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# California Groundwater Management, Science-policy Interfaces, and the Legacies of Artificial Legal Distinctions

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# California groundwater management, science-policy interfaces, and the legacies of artificial legal distinctions

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## Abstract

California water law has traditionally treated groundwater and surface water as separate resources. The 2014 Sustainable Groundwater Management Act (SGMA) broke with this tradition by requiring groundwater managers to avoid significant and unreasonable adverse impacts to beneficial uses of surface water. This paper considers the trajectory of this partial integration of science, law, and resource management policy. Drawing on legal analysis and participatory workshops with subject area experts, we describe the challenges of reconciling the separate legal systems that grew out of an artificial legal distinction between different aspects of the same resource. Our analysis offers two main contributions. First, it demonstrates that laws that subdivide an interconnected resource can have legacy effects that linger long after lawmakers begin dismantling the artificial divides. Using SGMA as a case study, the article illustrates the complexities of reconciling law with science, showing that reconciliation is a process that does not end with updating statutes, or with any other single intervention. Second, we introduce a framework for evaluating the elements of an effort to reconcile law with scientific understanding, whether that reform effort involves groundwater or some other resource. Applying that framework helps reveal where lingering legacy effects still need to be addressed. More generally, it reveals the need for literature addressing science-policy interactions to devote more attention to the multifaceted nature of law and policy reform. Much of that literature describes policy-making in broad and undifferentiated terms, often referring simply to 'the science-policy interface.' But as the SGMA case study illustrates, the complex and multi-layered nature of policy-making means that a successful reform effort may need to address many science-policy interfaces.

## 1. Introduction

For decades, observers have noted the close yet troubled relationships between environmental science and law [1]. Science and law are often intimately linked and shape one another: many environmental laws call for decisions grounded in 'the best available science,' and, in turn, legal requirements often shape scientific research priorities [2, 3]. But the relationships are rarely frictionless. Laws may not reflect scientific understanding at the time they are made. And as scientific understanding evolves, laws that originally reflected contemporary science can become outdated. The resulting artificial or outdated legal distinctions can make effective natural resource management difficult.

Partly in response to these problems, many studies of environmental law, science, and policy have sought to understand how science can better inform environmental policy and management [4, 5]. Within this broad arena, legal scholarship has focused on catching law up to science—that is, on ensuring that legal decision-makers understand, and that laws are grounded in, the latest and best scientific research [6, 7]. Scholars

have also focused on making sensible decisions in contexts where important scientific uncertainties remain [8, 9]. Similarly, science and social science literature often addresses the challenges of aligning scientific research priorities with decision-makers' needs, and of establishing and maintaining communication between researchers and policy actors [4, 5, 10].

These literatures leave a different question underexplored: what happens when policy-makers begin to correct artificial legal distinctions, but institutions and practices that were built around those distinctions remain? Put another way, how do legal systems and management institutions respond to the legacy effects of years of getting science wrong?

This article addresses these questions, using California groundwater management as a case study. The state's laws have long drawn an artificial distinction between surface water and groundwater, creating the legal fiction that the two resources are distinct [11–13]. This divergence occurred even though both scientists and lawyers have long realized it does not reflect hydrologic reality [11, 14]. By explicitly recognizing connections between groundwater and surface water, California's 2014 Sustainable Groundwater Management Act (SGMA) [15] partially dismantled this boundary [16]. Specifically, SGMA requires groundwater managers to avoid '[d]epletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water' [17].

This legislative recognition of scientific reality is only part of the course-correction process, however. In practice, the fragmentation and separate evolution of natural resource management systems can present a variety of continuing challenges to more integrated management. California exemplifies these challenges: the separation of groundwater and surface water law generated different, and sometimes conflicting, rules, which were implemented by different government entities through different processes, with no traditional venue or process for resolving conflicts.

In the environmental field, this kind of scientifically-ungrounded legal distinction is common [3, 18, 19]. For example, jurisdictional boundaries frequently cut through watersheds [20]. Distinctions between subject areas, such as water law, land-use law, and environmental law, artificially segment environmental governance [3]. Some divisions are the unavoidable product of needing to subdivide the world into manageable units, but others reflect outdated scientific beliefs, misunderstandings, or deliberate oversimplifications [7]. Anywhere lawmakers attempt to address these distinctions, the basic challenges California now faces are likely to recur.

We argue that modernizing and integrating these fragmented legal regimes requires more than just updating the statutory framework to align with biophysical reality. Instead, it requires taking a comprehensive view of law and policy—a view that encompasses underlying principles, related statutes, regulations, agency practices, and institutional context as well as core statutory requirements—and using that comprehensive view to identify steps needed to reconcile science and law. We develop a framework for such an evaluation, demonstrate its utility by applying it to SGMA, and address its broader generalizability.

