	Extremely Wet
3 to 3.9	Very Moist Spell	1.5 to 1.99	Very Wet
2.0 to 2.9 to -1.24	Unusual Moist Spell	1.0 to 1.49	Moderately Wet
1.9 to -1.9	Near Normal	-0.99 to 0.99	Near Normal
-2.00 to -2.9	Moderate Drought	-1.0 to -1.49	Moderately Dry
-3.00 to -3.9 and below	Severe Drought	-1.5 to -1.99	Severely Dry
-4.0 or less	Extreme Drought	-2.0 or less	Extremely Dry

groundwater stores, threatened and endangered species, and myriad other factors (Steinemann and Cavalcanti, 2006). However, utilizing tools such as the PDSI or SPI can provide a quantitative metric to depoliticize the process of evoking severe drought policies and procedures. Precedent exists for this practice at the municipal level (Moreau and Little 1989; Howe 1992), but review of drought plans shows few river basins have clear, actionable response mechanisms in place to cope with drought.

Emergency Water Banks

Water banks are institutional structures allowing water right holders to lease, and interested parties to purchase water (Michelsen 1994). State-brokered water transfers, or Markets by Agency (MBAs) (Ballestero et al. 2002) are generally not an appealing option during times of 'normal' water supply and the appropriateness of their use has been questioned (Dellapenna 2000; Ballestero et al. 2002; Zetland 2009; Debaere et al. 2014). Despite substantial efforts to study and facilitate their functioning, free-market reallocations of bulk water have proven to be too difficult to reallocate substantial quantities of water in short periods of time, because of political, administrative, social, implementation, monitoring, and enforcement costs (Gould 1988; Barthold 1994; Bauer 1997; Howe 2000; Hennessy 2004; Krutilla 2010; Dustin and Aylward 2012). Having the ability to institute an Emergency Water Bank (EMB), which may vary in operation from any existing water transfer mechanism in how it temporally, spatially, and institutionally reallocates water (Ballestero et al. 2002), during times of extreme water duress can be viewed as a contingency option to avoid water allocations being made via judicial decree; this should be viewed as particularly advantageous in basins lacking water rights adjudications as determining priority of water use in those locations is particularly difficult.

Once drought conditions begin, creation of a water bank would be difficult as tensions among various water users escalate. Studying the creation of a water bank needs to be done as a proactive measure, and at least the discussion of adding a drought water bank would be a worthwhile addition to drought management plans. Effective implementation of an EWB or any MBA requires deliberation over a series of engineering and administrative hurdles, which include:

- determining the best method for initiating such a water bank;
- evaluating several options for determining eligible sellers of water;
- identifying water users with critical needs and determining the order in which they can purchase water;
- determining how much water a given entity can buy;

- investigating how prices for purchasing and selling water should be made;
- creating a mechanism that protects third-party property rights; and
- how best to protect ecosystem functions.

The California Model

In 1991, the State of California implemented its Drought Emergency Water Bank (CDEWB) state-run drought water bank that was successful in reallocating 800,000 acre-feet of water in approximately two months (Wahl 1993; Israel and Lund 1995). The operators of the CDEWB were praised for their innovative approaches to deal with the many hurdles that prevent effective water banking (Wahl 1993). While far from perfect, the CDEWB represents the largest short-term water reallocation mechanism ever utilized in the western United States.

An EMB, like what was used in California, varies in operation from a 'traditional' water bank (Dellapenna 2005). By necessity, they involve substantial state government involvement. For example, the CDEWB required certain short-term administrative changes in how water rights were evaluated. These administrative changes required legislative consent and could only be conducted by the state, necessitating the substantial government involvement (Wahl 1993). This kind of "hands-on" approach by states is not something most water right holders and water professionals are comfortable with as a standard operating paradigm (Dellapenna 2000; Ballestero et al. 2002; Dellapenna 2005), but in times of extreme drought, for example, a score of -3.4 on the PDSI or -1.6 on the SPI (Table 2) for a given basin, this approach may be one of necessity.

In 1991, the State of California faced its fifth consecutive year of prolonged drought. The snow-pack for central California was low, and water available for diversion was expected to be near record lows, with irrigators in the Central Valley Project to receive between 10 and 75% of their normal water deliveries (Wahl 1993). In the spring of 1991, acting on the recommendations of the state Drought Action Team, then Governor Wilson signed California Executive Order W-3-91 (1991) creating the Drought Emergency Water Bank.

Water Bank Operations

The CDEWB began operations in April of 1991. The California Department of Water Resources (DWR) administered the water bank, evaluated water rights, and created strict rules over how all water would be purchased and sold. DWR identified the users that the agency deemed qualified to purchase water; those it identified as having "critical needs" could buy or sell water to the water bank. The water bank was strictly government controlled; the State of California was the only buyer (and the DWR made the determination of who was eligible to "bank" water) and the only seller of water (Wahl 1993; Dellapenna 2000; Yolles 2001).

The state recognized several methods for conserving water to sell in the water bank. These were:

- crop fallowing;
- substituting groundwater use for surface water use; and
- reallocating surface water, including transferring water from local reservoirs.

The contributions to the water bank by each of these sources can be seen in Table 3.

