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PERC POLICY REPORT | SEPTEMBER 2022

THE FUTURE OF WATER MARKETS

OBSTACLES AND OPPORTUNITIES

EDITED BY
ERIC EDWARDS AND
SHAWN REGAN

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An irrigated almond orchard in California ©Bruce Barnett

Introduction

Eric Edwards and Shawn Regan

In recent decades, the idea of using markets to allocate water has gained traction in the American West. Water markets are now being harnessed in a variety of contexts to allocate water in economically productive and environmentally sensitive ways, encourage conservation, and protect ecosystems. These markets take several forms, including markets for traditional surface water rights, instream flows, groundwater, water quality, stream mitigation banking, and even financial derivatives.

The development of water markets in recent decades is timely given that drought has plagued much of the American West over the same period. The federal government recently declared an unprecedented water shortage in the Colorado River Basin, and many other states face simultaneous challenges of growing populations and dwindling water supplies. Thankfully, markets offer a means to help allocate increasingly scarce water.

The proliferation of water markets has also raised new questions about the determinants of market form and function, relative performance, and future viability. Are water markets living up to their promise of providing "win-win" transfers to sellers and buyers? What lessons can be gleaned from novel groundwater, instream-flow, and water-quality markets? What are the ongoing and future challenges that water markets can address through innovations in property rights, regulation, and market design? With several decades worth of experience with water markets now available, these and other related questions can be addressed.

In the fall of 2021, PERC convened a workshop to address the future of water markets, with an emphasis on the challenges to sustaining and enhancing such markets. The workshop explored a range of topics, including groundwater markets, instream-flow transactions, tribal water leasing, water-quality trading, futures markets, and more. The workshop involved both researchers and practitioners assessing the state of water markets today and the challenges they face moving forward.

The following essays are the result of that workshop, authored by a group of leading water experts. Each addresses a timely water policy topic and provides policy recommendations to enhance the future of water markets. Together, the essays explore how markets can continue to be harnessed to allow competing water users to cooperate rather than fight over scarce water resources, encourage conservation, and alleviate the economic and environmental effects of water scarcity now and in the future.

1 Designing Groundwater Markets in Practice

Lessons from three California groundwater basins

Andrew Ayres, Christina Babbitt, Ellen M. Bruno, and Arthur R. Wardle

In many areas of the western United States, groundwater reserves have been and are increasingly overdrawn. When surface water supplies from rivers, reservoirs, or lakes are low, farmers often extract and use more groundwater from underground aquifers. Issues resulting from groundwater overdraft—such as increased energy costs to pump, domestic drinking water wells going dry, land subsidence, and saltwater intrusion—are leading regulators to consider pumping restrictions to stabilize water tables. Allowing trade of limited pumpable water can cut the costs of achieving sustainable management dramatically.[1] By trading allocations, pumpers with lower-value water uses can benefit from curtailing or ceasing pumping and selling their allocations to higher-value uses. Farmers and municipalities can compensate their neighbors for making conserved water available, thereby allowing scarce water to flow to its highest-valued uses.

Managing groundwater optimally, however, isn't quite so simple because groundwater is spatially interconnected—in other words, groundwater extracted in one location can affect groundwater resources elsewhere in the same basin. Surface water and groundwater are also hydrologically connected, meaning that pumping near a stream could affect streamflows at the surface.[2] Thus, groundwater extraction in one location can have unintended and uncompensated adverse impacts on the environment that may be different from impacts incurred in another location from the same amount of extraction.[3] Pumping that has no apparent impact at one site, for example, could dewater a wetland if pumped from elsewhere in a basin.[4] Regulators in groundwater basins are challenged to formulate and design market institutions that maintain flexibility with limited information about the potential effects of a new spatial distribution of pumping.

Given these realities, three prerequisites for an effective groundwater trading program include 1) developing a water budget to inform accounting, 2) establishing an initial allocation of groundwater pumping rights to groundwater users within a management area, and 3) addressing the differential impacts that groundwater pumping can have within a single basin. A water budget that accounts for groundwater and surface water interactions is foundational to the development of a market and any rules to mitigate unintended environmental consequences.

Such a budget should also be coupled with an understanding of the water demands of various users, including for environmental purposes. The water budget determines the cap on the aggregate amount of water that can be extracted, constraining extraction to match the sustainability goals of the basin. The initial allocation of groundwater rights determines the baseline distribution of pumping, which can change if and when trades occur.

To address the fact that pumping has varying impacts depending on where it occurs in a basin, economists have proposed trading programs that assign trading ratios that adjust the volume of groundwater trades by multipliers to account for spatial consequences.[5] These types of policies are intended to maximize overall well-being, balancing the gains from trade with the mitigation of location-specific, third-party impacts of pumping.

This policy suggestion, however, abstracts away from the real-world costs of collecting information about each source's unique impacts, which could prove substantial. Instead, others have proposed simpler market rules, such as designating smaller trading zones within a basin or setting geographic trading restrictions.[6] While these more streamlined market rules may be easier to implement, they add additional barriers to trade that can constrain market activity.

In this essay, we discuss the relevance of these issues to California groundwater management and provide lessons for groundwater managers in other states. Addressing the spatial impacts of groundwater trading is a particularly timely concern in California, where groundwater markets are emerging under the Sustainable Groundwater Management Act. We provide background on this legislation and draw upon three case studies at various stages of development and implementation to assess how unintended third-party consequences are currently being recognized and addressed. We conclude by highlighting important trade-offs in the design of these mechanisms.

Highlights

- **Groundwater is spatially interconnected, which means that pumping in one location can have direct, unintended impacts on third parties that are different from the impacts of pumping in other locations.**
- **As a result, the development of groundwater markets requires careful accounting and design to balance gains from trade with the costs of uncompensated third-party effects.**
- **In California, several groundwater markets have emerged that attempt to address these challenges, providing lessons for the development of other groundwater markets.**
- **Solutions such as designating distinct trading zones or setting geographic trading restrictions can leverage existing information about the resource to reduce third-party effects, but they may also create barriers to trade that constrain market activity.**

The Sustainable Groundwater Management Act of California

In 2014, California revolutionized its groundwater management practices by passing three bills, collectively called the Sustainable Groundwater Management Act (SGMA). Until the act's passage, most groundwater in the state was an open-access resource, with any overlying landowner practically able to extract as much water as they could put to "reasonable and beneficial" use on their land. Lacking incentives to limit extraction apart from the costs of pumping, groundwater users had little reason to conserve the resource. The result was often long-term drawdown, as is common throughout the western United States, with costly side effects such as land subsidence and seawater intrusion.

SGMA contains many pieces, but the core of the policy mandates the creation of new local groundwater authorities known as groundwater sustainability agencies, requires those authorities to develop plans to achieve sustainability over the next two decades, and grants additional powers to those authorities that enable the enforcement of the plans. This rapid development of dozens of sustainability plans induced by SGMA, many of which propose developing groundwater markets, makes the California context especially fruitful for studying how market design handles environmental concerns in practice.

SGMA defines sustainability as avoiding the "significant and unreasonable" occurrence of six "undesirable results": 1) persistent drawdown, 2) reductions in storage capacity, 3) saltwater intrusion, 4) degradation of water quality, 5) land subsidence, and 6) depletion of interconnected surface water. Of these, surface water depletion is most tightly linked to ecosystem challenges, with impacts on wetlands, streams, rivers, and lakes. Declines in groundwater levels can also affect vegetation and alter water temperatures and flows vital for the maintenance of spawning or rearing habitat for native fish.[7]

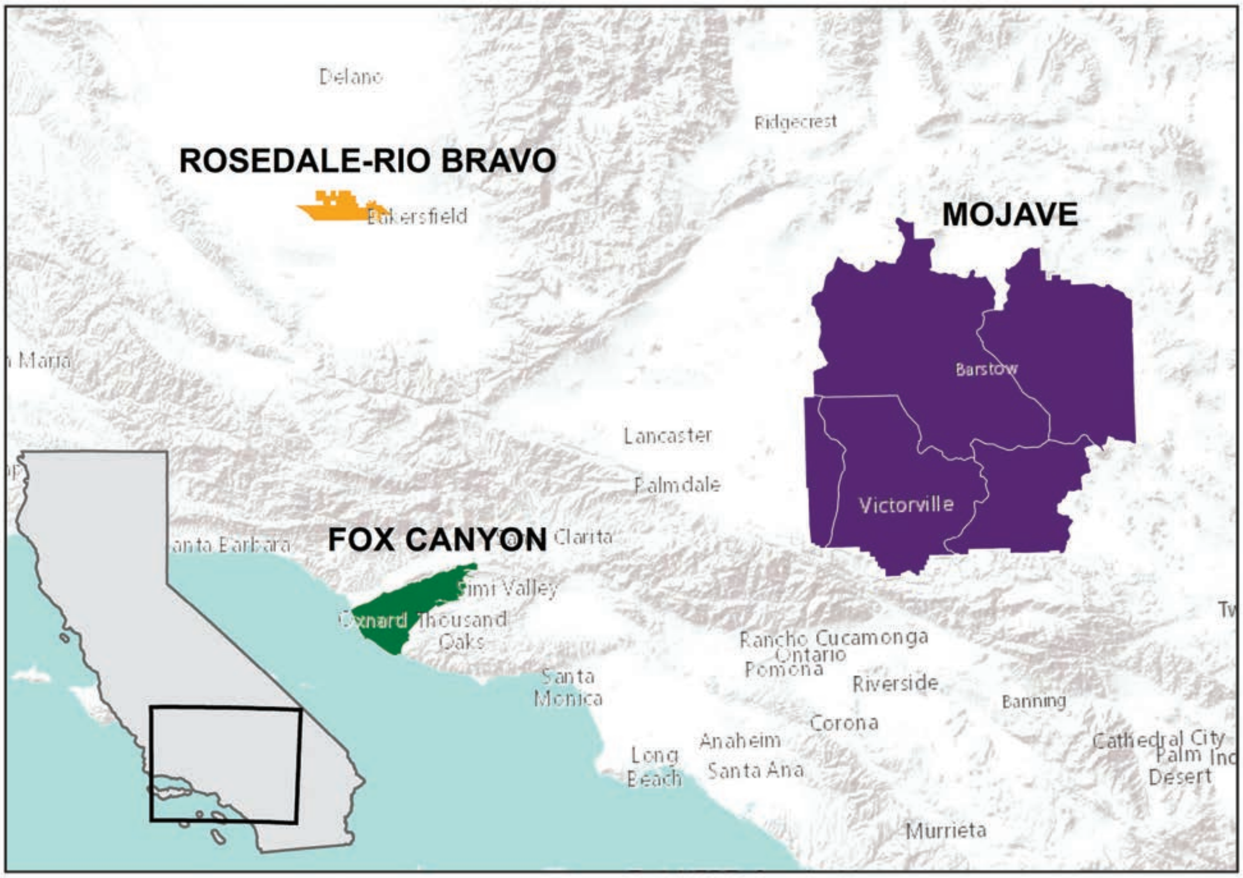
California groundwater sustainability agencies have a great deal of leeway in designing management schemes to avoid the six "undesirable results," with few prescriptions in the law itself for how these goals must be achieved.[8] Many basins in California are large, and most basins that face sustainability mandates have multiple new agencies that are required to coordinate their plans. Drafts of sustainability plans released so far reveal significant variation in proposed management strategies. Some focus primarily on funding groundwater recharge projects, which seek to divert stormwater or wastewater back into underlying aquifers. Others consider various demand management projects, ranging from extraction fees to pumping restrictions. California law prevents groundwater agencies from modifying the common law system of water rights, but new management tools authorized under SGMA allow agencies to set and enforce volumetric pumping allocations and enable the trading of those allocations.[9]

Many submitted management plans do not clearly differentiate between which management actions will be pursued and which are merely on the table. Of the 107 currently submitted plans, 50 mention the possibility of setting allocations, and 17 of those are definite about it.[10] Among all plans considering allocations, 31 are also considering a trading scheme. Most existing plans are still pending state approval. While the prevalence of allocations and trading in current submissions demonstrate that groundwater markets will be a key facet of California groundwater management moving forward, it may be the case that concerns over potential third-party impacts from groundwater trading—and how to deal with them—are impeding more widespread adoption of this policy instrument.

Market Design in Practice

We draw upon three case studies at various stages of development and implementation to evaluate how third-party impacts of groundwater trading are being addressed in practice. First we consider the Mojave Basin in Southern California, which began trading in 1996, before the passage of SGMA and after a long and costly adjudication process.[11] Next, we discuss environmental protections in the Fox Canyon groundwater market, SGMA's first active groundwater market. Groundwater management had been ongoing in Fox Canyon prior to SGMA, so groundwater users in the basin were able to implement a groundwater market more quickly, having built upon prior data collection, trust, and governance. Finally, we consider a market currently being developed by Rosedale-Rio Bravo Water Storage District (Rosedale), which has yet to begin trading. Rosedale, like many other local agencies under SGMA, is coordinating basin-wide water budgeting activities to inform groundwater allocations and has established an open-source water accounting platform that can serve as the foundation for a future water trading program.

Figure 1. **Map of Southern California Groundwater Management Case Studies**



Three case studies at various stages of development and implementation—the Mojave Basin, the Fox Canyon groundwater market, and the Rosedale-Rio Bravo Water Storage District—help illuminate how third-party impacts of groundwater trading are being addressed in practice.

Mojave Basin

The Mojave Groundwater Basin resides along the north side of the San Bernardino Mountains in Southern California, just north of the eastern portions of the Los Angeles metropolitan area and in one of the driest areas in North America. Throughout much of the 20th century, more or less unconstrained groundwater pumping led to a precipitous decline in the groundwater table. From 1990 to 1996, the Mojave's groundwater pumpers negotiated a settlement that set total limits on extraction and allocated pumping rights to individual users and municipalities. This adjudication of water rights laid the groundwork for a market to emerge that includes several hundred users.

The groundwater market in the Mojave is one of the most active in the American West. Every year since 1998 more than 20,000 acre-feet of water have been transacted on the spot market, accounting for between 15 and 20 percent of annual pumping in the basin. Permanent transfer of pumping rights is also common in some areas. The market has delivered economically meaningful benefits to groundwater users; a recent analysis estimates benefits of almost $500 million.[12]

This robust market activity occurs alongside various design features aimed at addressing spatial pumping impacts. Some of these design features affect foundational market rules, such as who can trade with whom. Most enable discretionary activity by either the third-party administrator (the "watermaster") or other entities to address impacts. In some cases, these features have benefited the environment by improving overall groundwater conditions, while others specifically target ecological improvements. We consider three examples below.

In many cases, smart design of groundwater markets will depend upon the hydrogeologic characteristics of the resource. The Mojave adjudicated area, encompassing more than 3,400 square miles, shares interconnected groundwater resources, but some areas are more connected than others. The market is broken into five administrative subareas, and trading across subarea boundaries requires watermaster approval. These constraints reduce the risk that trades into one subarea could upset local hydrologic balance and ultimately affect the inflows from, or outflows to, other adjacent subareas.[13]

Furthermore, the Mojave agreement defined obligations between subareas each year, which are estimated by the watermaster to ensure that any changes in pumping in one subarea that might impact water level conditions in another are addressed. The agreement established subsurface flow conditions between subareas, and one surface water obligation. Subsurface and surface flow obligations require the upstream Alto subarea to guarantee flow to the downstream Centro subarea (to be determined in a geographic area between the two subareas). If total flows from an upstream subarea are insufficient, users in the upstream subarea must purchase "make up water" or otherwise offset the impact.

Beyond attempting to stabilize long-term water tables in the region's groundwater subareas, the new regime also defined groundwater level thresholds along the Mojave River. These were designed in part to maintain sufficient groundwater availability for riparian vegetation that is important for endangered species. Groundwater levels at these sites are regularly monitored, and if they fall below certain thresholds, the watermaster can disburse resources from the Biological Resources Trust Fund, an account financed by small fees on pumping (less than $1/acre-foot in 2019-20) to purchase pumping entitlements or implement other activities. In many cases, these funds are used by the California Department of Fish and Wildlife to undertake conservation projects; for example, a two-year, $30,000 project removed groundwater-intensive invasive species (tamarisk, a shrub) from the floodplain in 2019-20. The funds are only available for projects inside several specially identified zones (totaling several dozen square miles), highlighting the importance of mitigating particularly high pumping damages in this area.

Finally, the market allows for voluntary purchases of water rights to address local pumping impacts. When one party is significantly impacted by another's pumping and well-defined rights to said pumping exist, negotiations among affected parties to reduce those impacts may prove sufficient. In 2001, the Department of Fish and Wildlife did just that with a property adjacent to Camp Cady, a restoration site it owns within the Mojave River floodplain. By purchasing the neighboring parcel and associated water rights, it was able to not only reduce nearby pumping by 90 percent but also use the balance of the acquired rights for irrigation of riparian vegetation. The improvements at Camp Cady have supported natural revegetation and resident and migratory bird species.

