Self-governance From Above:

Principles of Polycentric Governance in Large-Scale Water Infrastructure

by

Skaidra Smith-Heisters

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Graduate Supervisory Committee:

Marco A. Janssen, Chair
Rimjhim M. Aggarwal
Michael L. Schoon

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ABSTRACT

Governance of complex social-ecological systems is partly characterized by processes of autonomous decision making and voluntary mutual adjustment by multiple authorities with overlapping jurisdictions. From a policy perspective, understanding these polycentric processes could provide valuable insight for solving environmental problems. Paradoxically, however, polycentric governance theory seems to proscribe conventional policy applications: the logic of polycentricity cautions against prescriptive, top-down interventions. Water resources governance, and large-scale water infrastructure systems in particular, offer a paradigm for interpretation of what Vincent Ostrom called the "counterintentional and counterintuitive patterns" of polycentricity. Nearly a century of philosophical inquiry and a generation of governance research into polycentricity, and the overarching institutional frameworks within which polycentric processes operate, provide context for this study. Based on a historically- and theoretically-grounded understanding of water systems as a polycentric paradigm, I argue for a realist approach to operationalizing principles of polycentricity for contribution to policy discourses. Specifically, this requires an actor-centered approach that mobilizes subjective experiences, knowledge, and narratives about contingent decision making.

I use the case of large-scale water infrastructure in Arizona to explore a novel approach to measurement of polycentric decision making contexts. Through semi-structured interviews with water operators in the Arizona water system, this research explores how qualitative and quantitative comparisons can be made between polycentric governance constructs as they are understood by institutional scholars,

experienced by actors in polycentric systems, and represented in public policy discourses. I introduce several measures of conditions of polycentricity at a subjective level, including the extents to which actors: experience variety in the work assigned to them; define strong operational priorities; perceive their priorities to be shared by others; identify discrete, critical decisions in the course of their work responsibilities; recall information and action dependencies in their decision making processes; relate communicating their decisions to other dependent decision makers; describe constraints in their process; and evaluate their own independence to make decisions. I use configurational analysis and narrative analysis to show how decision making and governance are understood by operators within the Arizona water system. These results contribute to practical approaches for diagnosis of polycentric systems and theory-building in self-governance.

For my family, forsaken in the pursuit of a graduate education—and most particularly my father, whose graduate advisor has yet to make a clear impression. May this document have some small part in our redemption.

And to Vincent and Elinor Ostrom, whose words, writings, and ideas have been my constant companions.

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CHAPTER 1

INTRODUCTION

In the current moment, long-term thinking is almost synonymous with sustainability, but that hasn't always been the case. Long-term thinking has also been concerned with legacy, transformation, reclamation and other concerns. The "world's first explicit attempt to reverse human-induced climate change," in 1948, was one such transformational long-term project (Brain, 2011, p. 140). The Great Stalin Plan for the Transformation of Nature sought to usher in a more favorable climate through the "reorganization" of forests across southern Russia and afforestation of the Eurasian steppe, a plan which predated the Russian Revolution (Brain, 2011). The most emblematic of these long-term transformation and reclamation efforts, in my mind, is the rerouting of rivers—geoengineering at a continental level. In Soviet Russia, Joseph Stalin's planned forest belts were meant to protect rivers and the agricultural production that depended on them; these ambitions were modest in comparison to seemingly perennial plans to reverse the flow of the Siberian rivers from the Arctic, south to the Central Asian desert, culminating in a 900-mile canal to the Aral Sea. The equal to this scheme, on the North American continent, can be seen in the Pacific Southwest Water Plan, which Secretary of the Interior Stewart Udall pledged, in 1965, would build the "the world's largest aqueduct," rerouting the Columbia River in Oregon's temperate rain forests to serve the desert regions of Arizona and New Mexico (as cited in Coate, 1995, p. 79). The project would have tied the California State Water Project, then under construction (now 700 miles long)—in turn, connected to the federal Central Valley Project—together with the Colorado River and a proposed southwestern aqueduct under a new regional government authority. This infrastructure would complement the plans of

the North American Water and Power Alliance to turn Alaska and Canada's rivers toward the Great Lakes and the Gulf of California, "a panacea for all the continent's water problems" (Quinn, 1968, p. 119). For Wittfogel (1957), writing his important thesis on "agromanagerial and agrobureaucratic" hydraulic despotism, projects like these must have been curious fuel for the imagination.

Stalin's particular vision for the geoengineering of Russia did not survive him, and after his death in 1953, Soviet leaders chose a new route for a major irrigation canal from the river Amu Darya and across the Karakum Desert in Turkmenistan. Completed in the 1980s, the canal stretched 857 miles in length, an "artificial river" that got its start in a 1907 engineering scheme (Zonn, 2012). In the 1990s, independence of the Central Asian states required an overhaul of water management institutions, as land reforms abolished the organizational structures of collective farming. The new governments issued mandates for thousands of water users associations to be formed to take up water infrastructure operations, but these associations amounted to little more than paper jurisdictions lacking means to improve water governance (Abdullaev et al., 2010). The result was an institutional puzzle, with farmers self-organizing in the attempt to manage critical water infrastructure, international agencies heavily promoting institutional models like irrigation management transfer and integrated water resources management, and state authorities focused on engineering problems (Froebrich & Wegerich, 2007).

Similarly, it took nearly a century to build the Central Arizona Project canal system, nascent in the first designs of the people of Arizona in their bid for statehood at the turn of the 20th century, but beginning in earnest in the 1940s with Carl Hayden and the Arizona Congressional delegation's several-decades-long lobbying effort. When the

project was authorized in 1968, the 336-mile span from Parker Dam on the Colorado River to Tucson, near the Mexican border, was heralded as just the first step in a Pacific Southwest water infrastructure that would ultimately "last for a thousand years" (Coate, 1995, p. 93). Yet, well before construction was complete in 1993, the inability of the state's agricultural producers to afford water from the project—long projected by economists—had at last become a widely-acknowledged crisis (Martin et al., 1982). The hard-fought marvel of engineering was something of an institutional question mark, as the threat of irrigation district bankruptcies revealed an intractable tangle of newly created intra- and inter-sectoral interdependencies (Wilson, 1997). In response, a remarkable plurality of water governance institutions emerged to support a singular piece of water infrastructure.

Arguably, the most enduring products of long-term thinking haven't been planned at all. Some of the oldest and largest infrastructure systems known in the world are freshwater aquaculture technologies, like the Sebasticook fish weir complex in Maine, USA, and the Gunditjmara traditional aquaculture system at Budj Bim in Victoria, Australia (Petersen et al., 1994; Rose et al., 2016). Though such infrastructures took considerable labor and cooperation to construct and maintain, for which people certainly planned and strategized, there was no plan for them to operate as they do today, some 6,000 years later. This distinction between short-term plans and long-term outcomes is itself an artifact of systems constructed, not to satisfy the purpose of a single commanding vision, but to meet the many contingent purposes of people working together in a rivalrous resource landscape. Other sites of long-enduring water infrastructure, the Indus civilization cities of Harappa and Mohenjo Daro (c. 2600–1900 BC), are thought to be the product of heterarchical and egalitarian collective action,

sufficient in its time to support construction of elaborate pools, private wells and baths, water drainage systems, and urban architecture (Green, 2020). A system of common weights and measures across the cities suggests productive cooperation and competition between heterogeneous political and social groups, facilitated by overarching institutions and abundant, small, public spaces (Green, 2018). Abrupt change in the environmental flow of water is a primary threat to such coupled social-ecological infrastructure systems; in contemporary contexts, this includes disruptive impacts of large-scale state water and drainage projects (for Budj Bim, see, e.g., Rose et al., 2016). Still other examples of long-enduring water infrastructure have been more or less continuously maintained, and today lie underneath and embedded within current systems.

Ostrom (1990) chose these kinds of environments for her foundational study of processes of self-organization and self-governance, including systems like the *huerta* irrigation institutions of the Segura, Turia, and Monnegre rivers, in Spain, and the *zanjera* irrigation of Ilocos Norte, Philippines, which endured for hundreds of years. Records show these systems relied on reciprocal monitoring and public, peer-based adjudication of conflicts to achieve high levels of rule conformance, and as a result, irrigators were largely able to avoid chronic conflicts (E. Ostrom, 1990). This led me to wonder: could a bottom-up approach to large-scale water infrastructure yield a thesis on peaceful, positive hydraulic anarchy, at least as instructive in approaches to cooperation and collaboration as Wittfogel's thesis was on despotic social control?

Fennell (2011) gives Ostrom's Law as: "A resource arrangement that works in practice can work in theory." There is general skepticism that self-governance works *anywhere*, least of all in water resource systems. As a hypothesis-building exercise, insights into the practices of self-governance in large-scale water infrastructure systems

would show that self-governance works *everywhere*. After considering study sites from California and the Colorado River basin to Uzbekistan and the Aral Sea basin, my final inspiration for this thesis came from environmental social science colleagues working outside these regions altogether. They described the combined challenges of translating survey instruments and concepts into local languages and engaging with local water users to learn how systems are governed. Measuring governance, I grew to appreciate, requires a kind of triangulation between the analytical constructs important to researchers, the experiences of people in a governance situation, and the institutionalized narratives, or rules on paper, about how systems are or should be operated. Successful long-term thinking is made up of repeated decisions, in contexts that can only be known to the decision makers themselves, but which create enduring results in the institutions and social expectations of a group of people. Learning about these processes, I determined, would require grappling with the subjective and individual nature of decision making. It is an axiom among institutional scholars that self-governance happens "from the bottom up." Alternatively, some visualize that self-governance and self-organization happen from within—that is, among peers inside a group. In that case, each of us is an outsider to some governance arrangements which we would benefit in the long term from understanding; this is the task of learning about self-governance from above.

This dissertation proceeds in three parts to address interrelated questions: what should be operationalized in a definition of polycentricity; how should we measure polycentricity; and, why might diagnostic measures of polycentricity matter in practical applications? In Chapter 2, I address the question of operationalizing dimensions of polycentricity, first by tracing the historical development of the concept through

foundational writing about polycentricity, and then by animating those dimensions through a water infrastructure paradigm. I argue for a more multifaceted operationalization of polycentricity than has been typical thus far in institutional scholarship—understanding measurement of polycentricity as neither a matter of absolute presence or absence, nor a matter of degrees, but rather as a matter of opportunities to engage productively in processes afforded to actors by institutional structures. In particular, I use the paradigm of water resources to show how choices with contingent outcomes between autonomous authorities, and feedbacks between variously overlapping jurisdictions, might be experienced by operational actors in complex water governance contexts. I build on these observations in Chapter 3 by proposing a set of diagnostic conditions for measurement of a "polycentric workplace." I test the proposed measures through qualitative comparative data analysis of a survey of water operators in several operational centers in the Arizona water system. This actor-centered approach, while complicated by issues of data collection quality and quantity, attends to the potential sensitivities of operators in polycentric decision making contexts to both information about changes in the biophysical resource as well as the meanings and purposes of shared institutional governance arrangements. I argue for a diagnostic approach to measuring polycentric governance and decision making processes that emphasizes the quality of actors' interactions and their perceived opportunities to achieve the goals they have identified for themselves. Application of these approaches could facilitate operational actors' shared understandings and sense of common purpose toward improving governance outcomes, which otherwise are conditions of polycentric governance that can be vulnerable to breakdown. Finally, in Chapter 4, I use the Arizona water system as a case for exploring the meaning of patterns of cooperation,

competition, conflict, and conflict mitigation between three juxtaposed discourses: the prominent narrative of “water wars” in historical and current news accounts of water governance in Arizona; the language related to polycentric governance and decision making that is conceptually important to institutional scholars; and interpretations of the causal explanations offered in Arizona water operators’ descriptions of their work and the system in which they work. Comparison of these perspectives shows little concurrence between these three ways governance of the Arizona water system might be understood. However, the divergence in causal explanations and narratives underscores the potential utility of using diagnostic approaches to elicit understandings of complex resource governance problems that are sensitive to polycentric contexts. Most importantly, the combination of an actor-centered approach and a focus on dynamic processes and affordances within polycentric governance provides potential insights into how operational responses to changes in decision making contexts can drive institutional adaptation within complex social-ecological systems.

CHAPTER 2

OPERATIONALIZING DIMENSIONS OF POLYCENTRIC GOVERNANCE THROUGH A WATER INFRASTRUCTURE PARADIGM

1. Introduction

Water governance is contrary: water is finite and abundant at the global level, seasonal and uncertain at a local level, and water use is, counterintuitively, simultaneously competitive and cooperative. Local and regional water use rules that have emerged around the world undergird a diverse array of historically stable and sustainable water use regimes, but at the national and international levels water governance principles are contradictory. There is no set of best practices in water governance that we can delineate from a survey of water governance as a whole. As a broad generalization, water governing authorities tend to be small, numerous, and—as I will discuss in depth—trend towards polycentricity. Since the institutional turn that has marked discourse about water governance, international policy, and politics from the 1990s forward, the supply-side, state-centered approach to water resources development and management has been largely set aside, with an inconsistent heterodoxy rising in its place.

For an example of this contradictory state of current affairs, consider two of the four principles that guide international water resources management formalized in the 1992 Dublin Statement on Water and Sustainable Development that speak to the ideal form of water governance. The first principle states that effective water resources management requires a *holistic approach* at the level of the catchment area (watershed/basin) or groundwater aquifer. The second principle states that water resources management should be based on a *participatory approach*, with decisions

made at the "lowest appropriate level" (International Conference on Water and Environment, 1992). This first approach has been taken up in the subsequent decades' policy emphasis on integrated water resources management (IWRM) and, more recently, "nexus" approaches, which advocate water governance within an integrated multi-sector framework (Benson & Rouillard, 2015). Meanwhile, the second, participatory approach—governance based on certain principles of subsidiarity and devolution—has been enacted in irrigation management transfers from state agencies to water users associations or, more minimally, co-management schemes (Garcés-Restrepo & Vermillion, 2007). The two principles are seemingly contradictory because a governance system optimized according to one approach would be deficient as measured by the other.[1] If a system of governance is holistic at the level of the watershed, then the lowest appropriate level of decision making must likewise be at the watershed level. But how do water users operating at the farm or irrigation district level meaningfully participate in governance at a hydrologically holistic scale? Alternatively, if sectoral coordination is deemed the highest value and water governance must be integrated with governance of other resource domains like energy and food production, then the hydrological scale is necessarily subsumed under market forces and policymaking by technocratic elites. How do local water operators meaningfully participate in global markets and economy-wide natural resource planning processes?

Contradictory and competing institutional arrangements are a feature of water governance, not a problem to be solved. Empirically, as Huitema et al. (2009) have

[1] The Dublin Principles aren't the only example of such formal contradiction in international law; the UN Watercourses Convention, which pertains to transboundary water resources, for example, aims to promote both "equitable and reasonable" use of water while preventing "significant harm" to water use of co-riparians.

written, researchers might agree that all water governance systems are polycentric, "but in different degrees and in different ways."

All polycentric systems of order are, in turn, "subject to counterintentional and counterintuitive patterns" (V. Ostrom, 1991, p. 243). Many empirical questions about variations in polycentric governance have been posed in recent scholarship aimed at setting a research agenda in institutional analysis (Carlisle & Gruby, 2017; Heikkila et al., 2018; McGinnis & Ostrom, 2012; Schoon et al., 2015; Thiel, 2017; Thiel & Moser, 2018). At the same time, shortcomings of recent water governance reorganization initiatives such as irrigation management transfer and the creation of new basin organizations might be understood, in polycentric terms, as ineffectual forms of authority, jurisdiction, and institutional choice. I argue that, for practitioners and scholars of governance, water governance systems should be considered the fundamental or paradigmatic test case for questions about polycentricity.

The following section reviews the normative case for polycentricity as it informs the empirical tasks of describing and measuring variations in governance systems, including the hypothetical benefits of polycentric governance and the mechanisms by which beneficial outcomes are produced in polycentric systems. The subsequent section considers strengths and weaknesses of the contemporary, largely diagnostic, agenda in the scholarship of polycentric governance. Finally, I demonstrate how definitional dimensions of polycentricity are illuminated when applied to water governance generally, and irrigation governance in particular, because of specific features of these coupled (socio-technical, or social-ecological) infrastructure systems. When practitioners and scholars can measure meaningful dimensions of polycentricity in irrigation systems, we can improve the science of self-governance at all scales and levels of heterogeneity.

2. Polycentric Processes and Polycentric Outcomes

The concept of polycentric governance has had both normative and positive (that is, empirically real) importance from its beginnings in public administration and political economy scholarship leading up to and through the Cold War. Today, institutional scholars are familiar with the formulation of polycentricity originated by Charles Tiebout, Vincent Ostrom, and Robert Warren in an article first published in *The American Political Science Review* (V. Ostrom et al., 1961) which defined a *polycentric political system* as a system "composed of (1) many autonomous units formally independent of one another, (2) choosing to act in ways that take account of others, (3) through processes of cooperation, competition, conflict, and conflict resolution" (Ostrom, 1991, p. 225). The principal case of polycentricity that Ostrom, Tiebout, and Warren were concerned with at the time was metropolitan government, though they immediately clarified that the concept was "equally applicable to regional administration of water resources" and other situations (V. Ostrom et al., 1961, p. 831).[2] Predating this use of the term by a decade, Michael Polanyi offered the first definition of the concept when he coined the terms *polycentricity* and *polycentric problem* to describe how the self-coordination that Adam Smith had observed in markets was also present in other dynamic systems (Polanyi, 1951). Polanyi was principally concerned with intellectual spontaneous orders (e.g., arts, sciences, and law), but he wrote in close concert with his contemporary, Friedrich Hayek, who extensively developed the theory of spontaneous orders in broader society and nature. Ostrom (1972) reflected that the rule-ordered nature of polycentric systems was an important aspect neglected in his original

[2] The term *polycentricity* has a separate, mostly unrelated, meaning in study of patterns of urban growth. (Cities of the Indus civilization have been described as "polycentric" in both senses.)

definition but supplied by Polanyi. Polanyi defined a *polycentric problem* as a social task "which, if manageable, can only be performed by spontaneous mutual adjustment," wherein individuals and corporate actors coordinate their efforts according to their own logic, knowledge, and judgement toward a joint purpose within a given institutional framework; the processes of mutual adjustment identified by Polanyi were consultation, competition, and persuasion (Polanyi, 1951, p. 209). For Hayek, who articulated the problem to be solved by a polycentric system as a *knowledge problem*, the focal processes were those by which an individual could form, act on, and revise expectations based on their situated knowledge and the rule of law (Hayek, 1945). Hayek's conception, while consistent with the others, also emphasized processes like learning, imitation, disappointment, and accident as experiential and experimental parts of organic institutional emergence. These independently-originating concepts of polycentricity—emphasizing, in turn, organizations, communities, and individuals in society—are important to consider together, as they each bring different strengths of emphasis.

An important similarity in these two origins of polycentrism—from Polanyi and Hayek on the one hand, and Ostrom et al. on the other—is that both were formulated in reaction against centralizing, authoritative movements in public administration. Polanyi was inspired to oppose the instrumentalist ideas motivating certain Marxist totalitarian efforts to direct science to technological applications useful to the state. He feared that a society without polycentric pursuit of truth, justice, charity, and tolerance through pure science and academic freedom in law and the humanities would be morally bankrupt. To Polanyi, tacit knowledge—the situated, intuitive knowledge that can only be shared within a community of practice—was so indispensable to these pursuits that central

planning was impossible, “in the same sense in which it is impossible for a cat to swim the Atlantic” (Polanyi, 1951, p. 154; see also, Polanyi 1966). (The fact that it was impossible did not lessen the threat that it would be tried.) Hayek, likewise, was concerned about the rise of totalitarian governments during World War II and the continued global interest in centrally-planned economies in the decades that followed. His conception of economic policy was as “a problem of how to secure the best use of resources known to any of the members of society” (Hayek, 1945, p. 520). Since the practical knowledge required—the knowledge of particular circumstances of time and place, including local conditions—was fundamentally dispersed through society, it was in other words, “a problem of the utilization of knowledge not given to anyone in its totality” (Hayek, 1945, p. 520). Though a small organization, like a household or a corporation, might deliberately plan an economy, Hayek argued that more complex orders, like society, could only grow and progress through institutions supporting the formation of spontaneous orders (Hayek, 1973b). Ostrom, Tiebout, and Warren advocated for studying the advantages in providing public goods at appropriate scales instead of labelling polycentric metropolitan regional assemblages as “pathological” and prescribing a centralized government system in their place. Ostrom (1991) in particular wrote out of concern that the strengths of constitutional and federated government might be eroded in the United States, wary a rise in autocracy after the end of the Cold War. Aligica and Boettke (2011) argue that the fundamental fallibility of decision makers in Ostrom’s view reinforced the need for polycentrism and the opportunity inherent in it to learn from mistakes, which in turn reinforced the need to study polycentrism. Thus, from their perspective, Vincent Ostrom’s joint research program with Elinor Ostrom in polycentricity is notable as a contribution to the field of positive anarchy studies—a topic

otherwise best known for normative literature (Aligica, 2014). While Ostrom, Tiebout, and Warren focused on the threat to heterogeneous provisioning and production at appropriate scales, and Polanyi and Hayek focused on the threat to knowledge situated in communities of productive practice, all supported polycentric systems as fundamental to social welfare.

We can also find the disputes between these two originating schools of polycentric thought illuminating, especially as they resolve what might appear superficially to be a paradox inherent in normative polycentrism, namely: the prescription against prescriptions. Ostrom objected to Polanyi and Hayek's uses of the term "spontaneous" to characterize polycentric systems, because it implied that "a development has occurred without the intention of those involved," when, to the contrary, "polycentric systems of order depend upon a good deal of deliberateness in their creation, operation, and maintenance over time" (V. Ostrom, 1991, p. 226). The point is important because it connects *processes* of polycentric governance with the *outcome* of spontaneous order. And indeed, when we consider polycentricity in terms of processes and outcomes, rhetorical disagreement appears to dissolve between the two camps. (Though, as Ostrom, Polanyi, and Hayek would also remind us—the meanings of words matter.) Elsewhere, Ostrom accepted Polanyi's use of "polycentric" and "spontaneous" as synonyms because, as he reflected, self-generating and self-organizing ordered relationships could be viewed as a defining characteristic of polycentricity (V. Ostrom, 1972). For his part, Hayek, in later years, agreed that the terms "'self-generating order' or 'self-organizing structures' are sometimes more precise and unambiguous" than "spontaneous order," and appreciated that the term *system* had become a useful synonym for "order" (Hayek, 1973a, pp. xviii–xiv).

Polanyi described the relationship between deliberate and spontaneous tasks (he also used the word "dynamic"), as coexisting but mutually exclusive, combining by "each fitting into a gap left open by the other" (Polanyi, 1951, p. 192). Thus, while a single given process cannot simultaneously be polycentric and non-polycentric, the system that emerges can be the result of both polycentric and non-polycentric processes. Polanyi (1951) also went a step further, by specifying that deliberate and spontaneous orders are not mutually exclusive because mutual, self-coordinated adjustments are always occurring between individuals; the distinction of a system of deliberate, hierarchical, authority is that the actions of subordinates are not determined by mutual self-coordination overall. The inverse—a comprehensively polycentric order that encompasses non-polycentric processes—is evoked in turn by Hayek (1973b). Households, corporations, governments, and other organizations are examples of predominantly deliberate, directed, exogenous orders; coordination between such organizations, and between individuals, is due to the endogenous, self-generating, polycentric processes that "grow" an encompassing spontaneous order (Hayek 1973b).[3] Further, Hayek describes three types of rules—what Crawford and Ostrom (1995), in their institutional grammar, would later formalize as shared strategies, norms, and rules—and distinguishes these rules from commands. Hayek observes that as both types of order can result from rules that are themselves either deliberately designed or evolved, institutional origins must be distinguished from their results (Hayek 1973b). Polycentric orders, in his view, can be improved by revising their underlying rules or constituent organizations, but not by commanding certain results. These distinctions of process and

[3] This point about the non-exclusive interplay between monocentric and polycentric orders was reiterated by Ostrom (1972).

outcome would ultimately form the basis of a theory of justice for Hayek, but for our purposes here, they complete and unify the conception of polycentricity as pertains to process and outcome in these independent schools of thought. Taken together, this basic ontology of polycentricity also resolves what would otherwise appear to be self-contradictory expressions—the polycentric *prescription against prescription*, and related *governance without government*, and *rule without rulers*—as distinctions between process and outcome. Polycentric systems are rule-ordered, but when those rules are prescribed the outcomes are not, and still other institutions will arise without deliberate prescription to fill important functions (i.e., *order without orders*).

Understanding that there are both polycentric processes and polycentric outcomes, we should also examine how, or to what extent, such processes and outcomes are causally directed. As I have established, originators of polycentric theory agreed that polycentric processes could be deliberate while the outcome was not, and that while much empirical polycentrism is evident in the social world, it is also vulnerable to centralizing and authoritative or authoritarian trends in public administration. Polycentric systems are not inevitable, at least in a comprehensive or enduring sense. Part of Ostrom's (1991, p. 240) objection to the term "spontaneous" hinged on this point, as he wrote about examples of polycentric orders such as markets and competitive political systems being vulnerable to strategies by a few to seek dominance over others: "Spontaneity is not a sufficient condition for the maintenance of polycentric systems of order. A self-governing people need to understand when failures occur and how to reform their systems of order" (see also V. Ostrom, 1973, 1997; V. Ostrom et al., 2008). The origins of polycentric theory are all based on methodological individualism, meaning that individual actors, households, and corporate actors are assumed to be the causal

agents of social order.[4] In coupled systems like large-scale water infrastructure, biophysical conditions are instrumental in patterns of polycentricity, but not fully determining—otherwise there could be no concerns about social direction. Wittfogel (1957) conducted an important normative study in this respect, because though he set out to compare historical large-scale water infrastructure development as a refutation of Marxist unilinear material determinism, his theory of totalitarian bureaucracy in "hydraulic society" is widely understood as an argument in favor of environmental or geographic determinism.[5] Strictly deterministic narratives are easily contradicted by their exceptions, as Wittfogel has been contradicted in the domain of water governance (Hanemann, 2006; Tang, 1992), yet other experts in water governance have found the premise of Wittfogel's work a useful point of departure (Meinzen-Dick, 2007; Molle et al., 2009).

Wittfogel worked during what geographers have described as an era of "cultural possibilism," succeeding the environmental determinism of the early 20th century and preceding scholarly thinking in terms of systems, behavioralism, and structuralism which persist into the present (Judkins et al., 2008), and his theories are consistent with this milieu. He begins by observing specific physical characteristics of water relative to other agricultural inputs—it is heavy, made mobile by gravity, and bulky—and the fact that water is unevenly distributed on the landscape. Historically, he reasons, moving

[4] For the sake of the current discussion, I take a realist perspective on methodological individualism: individual agency (and the analysis of such agency through actor-centered approaches) is epistemologically useful and seems to be evident in real-world phenomena. Other scholars of polycentricity have found proximal analyses, such as transaction cost analyses, useful (see, e.g., Mewhirter et al., 2018), especially in a networked governance context.

[5] Price (1994) argues that Wittfogel's thesis is oversimplified and misunderstood; in different versions of Wittfogel's typology of hydraulic societies he allows that some conditions favor development of decentralized "hydroagricultural" systems.

large quantities of water for use in agriculture required large, coordinated labor forces. A central authority capable of coordinating such a labor force has "the opportunity, not the necessity" of engaging in despotic government and managerial absolutism (Wittfogel, 1957, p. 12). Wittfogel (1957) emphasizes that institutional and cultural factors are primary in the collective choice to transform built water infrastructure, and that neither environmental conditions (too much or too little water) nor institutional conditions (governmental control of water) determine a despotic outcome, demonstrating the embeddedness of his theory in the milieu of cultural possibilism. However, while not deterministic, his account of "failures" in development sequences belies assumptions about the direction of institutional evolution—from, for example, rainfed agriculture to irrigated agriculture, or from construction of irrigation infrastructure to use of this infrastructure for navigation, drinking water, other public interests, and structures of the authoritarian state, including tombs and palaces. Wittfogel's work was grounded in a sociology that viewed feudal institutions, elevated in part by rainfed agriculture, as a precursor to industrial development and liberal society (see, e.g., Wittfogel, 1957, pp. 414-418).

Many critics have found fault with Wittfogel's historical accuracy; if we wanted to be generous, we might conclude that his central concern about despotic path dependencies made him overlook exceptions to his thesis. Wittfogel qualifies his grand narrative with implausible stipulations, such as, in turn: institutional conditions being equal, historical conditions being equal, or natural conditions being equal. When he finds diversity in these conditions, he is quick to dismiss it as inconsequential to the analysis of totalitarianism, and thus his examples become teleological. Some of these errors no doubt can be attributed to bad data, some to ideological bias, while others

might have been avoided if Wittfogel had the analytical tools for institutional analysis that we have now. It is worth reconciling these premises of Wittfogel's comparative work on large-scale resources with the analytical assumptions developed by the Ostroms and their colleagues at the Ostrom Workshop and formalized as the Institutional Analysis and Development (IAD) framework (Kiser & Ostrom, 1982). Both analytical frames put individual choice at the center of explanation, where decisions are constrained by institutional, biophysical, and community contexts. Where Wittfogel grappled with a directed, dialectical transformation of coupled human-environmental systems, the IAD framework posits uncertain linkages of individual actions to outcomes through institutional and biophysical transformation, creating feedback into subsequent choices and into the decision making contexts of other actors in the same domain (Anderies et al., 2004; Kiser & Ostrom, 1982). Yet, concerns articulated in Wittfogel's theory of hydraulic bureaucracy about the fundamental nature of water resources development and management, his view of water infrastructure provisioning as essentially an organizational problem, and, in particular, the scales at which such social-environmental transformations must occur, are important to carry forward into our discussion of large-scale water infrastructure as paradigmatic of polycentric systems.