To increase the amount of water 'banked' by irrigation districts, the California legislature included a waiver regarding geographic considerations. For 1991 and 1992 any provisions prohibiting water from exiting the boundaries of an irrigation or conservation district were waived (DWR 1992). This administrative decision is one that could only be accomplished by the state, strengthening the case for a state-run water bank during severe conditions, and allowed water transfers that are not possible during 'normal' years.

Crop fallowing was the largest source of water entering the bank in 1991 with 325 fallowing contracts making 414,743 acre-feet of water available to purchasers fallowing 166,094 acres (Israel and Lund 1995). Crop fallowing made economic sense when the price the state was willing to pay for water per fallowed acre of cropland was higher than the net profit per acre of crop. Corn was the largest crop fallowed (Wahl 1993). Farmers had to show they had irrigated the land the previous year—this was one of the criteria implemented by the state to ensure what was being

Table 3. Sources of banked water for the 1991 CDEWB (CA Water Board 1992).

Source	Amount Transferred to Bank (acre-feet)	Percentage of Total Water Transferred to Bank
Crop allowing	414,743	50
Groundwater substitution	258,590	32
Reallocating surface water (including reservoirs)	147,332	18

banked represented "wet water." The quantity of water credited to a farmer for each acre of irrigated land retired was determined by a formula based on the crop grown the previous year. This fixed allotment was integral to quick water transfers; once a transaction began, determining the water credits being sold became a simple arithmetic equation. This consumptive amount served as the fallowed-acre credit for those 'banking water' (DWR 1992).

Third-Party Considerations

A water transfer has a high likelihood of impacting more than just those parties involved in the transaction. These third-party impacts are often difficult to assess and quantify, making this evaluation process the most common source of transaction costs (Gould 1988; Gould 1989; Howe and Goremans 2003). For the Emergency Water Bank, the California state legislature allowed the Department of Water Resources to largely ignore third-party impact investigations when making purchases of water using the criteria listed below (Wahl 1993). This significantly reduced the cost and time it took to purchase water. This approach expedited purchases by the Water Bank.

The state determined eligible buyers of water; only those deemed to have 'critical needs' for water were included (Wahl 1993; Yolles 2000; Zilberman 2003). Critical needs fell into one of the following categories (DWR 1992):

- water to meet identified emergency needs, such as health and safety;
- water for areas with critical needs defined as: urban water users with less than a 75% supply, agricultural users who need water to assure the survival of permanent or high value crops, and fish and wildlife resources;
- water for entities previously receiving allocations for critical needs and who need additional supplies to reduce substantial economic impacts resulting from reduced water supplies; and
- carryover water for the State Water Project (SWP). SWP purchase of any remaining, unallocated Water Bank supplies provided the financial backstop for the program.

In addition to these critical needs, 165,000 of the approximately 800,000 acre-feet purchased by the state were left in the Delta to improve water quality (Wahl 1993). Water quality issues, many of which (e.g. high salinity zones) have been linked to lower water levels, plague the San Joaquin-Sacramento River Delta, and have been identified as a likely factor in the peril of the Delta Smelt (*Hypomesus transpacificus*) (USFWS 2010; Interagency Ecological Program 2015). The ability of a drought water bank to provide more water for ecosystem protection reduces the likelihood irrigators will have their water deliveries shut-off. In this case, willing sellers would be compensated for providing water for the protection of Threatened and Endangered Species instead of that water coming from irrigation districts at large. In an additional initiative to provide ecosystem protection, the California Department of Fish and Game was also given the opportunity to purchase water from the 1991 water bank.

1991 Water Bank Pricing

The Department of Water Resources created a set purchase price for 'banked' water. No water bank of this scale had ever existed, so there was a lack of empirical examples from which to base prices (Howitt et al. 1992; Wahl 1993). The DWR created a Water Purchase Price Committee to study this issue (DWR 1992). The Committee consulted many stakeholder groups, and farm budgets were analyzed to estimate a market clearing price that would entice irrigators to enter the water bank.

The Department of Water Resources offered $125 per acre-foot of water to eligible sellers (Wahl 1993). This uniformity of pricing eliminated the need for contract negotiations, reducing transaction costs and expediting transfers. It can be assumed most of those selling water to the bank were using water in a manner which yielded a net benefit of less than $125 per acre-foot.

The DWR purchased 820,665 acre-feet of water in 1991 from 351 sellers (DWR 1992). The Department of Water Resources sold water to interested parties at the cost of $175 per acre-foot. The actual cost of the water was $125, the same price at which the bank purchased water. A $45 fee was charged to cover transaction costs and administrative fees, and $5 was a conveyance fee for moving water through the Sacramento-San Joaquin Delta (Wahl 1993). Water was 'delivered' by the Department of Water Resources to the State Water Project's Delta Pumping Plant. Purchasers of water were responsible for contracting with whatever agencies necessary to move water from the Delta to their place of use. The majority of water users contracted with the State Water Project to deliver water from the San Joaquin Delta to their place of use (Israel and Lund 1995) with most uses occurring south of the Delta.

1991 Water Bank Purchases

The Department of Water Resources' narrow determination of entities eligible to purchase water constrained the quantity of water purchased: there were only 12 buyers of water. Had the DWR defined "critical needs" more liberally, it is likely demand would have exceeded available supply. Such an event would have required water bank administrators to make further determinations on who should have the right to purchase, and how much water they should be able to purchase. The largest purchaser was the Municipal Water District (MWD) of Southern California; the MWD accounted for 55% of all purchases (DWR 1992).