Management of spatial impacts in the Mojave includes a portfolio of approaches that reflect varying needs to trade off the complexity of management rules with a need to target the most important impacts. In cases where the number of impacted parties is small, market transactions help to resolve disputes, while the risk of reduced flows between subareas—affecting hundreds of parties in ways difficult to measure—was successfully resolved using a mixture of foundational trading restrictions and offset mechanisms. Meanwhile, the independent market administrator has leeway to use funds from local pumpers to address impacts in easily identified areas where the costs of declining groundwater tables would be high. Together, these approaches provide a basic structure to control important spatial impacts and flexible opportunities to address new ones as they arise; moreover, they do so in a way that allows for extensive, mutually beneficial trading to continue.

Fox Canyon Groundwater Management Agency

The Fox Canyon Groundwater Management Agency (GMA), a Special Act District created in 1982, manages a 183-square-mile wedge of Ventura County, California. Due to its proximity to the ocean, groundwater pumping in this area has led to seawater intrusion into the underlying aquifer, where saltwater enters into freshwater wells. Issues of seawater intrusion dating back to the 1950s led to the establishment of the agency. Early local groundwater management included reporting on levels of groundwater extraction, a practice that is still not widely adopted throughout the state today.

Now acting as a groundwater sustainability agency under SGMA, the Fox Canyon GMA developed and implemented a groundwater trading scheme for the Oxnard Basin in Ventura County, in conjunction with California Lutheran University and the Nature Conservancy. The Fox Canyon groundwater market began trading as a pilot in 2020. The speed at which the market was developed is largely attributable to the fact that local management was in place long before SGMA.

Building upon a previous foundation of local governance, data collection, and water accounting, the Fox Canyon GMA was able to establish a groundwater market under SGMA that includes protections for the environment. Two special management areas were designated in the basin's groundwater sustainability plan to ensure protections against seawater intrusion and overuse. As a part of the market's rules, the special management areas were given directional trading restrictions whereby pumpers in those areas are restricted from buying pumping rights from those located outside, so as not to increase pumping within the special areas. They can sell the right to pump groundwater to those outside or trade with others within the special management area.

The Fox Canyon GMA recognizes that trades can create cones of depression and concentrations of pumping in certain areas that can inadvertently reduce surface water flows, with negative environmental impacts, and that market rules may need to adapt over time.[14] At the end of the pilot market's first year of trading, nearly 200 acre-feet of groundwater pumping rights were transferred out of the two special management areas, demonstrating that the approach reduced pumping around sensitive resources.

Rosedale-Rio Bravo Water Storage District

The Rosedale-Rio Bravo Water Storage District is located within Kern County, at the southern end of California's San Joaquin Valley. The district participates as one of 16 member entities within the Kern Groundwater Authority, an entity tasked with coordinating SGMA-related activities between its members. Rosedale's management area covers approximately 75 square miles.

The district's groundwater sustainability plan outlines several projects and actions, including a water accounting framework that establishes allocations and develops a web-based water supply accounting database that allows the district and its landowners to track water usage. It also includes a water charge demand reduction strategy, that, if needed, would assess a fee based on the volume of water used over and above a designated amount to prevent overdraft.[15] Further, Rosedale's plan highlights that water transfers will be considered.[16] As a component of the water accounting framework project, Rosedale has worked with Environmental Defense Fund to co-create an open-source water accounting platform that has billing and trading components that can be enabled when the district determines there is a need for this functionality.[17]

Rosedale's plans equip landowners with several tools to manage water resources in response to SGMA. The water accounting platform is designed to enable water managers and farmers to develop accurate water budgets and facilitate water trading. Recognizing the need for basin-wide coordination, accounting, and management strategies, the platform was developed using open-source code so that other areas of the Central Valley that face similar water challenges can leverage and adapt the platform. Rosedale has also been an early adopter of satellite-based evapotranspiration data provided by OpenET to measure consumptive water use and is making this data widely accessible to landowners through the accounting platform.[18]

The platform will also integrate an open-source groundwater modeling decision-support tool. It will allow water managers and stakeholders to model trading scenarios to better understand the potential impacts of water transfers on groundwater levels and water users within basins, which can inform rules that address impacts to communities and the environment.

Lessons Learned and Policy Implications

The value of water markets stems from their ability to flexibly reallocate scarce water from lower-value uses to higher-value uses. When it comes to groundwater management, allowing trade of pumping allocations can generate gains that buffer the costs of groundwater cutbacks. However, groundwater is a spatially interconnected resource; pumping in one location can have direct, unintended, and uncompensated impacts that are different from the impacts of pumping in other locations. Certain restrictions or controls may be needed to mitigate these differential impacts. Yet market restrictions hinder the ability of buyers and sellers to flexibly reallocate, reducing the economic gains from trade. As a result, the development of groundwater markets requires careful accounting and design to effectively balance gains from trade with avoidance of uncompensated third-party effects. Groundwater management agencies under SGMA that are not currently considering markets out of concern over third-party impacts may look to these case studies for practical solutions.

Solutions such as trading zones with restricted or unilateral trading between zones, as seen in Mojave and Fox Canyon, respectively, economize on the information that groundwater agencies must gather. They also provide a relatively simple trading scheme for market participants. Trading activity from the Mojave also illustrates the value of users themselves devising local solutions. In cases where the number of bargaining parties is small—such as across neighboring parcels—informational requirements are lower, and it may be simplest for parties to contract for reduced pumping as a solution. Though lacking the complete information required of the ideal theoretical solution, market design and activity observed in practice can effectively address salient spatial impacts associated with trading while facilitating trades.

Since SGMA requires the avoidance of undesirable results, designing trading programs that address impacts to the environment will not only be good practice, it will also be necessary. Even though the act passed nearly eight years ago, many local agencies continue to struggle with how to collect, coordinate, and make available water-use data to inform actions within user groups and across larger basins. Accurate, trusted accounting systems are critical to inform water decision-making and in facilitating the development of groundwater trading programs across California and elsewhere.

Similar to previous data collection efforts in Mojave and Fox Canyon, groundwater sustainability agencies in California will be able to leverage the information required under SGMA to inform spatial considerations for groundwater market design. Management tools like those being developed in Rosedale can enable additional granularity in managing the differential consequences of groundwater trades, especially in areas where pumping is spatially concentrated. In June 2021, Environmental Defense Fund, the California Water Data Consortium, the California Department of Water Resources, and the State Water Resources Control Board, along with several local agencies, including Rosedale, launched a partnership to further expand and scale the water accounting platform with an eye toward supporting water trading programs into the future.[19] Other technological advances in groundwater monitoring could further expand the agencies' administrative capacity to oversee groundwater markets.

Conclusion

In California, many local agencies are developing groundwater trading programs under SGMA. The case studies explored in this report illustrate how several groundwater markets in California are currently balancing the gains from trade with avoidance of third-party effects in the presence of unintended spatial consequences.

The vast majority of California's groundwater sustainability agencies that are exploring groundwater market feasibility have not yet determined practices for avoiding or mitigating the potential unintended consequences of spatially reallocating groundwater extraction. Policies designed to address third-party impacts need to take informational requirements into consideration while defining impact thresholds that are objective, measurable, and tied as clearly as possible to pumping. Solutions that encourage interaction among affected parties will be the most likely to lead to beneficial outcomes.

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Endnotes

1 E. Bruno and R. Sexton, "The Gains from Agricultural Groundwater Trade and the Potential for Market Power: Theory and Application," *American Journal of Agricultural Economics* 102, no. 3 (2020): 884-910.

2 B. Venn et al., "Hydrologic Impacts Due to Changes in Conveyance and Conversion from Flood to Sprinkler Irrigation Practices," *Journal of Irrigation and Drainage Engineering* 130, no. 3 (2004): 192-200.

3 Economists refer to these spatially varying negative consequences as non-uniform marginal external damages. Third-party effects from groundwater trading may also arise for communities and other landowners with, for example, shallow drinking water wells. Our focus in this essay is on environmental considerations, but much of this discussion can also be applied to other types of third-party effects.

4 Contrast this with globally dispersing pollutants like carbon dioxide emissions, where a uniform tax or trading scheme could be appropriate. Regardless of the source location, all carbon emissions have the same impact on global warming because carbon is a global pollutant.

5 R. S. Farrow et al., "Pollution Trading in Water Quality Limited Areas: Use of Benefits Assessment and Cost-effective Trading Ratios," *Land Economics* 81, no. 2 (2005): 191-205. Nicholas Muller and Robert Mendelsohn, "Efficient Pollution Regulation: Getting the Prices Right," *American Economic Review* 99, no. 5 (2009): 1714-39.

6 N.G. Nylen et al., "Trading Sustainably: Critical Considerations for Local Groundwater Markets Under the Sustainable Groundwater Management Act," *Berkeley Law, Center for Law, Energy & the Environment* (2017) https://www.law.berkeley.edu/research/clee/research/wheeler/trading-sustainably/.

7 The Nature Conservancy, "Groundwater Dependent Ecosystems Under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans," (2018) https://groundwaterresourcehub.org/public/uploads/pdfs/GWR_Hub_GDE_Guidance_Doc_1-31-18.pdf.

8 The statute requires that the state step in and take over management if local groundwater agencies fail to achieve the outcomes required by SGMA.

9 As such, some sustainability plans have outlined a block rate scheme for pumping fees that would make pumping nearly free up to some defined limit, then prohibitively expensive thereafter. The water volume charged under the initial, cheaper block would be allocated among pumpers, who could then trade their volumes under that block amongst themselves. Though stopping short of instituting new property rights to a volumetric allocation, this system incorporates many of the design features of markets that enable them to allocate water efficiently. E. Garner et al., "The Sustainable Groundwater Management Act and the Common Law of Groundwater Rights—Finding a Consistent Path Forward for Groundwater Allocation," *UCLA Journal of Environmental Law and Policy* 38, no. 2 (2020).

10 Groundwater Sustainability Plans can be accessed through the California Department of Water Resources SGMA Portal, available at: https://sgma.water.ca.gov/portal/gsp/status. Fifty-six percent of the groundwater sustainability agencies had a submission deadline of January 2020. More basins faced a deadline of January 2022.

11 In this context, "adjudication" refers to a court-led process to redefine (ground)water access rights by delineating volumetric entitlements. Historically in California, adjudication processes were initiated by resource users, with negotiations over final allocations facilitated and finalized by courts.

12 A. Ayres et al., "Do Environmental Markets Improve on Open Access? Evidence from California Groundwater Rights," *Journal of Political Economy* 129, no. 10 (2021): 2817-60.

13 For example, if cross-subarea trades increase pumping in one subarea, and the water table falls as a result, then subareas that typically receive inflows from that subarea may receive less and suffer a declining water table themselves.

14 S. Heard et al., "The First SGMA Groundwater Market is Trading: The Importance of Good Design and the Risks of Getting it Wrong," *California Agriculture* 75, no. 2 (2021): 50-56.

15 Rosedale-Rio Bravo Water Storage District, "2018 Engineer's Report in Support of Proposed Assessment Increase and Implementation of a Water Charge," GEI Project No: 1701276 (2018), available as "Appendix K – Engineer's Report" at https://www.rrbwsd.com/wp-content/uploads/2019/12/Appendices-E-K.pdf

16 Kern Groundwater Authority Groundwater Sustainability Agency, "Groundwater Sustainability Plan Chapter for the Rosedale-Rio Bravo Management Area," (2019): 80, https://www.rrbwsd.com/wp-content/uploads/2021/10/14.-4-2019-12-10-com.-RRBMA-GSP-FINAL-Chapter.pdf

17 C. Babbitt, "A Craigslist for Water Trading? Learn How this New Water Management Platform Works," Environmental Defense Fund (2020) http://blogs.edf.org/growingreturns/2020/10/07/new-water-accounting-trading-platform-sgma/. For additional information on the Water Accounting Platform, visit: edf.org/waterplatformstory.

18 OpenET is a collaborative initiative that uses best available science to provide easily accessible satellite-based estimates of evapotranspiration (ET) for improved water management across the western United States. To learn more, visit: https://openetdata.org/faq. Satellite-based ET data is particularly well suited for Rosedale because the district brings in surface water, which is then recharged underground, and landowners then pump the groundwater. The district does not have the more complex, coupled surface water and groundwater pumping systems that many other basins have. In most hydrologic and geologic settings, additional information is needed to track water usage.

19 California Department of Water Resources, "State Water Agencies, CA Water Data Consortium and EDF Partner on Groundwater Accounting Platform and Data Standards," (2021) https://water.ca.gov/News/News-Releases/2021/May-21/Groundwater-Accounting-Platform-and-Data-Standards.

2 Addressing Institutional Barriers to Native American Water Marketing

Policy reforms can give tribes full value of their water rights

Leslie Sanchez

On August 16, 2021, the federal government declared the first-ever shortage on the Colorado River, as measured at the Lake Mead reservoir, triggering cuts to water users in Arizona, Nevada, and Mexico. While the declaration underscores the severity of water scarcity in the basin, it was not unexpected. Lake Mead's elevation has hovered around the 1,075-foot threshold for a "Tier 1" shortage for years, and maintaining even that level has required water marketing agreements with Native American tribes.

In recent years, the Gila River Indian Community and Colorado River Indian Tribes have helped maintain Lake Mead's water levels above the curtailment threshold by entering into leasing and forbearance agreements with federal agencies, states, and municipal governments in the Lower Colorado River Basin.[1] In exchange for banking water rights in Lake Mead, the two tribes received millions of dollars in revenue—more than they would have generated through on-reservation water use—which they have reinvested in more efficient water infrastructure and reservation economies.[2] Meanwhile, off-reservation water users staved off costly, mandatory cuts from the federally declared shortage.

The combination of regional water scarcity and mandatory reductions in water use has amplified the need for water markets to encourage conservation and redirect water to its highest-value uses. With some of the most extensive and senior water rights in the West, the potential influence of Native American tribes over water markets and trajectories of future water use cannot be overstated. The Colorado River Basin's 29 federally recognized tribes hold combined rights to 3.6 million acre-feet (AF) of water, or roughly 25 percent of the Colorado River's annual flow. This share could increase by up to 0.5 million AF as remaining basin tribes settle their water rights—just as off-reservation water users face additional curtailments.[3]

Despite clear benefits of tribes marketing water to off-reservation users, federal law severely restricts them from doing so. Tribes are prohibited from marketing water off reservation without ad hoc authorization from Congress. Even then, additional barriers limit how tribes can market water. These obstacles to water marketing reduce potential gains from trade, deprive tribes of significant revenues and decision-making power, generate uncertainty for other water users, and entrench water use in relatively low-value, low-efficiency activities. Reforms that remove such barriers would not only give tribes the autonomy they deserve when it comes to their water rights, but they would also benefit the tribes and off-reservation water users who participate in water marketing.

Highlights

- **Despite the clear mutual benefits of water marketing between tribes and off-reservation water users, federal law severely restricts tribes from marketing their water rights.**
- **Because of these restrictions, Colorado River Basin tribes may be forgoing $563 million to $1.3 billion dollars annually, or between $3,200 and $7,300 per person residing on the corresponding reservations.**
- **Authorizing tribes to lease water off reservation would enable tribes to capture the full value of their water rights, enhance water management flexibility through expanded market activity, and improve regional resiliency to protracted drought and growing water demand.**

Recommendations

- **Congress should pass legislation to uniformly authorize tribes to lease water rights off reservation if they choose to do so.**
- **Contingent on tribal support, water settlements should include financial and administrative support for tribes to develop water markets.**

Tribal Water Rights and Use

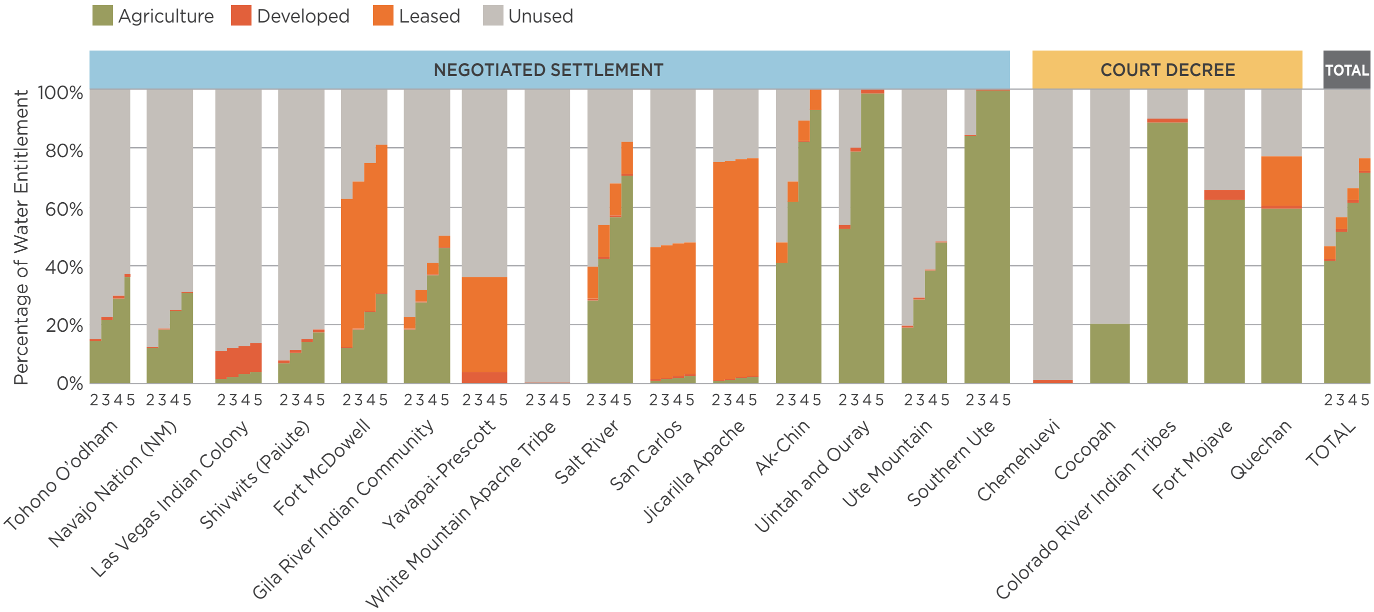
Surface water in western states is governed by the prior appropriation doctrine. Water rights are established based on a "first in time, first in right" chronological priority system and maintained through continuous beneficial use. The first prior appropriation water rights were assigned to irrigated agriculture between 1850 and 1920, just as tribes were relegated to reservations, and are administered under state law.

