www.water-alternatives.org Volume 11 | Issue 3

Milman, A.; Galindo, L.; Blomquist, W. and Conrad, E. 2018.
Establishment of agencies for local groundwater governance
under California's Sustainable Groundwater Management Act.
Water Alternatives 11(3): 458-480

Establishment of Agencies for Local Groundwater Governance under California's Sustainable Groundwater Management Act

Anita Milman

Department of Environmental Conservation, University of Massachusetts-Amherst, Amherst, Massachusetts, US; amilman@eco.umass.edu

Luisa Galindo

Department of Environmental Conservation, University of Massachusetts-Amherst, Amherst, Massachusetts, US; lgalindo@eco.umass.edu

William Blomquist

Department of Political Science, Indiana University-Purdue University Indianapolis, Indianapolis, Indiana, US; blomquis@iupui.edu

Esther Conrad

Community Engaged Learning for Environmental Sustainability, Haas Center for Public Service, Stanford University, Stanford, CA, US; esther@stanford.edu

ABSTRACT: With the passage of its 'Sustainable Groundwater Management Act' (SGMA), California devolved both authority and responsibility for achieving sustainable groundwater management to the local level, with state-level oversight. The passage of SGMA created a new political situation within each groundwater basin covered by the law, as public agencies were tasked with self-organizing to establish local Groundwater Sustainability Agencies (GSAs). This research examines GSA formation decisions to determine where GSAs formed, whether they were formed by a single agency or a partnership, and whether agencies chose to pursue sustainable groundwater management by way of a single basin-wide organization or by coordinating across multiple organizational structures. The research then tests hypotheses regarding the relative influence of control over the resource, control over decision making, transaction costs, heterogeneity and institutional bricolage on GSA formation decisions. Results indicate mixed preferences for GSA structure, though a majority of public water agencies preferred to independently form a GSA rather than to partner in forming a GSA. Results also suggest GSA formation decisions are the result of overlapping and interacting concerns about control, heterogeneity, and transaction costs. Future research should examine how GSA formation choices serve to influence achievement of groundwater sustainability at the basin scale.

KEYWORDS: Groundwater, governance, politics, mandate implementation, California

INTRODUCTION

The continuing and accelerating trend of groundwater overuse is a problem of global scope and consequence (Wada et al., 2010; Famiglietti, 2014). Despite their significance, groundwater resources are commonly overused and poorly managed, if at all (Foster et al., 2013; Hoogesteger and Wester, 2015). Addressing groundwater challenges requires the development of effective governance, yet establishing effective structures and processes is complex and difficult (Feitelson, 2003; Wester et al., 2011). Top-down imposition of governance is often met with resistance by groundwater users and other local-level stakeholders (Ashley and Smith, 1999; Llamas and Martínez-Santos, 2005). Local management by groundwater users themselves receives greater support (Schlager, 2007; Hoogesteger and Wester, 2015), yet where jurisdictional boundaries do not align with groundwater basin boundaries, management decisions may not account for the full impacts of groundwater use across the basin (Folke et al., 2007).

In California, state-level attempts for more stringent groundwater management have met with limited success, in part because the politics of groundwater governance in California has always featured opposition to state-level groundwater policy making and management (Helweg and Gardner, 1979; Bachman et al., 1997; Hedges, 2010). In 2014, with the adoption of the Sustainable Groundwater Management Act (SGMA), California undertook a novel approach to overcoming the political tensions inherent in developing new systems for groundwater governance. SGMA (described further in Section 2) devolves authority and responsibility for achieving sustainable groundwater management to the local level, mandating the establishment of local Groundwater Sustainability Agencies (GSAs). GSAs are then required to develop and implement Groundwater Sustainability Plans (GSPs). The jurisdictional boundaries of GSAs are not required to match basin[1] boundaries, yet where multiple GSAs formed in a basin, SGMA requires them to coordinate their sustainability planning and management to achieve sustainability at the basin scale.

The passage of SGMA shifted the locus of politics from state-local to local-local, creating a new political situation within each groundwater basin covered by the law. Decision makers within local government units – both general-purpose local governments such as cities and counties and special-purpose local governments such as local water districts – faced a sequence of three interrelated political choices. The first choice was whether to reach for control of decision making by forming a GSA. Choosing to form a GSA brought additional power authorized by SGMA, but also obligations to develop and implement plans, institute extensive monitoring and reporting practices, and undertake the sensitive and controversial tasks of limiting groundwater use in areas where groundwater users have been accustomed to pumping without restrictions (Cal. Water Code §10725 – 32). Choosing not to form a GSA raised the prospects that some other local government within the basin would do so, or, if no local unit within the basin sought GSA status, that the state would intervene (Cal. Water Code §10733 – 36). The second choice, for those local governments that considered forming GSAs, was whether to act alone in doing so or to enter into a partnership with one or more other local governments within a groundwater basin to form a multi-agency GSA. The third choice was whether to form a GSA whose jurisdiction corresponded with the recognized boundaries of the groundwater basin. Given the requirement to achieve groundwater sustainability at the basin scale, this choice entails the decision whether to negotiate future groundwater politics within a single organizational structure or when coordinating across organizations.

Our research investigates the choices made in the formation of GSAs. Specifically, we examine whether water agencies and districts within a groundwater basin responded to SGMA's mandate by i) forming a basin-wide GSA or forming multiple GSAs at other scales that will have to coordinate on basin-level planning and actions later; ii) individually forming a GSA or forming a GSA through intergovernmental partnerships such as joint-powers agreements or memoranda of understanding/agreement. We then draw upon the literature on regional governance, institutional

[1] The term 'basin' can apply both to a surface water or a groundwater watershed/catchment. Throughout the document, the term 'basin' refers specifically to the boundaries of a groundwater system. Under SGMA, surface water rights and management systems are unchanged. However, in planning for groundwater sustainability, GSAs are required to consider and avoid undesirable impacts on interconnected surface water supplies.

collective action, institutional design, and inter-organizational coordination, in order to identify and examine possible explanations for GSA formation choices.

The topic of effective governance and policy at multiple and overlapping scales (Cumming et al., 2006; Termeer et al., 2010), including how organizations in multi-level governance structures coordinate policy goals, instruments, and implementation (Marks and Hooghe, 2004; Freeman and Rossi, 2012; Peters, 2013; Thomann and Sager, 2017) is of acute intellectual and practical concern. While different inter-organizational coordination structures are more likely to be effective in some contexts over others (Alexander, 1995; Mandell and Steelman, 2003; Provan and Kenis, 2008), to date there has been no research that examines which structures the organizations would select for themselves. Analysis of GSA formation under SGMA will help develop new understandings about which institutional structures are preferred for achieving groundwater sustainability and under what circumstances.

The article proceeds as follows. Section 2 briefly describes the SGMA's provisions and implementation processes. Section 3 reviews pertinent literature on institutional design, regional governance, and inter-organizational coordination, and develops hypotheses about GSA formation choices. Section 4 describes our data collection and analysis methods. Section 5 describes the GSAs that formed. Section 6 analyzes GSA formation in relation to our hypotheses. Section 7 concludes with a discussion of implications as well as future research.

THE SUSTAINABLE GROUNDWATER MANAGEMENT ACT

Groundwater management in California occurs within a complex legal and institutional environment. The right to use groundwater is based on common law, guided by a series of court precedents, and treated separately from surface water use. Prior to SGMA, the regulation of groundwater use, where it has existed at all in California, has occurred at the local level, within a context of state policies and programmes to address water quality, surface water use, watershed management, water resources planning, infrastructure and other topics related to management (Brown, 2015). While state government control over surface water use has been extensive, groundwater management in California has been local, performed by a variety of public and private entities.

On several occasions over the past 30 years, state government in California has tried to enable and incentivize local-level agencies and entities to engage in planning and regulation of groundwater resources.[2] The state has enacted legislation granting local water agencies the authority to engage in groundwater planning (Assembly Bill 3030), provided funding for projects contingent upon groundwater planning (Senate Bill 1938), and provided funding for locally initiated Integrated Regional Water Management (IWRM) processes (Conrad, 2015). These state policy efforts to stimulate local action on groundwater planning and management were partially successful – 119 groundwater management plans (hereafter, pre-SGMA groundwater management plans) cover 20% of the state, (Department of Water Resources, 2015) and many local governments participated in IRWM processes to promote various water resource projects. On the other hand, local action remained voluntary and highly uneven across the state (Sandino, 2005). Also, none of these statutes or programmes authorized local agencies to determine, allocate, or restrict groundwater pumping rights.

In the Autumn of 2014, the California legislature passed and Governor Jerry Brown signed the Sustainable Groundwater Management Act (SGMA).[3] With a few exceptions, the law required that local governments in the groundwater basins that have been identified by the California Department of Water Resources as 'high- or medium-priority' establish Groundwater Sustainability Agencies (GSAs) by

[2] For a detailed review of California Groundwater Law and Policy see Brown (2015)

[3] For a detailed account of the development and adoption of SGMA see Leahy (2015).