3. The Polycentric Agenda

Perhaps as a result of the unresolved tensions between normative and empirical inquiry in earlier scholarship on polycentricity, contemporary scholarship on polycentricity tends toward diagnostic applications (see Chapter 3). Wittfogel's (1957) effort was taxonomical at the same time that it was normative, because his hydraulic theory tried to explain why some patterns of development did not result in the open, multicentered societies that were familiar and valued in Europe and the western world.

Contemporary scholarship on water governance has, at times, shown uncritical normative commitment to governance as represented through trendy managerial schemes—showing, for example, "a tendency to equate 'governance' with 'management' or 'steering'" (Teisman et al., 2013, p. 3). The Ostrom school of institutional analysis, by "pivoting and functioning as a link between normative and positive theory," (Aligica, 2014, p. 22) informs the diagnostic agenda in polycentricity and potentially offers analytical tools, including the IAD framework, useful in understanding water resources from a governance perspective if we remain sensitive to the biases of this perspective.

An important starting point in contemporary scholarship is McGinnis' (2011a) work cataloging and contextualizing the work of the Ostrom Workshop. McGinnis provides an oft-cited definition of polycentricity: "a system of governance in which authorities from overlapping jurisdictions (or centers of authority) interact to determine the conditions under which these authorities, as well as the citizens subject to these jurisdictional units, are authorized to act as well as the constraints put upon their activities for public purposes" (McGinnis, 2011a, p. 171). This definition gives us the critical aspects of *autonomous authorities* and *overlapping jurisdictions* that help to differentiate polycentric governance from *federalism*—something that was important to Vincent Ostrom—while still strongly embedding the concept in the context of public administration (McGinnis & Ostrom, 2012). To be clear, it is a heterodox idea of public administration—one focused on the different scales at which different public goods can be provisioned and produced by public entrepreneurs—which McGinnis (2011a) further emphasizes by specifying that in addition to being multilevel, polycentric systems combine multiple types of jurisdictions (general/nested and specialized/cross-jurisdictional), multiple sectors (public, private, voluntary, community-based, and

hybrid), and multiple functions (provisioning, producing, financing, coordinating, monitoring, sanctioning, and resolving disputes). A weakness of this definition from a diagnostic perspective is that it favors polycentric outcomes over polycentric processes. A system with all of these characteristics could exhibit a high degree of organizational diversity and institutional hybridity without necessarily being the product of complex polycentric processes. (McGinnis has emphasized and illuminated, instead, the relevance of polycentric theory to understanding *networked governance* [McGinnis, 2011b] with an approach grounded in the IAD framework—something I will return to in the next section below.) Two-dimensional typologies derived from this definition might count the number of levels of governance along one axis and the number of types of actors along the second axis (what in some contexts are often considered vertical and horizontal dimensions, respectively). While this helps to define polycentrism as a matter of degree, and to differentiate a polycentric system from the simplest of monocentric systems—a single, absolute authority with a single, totalitarian jurisdiction—it is not as useful for differentiating functional polycentricity from fragmented chaos.[6] Polycentricity is only meaningfully studied in the context of interposed systems of predominantly monocentric order, on the one hand, and socially suboptimal discoordination on the other.

Several recent typologies of polycentricity take such a two-dimensional jumping-off point to different ends. Galaz et al. (2012) propose that the successive addition of a few generic processes transforms a "weak" polycentric order into a "strong" one. Using a network approach, they describe how the strength of network connections increases between actors who move from simple information sharing relationships, to formal partnerships, to tangible joint projects. A key premise is that mutual commitment

[6] For clarification of his suggested approach, see McGinnis (1999, p. 6).

and trust increases with this trajectory, which requires a costlier "investment" but also potentially higher "benefits" (Galaz et al., 2012, p. 23). Along an implied second dimension is the diversity of actors engaged in the network, with some gaining importance because of the number of formal partnerships and joint projects they engage in, but the authors also warn that large group size can increase coordination costs—so, presumably, they envision an upper limit in size. The network characteristics described by Galaz et al. (2012) are in no way unique to polycentricity as understood in the work thus far highlighted, therefore, unsurprisingly, the authors cite the federal systems of the United States and the European Union as examples of "strong" polycentric orders (p. 24). (Indeed, it is only this formally federated order that they consider sufficiently institutionalized to be considered a polycentric *system*. Ostrom, Tiebout, and Warren also distinguish a polycentric system from polycentric *order*, but their distinction maintains formal independence of authorities.)

Schoon et al. (2015) provide an example of a *polycentricity of degrees* which more directly carries forward the definition of polycentricity from McGinnis (2011a) quoted earlier, while building from Galaz et al. (2012). To the weak-strong dimension defined by increasing formality, commitment, and investment of relationships, which Schoon et al. (2015) term *collaborative degree*, the authors add concepts of modularity and connectivity, both apparent measures of the subsidiarity of relationships. (Subsidiarity seems to have two counterbalancing effects in this conceptualization, as a high degree of modularity allows for experiments to fail safely, while a high degree of connectivity provides a reserve of institutional redundancy to borrow from.) They also endeavor to emphasize the ways in which polycentric orders uniquely deal with issues of scale, through enabling experimentation, participation, and other processes that improve

institutional fit. To that end, Schoon et al. (2015) count a second dimension, *breadth of inclusion*, as increasing numbers of centers of authority. This dimension—as opposed to counting the numbers or diversity of actors engaged in the polycentric order—measures the degree to which decision-making authority is devolved to the lowest appropriate level.

A yet more fully-realized operationalization of two-dimensional polycentricity is provided by Pahl-Wostl and Knieper (2014). Noting the inadequacy of some contemporary attempts to apply polycentric theory as practice—in particular, those that equate polycentricity with decentralization by neglecting the role of overarching rules in coordinating polycentric authorities—the authors set forward an institutional performance analysis that distinguishes governance regimes based on their degree of coordination and centralization. On this continuum, a regime is only polycentric if it is both highly coordinated and highly decentralized; a regime with low coordination and high decentralization is considered "fragmented," while the opposite is "hierarchical" (Pahl-Wostl & Knieper, 2014, p. 141). Testing this operationalization of the polycentric continuum hinges on definitions of coordination, and whether coordination can be measured in a way which includes the many processes of mutual adjustment that are recognized in polycentric theory. Another operationalization of polycentricity that emphasizes the degree of coordination is provided by Thiel and Moser (2018), who pair coordination with either *alternate* or *duplicate* models of the provision or production of a good, based on the production characteristics of that good.

Aligica (2014, citing Goertz, 2007), attempting to generalize a definition of polycentricity for application to a wider range of social phenomena, suggests that a logical structure of polycentricity be understood through its *attributes* and *indicators*.

The attributes of polycentricity comprise its three basic features: "(1) many overlapping centers for decision-making, (2) a single [overarching] system of rules (be they institutionally or otherwise enforced), and (3) a spontaneous social order as the outcome of an evolutionary competition between different ideas, methods, and ways of life" (Aligica, 2014, pp. 56–57).[7] The indicators of each attribute make the proposed logical structure a diagnostic typology. So, for example, as regards the first attribute, two proposed indicators are necessary conditions for polycentricity: the multiplicity of decision-making centers must actively exercise diverse preferences, and the overlapping decision-making layers must be individually autonomous. Without the first condition, the system is only notionally polycentric; without the second condition, the system is hierarchical (Aligica, 2014). As an indicator of the overarching system of rules, the second attribute, Aligica proposes a last necessary condition of polycentricity: the rules must be considered useful to those who are subjected to them. Without this perceived incentives compatibility, the rules break down and a polycentric system degenerates into violent anarchy (Aligica, 2014). Several other indicators are offered as a matter of assessing degrees of and vulnerabilities of polycentric systems, consistent with Aligica's view of polycentric systems as productive, peaceful anarchies existing on a continuum between monocentric systems and chaotic, violent anarchies. This last conceptualization of the continuum of polycentricities and their pathologies is the one that most meaningfully addresses governance processes unique to polycentric systems as conceived by foundational scholars. It captures a key characteristic of the Ostrom (1991) definition of polycentricity neglected in some later work: formally independent social

[7] Aligica (2014) uses the term "evolutionary" synonymously with "trial-and-error" to describe emergent outcomes; as this is not "evolution" in the strict sense, we might also substitute the term "adaptive" to describe these processes.

actors *choosing* to act in ways that take others into account. An effective operationalization along similar lines is provided by Carlisle and Gruby (2017) in their theoretical model of polycentric governance of commons, however, their focus on adaptation, institutional fit, and risk mitigation has a more managerial emphasis.

Attempts to make sense of polycentricity as mere "multi-centeredness" without collective choice or collective action, grafting the concept onto familiar federal institutional structures or overlaying it on international management regimes, misses the important distinction between polycentric processes and polycentric outcomes that I have tried to illustrate thus far. Moreover, such approaches miss the ways in which processes of self-organizing and self-governing are believed to improve governance outcomes—the belief that motivated both the normative and empirical efforts of the originating polycentric theorists. To illustrate this part of the polycentric agenda, we can focus on the second-order processes that are afforded by the fact that polycentric systems are ordered polycentrically (see, e.g., Aligica & Boettke, 2009). These second-order affordances of polycentric systems include *forum-shaping* and *forum-shopping* (McGinnis, 2011b) or *scale-shopping* (Schoon et al., 2015), *level-shifting* (E. Ostrom, 1990), solving the paradox of rule enforcement, and self-correction. The opportunity for actors to shape forums for governance decision making is also reflected in adaptive co-management and participatory management schemes (Huitema et al., 2009), but polycentric systems do not limit such opportunities to a single, sanctioned forum—polycentricity entails co-production, co-management, and other meaningful participation in governance at multiple levels. As Pahl-Wostl et al. (2007, p. 5) aptly reflect, "effectiveness and legitimacy are related": the opportunity to participate at a relevant scale improves the legitimacy of the process, and presumably

overall acceptance and compliance with the outcome. The opportunity to move the decision to a new forum helps stakeholders bypass procedural roadblocks thrown up by tyrannical, corrupt, or otherwise unwilling participants while also matching the scale of the problem to the scale of the solution (Aligica & Tarko, 2014). Scholars have especially focused on forums for the governance functions of provisioning and producing, where, for example, polycentric affordances might take form through *exit* and *voice* (Thiel & Moser, 2018), or through "contracting up" and "contracting down" (Pennington, 2013)—however, forums for other governance decisions are also important. Through co-production, polycentric systems uniquely solve the *paradox of rule enforcement* that makes monitoring functions in hierarchical systems costly and ineffective (Aligica & Tarko, 2014). When monitoring is performed by third parties through subsidiary relationships, the monitors themselves require monitoring; when monitoring is performed by self-organized peers, incentives to uphold the rules are reciprocal. If rule-making is self-organized, this incentive structure is, itself, a result of collective choice, or the co-production of rules by appropriators. Self-organized rule-making, monitoring, and enforcement together create a potential surplus, as stakeholders with local knowledge are better able to promulgate rules that fit the particular context, those rules are easier to monitor and enforce, and resulting gains are retained within the group (E. Ostrom, 1990). Self-governance in polycentric systems will not always result in optimal institutional arrangements, but because polycentric processes make affordances for *self-correction*, reflexive improvement is possible (Aligica, 2014).

The affordances that are created in a predominantly polycentric system, where the internal logic is one of choice, could be considered pathologies in a predominantly monocentric system, where the internal logic is one of power (see, e.g., Aligica & Boettke,

2009). So, for example, in a study of fragmentation in various international institutions, loss of reliability and credibility are seen as negative effects of the absence of a single unitary system of international law, while the polycentric aspects of the same system have the positive effects of increasing the legitimacy and rule compliance (Hafner, 2004). We can also see how these competing internal logics can result in an unstable, "ongoing tension" while "one area or domain opened to polycentricity encourages polycentricity. . . . one area or domain opened to monocentricity drives monocentricity in other domains" (Aligica, 2014, p. 51). Polycentric systems are not inevitable, but neither are they escapable in their entirety. The example of water resources governance, taken from the perspective of water users with powerful but highly contingent autonomous decisions to make, helps to illustrate this point.

4. Water Systems as a Polycentric Paradigm

Common-pool water resources were used as an example in the initial definition of polycentricity from Ostrom, Tiebout, and Warren (1961) and explored in several of the most important polycentric case studies conducted thus far (e.g., Huitema et al., 2009; Heikkila et al., 2011; Pahl-Wostl & Knieper, 2014). Applications in the natural resource regimes in which the need for polycentric governance is thought to be most dire—for example, global climate change and international marine resources—has been fraught with difficulty. In Wittfogel (1957) we see a rare comparative study of historical water resource governance regimes that considers whether the attributes of water resources may, to some degree, determine the possible variation of institutional arrangements fitted to the resource—and, as we know, his conclusions do not support a polycentric approach. In this final section, I explore how the social-ecological characteristics of watersheds and socio-technical characteristics irrigation systems substantiate

polycentric theory in ways that other resource domains do not.

Water is one of the most critical resources in the world without well-developed markets—particularly the vast quantities of water used for agricultural irrigation, the largest category of water use by people globally. Water systems—especially those afforded by natural infrastructure—are often conceptualized as common-pool resource regimes, characterized by rivalry and the threat of over-exploitation. Infrastructure constructed for water management is often conceptualized as a type of "weakest link" public good (Cornes, 1993, citing Hirshleifer, 1983)—or, in the case of some of the biggest public works projects in the world, public goods that avoid "weakest link" issues only through government provisioning. A weakest-link public good is one where the availability of the public good is equal to the smallest contribution to the public good, as opposed to a sum of all contributions (Cornes, 1993). Still other water resources are treated as private or club goods (V. Ostrom & Ostrom, 1977). The production of water quality, however the good is consumed, has been characterized as "discontinuous," because below a given quality threshold consumers will seek an alternate source (Thiel & Moser, 2018). The prevalence and complexity of hybrid institutional arrangements will likely only increase with the accessibility of technologies for cleaning and transporting water for economic purposes. At the same time, non-economic values of water resources, from wildlife habitat to the "blue space" of canals and fountains, is increasingly enumerated for public policy (see, e.g., Grellier et al., 2017).

Using an institutional approach, the entry point into a systematic consideration of large-scale water resources as a polycentric paradigm is the position of individual water users in a water governance system. The position of every individual in a water system is different. These differences in position are not only a product of experience and

the tacit knowledge which contribute to heterogeneity of preference among individuals in a market system, and the differences of position are not only an artifact of the institutional structure, as they are when institutional positions are prescribed through subsidiarity in a hierarchy. Rather, the differences are fundamental to the fact that water resources are always in motion, or with high potential for motion, from one position to the next. As such, the people in those positions have different experiences but also different expectations. Because individual expectations for use of the resource are different and the resource is rivalrous, these expectations are contingent on the behavior of other users of the resource; that is, users' expectations must account for the actions of others. The pattern of contingency is asymmetrical from upstream to downstream (to such a degree that we use those words for any resource that moves like water), and may also produce nested externalities (Mewhirter et al., 2018; E. Ostrom, 2012). Such a system is vulnerable to upstream stationary bandits unless institutional arrangements are made to incentivize reciprocity.

We see institutions in agriculture that reflect how farmers have chosen to take other farmers into account, such as systems of traditional or customary land tenure that distribute an individual farmer's land throughout an agricultural catchment (e.g., a strip-field system). Some institutions define reciprocity between users based on their physical position in the system. Often, institutional incentives for reciprocity take form in self-governing and self-organizing water users' associations. In some water districts, including many irrigation districts, previously private water infrastructure, including wells, conveyance structures, and water storage impoundments, can be pooled to increase efficiency (e.g, running only the number of wells needed to meet demand, drawing only from the most efficient wells, conjunctive management of surface and

ground water resources), to improve water quality (e.g., blending water sources) or reliability of water delivery schedules (e.g., running canals at capacity to minimize time delays in conveyance), or to distribute costs and provide cost-sharing mechanisms (e.g., for rehabilitation of wells, purchase of special farm equipment, infrastructure upgrades like lining canals). Then, partly as an historical accident—the fact that downstream parts of water catchments globally tend to have been developed for agriculture first in time (Beaumont, 2000)—some localities develop institutions like *first in time, first in right* that position users "upstream" or "downstream" in time as well as geographic space.

Use of water resources is rivalrous, but usually not fully rivalrous on a unit-to-unit basis, because not all water use is fully consumptive. Agricultural water use, in particular, tends to have a lower rate of consumption among consumptive water uses, because some time after farmers divert water for use, water not taken up in the crop or lost through evaporation is typically returned to the system (indirectly, as through percolation into the aquifer, or return flow to surface waters, or more directly in backflow through irrigation infrastructure). As a result of institutional arrangements, public goods and positive externalities are generated by flow from the position of junior water rights holders upstream to senior water rights holders downstream, and many beneficiaries in the system have an incentive to protect these rights. Public goods aspects of irrigated agriculture may contribute to institutions that treat farming implicitly as a public interest enterprise (e.g., water subsidies and farm subsidies). Farmers themselves are often in a position to benefit from the success of other farmers in their own systems, setting irrigation districts up for success when they are at or near capacity, but vulnerable when users leave the system. The measurement of degree of diversity in actors in water governance systems must at least account for heterogeneity in position

along many dimensions: conveyance time and time sequence of use, patterns of contingent connectivity, physical location upstream or downstream, and additional institutional artifacts. Not all authorities in a polycentric system—organizations or other kinds of corporate actors—are end users, but all are stakeholders positioned in the system based on the logic of self-governance of the resource.

By "large-scale" water systems, I refer to systems at a high *levels* on *scales* that typically include both extensive and intensive qualities. Gibson et al. (2000, p. 218) define scalar "extent" as "the size of the spatial, temporal, quantitative, or analytical dimensions of a scale." I borrow from physics to contrast extensive scalar magnitudes with intensive properties: that is, qualities that are independent of magnitude, or the amount of the phenomenon measured. Extensively large-scale systems entail high volumes of water, large geographic areas, physically big infrastructure, and other conventionally measurable properties. Natural water infrastructure, rivers, and watersheds or catchments are, conceptually, easily demarcated into smaller, nested component parts. Globally, the continental divides mark the boundaries of the fresh water drainages flowing to the planet's largest oceans, seas, and gulfs. Secondary basins can be delineated by size into a multi-level nested hierarchy of hydrologic units—in the United States, the national Watershed Boundary Dataset currently counts 22 regional hydrological units, with smaller units all the way down to 101,534 6th-order subwatershed hydrologic units (USDA Natural Resources Conservation Service, 2018). Reaches of waterways and stream segments are similarly delineated, ignoring the boundaries of administrative or political jurisdictions. The United Nations counts 263 transboundary river and lake basins, and an even greater number of transboundary aquifers (UN-Water, 2008). Despite the potential for transboundary water disputes,

nationally and internationally, such shared water resources are generally considered a driver of peace, cooperation, and environmental sustainability (Intelligence Community, 2012; Subramanian et al., 2012). The United States and Mexico, and Poland and Germany, respectively, have operated binational water treatment plants on transboundary waters; the governments of Paraguay and Brazil operate a binational hydroelectric dam. (Historically, nations at war, like India and Pakistan, and Israel and Jordan, respectively, have drafted and upheld water treaties.)

Infrastructure constructed for water management, such as canal systems, are also *hierarchical*, but not necessarily *nested* in the sense that larger organizational units are constituted from the bottom up through the federation of smaller, independent units. Ostrom (1990) gives Spanish *huertas* and Philippine *zanjeras* as examples of nested irrigation systems, but many opposite examples might be given of large-scale irrigation infrastructure built by governments with little regard to the placement of tertiary canals, as well as systems that combine both patterns. At a finer resolution, the reality of water resource systems is more complicated. As Huitema et al. (2009, p. 37) have written, "The idea of 'the' river basin suggests a certain simplicity, which in reality does not exist." Catchment basins marked on a map or delineated in a river basin compact are notional constructs; areas within basins may not be hydrologically connected, and basins may be interconnected in surprising ways. Large populations live in irrigated, endorheic basins like the areas surrounding Mexico City, Salt Lake City, the Aral Sea, and Lake Chad, where dynamics of water scarcity, flooding, and pollution compound water resource challenges. Infrastructure to drain previously closed basins and connect otherwise hydrologically unconnected basins, including interbasin water diversion using pumps, siphons, and pipes, almost by definition entails cooperation, competition, consultation,

conflict, conflict resolution, and persuasion between multiple decision making authorities.

Large-scale water systems also may perform at greater levels of intensive scale, such as managing for both water quantity and water quality, conveying water from multiple sources, wheeling or transporting water for clients who are not members of the project, making deliveries on a more exacting time schedule, and trading water rights. Wittfogel (1957) observed that in feudal societies, irrigated areas were more intensively farmed and favored more small-scale production than agriculture based on rainfall. Today, at least in the United States, the picture is complicated by overall trends toward fewer, larger farms, and a move in irrigated acres from the west to the east—at least in part due to changing climate—but the value of production of irrigated acres is still disproportionate to their total footprint (USDA Economic Research Service, 2019).

We often conflate extensive and intensive scales because we have expectations that as systems progress from local-, to state-, provincial-, or national-level organizations, water infrastructure simultaneously scales up both intensively and extensively. This is a bad assumption, particularly in a federated system, where the hierarchy of governing bodies is exclusive—a state or province is a separate entity from the assemblage of local governments within its borders, and state, provincial, and national authorities hold different jurisdictions with respect to one another. We know that international and national water systems can be quite small in comparison to local or regional systems. (Contrast that with a national electrical power grid, for example, parts of which better resemble a mesh-like network of interconnected regional grids.) A better approach to thinking about levels of governing authority is suggested by the three levels of institutional analysis in Kiser and Ostrom (1982, p. 77): the interdependent

operational level (individual strategic action in the physical world), *collective-choice level* (decision rules), and *constitutional level* ("decisions about decision rules" or rules about rules). The constitutional level is not synonymous with the national level (Gibson et al., 2000), and, especially in polycentric systems, the same actors may engage in different roles at every level—though the constitutional level is considered the "deepest" and slowest to change (E. Ostrom, 1990, p. 52). The measurement of scalar levels in polycentric systems must take into consideration not merely action on multiple scales, but both intensive and extensive scalar dimensions, and the possibility that a decision-making authority may be positioned at different levels on multiple scales.

A more nuanced conceptualization of what it means for a polycentric system to be multilevel also improves how we can understand overlapping jurisdictions. Water use rights are perhaps the simplest kind of jurisdiction in water systems, but water rights never exist without additional institutional layers (an overarching system of rules) with their own respective jurisdictions over the same resource. The measurement of degrees of jurisdictional overlap must account for both "what" (e.g., resource domains, sectors) and "how" (e.g., operational, collective choice, constitutional) jurisdictions overlap. At first glance, farmers relying on irrigation infrastructure might seem to have limited opportunity or control, but in reality farmers in many systems have choices between such infrastructures (wells, aqueducts, irrigation tanks) and may even have the flexibility to combine water from multiple types of sources—private, public, common, and hybrid. In the United States, special districts with substantial autonomy and some jurisdiction over water resources (including water supply, drainage and flood control, sewerage, and soil and water conservation) account for at least 35 percent of single-function special districts and 26 percent of multiple-function special districts (U.S. Census Bureau,

2019). The number of special districts overall is increasing, including the number of districts that cross municipal, county, and state jurisdictions. Governance functions in such systems are carried out at many levels and by many parties beyond special districts, including general governments, agencies, and private for-profit and nonprofit companies.

Jurisdictions in large-scale water systems might overlap, for examples I have discussed, because one resource crosses multiple geopolitical boundaries, because qualitative properties of the resource fall under different authorities, or because there are opportunities for adjudication at more than one level. Even in a predominantly top-down government-run irrigation system, farmers and other agents with enough capital will engage in voluntary governance activities through their own provisioning, producing, financing, coordinating, monitoring, sanctioning, and conflict resolution. In large-scale water systems, a single particular unit of water might be simultaneously managed for irrigation, navigation, recreation, hydroelectric generation, flood control, and ecological values. Meanwhile, whether recognized by legal constructs or not, water resources frequently overlap vertically in their temporary forms as ground water, surface water, and atmospheric moisture, exchanged deliberately or inadvertently through pumping, evaporation, transpiration, percolation, seepage, injection, and precipitation. It is reasonable to hypothesize that these properties of water resources often create incentives for the self-organization of overlapping constituencies of stakeholders, with or without autonomous authority to govern this resource. Other times, problematic vertical overlaps in water resources are resolved by third-party conflict resolution mechanisms, as in the U.S. Supreme Court adjudication of groundwater pumping impacts on interstate river basin compacts (Heikkila et al., 2011).

Large-scale water systems constitute some of the most enduring built infrastructure in the world, including sites on the UNESCO World Heritage List dating to the 5th century BC, like the Shushtar hydraulic system in present-day Iran or the Jing–Hang Grand Canal in China, or, even older, the 6,600-year-old Budj Bim aquaculture network in Australia (World Heritage Centre, 2019). Some complex water-governing societies, like the stateless Indus River city of Mohenjo Daro, have been neglected in comparative studies because they do not fit the narrative that associates large-scale infrastructure with hierarchy and social stratification (Green, 2020). However, governance systems associated with this kind of large-scale infrastructure do not endure unchanged. Looking forward, large-scale deployment of technologies for public and private interests ranging from rainwater and atmospheric moisture harvesting, to direct water reuse, to dam decommissioning and downsizing overbuilt water systems will, in turn, disrupt current institutional arrangements in water governance. The governance systems that emerge from this will not be monocentric. The shape they take—the "different degrees" and "different ways" in which they are polycentric—will depend on what lessons we have learned as practitioners, scholars, and participants from self-governance and self-organization.

5. Conclusions

Social theory has been plagued by misleading metaphors, from the "invisible hand" to more insidious analogies (Janssen et al., 2019). Several other contemporary efforts to operationalize polycentricity do so by analogy, but most often these have built analogies between polycentric orders and familiar modes of governance and management, such as adaptive management, federalism, or multi-level governance. In contrast, a metaphor that makes use of the resource system coupled with the

institutional system helps us to see the ontological (i.e., real) properties of polycentricity, including the way polycentric systems are constructed through choices situated in the resource landscape.

Polycentric order exists in all but the most ideal monocentric system or disfunctional chaos because self-governance and self-organization occur everywhere that individuals collectively exercise choice. This basic reality underlies the institutional focus on rules-in-use as opposed to rules-on-paper. Thus, the success of future efforts to work through polycentric analogy depends on whether analysts are attentive to the decision-making context individual actors find themselves in, rather than the idealized models given in policy playbooks. When Polanyi, Hayek, Ostrom, Tiebout, and Warren were first formulating polycentric theory, polycentrism in the real world was under attack from well-meaning administrators and bureaucrats as well as Wittfogelian despots. As Hayek wrote:

> We discover again and again that necessary functions are discharged by spontaneous institutions. If we tried to run the system by deliberate regulation, we should have to invent such institutions, and yet at first we did not even understand them when we saw them.
>
> Unfortunately, this oldest and most general result of the theory of social phenomena has never been given a title which would secure it an adequate and permanent place in our thinking. (Hayek, 1933, pp. 129–130)

The first task of the scholarship of polycentric governance was to give this reality a name that would establish the existence of a social order between total chaos and the monocentric ideal of would-be administrators and autocrats. The second task was to show that polycentric orders worked to achieve social aims, like metropolitan governance, municipal water administration, and systems of common law. The task of understanding how polycentric processes produce these outcomes is one that we are still

engaged in—that we should, as polycentric actors, continuously attend to.

It should be emphasized that the relationship between water resources and polycentric governance is not deterministic in either direction. Rather, in keeping with the agenda set by the Ostroms, we should understand that the structure of common-pool resources, public goods, and other coupled systems is mutable, sensitive to changes in such factors as technology and the way our environment "represents itself" in our minds (paraphrasing Hayek, 1973b). Heikkila et al. (2018), observing a deficit in scholarship that has focused on the system and system outcomes, make a complementary point in their editorial on the agenda for polycentric scholarship, by urging more actor-centered approaches to improve our understanding of agency in polycentric systems. Practitioners of water governance, even if trained in economics or another discipline that teaches actor-centered analyses, frequently write and think from a systems perspective. I have sought to counteract that tendency by drawing from the polycentric ontologies of Hayek and Polanyi, which particularly emphasize individual, local knowledge, the affordances for decision making provided by institutional context, and the evolution of the rule of law through choice and experimentation.

In a polycentric water governance system, institutions based on the principle of holistic management and institutions based on the principle of participatory management provide contrary but complementary cross-cutting mechanisms. Affordances for forum-shopping are reduced in a system with a more bureaucratic separation of jurisdictions; affordances for level-shifting are fewer in a more hierarchical system of subsidiary authority. These affordances are both a process and an outcome of choice in a polycentric system, because, as Elinor Ostrom (1990) put it: "Individuals who have no self-organizing and self-governing authority are stuck in a single-tier world. The

structure of their problems is given to them. The best they can do is to adopt strategies within the bounds that are given" (p. 54). I have emphasized polycentricity as a process, as an inoculation against the “static” structural conceptualizations (Thiel, 2017) and two-dimensional operationalizations of polycentricity that have thus far prevailed in institutional scholarship. A multifaceted definition of polycentricity helps to illustrate why popular initiatives like decentralization, devolution, integration, and co-management—whether or not they are justified on other grounds—do not constitute an applied polycentric governance. The general proscription of conventional policy applications embedded in the underlying assumptions of polycentric governance theorists should not be understood to preclude critique of prescriptions like IWRM, “nexus” approaches to water resources, or unified river basin management through a polycentric lens to see how polycentric processes may be impacted by policy interventions. Indeed, it is my hope that they will be.