Agriculture accounted for 13% of the water purchased from the Water Bank despite the relatively high price of $175 per acre-foot. Irrigators of permanent crops made purchases to keep perennial crops alive (Wahl 1993). This provides empirical data that farmers can be a primary beneficiary from water banks during periods of water scarcity—sellers benefit from higher returns than they would receive from growing crops, and those growing perennial crops can obtain the water necessary to keep those crops alive.

Roughly 40% of the water banked in 1991 was not purchased. This can be attributed to the constraint on the number of purchasers (Wahl 1993). Alternatively, this could be viewed as a form of "market failure"; supply was poorly linked to demand of those with designated critical needs. While a market equilibrium was not established, the 'surplus' water purchased by the state was stored for the following year.

The State as a Broker

The state's manipulation of the water allocation was so invasive the operation of the CDEWB failed to meet the textbook definition of a market (Dellapenna 2000; Dellapenna 2005). Dellapenna's contention "true" markets do not, and likely will not exist for bulk raw water, is valid. Subsidies, transportation costs, and informational asymmetries do prevent perfectly functional markets. But, does this really matter? Rogers (2006, 29) states: "Today the honeymoon with the *laissez-faire* market-led model is over…", yet economic transactions not only still occur, but, as former U.S. Secretary of the Interior Babbitt stated, "Without water markets, we can't solve the problem of meeting the future water needs of the West" (McCoy and Zachary 1997).

If water can be reallocated to higher economic uses with price signals, while protecting third-party interests, is the fact that the reallocation does not meet the textbook definition of a market important? One of the primary critiques of the CDEWB was its failure to price water correctly (Wahl 1993; Dellapenna 2000). Most commodities are sold in imperfectly competitive markets; should water be different (Sax 1965; Pease 2012)?

During periods of severe water scarcity, spot-market conditions are likely to pervade; as long as transfers involve voluntary parties, and protect third-parties, is that not enough? These are the kinds of decisions policy makers must address and incorporate into drought plans before the next period of severe shortage.

Fast Forward: 2008

In 2008, much of California was at the end of the second straight year of drought, with projections of lower than normal snowpack for the winter of 2008-2009. In September 2008, the Department of Water Resources announced the planning phase of another EWB. Director Snow of the Department of Water Resources stated, "We would be negligent if we didn't prepare for the worst" (Weiser 2008). Snow added that administration of the bank would operate within the purview of the current state water operations Environmental Impact Study.

Since the 1991 CDEWB, the delta smelt (*Hypomesus transpacificus*) has been listed under the Federal Endangered Species Act and the California Endangered Species Act. This listing, along with renewed efforts to increase water levels in the Delta and its tributaries for the protection of Salmon runs (Chen 2011), reduces the managerial options to meet rising demands when streamflows drop. This is particularly significant for water transfers from Northern California to Southern California that must pass through the Delta, an issue exemplified by changes to water operations for the Central Valley Project and State Water Projects, which disallow pumping of water through the Central Valley Project under certain conditions (USFWS 2012).

In February 2009, then California Governor Schwarzenegger declared a Drought Emergency; this declaration also created the 2009 EWB. The 2009 EWB, with the goal of following the successful path of the 1991 and 1992 EWBs, was designed to allow environmental groups to purchase water and leave it in the Delta for ecosystem protection. The 2009 EWB exemplifies the need for pre-drought planning, and for the need for clear implementation steps linked to drought intensities. Several interested groups filed a protest to the implementation of the EWB without a California Environmental Quality Act (CEQA) compliance document (*Butte Environmental Council v. CA Department of Water Resources* 2010). The judge, in ruling in favor of the protesters said, "drought is not an emergency" covered under the Public Resources Code which may allow the state to avoid compliance with the California Environmental Quality Act (*Butte Environmental Council v. CA Department of Water Resources* 2010). Clearly, the ability to create a water bank in the same year as it is to be implemented is a relic of a bygone era. Drought water bank infrastructure and compliance work needs to be completed in periods of greater water abundance so they can be implemented when needed.

One of the primary critiques of EWB is their potential to negatively impact employment in basins of origin of any reallocated water (Bauer 1997; Howe 2000; Hanak et al. 2012; Broadbent et al. 2014). For any future CDEWB, socio-economic impacts must be addressed by a programmatic CEQA document. These types of analysis can be lengthy to complete and require public comment periods, meaning the time from initiation to implementation is likely to take over a year. To gain a better understanding of the economic and employment impacts of the drought, Howitt et al. (2014; 2015), used an IMPLAN economic input-output model to measure economic and employment losses. Their estimates suggest the 2014 drought led to the loss of 17,100 jobs (Table 4). These employment losses would have been greater had it not been for additional groundwater pumping of approximately 5 million acre-feet, which resulted in estimated direct costs to irrigators of $447 million USD (Howitt et al. 2014). The sustainability of this additional pumping can be questioned (Hanak et al. 2012; Christian-Smith et al. 2015; Cooley et al. 2015). These can be considered part-and-parcel the same issue. If water banking were effective, annual crops can be voluntarily fallowed and economic losses in higher marginal return areas can remain active, without additional groundwater pumping, something that will be constrained when the California Sustainable Groundwater Management Act (2014) becomes fully active across the state in 2042.