June 30, 2017.[4] GSAs must develop and implement Groundwater Sustainability Plans (GSPs), implementation of which must result in attainment of sustainable management within 20 years. Failure of local efforts to meet those requirements can result in the state government, via the State Water Resources Control Board, intervening to manage the basin (Cal. Water Code §10735-36)

SGMA allowed any local public agency with water management, water supply, or land use responsibilities to become a GSA, or to be part of a GSA in combination with one or more other qualified local agencies (Cal. Water Code §10723). GSAs could thus be formed by public water agencies/districts, counties, municipalities, or combinations thereof (e.g. through the establishment of a joint-powers agency or similar structure). Where multiple GSAs form within a basin, SGMA requires they either work together to develop a single groundwater sustainability plan (GSP) for the entire basin, or coordinate in developing and implementing their individual GSPs to avoid undesirable results. GSAs in a basin must use the same groundwater data in their GSPs, develop procedures for information exchange, and describe how their plans, implemented together, satisfy the requirements of SGMA (Cal. Water Code §10727.6). Thus, the political decision of where and how to establish a GSA is complicated: on the one hand, any local public agency with water or land use authority could be a GSA, but on the other hand, planning and achieving groundwater sustainability will be assessed in terms of basin boundaries. Local governments faced the dilemma of going their own way in order to maximize control over decision making yet having to organize at the groundwater basin scale to meet state policy goals.

ESTABLISHMENT OF NEW AGENCIES FOR GROUNDWATER GOVERNANCE

Theorizing institutional formation

As explained above, SGMA requires the formation of GSAs, yet allots discretion in GSA institutional design. The public agencies tasked with forming GSAs had the option of operating independently or joining together in partnerships, and could choose to form a single GSA that spans a groundwater-basin or could choose to form multiple GSAs within a basin. While it is likely that no single governance structure will work everywhere (Conrad et al., 2016), institutional design choice will influence the effectiveness of the GSAs (Kiparsky et al., 2017).

The simultaneous establishment of hundreds of new governing agencies is a distinctive phenomenon, for which research on institutions and governance does not provide matching examples. Scholarly work examining agency creation (including strategic choice and structural choice), institutional collective action and regional or other intergovernmental coordination, and incremental or path-dependent institutional development (bricolage) has generally studied and theorized about either (i) the creation of one or a few agencies at a time, or (ii) comparisons of agencies or regional structures that were established at different times through varying processes (Child, 1972; Moe, 1991; Macey, 1992; Wood and Bohte, 2004; Christensen and Nielsen, 2010; Cleaver, 2012). Despite extensive research on the topic, "there is still no consensus on… what variables are the main drivers for solving collective-action problems related to water" (Lubell and Balazs, 2018: 587). Nevertheless, we can draw upon these previous studies and attempts at theorizing, with the aims of synthesizing elements of an explanation for the patterns of GSA formation, and developing some testable hypotheses.

[4] The initial basin prioritization designated 127 basins as high- or medium-priority. However, SGMA included a basin-boundary modification process that allowed local-level agencies to request the revision of basin boundaries when scientific information on the geologic or hydrologic conditions indicates the basin boundaries merit redefinition, or, in limited cases, where modification of the boundary due to institutional jurisdictional arrangements will allow the basin to be more sustainably managed. Basin boundary modifications in 2016 led to the subdivision of some of the 127 high- or medium-priority boundaries, resulting in 135 high- and medium-priority basins. For more information see www.water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Basin-Boundary-Modifications

Scholarly work on strategic choice (as it was called in Child, 1972) and structural choice (as it has been called beginning with Moe, 1991) emphasizes that the choice of forming an organization – in this case, a GSA – is influenced not only by considerations of which kind of organization would best accomplish the stated policy goals (optimality), but also, and perhaps more so, by considerations of control. Thus the organized interests participating in the agency formation decisions will seek designs that protect their influence within and over the agency in the, often uncertain, future (Macey, 1992; Wood and Bohte, 2004).

Scholarly work on institutional collective action (e.g. Feiock, 2007), regional governance (e.g. Gerber and Gibson, 2009) and intergovernmental coordination (e.g. Peters, 2015) ascribe decisions whether to establish collaborative arrangements as the outcome of a weighing of the benefits of regional coordination versus its costs. Collaboration can lead to real gains, through the sharing of resources and knowledge, increased access to resources, and/or through improved operational efficiencies, including economies of scale, although these benefits do not always manifest themselves or may be unevenly distributed (Peters 2013). Further, the costs of regional coordination include not only its associated financial costs and benefits, but also the potential political risks and losses from regional decision making and the transaction costs of coordinating with other local governing bodies (Feiock, 2007).

The political costs of coordination identified in research on institutional collective action/coordination primarily include the loss of local control that derives from being part of a regional decision-making process that includes others' interests. Local-level actors may view shifts in control resulting from coordination as limiting their ability to act in the best interest of their constituencies (Schafer, 2016) and as reducing their autonomy. This reluctance to enter into regional governance arrangements has been described as 'defensive localism'. (Barron and Frug, 2005). Concerns about autonomy and control over decision making are more likely to occur where there is greater heterogeneity across local-level actors, either in their interests or in the resources, capacities, or political positioning that influence their power over decision making (Feiock, 2007; Kwon and Feiock, 2010).

Beyond potential political costs, there are real resource costs to institutional collective action. Forming a new institution and operating it requires time and effort to meet, communicate, and make decisions, among other tasks (Feiock, 2013). These transaction costs are higher when coordinating across diverse or heterogeneous interests, larger groups, and larger geographic expanses (Peters, 1998; Feiock, 2007; Provan and Kenis, 2008; Kwon and Feiock, 2010). Transaction costs are lower where norms, trust, and existing institutional structures and networks facilitate interactions (Booher and Innes, 2002; Blatter, 2003; Provan and Kenis, 2008; Brondizio, Ostrom and Young, 2009)

Research on incremental institutional change – characterized as 'bricolage' (Cleaver, 2012; Merrey and Cook, 2012) or as path dependence (Pierson, 2000) – posits that, rather than making institutional design choices anew, actors tend to continue previous choices by starting with, borrowing from, and/or adding on to existing structures (Neef, 2009; Merrey and Cook, 2012). Institutional change is incremental because "existing institutions are path-dependent, creating fairly stable norms and behaviours that are difficult to transform to a new way of interaction" (Lubell and Balazs, 2018: 578). Decision makers are likely to gravitate toward and repeat or amend previously established structures or agreements rather than design new ones (Gulati, 1995). Thus how institutions evolve, including the form of bricolage that occurs, will be the result of the saliency, capacity, and agency of existing institutions and how they are adapted or reconstructed to meet current needs (Cleaver and De Koning, 2015).

Synthesizing and hypothesizing

While the research described above employs multiple theoretical frameworks for understanding institutional formation, similarities exist between those theoretical frameworks and their differences are not incompatible. To examine the decisions made by local governments as they formed GSAs, and thus the institutional structures through which future groundwater sustainability planning and implementation will occur, we bring the aforementioned theoretical frameworks together in a set of hypotheses and identify potential quantitative metrics that can be used to test these hypotheses (See Table 1). Hypotheses 1 and 2 reflect the motivations of control and autonomy found in both the structural choice and the institutional collective action literatures. Hypothesis 3 reflects the rational-choice calculations of the pros and cons of forming new institutions found in the institutional collective action literature. Hypothesis 4 reflects findings from the institutional collective action literature about how heterogeneity can contribute to concerns about control as well as to increased transaction costs. Hypothesis 5 reflects the position that institutional formation entails incremental building upon existing structures, norms and processes. These hypotheses also match many of the factors identified as influencing the choice of GSA jurisdiction in the eight basins examined in Conrad et al.'s (2016) analysis of the early stages of GSA formation.

METHODS

To address the research questions, we adopted a mixed-methods approach that combines information on GSAs, the physical and social characteristics of groundwater basins, and pre-SGMA water management institutions. Data on GSAs was obtained from formal GSA formation filings posted on the SGMA GSA Portal (CA DWR, 2017b) as of September 1, 2017. Data on the physical and social characteristics of groundwater basins and pre-SGMA water management institutions was obtained from California Department of Water Resources datasets, the American Community Survey, and the National Land Use Database. Additional details on these datasets and how they were applied to the groundwater basins are included in the Appendix.

A two-step process was used to test the hypotheses regarding the factors influencing decisions about whether to form a single basin-wide GSA or multiple GSAs within a basin. First, for each hypothesis, each metric was tested individually to determine whether that metric is statistically different between basins with a single basin-wide GSA and basins with multiple GSAs. Next, a multivariate regression was performed with all of the variables identified as statistically significant in order to examine how the combination of hypothesized factors jointly influenced whether a single basin-wide or multiple GSAs formed in the basin.

To test the difference between basin types, for each hypothesized metric, a generalized linear model (GLM) with a binomial distribution (logit-function) was estimated. This model predicted a dependent variable of 0 = formation of a single basin-wide GSA and 1 = formation of multiple GSAs within the basin, with the hypothesized metric as the only independent variable. P-values of the estimated coefficient for the independent variable indicate whether or not that variable is statistically significant. This method produces results similar to a t-test between two groups, yet allows for a non-normal distribution of variables.