CHAPTER 3

A DIAGNOSTIC APPROACH TO ANALYZING PATTERNS OF POLYCENTRIC GOVERNANCE THROUGH SURVEY OF WATER SYSTEM OPERATORS

1. Introduction

An idealized government looks like and behaves according to its organizational chart, bylaws, and charter. Highly sought-after by modernist proponents of the scientific state and rational planning, this form of government functions as an *organization* (Hayek, 1973b). The deliberate organizational form of government is, in Scott's (1998) terms, most "legible" to political authorities, and, presumably, political science and public administration scholars. Organizational and management studies have, in the past, forwarded functionalist perspectives of organizations and the optimization of organizational design that follow logically from assumptions about the legibility, measurability, and predictability of organizations.

Taking an institutional turn, scholars in the mid-20th century diverged from assumptions about idealized states, idealized markets, and the "amorphous, fictitious, and omnicompetent entity called 'the government'" (E. Ostrom, 1990, p. 216). Governance scholars in the Ostromian tradition have emphasized the importance of rules-in-use, or informal institutions, and the counterintuitive and counterintentional processes and outcomes of *polycentric governance* (V. Ostrom, 1991). According to this heterodox school of thought, the outcomes of public policy and managerial schemes are hard to predict because they do not result primarily from deliberate planning by government (or organizational) officials, but from self-governance within and between organizations. In their view, the governance pattern that thus emerges—multiple autonomous authorities with overlapping jurisdiction, making mutual adjustments

toward contingent purposes through voluntary processes such as cooperation, competition, conflict, and consultation—produces desirable social order in the world (V. Ostrom et al., 1961).

Extensive research on small-scale common pool resource governance demonstrated how successful self-governance could be under some conditions (E. Ostrom, 1990, 2005). Some scholars have posited that governance of more complex systems are only achievable through polycentric orders (Hayek, 1973b), or that polycentric governance is the most effective approach for global problems (E. Ostrom, 2012). While celebrated, advances in polycentric governance theory, or "applying the same logic of self-governance to a larger level" (Aligica & Tarko, 2014, p. 67), have nevertheless been received into a political science and public administration context where they are, at best, largely illegible, and at worst, deemed pathological.

Those who read polycentricity from a policy perspective will want to apply the tools of policy evaluation to understand how polycentric institutions are performing and whether more or less polycentricity would be beneficial to achieving agreed-upon goals. However, taking a Hayekian perspective, we should be cautious about this application. First, because polycentricity is not a policy to be implemented. It does not arise as a solution to a given problem, but emerges through the many solutions that stakeholders continuously develop through processes of contestation and collaboration on a loosely defined set of contingent problems. Secondly, polycentricity is multifaceted, not a simple matter of degrees: "differences among polycentric governance arrangements do not make them *more polycentric or less*, but they do affect the ways in which those governance arrangements emerge, operate, and change, and the effects they have over time" (Thiel et al., 2019, p. 14, emphais added). Rather than approaching polycentric

analysis as a matter of policy evaluation, such regimes require what has been called a *diagnostic approach* (E. Ostrom, 2007; Pahl-Wostl, 2009).

In this study, I have attempted to make features of polycentric systems deemed important to governance scholars in the Ostrom tradition more legible to those who require something approximating a policy evaluation approach to make sense of governance arrangements. I use survey data from interviews with operators within a polycentric system to estimate qualitative values of several conditions that are thought to describe the polycentric decision making environment. Because few studies have been published that use survey data to measure polycentric configurations (see, for exceptions, Baldwin et al., 2018; Mewhirter et al., 2018), my motivation for this study was to explore the theoretical and practical frameworks that might allow for hypothesis-driven analysis of survey data for polycentric governance research in the future. Given the novelty of the approach, I expected that some aspects of the proposed analysis of survey data, such as the application of set-theoretical qualitative comparative analysis, would not yield conclusive results. However, I believed that useful insights might be gleaned about which approaches hold promise for polycentric diagnosis. From the outset, I made several assumptions about the level and type of analysis possible in the particular study context, including the selection and definition of large-scale water infrastructure in Arizona, USA, as an example of a polycentric system. I discuss these assumptions in light of the interviews I conducted with water operators and the analysis I subsequently performed on coded survey data. I conclude by sharing lessons from this study about what survey data might be used to diagnose patterns of polycentric governance within and between organizations.

2. Background

In the 1980s, Vincent Ostrom began to write about public administration extensively in terms of *artisanship* and *diagnosis*. These terms stand in contrast to the conventional idea of public administration as a domain of policy making and evaluation, and Ostrom used them to describe the craft of constituting and reforming public institutions through instrumentalities of self-governance; as a prominent example, he details Alexander Hamilton's "diagnosis" of patterns of constitutional government in *The Federalist* (V. Ostrom, 1991). Other institutional scholars likewise described their conjectional frameworks for analysis of institutional patterns as "diagnostic tools" (Oakerson, 1992). To these institutionalists, *diagnosis* connotes the analysis of system outcomes and an approach of working backward from outcomes to proximal causes (Oakerson, 1992). As in medical diagnosis, the process of institutional diagnosis involves distinguishing symptoms from underlying problems, and these institutional scholars were engaged in critiques of government programs—especially infrastructure development assistance projects—that, in their view, had been designed to fix symptoms without addressing the problems at their root (Bromley, 1992). It was with these failures in mind that scholars focused their efforts on improving diagnostic tools. Elinor Ostrom explained the relationship between prescription, diagnosis, and frameworks like this: "Frameworks organize diagnostic and prescriptive inquiry. . . . [they] provide a metatheoretical language that can be used to compare theories," while "theories focus on parts of a framework and make specific assumptions that are necessary for an analyst to diagnose a phenomenon, explain its processes, and predict outcomes" (E. Ostrom, 1999, p. 25; 2005, p. 28). Diagnosis in this context is more than mere analysis and separate from prescription or explanation; most often diagnosis is seen specifically in the context

of understanding how perverse outcomes result from counterintentional interactions in complex institutional systems.

Diagnosis has a similar place in the public administration subfield of organizational development, with core competencies aimed "to analyze and diagnose systems, to design and choose interventions, to facilitate processes, to develop clients' capability to manage their own change, and to evaluate organization change" (Cummings & Worley, 2009, p. 48). However, in organization development, diagnosis is seen as a step in a consultation process that is necessarily followed by intervention and evaluation, whereas intervention is sometimes viewed skeptically by institutional analysts and evaluation is accordingly de-emphasized. Skepticism of intervention is implied in the way the diagnostic approach is set against so-called "panacea thinking," or one-policy solutions (see, e.g., E. Ostrom, 2007; E. Ostrom & Cox, 2010). The same negative connotation with intervention is less prominent in organization development texts, though here, too practitioners are cautioned against taking the analogy with medical diagnosis too literally: diagnosis in organization development "is much more collaborative than such a medical perspective implies and does not accept the implicit assumption that something is wrong with the organization" (Cummings & Worley, 2009, p. 87). This suggests that institutional analysis and organization development practitioners both see themselves in a collaborative relationship with organizational subjects and institutions, and either downplay prescriptive outcomes of the process or believe any prescriptions for change should be made endogenously. Conventional program evaluation approaches that emphasize the use of focus group, interview, and other survey data could be synergistic with institutional approaches that emphasize the need to understand endogenous system logics.

The *diagnostic approach* was further delineated by E. Ostrom and other institutional scholars beginning with a special issue in *PNAS* in 2007. Ostrom, Janssen, and Anderies (2007) advocate a diagnostic approach especially as a way of examining attributes of a problem in a social-ecological system along parameters believed to be important in a particular context, and monitoring important system indicators for feedback on any changes as initial solutions are adopted. (Other diagnostic approaches are further distinguished from program evaluation approaches by monitoring feedback "signals" as opposed to system indicators.) Ostrom (2007, p. 15181) specifies a framework for diagnosing "problems and potentialities" of linked social-ecological systems through identification of combinations of structural variables that affect actors' incentives and choices under different systems of governance (see also Frey & Cox, 2015). This "step toward developing a diagnostic method" is aimed at understanding not just how a particular problem to a solution may improve outcomes of the system, but also how it might make outcomes worse—or, in other words, make the system more or less sustainable. Monitoring the proposed variables is presented as a necessary complement to adaptive management. In a final contribution to the proposed framework, Meinzen-Dick (2007) illustrates the particular panaceas and countervailing structural variables to be monitored in water governance systems.

Diagnostic approaches are not unique to institutional analysis in the Ostrom school. Broadly, diagnosis has come to contest if not replace many policy approaches that once advocated one-size-fits-all solutions. For example, in development economics, researchers in the same time period have articulated a *growth diagnostic framework* meant to replace the Washington Consensus with "context-specific and country-specific growth policies" (Sydykova & Rodriguez, 2018, p. 298). Though not explicit in this

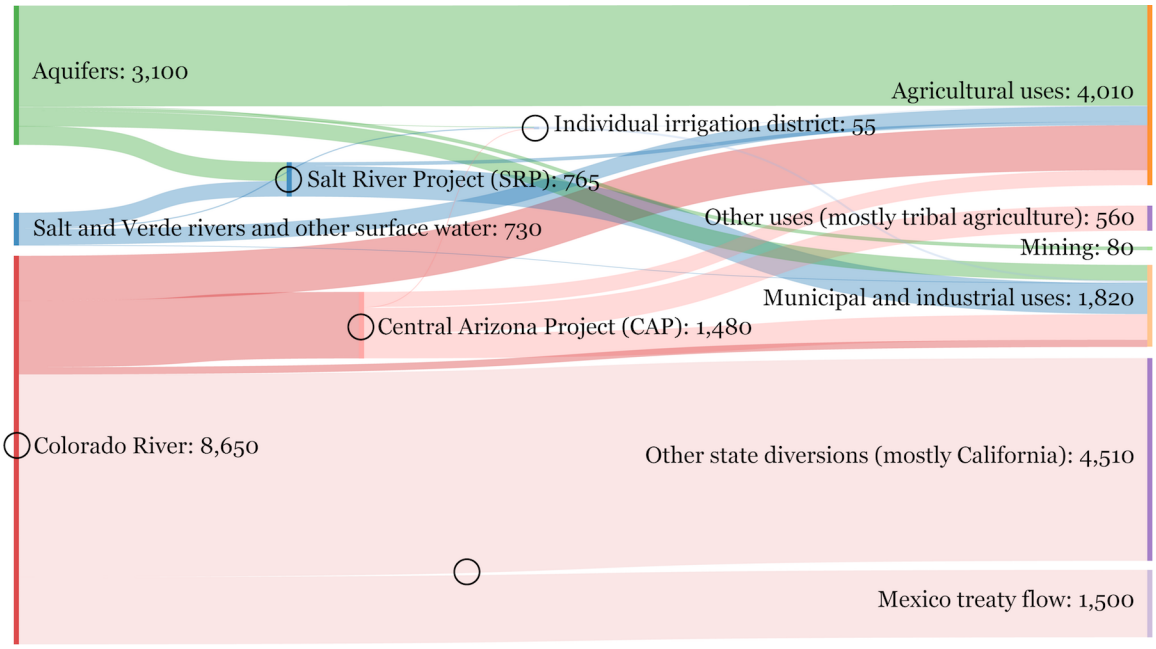
instance, this growth diagnostic framework examines constraints in what set theorists would recognize as a *configurational* approach, because it focuses on parsimonious description of "key circumstances which are named in theory and sustained by evidence as linked together in important ways" in a given local context (Olsen, 2011, p. 189). The linkages in configurational comparative analyses are not necessarily causal linkages, though they can be. Configurational analysis shifts emphasis away from scientific generalization and toward case differentiation. Moreover, it de-emphasizes policy prescriptions—whether one-size-fits all or not—because it implicitly assumes specific policies (and the absence of the same) produce their effects through assemblages of causal linkages in connection to other policies, thus key circumstances can be examples of a "long causal process" of both proximate and distal factors (Olsen, 2011, p. 190). As E. Ostrom (1999, p. 25) explained, one institution is not independent of the configuration of other institutions, thus, "In the case of institutional analysis, one needs to know the value of other variables rather than simply asserting that they are held constant." Even in its diagnostic modes, contemporary policy analysis and program evaluation tends to be more limited in the number of policies and programs considered together in a single analysis.

The context I selected for this study, irrigation infrastructure in the desert southwestern United States, is larger by some measures than the cases for which the social-ecological systems approach was developed. The study site comprises several linked large-scale irrigation and drinking water systems tied directly into two interstate and international river basins: the Salt-Verde River system, the largest tributary of the Gila River, originating in New Mexico (and fed by watersheds extending into Mexico), and the Colorado River, originating in the upper basin states of Wyoming, Utah, and

Colorado. The Colorado river basin takes in nearly the entire state of Arizona, and constitutes important borders between Arizona and its lower basin neighbors on either side, California and New Mexico. Water deliveries from the Colorado River terminate in Mexico, across an important international border. This basin is cataloged by the U.S. Geological Survey as the Lower Colorado River Region (Region 15) and is approximately 140,000 square miles (362,598 square kilometers) in area (U.S. Geological Survey, 2019).

Figure 1

Arizona Water System, 2018, Estimated Source Volume by Consumptive Use, TAF



Note. Flows in the diagram represent proportions of water characterized by source and use in thousands of acre-feet (TAF). The volume of water from the Colorado River source represents water that flows through Hoover Dam; most of this water is not available for use in Arizona. The volume of water used in agriculture, in particular, is not fully consumptive; much of this water returns to the aquifer (see Anderies et al., 2020 for a discussion of recharge rates). Also not depicted are system losses, which vary by conveyance but are generally very low in proportion to the overall volume of water managed, and institutional intricacies of water rights exchanged under water banking agreements. The circles represent points in the system where water operators were recruited for participation in this study. For symbolic purposes, an individual irrigation district is disaggregated from the agricultural water flow in this diagram; in reality, much of this water is governed by numerous irrigation districts. Municipal and industrial uses in Figure 1 include power generation.

In 2015, the most recent year available, the U.S. Geological Survey estimated total water consumption in Arizona was 6,700 thousand acre-feet (8,264 million cubic meters), of which 77 percent was used in agriculture (irrigation, livestock, and aquaculture; Dieter et al., 2018, p. 11). On the occasion of the fortieth anniversary of groundwater conservation measures enacted in the state, officials announced that Arizona was using the same amount of water (in total, from all sources) as it did in 1957, despite a near-quintupling of the state's population in that period; the state supported a population of 6.7 million people in 2018 (Arizona Department of Water Resources, 2020).

To the variables described in the diagnostic social-ecological systems framework, I add some key parameters derived from the structure of polycentric systems, specifically: exercise of diverse opinions and preferences and decision-making autonomy; shared goals with other institutional actors; perceived alignment between rules and incentives and legitimacy of rules from different sources; and access to information relevant to opportunities for institutional innovation (Aligica, 2014). I also consider basic conditions of complex decision making situations, as discussed below.

Other scholars have studied the large-scale water systems of the desert southwest through a polycentricity lens before. Schlager (1995) provided important early research from an institutional approach, using interviews with water policy experts conducted in 1994 to investigate the outcomes of Arizona's landmark 1980 Groundwater Management Act. Water policy experts in this study comprised both water users (e.g., members of water utilities and districts) and advocacy groups (e.g., members of public interest and environmental groups). Other accounts of Arizona water governance have been given, for example, from the perspectives of policy networks (Kupel, 2003) or sustainability (Larson et al., 2013). More recently, two studies characterized the region's water system

in terms of polycentricity. Holley et al. (2016) contrasted Arizona's water administrative system with groundwater governance in Colorado and Nebraska, with a focus on conjunctive water use. In their estimation, Colorado had the more polycentric system of the three states, because many specialized water agencies and arbiters share "concurrent and overlapping powers to govern water" without any single branch of government dominating (Holley et al., 2016, p. 242). Sullivan et al. (2019) considered the Central Arizona Project in the context of Colorado River basin planning through statements made by stakeholders in public meetings from 2016 to mid-2018. In their judgment, Colorado River basin governance should currently be characterized as "decentralized and uncoordinated, but not polycentric" (Sullivan et al., 2019, p. 47).

Set-theoretical qualitative comparative methods, or configurational comparative methods, have become a widely-accepted approach in institutional analysis of water resources. A definitive set-theoretical study in irrigation was Tang (1992), which studied self-governance in both simple and complex systems. More recently, Lam and Ostrom (2010) used crisp-set qualitative comparative analysis to study the outcomes of a policy intervention on fifteen irrigation systems in Nepal. Mollinga and Gondhalekar (2012) argued that Ostrom's work on small-scale farmer-managed irrigation systems is probably the most rigorous attempt at comparative water governance research, but that explicit, explanatory, comparative methods are still lacking. A more recent contribution to water governance research is the fuzzy-set qualitative comparative analysis of polycentric water governance in 29 river basins based on the Twin2Go dataset, conducted by Knieper and Pahl-Wostl (2016), which determined that river basins characterized by high per capita income, low corruption, and polycentric governance exhibited the outcome of "good governance" (defined in the study), but that use pressure

also coincided with other factors in the limited diversity of cases in the dataset.

3. Research Strategy

Over a six-month period beginning in December 2017, I surveyed ten people responsible for water resources in the Arizona water system, people whom I will refer to as *water operators*. Kiser and Ostrom (1982) state that individuals at the operational level are authorized to take direct actions within their jurisdiction without prior agreement with other individuals, and may also adopt strategies for future actions (paraphrased, p. 76). In comparison to individuals acting freely in society at large, individuals within an organization can be expected to have somewhat more constrained choices at the operational level—defined, for example, by their job descriptions. However, I considered that, to the extent that organizations in a polycentric order can be said to "act" at an operational level, individuals in operations can be considered representative of that organization's operational decision making. This assumption is not uncontroversial, and could be contested. Some of the most formal frameworks for analysis of polycentric configurations thus far have been based implicitly or explicitly on a polycentric order where individual actors are what I would consider largely undifferentiated in their formal roles. For example, Polanyi (1951) writes about polycentric orders of scientists, and others, including V. Ostrom (1972) and Aligica (2014), write about public service economies in which market institutions provide a basis for many individuals with similar authority to act (and organize to act) within the same jurisdiction. The water system in Arizona is an example of polycentricity distinguished more by the overlapping of jurisdiction than the number of similar authorities acting within it—indeed, this multiplicity of jurisdictions has, as we have seen, led some analysts to consider that water resources governance in the state might not be a good

example of a polycentric system (Holley et al., 2016; Sullivan et al., 2019). However, for the sake of the present effort, the *system* refers to Arizona water resources governance as a whole. In what follows, I detail each part of the research strategy, the conceptual considerations and decisions made at each step, and the outcomes of those decisions in terms of methods developed and data generated.

3.1. Survey Population and Participant Recruitment

I recruited people to participate in the survey whose job titles and duties formally included some aspect of day-to-day operations of large-scale water infrastructure, historically supplying agricultural irrigation. The operational level in institutional analysis is considered that which is predominantly concerned with provisioning, distribution, appropriation, assignment, and consumption of a resource (E. Ostrom, 1999) and the only level of analysis in which decisions directly change the physical flow of resources (Kiser & Ostrom, 1982). Job duties among the recruited participants ranged from water resources planning to operators of infrastructure control structures. Because some of the organizations involved in water operations in this system are public or pseudo-public entities, some of the job descriptions are formalized and publicly available for the purposes of transparency in hiring and compensation. For example, in the Central Arizona Project, according to official job descriptions, the water control dispatchers are primarily responsible for: controlling the flow of water throughout the aqueduct system; controlling the flow and distribution of water to customers while maintaining the overall integrity of the system; operating pumps, pump/generation units, control structure gates, and turnout structure gate positions and flows; and remotely monitoring tens of thousands of electrical and mechanical parameters related to these operations (Central Arizona Project, 2015a). However, water control dispatchers

have other responsibilities that formally account for 60 percent of the class specifications, for which they are expected to "have the ability to work independently and demonstrate initiative and leadership skills" and "have the ability to accept responsibility and make decisions during unusual situations and emergencies. . . . given a set of circumstances and constraints, [water control dispatchers] must be able to think quickly and logically to arrive at a plan of action" (Central Arizona Project, 2015a). The senior water control dispatcher, in addition to providing direction for these operations, performs many coordination tasks, such as taking, loging, and scheduling water orders from the water users and ordering water to be diverted from the Colorado River (Central Arizona Project, 2015b).

Despite the very large number of personnel required to operate such extensive water infrastructure, very few make day-to-day decisions directly affecting water distribution. The plurality of personnel in this system are *zanjeros* and field maintenance workers, who are primarily responsible for troubleshooting, verifying, and implementing real-time decisions made from central control rooms. In large organizations, control rooms are staffed by a pool of employees who cover shifts seven days a week. (There are variations among the organizations in how specialized members of this pool are; some operators may have planning or managerial roles in addition to shifts in the control room.) Among the many planning and analysis roles at larger agencies and organizations involved in water distribution in this system, the plurality are involved in regulatory, financial, legislative, legal aspects, property and facilities management, and power generation. I did not consider people in these roles to be candidates for recruitment in the survey. Additionally, the number of organizational actors (agencies and irrigation districts) is relatively small. End-users in this water system, for example, generally have

few short-term choices of how to appropriate water for irrigation, so the polycentric order is not as rich in some aspects of public economies, like entry and exit. At longer time scales, however, irrigation water users have options like switching between ground and surface water sources, organizing and influencing the policies within irrigation districts, and relocating or reconfiguring farm operations. Water operators participating in this survey were drawn from each type of organization active in water infrastructure operations in the state.

I did background research on the organizational and staffing structure, resource portfolios, and job descriptions (where publicly available) of key organizations involved in water resources in Arizona. I attended public meetings where I could introduce myself and the aims of the study to people who worked in target departments of these key organizations where I could, or wrote cold email requests to people I could not reach in person. Three interview participants were recruited directly this way. The remaining participants were referred to me by contacts I made in person (three participants) or by interview participants themselves (four additional participants). Two referrals made to me failed to lead to interviews, in one case because the prospective interviewee cancelled a scheduled meeting without rescheduling (and then left the position), and in the other because, despite an introduction by our mutual acquaintance, the prospective interviewee did not respond to requests for an interview. Thus, in this case, a nonprobability sampling strategy is not undermined by as much selection bias as either random sampling with a low response rate or convenience samples of previous acquaintances. Theoretical, purposive sampling strategies, such as I used, are considered a best practice in small-N QCA studies—as is adding or removing observations from a sample based on theoretical revisions (Greckhamer et al., 2018; Olsen, 2011). I would

have interviewed more people if my contacts had more referrals to make or if I had identified additional organizations with operations at a similar level to the scale of the organizations I reached.

3.2. Interviews and Qualitative Coding of Transcript Data

Each participating water operator completed a background survey questionnaire and a 11-question semi-structured interview, which I recorded, transcribed, and then iteratively coded in the qualitative data analysis software package, MAXQDA (VERBI Software, 2020). The basic interview questions were available to prospective participants (see Appendix A), but I emphasized that no preparation was required for the interviews, and in practice no survey recruits asked to see the questions in advance. This was important because the questions did not require any objective recall (e.g., of technical specifications) or consensus—rather, I wanted to hear as many individual perspectives as possible. I consider the interview semi-structured, rather than structured, because the full, written interview protocol included minor questions and additional prompts that were used on an as-needed basis in different interviews. My intention, as I informed participating water operators, was to design a protocol that could be used in an irrigation system of any size in any geographical location.

For practical reasons, the interview protocol was designed to be implemented one-on-one in a single session of no more than 40 minutes. In reality, participants typically were very generous with their time and willing to talk beyond the scheduled 40 minutes. An unexpected aspect of the interviews was that three participants wanted to be interviewed with a second member of the operations control room staffing pool of which they were a member. This was not ideal from a survey control perspective, because one participant's response will influence another participant's response when they are in the

same interview together. However, it is a clear preference of these interviewees, and I would plan for it in future interviews with this survey population. In interviews with two participants, I explained the importance of hearing both of their perspectives, and at necessary junctures, would ask them to either provide a second opinion or pause to consider their response before they heard their co-worker's response. This approach seemed to work well.

The questions were written with an aim to elicit narratives about those aspects of Aligica's (2014) proposed formal structure of polycentricity that I thought were reasonable to assess from a subjective perspective: (1) the extent to which common goals are shared and/or individual goals are pursued; (2) who makes the rules and how well they align with incentives; and (3) whether/with whom information about operational decisions is shared. This incorporates conditions of polycentric configurations from each of the three basic features of polycentric orders, respectively: a multiplicity of decision centers, an overarching system of rules, and a process of mutual and spontaneous adjustment (Aligica, 2014). As I have already suggested, some conditions proposed by Aligica either did not seem amenable to assessment from a subjective perspective (e.g., whether the opinions and preferences exercised are diverse), are easily assessed without surveying water operators (e.g., whether the jurisdictions of decision centers are territorial or non-territorial), and/or known to be limited (i.e., conditions of entry and exit).[8] In the formal structure he proposed, shared goals and individual goals are alternate potential patterns, and neither is considered a necessary condition.

After personal introductions, each interview started with a grounding question:

[8] I have argued elsewhere that large-scale water systems have distinct polycentric properties in these latter two respects (see Chapter 2).

"Could you describe in your own words what a typical work day or a typical work week is like for you?" [Q0]. This was followed by two questions about goals, "On a year-to-year basis, what are some of your most important operational goals?" [Q1] and "In general, what people or groups share these goals?" [Q2]. In interviews, participants were prompted to answer the questions on an annual basis, if possible, so that there would be a common frame of reference.

I produced three conditions related to Aligica's (2014) logical conception of basic polycentric orders through iterative coding of interview transcripts of these and one other question, which I discuss in more detail below [Q1, Q2, and Q7] (also see codebook in Appendix B):

Individual goals	INDGO	Whether a strong operational priority is defined by the actor (counterfactual: no priority is defined)
Shared goals	SHAGO	How broadly operational priorities are shared by other actors
Decision communication	DECOM	The extent to which decisions are communicated to other actors

Following the general goals questions, I asked three questions that tasked participants to elaborate on a particular goal that they had already identified: "Of the annual goals you've described, which is the most challenging?" [Q3], "How do you track your progress toward this challenging annual goal?" [Q4], and "What are some of the big decisions you have to make each year to meet important goals?" [Q5]. The purpose of this line of questioning was to render the relatively abstract topic of annual planning into a more discrete set of activities specific to the participant's subjective position. These questions built context about the decision making environment that each water operator experienced in their work. These questions derive, for example, from game theory literature about the attributes of decision situations: "(1) the number of decision makers

involved; (2) the types of choices available to the decision maker; (3) the linkages between actions and results; (4) complexity; (5) repetitiveness," among others (Kiser & Ostrom, 1982, p. 62). Because polycentric systems are complex decision making environments, we can reasonably expect the number of decision makers, types of choices, and linkages in a polycentric system to be relatively high; likewise, we might reasonably expect that the repetitiveness is relatively low.

I coded the transcripts for two additional conditions based on the first grounding question [Q0] and one of these context-building questions [Q5]:

Work variety	WOVAR	Whether the actor experiences diversity in typical tasks on a day-to-day or week-to-week basis (counterfactual: regularity of tasks)
Big decisions	BIGDE	The extent to which the actor perceives that a few, discrete, critical decisions define their work responsibilities on a annual basis

At the midpoint in each interview, I transitioned to ask about concrete aspects of the decisions participants had identified earlier in the interview. These questions included: "How many of these decisions require information or action by others before you can act?" [Q6], "How do others learn about and respond to the results of your decisions?" [Q7], and "If an unexpected opportunity to make progress toward a goal presented itself, what would constrain your ability to act on that opportunity?" [Q8]. As mentioned above, the question about information flow or communication [Q7] was used in the coding of DECOM. The other two questions [Q6 and Q8] I conceived of as being measures of decision-making autonomy, and I coded them according to ranked orders of dependencies and constraints, respectively:

Decision dependencies	DEDEP	How independent the actor is from waiting for information or others' actions before they can make big decisions

Constraints	CONST	Whether action on unexpected opportunities is institutionally unconstrained (i.e., whether decisions are conceived as being unlimited by anything other than the physical capacity of the system)

Since decision making responsibilities are explicitly outlined in the job descriptions typical of these water operators (if they work for an organization that has formally designated class specifications), I thought participants would be challenged but comfortable answering these questions about decision-making autonomy, especially if some context had been built by earlier questions. After making decisions during "unusual situations, which may occur at any time" and thinking quickly to make a plan "given a set of circumstances and constraints," the job description of the senior water control dispatcher, mentioned earlier, explicitly states that the position "Approves outages of up to one day on major equipment" (Central Arizona Project, 2015b). This language suggests that decision making is a recognized task in these positions, and that there may be internal metrics for the categories and magnitudes for the types of decisions that water operators might make. However, I was careful not to characterize these particular questions as measures of decision-making autonomy. In the question about decision dependencies, I asked what the water operator needed before they could act [Q6], while in the question about decision constraints, I asked what would stop them from acting or responding to relevant changes to conditions within their jurisdiction [Q8]. These questions were intended to align loosely with negative and positive concepts of autonomy, in the sense that a person in a position of high negative autonomy will have few external constraints (or, in this case, structural dependencies) and a person in a position of high positive autonomy will have few internal impediments or constraints (often also conceived of as having agency).