Tribes have federally reserved water rights that exist alongside prior appropriation rights. The federal government implicitly reserved water rights for tribes through reservation treaties. They trace their origins to the 1908 U.S. Supreme Court ruling in *Winters v. United States*, which established that tribes are entitled to a volume of water to fulfill their reservation homeland needs, with a priority date of when the reservation was established. Because reservation treaties remove federally reserved water from the public domain, reserved water rights cannot be forfeited through nonuse. However, the ruling did not quantify or establish tribes' water rights, so they remained unenforceable as surface water across the West was fully allocated to off-reservation water users.

As water scarcity has increased in recent decades, a growing number of tribes have sought legal titles to their long-unresolved water rights. Tribes can quantify their water rights through judicial rulings or settlement agreements negotiated between tribes and neighboring water users. Both strategies provide legally enforceable water rights, which are a precondition for formal water marketing. But whereas court rulings merely create the tribe's water rights, settlements typically include funding for the tribe to develop them, address the extent to which tribes can market water off reservation, and require an act of Congress.

Even so, actually securing federal settlement funding and then planning and constructing water infrastructure on reservations can take decades. In aggregate, the 20 basin tribes with deeded water rights have roughly 1 to 2 million AF of tribal water entitlements that remain unused available for free use by more junior appropriators

Figure 1. **Tribal Water Use Estimates**



Colorado River Basin tribes have a great deal of water entitlements that remain unused by them—and are therefore available for free use by more junior appropriators. The figure above shows estimates of tribal water use in 2012 for agricultural use, developed land use, and off-reservation water leasing. Agricultural and developed water use on reservations with negotiated settlements are estimated based on reservation land use derived from the U.S. Conterminous Wall-to-Wall Anthropogenic Land Use Trends (NWALT) geospatial data. Estimates assume use of 0.25 AF per acre for developed land and 2, 3, 4 or 5 AF per acre for agricultural land use, as depicted along the x-axis. Figure depicts actual water use for reservations with court decreed rights.

Sources: Data on negotiated settlement water use are available from Leslie Sanchez et al., "The Long-Term Outcomes of Restoring Indigenous Property Rights to Water," Minneapolis Federal Reserve Bank, Center for Indian Country Development, Working Paper (2021). Data on court-decreed water use are available from the Bureau of Reclamation, "Colorado River Basin Ten Tribes Partnership Tribal Water Study," Chapter 5: Assessment of Current Tribal Water Use and Projected Future Water Development (2018).

until the tribes can divert and use that water on reservation. In a basin where annual water withdrawals exceed inflows by 1.2 million AF, the opportunity costs to tribes of not leasing water off reservation may be billions of dollars.[4] In 2020, for example, Imperial Irrigation District in Southern California leased approximately 190,000 AF of its senior Colorado River water rights to the San Diego Conservation Water Authority for $679 per AF.[5] At that price, basin tribes' unused water rights amount to annual lost leasing revenues of $563 million to $1.3 billion, or between $3,200 and $7,300 for every person residing on these reservations.

Barriers to Tribal Water Marketing

Despite the clear mutual benefits of water marketing between tribes and off-reservation water users, federal law restricts tribes' abilities to market their water rights. Tribes cannot lease water off reservation without congressional authorization, which is granted on a case-by-case basis.[6] Even once authorized, most tribes face additional, settlement-specific barriers that restrict how they can lease water and often delay leasing agreements. Such obstacles to water marketing reduce potential efficiency gains from trade, deprive tribes of a significant revenue stream, generate uncertainty for off-reservation water users, and entrench water use in relatively low-value, low-efficiency activities.[7]

Irrigation canal, Gila River Indian Community ©Peter Howe

The Nonintercourse Act, a series of statutes passed in the 1790s and early 1800s, bars tribes from transferring Indian trust assets without an act of Congress.[8] Because tribal water rights are held in trust by the federal government, leasing those rights off reservation requires congressional authorization. As of 2020, 23 of the 34 congressionally enacted settlement agreements that defined water rights for tribes also allow some form of tribal water marketing. Tribes with court-decreed water rights must request permission to lease outside of the adjudication process. Restrictions on tribal water marketing limit the efficacy of water markets to flexibly reallocate water to its highest-value use.

The high costs of this policy are especially evident in the Lower Colorado River Basin. In 1963, 15 years before other tribes settled their water rights, five reservations located along the mainstem of the Colorado River on the border of California and Arizona received the senior-most rights to 952,000 AF—more than some states—through a Supreme Court ruling. The ruling and decrees that followed it mandated that water be used on the reservations and did not authorize water leasing.

While the reservations are located just upstream from major cities, such as Phoenix and Los Angeles, capital constraints severely limit economic diversification away from relatively low-value, flood-irrigated agriculture. Disparities in the marginal value of water use on and off reservation highlight the forgone benefits of water marketing. For instance, more efficient irrigation systems could enable the tribes to continue farming while also generating conserved water to lease off reservation. But absent authorization to lease water, they lack both the economic incentive and the capital to conserve water. Meanwhile, water users facing mandatory water curtailments in Arizona and Nevada lack options to lease water from the tribes.

Leasing Restrictions in Negotiated Settlements

In the context of settlement negotiations, tribes must bargain for permission to lease water off reservation. Because water access on reservations is severely limited and insecure before adjudication, other negotiating parties, such as cities, irrigation districts, and state and federal agencies, have had the power to dictate the terms of tribal water marketing.

Several settlements restrict tribal water marketing opportunities to leases approved in the settlements themselves. For instance, the Salt River Indian Community's water settlement limits water marketing to a set of 99-year lease agreements with specified cities in Arizona.[9] Other settlements restrict leases to specific water sources and are geographically bound. For example, the Yavapai-Prescott Indian Tribe's settlement restricts water marketing to effluent generated on reservation.[10] The Tohono O'odham's 1988 settlement initially limited leasing to water users in the Tucson active management area.[11]

All settlements prohibit tribes from selling their water rights, but long-term leases up to 100 years are possible. Most settlements contain leasing agreements between tribes and cities for this amount of time.[12] Still, other settlements limit tribal water marketing to only 99-year lease agreements specified in the individual agreements. While these long-term leases are undertaken to facilitate settlement agreements, they are not the same as affording ongoing flexibility to tribes via the ability to engage in short-term leasing agreements for other tribal water.

Tribal water rights cannot be marketed across state lines. Where reservations are geographically remote, disconnected from regional water infrastructure, or adjacent to a state line, these restrictions reduce the pool of potential lessees, raise transaction costs associated with market development, and erode the market power of tribes as they negotiate leases.

Transaction costs associated with marketing water in the West are notoriously high, with one analysis placing them at 20 percent of the market price of water.[13] While there are no systematic analyses of the transaction costs associated with tribal water marketing, anecdotal evidence suggests that federal oversight raises transaction costs by delaying leasing agreements.

Even after Congress has authorized tribal water marketing, most settlements stipulate that individual leases by tribes require approval by the secretary of the interior.[14] For example, the San Carlos Reservation's proposed lease to the City of Gilbert in Arizona was delayed by 10 years because the Bureau of Reclamation opposed the leasing terms.[15] Likewise, reconciling jurisdictional differences between federally reserved water and state rights to water as its use moves off reservation is legally complicated, particularly as tribal water marketing is relatively new and some legal aspects are unclear.[16]

Implications for Water Use

Although tribes never forfeit their paper water rights, doubts remain about whether such water will be made available to tribes or whether their unexercised water rights will be ultimately enforced once off-reservation populations come to rely on them. As such, without viable leasing options, tribes have an incentive to use their full water entitlements. Darryl Vigil, the Chairman of the Ten Tribes Partnership, a coalition of tribes in the Colorado River's Upper and Lower Basins, testified before a 2013 Senate subcommittee that "the Ten Tribes are very concerned that while they struggle to put their water to use, others with far more political clout are relying on unused tribal water supplies and will seek to curtail future tribal use to protect their own uses."[17] To combat this, tribes have expanded irrigated agriculture on reservations, diverting the water as a de facto legal protection against future competition from off-reservation water users.

More broadly, capital constraints on reservations and the federal government's historic underinvestment in reservation irrigation systems have meant that on-reservation agricultural water use is relatively inefficient.[18] More so than off-reservation farms, which have seen shifts to more efficient sprinkler and drip irrigation systems, reservation agriculture uses flood and furrow irrigation.[19] Thus, barring tribes from leasing water rights further entrenches water use in relatively low-efficiency agriculture and limits tribes' access to capital to invest in more efficient irrigation systems and productivity-boosting farm technologies.

Per prior appropriation rules, unused tribal water can be diverted by the next right holder in the priority order. Currently, off-reservation water users are benefiting from the free use of tribes' unexercised water rights. While the inability to lease water deprives tribes of a vital revenue stream, in the long term, it may also generate uncertainty for off-reservation water users who are relying on unused tribal water. As tribes gradually secure settlement funding and construct water delivery infrastructure, on-reservation water use will likely increase over time, thus reducing the volume of their unexercised water rights currently in use off reservation. Without the ability to enter into formal leasing agreements, tribes are limited to using water on reservation, while off-reservation water users remain uncertain about when their water access will be curtailed.

Recommendations

Reforms can remove barriers to tribal water marketing and give tribes the autonomy they deserve over their water rights, allowing them to realize the full value of those rights.

Congress should pass legislation to uniformly authorize tribes to lease water rights off reservation if they choose to do so.

Authorizing tribes to lease water off reservation would expand market activity, enable tribes to capture the full value of their water rights, and direct water to sectors where it is needed most. Federal legislation already authorizes tribes to lease other natural resources (e.g., minerals, oil, and gas), which demonstrates the political feasibility of passing similar legislation for water leasing.[20]

The piecemeal approach to authorizing tribal water marketing is shortsighted. First, growing water scarcity—and corresponding increases in water prices—may eventually prompt tribes with court-decreed water rights to pursue federal legislation, but this will likely only happen after water users incur substantial losses. Colorado River Indian Tribes acquired water rights in 1963 via court decree but only called for the introduction of federal legislation to authorize water marketing in 2020. In December 2021, Arizona's U.S. senators introduced federal legislation to authorize the Colorado River Indian Tribes to lease water rights off reservation.[21] The legislation, however, only applies to the Colorado River Indian Tribes and neglects potential leasing opportunities with others who have adjudicated water rights but are unauthorized to lease. Waiting to pass 13 individual pieces of legislation for each of the 13 tribes in western states with court-decreed water rights undermines the ability of water users in the region to respond to drought and manage water more responsibly. Rather than such a piecemeal approach, a bill that uniformly authorizes all reservations to market water would remove bureaucratic inequities that inhibit tribes from fully benefiting from their water rights while also enhancing regional resiliency to drought.

Second, such legislation would free tribes from having to bargain for permission to lease water as part of the process of securing their water rights. Most limitations on tribal water marketing are concessions made by tribes whose water access requires approval of off-reservation water users. Restricting water marketing to long-term agreements may benefit individual parties to water settlements, but it reduces overall efficiency gains and limits the capacity of water markets to address future water needs.

This is not to say that bargaining parties cannot reach water marketing agreements in the context of a settlement negotiation. In fact, many settlements rely on market mechanisms through which cities finance more efficient water systems for irrigation districts, which reallocate conserved water to tribes, who then lease portions of their newly acquired water rights to cities. However, a default ban on water marketing limits tribes' bargaining power in settlement negotiations and again as they negotiate individual leases later on.

Tribes should have sovereign authority to use water according to their own diverse and evolving needs and priorities. For many, farming and food sovereignty are important water use goals, which have been maintained and expanded even when water is marketed off reservation.[22] The option to lease provides tribes with more autonomy over water use decisions, generates revenue to reinvest in agriculture if that is a priority, supports economic diversification, and boosts tribes' influence in regional water policy and planning efforts. The voluntary nature of water markets means that tribes who oppose leasing water can opt out.

Contingent on tribal support, water settlements should include financial and administrative support for tribes to develop water markets.

Settlements contain federal funding for tribes to develop water conveyance infrastructure and for economic development.[23] However, financing and building infrastructure can take decades, while returns to water marketing are realized more quickly.[24] Funding to develop water market platforms that enable local water users to participate in a meaningful way could offset federal spending obligations, expedite benefits to tribes, and encourage market activity. Providing administrative and financial support for tribes to develop water marketing platforms, develop a customer base, and navigate the jurisdictional challenges that arise when federally reserved and appropriative water rights converge in a market could streamline the leasing process.

For instance, the Gila River Indian Community and Salt River Project in Arizona created a limited liability corporation in 2019 through which the community banks and then markets water rights to off-reservation municipal, industrial, and residential water users in Arizona.[25] By banking its unused water, the Indian Community accrues long-term storage credits that it can use once the water infrastructure on the reservation is completed. Relatedly, by storing groundwater for the Central Arizona Groundwater Replenishment District in a managed aquifer recharge site on the reservation, the Gila River Indian Community has revitalized streamflow on the reservation. Voluntarily abiding by Arizona's aquifer recharge and recovery regulations has enabled it to bank and lease groundwater credits both on and off reservation.

The Gila River Indian Community's water banking activities highlight the complexities of building successful water marketing platforms. Institutions that manage and mitigate transaction costs are fundamental to water market success.[26] Still, water markets tend to be highly localized, and institutions may not be scalable.[27] As such, supporting tribes as they build institutional capacity to market water in complex jurisdictional contexts may mean trading higher upfront costs of establishing water marketing institutions for lower transaction costs associated with individual transactions in the long term. While more research is needed, financial and administrative support for tribes to develop water marketing programs may facilitate quicker responses to changes in water supply and demand.

Conclusion

One of the primary benefits of water markets is that participation is voluntary. Tribes, like appropriative right holders, should be able to opt in or out of the market as they please. Restrictions on tribal water marketing violate tribal sovereignty, erode the value of tribes' water rights, and perpetuate inefficient and inequitable water use. Federal legislation and financial and administrative support are critical to reducing barriers to tribal water marketing.

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Endnotes

1 While the Gila River Indian Community banks water in Lake Mead through a leasing agreement, the Colorado River Indian Tribes do not have authority to lease water. Instead, the group has entered into a forbearance agreement—a de facto lease, but technically not a lease—through which it agrees to fallow previously farmed acreage and bank conserved water in Lake Mead. The forbearance agreement terms are slightly more onerous than a lease. The reservation must verify that fallowed acreage was previously farmed and ensure that the land no longer consumptively uses water. Moreover, the agreement is possible because the reservation's unique location almost immediately downstream from Lake Mead means that it can forgo water use and bank conserved water in Lake Mead without the risk that other water users will divert it. A. Woods, "Phoenix, Feds Will Pay Tribes to Leave Their Water in Lake Mead, Help Prevent Shortage," *AZcentral*, June 15, 2017. T. Davis, "Water Bailout? Colorado River Tribes Pose Statewide Leasing Idea," *Arizona Daily Star*, June 12, 2018.

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3 Water Banking Can Help Great Salt Lake

Utah's Water Banking Act offers a mechanism to allocate water to a drying Great Salt Lake

Sarah E. Null

Utah's Great Salt Lake is a treasured resource, yet dedicated flows have not been established to preserve the economic, ecological, and cultural values that the lake provides. Utah's prior appropriation law allocates water rights based on time of first use, meaning agricultural water uses typically have senior rights. Utah's Water Banking Act, which was adopted in 2020, presents an opportunity to reallocate some water to the environment within existing appropriative rights water law.