Prior to conducting the multivariate regression analysis, variables identified as statistically significant between the basin types were tested for high correlations. As the variables were not highly correlated,[5] they could be combined in a multivariate regression. The variables were then standardized by subtracting the mean and dividing by the standard deviation. A multivariate generalized linear model (GLM) with a binomial distribution (logit-function) was estimated. This model predicts a dependent variable of 0 = formation of a single basin-wide GSA and 1 = formation of multiple GSAs using multiple independent variables. In this model, the statistical significance of each variable is reflected by the p-value for its estimated coefficient.

[5] Only two sets of variables are correlated at $r > 0.6$. Number of Water Agencies/Total Population ($r = 0.64$) and Percent land changed to developed/percent total land cover change ($r = 0.88$).

Table 1. Hypotheses and metrics used to test the hypotheses.

Hypothesis	Metrics for testing
#1 Control over resources: Where the potential for competition over the use or allocation of the resource is higher, local-level actors will choose to form multiple GSAs within a basin in order to retain greater control over the resource	
1a) Multiple GSAs are more likely to form in basins with a higher number of potential water users	• Population • Number of groundwater wells
1b) Multiple GSAs are more likely to form in basins where groundwater has a greater role in the economy	• % of water supplied by groundwater • Portion of employment in highly water-dependent industries • % land cover agriculture
#2 Control over decision making: Where the positions of stakeholders within the basin are expected to change, local level actors will choose to form multiple GSAs within a basin in order to retain greater control over decision making	
2a) Multiple GSAs are more likely to form in basins with greater growth in the number of potential water users	• % Population Growth
2b) Multiple GSAs are more likely to form in basins where there have been recent changes in the types of water users	• % of land converted into developed • % of land converted into agriculture • % change in any land cover
#3 Transaction costs[6]: Where immediate transaction costs of forming a basin-wide GSA are higher, local-level actors will choose to form multiple GSAs in order to delay the transaction costs of coordination to the future	
3a) Multiple GSAs are more likely to form in basins with a greater number of agencies eligible to form GSAs	• Number of counties • Number of public water agencies
3b) Multiple GSAs are more likely to form in basins that extend across a greater geographic area	• Groundwater basin area
#4 Heterogeneity: Where there is greater diversity across water users, and thus greater potential differences in perspectives about the nature of the groundwater problem or how to solve it, local-level actors will choose to form multiple GSAs within a basin in order to both reduce transaction costs and increase autonomy.	
4a) Multiple GSAs are more likely to form in basins where there is a greater diversity of water users	• Land Cover Diversity Index[7] • Racial Diversity Index
#5 Bricolage: Local-level actors will build on the existing governance pathways within the basin rather than forging new ones	
5a) A single basin-wide GSA will form in basins where one agency's jurisdiction covers a large portion of the basin	• % of basin covered by largest water agency
5b) A single basin-wide GSA is likely to form when one pre-SGMA voluntary groundwater management plan covers a large portion of the basin	• % of basin covered by any one AB3030 or SB1938 groundwater management plan
5c) Multiple GSAs are likely to form when more than one pre-SGMA voluntary groundwater management plan existed.	• Number of pre-SGMA groundwater management plans

[6] As perceptions of whether transaction costs are relatively low or high may be influenced by actors' resources and capacity, we included basin-scale income, education, and poverty-level variables as controls. None of them was significantly associated with the patterns of GSA formation across basins, so they are not discussed further in this article

[7] See the appendix for details on the diversity indices used.

RESULTS: LOCAL-LEVEL GSA FORMATION DECISIONS

Overview of GSAs

Local-level compliance with the GSA formation stage of SGMA was extremely high, with 99% of the high- and medium-priority basins having formed GSAs by the June 30, 2017 deadline. While GSA formation is related to the desire to avoid state intervention, local-level actors had additional motivations for forming GSAs. For example, the Fox Canyon Groundwater Management Agency, one of the first agencies to declare itself a GSA, had limited jurisdictional authority to operate a groundwater replenishment programme (Fox Canyon Groundwater Management Agency, 2014). By forming a GSA and developing a GSP, the agency will gain greater authority to engage in basin replenishment. As another example, in the Upper Ventura Valley, the water provider is currently a party in a lawsuit about the impact of groundwater use on habitat and streamflow in the Ventura River. They hope forming a GSA and developing a GSP under SGMA will provide an alternative mechanism for resolving that dispute (Upper Ventura River Groundwater Agency, 2017).

As of June 30, 2017, 264 GSAs[8] formed across California (Figure 1a). Notably, local-level actors in eight low- and very-low priority basins were motivated to form GSAs, even though they were not required to do so. While five of those GSAs also cover parts of high- or medium-priority basins, three GSAs cover only low- and very-low priority basins. The Pleasant Valley Water District formed a GSA because district believes formation of a GSA is the best way to ensure local-level control and represent its landowners' interests (Fey et al., 2016). In the Santa Margarita Basin, local-level water agencies expect the basin will be upgraded to medium-priority the next time DWR prioritizes basins and thus pre-emptively formed a GSA (Santa Margarita Groundwater Advisory Committee, 2017). The San Francisco Public Utilities Commission declared itself a GSA to further support its pre-SGMA groundwater sustainability planning (San Francisco Public Utilities Commission, 2015). The agency has historically sought to follow sustainability practices, and by forming a GSA it gains the authorities delegated to GSAs and can apply for state funding set aside for GSAs.

These 264 GSAs cover a range of geographic scopes and institutional partnerships (Table 2). Most GSAs cover only part of a basin, though a number of GSAs cover either parts of multiple basins, a full basin, or a full basin plus a portion of another basin. In many of the basins in which multiple GSAs formed, the geography of governance is characterized by a high degree of fragmentation. Only 128 of 264 (48%) GSAs cover a contiguous area. The rest of the GSAs govern areas that are geographically separate from one another, with 119 GSAs covering 3 or more geographically separate areas (Figure 2). In many instances [26 of 119 (22%)], this is because counties opted to govern regions of the basin where no other GSA formed.

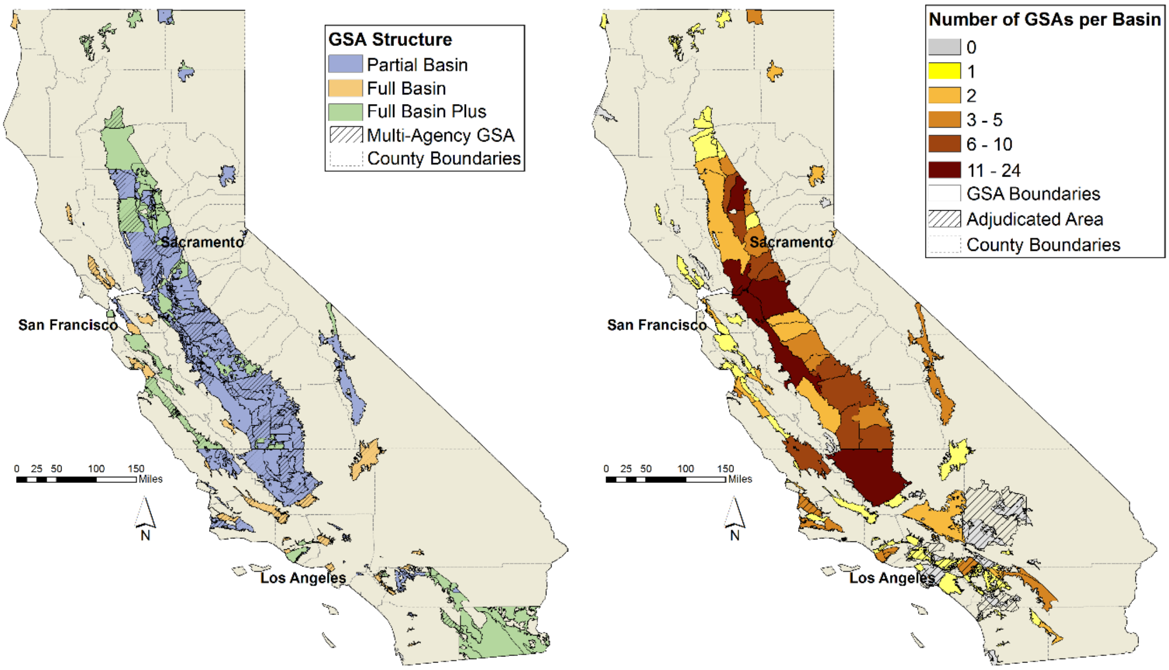
The majority of GSAs [190 of 264 (72%)] were formed by a single public agency rather than as a partnership among multiple agencies. In terms of partnerships, broadly speaking, Community Service Districts and Resource Conservation Districts were more likely to join partnerships when forming GSAs, whereas Reclamation Districts[9] were more likely to form their own single-agency GSAs. Counties, cities, irrigation, multi-purpose, and water districts are more mixed as to whether they chose to form a single-agency GSA versus partnering to form a multi-agency GSA. There were twelve Special Act Districts that SGMA explicitly authorized to form their own GSAs, and they did so (Cal. Water Code §10723).

---

[8] This analysis is based on GSAs formation notices as of July 1, 2017. Four additional GSAs filed notification between 8/17/2017 and 12/15/2017 and are not included in this analysis.

