

Streetlights and Tradeoffs: Better Understanding Water Uses and Values in the Middle Rio Grande Valley ¹

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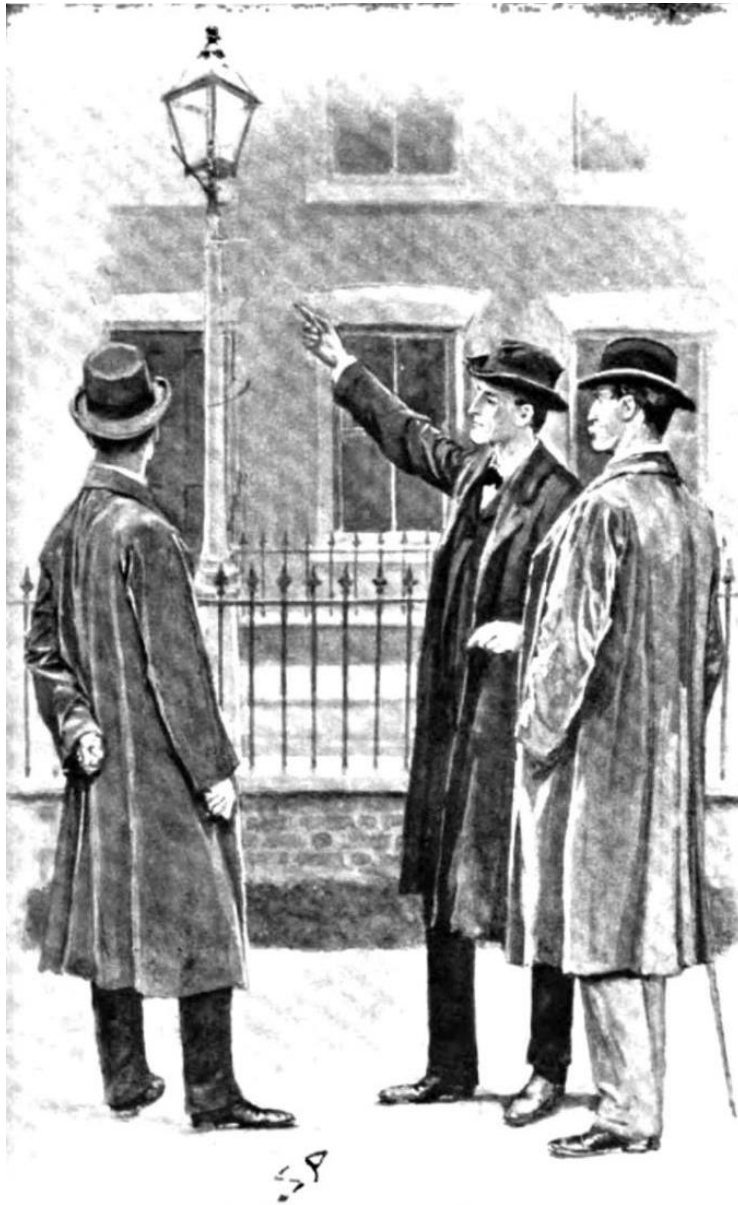
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Holmes pointed to the street lamp above our heads.

Conan Doyle, A. (1904, May). The adventure of the six Napoleons. *The Strand Magazine*, 27(161), 483–496.

Prologue

“Publicity is justly commended as a remedy for social and industrial diseases. Sunlight is said to be the best of disinfectants; electric light the most efficient policeman.”

Louis Brandeis (1914, p. 92), *Other People's Money*

The people living along the Rio Grande in central New Mexico, like many communities, face unprecedented challenges in adapting to a climate-changed world with less water. Changing community structures and values are colliding with the path-dependence and *taken-for-grantedness* of deeply embedded institutional approaches (Suchman, 1995; Cairney, 2019). This is colloquially known as “the streetlight effect”² after the old joke about a person looking for their lost keys under a streetlight despite having lost them elsewhere - “It’s the only place there’s any light!”. The joke captures a central feature of many political and policy processes, as our attempts to solve new problems are trapped in a maze of old informational tools developed to solve old problems.

In the work that follows, based on parts **compilation and synthesis** and a bit of original analysis, we argue for employing some additional streetlights to help us search for the keys to unlocking current problems. Our suggestions follow several threads:

- the use of powerful new remote sensing tools, satellite data that, when combined with decades of stream flow and aquifer measurements, allow us to see with fresh clarity how we are using water, and how that use has been changing over time, and across the landscape.
- reconsideration of water uses that in the past were commonly ignored as being *de minimis* - so small as to be irrelevant to policy discussions - that have grown in the 21st century to represent a substantial fraction of the water humans consume in New Mexico's Middle Rio Grande Valley
- a call for shifting our measurement tools to point more clearly at the definition of water *use* - to consider not merely how much water is diverted from a river or aquifer, but how much is consumed, unavailable for later use via return flows by humans or the ecosystem.
- valuation, looking beyond questions of *how much water, we are using* to think more carefully about *what value we are getting from that use*.

The old streetlights that dominate water policy discourse too often focus on specific gages and measures, and the management of water withdrawn from rivers and aquifers by government agencies. For many, this constrained perspective represents a broken water data information system (Shah & Doyle, 2026). After all, **agencies don't use water, people do**. And a substantial share of our consumptive use (i.e., evaporation and transpiration lost to regional system for further use), largely unpriced and unmetered yet important and valued, lies outside the illumination of the existing streetlights.

But the cost of observing how people consumptively use and value water, in making choices and tradeoffs as they go about their lives, is dropping. Better understanding consumptive water use will help in testing interventions and improve the generalizability and the replicability of our evidence (List 2026).

To preview, from our compilation and synthesis we offer a list of 12 recommended additional streetlights:

- (i) As first principles, we must move to a world of both increased metering of consumptive use of water, and an expectation that water users should pay a base fee to specifically cover improved metering and monitoring, with publicly accessible tracking of trends;
- (ii) In addition to GPCD, we should pursue showing the total consumptive use and the *consumptive* GPCD for all regulated community water systems (CWS's);

² Streetlight effect. (n.d.). *Wikipedia*. Retrieved May 20, 2026, from https://en.wikipedia.org/wiki/Streetlight_effect

- (iii) Regular collection should be widely made and reported of municipal charge rates for a broader set for residential usage levels, rather than just the standard 6,000 gallons monthly, with a clear tracking of trends in inflation-adjusted real dollar terms – to show both changes in residential affordability and incentives for conservation for higher use levels. The broader range of charges collected for differing usage levels will move this past non-consumptive indoor use and allow improved understanding of consumptive municipal uses (which are also important for public health) for all sizes of CWS's;
- (iv) *Prices* for all water rights transactions both temporary and permanent, for surface water and groundwater, should be public information and transparent to buyers and sellers;
- (v) Additional regulatory oversight tools should be considered for domestic wells, including both reviewing permitting terms and moving to regularly metering and tracking use from this important but dispersed consumptive water use. Collectively, it is clearly too big a use case to be considered *de minimis* any longer;
- (vi) Using democratized tools like OpenET, the community should be regularly tracking trends in ET (and *effective* ET) for a wide dispersion of geographies in the MRGV; concomitantly, there should be ongoing efforts to continuously improve the use and understanding of these remote sensing data sources;
- (vii) Rather than focusing on a few gages, AI tools should be leveraged to track trends in river diversion across all gages in the MRGV system;
- (viii) Available evidence on environmental and non-market values for water uses in the MRGV, such as provision of instream flows and outdoor recreational values for bosque and trail access, are either missing or generally outdated and need to be systematically updated;
- (ix) Similarly, there is a gap in research connecting consumptive water use and the value of trees (as one specific case of growing *particular* green things), which can provide a bundle of ecosystem goods and services (health and pollution, shade and heat mitigation);
- (x) There is a need for additional economic investigation into what gets bundled into important cultural, custom and lifestyle (CCL) values of noncommercial irrigated yards and agriculture, ranging from agricultural/greenspace tax dimensions and incidence to electricity rate structures charged (for pumping by different classifications of wells), to more direct valuation studies;
- (xi) There are demand techniques for separating out municipal indoor and outdoor (consumptive) use, which can be further pursued; and especially the large municipal water systems in the MRGV should start reporting this sorted information;
- (xii) We should think broadly about *wherever* consumptive water use is either unpriced or lacks any marginal conservation incentives (i.e., currently charges flat rates), and whether these are institutional arrangements we want to maintain as a community, including equity dimensions.

We make no claim our recommended list for consideration is complete. Rather, we hope to spur discussion of revisions, additions and refinements. We point to some new informational tools that might be of use, fleshing out some and suggesting preliminary explanations of what they might be telling us.

In the work behind the oft-quoted *sunlight and streetlights* passage above, Brandeis was making a mechanistic argument for the value of shedding light. Simply lighting these political and policy spaces, Brandeis argued, had causal efficacy; public awareness can be causal in improving political and public policy outcomes. Twenty-first century policy studies suggest a more complex landscape. This is in part because the nature of *publics* has changed since the time of Brandeis's writing (Dewey, 1927) and in part because our understanding of the challenges *bounded rationality* places on the political and policy processes on which we must depend to respond to these challenges (Kingdon & Stano, 1984). Our claim here is thus more modest than Brandeis's. While perhaps not sufficient, we believe additional streetlights are at the very least a necessary first step to better outcomes as the communities of New Mexico's Middle Rio Grande adapt to the changes to come.

Declarations on AI Use

The regular 2025-2026 workshop organized to produce this whitepaper and various ongoing water investigations (e.g., background for book writing, and dissertations, etc.) gathered weekly in the comfortable commons room of the UNM Water Resources Program. It included a larger group of water-interested UNM students, but perhaps critically no specific class context. Therein we attempted to adopt an open and frank collective discussion framework on uses of the rapidly expanding bundle of artificial intelligence (AI) tools for conducting research.

S.A.A: I have used ChatGPT for grammar checking, translating text between Spanish and English, improving the formatting of tables and references, generating figures based on specific design ideas, and assisting with Stata coding to improve graph formatting and achieve specific visual layouts. ChatGPT was also used for brainstorming, organizing information, and locating relevant references. I have used Claude for verifying citations and methodological terminology against original source documents, cross-checking numerical values and calculations reported in the literature against the original studies, drafting and revising prose for clarity and tone, and identifying inconsistencies between the text and the data presented in tables. All data collection, analysis, calculations, interpretation of results, and final writing decisions were completed, reviewed, and verified by me. The final text, analysis, and conclusions presented in this report are my own.

S.A.: During the preparation of this white paper, I used AI (Claude-Sonnet 4.6, Grammarly) to enhance the clarity and readability of my original writing. Also, I used Claude-Sonnet 4.6 to modify my custom Google Earth Engine scripts for data extraction. After using these tools, I reviewed and edited the content as needed.

R.B.: After subscribing to *Claude* in late May 2026, I have used AI in ideation, formatting, checking and revising style guidelines, constructing figures and helping prepare summary tables, creating the Table of Contents, and as a kind of supercharged search engine for references and materials. We regularly throughout the year brought many of these individual AI efforts and evidence back to the wider workshop to explore further as a group, which led to more data cross-checking and critiquing. Our discussions and review also prompted an AI search investigation to fill a gap. Specifically, I used AI extensively in iteratively compiling and cross-checking the background details for Figure 13, which was then constructed using *Claude* with numerous iterative requested revisions to the Figure design. Finally, I also used it in constructing the supporting cost tables in Appendix C that go with Figure 13. All my written text is my own.

J.F.: I have been actively experimenting with large language models (LLMs) since the November 2022 release of the first widely public model, ChatGPT. In the research that follows, I have used LLMs from Google, Anthropic, and OpenAI for ideation, experimental design, and writing much of the computer code used in the data analysis. The coding tools for water use analysis were built on the foundation provided by an archive of own previously written R language water data tool set. In addition, I have made extensive use of Google Earth Engine to conduct remote sensing and spatial analysis done in support of this work. The code used for the data in this report is available for public analysis and replication on Github: <https://johnrfleck.github.io/New-Mexico-Middle-Rio-Grande-Valley-water-use-analysis/docs/index.html> All my written text, including the explanatory material included in the Github replication notebooks, is my own. Methodological details in the Github repository have been written by AI tools and revised and approved by me.

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I. INTRODUCTION

There's less water, what do we do?

For arid regions facing a changing climate, like the Middle Rio Grande Valley (MRGV)³ in the state of New Mexico (NM), United States (US), there are no simple answers. In an arena noteworthy for polycentric governance and the common absence of market signals, different water management agencies often focus on their individual remits and allocations of water. They aren't necessarily charged with thinking in terms of tradeoffs and how regional communities value water in alternative uses. Information on economic values can aid public deliberations around inevitable tradeoffs (Young & Loomis, 2014). Arguably, public deliberations about desired future conditions are informed by providing accessible knowledge about how people use and value water. Yet, ours is not an attempt to synoptically cover all community values for water in the MRGV, even as we accept that economic efficiency measures are not the only ethical or social desiderata for community development and wellbeing (Sen, 1999).

Periodically, economists and other scholars have investigated the value of water in alternative uses in the MRGV. Perhaps the first initial analyses roughly correspond to when the region began experiencing significant population growth, and the introduction of the engineering works of the new Middle Rio Grande Conservancy District (MRGCD), which greatly altered both institutional governance and the hydrology of the region (Cockerill & Walker, 1931; Walker & Cockerill, 1930, 1933). Another occurred when the region was contemplating a significant supply injection of trans-basin water transfers from the then forthcoming San Juan-Chama Transmountain Diversion Project (Wollman et al., 1962), now commonly known as the San Juan-Chama Project (SJCP). Additional investigation occurred when greater Albuquerque explicitly began to recognize the limits to its municipal groundwater supply and added a focus on building a safety reserve (Brown et al., 1996; DuMars & Nunn, 1993). Since, there has been work by prominent economists, such as Frank Ward and Brian Hurd (New Mexico State University [NMSU]) and colleagues, and David Brookshire, F. Lee Brown, and Janie Chermak (University of New Mexico [UNM]) and colleagues, as well as others investigating competing uses and values.

However, a suite of issues is converging on the MRGV's water future:

- climate change's increased temperature and reduced streamflow (Dunbar et al., 2022)
- continued population growth (if dampening somewhat lately in NM)
- significant success in municipal conservation, but continuing challenges
- a gradual squeezing of commercial agriculture
- prominent endangered species issues (Tara, 2025)

The time is thus ripe to synthesize what we know about the economic value of water in alternative uses. However, it also is important to embed that within the context of emergent trends in consumptive water use.⁴ Here, we follow the general recommendation of Garrick et al. (2020) in seeking to broaden our

³ The MRGV refers to the roughly 160-mile segment of the Rio Grande flowing from Cochiti Dam to San Marcial, near the northern end of the Elephant Butte Reservoir. The MRGV is often used interchangeably with the geologically broader Middle Rio Grande Basin (MRGB), which encompasses the drainage basin (see Map 1). The Rio Grande cuts through the city of Albuquerque, while the MRGB contains most of but not the entirety of the Albuquerque Metropolitan Statistical Area (MSA), with a census population of over 920,000 in 2020. For a history of the public administration of the Rio Grande and its relationship to a growing Albuquerque, see Fleck and Berrens (2026).

⁴ To clarify terminology, by *consumptive use*, here we will be following (USGS, 2025): "Not all water withdrawals are returned to the local environment. Some water is lost because it is evaporated, transpired, incorporated into

focus to combine some physical quantity measures (or trends) with economic measures.⁵ With our geographic focus on the MRGV, this is largely a **compilation and synthesis study**, with a bit of original analysis (e.g., calculations and trends), and some offered interpretations of what we find.

One primary objective of this investigation is to employ benefit transfer-style tools and approaches (Rosenberger & Loomis, 2017) for collecting non-market values, and market evidence where available; we draw from disparate studies to synthesize in comparable units and frames what we currently know about economics values for alternative water use in the MRGV and identify gaps in knowledge. More specifically, we compile all the *indirect evidence*, as calculated or computed from a wide variety of analytical approaches, for the economic value of water in alternative uses. We also compile all the *direct evidence*, from reported market or transaction values (prices) for water rights, both for permanent sales and for temporary leases. Additionally, while they aren't economic value measures per se, for completeness we also compile what people get charged for water. We compile what is known about current administrative charges and rates for water service delivery (and sometimes payments for curtailments or fallowing) by varying public entities in the MRGV. For municipal water providers these typically involve complex rate structures for water service, which can be looked up for different utilities. Here, to allow comparisons, we compile the residential charge rate (water and sewer combined) for single level of use for all community water systems above 1,000 residential connections in the MRGV. The level is 6,000 gallons per month (or 50 gpcd for a family of four for 30 days), which would typically be expected to be nonconsumptive indoor residential use. Finally, we explore what is paid to access 1.5 AF of consumptive water use (e.g., outdoor use), across more than a dozen sources.⁶ Together these studies, and filling in the gaps, point to one of the most important new streetlights the communities of the MRGV will need to help illuminate the tradeoffs they face as they confront a future with less water: How do we *actually value the water* we are using now?

A second primary objective is to contextualize this information about economic measures by looking at some emergent trends in water use: (i) What can we say about municipal consumptive use including for the largest municipal provider in the MRGV?; and (ii) What can we say about trends in consumptive use of water as measured by remote sensing tools like OpenET that use satellite-based measures of evapotranspiration (ET), as measured for varying geographies (using various physical and political boundaries) in the MRGV; (iii) What can we say about the growth of domestic wells and their consumptive use of water, as a largely unmetered sector of water use?; and (iv) What can we say about trends in *net flow reduction* in the Middle Rio Grande, where we define NFR= (Otowi gage inflow to the north of Cochiti Dam) – (San Marcial gage outflow to the south), given its importance in governance constraints like the interstate Rio Grande Compact? On the physical side, while much of what we do is collecting and analyzing administrative data, we also do some original analyses, mapping (e.g., using GIS and OpenET tools), and trend analyses. Together these help point to the second important streetlight that works in tandem with the first: How are we *actually using water* in the MRGV?

products or crops, or otherwise made unavailable for immediate use. Water use that does not return to the local environment is called consumptive use.” By this definition then, the portion of water diverted or withdrawn that is not consumptive use, we will refer to as nonconsumptive. The caution to the reader is that some sources may treat all diverted water, say, from a river as consumptive (i.e., without accounting for the portion returning to the system).

⁵ More specifically, Garrick et al. (2020) argue that central lesson for research and policy is that “quantity signals are as important as price signals.” Other central lessons from their review of the economics of water include: institutions for collective coordination are necessary; blended solutions require blended governance (public and private); economic policy levers outside of water are important; and that crisis can create opportunity for policy reform.

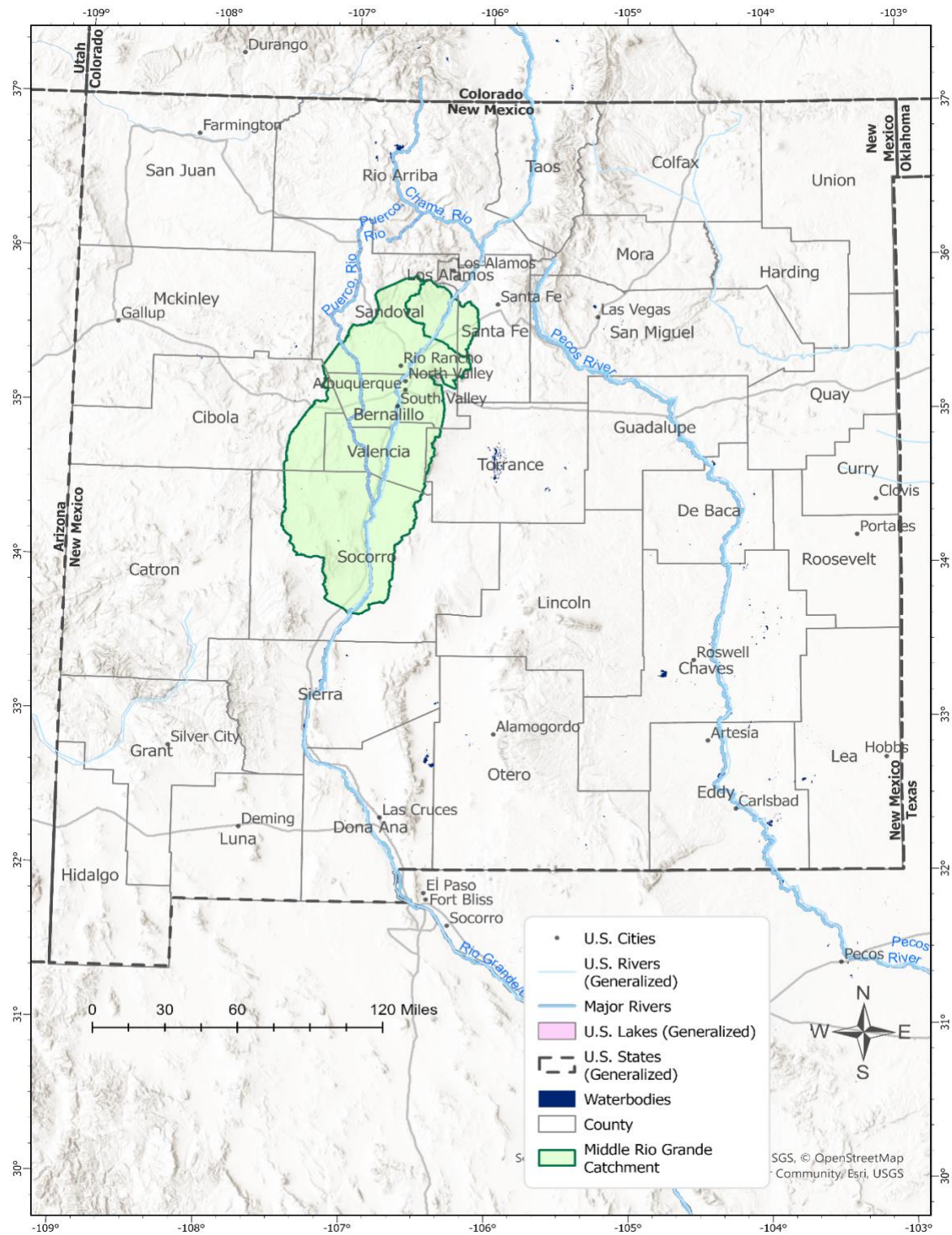
⁶ A common western US measure of water use, an acre-foot represents 325,851 gallons. 748.05 gallons of water is equivalent to 100 cubic feet, commonly defined by providers as 1 “unit” (i.e., 6,000 gallons/mo represents 8 units).

We are not alone in our advocacy for and pursuit of the creation and use of new streetlights. The New Mexico Water Data Initiative (WDI), under the auspices of the New Mexico Bureau of Geology and Mineral Resources, is the region's most prominent example. The WDI is bringing a host of independent data sets together under one computational roof "to share, integrate and improve the management of water data." (New Mexico Water Data, n.d.) The Albuquerque Bernalillo County Water Utility is currently updating its long-range water resources management strategy, to be called Water 2130, including new water supply and use modeling for customers using the municipal system (ABCWUA, 2026). The New Mexico Office of State Engineer has updated its public dataset of irrigation wells to more accurately capture active wells in the Middle Rio Grande Valley (New Mexico Office of the State Engineer, 2026).

We explore our two major objectives in reverse order. In section II, **TRENDS IN SELECT PHYSICAL MEASURES OF AVAILABLE WATER AND ITS USES**, we provide some general background discussion and then look at these four physical trends related to water use. We perhaps generate more questions than we answer. In section III, **ECONOMIC VALUES AND MEASURES FOR ALTERNATIVE WATER USES**, we provide some general background discussion and then provide and summarize this economic information in five detailed summary sections, with various detailed appendix tables for further details. Section IV, **CONCLUSIONS AND RECOMMENDATIONS**, provides some concluding thoughts and a modest set of recommendations.

Finally, this **compilation and synthesis** study of economic measures, matched with information on physical trends is intended to help inform our own larger water research investigations both individually and collectively, and we hope others may find this compilation useful. It reflects where we are currently pointing our flashlights.

Map 1. Middle Rio Grande in New Mexico



Source: Olofinsao et al. (2026).

II. TRENDS IN SELECT PHYSICAL MEASURES OF AVAILABLE WATER AND ITS USES

II.1. Background

Under the existing web of rules and regulations, and perhaps most importantly the multi-state Rio Grande Compact,⁷ the MRGV gets an allocation of water at the top (north) of the system and has a delivery obligation at the bottom (south). Under a complex running system of debits and credits, Figure 1 shows the historical trend in New Mexico's compact obligations. Breaching the Compact compliance limit (when the accumulated debt reaches -200,000 AF) places restrictions on how we can store and manage water in the MRGV. From recent research using an autoregressive integrated moving average (ARIMA) model, the annual compact deliveries of CO (to NM) are well predicted by available water supplies over prior several years, but the deliveries of NM (to TX), whether debit or credit, are not well understood statistically (see Trueblood et al., 2024).

Yet, the simple interpretation of Figure 1 is that New Mexico's Compact balance is trending down in the 21st century. This represents the over-arching institutional obligation system the MRGV exists within. Consonantly, Figure 2 shows the general trends since 1990 in: (i) annual flows of the Rio Grande through the MRGV (top panel); and (ii) the aggregate population growth in the Albuquerque Metropolitan Statistical Area (MSA) (bottom panel). In the set of traditional measures/gages for the MRGV, the Compact debit/credit balance may be the most important. Ours is *not* an argument that, somehow, we can ignore these downstream obligations. Rather, it is an argument to re-orient our focus, and flip on a few additional light switches, onto how we consumptively use and value the remaining water that is in the MRGV. Afterall, **agencies don't use water, people do**. And those people have less water per person to consumptively use.

⁷ The Rio Grande Compact is an interstate water agreement in the US, signed by Colorado (CO), New Mexico (NM) and Texas (TX) in 1938, and ratified by the US Congress in 1939. The Compact supports the provisions of the federal Rio Grande Project (RGP), for irrigation, drainage, and water deliveries in the Lower Rio Grande Valley (LRGV) of NM and TX. As a rule-based allocation system, the Compact proportions available water supply in the Rio Grande, with an allowed running system of debits and credits for the upstream states of CO and NM. [See: OSE ISC, n.d.] For historical discussion, see Hill (1974). The Compact has been under suit, under the jurisdiction of the US Supreme Court, for under deliveries downstream to TX since 2011. In early June 2026, the US Supreme Court (*Texas v. New Mexico and Colorado*) accepted the provision of an earlier negotiated agreement requiring NM to reduce historical over pumping of groundwater in the NM portion of the LRGV (and thus the Elephant Butte Irrigation District [EBID]) by approximately 18,000 AFY (see: Office of the Governor of New Mexico, 2026; and O'Melveny & Myers LLP., 2026)). Speculatively, one scenario is that in meeting these requirements the state of NM would pursue buying out water rights with some public funding mechanism.

Figure 1. New Mexico's Rio Grande Compact Balance

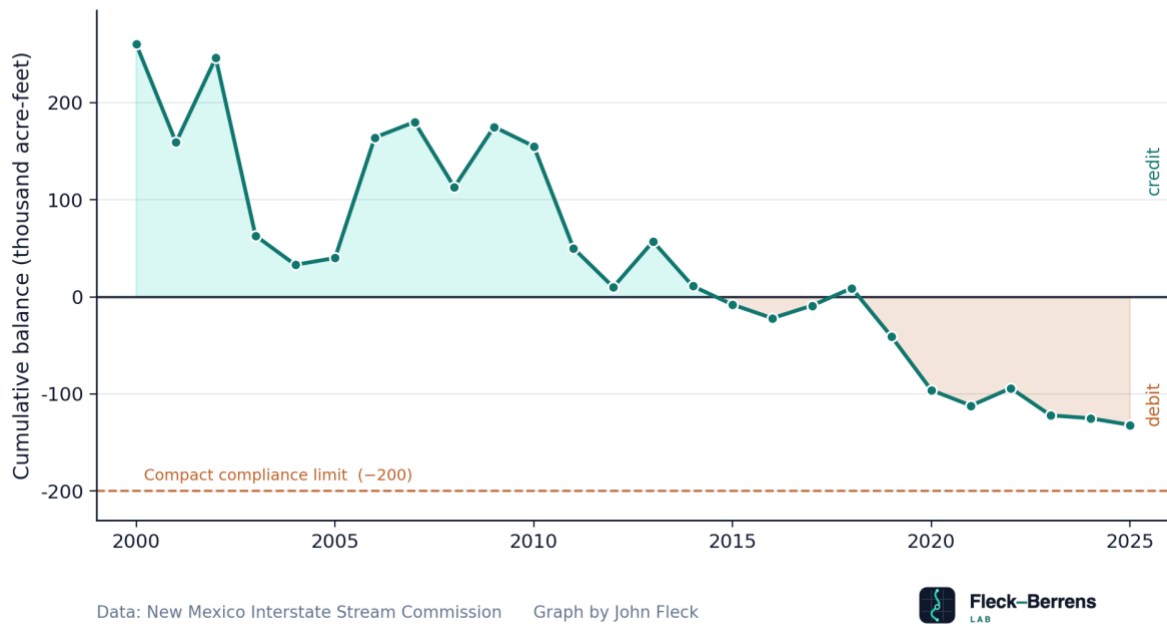
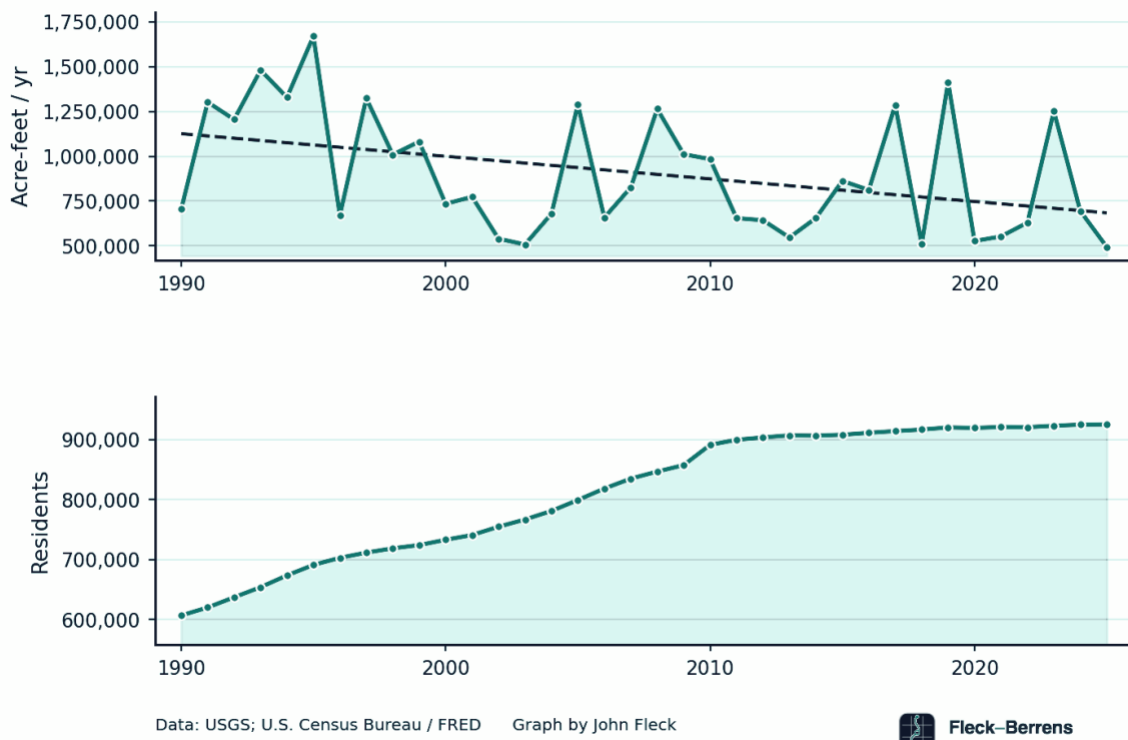


Figure 2. A Shrinking River, and a Growing Metropolitan Area



Thus, with NM's Compact balance going down, Rio Grande flows trending downward, and population in the MRGV still trending upward (albeit slowing), it is important to understand what is going on in between the top and bottom of the MRGV.