In modeling the attributes of the decision situation—by, for example, using the Institutional Analysis and Development (IAD) framework (Kiser & Ostrom, 1982)—I would consider decision dependencies (DEDEP) and constraints (CONST) to represent linkages between institutional, social, and biophysical conditions that are exogenous to the decision situation, perceived as signals by the actor making a decision. Similarly, I would consider decision communication (DECOM) to represent linkages between the action taken in the decision situation and its outcome. This linkage is inferred by the actor making a decision, and becomes a signal to others in linked action situations. The "communication" in this case may be literal communication, but in a water system it is often biophysical—for example, as downstream stakeholders notice changes in water releases.

Finally, the semi-structured interview concluded with a question asking participants to rank, on a scale of one to five, how much independence in making "big decisions" they experience overall in their position:

Self-reported independence	SINDE	How much independence the actor reports they have in their position to make big decisions

Importantly, the term *big decisions* was introduced and contextualized by preceding questions; the term *independence* was not. Survey participants were primed with an explanation, at the very beginning of our interview, that the study concerned *decision-making autonomy* (they also had been provided the title of the study, which uses neither the term "autonomy" nor the term "independence"). In only one instance, in one interview, did a participant use the word "independence" prior to the question

asking them to rank their own independence (see Appendix A for interview questions).[9] Therefore, I contend that participants had been guided to understand what I meant by "big decisions," and may have been influenced by previous questions asking about adjacent topics (particularly the questions about decision dependencies and constraints), but were otherwise free to use their own subjective interpretation of what counts as independence to make big decisions.

After transcribing the full interviews in MAXQDA and initially coding each section of each interview that corresponded with the eight conditions described above, I developed ranking criteria for each of the seven conditions for which I had only qualitative answers. (That is, all but SINDE, which was ranked by participants themselves.) The details of the ranking criteria for each condition, along with the corresponding interview prompt, and additional data not used in the present study are provided in the codebook in Appendix B. Below, I describe the process of ranking in more detail.

3.3. Ranking Qualitative Data and Comparative Analysis of Coded Sets

In order to build a fuzzy data set, I re-coded each of the nominal values of the seven explanatory conditions with an ordinal set membership value between one (low) and five (high)(see Table 1). These scores correspond with ranking criteria that I developed after comparing statements made by interview participants across all the transcript segments coded with the given condition (i.e., INDGO, SHAGO, DECOM, WOVAR, BIGDE, DEDEP, and CONST). I developed the ranks for each condition through constant comparison (Parry, 2004) rather than deductively applying an abstract

[9] Two survey participants spoke about autonomy in their answers to questions, presumably because they understood that was what I wanted to hear about (see Chapter 4 for details).

cumulative or inclusive ranking such as a Guttman scale (see below for further discussion of the comparative merits of these approaches). I identified examples of responses that fit my intuitive sense of the scale of each condition and then synthesized a representative statement for each rank of each condition. For example, on the condition WOVAR, the statement representative of the highest rank is "Every day is different." Once I had synthesized this representative statement, I went back through each interview segment where participants answered the question, "What is a typical work day or week like for you?," [Q0] or elsewhere in the transcript where I had previously coded their response was relevant to the question of work variety, and I scored their response as a five if they said something close to "In this position, every day is different." On this scale, the highest level of work variety is, logically, a position in which there is no "typical" day, because every day presents a different set of decisions to make and tasks to complete. Because participants' answers are usually much longer and more nuanced than a single representative statement, and because interviews included conversation, follow-up prompts, and clarification of prompts, in each interview there could be statements corresponding with more than one rank of the scale. (In total, I coded a range from 17 to 30 coded segments for each condition.) In these instances, I recorded the highest-valued statement as the score for that observation. I did not find a response from the interviews to fit every score on every condition; where there was no response, I did not synthesize a representative statement. (These and other considerations are indicated in the codebook.) Some scores for SINDE are integers, while others are not (if, for example, a participant ranked their own decision-making independence at "between a three-and-a-half and four").

Table 1

Raw Set Scores After Ranking Ten Operator Interviews

wovar	indgo	shago	bigde	dedep	decom	const	sinde
5.00	5.00	5.00	5.00	5.00	5.00	4.00	5.00
5.00	3.00	3.00	4.00	4.00	4.00	3.00	1.00
3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
4.00	4.00	4.00	3.00	4.00	4.00	4.00	4.25
4.00	3.00	3.00	3.00	5.00	4.00	4.00	5.00
2.00	5.00	4.00	5.00	5.00	4.00	4.00	4.00
3.00	4.00	5.00	3.00	4.00	5.00	4.00	2.00
2.00	5.00	5.00	5.00	4.00	5.00	4.00	3.00
3.00	4.00	4.00	4.00	4.00	4.00	2.00	2.75
2.00	5.00	4.00	2.00	3.00	4.00	2.00	3.75

The approach described worked well on those conditions where I was able to write more or less parallel statements for each rank of the condition. Parallelism in constant comparison requires constructing these kinds of categorical statements with similar words and syntax so that the contrasts in content and function between statements are easy to understand (Sandelowski, 2011). Ideally, these parallel constructions make it clear that ranks aren't each mutually exclusive, but exist along a gradient where a participant's responses are most likely to correspond with a score of four or five, or two or three. Yet, the scale is constructed such that one participant would be unlikely to respond with statements corresponding with ends of the scale, such as a one and a five. In addition to WOVAR, a condition for which it was relatively simple to construct parallel ranking statements was SHAGO, the condition related to how broadly

operational priorities are shared. This is because we have an intuitive idea of what "broadly" means in an organizational context—"very broadly" would correspond with actors both internal to and external to the organization, while "not very broadly" corresponds with internal differences in goals. Thus, the ranking statement corresponding with a score of five on SHAGO is "Interest in meeting our goals goes beyond direct stakeholders to other users of the resource and/or the general public" while the statement corresponding with a score of two is "There is contention within the organization about shared goals." The order of these statements is almost quantitative, insofar as we could imagine a broadly-held goal would be shared by an objectively large number of actors, while at the other end a goal would only be held by one actor. However, this does not necessarily represent real conditions. In a real organization, there could be contention within the organization about what the most important operational goals are, and yet an operator within the organization could feel that there was broad support for his own individual goals outside the organization.

In this study, there did not happen to be deviation from the naïve assumption that the SHAGO condition is ordered on a scale of "few/less" to "many/more." However, other conditions were more problematic. The condition CONST is an example of a more problematic ranking. The interview question associated with this condition was, "If an unexpected opportunity to make progress toward a goal presented itself, what would constrain your ability to act on that opportunity?" [Q8]. There were a total of 27 coded segments for this condition. The question doesn't ask "How constrained are your decisions?," which would be a very abstract question to answer—the question (and any additional prompts used in the interview) asks for concrete examples of constraints. Because the survey population is exclusively people whose job responsibilities include

some decision making, we don't expect anyone would state that they have no decision making discretion whatsoever—and in this study, nobody did—but this would correspond with the low score of one. The high score, five, would logically correspond with an utterly unconstrained position—here, too, we might not expect to observe any responses because people generally live in a world where they recognize, at a minimum, some laws of nature constrain their decisions. Thus, the next-highest score, four, is represented by the ranking statement, "Physical infrastructure capacity is the only potential constraint when opportunities arise." Operators identified many physical constraints in these interviews, such as the capacity of canals to transport water or the capacity of dams to store water. Any concrete example of a constraint that I considered largely physical in nature I scored "four." The remaining two ranks cannot be deduced by a quantitative logic, however. For the middle rank, I considered constraints that were mostly demand-related, because these have some interplay with system physical capacities. For the rank below that, I considered more abstract political constraints like organizational inertia. Answers that corresponded with these low scores indicated that an operator's discretion was curtailed by anticipation that an action might be viewed disfavorably by other decision makers in the structure of the organization. The statement "Physical infrastructure capacity is the only potential constraint when opportunities arise" and the statement "Political considerations within the organization or precedent limit flexibility in operations" are not very parallel constructions. One of the glaring ways these statements differ is that the first is exclusive—it refers to the absence of other constraints—while the second is not. Inconsistencies like this can be an indication that a construct is insufficiently theorized (Sandelowski, 2011). Although the construct forms a

ranked scale in my own mind, further tests would be required to determine whether this construct is also intelligible and coherent as applied to further observations.

3.4. Analyzing Sets

Ranking the responses to coded conditions resulted in eight scored sets that I could then calibrate using the qualitative comparative analysis (QCA) software, fsQCA 3.1b (Ragin & Davey, 2016). For the initial analysis, I set default full, crossover, and nonmembership values (i.e., 5, 3, and 1) for the calibration without making theoretical or empirical adjustments.[10] Each observation is thus considered "fully in" the set if the coded ordinal value is five, and "fully out" if the coded ordinal value is one. Taken together, the entire set of ten observations (coded interviews) over eight conditional variables is certainly not large enough for exclusively quantitative analyses, but, conceptually, it does meet minimum criteria for QCA (see Table 2).

This study was designed on the premise that the decision making environment that operators in this system experience is structured in part by being situated in a polycentric governance system. Thus, every condition I measured is intermediate between a distal cause (polycentric governance) and outcome (water delivery) that are not, in themselves, measured by the study. There could be good reasons to consider any of these eight conditions as a more proximate outcome of the other seven. Here, however, I consider operators' self-reported independence to make big decisions (SINDE) to be the outcome of interest.

[10] One condition, CONST, could not be calibrated using the software, possibly because there were only three values in the set. This condition was manually assigned the same calibrated values as the other conditions.

Table 2

Calibrated Set Scores From Ten Operator Interviews

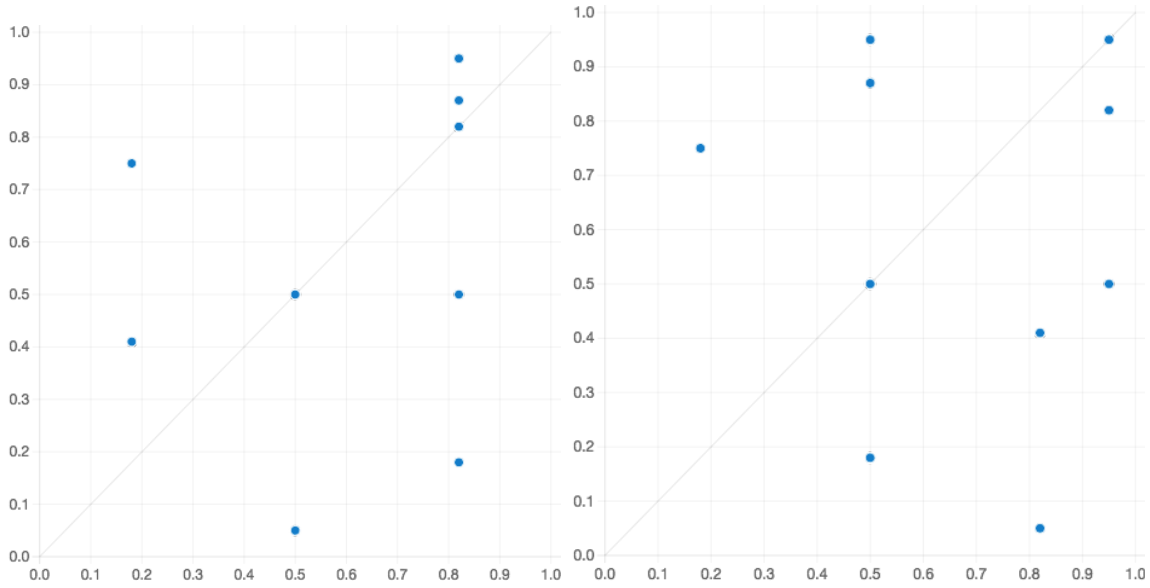
wovarc	indgoc	shagoc	bigdec	dedepc	decomc	constc	sindec	
0.95	0.95	0.95	0.95	0.95	0.95	0.82	0.95	†, ††
0.95	0.50	0.50	0.82	0.82	0.82	0.50	0.05	
0.50	0.18	0.50	0.50	0.50	0.50	0.50	0.50	†
0.82	0.82	0.82	0.50	0.82	0.82	0.82	0.87	†
0.82	0.50	0.50	0.50	0.95	0.82	0.82	0.95	†
0.18	0.95	0.82	0.95	0.95	0.82	0.82	0.82	†, ††
0.50	0.82	0.95	0.50	0.82	0.95	0.82	0.18	
0.18	0.95	0.95	0.95	0.82	0.95	0.82	0.50	†, ††
0.50	0.82	0.82	0.82	0.82	0.82	0.18	0.41	
0.18	0.95	0.82	0.18	0.50	0.82	0.18	0.75	†

Note. The "c" at the end of the name simply indicates the same previous sets are shown calibrated.
† Indicates observations at or above the threshold for membership in the set outcome.
†† Indicates observations used in the truth table.

Out of ten observations, five were over the threshold for membership in the set SINDE, two were at the crossover point, and three were below. Considered in pairs, the condition that best represents a subset of the outcome, SINDE, is CONST (consistency of CONST <= SINDE is 0.78). In contrast, the condition that least represents a subset of the outcome is BIGDE (consistency of BIGDE <= SINDE is 0.69). A consistency score of 1.00 represents 100 percent consistency, but perfect consistency is rare in QCA (Ragin, 2008).

Figure 2

Examples of High (CONST) and Low (BIGDE) Subset Relations to the Outcome



Note. SINDE is plotted on the Y axis, with CONST (left) and BIGDE (right) plotted on the X axis. Points above the diagonal are those that can be reasonably considered to have a fuzzy subset relation consistent with sufficiency for the outcome. Points below the diagonal contradict the set-theoretic claim. The plot for CONST only has nine points shown because two observations occupy the uppermost coordinates (0.82, 0.95).

As shown in the right half of Figure 2, there are more observations of BIGDE >= SINDE than the other way around (consistency of 0.77). This is also true of the other conditions, with the exception of WOVAR. I return to discuss this finding below. However, every condition has a higher subset relation consistent with sufficiency with SINDE than it does with the negation of SINDE (see Table 3). Pairwise consistency does not need to be high to support the conjecture that these conditions work in a configurational manner to produce the outcome, SINDE, even though none of them would appear to be highly sufficient individually. The intent of this study, as in other QCA studies, is to assess the effect of these conditions in combination. Additionally, because the QCA approach allows for causal asymmetry, it is assumed that it is possible for a different causal configuration

to be responsible for the presence of an outcome than the conditions leading to the negation of the same outcome.

Table 3

Consistency of Individual Conditions as Subsets of Outcome and Negation of Outcome

	wovarc	indgoc	shagoc	bigdec	dedepc	decomc	constc
sindec	0.77	0.69	0.72	0.69	0.71	0.70	0.78
~sindec	0.58	0.44	0.47	0.52	0.49	0.47	0.49

Because there are seven conditions, and an observation can be either in or out of the set for each condition, there are 2^7 configurations logically possible to explain the outcome SINDE. (For investigative purposes, we could calculate the fuzzy membership of each observation in each of the 128 configurations.) However, the truth table analysis for SINDE only actively uses three observations to find two configurations that result in SINDE (indicated by †† in Table 2), though others are used as counterfactuals. The first configuration, represented by two observations, is the presence of all seven except WOVAR. The second configuration is simply the presence of all seven conditions. This indicates that WOVAR is not especially relevant to the configurational model.

Table 4

Truth Table, Partial

wovarc	indgoc	shagoc	bigdec	dedepc	decomc	constc	Obser-vations	Raw consist.
0	1	1	1	1	1	1	2	0.80
1	1	1	1	1	1	1	1	0.79

Note. Truth table is partial because remainders are not shown.

The raw consistency scores for these solutions are 0.80 and 0.79, respectively. Ragin (2008) generally considers consistency scores below 0.75 as indicators of "substantial

inconsistency" (p. 144). The truth table algorithm in fsQCA also computes a more nuanced consistency score, PRI consistency, which is adjusted for the simultaneous membership of a configuration in both the subset of the presence of an outcome and the absence of the same outcome. The PRI consistency for the first and second configurations are 0.56 and 0.67, respectively (see Appendix C). A PRI score of less than 0.50 is an indicator of "significant inconsistency" (Greckhamer et al., 2018, p. 489). The solution thus specified is:

indgoc*shagoc*bigdec*dedepc*decomc*constc	Consistency:	0.78	Raw coverage: Unique coverage:	0.65 0.65
	Consistency:	0.78	Coverage:	0.65

The complex and intermediate solutions are the same, and because there is only one configuration in the solution, raw, unique, and solution coverage are all the same.

The reason only three observations appear in the truth table is partly because another four observations that are at or above the crossover point for membership in the outcome set, SINDE, are at or below the crossover point for membership in the set INDGO * SHAGO * BIGDE * DEDEP * DECOM * CONST. This is a structural problem with a fsQCA dataset that has many scores in the middle of the ranked order. Conceptually, it makes sense to calibrate the middle value as the crossover point for set membership, however, this makes set membership along many vectors ambiguous. Shifting the crossover point down to 2.9 instead of 3, in contrast, causes many more observations to be "more 'in' than 'out'" of membership in various sets (see Table 5). Varying calibration is a common practice for exploring the robustness of fsQCA results.

Table 5

Truth Table, Partial, with Crossover Point 2.9=0.5

wovard	indgod	shagod	bigded	dedepd	decomd	constd	Obser-vations	Raw consist.
1	1	1	1	1	1	1	5	0.79
0	1	1	1	1	1	1	2	0.83
0	1	1	0	1	1	0	1	1.00
1	0	1	1	1	1	1	1	0.81

Note. Truth table is partial because a fifth configuration was below the consistency cut-off and remainders are not shown. See Appendix C for the PRI consistency. The "d" at the end of the name indicates the previous sets calibrated with the lower crossover point.

The configurations contained in both the complex and the intermediate solutions (which are identical) are as follows:[11]

wovard*shagod*bigded*dedepd*decomd*constd	Consistency:	0.80	Raw coverage:	0.56
			Unique coverage:	0.57
indgod*shagod*bigded*dedepd*decomd*constd	Consistency:	0.78	Raw coverage:	0.67
			Unique coverage:	0.16
~wovard*indgod*shagod*~bigded*dedepd*decomd*~constd	Consistency:	1.00	Raw coverage:	0.26
			Unique coverage:	0.06
	Consistency:	0.81	Coverage:	0.78

With this recalibration, four additional observations are over the threshold for membership in the configuration INDGO * SHAGO * BIGDE * DEDEP * DECOM * CONST, which previously only had three members. This configuration thus remains the most compelling in terms of raw coverage. The third configuration, which includes

[11] When fsQCA performs the truth table analysis for this recalibrated dataset, two prime implicants are tied, and the software prompts the analyst to select one prime implicant to continue the analysis with. The two tied conditions are WOVAR and BIGDE. Here the earlier analysis can inform this decision, because we know that WOVAR is irrelevant to the solution of the truth table of the dataset with the more exclusive calibration of set memberships. Thus, I selected BIGDE as the prime implicant to continue the analysis with. This only affects the parsimonious solution, which is not discussed here because it is too simple to evoke interesting interpretations.

negation of WOVAR, BIGDE, and CONST (i.e., membership in the reverse of the measured condition) contributes very little coverage to the solution because it is based on only one, low-membership, observation. However, the recalibration gives us a second configuration to consider. This configuration has the same conditions as the first compelling configuration with one difference—WOVAR takes the place of INDGO.

To summarize, investigation through fsQCA suggests that there is some merit to the configurational model developed in this study. Of the seven conditions proposed in the model, five appear to work together to contribute to the outcome, SINDE, a subjective proxy of decision making autonomy in a polycentric governance system. When present, these conditions represent decision making contexts where: operators' goals are broadly shared; operators are responsible for making a few discrete, critical decisions on an annual basis; operators generally have the information they need to make these decisions; operators communicate broadly about their decisions to other stakeholders; and operators perceive few constraints on their ability to act on new opportunities or threats. These conditions work in combination with one of two other parts of the configurational model, either WOVAR or INDGO. In the former configuration, operators experience a high diversity in their day-to-day job responsibilities. In the latter configuration, operators describe their work as contributing to a discrete, overarching operational priority when considered on an annual basis. In my initial conception of the model, WOVAR was a context-building condition that was only distally related to polycentric governance (i.e., because we can expect complex systems to present significant variety at certain levels of analysis). INDGO was more proximal to polycentric governance, but I primarily included it in the survey to build context for the condition SHAGO (i.e., a definitive aspect of polycentricity, principally, that the system serves a

function to multiple actors who choose to take each other into account). Thus, the fsQCA suggests a core coherence to the proposed conditions I conceived of as most proximate to polycentric order, with some variation in context.

4. Discussion

I made three large but useful assumptions in the design of this study that must be scrutinized in light of the implementation of the study protocol and its results. First, that the cases I observed could all be recognized as decision making centers, or authorities, within a single polycentric water system. Second, that subjective measures of that system could provide meaningful insight into patterns of polycentricity in that—or any—system as a whole. Third, that the governance that occurs at the operational level is significant relative to the governance that occurs at more removed levels, even within exceptionally large-scale infrastructure systems. I will consider each of these in turn, beginning with the last.

From the smallest to the largest organization in this study, interview participants related that a portion of their job responsibilities include implementing policies, working within budgets, and reporting outcomes back to positions inside and outside their organizations that set water delivery agendas. The amount of discretion that water operators have in implementing the decisions codified in standard operating procedures, annual operating plans, and budgets might best be understood as *operational flexibility*. Interview participants described their decision making roles as subsidiary to other's, but also described having considerable operational flexibility (see Chapter 4 for operators' subjective experiences). Decisions made within this space for operational flexibility—whether or not they are recognized as governance decisions by those involved—are, by definition, self-governed. As a result of the figurative and literal

distance between constitutional rule-setting and actions taken at the operational level to change the physical flow of water resources in large-scale infrastructure systems, actors at different levels within an organization might have different real opportunities to engage in polycentric processes of decision making than either the organization "acting" as a whole, or the formal rules would suggest. The only way to shed light on these differences are analyses that are in some way subjective.

The protocol used here was subjective in at least two major ways. The measurement of the system is subjective to the interview participant. Additionally, the measurement of the interview data is subjective to the analyst. Though it is uncommon for qualitative set analyses in the water sector to be based entirely on subjective data and analysis, some element of subjectivity is almost always present in these types of studies (see Rantala & Hellström, 2001, for an important example outside of the water sector).

One way that researchers attempt to reduce the layers of subjectivity in an analysis like this one is through applying deductive ranking criteria for each condition. Indeed, developing such deductive criteria could be a further impact of the present research. At the most abstract level, deductive criteria might be used to structure an inclusive or cumulative scale, and interview participants could be asked to select the ranked response that best fit their experience. For example, in Guttman scaling, a set of items are combined into a theoretical construct—or, in terms more typical to qualitative comparative analysis, a set of conditions are combined into a single condition—such that each item on the scale logically includes all the lower-ranked items on the scale (Carmines & Woods, 2004). In applying a Guttman scale, both the items (e.g., attitudes) and the observations (e.g., in this case, responses of interview participants) are ordered "along an underlying cumulative dimension according to intensity" (Carmines & Woods,

2004, p. 449). Another way to think of this would be: for each condition, there is a superset that includes all the possible responses of all the respondents, within which the actual responses are hierarchically nested in progressively smaller subsets. (Presumably, the researcher performing a fuzzy set qualitative comparative analysis using a Guttman-scaled condition would still determine a threshold by which to break the largest subsets—those indicating the lowest intensity—out of the set membership to focus on how the set of higher-ranked observations contribute to an outcome of interest.)

The potential drawbacks of such an approach are twofold: few social science constructs are neatly ordered along a cumulative dimension, and presenting an instrument of this kind to an interview participant might coerce them, to some degree, into fitting their own experiences into an abstract order that did not represent their subjective experience of the phenomenon in question. In effect, this approach would increase the subjective input of the analyst up front with results that would appear more ordered, but in actuality might only be confirmation of those initial biases. Open-ended interview questions avoid this problem entirely, but certainly there are hybrid approaches that might yet be advantageous. If I developed inclusive ranking criteria for the conditions in this study, I would either not use them as part of the interview protocol, or I would only use them as a follow-up to an open-ended question designed to inquire about the same condition. That way, the deviation between the scale and the response could be observed. (This is consistent with standard practices, as applications of Guttman scaling are often concerned with deviation.)

On paper, the rules governing water rights in Arizona do not fully recognize that water is interchanged between different water rights holders (most notably, between ground and surface water rights). In reality, interchange occurs to some degree all the

time and is represented in some biophysical models (e.g., geophysical models of aquifer recharge rates). V. Ostrom (1991) distinguished a polycentric system, as opposed to mere polycentricity, as a case where formally independent centers of decision making "take each other into account in competitive relationships, enter into various contractual and cooperative undertakings, or have recourse to mediating mechanisms to resolve conflicts" (p. 138). Polanyi envisioned the extent of a polycentric system with a physical metaphor that speaks to the biophysical network of connections, as he described how displacement of one center within a polycentric order would cause mutual adjustments of every other center in the system (Polanyi, 1951). In a more general vein, he wrote:

> When order is achieved among human beings by allowing them to interact with each other on their own initiative—subject only to laws which uniformly apply to all of them. . . . An aggregate of individual initiatives can lead to the establishment of spontaneous order only if each takes into account in its action what the others have done in the same context before. (Polanyi, 1951, p. 195)

Note that Hayek (1973a) and Polanyi use the term *order* somewhat synonymously with *system*, because the latter term was only widely adopted later in their careers. Even where water subsystems in this study do not formally exchange either physical or paper water—and several do—operations certainly take into account rival water users and water use precedents.

As should be clear from this discussion, aspects of these last two assumptions in my research strategy are so far outside of the normal practice in qualitative comparative analysis that they might be considered design flaws. To my knowledge, no set-theoretical study of irrigation systems has made multiple observations within a single system for a single timeframe. The observations in set-theoretical studies of irrigation systems are usually derived from classic case studies in their own right, and the analytical

comparisons—inquiry into commonalities between select extant cases—are made across several such case studies. This study begins with observations that already have some underlying commonality in the fact that they can be considered parts of one large, complex water governance system. An interrelated potential design flaw is the fact that both the explanatory conditions and the outcome in this analysis were measured from a subjective perspective. Other diagnostic studies of irrigation systems have typically analyzed objective performance criteria as outcomes. While multiple observations within a system could be combined (e.g., averaged) in a meaningful way where the conditions being considered were nominally quantitative, it makes less sense to combine qualitative measures. However, the largest problem with the design of the study is probably lack of clarity in the definition of the outcome of interest (for best practices, see Greckhamer et al., 2018).

Weak definitions of outcomes in QCA approaches might be expected to hinder the consideration of which conditions should be included in the configurational model. In this study, the opposite was true; the selection and measurement of conditions was driven by polycentric theory. The low coverage of the configurations that led to the outcome in this study (only three cases contributing to the configurations) is a reminder that theorization of these complex causal conditions is in its infancy—it is not a problem with QCA as a method (Greckhamer et al., 2018). My analysis, while not revealing different "patterns of polycentricity" in the form of multiple, diverse, equifinal configurations, does yet support further hypothesis-building around the relationships of the measured conditions to each other. In future work, I would still work with these seven conditions, though I would iterate to develop more fine-grained interview protocols and ranking criteria. For example, it would be useful to lead into the interview

question about annual goals by first establishing some broader annual baseline, like what subjects would consider a "good year" in their work (see Chapter 4 for discussion of participants' responses to this specific question). Additionally, follow-up prompts might be better developed in order to bracket answers to open-ended questions. The questions in the interview protocol ask for positive examples, e.g., with whom goals are shared; follow-up questions could bracket these positive responses with negative examples, e.g., with whom goals are not shared. Interview participants tended to do this themselves in response to some of the more successful questions, for example, beginning their discussion of constraints by listing things that do not constrain their ability to act.

The two alternate configurations, as distinguished by the presence of either WOVAR or INDGO in the solution after membership calibration was relaxed, suggests a particular opportunity for follow up with better definitions of diversity and complexity in the polycentric workplace. Institutional researchers have hypothesized that polycentric governance regimes, being more "complex and diverse," have higher adaptive capacities (see, e.g., Pahl-Wostl, 2009), but it is not clear from these results how we should expect such diversity and complexity to manifest at the operational level.

I am receptive to the critique that SINDE over-simplifies polycentricity as an outcome, after all, the study is based on a multifaceted view of polycentric order. However, a more fundamental issue with SINDE as an outcome is that some of the conditions in the configurational model may just as well be considered outcomes. As mentioned above, with the exception of WOVAR, in this study $X_i >= Y_i$. In other words, the data are more consistent with pairwise relationships of necessity than they are with relationships of sufficiency (see Table 6). Three conditions—SHAGO, DEDEP, and DECOM—are above the threshold, 0.9, sometimes recommended for analysis of

necessary conditions (Knieper & Pahl-Wostl, 2016, after Skaaning, 2011).

Table 6

Consistency of Individual Conditions as Supersets of Outcome and Negation of Outcome

	wovarc	indgoc	shagoc	bigdec	dedepc	decomc	constc
sindec	0.71	0.86	0.92	0.77	0.95	0.97	0.81
~sindec	0.80	0.81	0.89	0.87	0.97	0.97	0.77

Note. The formula for the consistency of necessity relationships (scores shown above) is the same as the formula for the calculation of the coverage of sufficiency relationships (scores shown in Table 3) in fsQCA.

