A Survey of the Bureau of Reclamation's Decree Accounting Reports in the Lower Colorado River Basin

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Abstract: From the Rocky Mountains in the US to the Sea of Cortez in Mexico, the Colorado River is one of the most managed and monitored rivers in the world. As decreasing river flows from drought and climate change continue to impact the Colorado River Basin, the US federal government, seven US states, and Mexico have signed agreements that would reduce deliveries, including a Drought Contingency Plan (DCP), an agreement among the US states and the Bureau of Reclamation, and Minute 323 (a treaty agreement between the US and Mexico). As part of the DCP, the US Bureau of Reclamation (Reclamation) committed to increasing conservation efforts to augment storage in Lake Mead. This paper presents an analysis of Reclamation's Decree Accounting Reports that record water deliveries and conservation savings from 1964 to 2019. Overall, this analysis illustrates that (1) the agency has implemented significant conservation actions over the last three decades, (2) the agency has responded to increased accounting needs as dictated by national and international management agreements, (3) some actions have resulted in environmental costs, and (4) future actions could be designed to avoid environmental harms while also augmenting Lake Mead levels. As climate change continues to constrain Colorado River water supply, detailed accounting may help reveal areas for potential efficiencies or demonstrate where the greatest levels of savings have been reached while ensuring that environmental and social benefits are preserved. **DOI: 10.1061/(ASCE)WR.1943-5452.0001626.** © *2022 American Society of Civil Engineers.*

Practical Applications: Over the last 100 years, humans have changed the path and personality of the Colorado River by distributing water to cities, communities, and agricultural fields to support over 40 million people. Throughout the twentieth century, the US federal government, seven US, and Mexico signed agreements enabling development of Colorado River water. By the early 21st century, as it became evident that water demands and climate change were reducing available supplies, these same governments signed agreements to reduce pressure on the river. All these agreements have, in part, been tracked by the US federal agency that manages the river, the Bureau of Reclamation (Reclamation), through Decree Accounting Reports. Since 1964, these reports have recorded how water is or is not accounted for that might be important to the future of the river. This paper examines those reports and reveals four main findings: (1) Reclamation has implemented numerous water conservation projects, (2) they have responded to new management agreements, (3) some of their actions have impacted the environment, and (4) there are proactive ways they can reduce environmental impacts and bolster water supplies in the future.

Introduction

> Water efficiency bears a patina of environmental respectability, and it is frequently seen as a way to conjure more water out of thin air. But a profound paradox stands at the heart of the logic of efficiency: Increased efficiency creates losers as well as winners, and the victims often inhabit places far beyond the public eye. (Jenkins 2007)

After nearly 2 decades of sustained drought, growing population, and overallocated water supplies, there is an ever-growing demand for creative and adaptive water conservation and management approaches throughout the Colorado River Basin. One of the most managed, monitored, and carefully controlled rivers in the world, the Colorado River system includes a vast network of dams, pipes and canals that convey water to support more than 40 million people and to irrigate more than 2.2 million ha (5.5 million acres) of farms and ranches. At the same time, the rivers of the Colorado River Basin are the lifeblood for Native American tribes that have lived in the region for millennia, a beloved resource that underlies a $26 billion recreation economy, home to legendary and globally iconic protected natural areas like Rocky Mountain National Park and Grand Canyon National Park, and vital habitat for wildlife in the region including dozens of endangered species. With so many uses depending on it, the Colorado River has been developed so fully that it flowed only occasionally to its mouth at the Upper Gulf of California in the last half century. The Colorado River Delta that historically extended over 600,000 ha (1.5 million acres) is largely gone, and the Colorado River in its final 160 km (100 mi) is vastly diminished and often completely dry.

Water demands continue to evolve as populations and economies transform over time. Simultaneously, the Colorado River water supply is historically variable, currently in the grip of a multidecadal drought, and subject to considerable decline going forward due to the impacts of climate change (Udall and Overpeck 2017; Milly et al. 2005; Milly and Dunne 2020). These dynamics are challenging managers, policy makers, and stakeholders to develop effective management methods that can better adapt to changing

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conditions and incorporate diverse needs (Bureau of Reclamation 2012, 2015).

Water accounting in river systems endeavor to monitor and track diversions, deliveries, inefficiencies, and savings. Theoretically, water accounting creates transparency for the public, and can be a tool to improve river and water management, particularly as demands grow and supplies are nearly or fully allocated. However, accounting also reflects the historic cultural conditions that were in place when water laws, policies, and infrastructure were initially developed in the modern era. Rivers are complex systems, and accounting often takes a focused lens on elements that directly relate to the economy, such as consumptive use for agriculture and cities. This focus excludes complex elements that are difficult to track, that are not a direct part of the economic system, that are nonconsumptive uses, or that do not have legal allocations or entitlements. In the Colorado River system, elements outside of the historically constructed legal and accounting systems have included environmental uses, tribal water, and in many cases, groundwater. Because these water uses have not been accounted for, any degradation or changes can more easily go unnoticed.

The US Bureau of Reclamation (Reclamation) administers five regions in 17 US western states to implement its mission to "manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public" (Bureau of Reclamation 2018). Reclamation manages the Lower Colorado River Region through the rights and obligations established under a collection of laws, compacts, agreements, legal settlements, and Treaty minutes that comprise the Law of the River. To comply with historic agreements and meet the evolving needs of the Colorado River Basin, Reclamation serves as the Secretary of the Interior's Watermaster on the Lower Colorado River, in collaboration with the seven Colorado River Basin states, Tribal governments, the Republic of Mexico, and the range of agricultural, municipal, and public interest groups in the Region.

Reclamation was established as a federal agency in 1902, but it was not until the early 1960s, just as Lake Powell was filling and regular flows no longer reached the Colorado River Delta, that the agency's role was expanded to include Colorado River accounting. The 1963 Consolidated Decree of the US Supreme Court in *Arizona v. California* established Reclamation's role as Watermaster on the Lower Colorado River and required Reclamation to publish annual reports called the *Colorado River Accounting and Water Use Report: Arizona, California, and Nevada* (Bureau of Reclamation 2022b). The reports are necessary to account for the following:

> Diversions of water from the mainstream, return flow of such water to the stream as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation, and consumptive use of such water. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California and Nevada. (Supreme Court of the United States 1964)

Additional documents provide guidance to the Decree Accounting Reports, including the 2010 Lower Colorado Region Policy for Apportioned but Unused Water, the 2007 Interim Guidelines, the 2006 Inadvertent Overrun and Payback Policy, 43 CFR Part 417 related to Implementing Conservation Measures, and the 2003 Yuma Area Water Accounting Policy (Bureau of Reclamation 2007, 2010, 2003, 2006).

From 1995 to 2014, Reclamation also produced reports on evaporation and evapotranspiration, using remote sensing technology. These Lower Colorado River Accounting System (LCRAS) reports provided estimates of annual agricultural, riparian vegetation, and open water acreages and water uses along the Lower Colorado River from Hoover Dam to the Southerly International Boundary with Mexico (Bureau of Reclamation 2004). LCRAS was developed to improve reporting on crop consumptive use and included some elements of ecosystem and riparian consumptive use rates. However, Reclamation no longer publishes the LCRAS reports, and continues to rely on the Decree Accounting methodology, which measures diversions and return flows, reflecting the management importance of return flows as a component of downstream water deliveries.

Reclamation has prepared Colorado River Decree Accounting Reports for nearly 60 years. During this period, Reclamation's accounting process has grown substantially, capturing the details of increasing efforts to track every drop of water in a Lower Colorado River Basin where water demands have increased and the river's water supply has diminished under increasing temperature trends of climate change. This paper explores the evolution of Reclamation's Colorado River Decree Accounting Reports as a window through which to see Reclamation's evolving role in Colorado River management as well as to explore the impact of Reclamation's management regimes on environmental resources that are not included in accounting processes.

Water Deliveries to Mexico

As set forth in the 1922 Colorado River Compact, 1928 Boulder Canyon Act, and the Mexican Water Treaty of 1944, the waters of the Colorado River are shared among seven western US states and the Republic of Mexico, with a 1.85 billion m^3 (1.5 million acre-ft) annual delivery owed to Mexico (US Congress 1921, 1928; US Department of State 1944). As the last delivery on the system, the water that Mexico receives reflects the condition and stresses of the upstream watershed. Although the Treaty provides for a minimum flow of water to Mexico each year, the amount guaranteed to Mexico represents only around 10% of the Colorado River's flows that historically reached its Delta. Mexico typically diverts its Treaty-allocated water at Morelos Dam, built in 1950, for use in irrigated agriculture and for the cities of Mexicali and Tijuana.

As the US has continued to build dams and diversions upstream, improve infrastructure efficiencies, and increase water accounting, Mexico has seen dramatic reductions in river flows. Throughout the 1950s, the volume of water arriving at Morelos Dam, the structure Mexico built to divert its Treaty-allocated water, was greater than Mexico's Treaty allocation, meaning Mexico and the Colorado River Delta benefited from so-called excess flows across the international border. But with the development of the Glen Canyon Dam in the 1960s, flows that were in excess of the Treaty-allocated volume of water diminished. With the exception of some very large flows in the early 1980s (the result of significant snowpack and the inability to store water in the newly filled Lake Powell), the river, for the most part, has ceased to exist in its delta. Today, any excess flows delivered to Mexico are typically so small—in the realm of 37 million m^3 (30,000 acre-ft) annually—that Mexico diverts most of them along with its Treaty-allocated water.

In a system that is defined by, and managed for, legal allocations, any deliveries that are made above and beyond those allocation limits are considered to be excess or losses, which leaves very little (if any) room for water needs that do not have a predefined allocation (e.g., environmental uses) and further underscores the

limitations of water governance based on allocations as well as the challenges of direct accounting methods. This point is demonstrated in the Decree Accounting Reports, which have documented excess flows to Mexico based on concern for losses to water available for consumptive uses in the US rather than any acknowledged mandate to account for water-dependent ecosystem values in the Colorado River Delta. It is important to note that a 2001 legal decision (Defenders of Wildlife v. Babbitt 2003) established that Reclamation does not have discretion to provide water for endangered species on the Colorado River mainstem in Mexico in the context of "a Supreme Court injunction, an international treaty, federal statutes, and contracts between the government and water users that account for every acre-foot of Lower Colorado River water" (Defenders of Wildlife v. Babbitt 2003). Fig. 2 illustrates excess flows delivered to Mexico since 1966, demonstrating that other than years with abundant precipitation, excess deliveries to Mexico have been constrained near or at the treaty volumes. Importantly and as discussed subsequently in the context of the All American Canal, groundwater flows from canal leakages in the US to Mexico are not accounted for in the Decree Accounting Report and did play an important role in bolstering groundwater tables and wetlands in the Mexicali Valley (Lesser et al. 2019).

As water deliveries to Mexico have fallen, the US–Mexico water relationship has been punctuated by conflicts over degraded water quality, the lining of the All-American Canal in California (which significantly impacted groundwater users in Mexico), and the adoption of operations and infrastructure that increasingly allow Reclamation to capture the "excess" for storage or use in the US (Bureau of Reclamation 2007). These conflicts also reflect fundamentally different and opposing narratives that have been maintained by the US and Mexico about the nature and significance of river management, including the relative benefits and consequences of perceived and actual efficiencies. One of the most acute examples of these conflicts arose in the late 2000s with the lining of the All-American Canal. Originally built in the 1930s and completed in 1942 to deliver water from the Colorado River to California's Imperial Valley, seepage from the unlined canal entered Mexico, and raised groundwater tables, where it was utilized for Mexicali Valley irrigation and supported local wetlands in Mexico (Lesser et al. 2019; Hinojosa-Huerta et al. 2002). Driven by federal and state pressure to reduce California's Colorado River consumptive use to the state's allocated share, the canal was lined in 2009 despite lawsuits from Mexicali businesses and US-based environmental groups (Corez-Lara and García-Acevedo 2000; Calleros 1991). Paradoxically, in lining the canal to improve delivery efficiencies in the US, Mexicali agricultural operations and wetlands lost roughly 86.3 million m^3 (70,000 AF) and US–Mexico relations were significantly strained (Sánchez Munguía 2006; Sanchez et al. 2016).

Minutes No. 319 and 323, two major international agreements that were negotiated over the course of the last decade, have taken significant steps toward moving past historic conflicts and establishing a new binational narrative built around mutual cooperation (IBWC 2012, 2017). The Minutes, which interpret and expand key elements of the 1944 Treaty, represent a breakthrough on a series of difficult and long-standing issues between the US and Mexico. This includes establishing rules for sharing of shortages and surpluses, opening US reservoirs to use for water storage by Mexico, and—perhaps most significantly—making binational commitments to provide water to the highly degraded Colorado River Delta ecosystem and restore functional riparian habitats along the long-dry river channel via an ongoing environmental flow and restoration program (Cohen et al. 2001; Glenn et al. 2013; Zamora-Arroyo et al. 2008).

Current Management Actions

The management of the Lower Colorado River is at a critical point, with an urgent need to respond and adapt to continued climate change–driven drought conditions (Cook et al. 2015, 2019), increasing temperatures that diminish streamflows (Udall and Overpeck 2017; Milly and Dunne 2020), ongoing water quality issues on the border (Tillman et al. 2019), and making adjustments to deliveries to be in line with annual supplies and reservoir storage (Cook 2004; Cook et al. 2018). By 2022, Reclamation will embark on a 5-year renegotiation of the 2007 *Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead* (Bureau of Reclamation 2020). The 2007 Interim Guidelines are in place from 2008 through December 31, 2025, and provide an opportunity to gain experience managing Lake Powell and Lake Mead under modified operations and explore possible actions to respond to evolving hydrologic conditions. The first step toward the renegotiation of the 2007 Interim Guidelines began in 2020 with a formal review of the effectiveness of the Guidelines (Bureau of Reclamation 2020).

Additionally, in 2019, the seven Colorado River Basin States (Wyoming, Utah, Colorado, New Mexico, Arizona, and California) and the Republic of Mexico developed the Drought Contingency Plan (DCP) and Minute 323, which outline a series of voluntary actions to curtail deliveries and protect Lake Mead Reservoir levels (116th Congress 2019; IBWC 2017, Minute 323). As part of the DCP, Reclamation pledged to pursue actions that would conserve up to 1.2 billion m^3 (100,000 AF) of water to benefit Lake Mead. Because Reclamation does not have any legal water rights, conservation activities focus on infrastructure and system efficiencies.

Notably, Reclamation's management to address tribal water has left many tribes unable to realize the full value of their sovereign treaty-based water rights due to infrastructure, economic, and legal constraints. Although tribes in the Lower Colorado River basin can claim several billion m^3 (several million acre-ft) in water rights, in many cases they have not had access to the funding needed to develop these rights. In 2018 Reclamation, in partnership with the Ten Tribes Partnership, published the *Colorado River Basin Ten Tribes Partnership Tribal Water Study* documenting these rights as well as where they have yet to be developed (Ten Tribes Partnership 2018). Because the Colorado River is used to extinction, it is clear that nontribal water users today benefit from some tribes' constrained capacity to develop their water.

The Decree Accounting Reports provide a historical roadmap of the on-the-ground implementation and water delivery impacts from significant policy actions, climate events, and conservation programs from 1964 to 2019 on the Lower Colorado River. The increasing length and level of detail in the reports reflects Reclamation's efforts to keep pace with legal, policy, and hydrologic changes on the Lower Colorado River and provide sufficient information to make informed and effective policy decisions. By illustrating how the Decree Accounting Reports have changed over the last 55 years, this paper examines Reclamation's management of the Colorado River in response to an evolving relationship with Mexico and highly variable hydrologic conditions. The analysis also attempts to highlight how the evolution of the Lower Colorado policy landscape has prioritized protecting Lake Mead elevations through conservation programs, multistate agreements, incentives for water users to store water in Lake Mead for future use, and ratcheting down overdeliveries to Mexico through infrastructure upgrades, even though there is not a parallel mandate to account for the Colorado River's water-dependent ecosystem values in Mexico.

Decree Accounting Reports Analysis Methodology

To explore how the Decree Accounting Reports serve as a historical record of Reclamation's management efforts over time, reports from 1964 to 2019 were analyzed. This review focuses on identifying elements that were added to or modified within the report over the last half century. Several specific areas within the Decree Accounting Reports were noted, including (1) the progressive addition of new users to the system, (2) evidence of efforts to tighten the system by accounting for water ordered but not diverted, return flows, and losses to the system, (3) implementation of conservation programs in response to the warming and drying effects of climate change, and (4) the absences of accounting data on water quality, environmental water uses and values, alluvial groundwater at the border, and environmental impacts.

The material for this analysis was derived from portable document formats (PDFs) of US Bureau of Reclamation Decree Accounting Reports from 1964 to 2019 that were downloaded in bulk from Reclamation's website in September of 2020 (Bureau of Reclamation 2022a). To assist in identifying when elements were added to the Decree Accounting Reports and how those additions reflected the evolution of the system itself, a series of word extraction analyses were performed. The analysis was executed using a custom function built in R (Version 4.0.2, Taking Off Again) leveraging the *magick* package to process, trim and convert multipage PDFs to images before using Google's open-source Tesseract optical character recognition (OCR) engine in R (the *tesseract* package) to extract text into a corpus. From this list, extracted word count estimates were built to assist with analyses and figures. Two main text data sets for analysis were generated, one with a list of individual words, and a second with a list of word pairs (bigrams) to search the decree reports for important historical phrases. For comparisons of key words between years, a dictionary of 133,245 English words was used to filter data before comparing. This filter was not used when generating word count estimates for reports, given the frequency of technical terms and proper nouns in reports that might be removed by such a filter. Although the word count estimate methodology was useful for this analysis, it is worth noting that it is based on an optical character recognition algorithm, so some character recognition may be incorrect, and the word counts listed are estimates that likely include some errors.

Historic hydrologic and climate data were collected from several sources. Storage data were gathered from Bureau of Reclamation data curated by John Fleck from the University of New Mexico (Fleck 2022). All other hydrologic data came from the Bureau of Reclamation's Hydrologic Database (HDB).

Hydrologic and climate data were all annualized before plotting, and all plotting and data management and summarization was done in R.

All data and code are archived (Wilson 2021).

Results

The summary of results for the Decree Accounting Report analysis are presented in three eras: (1) 1964–1973, (2) 1974–2003, and (3) 2004–present. The first era comprises the first decade following the 1964 *California v. Arizona* decision and the first decade of the Decree Accounting Reports. Although the changes during this first decade were incremental, there were significant additions that increased the level of accounting detail. The second era from 1974 to 2003 begins with the passage of Minute 242 to the 1944 US–Mexico Treaty, which added new salinity thresholds within annual water deliveries to Mexico. These water quality requirements can be partially traced through the addition of additional Decree Accounting elements. The third era marks the passage of the Quantification Settlement Agreement (QSA) that enabled California to implement water transfers and supply programs as a means of living within its 5.4 billion m^3 (4.4 million acre-ft) annual Colorado River apportionment (Imperial Irrigation District, Metropolitan Water District of Southern California, and Coachella Valley Water District 2003). The Decree Accounting Reports nearly tripled in size in the early 2000s, in part due to the QSA and in tandem with the beginning of a persistent and prolonged drought that has brought hotter temperatures, reduced precipitation, and diminished streamflows (Udall and Overpeck 2017; Milly and Dunne 2020). These three eras illustrate how the Decree Accounting Reports can provide a window into the relationship between hydrologic conditions and policy actions on the Lower Colorado River. Fig. 2 illustrates a timeline of the expansion of the Decree Accounting Reports from 1964 to 2019 and notes key historical events that have shaped how water is monitored and accounted for on the Lower Colorado River.

1964–1973: Building out the Accounting as Uses Increased

The first Decree Accounting Report was released for the year 1964, following the finalization of the *Arizona v. California* Decree. As stipulated, the report enumerates the final records of diversions from "the mainstream of the Colorado River, return flow of such water to the mainstream and consumptive use of such water by water user agencies which have contracts with the United States" (US Department of the Interior 1964, p. 3). The records were furnished by US Geological Survey (USGS), International Boundary and Water Commission, Bureau of Indian Affairs, Bureau of Reclamation, National Park Service, and water user agencies.

At a slim 19 pages and 3,712 words, the 1964 report only focused on Arizona, California, and Nevada, and reported a total consumptive use in the Lower Basin of a little more than 7.6 billion m^3 (6.2 million AF). California was using more than 6.5 billion m^3 (5.3 million AF), considerably more than its allocated right of 5.4 billion m^3 (4.4 million AF), whereas both Arizona and Nevada were using less than their allocated shares. The report did not include a tabulation of deliveries to Mexico, nor did it provide any detail on water that was ordered but not delivered to the intended water user.

This first report establishes measurement methodologies that evolved with improvements in technology and are reflected in subsequent reports. Beginning in the 1964 report, diversions to the All-American Canal and the Gila Gravity Main Canal at Imperial Dam were assigned to users based on "deliveries to each user at its turnout from the canal and a prorated amount of the conveyance loss from the canal. The loss proration was based on the quantity delivered to each user and the length of the canal through which it was carried" (US Department of the Interior 1964, p. 3). Water-use estimates for water users other than those that had contracts with the US Government and for groundwater pumping were based on an inventory made of crops irrigated in 1964 and an "assumed annual diversion of six acre-feet per irrigated acre" (US Department of the Interior 1964, p. 3).

The 1965 Decree Accounting Report expanded to 3,712 words and included four new water users with contracted diversions in the system (US Department of the Interior 1965). From 1965 to 1973, between one and three new users appeared each year with one exception in 1970, when no new users were recorded. In at least one case, the new user was taking over a diversion already accounted for in the Decree Report. Additionally, in 1983, 12 new water users appeared in the accounting—eight of which were entities with existing subcontracts with the Yuma Mesa Irrigation and Drainage

District, Unit B Irrigation and Drainage District, and Yuma County Water Users Association, whose specific diversion amounts had previously been recorded in the footnotes.

A new section that tabulated water that was ordered but not delivered to US water users was also included in the 1965 Report. Water ordered but not diverted was calculated as the positive difference between the approved daily order and the mean volume that was requested on the day the diversion was made. In reporting the details of water that was ordered but not diverted, there were four categories: (1) Ordered but not Diverted, (2) Delivered to Mexico, (3) Diverted by Others, and (4) Delivered to Storage. Notably, there are lines documenting the volume of water from a number of users that was diverted by others, freely and without compensation. Although today, this circumstance has largely been eliminated in the Lower Basin, it persists where tribes have not developed their Colorado River rights, and is a source of conflict around the sovereignty of Tribes within the Colorado River Basin (Ten Tribes Partnership 2018).

The 1965 report was the first report to note the volumes of water delivered to Mexico in satisfaction of the 1944 Treaty. Deliveries to Mexico were scheduled based on Mexico's daily orders and were considered to have been made "entirely from releases from storage and from return flows scheduled for that purpose and not from water ordered but not diverted by other Colorado River water users" (US Department of the Interior 1964, p. 23). The report specifically notes that water ordered but not delivered to US water users is not included in deliveries to Mexico that were made in accordance with the 1944 Treaty.

In 1966, the Decree Accounting Report increased by only two pages and 235 words. One relatively small but important change increased the level of accounting for the Colorado River Indian Reservation by adding diversions for water pumped from wells in Parker and Poston (US Department of the Interior 1966, p. 31), reflecting the understanding that groundwater pumped from locations adjacent to the river is alluvial and should be accounted for as Colorado River water. A line for groundwater pumping was also added to the diversion volume for the Cocopah Indian Reservation (US Department of the Interior 1966, p. 32). A full page of footnotes was added expounding on various Arizona deliveries.

Three notable additions to the report occurred in 1970. First, a map of the Lower Colorado River was added to the reports (US Department of the Interior 1970, p. 3). Second, a taskforce of state and federal members was organized to provide advice and guidance to Reclamation and USGS in determining the amounts and location of "unmeasured return flow reaching the Colorado River by means of underground flow from aquifers underlying water use areas" (US Department of the Interior 1970, p. 9). Third, additional details were provided for over deliveries to include water "Delivered to Mexico in Satisfaction of Treaty, Diverted by Others, Delivered to Storage, and Delivered to Mexico in Excess of Treaty" (US Department of the Interior 1970, pp. 32–36).

This first decade of reports occurred as Lake Powell was filling, overall storage capacity was increasing, and new US water users were added to the system (US Department of the Interior 1964, 1974). The sum impact of increased storage and new users on Mexico was twofold. First, when Glen Canyon Dam was completed on September 13, 1963, Lake Powell captured the flows that historically flowed to Mexico, in excess of Mexico's allocation, and nourished the Colorado River Delta. As Lake Powell filled, the Delta shrank and by the late 1970s had nearly disappeared save for scattered and disconnected habitats (Fradkin 1981; Luecke et al. 1999). Second, deliveries to Mexico were capped as close as possible to the Treaty requirements of 1.85 billion m^3 (1.5 million AF), which not only damaged the Delta but also significantly changed the quality of deliveries to water users (principally farmers) in Mexico.

1974–2003

Mexico and Salinity Management

Overall, the size of reports remains fairly constant throughout this period at around 7,000 words, although there are substantial changes in content, detailed subsequently (Fig. 2).

Due to the 1950s development of a number of drainage projects—most notably a project to drain hypersaline wastewater out of the Wellton-Mohawk Irrigation and Drainage District (near Yuma, Arizona)—water delivered to Mexico grew increasingly salty. As the volume of water flowing to Mexico on the Colorado River was decreasing, wastewater returns remained constant, and salinity levels in the River increased to unacceptably high levels, from an average of around 800 parts per million (ppm) to more than 1,500 ppm. This caused widespread damage to crop and farming operations in Mexico, creating significant social, economic, and diplomatic crises.

Claiming agricultural damages, Mexico lodged a formal protest with the US. Mexico also installed wells along the US–Mexico border to intercept groundwater that could be used to dilute saline water coming from the US. The US countered by installing its own groundwater wells along the border, capturing groundwater before it left the US. In response to Mexico's protest and a growing pumping war, Minute 242 was developed and signed by the US and Mexico in 1973 to establish a salinity standard for Colorado River water deliveries to Mexico (IBWC 1973, Minute 242).

Resolution 1(a) of Minute 242 established a salinity differential where "The United States shall adopt measures to assure that . . . the approximately 1.7 billion cubic meters (1,360,000 acre-feet) delivered to Mexico upstream of Morelos Dam, have an annual average salinity of no more than 115 p.p.m. $\pm$ 30 p.p.m. over the annual average salinity of Colorado River waters which arrive at Imperial Dam." Resolution 1(b) of Minute 242 states, "The United States will continue to deliver to Mexico on the land boundary at San Luis and in the limotrophe section of the Colorado River downstream from Morelos Dam approximately 173 million cubic meters (140,000 acre-feet) annually with a salinity substantially the same as that of the waters customarily delivered there."

Notwithstanding the addition of this new legal requirement, Reclamation did not add salinity data to the Decree Accounting Reports. Nonetheless, salinity has been a major driver in Reclamation's Colorado River management actions ever since.

To meet the salinity standard established under Minute 242 (first noted in the 1975 report), the 1974 Colorado River Basin Salinity Control Act (CRBSCA) authorized a complex set of infrastructure arrangements and operations designed to limit the impact of Minute 242 on the Colorado River water supply available to users in the US. The complexity of the Decree Accounting Reports grew to reflect these arrangements (without describing them as specifically related to salinity management). Specifically, the CRBSCA authorized construction of two pieces of infrastructure to help treat or discard highly saline return flows: a bypass drain referred to as the Main Outlet Drain Extension (MODE) and the Yuma Desalting Plant (US Congress 1974).

The precursor to the MODE was authorized within the International Boundary and Water Commission (IBWC) Minute 218 and resulted in significant, if unintended, ecological benefits to the Colorado River Delta. The project rerouted brackish drainage waters away from the mainstem of the Colorado River and into the Main Outlet Drain (MOD). In 1970, a footnote was added to the Decree Accounting Reports that indicated water delivered pursuant

to Minute 218, although it was not added as a line item within the reports until 1994 (US Department of the Interior 1994, p. 10). In 1977, the MODE was developed to better support the needs of the system, with a capacity of 259 million m^3/year (210,000 AF/year). The MODE canal and bypass drain system were used to transport untreated return flows from Wellton-Mohawk Irrigation and Drainage District (WMIDD) into the Colorado River Delta, which resulted in the re-formation of a historic wetland, the Ciénega de Santa Clara in Mexico (Pitt et al. 2002). The Ciénega formed in a channel meander of the historic Delta and today receives approximately 90% of its water from MODE canal flows, with 10% arriving from small input from local agricultural drain water, effluent, and groundwater. As the largest remaining marsh in the Colorado River Delta and an essential island of habitat in the Pacific flyway, the Ciénega is a key component of the Upper Gulf of California and Colorado River Delta Biosphere Reserve.

Bypassing the WMIDD return flows through the MODE canal (instead of discharging this water to the Colorado River) has enabled the US to meet the salinity standards in Minute 242. However, these descriptively named bypass flows do not count against Mexico's Treaty entitlement, nor do they count against the water use entitlements of any US water users. Instead, in the CRBSCA, Congress undertook to commit to the replacement of the MODE flows under Minute 242 as an intended, but not legally required, "national obligation" (US Congress 1974). Although Reclamation did not take action to replace bypass flows through 2002, Arizona's water managers, concerned about their state's disproportionate shortage risk, began to express concern in the early 2000s as drought decreased reservoir storage. Today, there are perspectives that the flow in the MODE has contributed to an ongoing and contentious "system deficit" that cuts into storage in Lake Mead and increases shortage risk in the Lower Basin including Mexico (Arizona Department of Water Resources and Bureau of Reclamation 2016).

The infrastructure and water delivery points that are key to implementation of Minute 242 were added to the Decree Accounting Report between 1974 and 2003, without adding substantial additions to the length of the report (Fig. 2). The first addition was immediate in 1975, when a footnote was added to account for water delivered pursuant to Minute 242. The 1990 Decree Accounting Report was the first year that a significant change was made to the section detailing water delivered to Mexico [DA Report 1990, Article V (Bureau of Reclamation 1984)]. The reorganization introduced five elements: (1) To Mexico in Satisfaction of Treaty, (2) To Mexico as Scheduled, (3) To Mexico in Excess of Schedule, (4) Bypass Pursuant to Minute 242, and (5) Ordered but Not Diverted. Additional elements relevant to Minute 242 were added to the report in 1994, including (1) Delivery at Northerly International Boundary, and (2) Delivery at Southerly International Land Boundary (US Department of the Interior 1994, p. 29). These are important because deliveries to Mexico at the Northerly International Boundary are controlled by the salinity standard in Minute 242, whereas deliveries at the Southerly International Boundary are not (although they are limited in volume).

Not Accounted for: The Colorado River Delta in Mexico

Lake Powell filled from 1964 to 1980, capturing nearly all Colorado River water not needed for downstream deliveries. Aside from MODE deliveries to the Ciénega de Santa Clara, overdeliveries to Mexico were minimal through that period (Fig. 1). In 1983, 3 years after Lake Powell filled, a distinctly long winter was fueled by the 1982–1983 El Niño, dropping exceptional snowpack throughout the basin. Dam managers had projected a normal winter, but spring ended with a sudden influx of warm weather, snowmelt, and then rain. Upper Basin reservoirs were overwhelmed, and water rushed into Lake Powell, nearly breaking the structural components of Glen Canyon Dam (Bureau of Reclamation 1984). In response, Reclamation managers released significant volumes of water from the Glen Canyon and Hoover Dam to avoid the potential for catastrophic breaches. The excess water rushed downriver in a channel that had not seen flows of this magnitude in years, causing considerable damage to property in both the US and Mexico, and in Mexico sparked a renewal of the Colorado River Delta as water returned to the river's floodplain and promoted an extensive resurgence of native habitat (Glenn et al. 2004). Although the Delta's demise had already been described (Fradkin 1981) Reclamation did not acknowledge the role these large volumes of water played in supporting river ecosystem values because the Law of the River contained no provisions for such an accounting. These abundant flows were short-lived, and by 1990, the US was again able to ratchet back deliveries to the minimum Treaty requirement, save for El Niño years in 1994 and 1998–1999 (Fig. 1).

First Signs of Water Supply Limits

As Reclamation began to focus on salinity management to comply with Minute 242, the Decree Accounting Reports began to include more information about Yuma area pumped drainage, although without adding substantial length to the report (Fig. 2). Although a portion of Colorado River water that is delivered to Mexico is comprised of Yuma area return flows (including pumped drainage), this is not directly accounted for within the Decree Reports. Just as the drainage from WMIDD is withheld from deliveries to Mexico, annually varying volumes of pumped drainage from Yuma are also withheld from direct delivery to Mexico due to the salinity limit in Minute 242.

In early Reports, Reclamation reported pumped drainage as a single volume. Starting in 1983, Reclamation sought to account more precisely for Yuma area return flows, assigning a percentage of the total volume to a handful of irrigation districts. Reclamation does not document the disposition of the pumped drainage (to Mexico's delivery or to the MODE). The effect of reporting drainage volumes assigned to specific water users is to define the volume of each district's consumptive use more accurately, enabling these districts to participate in water market transactions. Better consumptive use quantification would have been important for the first significant water rights transfer in the Yuma area, in which the federal government purchased approximately 58 million m^3 (47,500 AF) of water from the Yuma Mesa Irrigation District and transferred them to the Central Arizona Project (CAP), implemented as part of the Ak-Chin Indian Community Water Rights Settlement Act of 1984 (Public Law 98-530). This was followed in 1988 with another water rights transfer when Reclamation purchased 27 million m^3 (22,000 AF) from the Wellton Mohawk Irrigation and Drainage District for transfer to the CAP canal for the Salt River Pima-Maricopa Indian Community Water Rights Settlement (Salt River Pima-Maricopa Indian Community 1988).

While water was being moved around with market transactions in Arizona, California continued to exceed its right to Colorado River water. Deliveries to California were consistently above the Colorado River Compact allocation of 5.4 billion m^3 (4.4 million AF) from 1964 through 2003 (the two exceptions were 1983 and 1984, when El Niño delivered enough precipitation to offset the need for Colorado River water deliveries) (Fig. 1). Reclamation used the 2001 *Colorado River Surplus Guidelines* to establish a programmatic approach temporarily justifying deliveries to California that exceeded the state's 5.4 billion m^3 (4.4-million-acre-foot)

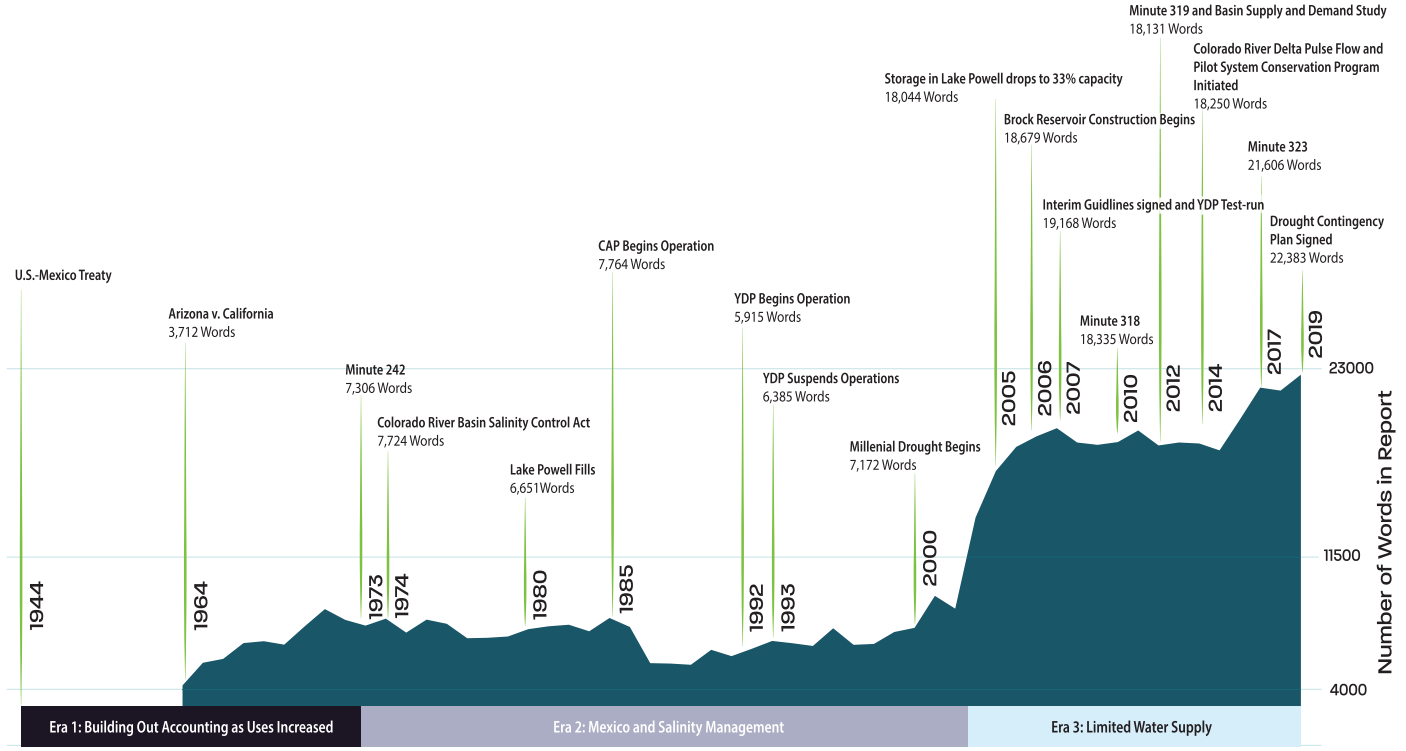

Fig. 1. Timeline of historic events on the Colorado River and word counts in the Bureau of Reclamation's Decree Accounting Reports from 1944 to 2019. Word counts (a proxy for accounting level) from yearly reports were extracted using optical character recognition. (Data from US Department of State 1944; Bureau of Reclamation 2022b.)

allocation, as well as to ensure the eventual return to a cap of 5.4 billion m^3 (4.4 million AF) delivery to California over time (Department of the Interior 2001). California's Colorado River water users at the same time adopted the Colorado River Quantification Settlement Agreement (QSA), which enabled a series of water transfers meant to allow California to live within its 5.4 billion m^3 (4.4 million acre-foot) allocation. For the first time in 2003, the Decree Accounting Report included the planned schedule for these transfers.

2004–2019

Era of Limited Water Supply

The most recent era of Decree Accounting Reports is marked by the onset of the Millennial Drought and implementation of the QSA. As Colorado River water users worked to increase both efficiency and conservation to respond to legal limits and a declining water supply, Reclamation and partners have implemented both policy and infrastructure projects.

Following implementation of the QSA, the Decree Accounting Reports jumped from around roughly 8,350 words in 2002 to 18,000 words in 2005. This significant increase in the report's length can be attributed to an entirely new section entitled "Information Supplemental to the Requirements of the Decree of the Supreme Court in *Arizona v. California et. al*." (US Department of the Interior 2004, p. 33). The added length and complexity of these reports speak to the transactional nature of California's solutions to bringing Colorado River water use down to its allocation, as well as new interstate water transactions that were implemented voluntarily as the Lower Basin states sought additional water management flexibility in the context of the Law of the River. The new section includes a narrative explanation of each component, as well as line-item accounting and explanatory footnotes for numerous policies focused on water deliveries, reconciliation of over deliveries, water storage, and conservation, including but not limited to policies focused on water banking among the Lower Basin states (Secretary of the Interior et al. 2002), overrun and paybacks of water deliveries (Bureau of Reclamation 2003), and conservation transfer and exchange agreements (Colorado River Governance Initiative 2013). These new elements initially added 20 pages to the 1994 Decree Accounting Report and have grown beyond 30 pages over the following years to include new programs and activities. The sum impact of these agreements reflects an increasing effort to control the flow of water in the Lower Basin and tighten the operation of the system toward ever greater levels of consumptive use efficiency.

Preparing for Scarcity: Shortages and Transactions

From defining a programmatic approach to surplus allocations on the Lower Colorado River in the early 2000s, Reclamation quickly pivoted to define shortage management in response to emerging drought conditions and developed the 2007 *Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead* (Bureau of Reclamation 2007). The Interim Guidelines identified the conditions for shortage determinations and the details of coordinated reservoir operations in response to the worsening drought. A signature component of the Guidelines included a new program designed to incentivize conservation and storage in Lake Mead. The Intentionally Created Surplus (ICS) program enabled Lower Basin users to implement conservation measures such as importing water, lining canals, and fallowing agricultural lands to create water credits that could be used at a later date. ICS accounting first appeared in the Decree Reports in 2006.

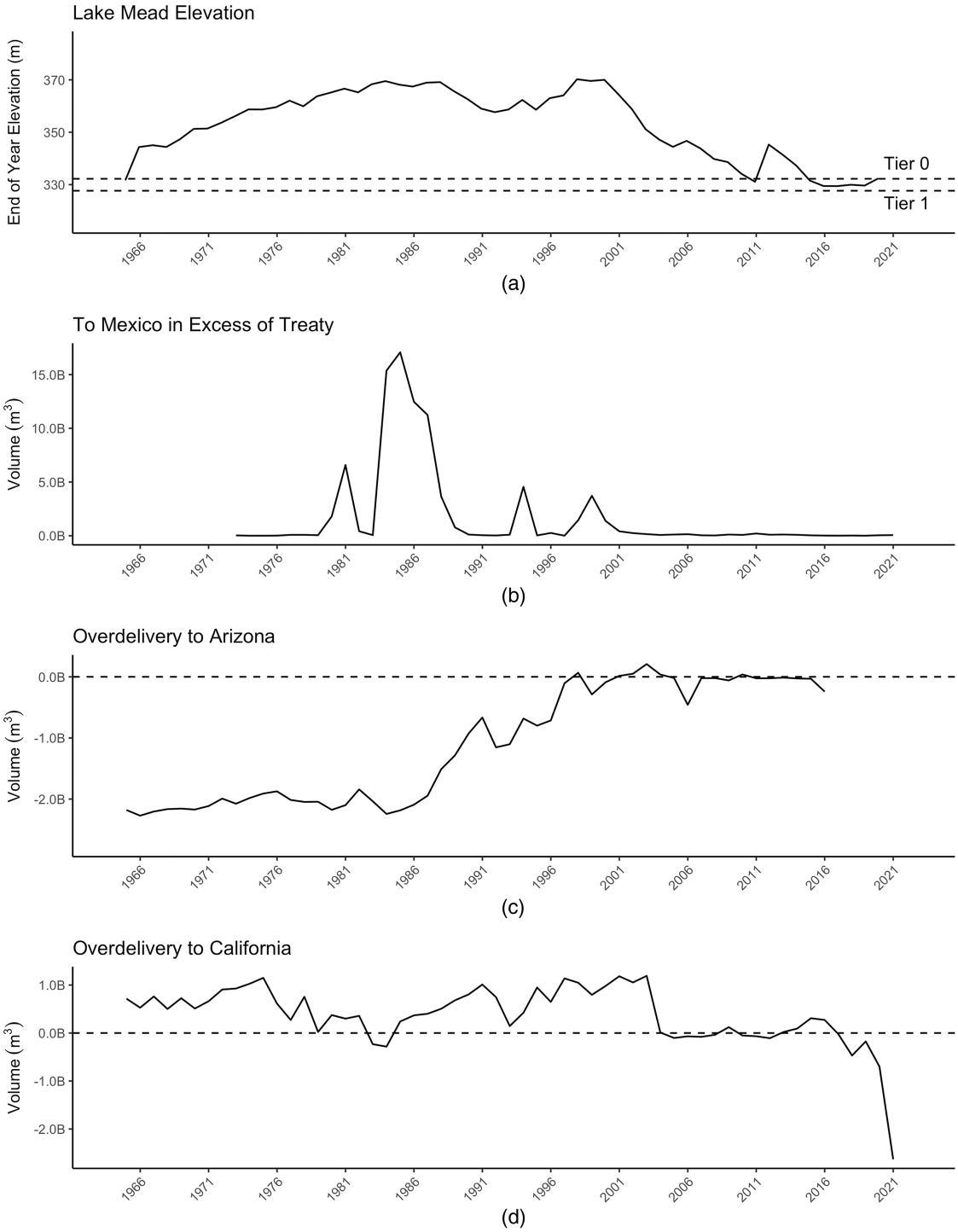

Fig. 2. Accounting and overdeliveries on the Colorado River: (a) Lake Mead elevation levels, where dashed lines represent Tier 0 and Tier 1 elevations; (b) water passed to Mexico in excess of treaty; (c) overdeliveries to Arizona, where values plotted above the dashed line at 0 m^3 (0 AF) indicate overdeliveries to Arizona; and (d) overdeliveries to California, where values plotted above the dashed line at 0 m^3 indicate overdeliveries to California. In all panels, solid lines denote annualized sums of volume of water or elevation levels. All volumetric data are presented in cubic meters. (Data from Bureau of Reclamation 2022b.)

In 2010, Reclamation demonstrated operation of the Yuma Desalting Plant (YDP), built 20 years previously to treat the brackish water draining from the Wellton Mohawk Irrigation and Drainage District and make it suitable for delivery to Mexico under the limits of Minute 242 (this demonstration helped Reclamation identify the significant capital cost of repairs needed at the plant to make it truly operable, and the plant has not operated since). In response to concerns from environmental interests and Mexico, the US negotiated Minute 316 with Mexico to ensure that the pilot YDP operation would not deplete the water supply at the Cienega de Santa Clara (IBWC 2010). The 2011 Decree Accounting Report lists "water arranged for the Cienega—US portion," which is the first formal accounting for environmental water in the Colorado River Delta.

After adopting shortage rules for the US states in the Lower Basin, Reclamation turned to Mexico to address Colorado River shortages, which were acknowledged but not quantified in the 1944 Colorado River Treaty. In 2010, an earthquake rocked the Mexicali Valley, the agricultural district irrigated with Colorado River water. Mexico's Colorado River water managers requested US permission to store water that could not be used due to earthquake damage, setting a precedent for storing water in Lake Mead in the same manner that US Lower Basin water users store water through the provisions of Intentionally Created Surplus. By 2012, the two countries signed Minute 319, a broad agreement that not only addressed shortages, but also extended Mexico's permission to store water in US reservoirs and provided for binational investment in water conservation and exchanges, as well as binational commitments of water and dollars to enable a binational, collaborative process to initiate habitat restoration in the Colorado River Delta (IBWC 2012). Pursuant to these agreements the Decree Accounting documents three significant bi-national acts of cooperation: (1) in 2011, the US stores Mexico's unused water in Lake Mead, (2) in 2014, the US delivers Mexico's stored water for environmental purposes to the Colorado River Delta, and (3) in 2017, a volume of Mexico's conserved water is transferred to the US.

Staving off Scarcity: Expanding Storage

The Warren H. Brock Reservoir is a Reclamation facility that was completed in 2010 (and first mentioned in the 2010 Report) to help manage flows and prevent excess deliveries to Mexico. When water users on the Lower Colorado River place a water order, it typically takes about 3 days to reach them. During this time, unexpected canal outages, weather conditions, and high runoff in the river may affect the need for water, and prior to 2010, this unneeded water would continue to flow into Mexico, where it was not accounted for Mexico's treaty delivery but rather as excess delivery. Brock Reservoir can conserve water on a temporary basis to hold excess water orders in the US and create operational flexibility to meet delivery needs, amounting to an average conservation savings of 86 million m^3/year (70,000 AF/year). Although the actual storage capacity is much lower, the annual volume of water savings is higher because the reservoir fills and delivers water in short order.

The Brock Reservoir project cost over $172 million and was covered through contributions from Lower Basin water users. For that financial support, 740 million m^3 (600,000 AF) of water was allocated to those water users for later use and from 2010 to 2017, 1.2 billion m^3 (968,505 AF) has been stored in Lake Mead and accounted for as Water Made Available by Conservation in the Annual Decree Accounting Reports. These water savings will continue to accrue in Lake Mead as a contribution to system storage.

Buffering Scarcity: Tapping Groundwater Sources

The groundwater zone on either side of the international border between southwestern Arizona and northwestern Sonora includes wellfields for both the US and Mexico. Since 1975, after the passage of Minute 242, the US has utilized groundwater pumping to capture underground water that flows south from the Yuma area to Mexico to augment deliveries to Mexico. This groundwater is higher quality and less salty than existing agricultural drainage water in Yuma area. Currently, the 242 wellfield supplies about 43 million m^3 (35,000 AF) per year to the Southerly International Boundary for deliveries to Mexico (IBWC 2016b). Although the Decree Accounting Reports document use of alluvial groundwater elsewhere (noting Colorado River water uses pumped from wells in proximity of the river where groundwater and surface water are understood to be connected), groundwater pumping in the Minute 242 wellfield is neither accounted for, nor reflected, in the Decree Accounting Reports. This exception is based on Reclamation's determination that this groundwater sits outside of the "accounting surface" for Colorado River water. The accounting surface does not include groundwater pumped from areas including the Colorado River floodplain or the underlying aquifer south of the Northerly International Boundary, where such groundwater would otherwise flow to Mexico rather than to the Colorado River north of the Northerly International Boundary. The distinction here is that the US and Mexico do not have an agreement governing transboundary groundwater flow (Bureau of Reclamation 2006).

Although the Minute 242 wellfield does help deliver higher quality water to Mexico, there are environmental impacts from increased pumping at the wellfield as well as Mexico's groundwater pumping operations. Conservation nongovernmental organizations (NGOs) have expressed concerns about a decline in groundwater straddling the Yuma and Mexicali Valleys that is already impacting habitat restoration areas developed under the recent US–Mexico Colorado River agreements (Minutes 319 and 323) (Kennedy et al. 2017; Ramírez-Hernández et al. 2013). Although the Decree Accounting Reports do not document the volume of water pumped outside the accounting surface, the impact of declining groundwater has been documented in reports monitoring habitat restoration efforts under Minute 323 (IBWC 2016a). However, the US and Mexico have not developed a transboundary groundwater model, making it impossible to quantify the impact of the Minute 242 wellfield pumping on these habitat areas.

What Comes Next?

There is a large and growing body of work discussing coming challenges on the Colorado River. We speculate that as Reclamation, Colorado River Basin states, Tribes, water managers, and stakeholders work to address these challenges, the complexity of the Decree Accounting Reports will grow.

Tribal Water

As mentioned previously, the Decree Accounting Reports have successfully documented water that belongs to one user and is diverted by another. This accounting could be applied to provide a measure of accountability for water being used that belongs to tribes with Colorado River water rights. In 2012, Reclamation collaborated with representatives of the seven Colorado River Basin states to characterize current and future water supply and demand imbalances in the Basin, assess the risks to Basin resources, and complete the 2012 Colorado River Basin Supply and Demand Study (Basin Study) (Bureau of Reclamation 2012). The Basin Study was a monumental effort and drew significantly on documentation in the Decree Accounting Reports to demonstrate water allocations and deliveries consistent with the apportionments under the Law of the River.

The Basin Study revealed two significant realities. First, although Tribal water rights amounted to approximately 2.5 billion m^3 (2 million AF) of water in the Basin, a significant portion of that water has historically been, and is currently, diverted by lower-priority water users. The implications of this use meant that Tribes were not being compensated for use of their water (but non-Tribal water users could develop compensated water exchange agreements) and the use of that water inflated the volume of supplies available throughout the Basin. These issues were researched and presented in the 2018 Colorado River Basin Ten Tribes Partnership Tribal Water Study (Ten Tribes Partnership 2018). Crafting new ways of accounting for the use, transactions, and accessibility of Tribal water could be one of many ways to help bring more transparency to Tribal water challenges and opportunities.

Reclamation's Management Response to Climate Change and Declining Colorado River Water Supply

Another reality illuminated by the Basin Study is that the prolonged impacts of drought and climate change would lead to significant shortfalls between projected water supplies and demands in the future (Bureau of Reclamation 2012). In response, Reclamation joined with the Colorado River Basin states and water users to explore additional ideas that could incentivize conservation and augment savings in Lake Mead. As Reclamation, Colorado River Basin states, and water users implement creative solutions to resolve the growing imbalance between supply and demand, Reclamation should continue to use the Decree Accounting Reports to document progress. For example, in 2014, Reclamation initiated the Pilot System Conservation Program that deployed funding from water users in both the Upper and Lower Colorado River Basins in support of water conservation projects that could increase storage levels in Lake Mead and Lake Powell (Bureau of Reclamation 2019). State-by-state savings related to this program were first reported in the Decree Accounting Reports in 2014.

The System Conservation Pilot Program (SCPP) Phase 1 was implemented from 2014 to 2016 and resulted in a total of 77 million m^3 (62,615 AF) water savings at a total cost of $9,335,400 ($149/AF). Drawing on the success of Phase 1, the 2016 Bypass Flows Workgroup recommended that System Conservation efforts be continued, in part as an option for replacing bypass flows. Savings in 2017 (Phase II) totaled 67 million m^3 (54,021 AF) of water [63 million m^3 (51,441 AF) from Arizona and 3.2 million m^3 (2,580 AF) from Nevada] for a total cost of $9,264,123 [$138/1,000 m^3 ($171/AF)]. Detailed accounting of the participants, state, water conservation method, and estimated water savings (in acre-ft) were added to the Decree Accounting Report in 2014. Reclamation has noted that System Conservation, in tandem with reserve water from Mexico, US Intentionally Created Surplus, and conservation volumes from the Central Arizona Project, has helped to keep Lake Mead above the critical Tier 1 elevation of 327 m (1,075 ft) above sea level.

Even though Reclamation-led policy initiatives have opened the door to new and innovative ways to conserve water, salinity management and associated bypass flows remain a vexing challenge. As discussed in this paper, Reclamation's management to address this challenge can have unaccounted-for transboundary impacts with potential to harm environmental resources. Since the early 2000s, there have been multiple stakeholder-driven processes and efforts to gather ideas and develop proposals for bypass flow replacement that recognize the importance of avoiding harms to the Ciénega de Santa Clara. In 2004, the Central Arizona Water Conservation District (CAWCD) convened a workgroup of Lower Basin stakeholders with an express goal to "develop solutions that would both offset the impact of the continued bypass of return flows from the Wellton-Mohawk Irrigation and Drainage District and preserve the Ciénega de Santa Clara" (CAWCD 2005). This goal statement represents an important pivot toward including the importance of the Ciénega in water management and policy discussions. In 2005, the workgroup recommended several short- and longer-term plans, including the following (CAWCD 2005):

- "To the extent possible and consistent with Arizona law, utilize Yuma area excess groundwater to meet Mexican Treaty delivery obligations."
- "The remaining component of the bypass flow replacement should be achieved through the development of additional excess groundwater in the Yuma area."
- "Identify and implement other programs that are not directly related to the bypass flows which will reduce the risk that a Lower Basin shortage will be declared as a result of the recent extraordinary drought."

To nudge the conversation a step further, Reclamation and Arizona Department of Water Resources (ADWR) convened a US-based Bypass Flows Workgroup in 2016 to explore opportunities to mitigate the impact of the bypass flows on declining Lake Mead levels (Arizona Department of Water Resources and Bureau of Reclamation 2016). The workgroup evaluated the full suite of water flows and existing infrastructure in the Yuma area and recommended eight options that could positively address bypass flows and aid in stabilizing Lake Mead's elevation. Despite the clarity of the recommendations around groundwater pumping and the fact that System Conservation programs were implemented to reduce the risk of a Lower Basin shortage, bypass flows remain a system deficit, although this may be more of a matter of accounting than generally acknowledged.

As documented by the Decree Accounting Reports, Reclamation has developed and implemented numerous water innovations to conserve water, including the construction of Brock Reservoir, the adoption of Minute 319, and adoption of Minute 323. Some of these projects arose out of recommendations from the 2005 and 2016 stakeholder processes, including construction and operation of the Warren Brock Reservoir, pursuing expansion of the Minute 242 Wellfield, and contributing to System Conservation projects. Whether or not the US has an obligation to replace the volume of brackish drainwater flowing from southwestern Arizona to the Ciénega de Santa Clara, Reclamation will continue to seek water conservation opportunities to address tribal water needs and the declining availability of the Colorado River water supply due to climate change.

As Reclamation searches for new water conservation opportunities, there are opportunities to track how those actions might impact water-dependent resources for which there is not yet accounting in place. Groundwater monitoring and accounting on the border is an important part of sustaining riparian habitat and restoration efforts in the Colorado River Delta, and too much groundwater extraction in Yuma will deplete the aquifers that support riparian habitat in Mexico. As previously acknowledged in Minute 316 and Reclamation's reporting on pilot runs of the Yuma Desalting Plant, further operation of the plant would deprive the Ciénega de Santa Clara of important flows and would disrupt the essential balance between flows and salinity levels in the wetland (Baeza 2013).

Conclusions

The Decree Accounting Reports provide a useful record of the Lower Colorado River from 1964 on not only of the river's increasing number of users and uses but also of Reclamation's management history. Although Reclamation is the Watermaster on the Lower Colorado River and does not have a federal water right, the agency has conserved a significant volume of water. These conservation actions and operations to improve system efficiency have augmented storage in Lake Mead; however, there are environmental costs to some conservation and efficiency actions. Furthermore, the Decree Accounting Reports illustrate that system accounting reflects only the uses that have an allocated volume of water and does not reflect the impacts to, nor the water needs of, environmental resources like the Colorado River Delta and the Ciénega de Santa Clara. As a result, the paradox of efficiency is heightened because the environmental costs of any conservation or efficiency action are not reported on or reflected in the Decree Accounting Reports and thus are rendered outside the lens of management discussions.

As the effects of climate change reduce flows on the Colorado River, management policies will increasingly need to incentivize and promote actions that bolster supplies and reduce demands. As part of the recent Drought Contingency Plan, Reclamation committed to conserving 123 million m^3 (100,000 AF) of water a year. As explored in this paper, Reclamation has successfully implemented, over many decades, numerous projects and activities that have resulted in conserved water, some of which have impacted environmental resources. As Reclamation continues to pursue projects and activities to conserve water, it would be helpful for the agency to use the Decree Accounting Reports to document the source of any conserved water, or the downstream location (be it in a river channel or an aquifer) that will no longer receive the water once conserved. This will help highlight how the environment, water demands, and the river can be monitored and managed in a future era of scarcity and water supply variability.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request. Non-PDF data, scripts and analysis are archived on Zenodo (DOI: 10.5281/zenodo.5048281). PDFs of Decree Accounting Reports are required for replication and can be downloaded at https://www.usbr.gov/lc/region/g4000/wtracct.html.

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