Supplemented by precipitation, side inflows from the valley's numerous arroyos and smaller tributaries, contributions from groundwater pumped by municipalities and added to the river as wastewater return flows, water lost as it percolates into the aquifer to refill cones of depression created by past pumping, the allocated budget tells us what the regional community can consume annually. If it is more than this, through depletions of river flows, and/or reservoir storage and aquifers, then it is unsustainable (e.g., see Richter et al., 2025). To support desired water uses, we divert it from the river or pump it up from municipal, domestic and irrigation wells and convey it to desired uses. This can be thought of as the system of diversions, which must be distinguished from water consumption, as a large slice of it (e.g., half, or more) may be returned to the system via wastewater treatment or agricultural return flows and credited against allocated rights, while also being made available for downstream uses and the riverine ecosystem. Water rights are typically legally defined in terms of consumptive use (e.g., so many acre feet per year (AFY)). Aside from evaporation from river and other water surfaces, consumptive use both inside and outside the river levees is primarily about the evapotranspiration (ET) of growing green things. Spatially and temporally, within the region and across time (increments and decrements to storage) we refer to this consumptive use as the *distribution of green*. Within the full distribution of green in a region, there are different types of green: commercial agriculture, noncommercial agriculture, gardens, yards, trees, public parks, and greenspaces, with the latter including golf courses (public and private), natural riverside vegetation, etc. We call this the *composition of green*.

Importantly, we expect this distribution and composition of green to both change across an arid landscape and over time, driven not just by climate change but also land development and water policy, and individual community members' choices in response to those policy frameworks.

To illustrate this point, we narrow our focus on the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) for 1984 to 2024. The period is longer than the current organizational structure of the greater Albuquerque area's largest municipal water service provider (ABCWUA was created in 2003). But also, long enough to show significant change in measures of green-ness. Certainly, household preferences for lawns and xeriscapes, and their watering and care, can change including in response to rate structures and other budget and conservation incentives. However, beyond ways directly connected to water conservation policies, we can expect the distribution and composition of green on an urban landscape to change both spatially and temporally. For example, this can happen through zoning regulations, through regulated electricity rates that affect groundwater pumping costs, or through reductions in ad valorem property taxes that incentivize irrigation for agricultural and quasi-agriculture use (e.g., Porter et al., 2023). This can happen in unexpected ways when we look at change, rather than historical patterns of green. Consider our case of the ABCWUA service area, in its current (2024) boundary configuration, which has expanded through time. Trees planted in post-WWII era neighborhoods (e.g., the near NE Heights) from the 1950's and 1960's grow old and may die faster than they are replanted (see O'Neill, 2026). Land uses change status, as agricultural lands in peri-urban areas are converted, public parks added, and new neighborhoods created (e.g., Far NE and Westside). All the while, a changing climate alters ET, as the growing season widens the shoulder seasons in early spring and late Summer into the Fall. This pattern of spatial change is illustrated for ABCWUA using one measure of green, the *Enhanced Vegetation Index* (EVI),⁸ with two different levels of pixelization in Map 2 (a and b).

⁸ While the Normalized Difference Vegetation Index (NDVI) came first in the MODIS system of biophysical indices, the Enhanced Vegetation Index (EVI) is a remote sensing index, incorporating blue band reflectance. Like

The pattern of spatial change can also be very similarly illustrated (perhaps more controversially) by applying the remote-sensed measure of annual ET (adjusted for precipitation, and what we refer to as effective ET), in Map 3, with a slightly larger geography (the Census-based Albuquerque urban area). Using our *exploratory* attempt to apply a form of Gaussian smoothing to spatial data (and see Vulova et al., 2023), Map 3 places areas within the greater Albuquerque urban area into six color bins for how they changed over the period 2001-2024: wet and gaining water; dry and gaining water; little or no change; wet and losing water; and dry and losing water. The trends appear to show the river valley floor (our collective ribbons of green) is using more water in a hotter world, and this includes areas not on the ABCWUA service area (e.g., Village of Corrales dependent on domestic wells), some urban areas using less water (e.g., the Near NE Heights), and some recent urban expansion areas using more water.

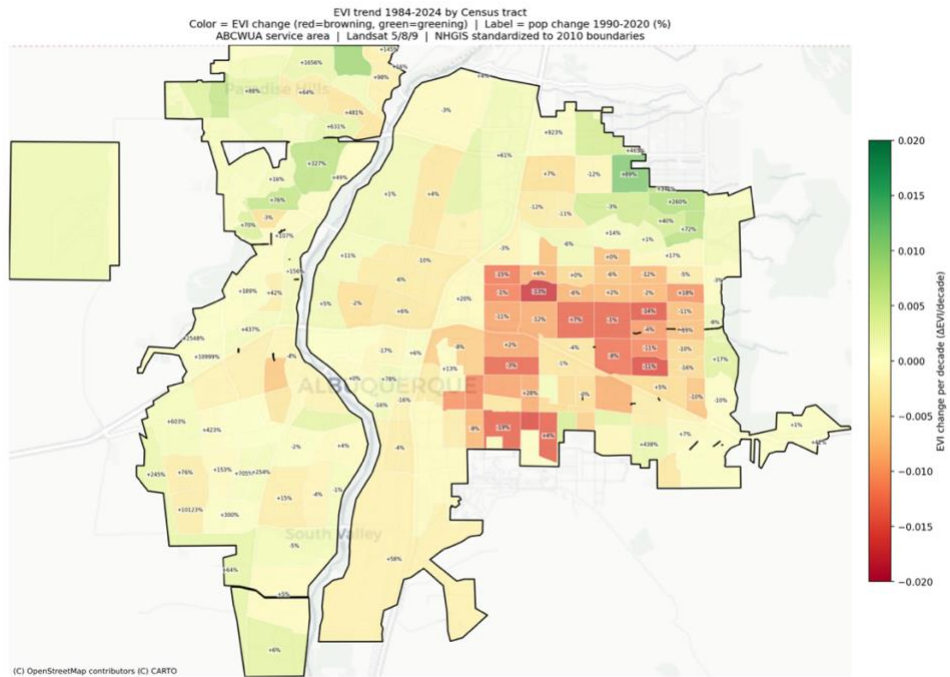
Growing green things, as reflected in EVI (Map 2 a and b), requires consumptive water use (Map 3). Together they help remind us of several things: (i) consumptive water use is always changing, and the reasons are more complex than just water policy; and (ii) we should expect complex landscape heterogeneity even when we compute overall trends for ET for different specific geographies, as we will do more of later. Remote sensing tools to help illuminate this story have long been available, but new large language models (LLM)-based coding tools combined with large scale data repositories such as Google Earth Engine have made them far more easily accessible for this type of analysis. This newly improved streetlight allows us to see how the use of water in the core of Albuquerque's urban area has changed over a time of significant population growth.⁹ It is the fingerprint of the choices community members have made about how they value water in alternative uses.

the NDVI, EVI was designed to measure vegetation greenness and health. The EVI is similar to NDVI but with improvements to reduce atmospheric noise and soil background effects. (See: Huete et al., 2002; Yan et al., 2025).

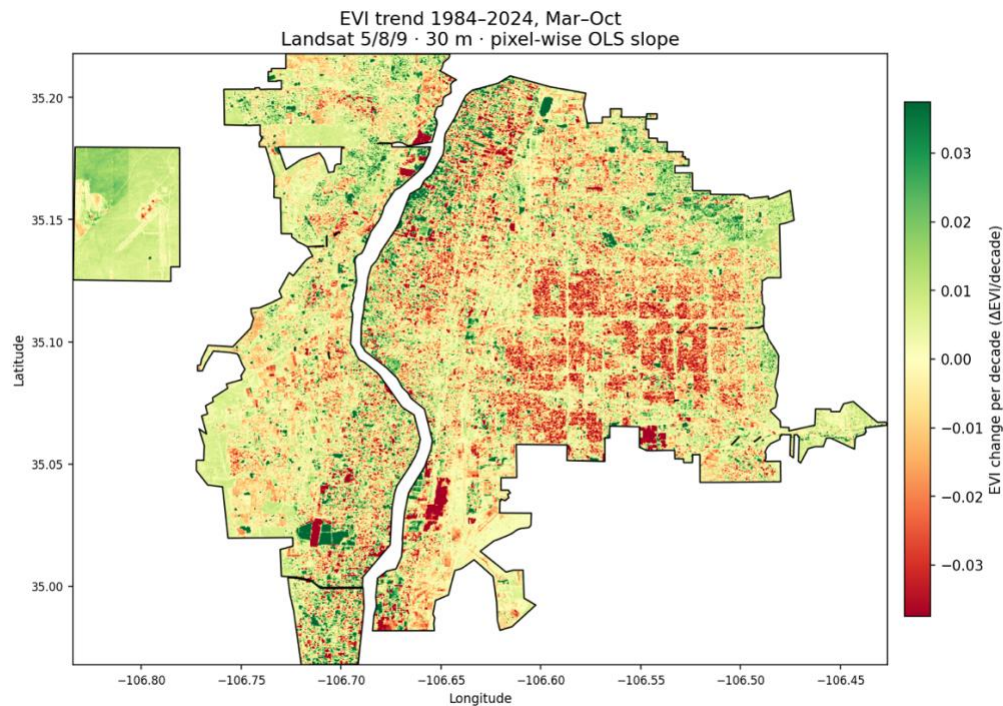
⁹ Bernalillo County's population grew 50% from 1984 to 2024 (U.S. Census Bureau, 2026), and see Figure 2.

Map 2: Trends in the Enhanced Vegetation Index (EVI), 1984-2024, ABCWUA Service Area

(a)



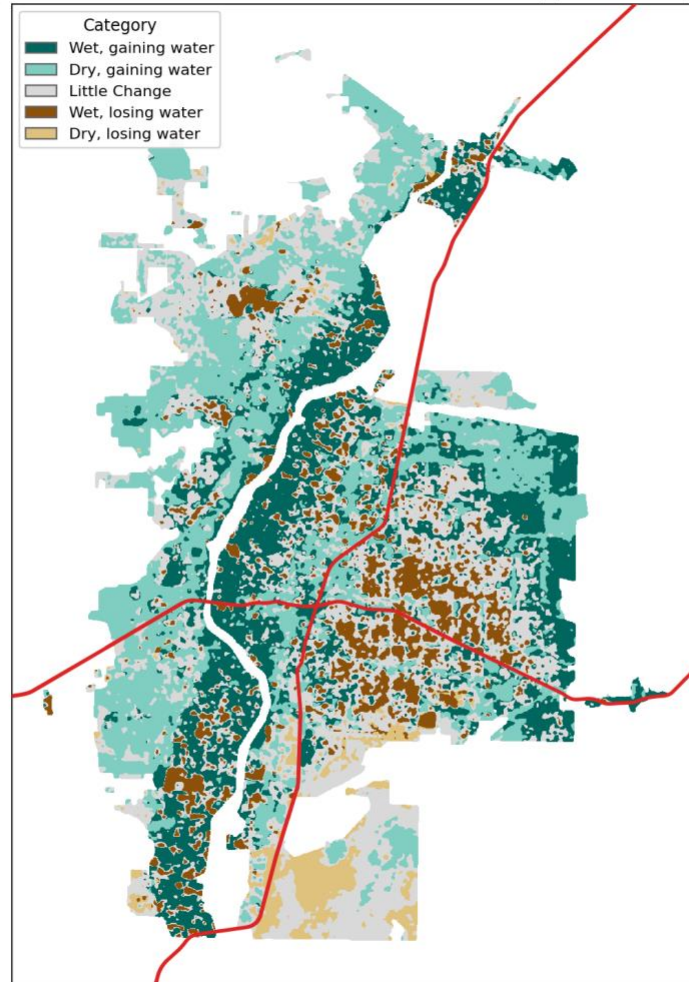
(b)



Notes: Trends in Enhanced Vegetation Index (Huete et al., 2002), representing increases/decreases in vegetation and, by implication, water use across the period of relatively reliable, available satellite data.

Map 3. Water Use Trends, for Albuquerque Urban Area

Albuquerque, NM Census Urban Area minus river corridor — effective ET (OpenET – $0.7 \times \text{precip}$), 2001-24



Fleck-Berrens
LAB

Data: OpenET, Analysis: John Fleck

Notes: Comparison of effective ET across the Albuquerque metropolitan area in the first five years of the 21st century. Dark green areas represent areas that were above median ET during the reference era and saw increasing ET. Dark brown areas were above median ET during the reference era and saw ET decline. Gaussian smoothing used to aid in visualization of statistically similar areas. Code and replication package at https://johnrfleck.github.io/New-Mexico-Middle-Rio-Grande-Valley-water-use-analysis/docs/quadrant_map/README.html

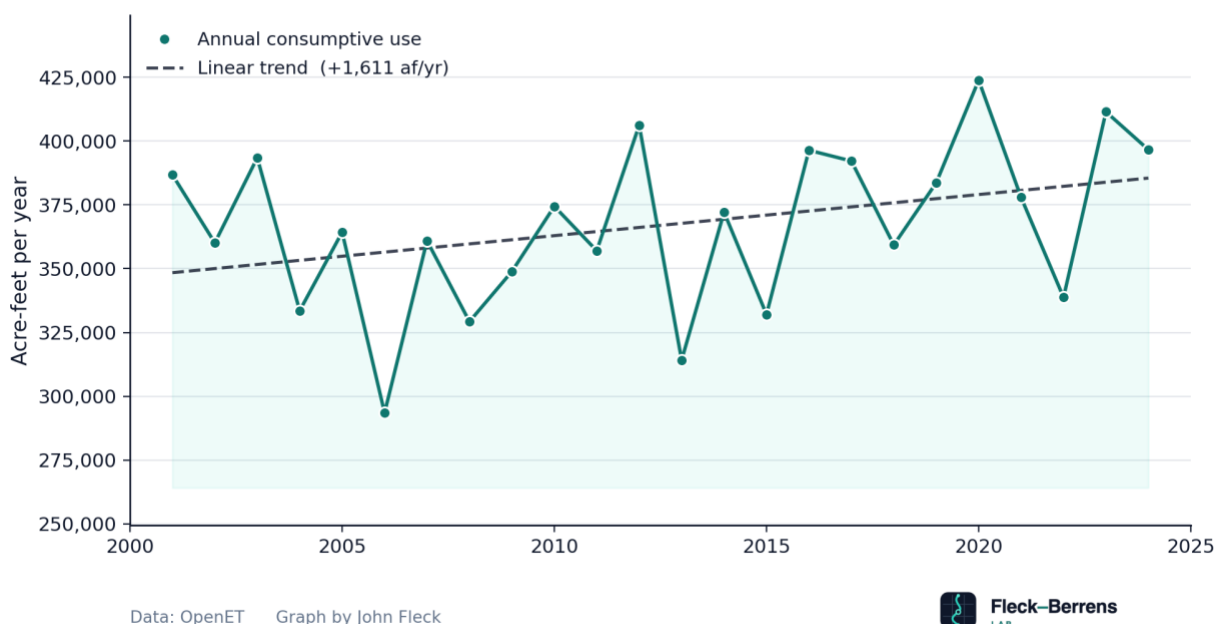
Scaling back outward from this localized spatial heterogeneity, regional climate modeling forecasts decreasing water availability for the Rio Grande in New Mexico (Holmes et al., 2022; Samimi et al., 2022). Increasing aridity is expected to reduce snowpack in headwaters, reduce soil moisture in the watershed more generally, and *increase* evapotranspiration (ET), and alter both the magnitude

(reductions) and timing of streamflow (Garfin et al., 2013; Dettinger et al., 2015). Looking just downriver from the MRGV, Samimi et al. (2022) investigated water availability for irrigated agriculture in the lower Rio Grande Basin in New Mexico, from below Caballo Reservoir to the Texas and Mexico border and including both Elephant Butte and Caballo Reservoirs. Historically, the LRGV is a much more profitable agricultural sector than in the MRGV, and *solely* from a commercial agricultural perspective, one might argue for transferring scarce water from the MRGV to the LRGV (e.g., Trail & Ward, 2024).¹⁰ Samimi et al. (2022) forecasted future inflows to the major surface water storage reservoirs, possible future reservoir releases, and groundwater pumping to sustain irrigated agriculture. Downscaled from a bias-corrected global climate model, their simulation forecasting examined roughly 100 managed streamflow scenarios (out to 2099), and combined that with an analysis of groundwater storage, irrigation, and soil moisture at a watershed scale. From that analysis, if we continue with the current status quo agricultural and land management practices, the following conclusions can be drawn: declining surface water availability and declining reservoir storage will increase pressure on strained groundwater supplies and deplete the regional aquifer under hotter and drier conditions. Consistent with this finding, but expanding out, a basin-wide modeling analysis for the Rio Grande/Rio Bravo in the United States and Mexico shows that consumptive water use in the river system overall is on an unsustainable path (Richter et al., 2025). Focusing on the part of the Rio Grande running through the state of New Mexico (which would include both the MRGV and Lower Rio Grande Basin in NM) it is estimated that 85% of consumptive use (direct and indirect) is overconsumption, which means that it is *unsustainable* going forward (and see in Olofinsao et al., 2026). For the Rio-Grande-Bravo more generally, Richter et al. (2025) find that over half (52%) of basin water consumption is unsustainable

If climate change implies less water, so that a regional system's water budget reflects increasing scarcity, we would expect to see changes to the distribution and composition of green. But warmer temperatures increase ET, and -- as will be seen and discussed more below -- measures of greenness and ET appear to be increasing in the 21st century in the MRGV *in the aggregate* (Figure 3). This may be hiding depletion to stocks elsewhere in the system (e.g., groundwater and regional aquifers [see Benavides et al., 2023; and Follingstad et al., 2026]). Increasing scarcity implies tradeoffs, which will play out in squeezing and altering the distribution and composition of green in the MRGV, and this may include across time.

¹⁰ As Trail and Ward (2024, p. 1) clearly state their integrated modeling analysis is nevertheless restricted to transferring water *within* irrigated agriculture "How can water trading programs be designed to help irrigated agriculture control economic losses from adapting to water shortages?"

Figure 3. Consumptive Use of Water on New Mexico's Middle Rio Grande



Notes: Effective ET in the Middle Rio Grande Valley from Cochiti to Bosque del Apache, including the greater Albuquerque urban area as defined by the Census Bureau. Data from the OpenET project (Melton et., 2022).

We clearly can't stay on this upward consumptive trend. But what's a region to do? We offer no simple prescriptions.

But we do know that we will have to collectively navigate this changing green-ness (this changing consumptive use of water), sometimes unhappily, within a web of institutional arrangements (the rules both informal and formal). This political economy includes some market mechanisms but mostly non-market allocation mechanisms (Randall, 1981; Champ et al., 2017). This all happens within a polycentric system of governance, where no single entity is in charge, and individual government agencies that are focused on their individual remits and water allocations and particular rule sets. Often, parts of the system are short on scarcity signals (e.g., when an aquifer is unmetered and being depleted). Other signals, like a drying stretch of river, as recently seen more commonly through the Albuquerque reach of the Rio Grande, are more obvious and visceral.

Commonly we rely on use measures to tell us something about scarcity. But these come with their own problems. Consider the classical case of the deceptively simple and widely used measure of municipal water use around which much water conservation goals are built: Gallons Per Capita Per Day (GPCD). There is no standardization across government units, but GPCD is typically (but not always) measured quite crudely as: total diversions in a municipal system divided by population of the service system area (Maloy, 2023).

If we solely target GPCD, say as applied to ABCWUA, it is a flawed measure in multiple ways. First, it is based on diversions, rather than consumptive use, and so doesn't capture or fully reflect the relevant measure for water 'use.' Second, while measuring average physical diversions per person it ignores the

resulting benefits (greenness etc.) or any net surplus value to municipal users (Ruddell & Rushforth, 2024; Bloetscher & Eustice, 2016). Third, it measures water diversions in the municipal system, but does not measure the *community's full diversions*, because it does not capture: (a) domestic wells (with at least 7,900 domestic wells within the ABCWUA boundaries, with permitted pumping rights of at least 22,000 AFY); (b) Non-ABCWUA major users within the community (Country Club golf course, University of New Mexico, Kirtland AFB, etc.); (c) Middle Rio Grande Conservancy District [MRGCD] irrigation of non-commercial agriculture and yards (which constitute the majority of irrigation users in at least three of four service counties (Sandoval, Bernalillo and Valencia, with the more rural Socorro County to the south the possible exception); and (d) Water use in the greater metro area – the Village of Corrales (about 8,500 people along the river, entirely served with domestic wells) and Sandia Peak Utility System area (about 6,000 people in far NE heights of Albuquerque). Fourth, it is a measure that can easily be ‘gamed’ if it becomes used as a conservation target (a phenomenon colloquially known as “Goodhart’s law” [Goodhart, 1975]).¹¹

To be clear, measuring, tracking, and understanding diversions, including diversions per estimated person served, are critical in municipal and agricultural systems from an engineering perspective and otherwise. The problems emerge when we start to manage for the score (e.g., GPCD) rather than the underlying consumption of water, because that score invites too simplistic comparisons. While GPCD has uses, it is a clear example of the “streetlight effect”: if we are using it to try to illuminate our overall consumption of water, we are looking for our keys in the wrong place. Thus, when a measure itself (e.g., GPCD) becomes the target, we must ask whether it is still a good measure? Or perhaps better to ask: what other measures are needed?

Below we focus on several alternative measures of how we are using water, before attempting to synthesize what we know about economic values for water in the MRGV.

II.2. Trends in Consumptive GPCD

When we talk about how much water a city uses, GPCD tells us how much measured water is withdrawn from rivers or groundwater and distributed through the utility system, divided by the number of people served and the number of days in each period. GPCD is widely used by water utilities across the United States (US) because it provides a consistent and simple way to monitor total demand and evaluate conservation efforts over time.

GPCD is a crucial engineering measure – it informs water agency managers how much water they need to be able to deliver to homes and businesses. But when we use it as the primary tool used to measure how much water a community’s members are using, we fall prey to a classic example of the streetlight effect. Urban water systems also generate return flows, meaning water that eventually returns to the system through wastewater treatment, at which point the water is once again available for use in ecosystems, and to downstream users. Because of this, not all withdrawn water represents a permanent loss from the local water supply. Water *consumption* refers to the portion of withdrawn water that is lost through evapotranspiration, evaporation, or outdoor water uses (e.g., Young & Loomis, 2014). It is *consumptive*

¹¹ Per *Wikipedia* (https://en.wikipedia.org/wiki/Goodhart%27s_law): “Goodhart's Law, named after British economist Charles Goodhart, was first articulated in 1975 in the context of monetary policy in the United Kingdom. The law highlights that any statistical measure or indicator loses its reliability once it is used as a target for decision-making or control, because individuals or organizations will adjust their behavior to meet the target, often undermining the original purpose of the measure.”

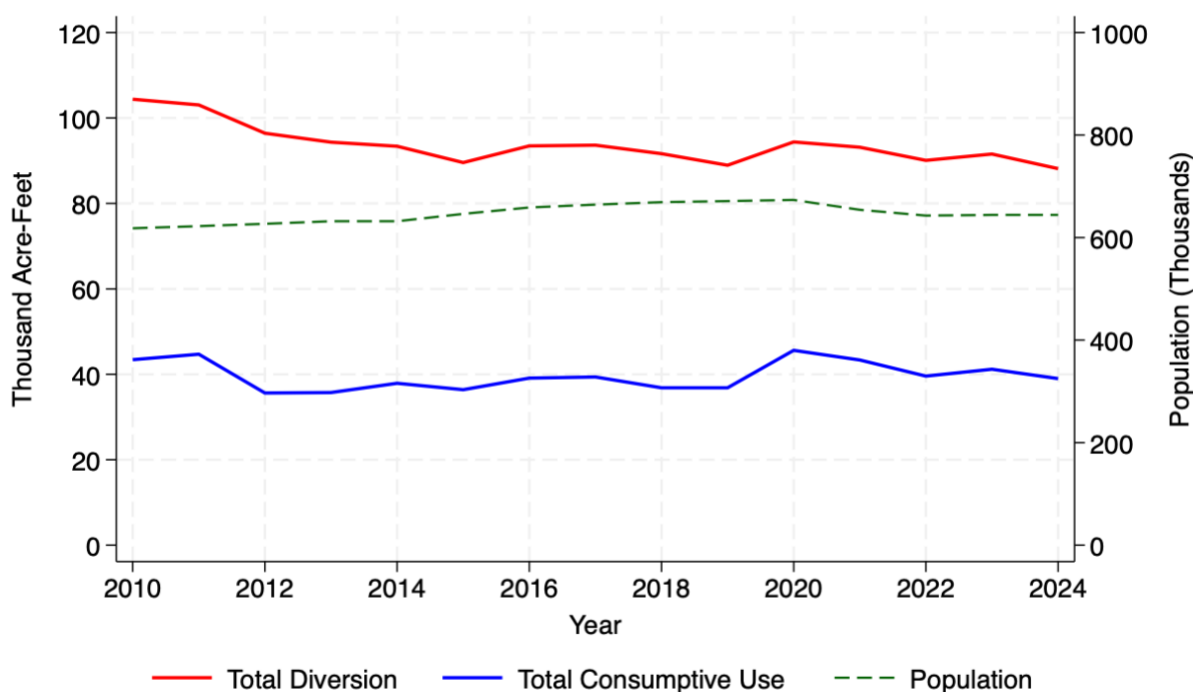
use that is the more important measure for tracking the available supply and demand of a region's water. For this reason, GPCD does not distinguish between water that eventually returns to the system and water that is lost. A new streetlight is needed.

To examine this difference more directly, two related measures are constructed: GPCD and Consumptive Gallons Per Capita Per Day (CGPCD). For this purpose, monthly data from the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) from 2010 to 2024 are used, including total system withdrawals, population served, and reported return flows.

CGPCD focuses on measuring the portion of water that does not return to the system. It is calculated as total withdrawals minus the amount of water that returns through return flows. By using the same per capita approach as GPCD, this measure allows total withdrawals and permanent water losses to be compared over time.

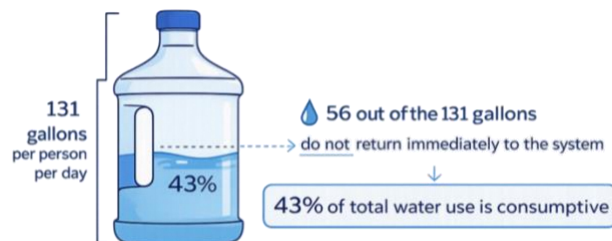
As a general trend, and as shown in Figure 4, total diversions have decreased over time. However, when examining total consumptive use, although fluctuations between years are still observed, the trend remains relatively stable, suggesting that there is no clear change in the overall level of consumptive water use throughout the period.

Figure 4: ABCWUA Annual Water Deliveries, Consumptive Use, and Population



Turning to per capita measures, looking at averages for the full period, and as shown in Figure 5, total GPCD within the ABCWUA service area is approximately 131 gallons per person per day, while consumptive GPCD (or CGPCD) is around 56 gallons per person per day. On average, around 43% of total water use is consumptive, while the remaining portion eventually returns to the system. In other words, a significant portion of water withdrawals does not represent permanent losses from the water supply.