Table 4. Estimated socio-economic impacts of recent drought years in California (derived from drought data Howitt et al. 2014; Howitt et al. 2015; NOAA 2016).

Year	SPI	PDSI	Surface Water Shortage (m ac-ft/m^3)	Hectares Fallowed	Direct Job Losses	Total Job Losses	Direct Costs (million USD)	Crop Revenue Losses (million USD)	Total Economic Impact (million USD)
2014	-1.83	-4.41	6.6/8.14b	173,205	6,920	17,100	$1,500	$810	$2,200
2015	-0.72	-3.91	8.7/10.7b	218,530	10,100	21,000	$1,800	$900	$2,700

Creating an Effective Drought Management Model

In a December 2007, New York Times editorial, Friedman expressed skepticism towards the proposed Global Climate Change Initiatives discussed in Bali, stating, "If you need an environmental expert to explain it to you, it's not real" (Friedman 2007). The same is likely true about water banks. While water banks may have complicated underlying architecture, they need to have a simple interface for interested buyers and sellers. This requires that water banks have clear rules and make it possible for those holding rights or looking to purchase bulk water to understand whether they are eligible to participate, and to understand the cost structures.

Commoditization of water has the potential to increase net withdraws from the river basin (Gould 1988; Corbridge 1998; Howe 2000). When the consumptive amount of a water right is undefined, the potential for a transfer of water to conflict with the actual historical consumptive amount (Corbridge 1998) of the water right increases. A water banking credit determined by a crop fallowing formula serves as a reasonably accurate, but not precise, proxy for the consumptive amount when an adjudication of water rights has not occurred. It would be up to each state to determine whether such an approximation is adequately precise to protect downstream water users during drought periods.

One of the reasons the 1991 CWB was successful was the efficacy with which water was reallocated to willing buyers. In river basins lacking large storage reservoirs, water scarcity is as close as one or two years with below average snowpack followed by a dry spring and summer. Prior to the next sustained drought, states interested in adopting a drought emergency water bank as a planning tool should evaluate how water should be valued and purchased. For a water bank to function properly, water rights need to be accurately appraised. This raises the question of whether fixed prices or a market-based approach should be utilized. Coase (1960) argued efficient solutions occur when a limited number of parties are free to negotiate, and transaction costs are minimal. Empirically, this does not occur (MacDonnell 1999; Dellapenna 2000), and these negotiations could prolong the time until water can be transferred. While Americans are generally inclined to favor market-based approaches to valuation, when the commodity is water, and the time frame of the lease is short, perhaps a fixed price may be more beneficial — emergency water banks are temporary measures during times of severe shortage, periods when spot markets may cause distorted price signals. The downside to a fixed-price approach is it does not account for differences in the priority date of water rights; under such approach, the (potentially dangerous) assumption is made that all water rights "banked" represent "wet water."

Water-rights appraisers are a developing but not fully evolved industry in many basins in the West. The number of transfers is too limited to produce replicable price signals under a wide variety of climatic and hydrologic conditions (Gray 2008; Garrick and Aylward 2012; Broadbent et al. 2014). If the state is required to value each individual water right, the result will be delays in purchases, and transaction costs that may exceed the value of the water. Whatever approach is adopted, this decision is likely best made in advance of the next drought so that guidelines can be developed to help the state agency in charge of making purchases. If this is left until the drought, the result may be delays and a more polarized and politicized system.

States can also expedite response to water shortages by creating the administrative documents for the operation of a drought water bank in advance. State legislatures could determine in advance what agencies, and what departments of these agencies are in charge of certain portions of the water bank. Additionally, documents such as the lease agreement could be drafted in advance, allowing potential participants to view the documents and start to make the decision whether they want to participate. Transparency in the form of making these lease agreements available in advance could affect water bank participation.

Creating a drought water bank framework in advance also provides the opportunity for stakeholders to decide whether to allow environmental groups the opportunity to purchase water for ecological needs. Allowing environmental groups an opportunity to purchase water arguably circumvents the appropriations system, when demand exceeds supply; purchases for the environment reduce supply for water right holders wanting to purchase water. Conversely, allowing purchases for instream flows is a mechanism to provide water to species and ecosystems in need of additional water — potentially reducing curtailment of diversions under the Endangered Species Act.

Alternative Drought Models

Two additional preemptive drought management tools are being implemented: Strategic Water Reserves (SWR) and reverse water auctions. Both of these models also involve substantial government involvement in water markets. While both of these methods are in their infancy, and little data are available, they both warrant consideration by water managers looking to diversify the mechanisms by which water can be reallocated in times of shortage.

SWR obtain water for use in periods of water shortage. This can take the form of obtaining permanent water rights, option leases, or physically storing water. In 2005, the New Mexico State Legislature created the "New Mexico Strategic Water Reserve" (New Mexico Statute 72-14-3.3, 2005). The purpose of this reserve is "to assist the state in complying with its interstate compacts and court decrees or to assist the state and water users in water management efforts for the benefit of threatened or endangered species or in a program intended to avoid additional listings of species".