[9] Just before the June 30, 2017 GSA formation deadline, 13 reclamation districts in the Delta groundwater basin filed as GSAs. Each notice said that these reclamation districts plan to work together to form a single GSA. These districts remain listed in the SGMA Portal as individual agencies and are treated as such in the statistical analysis below, though they have since signed a Joint Powers Agreement to form the Northern Delta Groundwater Sustainability Agency (see www.ndgsa.org/about-1/).

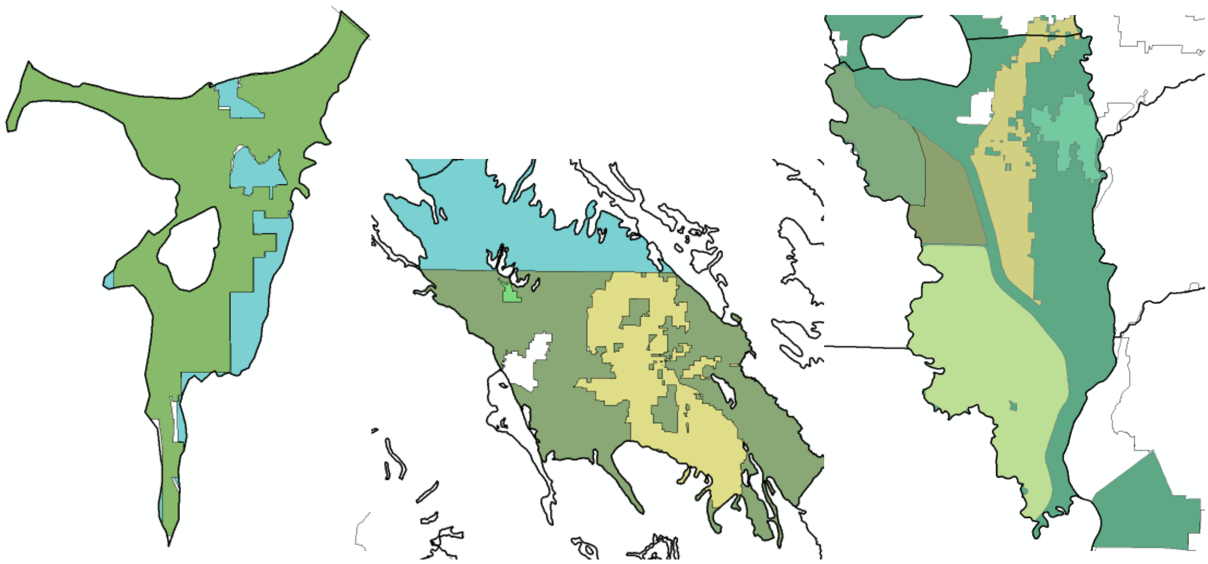
Figure 1. Map of GSA formation by a) GSA structure, b) number.



Note: a) By Geographic and institutional scope of GSAs across all basins: Colours indicate the portion of a basin or basins covered by a GSA. Cross-hatching indicates whether the GSA was formed by a single-agency or by a partnership across multiple agencies. GSAs in all basins (including low and very-low priority basins) are depicted. b) By Number of GSAs formed per basin across high- and medium-priority basins: Colours indicate the number of GSAs within a basin. Cross-hatching indicates locations covered by a groundwater adjudication. Only high- and medium-priority basins are depicted.

Figure 2. Three examples of basins in which GSAs are comprised of non-contiguous areas or have highly irregular boundaries.

a) Tahoe Valley Basin b) Salinas Valley c) Sacramento Valley



Note: Colours denote the boundaries of the GSAs within the basin. a) Two GSAs formed in the Tahoe Valley Basin; b) Four GSAs formed in the Salinas Valley, one of these GSAs also covers a portion of a neighbouring basin; c) Six GSAs formed in the Sacramento Valley, two of these GSAs also cover portions of neighbouring basins. Figures are not drawn to scale.

Table 2. GSA Formation: Geography and Partnerships

	Single agency GSA	Multi-agency GSA	All GSAs
Number of GSAs	190	74	264
Geographic expanse*			
Full basin plus	8	4	12
Full basin	8	21	29
Multiple parts of basins	26	2	28
Part of a basin	148	47	195
Fragmentation*			
Contiguous area	93	43	136
2 parts	25	6	31
3 or more parts	72	25	97
Number of partners			
1	190	---	190
2 to 3	---	26	26
4 to 7	---	30	30
8 +	---	18	18
Types of GSA member agencies **			
City	36	48	84
Community Services District	5	15	20
County	32	50	82
Flood Control District	2	2	4
Indian Tribe	0	1	1
Irrigation District	21	21	42
Multi-Purpose District	8	8	16
Other***	0	11	11
Reclamation District	26	6	32
Resource Conservation District	1	7	8
Special Act District	12	0	12
Water District	47	53	100

* Two GSAs, Sacramento County and Tulare County, were filed to cover unmanaged areas within the county. Their filings do not indicate the exact geographic area they cover; therefore they are not included in the statistics for these rows.

** Member agencies are the public entities eligible to form a GSA who joined together through a Memorandum of Understanding or Joint Powers Agreement to form the GSA.

*** Other includes the following types of districts: Drainage, Stormwater, Water Conservation, and Water Storage.

While single-agency GSAs are all public agencies and decisions are made by their existing governing bodies, 28 of 74 (36%) multi-agency GSAs include some non-member voting partners, generally non-public entities that were not eligible to form a GSA such as private water companies, landowners who pump groundwater outside of a water district, representatives of environmental organizations, and members of the general public. For example, the Arroyo Seco GSA included a local mutual (private) water company as a voting member while the Mound Basin Groundwater Sustainability Agency included an agricultural and an environmental voting representative. The governing documents of 20 of 74 (27%) multi-agency GSAs also create, or allow for the creation of, advisory committees that include non-public entities. This avenue for participation of interested parties in GSA governance is also open to single-agency GSAs, though information on advisory committees is not included in the formation notices of single-agency GSAs.

Further, many multi-agency GSAs [35 of 74 (47%)] developed provisions specifying how costs will be allocated across member agencies. In some cases, costs are shared equally, though in many others, allocation formulas take into account acres covered, amount of groundwater pumped, or number of wells. In some instances, this potential for cost sharing influenced formation decisions. For example, in Yolo County, despite having vocalized strong concerns and desires for autonomy, several very small reclamation districts decided to join a basin-wide GSA that was prepared to take on the tasks of writing grant proposals and hiring consultants to prepare a basin-wide GSP (Conrad et al., 2018). In the Santa Rosa Plain, Petaluma Valley and Sonoma Valley basins, local-level actors decided to reduce the costs of developing and implementing their GSPs by sharing staff and other resources across GSAs. Sonoma County, which is a partner agency in each of the 3 GSAs, will serve as the coordinator (Sonoma Valley Groundwater Sustainability Agency, 2017).

Coordination structure choice: Negotiating intra-local politics through single organization or across organizations

Local-level organizations were split between the decision to form a single basin-wide organization that would plan for sustainability and negotiate intra-local politics within that organization versus forming multiple organizations that would have to coordinate in planning for sustainability at the basin scale (Table 3). Of the 135 high- and medium-high priority basins, 23 (17%) were not covered by a GSA, primarily because they either were covered by a prior groundwater adjudication, had filed an alternative plan, or consist of federal or tribal land.[10] Of the remaining high- and medium-priority basins, 49 of 112 (44%) are entirely covered by a single GSA, 54 of 112 (48%) are covered by multiple GSAs, and 9 of 112 (8%) are partly covered by a GSA (Figure 1b).

Table 3. Summary of GSA formation decisions by basin.

	Basins with a single basin-wide GSA	Basins with multiple GSAs	All basins
Number of basins	49	63	112
Number of GSAs within the basin			
1 GSAs	49	9*	58
2 or 3 GSAs	--	34	34
4 to 6 GSAs	--	9	9
7 + GSAs	--	11	11
Types of GSAs within the basin**			
Single agency GSAs	21	33	54
Multi-agency GSAs	28	30	58

* Included in the above table are 9 basins that are partly covered and are counted as multi-GSA basins. These include 6 adjudicated basins in which a single GSA has formed, though that GSA does not cover the entire basin and 3 basins in which only one GSA formed yet it does not cover the entire basin.

** Not included in the above table are the 17 basins with adjudications nor the 6 basins in which no GSAs formed.

[10] SGMA provides the following exceptions to GSA formation in high- and medium-priority basins: GSA formation is not required where groundwater use rights had previously been settled via the courts in a process called 'adjudication', where local-level agencies submitted alternative plans prior to January 1, 2017, or over federal or tribal lands (Cal. Water Code §10720.7).

