THE UNIVERSITY OF NEW MEXICO

UTTON TRANSBOUNDARY RESOURCES CENTER

Lower Rio Chama Water Shortage Sharing Agreement

Water Curtailment, Watershed Health, and Community Values

November 2025

About The Utton Resources Transboundary Center

The Utton Transboundary Resources Center (Utton Center) promotes equitable and sustainable management of natural resources in New Mexico and across interstate and international boundaries. The Utton Center researches and provides information to the public about water, natural resources, and environmental issues. It supports collaborative natural resource management using multidisciplinary expertise and inclusive, diverse stakeholder involvement. The Center also includes the Joe M Stell Ombudsman Program, which offers pre-mediation education and information regarding adjudications to unrepresented water rights claimants and defendants. Its primary purpose is to streamline the adjudication process by providing claimants with unbiased information about this multifaceted process.

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Dedicado a mi mamá Lourdes Lemmen Meyer González - *AGLM*

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1 Introduction

Drought events are becoming more frequent and intense throughout the Southwest, and water shortages have become the baseline.[1] These events have led to more regular water delivery curtailments.[2]

Due to the new climate realities, irrigators have not consistently been able to rely solely on rainfall for irrigation. Furthermore, under prior appropriation laws, irrigators with senior water rights (i.e., older claims to water) can exercise their claim during times of water shortages by making a priority call on junior water users.[3] A priority call on water is an administrative process that a water user can exercise to access their full claim of water before junior water rights holders.[4] A call by senior water users can leave junior water rights users with little to no water.[5]

Although the most common form of appropriation is strict priority administration, not all communities in the Southwest use this method during water shortages. Some have adopted a community-based approach, where senior users share water with junior users during periods of curtailment. These alternative strategies to strict priority curtailments are widely used in New Mexico, which formalized them in 2004 as forms of alternative administration under state law in the Active Water Resources Management (AWRM) provision. NMSA 1978, section 72-2-9.1 was enacted in 2003 to authorize water rights administration even when adjudications are not complete. This statute was upheld by the Supreme Court in *Tri-State v. D'Antonio*. This report describes one such alternative administration approach—the Rio Chama Water Shortage Sharing Agreement—and assesses its economic, social, and environmental impacts on the Lower Rio Chama's water curtailment. We utilize Sadoff and Grey (2002)'s framework, categorizing these impacts into four groups: benefits for the river (environmental flows), benefits derived from the river (irrigation water requirements), cost reductions due to the river (fewer

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[1] https://www.ose.nm.gov/Drought/.
[2] *Id*.
[3] Article XVI, Section 2 of the New Mexico Constitution; Ed Merta, *Priority Administration*, 2015 WATER MATTERS! 10.
[4] https://www.ose.nm.gov/AWRM/PriorityAdmin.php, accessed 7.8.25.
[5] Article XVI, Section 2 of the New Mexico Constitution.

disputes/conflicts), and benefits beyond the river (equity, social cohesion, joint advocacy, and preservation of cultural values).

The New Mexico Administrative Code provides additional tools for addressing water shortages. Specifically, N.M. Admin. Code 19.25.13.7 outlines various forms of water administration, including “alternative administration" based on voluntary shortage sharing agreements. These agreements may involve percentage division, pro rata allocation, rotation of water use, or reduced diversions among affected water right owners. The state engineer and water master recognize such agreements, provided they do not impair the authority to regulate water distribution under the doctrine of prior appropriation.[6]

Our analysis finds that this agreement is an additional example,[7] where the benefits of proportionality —achieved through RCAA's rotation of water use— lead to a more robust and stable system.

2 Rio Chama Basin History

The Rio Chama River is a major tributary of the Rio Grande River.[8] It forms in the San Juan Mountains in Colorado, near the New Mexico Border, and traverses Rio Arriba County until it reaches the Rio Grande River north of Española.[9] The Rio Chama River receives water from the San Juan-Chama project, serving as a conduit between the Colorado River tributaries and the state of New Mexico's most populous cities.[10]

[6] NMAC 19.25.13.7.
[7] *Encounters with the Moral Economy of Water: Convergent Evolution in Valencia - Trawick - 2014 - WIREs Water - Wiley Online Library*, 87, https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wat2.1008 (last visited Jan. 20, 2025).
[8] https://www.ose.nm.gov/Basins/RioChama/index.php, see https://api.realfile.rtsclients.com/PublicFiles/5f809ddfc9864dad89f9d03375144a14/50c9455d-5c2b-42d2-8006-4ab696a51422/Final%20Tour%20Bookleet%20Upper%20Chama%20River%20Basin%20Aug%202013.pdf.
[9] https://www.ose.nm.gov/Basins/RioChama/index.php.
[10] *Id*.

Figure 1. Rio Chama Basin

The Rio Chama Basin had its first "residential settlements" in the lower reaches of the Rio Chama River (near the confluence of the Rio Chama River and the Rio Grande River).[11] The first permanent inhabitants were the Tewa people, such as the contemporary Pueblo of Ohkay Owingeh. Later, Spanish colonies settled northwest of Española in the 16th century.[12]

The Spanish brought with them irrigation systems known as acequias.[13] Tewa people also had traditional systems of irrigated agriculture.[14] Acequias are

[11] Samuel Duwe & Kurt F Anschuetz, *Ecological Uncertainty and Organizational Flexibility on the Prehispanic Tewa Landscape: Notes from the Northern Frontier.*, 98–100 (2013); Sam Markwell et al., *The Rio Chama Basin: A Social-Ecological History Linking Culture and Nature*, 12 (2016).
[12] Sam Markwell et al., *The Rio Chama Basin: A Social-Ecological History Linking Culture and Nature*, 12-16 (2016).
[13] Sam Markwell et al., *The Rio Chama Basin: A Social-Ecological History Linking Culture and Nature*, 5 (2016).; Rodriguez, Sylvia. Acequia: Water Sharing, Sanctity, and Place (2006).
[14] Sam Markwell et al., *The Rio Chama Basin: A Social-Ecological History Linking Culture and Nature*, 11 (2016).

community irrigation systems in the villages and pueblos of New Mexico.[15] "The Pueblos collected and shared water for centuries before the arrival of Spanish colonists in 1598."[16] "The Spanish settlers brought technical knowledge and institutional frameworks for governing irrigation systems, which originated in the Moors' seven-century occupation of Spain."[17] Both traditions are important to an understanding of New Mexico's acequia heritage and the continuing relevance of these "water democracies."[18] Acequias and traditional Pueblo irrigation practices have melded with current New Mexico water law.[19]

Acequias are both a gravity flood irrigation system and a community governance institution where irrigators commonly share water.[20] Acequias contribute to extending the narrow confines of the river channels by mimicking the physics of natural watercourses with their "earthen ditches."[21] The value of "Reparto" (customary water-sharing practices for the benefit of the common good) is deeply rooted in this water practice and amongst these communities.[22]

Nobel Prize winner Elinor Ostrom's economic studies on equivalent local governance structures in Spain have found that they "have proved adequate for resolving conflicts, allocating water predictably, and ensuring stability" in semiarid regions with extreme rainfall variability.[23]

"The acequia irrigation systems of northcentral New Mexico and southern Colorado are the oldest, continuously functioning water management institutions in the United States."[24] These institutions are operated as "water democracies" where acequias govern their water and have survived the test of time with minor adjustments under three sovereigns (Spain, Mexico, and the United States).[25] Current New Mexico law recognizes acequias as political subdivisions of the state.[26]

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[15] Brigette Buynak, Jerold Widdison & Darcy Bushnell, *Acequias*, 2015 WATER MATTERS! 4, 4–1 (2013).
[16] *Id.*
[17] *Id.*
[18] *Id.*
[19] *Id.*
[20] SYLVIA RODRIGUEZ, ACEQUIA: WATER SHARING, SANCTITY, AND PLACE 2 (2006).
[21] José A. Rivera, *Water Democracies on the Upper Rio Grande, 1598-1998*, *in* RIO GRANDE ECOSYSTEMS: LINKING LAND, WATER, AND PEOPLE. TOWARD A SUSTAINABLE FUTURE FOR THE MIDDLE RIO GRANDE BASIN 20, 20 (1999).
[22] Rodriguez, Sylvia. Acequia: Water Sharing, Sanctity, and Place. (2006).
[23] Ostrom, Elinor. "Governing the Commons: The Evolution of Institutions for Collective Action" (2015).
[24] Rivera, *supra* note 20 at 20.
[25] Rivera, *supra* note 20.
[26] NMSA 1978 § 73.2.28.

Water rights priority dates reflect the history of the Rio Chama watershed. The Pueblo of Ohkay Owingeh is the most senior water user on the Rio Chama.[27] They are followed by the acequias Chamita, Los Salazares, and Hernandez, with a priority date of 1600.[28] At the Pueblo of Ohkay Owingeh (formerly known as San Juan Pueblo), on July 11, 1598, *Capitán General* Juan de Oñate arrived and "established the first European colony in this northern Spanish frontier."[29] The Upper Rio Chama irrigation water users' priority dates are junior to those of the Lower Rio Chama water users participating in shortage sharing, with the most senior priority dates dating back to the 18th century.[30] This reflects the later use of water in the Upper Rio Chama watershed.[31]

3 Water Management in the Rio Chama

Water shortage sharing in New Mexico refers to mechanisms and legal frameworks designed to address water scarcity by allocating limited water resources among users in a manner consistent with state laws and doctrines.[32] The doctrine of prior appropriation, the foundation of water law in New Mexico, plays a central role in determining water rights and their administration during periods of water shortages.[33] Under New Mexico law, water rights adjudications are governed by state law.[34] Water rights adjudications are the legal process that brings all claimants who use water within a stream system as parties to the legal proceedings.[35] Because the court overseeing the adjudication has exclusive jurisdiction to determine all questions necessary for adjudicating water rights, including priority, amount, purpose, and place of use, and also requires the state engineer to conduct hydrographic surveys to gather data necessary for resolving the rights involved, this process can be lengthy.[36]

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[27] Piña, Joseph, Lower Chama Water Master, Water Rights Division, OSE, 2024 Lower Rio Chama Water Master Report, https://www.ose.nm.gov/Basins/RioChama/index.php.
[28] *Id*.
[29] Rivera, *supra* note 20 at 20.
[30] Piña, Joseph, Lower Chama Water Master, Water Rights Division, OSE, 2024 Lower Rio Chama Water Master Report, https://www.ose.nm.gov/Basins/RioChama/index.php.
[31] Piña, Joseph, Lower Chama Water Master, Water Rights Division, OSE, 2024 Lower Rio Chama Water Master Report, https://www.ose.nm.gov/Basins/RioChama/index.php.
[32] NMAC 19.25.13.
[33] Article XVI, Section 2 of the New Mexico Constitution, NMSA 1978, § 72-2-9.1, see NMAC 19.25.13.1.
[34] NMSA 1978, § 72-4-15 and § 72-4-17.
[35] NMSA 1978, § 72-4-15 and § 72-4-17.
[36] *Id*.