This result suggests that the sets of measures constructed for the configurational model here and the set of outcomes might more or less coincide, as opposed to one being the subset of the other. If further research bore out this relationship, it would not be surprising. I have argued elsewhere (Chapter 2) that water resources governance is paradigmatic of polycentric governance in part because of biophysical characteristics of the resource, and that these biophysical characteristics motivate overarching institutional arrangements even at a high level, abstracted from the operational level. If we accept the premise that governance at an operational level, overarching institutional arrangements, and biophysical transformations produce continuous cross-scale feedbacks in a polycentric system, then a measure like SINDE is both a result of existing polycentric arrangements and a cause of future polycentric arrangements. The counterfactual causal argument is at least worth considering: that is, when SINDE is low or absent, other aspects of the configurational polycentric model will be impacted. In other words, a water operator with little feeling of independence to make big decisions might also identify few people outside of their immediate circle who share their operational goals (~SHAGO), report that they often lack information to make a decision

(~DEDEP), and indicate that they have little need to communicate about their decisions (~DECOM). I would expect the coverage of such configurations to be low in a complex system.

5. Conclusion

This study introduces several measures of conditions of polycentricity at a subjective level, based on previous theory. These conditions include the extents to which actors: experience variety in the work assigned to them; define strong operational priorities; perceive their priorities to be shared by others; identify discrete, critical decisions in the course of their work responsibilities; recall information and action dependencies in their decision making processes; relate communicating their decisions to other dependent decision makers; describe constraints in their process; and evaluate their own independence to make decisions. These types of measures will not be entirely unfamiliar to practitioners of program evaluation in conventional organization development approaches. However, the subjectivity of the proposed measurements might be seen as a departure from institutional approaches, and a partial response to the call for more attention to actors and agency in institutional systems analyses (Heikkila et al., 2018). The question is, what might measures of these conditions tell practitioners about patterns of polycentricity in a given system?

Blomquist and Schröder (2019) argue for diagnostic inquiry of polycentric systems that presumes and anticipates that each organizational actor in a polycentric order is different in terms of their functions and operations. The measures proposed in this study additionally assume that individuals within an organization have different experiences of polycentricity, and this can be borne out by survey results. Further, they emphasize understanding how knowledge and perceptions of the characteristics of a given resource

system change over time, including contestation over differences in information (Blomquist & Schröder, 2019). The process-oriented nature of the measures proposed here tries to address these dynamics at a single point in time, but would also be appropriate for time series approaches. Other recommendations include inquiry into the kinds of decision making autonomy that actors have and the relationships they have with other actors, whether competitive, cooperative, or collaborative (Blomquist & Schröder, 2019). Bruns (2019) builds on these recommendations, by suggesting participatory social science approaches to understanding how actors' interests and priorities for change connect, converge, or conflict with one another. The measures proposed here approach these issues with attention to how individual goals, identified by an interviewee, are shared by other actors in the interviewee's sphere of relationships. These interviews would be enriched through participatory methods such as fuzzy cognitive mapping, to produce more fully-realized and reliably comparable subjective accounts of actors' contingent decision making contexts (Reckien et al., 2013).

A diagnostic approach to analyzing patterns of polycentricity should assess the quality of actors' interactions and opportunities to achieve subjective goals; it should not be used to prescribe a policy intervention. Polycentric processes are active in the choices of actors in all complex systems. This does not mean, however, that we cannot find situations when these processes are absent. Following Aligica (2014), polycentricity can break down into either monocentricity or chaos. Among the conditions measured subjectively in this study, the condition most vulnerable to breakdown is that of shared goals (Aligica, 2014). A system based on shared goals is represented at the subjective level in this study by the measure of SHAGO. In the case of large-scale water infrastructure systems in Arizona, though participants in this study were heterogeneous

in their perceptions of the extent to which goals are shared, scores on this measure were generally high, even when their self-ranked independence to make decisions (SINDE) was not. This, interestingly, was despite heterogeneity in the particular goals participants identified (INDGO), suggesting a complex pattern of joint purpose toward achieving contingent goals. This system has meaning, there is a "sense of common purpose," that may define the function of the system more strongly than individual goals (Aligica, 2014, p. 63). In further refinement of the diagnostic approach in general, and in assessment of polycentricity in the particular case of Arizona water infrastructure systems, understanding the vulnerabilities of the purposes shared by participants in the system should be paramount.

CHAPTER 4

RUNNING THE RIVER: THE SUBJECTIVE EXPERIENCE OF OPERATING COMPLEX WATER INFRASTRUCTURE SYSTEMS IN ARIZONA

1. Narratives of War and Polycentricity

One of the most colorful chapters in Arizona's storied water governance history happened before Hoover Dam was completed and Lake Mead was first filled, before the large-scale municipal aqueducts of the lower Colorado River basin were constructed, and before Arizona signed on to the agreement that apportioned the water of the Colorado River between its basin states—the Colorado River Compact. In 1931, the U.S. Supreme Court had ruled that Arizona could not prevent the federal government's construction of Hoover Dam, because the federal government had jurisdiction of navigable waterways under the interstate commerce clause of the U.S. Constitution (Billington & Jackson, 2006). Three years later, at an apparent loss as to how to stop the construction downstream from Hoover of a second dam, the governor sent the Arizona National Guard to defend the state's interests. At the dam site near Parker, the Colorado River defined the border between Arizona and the state of California. The federal Bureau of Reclamation was on site, surveying in preparation for the work they would complete on behalf of the Metropolitan Water District of Southern California. When the contingent from the National Guard, flying the Arizona flag, took a steamboat up to observe the site—as the story goes—the troops got stuck and had to be "delivered to their campsite by the Los Angeles Department of Water and Power's fast motor launch" (J. Fleck, 2016, p. 72; Reisner, 1986, p. 258). Of the seven basin states, only Arizona fell mostly within the Colorado River basin. The state already had Roosevelt Dam and other dams of the Salt River Project, as well as the smaller Coolidge and Pleasant dams on the Gila and Agua

Fria rivers, capable together of impounding most, if not all, of Arizona's Colorado River apportionment. It was at least conceivable that the state would have to be satisfied with use of these Colorado River tributaries, especially if Parker Dam enabled California to draw away the available flow of the main stem of the Colorado River. The rival parties camped out at the proposed dam site for seven months, during which time the Secretary of the Interior called for a pause in construction while they appealed again to the U.S. Supreme Court to settle the conflict. This time, the court sided with Arizona, but only because the Bureau of Reclamation had begun construction of Parker Dam without authorization from Congress. This legality was soon resolved, as Congress authorized the dam and construction was completed in 1938.

Reisner (1986) called it "a *real* war" that left Arizona "without recourse, unless it wanted to declare war on the United States" (pp. 258-259). Los Angeles newspaper writers mocked what they characterized as the military campaign of the "Arizona Navy." Fleck (2016), while largely debunking the idea of intractable water conflicts, called it "the closest the West has ever come to a literal war over water" (p. 71). The narrative of water war is attention-grabbing and affective, which could serve a purpose—if it draws attention to what happens in place of real, literal wars. Ultimately, Parker Dam did help California to divert a disproportionate share of the flow of the Colorado River to its southern metropolises (an interbasin transfer), but it also became the diversion point for the Central Arizona Project, which augmented Arizona's water supplies beyond just those sources originating, or primarily originating, within the state. Johnson (1977), who successfully lobbied for this supplemental supply of water as president of the Central Arizona Project Association, explains the incidents surrounding construction of Parker Dam in less sensational terms:

> Why did Arizona follow this obstructive course? Perhaps a major reason, aside from the political opportunism previously mentioned, was the fact that there was no official state planning effort and no state agency with planning authority at that time, and no urgent need for Colorado River water. There was no great driving force for new water development in Arizona as there was in California. (p. 18)

In 1939, Arizona political leaders submitted to the authority of the federal government over allocation of the Colorado River by joining California and applying for a water delivery contract.

In contrast to the "water war" narrative, we could understand this episode as an example of a polycentric political system in which multiple autonomous authorities with overlapping jurisdictions "take each other into account in competitive relationships, enter into various contractual and cooperative undertakings," and "have recourse to mediating mechanisms to resolve conflicts" (V. Ostrom, 1991, p. 138). Moreover, a polycentric system is achieved when actors "interact with each other on their own initiative—subject only to laws which uniformly apply to all of them," in this case, the Law of the River and the precedents set by the U.S. Supreme Court over time (Polanyi, 1951, p. 195). The absence of a single authority directing water use and development plans for the Colorado River, or even a state-level water planning authority in Arizona (at the time) might seem chaotic, but a system can have order even when the precise outcome is not determined. Polanyi (1951), who coined the term *polycentric*, describes the conditions under which these types of order emerge:

> An aggregate of individual initiatives can lead to the establishment of spontaneous order only if each takes into account in its action what the others have done in the same context before. Where large numbers are involved, such mutual adjustment must be indirect. . . . This requires that information about the state of affairs in question should be available to each member of the aggregate; as in the case of such communal states of affairs as the condition of various markets, the current achievements of scientific progress, or the position of the law up to date. (p. 196)

Polycentric orders were initially called *spontaneous*, because they result from dynamic processes of self-governance and self-organization. These dynamic processes could be seen in the campout at the Parker Dam construction site, an information-gathering mission, informed by the experience of the construction of Hoover Dam, with the aim that Arizona would not lose further ground to its competitors. The National Guard sent regular updates by telegram to Arizona Governor Moeur. No shots were fired.

We could speculate about why the narrative of war is so dominant in the history of the construction of Parker Dam. Recent accounts of the event are virtually unanimous in their characterization: "Arizona stood on the brink of armed conflict" (Stanley, 2013); "it was a show of force. . . .'the last occurrence in American history when one state took up arms against another'" (Rodriguez, 2013); the "fight between California and Arizona over water actually veered from cold war to hot war—almost" (Harrison, 2015); and the "Parker Dam War was only the opening battle" in conflict that persists in a "legacy of mistrust and noncooperation" (Rosen, 2013). These journalistic narratives simply echo the Los Angeles newspaper headlines of 1934 and 1935, when contemporary journalists described the events at Parker Dam in terms of a violent conflict. In other headline news, the country was suffering the worst storms of the Dust Bowl, displacing people from the agricultural counties where winter wheat was grown. In Europe and Asia, authoritarian nationalist governments were conducting violent incursions into neighboring countries. Newspaper editors might have imagined the conflict between Arizona and California would read better as a parody of international conflicts as opposed to another chapter in the country's natural resource management initiatives, spurred by drought and the Great Depression.

Trends in research and scholarship are also affected by world events. I have written elsewhere about the politics that motivated the initial scholarship on polycentricity (Chapter 2). In contrast to journalistic narratives, the theoretical assumptions underlying scholarship on polycentricity should be tested. I follow Hayek (1945) in understanding polycentricity as fundamentally a product of the social use of knowledge and information through cooperative and competitive means. The question is, how do subjects in a polycentric, complex, large-scale water infrastructure system see the system? Do their accounts more closely approximate the news headlines, or the abstract assumptions of institutional scholars in academic discourse? The answers are important to a realist understanding of polycentricity, in which we assume local knowledge and discourses are factors that shape polycentric governance systems, and seek to describe the rules and norms internal to those discourses (see Olsen, 2011). The answers are also practically significant for public administrators and others who represent the public interest in large-scale water infrastructure, whose lives and livelihoods depend on the real outcome of competition, cooperation, conflict, and conflict resolution in the production of water resources. The persistence of the water war narrative from pre-WWII into the new century might suggest it has "acquired a life of its own," a potential threat to the public interest, which I will return to in conclusion (Molle, 2008, after Roe, 1991).

2. Arizona Drought Contingencies and Water Agencies

Although the peaceful resolution of the conflict at Parker Dam created mutual benefits to both Arizona and California water interests, the lower Colorado River basin and its principle watersheds in Arizona continue to be an interesting case study of complex water governance, characterized by a multitude of water users and decision

makers with overlapping jurisdictions. Since the pre-WWII boom era of federal reclamation projects, water infrastructure capacity continued to be augmented through projects like Glen Canyon Dam, New Waddell Dam (replacing Pleasant Dam), and raising Roosevelt Dam. These projects, along with projects proposed and never completed, each represent significant conflict, and conflict resolution, and cooperation between interests (see, e.g., Espeland, 1998 on Orme Dam). The Central Arizona Project, built by the Bureau of Reclamation and operated by the Central Arizona Water Conservation District, facilitated an increase in passive and managed groundwater recharge projects, water exchange and conjunctive use, and wheeling of non-project water (Avery, 2018; Scanlon et al., 2016). The Gila River and its tributaries, the source of water for dams built by the Bureau of Reclamation and the Bureau of Indian Affairs for the Salt River Project, Central Arizona Project, San Carlos Agency, and other infrastructure projects, has yet to be fully adjudicated—legal rights to surface and ground waters may always be ambiguous within the state (Feller, 2007; Larson, 2018). At the same time, water shortages on the Colorado River may soon exceed the combination of voluntary and mandatory mitigation efforts that have, to this point, kept water imports flowing to Arizona's desert regions—an eventuality that has been planned for for decades, but which still poses many uncertainties (Buschatzke & Klobas, 2018). Water appropriations are made directly by a variety of decision makers, agents and agencies, which include private individuals, private for-profit corporations (e.g., EPCOR), private non-profit corporations (e.g., Salt River Valley Water Users' Association, which operates the Salt River Project), tribal governments, municipal governments, irrigation districts with special taxing authority conveyed by county governments, and multi-county water conservation districts with authority conveyed by the state (e.g., Central Arizona Water

Conservation District). All of these are autonomous, typically functioning as private or municipal corporations, as opposed to subordinate agencies of the state or local governments. In addition, agencies of the federal government play significant water provisioning and production roles (e.g., U.S. Bureau of Reclamation and U.S. Bureau of Indian Affairs).

This study draws from in-person interviews I conducted with ten employees of organizations with authority and jurisdiction for water resources production, provision, and appropriation in Arizona, between December 2017 and June 2018. The interviews were semi-structured, with open-ended questions related to a proposed formal structure of polycentricity (Aligica, 2014) and decision making contexts (Kiser & Ostrom, 1982). The questions were written in advance without using jargon, like the word "polycentricity." Interview duration was, on average, 48 minutes per person. I recorded and transcribed the interviews and used the qualitative data analysis software package, MAXQDA, to facilitate quantitative text analysis and iterative coding of themes in the transcript texts (VERBI Software, 2020). Each of the people I interviewed were responsible for some level of operational decision-making in large-scale water infrastructure systems across Arizona, invited to participate in the study from the types of agencies described above through purposive theoretical sampling (Rapley, 2014). I refer to them as *water operators* because their work is concerned with the physical appropriation and distribution of water, but approximately half of them performed symbolic decision making about water appropriation at least part time (Kiser & Ostrom, 1982).[12] Of the ten people interviewed, the mean length of their tenure in their position

[12] Some of the organizations in which study participants were employed have operations departments; my use of the term "operations" is not necessarily consistent with how the term might be used within these organizations.

was 13.1 years (standard deviation 10.7), and the mean length of tenure in the organization, i.e., including previous positions held prior to promotion or transfer to the current position was 22.7 years (standard deviation 11.1). Interviewees typically had started their careers within the organization and many had significant experience within that organization. Of the two interviewees who started their careers outside of the organization they worked for at the time of the interview, one had previously worked in water resources planning, and one had worked in an adjacent (not water-focused) engineering field. Knowing that several studies have been conducted using interviews of water sector managers, water users, and water stakeholders in recent years, I sought interviews with people who were less-frequent participants in academic studies. Two of the ten people I interviewed reported that they had been interviewed for a research study "recently," however, two more had been interviewed more than five years previously; an additional two interviewees regularly answered inquiries from the media or professional organizations.

Previous interviews of people working in the Arizona water sector have tended to focus on water experts, as represented by state and city water managers, and water stakeholders, most often agricultural water suppliers and users. In 2005, interviewers asked water managers at city and state water agencies with planning and decision-making authorities in the Phoenix metropolitan area, along with four respondents from the Salt River Project, about the relationship between water science and the political process of policy decision making; respondents unanimously characterized the decision making context of water management as uncertain, while those with more exposure to political processes were more sensitive to political aspects of water management (White et al., 2008). City water managers interviewed in 2009

about responses to drought described the Central Arizona Project infrastructure as facilitating a regional perspective on water management, encouraging city water managers to "push, pull, and challenge one another during drought events" informally (in the words of the researcher); they identified their lack of decision-making autonomy regarding financing for capital improvements as a limitation in drought preparedness (Engle, 2012, p. 1144). Water sector experts, including agricultural water users and managers at irrigation districts, water conservation districts, and the Arizona Department of Water Resources have indicated that, because water supply, pump and canal capacities, and irrigation technologies are generally not very flexible over the short- to mid-term, farmers in central Arizona tend to respond to changes in water costs with changes in multi-year crop and fallowing patterns (B. E. Fleck, 2013). Interviews with people in state water planning, agricultural and municipal stakeholders' associations, and agricultural water users have explored the combinations of cost savings and increased profits that would incentivize adoption of more efficient irrigation technologies (Budiyanto, 2014). Interviews with water and agricultural stakeholders and experts informed researchers' efforts to "open up" alternative narratives about the prospects for continued irrigated agriculture in central Arizona, as opposed to "closing down" around the institutionalized, dominant narrative of agricultural decline and urbanization (Bausch et al., 2015). The authors suggested that the prognostic and motivational aspects of the narrative of agricultural obsolescence may account for its current prevalence in Arizona water discourse (Bausch et al., 2015), though, I would additionally emphasize, the prevalence of different narratives can also be attributable to the number and diversity of actors involved. Most recently, interviews and focus group discussions with water, land, and conservation stakeholders in the Phoenix metropolitan

area were used to elicit salient connections between actors and issues in the food-energy-water nexus; interviewees consistently named the Arizona Department of Water Resources, Central Arizona Project, and Salt River Project as the stakeholders with the most influence over food, energy, and water systems (White et al., 2017).

Total annual water appropriation in Arizona was last estimated by the U.S. Geological Survey at 6.7 million acre-feet (8,264 million cubic meters) (Dieter et al., 2018). Of that total, 3.6 million acre-feet came from surface water sources, including rivers and project water, and 3.1 million acre-feet from ground water (Dieter et al., 2018). Peak historical water use for the state was in about 1980. Deliveries of Colorado River water in 2018 through the Central Arizona Project were 1.5 million acre feet, and trending downward, primarily through planned reduction of agricultural irrigation water (Central Arizona Water Conservation District, 2019). Deliveries through the Salt River Project in 2018 totalled 0.766 million acre feet, a relatively low-delivery year in which deliveries exceeded the year's natural runoff, thus surface and ground water stores were used (Salt River Project, 2019; in wet years the project receives over 1 million acre feet of runoff). The state was in a multi-year drought. These figures, including the trends and year-to-year dynamics evident in this snapshot, more or less represent business-as-usual in the Arizona water system.

Objective measures, such as water deliveries and trends, should not be taken to mean that what water operators and other people in the Arizona water system experience is business-as-usual. As I have discussed elsewhere (Chapter 3), water operators' job descriptions include such provisions as the abilities "to accept responsibility and make decisions during unusual situations and emergencies" and "to think quickly and logically to arrive at a plan of action" (Central Arizona Project, 2015).

In interviews, they describe their work as variable, complex, and interesting—in other words, characterized by change and novelty. From a public perspective, as well, the Arizona water system often appears to be a site of controversy and challenge, where business-as-usual is presumed to be untenable. In April 2017, *The Arizona Republic* published an editorial from two members of the board of the Central Arizona Water Conservation District, outlining their organization's preferred drought plan, followed by an opposing editorial from the state's water director (Buschatzke, 2017; Taylor & Arboleda, 2017). A newspaper editorialist opined in one headline that "Arizona's water war is escalating" and, in another, "Water will be the issue in 2018, and that scares me" (Allhands, 2017a, 2017b). At the start of 2018, during the period the interviews for this study took place, there was a lot of pessimism shared in *Arizona Republic* editorials and news features; the editorial staff condemned disagreements between the Arizona Department of Water Resources, Central Arizona Water Conservation District, state legislature, and Governor's office as parochial "turf battles" wherein each was acting independently without recognition of shared interests ("Our View: Nasty Fights Are Threatening the Water We All Need to Live in Arizona," 2018).[13] However, by the end of the year, these groups, along with the Gila River Indian Community and other major decision makers, had mostly mapped out a Drought Contingency Plan heralded as a bipartisan turning point in Arizona water history (Gammage, 2019). The other lower basin states and the government of Mexico also joined agreements on how to share expected water shortages on the Colorado River.

[13] One dispute involved claims to sovereign immunity made in court proceedings by the Central Arizona Water Conservation District, a relevant issue, but not one that is necessary to detail here.

3. Terminologies of Polycentric Governance, Workplace Evaluation, and "Authority"

The broad view of polycentric governance of natural resources is that it comprises all those processes that organize resource users within and between the formal organizational structures of organizations (see, e.g., Hayek, 1973b).[14] Challenging processes of mutual adjustment are conceived of by some scholars as fundamentally economic problems, because they involve optimizing the uses of resources—or "elements" of the problem—within constraints, toward a joint purpose (Polanyi, 1951 p. 217). Further, polycentric resource governance tasks involve planning (on an individual level), because economic problems arise only as a result of changes which require resource users, or their agents, to make new decisions (Hayek, 1945). Resource users are thought to be sensitive to changes in the system because of their proximity to first- and second-order institutional and biophysical feedbacks. These processes, summarized in Table 7, are what some institutional scholars mean by the term *governance*.

The governance processes listed here come from a large literature in institutional analysis and governance scholarship, and each is a technical term with a specific definition (or multiple definitions) in this literature. Here I have represented the terms, to the degree that seemed practical, using gerund verb forms ending in the English suffix *-ing*, to emphasize that these are all types of actions or series of activities (i.e., processes). This is consistent, for the most part, in how these terms are used in the technical literature. A few of the ideas are not represented well by a one-word gerund, and instead are included as a compound term with both a gerund and an object, e.g., "experiencing conflict" or "perceiving risks." Several terms are already undergoing a

[14] In this view, governments are one type of organization.

transition in their use in the literature to a hyphenated compound form that serves this same purpose: i.e., “rule-making,” “forum-shaping,” “forum-shopping,” “level-shifting,” and “self-correcting.” The most complicated of the compound terms in Table 7 is also the newest, and least codified in relevant literature, the terms referring to the making and testing of cross-scale linking compacts. I have included it here based on analytical framing used by Heikkila et al. (2011) in research specific to polycentric governance of water resources, in which river basin compacts frequently form a potential basis of constitutional rule-making between agents and agencies with autonomous authority and overlapping jurisdiction within a watershed. (In the Arizona water system, the 1922 Colorado River Compact is the eponymous agreement of this type, but the recognized “Law of the River” and the overarching constitutional-level system of rules actually comprise this and many subsequent compacts, federal rules, and court decisions—including, most recently, the Colorado River Drought Contingency Plans.) I include the terms “making cross-scale linking compacts” and “testing cross-scale linking compacts” because scholarly consensus on polycentric governance processes is not complete, and, particularly at larger spatial scales and higher levels of system complexity, there is yet room for useful analytical distinctions to be made. Other expressions could be substituted in place of these terms.

Table 7

Processes of Self-Governance in a Polycentric System

	Processes of mutual adjustment in a polycentric order	**Individual actions and institutional feedbacks**	**Generic tasks of polycentric governance[5]**	**Polycentric processes as feedbacks in a polycentric order**
Time step 1 /First order	Cooperating[1] Competing[1, 2] Experiencing conflict[1] Resolving conflict[1] Consulting[2] Persuading[2]	Learning[4] Perceiving risks Inferring outcomes Provisioning[6] Producing[6] Distributing[6] Appropriating[6] Assigning[6] Consuming[6]	Consuming[5] Financing[5] Producing[5] Provisioning[5] Monitoring[5] Sanctioning[5] Rule-making[5] Coordinating[5] Resolving disputes[5]	Testing cross-scale linking compacts[7]
Time step 2 /Second order	Learning[3] Imitating[3] Being disappointed[3] Experiencing accidents[3]	Prescribing[6] Invoking[6] Monitoring[6] Applying[6] Enforcing[6] Conjecturing[4] Reflecting[4] Judging[4]	Internalizing social norms[5] Constructing collective entities[5] Making cross-scale linking compacts[7]	Forum-shaping[8] Forum-shopping[8] Level-shifting[8] Self-correcting

Note. [1](V. Ostrom et al., 1961); [2](Polanyi, 1951); [3]Hayek; [4](V. Ostrom, 1997); [5](McGinnis, 2011); [6](E. Ostrom, 1999); [7](Heikkila et al., 2011); [8](Aligica & Tarko, 2014)

At a glance, it is evident that some of the gerunds in Table 7 are too generic to be significant objects of analysis, especially when the verb is separated from its compound object in the technical term. A word frequency analysis shows, not surprisingly, that "making" and "being" are the two terms from the table that appear most often in the transcriptions of the interviews of Arizona water operators. So, too, are frequent terms, like "level" and "scale." The term *level* was used by participants in all but one interview, to refer, variously, to water levels (e.g., in reservoir or canal operations) and to abstract political levels (e.g., the senior management level in the participants' organizations). Because I used the terms *decision making*, *scale* (e.g., "large-scale," "time scale"), *learn*, and *experience* in the interview protocol, priming effects interfere with meaningful

analysis of these generic terms.

The majority of the terms in Table 7 do not appear at all in the transcripts. If you count both the terms as they are given in the table, and the verb root or lemma of each term, a third of the words do not appear in the transcripts. This is relevant because it indicates that specialized terminology exists in the institutional literature that may not be in common use among subjects in the system, particularly conversationally.

Besides terminology that appears superficially not to be shared in common between the lexicons of water operators and the technical literature, we should also be aware of terms that occur with some frequency in both how interviewees expressed themselves and how institutional scholars write about governance (again, Table 7). Based on word frequency analysis of the interview transcripts, considering both the overall frequency and the proportion of interviews in which the terms were used, these terms include "coordinating"/*coordinat-* and "producing"/*produc-* (used with some frequency, in all but one interview). Terms that occurred less frequently, but are still worth mentioning, include "consulting"/*consult-*, "monitoring"/*monitor-*, and "conflict." These terms are important because analysts should be aware that the terms may have different meanings for the subjects, in this case water operators, than the ways they are defined in institutional analysis and governance literatures. I will return to discuss the term *conflict* as it relates to the narrative of water wars below.

Direct feedback on the questions asked in the interview protocol gives valuable insight into whether, or to what extent, Arizona water operators have similar ways of talking about water governance as do institutional scholars. The interview protocol in this study comprised ten analytical questions in an order intended to build cumulatively on previous answers (see Appendix A, Chapter 3 for details). I asked interviewees to

answer from their own experience and encouraged them to both interpret the questions in whatever way made sense to them, and to ask me to clarify questions that didn't make sense. One participant actively restated my questions to make sure he understood what I was asking. For example, in the second question, I asked which people or groups of people share the annual operational goals that the participant has identified in the first question. This active participant asked me to clarify whether I was talking about groups within the organization or groups outside the organization. A second participant asked for the same clarification. This type of request for clarification is welcome, and shouldn't automatically indicate any problem with shared understanding. Several participants asked for a question to be repeated, but there was no clear pattern to questions which elicited this response. A few times participants commented substantively on the question I asked. For example, one participant said that identifying annual operation goals was "an *easy* question," while a second participant said, "I don't really know if I could say I look at things on an *annual* basis" (Participant A, Participant B). On a similar theme, a third and fourth participant, asked what a typical work day or work week is like, clarified: "First off, I would say there's probably no 'typical' week" and "we don't ever have any—we don't have *set jobs* to do, we have things that have to get done" (Participant C, Participant D). This feedback is useful, but in this case didn't indicate any systematic problems with the interview protocol.

The most analytically significant feedback on the interview protocol are the revisions and interpretations of the interview prompts that water operators gave indirectly in answering open-ended questions. For example, when asked about how others in the system learn about and respond to the results of water operations decisions, one participant spoke about *transparency*. Another participant, asked how

they track progress toward challenging goals, spoke about it in terms of *efficiency* and *customer satisfaction*:

> We do have deadlines throughout the day that we try to meet, or achieve, or exceed. If you find yourself *not*, then you know that either the *system* is challenging you—and it does, sometimes, because there's just unplanned things that happen that you have to roll with—but on any given day, if it's perfect, and you're efficient, you're always spot-on with what you're trying to achieve. I've always thought, if I was doing a good job, or I *thought* I was doing a good job, the only way to confirm that is a lot of times you get pretty direct and quick, swift feedback from your customers. (Participant B)

Transparency, efficiency, and customer satisfaction are examples of workplace evaluation constructs, perhaps especially in public or pseudo-public agencies, which may significantly shape narratives around communication and progress in these settings. The meanings of these interpreted constructs diverge somewhat from the constructs I had initially intended to assess.

A similar example was a participant who answered the question about identifying the people or groups of people who share the annual operation goals in part by identifying indirect and external *stakeholders*. In this instance, the participant used a construct that is familiar in public policy and program evaluation processes, and which can have a technical meaning in that context. Of the interviewees, this individual had the most planning and policy experience in a public agency; three other participants, who likewise had work experience in a public agency, also used the term "stakeholder." For example, in relating who shares their annual operating goals, one of these three water operators said:

> [We] maintain our database and the information we post on the website so that we can try to make our operations transparent so that our stakeholders can rely on that. Some of our stakeholders review our website multiple times a day every day, so when we have an outage or any downtime, a lot of times we're *quickly* notified about it. (Participant E)

In each case, the participant used the term first, early in the interview, without my introducing it or asking a question directly about stakeholders. A term such as "stakeholder" or "customer" can also be seen as part of a workplace culture, where norms or rules may suggest which terms are socially preferable to refer to water users and people with water rights who are eligible to receive deliveries from the water system.