GSAs were limited to the geographic jurisdiction of the public agencies forming them. Thus, for a local-level public agency to form a basin-wide GSA, it either had to have geographic jurisdiction across the entire basin or it needed to partner with other local-level agencies eligible to form a GSA. There is no statistical difference[11] between the number of single-GSA basins in which the GSA is a partnership and the number of multi-GSA basins in which the GSAs formed as a partnership. In other words, local-level actors partnered to form basin-wide GSAs just as much as they partnered to form non-basin-wide GSAs. This indicates that the decision to form a single-GSA that spans the entire basin versus multiple GSAs that will have to coordinate sustainability planning does not appear to be related to willingness to enter into partnerships.[12]

DETERMINANTS OF GSA FORMATION

To test our hypotheses about the factors influencing GSA formation, we first examined differences in the test metrics across the basins. Basins in which a single basin-wide GSA formed are significantly different from basins in which multiple GSAs formed across 9 of the 20 metrics tested (see Appendix Table A2). A multivariate analysis using the 9 metrics identified as statistically different between basins with a single basin-wide GSA and basins in which multiple GSAs formed was carried out in order to understand how our hypotheses worked together to influence GSA formation decisions (see Appendix Table A3).[13]

Hypothesis #1 We hypothesized that where the potential for competition over the use or allocation of groundwater is higher, local level actors will choose to form multiple GSAs within a basin in order to retain greater control over the groundwater resource. Both population and the percent of the land of the basin used for agriculture significantly differentiate basins in which a single basin-wide GSA formed and in which multiple GSAs formed. Yet the number of wells, reliance on groundwater for water supply and the share of employment in water-dependent industries are not significant. In the multivariate model, percent of land covered in agriculture is statistically significant while population is not. The agricultural variable has a large effect size, indicating that as the portion of the basin that is used for agriculture increases, there is a strong tendency to form multiple GSAs within the basin.

As only two of the metrics associated with hypothesis 1 are significant, it cannot be concluded that competition over the resources is leading to the formation of multiple GSAs within the basin. The agricultural metric may be capturing underlying concerns of local-level actors that are not captured elsewhere in the model (unobserved variable bias). Within agricultural areas in California, there can be substantial variation in how water is used and in the institutional processes of the agencies providing water services (Hanak, 2011). Although the multivariate analysis controls for the number of water agencies and the number of counties in a basin, it may be that differences in the nature of those agencies and their constituencies, rather than the actual quantity of the resource itself, have affected the formation of multiple GSAs in highly agricultural areas. Without a dataset on agricultural users and on water agency governance structures, we cannot account for the impacts in the influence of those variables on GSA formation decisions.

Hypothesis #2 We hypothesized that where the relative power position of stakeholders is expected to change, local actors will form multiple GSAs within a basin in order to retain control over decision making. None of the metrics used to represent potential changes in conditions (population growth and

[11] Chi-square test of difference $\chi 2 = 1.0013$, p-value = 0.317

[12] While to partner or not to partner may not be a deciding factor, as examined in the regression analysis below, formation of a basin-wide GSA may be related to the number of partners required.

[13] Basins not fully covered by GSAs were not included in the statistical analysis because they cannot be accurately represented using the binary metric of the dependent variable.

land cover change) vary significantly between single-GSA basins and multiple-GSA basins. This finding indicates change within the basin does not appear to be a driving factor influencing decision making. As these metrics do not differ across basins, they were not included in the multivariate analysis.

Hypothesis #3 We hypothesized that where immediate transaction costs of forming a basin-wide GSA are higher, local-level actors will choose to form multiple GSAs and defer the transaction costs of coordination to the future. While all three of the hypothesized metrics for transaction costs (number of counties, number of water agencies, basin size) differed significantly between single-GSA basins and multiple-GSA basins, in the multivariate model, only the number of counties is significant. The fact that the number of water agencies and basin size are significant when tested individually but not in the multivariate model indicates that the number of counties, the number of water districts, and basin size are capturing some of the same basin characteristics. Although the variables are not highly correlated, basins that span more counties also tend to be larger and contain more water districts.

The significant role of counties in GSA formation likely arises from the fact that SGMA designates counties as the default GSAs where no other eligible entities form a GSA (Cal. Water Code §10724). Multiple GSAs formed in 36 of the 50 (72%) high- and medium-priority basins that extend across more than one county. Further, 26 of the 32 single-agency GSAs that were formed by counties were formed by counties governing regions of the basin where no other GSA formed.

The fact that basin area is not significant may reflect that transaction costs are not necessarily correlated with basin size. The majority of basins in which a single basin-wide GSA formed [45 of 49 (92%)] cover areas less that 500 km^2, yet 22 of the 63 basins in which multiple GSAs formed span less than 500 km^2. This indicates that a smaller basin size is not a sufficient condition for forming a single basin-wide GSA. In terms of larger basins, a single basin-wide GSA formed in only three high- or medium-priority basins larger than 800 km^2, and each of those basins has unique circumstances that likely affected transaction costs. One basin, Redbluff, is covered by a GSA comprised of a single agency that extends across all of the high- and medium priority basins in the county yet includes representation from all of the eligible entities (Antone, 2016). The second basin, Indian Wells Valley, is fully reliant on groundwater and located far from the seats of the counties it traverses. The GSA formed as a partnership across all of the public entities eligible to form a GSA in the basin (Cosner, 2016). In the third basin, Cuyama Basin, after SGMA was passed, local agricultural growers in the basin rushed to form a new water district that would be eligible to form a GSA in order to ensure their representation in the process (Swanston, 2016). This new agency partnered with the counties and the community service district that covers a small portion of the basin to form a GSA (Jacobs, 2018).

Lastly, the fact that the number of water agencies is not a significant predictor of whether a single basin-wide GSA formed within the basin may reflect that it is not the overall number of water agencies that determine transaction costs, but rather other characteristics of the agencies determine the ease or difficulty of coordination. For example, partnerships across agencies forming GSAs (Table 2) varied by agency type, and even within a single type of agency (e.g. city, irrigation district, etc) some agencies entered into partnerships while others did not, suggesting that agency type and structure matter.

Hypothesis #4 We hypothesized that where there is greater diversity across water users, and thus greater potential differences in perspectives about the nature of the groundwater problem or how to solve it, local-level actors will choose to form multiple GSAs within a basin in order to both reduce transaction costs and increase autonomy. Two metrics were used to test for the influence of heterogeneity on GSA formation within a basin. The land cover diversity index serves as a proxy for heterogeneity in the nature of water use in the basin. The portion of land covered by forested, grasslands, wetlands and barren land does not statistically vary between single-GSA basins and multiple-GSA basins. The percentage of land covered by agriculture is greater in basins with multiple GSAs, while the percentage of developed land is greater in basins with a single basin-wide GSA. Yet the diversity index, which reflects the relative amounts of the land covers in relation to one another, is not significant, indicating that there are no patterns in the relative portions of agriculture and developed lands across the basin types. In terms of the hypothesis, this suggests differences between the relative amounts of developed and agricultural lands within a basin do not contribute to greater concerns about control or greater transaction costs.

While land cover diversity is not a significant predictor of the decision to form multiple GSAs within a basin, there are examples where GSA formation decisions were driven by concerns about heterogeneity in the type of water user. For example, local-level actors in Placer County decided to form two GSAs in the portion of the county that lies in the North American Basin. One GSA is governed solely by the county. The other entails a partnership with the South Sutter Water District GSA. This decision was made in order to consolidate the agricultural stakeholders in one GSA and non-agricultural stakeholders in another. The two GSAs plan to work with each other and with the other GSAs in the basin to develop a single groundwater sustainability plan. By having separate GSAs, each group of stakeholders has a clear path for representation in the development and implementation of the groundwater sustainability plans (Personal communication, Placer County, August 20, 2016). Similar preferences for having GSAs representing different sets of groundwater users reportedly contributed to the formation of multiple GSAs in the Kings Basin (Conrad et al., 2016: 27-28) and Eastern San Joaquin Basin (Conrad et al., 2018: 46-47).

The racial diversity index serves as a proxy for social and cultural differences within the basin. This index varies across basins with a single basin-wide GSA and basins with multiple GSAs and is significant in the multivariate model with a large effect size. As racial diversity increases, there is a strong tendency to form multiple GSAs. An explanation for this trend requires further investigation.

The racial diversity index reflects diversity across the entire population within the basin, yet GSA formation decisions were made by eligible public agencies serving the local population, rather than local-level individuals themselves. While we do not have data on the constituencies of the entities eligible to form GSAs, it is well documented that within California, drought has had a greater impact on small public water systems, especially those serving disadvantaged communities (Feinstein et al., 2017) and that small community water systems serving disadvantaged communities (including a large percentage of latino hispanic and non-hispanic people of colour) tend to have a disproportionate number of safe drinking act violations (Balazs et al., 2012). Thus the racial diversity index may be capturing capacity differences across entities eligible to form GSAs along with any concerns about control or increased transaction costs arising from socio and cultural differences.

Hypothesis #5 We hypothesized that local-level actors will build on the existing governance pathways rather than forging new ones. The two types of basins do not vary in terms of the percentage of the basin covered by the largest water district nor the percentage covered by the largest pre-SGMA groundwater management plan. This indicates that the presence of a larger single agency or prior groundwater management effort did not directly lead to formation of a single basin-wide GSA.

