

1 **Institutional Analysis of Water Governance in the Colorado River 2 Basin, 1922-2022**

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13 **Abstract**

14 The 1922 Colorado River Compact started the long history of water governance in the Colorado
15 River Basin. Over the last century, the institutional structure has shaped water governance in the
16 basin. However, an understanding of the long-term evolution is lacking. This study examines how
17 water management strategies have evolved at the basin scale by incorporating institutional, temporal,
18 and network structure analysis methods to examine long-term changes. Content analysis was
19 employed to systematically investigate encouraged and/or discouraged water management actions at
20 different rule levels. The water governance network was examined at four points in time to map the
21 institutional structure, actors, and governance level at which rules are issued and targeted. Using
22 institutional analysis, we found constitutional, operational, and collective-choice level rules for water
23 supply, storage, movement, and use have been altered via layering of new governance rules without
24 major rule or responsibility alteration. The network analysis results indicate that key decision-making
25 positions have remained and actors who issue and are targeted by the rules lack significant change.
26 We found original positions of power have been maintained, potentially stagnating the space for
27 problem-solving and management strategy renegotiation. Our results indicate that path dependency
28 has shaped water governance and who is able to influence decision-making.

29 **1 Introduction**

30 Water has been the source of tension, contestation, and disagreement for over a century in the
31 Colorado River Basin (CRB) (Mirumachi et al., 2021; Sullivan et al., 2019). Before 1900,
32 communities used water locally without basin-wide impact (Kuhn & Fleck, 2019). From the early
33 1900s, questions arose about equitable allocations of Colorado River water with the expansion of
34 irrigation and other water diversion projects (National Research Council, 2007). Consequently, the
35 1922 Colorado River Compact (CRC) was created to clarify allocations. During the 1920s, the water
36 management paradigm shifted from pre-modern to industrial modernization via federal investments
37 in large, regional water diversions and storage projects, resulting in basin-wide changes to the spatial
38 and temporal distribution of water (Allan, 2003; Mirumachi et al., 2021). Specifically, these changes

39 led to altered streamflow variability, habitat degradation, and salinization (Barnett & Pierce, 2008;
40 Furnish & Ladman, 1975; Glenn et al., 2001; Hwang et al., 2021). The Colorado River in the
41 American Southwest is one of the most important rivers in the world as it supplies drinking water,
42 water for livelihoods, and has significant cultural and ecological value to 40 million Americans,
43 including Tribal and Indigenous Peoples (Elias et al., 2023; Juricich, 2022; USBR, 2012). While the
44 physical infrastructure is critical to the sustainability of the CRB, so is the social infrastructure, or the
45 institutions that govern water access and infrastructure operation. Institutions are norms and rules that
46 influence and shape human-human and human-nature interactions, including the way people make
47 decisions and manage water resources (Cave et al., 2013). Institutional analysis can provide insights
48 into water governance as actors interact to make decisions about new or altered rules, governance
49 strategies, and management regimes (McGinnis, 2011). Examining the institutional context in the
50 CRB illuminates how institutions evolved under social and environmental change.

51 On June 14, 2022, the U.S. Bureau of Reclamation (USBR) instructed CRB states to develop a plan
52 to reduce 2-4 million acre-feet (MAF), or 19% to 38% respectively, of annual water use within 60
53 days (USBR, 2024a, 2024b). The 60-day period has passed without a consensus and shortly after the
54 USBR declared a Tier 2a shortage for the following year, resulting in reduced water availability for
55 Arizona and Nevada (Schlageter, 2021; Stern, 2023). The shortage operation guidelines were
56 produced via multiple negotiated agreements, illustrating long-term rule accumulation (Department
57 of the Interior, 2007; USBR, 2019). USBR's instruction to the Basin States demonstrates the scale of
58 the regional water security challenges. The states' delay illustrates the complexity of negotiation in
59 the context of a century's worth of accumulated rules and agreements in the CRB. In addition to the
60 current request to reduce water use in the short term, the Basin States are negotiating new long-term
61 rules for coordinated operations of Lake Powell and Lake Mead. Insight into how we have arrived at
62 the current water crisis can help inform the redesign of operating rules. Such insight requires a better
63 understanding of the evolution of water governance institutions.

64 Water governance is a set of interacting social, economic, and political systems that enable society to
65 develop, plan, and manage water resources across time and space (Larson et al., 2013; Pahl-Wostl et
66 al., 2010; Rogers & Hall, 2003; Wiek & Larson, 2012). Common pool resources, such as water, are
67 rival, meaning usage diminishes others' ability to use the resource, and non-excludable, meaning
68 excluding users is prohibitively difficult (Ostrom, 2005). Common pool resource use often results in
69 conflicts when supply does not align with demand. Governance of natural resources can alleviate this
70 conflict with rules that are created to allocate and distribute resources (Ostrom, 2011).

71 Water systems are nested, dynamic, and layered, therefore institutional arrangements must be able to
72 fit the characteristics of water (Lebel et al., 2013; Young, 2002). Nested systems include connections
73 and networks within a larger analytical unit. For example, smaller spatial entities (e.g., sub-basin,
74 state) are nested in larger systems, such as watersheds or river basins. Dynamics can persist over
75 time, as is characteristic of water systems with water management regimes that last for decades or
76 centuries (Elshafei et al., 2014; Garcia et al., 2016). The introduction of new dynamics and
77 conflicting institutional arrangements can limit and direct water governance decision-making and
78 actions (Olivier & Schlager, 2021). Layering can be conceptualized as concurrent system inputs,
79 where impacts accumulate as each layer is considered (Green & Dzidic, 2014). Multi-level water
80 governance responds to these system characteristics. Broadly, level pertains to institutional
81 jurisdictions such as government at International, National, Sub-national, or Local levels (McGinnis,
82 2015). Between levels there is a hierarchy; the higher levels of organization are arranged in a formal
83 way by law.

84 Multi-level governance is concerned with how actors operating at different institutional levels
85 collaborate to solve shared problems (Cash et al., 2006; Heinen et al., 2021; Marks, 1993; Pahl-
86 Wostl, 2009). Multi-level governance scholarship is characterized by strong descriptive elements that
87 document changes in governance arrangements (Bisaro et al., 2020; Liu & Lo, 2021). While multi-
88 level governance is concerned with common goals, it acknowledges that power and authority are split
89 among governance levels (Harmes, 2006). Thus, it is important to note that multi-level governance
90 processes and outcomes are influenced by relationships and power dynamics between actors and
91 decision-makers (Ishtiaque et al., 2021; Nunan, 2018). Current multi-level governance research
92 challenges include uncertainty and nested relationships stemming from actors' differing goals and
93 agendas coupled with a changing climate (Jones & White, 2022; Sullivan & White, 2019).

94 One century later, the 1922 CRC remains in place and is supplemented by new agreements, court
95 decisions, and other rules. Despite a substantial body of water governance research, the long-term
96 evolution of the institutional structure that shaped the CRB over the last century is not fully
97 explained. We know that current management actions and our understanding of these actions have
98 not kept pace with increasingly arid conditions and growing demand (York et al., 2019). Water
99 scarcity in the American Southwest is exacerbated by increasing water demands and climate changes,
100 particularly higher temperatures that increase evapotranspiration (MacDonald, 2010; Udall &
101 Overpeck, 2017). Williams et al. (2022) found that from 2000 to 2021 the Southwest has been in the
102 most severe drought in at least 1,200 years. This raises the question of why water management has
103 not changed more significantly in response to increasing scarcity. Path dependency of institutions
104 may play a role. Repetitive practices and patterns resulting from socially constructed rules and norms
105 give rise to path dependency (Schmidt, 2010).

106 Understanding how the tension between changing environmental conditions and path dependency
107 have shaped past changes in water management can inform policy responses to the current challenge.
108 This motivates two research questions: 1) How has the emphasis on different water management
109 actions and rule levels changed over time? 2) How has the distribution of authority changed across
110 actors and institutional levels in the CRB over the last century? We examine path dependency by
111 extracting and analyzing the incentives and constraints that guide water governance choices from
112 formal water management rules. We anticipate that path dependency has shaped the emphasis on
113 different water management actions and rule levels over time. Further, we hypothesize the
114 distribution of authority changes from a few central actors to a larger number of actors as the network
115 increases. This is measured based on the actors involved and the alteration of responsibilities for
116 water management actions to examine how authority is distributed across actors and institutional
117 choice levels over the last century.

118 **2 Theoretical Framing**

119 **2.1 Institutional Theory**

120 Institutional theory has foundations in organizations and organizational theory (Barnard, 1968; Scott,
121 1987; Selznick, 1948), economics (Nee, 2005; Williamson, 1981), and sociology (Fligstein, 1997;
122 Meyer, 2010; Zucker, 1987). North (1991) distinguishes institutions from organizations stating that
123 organizations play the game per the rules and that institutions set the rules of the game and the
124 players. Institutional theory is concerned with procedural rules and posits that certain aspects of
125 government structure can empower or obstruct political interests (Kraft & Furlong, 2013; Peters,
126 2022; Peters et al., 2005). According to Scott (2005), institutional theory combines components from
127 historical and comparative research and focuses on deeper social structures such as norms and

128 routines. Institution refers to the “rules used to structure patterns of interaction within and across
129 organizations”, thus the rules that govern or induce behavior (Ostrom, 2007, pg. 22). Rules specify
130 authority and constraints by creating or restricting authority via limits, timing, and how infrastructure
131 can be used. Institutional scholars and theorists Gary Libecap (1989) and Elinor Ostrom (2005), view
132 institutional change through a design-based lens where change is conceptualized as collective-choice
133 processes of rule creation outcome. Further, the analysis of how institutions change over time is a key
134 field of research within institutional theory (Coccia, 2018). Institutional change is shaped by higher-
135 level rules and is dependent on decision-maker’s perception of the probable effects of rule changes
136 (Libecap, 1993; Ostrom, 2005). Institutional change can be examined to understand how resource,
137 water, in this case, governance has evolved (Olivier, 2019).

138 The Institutional Analysis and Development (IAD) Framework (Figure 1), aids in evaluating and
139 understanding institutional arrangements (Heikkila & Andersson, 2018). While the Social-Ecological
140 Systems Framework is suitable for policy studies similar to ours, we chose to use the IAD
141 Framework because it facilitates analysis of how governance unfolds, in our case, water use and
142 management and focuses on institutional arrangements as opposed to the interaction between actors
143 and ecological systems and the biophysical context (Andries et al., 2018; Andries & Janssen, 2013;
144 McGinnis & Ostrom, 2014; Schlager & Cox, 2018). The IAD Framework provides a foundation for
145 examining rules and is well-established through insights from hundreds of natural resource case
146 studies (Ostrom, 2005; Sullivan et al., 2019). Rules each actor must abide by, their rights,
147 obligations, and constraints based on official (i.e., written), legislatively specified rules, are called
148 rules-in-form. Rules-in-form are formal rules within official and other written documents that
149 provide clarity on governance arrangements (i.e., roles, responsibilities, incentivized and
150 disincentivized actions, and goals) and help provide a picture of the rules-in-use (Brady et al., 2018;
151 Cole, 2017; Ostrom, 2011). Rules-in-use are rules that are in action and include both rules-in-form
152 and informal rules (i.e., norms and customs that are not explicitly stated or written) (Ostrom &
153 Basurto, 2011; Schlager & Cox, 2018). The IAD Framework can be extended to consider the
154 feedback loops from policy outcomes to rules-in-use (Figure 1) to aid in understanding the changes
155 to the institutional structure as rules layer upon each other over time, enabling analysis of the
156 evolution of governance regimes (Hardy & Koontz, 2009; Heikkila & Andersson, 2018; McGinnis,
157 2015; McGinnis & Ostrom, 2014; Ostrom, 2011; Ran et al., 2020). The Action Situation, within the
158 IAD Framework, is a social space where actors are positioned, interact, and act under rules that
159 determine a set of potential actions that can or must be taken regarding a given theme that is linked to
160 and produces potential outcomes (Kellner, 2021; Ostrom, 1999, 2005; Ran et al., 2020). One IAD
161 Framework strength is that it connects outcomes at different levels of analysis explicitly (Ostrom,
162 2005). Moreover, as policy decisions are made rules-in-use are added or revised, thus changing the
163 structure and process for future rule change.

164 To sort linkages between specific rules and help assess the institutional structure, rules can be
165 organized based on their rule level, also known as level of analysis. Rule level pertains to the range
166 of actions that actors are allowed, required, and/or prohibited to take. The IAD Framework
167 characterizes three rule levels where different types of choice processes occur: constitutional,
168 collective-choice, and operational. Constitutional level rules define the scope and identify actors that
169 can be involved in collective decisions; collective-choice level rules determine the strategies, norms,
170 and rules available for policy-making for actors with defined roles; and operational level rules
171 describe how actors make choices amongst available options set by the collective choice processes
172 (Cole, 2017; McGinnis & Ostrom, 2014; Ostrom, 2005).

173 **2.2 Path Dependency Theory**

Path dependency theory, stemming from historical institutionalism (Mahoney & Rueschemeyer, 2003; Peters et al., 2005; Thelen, 2003), is well-established in social science and institutional change literature (Gains et al., 2005; Kessy, 2018; Krasner, 1984; Peters et al., 2005). Path dependency is referred to as routine patterns and practices that are formed by socially framed and constructed, norms and rules (Schmidt, 2010). The theory argues that there is an inertial tendency for original choices to persist once an organization or governmental program instigates a particular policy or style of action (Krasner, 1984; Peters, 2019; Pierson, 2000). The causal structure of path dependency theory proposes that essential decisions at starting points result in outcomes whose self-reinforcing processes and lock-in of system features make the initial selection difficult to break from (Arthur, 1989; Katzenbach et al., 2003; Kay, 2005; Newig et al., 2019). Path dependency can occur early on in policy-making processes when one strives to maintain their negotiating position as an exertion of power and is shaped by lock-in effects that direct decision-making into existing, often perpetuating, directions (Gillette, 1998; Mirumachi et al., 2021; Wilson, 2014). These choices are locked into the institutional structure and become apparent when institutions do not adjust to system changes (Gillette, 1998).

Conversely, network structure changes can be evidence of changes in power dynamics. To investigate such network changes, social network analysis is commonly used. Social network analysis is commonly used to assess the relationship between nodes (actors in our case) through their connections (Jones & White, 2021; Olivier et al., 2020; Prell et al., 2009). Such relational information helps identify institutional network structures. Network analyses can be used to examine multi-level networks, often found in natural resource governance (Friemel, 2017). Network metrics, betweenness, and degree centrality provide information on actor connectivity within the network. Betweenness centrality indicates how much control a node has via being a part of the connection between other nodes. Thus, high betweenness denotes entities that act as key bridges in the network, as they have more information flow control compared to other entities (Olivier, 2019). Degree centrality is comprised of the in-degree, the number of connections directed to a node, and out-degree, the number of the node's outgoing connections. High in-degree values indicate which nodes are the main rule targets, on the other hand, high out-degree values indicate which nodes are the main rule issuers. Identifying actors that issue rules and are the targets of rules can help improve the understanding of power dynamics within and across institutional levels. The institutional level refers to formal government jurisdictions (e.g., National, Basin, Sub-basin, State, Sub-state).

2.3 Power Dynamics and Water Governance

Power dynamics impact how natural resource governance is conducted and carried out. The concept of power dates back to Aristotle (Lukes, 2005; Malik & Abeuova, 2023). More recent contributions from theorists include Lukes (1974, 2005) and Foucault's (1980) work on the dimensions of power; power as domination which is frequently considered *power over* others using coercion and manipulation, power as empowerment is commonly considered the *power to* act as an individual and in an indirect relational way including the ability to resist and empower others, and *power with* is theorized as a concept of learning and cooperation between actors including the ability to act collectively (Haugaard, 2012). There are other ways power has been conceptualized in natural resource governance studies (Mehta, 2010; Morrison et al., 2019; Werker et al., 2018). We conceptualize power as a socially constructed and multi-faceted influence, with multiple related dimensions, that shape how actors engage with natural resource governance regimes (Arts & Tatenhove, 2004; Molle, 2008; Partzsch, 2017). Power by design (i.e., the power written in incentives, rules, institutions, and legislation) is a type of power that is useful to consider for studying

219 governance rules because actors are given power via written rules and legislation (Morrison et al.,
220 2019; Mudliar, 2021).

221 Water governance rules have three types of power that interact: power dynamics within and across
222 institutional levels, power as a theoretical understanding of how rules affect actors' empowerment to
223 achieve their objectives, and power in the policy-making process (Kashwan et al., 2019). The power
224 to make decisions for CRB governance is granted to actors, in part, by formalized policy and rules
225 (Kenney, 1995). Water governance rules and actors' roles and positions are laid out by formal rules in
226 policy documents such as the 1922 CRC (Kenney, 1995). Power dynamics within and across
227 institutional levels for CRB water governance are reflected by the administration of governance rules
228 by actors with differing granted authorities and positions within the institutional structure. Further,
229 between Federal and State level actors there are power imbalances, where those at the Federal level
230 have more, and concentrated, power to shape CRB governance than State and lower-level actors
231 (Kenney, 1995; Molle, 2008). Within the actor-centered power approach, power is conceptualized as
232 stemming from structural power, such as social structures based on rules, where the rules are a source
233 of power for actors to leverage to empower themselves to achieve their objectives (Krott et al., 2014).
234 Formal rules can grant power to any given water governance actor (Coccia, 2018; Levi, 1990). Power
235 in the policy-making process is often referred to as political power. An actor's amount of political
236 power can be conceptualized by studying their participation in water governance. The more power an
237 actor has, the more they are able to participate which reflects asymmetries in power (Molle, 2008;
238 Wilder & Ingram, 2016). One example of powerful actors shaping the policy-making process can be
239 seen in the early 1920s when CRB water governance decision-makers used their power to
240 "selectively use the available science as a tool to sell their projects and vision for the river's future"
241 instead of taking the hydrologic scientists, who brought the best available streamflow estimates to the
242 decision-makers, seriously and considering the actual streamflow for development (Kuhn & Fleck,
243 2019, pg. 5).

244 3 Water Governance of the Colorado River Basin

245 Tribal and Indigenous peoples have lived and prospered within the Colorado River Basin and
246 managed the Colorado River water since time immemorial (Hundley, 2009; Kuhn & Fleck, 2019;
247 Wescoat, 2023). Indigenous communities have rights to their historic lands, waters, and use and
248 access to natural resources as the original peoples and stewards of the land in the CRB. These rights
249 were formalized with the colonization of the river in the 1908 Supreme Court ruling for the *Winters*
250 *v. United States* case which grants Tribes water rights based on when their reservation (i.e., non-
251 ancestral land they were forcibly moved to) was created by the federal government (Bark & Jacobs,
252 2009; Formisano, 2021; McKenna & Supreme Court of the United States, 1908). Today, several of
253 these water rights remain unsettled or have just recently been adjudicated. First proposed in 1994, the
254 negotiations for settling the Hopi Tribe, Navajo Nation, and San Juan Southern Paiute Tribe water
255 rights claims, which include claims to the Upper and Lower CRB, remain unsettled. The last notable
256 progress for these settlements was in May 2024, when the Hopi Tribe, Navajo Nation, and San Juan
257 Southern Paiute Tribe approved the proposed Northeastern Arizona Indian Water Rights Settlement
258 but await settlement ratification via Congress (Arizona Superior Court, 2024).

259 Priority rights to water in the West are based upon the doctrine of prior appropriation; whoever first
260 diverts river or stream water and puts it to beneficial use may claim priority rights to that amount of
261 water. In 1922, the CRC was crafted by the seven Basin States (Arizona (AZ), California (CA),
262 Nevada (NV), New Mexico (NM), Colorado (CO), Utah (UT), and Wyoming (WY)) and the Federal
263 Government which established the Upper Basin (UB) and Lower Basin (LB) boundaries (Figure 2).

264 The goal of the 1922 CRC was to equitably allocate water across the basin with an average of 7.5
265 MAF allotted annually to each sub-basin (Fleck, 2016). The LB was allotted an additional 1 MAF for
266 treaty obligations to Mexico (MX) (Owen, 2018), despite the exclusion of MX and Native America
267 Tribes in the creation and signing of the 1922 CRC (Méndez-Barrientos et al., 2024) Further, the
268 water rights and governance of the CRB were set “...within a settler-colonial context...based on
269 expropriation, unequal access, and injustice” (Méndez-Barrientos et al., 2024, pg. 192). AZ chose not
270 to ratify the 1922 CRC, partially due to the treatment of its tributary rivers (Gila and Salt) (Hundley,
271 2009; Sullivan et al., 2017). In 1928, the Boulder Canyon Project Act (1928 BCPA) approved
272 Hoover Dam construction so long as the 1922 CRC was ratified by six Basin States and authorized
273 splitting the LB’s 7.5 MAF of Colorado River water between the LB states: CA allotted 4.4 MAF,
274 AZ allotted 2.8 MAF, and NV allotted 300,000 MAF annually. The ratification appointed the
275 Secretary of Interior (SOI) as the authority for LB water use (Kuhn & Fleck, 2019). Arizona opposed
276 this and filed Supreme Court cases from 1930-1936 to nullify the 1928 BCPA, but the Supreme
277 Court declined to hear the cases and in 1936 the Hoover Dam was completed.

278 The 1940s to the early 1990s was a period of water allocation and infrastructure development in the
279 CRB. The 1944 Mexican Water Treaty allocated 1.5 MAF of water to MX in normal flow years,
280 marking the first time MX had a formally identified role in managing Colorado River water. In 1944,
281 the AZ legislature ratified the 1922 CRC. Post-WWII, the population in the Southwest increased
282 massively, driving a subsequent growth in water demand (Terrill, 2022). The Upper Colorado River
283 Basin Compact of 1948 (1948 UCRB) addressed demand growth by creating the Upper Colorado
284 River Commission (UCRC) for new water projects and apportionment of water. Under the 1948
285 UCRB of the Colorado River Storage Project Act of 1956 was created and approved two major UB
286 water storage projects: Flaming Gorge Dam and Glen Canyon Dam. Plans for the Central Arizona
287 Project (CAP), a system of canals and pumps to deliver water to Phoenix, Tucson, AZ farmers, and
288 Tribes, were introduced in the 1940s. Congressional approval was required to move the CAP forward
289 and Congress would only approve if AZ and CA settled their differences. Ultimately, the Arizona v.
290 California U.S. Supreme Court Decision of 1964 provided a resolution and upheld the 1928 BCPA
291 water allotments. Later, the 1968 Colorado River Basin Project Act was passed, and Congress agreed
292 to fund the CAP, which finished construction in 1993.

293 Since the mid-1990s Colorado River water governance has focused on demand management under
294 variable hydrology. Initially, during this period, the basin had high flows and policy innovation to
295 allocate and locally store surplus supplies. This is evident via the 1999 interstate banking rule
296 allowing LB states to store water in AZ aquifers and the 2001 Surplus Sharing Agreement (Sullivan
297 et al., 2017). Around 2000, the Millennium Drought began, shifting the basin to low flows, resulting
298 in management aimed at stabilizing and decreasing demand. From 2005 to 2007, water scarcity and
299 drought increased, and in 2005 Lake Powell storage dropped to 33% of capacity (Water Education
300 Foundation, 2022). In 2007 the Colorado River Interim Guidelines for Lower Basin Shortages and
301 the Coordinated Operations of Lake Powell and Lake Mead (2007 IG) were signed. These operations
302 included guidelines to conserve water in Lake Mead and equalize storage between the main
303 reservoirs (Lake Mead and Lake Powell).

304 Also, during this period, the criteria for decision-making expanded to include diverse human and
305 natural uses of water supplies. The 1992 Grand Canyon Protection Act required Glen Canyon Dam
306 water releases to meet tribal, environmental, cultural, and recreational needs. In 1992, the Ten Tribes
307 CRB Partnership was established to strengthen tribal influence among the Basin States for supply use
308 and management (CRWUA, 2021). Further expansion of actors formally included as decision-makers
309 took place from 2014 to 2018, expanding consideration of ecology and extending tribal rights.

310 Regarding ecology, a pulse flow released in 2014 to a 24-mile stretch along the US-MX border and
311 Delta that historically was 2 MA of riparian habitat and wetland (Owen, 2018). Furthermore, the US
312 and MX signed Minute 323 in 2017, supporting increased conservation and storage in Lake Mead to
313 help offset drought, prevent triggering shortages, and dedicating 210,000 AF over nine years for
314 Colorado River Delta environmental restoration (Water Education Foundation, 2022). Regarding
315 tribal rights, the USBR released a Tribal Water Study in 2018 that described how tribal water use fits
316 into Colorado River management and ways future tribal water resource development could influence
317 CRB operations. Additionally, Tribal Nations have been significantly excluded from water
318 governance and programs over the last century although they hold rights to 25%-30% of the
319 Colorado River's historic flow (Karambelkar & Gerlak, 2020; Méndez-Barrientos et al., 2024). There
320 are 182 Federally Recognized Tribes and several state-recognized Tribes and Tribes seeking federal
321 or state recognition in the Southwest, yet recognitional justice is lacking as there are inequities in
322 water distribution both historically and in present times (Bureau of Indian Affairs, 2017; Elias et al.,
323 2023; Indian Affairs Bureau, 2020).

324 The current water management period is focused on responding to drought, climate change,
325 aridification, and increasing demand. The 2019 LB and UB Drought Contingency Plans encouraged
326 the seven Basin States to consider all water users, beyond junior rights holders, as having a stake in
327 keeping the system intact via voluntary water reductions. In 2021, the first-ever Tier 1 shortage was
328 declared and required AZ, NV, and MX to reduce their Colorado River water delivery (Schlageter,
329 2021). In 2022, as water shortage conditions continued, a Tier 2a shortage was declared, which cut
330 the 2023 Colorado River supply for AZ, NV, and MX. The USBR further demanded in 2023 that
331 water use be cut an additional 2-4 MAF by the Basin States and Tribes reliant on the Colorado River
332 (Stern, 2023).

333 Presently, tensions are elevated about CRB's water governance amidst an uncertain climate and
334 water supply (Gerlak et al., 2021; Karambelkar & Gerlak, 2020; Sullivan et al., 2019). In part, some
335 tensions result from differing goals between the UB and LB (e.g., separate drought contingency
336 plans). Furthermore, the UB has not historically used its full allocation while the LB has, and at
337 times, used more. Today, we have detailed records showing the average annual flow through the
338 basin was 14.67 MAF from 1906 to 2021 and 12.3 MAF from 2000 to 2021 (Salehabadi et al., 2022),
339 both less than the 17.5 MAF early western water decision-makers assumed (Kuhn & Fleck, 2019).
340 While water governance management strategies and water action responsibilities have changed over
341 time, we do not fully know how those changes have shaped water management actions and actors'
342 roles. Our research describes changes in rules-in-form over a one-hundred-year period and analyzes
343 these changes in the context of the case history.

344 4 Methods

345 For this analysis, we examined written rules for governing the physical supply of water in the CRB
346 (Ostrom, 2011). To identify rules that guide governance decisions, we use a systematic approach to
347 determine how water management actions are described in written formal governance documents to
348 address concepts related to water governance at the basin and sub-basin scale. Then, we used content
349 analysis to determine how internal decision-making processes are expressed in formal documents
350 (Bernard et al., 2016; Bowen, 2009). Next, we characterized each rule based on spatial scale and
351 whether the rule grants or constrains authority based on rule issuer and target. This information is
352 used to map the institutional structure using social network analysis. Lastly, the results are interpreted
353 in the context of the case history presented in Section 6.

354 **4.1 Data and Rule Selection**

355 To understand the evolution of the water governance structure, we analyzed documented rules and
356 agreements in formal, written water management documents for the American Southwest from 1922
357 to 2022. This analysis only considered formal documents with legal or regulatory standing regarding
358 Colorado River Basin water governance. The resulting set of documents are called the “Law of the
359 River” documents (Sullivan et al., 2017; Wescoat, 2023). Next, the scope of the document population
360 was specified via the following document selection criteria: 1) address formal rules pertaining to at
361 least one of the following: the Upper CRB, the Lower CRB (including Mexico), and the CRB
362 (excluding water export areas); 2) fit within basin or sub-basin institutional level boundaries; 3)
363 published between 1922 and 2022; and 4) directly address the Colorado River Basin, physical water
364 availability, and/or water management activities. This search and screening process yielded 14
365 documents for further analysis (Table 1).

366 Empirical and theoretical governance literature was drawn upon for the thematic rule selection.
367 Existing natural resource governance case studies were used to ascertain broad categories with
368 specific aims related to water systems (Larson et al., 2013; Wiek & Larson, 2012). From the
369 literature, we identified four main domains associated with water system management: water supply,
370 storage, movement, and use activities (Garcia et al., 2019; Mirumachi et al., 2021; Wiek & Larson,
371 2012). Next, we defined and created keywords based on theoretical water resource concepts (Kallis,
372 2010; York et al., 2019) and mapped these to the four types of water management to create a water
373 management type coding guide (Table 2). Rules were selected if the rule is within at least one of the
374 institutional level boundaries of interest and addresses at least one CRB water management domain.

375 We conducted content analysis using codes derived from theory and prior knowledge of water
376 governance and institutions (Akamani & Wilson, 2011; Mirumachi et al., 2021). We inductively
377 coded the rules based on the identified keywords informed by existing water governance scholarship
378 (Table 2). To better understand and document the institutional arrangements, we characterized the
379 rule level, spatial scale, issuer, and target of each rule without mutual exclusion. The three rule levels
380 (constitutional, collective-choice, and operational) defined within the IAD Framework were utilized
381 to assign levels to the rules based on what the rule choice process was discussed. Next, to understand
382 the network of actors, we coded each rule’s spatial scale based on politically defined boundaries,
383 issuer(s) based on actor(s) that impose rules, and target(s) based on actor(s) that rules are imposed
384 upon. The first two authors used consensus coding to reach intercoder agreement (Cascio et al., 2019;
385 Hill et al., 1997).

386 **4.2 Network Analysis**

387 We constructed a directed network based on the rule characterizations above using the igraph
388 package (Gabor & Nepusz, 2006) in R. Directed networks indicate the flow of information, or in our
389 case, rule direction from the issuer to the target. To test our hypothesis that the distribution of
390 authority changes over time and is split as the network size increases, we looked at the degree
391 (number of ties) and linkages (betweenness) within the network (Hermans et al., 2017; Kharanagh et
392 al., 2020). As is commonplace to examine network linkages, also called bridging behavior, we
393 calculated the measure of in- and out-degree centrality and betweenness centrality (Friemel, 2017;
394 Jones & White, 2021; Olivier, 2019). To clarify, we counted the rule issuer and target separately by
395 using both the in- and out-degree centrality measures.

396 **5 Results**

397 **5.1 Evaluation of Rules**

398 Constitutional, operational, and collective-choice rules related to water supply, storage, movement,
399 and use were effectively modified by the addition and layering of new rules (Figure 3a). In total, 118
400 rules were extracted and examined from the 14 documents. The rules are spread across the
401 documents ranging from two in the 1956 Colorado River Storage Project Act to the highest amount
402 of 40 in the 2007 Interim Guidelines (Figure 3b). While the Millennium Drought began in 2000, the
403 significant increase in rules via the 2007 Interim Guidelines indicates a delayed, but robust policy
404 response. Additionally, no formal rules have been rescinded and as a result, the rules are layered
405 upon each other. This is an important finding because, while new rules have been added, the initial
406 water management activities and responsibilities have been maintained over the long term. Through
407 this analysis, we found that through lock-in effects rules have, as anticipated, stayed in place and
408 shaped subsequent rules-in-form over time across the CRB (Bardach, 2006).

409 The number of rules by rule level and water management action type were calculated from the
410 extracted and coded rules (Figure 3a). Of the extracted rules, operational rules are the most common
411 and constitutional level rules are the least common. To further investigate rule levels, we examined
412 the occurrence of each rule level by document (Figure 3b). As the documents were developed over
413 time, this allowed us to parse out the timing and context of additions of rules by level. Operational
414 level rules are most common and are found in each document. Collective choice rules are the second
415 most prevalent and constitutional rules are least prevalent. Such findings demonstrate that policy
416 change in the CRB has been at the operational level, signaling that the focus of change has been on
417 further specifying how practical decisions are made. Further, the focus of change has not been on the
418 way decisions are made although there have been some collective-choice level rule additions,
419 indicating that the way policy is made is evolving but at a slower pace. There are only two
420 constitutional level rules, one in the 1922 CRC and the second in the 1948 UCBR (Figure 3b) which
421 is surprising as both documents set up major governance structures. The lack of change is of note
422 because many new actors are added over time and part of the job of constitutional level rules is to
423 specify actor roles in lower-level rules. As constitutional level rules occurred least, this signals that
424 there are informal processes for selecting decision-makers or that these are out of scope given our
425 selection criteria.

426 We analyzed the occurrence of each water management type per document based on the extracted
427 rules. Since the rules in these documents have stayed in place since their implementation, we
428 examined the cumulative count of rules over time based on the type of water management (Figure
429 3c). Use and movement rules follow similar increasing patterns while storage and supply rules follow
430 similar, but slower, increasing patterns over time. Also, rules regarding water use and movement
431 actions occurred most often in the documents. Water movement rules are tied for least prevalent in
432 1922 to the second most prevalent in 2019 (Figure 3c). This makes sense as the period of water
433 allocation and infrastructure development paved the way for moving water and aided in the
434 expansion of rules regarding the physical dispersion of CRB water. Notably, storage rules were the
435 least prevalent until 2007 when the coordinated operations between Lake Mead and Lake Powell, as
436 well as the use of storage by individual water users, became important strategies to cope with drought
437 (Figure 3c). This increase in prevalence is in alignment with the water governance period of demand
438 management under variable hydrology starting in the mid-1990s as well as the current water
439 management period focused on drought. Water supply rules start as second most prevalent in 1922
440 and fall to least prevalent in 2007 although the 2007 Interim Guidelines were set for drought
441 management (Figure 3c). Despite the 2019 DCPs, also established for drought management,
442 currently, water supply rules are least prevalent even though the CRB has historically struggled with

443 water supplies and overallocation. This may be due to the doctrine of prior appropriation driving
444 priority water rights in the West and challenging changes to allocations of water supplies.

445 **5.2 Water Governance Network**

446 Figures 4a-d illustrate the water governance network in 1922, 1948, 1973, and 2019, respectively.
447 The circular nodes represent actors while the arrows represent and indicate the rule direction between
448 the rule issuer and target. The color-coding in Figure 4a-d aligns with the governance level of the
449 actors as listed in Table 3. When comparing the 1922 (Figure 4a) with the 1948 network diagram
450 (Figure 4b) there is a significant increase in the number of actors in the network from 6 to 27 and the
451 number of connections. This finding aligns with the addition of national, state, and sub-state actors to
452 the water governance network, particularly via the 1944 MWT. The most notable finding is the
453 increase in the number of actors involved and the total number of rules connecting the rule issuers
454 and targets when comparing the 1922 (Figure 4a) and 2019 (Figure 4d) networks. These substantial
455 differences demonstrate the network structure changed via a six-fold increase (from 6 to 35) in the
456 number of actors involved and by one order of magnitude (from 10 to 178) in the number of
457 connections between actors via the rules. Rules can be used to impose authority (i.e., rule issuers
458 exert their power over rule issuees) and grant authority (i.e., rule issuers their power to give new
459 powers to rule issuees) (Coccia, 2018; Kenney, 1995; Levi, 1990; Molle, 2008). Both of these
460 processes are reflected in Figures 4a-d which show changes in the distribution of authority over time
461 as the network grows, as more actors have authority granted to them via formal rules, they can issue
462 rules to other actors. The growth of the network in the number of actors and rules aligns with the
463 governance period starting in the mid-1990s with a focus on expanding the criteria for decision-
464 making and actors formally included as decision-makers.

465 Different processes, rule issuing and targeting, are dominant at different governance levels (Bodin &
466 Crona, 2009). Table 3 shows the total amount of rules issued by and targeted at actors at the same
467 governance level throughout all 14 documents analyzed. A significant portion of the rules are issued,
468 and thus originate, at the national level (Table 3). Rule targets at the national level delegate rule
469 implementation to lower levels of governance, most frequently (51) to the sub-state level. The second
470 most rules are issued at the sub-basin level (Table 3). This makes sense because as actors, the UB and
471 LB receive rules from actors at the national level and then make specific operational rules for states
472 and sub-state actors. The distribution of rules in the sub-basins is possible via state members'
473 voluntary agreement permitting both basins the power to issue rules. Sub-state actors are the most
474 targeted by the rules (Table 3). As rules can grant or constrain authority, thus, even if an actor is the
475 target of several rules, they are not necessarily heavily constrained or without authority for decision-
476 making. Interestingly, the second most targeted levels are both the national and state, even though the
477 national is the main rule issuer. These findings are consistent with a top-down structure of authority
478 where actors with higher levels of governance (e.g., national) have more authority and use this
479 authority to issue rules than actors with lower levels of governance (e.g., sub-state).

480 By looking at the top five actors for each metric, we found that the distribution of authority does not
481 significantly change over time due to a lack of alteration to responsibilities for water management
482 actions. Tables 4-6 are breakdowns of the top five actors' centrality measurements at each time
483 snapshot. The U.S. is the main rule target, indicated via high in-degree values (Table 4), thus the U.S.
484 plays a major role in responding to rules. The actors with high in-degree values are less consistent as
485 only the U.S. and BS remained in the top five from 1948 to 2019 (Table 4). The SOI dominates the
486 network over time as the entity that issues the most rules, as indicated by high out-degree values from
487 1948 onward (Table 5). From 1948 on, there are a small number of actors, SOI, IBWC, USBR, and

488 UCRC, who consistently have high out-degree metric values indicating they issue the most rules.
489 Actors that act as intermediaries have high betweenness values. There is less consistency in the top
490 five actors with the highest betweenness metric values. From 1948 to 2019 the UB and USBR are the
491 only actors that remain in the top five. In the case of the highest betweenness value per time
492 snapshot, the USBR, UB, and SOI are indicated as the top intermediaries (Table 6), but we know that
493 multiple intermediaries receive rules and then make specific operational rules for other entities (i.e.,
494 states and water suppliers). Considering betweenness is a representation of actors that serve as links
495 by receiving and issuing rules, it makes sense that when the network is smaller and simpler fewer
496 actors have a linking role. Betweenness, in this case, may be a measure of the increasing complexity
497 of the network and institutional structure over time. We found that the actors who are rule issuers and
498 targets do not vary widely. The same cohort of actors, the CRB, USBR, U.S., SOI, and UB (Tables 4-
499 6), have the highest centrality values over time, indicating the bureaucratic hierarchy has remained
500 because actors in positions of power in the water governance network have been maintained over the
501 last 100 years.

502 **6 Discussion**

503 In our combined spatial, temporal, and network analyses covering the past century, we observed how
504 Colorado River Basin water governance has been influenced by the legacy of policy. We present a
505 100-year temporal analysis, drawing on formal documents and rules that shape CRB water
506 governance by integrating case history, institutional analysis, and social network analysis. We found
507 that the rules have evolved water management strategies over time, shifted the emphasis of various
508 water management actions, and changed the distribution of authority across actors and levels. The
509 rules span multiple scales from sub-state to national, indicating the multi-level governance system
510 structure that is characteristic of Colorado River Basin water governance.

511 In the institutional analysis, we found that water system dynamics persist over time with the layering
512 of rules (Figure 3c), consistent with other water management studies (Elshafei et al., 2014; Gleick,
513 2003; Pulwarty et al., 2005). The maintenance of the original rules via the addition of rules that have
514 created layers within the water governance institutions and the actor network is evidence of path
515 dependency (Lewis & Steinmo, 2012; Peters, 2019). The layering of new rules has permitted CRB
516 water governance to remain viable through new operating conditions and infrastructure integrations
517 as seen in the case history. However, there are limitations to what incremental adaptations can do to
518 sustain systems over the long term (Kates et al., 2012; O'Brien et al., 2012). The layered incremental
519 adaptation approach for the CRB has not kept pace with accelerating climate change, drought,
520 aridification, and increasing demand. This is evident via the USBR's demand to reduce an additional
521 2-4 MAF of water for use in 2023. USBR's demand – and the BS's difficulty in meeting it – gives an
522 example of the challenge of negotiating new rules in the context of 100 years of history and the
523 evolution of water governance in the CRB. Our findings that approaches used over the last century
524 have not kept pace with water management challenges in terms of climatic and governance regime
525 changes align with other water governance studies (Hileman & Lubell, 2018; Olivier et al., 2020;
526 Vano et al., 2014; York et al., 2020).