An issue at the crux of this study is whether people who work in what we might consider—as a mental shortcut—a "polycentric workplace" experience autonomous decision-making at a subjective level, and with it, the need to adjust those decisions based on the decisions of other autonomous authorities with overlapping jurisdiction in the same system. In the interview protocol, I used the phrases "decision-making autonomy" and "independence to make big decisions" to explain the purpose of the project and the final analytical question of the protocol, which asked water operators to rank their own subjective experience of autonomy on a scale of one to five.[15] Two of the water operators I interviewed also used the term *autonomy* in their responses to open-ended questions: one used the term in response to the question about "independence to make big decisions," suggesting that he understands the two terms to be synonyms; another water operator used the term throughout the second half of interview, indicating that he understood the overall aim of the interview was an inquiry into autonomy. (Both scored their independence to make big decisions fairly high, 5 and 4, respectively.) The use of this term is not analytically significant, since there could have been a priming effect by my own use of the term.

More interesting are the alternative terms that participants volunteered in

[15] The mean of the self-ranked scores given by water operators was 3.4, with a standard deviation of 1.2.

descriptions of their decision making environment—most notably, the term "authority"/*authoriz-*.[16] As one water operator said, while explaining why he didn't rank his independence to make big decisions higher:

> There are certain—and it is right to have it this way—there are certain thresholds that I need to have approval above me. So in my mind, when you say, "Give me a five," I have absolute authority to make any decision I want. Okay, well, I don't have that. So, that's why I settled on four. (Participant F)

Another water operator explained the connection between several of these concepts in his thinking in response to a question about what would constrain his ability to act on an unexpected opportunity or a sudden threat:

> If that dam were to flood, or there was an earthquake that weakened the structure, or something catastrophic was going to happen there, there's *rules* of steps that we should follow and procedures we should take. But again, I wouldn't say we need to get *authorization* to do those, or make those decisions. Some of those decisions are *prescribed*, and we're supposed to follow those guidelines, with the understanding [laughing] that you're responsible for any of the consequences that follow [. . .]. But the *decision making* autonomy in that is still retained within the specified group. (Participant A)

A third water operator also connected the term *authority* to the question of what might constrain his ability to act on an opportunity, providing the example of a novel water exchange initiative between entities in the Arizona water system (an example of the cooperation facilitated by infrastructure developments that I mentioned above). In his additional comments after the final analytical question in the interview protocol, he elaborated on his perspective about balancing multiple concerns in water decision making:

> Decision making, sometimes it is sort of held out there as this kind of mysterious thing, and, of course, we make decisions all the time, right [laughing]? The water resource kinds of decisions are fairly rarely *pure*—I haven't actually been in a situation to make *pure* allocation decisions. They're typically much more

[16] At least two organizations in the water system are legally designated as authorities, the Southern Nevada Water Authority, and the Arizona Water Banking Authority.

> nuanced. [...] You can either *start* large—like we need to add new flexibility, or we want to be able to accomplish a policy goal—and then think of all the little pieces that you have to tinker, and how you can interpret a provision in a contract, and what statutory authority to grant you that ability. Or, sometimes it does actually come from the other side. Which is, you *have* a very detailed, specific question and you need to make a specific decision, but you have to keep it sort of like, "Am I having an impact on this larger issue?" (Participant G)

He likened this role to *decision validation*, saying that, in his view, data visualization in particular helps to reframe water issues so that multiple concerns—for example, short-term and long-term objectives—can be considered together without prematurely closing in on a solution.

This observation about decision validation framings also highlights one of the challenges of talking about decision making autonomy with water operators, as they sometimes consider themselves to be in support roles to the official decision makers, which can include an elected board, in the case of irrigation districts and public or municipal corporations. An alternative construct, provided by another participant to distinguish what operators in his position do from the type of autonomous decision making that others in his organization regularly perform, is instructive on this point. He explained, "Our procedures and policies have been laid out, you know, pretty well before us, so it's—I would categorize it as sort of, standard procedure, but falling into the *extreme* side of standard when we have to exercise a lot of judgement" (Participant E). The authority to exercise discretion or judgement may be more in keeping with the kind of autonomy that water operators experience than *decision making* per se.

In total, four water operators used the term *authority* in connection with decision-making autonomy, in much the same way that an institutional scholar would think about polycentric governance. Water operators in Arizona are all familiar with

authority as it relates to water law. Much of the large-scale water infrastructure in Arizona is first "authorized" by Congress in order to establish legal rights and federal financing. As background information, one water operator explained to me that Congress' authorization makes Bureau of Reclamation infrastructure possible, that Congress designates the Secretary of Interior as the Water Master of the Colorado River system, "but then all of that authority gets delegated all the way down" (Participant H). Given this common referent, it is worth noting that the majority of water operators in this study actually did not discuss authority.

4. Narratives of Running the River and Operating Operationally

In the previous section I compared the responses of Arizona water operators in interviews to preconceived ideas about polycentric governance, which is useful for revealing how one kind of technical expertise (e.g., institutional scholarship) might bias attempts to understand another kind of technical expertise (water operations). In this section I take an emic approach, to study participants' interview responses in an inductive mode, and discover narratives in use in their own explanations of the Arizona water system.

One of the most striking, immediate patterns of how water operators talked about their workplace decision making environment was the array of prepositional phrases and metaphors that participants used to locate processes in their organization and position themselves relative to those processes. In larger organizations in this system, water operators work in a control room or operations room as part of a rotating pool of workers. Water dispatch decisions are implemented remotely in these rooms, at an equivalent desk in smaller organizations, or even by telephone and email from home during overnight or weekend shifts. So, from the outset, some people are "in" control

and/or operations in both a literal, physical and figurative sense. Water orders are called in and out, and there is both a figurative workflow and the physical water to manage each day. From the "top" of the subsystem it takes time for water to travel to the "bottom" of the system—about two days, for example, from Lake Mohave to Lake Havasu, and three days, from Parker Dam to Imperial Dam on the Colorado River. (At an even larger scale, flow from the Upper Basin to the Lower Basin is in the back of everybody's minds, if not a daily concern.) Operators' day-to-day planning takes these physical limitations into account, while also moving water virtually in the system, as stakeholders, customers, or contractors upstream and downstream make changes in their initial water orders. Because of the time it takes to deliver water in large-scale systems, changes in water orders can mean that an amount of water already being delivered needs to be delivered somewhere else on short notice; many segments of the system have little storage capacity. One participant, in particular, drew self-conscious similarities between the structure of decision making in his organization and upstream-downstream flows:

> In my little group [we're] sort of in the middle of a chain of things that would lead to a decision. So, upstream of me would be staff work to compile data, to run some models, or do some research, and that might be coming from *other* [internal] groups as well [. . .]. Typically, in a kind of decision-making role, making planning or policy recommendations, that are then going to go from me *up* a bit, and then many of those are ultimately going to go *through* our board. So, I would say there's probably more—there's sort of more raw data-analytical things that feed into *my* decision making, but my decision making is going to feed more into the, kind of, policy apparatus that goes within our organization. Some of the decisions come without a whole lot of need for—if we know the issue well enough or have access to the information *itself* to make a decision—I do obviously depend on other people to help support that. I would say more of the flow is *up*, than coming *from below*, up. (Participant G)

All of the operators I interviewed described working in a management structure with

other decision makers above and below them. Another interviewee with some planning responsibilities described, similarly to the quote above (from Participant G), that information flows "from the bottom up," for example from stream gauges, to support operations and projections (Participant I). Approval and authorization come down from above, but so do challenges: "if you're flexible with whatever else comes down the pike, that's your success," said a water operator explaining how he knows he's making progress (Participant B). In smaller subsystems, operators may have more of a level experience of running important decisions through the general manager, who then brings the issue to the board for approval, and not see much need to share information with those below them—these systems can operate on more of a need-to-know basis, with quick check-ins to compare information before a decision is made. In the largest subsystem, the amount of time that agreements take to be circulated and finalized can be a source of concern for operators waiting for direction to be "handed down" from upper management (Participant E). However, in the middle, many operators described approval of plans and projections by boards or managers as somewhat of a formality, with few surprises:

> I already know what I can do. I know what I'm going to do, I know if I need to call [a manager]. [. . .] As long as I don't have one of these guys sitting there with a red face in front of somebody I did okay. If they already knew, they're: "Oh, yeah, we already knew about that." It's handled. So, I have a, I would say, a lot of freedom on decision making, but you were asking about the *big* decisions. I mean, I make decisions all day long, that I never have to say or do anything about, as long as the farmers are happy. [. . .] I already know if I can do it before we talk to him, but we're still going to talk about it." (Participant D)

The "big" decisions, in this sense, might by definition be the ones that aren't a water operator's responsibility.

These ways of thinking about decision and information flows are probably

common to many types of workplaces. For example, in addition to the participant quoted earlier, three other interviewees referred to decisions or information going up the "chain of command," a metaphor associated with military hierarchies. The metaphor of a *chain of command* conveys both the importance of each individual "link" in the chain to the overall structure and also the imperative for an individual to "follow the chain of command" by relaying information along the chain as opposed to addressing themselves to someone above their station. (Polycentric processes of level-shifting and level-shopping violate a chain-of-command model.)

A metaphor is only half of a narrative, if it is part of a narrative at all. Molle (2008) observes that in water resources development discourses, narratives are simple stories about why two negative aspects of a particular problem are causally related—for example, problems like water waste, pollution, insufficient price structures, floods, droughts, deforestation, irrigation inefficiencies, evaporative losses, lack of human capital, bureaucratic obstructions, insecure tenure, or insufficient property rights are connected in narratives in a way that simplifies complexities and points to a stable and rational solution. (In actuality, narratives, because they are self-validating, are the most stable part of the conceptual map, and over time can rationalize a variety of solutions.) An example he gives that is very salient in the Arizona water system is the *lion's share* narrative (Molle, 2008, p. 137). One variant of this narrative states that agriculture uses too much water because irrigation efficiencies are not optimized; thus, better water pricing will solve the problem and make more water available for preferred uses (e.g., urban development or ecological flows).

Decision making was not a problem for participants in this study. In interviews, water operators explained how their experience in their positions had prepared them to

handle difficult and novel situations. For some, peer support, managerial checks and balances, and practices like having a standard operating procedure (SOP), annual operating plan (AOP), modeling projections, and data visualization, give reassurance that decisions will hold up to scrutiny. However much these help support decisions, though, ultimately it comes down to, as one water operator put it, "being a really good guesser":

> It is always nice to make a data-based decision. Those are easy—it's a much easier justification about why you did it, or why you *didn't* do it. Sometimes, if you've done the same thing over and over for a while you get a little less likely to follow your data, because you just kind of *know* what you're doing—or at least you *think* you do. [. . .] Once you make maybe the same decision over a number of times, you get really comfortable with the risks associated with that decision. So, you know, maybe the model is not telling me everything I need to know about that thing, but I'm going to go ahead and make this decision because I'm pretty comfortable about what the *real* answer is. [. . .] You have those tools, they're an important piece, but they're not the *only* piece. I certainly feel that it's a mix of things. It's nice to have people to collaborate with, it's nice to have other opinions, it's good to have a tool- and a data-based approach, and it's great to have some institutional knowledge and experience and comfort with what the risks are to make a sound decision, over and over again. (Participant A)

A water operator in a different subsystem called using models for trying to predict operational parameters is a combination of art and experience:

> Typically we'll override what the model tells us anyway, because we'll know in the actual what it is. [. . .] There's a learning curve. Like I say, the *science* is easy, but the *art* is the challenge, and that's requiring years of experience looking at the numbers. (Participant H)

This participant went on to elaborate that models can never be perfect because, despite decades of historical records, "We haven't seen a repeated pattern yet. None. . . . Every year is different" (Participant H). Two other participants spoke about how important it was to minimize "surprises," either for themselves, for others in their organization, or for water stakeholders; they mentioned data tracking, models, and water stakeholders as

sources and sites of potential surprises.

Mostly, water operators seem to be successful in minimizing surprises, particularly those changes to expectations that could surprise others within their own organization. As a result, many processes have what appear to water operators to have essentially forgone conclusions:

> [The board] makes the decision, and *they* actually will officially on paper *approve* the plan. So, I guess, officially on paper, they could *not* approve the plan, and they could direct you to do something different. I've *never* seen that happen. But, in terms of the chain of command—that *is* the chain of command. They have the final, ultimate say on approving the plan. So, it does need to go through that level, but again, even for them, it shouldn't be a surprise. They will have known where we're headed, how conditions are, and—like I said—I've never seen them direct to do something different. (Participant C)

As mentioned above, water operators participating in this study had, on average, 22.7 years' experience within their respective organizations. The participants with less than ten years of experience included the water operator who spoke about surprises primarily in the context of stakeholder relationships—expressing the wish that, for example, that the dynamics of agricultural demands could be modeled with greater certainty. (One participant considered operators with less than five years' experience to be "new.") It is plausible that those who participate in a study of this kind would tend to have more experience, on average, than others within their organization, because, organizationally, they defer to people with more experience to give authoritative answers to unfamiliar questions.[17]

Operators credited their length of tenure, and in some cases the expertise of predecessors in their positions, for why decisions that might have been "big" to someone

[17] The contrary assumption, that, organizationally, research recruitment will favor people with less experience, because their time is considered less valuable, is equally plausible. However, I saw no evidence of that in this case.

with less experience were easy for them. Some of the participants have been involved in training new water dispatchers, especially since the long tenure of current water operators necessarily means that many are nearing retirement age. Water operators related how it may take several years for a trainee to understand the system:

> We always say in there [the control room], you have the individual's abilities, and that's part of it, but there's also the other side of it—that you're fortunate or unfortunate. We call it "unfortunately lucky" that you experience a lot of things that went wrong. So, as you gain that knowledge and experience from all of these events that you were fortunately unlucky to experience, that light comes on a little earlier. (Participant F)

Another water operator described the easy quality of decision making that comes with experience as just "second nature," explaining that the operators who work with him "know exactly what I have in mind before I even think it" (Participant J).

While experience helps to explain why operators are confident about their work, it doesn't explain several contradictory aspects about how the work is characterized in our interviews. This work is characterized as challenging, and highly varied, with no two days or two years alike. (Many said they loved this about their work.) The system is described as both simple and complex. Some interview participants said they often thought about the magnitude and value of the work. At the same time, operators don't give a strong indication that either they themselves, or others in the immediate organizational structure, are making "big" decisions. They can't rely on instruments like models to make decisions for them, and though there are checks and balances in the decision making processes in these organizations, from the perspective of water operators, the outcomes of many of these processes—whether formal or informal—are often well-foreseen. In particular, in answering interview questions about what constrains their abilities to act, water operators described themselves as relatively

unconstrained by anything like political considerations, precedent, or supply and demand. Yet, they also tended to say they had little flexibility, and that many actions were prescribed.

Two interrelated narratives resolve the seeming contradiction between the unconstrained-yet-strict decision context that water operators describe: *running the river* and *operating operationally*. These narratives both explain that challenging tasks in this complex system are not problems, because the system "dictates" the tough decisions. In the part of the Arizona water system that is natural infrastructure (but most specifically the Colorado River), the simplest narrative of running the river is given by the idea that the Law of the River dictates all operations on the river—broad policies are narrowly implemented in operations. People in other parts of the water system, in both natural and built infrastructure, have similar operational logics, however. Since operators refer to using built water conveyance infrastructure as "running the canal"—as engineers might talk about any variety of systems—it is not hard to understand why they might also refer to those who operate storage and diversion infrastructure on the rivers as "operating the river." In the highly mediated control centers that much water dispatch and day-to-day decisions are made in, operators *run* models, pumps, pumping plants, gates, calculations, risks, analyses, power plants, reports, and canals. In this view, the system mechanics are, in a sense, "mechanical."

However, the system itself can be slow to respond to operational changes, limiting "operational flexibility to run the river, to *respond* to certain conditions" (Participant E). Some operators characterized their day-to-day work as highly responsive, like "putting out fires" all day—as two operators put it—or dealing with "what's in front of me, based on what's thrown at me" (Participant D, Participant K, and

Participant B, respectively). Again, in this narrative, operators primarily respond to the system, and they know from experience what response the system requires:

> We make some *really* big decisions as dispatchers in this room. [. . . But] they're fairly easy to make because it is what it is. When you learn a system, and you know the system, and you know how to operate it, it is what it is. (Participant F)

The system presents challenges, as quoted earlier, and "it isn't *his* decision, it isn't [a] *management* decision, the canal is making it for you" (Participant B). These impressions of how the system, whether conceived of as the built infrastructure, natural infrastructure, or institutional infrastructure (i.e., Law of the River) dictate operations may not have been fully shared by all the operators who participated in the study, but there were elements of this narrative in most of the interviews.

Variants of the narratives of running the river and operating operationally can be seen in two somewhat more abstracted contexts as well, perhaps speaking more to the experience of those participants in this study who are more involved in planning and coordinating than dispatch and control. The first of these is the idea that water commands a certain type of response from people:

> I would not want to be in this position and not respect the resource, because I think you would run the risk of not making the right decisions then. [. . .] Maybe part of it is innate within me, but I know that everybody else out here that works for me is exactly the same way. I really think that that contextual aspect of being so in tune with the resource helps you make better decisions, because you just have that respect for the value of the water. [. . .] But I think it's so important that there's just something about water. (Participant C)

In this view, the resource that decisions are being made *about* matters—water is not like other resources. In the second view, it is *how* decisions are being made that matters, including whether a decision can be considered a decision at all. This, in particular, typifies the *operating operationally* narrative:

> The operational-type decisions that I make can be made *operationally*, like, in

> response to current conditions and the appropriate operational factors at the time. That doesn't speak very well to a decision that might be made from a *policy* basis, but I don't make a lot of policy decisions. They're mostly about what we're going to do or how we're going to deliver or utilize our resource. (Participant A)

Similar to others interviewed, Participant A said "operating," or responsibility for managing resources, was the part of the job he really liked—in his case, contrasted with engineering or policy making components of the position. *Decision-making autonomy*, the topic of these interviews, is not as relevant to the way operators see their jobs as *operational flexibility*. Good policy gives them operational flexibility, but physical constraints of the system limit operations. Operating operationally and running the river mean that the kinds of decisions water operators make are big, easy, challenging, important—and not really decisions at all.

5. Nirvana Concepts and Responding to Change

Polycentricity is an example of a *nirvana concept* in water governance (Molle, 2008). Polycentric theory serves scholars as a counterpoint to the assumptions based on the command-and-control models of water governance that prevail at times in policy discourses and news journalism. As a water governance realist, my task is twofold: I aim to understand how these systems really work, but I also need to be aware of how (and for whom) competing concepts of how these systems work are useful. The nirvana concept of polycentricity supports narratives in which consulting, persuading, learning, cooperating, and equivalent processes cause competing and potentially conflicting agents to jointly achieve contingent goals. As polycentricity's most eloquent scholar put it: "The pathway to peace in self-governing societies requires as much attention in reflecting on where one has been and on narratives about where others have gone before as on the course to take in further steps along the way" (V. Ostrom, 1997, p. 293).

To be sure, there are more ubiquitous nirvana concepts in water governance, such as *integrated water resources management* (Molle, 2008). Integrated water resources management is, likewise, a counterpoint to the seeming dysfunction or chaos that may otherwise characterize the sector, particularly to outsiders. However, in contrast to polycentricity, integrated water resources management supports narratives in which government agencies bring about ideal conditions in water systems by doing "what government agencies traditionally do (or at least are purported to do): identifying gaps, building capacity, raising awareness, fostering 'rational' cyclical/iterative policy or planning processes, convening stakeholders, monitoring, etc." (Molle, 2008, p. 134). The risk inherent in any nirvana concept is that it will be used to serve the status quo at a time when adaptation to changes in the system are needed.

Endogenous narratives are important because they provide causal explanations of water problems and their embedded solutions that are sensitive to context. Narratives internal to water operations may or may not be more accurate than prevailing or sanctioned explanations (e.g., "best practices"), but, so far as they belong to agents responsible for change in a particular system, they are highly relevant to outcomes. These assumptions are embedded in scholarly traditions of polycentric governance theory that posit that patterns of polycentric governance are always unique because they emerge responsively from unique local conditions. Paradoxically, though this aspect of polycentric governance is thought to be an explanation for the capacity of polycentric systems to adapt to change, and thus highly desirable from a social perspective, it prevents one successful example of polycentric water governance from being an effective model for application in other locations (see Chapter 2 for discussion of polycentric paradoxes).

By the same token, because narratives contain normative assumptions about what problems and solutions exist, analysts should (minimally) examine discourses for alternative narratives that may point toward more desirable outcomes. What outcome—or nirvana concept—the *water wars* narrative serves is speculation, but from a social perspective surely peaceful outcomes are preferable. According to the water wars narrative, violent conflict is the inevitable result of water scarcity. Under the U.S. federal public works concept of *reclamation*—an era as significantly motivated by catastrophic floods as by water scarcity—the water wars narrative helped to justify further augmentation of water supplies (e.g., more dams) as a common sense solution. As I have already asserted, many people have benefitted from the water storage and conveyance infrastructure completed in Arizona as a means of augmenting supplies, however, this solution did not resolve water scarcity. The subjective experience of users of natural resources that—like water in a desert—we consider scarce, is necessarily an experience of rivalry. In contrast to the water wars narrative, other prevalent narratives about the water sector in Arizona explain resource rivalry as a competition that fosters innovation, pragmatism (Gammage, 2019), and resilience (Bausch et al., 2015). Though many people believe the era of big reclamation projects is over, today the *water wars* narrative appears to be having a second life in service of governance and policy solutions to drought and climate change.

The day-to-day work that operators do in the Arizona water system is varied, complex, and contrary. It takes such particular experience to do this work, that replacing operators when they retire is a serious concern for some participants in this study. Some of what water operators do is what institutional scholars would consider *governance*. As discussed above, relatively little of the day-to-day work of water operations in Arizona is

what the operators themselves would consider *decision making*. Water operators have goals within their subsystems that range from filling (but not over-filling) reservoirs, to delivering allocations (but no excess water), to running canals as efficiently as possible in terms of water waste and electrical costs (see Chapter 3 for discussion of measuring individual and shared goals). There have been conflicts, and potential conflicts. Particularly in the spring and summer, there are conflicts between competing demands for water and between water and hydropower demands—"there is strong demand for water in the summer in central Arizona, breaking news!" (Participant A). There is conflict between different uses on the river, especially during peak seasons for water recreation. There was, at the time of these interviews, conflict between multiple organizations involved in drought contingency planning, and the planning itself was made urgent because of low water storage and overallocation of the Colorado River—as one participant put it, "we wouldn't be having all those discussions and potential conflicts if they [reservoirs] were a lot more full" (Participant C). It is worth considering whether the care that water operators take to avoid making decisions in a way that would be controversial or surprising, and the deference they show to other decision makers (particularly within their organization), is not a factor in the lack of conflict in these workplaces more generally.

From a polycentric governance perspective, the most important decision water operators make is "choosing to act in ways that take account of others" (V. Ostrom, 1991, p. 225). Maybe that's what the Arizona National Guard and the Los Angeles Department of Water were doing at the Parker Dam site in 1934. Polanyi made a strong case for paying attention to narratives when he wrote that polycentricity between rivalrous agents and agencies was possible "*only* if each takes into account in its action what the

others have done in the same context before" (1951, p. 195, emphasis added). Narratives tell one part of this story, and the experience of water operators records the other.

CHAPTER 5

CONCLUSION

In my graduate research I have tried to attend to the history of ideas behind what scholars today understand as polycentric governance, while attaching this history to the only measure of these ideas that matters: contribution to solving problems of self-governance. Like others engaged in this field, I have conceived of three communities of practice for whom this work is potentially relevant: people who make day-to-day decisions about use of resources at an operational level, people who aim to build the enterprises of knowledge and learning through research, and people who (formally or informally) are responsible for making the policies that structure what is possible in our public lives. My strategy for this work has been to make the subjective experiences and situated knowledge of operational decision makers—specifically, water operators in the desert southwestern United States—accessible to policy makers. Because I am neither a water operator nor a policy maker myself, this strategy is fraught with all the usual possibilities and pitfalls that accompany communication in general. However, I have tried to approach this work with attention to the idea, as Vincent Ostrom wrote:

> How people act in governing their own affairs as individuals and in association with others is as essential to the constitution of a democratic society as is the action of those who make it their business to process conflict, facilitate conflict resolution, and act on behalf of the complementarities necessary for human communities. (Ostrom, 1991, p. 259)

I approached this work with the conviction that institutional scholarship could (and should) be scrutinized at the same time as it is offered as a potential source of insights into complex governance systems.

In the last ten years, a groundswell has occurred in scholarship on polycentric

governance. At the start of the decade, though gratified by Elinor Ostrom's recognition by the Royal Swedish Academy of Sciences with the 2009 Nobel Prize in economic sciences, some commons scholars worried that the idea of polycentric governance risked becoming the very sort of "panacea thinking" that Ostrom had fought so hard to dispel. Conference sessions and working groups were convened, special issues of publications organized, and books written to explore both the legacy of Elinor and Vincent Ostrom's combined lives' work, and the practical applications of polycentric theory. In my graduate studies over this intervening decade, the writings of several authors, documenting and codifying the influence and influences of the so-called Bloomington School of institutional analysis—a.k.a. Ostrom Workshop—have relieved my concern that polycentricity will be misunderstood (see, specifically, Aligica, 2014; Aligica & Boettke, 2009; Aligica & Tarko, 2014; McGinnis & Ostrom, 2012; Thiel, Garrick, & Blomquist, 2019). I hope that the issues that have emerged through my own research into operationalizing polycentricity will increasingly be recognized within this growing research community—most pointedly, the importance of understanding polycentricity as multifaceted, incorporating subjective measures of polycentric decision making contexts into diagnoses of patterns of polycentricity, and focusing on polycentric processes, including both governance processes and causal explanations of how systems work.

I have sought to show in this dissertation why a historically-grounded conceptualization of polycentricity is important in protecting the fidelity of the idea from the self-referentiality, dogmatism, faddishness, or servility to which academic knowledge in service of policy intervention and public dialogue sometimes succumbs (Burawoy, 2005, in Mollinga, 2008). In my view, the agenda for a scholarship of polycentric governance was most importantly set by Friedrich Hayek (1933), when he wrote:

> We discover again and again that necessary functions are discharged by spontaneous institutions. If we tried to run the system by deliberate regulation, we should have to invent such institutions, and yet at first we did not even understand them when we saw them.
>
> Unfortunately, this oldest and most general result of the theory of social phenomena has never been given a title which would secure it an adequate and permanent place in our thinking. The limitations of language make it almost impossible to state it without using misleading metaphorical words. (p. 129-130)

The needed title was supplied by Michael Polanyi (1951), when he coined the term *polycentric* and described polycentric problems. For both Hayek and Polanyi, the fundamental nature of polycentric problems was the individual experience and ordering of situational knowledge, without which the accomplishments of broader society would be impossible. Their writing is indispensable for understanding the sense of mutualism—encompassing both the processes by which individuals relate to one another and to the institutions they have constructed—that underlies polycentricity as an explanation for human achievements and an inspiration for solving social problems. Independently, Vincent Ostrom, Charles Tiebout, and Robert Warren (1961) reached a similar conclusion in their study of metropolitan governance, and gave it the same name, "polycentric."

The definition of polycentric governance detailed by Ostrom, Tiebout, and Warren (a.k.a. "OTW") supplies most but not all of the aspects of polycentricity that are critical for a multifaceted understanding of the concept. The OTW definition provides that polycentric governance occurs when there are *multiple autonomous decision makers*, individuals who are "formally independent of each other," who *choose* to "take

each other into account" through mutual processes (Ostrom et al., 1961, p. 831).[18] As Ostrom would reflect later, the OTW definition of polycentricity neglected to emphasize the *overarching system of rules* that provide the institutional context and coherency of polycentric governance according to Polanyi and Hayek, and a key distinction between *governance* and *government* (Ostrom, 1972). Aligica (2014, p. 61), in formalizing a logical structure of polycentricity, is careful to include this facet of the definition of polycentric governance, particularly as it relates to the variation between different instances of polycentricity, when he details some of the different ways the "characteristics of the institutional/cultural framework (the overarching system of rules)" might be organized. As Aligica (2014, p. 59) points out, the contributions of the Ostrom school to institutional analysis, particularly through the Institutional Analysis and Development (IAD) framework, have clarified how insiders and outsiders should be distinguished in analyzing the emergence of institutional arrangements. This last observation also specifically identifies polycentric governance as a system of self-governance within a given resource domain.

Last, but not least, McGinnis (2011) draws emphasis to the *overlapping jurisdictions* of the multiple autonomous decision makers involved in polycentric governance systems. I argue that this definitional facet of polycentricity is crucial to understanding polycentricity as more than merely additive; the jurisdictions within which authorities act overlap not just on *extensive* scales (e.g., geographically) but on multiple *intensive* scales (see Chapter 2). McGinnis (2011) gives some examples of these scales, explaining

[18] OTW and others, including McGinnis (2011), sometimes use the more ambiguous term "centers of decision-making" or "centers of authority" rather than "decision makers." While this allows recognition that some decisions are officially made organizationally, I avoid this term because it encourages reification of literal "centers," i.e., formal corporate operational headquarters, as primary actors in polycentric systems.

that jurisdictional units in polycentric systems are: multi-level (from local to global), multi-type (from nested general purpose units to cross-jurisdictional units), multi-sectoral (from private to public, including hybrids), and multi-functional (from provisioning to producing and all other governance functions). In addition, we can draw from Kiser and Ostrom (1982) and the IAD framework to elaborate that these governance functions are analytically nested along operational choice, collective choice, constitutional choice, and meta-constitutional levels.