The number of pre-SGMA groundwater management plans varies across basins: basins in which multiple GSAs formed have a higher number of prior voluntary groundwater management plans than basins in which a single basin-wide GSA formed. Nonetheless, in the multivariate regression, the number of prior voluntary groundwater management plans is not statistically significant. Approximately 70% of the area of high- and medium-priority basins were covered by a pre-SGMA groundwater management plan. Some areas are overlapped by multiple plans. Most of the plans do not match basin boundaries. Further, the boundaries of only 43 of 264 (16%) of GSAs match the boundaries of pre-SGMA groundwater management planning, yet 7 of those GSAs fill the areas lying outside of prior groundwater management planning, rather than encompassing the boundaries of prior groundwater planning. Most local actors formed new institutional structures for groundwater planning rather than continuing pre-SGMA groundwater management planning efforts. It also suggests that the finding that basins with multiple GSAs have more prior voluntary groundwater management plans may simply reflect the fact that many of those basins encompass a larger geographic expanse.

DISCUSSION AND CONCLUSIONS

SGMA is a novel model that seeks to overcome the challenges of developing new systems for groundwater governance at the state and at the local level. The legislation has struck a compromise between purely voluntary local management on the one hand and the imposition of a state-wide structure on the other. Under this compromise, local decision-makers are required to act but have extensive discretion over how they act. The high degree of compliance with the first phase of SGMA suggests that, at minimum, such a mandate can be effective in fomenting local-level formation of new governance systems. SGMA therefore leaves substantial room for local-level dynamics to influence agency formation, and we have examined several of those possible influence pathways.

SGMA requires groundwater sustainability be achieved at the basin level. Where multiple GSAs formed in a basin, they must coordinate their groundwater management activities. Local actors complying with SGMA's requirements have had to choose between developing a GSA to match basin boundaries or developing multiple GSAs within a basin and coordinating basin-wide GSP development and implementation across those GSAs. The basin-wide GSA option entails higher upfront transaction costs and navigation of the politics of control and decision making within a structured organizational framework. The multiple GSAs option entails higher future transaction costs and navigation of the politics of control and decision making across organizational frameworks. Notably, preferences between these options were split with almost equal numbers of basins (49 vs 54) choosing to form a single GSA that covers the entire basin and those choosing to form multiple GSAs within a basin. This split suggests the trade-offs between the two options and actors' responses to those trade-offs vary with context.

While the geography of GSA formation was equally split, local-level actors had a strong preference for acting independently, with 190 of 264 (72%) of the GSAs formed by a single-agency. Further, the fact that the prevalence of single agency vs. multi-agency GSAs does not vary across single and multi-GSA basins indicates that the need to collaborate in forming a new agency was not the limiting factor in the decision to form a basin-wide GSA.

In examining potential explanations for the decision to form a basin-wide GSA versus multiple GSAs in the basin, three of the variables tested in the multivariate analysis are significant predictors: percentage of the land for agriculture, the number of counties, and racial diversity. The significance of these three variables in the multivariate analysis supports our assumption that GSA formation decisions involve weighting multiple considerations. Even though these variables explain 39.9% of the variation across basins, their significance does not unequivocally confirm our hypotheses about the factors driving GSA formation. While these variables could be interpreted as supporting the hypotheses about the influence of competition for groundwater, transaction costs, and heterogeneity on the GSAs formation, the fact that the other variables used to test these hypotheses were not significant raises the prospect that those metrics reflect other processes.[14] Future research employing other methods and analyzing different data may be able to shed light on other explanations for the significance of these metrics.

[14] Many of the theoretical drivers influencing institutional coordination decisions are non-tangible variables. The selection of an appropriate proxy is an innate challenge in trying to analyze complex qualitative processes using quantitative metrics. A strong need for future research on the topic of Inter-organizational coordination is an investigation of what metrics can best serve as proxies for the theoretical variables used to describe relationships and concerns of organizations.

Results from the multivariate model do not support our hypotheses related to change within the basin (control over decision making) or the presence of existing institutions (bricolage). Change within the basin was not significant, and rates of change in land cover and population growth across all basins were relatively low. While the presence of a large water agency or prior groundwater management plan does not appear to have served as a focal point for formation of a single basin-wide GSA, and pre-SGMA groundwater management plan boundaries did not correlate with GSAs boundaries, we cannot say that prior institutional arrangements were irrelevant to GSA formation decisions. Local-level entities eligible to form GSAs under SGMA all had pre-SGMA water and land management responsibilities and constraints. Many of those water and land responsibilities connect to other phenomena at other scales – surface water bodies, drinking water and wastewater distribution systems, and so on. For each of these local governments, GSA formation involved a choice about whether or not to operate at multiple scales (those of existing responsibility as well as at the basin level) as well as concerns about meeting those responsibilities, including about how stakeholder constituencies might interpret actions now aimed at the basin rather than the local-agency scale, also influenced GSA formation decisions. Furthermore, we did find that basins where multiple GSAs formed tended to have had multiple pre-SGMA groundwater management plans. The vast number of single-agency GSAs, particularly in the multiple-GSA basins, suggests that concerns about autonomy likely were important determinants of GSA formation.

In terms of the implications of GSA choices on groundwater sustainability, it is too soon to evaluate outcomes. In some basins, partitioning of a basin across multiple GSAs may serve to facilitate sustainable groundwater use. Where multiple GSAs plan to develop a joint GSP, the partitioning of the basin may enable local-level actors to create institutional structures that promote stakeholder buy-in, address the diversity of conditions and interests across the basin, and have access to localized knowledge and information. Further, where sub-regions within the basin are less connected to others, partitioning of the basin may serve to reduce the cost of groundwater sustainability planning, by limiting the need to coordinate to only planning aspects of the basin that are interconnected. Yet in other basins, partitioning of the basin across multiple-GSAs may hinder basin-level coordination, especially where partitioning is a reflection of competition or contention between stakeholders. Thus, how GSA formation will affect GSP development and implementation depends not only on whether multiple GSAs were formed in a basin, but why.

The governance of groundwater will be a formidable challenge for many locations across the world in this century. In California, for now, figuratively speaking, the table has been set and the seats assigned. With many others, we wait to observe and assess how the local choices that have been made so far will affect the success of the effort to attain sustainable groundwater management. Continued study of California's state-wide experiment in institutional creation and policy implementation will provide valuable insights into how local politics, organizational structures, and policy can successfully join together to achieve sustainability at the basin level.

ACKNOWLEDGEMENTS

We are grateful to the many individuals involved in the implementation of SGMA who spoke with us as part of this research. We would also like to thank Tara Moran, Jack Finn, and Michael Kiparsky for their insights and input and the special issue editors for the opportunity to share the results of this research. This paper is based upon work supported in part by the National Science Foundation Graduate Research Fellowship under Grant No. 1824066. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

APPENDIX

Variable definitions and data sources

Data used in the statistical analysis included information on the physical and social characteristics of groundwater basins and pre-SGMA water management institutions. The variables used in this analysis, the source of the data, and the method by which that data, which was available at varying units of analysis, was assigned to the basin-level is described in Table A1. An explanation of each aggregation method is given below.

Table A1: Definitions of the variables used in the statistical analysis

Hypothesis and metrics	Explanation	Source	Aggregation method
#1 Control over resources			
Population (log)	Total population, log transformed.	ACS	GIS census tract overlay
Wells (#)	Number of wells that draw from the basin.	CASGEM	Basin-level data
Water supplied by groundwater (%)	The degree to which persons overlying the basin rely on groundwater as the primary source of water.	CASGEM	Basin-level data
Portion of employment in highly water-dependent industries (%)	Percentage of the civilian employed population 16 years and over – Agriculture, forestry, fishing and hunting, and mining.	ACS	GIS census tract overlay
Land covered in Agriculture (%)	Percentage of land in the basin covered in agriculture. Includes both cultivated crops and pasture hay.	NLCD	GIS land use overlay
#2 Control over decision making			
Population Growth (%)	The rate of current and projected growth of the population overlying the basin.	CASGEM	Basin-level data
Land converted to developed (%)	Percentage of land in the basin that was transformed from any land cover to developed.	NLCD	GIS land use overlay 2001 – 2011
Land converted to agriculture (%)	Percentage of land in the basin that was transformed from any land cover to agriculture.	NLCD	GIS land use overlay 2001 – 2011
Land undergoing any conversion (%)	Percentage of land in the basin that was transformed from any land cover to any other land cover.	NLCD	GIS land use overlay 2001 – 2011
#3 Transaction Costs			
Counties (#)	Number of counties traversed by the basin.	CA GIC	Count
Water agencies (#)	Number of public water agencies whose jurisdiction covers any area within the basin.	DWR Atlas	Count

Geographic expanse (log km2)	Area of the basin, log transformed.	CA GIC	Basin-level data
#4 Heterogeneity			
Land Cover Diversity Index	Heterogeneity index (see below) based on 2011 data and calculated using seven categories of land cover: agriculture, barren, developed, forested, grassland, water, and wetland. Index ranges on a scale of 0 (least diverse) to 1.94 (most diverse)	NLCD	Heterogeneity metric
Racial Diversity Index	Heterogeneity index (see below) based on 2015 data and calculated using five categories for race. Categories include Hispanic or Latino of any race, Not Hispanic or Latino – White alone, Not Hispanic or Latino – Asian alone, Not Hispanic or Latino – Black or African American alone, and Not Hispanic or Latino – All others combined. Index ranges on a scale of 0 (least diverse) to 1.61 (most diverse)	ACS	Heterogeneity metric
#5 Bricolage			
Portion of basin covered by largest water agency (%)	Percentage of the basin area covered by the water agency that covers the largest amount of land area within the basin.	DWR Atlas	GIS
Portion of basin covered by largest prior groundwater management plan (%)	Percentage of the basin area covered by the pre-SGMA groundwater management plan (if any) that covers the largest amount of land area within the basin. Pre-SGMA groundwater management plans include any plan developed under AB 3030 or SB 1938 that was filed with the California Department of Water Resources. Includes only plans from 2002 onwards, as DWR considers only those plans to be active.	CA GIC	GIS
Prior groundwater management plans (#)	Number of pre-SGMA groundwater management plans that cover any area within the basin. Pre-SGMA groundwater management plans include any plan developed under AB 3030 or SB 1938 that was filed with the California Department of Water Resources. Includes only plans from 2002 onwards, as DWR considers only those plans to be active.	CA GIC	Count