SWR programs have some similarities to EMBs; both function on the premise of facilitating water reallocations to offset water shortages. Beyond this, the functionality of these two approaches quickly varies. The purpose for which SWR is obtained is usually limited. For example, the New Mexico SWR is only authorized to purchase water for two purposes, to help the state to comply with its Interstate River Compact obligations, and to "assist the state and water users in water management efforts for the benefit of threatened or endangered species or in a program intended to avoid additional listings of species". There is no mechanism to reallocate water to municipalities or other uses that may be suffering from severe water shortages.

Under the SWR legislation, the Office of the State Engineer is charged with the task of identifying basins in which to focus their purchasing efforts for that year. This decision is made based on the following factors:

1. The urgency of need for water or water rights to be held in the strategic water reserve in a river reach or basin.
2. The availability of water rights for sale or lease in the river reach or basin and/or whether storage exists for such water.
3. The cost, location, and seniority of the water or water rights in the river reach or basin.
4. Whether and to what extent water rights to be purchased or leased will assist the state in complying with its interstate stream compacts or court decrees or will assist the state in managing its waters for the benefit of threatened or endangered aquatic or obligate riparian species or avoid additional listings of species.
5. Whether water or water rights are available by donation. (NM Statute 72-14-3.3 2005)

Identifying priority basins is a logical method to focus water acquisition efforts. However, a watershed priority system could constrain the flexibility of the reserve. By choosing a highest priority basin for a given year, it reduces the ability of the state to make purchases in other basins, reducing the reserve's effectiveness if a lower priority basin develops severe water shortages; for example, the Pecos River Basin and the Middle Rio Grande, two basins plagued with ongoing endangered species listings have been selected as basins of priority. Both are governed by Interstate River Compacts, and both contain federally listed endangered fish species, namely the Middle Rio Grande Silvery Minnow (*Hybognathus amarus*) and the Pecos Bluntnose Shiner *(Notropis simus pecosensis*).

The SWR specifies that the state "shall acquire water or water rights at a price no higher than appraised market value, based upon the best available information…" (NM Stat 72-14.3.3). This provision was instituted to ensure the state does not over-pay for water. During times of drought, spot market conditions can occur. This temporary inflation in price could prevent the state from acquiring water, arguably at a time when it needs it the most. At a July 2008 Public meeting, representatives from the New Mexico Interstate Stream Commission, the state entity in charge of carrying out the Reserve, readily admitted it is probable that the funds allocated to the Reserve will be insufficient to allow the state to engage in a "bidding war" for water during periods of shortage.

New Mexico is not alone in its approach to voluntarily reallocate water. In 2016, California created draft rules for purchasing water for the Sacramento-San Joaquin Delta (California State Water Resources Control Board 1992). Additionally, Washington State runs a "Trust Water Rights Program", created by the state legislature in 1991, and expanded in 2003. In 2007, Washington State's Department of Ecology (WDOE) operated a reserve auction of water rights in the Yakima River Basin "to enhance stream and tributary flows in the Yakima Basin" (WDOE 2012). The reverse auction was conducted by the Department of Ecology, and asked interested parties with valid water rights to submit a selling price for their water. The auction was a failure with only one offer to sell made to the WDOE. The WDOE then commissioned a survey to determine why the program did not solicit bids. The results varied, but were largely based on the lack of valuation of water, repeating one of the issues seen with the CDEWB. In 2015, the Reverse Auction program was repeated in the Upper Yakima Basin. In total, the state invited 650 water rights holders to participate. Only ten bids were submitted to the WDOE. Of those, six were accepted, and 878 ac-ft/yr were leased for environmental flows by fallowing 122 hectares (302 acres) (WDOE 2015).

Washington has expanded the Trust Water Rights Program statewide. Since 2010, most water obtained by the state has come from donations by various water users (Table 5). Temporarily donating water allows right holders to avoid periods of non-use. They can also use this donation as a tax benefit.

Table 5. State of Washington trust donations since 2010 (Adopted from WDOE data 2016).

Year	Number of Instream Flow Donations	Instream Flow Donations (ac-ft)	Number of Groundwater Replenishment or Reservation	Groundwater Replenishment or Reservation (ac-ft)	Number of Multiple Use/ Other Donations	Multiple Use/Other Donations (ac-ft)
2010	21	4,358	2	2,837	2	28
2011	25	17,817	12	2,394	4	148
2012	23	11,736	14	3,357	10	3,019
2013	30	17,240	13	1,837	6	1,126
2014	49	27,508	19	4,478	4	604
2015	47	66,264	24	5,805	2	472

Comparison of Drought Water Banks and Strategic Water Reserves

A comparison of EWBs and SWR reveal distinct advantages and disadvantages of each approach. The SWR has an inherent advantage over Emergency Water Banks in long-term planning because it allows for permanent water transfers. The state can increase its water supply by purchasing water rights, providing perennial water for the reserve, meaning water is available for every year without the need for the state to seek out willing sellers.

SWRs can also be constrained by limitations on scope; in New Mexico, the legislation authorizing the creation of the SWR states "The Interstate Stream Commission shall not acquire water or water rights that are served by an irrigation district established pursuant to Chapter 73, Article 10 NMSA 1978, except through a contractual arrangement with the district board of directors…." (NM Stat 72-14.3.3). This provision may undermine the effectiveness of the Reserve. Many of the water rights in the state of New Mexico are located within acequias, communally organized irrigation ditches, or formally recognized irrigation districts. If the governing agencies do not want to create a precedent of water leaving the boundaries of their district, they can prevent willing sellers from selling or leasing water to the state. This could severely constrict the number of potential sellers of water. This provision could also cause a delay in transfers until the irrigation or acequia district board votes on whether to allow the transfer. This may seem innocuous, but some stream reaches in New Mexico dry quickly; this delay could result in water not being available when it is most needed.

Another disadvantage of the Strategic Water Reserve over a drought water bank is its reliance on annual state funding. During periods of budget shortage, SWR programs can be viewed as "non-essential" programs, leaving them vulnerable to cuts in funding, regardless of the merit of the program. This happened in New Mexico only three years into the Program (Buynak 2009), and remaining funds were 'swept'. Because drought cycles can occur during these periods of budgetary shortage, there is potential for the Water Reserve to lack the funds necessary to purchase water necessary to meet compact deliveries and to protect endangered species.

Conclusion

Both the water reserve model as well as drought water banks may have a place in western water management. States, as the holder in trust of water, have inherent advantages over private initiatives such as water brokers for reallocating water during periods of drought. Neither of these MBA tools are meant to permanently reallocate water, designed to drastically increase the amount of water marketed, nor are they intended to replace market-driven reallocations of water by private entities. Instead, these are tools to prevent the need for more draconian measures during drought. By having myriad tools, states can design drought plans that address the dynamic hydrologic scenarios they face during drought, and reflect the regional preferences for water management. However, and this cannot be stated strongly enough, if states wait until water scarcity intensifies to make decisions, litigation and stagnation will surely result.

Acknowledgments

We thank the anonymous reviewers for providing critical feedback and suggestions for the improvement of this paper.

Author Bio and Contact Information

Mike Pease (corresponding author) is an Associate Professor of Geography at Central Washington University. He can be reached at: Central Washington University, 400 E. University Dr. MC 7420, Ellensburg, WA 98926; or via email at Michael.Pease@cwu.edu.

Tricia Snyder is a graduate student in the Cultural and Environmental Resource Management program at Central Washington University. She can be reached at patricia.snyder@cwu.edu.

References

Bauer, C.J. 1997. Bringing water markets down to earth: The political economy of water rights in Chile, 1976–1995. *World Development* 25(5): 639-656.

Ballestero, E., S. Alarcon, and A. Garcia-Benabeau. 2002. Establishing politically feasible water markets: A multi-criteria approach. *Journal of Environmental Management* 65: 411-429.

Barthold, T. 1994. Issues in the design of environmental excise taxes. *The Journal of Economic Perspectives* 8: 133-151.

Broadbent, C.D., D.S. Brookshire, D. Coursey, and V. Tidwell. 2014. An experimental analysis of water leasing markets focusing on the agricultural sector. *Agricultural Water Management* 142: 88-98.

Butte Environmental Council v. CA Department of Water Resources. 2010. Superior Court for the State of California.

Buynak, B. 2009. Strategic Water Reserve. *Water Matters!* Available at: http://uttoncenter.unm.edu/pdfs/WM_Strategic_Water_Reserve.pdf. Accessed December 1, 2016.

California Executive Order No. W-3-91. 1991. California Executive Department. Sacramento, CA.

California State Water Resources Control Board.1992. California Water Bank. Technical Report. Sacramento, CA.

California Sustainable Groundwater Management Act. 2015. SB 1319, Ratified, September 16, 2014.

Chen, C.W. 2011. Framework to determine total maximum daily flow diversions for fish protection. *Journal of Environmental Engineering* 137: 1099-1102.

Christian-Smith, J., M. Levy, and P.H. Gleick. 2015. Maladaptation to drought: A case report from California, USA. *Sustainability Science* 10(3): 491-501.

Coase, R. 1960. The problem of social cost. *Journal of Law and Economics* 3:1-44.

Cooley, H., K. Donnelly, R. Phurisamban, and M. Subramanian. 2015. Impacts of California's Ongoing Drought: Agriculture. Pacific Institute. Available at: http://pacinst.org/app/uploads/2015/08/ImpactsOnCaliforniaDrought-Ag.pdf. Accessed December 1, 2016.

Corbridge, J.N. 1998. Historical water use and the protection of vested rights: A challenge for Colorado water law. *University of Colorado Law Review* 69: 503.

Cowell, C.M. and M.A. Urban. 2011. The changing geography of the U.S. water budget: Twentieth-century patterns and twenty-first-century projections. *Annals of the Association of American Geographers* 100(4): 740-754.

Dai, A. and National Center for Atmospheric Research Staff. 2016. The Climate Data Guide: Palmer Drought Severity Index. Available at: https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi. Accessed December 1, 2016.

Debaere, P., B.D. Richter, K. Davis, M. Duvall, J.A. Gephart, C.E. O'Bannon, C. Pelnik, E.M. Powell, and T.W. Smith. 2014. Water markets as a response to scarcity. *Water Policy* 16(4): 625-649.

Dellapenna, J.W. 2000. The importance of getting names right: The myth for water. *William and Mary Environmental Law and Policy Review* 25: 317-377.

Dellapenna, J.W. 2005. Markets for water: Time to put the myth to rest? *Journal of Contemporary Water Research and Education* 131: 33-41.

Friedman, T. 2007. What was that all about? *New York Times.* December 19, 2007.

Garrick, D. and B. Aylward. 2012. Transaction costs and institutional performance in market based environmental water allocation. *Land Economics* 88(3): 536-560.

Gould, G.A., 1988. Water rights transfers and third-party effects. *Land and Water Law Review* 23(1): 1-41.

Gould, G.A. 1989. Transfer of water rights. *Natural Resources Journal* 29(2): 457-478.

Gray, B.E. 2008. The market and the community: lessons from California's drought water bank. *Hastings College of the Law West-Northwest Journal of Environmental Law & Policy* 14(1): 41-104.

Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, and B. Thompson. 2012. Managing California's Water: From Conflict to Reconciliation. Public Policy Institute of California. San Francisco. Available at: http://www.ppic.org/content/pubs/report/R_211EHR.pdf. Accessed December 2, 2016.

Hayes, M., O. Wilhemi, and C. Knutson. 2004. Reducing drought risk: Bridging theory and practice. *Natural Hazards Review* 5(2):106-113.

Hennessy, M. 2004. Colorado River water rights: Property rights in transition. *University of Chicago Law Review* 71(4): 1661-1687.

Howe, C.W. 1992. Institutional innovation in drought response. In: *Improving the Environmental Problem-Solving Process: Lessons from the 1988-?? California Drought*. University of Colorado Press. Available at: http://www.colorado.edu/conflict/full_text_search/EnvCaseStudies/ch2wtpr.htm. Accessed August 11, 2017.

Howe, C.W. 2000. Protecting values in a water market setting: Improving water markets to increase economic efficiency and equity. *Denver University Law Review* 3(2): 357.

Howe, C.W. and C. Goemans. 2003. Water transfers and their impacts: Lessons from three Colorado water markets. *Journal of the American Water Resources Association* 39(5): 1055-1065.

Howitt, R., N. Moore, and R.T. Smith. 1992. *A Retrospective On California's 1991 Emergency Drought Water Bank,* A report prepared for the California Department of Water Resources, pp. 1-64.

Howitt, R.E., J. Medellin-Azuara, D. MacEwan, J.R. Lund, and D.A. Sumner. 2014. Economic Analysis of the 2014 Drought for California Agriculture. Center for Watershed Sciences, University of California, Davis, California. Available at: https://watershed.ucdavis.edu/files/content/news/Economic_Impact_of_the_2014_California_Water_Drought.pdf. Accessed December 1, 2016.

Howitt, R.E., D. MacEwan, J. Medellin-Azuara, J.R. Lund, and D.A. Sumner. 2015. Economic Analysis of the 2015 Drought for California Agriculture. Center for Watershed Sciences, University of California, Davis, California. Available at: https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf. Accessed August 17, 2016.

Interagency Ecological Program. 2015. An Updated Conceptual Model of Delta Smelt Biology: Our Evolving Understanding of an Estuarine Fish. Available at: http://www.water.ca.gov/iep/docs/Delta_Smelt_MAST_Synthesis_Report_January%202015.pdf. Accessed December 1, 2016.

IPCC. 2011. Summary for policymakers. In: *Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, C.B. Field, V.R. Barros, T. F. Stocker, D. Qin, D. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.K. Plattner, S. Allen, M. Tignor, and P.M. Midgley (Eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2014. Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. *Part A: Global and Sectoral Aspects*, C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (Eds.). Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Israel, M. and J. Lund. 1995. Recent California water transfers: Implications for water management. *Natural Resources Journal* 35:1-32.

Krutilla, K. 2010. Transaction costs and environmental policy: An assessment framework and literature review. *International Review of Environmental and Resource Economics* 4: 261-354.

MacDonnell, L.J. 1999. *From Reclamation to Sustainability: Water, Agriculture, and the Environment in the American West*. University of Colorado Press, Boulder, CO.

McCoy, C. and G.P. Zachary. 1997. Liquid assets: A bass play in water may presage big shift in its distribution — Los Angeles agency seats over supplies, gouging, but some see a harvest: Why markets seem inevitable. *Wall Street Journal* A1.

McKee, T.B., N.J. Doesken, and J. Kleist. 1993. The relationship of drought frequency and duration to time scales. Proc. Eight Conf. on Applied Climatology. Anaheim, CA, Amer. Meteor. Soc., pp. 179-184.

Michelsen, A. 1994. Administrative, institutional, and structural characteristics of an active water market. *Water Resources Bulletin* 30(6): 971-982.

Moreau, D. and K.W. Little. 1989. Managing Public Water Supplies During Droughts: Experiences in the United States in 1986 and 1988. Water Resources Research Institute of the University of North Carolina Report No. 250, September.

Nam, W., J. Choi, S. Yoo, and M. Jang. 2012. A decision support system for agricultural drought management using risk assessment. *Paddy and Water Environment* 10:197-207.

National Drought Mitigation Center. 2016. Current State Drought Plans. Available at: http://drought.unl.edu/Planning/DroughtPlans/StateDroughtPlans/CurrentStatePlans.aspx. Accessed December 1, 2016.

National Integrated Drought Information System. 2006. The National Integrated Drought Information System: Report to Congress. Available at: https://www.drought.gov/drought/sites/drought.gov.drought/files/media/whatisnidis/Documents/rpt_FINAL_NIDIS%20CongReport_Jan2016.pdf. Accessed, December 1, 2016.

National Oceanic and Atmospheric Administration. 2012. NCEP/Climate Prediction Center ATLAS.

Available at: http://www.cpc.ncep.noaa.gov/pacdir/cont_appe.html. Accessed December 1, 2016.

National Oceanic and Atmospheric Administration. 2016. North American Drought Monitor. Available at: https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/indices/spi/div#select-form. Accessed December 1, 2016.

New Mexico Statute 72-14-3.3. 2005. Interstate stream commission; additional powers; strategic water reserve.

Pease, M. 2012. Water transfer laws and policies: Tough questions and institutional reform for the western United States. *Journal of Natural Resource Policy Research* 4(2): 103-119.

Rogers, P. 2006. Water governance, water security, and water sustainability. In: *Water Scarcity: Myth or Reality*. Taylor Francis, London.

Rossi, G., Cancelliere, A., and Guliano, G. 2005. Case study: Multicriteria assessment of drought mitigation measures. *Journal of Water Resources Planning Management* 131(6): 449-457.

Rossi, G., V. Nicolosi, and A. Cancelliere. 2008. Strategic water shortage preparedness plan for complex water supply systems. *European Water* 23(24): 13-28.

Sax, J. 1965. *Water Law: Cases and Commentaries.* Pruett Press, Indianapolis, IN, pp. 442.

Stakhiv, E.Z. 2011. Pragmatic approaches for water management under climate change uncertainty. *Journal of the American Water Resources Association* 47(6): 1183-1196.

Steinemann, A.C. and L.F. Cavalcanti. 2006. Developing multiple indicators and triggers for drought plans. *Journal of Water Resources Planning and Management* 132(3): 164-174.

Stroup, L.F. 2011. Adaptation of U.S. water management to climate and environmental change. *The Professional Geographer* 63(4): 414-428.

United States Fish and Wildlife Service. 2010. Five Year Review for the Delta Smelt (Hypomesus transpacificus). Available at: http://ecos.fws.gov/docs/five_year_review/doc3570.pdf. Accessed December 1, 2016.

United States Fish and Wildlife Service. 2012. Smelt Working Group. Available at: http://www.fws.gov/sfbaydelta/documents/smelt_working_group/swg_notes_6-25-2012-2012.pdf. Accessed December 1, 2016.

Vicente-Serrano, S., S. Beguería, J. Lorenzo-Lacruz, J. Camarero, J. López-Moreno, C. Azorin-Molina, J. Revuelto, E. Morán-Tejada, and A. Sanchez-Lorenzo. 2012. Performance of drought indices for ecological, agricultural, and hydrological applications. *Earth Interactions* 16(10): 1-27.

Wahl, R. 1993. *Water Marketing in California: Past Experience, Future Prospects*. Policy Study No. 162, July, pp. 1-42.

Washington Department of Ecology. 2015. 2015 Yakima River Tributary Reverse Right Auction. Available at: http://www.ecy.wa.gov/programs/wr/cro/yrtrwra2015.html. Accessed December 1, 2016.

Washington Department of Ecology. 2016. Trust Water Right Donations. Available at: http://www.ecy.wa.gov/programs/wr/market/trstdocs_archive.html. Accessed December 1, 2016.

Weiser, M. 2008. California 'drought water bank' in the works. *The Sacramento Bee* A3. September 5, 2008.

Western Governors Association. 2016. Drought Forum. Available at: https://www.westgov.org/initiatives/drought-forum/resources. Accessed December 1, 2016.

Wilder, M., C.A. Scott, N.P. Pablos, R.G. Varady, G.M. Garfin, and J. McEvoy. 2010. Adapting across boundaries: Climate change, social learning, and resilience in the US–Mexico border region. *Annals of the Association of American Geographers* 100(4): 917-928.

Wilhite, D. and M. Glantz. 1985. Understanding the drought phenomenon: The role of definitions. *Water International* 10(3): 111-120.

Wilhite, D., M. Sivakumar, and R. Pulwarty. 2014. Managing drought risk in a changing climate. *Weather and Climate Extremes* 3: 4-13.

Whittlesey, N., J. Hamilton, and P. Halverson. 1986. "An Economic Study of the Potential for Water Markets in Idaho," report to the Snake River Technical Studies Committee, joint report of the Idaho and Washington Water Resources Research Institutes, Moscow. December.

World Meteorological Organization. 2012. Standardized Precipitation Index User Guide. Available at: http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf. Accessed December 1, 2016.

Yolles, P.L. 2001. Update 2000: Progress and limitations in developing a water market in California. *Water Resources Update* 118: 74-81.

Zetland, D. 2009. The end of abundance: How water bureaucrats created and destroyed the southern California oasis. *Water Alternatives* 2(3): 350-269.

Zilberman, D. 2003. Water marketing in California and the West. *International Journal of Public Administration* 26(3): 291-315.