Some, but not all, of this multifaceted definition is typically operationalized in contemporary studies of polycentricity. For example, Heikkila and Weible (2018) observe four "constructs" of polycentric governance (*multiple centers* of authority, *overlapping* centers of authority, *authority* or influence itself, and a *governance system*) and make the astute observation that institutional analysis of common pool resources have emphasized measures of decentralization (i.e., multiplicity of authority) as opposed to overlap of authority. I agree, but I note that the study in question does not make explicit use of the construct, *jurisdiction*, which potentially provides a better structure for how to measure the degree to which multiple authorities have influence over related domains (Heikkila & Weible, 2018). In my survey of operationalizations of polycentricity in institutional literature, the most truncated versions of the concept have represented it as the mere existence of multiple authorities within a jurisdiction. Using this truncated definition, it is difficult to distinguish any nested system of governance—including federated subsidiaries of governments and hierarchical, multi-level bureaucracies—from a polycentric system. Facets of polycentricity neglected in such a truncated definition are, first, the autonomy of the authorities (i.e., self-governance and self-organization) and thus also the processes of choice and mutual adjustment that structure the

polycentric decision-making context and, secondly, the unlimited diversity of jurisdictional units and, thus, infinite ways jurisdictions can overlap.

From their Greek etymology, words describing rule structures in English tend to be given by the suffix —*archy*, while rule processes are described by words ending in —*cracy* (Quinion, 2002). Taking just variations in autonomy of authority and exclusivity or overlap of jurisdiction, we can distinguish between the bureaucratic, federal, and hierarchical processes and structures often equated with systems of polycentric governance. Both bureaucratic and federal systems are characterized by exclusive or sovereign jurisdictions as opposed to overlapping jurisdictions. In bureaucratic systems, authorities in these separate jurisdictions, or bureaus, can be fairly autonomous from each other, while in a federal system authority tends to be carefully delegated. Changes in rules that seek to devolve authority can be visualized as a kind of flattening of a federal system into a more bureaucratic system. On the other hand, a move to centralize a federal system makes it more hierarchical. Authorities in a hierarchical system, like a federal system, have less autonomy than in bureaucratic or polycentric systems. However, in contrast to a federal system, multiple subsidiary authorities share nested jurisdictions in a hierarchy. This overlap of jurisdictions is similar to the overlap of polycentric jurisdictions, but without the autonomous authority that characterizes polycentric governance.

Interventions—in water policy, e.g., integrated water resources management, nexus approaches, and unified river basin management—typically seek to shift characteristics of systems from one structural type to another through devolution, delegation, integration, or decentralization. Such deliberate reorganizations can result in shortcomings that we can also see as different configurations of authority and

jurisdiction: assigning jurisdiction without authority (a problematic outcome of some devolution initiatives), authority without adequate jurisdiction (an outcome of some delegation and decentralization initiatives), or ineffectually limiting both authority and jurisdiction (an outcome of centralization and reorganization of subordinate authorities). The opportunities for actors to engage in polycentric processes like forum-shopping, forum-shaping, and level-shifting are reduced in more bureaucratic, federalized, and hierarchical systems, respectively. A system with only one authority—absolutism—or only one jurisdiction—totalitarianism—would hypothetically provide the least opportunity for polycentric processes, but in reality few situations like this exist. Likewise, without overarching institutions, chaotic rather than polycentric anarchy would result—however, situations completely without shared institutions are the exception, not the norm.

Thus, focusing on polycentric processes is an important way to ensure that this multifaceted understanding of polycentricity is less prone to two-dimensional operationalizations, but also important is to center the analysis on actors, as Heikkila et al. (2018) have, separately, also recommended. The processes that we should measure, if possible, are those opportunities that decision makers perceive, which are afforded by the particular pattern of polycentric governance that structures the context they find themselves in. A systems analysis of polycentric governance, when it focuses on outcomes that are easily quantified, can treat the agency of actors in the system as more or less the presence or absence of coordination. An actor-centered analysis should focus instead on the qualitative processes of mutual adjustment between actors—which entail many more processes, and messier processes, than mere coordination.

General avoidance of actor-centered approaches is surely partly attributable to

the difficulties of making consistent, qualitative measurements of subjective dynamics. At the outset, my aim was to contribute to developing a universally applicable survey protocol, relevant in both small and large systems, to draw out particular local contexts or patterns of polycentricity in operational decision making. Based on the historically-grounded, multifaceted understanding of polycentricity described above, I tried to identify conditions of polycentricity that might be elicited through interviews with operational decision makers. My configurational analysis of interview data from a survey of Arizona water operators was far from decisive (see Chapter 3), yet a configurational approach to understanding the differences and similarities in polycentric decision making contexts holds some promise.

Qualitative comparative analysis of the sets of conditions in my survey of operational decision makers in the Arizona water system suggested that, during the survey period (late 2017 to mid-2018) operators who ranked their own decision-making autonomy higher also perceived their priorities to be shared by others; identified discrete, critical decisions in the course of their work responsibilities; recalled few information and action dependencies in their decision making processes; related communicating their decisions to other dependent decision makers; and described few constraints in their decision making process. Two additional conditions formed alternate configurations together with the above; these conditions were measures of the experience of variety in the work assigned to them and, alternately, the operators' strong definition of operational priorities at the individual level. Because the complexity and diversity of polycentric governance regimes are thought to contribute to higher adaptive capacity (see, e.g., Pahl-Wostl, 2009) and the distinction between strongly shared goals versus individual goals has been proposed to be indicative of potential weaknesses in

polycentric organization (Aligica, 2014), these conditions at the margins of the experiences of these water operators are actually just as interesting for future research as those conditions which seem to coincide more closely with their experiences of decision making autonomy. It should go without saying that this dissertation research only scratches the surface of what might be possible in further development of subjective measurement of conditions of polycentric decision making, especially if the diagnostic approaches and frameworks of institutional analysis are brought to bear with the expertise in subjective diagnostic instruments already employed in program evaluation and organization development fields.

One of the concerns I had in my aim to develop a universally applicable survey protocol was that constructs important to institutional scholars would not either be imposed unintuitively or poorly translated into the languages and ways of thinking of operators in their unique polycentric contexts. After all, tacit knowledge and the knowledge of particulars is at the core of polycentric decision making. As a guard against this, I summarized the key processes that scholars attribute to polycentric governance and examined transcripts of my interviews with Arizona water operators to see whether and how this terminology was employed in their own answers to open-ended questions (see Chapter 4). Not surprisingly, few of the terms that make up a conceptual framework of polycentric processes for institutional scholars were used by these actors, despite evidence that they experience conditions of polycentric decision making in their day-to-day work. These processes include those already mentioned above, such as provisioning and producing and other generic tasks of governance; processes specific to polycentric governance arrangements, like forum-shaping, forum-shopping, and level-shifting; and potentially more specific tasks like making and testing cross-scale

linking compacts. Additional content analysis approaches could be leveraged to measure processes like these more deductively in interviews with decision makers in polycentric systems. In this case, it was not my intent to impose such a framework, but rather to triangulate between these constructs, the subjective experiences of the decision makers themselves, and expectations of how these systems work or should work.

The final piece of my analysis concerned these expectations of how polycentric governance in general and water governance specifically work. Polycentricity, as I have explored, is both a positive and normative concept. So, too, are the institutions which both prescribe expected behaviors and provide a basis for making inferences about what outcomes might come from discrete decisions. The distinction drawn in institutional analysis between rules on paper and rules in use points to a dialectic between processes as they are and processes as they are supposed to be. One way that mental models of causal variables in a system are expressed and reproduced is through narratives.

The narrative of *water wars*, as I discuss, is one that explains that water scarcity inevitably results (literally or figuratively) in violent conflict. This causal process might be used to justify, in Arizona for example, large infrastructure projects to augment water supplies and alleviate the threat of violence. Though this particular narrative is prevalent in journalistic discourses about water resources in Arizona during the timeframe of this study, I saw little evidence of conflict in either the terms used or explanations offered by Arizona water operators to describe how their system works. Neither did Arizona water operators explicitly employ the idea of conflict in the way that institutional scholars think of governance processes of experiencing conflict and having recourse to mediating mechanisms to resolve conflicts. Instead, these operators' experiences were grounded in interrelated causal explanations that I label *running the river* and *operating*

operationally. These narratives explain how operational flexibility and the physical constraints of the system are perceived to make critical judgements in the Arizona water system simultaneously easy and challenging. The tacit knowledge of these operators, made possible by experimentation over the long tenure of operators in the positions I interviewed, underscores the importance of centering institutional actors' experiences in analysis of governance and decision making. In contrast to the narratives of conflict that accompany various interventions that decision makers at other levels might like to impose on water governance, operators in the Arizona system have a sense of shared goals, and take care to minimize surprise or controversy that might result for others whose own goals are contingent on in operational decisions. To me, these observations validate the cause of understanding polycentric processes, both as these principles facilitate operations in challenging governance situations today, and as they might be facilitated to solve problems of governance in the future.

REFERENCES

Abdullaev, I., Kazbekov, J., Manthritilake, H., & Jumaboev, K. (2010). Water user groups in Central Asia: Emerging form of collective action in irrigation water management. *Water Resources Management*, *24*(5), 1029–1043. https://doi.org/10.1007/s11269-009-9484-4

Aligica, P. D. (2014). *Institutional diversity and political economy: The Ostroms and beyond*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199843909.001.0001

Aligica, P. D., & Boettke, P. J. (2009). *Challenging Institutional Analysis and Development: The Bloomington School*. Routledge. https://doi.org/10.4324/9780203876282

Aligica, P. D., & Boettke, P. J. (2011). The two social philosophies of Ostroms' institutionalism. *Policy Studies Journal*, *39*(1), 29–49. https://doi.org/10.1111/j.1541-0072.2010.0000395.x

Aligica, P. D., & Tarko, V. (2014). Institutional resilience and economic systems: Lessons from Elinor Ostrom's work. *Comparative Economic Studies*, *56*(1), 52–76. https://doi.org/10.1057/ces.2013.29

Allhands, J. (2017a, August 24). Allhands: Arizona's water war is escalating. *The Arizona Republic*. https://www.azcentral.com/story/opinion/op-ed/joannaallhands/2017/08/24/arizona-water-war-escalating/595348001/

Allhands, J. (2017b, November 30). Allhands: Water will be the issue in 2018, and that scares me more than it should. *The Arizona Republic*. https://www.azcentral.com/story/opinion/op-ed/joannaallhands/2017/11/30/arizona-water-policy-fight-legislature/899409001/

Anderies, J. M., Janssen, M. A., & Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society*, *9*(1). https://doi.org/10.5751/es-00610-090118

Anderies, J. M., Smith-Heisters, S., & Eakin, H. (2020). Modeling interdependent water uses at the regional scale to engage stakeholders and enhance resilience in Central Arizona. *Regional Environmental Change, 20*(3), 100. https://doi.org/10.1007/s10113-020-01654-1

Arizona Department of Water Resources. (2020, June 10). Press release: A statement on the 40th anniversary of Arizona Groundwater Management Act of 1980 [Government]. *Arizona Water News*. https://azwaternews.com/2020/06/10/press-release-a-statement-on-the-40th-anniversary-of-arizona-groundwater-management-act-of-1980/

Avery, C. E. (2018). New flexibility on the Central Arizona Project canal: The Tucson/Phoenix exchange and the system use agreement. *Arizona Journal of Environmental Law & Policy*, *8*(3), 89–100. https://www.ajelp.com/articles-summer-2018

Baldwin, E., McCord, P., Dell'Angelo, J., & Evans, T. (2018). Collective action in a polycentric water governance system. *Environmental Policy and Governance*, *28*(4), 212–222. https://doi.org/10.1002/eet.1810

Bausch, J. C., Eakin, H., Smith-Heisters, S., York, A. M., White, D. D., Rubiños, C., & Aggarwal, R. M. (2015). Development pathways at the agriculture–urban interface: The case of Central Arizona. *Agriculture and Human Values*, *32*(4), 743–759. https://doi.org/10.1007/s10460-015-9589-8

Beaumont, P. (2000). The 1997 UN Convention on the Law of Non-navigational Uses of International Watercourses: Its strengths and weaknesses from a water management perspective and the need for new workable guidelines. *International Journal of Water Resources Development*, *16*(4), 475–495. https://doi.org/10.1080/713672536

Benson, D., Gain, A., & Rouillard, J. (2015). Water governance in a comparative perspective: From IWRM to a "nexus" approach? *Water Alternatives*, *8*(1), 756–773. http://www.water-alternatives.org/index.php/alldoc/articles/vol8/v8issue1/275-a8-1-8/file

Billington, D. P., & Jackson, D. C. (2006). *Big dams of the New Deal era: A confluence of engineering and politics*. University of Oklahoma Press.

Blomquist, W., & Schröder, N. J. S. (2019). Seeing polycentrically: Examining governance situations using a polycentricity lens. In A. Thiel, D. Garrick, & W. A. Blomquist (Eds.), *Governing complexity: Analyzing and applying polycentricity* (pp. 45–64). Cambridge University Press.

Brain, S. (2011). Transformation: The Great Stalin Plan for the Transformation of Nature. In *Song of the forest: Russian forestry and Stalinist environmentalism, 1905–1953* (pp. 140–167). University of Pittsburgh Press. https://doi.org/10.2307/j.ctt5hjn2f

Bromley, D. W. (1992). The commons, property, and common-property regimes. In D. W. Bromley & D. Feeny (Eds.), *Making the commons work: Theory, practice, and policy* (pp. 3–16). ICS Press.

Bruns, B. (2019). Practicing polycentric governance. In A. Thiel, D. Garrick, & W. A. Blomquist (Eds.), *Governing complexity: Analyzing and applying polycentricity* (pp. 237–255). Cambridge University Press.

Budiyanto, Y. (2014). *Water efficiency in agriculture: A study of the adoption of water*

conserving and profitable irrigation technology in Arizona (UMI Number: 1571115) [M.S. thesis, Arizona State University]. ProQuest Dissertations & Theses Global.

Buschatzke, T. (2017, April 30). Arizona water director: I won't support CAP board's drought plan. *The Arizona Republic*. https://www.azcentral.com/story/opinion/op-ed/2017/05/01/arizona-drought-plan-buschatzke/306944001/

Buschatzke, T., & Klobas, N. D. (2018). Ensuring Arizona's future today: The lower basin Drought Contingency Plan and its implementation in Arizona. *Arizona Journal of Environmental Law & Policy*, *8*(3), 29–52. https://www.ajelp.com/articles-summer-2018

Carlisle, K., & Gruby, R. L. (2017). Polycentric systems of governance: A theoretical model for the commons. *Policy Studies Journal*, *47*(4), 921–946. https://doi.org/10.1111/psj.12212

Carmines, E. G., & Woods, J. (2004). Guttman scaling. In M. Lewis-Beck, A. Bryman, & T. Futing Liao (Eds.), *The SAGE Encyclopedia of Social Science Research Methods*. Sage Publications. https://doi.org/10.4135/9781412950589.n385

Central Arizona Project. (2015a). *Water Control Dispatcher* [Position Descriptions]. Central Arizona Project. https://www.cap-az.com/employment/position-descriptions

Central Arizona Project. (2015b). *Water Control Dispatcher, Senior* [Position Descriptions]. Central Arizona Project. https://www.cap-az.com/employment/position-descriptions

Central Arizona Water Conservation District. (2019). *Central Arizona Project 2020 / 2021 Biennial Budget* [Biennial Budget]. Central Arizona Water Conservation District. https://www.cap-az.com/documents/departments/finance/2020-21-Biennial-Budget.pdf

Coate, C. (1995). "The biggest water fight in American history": Stewart Udall and the Central Arizona Project. *Journal of the Southwest*, *37*(1), 79–101. http://www.jstor.org/stable/40169924

Cornes, R. (1993). Dyke maintenance and other stories: Some neglected types of public goods. *Quarterly Journal of Economics*, *108*(1), 259–271. https://doi.org/10.2307/2118503

Crawford, S. E. S., & Ostrom, E. (1995). A Grammar of institutions. *American Political Science Review*, *89*(3), 582–600. https://doi.org/10.2307/2082975

Cummings, T. G., & Worley, C. G. (2009). *Organization development & change*

(International ed., 9th ed.). South-Western; Cengage Learning.

Dieter, C. A., Maupin, M. A., Caldwell, R. R., Harris, M. A., Ivahnenko, T. I., Lovelace, J. K., Barber, N. L., & Linsey, K. S. (2018). *Estimated use of water in the United States in 2015* (Circular No. 1441; USGS Numbered Series). U.S. Geological Survey, Water Availability and Use Science Program. doi.org/10.3133/cir1441

Engle, N. L. (2012). Adaptation bridges and barriers in water planning and management: Insight from recent extreme droughts in Arizona and Georgia. *JAWRA Journal of the American Water Resources Association*, *48*(6), 1139–1150. https://doi.org/10.1111/j.1752-1688.2012.00676.x

Espeland, W. N. (1998). *The struggle for water: Politics, rationality, and identity in the American Southwest*. University of Chicago Press.

Feller, J. M. (2007). The adjudication that ate Arizona water law. *Arizona Law Review*, *49*, 405–441.

Fennell, L. A. (2011). Ostrom's Law: Property rights in the commons. *International Journal of the Commons*, *5*(1), 9–27. https://doi.org/10.18352/ijc.252

Fleck, B. E. (2013). *Factors affecting agricultural water use and sourcing in irrigation districts of central Arizona* (UMI Number: 1544387) [M.S. thesis, University of Arizona]. ProQuest Dissertations & Theses Global.

Fleck, J. (2016). *Water is for fighting over and other myths about water in the west*. Island Press.

Frey, U. J., & Cox, M. (2015). Building a diagnostic ontology of social-ecological systems. *International Journal of the Commons*, *9*(2), 595–618. https://doi.org/10.18352/ijc.505

Froebrich, J., & Wegerich, K. (2007). The fog problem in Central Asia: Deficiencies in international community research to support water and food security. *Irrigation and Drainage Systems*, *21*(3–4), 161–165. https://doi.org/10.1007/s10795-007-9039-x

Galaz, V., Crona, B., Österblom, H., Olsson, P., & Folke, C. (2012). Polycentric systems and interacting planetary boundaries—Emerging governance of climate change–ocean acidification–marine biodiversity. *Ecological Economics*, *81*, 21–32. https://doi.org/10.1016/j.ecolecon.2011.11.012

Gammage, G. (2019, January 1). 2018 was a turning point for Arizona. Here's how we make the most of it. *The Arizona Republic*. https://www.azcentral.com/story/opinion/op-ed/2019/01/01/arizona-2018-lessons-election-water-climate-change-gammage/2376509002/

Garcés-Restrepo, C., & Vermillion, D. (2007). *Irrigation management transfer: Worldwide efforts and results* (FAO Water Reports No. 32). Food and

Agriculture Organization of the United Nations, FAO Land and Water Division. http://www.fao.org/3/a1520e/a1520e00.htm

Gibson, C. C., Ostrom, E., & Ahn, T.-K. (2000). The concept of scale and the human dimensions of global change: A survey. *Ecological Economics*, *32*(2), 217–239.

Greckhamer, T., Furnari, S., Fiss, P. C., & Aguilera, R. V. (2018). Studying configurations with qualitative comparative analysis: Best practices in strategy and organization research. *Strategic Organization*, *16*(4), 482–495. https://doi.org/10.1177/1476127018786487

Green, A. S. (2018). Mohenjo-Daro's small public structures: Heterarchy, collective action and a re-visitation of old interpretations with GIS and 3D modelling. *Cambridge Archaeological Journal*, *28*(2), 205–223. https://doi.org/10.1017/S0959774317000774

Green, A. S. (2020). Killing the Priest-King: Addressing egalitarianism in the Indus civilization. *Journal of Archaeological Research*. https://doi.org/10.1007/s10814-020-09147-9

Grellier, J., White, M. P., Albin, M., Bell, S., Elliott, L. R., Gascón, M., Gualdi, S., Mancini, L., Nieuwenhuijsen, M. J., Sarigiannis, D. A., van den Bosch, M., Wolf, T., Wuijts, S., & Fleming, L. E. (2017). BlueHealth: A study programme protocol for mapping and quantifying the potential benefits to public health and well-being from Europe's blue spaces. *BMJ Open*, *7*(6), 1–10. https://doi.org/10.1136/bmjopen-2017-016188

Hafner, G. (2004). Pros and cons ensuing from fragmentation of international law. *Michigan Journal of International Law*, *25*(4), 849–863. https://repository.law.umich.edu/mjil/vol25/iss4/2/

Hanemann. (2006). The economic conception of water. In P. P. Rogers, M. R. Llamas, & L. Martínez-Cortina (Eds.), *Water crisis: Myth or reality?* (pp. 61–91). Taylor & Francis.

Harrison, S. (2015, August 30). California retrospective: How a 1930s water war between California and Arizona delayed Parker Dam. *Los Angeles Times*. https://www.latimes.com/local/california/la-me-parker-dam-20150831-story.html

Hayek, F. A. (1933). The trend of economic thinking. *Economica*, *40*, 121–137. https://doi.org/10.2307/2548761

Hayek, F. A. (1945). The use of knowledge in society. *American Economic Review*, *XXXV*(4), 519–530.

Hayek, F. A. (1973a). Consolidated preface to one-volume edition. In *Law, legislation and liberty* (pp. xv–xxi). Routledge.

Hayek, F. A. (1973b). Cosmos and taxis. In *Law, legislation and liberty* (pp. 35–54). Routledge.

Heikkila, T., Schlager, E., & Davis, M. W. (2011). The role of cross-scale institutional linkages in common pool resource management: Assessing interstate river compacts. *Policy Studies Journal*, *39*(1), 121–145. https://doi.org/10.1111/j.1541-0072.2010.00399.x

Heikkila, T., Villamayor-Tomas, S., & Garrick, D. (2018). Bringing polycentric systems into focus for environmental governance. *Environmental Policy and Governance*, *28*(4), 207–211. https://doi.org/10.1002/eet.1809

Heikkila, T., & Weible, C. M. (2018). A semiautomated approach to analyzing polycentricity. *Environmental Policy and Governance*, *28*(4), 308–318. https://doi.org/10.1002/eet.1817

Holley, C., Sinclair, D., Lopez-Gunn, E., & Schlager, E. (2016). Conjunctive management through collective action. In A. J. Jakeman, O. Barreteau, R. J. Hunt, J.-D. Rinaudo, & A. Ross (Eds.), *Integrated Groundwater Management* (pp. 229–252). Springer International Publishing. https://doi.org/10.1007/978-3-319-23576-9_9

Huitema, D., Mostert, E., Egas, W., Mollenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-)management from a governance perspective and defining a research agenda. *Ecology and Society*, *14*(1), 26. https://doi.org/10.5751/es-02827-140126

Intelligence Community. (2012). *Global water security* (Intelligence Community Assessment No. 2012–08; IC-Coordinated Paper). U.S. Office of the Director of National Intelligence. https://www.dni.gov/files/documents/Special%20Report_ICA%20Global%20Water%20Security.pdf

International Conference on Water and the Environment (ICWE). (1992, January 31). *The Dublin statement on water and sustainable development*. International Conference on Water and the Environment: Development Issues for the 21st Century, Dublin, Ireland. https://wedocs.unep.org/handle/20.500.11822/30961

Janssen, M. A., Smith-Heisters, S., Aggarwal, R., & Schoon, M. L. (2019). 'Tragedy of the commons' as conventional wisdom in sustainability education. *Environmental Education Research*, *25*(11), 1587–1604. https://doi.org/10.1080/13504622.2019.1632266

Johnson, R. (1977). *The Central Arizona Project: 1918-1968*. University of Arizona Press.

Judkins, G., Smith, M., & Keys, E. (2008). Determinism within human–environment research and the rediscovery of environmental causation. *The Geographical Journal*, *174*(1), 17–29. https://doi.org/10.1111/j.1475-4959.2008.00265.x

Kiser, L. L., & Ostrom, E. (1982). The three worlds of action: A metatheoretical synthesis of institutional approaches. In M. D. McGinnis (Ed.), *Polycentric games and institutions: Readings from the Workshop in Political Theory and Policy Analysis* (pp. 56–88). University of Michigan Press.

Knieper, C., & Pahl-Wostl, C. (2016). A comparative analysis of water governance, water management, and environmental performance in river basins. *Water Resources Management*, *30*(7), 2161–2177. https://doi.org/10.1007/s11269-016-1276-z

Kupel, D. E. (2003). *Fuel for growth: Water and Arizona's urban environment*. University of Arizona Press.

Lam, W. F., & Ostrom, E. (2010). Analyzing the dynamic complexity of development interventions: Lessons from an irrigation experiment in Nepal. *Policy Sciences*, *43*(1), 1–25. https://doi.org/10.1007/s11077-009-9082-6

Larson, K. L., Wiek, A., & Withycombe Keeler, L. (2013). A comprehensive sustainability appraisal of water governance in Phoenix, AZ. *Journal of Environmental Management*, *116*, 58–71. https://doi.org/10.1016/j.jenvman.2012.11.016

Larson, R. B. (2018). Overcoming constitutional obstacles to the resolution of general stream adjudications. *Arizona Journal of Environmental Law & Policy*, *8*(3), 52–68. https://www.ajelp.com/articles-summer-2018

Martin, W. E., Ingram, H., & Laney, N. K. (1982). A willingness to play: Analysis of water resources development. *Western Journal of Agricultural Economics*, 133–139.

McGinnis, M. D. (Ed.). (1999). *Polycentricity and local public economies: Readings from the Workshop in Political Theory and Policy Analysis*. University of Michigan Press.

McGinnis, M. D. (2011a). An introduction to IAD and the language of the Ostrom Workshop: A simple guide to a complex framework. *Policy Studies Journal*, *39*(1), 169–183. https://doi.org/10.1111/j.1541-0072.2010.00401.x

McGinnis, M. D. (2011b). Networks of adjacent action situations in polycentric governance. *Policy Studies Journal*, *39*(1), 51–78. https://doi.org/10.1111/j.1541-0072.2010.00396.x

McGinnis, M. D., & Ostrom, E. (2012). Reflections on Vincent Ostrom, public administration, and polycentricity. *Public Administration Review*, *72*(1), 15–25. https://doi.org/10.1111/j.1540-6210.2011.02488.x

Meinzen-Dick, R. (2007). Beyond panaceas in water institutions. *Proceedings of the National Academy of Sciences*, *104*(39), 15200–15205. https://doi.org/10.1073/pnas.0702296104

Mewhirter, J., Lubell, M., & Berardo, R. (2018). Institutional externalities and actor performance in polycentric governance systems. *Environmental Policy and*

Governance, *28*(4), 295–307. https://doi.org/10.1002/eet.1816

Molle, F. (2008). Nirvana concepts, narratives and policy models: Insights from the water sector. *Water Alternatives*, *1*(1), 131–156. http://www.water-alternatives.org/index.php/alldoc/articles/vol1/v1issue1/20-a-1-1-8/file

Molle, F., Mollinga, P. P., & Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. *Water Alternatives*, *2*(3), 328–349. http://www.water-alternatives.org/index.php/alldoc/articles/vol2/v2issue3/65-a2-3-3/file

Mollinga, P. P. (2008). Water, politics and development: Framing a political sociology of water resources management. *Water Alternatives*, *1*(1), 7–23. http://www.water-alternatives.org/index.php/alldoc/articles/vol1/v1issue1/15-a-1-1-2/file

Mollinga, Peter P., & Gondhalekar, D. (2012). *Theorising structured diversity: An approach to comparative research on water resources management* (ICCWaDS Working Paper No. 1). International Centre for Comparative Water and Development Studies. https://www.soas.ac.uk/water/publications/iccwads/file76157.pdf

Oakerson, R. J. (1992). Analyzing the commons: A framework. In D. W. Bromley & D. Feeny (Eds.), *Making the commons work: Theory, practice, and policy* (pp. 41–59). ICS Press.

Olsen, W. (2011). *Data collection: Key debates and methods in social research*. SAGE Publications.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.

Ostrom, E. (1999). Institutional rational choice: An assessment of the Institutional Analysis and Development Framework. In P. A. Sabatier (Ed.), *Theories of the Policy Process* (pp. 21–64). Westview Press.

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton University Press.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences*, *104*(39), 15181–15187. https://doi.org/10.1073/pnas.0702288104

Ostrom, E. (2012). Nested externalities and polycentric institutions: Must we wait for global solutions to climate change before taking actions at other scales? *Economic Theory*, *49*(2), 353–369. https://doi.org/10.1007/s00199-010-0558-6

Ostrom, E., & Cox, M. (2010). Moving beyond panaceas: A multi-tiered diagnostic

approach for social-ecological analysis. *Environmental Conservation*, *37*(4), 451–463. https://doi.org/10.1017/S0376892910000834

Ostrom, E., Janssen, M. A., & Anderies, J. M. (2007). Going beyond panaceas. *Proceedings of the National Academy of Sciences*, *104*(39), 15176–15178. https://doi.org/10.1073/pnas.0701886104

Ostrom, V. (1972). Polycentricity (Part 1). In M. D. McGinnis (Ed.), *Polycentricity and local public economies: Readings from the Workshop in Political Theory and Policy Analysis* (pp. 52–74). University of Michigan Press.

Ostrom, V. (1973). *The intellectual crisis in American public administration*. University of Alabama Press.

Ostrom, V. (1991). *The meaning of American federalism: Constituting a self-governing society*. ICS Press.

Ostrom, V. (1997). *The meaning of democracy and the vulnerability of democracies: A response to Tocqueville's challenge*. University of Michigan Press.

Ostrom, V., & Ostrom, Elinor. (1977). Public goods and public choices. In M. D. McGinnis (Ed.), *Polycentricity and local public economies: Readings from the Workshop in Political Theory and Policy Analysis* (pp. 75–103). University of Michigan Press.