Data Sources: 1) ACS: American Community Survey (U.S. Census Bureau 2015); 2) CA GIC: California Groundwater Information Center (CA DWR 2017); 3) CASGEM: California Statewide Groundwater Elevation Monitoring Program (CA DWR 2014); 4) DWR Atlas: California Department of Water Resources Atlas (CA DWR 2018); 5) NLCD: National Land Cover Dataset (Homer, C.G.; et al., 2015)

GIS Census Tract Overlay: The American Community Survey (ACS) dataset uses the census tract as the unit of analysis. To convert this information to the basin-level, a GIS layer of the groundwater basin was overlain on the census tracts to determine the portion of each census tract falling within a groundwater basin. For each socio-economic variable, the area-weighted portion of each census tract that falls within a groundwater basin was then summed. This method provides an estimate that assumes the population is evenly distributed within a census tract.

GIS Land Use Overlay: The National Land Cover Dataset includes raster data representing land cover in 2011 as well as raster data indicating transformation in land cover between 2001-2011. Land cover within a groundwater basin was determined by overlaying a GIS layer of the groundwater basin on the NLDC data and calculating the percent of the basin covered by agriculture. Agriculture includes both cultivated crops (code = 82) and pasture hay (code = 81). Land cover change within a basin was determined by calculating the percent of the basin that was transformed from any land cover to agriculture, from any land cover to developed (codes = 21, 22, 23, or 24), and from any land cover to any other land cover (total change) between 2001-2011.

Heterogeneity Metric: Land Cover Diversity and Racial Diversity were measured using Theil's H, an entropy index commonly used for measuring heterogeneity within a population (Iceland, 2004; Hansmann and Quigley).

$$D_i = \sum_{j=1}^{N} p_j * ln\left(\frac{1}{p_j}\right)$$

Where p_j is the proportion of the j^{th} variable for the i^{th} group. Higher index values reflect higher diversity. The maximum index value will be the natural log of the number of categories. Zero values were replaced with 1E-10 to enable calculation of the natural logarithm.

Results from statistical analysis

Table A2. Differences in test metrics across single GSA and multi-GSA basins.

Hypothesis and metrics	Basins with basin-wide GSA		Basins with multiple GSAs		Test of difference
Hypothesis and metrics	Mean	Std. Dev.	Mean	Std. Dev.	P-Value
#1 Control over resources					
Population (log)	4.2	0.9	4.7	1.0	0.011*
Wells (#)	2507	6882	4838	6380	0.116
Water supplied by groundwater (%)	63.9	31.9	57.6	30.9	0.312
Portion of employment in highly water-dependent industries (%)	7.4	9.8	10.5	12.2	0.168
Land covered in Agriculture (%)	20.8	19.6	41.7	27.3	0.000**
#2 Control over decision making					
Population Growth (%)	1.2	0.2	1.3	0.2	0.128
Land converted to developed (%)	2.0	3.2	1.5	2.4	0.352
Land converted to agriculture (%)	0.3	0.6	0.3	0.4	0.484
Land undergoing any conversion (%)	3.3	3.2	2.8	2.7	0.467
#3 Transaction Costs					
Counties (#)	1.2	0.6	1.9	0.9	0.000**
Water agencies (#)	4.6	2.8	9.3	6.5	0.000**
Geographic expanse (log km2)	2.2	0.5	2.8	0.6	0.000**
#4 Heterogeneity					
Land Cover Diversity Index	1.08	0.30	0.99	0.26	0.109
Racial Diversity Index	0.85	0.19	0.99	0.17	0.000**

#5 Bricolage					
Portion of basin covered by largest water agency (%)	64.4	39.4	60.2	34.0	0.559
Portion of basin covered by largest prior groundwater management plan (%)	58.4	45.1	50.6	38.6	0.344
Prior groundwater management plans (#)	0.9	0.6	1.9	1.9	0.002**

* Variable is significant at the 5% level

** Variable is significant at the 1% level

Table A3. Multivariate Analysis Results.

Hypothesis and metric	Logistic regression results			
	Coeff*	Std. Error	Wald's Z Chi2	P-Value
#1 Control over resources				
Population (log)	-0.553	0.410	-1.349	0.178
Land covered in agriculture (%)	1.184	0.411	2.878	0.004***
#3 Transaction costs				
Counties (#)	0.888	0.445	1.993	0.046**
Water agencies (#)	0.513	0.579	0.887	0.375
Geographic expanse (log km2)	0.481	0.401	1.2	0.230
#4 Heterogeneity				
Racial Diversity Index	1.278	0.406	3.145	0.002***
#5 Bricolage				
Prior groundwater management plans (#)	0.005	0.598	0.008	0.993
Null deviance: 142.546 on 102 degrees of freedom				
Residual deviance: 85.758 on 95 degrees of freedom				
McFadden's pseudo R-square, explained percent variation = 39.8%				

* Coefficient represents log-odds of a unit increase in the standardized independent variable on the likelihood that multiple GSAs formed in a basin as compared to the formation of a single basin-wide GSA. See (Politzer-Ahles, 2016) on interpretation of logistic regression results.

** Variable is significant at the 5% level

*** Variable is significant at the 1% level

REFERENCES

Alexander, E.R. 1995. *How organizations act together: Interorganizational coordination in theory and practice*. New York: Psychology Press.

Antone, G. 2016. Notice of intent to become a Groundwater Sustainability Agency for all 11 groundwater subbasins located within Tehama County. SGMA GSA Portal: California Department of Water Resources.

Ashley, J.S. and Smith, Z.A. 1999. *Groundwater management in the West*. Lincoln, Nebraska: University of Nebraska Press.

Bachman, S.; Hauge, C.; McGlothlin, R.; Neese, K.; Parker, T.; Saracino, A. and Slater, S. 1997. *California groundwater management*, pp. 160-198. Groundwater Resources Association of California, Sacramento. California.

Balazs, C.L.; Morello-Frosch, R.; Hubbard, A.E. and Ray, I. 2012. Environmental justice implications of arsenic contamination in California's San Joaquin Valley: A cross-sectional, cluster-design examining exposure and compliance in community drinking water systems. *Environmental Health* 11(1): 84-96.

Barron, D.J. and Frug, G.E. 2005. Defensive localism: A view of the field from the field. *Journal of Law & Politics* 21: 261-291.

Blatter, J. 2003. Beyond hierarchies and networks: Institutional logics and change in transboundary spaces. *Governance* 16(4): 503-526.

Booher, D.E. and Innes, J.E. 2002. Network power in collaborative planning. *Journal of Planning Education and Research* 21(3): 221-236.

Brondizio, E.; Ostrom, E. and Young, O.R. 2009. Connectivity and the governance of multilevel social-ecological systems: The role of social capital. *Annual Review of Environment and Resources* 34: 253-78.

Brown, J.A. 2015. Uncertainty below: A deeper look into California's groundwater law. *Environs: Envivronmental Law and Policy Journal* 39(45): 45-95.

CA DWR. 2017a. Groundwater Information Center Interactive Map Application. Data available at https://gis.water.ca.gov/app/gicima/

CA DWR. 2017b. DWR's SGMA Portal. Data available at http://sgma.water.ca.gov/portal/ – gsa.

CA DWR. 2014. California Statewide Groundwater Elevation Monitoring Program. Data available at https://water.ca.gov/Programs/Groundwater-Management/Groundwater-Elevation-Monitoring--CASGEM

CA DWR. 2018. DWR Atlas. CA Department of Water Resources GIS Data. Water Districts. Data available at http://atlas-dwr.opendata.arcgis.com/datasets?q=water%20districts

Child, J. 1972. Organizational structure, environment and performance: The role of strategic choice. *Sociology* 6(1): 1-22.

Christensen, J. and Nielsen, V.L. 2010. Administrative capacity, structural choice and the creation of EU agencies. *Journal of European Public Policy* 17(2): 176-204.

Cleaver, F. 2012. *Development through bricolage: Rethinking institutions for natural resource management.* Abingdon, Oxon: Routledge.

Cleaver, F. and De Koning, J. 2015. Furthering critical institutionalism. *International Journal of the Commons* 9(1): 1-18.

Conrad, E. 2015. Bridging the hierarchical and collaborative divide: The role of network managers in scaling up a network approach to water governance in California. *Policy & Politics* 43(3): 349-366.

Conrad, E.; Martinez, J.; Moran, T.; DuPraw, M.; Ceppos, D. and Blomquist, W. 2016. *To consolidate or coordinate? Status of the formation of groundwater sustainability agencies in California*. Palo Alto: Stanford Water in the West.

Conrad, E.; Moran, T.; DuPraw, M.E.; Ceppos, D.; Martinez, J. and Blomquist, W. 2018. Diverse stakeholders create collaborative, multilevel basin governance for groundwater sustainability. *California Agriculture* 72(1): 44-53.

Cosner, B. 2016. County approves GSA formation. *The News Review, 12 February* 2016.

Cumming, G.S.; Cumming, D.H.M. and Redman, C.L. 2006. Scale mismatches in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society* 11(1): Article 14.

Department of Water Resources. 2015. *California's groundwater update 2013. A compilation of enhanced content for California Water Plan update 2013*. Sacramento: California Department of Water Resources.

Famiglietti, J.S. 2014. The global groundwater crisis. *Nature Climate Change* 4(11): 945-948.

Feinstein, L.; Phurisamban, R.; Ford, A.; Tyler, C. and Crawford, A. 2017. *Drought and equity in California*. Oakland, CA: Pacific Institute.

Feiock, R.C. 2007. Rational choice and regional governance. *Journal of Urban Affairs* 29(1): 47-63.

Feiock, R.C. 2013. The institutional collective action framework. *Policy Studies Journal* 41(3): 397-425.

Feitelson, E. 2003. When and how would shared aquifers be managed? *Water International* 28(2): 145-153.

Fey, D.; Fleming, C.; Uc, G. and Lara, J. 2016. Pleasant Valley Water District municipal service review and sphere of influence update report to the Fresno Local Agency Formation Commission. Fresno, CA: Pleasant Valley Water District.

Folke, C.; Pritchard, R.; Berkes, F.; Colding, J. and Svedin, U. 2007. The problem of fit between ecosystems and institutions: Ten years later. *Ecology and Society* 12(1): Article 30.

Foster, S.; Chilton, J.; Nijsten, G.-J. and Richts, A. 2013. Groundwater – A global focus on the 'local resource'. *Current Opinion in Environmental Sustainability* 5(6): 685-695.

Fox Canyon Groundwater Management Agency. 2014. Minutes of the Fox Canyon Groundwater Management Agency's Special Board Meeting Friday 17 October 2014.

Freeman, J. and Rossi, J. 2012. Improving interagency coordination in shared regulatory space. *Administrative and Regulatory Law News* 38: 11-14.

Gerber, E. R. and Clark, C. G. 2009. Balancing regionalism and localism: How institutions and incentives shape American transportation policy. *American Journal of Political Science* 53(3): 633-648.

Gulati, R. 1995. Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. *The Academy of Management Journal* 38(1): 85-112.

Hanak, E. 2011. *Managing California's water: From conflict to reconciliation.* San Francisco, CA: Public Policy Institute of California.

Hedges, J. 2010. Currents in California water law: The push to integrate groundwater and surface water management through the courts. *University of Denver Water Law Review* 14: 375-402.

Helweg, O.J. and Gardner, B.D. 1979. Groundwater management problems in California. In Engelbert, E.A. (Ed), *California water planning and policy: Selected issues,* pp 46-64. Berkeley, CA: University of California.

Homer, C.G.; Dewitz, J.A.; Yang, L.; Jin, S.; Danielson, P.; Xian, G.; Coulston, J.; Herold, N.D.; Wickham, J.D. and Megown, K. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing* 81(5): 345-354. Data available at www.mrlc.gov/nlcd11_data.php

Hoogesteger, J. and Wester, P. 2015. Intensive groundwater use and (in)equity: Processes and governance challenges. *Environmental Science & Policy* 51: 117-124.

Iceland, J. 2004. The Multigroup Entropy Index (Also Known as Theil's H or the Information). US Census Bureau.

Jacobs, J. 2018. Thirsty vineyard, big ag test landmark aquifer law. *E&E News- Essential News for Energy and Environment Professionals*. 16 July 2018.

Kiparsky, M.; Milman, A.; Owen, D. and Fisher, A.T. 2017. The importance of institutional design for distributed local-level governance of groundwater: The case of California's Sustainable Groundwater Management Act. *Water* 9(10): 755-772.

Kwon, S.-W. and Feiock, R.C. 2010. Overcoming the barriers to cooperation: Intergovernmental service agreements. *Public Administration Review* 70(6): 876-884.

Leahy, T.C. 2015. Desperate times call for sensible measures: The making of the California Sustainable Groundwater Management Act. *Golden Gate University Environmental Law Journal* 9(1): Article 4.

Llamas, M.R. and Martínez-Santos, P. 2005. Intensive groundwater use: Silent revolution and potential source of social conflicts. *Journal of Water Resources Planning and Management* 131(5): 337-341.

Lubell, M. and Balazs, C. 2018. Integrated water resources management: Core research questions. In Conca, K. and Weinthal, E. (Eds), *The Oxford Handbook of Water Politics and Policy*, pp. 569-592. New York, NY: Oxford University Press.

Macey, J.R. 1992. Organizational design and political control of administrative agencies. *Journal of Law, Economics & Organization* 8(1): 93-110.

Mandell, M.P. and Steelman, T.A. 2003. Understanding what can be accomplished through interorganizational innovations. *Public Management Review* 5(2): 197-224.

Marks, G.W. and Hooghe, L. 2004. Contrasting visions of multi-level governance. In Bache, I. and Flinders, M. (Eds), *Multi-level governance*, pp 15-30. Oxford: Oxford Scholarship Online.

Merrey, D.J. and Cook, S. 2012. Fostering institutional creativity at multiple levels: Towards facilitated institutional bricolage. *Water Alternatives* 5(1): 1-19.

Moe, T.M. 1991. Politics and the theory of organization. *Journal of Law, Economics & Organization* 7: 106-129.

Neef, A. 2009. Transforming rural water governance: Towards deliberative and polycentric models? *Water Alternatives* 2(1): 53-60.

Peters, B.G. 1998. Managing horizontal government: The politics of co-ordination. *Public Administration* 76(2): 295-311.

Peters, B.G. 2013. Toward policy coordination: Alternatives to hierarchy. *Policy & Politics* 41(4): 569-584.

Peters, B.G. 2015. *Pursuing horizontal management: The politics of public sector coordination*. Lawrence, KS: University Press of Kansas.

Pierson, P. 2000. The limits of design: Explaining institutional origins and change. *Governance* 13(4): 475-499.

Politzer-Ahles, S. 2016. *Interpretation of coefficients in logistic regression*. Hong Kong Polytechnic University.

Provan, K.G. and Kenis, P. 2008. Modes of network governance: Structure, management, and effectiveness. *Journal of Public Administration Research and Theory* 18(2): 229-252.

San Francisco Public Utilities Commission. 2015. Public hearing and establishment of the San Francisco Public Utilities Commission as a Groundwater Sustainability Agency. 10 March 2015.

Sandino, D.A. 2005. California's groundwater management since the Governor's Commission Review: The consolidation of local control. *McGeorge Law Review* 36: 471-494.

Santa Margarita Groundwater Advisory Committee. 2017. California's Sustainable Groundwater Management Act meeting presentation 19 April 2017.

Schafer, J.G. 2016. Mandates to coordinate: The case of the Southern Nevada Public Lands Management Act. *Public Performance & Management Review* 40(1): 23-47.

Schlager, E. 2007. Community management of groundwater. In Giordano, M. and Villholth, K.G. (Eds), *The agricultural groundwater revolution: Opportunities and threats to development*, pp. 131-152. Oxfordshire, OX: CABI.

Sonoma Valley Groundwater Sustainability Agency. 2017. Joint exercise of powers agreement creating the Sonoma Valley Groundwater Sustainability Agency.

Swanston, B. 2016. Groundwater basin laws raise concerns in Santa Barbara County. *The Santa Maria Sun*. 25 May 2016.

Termeer, C.; Dewulf, A. and van Lieshout, M. 2010. Disentangling scale approaches in governance research: Comparing monocentric, multi-level and adaptive governance. *Ecology and Society* 15(4): Article 29.

Thomann, E. and Sager, F. 2017. Moving beyond legal compliance: Innovative approaches to EU multilevel implementation. *Journal of European Public Policy* 24(9): 1253-1268.

Upper Ventura River Groundwater Agency. 2017. Upper Ventura River Groundwater Agency Board of Directors Meeting 12 October 2017.

U.S. Census Bureau. 2015. American Community Survey Detailed Tables; generated by authors from https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

Wada, Y.; van Beek, L.P.H.; van Kempen, C.M.; Reckman, J.W.T.M.; Vasak, S. and Bierkens, M.F.P. 2010. A worldwide view of groundwater depletion. *Geophysical Research Letters* 37(20): L20402.

Wester, P.; Sandoval Minero, R. and Hoogesteger, J. 2011. Assessment of the development of aquifer management councils (COTAS) for sustainable groundwater management in Guanajuato, Mexico. *Hydrogeology Journal* 19(4): 889-899.

Wood, B.D. and Bohte, J. 2004. Political transaction costs and the politics of administrative design. *Journal of Politics* 66(1): 176-202.