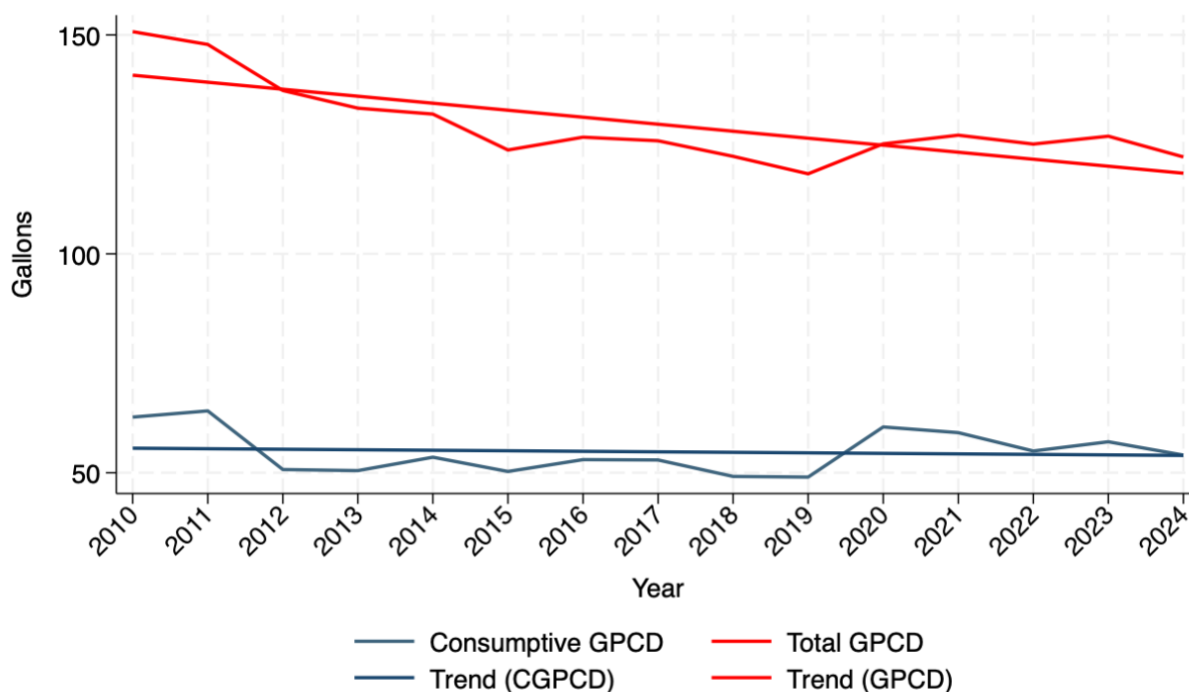
Figure 5: Total vs. Consumptive Water Use



While not displayed here, the data also show a clear seasonal pattern. Total water use increases during warmer months and decreases during winter, mainly because of increased outdoor irrigation. Because a large portion of outdoor water use is lost through ET, CGPCD tends to increase during these months. Throughout the year, monthly data present important fluctuations, suggesting that the timing of water use also influences the level of consumptive use. Smoothing out the seasonal fluctuation, we can look at annual trends.

Between 2010 and 2024, GPCD within ABCWUA shows a gradual decline, as observed in Figure 6. In 2010, total water use was close to 150 GPCD, while by 2024 it had decreased to approximately 120. CGPCD also presents variations across years; however, its changes are less pronounced throughout the period. While total water use shows a clearer downward trend, CGPCD remains relatively more stable between 2010 and 2024. They may both represent conservation stories, but they are not the same story.

Figure 6: Trends in GPCD and Consumptive GPCD (2010–2024)



The relationship between CGPCD and GPCD shows that the consumptive share of water remains relatively stable between 2010 and 2019, around 36–37% of total water use. However, after 2020 this proportion increases and remains close to 42% in the following years. On average, approximately 38% of total water use within ABCWUA was consumptive between 2010 and 2024.

In general, the results show that GPCD and CGPCD do not reflect the same behavior in water use. While total GPCD decreases, CGPCD changes much less throughout the period. Although total water withdrawals have decreased over time, the proportion of water that does not return to the system remains relatively more stable. This makes it important to consider both measures when analyzing changes.

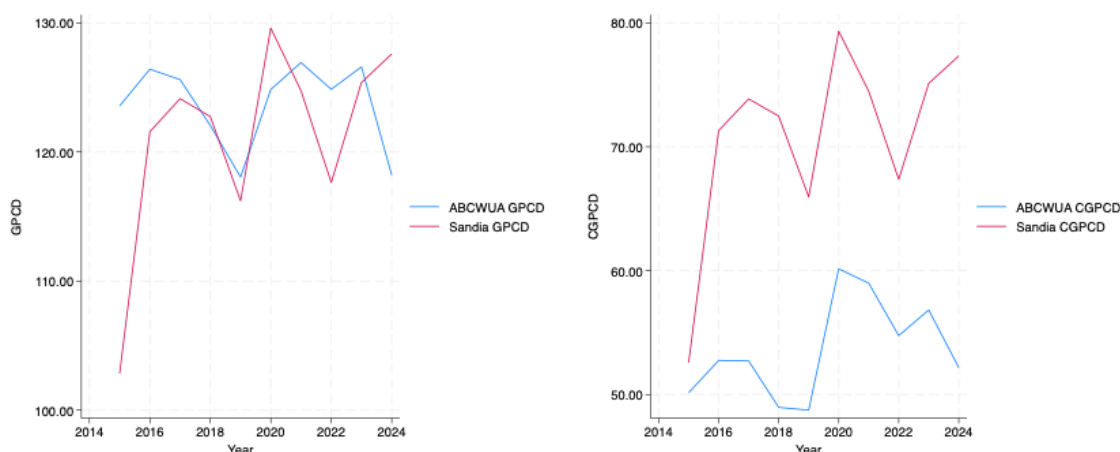
While ABCWUA is by far the biggest in the MRGV, it is not the only municipal and community water provider. There is enough additional residential use from these aggregated areas to counter CGPCD trends in ABCWUA. It is critical to start publicly tracking CGPCD for all community water providers.

Despite there being roughly a dozen community water providers with at least 1,000 residential connections, information about CGPCD is not easy to find or calculate. But to further examine how consumptive patterns may differ, the much smaller Sandia Peak Utility system is used as a comparison. Sitting just outside the NE boundary of the ABCWUA service area and serving about 6,000 people in a relatively affluent area, Sandia Peak Utility is entirely dependent on a system of three deep wells. It offers a nice contrast to ABCWUA. As shown in Figure 7, both systems tend to follow a similar pattern in their GPCD, although Sandia Peak shows a slight increase over time. However, the most important difference appears when comparing CGPCD. At the beginning of the period, both systems present relatively similar values; however, Sandia Peak's CGPCD gradually increases over time.

When also examining the proportion of consumptive use (CGPCD/GPCD) for each utility, the change becomes clearer. While between 2015 and 2024 ABCWUA maintained an average close to 43% consumptive use, Sandia Peak presented values above 58%. Part of this difference may be attributed to the fact that Sandia Peak does not have a complete sewer system. Since 2011, approximately only half of the population has been connected to the sewer system, and the increase in coverage during recent years has been less than 1%. As a result, a larger proportion of indoor water use does not return directly to the system, which may contribute to a higher level of consumptive use.

This analysis may raise more questions than it answers; certainly, one of those is to ask about longer time frames? We are pursuing what is possible to track further back in time from historical paper administrative files. But to emphasize, our argument is that GPCD and CGPCD don't move together, no one is tracking CGPCD, GPCD alone can be misleading as conservation indicator, and there is a need for all municipal providers to begin tracking both.

Figure 7: Comparison of GPCD and CGPCD Between ABCWUA and Sandia Peak Utility



Notes: Sandia Peak Utility CGPCD values for 2015–2024 were estimated using data reported in the Sandia Peak Utility Company Annual Reports, including number of residential accounts and total residential gallons sold. Following the same approach used by the NM OSE, GPCD was calculated by dividing total residential gallons by the number of accounts multiplied by the average household size, from the U.S. Census, and then divided by the number of days in the year. Consumptive GPCD estimates were then constructed using information from Sandia Peak Water Quality Reports regarding approximate indoor water use. Return flows were estimated based on the approximately 48.8% of the population connected to the sewer system, if only indoor water use from sewer-connected households returns to the system.

II.3. Consumptive Water Use: Trends in Effective ET for Varying Geographies in MRGV

II.3.a. Approach

As we first pointed to in Figure 3, this exploratory section analyzes trends in actual consumptive water use across selected regions of the MRGV and how this use has changed over roughly the last 25 years (2000 to 2024). Again, to emphasize this approach slightly deviates from the conventional water-use concept of ‘demand use’ or diversions and targets actual consumption or ‘consumptive use. Diverted water is water transferred from a water source (Vickers, 1999) through conveyances such as pipes and canals. Consumptive use is a fraction of the diverted water that is lost or consumed by plants, crops, humans, or livestock and hence not returned to the local source for reuse (U.S. Geological Survey [USGS], 2019). Consequently, consumptive use can be expressed as the difference between diverted water and return flows. This difference between diversions and consumptive use is analytically important for sustainable water management. As explained by Hoekstra et al. (2012, p. 1) generally a considerable slice of diversions becomes return flows (and thus available sequentially downstream):

“[A]bout 40% of agricultural water withdrawals typically return to local rivers and aquifers and therefore can be reused, so that the volume of water consumed provides a more accurate basis for estimating scarcity than the volume of water withdrawn.”

In the MRGV, water is crucial for agricultural irrigation, municipal, industrial, recreational, and environmental purposes (USBR, 2016). However, a significant fraction of this water is lost to evaporation from soil and open water surfaces and to transpiration from plants in arid to semi-arid regions like the MRGV. In this context, we use evapotranspiration (ET) as an indirect measure of consumptive use. Evapotranspiration is the scientific term for water loss from soil and plants to the atmosphere as vapor

(Allen et al., 1998). It combines evaporation (E) and transpiration (T). Evaporation is the process by which water turns into vapor and is removed from surfaces such as lakes, oceans, soil surfaces, and wet plant leaves (Allen et al., 1998). Transpiration is the movement of water from plants to the atmosphere through the plant leaf stomata. Together, ET helps monitor the distribution and composition of “green” water use across urban, agricultural, and riparian zones. With increasing pressure on water supplies in the MRGV due to a combination of climate change, population growth, competing sectoral demands, and the Rio Grande Compact, the long-term trend toward diminished streamflow in the region's rivers and reservoirs is clear, even accounting for year-to-year variability in monsoon intensity and snowpack (Gaume, as quoted by Paskus, 2026). Investigating consumptive use through ET provides a deeper understanding of how and where water is used and supports discussions of future allocations, tradeoffs, and management interventions.

Arguably, advances in remote sensing provide a reliable, cost-effective, and practical means to measure field-scale ET (Derardja et al., 2024) across the western US – a potentially valuable new streetlight. We access OpenET’s satellite-based evapotranspiration estimates through Google Earth Engine’s cloud computing infrastructure. OpenET is a community-driven effort that is building upon these advances in remote sensing to develop an operational system for generating and distributing ET data at a field scale using an ensemble of six well-established (eeMETRIC, SIMS, PT-JPL, SSEBop, DisALEXI, geeSEBAL) satellite-based approaches (Melton et., 2022). The platform also provides a combined-model output, referred to as the *ensemble mean*, which averages all six different models and hence improves accuracy in arid and semi-arid areas (Melton et., 2022). We derived ensemble mean ET values at a 30-m resolution for the time frame (2000-2024) and then aggregated to our regions of interest.

To illustrate this potential, and using the ensemble means in this exploratory investigation, we select a diverse mix of geographies, large and small, with varying characteristics, which include the following:

1. Albuquerque Bernalillo County Water Utility Authority (ABCWUA) service area
2. Levee zones (the riparian “bosque” between the levees) within ABCWUA
3. Village of Corrales (separate from Rio Rancho and Albuquerque, and dependent on domestic wells)
4. Levee zones (levee-to-levee) for the entire MRGV study area
5. Middle Rio Grande Conservancy District (MRGCD) boundary area, including levee zones
6. MRGCD boundary area excluding the levee zone area
7. The full Bosque del Apache National Wildlife Refuge (BDANWR) boundary area
8. MRGCD-intersected area within the BDANWR
9. A constrained (meeting a 0.275-EVI-Threshold requirement) MRGCD-intersected area within the BDANWR boundary area
10. A composite area of seven community water system boundaries in the greater Grant area (in MRGB), above Horace Springs on the Rio San Jose (tributary to the Rio Grande) and the Acoma Pueblo¹²
11. Sandia Peak Utility (separate utility in Albuquerque’s far NE Heights, dependent on wells)

ET measures alone do not fully capture the water balance in a field or region, as they do not effectively account for precipitation inputs. Thus, to estimate what can be referred to as *effective ET*, we use the

¹² The seven community water providers include Bluewater Lake Mutual Domestic Water Consumers Association, Bluewater Acres Water Users Association, Plano Colorado Estates, Milan Community Water System, Grants Domestic Water System, San Rafael Water and Sanitation District, Blue Water and Sanitation District.

formula (ET – effective precipitation). Effective precipitation is derived using the U.S Bureau of Reclamation rainfall adjustment method (Blaney & Criddle, 1962, as cited in Valdez et al., 2024), which expresses effective rainfall as function of total rainfall. The rationale is that not all rainfall is available for plant use. Some fraction of the total rainfall is lost to runoffs and deep percolation. This adjustment is crucial especially in arid regions and in theory gives a more valid measurement of consumptive use.

To be clear, OpenET was originally designed and calibrated for agricultural fields in the western US (Melton et al., 2022). In that way our geographies #6 and #9 are probably the closest to what OpenET was originally calibrated for (with #3 and #8 next closest). But research is beginning to move into applications in wider settings and understanding the needed calibration or appropriate choice of measure (Volk et al., 2024). In that same spirit of exploration, we pursue our 11 example geographies.

II.3.b. Results

While total unadjusted ET estimates remained relatively stable across most of the selected regions, consumptive use, as measured by *effective ET*, tends to show a generally upward trend. Our focus here, beginning with Table 1 will be on summarizing effective ET trends. For additional detail, see Appendix A for the data generation process, trends, and GIS maps of each of the 11 geographical areas we investigate.

Table 1. Summary of Effective ET (USBR adjusted Rainfall) Estimates for Select Geographies in the MRGV

Geography	Start Date (2000) AFY	End Date (2024) AFY	Linear Trendline (slope in AFY)
#1 ABCWUA service area	47,932	70,065	Upward (1,024*)
#2 Levee zone within ABCWUA	13,950	12,615	Not significant
#3 Village of Corrales	7,149	8,876	Upward (95***)
#4 Levee zone for MRGV	109,933	117,880	Upward (450*)
#5 Within outer MRGCD boundary	347,978	408,036	Upward (2,143*)
#6 MRGCD boundary, excluding levee zone	235,704	280,902	Not significant
#7 Full BDANWR boundary	20,090	34,620	Upward (477**)
#8 MRGCD-intersected areas in the BDANWR	27,864	31,645	Upward (229**)
#9 0.275-EVI-Threshold MRGCD in BDANWR	27,111	29,644	Upward (173**)
#10 Seven community water system boundaries (combined) in Grants area	2,343	1,361	Not significant
#11 Sandia Peak Utility service area	-136	1,180	Upward (50***)

Notes: The trendline indicates the direction of the effective ET over the study period. Upward implies statistically confirmed increasing trends (positive slope significant at 1%, 5% and 10% levels). Not significant denotes no statistically significant slope (upward or downward) at 1%, 5% and 10% significance levels (cannot reject the null hypothesis of no effect). The figures in brackets represent the linear slope coefficient, signifying the average annual rate of change in effective ET in acre-feet per year. Significance expressed as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Focusing on the adjusted measures, Table 1 presents effective ET estimates for the selected geographies, derived by adjusting total ET for precipitation using the USBR effective rainfall method. As a first conclusion, none of the 11 geographies evaluated show a significant downward trend, while nine show a significant upward trend.

Starting with the largest municipal water provider in the MRGV (and the state of NM), in the ABCWUA service area (#1), which covers the entire city of Albuquerque and most of Bernalillo County, effective ET increased from roughly 47,931.5 AF in 2000 to 70,065 AF in 2024, indicating increased consumptive water use. On average, consumptive use increased by about 1,024 AFY. Notably, effective ET measured within the ABCWUA service area is *not* equivalent to consumptive use of ABCWUA supplied water. The effective ET estimate captures all consumptive occurring within the service area, including water drawn from domestic wells and irrigation ditches that fall outside ABCWUA's delivery system. By conjecture, the increasing trend in consumptive use in the ABCWUA area might be attributed to several factors, including rising temperatures, which drive evaporative demand; population growth over the study period; and the increased outdoor use required to maintain existing landscaping (grass, trees, shrubs) under hotter conditions. But clearly, this consumptive trend is something that ought to give use pause.

The levee zone #2, containing the bosque but within the just ABCWUA service area showed no significant trend; i.e., the evidence supports relatively stable consumptive use within this riparian area. Speculatively, no one is applying water to this area and perhaps that explains the flat slope. However, the same flatness doesn't hold for the more extensive levee zone #4. For the levee-to-levee corridor, representing the active riparian zone between the levee system and the banks of the Rio Grande, and extending throughout the MRGV, there were effective ET estimates ranging from 109,993 to 117,880 AFY with a mean annual increment of approximately 450 AF, with a statistically significant upward trend.

Looking at the largest water allocator in the MRGV, within the full area served by the Middle Rio Grande Conservancy District (MRGCD) boundary (#5), estimated consumptive water use, as measured by effective ET, increased from 347,978 AF to 408,036 AF, with a statistically significant average annual increase of about 2,143 AF. Like with the ABCWUA service area, this estimate captures all consumptive use occurring within the District's geographic boundaries and is *not* equivalent to water delivered by the MRGCD. The effective ET figures capture consumptive use from all sources within the boundary, including domestic wells and irrigation ditches and any water not supplied by the MRGCD'S delivery system. This upward trend is consistent with evidence of increasing evaporative demand associated with hotter conditions in arid and semi-arid environments (Williams & Abatzoglou, 2025). The MRGCD lands excluding levee zones (#6), representing the non-riparian portions of the District, had an effective ET that rose from a starting point of 235,704 to 280,902 AF over the period, but the trend line was not statistically significant. .

Turning to our targeted irrigated agricultural site used for environmental purposes, in the full¹³ Bosque del Apache National Wildlife Refuge (BDANWR) (#7), a site well known for the many thousands of cranes, geese, and ducks who winter there annually, consumptive demand measured with effective ET rose from 20,090 to 34,620 AF, with a statistically significant average of 477 AFY. Again, the presumption is that upward trend reflects rising evaporative demand due to regional warming, which requires more water to maintain wetland conditions necessary for migratory waterfowl and other wildlife. However, to better represent consumptive use associated with the specific managed irrigation and wetland water delivery for the area, we intersected the MRGCD jurisdictional boundary with the Refuge boundary to isolate irrigated agricultural and wetlands within the Refuge. The MRGCD-intersected area within the BDANWR of 17,753 acres (#8) showed a similar upward trajectory, with consumptive use ranging from 27,864 to 31,645 AF, with a statistically significant average increment of 229 AFY. As an even further investigation into accurately capturing the agricultural and wetland areas within the BDANWR, an alternative approach

¹³ The full Bosque del Apache NWR denotes the original polygon extracted from the US FWS National Realty Boundaries dataset. The full BDANWR encompasses a mixture of wetlands, irrigated agricultural fields, riparian wetlands, and arid desert areas. No adjustment was made to the extracted polygon. The NWR covers 57,254 acres.

(#9) was developed that uses the maximum Enhanced Vegetation Index (EVI) derived from Sentinel-2 imagery for the period 2015-2025. The EVI threshold of 0.275 or greater was applied to isolate pixels denoting active vegetation, and the resulting area was intersected with the MRGCD boundary, rather than separating floodplain from desert. The resulting area of approximately 13,702 acres yielded consumptive use estimates ranging from 27,111 to 29,644 AF, with a statistically significant average increment of 173 AFY. It is worth noting that the inclusion of the desert vegetation within the Refuge boundary may be accounting for the lower ET or consumptive use values. This likely explains why the two approaches (MRGCD-intersected and EVI-based approach), despite covering lower acreages, closely matches the full Refuge values, as both approaches attempt to isolate the vegetated areas where a large portion of consumptive use happens. While still in exploratory stages, we argue that this initial evidence pattern reinforces the general efficacy of the OpenET tool in capturing consumptive use in vegetated and wetland areas.

Turning to an example for a set of communities that lie outside of the Rio Grande mainstem (but in the MRGB), we combine the geographies (#10) for the service areas of seven community water providers in the Grant, NM area that lie above Horace Springs (and thus above Acoma Pueblo) on the Rio San Jose. Lying within the MRGV, the Rio San Jose is a tributary to Rio Puerco (see Map 1), which is itself a tributary to the Rio Grande. Their combined water use is a natural policy concern for the Acoma and Laguna Pueblos as they wait for final US Congressional settlement of water rights disputes that stretch back nearly 50 years (Hopinkah, 2026). The effective ET results on consumptive use showed no significant trend line (i.e., relatively flat); thus, the evidence support the null hypothesis of no change. While of important NM policy interest (e.g., the Acoma and Laguna Pueblos' settlement cases before the US Congress), (Hopinkah, 2026), we also selected this combined Rio San Jose area as a control region to provide a baseline comparison against the other study geographies. These small municipal water systems are in arid uplands with virtually no irrigated agriculture or riparian vegetation. The observed near-stable, statistically insignificant trends found here are consonant with the conjecture that confirmed upward trends seen across most selected geographies (MRGCD, Corrales, BDANWR) might indicate genuine increases in consumptive-use-driven by rising temperature, irrigated agriculture, and dense riparian vegetation.

We also examine two greater Albuquerque area communities that are entirely dependent on wells for water supply, one is on the valley floor (Corrales) and the other (Sandia Peak Utility) is relatively high up the eastern mesa (i.e., they have very different pumping cost requirements and depth to groundwater). For the Village of Corrales (#3) (a small community of 8,500 residents along the Rio Grande, north of Albuquerque and east of Rio Rancho, and dependent on domestic wells), effective ET rose from 7,149 to 8,876 AF with a statistically significant annual average increment of 95 AFY. Sandia Peak Utility (#11) (serving a population of approximately 7,500; Sandia Heights Services, n.d.)— a water service area around the Sandia foothill northeast of central Albuquerque has effective ET estimates ranging from -130 to 1,180 AF with an annual average increment of 50 AFY.

Finally, to be clear this section is *exploratory* and we are pushing against the capabilities of applying OpenET, which was originally built and calibrated for larger agricultural parcels. But change in this research arena appears rapid (e.g., new tools for down-scaling to improve estimates for smaller parcels, other ways to reduce systematic errors, and application to urban areas). In our own work, efforts are underway to refine calibration and comparisons of the effective ET estimates, as calibrated from OpenET, to smart irrigation system measured water applications to the more than 200 irrigated parks within the City of Albuquerque (see preliminary discussion in O'Neill, 2026) and to residential parcels served by the ABCWUA.

This section may raise more questions than it answers; however, using this promising new streetlight of effective ET (using OpenET, adjusted) to explore different observed geographies in the MRGV seems to

indicate a pattern of increasing (or occasionally flat) consumptive water use in a changing climate, but with substantial heterogeneity at finer scale (e.g., individual neighborhoods). Understanding where water use is going up and where it is going down, and what the sources of water are at these finer scales, will be critical to informing judgments about our response to increasing scarcity.

II.4. Trends in Domestic Wells

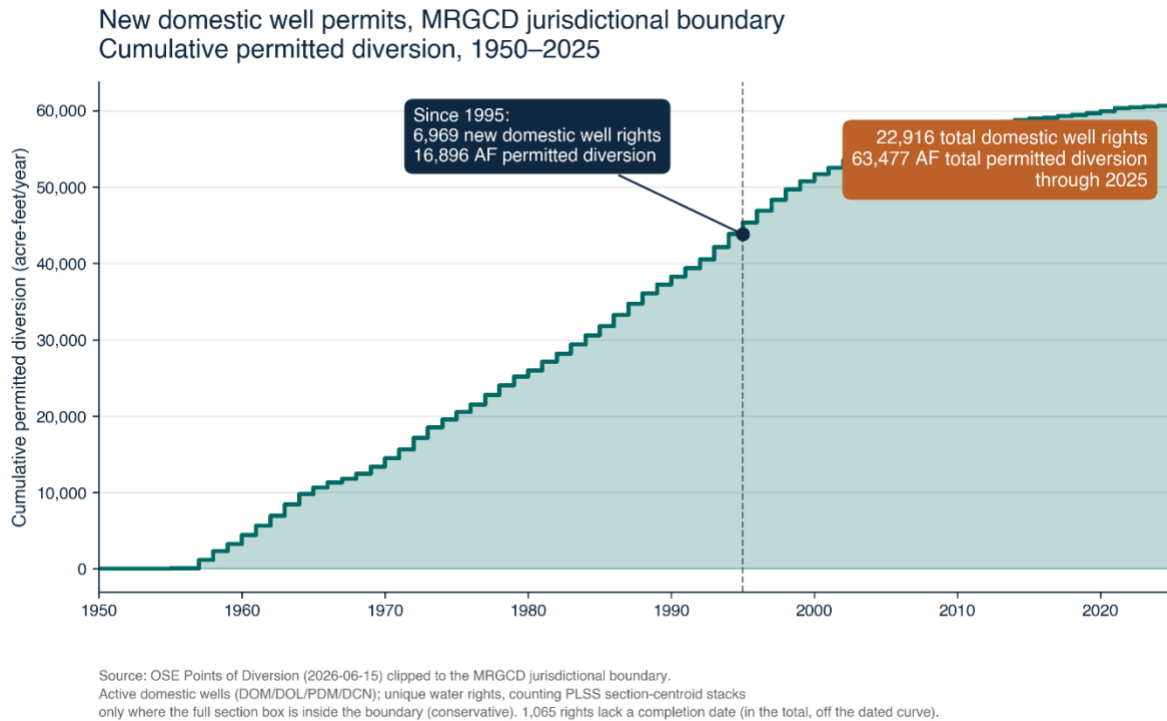
One of the most important areas of water use falling outside of traditional management streetlights in the MRGV is domestic wells. Further, rising effective ET results in Corrales pique our interest in domestic wells.

NM state statute grants homeowners the right to drill a well to meet domestic needs. Prior to 2006, a homeowner was permitted to pump up to three AFY from domestic wells, with new permits issued since 2006 limited to 1AFY. With a small number of exceptions, there is no metering or monitoring requirement (Bossert & Armstrong, 2014). The resulting patterns of water development and use in the MRGV have been heavily influenced by this use of water, with some communities, most notably the Village of Corrales in Sandoval County, entirely dependent on unmetered domestic wells for residents' supplies.

There is significant uncertainty about the locations of many wells, and no available data on whether wells listed as “active” in the NM Office of State Engineer (OSE) database, especially well permits issued prior to 1990, are being used. But a conservative estimate of the total number of domestic wells in the MRGV suggests a substantial unmeasured, unquantified, and therefore unmanaged use of water that has continued to grow across the last half century.

As shown in Figure 8, within the valley floor area of the MRGV, we have conservatively identified at least 22,916 unique domestic well water rights, with total permitted pumping rights of 63,477 AFY. Within the ABCWUA service area, we have identified 7,901 unique domestic well water rights, with total permitted pumping rights of 22,465 AFY. In both cases, the number of domestic wells continues to rise.

Figure 8. Cumulative Domestic Well Water Rights on the Floor of New Mexico’s Middle Rio Grande Valley



For comparison, assuming domestic wells are currently pumping their permitted rights or eventually increase their pumping to what is legally allowed, for the less than 8,000 domestic wells just in the ABCWUA service area, the 22,500 AFY of consumptive use would be equivalent to ~55% percent of the total annual consumptive by water users connected to municipal water in the entire ABCWUA, with approximately 193,000 residential connections, and an estimated population served of 660,000 (Albuquerque Bernalillo County Water Utility Authority 2025, p. 101 and 125). It is worth highlighting the magnitude of this result. If we consider the aggregate number of domestic wells across the floor of the MRGCD, and make the same assumption, then combined annual consumptive use via domestic wells would be greater than the entire combined Albuquerque and Rio Rancho municipal systems (consumptive use, and not just on the valley floor).

Individually, domestic wells may be thought of as a *de minimis* use, but in their aggregate consumption they appear to have grown over the last two generations to now be larger than the primary municipal providers. Without accurate records on current use, including metering, we do not know how much of the valley’s current human usage is the result of domestic well pumping. Is it less than the total permitted? Is it more? This cries out for the development of new streetlights, whether using remote sensing tools like OpenET or through mandatory metering.

Efforts are currently underway by the New Mexico Interstate Stream Commission (ISC) to begin to create the new observational tools needed to bring domestic wells into the field of view of our water management streetlights. One key finding (Lewis, 2026B) is that parcels connected to a public water supply system that also have a domestic well tend to consume more water for outdoor irrigation, such as those identified above within the ABCWUA boundaries. This appears to be more common on the Rio

Grande Valley floor, where groundwater is shallow and therefore pumping costs are relatively low. (Lewis, 2026B). This suggests an important gap in our understanding of community water use when we focus solely on the portion of a community's consumptive use needs met by public water systems. Efforts also are underway to quantify the amount of water used by homes with domestic wells that are providing the homes' sole source of water, though, with no metering, uncertainty bounds are wide (Lewis, 2026A).

To help shine a bit more light on the domestic well issue for the MRGV, we provide several additional pieces of exploratory evidence (Fleck and Oglesby, 2026). In the first, we take Map 3, which presented spatial trend patterns in consumptive water use (effective ET) for the Albuquerque urban area, and overlay with the spatial pattern of domestic well density (Map 4 below). The areas of "wet and gaining water" (Maps 3 and 4) appear heavily correlated with the density (and growing count [Figure 8]) of domestic wells.