Ostrom, V., Sproule-Jones, M., Allen, B., & Sabetti, F. (Eds.). (2008). *The struggle to constitute and sustain productive orders: Vincent Ostrom's quest to understand human affairs*. Lexington Books.

Ostrom, V., Tiebout, C. M., & Warren, R. (1961). The organization of government in metropolitan areas: A theoretical inquiry. *The American Political Science Review*, *55*(4), 831–842. https://doi.org/10.1017/s0003055400125973

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365. https://doi.org/10.1016/j.gloenvcha.2009.06.001

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society*, *12*(2), 5. https://www.ecologyandsociety.org/vol12/iss2/art5/

Pahl-Wostl, C., & Knieper, C. (2014). The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*, *29*, 139–154. https://doi.org/10.1016/j.gloenvcha.2014.09.003

Parry, K. W. (2004). Constant comparison. In M. Lewis-Beck, A. Bryman, & T. Futing

Liao (Eds.), *The SAGE Encyclopedia of Social Science Research Methods*. Sage Publications. https://doi.org/10.4135/9781412950589.n161

Pennington, M. (2013). Elinor Ostrom and the robust political economy of common-pool resources. *Journal of Institutional Economics*, *9*(4), 449–468. https://doi.org/10.1017/S1744137413000258

Petersen, J. B., Robinson, B. S., Belknap, D. F., & Stark, J. (1994). An archaic and woodland period fish weir complex in central Maine. *Archaeology of Eastern North America*, *22*, 197–222.

Polanyi, M. (1951). *The logic of liberty: Reflections and rejoinders*. Liberty Fund.

Polanyi, Michael. (1966). *The tacit dimension*. University of Chicago Press.

Price, D. H. (1994). Wittfogel's neglected hydraulic/hydroagricultural distinction. *Journal of Anthropological Research*, *50*(2), 187–204. https://doi.org/10.1086/jar.50.2.3630459

Quinion, M. (2002). *Ologies and isms: Word beginnings and endings*. Oxford University Press.

Quinn, F. (1968). Water transfers: Must the American West be won again? *Geographical Review*, 108–132. https://doi.org/10.2307/212834

Ragin, C. C. (2008). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press.

Ragin, C. C., & Davey, S. (2016). *Fuzzy-Set/Qualitative Comparative Analysis 3.0*. Department of Sociology, University of California.

Rantala, K., & Hellström, E. (2001). Qualitative comparative analysis and a hermeneutic approach to interview data. *International Journal of Social Research Methodology*, *4*(2), 87–100. https://doi.org/10.1080/13645570118545

Rapley, T. (2014). Sampling strategies in qualitative research. In U. Flick (Ed.), *The SAGE Handbook of Qualitative Data Analysis*. SAGE Publications. https://doi.org/10.4135/9781446282243

Reckien, D., Wildenberg, M., & Bachhofer, M. (2013). Subjective realities of climate change: How mental maps of impacts deliver socially sensible adaptation options. *Sustainability Science*, *8*(2), 159–172. https://doi.org/10.1007/s11625-012-0179-z

Reisner, M. (1986). *Cadillac desert: The American West and its disappearing water*. Penguin Books.

Rodriguez, N. A. (2013, November 22). *Did you know: Arizona Navy deployed In 1934*. KJZZ.

https://kjzz.org/content/11126/did-you-know-arizona-navy-deployed-1934

Rose, D., Bell, D., & Crook, D. A. (2016). Restoring habitat and cultural practice in Australia's oldest and largest traditional aquaculture system. *Reviews in Fish Biology and Fisheries*, *26*(3), 589–600. https://doi.org/10.1007/s11160-016-9426-1

Rosen, J. (2013, November 10). November 10, 1934: Arizona declares war against California at Parker Dam. *Earth Magazine*. American Geosciences Institute (AGI). https://www.earthmagazine.org/article/november-10-1934-arizona-declares-war-against-california-parker-dam

Salt River Project. (2019). *Salt River Project 2019 Annual Report* [Annual Report]. https://www.srpnet.com/about/financial/pdfx/2019_Annual_Report_WEB.pdf

Sandelowski, M. (2011). Parallelism in constant comparison analysis: Editorial. *Research in Nursing & Health*, *34*(6), 433–434. https://doi.org/10.1002/nur.20455

Scanlon, B. R., Reedy, R. C., Faunt, C. C., Pool, D., & Uhlman, K. (2016). Enhancing drought resilience with conjunctive use and managed aquifer recharge in California and Arizona. *Environmental Research Letters*, *11*(3), 035013. https://doi.org/10.1088/1748-9326/11/3/035013

Schlager, E. (1995, May 25). *State-centered management and local level revolt: The case of Arizona groundwater management* [Conference presentation]. International Association for the Study of Common Property Conference, Bodø, Norway.

Schoon, M. L., Robards, M. D., Meek, C. L., & Galaz, V. (2015). Principle 7: Promote polycentric governance systems. In R. Biggs, M. Schlueter, & M. L. Schoon (Eds.), *Principles for building resilience: Sustaining ecosystem services in social-ecological systems* (pp. 226–249). Cambridge University Press. https://doi.org/10.1017/cbo9781316014240

Scott, J. C. (1998). *Seeing like a state: How certain schemes to improve the human condition have failed*. Yale University Press. https://doi.org/10.12987/9780300128789

Stanley, J. (2013, July 15). Arizona Explained: Parker Dam almost started war. *The Arizona Republic*. http://archive.azcentral.com/travel/articles/20130708parker-dam-arizona-explained.html

Subramanian, A., Brown, B., & Wolf, A. (2012). *Reaching across the waters: Facing the risks of cooperation in international waters* (Water Papers). The World Bank; Water Partnership Program. https://openknowledge.worldbank.org/handle/10986/17256

Sullivan, A., White, D. D., & Hanemann, M. (2019). Designing collaborative governance:

Insights from the drought contingency planning process for the lower Colorado River basin. *Environmental Science & Policy*, *91*, 39–49. https://doi.org/10.1016/j.envsci.2018.10.011

Sydykova, M., & Rodriguez, C. (2018). Diagnosing growth constraints in Central Asia: The case of the Kyrgyz Republic. *Journal of Developing Societies*, *34*(3), 297–324. https://doi.org/10.1177/0169796X18784783

Tang, S. Y. (1992). *Institutions and collective action: Self-governance in irrigation*. ICS Press.

Taylor, M., & Arboleda, A. (2017, April 21). Viewpoints: Everyone loses if we can't agree on water. *The Arizona Republic*. https://www.azcentral.com/story/opinion/op-ed/2017/04/21/drought-contingency-plan-cap/100611034/

Teisman, G., van Buuren, A., Edelenbos, J., & Warner, J. (2013). Water governance: Facing the limits of managerialism, determinism, water-centricity, and technocratic problem-solving. *International Journal of Water Governance*, *1*(1), 1–11. https://doi.org/10.7564/12-IJWG4

The Arizona Republic. (2018, April 8). Our view: Nasty fights are threatening the water we all need to live in Arizona. *The Arizona Republic*. https://www.azcentral.com/story/opinion/editorial/2018/04/08/arizona-water-fights-mar-larger-conservation-desalination-debate/487868002/

Thiel, A. (2017). The scope of polycentric governance analysis and resulting challenges. *Journal of Self-Governance and Management Economics*, *5*(3), 52–82. https://doi.org/10.22381/JSME5320173

Thiel, A., Garrick, D., & Blomquist, W. A. (Eds.). (2019). *Governing complexity: Analyzing and applying polycentricity*. Cambridge University Press. https://doi.org/10.1017/9781108325721

Thiel, A., & Moser, C. (2018). Toward comparative institutional analysis of polycentric social-ecological systems governance. *Environmental Policy and Governance*, *28*(4), 269–283. https://doi.org/10.1002/eet.1814

UN-Water. (2008). *Transboundary waters: Sharing benefits, sharing responsibilities* (pp. 1–16) [UN-Water Thematic Paper]. United Nations. https://www.unwater.org/app/uploads/2017/05/UNW_TRANSBOUNDARY.pdf

U.S. Census Bureau. (2019). *Table 8. Special District Governments by Function and State: 2017* (No. CG1700ORG; Census of Governments). U.S. Department of Commerce. https://www.census.gov/data/tables/2017/econ/gus/2017-governments.html

U.S. Geological Survey. (2019, April 2). *Boundary descriptions and names of regions, subregions, accounting units and cataloging units*. Water Resources of the

United States. water.usgs.gov/GIS/huc_name.html

USDA Economic Research Service. (2019, September 23). *Irrigation & water use*. https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/#importance

USDA Natural Resources Conservation Service. (2018, March 19). *Watershed Boundary Dataset (WBD) facts: History*. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/watersheds/dataset/

VERBI Software. (2020). *MAXQDA Plus 2020 [computer software]*. VERBI Software. maxqda.com

White, D. D., Corley, E. A., & White, M. S. (2008). Water managers' perceptions of the science–policy interface in Phoenix, Arizona: Implications for an emerging boundary organization. *Society & Natural Resources*, *21*(3), 230–243. https://doi.org/10.1080/08941920701329678

White, D. D., Jones, J., Maciejewski, R., Aggarwal, R., & Mascaro, G. (2017). Stakeholder analysis for the food-energy-water nexus in Phoenix, Arizona: Implications for nexus governance. *Sustainability*, *9*(12), 2204. https://doi.org/10.3390/su9122204

Wilson, P. N. (1997). Economic discovery in federally supported irrigation districts: A tribute to William E. Martin and friends. *Journal of Agricultural and Resource Economics*, *22*(1), 61–77. https://jareonline.org/articles/economic-discovery-in-federally-supported-irrigation-districts-a-tribute-to-william-e-martin-and-friends/

Wittfogel, K. A. (1957). *Oriental despotism: A comparative study of total power*. Yale University Press.

World Heritage Centre. (2019). *World Heritage List*. United Nations, UNESCO World Heritage Centre. https://whc.unesco.org/en/list/

Zonn, I. S. (2012). Karakum Canal: Artificial river in a desert. In I. S. Zonn & A. G. Kostianoy (Eds.), *The Turkmen Lake Altyn Asyr and Water Resources in Turkmenistan* (Vol. 28, pp. 95–106). Springer. https://doi.org/10.1007/698_2012_194

APPENDIX A

PARTICIPANT SURVEY

Title of project:

Principles of polycentric governance in large-scale water infrastructure

0. Could you tell me in your own words about your position? What is a typical work day or week like for you?

1. On a year-to-year basis, what are some of your most important operational goals? Please briefly describe these annual goals.

2. In general, what people or groups share these goals? Discuss each goal separately if appropriate.

3. Of the annual goals you've described, which is the most challenging? Why?

4. How do you track your progress toward this challenging annual goal? Please describe how and when you would know the goal has been achieved.

5. What are some of the big decisions you have to make each year to meet important goals?

6. How many of these decisions require information or action by others before you can act? Please explain your answer.

7. How do others learn about and respond to the results of your decisions?

8. If an unexpected opportunity to make progress toward a goal presented itself, what would constrain your ability to act on that opportunity? Use a recent example if it makes answering easier. (Alternatively, what would constrain your ability to respond to a sudden threat?)

9. Overall, how much independence do you have in your position to make big decisions?

	1	2	3	4	5	
Not much independence	◯	◯	◯	◯	◯	*A lot of independence*

10. From your experience, and based on the questions you just answered, is there any aspect of the operational decision making context in your position that you think we're missing? Please tell us if there's something you'd like to add.

APPENDIX B

CODEBOOK: PRINCIPLES OF POLYCENTRIC GOVERNANCE IN LARGE-SCALE WATER INFRASTRUCTURE

Coding of Subjective Data

The survey protocol included both a written questionnaire, typically completed prior to the interview, and an in-person semi-structured interview. Qualitative conditions coded for in the interview transcript generally correspond with the structure of the questions asked in the interview, but coding is inclusive—a given paragraph or partial paragraph could be coded under more than one code. Within a condition, coding is done iteratively to fit the observations to a ranked scale. The result is an interval scale variable value, since there is no true zero. (In application, I also found few low values, "1," which would have indicated the minimum set membership.) Where there was no observation, the ranking statement is left blank in this codebook. However, there should be a logical or intuitive statement that would fill these observational blanks. Between conditions, no comparison or reference is made, in an effort to keep within-observation conditions independent of coding bias.

	Condition/ condition name	Measure -ment level	Evaluative criteria	Values	Sample question
A.	Typical work/ TYPWO	Nominal	Include descriptions of work-related tasks in the participant's position and the positions they are responsible for.	*Examples:* There is no "typical" Responding to issues in real time Keeping routines and schedules	Interview Q0. Could you describe in your own words what a typical work day or a typical work week is like for you?
B.	Work variety/ WOVAR	Ordinal	If the participant gives more than one characterization, use the highest-valued statement.	1: 2: We have many prescribed time frames and a balance of several responsibilities 3: Every day we have a long list of tasks and new issues to deal with 4: Every day we deal with unscheduled real-time dynamics 5: Every day is different	How much regularity or variety is there in the job tasks in this position? Inferred from contrary and expansive answers to Interview Q0 (TYPWO).
C.	Individual goals/ INDGO	Ordinal	If the participant gives more than one characterization, use the highest-valued statement.	1: 2: We have to meet our maintenance needs within our budget every year 3: We have day-to-day accountability for the annual water delivery goal (measured, e.g., by efficiency) 4: We have several important, clear objectives that support our water delivery mandate 5: We have one, clear operational priority with a set metric for	Interview Q1. On a year-to-year basis, what are some of your most important operational goals? [Can you describe these annual goals? If there is one singular overarching goal, can you break it down? Are there secondary goals?]

				achieving it and objectives that support the overarching goal	
D.	Shared goals/ SHAGO	Ordinal	Include as direct stakeholders people/groups who receive water deliveries from the project. Exclude as direct stakeholders those who access the resource in an alternative way. Exclude people/groups who should share goals but who, in the participant's estimation, fail to understand the issues. If the participant gives more than one characterization, use the highest-valued statement.	1: 2: There is contention within the organization about shared goals 3: Positions within the organization, including board members, share the same goals 4: Direct external stakeholders are engaged with the organization in meeting shared goals 5: Interest in meeting our goals goes beyond direct stakeholders to other users of the resource and/or the general public	Interview Q2. In general, what people or groups share these goals? [Discuss each goal separately if appropriate.]
E.	Goal diversity/ GODIV	Ordinal	[Not completed due to conceptual ambiguity.]	1: 2: 3: 4: 5:	Is there an active exercise of diverse opinions and preferences in goal-setting? Inferred from overlap and/or contestation between INDGO and SHAGO.
F.	Goal challenge/ GOCHA	Nominal		*Examples:* Extremes of system dynamics Efficiency of deliveries Customer relations and stakeholder communications Maintaining institutional memory Coordinating outages Uncertainty about diversion and/or conjunctive management targets Estimating how much to invest in operational flexibility Anticipating energy costs	Interview Q3. Of the annual goals you've described, which is the most challenging? [Alternatively, what is the most challenging part of your overarching goal? Why?]
G.	Goal achievement/ GOACH	Nominal		*Examples:* Public rate-setting process Board procedures Flow gauge and sensor records Doppler radar "virtual gauge" data Annual operating plan schedules Monthly reporting for	Interview Q4. How do you track your progress toward this challenging annual goal? [How and when you would know the goal has been achieved?]

				rolling (e.g., 24-month) projections Feedback from stakeholder communications	
H.	Big decisions/ BIGDE	Ordinal	Include as "big decisions" any operational objective the person takes part in setting. Exclude decisions made entirely by someone in another position. If the participant gives more than one characterization, use the highest-valued statement.	1: 2: What we do is largely prescribed (e.g., by standard operating procedure or institutions) or only decision support 3: Big decisions arise during the year that can't be anticipated in advance, but are critical for achieving the goal 4: There are some big decisions we can name, and lots of other big decisions we can't list or describe 5: There are a discrete small number (e.g., two or three) of clearly conceived, critical decisions	Interview Q5. What are some of the big decisions you have to make each year to meet important goals?
I.	Decision depen-dencies/ DEDEP	Ordinal	If the participant gives more than one characterization, use the highest-valued statement.	1: 2: Sometimes it seems like we're the last to know the information we need—we move on the best we can 3: Raw data about operations or operational conditions feed into my decisions, which I pass on to others—my work depends on all that data entirely 4: It is critical to coordinate with one or two others to know what is planned for the year (e.g., in terms of capacity)—my work depends on a few key pieces of information 5: We usually have all the information we need	Interview Q6. How many of these decisions require information or action by others before you can act? [Can you explain your answer?] [What proportion of your work depends on waiting for information? Do you have to make decisions where you don't have enough information? How dependent are you on the decisions of others? Where do you fit into the flow of decision making?]
J.	Decision commun-ication/ DECOM	Ordinal	Include communications that the participant contributes to directly. Exclude communications carried out by another responsible party, e.g., an external regulatory agency. If the participant	1: 2: Communication stops once it reaches this position 3: Few people outside our position need to know much about our decisions—communicati	Interview Q7. How do others learn about and respond to the results of your decisions? [Either formally or informally.] [For example, how do those who your decisions are most important to

			gives more than one characterization, use the highest-valued statement.	ons on a need-to-know basis 4: We communicate with our subordinates (if any) and make reports; supervisors present information up the chain—chain-of-command communications 5: We have frequent internal coordination communications (e.g., meetings), stakeholder meetings, public forums and open comment periods—informal and formal internal and external communications (redundant systems)	know how/when to act based on choices you made?]
K.	Constraints/ CONST	Ordinal	Include constraints that have or are likely to impact decisions. Don't include speculation about hypothetical or unknown constraints. If the participant gives more than one characterization, use the highest-valued statement.	1: 2: Political considerations within the organization or precedent (e.g., institutional inertia) limit flexibility in operations 3: Low delivery demand or high co-generation demands are a constraint when opportunities (e.g., to buy cheap water) arise 4: Physical infrastructure capacity is the only potential constraint when opportunities arise (e.g., to use cheap pumping energy) 5:	Interview Q8. If an unexpected opportunity to make progress toward a goal presented itself, what would constrain your ability to act on that opportunity? [Use a recent example if it makes answering easier.] [Alternatively, what would limit your ability to respond to a sudden threat?]
L.	Self-reported independence / SINDE	Ordinal	Self-reported. If the participant gives a range of scores, record the midpoint.	1: "Not much independence" 5: "A lot of independence"	Interview Q9. Overall, how much independence do you have in your position to make big decisions? [On a scale of one to five, where [If, e.g., "four," why not five?]
M.	Additional context/ ADCON	Nominal			Interview Q10. From your experience, and based on the questions you just answered, is there any aspect of the operational decision making context in your position that you think we're missing? [Is there something you'd like to

					add?]

N.	Position	Nominal	Self-reported		Questionnaire Q1.a. Job title?
O.	Department	Nominal	Self-reported		Questionnaire Q1.b. Organization/department?
P.	Starting date	Nominal	Self-reported		Questionnaire Q1.c. Starting date (month/year)?
Q.	Tenure in position	Continuous	Inferred from self-reported data		What is the length of time in the current position given Questionnaire Q1.c. (month/year), subtracted from interview date?
R.	Supervisor's position	Nominal	Self-reported		Questionnaire Q1.d. Supervisor's job title?
S.	People supervised	Continuous	Self-reported		Questionnaire Q1.e. Number of people you supervise?
T.	Positions supervised	Nominal			
U.	Location	Nominal	Self-reported		Questionnaire Q1.f. Office location (city/town)?

V.	PPosition	Nominal	Self-reported		Questionnaire Q2.a. Previous position job title?
W.	PDepartment	Nominal	Self-reported		Questionnaire Q2.b. Previous position organization/department?
X.	Continuous tenure	Binary	Inferred from self-reported data	0: No 1: Yes	Are organizations reported in Questionnaire Q2.b. and Questionnaire Q1.b. the same?
Y.	PStarting date	Nominal	Self-reported		Questionnaire Q2.c. Previous position starting date (month/year)?
Z.	PEnding date	Nominal	Self-reported		Questionnaire Q2.d. Previous position ending date (month/year)?

AA.	PSupervisor's position	Nominal	Self-reported		Questionnaire Q2.e. Previous position immediate supervisor's job title?
AB.	Promotion	Binary	Inferred from self-reported data	0: No 1: Yes	Were you promoted to your previous supervisor's position (i.e., Questionnaire Q1.a. and Questionnaire Q2.e. are the same)?
AC.	PLocation	Nominal	Self-reported		Questionnaire Q2.f. Previous position office location (city/town)?

AD.	Previous interviews	Nominal	Self-reported	0: No 1: Yes	Questionnaire Q3.a. Have you been interviewed or answered a questionnaire for research purposes recently? If "yes," how recently?
AE.	Type of interviews	Nominal	Self-reported	N/A: Not applicable	Questionnaire Q3.b. For what type of study were you interviewed previously? (N/A if answer to Questionnaire Q3.a. is "no.")
AF.	Public interaction	Nominal	Self-reported	No: None Very rarely: Less than 1 annually Rarely: 1-3 times annually Occasionally: 4-12 times annually Frequently: More than 1 a month	Questionnaire Q4.a. Do your job duties include general interest interviews, e.g., with reporters or educators?
AG.	Type of interaction	Nominal	Self-reported	Not applicable School field trip visitors	Questionnaire Q4.b. What types of interviews? (N/A if answer to Questionnaire Q4.a. is "no.")
AH.	Interview date	Nominal	Automatic	[12/19/17, …, 6/12/18]	Date interview took place.
AI.	Subsystem	Nominal	Automatic	CAP SRP USBR MWD	Location within the system that the interview took place.

AJ.	System level	Ordinal	Experimental values	1: Tertiary canal 2: Primary canal tail	

				3: Secondary canal tail 4: Secondary canal head 5: Primary canal head	
AK.	Job type	Ordinal	Experimental values	1: Maintenance 2: Operations 3: Operations management 4: Water resources planning 5:	

Calibration C

	Coded	Expected fuzzy score	Resulting fuzzy score
Full nonmembership	1	0.05	0.05
	2		0.18
Crossover point	3	0.50	0.50
	4		0.82
Full membership	5	0.95	0.95

Calibration D

	Coded	Expected fuzzy score	Resulting fuzzy score
Full nonmembership	1	0.05	0.05
	2		0.19
Crossover point	2.9	0.50	
	3		0.54
	4		0.83
Full membership	5	0.95	0.95

APPENDIX C

TRUTH TABLES & XY PLOTS

Table C1

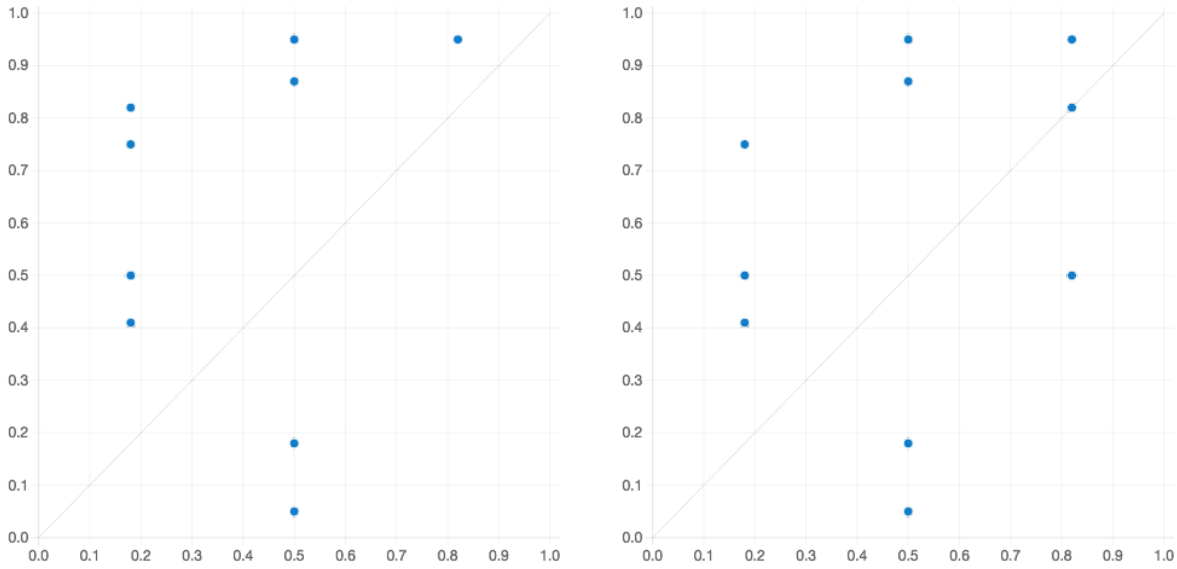
Truth table, partial, with calibration of crossover point set at 3=0.5

wovarc	indgoc	shagoc	bigdec	dedepc	decomc	constc	number	sindec	cases	raw consist.	PRI consist.	SYM consist
0	1	1	1	1	1	1	2	1		0.796178	0.561644	0.719298
1	1	1	1	1	1	1	1	1		0.793011	0.673729	0.673729

Note. Truth table is partial because remainders are not shown.

Figure C1

XY plots of consistency of two configurations found in Table C1



Note. Left: observations' degree of membership in the configuration of all conditions plotted against degree of membership in the outcome (SINDE), on the Y axis. The observation found in the truth table is in the upper-right corner (0.82, 0.95). Right: all conditions except WOVAR. The observations found in the truth table are (0.82, .082) and (0.82, 0.5).

Table C2

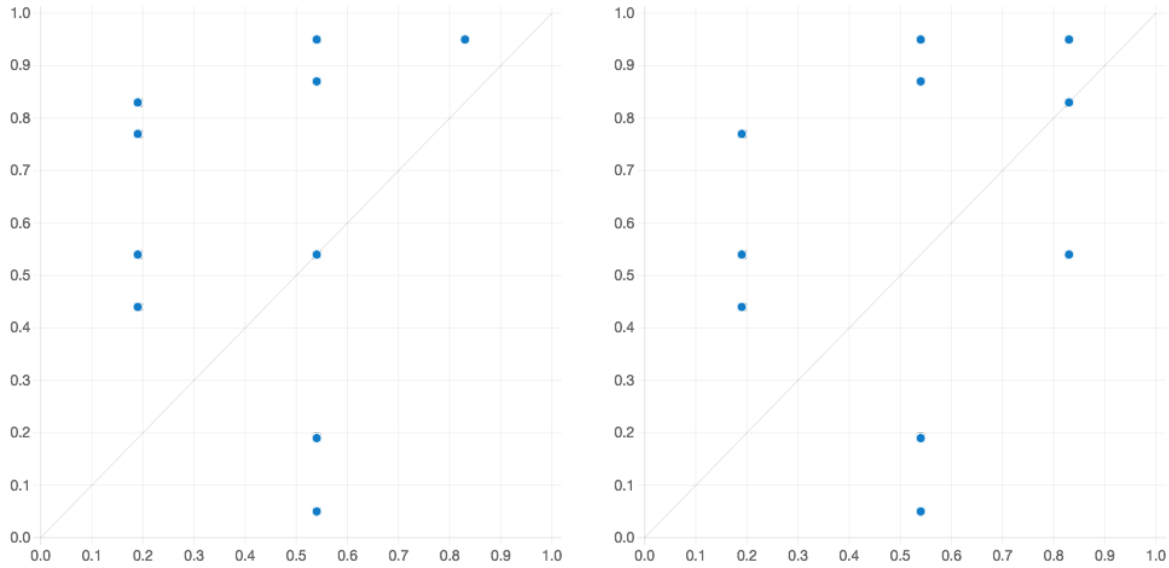
Truth table, partial, with calibration of crossover point set at 2.9=0.5

wovard	indgod	shagod	bigded	dedepd	decomd	constd	number	sinded	cases	raw consist.	PRI consist.	SYM consist
1	1	1	1	1	1	1	5	1		0.786802	0.669291	0.669291
0	1	1	1	1	1	1	2	1		0.825243	0.619718	0.765217
0	1	1	0	1	1	0	1	1		1	1	1
1	0	1	1	1	1	1	1	1		0.81106	0.56383	0.56383
1	1	1	1	1	1	0	1	0		0.7875	0.354431	0.354431

Note. Truth table is partial because remainders are not shown.

Figure C2

XY plots of consistency of two configurations found in Table C2



Note. Left: observations' degree of membership in the configuration WOVAR * SHAGO * BIGDE * DEDEP * DECOM * CONST plotted against degree of membership in the outcome (SINDE), on the Y axis. The observations with partial membership in the configuration are: (0.83,0.95), (0.54,0.05), (0.54,0.54), (0.54,0.87), (0.54,0.95), (0.54,0.19). Right: Membership in the configuration INDGO * SHAGO * BIGDE * DEDEP * DECOM * CONST. Observations with partial membership in the configuration are: (0.83,0.95), (0.83,0.83), (0.83,0.54), (0.54,0.05), (0.54,0.87), (0.54,0.95), (0.54,0.19).

APPENDIX D

DOCUMENTATION OF EXEMPTION GRANTED

FOR HUMAN SUBJECT TESTING

EXEMPTION GRANTED

Marcus Janssen
Sustainability, School of
480/727-7067
Marco.Janssen@asu.edu

Dear Marcus Janssen:

On 4/26/2017 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Principles of polycentric governance in large-scale water infrastructure
Investigator:	Marcus Janssen
IRB ID:	STUDY00006172
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Survey documents_Smith-Heisters_Attachment B.pdf, Category: Recruitment Materials; • HRP-503a_SocialBehavioral_Smith-Heisters(2).pdf, Category: IRB Protocol; • Survey documents_Smith-Heisters(2).pdf, Category: Consent Form;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 4/26/2017.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator