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Improving California's Water Market

How Water Trading and Banking Can Support Groundwater Management

Technical Appendix C. Mojave Groundwater Market Assessment

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Introduction

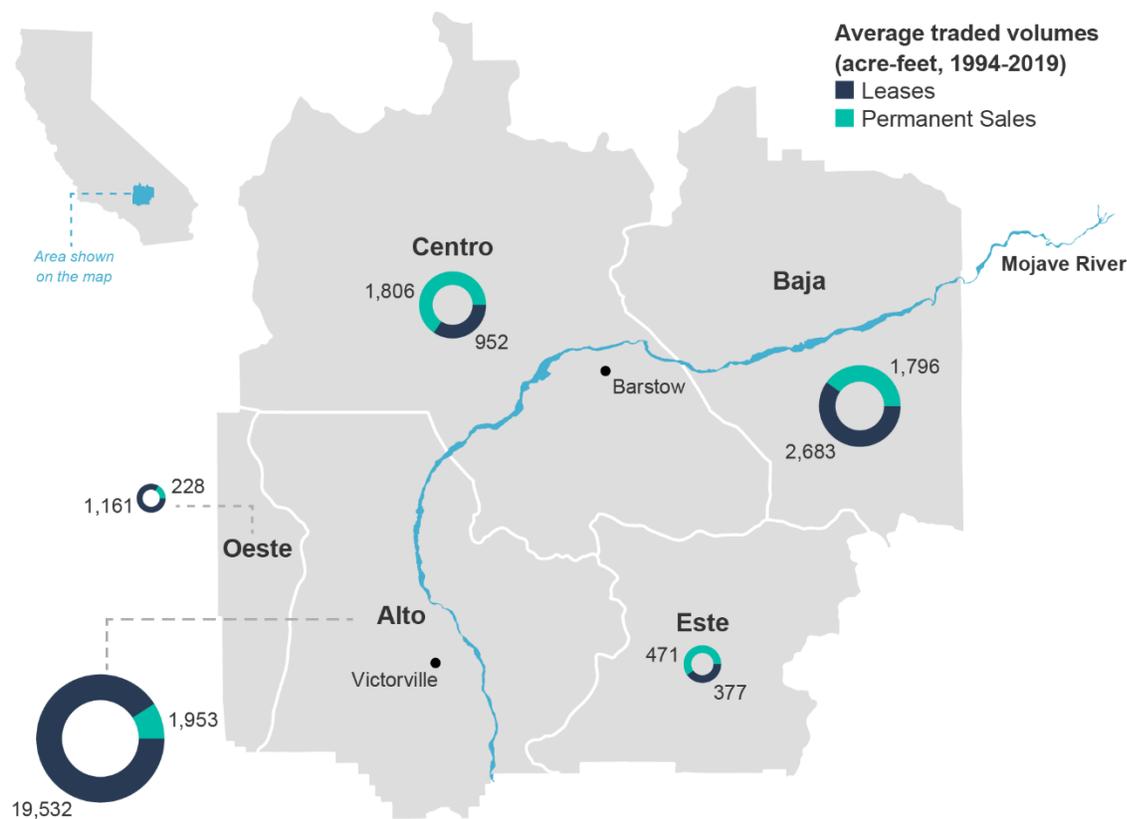
This appendix documents trading activity in the Mojave groundwater market and investigates how the market has provided a platform to resolve shared water management challenges. In the 1990s, water users in the western Mojave Desert undertook a court adjudication process that would redefine groundwater rights and create a market to trade those rights. Today, the Mojave's is one of the most liquid groundwater markets in California. This market provides real value to water users: a recent analysis suggests that over \$400 million in economic gains have resulted from the adjudication (Ayres et al., 2021).

Background

Figure C1 presents the adjudicated area of the Mojave, delineates the subareas that make up distinct groundwater markets, and provides measures of average trading volumes. Aside from agricultural and other undeveloped lands, this area includes the cities of Victorville, Hesperia, and Barstow. The Mojave River drains the north side of the San Bernardino Mountains and represents a major source of native groundwater recharge. Imports from the State Water Project have also recharged the basin since 1990.

FIGURE C1

The Mojave's subareas have lease and sale markets with varying levels of activity



SOURCE: Author calculations using data from Mojave Watermaster. Boundary designations from watermaster.

NOTE: The Mojave adjudicated area in gray, with its subareas outlined. Circles are sized by 2014-15 production, and report annual averages for water leased (blue; FPA) and sold (green; BAP) in acre-feet per year. Data from water years 1994-95 to 2018-19.

The Mojave groundwater market is not truly one market, but instead a collection of several. Certain regions, or subareas, in the adjudicated zone exhibit greater hydrologic connection within themselves than they do with other areas. A trade that moves pumping rights from one area into another would result in an increase in total pumping—and consumptive use—in the receiving subarea that could set it out of long-term hydrologic balance. Such transfers are prohibited outside of exceptional cases requiring watermaster approval, so five separate markets have emerged.

Each year, hundreds of trades take place—mostly one-time annual leases of production allowance, but also permanent transfers of rights to pump year after year. Groundwater pumping rights were defined volumetrically and allocated based on pumping during the five-year period immediately prior to adjudication (1986-1990); they are commonly referred to as Base Annual Production rights (BAP). Each year, each acre-foot of BAP generates Free Production Allowance (FPA), which entitles a holder of FPA to pump a specified amount of water. Where a pumper exceeds his or her allocation in any given year, the difference must be offset: options include leasing FPA from other users, purchasing replenishment water (imported via the SWP) from the watermaster, and using carryover FPA from previous years.

Several features of the Mojave groundwater market warrant description. First, carryover of FPA is allowed—but only for one year. A unit of FPA that goes unused in the year it is generated may be carried over to the next year; however, it can no longer be used for pumping in the year after that. (Other adjudicated basins adopt similar limitations to avoid concentrated pumping impacts in any given year.) The ability to carry over aids water users in managing variable demands, and carried-over FPA may be transferred in the same manner as current-year FPA.

Second, because the adjudication allocated rights according to the pre-adjudication pumping regime, and the basin was in a state of overdraft at the time, in order to move total extraction in each subarea toward safe yield—and ultimately bring the subareas into balance—the FPA return on BAP has declined over time. Allocations of FPA began at 100 percent of BAP and were planned to ramp down to 80 percent over the first five years, with the watermaster assessing evidence of continued overdraft to recommend additional ramp-down in years thereafter. Some subareas have seen additional ramp-down; for example, in Baja, the 2020-21 FPA yield was 25 percent. In the interim, some “transitional pumping” has occurred, generating additional drawdown. Many users are contemplating similar approaches under SGMA. In Mojave, rights to pump this transitional water have been tradable, which has helped to simplify administration, allocate the transitional water efficiently, and expand the set of assets pumpers can flexibly monetize.

Finally, inter-subarea trading, despite being prohibited in most cases, is regularly allowed for one purpose. When insufficient water flows from the Alto subarea to the Centro subarea, pumpers in Alto incur a make-up obligation. This can be met either by paying the watermaster for imported water or by purchasing FPA from Centro pumpers. The final section of this appendix evaluates the benefits of resolving this management issue using markets.