However, across Maps 3 and 4, it would have to be recognized that the consumptive use can have multiple, sometimes overlapping water sources (domestic wells, and/or ABCWUA municipal service (or some other municipality), and/or MRGCD ditch access). Thus, to begin sorting through multiple sourcing questions, and further investigate questions of domestic well consumptive use in the aggregate, and in relative terms, we present Figures 9 through 12.¹⁴ Figures 9 to 11 focus on the roughly 200,000 residential parcels in the ABCWUA service area. Figure 12 extends out to the broader MRGV, to look at major use categories.

Figure 9 shows that lots with domestic wells and/or (MRGCD) ditch water tend to be bigger on average.

Figure 10 shows that lots with domestic wells and/or (MRGCD) ditch water access are greener on average.

Figure 11 shows that bigger, greener lots mean much higher use per parcel.

Figure 12 aggregates our consumptive use of water in the larger MRGV into the four major use categories, based on best available estimates (recalling that much of this is unmetered).¹⁵ As shown, and unsurprisingly, the largest use category is agricultural use (excluding the Pueblos and protecting their data sovereignty). Roughly half of that agricultural consumptive use is estimated to be commercial irrigators and roughly half is estimated to small noncommercial irrigators (Olofinsao, 2025; Olofinsao et al., 2026). With large error bars, it is estimated that aggregate domestic well use would be about the size of that noncommercial agricultural irrigation use. While the lowest major consumptive use would be the combined MRGV municipal users. For context, the rough estimate of the MRGV bosque (between the levees riparian areas may be about the size of the combined agricultural consumptive use (see Table 1).

There is a lot to further investigate and illuminate (e.g., to begin thinking about how these uses get valued). And we emphasize that this initial look (Figures 9-11) was for the ABCWUA service area and doesn't explore consumptive use in areas of well density (e.g., Village of Corrales and North Albuquerque Acres) outside of municipal service areas. But there is one clear conclusion about domestic well use in the MRGV: *de minimis no more* (and see Fleck and Oglesby, 2026).

¹⁴ Replication and data repository: <https://github.com/johnrfleck/New-Mexico-Middle-Rio-Grande-Valley-water-use-analysis>

¹⁵ It might be controversial to some to include the between-the-levees bosque as a use category, we include it for reference. Yet it is part of a highly engineered system, where we regularly make management choices that affect it.

Map 4. Domestic Wells and Water Use Trends (Combined), for Albuquerque Urban Area

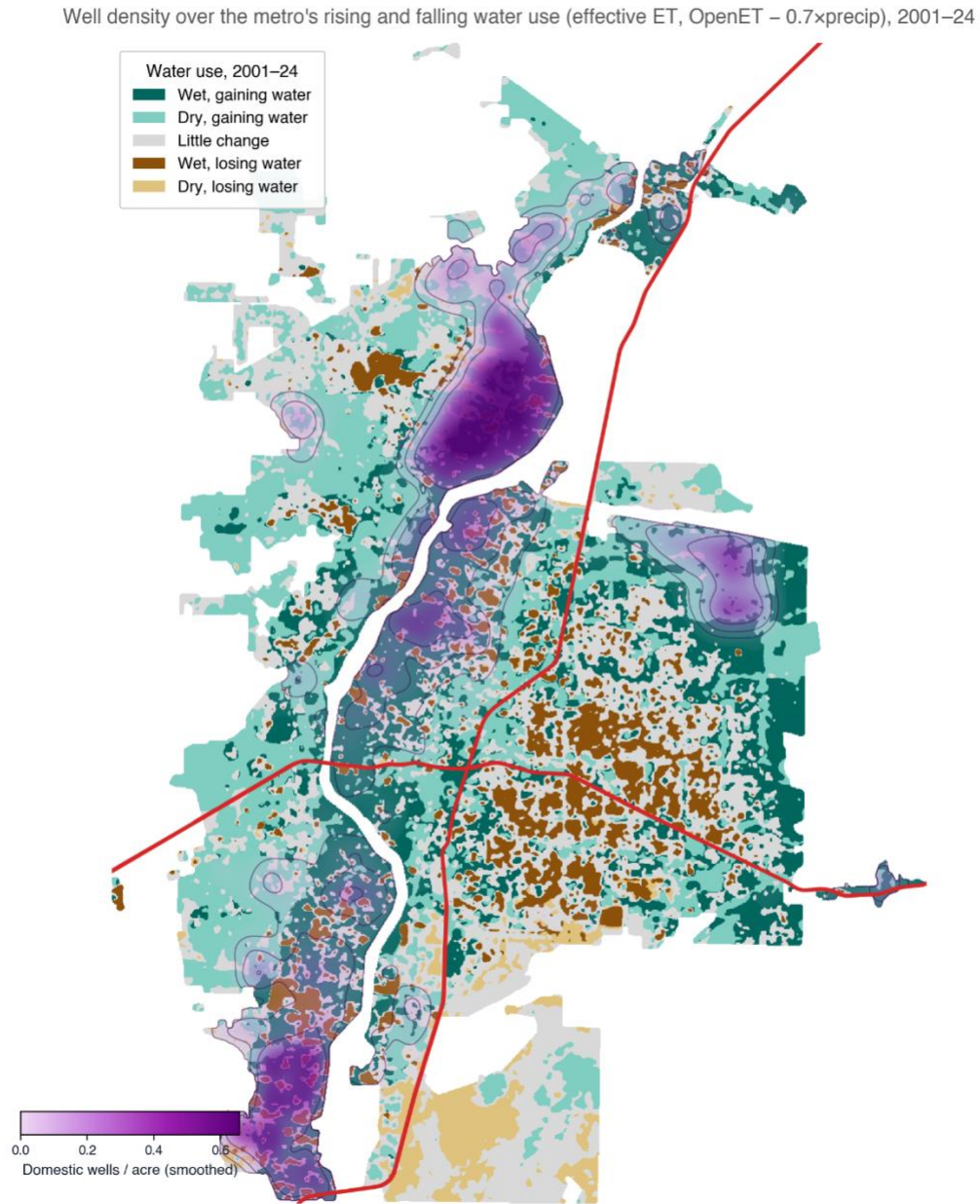


Figure 9. Lot Size by Water Source Access, ABCWUA Service Area

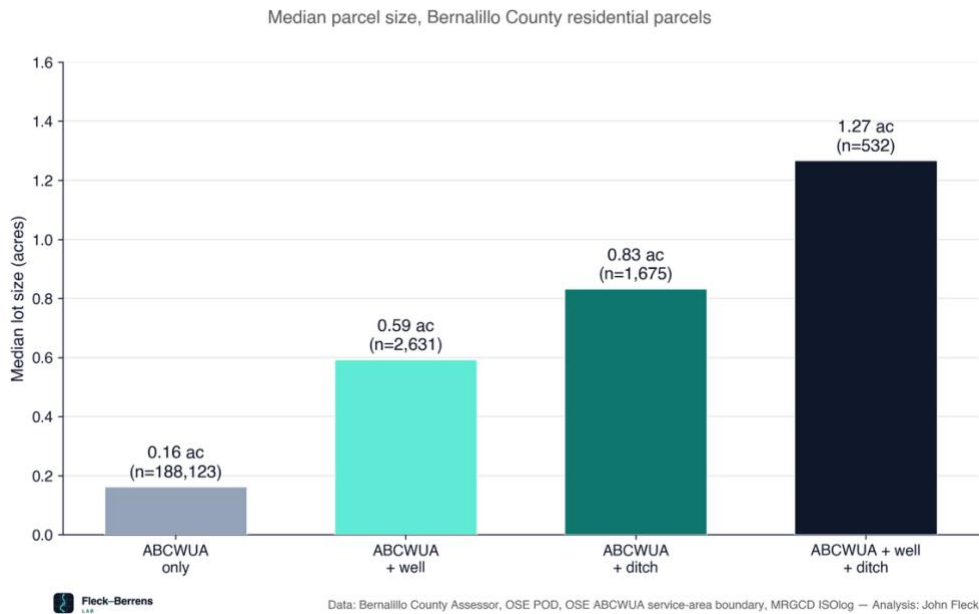


Figure 10. Effective ET, by Water Source Access, ABCWUA Service Area

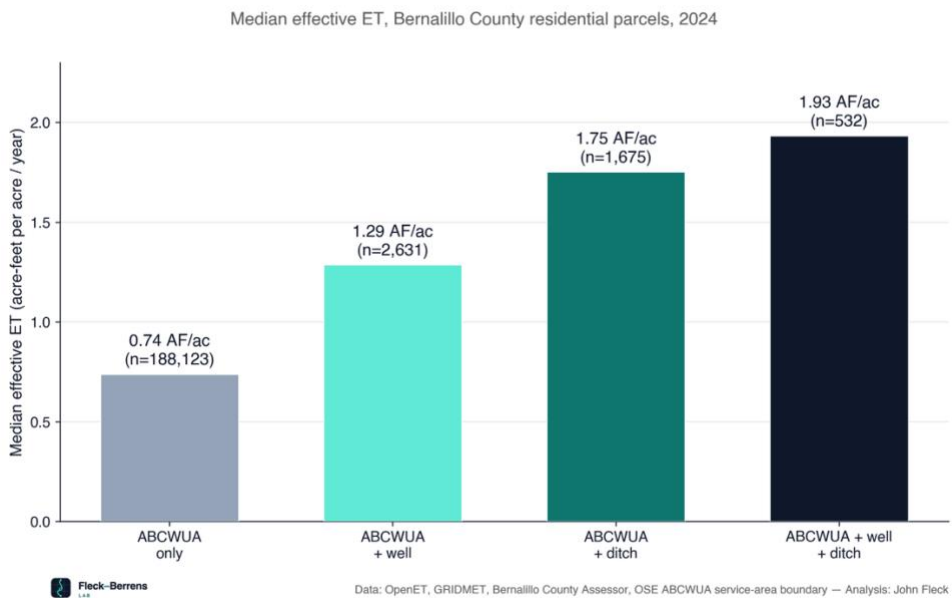


Figure 11. Total Water Use by Water Access in the ABCWUA Service Area

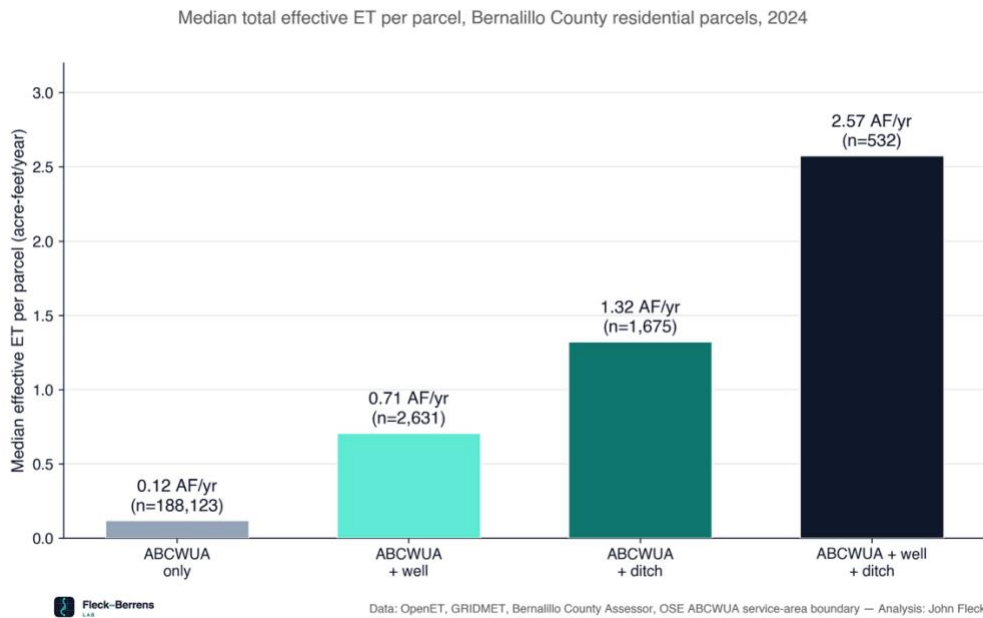
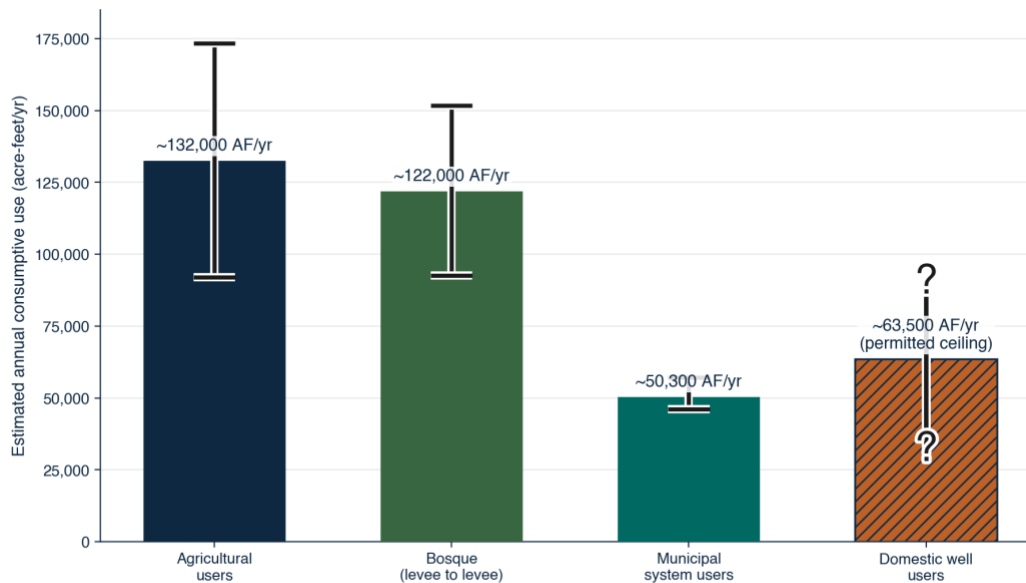


Figure 12: Estimated Annual Consumptive Use by Major Category MRGV/Greater Albuquerque



II.5. Trends in Net River Flow Reduction

II.5.a. A Growing Deficit Creates Risk to the MRGV

One of the most important streetlights illuminating water use and management in New Mexico's Middle Rio Grande Valley is the annual calculation of how much water the valley "owes" to downstream users in southern New Mexico and Texas under the requirements of the Rio Grande Compact, and how much is delivered into Elephant Butte Reservoir. Matching actual deliveries with Compact requirements has vexed New Mexico water managers and their federal partners for much of the last century (Reynolds & Mutz, 1974; Trueblood et al., 2024). As previously shown in Figure 1, in recent years New Mexico's deficit has grown, running a risk that New Mexico's debt could cross a tripwire leading to interstate litigation, with Texas suing New Mexico on behalf of those downstream users. That has led to calls for regulation of water use in the Middle Rio Grande to prevent such an outcome (New Mexico Water Advocates, 2026).

New Mexico's Rio Grande Compact obligation is based on a formula relating inflow to the Middle Valley at the Otowi gage to the amount of water arriving at Elephant Butte Reservoir. It is calculated annually, and includes adjustments based on upstream reservoir storage and trans-basin diversions that since the completion of the San Juan-Chama project for the importation of Colorado River Basin water into the Rio Grande Valley in the 1970s have added water to the Rio Grande's flow. Those adjustments make teasing out the actual consumptive use in the Middle Valley, and its relationship to our Compact debt, difficult to apply to the necessary public policy discussions in which we must engage. Efforts to tease out statistical relationships in NM's Compact accounting flows have been unsuccessful (Trueblood et al., 2024).

To understand the challenge, our "streetlight" metaphor requires an ad hoc modification, because to deal with the challenges we need two sets of keys. The first is the annual Rio Grande Compact credit and debit report. We need this to comply with our legal and moral obligations to downstream communities. But, as we will see below, the adjustments for reservoir storage and trans-basin diversions that are included in the calculation as a legal necessity obscure the second set of keys we need – a clearer understanding of how we are actually using water in the Middle Rio Grande Valley, to help guide the difficult choices we face as we reduce our consumption.

To begin to fill this gap, we suggest a second approach - Net Flow Reduction (NFR). It represents a simple mass balance difference between the total amount of water flowing into the MRGV at Otowi each year, minus the total amount of water flowing out of the valley at San Marcial. By sidestepping the statistical challenges posed by adjustments included in the formal Compact credit/debit calculation, it allows us to begin teasing out details of changes in how we use water.

It allows us to pose a series of basic questions:

- Has actual San Marcial outflow for a given Otowi inflow changed over time?
- What impact has changing climate had on the inflow–outflow relationship?
- What impact have changing population and water management activities had on the inflow–outflow relationship over time?
- How has the relationship between measured flows along the river changed over time, and how do those relationships compare to changes in river diversions and return flows by major water users?
- How does the changing hydrology of the stretch of Rio Grande downstream of San Marcial – the Elephant Butte Reservoir delta – influence New Mexico's ability to meet its Compact obligations?

NFR is not intended to be a replacement for one of the most powerful new streetlights currently under construction, the New Mexico Interstate Stream Commission's MIKE SHE modeling framework (NMBGMR 2021). [While in development for several years, MIKE SHE is not publicly available, or yet

open to verification.] Rather, we view the proposed NFR as potentially providing a conceptual framework that is complementary to the MIKE SHE works in allowing consideration of a much longer time frame to understand the changes in MRGV water inflows and outflows over modern era of river management, dating to the early 1950s. Most importantly, it creates a relatively easily replicable and extensible tool that leverages open data and new, more accessible data analysis tools made possible by LLM coding agents to *democratize* access to this critical water management question: a do-it-yourself streetlight.

II.5.b. Net Flow Reduction Over Time

To create our Net Flow Reduction dataset, we subtract total MRGV outflow, as measured in acre feet per year at two gages at San Marcial (the Rio Grande’s main channel and the adjacent Low Flow Conveyance Channel), from total inflow at the US Geological Survey gage at Otowi. Calculated over 1952 to 2019 – the period for which stream gage data allows reliable inflow-outflow calculations – our Net Flow Reduction analysis supports the observation driving current Rio Grande Compact compliance water policy discourse: for a given inflow at Otowi, less water is reaching San Marcial. Prior to the 2000, the river’s flow declined by 26% as it passed through the MRGV. Since 2000, the river’s flow has declined by 40%. This finding appears consistent across dry years and wet years and is like the results when Compact accounting index flows are used (Trueblood et al., 2024; authors’ calculations).

This suggests several hypotheses worth testing as possible explanations for decreasing outflow:

- a warming climate increasing evaporative demand on the valley’s ribbons of green;
- an increase in groundwater wells on the Rio Grande Valley floor, which in drawing water from the shallow aquifer may be causing near-term reductions in flow—both agricultural and domestic;
- an increase in deep groundwater pumping with municipal wells, which by creating a cone of depression may cause longer-term reduction in flows as water seeps from the riverbed and shallow aquifer to fill the cone of depression.

Our preliminary screening analysis suggests rising temperature, while significant, is insufficient to explain the net reduction in river flow, and the impact of changing summer monsoon rains is negligible. Our results are also robust exclusion or inclusion of measured side inflows from the Rio Puerco, the largest natural tributary in the MRGV.

Our preliminary analysis also suggests at least two countervailing forces which might, at various time scales, have led to an increase in outflow for a given inflow:¹⁶

- a “river subsidy” caused by deep municipal groundwater pumping, which in the long run reduces the river’s flow by drawing down the cone of depression, but in the short run might have increased flow as pumped groundwater used indoors was treated at the valley’s municipal wastewater plants and discharged into the river;
- a decline in irrigated acreage, a trend in reduced farming in the Middle Rio Grande Valley documented in the Census of Agriculture (U.S. Department of Agriculture, National Agricultural Statistics Service, various years).

This discussion may raise more questions than it answers, and it may shine light in places we do not need it – because it is not a likely place where we have lost our keys. But the point is about expanding streetlights and experimenting with their utility.

¹⁶ Replication code and detailed description of methodology available at <https://johnrfleck.github.io/New-Mexico-Middle-Rio-Grande-Valley-water-use-analysis/docs/index.html#>

III. ECONOMIC VALUES AND MEASURES FOR ALTERNATIVE USES OF WATER

III.1. Background Discussion

Even if we push discussions toward tracking both water diversions and consumptive uses, with a burgeoning set of technological and democratized tools (e.g., use of OpenET, or use of AI tools to bring domestic wells into the discussion), a corollary question seldom discussed is: what economic values are generated by different and competing water uses? Economic values rarely enter the public sphere around water. To wit, public entities rarely charge for water itself, or how scarce it might be (Hanemann, 2006). For example, in their recent review, Garrison et al. (2026, p. 1) find that most water sourced through the federal government on the Colorado River and elsewhere in the western US is provided at charge amounts that do not reflect scarcity; For the federal wholesale providers on the lower Colorado River:

“[T]he price paid by wholesalers, districts, and utilities reflect only the cost for delivery of the water—the capital costs of the conveyance infrastructure or the cost for operations and maintenance—and even then, the price remains inexpensive. The water itself, the actual corpus of water taken from the Colorado River and other streams, is free or nearly free.”

As with other forms of natural capital treated similarly, the trap, as argued by Sir Parth Dasgupta (2025), is that as individuals, communities and policymakers take nature for granted as a free resource, then depletion trends may be accelerating; Dasgupta advocates for recognizing the value of nature as an asset that is increasingly unable to replenish itself at the same rate with a changing climate.

We are interested in economic value estimates because water is scarce -- and thus involves tradeoffs -- and is growing scarcer with climate change. Relative values help us help us understand choices, and their opportunity costs (in terms of foregone benefits), and help us understand incentives (e.g., where transfers may be likely to occur, or investments made). This is a glaring example of a missing streetlight – not simply how much water is being used, and where, but what are the values communities get from that use?

But it is a conceptually challenging streetlight to build because, as discussed by Garrick et al. (2020; and see Young & Loomis, 2014), water is different. It is not like economic goods that are commonly priced and traded in functioning markets. Garrick et al. (2020) describe water as different in the following ways:

- (i) Water is mobile.
- (ii) Water supply is highly variable, spatially, temporally and in terms of quality.
- (iii) Water is heavy and this mass creates economic cost problems.
- (iv) Water can have multiple uses, which in differing settings may be simultaneous, rival, or sequential.
- (v) Water may be non-rival in those cases (e.g., instream flows), where one person’s valuing doesn’t reduce that of others.

Water can be both the desired good itself, and an input into other goods. Taken together, these characteristics imply that there are significant challenges to implementing efficient markets. Perhaps most prominently, there are high transactions costs (Womble & Hanemann, 2020).¹⁷ The implication is that

¹⁷ Beyond the costs of producing or provisioning a good or service, transactions costs (TC) are additional expenses incurred when attempting to transfer that good or service and are generally considered a significant source of inefficiency in capturing gains from trade. In the context of water resources, where TC can be significant, these might include search and information costs, including matching buyers and sellers in thin markets, bargaining costs, monitoring (water quantity and quality) costs, and legal or administrative costs of leasing or selling water rights and then enforcing the terms of those exchanges. Policy-induced transaction costs (PITC) can include required hydrologic and engineering studies. While some transaction costs are a function of the physical characteristics of

often there will be combinations of market, as well as non-market (collective) provisioning of water uses. In response, economists use combinations of direct market assessments, and a battery of non-market approaches to investigate water values.

The literature investigating the value of water, involving both economists and other scholars, is vast, and we make no pretense of fully reviewing it here.¹⁸ Rather, the objective is to provide a cataloguing of known estimates of the economic value of water in alternatives categories of use and protection in the Midde Rio Grande Valley (MRGV). The set of values is incomplete, often hard to compare across uses and estimation methods or approaches. Some select estimates are for consumptive water uses (i.e., ET); this consumptive use is sometimes called depletion as in the water is no longer available in the system for additional use. In some cases, these values are for water at the top of a system (“at-source”), releases or melt from snowpack. In many cases these values are for delivered water at a particular location which may or may not be the location of expected use (“at-site”). Water varies not just in location, but in quantity, quality, and timing. It may be treated and piped to a desired site. Or it may simply be diverted and conveyed through an acequia, ditch or canal. Water can also be placed or left in storage (reservoir or aquifer) for some future use or option, or in the case of a reservoir maintained for a current use (e.g., boating or fishing). Here the reservoir would be subject to evaporation losses (and thus consumption in maintaining a desired lake level). Water may also be placed or left in a river for either endangered species and habitat protection, or outdoor recreation and rafting, or all the these. If left in river for desired uses, it may need to be shepherded downstream to meet that use. While water in a river is not typically thought of as consumptive use, there will be some surface evaporation, and some ET by riparian vegetation (as well as some connectivity with the shallow aquifer). The key point is that all of these can create problems for

water, PITC’s can be part of water market design (McCann & Garrick, 2014), such as the locus of who bears TC (i.e., an applicant or objector to proposed transactions). For example, Colby (1990) argues that PITC can be used to force the consideration of social and environmental externalities, that might otherwise be ignored by water buyers and sellers and potentially be a legitimate tool for improving social welfare.

¹⁸ For some context, a reviewer provided some key references and suggested a footnote on the water-as-a-right versus water-as-a-good framings that are sometimes juxtaposed against each other. Briefly, an example of a normative claim for water as a human right rather than a good rests on the essentialness for life and health via access to the first few units. See: UN General Assembly (2010) Resolution 64/292, which (p. 2) “Recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights.” The caveat is this resolution goes on to also recognize the global challenges of needed funding and financial resources (i.e., provision of meeting these human rights isn’t costless). Further, there can also be religious arguments to protecting access to water more generally, and philosophical arguments to any *privatization* of water (e.g., Barlow, 2007). For a related MRGB example, see the discussion of the Isleta Pueblo/City of Albuquerque legal water quality case that began in the 1990s (Fleck & Berrens, 2026). An example of the counter framing (water-as-a-good) is seen in the *Dublin Statement on Water and Sustainable Development* (International Conference on Water and the Environment, 1992, no pagination), which holds that “water has an economic value in all its competing uses and should be recognized as an economic good.” Here the argument is that allowing water to be treated as a right (beyond minimum needs) risks it being treated as an open access resource (unpriced, unmeasured and unmanaged). Even pricing it below the full costs of supply removes the scarcity signal that would otherwise encourage conservation, direct water toward beneficial uses, and generate needed revenues to fund provision (Rogers, de Silva, and Bhatia, 2002). Putting aside the *res nullius* case, treating water as free is not neutral in a managed system (e.g., even “shepherding” instream flows has costly monitoring). However, the caveat here is that the Dublin Statement’s Principle 4 includes the careful qualification of recognizing human rights to accessing clean water and sanitation at *affordable prices* (i.e., there is an equity dimension and a need for collective involvement if not provision). Philosophical efforts at reconciliation in such debates often lie in not converting water provision to a mutually exclusive, either-or choice (economic-good vs. human-right framing). For example, the two positions are commonly reconciled in collective provision systems through implementation of tiered pricing (i.e., increasing block rates [IBR]), or pairing low initial charges with conservation surcharges inside constrained supply systems. As found elsewhere, our review shows both philosophic perspectives actively argued or asserted in the MRGV.

meeting any given desired use, and thus costly efforts to alter some dimension will affect the net value of that desired use. This illustrates the difficulty of building and using a valuation-based streetlights. But that difficulty is no reason to ignore the question. The value received for water in alternative uses must be an element of our discussion of the needed tradeoffs. We must do our best to illuminate this space.

For the economist, water provides an instrumental value that generates utility to consumers and producers. This value can be monetized in well-functioning markets, through either permanent sales or temporary leases, as revealed in prices. The price of water (for either sales or leases) in such markets represents the value of water, from an efficiency perspective (Ward & Pulido-Velazquez, 2009). But as noted by Brown et al. (2025), “When markets are thin (i.e., not enough buyers or sellers), weak (i.e., contain information asymmetries, excessive transaction costs, poor property rights, etc.), or nonexistent, then water cannot be accurately priced—but people still value it.” Further, unlike, say, standard, graded agricultural commodities, we don’t expect the *law of one price* to regularly hold (see Edwards & Libecap, 2015). With water, it would not be unexpected to see different buyers (e.g., environmental, municipal, and industrial users) paying more than agricultural users, or for prices or rates charged to vary in ways not easily explained by underlying costs of provision.

To provide a bit of preliminary context, outside of the MRGV but in a prominent western US location, we can consider San Diego. Of note, municipal water rates charged to households are considered relatively high in San Diego, where the cost of providing desalinization water to municipal users for the San Diego Water Authority was recently reported as roughly \$3,500/AF, while acquiring (leasing) untreated water from Imperial Valley farmers was about \$850/AF, and \$1,528/AF if purchased from the Metropolitan Water District of Southern California (Elmer, 2026). This can be contrasted with farmers in the Imperial Irrigation District (IID), which in recent years have paid roughly \$20/AF for their deliveries of Colorado River water, through a system of federal projects (Elmer, 2023). While this indicates the kind of range that can be observed across different supply sources, none of these are prices for access to a permanent annual water right, typically referring to some surface water diversion or groundwater extraction; here the observed purchase amounts across the western US can range from a few thousand dollars to over \$50,000. The takeaway point here being not just variability, but also understanding context (e.g., what current or historical subsidies may be happening within a federalist system), and what exchange is taking place.

Since it can be difficult to keep terms sorted, we will attempt to reserve the use of the term price to refer to a situation where a market exchange or transaction occurs between a willing buyer and seller, and the seller is attempting to make some profit or return above their costs of providing the water; the term charge will be used to refer to the monetary amount some public entity charges users for providing water; and the term rate or rate structure will be reserved for the payment structure (e.g., two-part, fixed and volumetric) that consumers must pay to use water from some municipal or community water provider. We will reserve the use of the term cost to refer to supply side monetary requirements for providing water. Economists think about the benefits¹⁹ (or demand-side), of water use separately from the costs (or supply-side) or

¹⁹ To help understand the complexity for comparing alternative water uses, and what may be left out of any given study, consider Ward and Pulido Velazquez’s (2009, pp. 297-298) conceptual discussion of measuring just the benefits-side in their partial equilibrium, regional modeling efforts for the Rio Grande:

“Water decisions in the Basin can produce both use-related benefits and environmental benefits. Both are defined by the total willingness to pay. For agricultural uses, the willingness to pay is measured by the contribution of water to net farm income. For urban uses, it is measured by price per unit water times the number of units sold to the customer plus any consumer surplus. Consumer surplus is measured as the area beneath the demand function and above actual price charged. For environmental benefits, willingness to pay is measured as the maximum price that could be charged to visitors at the Basin’s six major reservoir-based recreation sites. Important excluded environmental values include benefits produced by instream flows at non-reservoir nodes as well as any environmental values, such as option, existence, or bequest

water use. It is important to differentiate between a benefit measure, a cost measure, or a net-benefit measure, since the word “value” may be attached to any of these, and our focus is on welfare-based, net-benefits measures.

Most purely, economic values for water in monetary terms are indices of substitution. Economic values reflect how tradeoffs are perceived in dollar terms; they indicate how much humans are willing to pay (or accept compensation) for some change (increment or decrement) in one or more dimension of water, which might be quantity or quality and might be delivered or perhaps protected at varying locations and times. All of which can affect economic values. From the perspective of human preferences, the reference point for the change, and whether the change is viewed as a good or bad thing, and whether the individual has either an obligation or claim to the change, can also all affect economic value. The probability of being realized or the degree of uncertainty, about say either delivery or protection, can also affect economic value. Economic values are typically framed from the perspective of methodological individualism, i.e., they are conceptualized if not always measured for an individual economic agent, either the individual (most often the household) or the firm (most often the farm or agricultural user) and then aggregated. A net economic value is then some net benefits measure, such the net willingness to pay of the outdoor recreationist for some provision of instream flows (consumer surplus in a market context), or the producer surplus or net farm income of the farm for some delivery and application of irrigation water (where profit has to further account for fixed costs and accruals [Loy et al., 2025]).²⁰

Further, for our analysis here, we will focus on per-unit measures of economic value for water in the MRGV. In other words, we won’t be trying to aggregate and look at total (net) economic value across some given region or geography. That said, it is important to emphasize that marginal values for the next unit of use or curtailment can be expected to often differ significantly from average values for water. This distinction between marginal and average, and how they can differ greatly, is especially important for water where initial units can be essential for both plant and animal life, including humans. This realization helps economists unravel the so-called water-diamonds paradox. For any given water use, we can expect significant variation in marginal values, and a difference between marginal and average values. And for any competing uses, we must sort whether we are comparing marginal to average values, and vice versa. However, this is not always straightforward or clear (e.g., in the reporting or interpreting of values estimates) for comparisons, especially when a host of different measurement approaches are applied to different use categories. One complication is that some estimates are for discrete, rather than continuous,

values influenced by variations in reservoir levels or by other water decisions. To the extent that unmeasured instream flow values of the environment are found to be high, the model under allocates water to supplying those flows. A similar bias exists with respect to reservoir volumes.”

Despite considerable economic investigation, there are no computable general equilibrium (CGE) models for the MRGV solving for a full set of marginal values for all market and non-market (or non-pecuniary) uses of water. We are always pulling together different value estimates and trying to compare them and avoid double counting.

²⁰ To clarify, we are not looking at *economic impact* measures. Sometimes regional economic impacts, typically in response to a shock to a system some change sales or expenditure-based measure is treated as an economic benefit measure; this is then combined with indirect (economic multiplier) effects within a region to measure impacts (direct + indirect). This will also be seen in water resource applications. For example, Texas Water 2002 (p. 120) defines per AF measures for various classes of water uses as follows: “Direct impacts per acre-foot of water were estimated by taking the total economic benefit of a water use and dividing it by the amount of water used to attain that economic benefit. Economic benefit is measured in terms of product sales to final consumption, including exports, but excluding those sales that are used as inputs in the production of a different product in the region.” https://www.twdb.texas.gov/publications/State_Water_Plan/2002/WaterforTexas2002.pdf These expenditure-based economic benefit measures will produce much larger values than net-surplus or welfare-based measures.

increments or decrements in the provision of water, and there is either a lumpiness to describing it as a marginal value, or an inaccuracy in describing this as an average when it applies to only the change. Simply put, interpretation always requires caution.

Even with this caution, we can add an ontological layer of complication. That is, economic values represent a particular type, within broader discussions around different types of value for water. As Brown (1984) notes, economic values are a “species of the genus value.” As discussed by Brown et al. (2007):

Economic value is a type of "assigned" value, assigned value being the relative importance or worth of something to a person or group in a particular context. [Brown, 1984] Assigned value is one of several value realms, others being held value (an enduring conception of the preferable that influences choice and action, such as honesty and beauty) and functional value (dealing with biological or physical relationships of one non-human entity to another). When ecologists talk of, for example, the value of riparian vegetation in controlling stream temperature or the value of nitrogen in tree growth, they are talking of functional value. Functional values exist whether we are aware of them and are the object of scientific discovery. Assigned and held values are indications of human preference and are an object of investigation by economists and psychologists, among others.

So, one might reject economic values for water, and instead argue for focusing on, say, functional values from ecology, or community values, or some combination however vaguely defined but importantly not anchored in individual household preferences or firm profit functions. For example, such a perspective might be seen in arguments to reject any commodification of water (see footnote 16). Albeit the buying or leasing of water rights, or at least land with bundled water access, has been happening in one form or another in NM and southwestern US for several hundred years (with direct sales over 150 years old).

Nevertheless, the gradual emergence of market exchange for water and water rights often has been a significant source of conflict, especially as it confronts the water values of traditional Native American (Tribal and Pueblo) and Hispanic communities (Brown, 2017). As noted by long-time New Mexico water scholar and economist, F. Lee Brown, treating water as a commodity for trade is viewed by some as “directly antagonistic to **these culturally based perspectives.**” But Brown (2017, p. 231) goes on to say:

Traditional communities faced with water scarcity have always treated water as an economic good, i.e., a substance necessitating tradeoff decisions in times of drought or shortage. Otherwise, they would not have survived for centuries or millennia. Their objections to water markets and pricing of water rest instead with its commercialization as a commodity devoid of religious, cultural and aesthetic values considered just as important, if not more so. Rather than treat these viewpoints as archaic anachronisms, water policymakers should instead look closely at the institutional practices for handling scarcity that these societies have evolved over time and converse in tradeoff terminology. The end objective is increased accommodation to water scarcity in the face of growing demand rather than the imposition of any means for accomplishing that objective. With understanding, respect for competing values and time, solutions can frequently evolve.

Brown’s is an argument for interpreting evolving institutional arrangements as the way we navigate necessary tradeoffs. So perhaps someone might choose to reject the monetization of water values, but it would be difficult to reject the tradeoffs inherent in any allocation of scarce water in a high desert system.

Through a series of recent papers, the geographer and sustainability scholar Christopher Schulz and co-authors have advanced the *water values landscape*, As Schulz et al. (2017, p. 243) note,

“Scholars discuss and contrast different conceptualizations of the value base for water governance from the perspectives of philosophy, anthropology, sociology, political science, political ecology, and others. Value pluralists reject so-called value monism (e.g., selecting, say, human wellbeing as a single ultimate value, usually measured in monetary terms), but rather argue that there are always a variety or bundle of basic values, which importantly “cannot be converted into each other or ranked according to an ultimate principle, i.e., values are Incommensurable.”

Pragmatically, economists can be seen working with incommensurability, and inherent uncertainty or potential irreversible loss of a resources, especially around implementing strong sustainability constraints (Barbier & Markanda, 2013; and Pearce & Turner, 1989). In the western US, this can be seen in advocating protecting safety reserves for municipal groundwater use in greater Albuquerque (Brown et al., 1996), articulating safe minimum standards (SMS) for endangered fish species preservation (Ciriacy-Wantrup, 1952; Castle & Berrens, 1993; Castle et al., 1996; and Berrens, 2001), including in the Colorado River Basin (Berrens et al., 1996), and in SMS constraints in protected flow regimes for regional hydro-economic modeling (e.g., Ward & Pulido-Velazquez, 2009)

In closing, we are not trying to argue against the use of any sustainability or SMS-type constraint, or against community values or any other type of value system. There is a broad literature across philosophy and ethics (including applications to water [e.g., Groenfeldt, 2013]), sustainability (e.g., Norton [1987]) and the social sciences investigating and articulating different value realms, and there is no claim to providing a comprehensive account here. Nor are we asserting the primacy of economic values over any other species in the genus value. We recognize that economic values for water are assigned or held values; they are highly heterogeneous, reference dependent (on where they are measured from, including the institutional context), and difficult to sort through. But we *are* arguing that what we know about relative economic value(s),²¹ and where the gaps are, ought to be part of the *admissible evidence* in larger, ongoing public deliberations over water allocation and consumption in the Middle Rio Grande Valley. The fact that this is a difficult streetlight to build should not give us leave to ignore the darkness.²²

III.2. Estimates of Economic Values, Prices, Administrative Charges & Rates for Water

We turn now to compiling and presenting information on the economic values, prices, administrative charges and rates for water in the MRGV. But we start with a bit of background context, illustrating how NM economists and other scholars have been pursuing these questions for several generations.

An early NM interdisciplinary study (Wollman et al., 1962) examining the value of water in alternative uses was conducted by a special committee under a grant from what was to become a prominent

²¹ Not all economic studies of water use in the MRGV, produce dollar value estimates that can be converted into annual per AF measures. As example, in the urban water use category, Brookshire et al. (2002) consider the shadow value of depleting the aquifer. The argument is that this shadow value or marginal user cost (MUC) is generally not priced (or at least fully priced) into administrative water rate structures for municipal and industrial (M&I) uses. They use literature estimates of the ratio of unpriced MUC's to calculate percentage adder values on the top of base rates, to show how current M&I rate structures would need to be increased.

²² While important elements of naturalness remain (and can be enhanced), the Middle Rio Grande is a highly engineered river system and has been for a long time (Fleck & Berrens, 2026). As we confront choices about that managed system, one reviewer notes: “[E]conomic values are needed to assess tradeoffs. in addition, at the end of the day water is not free. [I]t has to be cleaned, transported, etc. all with associated costs. [N]ow, it is possible that the government could simply pay for all of this and provide free water with no prices for anybody. [B]ut, this does not happen in our society. Moreover, governments have budget constraints and must evaluate money spent on water with other things.” We agree with this reviewer.

environmental economics think tank based out of Washington DC, *Resources for the Future* (RFF). In one of their very first set of studies into water resources, RFF commissioned a study in NM to examine *inter alia* the potential effects of the then proposed transmountain diversion project, eventually to become San Juan Chama Project (SJCP). Under the leadership of the economist Nathaniel Wollman (UNM), the research team included geologists, engineers, biologists, agricultural economists, economists and business scholars, with participation from UNM, NMSU and various agencies of the state of NM (including the Office of the State Engineer [OSE]). The work was conducted in the late 1950s, with an early report version produced circa 1959, and then an RFF book published in 1962 (426 pp). In the ensuing 64 years the book has not been heavily cited with only a bit over 110 Google Scholars citations as of mid 2026.²³

Focused on the potential for the newly available, unappropriated waters of the SJCP, the study focused on two scenarios: an injection of 110K AFY (a bit larger than what eventually transpired); and a more speculative injection of a larger 235K AFY, into the MRGV. The study then investigated the questions of: *How should water be used in regions of water shortage?* and *Should the traditional emphasis on irrigated agriculture be perpetuated in the Southwest, where desert or semidesert conditions prevail?* In the decade prior to the study (late 1940s) it was estimated that about 90% of the state of NM's consumption use of diverted waters was by irrigated agriculture. But the population in the urban counties of the MRGV was on its way to roughly doubling in the 1950s. As the study noted (Wollman et al., 1962, p. xi) for the Rio Grande Basin, "virtually all of the recent growth has been urban, reflecting rapid expansion throughout the whole range of nonagricultural pursuits."

The study used a combination of approaches best described as a kind of expenditure-change driven, commercial, net value added (primary value added plus one round of new purchases) methodology (i.e., contributions to GDP), based on the assumed effects of potential SJCP increment(s) of water to the MRGV. The mid-1950s (1954) was the reference starting point, with evaluations projected forward to 1975. The included sectors included a municipal and industrial (M&I) sector, the irrigated agricultural sector, and a recreational sector focused on fishing and recreation on lakes and rivers/streams in northern NM and the MRGV. While this late 1950s study produces some AF values for water in different sectors, it is hard to make comparisons to those produced from the range of more recent tools/studies we report below. Rather, instead we focus on the benefit-cost ratios, produced by Allen V. Kneese and shown in the last appendix (Wollman et al, 1962, p. 426) of the report. For M&I Uses, the calculated B/C ratios across alternative modeling assumptions ranged from 8.19/1 to a low of 4.11/1 with the latter produced in the relatively realistic 110K AFY scenario; for Agricultural Uses the B/C ratios ranged 0.61/1 to 0.54/1 with a ratio of 0.55/1 in the 110KAF scenario.²⁴ The BC ratio for Recreational Uses was only calculated for one

²³ Perhaps its most noteworthy contribution is that the analysis contained extensive contributions by Alan V. Kneese, who had earned a PhD in economics from Indiana University in 1956, before spending several years on the faculty of UNM (and then eventually joining RFF in DC in the early 1960s). Kneese would go on to be one of the pioneers of the field of environmental economics. Among other career accomplishments, Kneese was the first president of the *Association of Environmental and Resource Economists* and was one of the founding editors of both the *Journal of Environmental Economics and Management* and *Water Resources Research*. See the Wikipedia page for Allen V. Kneese for more biographical detail: https://en.wikipedia.org/wiki/Allen_V._Kneese

²⁴ It might have been a bit of shock when it first came out in 1958/1959, that any new diversions to agriculture in the MRGV badly failed a B/C ratio. However, Wollman et al. (1962, p.xix) noted that the major conclusion "was not that subsidization of agriculture was *per se* undesirable..." but that other more efficient paths of development were available. Further, they made what might now be described as an option value argument: it was noted that continued agricultural uses of water in the region helped guard the legitimate interests of the region, and guard against any revision of the terms of interstate compacts (p. xx). Subsequently, a new supplement of water to agriculture irrigation in the MRGV was not to be left out of the SJCP. Eventually the vast majority of SJCP water deliveries would go to M&I contractors, but still about one-fifth went to agricultural users, about one-twentieth to a recreational pool (Cochiti Reservoir) and eventually even some going to instream flows via water transfers (e.g.,

scenario, with higher water availability of 235K AFY (and 37K AFY of that going to a recreational increment) and produced a ratio of 2.11/1. What may be most of interest here is the relative BCA ranking, where municipal use ratios were 7.5 to more than 10 times larger than agricultural use ratios, with recreational/environmental use ratios somewhere in the middle.²⁵ As will be evident from our review, in broad strokes this relationship appears to roughly hold several generations later, and at a minimum sets the stage for the compilation of water values in alternative uses seen over the next several decades.

The compilations that follow were sourced using a combination of the personal files of studies from several of the authors, combined with Google Scholar and AI literature searches, with rounds of validation and review. Importantly, we continue to add studies and are pursuing econometric meta-analyses (e.g., of the compiled indirect values and market values) as additional future research.

III.2.a. Estimates of Economic Value for Water in Alternative Uses, with a Focus on MRGV and Western US

We turn now to one of our primary objectives, compiling current available evidence for the economic value of water in alternative uses. Here our focus is on estimates where the measure is indirect, it is the value in the use (or protection), rather than a direct transaction price for buying/leasing water rights.

Outside of direct water market transactions, a wide variety of approaches are used by economists for indirectly estimating water values across alternative uses. While beyond our scope here in fully explaining these methods, briefly these include: econometric estimation of production and demand functions, Travel Cost Method (TCM), Hedonic Property Value Method (HPM), Contingent Valuation Method (CVM), Choice Modeling (CM), Benefit Transfer, Basic Residual Method, Mathematical Programming (where reported values are typically shadow values -- the marginal value of an additional unit of water implied by the optimization model rather than an observed market price), and Alternative Cost Method. [We direct the reader to Young and Loomis (2014), Koundouri and Rulleau, 2019, and (2023) et al. for further methodological detail.] Appendix Table B1 provides the full compilation of over 70 estimates from more than 30 studies. Estimates are drawn from studies spanning agriculture, municipal, recreation, environmental, hydropower and urban uses and are reported in 2025 dollars per AFY, whenever possible.

As discussed in Section II.2, not all water withdrawn from the system represents a permanent loss. In the ABCWUA system, only about 43% of total water withdrawals are consumptive, while the remaining share eventually returns to the system. Most water value estimates in the literature, however, are reported on a diverted basis because that is what utilities and irrigation districts typically measure, and thus the evidence often follows that convention.

To highlight some results from the very lengthy Appendix Table B1, one-line snapshots of various studies are presented in Table 2 below, summarizing published estimates of water values across alternative uses. They are illustrative in a kind of broad way (e.g., reflecting the great variability, and general

later contracts with the Jicarilla Apache allocation). Implemented post 1962 (with US Congressional Approval under an amendment to the Colorado River Storage Act of 1956), a full allocation delivered to contractors for consumptive use is about 96K AFY, when available (USBR, n. d.). The five largest contractors, out of 20, are: the City of Albuquerque (48,200 AFY) the Middle Rio Grande Conservancy District (20,900 AFY), Jicarilla Apache (6,500 AFY), City of Santa Fe (5,230 AFY) and the Cochiti Reservoir Recreation Pool, operated by the US Army Corps of Engineers (4,290). The delivered allocation for consumptive use in any year can be greatly affected by drought and water supply in the Upper Basin of the Colorado River.

relationships), but we caution the reader from taking any dollar value estimate out of context, since things like marginal versus average, consumptive versus nonconsumptive, and at-site (delivered or conveyed) versus at-source, all matter in addition to the method of estimation and year of analysis. Rows in gray in Table 2 below are for value estimates outside of the MRGV and are for comparison purposes.

Table 2. Select Economic Value of Water Estimates Across Alternative Uses (2025 Dollars)

Year of Analysis	Author(s)	Category of Water Use	Value (\$ 2025)
1954 -1960	Hartman & Anderson, 1962	Irrigated Agriculture	\$322.49 per AFY
1972*	Young & Gray, 1972	Municipal — Outdoor Use	\$498.64 per AFY
1972*	Young & Gray, 1972	Municipal — Indoor Use	\$883.46 per AFY
1973	Kelso et al. , 1973	Irrigated Agriculture	\$10.84 per AFY
1973	Kelso et al. ,1973	Irrigated Agriculture	\$639.56 per AFY
1973	Shumway ,1973	Irrigated Agriculture	\$56.91 per AFY
1973	Shumway, 1973	Irrigated Agriculture	\$154.47 per AFY
1976*	Bush, 1976	Environmental — Aquatic Habitat	\$89.43 per AFY
1978	Daubert & Young, 1979	Environmental — River Recreation	\$59.62 per AFY
1978	Daubert & Young, 1979	Environmental — River Recreation	\$43.36 per AFY
1978	Walsh et al., 1980	Environmental — River Recreation	\$59.62 per AFY
1978	Walsh et al., 1980	Environmental — River Recreation	\$13.55 per AFY
1978	Walsh et al., 1980	Environmental — River Recreation	\$10.84 per AFY
1978	Walsh et al., 1980	Environmental — Reservoir Recreation	\$138.21 per AFY
1979*	Bollman, 1979	Environmental — Aquatic Habitat	\$143.63 per AFY
1977	Martin & Snider, 1980	Irrigated Agriculture	\$89.43 per AFY
1977	Martin & Snider, 1980	Irrigated Agriculture	\$425.47 per AFY
1974-1975	Gisser et al., 1979	Irrigated Agriculture	\$43.36 per AFY
1981*	Gollehon et al., 1981	Irrigated Agriculture	\$43.36 per AFY
1982	Ward, 1987	Environmental — Reservoir Recreation	\$60.98 per AFY
1982	Ward, 1987	Environmental — River Recreation	\$2,565 per AF
1982	Ward, 1987	Environmental — River Recreation	\$3,135 per AF
1984*	Amirfathi et al., 1984	Environmental — River Recreation	\$233.06 per AFY
1984*	Young, 1984	Irrigated Agriculture	\$149.05 per AFY
1984	Bush & Martin, 1986	Irrigated Agriculture	\$102.98 per AFY
1986	Bush & Martin, 1986	Irrigated Agriculture	\$360.43 per AFY
1986*	Gibbons, 1986	Municipal — Indoor Use	\$317.07 per AFY
1986*	Gibbons, 1986	Municipal — Outdoor Use	\$108.40 per AFY
1986*	Gibbons, 1986	Hydropower	\$89.43 per AFY
1986*	Gibbons, 1986	Hydropower	\$219.51 per AFY
1988	Duffield et al., 1991	Environmental — Minimum Streamflow	\$115 per AF

1995	Berrens et al., 1996	Environmental — Minimum Streamflow	\$60 per household/year
1995	Berrens et al., 1996	Environmental — Minimum Streamflow	\$185 per household/year
1995-1996	Berrens et al., 1998	Environmental — Nonuse Value	\$145 per household/year
1995-1996	Berrens et al., 1998	Environmental — Nonuse Value	\$158 per household/year
1995-1996	Berrens et al., 2000	Environmental — Nonuse Value	\$47 per household/year
1995-1996	Berrens et al., 2000	Environmental — Nonuse Value	\$103 per household/year
2000	Hurd & Coonrod, 2012	Headwater Supply	\$32.3 per AF
2000	Hurd & Coonrod, 2012	Headwater Supply	\$125.1 per AF
2000	Williams et al., 2017	Groundwater — Conservation Value	\$172 per AF
2005	Ward & Pulido-Velázquez, 2009	Municipal — Consumer Surplus	\$3,000 per AF
2005	Ward & Pulido-Velázquez, 2009	Municipal — Consumer Surplus	\$6,200 per AF
2005	Ward & Pulido-Velázquez, 2009	Environmental — Reservoir Recreation	\$3 per AF
2005	Ward & Pulido-Velázquez, 2009	Environmental — Reservoir Recreation	\$6 per AF
2006	Weber & Stewart, 2009	Environmental — River Restoration (full restoration, CM)	\$156.60 per household/year
2006	Weber & Stewart, 2009	Environmental — River Restoration (full restoration, CVM)	\$46.80 per household/year
2007	Yoskowitz & Montagna, 2009	Environmental — Instream Flow Protection	\$129 per household (one-time donation)
2010	Loomis & McTernan, 2014	Environmental — River Recreation	\$298 per AF
2014	Weber et al., 2016	Environmental — River Recreation	\$27 per person/day
2014	Weber et al., 2016	Environmental — River Recreation	\$40 per person/day
2017-2021	Idhirji & Ward, 2025	Irrigated Agriculture — Shadow Value	\$27.00 per AF
2017-2021	Idhirji & Ward, 2025	Irrigated Agriculture — Shadow Value	\$77.62 per AF
2017	Trail & Ward, 2024	Irrigated Agriculture — Shadow Value	\$34.94 per AF
2017	Wang, Mu & Ziolkowska, 2021	Environmental — Ecosystem Services (habitat for wildlife)	\$26.2 per household/year
2017	Wang, Mu & Ziolkowska, 2021	Environmental — Ecosystem Services (recreational activities)	\$8.1 per household/year
2017	Wang, Mu & Ziolkowska, 2021	Environmental — Ecosystem Services (cultural heritage)	\$7.1 per household/year
2017	Williams et al.	Groundwater — Conservation Value	\$172 per AF
2018	Trail & Ward, 2024	Irrigated Agriculture — Shadow Value	\$46.28 per AF
2019	Edwards et al., 2025	Irrigated Agriculture — Groundwater Access Rights	\$61.89 per AFY
2019	Trail & Ward, 2024	Irrigated Agriculture — Shadow Value	\$43.23 per AF
2020	Trail & Ward, 2024	Irrigated Agriculture — Shadow Value	\$46.77 per AF
2020	Olofinsao et al., 2025	Irrigated Agriculture — Shadow Value	\$28.30 per AF
2020	Olofinsao et al., 2025	Urban Greenspace	\$205.26 per AF

2020	Olofinsao et al., 2025	Environmental — Minimum Streamflow	\$220.39 per AF
2021	Trail & Ward, 2024	Irrigated Agriculture — Shadow Value	\$45.68 per AF
2021	Olofinsao et al., 2026	Irrigated Agriculture	\$94.29 per AF
2018-2023	Samimimotlagh & Wang, 2024	Muni (Residential)— Consumer Surplus	\$4,189.52 per AF
2018-2023	Samimimotlagh & Wang, 2024	Muni (Commercial)— Consumer Surplus	\$11,572.29 per AF
2018-2023	Samimimotlagh & Wang, 2024	Muni(Institut.)— Consumer Surplus	\$11,832.59 per AF
2018-2023	Samimimotlagh & Wang, 2024	Muni(City) — Consumer Surplus	\$9,934.49 per AF

Notes: Rows shaded in gray indicate estimates derived from studies conducted outside the Midde Rio Grande Valley (MRGV) and are presented for comparison purposes only. Studies with year of analysis marked as * indicate some ambiguity, and thus year of publication used.

Across a blend of public goods, private goods, club goods and common pool settings, the economic value of water depends on the context, the use, and the conditions under which it is evaluated. For this reason, the values presented in the previous table range from as little as \$3 to more than \$11,000 per AF. This wide variation reflects the different sectors and uses that generate different economic values to water, which are discussed below.

In New Mexico, more than 75% of water is allocated to the agricultural sector, making it particularly important to understand the economic value of water in this use (Valdez et al., 2024). The studies collected show a wide variation in agricultural water values, with estimates ranging from approximately \$11 to \$640 per AFY. These differences reflect variations in methods used, crops produced and climatic conditions considered in each study. However, most estimates fall below \$150 per AFY, with a median of approximately \$67 per AFY and a mean of approximately \$142 per AFY, although this result is influenced by several high values. Under normal water allocation and trading conditions, agricultural water values generally range from approximately \$28 to \$97 per AFY (with a median of roughly \$54 per AFY for the MRGV. In contrast, the highest values emerge in scenarios where water trading is not allowed and scarcity becomes more severe. For example, the estimated value of water for onions (a relatively high value crop) reaches \$622.71 per AFY, whereas for wheat it is only \$3.59 per AFY (Trail & Ward, 2024). In this sense, the broad range observed in agriculture reflects two distinct realities: one associated with water markets that operate (or could operate with less friction) with trading mechanisms and generate relatively stable values, and another linked to restricted scenarios where scarcity and the specific characteristics of certain crops produce more extreme values.

Although the studies reviewed use different methods, they all ultimately analyze activities linked to commercial agricultural production or assets associated with it. Almost all these water values measure the value of what water produces. However, within the agricultural category there was one estimate that exceeded all the others, reaching \$1,213 per AF (Edwards et al., 2025), and merits discussion, as it needed converted. This value measures something different, as it does not represent the value of water in agricultural production in a given year, but rather the capitalized net present value of the marginal implicit price of groundwater access (as part of the land it is appurtenant to) over an expected stream of years. Using the HPM, the study measures how those groundwater access per AFY rights increase the value of agricultural land. If we annualized this capitalized present value of \$1,213 over 30 years with a 3 percent

interest rate, we get a value of about \$61.5 per AFY (or \$78 per AFY for 5 percent), which is more in line with what we tend to find for commercial crop production.²⁶ We use a value of \$61.5 per AFY.

Another important gap area, that is missing any streetlight although there is ongoing research underway, is what might be called cultural, custom, and lifestyle (CCL) values of irrigation water use.²⁷ Such CCL irrigators are large in number in the MRGV and not represented in Table 2 (or Appendix Table B1). Unlike commercial producers, their activities are not primarily market oriented, which is not to say they don't have economic value. Specific to the MRGCD, nearly 98% of irrigated farms are smaller than 30 acres, and approximately 78% cultivate fewer than 5 acres, with a median of just a couple acres (Olofinsao, 2025). Yet most of the agricultural values reported here are derived from studies of commercial production, leaving a substantial share of the values associated with water used by small irrigators unmeasured. Historically, over a generation or more, US Department of Agriculture (USDA) Census of Agriculture statistics will often show the average net farm income in the four counties of the MRGCD to be near zero or even negative in many cases. This is especially so for the more urban counties of Bernalillo, Sandoval and Valencia, consistent with the mostly small, non-commercial status of irrigators. Economically, we do know that for many small irrigators, agricultural valuation reductions to ad valorem property taxes can be sufficient in magnitude to cover most or all the observed losses in net farm income (Porter et al., 2023). But this gives us a very crude indicator of value to the irrigators themselves. Further, these water use values would not just be limited to ditch irrigators, they could be domestic well owners with outdoor use or be a combination (ditch irrigation and domestic well use for outdoor use). Recall that pre-2006 OSE rules on domestic wells allowed up to 3 AFY.

There are some promising strands of ongoing and future research related to CCL water values. First, hedonic pricing methods (HPM) might be developed and applied to econometrically decompose the property value and then isolate the value of different types of water access (MRGCD ditch, domestic well), or different types of green (Coinon et al., 2026), and then convert this into an annualized, consumptive (ET) use value. Such an approach is complicated by the absence of property sales price disclosure laws in NM (Berrens & McKee, 2004). Second, since well water is unpriced, and with the significantly increasing number of domestic well owners (II.4.), alternative revealed preference approaches might be applied (e.g., using, say, variable depth pumping costs as a price proxy, similar to travel cost methods in nonmarket valuation [Champ et al., 2017]). Third, ongoing research is exploring the use of results from a 2026 survey of more than 2,000 MRGCD irrigators to elicit their willingness to accept (WTA) compensation to fallow land for the MRGCD's Environmental Water Leasing Program (EWLP) (see Wood 2023 for background on the EWLP). Consistent with Hicksian welfare change theory, a WTA measure would represent the marginal value for some decrement or curtailment (e.g., per acre, with some implied expectation of consumptive use). The issue here is that the EWLP is a shortage sharing system (i.e., the amount of water conserved varies with the annual water supply in the MRGCD system),

²⁶ We can apply the capital recovery factor formula ($A = PV \times [i(1+i)^n] / [(1+i)^n - 1]$), which converts a Present Value (PV), the lump sum amount in today's dollars (\$1,213 in this case), into A, an equal Annual payment spread over n periods (e.g., 30 years) at interest rate i. This produces: at 3% the annual value is ~\$61.89 AFY; and at 5% the annual is ~\$78.90 AFY. See: Blank and Tarquin (2023), and OMB (2023).

²⁷ In a recent dissertation analysis, Olofinsao (2025, chapter 2) notes that "Traditional economic models often assume farmers simply maximize profit, but ...many small farmers in the MRGB continue farming for reasons beyond profit – such as cultural heritage, lifestyle fulfillment, attachment to land, and environmental or community values." see Hasenbeck et al., 2025; Holmes and Skaggs, 2014; and Skaggs, 2011). Olofinsao (2025) refers to this set of motivations as "Custom, Cultural & Lifestyle" (CC&L) values, and goes on to treat ET as a "proxy for cultural and landscape value because higher ET reflects greener, actively irrigated fields—an aesthetic and cultural attribute that many smallholders in the MRGB strongly associate with heritage, land stewardship, and the continuation of traditional farming practices." This green proxy, as variously affected by different policies, is then used as an argument in the household utility function in a dynamic optimization model but not monetized.

so again converting the WTA per acre into a value for consumptive use (ET) will be complicated. Again, this idea of attempting to drill down to the value of consumptive use (or its curtailment) itself is a general theme.

Relatedly, it is important to note that value estimates for water in commercial agriculture are typically reported on a diverted basis; they reflect the value of water as it is delivered and applied by the farmer in the system rather than the amount of water consumed by the crop (lost from the system). In practice, a significant share of diverted water is not evapotranspiration and becomes return flow. If one attempted to convert these values to an implied consumptive basis, *something not typically done*, then it would require accounting for how water is applied. For example, in NM, approximately 63% of irrigation water is applied through flood systems and 37% through sprinkler systems (USDA, 2024). Flood irrigation operates at roughly 55% efficiency, while sprinkler systems operate at around 75% (Olofinsao, 2025). Naively, applying these efficiency rates would increase reported agricultural values by roughly 64% on average. Under typical operating conditions in the MRGV, values that cluster between \$28 to \$94 per AFY diverted would translate to approximately \$46 to \$155 per AFY, on an implied consumptive basis. However, the caution, varying in magnitude by the individual farm and regional setting, is that some return flows may serve a purpose (e.g., *net* positive contribution to reducing salinization). That is, not all of the estimated net value of water services can be attributed solely to consumptive use. For example, there can be tradeoffs between applied water savings and preventing salinization in dryland irrigation (Karimzadeh et al., 2024), and leaching of salts and deep percolation might offer regional water system benefits (Grafton et al., 2018; Ward 2020). We found no economic studies that attempted to proportion the value of applied irrigation water to its consumptive component.

This general theme is that most reported economic values apply to access to delivered water also applies to municipal water provision. Nonconsumptive use of municipal water clearly provides consumer surplus (e.g., hygiene and cleaning, etc.) but comes with a disposal cost. In Table 2, we found only one case where consumptive (outdoor use) was isolated to be roughly \$500 AFY, from a simple calculation from a 1972 non-MRGV study. But it seems feasible that additional such valuation sorting could be applied.

The difference to note for municipal provision is that this involves piped and *treated* water (varying in quality by provider but having to meet safe drinking water standards). Even though this treated water is more costly in production, in magnitude the consumer surplus (CS) estimates for urban water uses, by contrast with commercial agriculture, are substantially higher. From one study, estimated residential municipal CS values range from approximately \$3,000 to \$6,200 per AF in the Upper Rio Grande Basin (Ward & Pulido-Velázquez, 2009). This range brackets a more recent econometric demand modeling estimate of CS of approximately \$4,190 per AF in Albuquerque (Samimotlagh & Wang, 2024). Residential municipal use tends to be relatively price inelastic (as estimated using the variation in average price paid, via block rates, by different households). Estimates of commercial and institutional uses exhibit even higher CS values, approximately \$11,572 and \$11,833 per AF, respectively. These sectors also face higher average water rates but exhibit lower price (or rate) elasticities than residential users (Samimotlagh & Wang, 2024). These municipal CS estimates reflect what users would be willing to pay above the amount they pay for water, capturing net benefits that are not observable through water rate structures alone. Among the urban values discussed, perhaps only the *residential* CS estimate might allow the consumptive use value to be econometrically isolated with current approaches. There is work in progress at UNM to do this with ABCWUA data. But again, this is not commonly done.

Turning away from estimates of value based on municipal water demand modeling, various studies also recognize residential values of consumptive water use from proximity to urban public greenspace (rather than their own residential consumption). For example, Olofinsao et al. (2026) calibrate an average value of approximately \$205 per AF for urban greenspace (from a prior meta-analysis [(Brander & Koetse, 2011)]), highlighting that spaces such as parks, green areas, and tree-covered zones also generate

economic benefits for communities. Although these benefits are not usually observed directly in markets, they can be capitalized into residential housing values as they contribute to well-being, recreation, and a connection with nature within cities. These results suggest that an important portion of the economic value of urban water comes from services and benefits of public green spaces. To help improve these estimates for the greater Albuquerque area, there is also current research underway applying original HPM econometric analysis (using multi-year Zillow-based price estimate data) and attempting to isolate the value of proximity to greenspace, with known watering use (measured application) for nearby parks.

Generally, we have tried to be somewhat agnostic in this whitepaper about the *choice* of green things people apply water to grow (or whose growth they protect, as in more natural settings). But we would be remiss not to note the gap in MRGV environmental valuation and benefits research that investigates specific connections between consumptive water use and growing *trees*.²⁸ Here we would include both urban trees in parks and yards (as mentioned above), as well as the *bosque*. Clearly, there could be pressure in a climate-altered world to squeeze remnant oxbows and riparian areas, along the ribbons of green that line the Rio Grande (Fleck & Berrens, 2026). The bosque provides a bundle of ecosystem goods and services including carbon sequestration, health benefits, heat mitigation, amenities and outdoor recreation. There has been some interesting work around these issues (O'Neill, 2026; Davis, 2024; Jones & Fleck, 2018), but not a focus on connecting consumptive water use and benefits.

More broadly, the environmental sector accounts for the second largest share of observations in the sample (22 estimates). However, unlike the agricultural and municipal sectors, comparisons within this category are much more difficult to make. While many agricultural and urban demand studies report values directly in dollars per AF, environmental studies use a wide variety of measures, including dollars per trip, per person, per household, or per day. This diversity of metrics makes direct comparisons between studies less clear and highlights one of the principal challenges of environmental valuation: how to express very different benefits using a common measure.

Several economic studies investigate various ecosystems services, either bundled or disaggregated (e.g., degree of naturalness, tree cover or canopy, recreation access, etc.) in the Rio Grande and associated riparian areas. Such goods would be obviously affected by river flows but aren't directly connected to specific changes in flows or amounts of water. Thus, environmental value estimates rely on survey-based, stated preference estimates that are costly to create, infrequently updated, and difficult to connect to water use. Thus, no standardized water value could be estimated. Examples of this are (i) Wang et al. (2021), and their household survey-based contingent valuation method (CVM) study for ecosystem services in the Lower Rio Grande/Rio Bravo in Texas; (ii) the Yoskowitz and Montagna (2017) household survey CVM study of the value of protecting *unspecified* flow levels on the Lower Rio Grande; and (iii) the earlier Weber and Stewart (2009) household stated preference survey, a combination choice experiment and contingent valuation study, for river restoration in the Middle Rio Grande corridor.

Where estimates can be connected to dedicated water quantities, some of the estimates reported in recent benefit transfer studies (e.g., comparing water sectors values), continue to draw on annual household willingness-to-pay (WTP) values collected decades ago. Olofinsao et al. (2026), for example, apply a benefit-transfer approach to estimate environmental instream flow protection values (with specific flow minimum protection levels that can be connected to implied AF of water) relying on WTP estimates originally derived from CVM surveys conducted in the mid-1990s by Berrens et al. (1996, 1998, 2000).

²⁸ As a reviewer points out, this connects to a variety of consumptive use tradeoffs that will be increasingly confronted by having less water available, including individual and community choices about lawns versus trees, and whether (or not) and where to locate public parks and golf courses. These tradeoffs underline our emphasis on public discourse around the distribution and composition of green things and note that all these choices can be informed by comparative economic benefit studies.

In comparison, agricultural and municipal values are often updated using newer production, administrative, or market data, whereas environmental values frequently remain tied to older stated preference survey instruments. Given that preferences can be malleable, with respect to the effects of climate change, this is an important limitation (Berger & Creutzig, 2026).

Perhaps unsurprisingly then, the broad category of environmental benefits of water use exhibits one of the widest ranges of values observed (Appendix Table B1). Estimates range from approximately \$3 per AF to more than \$3,000 per AF, depending on environmental service being valued. At the lower end of the distribution are reservoir recreation values of approximately \$3 to \$6 per AF (Ward & Pulido-Velázquez, 2009), while the highest estimates exceed \$3,000 per AF and are associated with recreation benefits from reservoir releases that increase low flows in a river (Ward, 1987). Between these extremes, many instream flow, habitat, and recreation estimates fall between approximately \$60 and \$338 per AF.

One of the most notable characteristics of the literature collected is the wide variation observed across sectors, and even within the same sector. The environmental sector illustrates this challenge particularly well, but it is not the only area where information remains limited. Some sectors remain underrepresented within the literature collected, particularly the value of snowpack (i.e., additional mountain snowpack water at the top of a watershed system), the value of agricultural groundwater conservation or protection (the value of the shallow aquifer for irrigation), and the value of water for hydropower (although there is no meaningful hydropower generation in the MRGV). The values reported for these sectors also show some variation, ranging from approximately \$30 to \$125 per AF for some snowpack estimates (flowing into the MRGV) (Hurd & Coonrod, 2012) and from \$11 to \$334 per AF for groundwater conservation (Williams et al., 2017) in the Pecos River Basin, with a mean value of approximately \$172 per AF (at-site). We found no such estimates specific to the MRGV. Without more estimates for these categories, it remains difficult to compare these values with the agricultural, municipal, and environmental values reported.

Notably, the absence of a shadow value estimate for protecting the shallow aquifer in the MRGV especially stands out as a clear gap. Economists refer to the shadow value (or the user cost in terms of foregone use) of protecting an aquifer as the shadow value (sometimes differentiating between shadow value in the aggregate and shadow price in per unit of use). But it is not something researchers will necessarily have a good handle on, especially if there is a large or emergent consumptive uses that are unmetered or unmonitored, when no one is watching. While this is still a potential issue for permitted groundwater wells, our argument is the largely unregulated -- and unpriced -- domestic well use has crossed that line, and merits much greater public scrutiny.

Notably, the absence of a shadow value estimate for protecting the shallow aquifer in the MRGV stands out as a clear gap. Economists refer to the value of protecting an aquifer, the user cost of extracting water today in terms of foregone future use, as its shadow value, whether expressed as a per-unit price (e.g., dollars per acre-foot) or as an aggregate value over the relevant volume and time horizon. But this is not something researchers will necessarily have a good handle on, especially where there is large or emergent consumptive uses that are unmetered or unmonitored -- when no one is watching to keep with our streetlight metaphor. This is still a potential issue even for permitted groundwater wells, but our argument is that largely unregulated and unpriced domestic well use might have crossed the threshold at which its draw on the aquifer's shadow value becomes too large to ignore, and merits much greater public scrutiny.

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²⁹ While there are related studies elsewhere (e.g., Williams et al., 2017; Zheng et al., 2019), there is no published estimate we are aware of providing a basin-specific shadow value for the Santa Fe Group aquifer underlying the MRGV. For other NM basins, the optimal control modeling of Gisser and Sánchez (1980) and Gisser (1983) found that, for pumping for irrigated agriculture, the welfare difference between competitive (unrestricted) and optimal

The estimates compiled in Table 2 (and see Appendix Table B1) show that the economic value of water depends not only on the sector in which it is used, but also on the method used to measure that value. The estimates reported here measure fundamentally different benefits, ranging from commercial agricultural values that are often below \$150 per AFY to urban CS estimates that are typically well over \$1,000 per AF, sometimes exceeding \$10,000 per AF for different commercial and industrial uses. Environmental uses, such as recreation, instream flows, and environmental preservation tend to be in the middle.

With similarity in the *relative* relationships to those found in Wollman et al. (1962) for the late 1950s, and discussed at the start of section III.2, Table 3 provides summary *median values* (\$2025) from accumulated economic studies over the last several generations for the three primary categories of values: Commercial Irrigated Agriculture (but excluding unmeasured CCL consumptive use values); Municipal (all types, including both nonconsumptive indoor and consumptive outdoor); and a collection of environmental valuation studies. For the latter, the primary focus (while dated) has been on instream flow values, which today would come with the concurrent benefit of helping the MRGV contribute to NM's Compact delivery obligations (assuming they were shepherded through to TX).

Table 3. Summary Median Economic Values by Major Use Category (2025 Dollars)

Category of Water Use	N observations	Overall median	MRGV median
Irrigated Agriculture (Commercial)	49 (23)	\$87.57 per AFY	\$53.48 per AFY
Municipal	9 (5)	\$4,189.52 per AF	\$9,934.49 per AF
Environmental	19 (4)	\$138.21 per AF	\$210.62 per AF

Notes: All values are drawn from the expanded version presented in Appendix Table B1. Medians include *only* estimates reported on a per-AF or per-AFY basis. N observations reflect the total number of estimates within each category, with the number in parentheses indicating how many of those estimates were for the MRGV.

In closing, bringing these values together, and recognizing the gaps, helps place very different uses of water within the same discussion. After all, the same water resource is ultimately allocated across these sectors, and decisions about its use often require comparing values that were measured in very different ways. Both agricultural values and residential municipal values estimates have almost entirely been focused on delivered basis (but have consumptive components). Environmental water, where the value lies in the water staying in the river, presents a different case; a consumptive dimension exists through evaporation and riparian losses, but cannot be quantified here with available data (which might change).

extraction was negligible when extraction was small relative to a large storage capacity; notably, this is a ratio that worsens as depletion accumulates. The implication is that welfare gains from active management should grow as storage margins shrink. To wit, Galanter and Curry (2019) document substantial drawdown from predevelopment through 2016 across the Santa Fe Group aquifer system in the Albuquerque area. Expanding to a broader scale, Richter et al. (2025) find that over half (52%) of Rio Grande-Bravo basin water consumption is unsustainable, depleting aquifers, reservoirs, and river flows faster than natural replenishment. While not a per-AF shadow value, Ward and Pulido-Velázquez's (2012) multi-decade hydro-economic optimization model, calibrated to Upper Rio Grande conditions, finds that protecting the sustainability of the basin's water stocks (reservoirs and aquifers) carries a cost of 6–11 percent of the basin's average annual total economic value of water over the planning horizon. The case for ignoring aquifer protection breaks down further when there are affected nonmarket uses (e.g., conjunctive effects on environmental surface flows) or growing alternative uses with different demands (Koundouri, 2004). More broadly, we need a better economic understanding of consumptive demands in the MRGV and greater Albuquerque area, especially if unregulated domestic well use is growing.

The point is not to choose one single measure over another, but to recognize that each reveal something different about the broader resource. Finally, there is room for additional economic streetlights, especially innovative analyses that connect consumptive use (or its curtailment) with value.

III.2.b. Market Prices for Permanent Sales and Temporary Leases of Water Rights, with a Focus on MRGV and Western US

The section attempts to shed light on the use and value of water in understanding tradeoffs by using direct observations on the historical and current market prices for permanent sales and temporary leases of water rights, with particular emphasis on the MRGV and Western US. Economists and other scholars will employ both what might be called the “raw” price data and predicted water price data from hedonic pricing models (HPM). As commonly used for housing studies, and as employed for any heterogeneous good, HPM’s use econometric modeling to isolate the variation in observed prices that is explained by any given attribute or characteristic (referred to as the marginal implicit price for that attribute). Observed water prices are no different. The prices presented here are obtained from a range of peer-reviewed econometric HPM studies and market observation reports of water rights transactions in the MRGV and Western US. All reported prices are inflated to 2025 dollars using the Consumer Price Index for All Urban Consumers (CPI-U). Permanent water rights sales are defined in terms of AF consumptive use each year, so are effectively AFY. Lease sales prices are temporary for any given season or year and are in AF. Appendix Table B2 provides the full listing of collected studies, which range in study year from 1993 to 2026, with more detailed methodological notes.

While not in our main table (Appendix Table B2), the economists Alan V. Kneese and F. Lee Brown (1978) provided an early NM snapshot of price comparisons for permanent water rights transactions from the late 1960’s to mid-1970s – or more than 50 years ago, which we highlight in the Table 4 below, with all values converted into \$2025.

Table 4. Early Price Comparisons per AFY of Consumptive Water Rights in Five NM River Basins

NM Basin	Price of Water Right in \$2025	Year of Collection
San Juan	597	1970
	1,317	1972
Roswell/Artesia	1,975	1970
	3,553	1976
Rio Grande (excluding Santa Fe)	2,193	1969
	3,184	1975
Santa Fe	5,763	1969
	9,634	1975
Gila	29,674	1971
	61,724	1976

Notes: Dollar values are converted from original to \$2025 using CPI-U. Taken from Table 4-A-1 in Kneese and Brown (1978), who also cite Khoshakhlagh et al. (1977) as an original source. No information is provided on the move-from (original) water right use or the move-to (subsequent) water right use.

Table 4 helps provide some context for our collected studies in the intervening period and demonstrates the considerable heterogeneity, even within NM, in water rights prices that existed even 50 years ago. In real dollar terms, some values paid remain relatively high today. But Kneese and Brown (1978, p. 98)

cautioned that while the collective values relay useful information on relative values at the time (late 1960s to mid-1970s), the market for water rights in general in NM was “extremely rudimentary compared to more sophisticated markets for other commodities.”

To extend from historical background, we can ask if water rights sales and lease price have a required public disclosure? Like the conundrum around real estate sales price public disclosure (or the absence of full disclosure) in NM (Berrens & McKee, 2004), the answer is a surprisingly they don’t. There is little sunshine on these markets. Construction of this potentially valuable streetlight is currently prohibited.

Notably there has been considerable investigation into potential future *design features* for expanding *temporary water leasing markets* in the MRGV (avoiding so-called buy-and-dry scenarios that take water permanently out of the agricultural sector). In a series of experimental economics laboratory investigations (with real participants and real incentive payments, with choices under various randomized scenario simulations) Broadbent et al. (2009, 2014 and 2017) coupled hydrological and economic modeling features. With various realistic features (e.g., spatial heterogeneity in river reaches, water carriage and returns, different water use sectors), this research variously assessed the impact of transfers (by the experiment participants in different scenarios) on the physical system, parameters and regional economic parameters affecting the price formation process. Their works included investigation of features like water banking and allowing futures trading (versus restriction to a spot market where transfers between a buyer and seller must be immediate). In sum, it is a body of research that indicates how facilitating water leasing is generally welfare-enhancing (increases net economic benefits in the region) and would likely add considerable regional flexibility in responding to increasing scarcity.

What makes the absence of sunshine (e.g., absence of public price disclosure and enhanced features for water leasing) surprising, is that water rights in NM are essentially use rights granted by the public. Under the NM Constitution the natural water within the state belongs to the public, and water rights are usufructuary; that is, rights-holders possess only the right to *use* a specified quantity of water for a beneficial purpose, but do not own the water itself. However, with respect to transactions it is the priority and entitlement to use water that is bought, sold or leased, which is albeit very different from, say, a more standard commodity.³⁰

The implication for our compilation is that water sales and lease prices are often inconsistent and incomplete (in NM and some other western states), and market price discovery is difficult. While the NM OSE New Mexico Office of the maintains the publicly accessible NM Water Rights Reporting System (NMWRRS), which records transfers and change-of-ownership filings, these records typically document the fact of a transaction but do not systematically require disclosure of the prices paid (Miller, 2014). Rather, water prices are frequently treated as proprietary or private information. This data challenge is not something new to water resource economists. Colby (1993) documented substantial price dispersion in western water markets and attributed part of it to high information and search costs. Colby (2018) noted that incomplete and non-public transaction records were a central obstacle to modeling water prices. For his summary research, US Forest Service economist T.C. Brown (2006) relied heavily on the *Water Strategist*, a trade publication containing voluntarily reported transaction prices. Free access to data ceased circa 2010. Today the comprehensive price data has moved to proprietary commercial databases such as Waterlitix™ (WestWater Research).³¹ To summarize, while water rights transfers in NM are public record, the prices associated with those transfers are mostly not, absent some occasional voluntary

³⁰ The NM Supreme Court case *State ex rel. Reynolds v. South Springs Co.*, 80 N.M. 144, 452 P.2d 478 (1969) reinforced that water rights are usufructuary and subject to NM’s prior appropriation doctrine. See Dumars and Minnis (1989) for a review of the public ownership status of NM water and waters.

³¹ See: <https://westwaterresearch.com/waterlitix/>

disclosure. The economic implication is that this almost certainly significantly raises transactions costs. Search most published studies close enough, and one will find restrictions on data access.

With this important clarification, we turn next to one of the earliest rigorous studies of water market transactions in the State of New Mexico. Colby et al. (1993) focused on the Gila-San Francisco Basin in southern Western New Mexico, drained by the upper Gila and San Francisco Rivers, and tributaries into the lower Colorado River to the east. Although not part of the MRGV, the study's analysis of 95 permanent water-rights sales provides one of the first econometric (hedonic) analyses of the water market in the State of New Mexico. These 95 transactions occurred between 1971 and 1987. Colby et al. (1993) noted that market prices in the Gila Subbasin slowly rose from roughly \$1,300 per AFY in the late 1960s to about \$1,550 per AFY in the mid-1970s. These figures, when converted, represent about \$3,684 to \$4,393 per AFY in 2025 U.S. dollars. During the study period, prices had fallen slightly to about \$1,200 to \$3,300 per AFY in 1987 dollars – equivalent to about \$ 3,400 to \$9,352 per AFY in 2025 U.S. dollars, with the 1980 peak reaching the upper limit of this range. The econometric analysis revealed that water prices increased by \$47 per AFY in 1987 dollars - equivalent to about \$133 per AFY in 2025 dollars throughout the study period, with factors such as mining activities, city growth, and vacation home developments driving increases in real water values. The study identified several price determinants that remain relevant in today's market. Senior water rights command higher prices than junior water rights. That is, buyers pay about \$370 per AFY extra for rights with pre-1940 priority dates. Municipal and corporate buyers paid \$1,125 more per AFY for water rights than agricultural buyers. The location of the Basin also plays a major role in determining water prices, as water rights in the Gila subbasin were priced at about \$1,155 per AFY, higher than those in the San Francisco subbasin. Larger volumes of water rights were associated with lower unit prices, consistent with notions of economies of scale.

De Mouche et al. (2011) analyzed observed permanent water-right sales in the Lower Rio Grande Basin of New Mexico from 1980 to 2007. Sales prices ranged from \$490 to \$4,154 per AFY, with an average of \$2,128.65 per AFY equivalent to \$761 to \$6,451 per AFY and \$3,305 per AFY on average in 2025 dollars. The HPM econometric model identified urban consumptive use, priority year, quantity of water rights traded, regional reservoir storage volume, and regional farm income as potential determinants of prices. Notably the only statistically significant (at the <0.10 level) attribute of water rights prices was the measure of regional farm income (agricultural cash sales receipts in the given county and year of sale). Using the estimated HPM model, the study also produced price forecasts for the period 2010 to 2020 across four scenarios. The first scenario, which assumed no food price growth and no urban conservation, water right prices were forecast as roughly \$4,377 per AFY. The second scenario, incorporating food price growth but no urban conservation, forecasted a range from \$4,376 to \$4,676 per AFY. The third scenario assumes no food price growth and urban water conservation, resulting in a constant-price forecast of \$4,377 per AFY. The last scenario assumes food price growth and urban water conservation, resulting in a range of \$4,377 to \$3,986 per AFY, all expressed in 2025 dollars.

Brookshire et al. (2004) investigated the agricultural water rights market sales transactions (permanent sales) for the period 1990 to 2001 in three Southwestern states. These markets included the Central Arizona Project (CAP) in Arizona, the Colorado Big Thompson Project in Colorado, and the Middle Rio Grande Conservancy District (MRGCD) in New Mexico. Average observed prices were \$2,118 per AFY for the Middle Rio Grande Conservancy District, \$613 per AFY for the Central Arizona Project, and \$5,312 per AFY for the Colorado Big Thompson Project, all expressed in 1996 dollars. Inflated to 2025 dollars, these values are equivalent to about \$4,346, \$1,258, and \$10,900 per AFY, respectively. Estimated HPM equations indicate that agricultural and municipal buyers paid the same amount for water rights. In contrast, federal or state government buyers paid less, indicating that these acquisitions were largely driven by mandated requirements for species and habitat protection (Brookshire et al., 2004), and thus probably don't reflect efficient market prices.

Professor F. Lee Brown, a long-time NM water resources economics scholar regularly documented and commented on comprehensive water market prices from basins across New Mexico and the Western States. Consistent with our background context on the lack of public access to water sales and lease prices, writing in 2007 (Brown, 2007, p. 49), he commented:

“I have obtained price information for New Mexico from numerous sources on an ad hoc basis since there is no organized market or other mechanism for tabulating and reporting prices.”

In his report, permanent water right sales ranged from roughly \$302 per AFY in Oregon to about \$250,000 per AFY on the Monterey Peninsula of California (the highest amount recorded). In the Middle Rio Grande Valley, permanent water rights ranged between \$9,000 and \$35,000 per AFY in 2007 dollars - equivalent to \$13,973 to \$54,341 per AFY in 2025 dollars. The upper basin commands higher prices than the lower basin because of premium paid by buyers to transfer rights to the Santa Fe area. The Santa Fe tributaries commanded the highest prices in New Mexico, with a price range of about \$35,000 to \$45,000 per AFY (in 2007 dollars), translating to roughly \$54,341 to \$69,867 per AFY in 2025 dollars.

More recently, the studies by Burns et al. (2022) and Toll et al. (2019) provide a comprehensive analysis of western water markets across multiple basins. These studies cover thousands of transactions across 13 Basins from 1987 to 2019. Specifically, Burns et al. (2022) covered lease and sale transactions totaling over 7,000 from 2002 to 2019. Toll et al. (2019) covered 690 water lease and 1,351 water right sales transactions from 1987 to 2022. The findings from both studies consistently place New Mexico among the lowest short-term lease price markets in the West. According to Burns et al. (2022), the average lease price in the Middle Rio Grande Valley was about \$217 per AF in 2025 U.S dollars for the period 2002-2019, compared to Colorado's Arkansas River and South Platte River Basin's \$682 per AF and \$340 per AF in Arizona's Active Management Areas. At the statewide level, Toll et al. (2019) report New Mexico's average lease price at \$304 per AF, which is well below California's \$905 per AF, Arizona's \$864 per AF, Colorado's \$1,095 per AF, and Nevada's \$3,712 per AF, all in 2025 dollars.

However, in the MRGV, permanent sales appear to offer a different narrative on the price of water rights. Burns et al. (2022) noted that the average permanent sale of a water right in the MRGV was about \$19,404 per AFY in 2025 dollars for the period 2002-2019. Payne and Smith (2013), in their econometric analysis of 135 water rights transactions in the MRGV, also report that prices for permanent sales rights ranged from \$5,000 to \$49,955 per AFY in 2025 dollars, with an average of \$19,173 per AFY in 2025 dollars for the period between 2000 and 2009. Statewide, Toll et al. (2019) report average permanent sales prices of \$5,235 per AFY in New Mexico, \$2,884 per AFY in Arizona, \$30,680 per AFY in California, \$13,773 per AFY in Colorado, and \$11,984 per AFY in Nevada, all in 2025 dollars. These figures confirm that while New Mexico's short-term lease prices are among the lowest in the West, permanent water rights in the Middle Rio Grande Valley are among the most expensive.

Moving forward, Hartwell et al. (2016), in their *San Juan-Chama Return on Investment* study for the Rio Grande Water Fund,³² highlighted an important difference between how we interpret the low figures for San Juan-Chama Project (SJCP) water. Among contractors, SJCP water is valued roughly at \$100 per AF, a figure ABCWUA itself uses as an estimate of “market” price of Project water (Hartwell et al., 2016). This figure, however, is not the competitively determined market clearing price, but an administrative charge, and hence does not fully capture the water's economic value. However, given that ABCWUA also depends on the San Juan-Chama water for more than 50% of its total water supply (Hartwell et al., 2016),

³² The Rio Grande Water Fund is an innovative project of The Nature Conservancy, in collaboration with other partners, designed to restore forested lands in the Rio Grande watershed (including high-risk fire areas), to secure fresh water (Hartwell et al., 2016; [About | Rio Grande Water Fund](#))

the true economic value of this project water, measured by the utility's willingness-to-pay based on the marginal cost of acquiring alternative water supply ranged from \$476 to 1,500 per AF (in 2016 dollars) - equivalent to \$639 to \$2,012 per AF in 2025 dollars.

Another piece of contextual information in Hartwell et al (2016) reinforces this point: the cost of developing new supply. Under its Water 2120 Strategy³³, ABCWUA has identified planned aquifer storage and recovery, and water use projects whose cost serves a proxy for what the utility would have to pay to replace lost SJCP water. Hartwell et al. (2016) report planned water reuse projects on the eastside (Tijeras) to cost about \$1,465 per AF, \$1,643 per AF for the westside (Bosque), and aquifer storage and recovery (ASR) with a low end of about \$476 per AF – equivalent to about \$1,965, \$2,204 and \$639 per AF respectively in 2025 dollars. Notably, these figures denote the *cost* of infrastructure, treatment, storage, and associated technologies required to develop additional supplies, rather than the market price of a permanent annual water right. They are cited here only as a measure of the replacement cost the utility would incur to replace SJCP water. Similarly, the study also estimates the cost of lost SJCP water for the city of Santa Fe to be between \$532 and \$1,000 per AF - translating to about \$714 to \$1,341 per AF in 2025 dollars.

An observed lease transaction provides a useful comparison to the Hartwell et al. (2016) cost proxies. In 2022/2023, the Jicarilla Apache Nation and the New Mexico Interstate Stream Commission (ISC) entered into a negotiated 10-year agreement, supported by The Nature Conservancy, allowing ISC to lease up to 20,000 AF of untreated surface water annually, to be used by the ISC in New Mexico. The Nation has approximately 45,000 AF of settle water rights in the San Juan Basin. The full 20,000 AF was leased in 2023 at \$88 per AF (KRQE New 13, 2022) – equivalent to \$93 per AF in 2025 dollars, with the lease price adjusted for inflation every two years; the agreement was extended through 2025 (The Nature Conservancy, 2022 and 2025). Unlike the Hartwell et al. (2016) cost proxies, this agreement represents an observed, negotiated, short-term lease price for untreated surface water used to support endangered species and enhance New Mexico's water security (KRQE News 13, 2022).

A recent study by WestWater Research (2026), using their proprietary data, examined 968 water market transactions across Arizona's Phoenix, Pinal, and Tucson active management areas, Long-term Storage Credit (LTSC) markets, Central Arizona Project (CAP) water, effluent and other supply types from 2013 to 2025. For the LTSC market specifically, the study notes that each credit authorizes the one-time recovery and use of one AF of previously stored, and it's transferable within the active managements areas where the water is stored (WestWater Research, 2026). Therefore, these are one-time sales of physical volume of water and not a permanent water right sale. Using an HPM econometric approach, the study modeled prices as a function of factors such as supply type, seller or buyer characteristics, CAP delivery volume, transaction size, and location. CAP water supply was found to be a negative and statistically significant (at the < 0.01 level) determinant of market prices. LTSC prices across three CAP deliveries scenarios were also projected using the regression model. First, a Baseline Scenario with about 900,000 AF of CAP deliveries. Second, a Basic Coordination Scenario with about 236,900 AF of CAP deliveries, and third, an Extreme Shortage Scenario with zero CAP deliveries. The projected market prices for LTSCs vary significantly depending on water delivery conditions. Prices are estimated to be about \$500 per AF for the baseline scenario, \$1,550 per AF for the Basic Coordination scenario, and \$12,840 per AF for the Extreme Shortage Scenario. Notably, LTSC prices move in the opposite direction of CAP water deliveries. That is, as supplies fall, prices climb steeply, reflecting a scarcity premium.

³³ Water 2120 strategy outlines ABCWUA's 100-year plan for the region's water supply
https://www.abcwua.org/wp-content/uploads/Your_Drinking_Water-PDFs/Water_2120_Volume_1.pdf

Womble et al. (2025) examined environmental instream-flow water-right leases in the Upper Colorado, using about 115 water-lease prices (88 from past environmental lease transactions and 27 publicly advertised district prices) for the period 2012 to 2023, and estimated them with an HPM econometric model. Three major price determinants were statistically significant in explaining environmental water rights leasing prices across western Colorado (excluding the San Juan/Dolores regions), each expressed as a premium relative to the baseline agricultural, non-transbasin and protected lease. The HPM econometric model predicted the price of leases from Municipal and Industrial (M&I) sellers commanded a premium of \$119 per AF in 2017 dollars - equivalent to about \$156 per AF in 2025 dollars, *over* agricultural sellers. M&I leases from transbasin diversion sources commanded an additional premium of \$642 per AF in 2017 dollars - equivalent to \$843 in 2025 dollars. Unprotected lease prices were about \$97 per AF (in 2017 dollars) - equivalent to \$127 in 2025 dollars, *higher* than other leases. Publicly available leasing prices for select reservoirs in the San Juan/Upper Dolores region included \$410 per AF of consumptive use for Lemon Reservoir, \$245 per AF for Vallecito Reservoir, \$190 per AF for McPhee Reservoir, and \$74 per AF for Groundhog Reservoir, all expressed in 2025 dollars.

Aside from the exploration of water prices, Womble and Hanemann (2020a, 2020b) shed light on the magnitude of *transaction costs* that are largely opaque in public data. Womble and Hanemann (2020b) focused on what they term *procedural transaction costs*, which consist of the legal and hydrologist fees required to secure state approval of a water-rights transfer. These costs are privately negotiated, rarely reported, and essentially unmeasured in the literature. Womble and Hanemann (2020b) addressed this directly by surveying 100 Colorado water professionals (63 lawyers, 35 hydrologists, 1 water planner, and 1 administrator) to gather fee estimates for water transfers with varying volumes of consumptive use, water right seniority, water division, and legal outcome. Expected transaction costs are estimated using a two-stages structure: (i) first modeling the probabilities of legal outcome; and then (ii) modeling costs based on each outcome. The results revealed that larger transfer volumes reduce transaction costs, higher-conflict court outcomes and senior water rights raise costs, and transfers in water-scarce regions have higher costs. For a 100 AFY senior rights transfer in Division 1 (South Platte River Division), the expected cost for all outcomes was \$2,208 per AFY - equivalent to \$2,900 per AFY in 2025 dollars. The same transfer in Divisions 4/6/7 (Gunnison, Yampa/White, San Juan/Dolores) had an expected cost of \$787 per AFY – equivalent to \$1,034 per AFY in 2025 dollars. For a very large 40,000 AFY transfer in Division 1, expected cost fell to \$20 per AFY – equivalent to \$26 per AFY in 2025 dollars. Again, the study compared some of these transaction cost estimates against actual market prices in the WestWater dataset (523 transactions, 2008-2018). Expected transaction costs averaged 35.7% of combined market price plus transaction cost, which is significantly higher than the average of 12% Colby (1990) reported. Also, transactions for smaller transfers can exceed the expected water's market prices many times. For instance, in Division 1, the expected transaction costs are 3.41 times the expected market price for a 1 AFY transfer. However, transactions cost decline as the volume of the transfers becomes larger.

Overall, our literature review reveals some interesting aspects of water markets across the western US. First, as would be expected, sales of permanent water rights are always substantially more expensive than short-term leases. For instance, the MRGV demonstrates this pattern particularly well. That is, lease prices are among the lowest in the West, yet permanent water right sales are among the highest in the region. Across all markets, the problem of scarcity is a dominant determinant of price, as demonstrated by WestWater Research's (2026) projections for Arizona's CAP market, where prices increase dramatically from \$500 to \$12,840 per AF as supplies fall to zero. Transaction costs, that is the legal and hydrologist fees required to complete a transfer, are a substantial yet largely unobserved cost component of water reallocation. These costs are rarely reported and can exceed the price of water itself for small transfers.

With climate change, and a growing Rio Grande Compact debt in NM, there appear to be many entities (both public and private) competing for scarce water rights purchases in the MRGV. In closing, Table 5 provides a summary of water market prices in the MRGV from post 2000 reported studies and

compilations, with some select external comparisons. We have heard more recent (unverified) anecdotal reports of even higher permanent sales values in the MRGV. The summary evidence from Table 5 (i.e., median values for MRGV) indicates that market values for permanent sales run more than 130 times the value of temporary annual lease rates. If the water right was assumed to reflect a perpetuity, then the implied discount rate is less than 1% (i.e., the future value of water is not being heavily discounted). But we emphasize how *little public sunshine* there is on this market. For example, we don't have detailed characteristics of the of the water rights being sold (e.g., priority status), and we don't have records of the move-from/move-to locations and categories of use that are connected to particular sales and prices (in this high transactions costs, public nondisclosure NM setting). While leases settings often can be much easier, this remains a heavily broker-dependent market for permanent sales (and might still be even with public price disclosure because of complicated rights histories, legal statuses, and the physical characteristics of water). Yet, if public entities continue to have to move into this MRGV market (e.g., municipalities, the state [NM OSE under the Strategic Water Reserve (see Veihl, 2023)], or public corporations like the MRGCD), then there is a sunshine argument for fuller disclosure.

Table 5. Summary of Water Market Prices in MRGV, with Select NM and Western US Comparisons, 21st-Century Studies (2025 Dollars)

Transaction Type / Region	N studies (segments)	Median	Conservative Range
Permanent sales (\$/AFY)			
Middle Rio Grande Valley	3 (4)	\$20,958	\$19,173 – \$42,697
Other New Mexico basins	1 (5)	\$17,079	\$3,649 – \$62,104
Other Western US markets	2 (18)	\$3,450	\$933 – \$39,203
Temporary leases (\$/AF)			
Middle Rio Grande Valley	2 (2)	\$155	\$93 – \$217
Other Western US markets	2 (10)	\$293	\$74 – \$682

Notes: The table summarizes water market transaction evidence in Appendix Table B2, restricted here to studies whose transaction data begin in 2000 or later. Each study contributes one central value: the study-reported mean where available, or the midpoint of the reported price range otherwise. To be conservative, the Median is then calculated across these central values, and the Range reports their minimum and maximum. NM and MRGV sales are not public and draw on secondary reporting, including Brown (2007), Payne & Smith (2013; 135 transactions, 2000–2009), and Burns et al. (2022; MRGB 2002–2019). Other NM sales information comes from Brown (2007) while Other Western US markets draw on Brown (2007) and Burns et al. (2022). MRGV leases values are taken from the Burns et al. (2022) MRGB mean and the 2023 Jicarilla Apache Nation–NM ISC bulk lease (\$93 per AF); no lease evidence from this period is available for Other NM basins. Other Western US leases draw on Burns et al. (2022) and the Womble et al. (2025) reservoir lease prices in southwestern Colorado. Notably, individual transaction extremes within the underlying studies span considerably wider intervals than represented here.

III.2.c. Various Public Administrative Charges and Payments for Water, with a Focus on MRGV and Western US

In much of the western US, historical systems of administrative water charges probably say more about covering the operation costs of delivery and conveyance systems (pipes, canals, and pumping) than about scarcity. In many cases, what users pay for water has little to do with the water's actual value (see Randall, 1981). Rather it is more likely to reflect how far water has traveled and the cost of moving it. Even then both the capital amortization and even some delivery costs may be heavily federally subsidized (e.g., purposefully to provide access, and incentivize use and resource development), to keep user charges low.

Such subsidy patterns may have long institutional histories (and arguably inertia). The important point is that the observed pattern of administrative charges and payments by users do not reflect theoretical welfare measures of economic value.

Appendix Table B3 presents this pattern of various public administrative charges for water in the MRGV and some comparative western US. All figures in the table are expressed in 2025 dollars, adjusted year-over-year using the CPI-U (Consumer Price Index for All Urban Consumers). The differences are substantial, with some programs charging almost zero dollars per AF, while others cost several hundred dollars per AF. This variation does not imply that water is inherently more valuable in some places than others. Instead, these differences are tied to the history of each project, the way rates were set over time, and the level of federal assistance (or subsidy) behind the infrastructure.

Administrative charges are probably the clearest example of water rates that have little to do with the scarcity value of water itself. The MRGCD Water Service Charge (WSC), for example, equals about \$21.73 per AF in 2025 dollars. This figure is derived from the MRGCD's 2024 assessment of \$51.25 per acre³⁴ (MRGCD, 2024 Water Service Delivery Contract, Resolution No. M-01-08-24-205), converted using an effective ET rate of 2.42 AF per acre across approximately 42,000 *irrigable* parcels (using the 2022 ISO-log files with the assumption that, it remained unchanged in 2024).³⁵ The charge mainly covers canal operations and maintenance rather than the water itself. The MRGCD's Water Bank leasing rate operates similarly. Irrigators with pre-1907 water rights can place water into the District's Water Bank (MRGCD, Revised Rule No. 23: Water Bank Rules, 2021), where other irrigators may lease it at \$50 per acre per year (MRGCD, Assessments Department, n.d.), equating to about \$23.81 per AF using the NM OSE's allowable consumptive irrigation requirement (CIR) of 2.1 AF per acre (Harding & McCord, 2005).

The same general principle happens on a far larger scale across the Colorado River. The US Bureau of Reclamation (USBR) sells water to the Central Arizona Project (CAP) at \$0.26 per AF. The Central Arizona Water Conservation District (CAWCD) then delivers that water to Phoenix and Tucson at roughly \$241 per AF. The difference has nothing to do with the water becoming more valuable along the way. It reflects the cost of building and running a 336-mile aqueduct across the Sonoran Desert. California's State Water Project and the federal Central Valley Project (CVP) operate the same way. Agricultural users pay between \$40 and \$100 per AF. The water itself is free. The charge is to partially cover the infrastructure cost. The inherent problem with tying water charges to delivery costs is that the effective incentive 'price' to users remains stable even during a drought, when one would expect the economic value of water to increase substantially. I.e., there is no true scarcity signal or conservation incentive. In the Lower Colorado Basin, agricultural districts with direct federal diversion rights pay only minimal delivery charges while municipal wholesale buyers in the same basin pay several hundred dollars per AF for essentially the same water from the same system. Such differences make it difficult to characterize these charges as market signals reflecting the scarcity of a resource. Rather, they reflect institutional

³⁴ Note that for 2026, this rate was increased to \$61.03 per acre. The statutory authority to impose the WSC comes from the NM Conservancy Act, as amended. [NMSA § 73-18-8.1] The 1993 amendments (with effect beginning in 1995 irrigation season) imposed a \$28 per acre WSC and limited the rate of increase to no more than the rate of inflation. In inflationary terms, the \$2026 value of the initial \$28 WSC (of 1995) would be about \$61.57. So, this is essentially a flat rate, in real terms. For some of the detailed history around this, see Fleck and Berrens (2026).

³⁵ Owners of irrigable acres within MRGCD boundaries can petition or request that their lands be taken off or excluded from the charge, and some of this appears to happen every year. In some cases, parcels can be added.

arrangements from the *Reclamation Era*,³⁶ when agricultural access to water was intentionally subsidized and priced at the cost of delivery rather than scarcity value. Much of that pricing structure remains in place despite growing pressure on the Colorado River system. This outcome is what Grafton et al. (2020) describe as the “paradox of water pricing,” in which water prices almost never reflect its economic value.

The voluntary programs work differently because irrigators usually enroll only when the payment exceeds what they expect to earn from irrigating that season, at least for commercial irrigators. In other words, participation depends on a tradeoff between compensation and the value of foregone agricultural production. To incorporate non-commercial irrigators, on the intensive margin, we would expect them to sign up when the payment per acre exceeds their minimum willingness to accept (WTA) compensation for that acre ($\text{PAYMENT} > \text{WTA}$). That makes the compensation rates a reasonable proxy for what it costs irrigators to give up water. The USBR *Supplemental Water Leasing Program*, known informally as Minnow water, paid San Juan Chama Project contractors an average of \$96.81 per acre foot over the 2003 to 2021 period, in 2025 dollars, to release stored water for the Rio Grande silvery minnow. As listed since 1994, the silvery minnow in the MRGV is a protected species under the U.S. Endangered Species Act (ESA). Since this water is returned to the river rather than consumptively used in net (there will always be some associated riparian ET), the rate serves as a rough estimate of what irrigators in the Middle Rio Grande have historically been minimally willing to accept (WTA) as compensation in order to forgo delivery of stored supply in federally controlled reservoirs. In any given year, it is a fixed administrative rate though and doesn’t allow us to trace out a WTA compensation supply function and calculate a Hicksian welfare change measure of value (Freeman et al., 2014).

The MRGCD Environmental Water Leasing Program (EWLP) tells a somewhat similar story. The program pays irrigators per acre of land enrolled in seasonal fallowing. If we were to assume those per-acre payments can be converted to a per AF basis using calculated 2021 ET rates in MRGCD of 2.6 AF per acre for commercial irrigators and 1.76 AF per acre for small non-commercial operators (Olofinsao, 2025), we can obtain an implied value for consumptive use. The implied value for commercial irrigators increased from approximately \$71 per AF in the 2020 partial-season leasing program to \$274 in the 2024 full-season program. That is almost four times higher in four years, most likely driven by worsening drought and growing pressure to keep water in the river for compact deliveries and endangered species reasons. The 2026 enrollment cycle announced by the MRGCD in April 2026 suggests some moderation in the leasing values, with partial season commercial rates at an implied \$67 per AF and multi-year full season rates at an implied \$210 per AF. It remains unclear whether this reflects improvements in river conditions or is simply a change in program design. A similar pattern is observed for small non-commercial irrigators as well. The implied value increased from about \$106 per AF in the 2020 partial season to \$408 in the 2024 full season. The partial-season small non-commercial rates are about \$99 per AF, and multi-year full-season rates are \$313 per AF.

The Lower Rio Grande Groundwater Conservation Program, administered by the NM Interstate Stream Commission (ISC), operates on a similar principle but focuses on groundwater rather than surface water. The program pays irrigators \$750 to \$800 per acre per year to voluntarily suspend pumping for one to three years. Using the Consumptive Irrigation Requirement of 2.6 AF per acre for groundwater-only land – a standard established in the *2025 Texas v. New Mexico Groundwater Settlement Agreement*, those

³⁶ The Reclamation Era denotes the early 20th-Century period starting with the Reclamation Act of 1902 and running to about the 1970s, which established the U.S. Bureau of Reclamation to finance and implement the construction of large scale irrigation systems for the storage, diversion, and development of water in Western States (Western Water Council, 2020, <https://westernstateswater.org/resolutions/2020/position451/>). Water users under the act were required to repay construction expenses, (The Bureau of Reclamation: A Very Brief History, <https://www.usbr.gov/history/borhist.html>). but typically, this would be on very favorable terms and often did not happen, or costs were only partially recovered.

payments translate to implied consumptive-use values of roughly \$296 to \$316 per AF for one to three-year enrollments. Considering diverted volumes, the figures are lower, about \$171 to \$182 per AF when converted using the Farm Delivery Requirement of 4.5 AF per acre (NMOSE, Lower Rio Grande Water Master Report, 2024, p.5). Either way, the figures roughly match what MRGCD irrigators were accepting in the EWLP's mid-period years.

Importantly, not all environmental water moves through a program with a payment rate. Along the Isleta Reach of the Rio Grande, a 34-mile stretch from Isleta Diversion Dam to San Acacia Diversion Dam, some of the most meaningful water transactions of the past decade involved no payments at all. In 2016, Audubon New Mexico facilitated a series of contributions in which four sovereign Pueblos (Sandia, Isleta, Cochiti, and Santa Ana), each released 100 AF of their Prior and Paramount water rights into the river to support in-stream flow. Sandia and Isleta donated outright. Cochiti and Santa Ana provided water in exchange for funding for riparian restoration on their lands. This in-kind arrangement puts a value on habitat work rather than on the water itself. The Club at Las Campanas, a private golf club in Santa Fe, later donated an additional 399 AF, bringing the 2016 total to 799 AF. Starting in 2018, during the extremely dry season, 999 AF of water were supplied from Isleta Pueblo, the Village of Los Lunas, and the Town of Belen, including potential renewal for ten years (Simpson & Grabau, 2018). Participants indicate that this shared effort aims to prevent the river from drying up.

A final group we consider, which shows some of the most expensive administrative charges, is *bulk water*. The term gets used differently and sometimes is applied to untreated water; but more generally is applied to non-piped, potable water. An example of a common definition would be: bulk water is potable water delivered to a customer by means other than a pipeline or sealed bottle, typically dispensed at a metered fill station and hauled away by the buyer in a truck-mounted tank (Vermont DEC, Water Supply Rule, 2024). As local examples, the City of Rio Rancho charges \$10.50 per 1,000 gallons or about \$3,421 per AF, with this charge set to increase by 5 percent annually through 2030. Santa Fe County's Ojo de Agua station charges residents \$0.01 per gallon – equivalent to \$3,259 per AF and commercial customers \$0.02 per gallon – equivalent to \$6,517 per AF. The Town of Mountainair (outside the MRGV) is the highest of all, at \$0.05 per gallon for residential buyers and \$0.15 per gallon for commercial buyers, which translates to about \$16,293 and \$48,878 per AF, respectively.

Overall, the programs, as presented Appendix Table B3, show that administrative water rates serve very different purposes across the region. Some charges are mainly intended to recover the cost of infrastructure and delivery. Environmental water leasing programs, on the other hand, are voluntary programs that attempt to compensate for a reduction in consumptive irrigation use and provide a clearer indication of the opportunity cost irrigators associated with giving up water use. The widening gap between the cost of irrigation water delivery and the compensation required to voluntarily reduce water use suggests that securing environmental or conservation water is becoming increasingly expensive. While irrigators continue to pay relatively low charges for water delivery, conservation programs must offer substantially higher payments to encourage participation. This widening gap (low delivery charges and rising conservation payments) is consistent with increasing scarcity and growing competition for water resources in the region. Donations reflect an entirely different set of values, especially when stakeholders are motivated by cultural and ecological reasons rather than direct financial benefits

Table 6 present summary information on administrative charges and payments by public entities for water in the MRGV.

Table 6. Summary of Administrative Charges and Payments for Water in MRGV, with Select Outside Comparisons (2025 Dollars per AF)

Category (Water Type / Purpose / Location)	N rates	Median	Range
Untreated (raw) water			
MRGCD administrative charges, MRGV (Water Service Charge; Water Bank lease)	2	\$23	\$21.73 – \$23.81
Environmental leasing/fallowing payments, MRGV (MRGCD EWLP; USBR supplemental water)	15	\$121	\$71.22 – \$408.07
Fallowing payments, other NM (LRG Groundwater Conservation Program)	4	\$239	\$171 – \$316
Project wholesale rates, outside NM (CAP, SWP, CVP, Lower Colorado)	8	\$75	\$0.26 – \$540
Treated (potable) water			
Municipal bulk-fill / hauled water, MRGV area (Rio Rancho; Santa Fe County)	3	\$3,421	\$3,259 – \$6,517

Notes: This table summarizes some select administrative charges and payments reported in Appendix Table B3; the median and range are taken across the individual reported rates in each category. MRGCD charges are converted from per-acre billing to dollars per AF of expected consumptive use (and thus probably exhibit considerable uncertainty). Environmental leasing and fallowing payments are expressed per AF of effective evapotranspiration forgone and include MRGCD EWLP rates for commercial and small non-commercial irrigators (2020–2024 seasons) and the US Bureau of Reclamation supplemental water leasing program. The Lower Rio Grande (LRG) Groundwater Conservation Program range reflects payment on a diverted (versus consumptive) basis and one year (vs three year) enrollment. Project wholesale rates are volume-weighted averages that recover delivery, operation and maintenance, and capital costs rather than the value of the water itself; the \$0.26 per AF rate is the US Bureau of Reclamation charge to the Central Arizona Water Conservation District. Treated bulk water reflects retail potable water sold per gallon at municipal fill stations in the MRGV, converted at 325,851 gallons per AF.

III.2.d. What do Households Pay for Nonconsumptive Use? Comparable Community Water Provider Rates for Water & Sewer Services for Standardized Residential Indoor Monthly Use (6,000 gallons) in the MRGV

Lest we focus too much on consumptive use, we can ask about the general status of affordability of non-consumptive (indoor) residential use in the MRGV? As summarized here, Appendix Table B4 provides survey-based, combined residential water and sewer charges for the 6,000-gallon-per-month standard across a selection of reporting community water systems (CWS's) in the MRGV. We use CWS's here interchangeably with providers. CWS's were included only if they serve 1,000 or more single family residential connections, thereby focusing on larger community water systems that serve most residents in the region. This summary covers Bernalillo, Sandoval, Valencia, and Socorro counties. Using starting points from 2002-2003 and ending points from 2022-2023, the data were obtained from an annual survey conducted by the New Mexico Environment Department (NMED). The data often has missing values as not all providers respond in all years. All rates are expressed in 2025 U.S. dollars using a period-level Consumer Price Index (CPI-U) multiplier, where the early period spanning 2002–2003 uses a multiplier of ($\times 1.769$) and the recent period spanning 2022–2023 uses a multiplier of ($\times 1.078$). This inflation adjustment enables consistent comparison of combined residential water and sewer rates over the 20 years to assess whether these rates have increased or decreased. Appendix Table B4 covers a total of 11 community water systems, which vary in size from 1,450 to 182,326 single family residential

connections. None of the private systems serves more than 3,750 single family connections. Collectively, they provide water and sewer services to about 231,888 single family households,³⁷ in addition to the other multi-family households and other sectors they serve. As by far the largest system, ABCWUA alone serves two-thirds of the total single-family connections.

We start with Bernalillo County. For the publicly owned water systems in Bernalillo County, the Albuquerque system (ABCWUA) recorded a 10.6% decline in combined water and sewer rates in 2025 dollars between the two periods. A reduction in recent sewer rates largely drives the change. With a 2022-2023 value of \$53.84, the lowest reported, ABCWUA establishes the floor, with its large size and likely economies of scale. Yet, production, needed treatment and sourcing costs all matter, and select smaller systems are not far off. For example, the Sandia Peak Utility, a privately owned water system in Bernalillo County, reported a combined rate of \$58.31 per month in the recent period. However, no early-period data are available for direct comparison. In Sandoval County, the Bernalillo (Town) water system recorded an increase of approximately 28.4%, with combined rates going from \$65.71 to \$84.37, making it the second-largest increase among reporting providers, though its recent figures are based solely on 2022 data. The Rio Rancho Water and Wastewater service has an early-period combined rate of \$93.57 per month, with no recent-period reported in the survey.

In Valencia County, the Bosque Farms Water Supply System and the Los Lunas Water System are the two publicly owned water systems with complete data for both periods. The Bosque Farms Water Supply System recorded a 7.22% increase in combined rates, increasing from \$70.78 to \$75.89 per month. Similarly, the Los Lunas Water System recorded a 11.11% increase, with combined rates moving from \$85.93 to \$95.48 per month. The Rio Communities and Rio Del Oro Water Systems in Valencia County report the highest combined rates among privately owned water systems, at \$110.30 per month, though these figures are based only on 2023 data. In Socorro County, the Socorro Water System is the only publicly owned water system that met the defined threshold of more than 1,000 residential water connections. The system recorded a 9.76% increase in combined rates, from \$62.01 to \$68.06 per month, though its recent figures are based solely on 2023 data.

These figures reflect what providers responded to the NMED survey as to what they charge for water and sewer, for a commonly used standard (6,000 gallons monthly). But two recent investigations dig further into what those charges mean for the residents paying them. Specifically, questions about affordability across the State of New Mexico are explored in detail, Magee's (2025) UNM master's thesis, and the Samimi et al. (2025) UNM Economics water equity report. Both studies employed the same standard minimum requirement of 50 gallons per capita per day (GPCD) for basic nonconsumptive indoor use (Gleick 1996, as cited in Samimi et al., 2025) to answer questions about water affordability. The general inference drawn from both studies is that water charges remain largely quite affordable in New Mexico (for the full spectrum of reporting CWP's across the state). Magee's (2025) study found that the monthly charge for a standard 6,000 gallons - equivalent to 50 GPCD for a standard four-person household, is on average close to or even below 1% of median income for water-only and 1.71% for combined water and sewer charges. These results are far below the US Environmental Protection Agency's recommended 2-2.5% and 3-4.5% thresholds for water-only and combined water and sewage charges, respectively, even though rates have consistently risen faster than inflation across all system sizes (Magee, 2025). Magee (2025) also conducted a variety of sensitivity analyses for low-income households (e.g., bottom quartile, and relative to poverty definitions, and found a general pattern of affordability. Similarly, Samimi et al.'s (2025) water equity study for a more targeted slice of urban New Mexico, which assessed water affordability in the ABCWUA service area at the block-group level, found that only one of the 411 block

³⁷ This equates to a large slice of the total NM population. The single-family household residential connections summarized here would amount to a population of roughly 557,000. This assumes they roughly match the 2024 American Community Survey (ACS) NM average household population average of 2.4 (or just under the US national average of 2.5) (US Census Bureau, 2024).

groups considered exceeded the income threshold for indoor water use. That is, 99.76% of the 411 block groups in Albuquerque fell below the 4.5% income threshold.

Table 7 provides some summary information. The empirical evidence for the MRGV indicates that municipal water rate structures for a relatively generous indoor use level appear to be consistently affordable, under most providers of even modest scale and even for most low-income households. To be clear though, such conclusions pertain to residential rates (i.e., for single-family homes). Most renters pay for water bundled in rental rates. Finally, very small systems may represent a different case and are less investigated (but see Warner et al. (2021) for a statewide review of small systems in NM, with a focus on governance and capacity).