527 Over the last century, change has occurred, but we found that the path dependency of institutions has
528 played a role in the magnitude of change to water management. The persistence of original decisions
529 is evidence that path dependency has shaped how water governance has changed. Other studies of
530 path dependency and water policy have similar findings (Anderson et al., 2018; Ingram & Fraser,
531 2017; Marshall & Alexandra, 2016). Although we observed the addition of operational and collective
532 choice rules throughout the period, observation rules are more prevalent (Figures 3a-b). This

533 indicates that rulemaking has focused on operations but that some shifts in the way decisions are
534 made have been made throughout the past one hundred years. We observe only one additional
535 constitutional level rule after the CRC indicating that the processes for selecting decision-makers are
536 informal, and/or constitutional level rules are not captured within our selection criteria scope.

537 Despite struggles with water overallocation since the early 1920s (Hundley, 2009; Kuhn & Fleck,
538 2019), there are few supply rules (Figure 3c), demonstrating how early allocation agreements endure
539 even with changes over time. Water use rules are present in every document (Figure 3b). This may be
540 because the pre-1920s doctrine of prior appropriation and the 1922 CRC set rules in alignment with
541 the doctrine for beneficial use. These findings are in agreement with other study findings that water
542 management in the CRB is path dependent and that rules have been shaped by early rules,
543 particularly ones set via the 1922 CRC (Heinmiller, 2009; Loos et al., 2022; Turley, 2021). As a case
544 in point, the overallocation since the inception of the 1922 CRC has not been addressed in the rules-
545 in-form within the Law of the River documents.

546 As the challenges facing the CRB have evolved over the last century, so too has water governance
547 and the structure of the actor network. Over time, actors across institutional levels and types of water
548 management were added (Figure 4a-d). Overall, the central network structure remained stable
549 without actor replacement or removal, only additions. As the actor network grew, the distribution of
550 authority changed from a few central actors to many actors in the current large and complex network.
551 Network growth is due in part to the mid-1990s and 2014 to 2018 expansion of criteria for actors
552 formally included in the decision-making for natural and human uses of Colorado River water.
553 Changes in the network reflect changing values as more attention was paid to diversity, equity, and
554 inclusion as evidenced by the addition of new actors (Mexico, IWBC, etc.). Such network additions
555 support our hypothesis that over time authority has been distributed across a growing number of
556 actors.

557 Our analysis found that the key decision-making positions remained the same. The actors who issue
558 rules lack significant change over the last century (Tables 4 and 5). Original positions of power have
559 been maintained over time, narrowing the space for problem-solving and renegotiation. Generally, in
560 systems with centralized power, substantive changes are harder to make because powerful actors may
561 use their power to maintain the status quo or exert their power over less powerful actors (Ishtiaque et
562 al., 2021; Partzsch, 2017). Consistent with existing literature (Berggren, 2018), the findings support
563 our hypothesis that path dependency has shaped how water governance evolves and who is able to
564 influence decisions.

565 In contrast to Olivier & Schlager (2021), we found the addition of dynamics and institutional
566 arrangements did not limit or change the direction of water governance decision-making and actions.
567 The governance system complexity increased and became highly institutionalized as more water
568 management rules were created. Highly institutionalized governance systems are fragile and have
569 limited opportunity for flexibility because there are tensions and constraints for change and limits on
570 possible choices (Gillette, 1998; Ishtiaque et al., 2021). Actors in these types of governance systems
571 are incentivized to maintain the system and there is less space for experimentation and innovation
572 between the rules. Thus, our finding that water management responsibilities also remained stable
573 over time aligns with and empirically contributes to the literature on institutions and path dependency
574 (Kessy, 2018; Marshall & Alexandra, 2016; Wilson, 2014). Our findings are in agreeance with other
575 cases that have found that water resource governance does not significantly evolve, change, and shift
576 over time as they are shaped by the path dependence set by the original governance structure (Möck
577 et al., 2022; Pahl-Wostl, 2015; Thiel et al., 2019).

578 Although the network has evolved with the addition of rules and actors and an increase in the number
579 of connections between actors (Table 3 and Figures 4a-d), issues recur as there has been no major
580 structural change or reform of the institutional network. These findings are important as substantial
581 differences in governance outcomes and processes cannot be expected without changes to the water
582 governance network (Bodin & Crona, 2009; Das et al., 2019). Due to the lack of major alteration, the
583 water governance structure has not kept pace with an increasingly changing climate in the
584 Anthropocene and is unable to respond sufficiently. Further, the current system for water governance
585 does not fully address the context in which the CRB is operating, and management rules have not
586 kept pace with the changing water system. Our case history details changing priorities and the
587 increasing challenge of water scarcity. An improved understanding of current CRB governance and
588 how it has evolved can help provide insight to inform the redesign of operating rules and fill the
589 knowledge gap of how we have arrived at the critical water situation we are in today.

590 Our study is novel because we surpass existing descriptive studies and their critiques by taking an
591 analytical approach to examine the content within the majority (14) of Law of the River Documents
592 (Table 1) (Ingram et al., 1984; Wescoat, 2023). Additionally, our study goes beyond other
593 institutional studies of the CRB that focus on water quality, hydropower operations, the state-level,
594 reservoir operation, and the decision-making process by using an analytical lens including a 100-year
595 time scale, five levels of governance, and management actions related to supply, storage, movement,
596 and use (Berggren, 2018; Karambelkar, 2018; Sullivan et al., 2019; Turley et al., 2022).

597 It is important to note that other variables not examined in this study may influence the findings. For
598 example, informal stakeholder groups referred to as shadow networks by Wutich et al. (2020) may
599 influence decision-making via informal drivers and factors (e.g., unplanned interactions, social
600 influence, social norms) and impact how decisions are made regarding resource management. Our
601 study is limited as we only cover changes to water management strategies and responsibilities based
602 on formal rules across high institutional levels. Informal rules and norms are not included in the data
603 set or analysis, as a result, our study could be missing changes to water management influenced by
604 informal rules across lower institutional levels. Thus, the full story of the deficiency of past water
605 management and incremental changes amidst rapid climatic change has not been captured. To fill this
606 gap, other studies could be conducted to understand how path dependency, adaptations, and informal
607 rules have and have not contributed to sustainable water management in the CRB. Identifying the
608 shortcomings of historic and legacy water governance may help inform more effective strategies for
609 future adaptations.

610 This study acknowledges the long, but not full, history of the evolution of the CRB water system
611 from open access to a highly regulated resource. Indigenous peoples' water use and management of
612 the basin has an even longer history that we do not cover in this study but recognize as an important
613 piece of the larger story of water in the West. To improve the understanding of how the CRB water
614 system evolved, future analysis should take the larger history into account, especially with our
615 increased understanding of the importance of Tribal perspectives and input.

616 Taken together the institutional analysis, social network analysis, and case history indicate a tension
617 between path dependency, a changing environment, and shifting values. Through examining the case
618 history we found that CRB water management has shifted from managing demand growth to
619 managing conflict over time, marked by the evolution of water resource management to reservoir
620 development, then to managing water scarcity. The institutional analysis empirically demonstrates
621 the path dependency of institutions over the century-long, and ongoing, water governance regime.
622 We contribute to understanding the evolution of water governance in the CRB with our analysis

623 where we found a layering of new rules without the removal of existing rules and an expanding
624 network of actors over the last century. Expansion of the network demonstrates a shift in values to be
625 more inclusive of actors within the water governance network. To build upon this scholarship, factors
626 that may shape and influence decision-making, such as informal rules and norms as well as shadow
627 networks, should be studied to help tell the larger story of how water governance has evolved in the
628 CRB over time. Future research could apply our approach to other basins with histories of water
629 policy and conduct cross-case comparisons with our study as well as existing studies to add to water
630 governance knowledge and literature.

631 **7 Author Contributions**

632 KLL: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft,
633 Writing - review & editing. MG: Conceptualization, Funding acquisition, Project Administration,
634 Writing – review & editing. DDW: Validation, Writing – review & editing.

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639 **9 Conflict of Interest**

640 *The authors declare that the research was conducted in the absence of any commercial or financial
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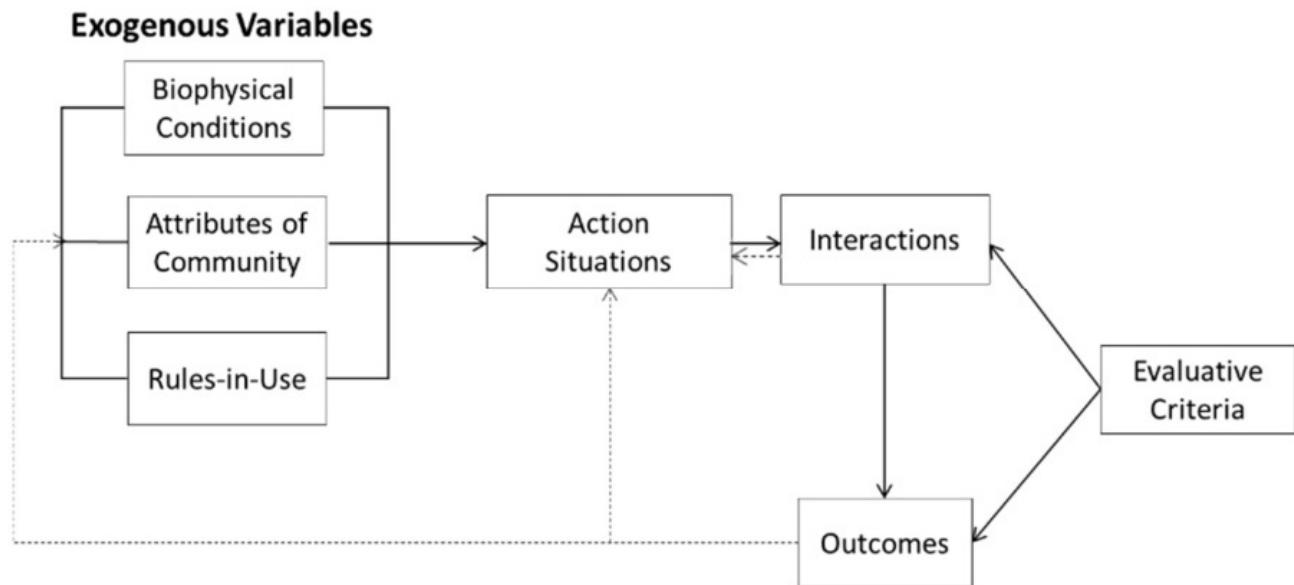
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1052 **Figures**

1053 **Figure 1:** IAD Framework (Ran et al., 2020) adapted from Ostrom (2005).



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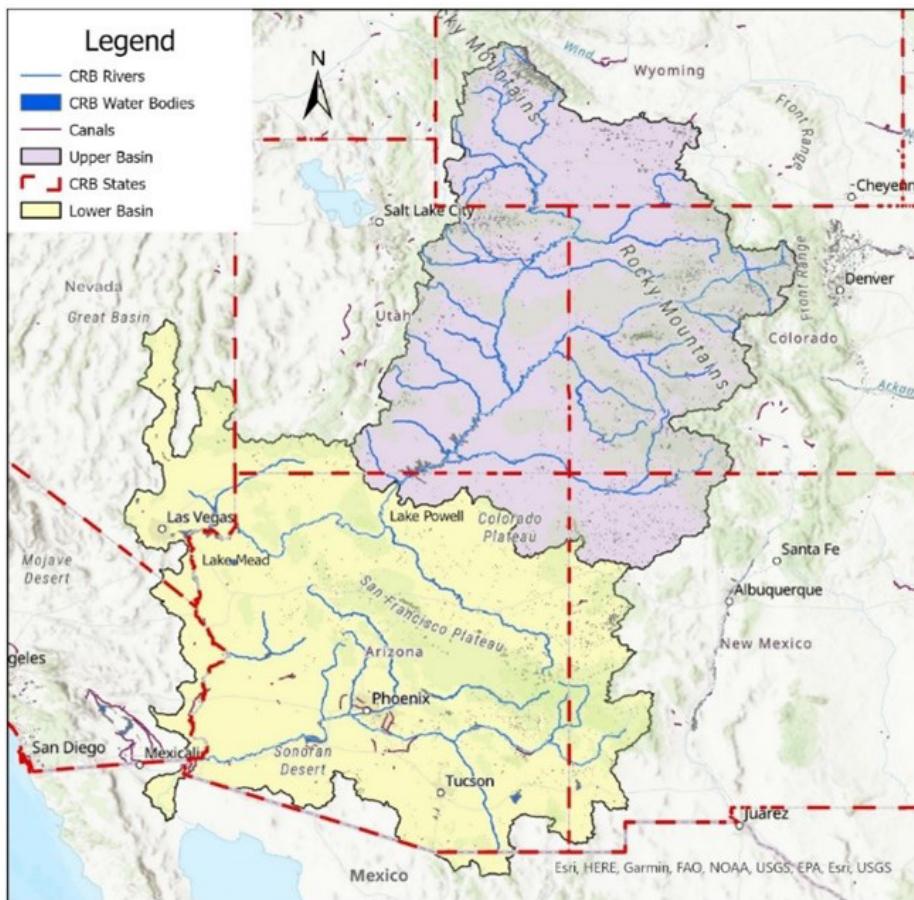
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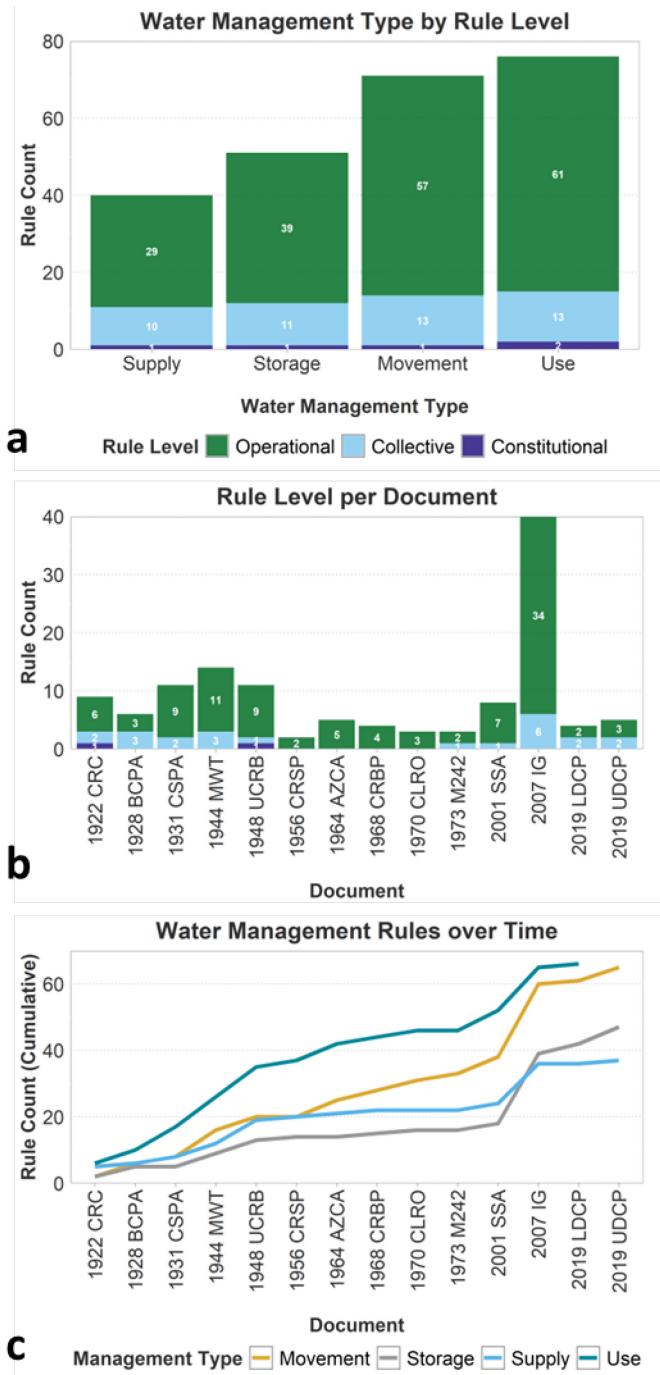
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1070 **Figure 2:** Case Study Location, Colorado River Basin, U.S.



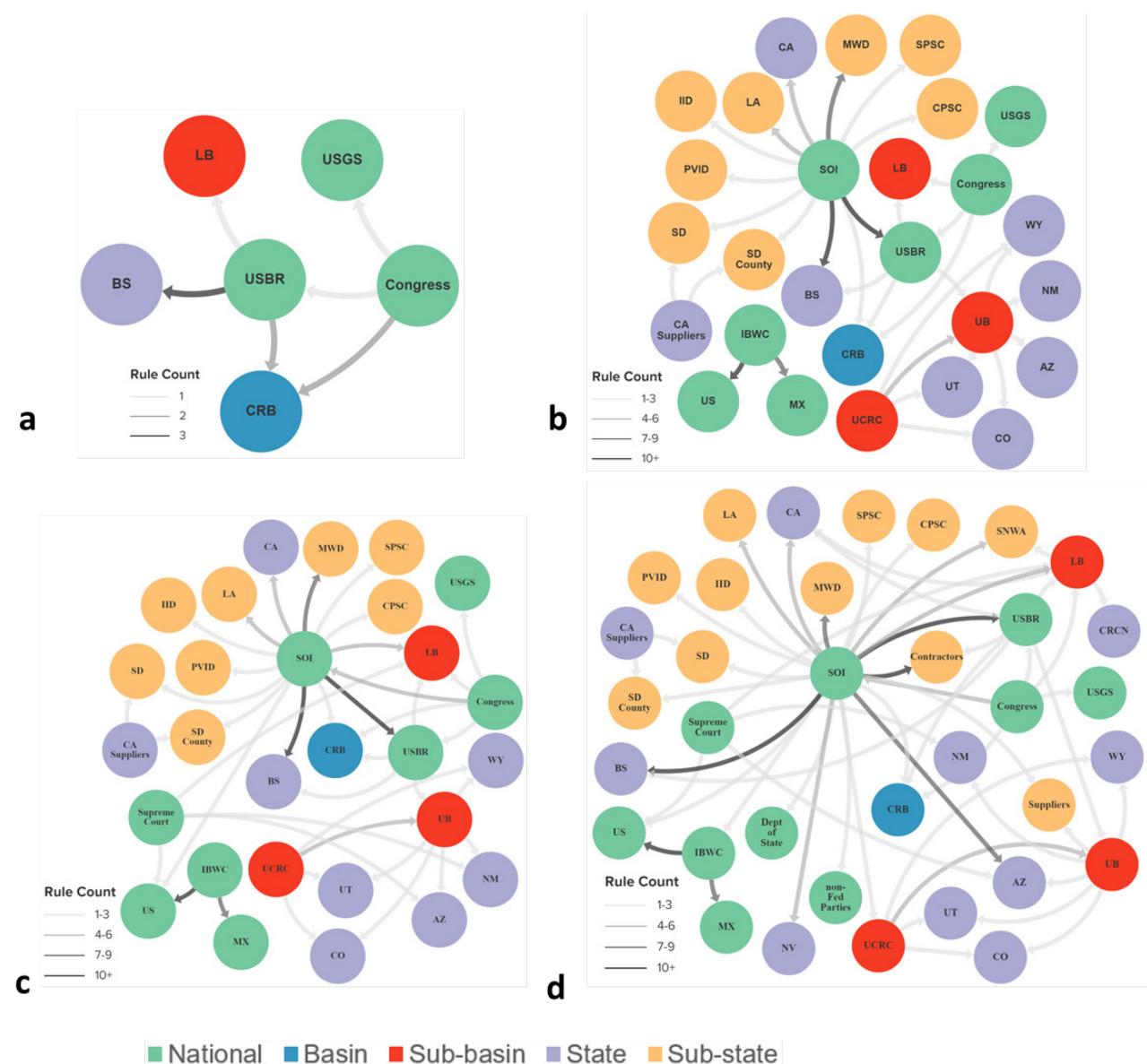
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1072 **Figure 3:** a) Rule Level per Water Management Type; b) Rule Level Count per Document; c)
 1073 Cumulative Water Management Rules over Time.



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Figure 4: Network Diagram Snapshots a) 1922; b) 1948; c) 1973; d) 2019.

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1099 **Tables**1100 **Table 1:** Colorado River Water Governance Document Selection.

Document	Abbreviation
Colorado River Compact of 1922	1922 CRC
Boulder Canyon Project Act of 1928	1928 BCPA
California Seven Party Agreement of 1931	1931 CSPA
Mexican Water Treaty of 1944	1944 MWT
Upper Colorado River Basin Compact of 1948	1948 UCRB
Colorado River Storage Project Act of 1956	1956 CRSP
The Arizona v. California U.S. Supreme Court Decision of 1964	1964 AZCA
The Colorado River Basin Project Act of 1968	1968 CRBP
The Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs of 1970	1970 CLRO
Minute 242 of the U.S.-Mexico International Boundary and Water Commission of 1973	1973 M242
2001 Surplus Sharing Agreement	2001 SSA
2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations of Lake Powell and Lake Mead	2007 IG
2019 Lower Basin Drought Contingency Plan	2019 LDCP
2019 Upper Basin Drought Contingency Plan	2019 UDCP

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1102 **Table 2:** Water Management Action Type Coding Guide.

Management	Definition	Keywords
Supply	Physical water amount	water right, water permit, physical availability, quantity, apportion*, allocat*, water source, allot*
Storage	Containment of the physical water amount	storage, reservoir, ICS, storage credit, surplus, stock, accumulat*, groundwater bank*, aquifer storage
Movement	Relocation of the physical water amount	deliver*, conveyance, interbasin transfer, releas*, interstate, withdraw*
Use	Consumption of the physical water amount	water use, water demand, demand management, water conservation

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1105 **Table 3:** Rule Issuers and Targets by Governance Level with Rule Count Totals.

Governance Level	Actors	Rules Issued	Rules Targeted
National	US, MX, USBR, SOI, Congress, Supreme Court, Dept of State, non-Fed Parties, USGS, IBWC	153	48
Basin	CRB	0	9
Sub-basin	Upper and Lower Basin, UCRC	23	17
State	Basin States, AZ, CA, CA Suppliers, NV, CO, WY, NM, UT, CRCN	2	48
Sub-state	MWD, SNWA, PVID, IID, CPSC, LA, SPSC, Contractors, Suppliers, SD, SD County	0	51

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1107 **Table 4:** Top 5 Actors In-Degree Value per Snapshot Year.

1922		1948		1973		2019	
Actor	Value	Actor	Value	Actor	Value	Actor	Value
CRB	4	US	13	US	17	US	19
BS	3	MX	9	MX	9	Contractors	15
USBR	1	CRB	7	CRB	8	USBR	14
USGS	1	BS	4	BS	6	BS	13
LB	1	MWD	4	LB	5	AZ	10

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1109 **Table 5:** Top 5 Actors Out-Degree Value per Snapshot Year.

1922		1948		1973		2019	
Actor	Value	Actor	Value	Actor	Value	Actor	Value
USBR	6	SOI	24	SOI	29	SOI	103
Congress	4	IBWC	22	IBWC	24	IBWC	24
		UCRC	9	Congress	11	Congress	11
		USBR	7	UCRC	9	UCRC	11
		UB	7	USBR	7	USBR	10

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1111 **Table 6:** Top 5 Actors Betweenness Value per Snapshot Year

1922		1948		1973		2019	
Actor	Value	Actor	Value	Actor	Value	Actor	Value
USBR	2	UB	17	UB	17	SOI	23
		USBR	14	USBR	12.2	UB	11.7
				SOI	10.8	LB	7.1
						UCRC	5.6
						USBR	4.5

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