The adjudication process culminates in a decree that specifies the elements of each water right, including priority, amount, purpose, and place of use.[37] This ensures the clarity and enforceability of water rights within the stream system. However, alternative approaches, such as voluntary shortage sharing agreements, are also recognized under state regulations.[38]

Water shortage sharing in New Mexico is governed by the doctrine of prior appropriation, which establishes that "priority of appropriation shall give the better right" to water use. This principle is enshrined in Article XVI, Section 2 of the New Mexico Constitution and serves as the basis for administering water rights in the state.[39] Under this doctrine, senior water rights holders—those with earlier priority dates—are entitled to water before junior rights holders during times of scarcity.[40]

The New Mexico Administrative Code provides additional mechanisms for addressing water shortages. Specifically, N.M. Admin. Code 19.25.13.7 outlines various forms of water administration, including "alternative administration" based on voluntary shortage sharing agreements.[41] These agreements may involve percentage division, pro rata allocation, rotation of water use, or reduced diversions among affected water right owners.[42] The state engineer and water master recognize such agreements, provided they do not impair the authority to regulate water distribution under the doctrine of prior appropriation.[43] Water-sharing agreements (also known as shortage-sharing agreements) and other forms of “alternative administration”[44] are sanctioned under the State’s Active Water Resources Management (AWRM) initiative, which was established by the state legislature in January 2004 in response to severe drought conditions.[45]

When the NM state legislature authorized AWRM, it was recognized that the adjudication process is lengthy, and the water administration needed to occur now,

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[37] *Id*.
[38] *Id*.
[39] *State Engineer of New Mexico* v. *Diamond K Bar Ranch, LLC*, 385 P.3d 626 (2016).
[40] *Id*.
[41] NMAC 19.25.13.7
[42] *Id.*
[43] *Id*.
[44] New Mexico water users and state officials generally embrace the legal doctrine known as priority administration as a tool for dealing with shortages. This is the principle of “first in time, first in right.” When this principle is applied, the right with the older priority gets its full amount, before any water goes to newer or junior rights.
[45] NMSA 1978, § 72-2-9.1.

when the shortages and drying were occurring.[46] Furthermore, the State of New Mexico was also required to comply with interstate compacts, and the legislature determined that the Office of the State Engineer has the authority to administer water allocations in accordance with water right priorities recorded, rights declared, or otherwise made available to the state engineer.[47] It charged the Office of the State Engineer (OSE) with adopting rules for priority administration that would, "Ensure that authority is exercised: (1) so as not to interfere with future or pending adjudications; (2) so as to create no impairment of water rights, other than what is required to enforce priorities; and (3) so as to create no increased depletions."[48]

The tools for AWRM include measuring and metering, rules and regulations, creation of water districts, appointment of a water master, and development of water master manuals.[49] The staff of the Office of the State Engineer has encouraged and facilitated sharing agreements among water users to address shortages.[50]

The OSE has created teams to address AWRM in each priority stream system (each basin team should include a project manager, hydrologist, attorney, communication manager, personnel manager, and technical support staff).[51] Still, the agency does not currently have enough capacity to meet demand.[52] Many communities wish to develop new water-sharing agreements. Still, they are unable to do so due to insufficient local capacity and resources, including critically needed legal, scientific (hydrological), and social support (facilitation and mediation).[53] In the resilience assessment phase of the state's 50-year water plan, members of the water community frequently mentioned water-sharing agreements as a pragmatic tool for adapting to an increasingly warm and arid climate.[54]

As much of New Mexico remains unadjudicated, the State Engineer (OSE) does not have a complete list of administrable water rights to use as the basis for priority

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[46] NMSA 1978, § 72-2-9.1.
[47] NMSA § 72.2.9.1[a].
[48] NMSA 1978 § 72.2.9.1[a].
[49] https://www.ose.nm.gov/AWRM/index.php, *see* NMAC 19.25.13.7.
[50] https://www.ose.nm.gov/AWRM/index.php, *see* NMAC 19.25.13.7.
[51] https://www.ose.nm.gov/AWRM/index.php, *see* NMAC 19.25.13.7.
[52] It is important to note that many New Mexico water right holders, such as those in acequias and Pueblos, have historically found other means to deal with water shortages, such as sharing of available water.
[53] https://storymaps.arcgis.com/stories/7db7e0f78c9243b2902c221b023333cb.
[54] *Id*.

administration.[55] Even when there has been an adjudication or partial adjudication, the OSE must administer water rights.[56] Therefore, the OSE can administer water rights through alternative means other than just strict priority administration.[57] This statute was upheld by the Supreme Court in *Tri-State* v. *D'Antonio*. Active Water Resources Management ("AWRM") is one alternative method to administer water rights.[58] Further, while voluntary shortage sharing agreements provide flexibility, they must align with the doctrine of prior appropriation, which remains the prevailing system of water law in New Mexico.[59] AWRM is a combination of the tools and elements needed to enable the State Engineer to manage New Mexico's water resources actively.[60] One of the tools under the AWRM framework is the appointment of Water Masters to priority basins.[61] The State Engineer has chosen the entire Rio Chama watershed as a priority basin in New Mexico for Active Water Resource Management (AWRM).[62] The Water Master communicates with Stakeholders, oversees the distribution of water, and maintains records of water diversion for stakeholders.[63] Another tool includes the installation and use of metering and measurement stations within the infrastructure of New Mexico's vast and historic system of acequias to help manage available water in a fair and consistent manner.[64] The appointed Water Master(s) are tasked with maintaining these metering stations within their assigned basin.[65] The State Engineer can also use other AWRM alternative administration tools, such as shortage sharing and rotation agreements amongst users.[66] The OSE staff has encouraged and facilitated sharing agreements among water users to address shortages.[67]

Shortage sharing agreements are voluntary agreements in which all users share water and bear the shortage.[68] This contrasts with traditional priority date administration, in which senior water rights holders must make a "call on the river" and request that the OSE enforce priority administration.[69] However, priority

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[55] NMSA 1978, § 72-2-9.1.
[56] NMSA 1978, § 72-2-9.1.
[57] NMSA 1978, § 72-2-9.1.
[58] NMSA 1978, § 72-2-9.1, *See* https://www.ose.nm.gov/Basins/RioChama/index.php.
[59] Article XVI, Section 2 of the New Mexico Constitution, NMSA 1978, § 72-2-9.1, see NMAC 19.25.13.1
[60] NMAC 19.25.13.2. 19.25.13.3.
[61] NMAC 19.25.13.7 V.
[62] https://www.ose.nm.gov/Basins/RioChama/index.php.
[63] NMAC 19.25.13.7 .
[64] NMAC 19.25.13.7 T.
[65] NMAC 19.25.13.7.
[66] NMAC 19.25.13.7 EE.
[67] https://www.ose.nm.gov/AWRM/index.php.
[68] https://storymaps.arcgis.com/stories/7db7e0f78c9243b2902c221b023333cb.
[69] NMSA 1978, § 72-2-9.

administration can and is often still taken into consideration.[70] These voluntary agreements can still give the senior user better priority while allowing junior users to receive water.[71] A notable example of this type of agreement can be found in the Chama Basin watershed.

"The Chama Basin watershed consists of the Rio Chama, the largest tributary to the Rio Grande, and all of its perennial and ephemeral tributary streams. The entire watershed encompasses more than 3,000 square miles, with the headwaters located in the San Juan Mountains of southern Colorado."[72]

"In New Mexico, the Rio Chama watershed extends from the state line, just north of the Village of Chama, south to its confluence with the Rio Grande, north of Espanola."[73] "The western boundary of the Chama watershed is the continental divide, while the southern extent of the San Juan Mountains in New Mexico forms the primary boundary to the east."[74] "An additional source of water in the Chama Basin comes from the San Juan-Chama transmountain diversion. Three major reservoirs are located in the basin. El Vado and Abiquiu Reservoirs are located on the Chama, and Heron is located on Willow Creek, a tributary to the Chama."[75] "The State Engineer administers the release and delivery of the San Juan-Chama Project water in the Rio Chama Basin."[76]

The lower Rio Chama is the mainstream section of the Rio Chama, which flows 32 miles from the base of Abiquiu Dam to its confluence with the Rio Grande. "This stretch of the Rio Chama arises as a controlled discharge from Abiquiu Dam, a 325-foot-high dam completed in 1963 by the U.S. Army Corps of Engineers for flood and sediment control. The reservoir formed by the dam receives runoff from a 2,146-square-mile mountainous watershed, along with additional diverted water from the SJCP. Water released from Abiquiu Dam is supplemented by inflow from Abiquiu Creek, El Rito Creek, Rio del Oso, and the Rio Ojo Caliente to the Rio Chama above the confluence with the Rio Grande near Hernandez, NM."[77]

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[70] NMAC 19.25.13.7 U.
[71] https://www.ose.nm.gov/Basins/RioChama/index.php.
[72] *Id*.
[73] *Id*.
[74] *Id*.
[75] Office of the State Engineer & Interstate Stream Commission, *Rio Chama Basin*, OFFICE OF THE STATE ENGINEER WEBSITE, https://www.ose.nm.gov/Basins/RioChama/index.php (last visited Jul. 7, 2025).
[76] *Id.*
[77] DISTRICT IV, OSE, 2021 LOWER RIO CHAMA, WATER MASTER REPORT 2 (2021).

Figure 2. Rio Chama Basin Management Timeline

Over the past five decades, basin management in the Chama River has undergone a progression from a top-down implementation of strict priority administration to a more collaborative governance through alternative administration.[78] From 1972 to 2015, the system operated under a strict priority-based administration.[79] During this period, the Lower Chama was actively managed on the ground, whereas the Upper Chama had no formal administration due to the absence of measuring infrastructure. At the end of the 2014-2015 time period, discussions about shortage-sharing arrangements began, and measurement infrastructure was installed in the Upper Chama.[80]

The period from 2016 to 2020 represented a testing phase of alternative administration with top-down agreements (agreements between senior and junior set by OSE), where senior water users had limited input in the decision-making process.[81] The Upper Chama was included in alternative administration for the first

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[78] E-mail interview, Tyler Lystash, former AWRM Manager, May 20, 2024.
[79] *Id*.
[80] *Id*.
[81] *Id*.

time in 2016, and in 2020, more active on-the-ground management began.[82] The current phase, from 2021 to 2024, features a bottom-up shortage-sharing approach (proposed agreements in collaboration with water users and acequias) in the Lower Chama and voluntary pre-emptive reductions in the Upper Chama, representing a significant shift toward collaborative management that incorporates direct input from water users.[83] Water masters actively enforce and monitor both the Upper and Lower Chama during curtailment.[84] This evolution reflects a broader trend in water management, shifting from top-down approaches to more flexible, participatory approaches that can better adapt to changing hydrological conditions and the needs of water users.

4 Rio Chama Shortage Sharing Overview

The Rio Chama basin has dealt with periods of drought for centuries.[85] In 2018, a water-sharing agreement was reached between Northern New Mexico's Acequias Norteñas (AN), the Rio Chama Acequia Association (RCAA), and the Pueblo of Ohkay Owingeh.[86] The 2023 version of this agreement is a central piece of the Ohkay Owingeh Rio Chama Settlement. The AWRM water masters have facilitated the agreement.

Figure 3 below depicts how water would be discharged based on a strict administration of water rights by priority date, and Figure 4 below depicts water allocations based on the Rio Chama Shortage-Sharing Agreement.[87] Distinct from strict priority administration, the parties to the agreement in the Lower Rio Chama share the impacts of drought amongst all water users.

[82] *Id*.
[83] *Id*.
[84] *Id*.
[85] *Id*.
[86] H.R.1323 — 119th Congress (2025-2026), https://www.congress.gov/bill/119th-congress/house-bill/1323, *State of New Mexico, ex rel. State Engineer* v. *Roman Aragon, et al*., Case No. 69-cv-07941KWR/KK (D.N.M.) *see* https://www.ose.nm.gov/Legal/settlements/RioChama/index.php.
[87] As the basin had not been adjudicated, the water rights quantities used in Figure 3 correspond to the quantities used by AWRM in 2021. These AWRM quantities could have differed from the final adjudication water rights quantities.

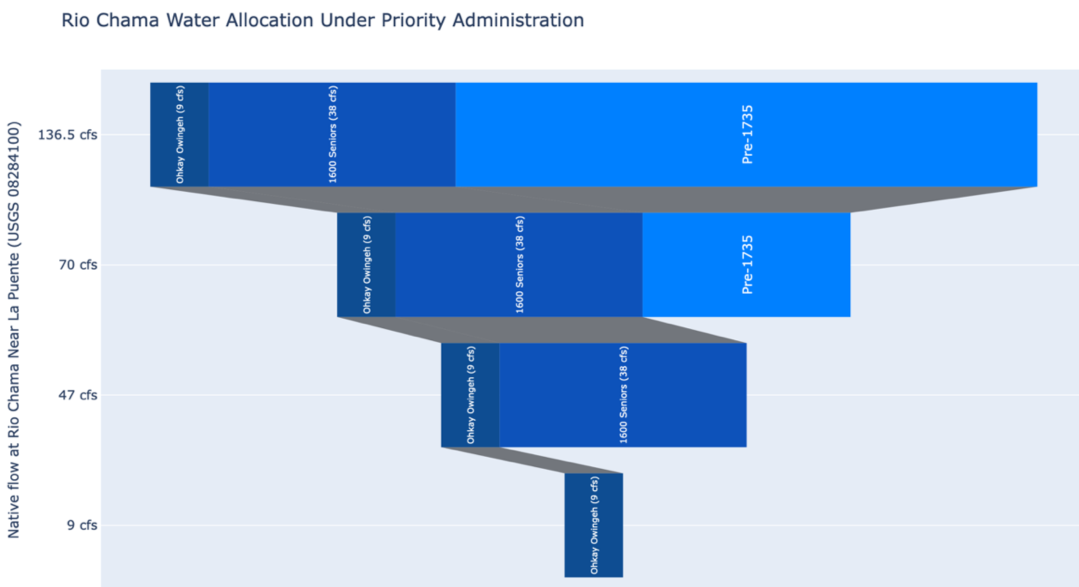

Figure 3. Rio Chama Water Allocation Under Priority Call

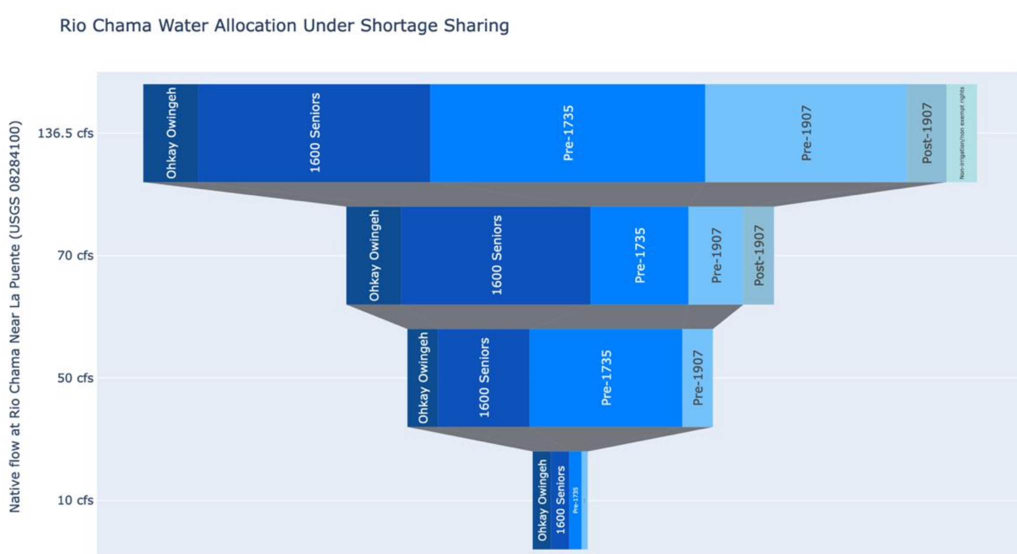

Figure 4. Rio Chama Water Allocation Under Shortage Sharing

In the Lower Rio Chama, the agreement triggers shortage sharing when the U.S. Geological Survey (USGS) Rio Chama gage near La Puente reaches 50 cubic feet per second (cfs), and severe restrictions begin. The agreement divides curtailment into two parts. In the Lower Rio Chama, the RCAA and Ohkay Owingeh created a rotation schedule for all diversions below the Abiquiu reservoir. In the Upper Rio Chama, the Acequias Norteñas agreed to make voluntary reductions at the recommendation of the Upper Rio Chama Water Master.[88] Then, stricter restrictions are implemented when the water reaches the 50 cfs trigger.

Water Shortage Sharing in 2021

To illustrate the Lower Rio Chama's rotation, let's look at the 2021 irrigation season. The Lower Rio Chama experienced a below average irrigation year. The native flow at Rio Chama Near La Puente (USGS 08284100) was below 50 cfs on July 10th, triggering the start of shortage sharing. The daily available flows were distributed during shortage sharing according to the schedule in Figure 5. This water sharing schedule shows senior water users diverted water at least three days a week, while junior users diverted water at least two days. By taking turns, the water users are equitably sharing the irrigation season's scarcity.

2021 RCAA Water Sharing									
	Diversion	Group %	Monday daily cfs	Tuesday daily cfs	Wednesday daily cfs	Thursday daily cfs	Friday daily cfs	Saturday daily cfs	Sunday daily cfs
Group *									
JP Gonzales (Tu/W)/Hernandez (M	16.0	29%	14.5	14.5	14.5				
Salazar	13.0	24%	11.8	11.8	11.8				
Chili	8.0	15%	7.3	7.3	7.3				
Chamita (Pueblo)	18.0	33%	16.4	16.4	8.2				
Group Total	55.0	36%	50.0	50.0	41.8				
Group ^									
Chamita (non-Pueblo)	18.0	35%			8.2	17.5	17.5		
Rio de Chama	11.0	21%				10.7	10.7		
Martinez y Garcia	15.0	29%				14.6	14.6		
Manzanares y Montoya	1.5	3%				1.5	1.5		
Gonzales	6.0	12%				5.8	5.8		
Group Total	51.5	33%			8.2	50.0	50.0		
Group #									
La Puente	5.0	10%						5.2	5.2
Quintana	1.0	2%						1.0	1.0
Valentine Martinez	1.0	2%						1.0	1.0
Tierra Azul	7.0	15%						7.3	7.3
Mariano	4.0	8%						4.2	4.2
Ferran	4.0	8%						4.2	4.2
JV Martinez	4.0	8%						4.2	4.2
Hernandez	16.0	33%						16.7	16.7
Abeyta Trujilo	6.0	13%						6.3	6.3
Group Total	48.0	31%						50	50
RCAA Total	154.5		50.0	50.0	50.0	50.0	50.0	50.0	50.0
Available water	50							50.0 weekly avg.	

Figure 5. Lower Rio Chama Rotation Schedule,
Source 2021 Lower Rio Chama Water Master Report

[88] In the 2023 local Ohkay Owingeh Rio Chama water rights adjudication settlement, there was a further clarification of the voluntary reductions: "water sharing schedule shall strive to make available to Signatory Acéquias that are members of the Acéquias Norteñas an equitable amount of water to enable each of them to deliver irrigation water to their Parciantes through July 31st, or the critical period for irrigation. For this purpose, an equitable amount of water is sufficient for one cutting of hay, and after that, water for livestock purposes after irrigation diversions cease." Ohkay Owingeh Rio Chama Water Rights Settlement, State of New Mexico, ex rel. State Engineer v. Roman Aragon, et al., Case No. 69-cv-07941-KWR/KK (D.N.M.), Local Settlement Agreement (2023-07-05).

An alternative visualization of how water is divided among the users in the Rio Chama is depicted in Figures 6 and 7. Figure 6 illustrates how water would be allocated among users under strict priority administration. Figure 7 depicts how water was divided among users under alternative administration.

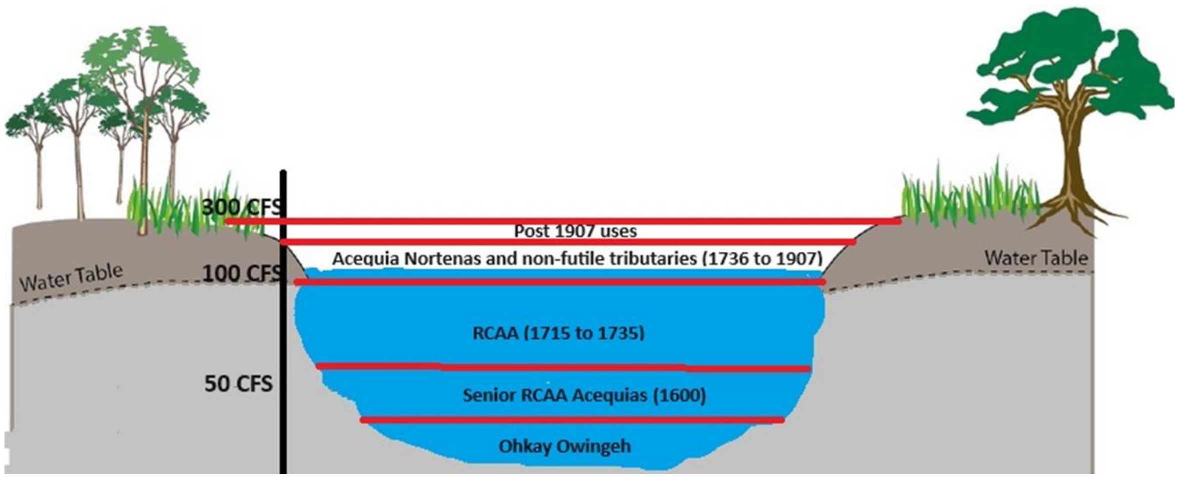

Figure 6. Strict Priority Administration in Rio Chama Basin, Source Darel Madrid, RCAA

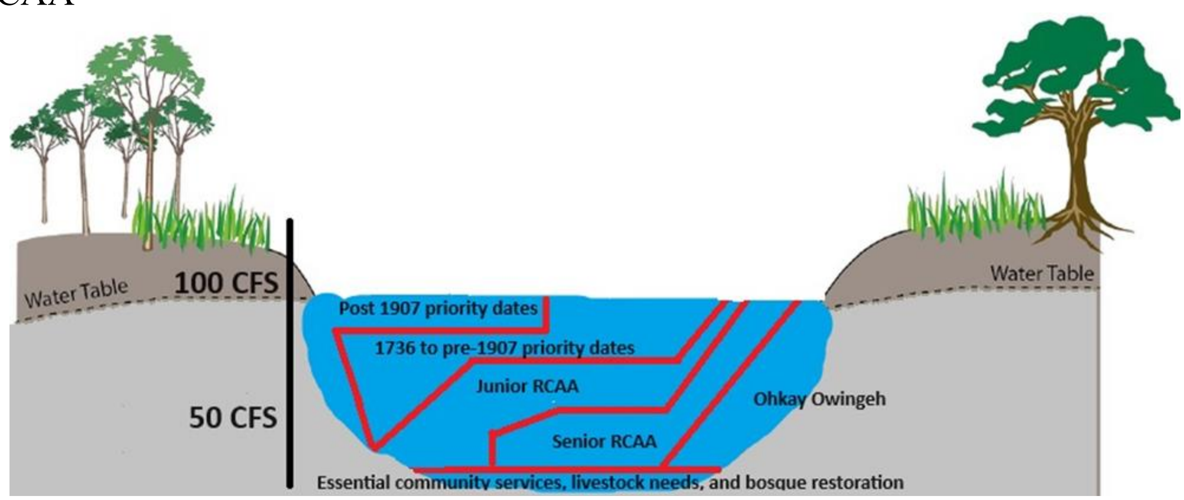

Figure 7. Alternative Priority Call (Shortage Sharing) in Rio Chama Basin, Source Darel Madrid, RCAA

The RCAA shortage-sharing agreement can be viewed as a mechanism that creates a nested hierarchy of communally managed water systems, where each water system (RCAA acequias and the Pueblo of Ohkay Owingeh) receives water according to the water-sharing agreement, and each water system then distributes this water to its members in accordance with their bylaws.

This agreement incorporates many of the principles that Ostrom's research observed in local institutions that have successfully managed common-pool resources, specifically surface water. Table 1 compares the RCAA alternative administration agreements to the eight principles of successful self-governing commons identified by Elinor Ostrom.[89]

Table 1. RCAA Shortage Sharing Agreement and Ostrom's 8 Principles illustrated by long-enduring common pool resource institutions

	Principle	Definition	How the The Rio Chama Water Shortage Sharing Agreement fits Elinor Ostrom's 8 Principles
1	Clearly defined boundaries	The boundaries of the CPR and the appropriators authorized to use it must be clearly defined.	- Authorized appropriators of the Rio Chama river and their permitted water allocations are clearly defined in the agreement. So too is the point at which the agreement activates: when river flow (measured at the La Puente gage) drops below 50 cfs.
2	Congruence Between Appropriate & Provision Rules and Local Conditions	Rules (about how, when, and how much to use the resource) must be "good-fitting," reflectling local environmental and social conditions.	- Rules account for the semiarid conditions of Northern New Mexico, including contingencies based on actual water flow. - Appropriator priority date plays a role in water distribution during shortage periods. A rotating schedule is triggered in which senior water users take turns diverting water throughout a week. The rotation schedule introduces a version of proportionality into the agreement, where the water users share the impacts of the shortage by distributing water among all users. - The agreement is reflective of Northern New Mexico's acequia communities' cultural values, particularly that of Reparto (sharing water based on need during times of shortage). Members of the agreement comply not just because of enforcement, but because of shared values and community norms.
3	Collective-Choice Arrangements	Most individuals affected by the operational rules of the CPR can participate in modifying those operational rules.	- The water users who took part in this agreement were involved in its negotiation.
4	Monitoring *(Transparency)*	Resource use and user behavior are monitored by the users themselves or by monitors accountable to them.	- The Rio Chama Water Masters, appointed by the state and accountable to local communities and the U.S. District Court, oversee water use with metering stations and record keeping. - Monitoring is both top-down (via the OSE) and bottom-up (via mutual surveillance, informal enforcement, and social pressure).
5	Graduated Sanctions	Insiders - fellow appropriators authorized to use the CPR or officials accountable to them - are responsible for sanctioning users who violate CPR rules. Sanctions are context dependent, flexible, and graduating in severity.	
6	Conflict-Resolution Mechanisms	Low-cost, quick, and accessible mechanisms exist to discuss & resolve infractions of the rules or disputes.	- The OSE Water Masters act as mediators, applying the agreement rules and regulations.
7	Minimal Recognition of Rights to Organize	External authorities do not challenge the community's right to self-organize. Thus compliance is not undermined.	- The agreement is officially supported by the New Mexico Office of the State Engineer (OSE) under the Active Water Resource Management (AWRM) framework.
8	Nested Enterprises	Governance tasks are organized in multiple layers, as to accommodate differences in those layers.	- Governance is organized into layers: the acequia and pueblo bylaws at the most local layer, the rotation agreement is the middle layer coordinating RCAA acequias and the Pueblo, and at the OSE Water Master Districts as the basin/regional level.

[89] Ostrom, Elinor. "Governing the Commons: The Evolution of Institutions for Collective Action" (2015).

5 Formation of the Agreement

The Rio Chama has a long history of communities sharing water during shortages, with traditions dating back to the 1600s.[90] Water management practices, including rotating irrigation schedules and trade-offs between farmers, and the involvement of a Water Master, have helped these communities adapt to varying water availability.[91]

The Rio Chama Water Master serves under the direction of the State Engineer and the general supervision of the United States District Court in accordance with the Partial Final Judgment and Decree No. 7941, adjudication of the Rio Chama Mainstream Section.[92] The Rio Chama Water Master was appointed water master of the El Rito Section on June 25, 1973.[93] Mr. George Shaw, a previous water master, developed and filed additional water master Rules and Regulations governing the administration of the Rio Chama adjudication in the U.S. District Court for New Mexico.[94] These water master Rules and Regulations were issued pursuant to Paragraph 9 of the original Partial Final Judgment and Decree of the Court.[95]

On January 19, 2007, the State Engineer signed Order No. 179 creating the Chama Water Master District under Active Water Resource Management (AWRM) authorities.[96] The Lower Rio Chama is now administered under a hybrid of the May 30, 1972, Water Master Rules and Regulations and by NMAC Title 19 Chapter 25 Part 13.[97] There have been several Rio Chama Water Masters along the Rio Chama.[98]

Mr. John Mumm was the recognized and appointed Lower Chama Water Master, and Mr. Tyler Lystash was the Upper Chama Water Master.[99] Mr. Mumm and Mr. Lystash partnered and shared the Water Master duties, responsibilities, and administration of the Lower Rio Chama basin.[100] Mr. Mumm was appointed the Rio

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[90] José A. Rivera, Water Democracies on the Upper Rio Grande, 1598-1998, in RIO GRANDE ECOSYSTEMS: LINKING LAND, WATER, AND PEOPLE. TOWARD A SUSTAINABLE FUTURE FOR THE MIDDLE RIO GRANDE BASIN 20, (1999).
[91] State of New Mexico, ex rel. State Engineer v. Roman Aragon, et al., Case No. 69-cv-07941KWR/KK (D.N.M.).
[92] Mumm, John, Lower Chama Water Master, Water Rights Division, OSE, 2020 Lower Rio Chama Water Master Report, https://www.ose.nm.gov/Basins/RioChama/index.php.
[93] *Id*.
[94] State of New Mexico, ex rel. State Engineer v. Roman Aragon, et al., Case No. 69-cv-07941KWR/KK (D.N.M.).
[95] Wells, Simon, Rio Chama Water Master, Water Rights Division, OSE, 2004 Rio Chama Water Master Report, https://www.ose.nm.gov/Basins/RioChama/index.php.
[96] NMAC 19.25.13.
[97] *Id*.
[98] https://www.ose.nm.gov/Basins/RioChama/index.php.
[99] *Id*.
[100] *Id*.

Chama Water Master by Court Order through the US District Court for the District of New Mexico on the Adjudication and Partial Final Judgment and Decree of the Main Stream Section, on June 15, 2020.[101] The appointed Water Master court order was the start of reestablishing the Water Master reports and the ultimate catalyst to transition from OSE set agreements to bottom-up RCAA and Upper Chama shortage sharing agreements by the acequias, which began in the spring of 2021.[102]

WATER MASTER TIMELINE[103]

- ***1971-1972:*** George Shaw, Rio Chama Water Master
- ***2004-2009:*** Stermon M. Wells, Rio Chama Water Master
- ***2009-2014:*** Antonio Trujillo, Rio Chama Water Master[104]
- ***2014:*** Frank Scott, Rio Chama Water Master
- ***2019-2020:*** John Mumm, Lower Rio Chama Water Master
- ***2021:*** Tyler Lystash, AWRM Manager; Holly Wilkie, Upper Chama Water Master; Joseph Piña, Lower Rio Chama Water Master
- ***2022-Present (2025):*** Joseph Piña, Water Master, Lower Rio Chama

6 Critical Roles of Community Values and Cooperation for Water Shortage Sharing

Culture has a direct influence on how water is perceived, regulated, and utilized.[105] In New Mexico, the willingness to share water resources for the benefit of all, even during periods of shortage, runs deep in the state's history. The state has been home to people who value water stewardship for centuries. Values that are integral to communities in New Mexico, such as Reparto or Repartimiento (the sharing of water during droughts or shortages) and "El agua es vida" ("Water is Life"), have instilled a willingness in many New Mexicans to share water with other members of their communities when water levels are low.[106] This is particularly visible in many acequias.[107]

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[101] https://www.ose.nm.gov/Basins/RioChama/index.php.
[102] E-mail interview, John Mumm, former Water Master, October 21, 2025.
[103] https://www.ose.nm.gov/Basins/RioChama/index.php.
[104] E-mail interview, John Mumm, former Water Master, October 21, 2025.
[105] UNESCO WORLD WATER ASSESSMENT PROGRAMME, THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 2021: VALUING WATER 98 (2021).
[106] RODRIGUEZ, *supra* note 19 at 5.
[107] *Id.*

“[Acequia] Parciantes believe that water should be shared according to need and equity rather than owned exclusively, based on a principle of prior appropriation.”

Sylvia Rodríguez

Acequia: Water Sharing, Sanctity, and Place p. 5

We define "values" as the goals and motivations behind people's actions, which significantly impact their willingness to participate in conservation. Multiple research studies have found that community values, such as trust and cooperation, or a cultural heritage of stewardship and respect for the natural world, are often more successful long-term motivators for conservation than monetary rewards, and are therefore a preferable option.[108] Activating social norms, such as intrinsic values, can have far-reaching effects on environmental action.[109]

Anthropological scholarship has consistently documented people relying on water sharing “to cope with chronic and acute water insecurity”, and “ethnographic work on water sharing continues to examine the diverse motivations, beliefs, and worldviews that prompt these exchanges.”[110] Some motivations explored include social insurance (sharing in times of need with the expectation that such favors would be reciprocated if needed in the future), a moral economy model (“deeply held beliefs in a communal right to survival”), or to display prestige or social status.[111]

[108] Rode, Julian; Erik Gómez-Baggethun; and Torsten Krause. "Motivation crowding by economic incentives in conservation policy: A review of the empirical evidence" (2015).
[109] Crompton, Tom; and Tim Kasser. "Meeting Environmental Challenges: The Role of Human Identity" (2009).
[110] Amber Wutich et al., *Water Security and Scarcity*, *in* OXFORD RESEARCH ENCYCLOPEDIA OF ANTHROPOLOGY , 14 (2022), https://oxfordre.com/anthropology/display/10.1093/acrefore/9780190854584.001.0001/acrefore-9780190854584-e-475.
[111] *Id.* at 15.

Motivations such as a moral economy or Indigenous relational approaches to water-human relations can lead a community to prioritize the ecological, cultural, or relational benefits of water sharing over individual economic value. In our report, we research the presence of these values in the Rio Chama.

We did a literature review on New Mexico acequias and pueblos to identify the diverse beliefs and worldviews that may have prompted these exchanges. This research was further corroborated with a set of semi-structured interviews with Acequia members.

In our literature review of New Mexican Acequias' community values, we find that values like "Repartimiento" ("Reparto") are rooted in a desire for equity and are cornerstones of acequia culture.[112]

In 2023, the Utton Transboundary Resources Center interviewed acequia members, the RCAA leadership, and the Office of the State Engineer's Lower Chama and Rio Chama Manager Water Masters.[113] These interviews further highlighted *Repartimiento* as a value within the Rio Chama communities.

Some interviewees' quotes supporting this value include:

> "We have always been agrarian…if your crops failed you were in danger of starving to death…so I can envision that the people down here helped the people up there when the crops failed and vice versa" "We are all in this together" "We are all suffering right now." "…what would be the purpose to hog up a small amount of water that is in the river in the first place. Let's just share what we have you know and that has been a long-standing kind of arrangement in Northern New Mexico, and it is not like that in different parts of the country."
>
> "Things are tough all over when it happens. The junior ditches and the senior ditches suffer as well." "I just think it is the right thing to do to share the water in shortage times." - Chris Roybal, Treasurer of the Commission, San Jose de Hernandez Community Ditch (senior water-rights holder acequia), 05:39-06:29 [114]

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[112] WATER FOR THE PEOPLE: THE ACEQUIA HERITAGE OF NEW MEXICO IN A GLOBAL CONTEXT 24 (Enrique Lamadrid & José A. Rivera eds., 2023); Rivera, *supra* note 20; RODRIGUEZ, *supra* note 19 at 5.
[113] Utton Transboundary Resources Center, *New Mexico: Water Shortage-Sharing Agreements*, (Aug. 7, 2024), https://storymaps.arcgis.com/stories/3a71790a48a34716b7808cb020ffe9b3.
[114] *Id.*

Our literature review and interviews with some of the participating parties indicate that traditional cultural values, particularly *Repartimiento*, are deeply embedded in the regional water management culture and appear to have been instrumental in facilitating the negotiation and adoption of the water shortage sharing agreement in the Rio Chama.

7 Benefits of Water Shortage Sharing in the Lower Rio Chama

The impacts of a water management system are multifaceted and go beyond how water is distributed amongst users. These impacts can include effects on environmental flows, riparian areas, agricultural production, cultural values, and social cohesion. Being able to compare these effects across different systems can allow us to identify and devise systems that maintain desired characteristics even in the face of periodic droughts that are increasing in frequency and duration.

In 2023, the Utton Transboundary Resources Center interviewed RCAA leaders and Rio Chama Water Masters to gather their perspectives on the benefits and challenges of the Rio Chama water sharing agreement. These interviews highlighted a diverse set of benefits, ranging from climate risk sharing to a decrease in water-related conflicts and an increase in trust and cooperation.[115]

The various types of benefits from these agreements underscore the need to broaden our perspective beyond a zero-sum game focused solely on water allocation, where one user's allocation decreases that of another. As Sadoff and Grey, world experts in water security and integrated resource management, state, "While physical water resources are, indeed, finite, the quantity of available water resources can be influenced by management actions. This is particularly true where rainfall is low and highly variable. Good water management practices can effectively increase the available water resources in a system by, for example, protecting watersheds to minimize erosion, maximize infiltration and extend the period of run-off".[116]

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[115] *Id.*
[116] Claudia W Sadoff & David Grey, *Beyond the River: The Benefits of Cooperation on International Rivers*, 4 WATER POLICY 389, 395 (2002).

We follow the framework of Sadoff and Grey (2002) for categorizing the benefits of conflict or cooperation in different agreements. In this framework, benefits are classified in four categories: *benefits for the river (*such as environmental flows), *benefits from the river* (such as increased food production), *reduction in costs because of the river* (such as reduced dispute/conflict expenditures), and *benefits beyond the river* (such as regional infrastructure, economic integration and preservation of cultural values).

To identify and quantify the benefits of shortage sharing in the Lower Rio Chama basin, we leverage qualitative data from semi-structured interviews and quantitative data, such as discharge data and water rights information. For context on these benefits, we additionally show what would have been observed under strict water rights priority curtailment, which serves as a reference point. The counterfactual or "what-if" benefits under strict water rights priority curtailment are computed using the simulated water discharge that the Lower Rio Chama water users would have received had water been distributed strictly based on their water right priority date.

Based on a simulation comparing observations under shortage sharing with those under strict priority administration, we find the following overall benefits for the Lower Rio Chama watershed in terms of ecological health, cultural values, and economic and social outcomes.

7.1 "What-if" discharge under strict water right priority date administration

To estimate the counterfactual water diversions, we simulate the water allocation each RCAA acequia would have received each day under curtailment based on the available daily native flow, their priority date, and maximum diversion amount. According to Rio Chama Water Master documentation, the daily native flow available for Lower Chama water users is equal to:[117]

Native Available Flow = Flow at USGS La Puente + Precipitation gains at USGS Above Abiquiu – Loss Rates

[117] June 7, 2021, Native Available Diversion Calculation for Rio Chama Shortage Sharing Memorandum.

Water Master curtailment notes reveal that water users often diverted less than the full amount of native flow available due to reasons such as storms impacting an acequia's infrastructure or irrigators deciding not to divert because of the high level of sediment in the water. Given this, for our simulation, instead of using the daily native available flow as the amount to be allocated amongst water users, we use the sum of what each acequia discharged each curtailment day as the flow available for apportionment. This makes both curtailment approaches have the same amount of water to be allocated each day.

To compute the counterfactual strict priority administration allocation, we simulate how the total discharge would have been allocated based on each acequia's priority date and maximum diversion amounts. See Appendix I for details on these simulations.

There were days during curtailment when some acequias did not divert their full allocation due to reasons such as miscommunications between irrigators on daily implementation times, gage measurement errors, acequia infrastructure damages due to rain or unidentified leaks, or concerns about potential damages due to murky water.[118] These choices led to slight differences between the actual (implemented) shortage-sharing discharge and the exact apportioned amount according to the shortage-sharing agreement. To minimize the effect of these choices in our comparisons between curtailment strategies, we also simulate the shortage-sharing allocation based only on the agreement rules. The simulated shortage-sharing allocation allows us to have an additional reference point of comparison. For the simulated shortage sharing computation, we follow the 2021 rotation schedule and, like when simulating strict priority administration allocation, we use the total discharge amount allocated amongst water users as the daily flow available for apportionment.

The Rio Chama irrigation season starts on April 1st and ends on October 31st. Figure 8 depicts in a light coral shade the periods during the 2021 irrigation season when curtailment was in place. That year La Puente (USGS 08284100) was below 50 cfs for the first time on July 10th, which marked the start of curtailment. Curtailment was lifted between July 26th and August 9th, restarting after this period and lasting until October 21st.

[118] 2021 Lower Rio Chama water master curtailment notes.

Figure 8 shows the three scenarios used in our analysis: the actual discharge observed in 2021 with the RCAA shortage sharing agreement (Figure 8a), the simulated shortage-sharing discharge based only on the RCAA shortage sharing agreement rules (Figure 8b)[119], and the simulated discharge under strict priority administration (Figure 8c).

[119] Water master curtailment notes reveal that often water users diverted less than the full amount of native flow available because of reasons such as storms impacting an acequia's infrastructure or irrigators deciding not to divert given the high level of sediment in the water. Given this, the shortage sharing allocation actually observed will slightly differ from the exact apportionment that would have been seen if it has been done exactly based on the shortage sharing agreement. To avoid these choices impacting our results, we also simulate the discharge under the shortage sharing agreement in our study.

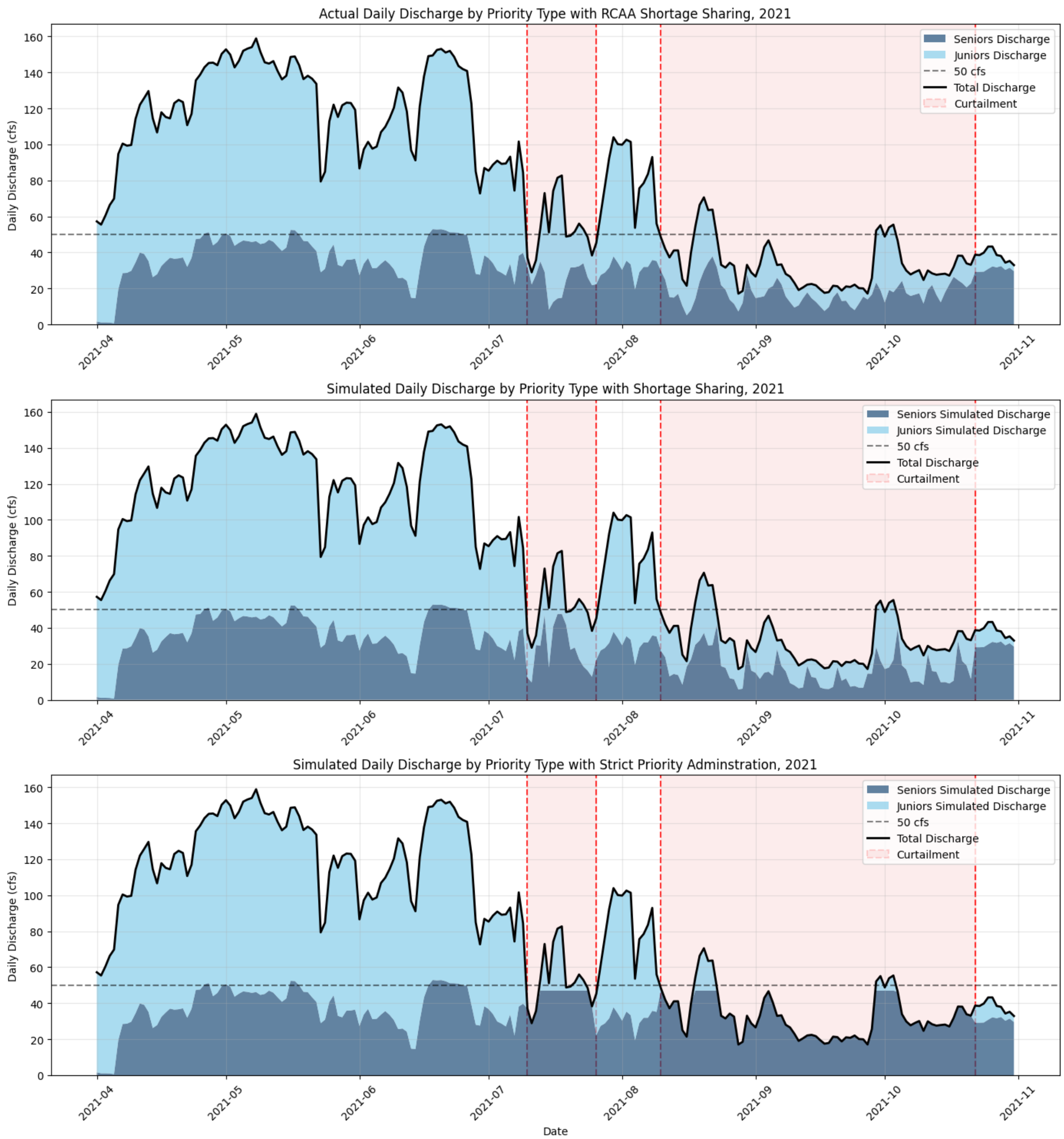

Figure 8. RCAA Acequias' Discharge Apportionment by Priority Type under (a) Actual Shortage Sharing, (b) Simulated Shortage Sharing, and (c) Simulated Strict Priority Administration

The three subplots of Figure 8 depict the total daily discharge by junior and senior water users (black line), the total daily discharge made by senior water users (dark blue area), and the total discharge made by junior water users (light blue area). The total daily discharge is the same in the three plots.

The apportionments to senior and junior water right users differ in these three scenarios. The actual discharge with shortage sharing (Figure 8a) and the simulated discharge with shortage sharing (Figure 8b) exhibit only slight differences when comparing the juniors' and seniors' discharges (light blue and dark blue areas, respectively). When we compare the apportionment between junior and senior users under strict priority (Figure 8c) with the shortage sharing graphs (Figures 8a and 8b), we notice that under strict priority, the senior water right holders' discharge (dark blue area) would been larger during curtailment, accounting for 100% of the total daily discharge on most curtailment days.

Figure 9 depicts the percentage of daily discharge apportioned to juniors under each scenario. We can see that under the simulated strict priority curtailment, the percentage allocated to juniors equals zero (juniors receive no water) for extended periods of time during the irrigation season.

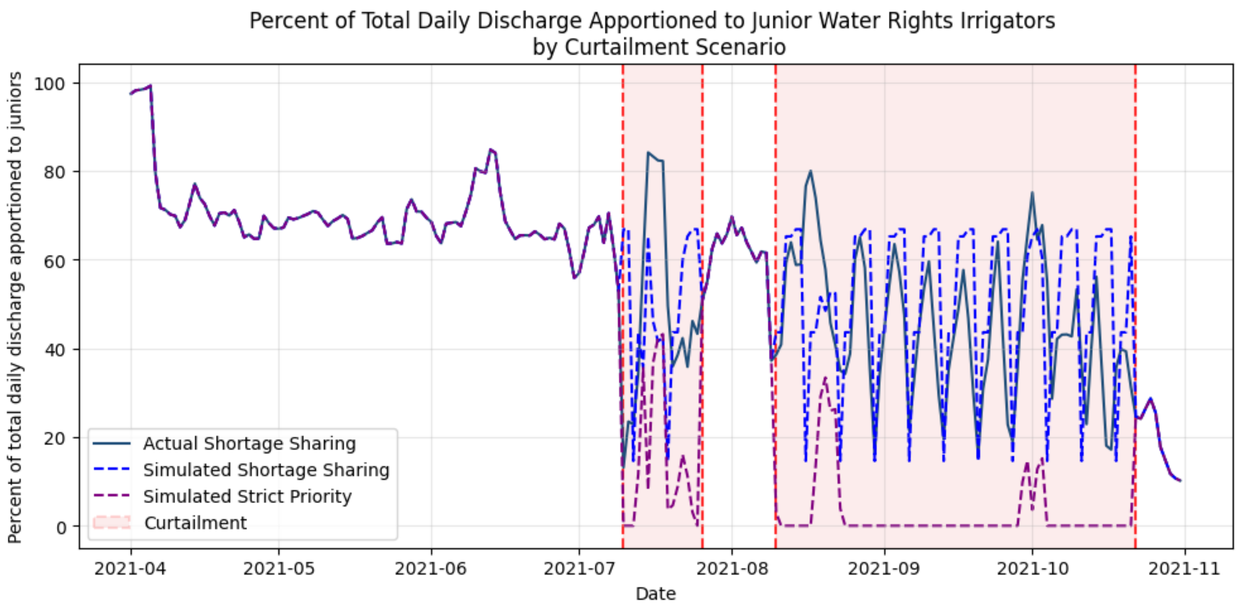

Figure 9. Percent of Total Daily Discharge Apportioned to RCAA Junior Acequias Water Right Holders by Curtailment Scenario

There were 89 days of curtailment during the 2021 irrigation season. Under Strict priority, 65 days out of these 89 curtailment days, juniors would have been allocated zero, while under the actual (and simulated) shortage sharing curtailment scenarios, juniors received some water on all 89 curtailment days.

The average number of days without water, the zero-flow spell, for junior water right holders, differs under both curtailment strategies. Table 2 shows there were five zero-flow spells under strict priority for junior acequias, with the average no-flow spell being 13 days. Under shortage sharing, there were no such spells, i.e., the average length of a zero-flow spell was zero as at least one junior acequia had some water allocated.

Table 2. Zero-flow Spells for Junior Water Right Holders, Strict Priority Curtailment Scenario

Spell Number	Spell Length	Start Date	End Date
1	3	7/10/2021	7/12/2021
2	1	7/25/2021	7/25/2021
3	7	8/11/2021	8/17/2021
4	36	8/24/2021	9/28/2021
5	18	10/4/2021	10/21/2021

NOTES:
A zero-flow spell is defined as the number of consecutive days where all junior RCAA acequia water right holders have a zero-flow allocation.

In the following subsections, we describe how the curtailments' allocations translate into different benefits for the watershed. We measure the benefits that were and would have been observed in the lower Chama subbasin under the three apportionments derived from these curtailment scenarios.

7.2 Benefits for the river

The second type of benefits are the *benefits for the river*. Cooperation can enable better management of these ecosystems. Rather than entirely cutting off junior users, the collaborative approach spreads out water use reductions, keeping stretches of the riverbank from going completely dry during the warmest months of the year.

There are expected benefits to riparian areas, soil moisture, temperature, and water quality from the reduction in zero-flow days and zero-flow spells in areas irrigated by junior water right holders compared to the simulated zero-flow days that would have been observed under strict priority administration.

We also measure additional environmental flow benefits. We use indicators from the Upper Rio Grande eco-health report card – of which the Rio Chama is part – developed by Audubon Southwest, the University of Massachusetts Amherst, the University of Maryland Center for Environmental Science (UMCES), and the World Wildlife Fund (WWF) to measure these benefits, specifically the "annual low flow" indicator.[120] The annual low flow measures the mean flow during the driest 7-day period in any given year. Following the approach used by UMCES to calculate this metric, we compute the annual low flow indicator for the warmest month in the Lower Rio Chama – July.

Figure 10 graphs the (July) annual low flow at USGS La Puente for the years between 2000 and 2024. This graph shows that since the actual implementation of the water shortage sharing agreement (in 2021), the annual low flow in July at La Puente has consistently been above 50 cfs. Note that even if the Annual Low Flow in July didn't reach 50 cfs, the Annual Low Flow when using August or September as the reference month was below 50 cfs for all years since the agreement, except for 2022, when there was above-average precipitation.

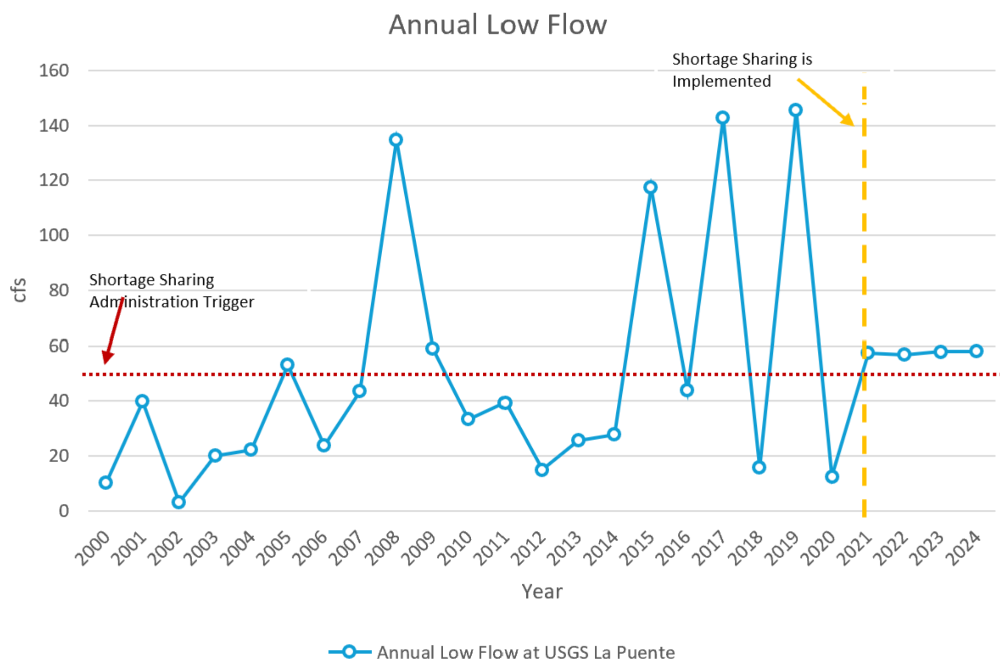

Figure 10. Yearly Annual Low Flow (July)

We measure the stability in Annual Low Flow since the agreement was introduced by comparing its standard deviation (std. dev)[121] and coefficient of variation (cv)

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[120] ALEJANDRA FRIES, KATIE MAY LAUMANN & NATHA MILLER, A REPORT CARD FOR THE UPPER RIO GRANDE BASIN (2022), https://ian.umces.edu/site/assets/files/29212/a-report-card-for-the-upper-rio-grande-basin.pdf.

[121] The standard deviation of the annual low flow is a statistical measure that quantifies the variability of annual low flow values around their mean. A lower standard deviation suggests the values cluster closely around the mean, indicating consistency, while a higher standard deviation indicates greater variability in annual low flow across the years in the interval period.

[122]since its implementation (2021-2024) with that of the four years before its implementation (2017-2020) and with that of for the four years before this comparison period (2016-2013). We observe a sharp change in the dispersion of the annual flow since the introduction of the shortage sharing agreement, moving from a std. dev. of 75.1 cfs and a cv of 95% (2017-2020) and of 43.3 cfs and 81% (2016-2013) before the agreement to .56 cfs and .97% (2021-2024) since the agreement was implemented.

The significant change in the variability in annual low flow of more than a 94% decrease in the cv between the four years before and after the agreement was not observed in USGS gages in the same basin, such as USGS Ojo Caliente at La Madera (08289000), who saw an 8% increase in its cv during this period.

Environmental flows are beneficial for the river, as they help dilute pollutants and transport sediments, preventing the buildup of contaminants that can harm biodiversity.[123] Additionally, these flows help maintain riparian vegetation, which provides shade and maintains suitable temperatures for a diverse array of microorganisms.[124] "Very low flows can diminish water quality, harm fish, reduce the amount of water available for people to use, and disrupt economic activities like river shipping."[125] The agreement decreased the variability in the average annual low flow. This finding supports the fact that shortage-sharing also has a positive impact on the river itself.

7.3 Benefits from the river

Besides the benefits described in the previous sections, the agreement also changed the *benefits from the river*. Figure 10 illustrates that since the implementation of the agreement in 2021, the voluntary reductions from the Upper Rio Chama acequias have been conducive to the Lower Rio Chama receiving a more consistent annual low flow of approximately 50 cfs, which was not the case prior to the agreement. In this way, sharing also has had flow benefits for the more

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[122] The coefficient of variation is a statistical measure that quantifies the degree of variability of annual low flows in a way that allows to compare it to the variability in other streams or periods that may have a different reference discharge level by calculating the ratio of the standard deviation to the mean times 100.

[123] ALEJANDRA FRIES, KATIE MAY LAUMANN & NATHA MILLER, A REPORT CARD FOR THE UPPER RIO GRANDE BASIN (2022), https://ian.umces.edu/site/assets/files/29212/a-report-card-for-the-upper-rio-grande-basin.pdf.

[124] ALEJANDRA FRIES, KATIE MAY LAUMANN & NATHA MILLER, A REPORT CARD FOR THE UPPER RIO GRANDE BASIN (2022), https://ian.umces.edu/site/assets/files/29212/a-report-card-for-the-upper-rio-grande-basin.pdf.

[125] OAR US EPA, *Climate Change Indicators: Streamflow*, (Jul. 1, 2016), https://www.epa.gov/climate-indicators/climate-change-indicators-streamflow.

senior water right holders in the Lower Rio Chama acequias (which have more senior water rights than the Upper Rio Chama water users). Future statistical analysis will measure the impact of the agreement on the average annual low flow and on its coefficient of variation, incorporating inflow, temperature, and precipitation controls.

Given the project's scope, besides the more consistent flows to lower Rio Chama acequias, we restrict our report to quantifying the benefits in crop production. We encourage further research to be devoted to quantifying other *benefits from the river*.

Alfalfa is the main crop grown in the Lower Rio Chama. Agriculture is a secondary source of income for the Lower Chama Acequias. Irrigation water is mainly used for gardens, orchards, and alfalfa.

We estimate indirectly the impact on crop production that the shortage-sharing agreement had in the lower Rio Chama basin in 2021 by measuring the deficit in irrigation water requirements (IWR) under each water curtailment scenario and their implied alfalfa production.

The RCAA acequias' maximum diversion amount is 136.5 cfs, corresponding to a maximum of 57,939.17 AF diverted per irrigation season. During the 2021 irrigation season, 33,437.5 AF were diverted, 58% of the maximum diversion amount.[126] We estimate the IWR using the same methodology employed by the Office of the State Engineer in the 2021 Lower Rio Chama Water Master Report.

The irrigation water requirement (IWR) per acre in the Lower Rio Chama is used to quantify the monthly alfalfa irrigation needs per acre. To compute the IWR, we estimate the evapotranspiration (ET) for alfalfa (i.e., the monthly inches of water needed for alfalfa that is well-watered and free of disease), subtract the effective average precipitation in the month, and adjust this quantity by the irrigation efficiency. We use a 50% irrigation efficiency based on the OSE 2021 Water Master report for the Lower Rio Chama.

Table 3 Column B depicts the monthly ET for alfalfa. ET for alfalfa during the irrigation season ranges between 0 inches (in April and October) and 9.54 inches

[126] DISTRICT IV, OSE, *supra* note 76.

(in July). Table 3 Column E depicts the Consumptive Irrigation Requirement (CIR) in inches for 2021 by month.[127] Table 3 Column I shows the total monthly IWR for Lower Rio Chama acequias in AF.[128] These values show that the highest irrigation needs in the Lower Rio Chama were between June and August. The Total IWR for the 2021 irrigation season was 22,742 AF. The IWR during the months with alternative administration (July-October) was 15,432.32 AF. The total discharge during curtailment months was 11,383.83 AF, with a deficit of 6,339.57 AF.[129]

Table 3. Monthly Evapotranspiration for Alfalfa and IWR in the Lower Rio Chama

[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]
Month of year 2021	**Total ET (in) [1]**	**Monthly Total Precipitation for Abiquiu Dam NM (in) [2]**	**Effective Preccipitaiton (in) [3]**	**CIR (in) (A-D)**	**CIR (feet) (E/12)**	**IWR (ft) (F/.5)**	**Acres Lower Chama [4]**	**IWR (AF) (G*H)**	**Discharge Irrigation Season (AF) [5]**	**Deficit Irrigation Season (AF) [6]**	**Deficit % Irrigation Season (K/I)**
January	0	0.05	0.0000	0	0	0	4,523.95	0			
February	0	0.40	0.1500	0	0	0	4,523.95	0			
March	0	1.54	1.0050	0	0	0	4,523.95	0			
April	0	0.49	0.2175	0	0	0	4,523.95	0	6,671.58	0	0%
May	2.97	0.81	0.4575	2.5125	0.2094	0.4188	4,523.95	1,894.40	8,329.00	0	0%
June	8	1.29	0.8175	7.1825	0.5985	1.1971	4,523.95	5,415.55	7,153.80	0	0%
July	9.54	2.38	1.6350	7.9050	0.6588	1.3175	4,523.95	5,960.30	4,241.45	(1,718.85)	-29%
August	8.03	0.53	0.2475	7.7825	0.6485	1.2971	4,523.95	5,867.94	3,245.08	(2,622.86)	-45%
September	5.05	0.56	0.2700	4.7800	0.3983	0.7967	4,523.95	3,604.08	1,606.22	(1,997.86)	-55%
October	0	0.13	0	0	0	0	4,523.95	0	2,193.86	0	0%
November	0	0.04	0	0	0	0	4,523.95	0			
December	0	0.04	0	0	0	0	4,523.95	0			
									TOTAL DEFICIT	**(6,339.57)**	

NOTES:
The deficit estimate follows the same methodology and data sources as those used by the Office of the State Engineer's District VI Water Master in the 2021 Water Master Report for the Lower Rio Chama.
[1] ET estimate is for northern alfalfa obtained using the United States Department of Agriculture's (USDA) Irrigation Water Requirement (IWR) Calculator for northern alfalfa for the Upper Rio Chama (https://efotg.sc.egov.usda.gov/references/public/NM/chama-cu.pdf).
[2] Precipitation data is obtained from the National Weather Service Forecast Office in Albuquerque, NM (https://xmacis.rcc-acis.org/) OSE uses terminology directly from the National Weather Service and has made no alterations to the precipitation data presented.
[3] Effective precipitation estimates are computed as: Effective Precipitation = (Precipitation – 0.2 Inches) * 0.75.
[4] OSE Red Book as of February 2024.
[5] 2021 Lower Rio Chama Water Master Report.
[6] The total deficit during curtailment is calculated as the sum of the monthly deficits from July to October 2021. If the discharge is less than the monthly IWR, the deficit equals the monthly IWR minus the discharge; otherwise, the deficit equals zero.

[127] To compute the CIR (the water needed for alfalfa in one month exclusive of effective rainfall) we subtract the effective average precipitation from the monthly ET.
[128] The IWR is computed by adjusting the CIR by the irrigation efficiency and multiplying this amount by the acres served by these water rights.
[129] The total deficit during curtailment is computed as the sum of the monthly deficits between July and October, 2021. The 2021 Lower Rio Chama Water Master Report estimates a deficit of 6,514.9 AF during alternative administration, which closely matches our deficit estimate of 6,339.57 AF.

Table 4 details how the water deficit during curtailment was shared between junior and senior water right holders. Overall, native flows could not serve 31%, 45%, and 57% of the irrigation water requirements during July, August, and September, respectively.[130] During these months, senior water right holders experienced a monthly deficit of between 20% and 34% of water requirements, while junior water right holders faced a deficit of between 37% and 69%.

Table 4. 2021 Lower Rio Chama Irrigation Water Requirement and Deficit

IRRIGATION WATER REQUIREMENT (IWR) FOR LOWER CHAMA ACEQUIAS IN 2021					
Water Right Priority	**Total Acres Served**	**IWR July (AF)**	**IWR August (AF)**	**IWR September (AF)**	**IWR October (AF)**
Junior	2,961.82	3,902.20	3,841.73	2,359.58	-
Senior	1,562.13	2,058.11	2,026.21	1,244.50	-
All	**4,523.95**	**5,960.30**	**5,867.94**	**3,604.08**	**-**
OBSERVED WATER DEFICIT WITH RCAA SHORTAGE SHARING IN 2021					
Water Right Priority	**Total Acres Served**	**Deficit IWR July (AF)**	**Deficit IWR August (AF)**	**Deficit IWR September (AF)**	**Deficit IWR October (AF)**
Junior	2,961.82	1,425.32	2,005.67	1,636.14	-
Senior	1,562.13	416.23	617.19	423.42	-
All	**4,523.95**	**1,841.54**	**2,622.86**	**2,059.57**	**-**
OBSERVED WATER DEFICIT AS PERCENTAGE OF IWR WITH RCAA SHORTAGE SHARING (2021)					
Water Right Priority	**Share Acres Served of Total**	**Share Deficit over IWR July (AF)**	**Share Deficit over IWR August (AF)**	**Share Deficit over IWR September (AF)**	**Share Deficit over IWR October (AF)**
Junior	65%	37%	52%	69%	N/A
Senior	35%	20%	30%	34%	N/A
All	**100%**	**31%**	**45%**	**57%**	**N/A**

The seventeen RCAA acequias participating in the lower Rio Chama rotation of water use have 4,523.95 acres served.[131] The acres served by these acequias were 4% of the total acres harvested for alfalfa in New Mexico in 2021. [132] This year the average alfalfa yield (tons per acre) in New Mexico was 5 tons per acre harvested; if we assume the lower Rio Chama had a similar yield for all acres served by the irrigators participating in the Lower Rio Chama agreement, 22,619.75 tons of alfalfa would have been harvested that year.[133]

To measure the impact of shortage sharing in alfalfa production, we estimate the average alfalfa yield (tons per acre) for strict priority administration and shortage

[130] The slight differences between the deficit percentages between Tables 3 and 4 are because the deficits in Table 3 are computed at the lower Chama level, while in Table 4 the deficit is computed first by acequia and then aggregated at the lower Chama.
[131] Based on the OSE Red Book priority dates for Rio Chama ditches as of February 2024.
[132] NEW MEXICO AGRICULTURAL STATISTICS 2021 ANNUAL BULLETIN 42 (2021).
[133] *Id.*

sharing as a function of the deficit in IWR. The number of tons per acre of alfalfa harvested is a function of the deficit in IWR. The greater the deficit, the lower the number of tons per acre of alfalfa harvested. Hence, we can estimate the average alfalfa harvested under both curtailment approaches as follows:

The alfalfa yield, or tons of alfalfa per acre, y_a for acequia a is equal to the average yield in New Mexico y^{NM} scaled by a factor $f(\cdot)$ that allows for larger benefits of irrigation water for alfalfa crop growth at low levels of the IWR, with diminishing marginal benefits as available irrigation water approaches IWR. We depict this relationship with the following formula

$$y_a = y^{NM} \times f(deficit\_ratio_a)$$

where:
$f(deficit_a)$ is a factor that takes values between zero and one, The factor is equal to one when the discharge allocated to acequia *a* meets or exceeds the IWR. We model the desired relationship between productivity and 1 minus the deficit-ratio with a concave function equal to:

$$f(deficit\_ratio) = 2 \times (1 - deficit\_ratio) - (1 - deficit\_ratio)^2$$

$$deficit\_ratio = \begin{cases} \dfrac{IWR - discharge}{IWR} & if\ discharge < IWR \\ 0 & if\ discharge \geq IWR \end{cases}$$

Hence, the total tons of alfalfa produced under each curtailment strategy is equal to the sum of each acequia's yield times the acequia's acreage $acequia_a$, i.e.

$$Y_{curtailment\_type} = \sum_a y_a \times acres_a$$

Table 5 depicts the total alfalfa production under strict priority administration and under shortage sharing. The results show significant differences in crop production between the two curtailment approaches. The estimated average yield for the Lower Rio Chama is lower under simulated strict priority administration than what would have been observed with the actual shortage sharing agreement: 2.99 vs. 3.61 tons per acre. This difference implies that if strict priority administration had been the curtailment strategy implemented, the increased crop production by senior water right holders (4.88 tons/acre vs. 4.36 tons/acre under RCAA shortage sharing) would not have compensated for the decrease in crop production of junior water users, who receive lower allocations (1.79 tons/acre vs. 2.88 tons/acre under RCAA shortage sharing).

The asymmetric impacts on senior and junior yields stem from the larger marginal benefits of irrigation water for alfalfa crop growth at low water supply levels. Under strict priority administration, water is distributed in a way that fails to capitalize on the larger benefits that would result from allocating water to areas with low irrigation water requirements (IWR).

Table 5. 2021 Lower Rio Chama Estimated Crop Production, Yield, and Revenue by Curtailment Type and Water Right Priority

ESTIMATED 2021 ALFALFA YIELD (Tons/Acre)			
Water Rights User Priority	**Shortage Sharing (actual)**	**Simulated Shortage Sharing**	**Simulated Strict Priority Administration**
Senior	4.36	4.09	4.88
Junior	2.88	3.21	1.79
ALL	**3.61**	**3.75**	**2.99**

ESTIMATED 2021 ALFALFA OUTPUT (Tons)			
Water Rights User Priority	**Actual Shortage Sharing**	**Simulated Shortage Sharing**	**Simulated Strict Priority Administration**
Senior	6,816.60	6,388.56	7,623.27
Junior	9,502.55	10,594.19	5,919.77
All	**16,319.15**	**16,982.76**	**13,543.04**

ESTIMATED 2021 ALFALFA VALUE OF PRODUCTION REVENUE (Dollars)			
Water Rights User Priority	**Actual Shortage Sharing**	**Simulated Shortage Sharing**	**Simulated Strict Priority Administration**
All	**$ 3,851,319.73**	**$ 4,007,930.64**	**$ 3,196,156.58**

Notes
[1] We assume that the 4,523.95 acres served by the water rights are used to grow alfalfa.
[2] The 2021 average alfalfa yield for NM was 5 tons per acre, and the alfalfa price per ton $236. Source: the NEW MEXICO AGRICULTURAL STATISTICS 2021 ANNUAL BULLETIN 42 (2021).

The difference in yields between the curtailment strategies resulted in an estimated increase of 807 tons of alfalfa production by senior water users and a decrease of 3,583 tons of alfalfa production by junior water users. Overall, crop production for the lower Chama basin acequias would have decreased by 2,776 tons of alfalfa had strict priority administration been implemented. Given that the average price of alfalfa was $236 per ton in 2021 in New Mexico[134], this would translate to an economic loss of $655,163 in production value—17% lower than the estimated value under the shortage-sharing agreement.

Table 5 also depicts a difference of $156,611 between the simulated and actual shortage sharing agreement. This difference is mostly driven by reasons described in section 7.1. Allocating resources to minimize some of the controllable reasons could close the deviation between the actual agreement and what is actually implemented.

7.4 Reduction in costs because of the river

Sadoff and Grey (2002) describe the *reduction in costs because of the river* as one of the central benefits of cooperation on shared waterways. This refers to both the reduction in costs incurred from water-related conflict as well as to the compounding reduction in costs that would result from noncooperation. They argue that cooperation is the linchpin of all four benefits in their framework: Reductions in conflict (*reduction in costs because of the river)* enable sustainable river management and greater ecological health (*Benefits to the river*) and leads to greater water security in the area (*Benefits from the river*). Our research on the Rio Chama Water Shortage Sharing Agreement also confirms a *reduction in costs because of the river* in the Lower Rio Chama.

Qualitative evidence suggests that cooperation reduced the incidence of conflict among irrigators in the Lower Rio Chama. As Joseph Pina, a Water Master and third-generation farmer, explained in an interview,[135] irrigators experienced fewer disputes and acts of violence once the agreement was implemented, as they increasingly perceived AWRM water masters as a legitimate third-party enforcer.

The OSE's 2021 Lower Rio Chama Water Master Report illustrates the compounding effect of reduced monitoring and enforcement costs of a voluntary agreement implemented in collaboration with the Rio Chama Acequia Association, the Acequias Nortenas, and Ohkay Owingeh. Compared to 2020, manpower use in 2021 dropped by 80% (freeing 2,900 staff hours, equal to 1.39 full-time positions), vehicle use was reduced by 12,320 miles (saving about $8,378 in mileage and fuel), and administrative efficiency more than doubled at only one-fifth of the

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[134] NEW MEXICO AGRICULTURAL STATISTICS 2021 ANNUAL BULLETIN 42 (2021).
[135] Utton Transboundary Resources Center, *supra* note 110. (Joe Piña, Lower Rio Chama Water Master).

manpower cost. Importantly, over diversions fell from 147 CFS over 36 days in 2020 to 45.9 CFS over just 22 days in 2021 (a 69% reduction in volume, with even greater improvements after gauge corrections).[136] The result is that the annual low flow at La Puente for July has been more stable every year since 2021. The change demonstrates the mechanisms Sadoff and Grey describe: cooperation reduced enforcement costs on the Rio Chama Basin, as it also increased predictability and security of water availability to irrigators.

The observed reduction in costs is in line with Elinor Ostrom's design principles for robust common-pool resource governance. Through clear boundary-setting, collective-choice arrangements, and the presence of an accountable monitoring institution, the result is stronger collective adherence to diversion rules, greater predictability and fairness in water distribution, which reinforces confidence in the system.[137]

Likewise, the results align with the framework in section 8.2 of the *United Nations World Water Development Report 2021: Valuing Water*, which emphasizes that the benefits of cooperation extend beyond economic gains to include strengthened social cohesion, reduced conflict, and enhanced trust in governance institutions.

We plan to solidify these findings with future research leveraging semi-structured interviews with acequia members to systematically evaluate perceptions of violence reduction and conflict within the community.

"Benefit-sharing yields far greater scope for mutually beneficial and sustainable arrangements among different stakeholders"

THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 2021 VALUING WATER

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[136] State of New Mexico, Office of the State Engineer, 2021 Lower Rio Chama Water Master Report, Exhibit E.
[137] Ostrom, Elinor. "Governing the Commons: The Evolution of Institutions for Collective Action" (2015).

7.5 Benefits beyond the river

7.5.1 Equity and Shortage Sharing Equity

We measure the equity of a curtailment policy's water allocation amongst water users by computing the Gini coefficient (or Gini index). The Gini coefficient is a metric traditionally used in economics to measure the inequality in the distribution of income in a country or subgroup. For our case study, the Gini coefficient measures the inequality or concentration of water apportionment across water users. The index takes a value between 0 and 1. A value of 0 reflects that everyone has the same water apportionment, while a Gini Coefficient of 1 reflects when one individual has all the resource. The Gini coefficient is used by institutions worldwide for the use case of income inequality, such as the US Census, the World Bank, and the Congressional Budget Office.

Table 6 depicts the monthly Gini coefficient for both curtailment strategies, the RCAA water shortage sharing agreement, and strict priority administration. The monthly Gini coefficients for shortage sharing range between .4 and .46, while for strict priority administration, the range is between .73 and .80. This implies that water concentration during curtailment is greater under strict priority than under shortage-sharing. The Column *% IWR Deficit* shows the monthly deficit between what the lower Chama acequias discharged and the month's irrigation water requirement. We observe that the concentration of water resources or Gini coefficient under shortage sharing remains mostly constant as the irrigation water requirement deficit increases, while under strict priority administration, when the shortage (deficit) increases, the allocation of water becomes more unequal.

Table 6. Monthly Gini Coefficient and IWR Deficit, 2021

Month 2021	% IWR Deficit	Gini Coeff. Strict Priority	Gini Coeff. Shortage Sharing
July	29%	0.73	0.43
August	45%	0.76	0.46
September	55%	0.81	0.43
October	0	0.80	0.40

Notes: See Appendix I for detailed calculations of the Gini Coefficient

A second benefit, beyond the river, identified as important for irrigators in the Chama, was the agreement's ability to "share the pain" of shortage. We define the property of a curtailment management policy to share equitably the impacts of a shortage amongst water users as *shortage sharing equity*. We measure the ability of a curtailment strategy to equitably share the impacts of a shortage among water users, using the correlation coefficient between the IWR deficit, which measures the severity of the shortage, and the Gini coefficient, which measures the equality of water distribution among irrigators. The closer the correlation coefficient is to zero, the greater shortage sharing equity a curtailment management policy has.

A correlation coefficient is a statistic that takes a value between -1 and 1 and measures the strength and direction of the relationship between two variables. When the correlation coefficient is positive (greater than zero), it implies that both variables move in the same direction; when the correlation coefficient is negative (less than zero), it implies that when one variable increases, the other variable moves in the opposite direction. Additionally, the closer the correlation coefficient is to 1 or -1, the stronger the relationship.

In our analysis, as we compute the correlation coefficient between the IWR deficit and the Gini coefficient, when the correlation coefficient is positive (greater than zero), it implies that as the irrigation deficit increases, the inequality in the apportionment of water amongst users increases; while, when this value is negative (less than zero), it implies that as the irrigation requirements increase, the available flow is distributed more equally amongst users.

The correlation coefficient between the IWR deficit and the Gini coefficient is equal to .02 under shortage sharing and equal to .98 under strict priority appropriation.[138] A correlation of .98 under strict priority appropriation implies a strong and positive relationship between the irrigation deficit and the inequality in the apportionment of water; in other words, under strict priority administration, as the irrigation deficit increases, the more unequal the distribution of water becomes. This is not the case for shortage sharing, where the correlation between the two variables is close to zero.

In summary, relative to strict priority administration, the RCAA shortage-sharing agreement is a curtailment practice that achieves a higher measure of water equity and shortage sharing equity, allowing the water equity level to remain constant even in the face of seasonal low water levels or droughts.

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[138] We compute the correlation coefficient based on the monthly values between July and September only, as during these months, there was curtailment and a need for water irrigation to grow Alfalfa in the Lower Rio Chama.

Fairness, the Gini Coefficient, and the ultimatum game

As subnational water conflicts increase sharply worldwide,[139] the measure of fairness inherent in a water management policy is an important metric to include when measuring a policy's potential welfare impacts.

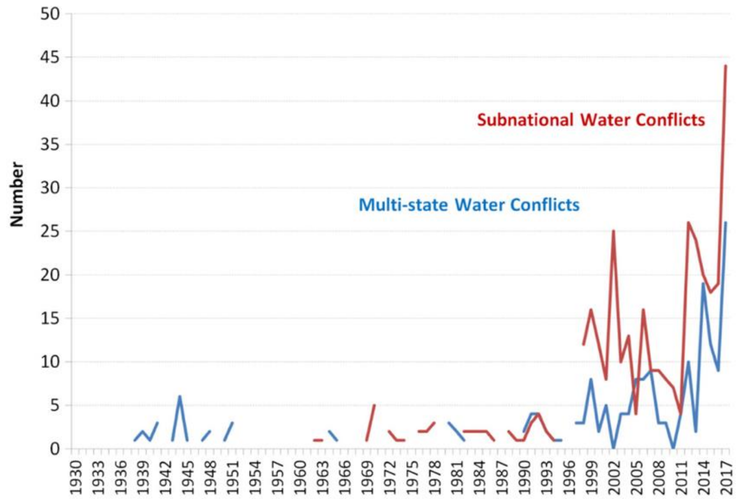

Fig. 2 Water-related violence through 2017: Multi-state water conflict events (blue) compared to subnational water conflict events (red). Data from the Water Conflict Chronology, https://www.worldwater.org/water-conflict/

Figure 11. Water-related violence,
Source: (Gleick, 2019).

When considering the effects of shortage-sharing agreements, one should factor the impact these have on producing agreements that are more stable long-term by decreasing water-related violence. In our study, we could consider the shortage sharing equity of a curtailment policy as a measure of fairness of the water allocation under a specific type of curtailment administration.

The importance people give to fairness to reach an agreement when distributing resources has been robustly documented in experimental economics research, which studies human choice through controlled, scientific experiments. The Ultimatum Game is one of these controlled experiments. The rules of this two-player-take-it-or-leave-it game are as follows. Player one is given a certain money amount, who then proposes how much of this amount to give the second player. The second player then decides if they reject or accept the offer. If the offer is

[139] Peter H. Gleick, *Water as a Weapon and Casualty of Conflict: Freshwater and International Humanitarian Law*. 33 WATER RESOUR MANAGE 1737 (2019).

accepted, they each keep the amount of money agreed upon. If the offer is rejected, the players take nothing.

The main finding of this experiment is that when facing an unfair proposal, players prefer to leave money on the table rather than take an unfair distribution.

7.5.2 Joint Advocacy

Interviews with the RCAA leadership highlighted that a benefit of this cooperative approach to water management is that it established the foundation for joint advocacy. RCAA leadership described how this approach has enabled collaborative advocacy efforts, resulting in improved access to grants and funding, as well as a stronger collective voice when negotiating Settlement terms or addressing RCAA water needs with other parties.

8 Conclusions

Robust water management systems that can maintain desired benefits even during fluctuations are of particular interest, given the increasing duration and frequency of extreme precipitation events. We highlighted the multiple benefits of water shortage-sharing that go beyond the direct benefits from the river to multifaceted long-term benefits of a more equitable distribution of water that span environmental, economic, and social dimensions.

We classified these benefits in four categories and found the following results:

- *benefits for the river (*such as environmental flows):
    - A reduction in zero-flow days in areas irrigated by junior water right holders compared to the simulated zero-flow days that would have been observed under strict priority administration. The average zero-flow spell for all junior users would have been 13 days, while under shortage sharing, there were no zero-flow spells. Prolonged spells with no water can have impacts on riparian areas, soil, temperature, and water quality. The agreement decreases the likelihood of these impacts.
    - A significant change in the variability in annual low flow – a 94% decrease in the coefficient of variation (from 95% to 1%) –between the four years before and after the agreement. This sharp drop was not

observed at other similar gages such as USGS Ojo Caliente at La Madera – an 8% increase in its cv.

- *benefits from the river* (such as increased food production):
  - There is an estimated average yield increase of .62 tons per acre for the Lower Rio Chama under the shortage sharing agreement than what under simulated strict priority administration. This difference in yield implies that overall crop production for the lower Chama basin acequias would have decreased by 2,776 tons of alfalfa had strict priority administration been implemented. Given that the average price of alfalfa was $236 per ton in 2021 in New Mexico,[140] this would translate to an economic loss of $655,163 in production value—17% lower than the estimated value under the shortage-sharing agreement.
  - The difference in yields between the curtailment strategies resulted in an estimated decrease of 807 tons of alfalfa production by senior water users (4.88 tons/acre vs. 4.36 tons/acre under RCAA shortage sharing) and an increase of 3,583 tons of alfalfa production by junior water users (1.79 tons/acre vs. 2.88 tons/acre under RCAA shortage sharing).This difference implies that if strict priority administration had been the curtailment strategy implemented, the increased crop production by senior water right holders would not have compensated for the decrease in crop production of junior water users, who receive lower allocations.
  - Under strict priority administration, water is distributed in a way that fails to capitalize on the larger benefits that would result from allocating water to areas with low IWR.
  - Allocating resources to minimize the controllable reasons for the deviation between the actual and simulated shortage sharing agreement is estimated to potentially lead to $156,611 increase in crop production; other benefits, such as reduction in dispute/conflicts and implementation costs would also be expected.

- *reduction in costs because of the river* (such as reduced dispute/conflict expenditures):
  - Qualitative evidence suggests that cooperation reduced the incidence of conflict among irrigators in the Lower Rio Chama, as they increasingly perceived AWRM program as a legitimate third-party.

[140] NEW MEXICO AGRICULTURAL STATISTICS 2021 ANNUAL BULLETIN 42 (2021).

- Compared to 2020, manpower use in 2021 dropped by 80% (freeing 2,900 staff hours, equal to 1.39 full-time positions), vehicle use was reduced by 12,320 miles (saving about $8,378 in mileage and fuel), and administrative efficiency more than doubled at only one-fifth of the manpower cost. Importantly, over diversions fell from 147 CFS over 36 days in 2020 to 45.9 CFS over just 22 days in 2021 (a 69% reduction in volume, with even greater improvements after gauge corrections).[141]
- The agreement illustrates the compounding effect of reduced monitoring and enforcement costs of a voluntary agreement implemented in collaboration with the Rio Chama Acequia Association, the Acequias Nortenas, and Ohkay Owingeh: cooperation reduced enforcement costs on the Rio Chama Basin, as it also increased predictability and security of water availability to irrigators.

- *benefits beyond the river*:
  - The agreement's monthly Gini coefficient range was between .4 and .46, while for strict priority administration, the coefficient's range would have been between .73 and .80. This implies that water concentration during curtailment was significantly lower under shortage-sharing than what would have been observed under strict priority administration.
  - Based on interviews with the RCAA leadership, the agreement helped establish the foundation for joint advocacy for the Ohkay Owingeh settlement agreement and for funding.
  - As subnational water conflicts increase sharply worldwide,[142] the measure of fairness inherent in a water management policy can have impacts on water-related violence and willingness to cooperate. The lower water concentration during curtailment under shortage-sharing and increased joint advocacy provides support for also prioritizing water management policies with higher measures of fairness during curtailment to foster cooperation and prevent water related conflicts.

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[141] State of New Mexico, Office of the State Engineer, 2021 Lower Rio Chama Water Master Report, Exhibit E.
[142] *Id.*

As the need to curtail water use increases in the Western States, the Rio Chama water shortage sharing agreement presents an alternative form of curtailment that mitigates impacts and fosters social cohesion to prevent long-term social conflict, creating a more robust and stable system. Furthermore, this agreement reflects the benefits of the *Repartimiento* value of acequia communities.

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