The conclusions on the general pattern of affordability on a residential, standard indoor usage is an important reference point but tells us very little about the general pattern of uses, incentives (or values) around residential consumptive (outdoor) use. There appears to be clear gap or a need for the annual NMED survey – or its equivalent -- to collect rate charges (water and sewer combined, and separate) for more than just a single 6,000-gallon monthly use level, especially as it relates to higher use levels and consumptive outdoor use. There is no *recent* research that has analyzed and compared the full distribution of rate structures, and their incentive properties around consumptive (outdoor use) across NM or MRGV community water systems. However, Hooper (2014) compiled and catalogued prior water rate structures for 30 NM municipalities and found that two-thirds had adopted some form of incentive-based (tiered/conservation) pricing, such as increasing block rates (IBR); In implementation they were often relatively flat. But there were notable exceptions (e.g., the City of Santa Fe). It is important to note that the general empirical evidence shows that rate incentives are often a much more cost-effective conservation approach than non-price alternatives (see Olmstead & Stavins, 2009).

Table 7. Summary of Monthly Residential Combined Water and Sewer Charges for Standardized 6,000-Gallon Use, MRGV Community Water Systems (2025 Dollars per Month)

Period	N providers	Mean	Median	Min – Max
2002–2003	7	\$71.28	\$65.71	\$60.22 – \$93.57
2022–2023	8	\$82.07	\$80.13	\$53.84 – \$110.30

Notes: The table summarizes the combined residential water and sewer charges reported in Appendix Table B4 for a standardized indoor use of 6,000 gallons per month, across reporting community water systems serving 1,000 or more single-family residential connections (Bernalillo, Sandoval, Valencia, and Socorro counties). All charges are inflated to 2025 dollars using period-level CPI-U multipliers. Note that the panel is unbalanced, as combined charges are in some cases unavailable for both periods. The 2022–2023 minimum is the Albuquerque (ABCWUA) system, and the maximum is the Rio Communities and Rio Del Oro systems.

III.2.e. What Do We Pay for 1.5 AF of Consumptive Water Use?– *Preliminary Investigation and Comparisons Across Various Sources.*

As noted, the general tendency is to neither focus on, nor compare across sources, what consumptive use costs to users (let alone what net economic values are attached to such use). To provide a *very preliminary* economic investigation and to give some sense of what someone must pay to obtain consumptive use (CU) of water, Figure 13 was created for the greater Albuquerque area (with a nod to Santa Fe municipal). While preliminary, we think the figure does a good job of reflecting the range of

relative payment amounts. However, current dollar values reported are sensitive to calculation assumptions across the different sources. Appendix C provides a detailed set of calculation notes, and we encourage further exploration.

To stay with our terminology, if someone is paying a water-allocating public entity then this is the charge for that 1.5 AF (=325,851 gallons); if someone is “producing” the water by pumping it to the surface then we might better call it a cost. We look at both payment types in Figure 13. We investigate the amount in current dollar terms that an individual person or entity must pay to grow green things with 1.5 AF of consumptive water use (incorporating a standard set of assumptions on irrigation efficiency for different sources for needed applications of water to achieve 1.5 AF of CU [see Appendix C]). Some of these might be green things we eat, but most would not. Our focus is *not* on commercial agriculture (although we include irrigation wells for comparison). As a starting point, for our 1.5 AF of consumptive use, one should think roughly in terms of a roughly 0.75-acre to 1-acre lot near the valley floor, but even this could vary depending on what is grown and how. We are not holding the land constant, or what is grown constant; we are holding the 1.5 AF water CU constant. For municipal sources of water (red bars in Figure 13), we start with the assumption of the same 6,000 gallons (= 8 units, where 1 unit equal 748 gallons or 100 CF) monthly indoor -- or assumed winter average [WA] use. This is important because outdoor (summer month) increasing block rates (IBR’s) or surcharges for our calculations are tied to this WA base. We also are careful to avoid any sewer charges. This fixed 1.5 AF CU amount is on the far end of the statistical distribution of what might be found in municipal residential data, and perhaps five times or more what a typical single-family residential lot might use. On the other hand, it is not hard to drive up and down the MRGV and see 0.75- to 1 acre residential green spaces. For example, the 1.5 AF CU is in the ballpark for what we believe per parcel domestic well use might average on the valley floor.

As a caveat, we will assume a high level of efficiency in delivery. To the extent that there are significant delivery or application losses back to the ground as percolation that recharges the shallow aquifer (and thus is not CU) for any of our sources (and thus more costly water is needed to achieve 1.5 AF CU), then our cost estimates will be understated. Note that this won’t matter if, say, a flat rate per acre minimum is charged for water delivery (e.g., MRGCD ditches).

Again, to emphasize, we are not interested here in the size of the plot or what green things someone wants to grow, rather we are interested in consumptive use (i.e., effective ET) and what someone must pay to obtain the 1.5 AF of CU. In some cases, this amount is the administrative charge (sometimes under a flat rate, sometimes under a complicated IBR), in other cases (e.g., agricultural or domestic well water) it represents the cost of pumping the water (which is set by the regulated electric provider (i.e., PNM), with sometimes a flat rate and sometimes an IBR depending on the well type). As shown in Figure 13, there is an incredible range, across multiple orders of magnitude, in the dollar payment amount for consumptively using 1.5 AF of CU water to grow green things, from \$0 to over \$13,000. Some of this is related to physical production costs (e.g., some of the water is piped and treated, but other sources aren’t). For un-priced domestic well water, much of the amount paid is driven by physical factors such as depth to groundwater and electricity pumping costs. Further, much of the variation is attributable to things like legal status, institutional and utility classification, and rate design philosophy. Also, as one important technical detail, for irrigation sources we note that the MRGCD flat per acre rate (WSC) is for an *allowed* surface water consumption, which may not be a realized consumptive use in a water scarce year (and thus we denote with the single slightly lighter green bar for reference in Figure 13. The converse is that in some water years average CU per acre MRGCD irrigated lands can be above 1.5 AF (see Olofinsao, 2025).

We close with several additional observations from Figure 13. To start, a \$0 value anchors the cheapest charge. But we note that for the six MRGV Pueblos, their combined *Prior and Paramount* status for

roughly 8,850 irrigated acres has legal priority on MRGCD surface deliveries (with no annual charge for water provision, as literally congressionally tied to their contributions to the creation story of the MRGCD) (see Fleck & Berrens, 2026).

Second, while effective agricultural charges for consumptive water use from irrigation well pumping are at the cheaper top end of Figure 13 and have arguably no conservation pricing incentives (flat electricity rates, no IBRs, etc.), our focus is not on commercial irrigated agriculture. From historical reviews of USDA *Census of Agriculture* statistics, this sector has been getting squeezed in the MRGV for some time.³⁸ For many commercial producers, there is little net margin to work with,³⁹ and outcomes in this sector will likely be driven by forces outside the MRGV (e.g., commodity prices). Hence, our targeting in Figure 13 of a modest 1.5 AF of consumptive use as our benchmark -- it represents an important practical reference point.

Thus, if we acknowledge the sovereignty of the six Pueblos' P&P water use, and if you take out a relatively modest commercial, irrigated agricultural sector, then everything else is mostly *noncommercial* consumptive use (with some private golf courses etc. to consider, as included in Figure 13).

This leads to what we view as a critical point. By any reasonable calculations (e.g., in adding up domestic well use, and aggregating use by small noncommercial irrigators [see Olofinsao, 2025]) a very large slice, perhaps even super-majority of this noncommercial, consumptive use of water in the MRGV occurs in the top end of Figure 13 (where water is cheap, with the green bars), not the high-charge bottom half of the figure (with the red bars). Simply put, our largest consumptive use sourcing categories have no strong (if any) marginal conservation incentives. By whatever complex historical paths the institutional arrangements governing water in the MRGV may have evolved along, it is hard to argue that economic incentives (or the absence thereof) aren't deeply affecting how we are consumptively using water today.

One inference is that focusing on the bottom half of Figure 13 (where the red bars are) might not be where we will achieve *significant additional* reductions in consumptive use. Consider the Figure 13 comparison for the ABCWUA municipal system of what a hypothetical charge would be without any of their current IBR conservation surcharges (the blue bar, at \$2,007) versus the actual ABCWUA red bar (\$4,272); this shows there are already significant conservation incentives at this use level (over 50 percent higher at 1.5 AF of CU). Other municipal providers have even higher charge levels. Further, the relatively rare residential municipal users in this 1.5 AF consumptive use range are likely to be higher income

³⁸ To give some sense of this, for the four counties for the 2025 period 1997-2022, US Department of Agriculture's regular Census of Agriculture (County data for NM, for 1997, 2002, 2007, 2012, 2017 and 2022) there is a clear downward trend in reported irrigated acreage. E.g., In the aggregate there was an approximate 44% decline from 1997 to 2022, from over 58,000 to 32,000 acres. Note: these figures would not include Pueblo irrigated acreage, or non-USDA defined farms, and thus for a variety of reasons might not match MRGCD irrigated acreage reports.

³⁹ Irrigated crop production in the MRGV is not economically significant as a slice of regional GDP, although it is socially, and culturally and politically important). For the 4-county region of the MRGCD, the agricultural sector represents about 0.12 percent of regional GDP, with livestock grazing (not dependent on irrigation) accounting for about half of this value. Socorro County is relatively different (at about 6.75 percent of their county-level GDP), but for the three northern counties, we are looking at the commercial irrigated agricultural sector as perhaps 0.015 percent of county economies. Numbers are taken from the US Department of Commerce's Bureau of Economic Analysis (BEA) and the NM Economic Development Department (EDD). See: (i) [NM EDD – December 2024 Quarterly Economic Summary, Bernalillo County](#) (BEA CAGDP2 data); (ii) [NM EDD – December 2024 Quarterly Economic Summary, Sandoval County](#) (iii) [NM EDD – December 2024 Quarterly Economic Summary, Valencia County](#) (iv) [NM EDD – December 2024 Quarterly Economic Summary, Socorro County](#) ; and (v) [BEA GDP by County \(CAGDP2\)](#); FRED series: [GDPALL35001](#), [GDPALL35043](#), [GDPALL35061](#), [GDPALL35053](#)

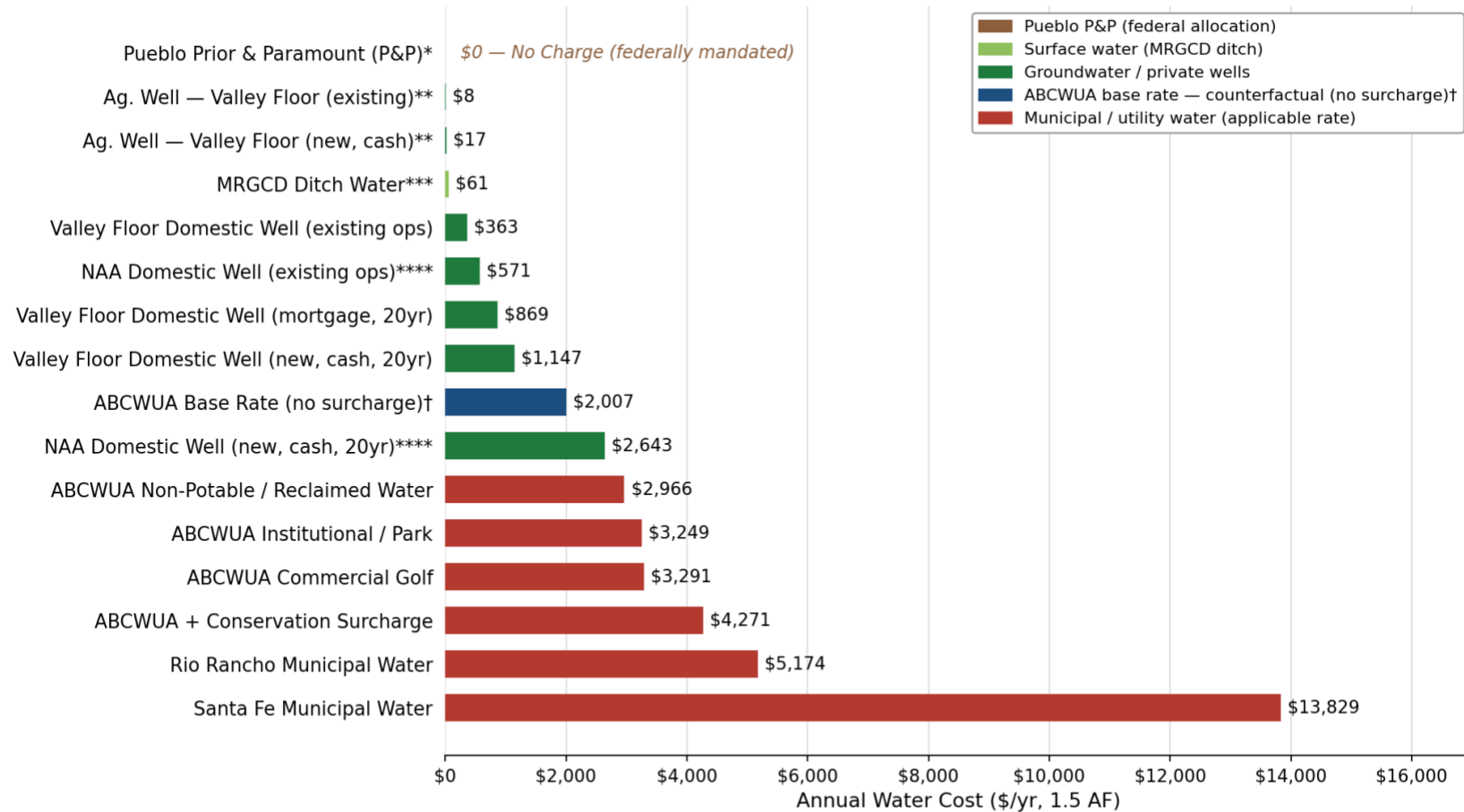
households who might be particularly price inelastic. As such, *excessive use* rate penalties on extreme high-end users could be a source of revenue generation, with some marginal conservation gains in consumptive use.⁴⁰ And to be clear, a focus on balancing municipal conservation and controlling large users may be extremely important to those community water providers and entities managing costly engineering provision of piped/treated water. But such a focus is not likely to move the needle from a *regional* perspective on consumptive use. Rather, if there were to become an agreed-to, broad regional goal to have people use less water consumptively, then we might re-think stronger marginal conservation incentives, across a broader range of sourcing options.

Based on our earlier compilation review, we emphasize that there remain significant gaps in understanding net economic values (Table 2) in relation to the estimated charges in Figure 13. Recall that in Table 2, available research has generally not been focused on isolating values per AF of consumptive use. This is perhaps not surprising as it is a system historically focused on key measured diversions (e.g., to agricultural irrigation deliveries to farms, or municipal residential deliveries). But that doesn't mean there isn't room for innovative future studies more focused on consumptive uses.

As one example, certainly there is room for analyses isolating residential outdoor use (and its specific consumer surplus) from indoor use. As a second example, considering the areas *between* the river levees points to the issue of what is missing in Figure 13. That is, what about the effective ET and consumptive use by the *bosque*, where the trend line on effective ET from section II.3.b. appears to show increasing consumption in a hotter world? A variety of entities make management choices about the configuration of the bosque, and lot of people move about and recreate in it, but we don't appear to have a base of *current* economic studies about the environmental benefits associated with this consumptive use. Relatedly, as a third example, there is a gap in understanding recreation along diversion ditches and drainage ditches. With new information tools, there are testable hypotheses. Do people recreate more along un-lined ditch trails with more trees versus concrete-lined ditches with few trees? Remote-sensed, satellite information for both trees and cell phone use should be applicable to answer this question. Economists are now advancing quickly in valuing recreational visitation with cell phone data (Yonjie et al., 2026). As a fourth example, thinking just outside the levees and the interconnected river valley floor, what is the actual effective ET and associated consumer surplus (net of shown costs in Figure 13) to the growing number of domestic well users? or to non-commercial ditch irrigators? or to the intersecting set of households with both supply sources? We believe the answers to these questions are discoverable with new tools and creative economic investigations. Thus, our hope is that Figure 13 is taken as a starting point, and spurs additional investigation into how people go about their daily lives in consuming water.

⁴⁰ An example is the *excessive use charge* (EUC) implemented in 2023 by the Las Vegas Valley Water District (LVVWD), which is a municipal provider in Nevada. The EUC is a separate per unit penalty on top of the existing IBR structure, as triggered by annual residential use above 252,000 gallons (0.77 AF), with seasonal considerations (LVVWD, n.d.). As evidence of significant price inelasticity, the program generated \$12.8 in revenues in its first six months (KTNV, 2023).

Figure 13. Estimated Amounts Typically Paid for 1.5 AF of Consumptive Use in Greater Albuquerque Area, Across Various Water-Sourcing Options



* Pueblo P&P: \$0 — federally mandated free delivery; shown for reference only.

** Ag. well costs spread over 200-acre commercial farm — 1/200 of maintenance & capital per acre.

*** MRGCD ditch water: \$61/yr WSC is a flat per-acre charge regardless of volume consumed.

**** NAA = North Albuquerque Acres (higher-elevation East Side residential area with deeper domestic wells; TDH includes 50 PSI household pressurization).

† ABCWUA base rate is a counterfactual under flat pricing. At 1.5 AF/yr the conservation surcharge automatically applies.

ABCWUA residential: 5/8" x 3/4" meter (\$11.51/mo fixed, post 0-24-1); WA = 8 CCF/mo; surcharge April–October (7 months).

Rio Rancho: FY2027 rate schedule (effective July 1, 2026; Ordinance Title V, Chapter 51.12).

IV. CONCLUSIONS AND RECOMMENDATIONS

Writing more than 70 years ago, the early natural resources economist Seigfried von Ciriacy-Wantrup (1955, p. 875) described western water development as, “a veritable Pandora’s box brimful with troublesome economic issues.” Today, water issues are complicated by climate change and increasing aridity in the MRGV, and elsewhere. Yet, paradoxically, we might see various entities seeking to buy up vetted water rights (and in some cases take them out of consumptive use and, say, put back into the Rio Grande for Compact or environmental purposes), while we also see the NM OSE issue new water rights (e.g., new domestic well permits).

Our aim in this *compilation and synthesis study* has been to help inform public deliberations about what we know (and don’t know) about the distribution and composition of green (actual consumptive water use), by illustrating some trends in physical measures or information that are not yet commonly focused on, while also summarizing what we know (and don’t know) about economic values and related measures. Advocating for a few more streetlights, if you will.

To quote a more recent western water resources commentator (Miller, 2026), “[W]e can’t have an honest discussion about tradeoffs if we aren’t honest about what the tradeoffs are.” Our position is that drilling down to understanding those tradeoffs to inform public discussions in unbiased ways requires getting actual, disaggregated consumptive water use information out into the open as much as possible. The caveat is the understanding that better science data alone won’t solve values conflicts, and may even exacerbate them (Sarewitz, 2004). Thus, we advocate for also linking to better information about who benefits and how from those alternative uses (and who is really paying what) and then exploring what values might be sacrificed when we inevitably must curtail uses. We must accept that competing values over water will involve difficult tradeoff discussions.

If we want to purposefully shape future water resource tradeoffs, then it will require collective action, or at least blended governance solutions (public and private) (Garrick et al., 2020). Within this public choice setting with a mix of market and nonmarket provision mechanisms, various Nobel Prize winners in economics have emphasized the importance of improving transparency in imperfect information systems. To wit, Supreme Court Justice Louis Brandeis’s streetlight metaphor that we opened with feels apt within the information economics paradigm of the economist Joseph Stiglitz (2004, p. 28):

“There are asymmetries of information between those governing and those governed, and just as markets strive to overcome asymmetries of information, we need to look for ways by which the scope for reducing asymmetries of information in political processes can be limited and their consequences mitigated.”

Similarly, this connects to the work of the institutional scholar Elinor Ostrom’s (1990) *Governing the Commons*, on the importance of a shared understanding of the data for successful common pool resource governance.

To help improve our understanding of how people consumptively use and value water, and help push water data transparency forward in New Mexico, we offer the following interrelated set of recommendations for our collective water community:

- (i) As first principles, we must move to a world of both increased metering of consumptive use of water, and an expectation that water users should pay a base fee to specifically cover improved metering and monitoring, with publicly accessible tracking of trends;
- (ii) In addition to GPCD, we should pursue showing the total consumptive use and the *consumptive* GPCD for all regulated community water systems (CWS's);
- (iii) Regular collection should be widely made and reported of municipal charge rates for a broader set for residential usage levels, rather than just the standard 6,000 gallons monthly, with a clear tracking of trends in inflation-adjusted real dollar terms – to show both changes in residential affordability and incentives for conservation for higher use levels. The broader range of charges collected for differing usage levels will move this past non-consumptive indoor use and allow improved understanding of consumptive municipal uses (which are also important for public health) for all sizes of CWS's;
- (iv) Prices for all water rights transactions both temporary and permanent, for surface water and groundwater, should be public information and transparent to buyers and sellers;
- (v) Additional regulatory oversight tools should be considered for domestic wells, including both reviewing permitting terms and moving to regularly metering and tracking use from this important but dispersed consumptive water use. Collectively, it is clearly too big a use case to be considered *de minimis* any longer;
- (vi) Using democratized tools like OpenET, the community should be regularly tracking trends in ET (and *effective* ET) for a wide dispersion of geographies in the MRGV; concomitantly, there should be ongoing efforts to continuously improve the use and understanding of these remote sensing data sources;
- (vii) Rather than focusing on a few gages, AI tools should be leveraged to track trends in river diversion across all gages in the MRGV system;
- (viii) Available evidence on environmental and non-market values for water uses in the MRGV, such as provision of instream flows and outdoor recreational values for bosque and trail access, are either missing or generally outdated and need to be systematically updated;
- (ix) Similarly, there is a gap in research connecting consumptive water use and the value of trees (as one specific case of growing particular green things), which can provide a bundle of ecosystem goods and services (health and pollution, shade and heat mitigation);
- (x) There is a need for additional economic investigation into what gets bundled into important cultural, custom and lifestyle (CCL) values of noncommercial irrigated yards and agriculture, ranging from agricultural/greenspace tax dimensions and incidence to electricity rate structures charged (for pumping by different classifications of wells), to more direct valuation studies;
- (xi) There are demand techniques for separating out municipal indoor and outdoor (consumptive) use, which can be further pursued; and especially the large municipal water systems in the MRGV should start reporting this sorted information;
- (xii) We should think broadly about *wherever* consumptive water use is either unpriced or lacks any marginal conservation incentives (i.e., currently charges flat rates), and whether these are institutional arrangements we want to maintain as a community, including equity dimensions.

This is not an exhaustive list, and we encourage discussion of revisions, additions, and further explorations.⁴¹ We certainly aren't first and aren't alone in New Mexico in pushing for improved water data.⁴² But we underline the need to be regularly including and updating economic information (e.g., prices, rates, charges, affordability indices, costs and benefits, etc.) about consumptive water use. And we underline the need to reduce water data information asymmetries between the governing and governed (Stiglitz, 2004).

We are arguably confronting an inflection point in how public deliberations and discussions are informed about water. We have dulled some of the most important streetlights of the past for illuminating and discussing trends in how people and communities use and value water. For example, dedicated, staffed, and funded local newspapers no longer operate at the same level or degree of continuity as they did in decades past. On the other hand, rapidly changing public accessibility to new AI tools can allow a level of information democracy about water, with more dimensionality, than ever experienced before.

The marginal costs of building technological tools to track all types of disaggregated, and spatially and temporally delineated, consumptive water uses in the MRGV and elsewhere appear to be significantly dropping, and rapidly. That, is, the cost of observing people in how they go about their lives consumptively using and valuing water (making tradeoffs) is dropping. The same holds for testing interventions and improving the generalizability and the replicability of our evidence (List 2026).

Public agencies and Water Data strategies can be an important part of that collective effort. So are the efforts of public dialogue and advocacy groups, as well as university researchers. The limited streetlights

⁴¹ Notably there is room for active exploration by NM economics and water resource students for dissertations, theses, and professional projects in the MRGV. With useful inputs from one of our reviewers, these might include: (i) formal causal/statistical decomposition of NFR drivers (e.g., a panel or time-series decomposition with explicit controls for temperature, groundwater pumping type, and irrigated acreage); (ii) validation of OpenET and effective ET performance at fine spatial scales, and the efficacy of down-scaling approaches with ground-truth comparisons (e.g., against the smart-irrigation-metered city parks or ABCWUA residential parcels etc.); (iii) exploration of standardized, method-adjusted meta-analysis of water values (e.g., consistent adjustments for marginal-vs-average, diverted-vs-consumptive, and at-site-vs-at-source distinctions). (iv) direct valuation of CCL and domestic-well outdoor use; (v) a distributional/equity analysis of who benefits from low-cost access to consumptive water use versus who bears the cost of conservation payments and administrative charges (e.g., see: Wilson 2026); (vi) revealed preference valuation study on outdoor recreation in MRGV bosque (riparian forest area) and connected ditch systems, especially using satellite-based, remote sensed cell phone mobility data on trip-taking behavior (Yongjie et al., 2026), especially as connected to water (diversions, levels and consumptive use); (vii) a meta-analysis of all available valuation studies [Appendix Table B1], with value per AF, as the dependent variable, while controlling for the effects of study type/year, major use categories, type of good, basin or location, marginal versus average measurement, etc.; (viii) dynamic optimization models that specifically attempt to isolate the shadow value for protection of the shallow aquifer in the MRGV; and (ix) a meta-analysis of all market values [Appendix Table B2] with value per AF as the dependent variable, while controlling for permanent versus temporary (leases), rights status, basin or location, rights status, observed versus estimated, etc..

⁴² Commendably, there is a strong NM state agency data effort already underway in the *Water Data Initiative* (<https://newmexicowaterdata.org/>). New Mexico enacted the Water Data Act of 2019 (NMSA 1978, § 72-4B), which involves multiple state agencies and federal partners, with the objectives of identifying and sharing critical water data. Similarly, it is our understanding that the NM Public Regulatory Commission (NM PRC) is working towards a centralized, publicly available, data sharing platform for all PRC-regulated CWS's. We applaud these efforts, and especially if shared data generation begins to be significantly embedded into governance. Relatedly, see the recent four-fold water governance recommendations of Shah and Doyle (2026): (i) initiating data-focused convenings of broad participants; (ii) investing in shared data platforms and visualization tools; (iii) using data convenings strategically to build relationships and trust among different participants; and (iv) using recognition of broken water data systems (that need to be fixed) as a unifying frame among participants.

of the past weren't perfect, and the new ones won't be either, but there can more of them. Perhaps there is a future AI-affected public sphere in water governance that is "overlit," where we become overwhelmed by the data that new technology offers, and there is not enough focus on *usefulness* to communities (see Acemoglu and Simon, 2023). Thinking through exactly which streetlights we want to expand will be important, and we have offered our thoughts. In a messy AI world, where new tools are inherently *social technologies* (Farrell & Shalizi, 2026), it will be important to think about creating both good producers and good consumers of credible water information. Certainly, there are strategic arguments for data-first, policy-second approaches (Shah & Doyle, 2026). But with a general nod to various *public sphere* scholars, from there we would let *small-d* democracy run its often-meandering, river-like course (Fleck & Berrens, 2026).⁴³

⁴³ Various influential social philosophers on the *public sphere* include scholars such as Dewey (1927), Habermas (2024) and Sen (1999), e.g., on pragmatism, deliberative democracy, and development as protection of freedom/capabilities, respectively.

List of Acronyms

ABCWUA	Albuquerque Bernalillo County Water Utility Authority
ACS	American Community Survey
AF	Acre-foot (325,851 gallons)
AFY	Acre-feet per year
AI	Artificial intelligence
ASR	Aquifer storage and recovery
BCA	Benefit-cost analysis
BDANWR	Bosque del Apache National Wildlife Refuge
BEA	U.S. Bureau of Economic Analysis
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CCL	Cultural, custom, and lifestyle (values)
CGE	Computable general equilibrium
CGPCD	Consumptive Gallons Per Capita Per Day
CPI-U	Consumer Price Index for All Urban Consumers
CS	Consumer surplus
CU	Consumptive use
CVM	Contingent Valuation Method
CWP	Community water provider
CWS	Community water system
EBID	Elephant Butte Irrigation District
EDD	New Mexico Economic Development Department
ESA	U.S. Endangered Species Act
ET	Evapotranspiration
EUC	Excessive use charge
EVI	Enhanced Vegetation Index
EWLP	Environmental Water Leasing Program (MRGCD)
FWS	U.S. Fish and Wildlife Service
GDP	Gross domestic product
GIS	Geographic information system
GPCD	Gallons Per Capita Per Day
HPM	Hedonic pricing method (property value method)
IBR	Increasing block rates
IID	Imperial Irrigation District
ISC	New Mexico Interstate Stream Commission
LLM	Large language model
LRGV	Lower Rio Grande Valley
LTSC	Long-Term Storage Credit
LVVWD	Las Vegas Valley Water District
MODIS	Moderate Resolution Imaging Spectroradiometer
MRGB	Middle Rio Grande Basin
MRGCD	Middle Rio Grande Conservancy District
MRGV	Middle Rio Grande Valley
MSA	Metropolitan Statistical Area
MUC	Marginal user cost
NDVI	Normalized Difference Vegetation Index
NFR	Net Flow Reduction
NM	New Mexico
NMED	New Mexico Environment Department

NMWRRS	New Mexico Water Rights Reporting System
OMB	U.S. Office of Management and Budget
OSE	New Mexico Office of the State Engineer
PITC	Policy-induced transaction costs
PRC	New Mexico Public Regulation Commission
PV	Present value
RFF	Resources for the Future
RGP	Rio Grande Project
SJCP	San Juan-Chama Project
TCM	Travel Cost Method
UNM	University of New Mexico
US	United States
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WDI	New Mexico Water Data Initiative
WSC	Water Service Charge
WTA	Willingness to accept
WTP	Willingness to pay

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