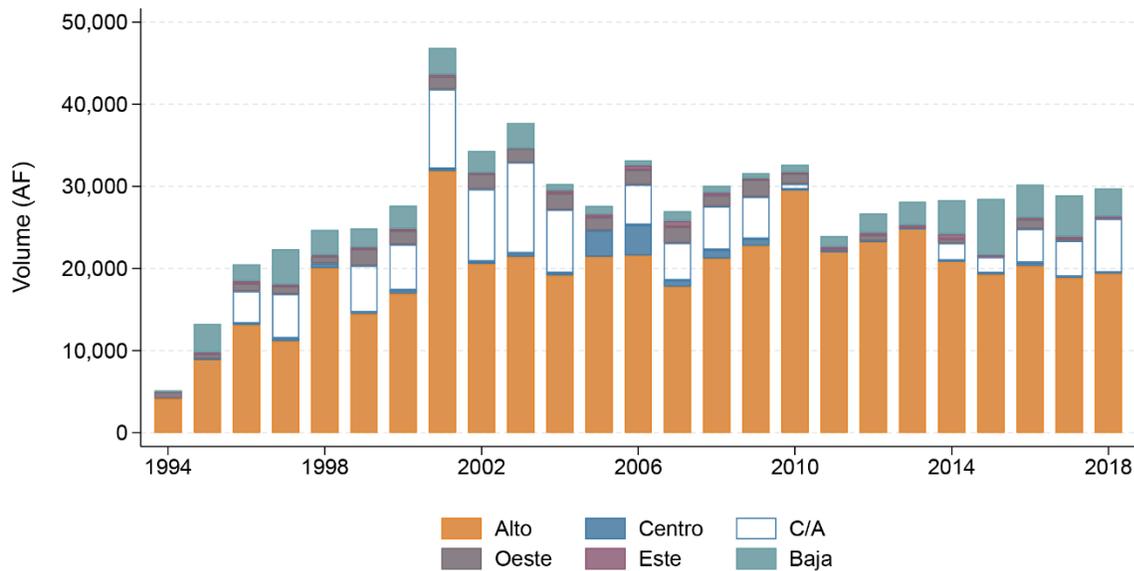
Market Activity

Figures C2 and C3 jointly capture the dynamics of the Mojave’s various water markets. Trading in the Alto subarea makes up the lion’s share of market activity, and it sees the highest prices for water. The Baja subarea in the northeastern area of the Mojave sees the second-highest trading volume. Trading

activity in the Este subarea is low, as there are few pumpers and water needs on the spot market are rare, in part because there has been limited ramp-down and in part because water uses tend to be similar. In years when Alto pumpers must resolve a make-up obligation to Centro pumpers, these transactions represent a substantial amount of total trading (and easily exceed intra-Centro trading). With the exception of the market’s very early years, trading of FPA has reliably exceeded 20,000 acre-feet per year, which equals 15-20 percent of average annual pumping.

FIGURE C2

Volume transacted on spot market has exceeded 20,000 acre-feet since the 1990s



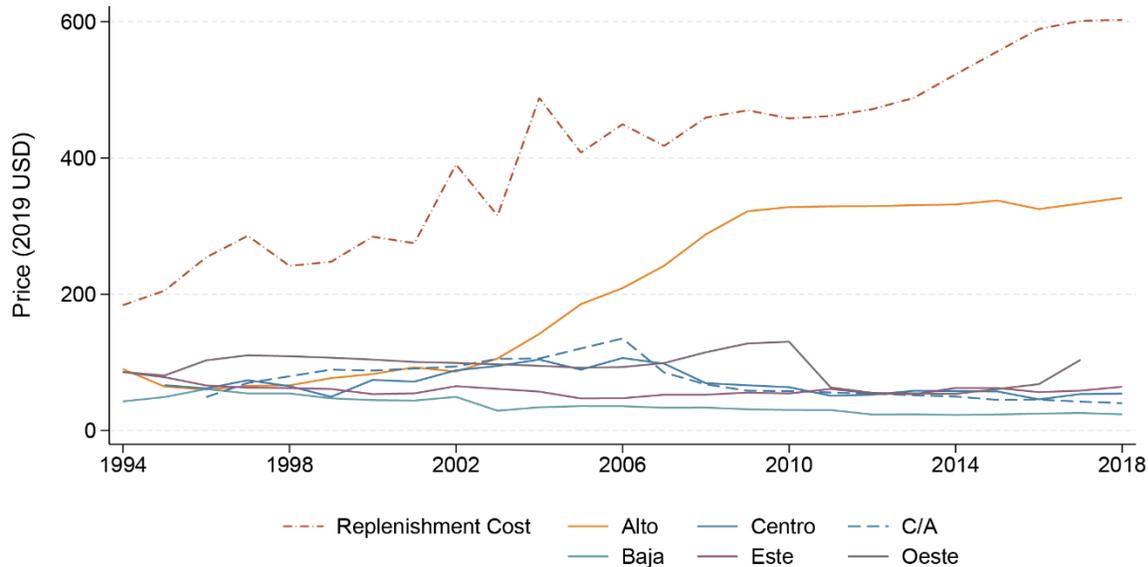
SOURCE: Author calculations using data from Mojave Watermaster.

NOTE: Lease volumes across Mojave’s five subareas. Both current-year FPA and carryover allowances included in calculation. “C/A” represents “make-up water” market between Alto buyers and Cento sellers. All values in acre-feet.

In general, the price of water is bounded by the replenishment cost. The watermaster levies this charge on pumpers who exceed their allotment. Increases in the rate of ramp-down in the early 2000s contributed to increasing allocations prices, especially in Alto, where particularly high-value water users found a regular need to make up allowance shortfalls on the market. Price declines in Centro and Oeste in the late 2000s reflect increased efficiency on the part of municipal providers and significant acquisitions of permanent rights on the part of large water users (obviating the need for spot market purchases), respectively.

FIGURE C3

Spot market prices have risen in some subareas and fallen in others



SOURCE: Author calculations using data from Mojave Watermaster.

NOTE: Mean annual lease prices for pumping allowances across Mojave's five subareas. Replenishment water cost provided for reference. Both current-year FPA and carryover allowances included in calculation. "C/A" represents "make-up water" market between Alto buyers and Cento sellers. All values are per acre-foot and in 2019 USD.

Across all subareas, almost half of all FPA transfers involve a municipal buyer. In the other half of transactions, buyers include agriculture, especially in subareas where municipal demands are limited; recreational lake operators, which are common in the Mojave; various industrial operations, including mining and cement production; and, in recent years, environmental interests. Transactions in which a municipal supplier sells to another municipality are rare, and those in which water leaves municipal use for another sector are practically nonexistent.

The role that municipal water users play in affecting the market price is reflected in Figure C4. In Centro, municipal water use reductions have led to the exit of suppliers from the purchasing market—and precipitated a decline in price.¹ Prices paid by municipal users historically had exceeded those paid by others, but, beginning in 2009, the slow exit of municipal users coincides with an approximate halving of the market price from around \$100 per acre-foot to \$50. In Alto, no such reduction has occurred, and indeed a wedge between the average price paid for water between urban and other users has emerged over time. Price discrimination on the part of brokers may be one explanation.

¹ For example, the utility serving Barstow pumped approximately 8,500 acre-feet in 2005, but total water pumped had declined to approximately 5,000 acre-feet by 2015. During this time, the utility began leasing FPA on the market.

FIGURE C4

Urban purchasers sometimes drive higher prices



SOURCE: Author calculations using data from Mojave Watermaster.

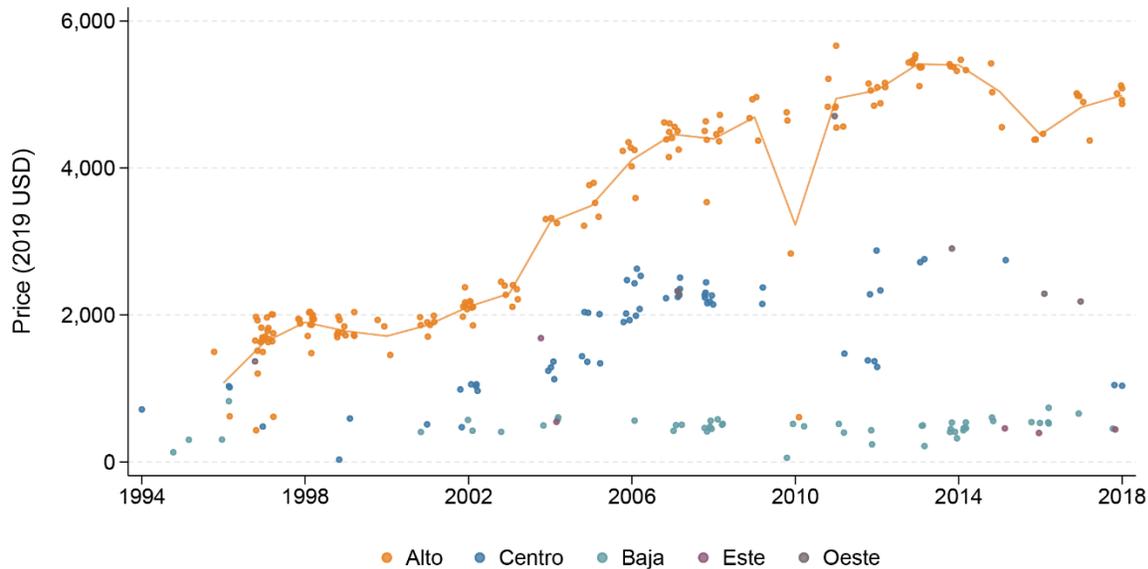
NOTE: Transactions marked with "x" designate urban buyers, while circles reflect other purchasers. Solid lines track prices paid by municipal users, and dashed lines track prices paid by others. All values are per acre-foot and in 2019 USD.

Market participants also trade permanent BAP entitlements, albeit less frequently than FPA or carryover entitlements. While thousands of FPA transfers have been undertaken since adjudication, slightly under 600 arm's-length BAP transfers were recorded through the 2018-19 water year. Figure C5 plots the per-acre-foot price of every arm's-length transaction over the 24 years for which data are available. The price of BAP entitlements capitalizes the value of being able to pump for many years and therefore exceeds the price of an acre-foot of FPA allowance by typically more than an order of magnitude. In total, arm's-length transactions have resulted in over 170,000 acre-feet of face-value BAP changing hands.²

² Because BAP entitles a user to pump for many years, it can be useful to translate face-value volumes into "committed water" using a standard perpetuity calculation. Using a 5% discount rate, arm's-length BAP transactions have committed over 3.5 million acre-feet of water to transfer to date.

FIGURE C5

Sale prices have risen the most in the Alto subarea



SOURCE: Author calculations using data from Mojave Watermaster.

NOTE: Permanent sale prices for production allowances across Mojave’s five subareas. Each dot represents one arm’s-length sale, and individual observations are binned by year but jittered to reduce overlap. Line follows the mean of Alto sales, the subarea with most consistent sales activity. All prices are per acre-foot of BAP and in 2019 USD.

The adjudication was motivated in large part by a need to safeguard future access for cities; today, municipal service providers play a large role in the long-term transfer market in areas with growing urban centers. In the Alto subarea, 47 percent of long-term trades have moved water into urban uses (50 percent of transferred water rights by volume). In contrast, the primarily agricultural Baja subarea has only seen 1 percent of permanently transferred water go to drinking water uses. Other prominent buyers of BAP include recreational lake organizations and solar power generation firms.

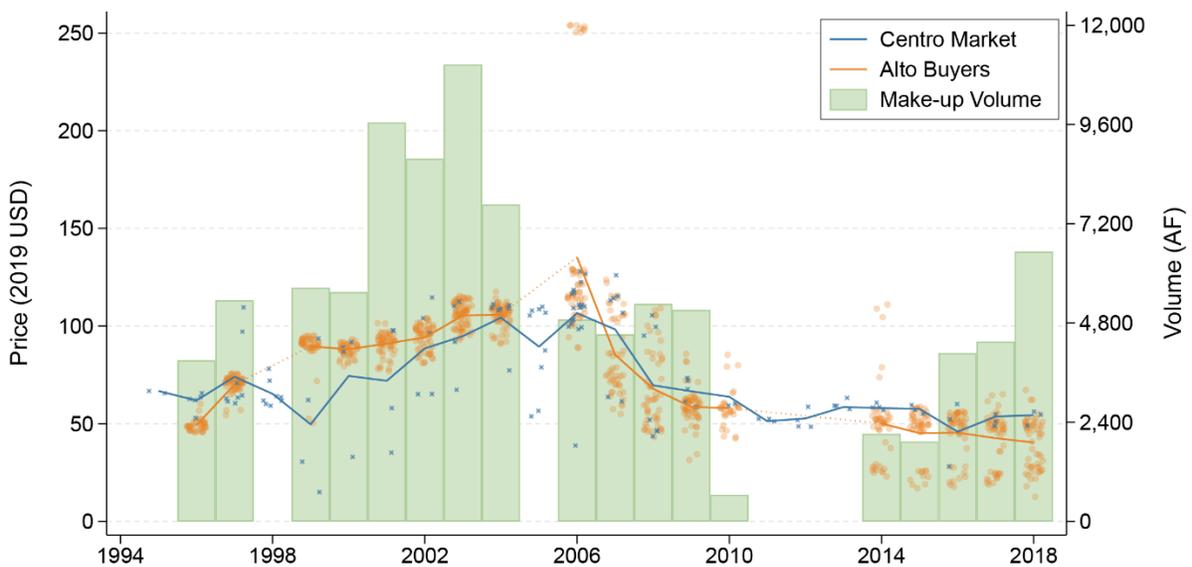
Market Solutions for Local Management Issues

The market for groundwater in the Mojave has provided an opportunity to resolve some disputes about water allocation and management that otherwise may have proved difficult to address through political or other means. Exchanges to make up for insufficient water delivery to downstream subareas are one such example.

Although the Mojave adjudication delineated hydrologically distinct subareas, pumping in one subarea can influence the amount of water that enters another. Therefore, the adjudication defined flow requirements between subareas. For example, Alto must deliver a certain amount of water to the downstream Centro subarea, and the watermaster estimates the relevant flows each year. When estimated annual flow falls below this level, all pumpers in the Alto subarea incur a one-time “make-up” obligation to offset this deficit. Each pumper’s proportional obligation is equal to his or her share of pumping within the cap for the year in which flow to Centro was insufficient. Although purchasing imported replenishment water from the watermaster is an option to address the shortfall, this obligation is typically offset by acquiring pumping rights from pumpers in Centro and retiring them (at a 2:1 rate).

This system resolves the dispute over downstream deliveries, but it also provides upstream pumpers in Alto with flexibility. Figure C6 depicts the lease market for pumping allowances in Centro. Allowances may be transacted within the Centro market or sold to buyers in Alto. For the most part, the price for leases purchased by buyers in Alto tracks that of intra-Centro leases. The option to lease to Alto buyers can provide an important outlet for Centro users to monetize their rights: Alto buyers accounted for over 80 percent of Centro sales by volume in 15 of the 18 years with positive makeup obligations. Overall, this market-based system allows (a) Alto users to offset the physical impacts of insufficient deliveries, (b) some Centro users to monetize pumping rights, and (c) Alto users to avoid undertaking costly cutbacks or purchasing expensive replenishment water. Had Alto users instead bought replenishment water to offset the volumes depicted in Figure 2, they would have incurred approximately \$15 million in additional costs.

FIGURE C6
Make-up obligations drive activity in the Centro groundwater market



SOURCE: Author calculations using data from Mojave Watermaster.

NOTE: Each dot represents one arm's-length sale, and individual observations are organized by year but jittered to reduce overlap. Lines follow mean of sales within Centro and to buyers in Alto. All prices are per acre-foot and in 2019 USD, and volumes are in acre-feet.

Introducing new buyers to the market may affect prices, and this relationship between make-up obligation volumes and the market price that Centro sellers face can be quantified. Table C1 presents coefficient estimates from naïve least squares as well as two-stage least squares regressions of the market price for Centro pumping permits on several variable sets. Column (3), the preferred specification, documents a highly elastic supply: historically, a 1,000 acre-foot increase in transaction volume was associated with an increase of just \$3.37 in the permit price. Centro pumpers may benefit from the market linkage by enjoying an outlet to monetize rights, but asset values only increase substantially in years with especially large make-up obligations.

TABLE C1

Effect of make-up purchase obligations on Centro permit price

	Effect on Market Price (2019 USD)		
	(1)	(2)	(3)
Volume of Make-up Purchased	3.55*** (0.91)		
Market Volume (Instrumented)		4.08*** (1.05)	3.37*** (0.86)
Year Trend			-1.45*** (0.43)
Observations	24	24	24

SOURCES: Author estimates using data from Mojave Watermaster.

NOTES: Coefficients for regressions of the market price of Centro annual pumping permits on the volume of make-up water purchased (in KAF) (column (1)), the total volume of market transactions, instrumented by make-up volume purchased using two-stage least squares regression (column (2)), and the instrumented volume, including a year-trend variable (column (3)). Make-up water purchased rarely deviates from the full make-up obligation, which is determined largely by lagged precipitation and estimated subterranean flows, rendering make-up volume a plausibly exogenous demand shifter. Robust standard errors in parentheses and statistical significance starred: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Participants have also leveraged markets to reduce groundwater drawdown as well as provide other public goods. For instance, the Mojave Water Agency (MWA) purchased some rights to address lingering overdraft. Although the ramp-down of rights was defined for the first five years of adjudication by the court judgement, additional ramp-down beyond that must be proposed by the watermaster and approved by the court. In some years, the court chose not to approve recommendations from the watermaster to lower FPA allocations in the Baja subarea, and at one point even adopted a moratorium on ramp-down. As a result, Baja remained in a state of overdraft for many years. In 2019, the MWA purchased approximately 7,200 acre-feet of BAP in order to conserve groundwater and thereby bring the basin closer to long-term balance. Where other approaches to address overdraft (i.e., a continuation of across-the-board ramp-downs) proved difficult to implement, a market solution that compensated parties for foregone benefits succeeded.

In other cases, environmental interests have acquired pumping rights for various purposes. The California Department of Fish & Wildlife (CDFW) has been a regular participant in Alto's FPA market in recent years for its Mojave Narrows Regional Park, and in 2001 it purchased over 900 acre-feet of BAP in Baja for its Camp Cady Wildlife Area. CDFW uses these water rights to irrigate some riparian habitat at Camp Cady. In 2019, the Department stated that it has continuing plans to purchase additional BAP rights throughout the Mojave Basin and retire them (Ellsworth, 2019). Private organizations have also taken part in the market, with BAP purchases by the Western Rivers Conservancy and the Mojave Desert Land Trust in 2015 and 2018, respectively. Such acquisitions often occur alongside land transactions, and the associated water rights can be sold, managed as an asset for financial return, or used directly to provide environmental benefit. While some of the purchases mentioned above were funded by tax dollars, alternative arrangements involving funding from environmental groups and other private parties are clearly also possible.

REFERENCE

- Ayres, A., K. C. Meng, and A. J. Plantinga. 2021. "Do Environmental Markets Improve on Open Access? Evidence from California Groundwater Rights." *Journal of Political Economy*, 129(10).
- Ellsworth, A. 2019. Declaration of Alisa Ellsworth in Support of the Department of Fish and Wildlife's Response to Watermaster's Motion to Adjust Free Production Allowance for the 2019-20 Water Year. Superior Court of the State of California for the County of Riverside. June 6.