Under the act, water users can create local water banks to temporarily lease water. Leased water can be used for various purposes, including environmental or agricultural uses. Water banking under the act allows right holders to lease some or all of their water and, crucially, protects banked water rights from forfeiture. Additionally, the water and money from leases remain in the local watershed. Water banking presents an opportunity to flexibly manage water and help preserve the dwindling Great Salt Lake. This analysis estimates the volume of water that could be delivered to Great Salt Lake and the lake's water level based on wet-year water banking in Utah's Cache Valley.

Highlights

- **Water banking allows water right holders to lease some or all of their water for environmental, agricultural, or other purposes. Banked water rights are protected from forfeiture, and the water and money from leases remain in the local watershed.**
- **Banking could help flexibly manage water and contribute water to Great Salt Lake, which is drying.**
- **Water banking could be a cost-effective strategy that would entail financing millions of dollars today to potentially save billions of dollars in future lake restoration, dust abatement, and human health costs.**

Great Salt Lake, Utah ©Sara Null

Environmental Water Management in Utah

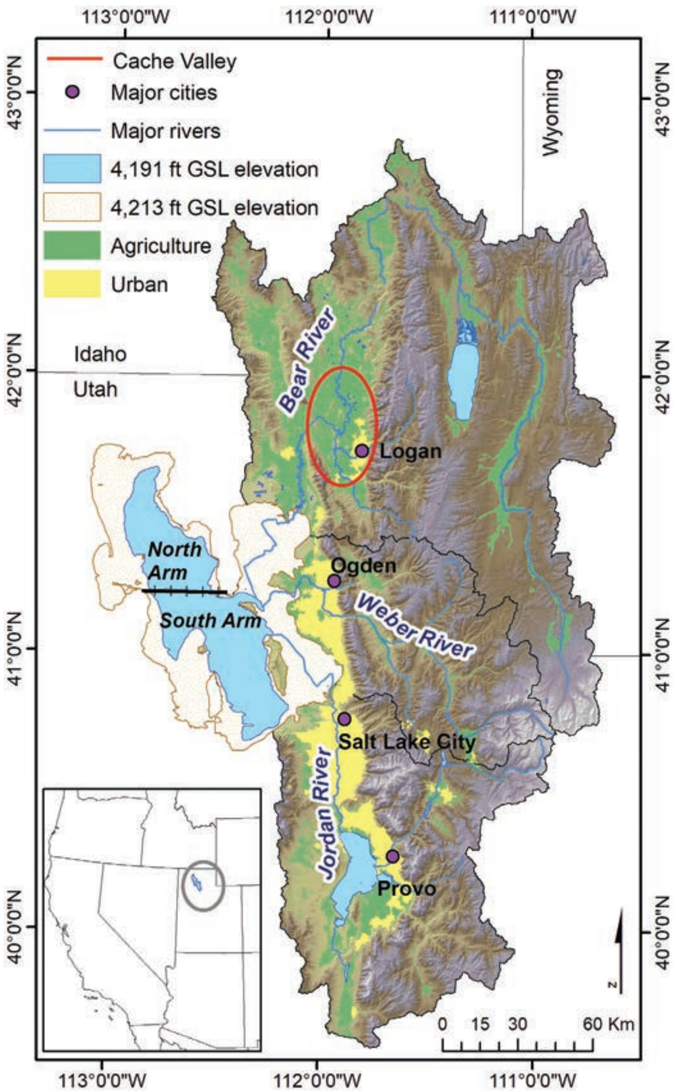
Legislation to codify environmental beneficial uses of water is relatively new to Utah. In 1986, instream flows were recognized as a legitimate water right in Utah, although only Utah's Division of Wildlife Resources could obtain instream flows for fish preservation.[1] A 1992 amendment expanded the law so that Utah's Division of Parks and Recreation could hold instream flow rights for public recreation or stream preservation.[2] In 2008, pilot legislation enabled private leasing of water for instream uses by fish conservation groups to restore habitat for native trout, and in 2019, that legislation was made permanent.[3] In 2020, the pilot Water Banking Act authorized voluntary water banking and split-season leasing,[4] and in 2022, Utah expanded the definition of beneficial use to broadly include instream flows and Great Salt Lake.[5]

The Water Banking Act promotes temporary, voluntary, and locally directed leasing arrangements for water rights. Water banking uses a market-based approach to protect water right ownership, generate local income, and provide flexible and expanded water access. Split-season leasing allows farmers to use their water for a portion of the season and lease it at other times. These changes to Utah's water code are the first formal mechanism to create a flexible source of water for environmental uses, such as preserving Great Salt Lake.[6]

Value and Vulnerability of Utah's Great Salt Lake

Great Salt Lake receives approximately 66 percent of its water from streamflow contributions, 31 percent from direct precipitation, and an estimated 3 percent from groundwater. Of the streamflow contributions, about 58 percent is from the Bear River, which flows through Wyoming, Idaho, and Utah and is predominantly fed by snowmelt from the Wasatch and Uinta Ranges. The average annual Bear River streamflow to Great Salt Lake is 1.2 million acre-feet (AF) per year, or 1,658 cubic feet per second.[7] Cache Valley is located along the Lower Bear River in northern Utah (see Figure 1), where agriculture is a dominant land use. The market value of Cache County agricultural products is $2.43 billion in inflation-adjusted dollars, with about 194,000 acres of irrigated farmland.[8]

Figure 1. **Great Salt Lake, Major Watersheds, and Cache Valley**



Great Salt Lake contributes an estimated $1.58 billion in inflation-adjusted dollars to Utah's economy through mineral extraction ($1.35 billion), recreation ($162.3 million), and brine shrimp harvest ($67.7 million).[9] However, due to an increase in consumptive water uses, the lake's water level has dropped at least 11 vertical feet since 19th-century pioneers arrived in northern Utah.[10] At record low lake levels in 2022, 53 percent of the lakebed was exposed. Exposed lakebed harms human health of nearby populations because fine dust (smaller than PM2.5) becomes airborne during high winds, increasing the prevalence of respiratory and cardiovascular diseases, inhibiting immune response, and increasing hospital visits and healthcare costs.[11] Dust-related human health costs are unknown.

Saline lakes have no outlet, so water leaves only through evaporation. As the level and volume of Great Salt Lake decline, salinity increases, threatening the lake's ecosystem. Brine shrimp are a keystone species in the lake. They control phytoplankton by grazing and are a predominant food source for many birds.[12] Maximum survival of brine shrimp declines when salinity exceeds 125 g/L,[13] and Great Salt Lake is bisected by a railroad causeway (as shown in Figure 1), creating non-uniform salinity and lake elevation in the north and south arms. The north arm is generally too saline to support brine shrimp.[14] The lake and its wetlands are a critical link in the Pacific Flyway, supporting approximately 4 to 6 million resident and migratory birds per year, comprising over 250 species.

While saline lakes are sensitive to climate, and lake levels vary naturally in response to wet and dry years, there has been no significant long-term change in precipitation that feeds rivers that flow to Great Salt Lake. However, agricultural and municipal water needs have increased dramatically over the past 150 years, causing the lake's decline.[15]

Cache Valley Water Banking

Water for Great Salt Lake could probably be leased by the state from water banks during wet years, when there is little competition for water, and water prices would be relatively inexpensive. This analysis focuses on physical water and ignores water right priorities and storage changes in upstream Bear Lake.[16] Water banking

Table 1. **Water Banking Alternatives with Estimated Cache Valley Irrigation Demands**

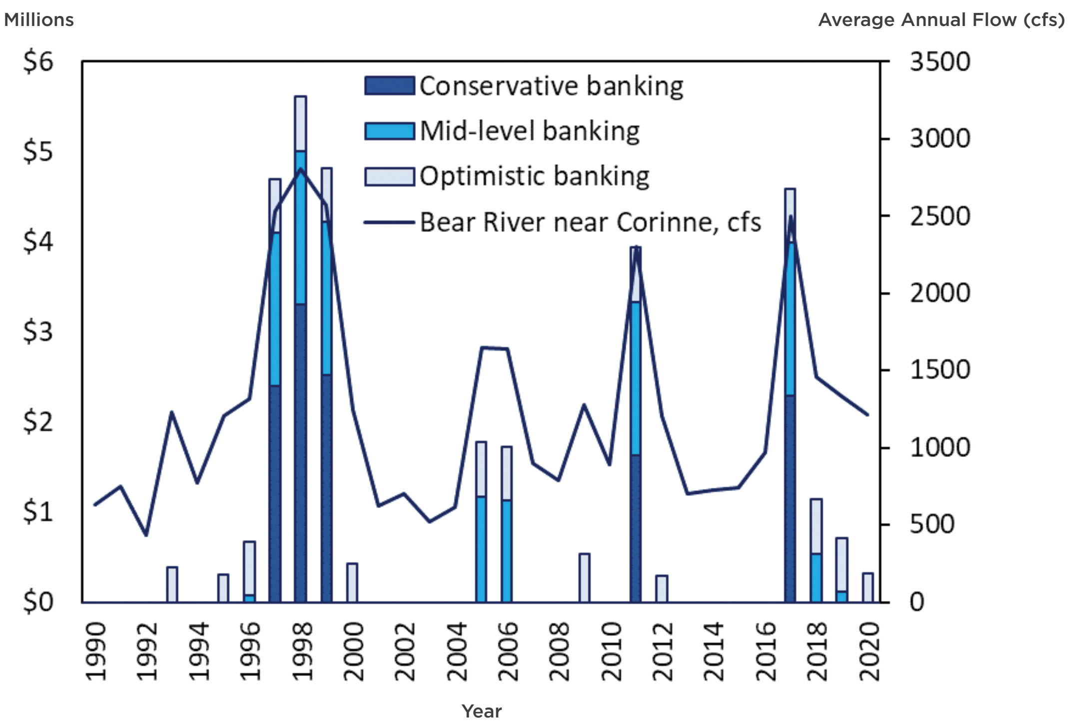
Water Banking Alternative	Irrigation Demand (AF per year)
Optimistic	185,000
Mid-level	215,000
Conservative	300,000

Source: J-U-B Engineers, "Cache County Water Master Plan," (2013).

could impair other water users or ecosystems, in which case water exchanges or other agreements would be needed. This analysis uses historical 1990-2020 data to estimate potential wet-year water leases to Great Salt Lake. A series of wet years occurred from 1987 through 1989, when water was pumped from Great Salt Lake to an adjoining basin to protect surrounding infrastructure. Water for Great Salt Lake would not have been leased during those years.

Three Cache Valley agricultural demand alternatives estimate wet-year water lease volumes to Great Salt Lake in excess of observed flows and represent the uncertainty to which irrigators would enter water banks. *Optimistic water banking* assumes that water in excess of 185,000 AF per year could have been leased for Great Salt Lake and added to observed streamflow to the lake, based off of average annual 2003-13 Cache County irrigation demand

Figure 2. **Annual Cost of Conservative, Mid-level, and Optimistic Water Banking**



Calculations are based on measured streamflow at USGS gage 10126000 (Bear River near Corinne).

Source: USGS and author's calculations.

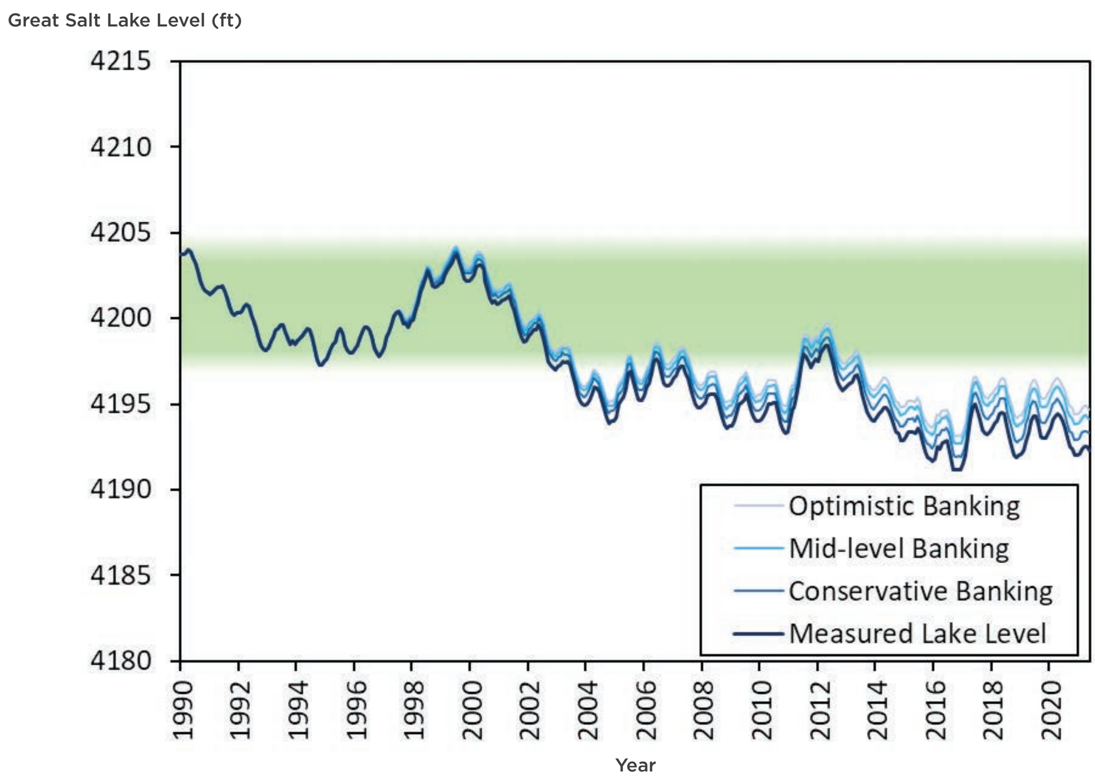
of 183,990 AF per year for 105,918 acres of irrigated cropland (see Table 1).[17] However, the Cache County Water Master Plan states that irrigators require an additional 30,000 AF per year of water for late season irrigation, so *Mid-level water banking* assumes water in excess of 215,000 AF per year could have been leased to Great Salt Lake.[18] The plan also states that ideally 300,000 AF per year of water would be supplied for Cache County agriculture, so flows in excess of that amount represent *Conservative water banking* leases to Great Salt Lake.[19]

In the 31-year time period used here, *Conservative water banking* would have occurred in five years, when Bear River streamflow through Cache Valley was 187 percent of normal or higher. *Mid-level water banking* would have occurred in 10 years, when streamflow was at least 107 percent of normal. *Optimistic water banking* would have occurred in 16 years, when streamflow was at least 97 percent of normal. Most wet-year water leases would have occurred in a handful of very wet years, including 1997-99, 2011, and 2017 (see Figure 2).

Great Salt Lake Water Banking Estimates

Prices are unavailable for Utah's nascent water banks. However, prices for Idaho's established agricultural water bank are $20/AF through 2022,[20] where 10 percent of fees support administrative costs and 90 percent compensate water right holders for the temporary use of water.[21] A uniform price of $20/AF was used here to estimate the cost of water leases to Great Salt Lake.[22] *Conservative water banking* would have cost $12.1 million

Figure 3. **Weighted Mean Elevation of Great Salt Lake**



Elevation measured at USGS gages 10010000 (Saltair Boat Harbor) and 10010100 (Near Saline, Utah), with estimates of Great Salt Lake level with Conservative, Mid-level, and Optimistic water banking in Cache Valley, Utah. The green band represents a healthy lake level range.

Source: Utah Department of Natural Resources Division of Forestry, Fire and State Lands, "Final Great Salt Lake Comprehensive Management Plan and Record of Decision," (2013).


Great Salt Lake, Utah ©Wayne Wurtsbaugh

and would have contributed 607,000 AF to Great Salt Lake. *Mid-level water banking* would have contributed 1,183,000 AF to Great Salt Lake at a cost of $23.7 million. *Optimistic water banking* would have contributed 1,597,000 AF to the lake and would have cost $31.9 million.

Great Salt Lake's water level was estimated using volume-stage relationships, with a weighted mean water level for the lake's north and south arms. The water volume from wet-year water leases was added to historical lake volume to estimate change in Great Salt Lake level from Cache Valley water banking. The ballpark estimates here do not account for increased evaporation, which is salinity dependent,[23] so results are upper-bound estimates of Great Salt Lake levels with water leases.

Had wet-year water leases for Great Salt Lake been practiced since 1990, *Conservative banking* would have raised Great Salt Lake water level by one foot and would have cost $12.1 million, *Mid-level banking* would have increased water level by 1.8 feet and would have cost $23.7 million, and *Optimistic banking* would have raised water level by 2.4 feet and would have cost $31.9 million.[24] Figure 3 shows the observed declining lake level (dark, bolded line) and estimated lake level with *Conservative*, *Mid-level*, and *Optimistic* water leases.

Healthy Great Salt Lake levels range from about 4,198 to 4,205 feet above sea level to best support economic, ecological, wildlife, and recreational benefits of the lake, and to prevent dust events.[25] Cache Valley water banking could have slowed lake level decline, but it would not have reversed it. A financing challenge for Great Salt Lake managers is that water leases would not occur uniformly in all years, rather, costs would be incurred in a handful of wet years (as shown in Figure 2).

Saline Lake Water Demands and Restoration Costs

Cache Valley water banking could have provided an average of 2.2 percent, 4.3 percent, or 5.8 percent more streamflow per year for *Conservative*, *Mid-level*, or *Optimistic* water banking, respectively. Previous research has recommended 20 percent,[26] 25 percent,[27] and 29 percent[28] more water to Great Salt Lake for a sustainable water level range most years. This implies that more widespread water banking would be required to sustain Great Salt Lake or that water banking could be one strategy among a portfolio of water management solutions for the lake.

Market-based environmental water allocation strategies have previously been shown to be cost-effective for Great Salt Lake. For instance, consistently providing Great Salt Lake with 20 percent more streamflow from cap-and-trade water cutbacks has been anticipated to cost $28 to $37 million based on more sophisticated cost curves than the uniform water banking costs estimated here.[29] Water conservation and cutback markets would not require water leasing costs but would likely involve more government oversight, monitoring, and enforcement.

Great Salt Lake's desiccation mirrors that of other saline lakes worldwide.[30] Saline lake restoration has used varied approaches including dust mitigation, litigation, environmental water purchases, water transfers, and diking.[31] In the United States, restoring saline lakes has been costly. Three examples from California are informative. To mitigate airborne dust for the dry bed of Owens Lake, Los Angeles Department of Water and Power anticipates spending $3.6 billion over 25 years.[32] The cost of replacement water for protecting Mono Lake public trust resources was estimated at $496 million in inflation-adjusted dollars over 20 years, until the lake reaches a target level. Increasing Mono Lake's water level has taken longer than 20 years, increasing costs. After the target level has been reached, replacement water costs might fall to about $6.4 million annually.[33] Salton Sea restoration is being legislated, and capital costs of restoration to increase streamflow, decrease salinity, and reduce airborne dust range from $631 million to $1.4 billion.[34]

To partially restore Walker Lake in Nevada, $76.7 million has been spent since 2009 to purchase water rights from willing sellers.[35] Restoration costs at these other saline lakes suggest that a proactive approach for increasing water deliveries to Great Salt Lake would be less costly than mitigation following environmental degradation.

Conclusion

More water is needed to sustain Great Salt Lake. The lake and most of Utah's freshwater ecosystems do not have dedicated water rights—although as of 2022, streams and lake beds are considered beneficial uses of water.[36] During droughts or periods of water scarcity, Great Salt Lake receives little water and bears substantial drought risk. Since Utah has been slow to dedicate and manage environmental water, water banking allows environmental interests to partner with water right holders for flexible water management within prior appropriation law.

Leasing water for Great Salt Lake through water banks is a cost-effective strategy to sustain the lake. Water banking could entail the state or another entity financing millions of dollars today to potentially save billions of dollars in future lake restoration, dust abatement, and human health costs. Water leases from Cache Valley water banking could be relatively cheap, costing approximately $12.1 to $31.9 million for 607,000 to 1,597,000 AF of water.[37] Restoration costs from other saline lakes illustrate the cost-effectiveness of water leasing to Great Salt Lake. Expanding water banks to regions outside of Cache Valley, and using a portfolio of environmental water management alternatives such as conservation, cutback markets, dedicating recycled water, or securing environmental water rights, could provide water to Great Salt Lake and play a role in sustainable management of an iconic lake.

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4 Delivering on the Promise of Water Quality Markets

Water quality markets can be a cost-effective way to reduce pollution

Zach Raff

In the United States, policies to control water pollution rely almost exclusively on regulating point source discharges of wastewater—effluent that polluters discharge to a surface waterbody through an identifiable source, such as a pipe. These regulations, part of the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act, have contributed to improvements in surface water quality in the United States since the 1970s.[1] However, the marginal costs of technological wastewater abatement at point sources, such as wastewater treatment plants, now often exceed the marginal benefits.[2] Expensive abatement technologies often deliver only negligible improvements to the concentrations of pollutants in effluent. Despite billions of dollars in investment to reduce the levels of pollution in point source discharges,[3] many surface waterbodies in the country remain impaired, meaning that they do not meet federal water quality standards. In many cases, impairments occur even though the point sources that discharge to these waterbodies comply with their individual NPDES permits.

Alternatively, nonpoint source water pollution, which consists of urban or agricultural runoff, is essentially ignored by the Clean Water Act and most state water pollution policies. These sources of water pollution are more difficult to identify, and the amount of their discharges to surface waterbodies are equally difficult to quantify. As a result, nonpoint source pollution has become the largest source of surface waterbody impairment in the United States.

The current challenge is to achieve greater marginal benefits of water pollution abatement at lower marginal costs from nonpoint sources. Altering the Clean Water Act to treat nonpoint source pollution like point source pollution (through discharge permits), however, would be difficult and politically challenging. But the Clean Water Act grants state environmental protection agencies the authority to establish water quality markets, where point and nonpoint sources can trade pollution offset credits to decrease overall water pollution in an area. In these markets, point sources avoid high marginal costs of water pollution abatement by paying other polluters to implement practices that reduce discharges elsewhere in a watershed.

Two types of trading can occur in such water quality markets. First, point sources can buy credits from other point sources that have lower marginal costs of pollution abatement; economists refer to this practice as water quality trading. Second, point sources can meet their NPDES-permitted discharge limits by paying upstream farmers to, for example, convert row crop agriculture to permanent vegetative cover. This practice, known as offset trading, can decrease a nonpoint source's loadings of pollutants to surface waterbodies by the same amount or more than if the point source decreased its discharges through technological abatement, but at a lower cost. In theory, water quality markets are more cost-effective than traditional command-and-control regulation, which often prescribes inflexible technological abatement strategies or allowable discharges, and produce the same or better water quality improvements.

As a result of the inherent benefits of water quality markets, the Environmental Protection Agency (EPA) and state environmental protection agencies, environmental nonprofits, and agricultural associations have encouraged their use for some time.[4] In 2019, the EPA produced a memorandum further encouraging the use of water quality markets, reiterating its "strong support for water quality trading and other market-based programs to maximize pollutant reduction efforts and improve water quality."[5]

Despite the promise of water quality markets and the broad support of their use, there are few programs where trades occur. Some programs, such as a water quality trading program in Pennsylvania, have successfully brokered trades. In most settings, however, substantial obstacles prevent success in water quality markets, resulting in business-as-usual command-and-control regulation. Several policy recommendations could help deliver on the promise of water quality markets.

Highlights

- **Policies to control water pollution from point sources, such as pipes discharging effluent into waterbodies, have contributed to improvements in U.S. surface water quality since the 1970s. The ongoing improvement of processes to remove contaminants from point sources means that today the costs of further reductions are high relative to other approaches.**
- **Nonpoint source water pollution, which consists of urban or agricultural runoff, is essentially ignored by most water pollution policies and has become the largest source of surface waterbody impairment in the country.**
- **Water quality markets allow point sources to avoid high marginal costs of abatement by paying other polluters to implement practices that reduce discharges elsewhere in a watershed.**
- **Despite the promise of water quality markets and the broad support of their use, there are few programs where trades occur. Several policy recommendations could help deliver on the promise of these markets.**

Recommendations

- **Document and categorize nonpoint source pollution.**
- **Expand the geographic scope of offset trading programs.**
- **Promote group compliance.**
- **Better incentivize market participants.**
- **Establish a third-party clearinghouse to facilitate offset trades.**

How Do Water Quality Markets Work?

Water quality markets, and pollution control markets in general, take one of two forms. The first is cap-and-trade, which economists consider the textbook pollution "trading" market. Under a cap-and-trade program, a central entity, such as the EPA or a state environmental protection agency, sets a "cap" on the total amount of wastewater discharge allowed in an identified market.[6] The regulator provides each pollution source within the market with an initial amount of discharge credits, or allowances. The regulated source can then take one of three actions: 1) discharge the allowed amount of the pollutant in question, 2) discharge below the allowed amount and sell remaining allowances on the market, or 3) discharge above the allowed amount and buy allowances on the market to make up the gap between actual and allowed discharges. A source's decision depends on the initial discharge allowance, the permit price, and marginal abatement costs.

Consider the example of an allowance buyer. The source's marginal costs to abate discharges to the level of their initial allowance are higher than the market price of discharge allowances, so the source can minimize costs by discharging more than their initially allowed amount and purchasing allowances to compensate for the difference. The most visible cap-and-trade programs in the United States control air pollution. One largely successful example, the EPA's Acid Rain Program, set a cap on the amount of sulfur dioxide emitted by electric utilities in the 1990s and 2000s, primarily in the Northeast. As part of the program, the EPA allowed electric utilities to buy and sell allowances with other electric utilities regulated under the program. For water pollution, however, no true cap-and-trade markets exist.

A second type of water quality market consists of offset trading in which pollution sources purchase "offsets" from other sources of the same pollutant, which reduce their discharges by at least the amount of the offset if not more. Like with cap-and-trade, a regulatory body is necessary to establish offset trading markets. As part of the Clean Water Act, individual NPDES permits require that point sources control their wastewater discharges, primarily through technological means. However, the Clean Water Act allows states to establish programs where point sources can comply with their individual NPDES permits through offset purchases. Buyers of offsets in these markets are sources with high amounts of discharges who wish to compensate for their excess pollution, while sellers of the offsets are sources that can sufficiently decrease their discharges to compensate for those of the buyers. After offset trading occurs, the resulting net discharge total is the same as if the buyer of the offset decreased discharges by the level of the offset and the seller of the offset did nothing. Importantly, the costs of the offsets are lower than the marginal costs of water pollution abatement for the buyers. Unlike cap-and-trade markets, several water quality offset trading programs exist in practice, such as those in Idaho and Wisconsin, although the number of offset trades in these programs remains low.

Differences Between Types of Water Quality Markets

Although policymakers frequently conflate the two, the differences between cap-and-trade and offset trading markets are consequential. First, cap-and-trade markets have an authoritative discharge cap. This cap represents the stringency of the program; the lower the cap, the more stringent the program. With offset trading, however, the overall stringency of the program is tied to individual pollution sources, rather than all market participants collectively. Polluters buy offsets to meet NPDES-permitted discharge limits at the source themselves. Point sources can purchase offset credits from other regulated sources, but they typically purchase offsets from polluters that the program does not regulate—nonpoint sources. As a result, when regulators decrease allowable discharge limits at point sources, the point sources must purchase additional offsets, which further reduces water pollution in the area.

Second, the sources of water pollution that each type of market regulates differ. In a cap-and-trade market, the regulating agency decides which sources the program regulates as subject to the aggregate discharge cap. In this setting, the market participants—potential buyers and sellers—are well identified, which helps to promote trade. In offset trading markets, however, regulators identify only the sources with NPDES permits as potential participants. Trade with others relies on the regulated sources identifying partners, most often outside of the program. Regulators must then verify and approve these trades, which results in the program regulating the nonpoint sources. Under this structure, transaction costs are likely to be high.

Finally, the reason for the existence of a water quality market is important. In a cap-and-trade setting, the purpose of the program and discharge cap is to create a market with buyers and sellers. In offset trading markets, the lack of a centralized discharge cap and identified market participants instead places the burden of finding trading partners on the regulated sources. In this sense, the "market" itself is not the purpose of the program but a way to help individual point sources comply with command-and-control regulations. Typically, more stringent regulations on individual point sources spur them to participate in the market.

Impediments to Water Quality Markets

Various significant obstacles have impeded the implementation of water quality markets in the United States.

The Current Regulatory Environment of Water Pollution Control

The inherent right to pollute that current water pollution control policy gives to nonpoint sources is a key obstacle to water quality markets. Nonpoint sources are responsible for most water pollution and their control represents the most cost-effective opportunity for pollution reductions. The participation of nonpoint sources in water quality markets is therefore imperative for the success of such markets. In the current environment, however, point sources must actively seek out nonpoint source trading partners. And if trade does not occur, a nonpoint source is no worse off than under the status quo scenario. Point sources must therefore incentivize nonpoint sources to participate in water quality markets, which often means paying a premium for offsets above the cost of the abatement practice for the nonpoint source. Without a regulatory burden to control their discharges, including nonpoint sources in water quality markets has proven difficult.

The Localized Nature of Water Pollution and Water Quality Market Requirements

Unlike air pollutants, such as greenhouse gases, water pollutants typically pose a localized problem.[7] As a result, regulating agencies impose water pollution control policy at the watershed level; most water pollution offset trading programs require that point sources purchase offsets from other, upstream sources in the same watershed. These localized markets tend to be thin, with few participants. In many watersheds, there is only one point source—typically a publicly owned wastewater treatment plant—so point-source-to-point-source offset trading is impossible. Similarly, urban or other watersheds with no agricultural presence represent even thinner markets, because there are few sellers of offset credits. These water quality markets with few buyers and sellers are likely inefficient.

Measurement

The amount of nonpoint source pollution that land users abate through various practices depends on precipitation, soil type, land slope, distance to surface waterbodies, and other factors. As a result, it is difficult to credit a certain offset amount for a point source given some particular nonpoint source abatement practice. Current offset trading markets identify credit amounts using ex ante input-output modeling. Regardless, the models are not perfect, so these programs require more offsets than the point source needs to meet its discharge limits. These "trading ratios" of nonpoint source discharge decrease to credited amount can range from 1.2:1.0 to as much as 5:1. In practice, the measurement difficulties and the presence of trading ratios increase transaction costs for point sources and discourage trade.

Uncertainty

Regulators often design wastewater discharge limits to represent a discharge concentration of each pollutant given the presence of specific abatement technology. These "technology-based effluent limits" leave little uncertainty concerning the compliance status of a facility with the technology present; point sources that install the appropriate abatement technology can rather easily control their compliance status. Also, abatement technology lasts several decades, so an initial purchase guarantees abatement into the future. Although most offset trades contain language guaranteeing that the nonpoint source continues abating into the future, most do not cover several decades. As such, changes in the environment, such as row crop price increases, can end agreements, leaving point sources to find alternate trading partners or be left in noncompliance. Relatedly, there is uncertainty about the future of regulation. Point sources must renew their NPDES discharge permits every five years. The regulating agency can therefore update the source's discharge limit relatively frequently. It is possible, then, that point sources bank allowances or offset credits for the future, rather than trade them, which further contributes to the lack of trades in these markets.

Transaction Costs

There are several forms of transaction costs in water quality markets, all of which impede market development. First, water quality markets are typically thin and noncompetitive, due to the localized nature of where trades must occur. Second, search costs for potential trading partners in water quality markets are high. Because nonpoint sources are unregulated, point sources are responsible for identifying trading partners and the amount of offsets that sellers can provide. Finally, identifying the price of offsets is difficult. In offset trading markets, there is no market price of each offset. In practice, nonpoint sources that implement identical water pollution control practices can be paid very different amounts for the practices. Negotiating offset prices between the offset buyer and seller is a significant impediment to trade in water quality markets.

Recommendations

Several policy recommendations could improve and expand the use of water quality markets, allowing them to deliver on the promise they offer.

Document and categorize nonpoint source pollution.

For any water quality market to successfully reduce pollution, the program must include nonpoint sources. However, it remains difficult to identify potential market participants and measure offset credits available to trade. As a prelude to establishing these markets, state agencies and other interested groups should better document and measure nonpoint source pollution. This would include creating a catalog of nonpoint source discharge locations and studying and improving the accuracy of the input-output models that quantify nonpoint source pollution.

Expand the geographic scope of offset trading programs.

Increasing the number of buyers and sellers in water quality markets is important in improving their efficacy. In small geographic areas, such as watersheds, water quality markets tend to be thin. But it is possible that expanding the geographic scope of trading areas could create pollution "hotspots."[8] Therefore, this recommendation is feasible only in some instances, such as in areas where several contiguous watersheds are subject to total maximum daily loads, which mandate a maximum amount of discharges of a pollutant that causes impairment throughout the watershed, including from nonpoint sources. In the Chesapeake Bay area, for example, an offset trading program consists of total maximum daily loads for several watersheds that contribute to the bay's impairment, which increases the competitiveness of these markets.

Promote group compliance.

In the United States, water quality trades have occurred in markets with joint compliance. In most offset trading markets, individual point sources comply with their NPDES permits by purchasing offset credits from other sources in the same watershed. However, the individualized nature of permits requires a point source itself to search for offsets and to negotiate their price, usually with unregulated sources that must be offered an incentive to trade. With group compliance, whereby a collection of point sources has an aggregate discharge limit, many point sources have the same incentive to comply and the joint permit inherently identifies potential point-source-to-point-source trading partners. In practice, group compliance has helped lead to water quality trades in the Neuse River Basin in North Carolina and in the Minnesota River Basin.

Better incentivize market participants.

Because current water pollution control policy generally ignores nonpoint sources, they must be incentivized to participate in water quality markets. To promote trade, regulators that administer trading programs can therefore provide incentives for potential participants to enter the market. For example, a regulating agency can cover the cost of the offset premium required to entice a nonpoint source to implement a pollution abatement practice, thereby minimizing trading costs for a point source. Additionally, regulatory incentives can minimize the temporal uncertainty faced by offset buyers. As another example, NPDES permit issuers can honor previous offset purchases by point sources during their next permit term in case their offset trading partner backs out or fails to successfully implement an abatement practice.

Establish a third-party clearinghouse to facilitate offset trades.

Most impediments to the successful implementation of water quality markets in the United States center on high transaction costs. To minimize these costs and promote trade in offset markets, a public or private group could establish a third-party trading clearinghouse. This clearinghouse would be responsible for identifying trading partners, establishing offset prices, and calculating the discharge decreases that result from various nonpoint source abatement practices. Such a third-party clearinghouse could minimize transaction costs of offset trading markets that do not exist in cap-and-trade markets. Point sources that wish to purchase offsets could go through the clearinghouse, which identifies the locations and amounts of offsets available, rather than performing the search on their own. The clearinghouse could also identify prices for the offsets, through negotiation itself or by establishing some standard price for each particular practice. The clearinghouse could exist under the umbrella of a regulating agency, or it could be a part of a private organization. In Pennsylvania's offset trading program, for example, the private Red Barn Trading Company orchestrates trade between buyers and sellers. The company maintains a central repository of offset locations, amounts, and prices that does not exist in other programs.

Conclusion

Policymakers and other organizations have long promoted water quality markets as a tool to cost effectively reduce water pollution. There are significant impediments, however, to the successful use of these markets in the United States. By increasing their competitiveness and minimizing transaction costs, it is possible to overcome these impediments and deliver on the promise of water quality markets.

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5 The Futures Market for California Water

Challenges and policy recommendations

Ellen M. Bruno and Heidi Schweizer

The American West has always been plagued with oscillating periods of dry and wet years. As a result, water users naturally face a level of risk and uncertainty associated with their water supplies and costs. In December 2020, the CME Group launched the world's first futures market for water—the Nasdaq Veles California Water Index (NQH2O)—in an attempt to help buffer water price risk. The futures market is intended to provide a way for California water users to protect against fluctuations in the price of their water. The importance of this financial instrument is even greater in the face of climate change, which is predicted to bring more extreme and more variable weather.[1]

The academic literature on futures contracts has established that commercially successful contracts meet several criteria. The most obvious are that a futures contract must serve as a hedging tool and attract speculator participation. In the case of California water futures contracts, however, spot market design may impede the futures market from successfully hedging risk and attracting market participants. Three factors in particular could prevent the futures market from becoming a commercial success: a thin underlying spot market, a lack of sufficiently inclusive price information, and minimal storability. Several policy reforms could increase futures market liquidity and improve its chances for success.

Highlights

- **Water users naturally face a level of risk and uncertainty associated with their water supplies and costs. Futures contracts can allow them to hedge their risk by locking in a price today for water they will need in the future, eliminating uncertainty in the price.**
- **In the case of California water futures contracts, a thin underlying spot market, a lack of sufficiently inclusive price information, and minimal storability may impede the futures market from successfully hedging risk and attracting market participants.**
- **Several policy reforms could increase futures market liquidity and improve its chances for success.**

Recommendations

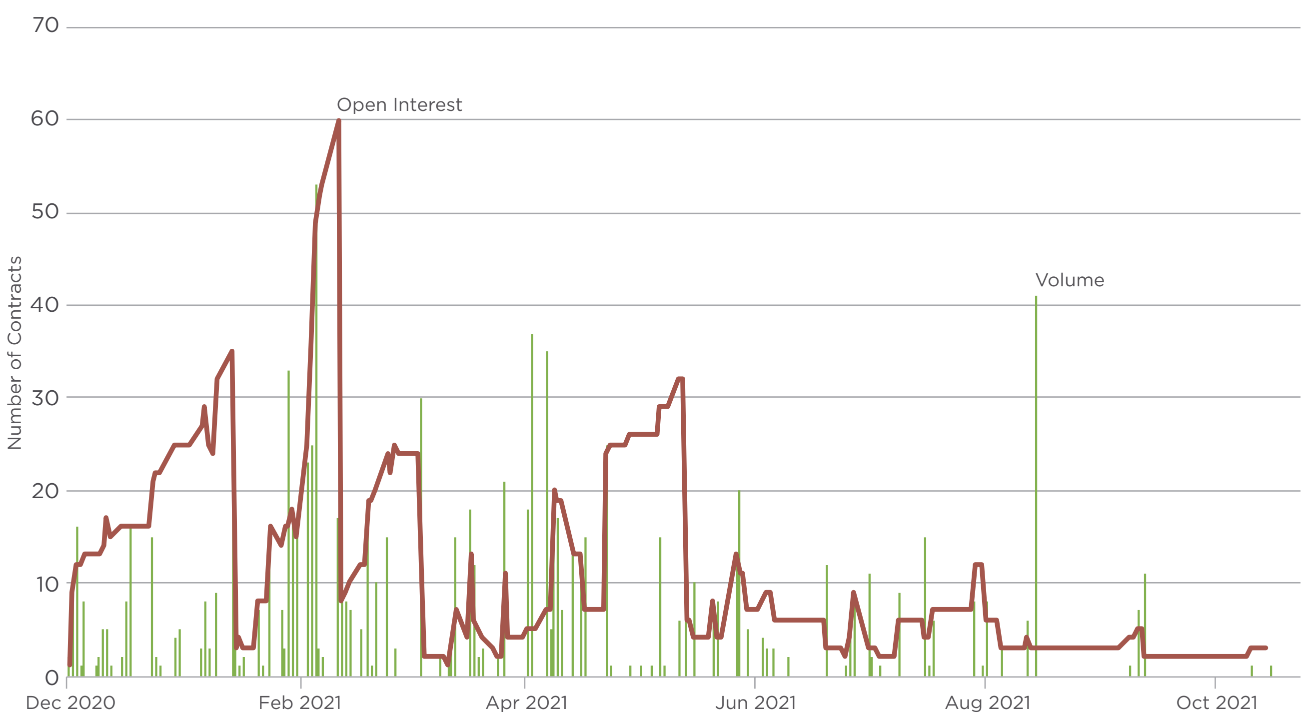
- **Increase liquidity with streamlined processes.**
- **Expand inclusiveness with better data.**
- **Improve storability through regulatory innovation.**

A Futures Contract for California Water

In a futures market, participants trade contracts that lock in the sale of a commodity on a specified future date at a price set today. In many cases, as is the case with the new contract for California water, modern futures contracts do not involve the exchange of a physical commodity. Instead, traders are credited or debited during final settlement based on the difference between the negotiated contract price and the value of the asset when the contract expires. In the water futures market, no exchange of physical water takes place, and the underlying legal rights to California water remain unaffected.

Traders of futures contracts can be classified as either hedgers or speculators. Hedgers are the participants that rely on the physical product, such as Californian farmers, while the speculators are anyone else. A successful futures contract needs both types of traders. Water users in California may use futures contracts to hedge their

Figure 1: **Nasdaq Veles California Water Index Futures Activity**



Trading activity in the Nasdaq Veles California Water Index from December 2020 to October 2021 showed that few water users were receiving any of the risk-hedging benefits of futures contracts. Volume and open interest, which indicate market liquidity and confidence, remained low, indicating that more liquidity is needed to make the futures market a viable tool for California water users to hedge price risk.

Note: Volume is the number of contracts bought and sold over a period of time. Open interest is the number of outstanding contracts being held at a given time.

Source: Bloomberg

risk by locking in a price today for water they will need in the future, eliminating uncertainty in the price. The participation of speculators accelerates trading and creates a robust environment that can easily allow hedgers to transfer risk.

Cash-settled contracts rely on an index for settlement that attempts to track the spot price.[2] The NQH2O index is a volume-weighted average of prices in the physical market for water traded in California's statewide surface water market and four local groundwater markets—Chino, Mojave, Central, and Main San Gabriel—adjusting for idiosyncrasies such as conveyance costs and other special pricing factors. The index includes both leases and sales.

A look at recent trading activity shows that few water users are receiving any of the risk-hedging benefits of water futures. Volume and open interest, which indicate market liquidity and confidence, are the two most common measures of futures market activity.[3] Average aggregate open interest during the month of August 2021 was five—representing just 50 acre-feet, a tiny fraction of the total market size. More liquidity is needed to make the futures market a viable tool for California water users seeking to manage water price risk.

Three Challenges to the Futures Market

Challenges for the California water futures market may stem from a thin underlying spot market, a lack of sufficiently inclusive price information, and minimal storability.

Thinness

The underlying spot market for water may not have enough trading to support an active futures market. When too few market participants trade in the spot market, it can cause high volatility, increasing risk for investors. Likewise, if a transaction, market participant, or location represents a large portion of activity relative to the total index volume, then there will also be a large influence on the NQH2O index used in final settlement of the futures contract.[4] The California surface water market is characterized by few transactions—representing just 5 percent of total water use in the state on average—and relatively few players. Among the four groundwater basins included in the NQH2O index, Mojave has the most active groundwater market, with trades representing 15 to 20 percent of annual pumping.

For a simple example of the effects of a thin spot market, consider when there are only two locations, Chino and Central, and no surface water transactions contributing to the index. If the majority of transactions occur in Chino one week, but in Central the next week, then the index will more closely reflect prices in Chino the first week and prices in Central the second week. If both locations have thin spot markets, this volatile pattern may regularly occur. Thin spot markets also create the potential for index manipulation near contract expiration. A hedger may choose to either expedite or postpone a spot market transaction during the week in which the index used for final settlement is generated. Even in the absence of manipulation, high volatility will dissuade potential participants who are risk averse. Therefore, even if the NQH2O index represents water scarcity *on average*, reluctance to trade the futures contract will persist.

Index-based cash settlement can also deter market participants because it makes trading more complex. When a contract is cash-settled to a volume-weighted index, speculators have to predict multiple prices, as well as their relative importance through time.[5] From the perspective of a speculator, thin spot markets mean less data and inconsistent data availability, increasing the difficulty of this process. Increasing the depth and activity in the spot market would reduce these challenges.

Inclusiveness

The cash-settlement index may not be representative of spot markets relevant to hedgers. Generally, larger underlying cash markets are associated with higher futures trading volumes.[6] Either the markets that feed data directly into the index must be large enough to support a futures market on their own, or they also must reflect price movements elsewhere. If the prices used to generate the NQH2O index are not representative of the market as a whole, or not representative of the market as a whole under certain conditions, hedgers will face increased basis risk.[7] This will reduce the hedging effectiveness of the futures contract and discourage participation among hedgers.

A hedge can only be perfectly executed when spot and futures prices are perfectly correlated. Hedgers face basis risk because both spot and futures prices change over time. For hedging to be effective, a hedger's local price must have sufficient co-movement with the prices included in the index.

However, because the NQH20 index is a volume-weighted average of surface water trades and groundwater trades in the four included basins, basis is likely non-zero for all hedgers, meaning that index prices are imperfectly correlated with local spot prices. Return to the example with only two contributors to the index. When the futures contract expires, basis at settlement for a hedger located in Central will only be zero if all trades occurred in Central, or if Central and Chino had the same spot prices. In order for basis at the time of cash settlement to be predictable, each location's contribution transactions must have stable relative volumes as well as stable price relationships. Basis variability is likely higher at lower levels of total spot market volumes and as volume variability increases.

The NQH20 index was constructed by Nasdaq using transaction data collected by the consulting firm WestWater Research. Although the index is calculated from the most comprehensive database of water trades in existence, the total market size is unknown. For example, it may be the case that informal trading occurs within irrigation districts that does not get captured in the index.[8] Additionally, none of the four groundwater basins that contribute transaction data to the index formulation are in the Central Valley, the main agricultural area in the state. While it is likely the case that the Central Valley and the four groundwater basins respond to similar supply and demand factors, it is unclear how stable these price and relative volume relationships may be.

If the spot markets used to produce the NQH20 index are not sufficiently related and widely representative of the prices hedgers face, futures contracts will be ineffective hedging tools. Hedgers will be discouraged from participating in futures markets if basis variability is too high because it increases the risk the hedger bears.[9] Adding transactions from new groundwater basins as their markets come online, in addition to increasing activity in the spot market, can stabilize basis.

Storability

Speculators may need more information about forward prices or expected inventories to be willing to participate in water futures markets. Since planting decisions can be made on long time horizons—on the order of several decades for some tree nuts—it would be most beneficial to farmers wanting to hedge to be able to lock in a price for distant dates. However, if information about the water supply is inaccurate for the distant future, or even the next year, then there may be limited willingness to trade for contracts that expire next year or the year after.

Suppose California's water supply came exclusively via rainfall. If this were the case, then the water futures contract would resemble a weather derivative. If information about water supply is inaccurate more than several weeks in advance, little can be established about expected supply for more distant dates. The dearth of accurate information adds additional challenges to an already complex process in establishing expectations of future spot market prices. Although there are no theoretical barriers, this seems to leave speculators without motivation to trade more distant contracts. Pure weather futures proliferated in the early and mid-2000s, but most were unsuccessful despite the academic support behind their introduction.[10]

However, many perishable and pseudo-storable commodities do have successful futures markets—examples are livestock, dairy, and electricity futures. In these cases, futures price determination depends heavily on the production processes. Importantly, the processes are generally known, and data about the inputs to production and intermediate goods are available. Often, significant portions of necessary inputs are storable. This gives hope that a lively water futures market may be possible if there is enough indication about future supply.

Luckily, in California the bulk of the surface water supply in a given year derives from the Sierra Nevada snowpack, which is then captured and stored in reservoirs for delivery throughout the state during the summer months. Most precipitation falls from December to March, several months in advance of the summer growing season. This allows expectations for water supply for that annual cycle to form in advance. However, this system of reservoir storage does nothing to establish expectations about water supply beyond the current year.

One way in which water can be stored across multiple years is through groundwater aquifers. California's Kern County features one of the West's most active and well-established water banks. Since 1995, imported water from the State Water Project, the Central Valley Project, and the Kern River has been banked via infiltration ponds to provide a reserve for the region's agricultural operations during droughts. The Kern Water Bank Authority, a joint powers authority that governs the bank, assumes a one-time 10 percent loss of banked water.[11] he remaining 90 percent is available for members to withdraw.

While the Kern Water Bank can store 1.5 million acre-feet of water underground, this is still small relative to the 34 million acre-feet used for irrigation in California in an average year. However, the potential to increase storage via groundwater is large. According to the Water Education Foundation, California's groundwater basins together have the potential to store about three times as much water as the state's reservoirs and lakes. With more groundwater banking being proposed under California's Sustainable Groundwater Management Act, it may be that enough water can be stored between years to provide participants with sufficient information about future-year inventories—and the water futures market could overcome the storability issue.

Recommendations

It is often the case that successful futures markets are underpinned by robust and active spot markets. California's water market is hindered by high transaction costs, including high search costs, regulatory hurdles, and delays in approval. Several policy reforms could improve the situation.

Increase liquidity with streamlined processes.

A recent report by the Public Policy Institute of California lays out a series of recommendations for improving water trading and banking in the state. Streamlining the review process for transfers and relaxing rules on where water can be delivered and used could increase liquidity while maintaining appropriate third-party protections.[12]

Expand inclusiveness with better data.

To address issues related to inclusiveness of the index, it will be important for the index to be updated with new transaction data as more groundwater markets come online. The Fox Canyon groundwater market in

Southern California began trading in 2020, and new markets are being proposed under California's Sustainable Groundwater Management Act. Additional transaction data will improve the index; this will reduce the risk of market manipulation and better represent agricultural hedgers as Central Valley districts begin trading. Basis risk will always be present due to the nature of a spatially constructed index, but basis may be more stable with a greater number of transactions and transactions that better represent where many hedgers are located.

Improve storability through regulatory innovation.

Storability—in other words, being able to put water in inventory—improves our ability to predict future inventories of water and enables water users to use the futures market to arbitrage across time. Would increased storability make the distribution of future prices tight enough that speculators would be willing to participate? This remains an unanswered question. But taking steps to improve storability will increase the likelihood of an active futures market. These may include improving local and regional conveyance, improving the State Water Board's approval process for authorizing recharge of unclaimed flood flows, and reducing administrative delays associated with trading and banking approvals.[13]

California has an opportunity to substantially increase water storability under the Sustainable Groundwater Management Act. Recently formed groundwater management agencies are incentivized to recharge winter flood flows into their basins and enhance flexibility for water users. Transparent groundwater banking can improve expectations of future water supply, increase speculator participation, and improve the chances that the California water futures market will help farmers hedge their price risk.

Conclusion

In theory, the Nasdaq Veles California Water Index can help water users in the state hedge risk. So far, issues with thinness, inclusivity, and storability have prevented the market from becoming a viable hedging tool for California farmers and other water users. We propose recommendations to increase liquidity of the underlying spot market, improve the representativeness of the index, and enhance storability. These changes could improve the likelihood that water futures can work for the states' water users, a need that will only become more important as climate change brings more unpredictable weather in the future.

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Endnotes

1 D.L. Swain et al., "Increasing Precipitation Volatility in Twenty-First-Century California," *Nature Climate Change* 8, no. 5 (2018): 427-33. X. Huang et al., "Future Precipitation Increase From Very High Resolution Ensemble Downscaling of Extreme Atmospheric River Storms in California," *Science Advances* 6, no. 29 (2020): eaba1323.

2 In contrast to a futures price, a spot price is the price for a trade that is executed and delivered immediately.

3 Volume is the number of contracts bought and sold over a period of time. Open interest is the number of outstanding contracts being held at a given time.

4 This issue can be mitigated through design features of the index. The NQH2O index is volume weighted with time lags to minimize volatility.

5 J. Białkowski and J. Koeman, "Does the Design of Spot Markets Matter for the Success of Futures Markets? Evidence From Dairy Futures," *Journal of Futures Markets* 38, no. 3 (2018): 373-89.

6 Huang et al., *Increasing Precipitation Volatility*.

7 The basis is the difference between a spot price and a futures price. Basis risk refers to the evolution of the difference between the spot price and the futures price over time.

8 This is not a concern if these transactions are small volumes that trade near the market price. As such, the index would still represent market value even without these trades powering the index.

9 D. Feuz et al., "Basis Variability on the Feeder Cattle Contract Versus the Failed Stocker Contract," Nebraska Beef Cattle Reports (2004) https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1188&context=animalscinbcr.

10 There has been success in over-the-counter markets where custom contracts are traded. The advantage of customization is that, in addition to price risk, weather-based volume risk can be addressed by specialized firms such as reinsurers. H. Till, "Why Haven't Weather Derivatives Been More Successful as Futures Contracts? A Case Study," *Journal of Governance and Regulation* 4, no. 4 (2015): 367-71.

11 This 10 percent accounts for evaporative losses and leaves some water available for purchase by neighboring districts for overdraft correction. This banked water can be sold to parties outside of Kern with an additional loss factor of 5 percent. M. Kiparsky et al., "Groundwater Recharge for a Regional Water Bank: Kern Water Bank, Kern County, California," *Case Studies in the Environment* 5, no. 1 (2021): 1223400.

12 A. Ayres et al., "Improving California's Water Market: How Water Trading and Banking Can Support Groundwater Management," Public Policy Institute of California (2021) https://www.ppic.org/publication/improving-californias-water-market/.

13 Ayres et al., *Improving California's Water Market*.

6 Engaging Irrigation Districts in Water Markets

Ideas to address modern water scarcity challenges

Andrew Ayres and Daniel Bigelow

Agriculture in the western United States is highly dependent on access to irrigation water, which is becoming increasingly scarce amid continued population growth and more frequent and longer droughts. Farmers in the West receive water delivered through various types of infrastructure networks, ranging from small-scale, single-user diversion ditches to enormous federal public works projects. While small-scale delivery canals may be maintained by individual users, larger infrastructure networks are typically managed by organizations known as irrigation districts.

The precise legal definition of an irrigation district varies across states, but they are generally considered to be quasi-public entities that have the ability to issue tax-exempt bonds, levy taxes and fees on the services they provide to member farmers and lands within the district, contract with the federal Bureau of Reclamation for water deliveries, and use eminent domain authority over service areas to ensure right-of-way for irrigation infrastructure. In addition, they can—and often do—hold the water rights supplying district members. Within an irrigation district, decision-making authority for water marketing often rests with an elected board made up of member farmers and, in some cases, other non-farm local water stakeholders.

The unique characteristics of irrigation districts allow them to overcome a number of barriers that limit the extent and success of other institutional forms that serve irrigation-dependent farmers, such as challenges in collecting payment, problems in monitoring withdrawals, and various other transaction costs.[1] For example, the eminent domain authority of irrigation districts can alleviate right-of-way hold ups that emerge when establishing a water delivery network that crosses the properties of multiple landowners. In addition, the coordination costs associated with getting interested landowners to jointly fund construction of a water delivery network, and maintain the infrastructure in later years, can be substantial without some sort of overarching organizing body. Water will pass by the farms of upstream landowners first, which gives these irrigators little incentive to maintain the delivery network for downstream farms. Irrigation districts overcome this free-rider problem by mandating compulsory water fees paid by all water users to cover the costs of canal maintenance.

Despite the innovation and creativity embodied in the original design of irrigation districts, the norms, rules, and laws governing their operations pose significant barriers to engaging districts and their members in voluntary water marketing efforts.[2] The general problem boils down to the fact that irrigation districts were not created under the assumption that the water they receive would ever be transferred to other entities outside of the districts. The advantages provided to districts throughout the early 20th century have now created new barriers and transaction costs to addressing modern water scarcity problems, including internal disputes about who should be able to sell water and who might be impacted.[3]

Although engaging irrigation districts in more water market activity is not straightforward, a number of policy and institutional rule changes have emerged over time that show incremental improvement along these lines. This essay discusses these incremental changes in the context of the barriers to enhanced irrigation district market participation and provides policy recommendations to foster further engagement.

Highlights

- **Agriculture in the West is highly dependent on access to increasingly scarce irrigation water, which is often delivered by collective organizations known as irrigation districts. Some unique characteristics of irrigation districts have allowed them to overcome barriers that limit other approaches for delivering water to farmers.**
- **Despite the innovation and ingenuity embodied in the original design of irrigation districts, many norms, rules, and laws governing their operations pose significant barriers to engaging districts and their members in voluntary water marketing efforts.**
- **Some approaches for moving water out of a district while addressing local concerns about hydrologic and economic conditions in the district and surrounding economy have been successful. Their expanded adoption could help to unlock more flexible water management strategies, a key tool as the West confronts continued population growth alongside more frequent and intense droughts.**

Irrigation District Water Ownership and Exclusion Rights

For water marketing to more meaningfully address water scarcity challenges in the West, engaging irrigation districts will be critical. Recently released data from the U.S. Department of Agriculture's 2019 Survey of Irrigation Organizations show that organizations of various types serve roughly 45 percent of the irrigated area in the West, delivering over 41 million acre-feet of the water used in agriculture. Irrigation districts make up 856 (34 percent) of the 2,543 irrigation organizations in operation, but they are responsible for water delivery to 63 percent of the 17.8 million acres of land served by surface water delivery organizations, or roughly one-third of the total irrigated area in the 17 western states. The average irrigation district in the West serves approximately 13,000 acres of land covering 166 individual farms.[4]

The overarching decision-making structure governing private water use within irrigation districts is a fundamental factor that prevents members from playing a bigger role in reallocating water through markets. In contrast to a system of purely private rights, rights within a district are held at least in part collectively. Moreover, district members not directly involved in a transaction can often effectively impede or veto it. This can exclude other members—potential traders—from exercising broader rights to the resource beyond use on their own properties, and it in practice keeps water local. The strength of these "exclusion rights" depends on the composition of irrigation district stakeholders, including the incentives faced by elected board members and the policies governing irrigation district and private actions.

Motivations to constrain trade include concerns about impacts to irrigation district finances, physical externalities imposed on non-trading district members, and local economic impacts felt by the broader community. The nature of district-level decision-making, including how irrigation district boards are elected, plays a role in these debates, alongside rules governing the use of water from the federal Bureau of Reclamation, which supplies water to some districts. In examining exclusion rights and how they are exercised, anecdotal evidence from several specific cases provides suggestive templates for how exclusionary barriers to greater district involvement in water trading may be overcome.

District Finances

Financing issues can play a role in the water marketing incentives faced by district boards, as district operations, maintenance, and amortization obligations are often funded through the fees and land assessments paid by farmers for the water they receive for irrigation. If an irrigator within a district chooses to sell their delivery entitlement outside of the district, they may thereby relinquish the obligation to pay for the water they would normally receive. This reduces the revenue accruing to the district, which may necessitate an increase in the charges levied on other non-transferring district members. Of course, this would fuel opposition to transfers by fellow district members.

Elected district managers may be reluctant to approve such transfers. Indeed, in California, many districts operate with strict rules governing transfer of water out of the district. Where district members are allowed to transfer water out of the district at all, sometimes it is only to their own outside lands.[5] In other cases, districts sometimes impose a strict hierarchy determining which external users may be eligible to receive transfers.

One potential solution is to ensure that fees and assessments normally owed to a district in exchange for water delivery are still paid in the event of a water transfer. Given the wide gaps between the marginal value of water in agriculture and urban uses, there is almost certain to be room to negotiate mutually beneficial exchanges, while not harming district finances in the process.[6] For example, in Colorado some recent trades from relatively low-value agricultural uses to urban areas have been priced at over $20,000 per acre-foot, far in excess of the water's value in agriculture.[7]

Some districts have experimented with fee systems that allow individual water users to transfer their allocations to other users outside the district only if the district members cover a substantial portion of the original service assessment. These transfer costs would typically be bid into the market price of water. Such a system gives farmers the flexibility to transfer while maintaining revenue and financial solvency for the district.

In other cases, districts may have a direct interest in capturing a portion of the gains from trade and decide to promote their own fixed-payment conservation programs to free up water for transfer. For example, Oakdale Irrigation District in California's Central Valley instituted a $400 per acre-foot payment to any farmer who made water available for sale during the most recent drought—and the district then transferred the water to willing buyers elsewhere. Such programs can cover necessary district costs for operations and maintenance with the difference between trading revenues and program participation payments; they also have the advantage of reducing transaction costs for small farmers, who otherwise may be unable to find willing buyers outside of the district and would likely face hurdles navigating the review process necessary to effectuate transfers.

Physical Impacts of Water Transfers

Concerns about the impact of transfers on return flows and local groundwater levels can also prompt opposition to water marketing efforts.[8] If water is transferred out of the basin where it originates, it reduces the return flow of water from irrigation (i.e., the water that seeps back into the stream), which can lead to opposition to trades by downstream district members. Additionally, reduced return flows may also reduce the availability of local groundwater used by local irrigators, especially during droughts when surface water deliveries are curtailed. In theory, these biophysical issues are easily overcome by allowing district members to trade only the amount of water that is actually consumed by their crops, leaving the level of return flow unchanged. However, the political pressure faced by district boards can incentivize them to act conservatively, overstating the risk of net water losses within the system resulting from trades, to appease non-trading members.

This issue loomed large in the Oakdale fallowing-based transfer system described above. Parties opposed to the transfer claimed that it would harm groundwater levels within the district and that a more comprehensive environmental review had been required under the California Environmental Quality Act. Following the transfer program's implementation, lawsuits were ultimately filed against board members who approved the program, and the issue has featured in attempts to recall at least one board member.

Local Economic Impacts

Beyond other individual district members who are not party to a trade, the broader local population often voices opposition to water transfers. At issue is how fallowing farmland to free up water for trading may impact local economic activity, including labor markets and firms upstream or downstream from farms engaged in trading.[9]

For example, if a nontrivial proportion of irrigated land within a district is fallowed for the purpose of freeing up water for transfer to non-agricultural consumers, it could reduce local demand for farm-related labor and other inputs, potentially reducing property and sales tax revenues. This constitutes a pecuniary externality, often termed a third-party effect. In many counties in California, concerns over third-party effects and groundwater overdraft (a physical impact) led to the adoption of groundwater export ordinances, which restrict farmers from trading their surface water to end users located outside of the county and then pumping local groundwater to meet their own usage needs.[10]

At the district level, one way to minimize third-party damages resulting from trades is to set a maximum threshold on the amount of land farmers are able to fallow. In the case of California's Palo Verde Irrigation District, farmers were allowed to fallow only between 7 and 29 percent of their land in a compact with two large urban water districts in Southern California.[11] In addition, financial compensation to third parties affected by trading may be necessary to pave the way for more trading and has proven to be effective in some of the cases discussed here.[12] Determining the appropriate level of remediation can be difficult, and offering compensation may invite unwarranted claims by parties not measurably impacted by trading. However, it may be in a district's best interest to share the gains from trading with local stakeholders if its trading activity would otherwise be subject to more burdensome local pushback and regulations, such as export restrictions that constrain a district's autonomy in how its water is used.

The conflict created by export ordinances has recently come to the surface in the context of California's Sustainable Groundwater Management Act (SGMA). Under SGMA, regulation of groundwater falls to local groundwater sustainability agencies, and county-level ordinances may inhibit levels of trading that remain consistent with agencies' newly adopted groundwater sustainability plans.

Irrigated alfalfa fields, Central California ©Ken Figlioli

Voting Practices and District Board Elections

When a member farmer within a district wishes to trade their water, the trade must typically be approved by an elected board of district supervisors. The voting rights of district members in electing boards and approving district operations can lead to an inefficiently low level of water transfers. Districts vary in terms of how votes are counted, with some using one vote per water user, some with votes weighted by irrigated acreage or the amount of water delivered, and others with voting privileges afforded to all individual citizens residing in the service area. If a single member wishes to participate in an external water market, they may be opposed by other members of the district, as well as members of the broader local community, who are concerned about potential adverse impacts from transfers out of the district. In the face of such opposition, district board members and managers concerned about their own job security may be reluctant to allow the creation of a system that supports out-of-district transfers, or they may act to block individual transfers.

District-level voting practices can influence water users' ability to initiate large-scale water transfers. In 2003, California's Imperial Irrigation District completed what is thought to be the largest agriculture-urban water transfer agreement in U.S. history. The transfer largely involved the sale of water from the district to San Diego County Water Authority, with a smaller quantity transferred to the Metropolitan Water District of Southern California, which supplies water to Los Angeles and other large urban areas. Imperial Irrigation District's five-member board is elected by all registered voters within its service area, regardless of whether they receive water from the district, making it responsive to a broad and diverse constituency. When the transfer agreement was first proposed, it was scuttled in a narrow 3-2 board vote, with opposition largely stemming from concerns over third-party effects resulting from fallowing land to free up water for transfer. The agreement eventually passed, but only following pressure from the Department of the Interior, the establishment of a fund to compensate local businesses and individuals harmed by the transfer, and the dedication of some of the transferred water to environmental mitigation.[13]

While the Imperial Irrigation District transfer was painstaking and fraught with controversy, one between the Palo Verde Irrigation District and the Metropolitan Water District of Southern California passed with relative ease.[14] Within the Palo Verde Irrigation District service area, voting is restricted to agricultural landowners, with votes weighted by the assessed value of their land. Farmers in the Palo Verde Irrigation District therefore have much more autonomy over what is done with their irrigation water rights, reducing the ability of non-trading parties to block potential transfers. Although both the Imperial and Palo Verde transfers involved third-party compensation funds, in the case of Palo Verde, the funds were established by the water purchaser preemptively as a token of goodwill, rather than as a way to appease reluctant board members in order for the deal to go through.[15]

Bureau of Reclamation Rules

Another important barrier to out-of-district trading concerns not districts themselves but their close relationships with one institutional supplier. As a result of legislation passed in 1926, districts became the sole direct recipient of water from the Bureau of Reclamation. The bureau remains a large supplier of water to irrigation organizations, supplying over 40 percent of all water deliveries according to the most recent Survey of Irrigation Organizations data.[16] While access to Reclamation project water secures water supplies for district members, the bureau's contracting rules can inhibit the transfer of water in a number of ways.

First, movement of water to locations outside Reclamation project area boundaries may be prohibitively challenging. This is due to the fact that project area boundaries are set in each project's enabling legislation. As such, the movement of water to locations outside of the original project area requires a new contract with the bureau, potentially requiring an act of Congress, which increases the transaction costs of such transfers. [17] The same also goes for the transfer of water for uses that fall outside the project's original scope of intent. For example, if a project was originally constructed for the sole purpose of providing water to agricultural users, new Reclamation contracts would be required to trade water to urban or municipal interests.

Second, the Bureau of Reclamation controls large storage reservoirs that it manages to meet the often competing water needs of the users within a given project. Different users, and different types of users, may hold contracts to water released at different points in the year. To ensure that contracted water deliveries are made, the bureau may in some cases impose reservoir refill obligations on customers who wish to trade their Reclamation contract entitlements. The refill obligations require transferors to replace the water removed from storage, which generally could entail foregoing receipt of their normal water entitlement in a subsequent year.[18]

Third, there is the matter of repayment obligations for the construction costs of project infrastructure. Bureau of Reclamation repayment plans typically involve zero interest and contract lengths of up to 40 years, but, for federal budgetary reasons, outstanding repayment obligations owed by a district can constrain the ability of members to trade their water.[19] As of 2012, 76 of the 130 (58 percent) irrigation-related Reclamation projects still had outstanding payment obligations.[20]

Discussion and Paths Forward

Despite their significance in the landscape of western water institutions, irrigation districts have played a complicated role in the transition toward greater use of water markets. The lack of engagement stems largely from the layers of exclusion rights that must be overcome by districts or individual district members potentially interested in trading their water rights or entitlements. These exclusion rights are an artifact of districts originally developing during a time when the transfer of water from agriculture to urban and industrial uses, or for environmental purposes, was inconceivable. While overcoming these institutional barriers will not be easy, it should be a key component of efforts to address western water scarcity through surface water reallocation.

Several options could promote greater irrigation district involvement in water marketing. First, non-trading district members will often balk at bearing increased costs for district maintenance due to the trading activity of fellow members. To address this challenge, assessing the normal water delivery fees on members who elect to trade their water allocation would alleviate concerns about the redistribution of district financing obligations to members who do not engage in trading. The significant arbitrage opportunities in transfers to non-agricultural users—with prices sometimes multiples of the returns to water use in agriculture—suggest that finding the funds to cover normal water delivery assessments should not be difficult.

Alternatively, in areas with relatively homogeneous crop choices, per acre land assessments that finance a district's physical infrastructure, as opposed to per acre-foot water charges, may encourage more trading. Although this would represent an additional encumbrance on the land, where value differentials suggest moving water is a valuable pursuit and the land has other productive uses (e.g., for development), such systems may lead to better water management outcomes. Some districts throughout the West have historically adopted such systems.

A second opportunity to engage district water users is to expand and embrace federal conservation programs. In many cases, these can help identify members who wish to participate in external transfers while providing a more direct path for covering district expenses. While not designed explicitly to facilitate water trading, federal conservation programs in particular have begun to address these challenges. A relatively unheralded update to the Environmental Quality Incentives Program (EQIP) passed under the 2018 Farm Bill allows the USDA's Natural Resources Conservation Service to provide group-level funding for qualifying irrigation districts that implement water conservation practices. The EQIP practices for which entities may receive funding cover a range of water conservation measures, including changes in water delivery scheduling, infrastructure alterations (e.g., ditch or canal lining), transitions to water-saving crops, deficit irrigation, and aquifer storage and recovery.

In essence, participation in the EQIP program would free up water that could be used for trading. While this type of federal initiative does not directly get around potential voting hold ups for individual water users who wish to conduct transfers, if a majority of members wish to engage in transactions, it provides a means for them to share in the gains from transfers. How the EQIP funding is split is something to be decided by district stakeholders, but it could be used as an incentive for reluctant water market participants, a source of compensation to ameliorate the concerns of district members unwilling to participate, or to offset foregone assessments. Where the district is in charge of marketing the saved water, revenues can cover foregone assessments directly.

Third, in many areas, interest is growing in artificially recharging aquifers to support long-term water table stability. New infrastructure is already being developed to introduce excess surface water (especially high-flood flows) into aquifers via recharge basins, flood irrigation, or other means. These managed aquifer recharge programs could open up a door for cost-effective options to alleviate the physical impacts of water transfers.

When a water user transfers water out of a district, often concerns about the impact on groundwater levels arise. However, with existing recharge infrastructure available, a user may be able to cost effectively trade their water entitlement during a dry year and acquire additional supplies equal to the lost return flow for additional recharge in wetter years. Where value differentials between dry and wet years are large, this could present an opportunity for arbitrage while leaving non-trading district members more or less whole. Under such a system, the transferring party would need to have a way to acquire additional flows for recharge and secure them for groundwater recharge under a valid water right.

Fourth, alongside managed aquifer recharge to support local groundwater tables, interest is also growing in groundwater banking to help address increasingly volatile swings in precipitation that create drier drys and wetter wets. Groundwater banking leverages available groundwater storage space by allowing users to store surface flows in aquifers for later extraction. But any given water district may not contain suitable locations for recharge and banking, so parties who wish to bank water sometimes need to physically move it out of the district. However, moving water for storage faces similar constraints to trading when district members fear it may not return to the district. This is increasingly likely as groundwater markets continue to emerge across the West, as they could allow parties storing water in underground banks to subsequently transfer that water and not bring it back to the district.[21]

In some cases, districts in California have allowed water to be transferred to such banks for storage, but only with a "return obligation," a requirement that the water (or an equivalent amount via exchange) be delivered back to the district. This represents an advance insofar as, previously, users may not have been able to move water from the district to the bank at all; however, it also complicates opportunities to store water from wet years for high-value use in dry years, since transferring water back to the district may be costly, face infrastructure capacity constraints, and clearly precludes the possibility of transfer to high-value uses directly from the bank.

Districts are not alone in requiring these "return obligations"—the Bureau of Reclamation does so as well for water delivered to lands that are part of the Central Valley Project in California. In the future, maximizing the value of water resources may involve coupling groundwater bank storage with transfers out of the bank to other, non-district parties. District policies in the future should consider relaxing these requirements, perhaps in tandem with the adoption of some of the solutions to financial impacts and other concerns described above.

Finally, policymakers should consider how to best resolve overlapping layers of water management jurisdiction, such as in the case of groundwater export ordinances and new rules under SGMA. In general, to the extent possible, management should be circumscribed by hydrological as opposed to political boundaries.

Conclusion

Irrigation districts are central and dominating institutions in water management throughout the West and are here to stay. Experimenting with new approaches to engage them in efficient and expeditious water marketing efforts must be part of a more comprehensive plan to address the water scarcity challenges that will sharpen in a continually changing climate.

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Postscript

High and Dry

Compensate rural communities to promote water markets

Gary D. Libecap

Unlike water, there is no shortage of dire warnings of climate change and threats to the amount, quality, location, and timing of freshwater availability. Temperatures are predicted to be higher, precipitation to be more variable across space and time, and severe drought to be more common. Water scarcity will increase. Competition among urban populations, agricultural producers, the energy sector, and environmental protection will intensify.

Despite all of this, the actual economic and social effects of increased water scarcity depend importantly upon the institutional response: centralized government regulation or water markets. The efficacy of each approach is very different. For most of the world, the decision already has been made. Freshwater is owned and managed by the state. In some parts, however, especially the semi-arid western United States, private water rights exist, and water markets are operating. If and how they expand to meet climate change depends upon political support and mitigating the negative effects of moving water. Agricultural communities that have historically used 60 to 80 percent of available water will almost certainly lose water, and they are up in arms.

The media highlights their concerns with the popular David-versus-Goliath narrative: Private buyers strip a region of its water, leave it "high and dry," ship the water elsewhere, and get rich. Local economies and the natural environment are devastated. Appeals are made to politicians and regulatory agency officials, as well as to advocacy groups that seek access to water via political mandates. These joint efforts block water market trades or so constrain them that their effectiveness is undermined. Addressing the concerns of rural communities directly can blunt political opposition, confront perceived equity and ecological effects, and advance water markets.

As a basis for comparison of outcomes, consider the two institutional options for responding to climate change and water availability. First, consider regulatory responses. Where tradable water rights do not exist, water is effectively a common pool resource by law. Government agencies determine how water is distributed across sectors and regions; mandate water conservation via restrictions on access, use, and timing; and make investments in infrastructure for water storage and allocation. The political and bureaucratic decisions are molded by constituent-group objectives, including those of agency staffs. Motivated by political agendas that may or may not overlap with overall welfare, politicians, bureaucrats, and administrative judges proceed without reliable information on relative values of water uses and conservation options across time and locations. Serious misallocation can result. The process is crisis-driven, which assists lobby-group mobilization; responses are lumpy and not flexible. Once water policies are implemented, groups have a stake in maintaining them, even if they do not advance overall welfare. Inefficiencies create their own constituencies. In light of new climatic conditions and shifts in water scarcity and values, regulatory responses take place within the established framework. There is no obvious mechanism for flexible, smooth reactions as circumstances change.

Given the recent experience with Covid regulations, it is easy to predict that some forms of agriculture, industrial production, urban use, and environmental protection will be deemed “essential” and get water access, whereas other allocations will be constrained. Regulation of demand entails mandated water conservation via greywater recycling, installation of low-flush toilets, limitations on landscape irrigation and other related “discretionary, but not essential” water uses. Mandates will determine agricultural crops and irrigation practices. In light of evasion incentives, compliance requires observation and monitoring of the use of so basic a commodity as water. These actions may or may not impact overall water consumption or pass any conventional cost-benefit analysis. In urban areas, the price of housing rises and water access is constrained, especially by the poor who consume a greater share of their incomes than do the rich. In rural areas, the value of agricultural output and employment fall.

Second, consider water markets. Despite common perceptions, water markets provide a more socially favorable outcome. Where freshwater is privately owned and tradable, it can be reallocated incrementally from lower-to higher-valued uses as new scarcity information emerges. The trading process generates additional information as users learn about options for water in competing settings and times. This information is an incredibly valuable public good. It encourages incremental adjustments in consumption, investment, and distribution. In light of the uncertainty associated with climate change and water, modifications can be made as additional evidence appears, raising both private and social returns. The market process both generates and responds to water-climate information. A crisis is not needed, and indeed can be avoided.

Untapped Markets

The western United States is fortunate to have the alternative of private water rights and markets, but they are controversial and often take a back seat to government actions. Why is that?

One reason is philosophical. Water is viewed by many as inherently a public (common-pool) resource so vital that it cannot be owned privately. This view is prevalent in much of the world, where water is already a state asset with incumbent regulators and aligned constituencies. For example, Pedro Arrojo-Agudo of the U.N. Human Rights Commission asserted in 2020 that “Water belongs to everyone and is a public good.” He claimed that it is too essential to be delegated to private parties and markets. Unfortunately, the opposite is more apt to be the case.

The rejection of water market trades as a means of addressing growing shortfalls between freshwater supply and demand leaves no clear mechanism for adjustment. Moreover, there are no general comparisons of the outcomes of regulatory responses versus water markets. There is scattered evidence that political objectives and related subsidies in agriculture undermine efforts to address water shortages and drawdown of aquifers during drought. Consider India, for example, with its huge rural agricultural population and declining groundwater for pumping. With competing constituencies, small and large farmers, and the different government agencies that support them, the complex policies ultimately adopted through the political-regulatory process encourage continued cultivation of water-intensive crops.[1]

A related reason for opposition is that water markets require tradable rights, and many object to such rights. In the western United States, new water claimants dismiss existing prior appropriation allocations as historic anomalies that are out of step with broader new demands. Instead of buying the rights and repositioning the water, well-organized groups turn to the political process to advance their demands. Politicians and members of regulatory agencies often are sympathetic, implementing new water agendas via mandated controls and distributions without paying for them or considering the longer-term efficiency losses.

A third reason is fear among rural communities that their way of life and economic activities are at risk with water trades. Seeking to maintain the status quo, community members turn to the state for protection. They may or may not be successful in their efforts because some water ultimately will move as climate change unfolds and urban constituencies demand more water. The political reaction, however, certainly will undermine markets and the public goods they provide.

Among the three sources of opposition to water markets, addressing community concerns is the most likely way of building broader support. But how might communities be mobilized to support and participate in water markets? What are the key issues to be addressed? Physical effects of trading seem unlikely to be major impediments to water market expansion. Any associated loss of water by non-trading rights holders or physical damage to the ecosystem can be handled effectively locally. Most rights holders are part of irrigation districts with existing rules regarding water use and exchange. Water often is traded short-term, informally among district members within this framework. Rules can be adjusted, such as no-harm to junior rights holders or downstream diversions or requirements that trades be limited to consumed water in order to limit the impact on return flows. Third-party effects, such as dust pollution or weed proliferation from fallowing also seemingly can be addressed within irrigation districts, water conservation districts, or by state agencies or courts. These effects are observable and measurable, and damages can be assessed to contributing parties.

The monetary effects of water trades, however, are more difficult. As water is moved and production patterns shift, labor and equipment requirements change. Some skills and machinery and its repair are no longer needed. Some workers may not easily move to new local production, and others may lose their jobs. Population levels may fall, pulling down housing values, commercial activity, local tax revenues, and school enrollments. Some of these patterns are part of longer-term declines in rural versus urban populations, but they are difficult to separate from clearly observable water market transactions. Those who sell water rights benefit, as do outside investors, who are portrayed as unconcerned about local conditions and equities. Politicians and the media react. Market participants are conveniently demonized, rather than focusing on the water problem and climate change.

One solution is to broaden the benefits of water transactions via local mitigation funds. The evidence suggests that there are sufficient gains from moving water from low- to high-valued uses to support such efforts. Doing so not only addresses equity concerns but also dampens political efforts to limit water markets and the public goods they provide.

To get a sense of the magnitudes involved, consider the values generated from moving water from the West Slope in Colorado to the East to address growing demands in Denver and related communities. The data indicate major benefits. Water from the Colorado-Big Thompson (CBT) Project can be traded routinely. In 2019, water prices reported by the Northern Colorado Conservancy District, which administers the CBT, were approximately $55,000 per acre-foot (AF). On the more fragmented West Slope, representative prices are more limited, and the costs of moving water 150 miles across the continental divide are high. Even so, some transactions indicate water prices of approximately $2,500 per AF.[2] Other estimates are that water generates $132,300 per AF in economic value on the East Slope, compared to $7,200 per AF on the West Slope, a difference of 18 times.[3] Although non-traded values may be excluded in market prices, they would have to be extremely high to offset the observed price difference.

There clearly are enough monetary gains to contribute to a mitigation fund. One vehicle is a local ad valorem tax. Thirty-four states have severance or related taxes, and 12 allow for local taxes. Because water markets are local, county-level taxes on the net value added of water moved would be a clear option. Rates for oil and gas range from 0.5 to 9 percent, depending on a variety of factors. Moreover, the tax rate could be adjusted as volumes increased to lessen negative impacts on recharge and local aquifers and ecosystems. The objective would be to generate funds for offsetting pecuniary and technological effects without inhibiting water market transactions. Temporary funding could be provided for retraining of labor disrupted by agricultural production shifts, for adjusting local businesses impacted by population movements, and for community searches for alternative new productive options in recreation or tourism.

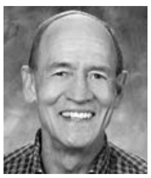
There are obviously potential concerns with such an approach. The design of the mitigation fund, timing, who is eligible, evidence, and categories for eligibility must be clear to avoid costly disputes and waste. There are differential experiences from community funds established for the Imperial and Palo Verde Irrigation Districts in Southern California that provide useful information for design.[4] The relevant comparison, however, is not with an idealized, unregulated water market, but rather a taxed water market, where rates are not so high as to choke off incentives for exchange. The objectives are 1) to avoid harmful intervention by states to restrict trading, such as limiting approved trades to some "reasonable" criteria or to hold them to an "anti-speculation" requirement, and 2) to share the value of the public good of water markets more broadly with local communities.

There are useful precedents in U.S. fisheries. Fisheries, like water, have been asserted to be public resources and, hence, not appropriate for private ownership. The record of government regulation under this imperative in preserving stocks and in supporting the economic welfare of fishing communities has not been positive. By the 1990s, in some fisheries, traditional harvest controls were replaced by establishing total annual allowable catches and distributing shares as individual fishing quotas (IFQs). The motivation was to have an individual property right that would change private incentives regarding fishing pressure and stock depletion, to reduce the number of vessels and fishers involved, and to allow for economically valuable reorganization. But as with water, there were concerns that small fishing communities would lose out to larger, more moneyed interests in the competition to buy and consolidate IFQs, leaving them "high and dry."

The political reaction led to constraints on the trade in IFQs via limits on the share of quota held by any single party and requiring that exchanges occur only to small vessel owners. While seemingly addressing equity concerns, the restrictions undermined the advantages of quota markets and the value generated in trading fishing quotas. Small communities appear not to have been helped. Economists Sara Sutherland and Eric Edwards find that populations still fell by 6 to 13 percent, that sales tax revenues declined by up to 20 percent, and that transfer restrictions lowered the value of rights up to 25 percent.[5] IFQs were and remain a major source of wealth in otherwise poor areas. Overall, the movement toward larger vessels and ports continued, but not as smoothly nor as efficiently as would have been the case with more vibrant fishing quota markets. Unfortunately, as noted earlier, major U.S. legislative revisions are unlikely, as influential constituencies continue to benefit and oppose a more active quota market. The objective is to avoid this outcome in water, where the losses can be even more extreme.

Conclusion

The United States is fortunate to have private water rights and potential for expanded water markets to address climate change. This opportunity is not predetermined, however. Political and bureaucratic imperatives and agendas of aligned groups to limit markets and to advance state regulation is a real challenge. Markets offer so much more in a broad social sense, but the actions of well-defined interests, including regulatory agencies themselves, can limit the potential gains. Because most of the water in the American West is used by agricultural communities, enlisting their support and allowing local populations to directly share in the benefits of water transactions is critical to advancing the future of water markets and the public goods they provide.



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Endnotes

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In recent decades, the idea of using markets to allocate water has gained traction in the United States. Water markets are now being harnessed in a variety of contexts, including markets for traditional surface water rights, instream flows, groundwater, water quality, stream mitigation banking, and even financial derivatives.

Are water markets living up to their promise? And what are the ongoing and future challenges that water markets can address through innovations in property rights, regulation, and market design? With several decades of experience now available, these and other related questions can be addressed.

The essays in this report address timely water topics and provide policy recommendations to enhance the future of water markets. Together, they explore how markets can continue to be harnessed to allow competing water users to cooperate rather than fight over scarce water resources, encourage conservation, and alleviate the economic and environmental effects of water scarcity now and in the future. Featuring essays by **Andrew Ayres, Christina Babbitt, Daniel Bigelow, Ellen M. Bruno, Gary D. Libecap, Sarah E. Null, Zach Raff, Leslie Sanchez, Heidi Schweizer,** and **Arthur R. Wardle**.

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