## 2. Methods

This article draws on legal research and participatory workshops. The legal research, which took place both before and after the workshops, drew on standard legal research methodology. Specifically, we reviewed the SGMA statute itself, its implementing regulations, other relevant state and federal statutes, relevant state and federal court decisions, and secondary sources that describe and critique these sources of law. We used this analysis to identify areas where governing law is relatively settled and areas where uncertainty or disagreement remain. We complemented that analysis with a literature review focused on technical and scientific issues associated with surface and groundwater management.

We used participatory workshops, based on the principle that actionable knowledge comes from interaction between researchers and their audiences [21, 22], to facilitate co-production of results [23]. We convened eighteen experts (table 1), including groundwater scientists, technical consultants, local government officials, legal experts, and state agency officials, for two day-long, facilitated, discussion-based workshops [24, 25]. We selected participants through a purposive sampling method [26] based on our knowledge of the field, as well as through consultation with experts in California groundwater management. In particular, we designed the workshop to include thought leaders from a range of organizational and disciplinary perspectives.

The first workshop was framed by preliminary presentations, which were delivered by the organizers, on technical and legal issues associated with SGMA and groundwater-surface water interactions. Through facilitated discussions, the group then identified and prioritized key unanswered questions about legal, institutional, and technical aspects of groundwater-surface water interactions under SGMA. We synthesized the group's identification of key issues and questions into a detailed outline, which we shared with participants prior to the second workshop.

For the second workshop, we used the group's prioritization of issues to select case studies of emerging management approaches. Workshop participants presented those case studies to the group. We also offered hypothetical solutions for legal and technical challenges. We used the case studies and the hypothetical solutions to frame discussions of solutions to the questions we had identified during the first workshop.

**Table 1.** Institutional affiliations of workshop participants.

| Institutional affiliation | | Number of participants |
|---|---|---|
| State agency | California Department of Water Resources | 4 |
| | California State Water Resources Control Board | |
| University | University of California[a] | 4 |
| Non-governmental organization | Community Water Center | |
| | Environmental Defense Fund | |
| | The Nature Conservancy | 3 |
| Law firm | | 2[b] |
| Local agency | | 2 |
| Water resources consulting firm | | 2 |
| Foundation | | 1 |

[a] Including three groundwater scientists and one environmental law scholar.

[b] Three other participants were also attorneys, but not with traditional law firms. In this table they are counted based on their type of employer.

Our goal was to understand where the group generally agreed upon solutions to SGMA-related challenges, what those solutions might be, and where the group perceived there to be major outstanding issues without ready solutions.

In addition to this article, our research generated a white paper containing guidance for practitioners [27].

## 3. Turning scientific knowledge into law: a conceptual framework

While statutory modification is a logical initial focus for efforts to reconcile law with science, it will often be insufficient for effective change. Legal systems' integration of new scientific knowledge will necessarily occur on multiple levels, and a clearer understanding of this reality will help those working to reconcile law with science.

The need for multifaceted reform arises partly from the complexity of policymaking and law. Legal scholars often emphasize that law is more than just the words in authoritative legal texts like constitutions, statutes, and court decisions. Rather, laws take effect through the interpretations and actions of a variety of institutions, governmental and otherwise, and those interpretations and actions often expand upon, and sometimes differ from, the letter of written law [28, 29]. Relatedly, administrative lawyers emphasize that statutes are often just a starting point for the development of legal rules, and that statutory mandates often need to be fleshed out through regulations, guidance documents, agency orders, and an accumulation of other discretionary decisions [30]. Reform also is likely to be incremental, even when scientists and policymakers alike realize that the old regime was premised on assumptions that were irreconcilable with science, because law is sticky [16]. People build businesses and governance institutions in reliance on existing legal regimes, so vested interests often support the status quo [31].

With limited exceptions (e.g. [32]), existing literature on the interactions between science, policy, and law, though extensive, does not address the multilayered legal, institutional, and political reality of natural resource policy implementation. Instead, it often focuses on communication systems and structures that will help deliver scientific information to policymakers and that will help scientists understand policymakers' needs [4, 5, 10]. Other work addresses the appropriate degree of engagement between scientists and political decision makers, with some writers arguing for greater engagement and others worrying that such engagement will undercut the integrity of scientific research [33]. Within this realm of 'science-policy interface' or 'knowledge-to-action' research, the category of policymaking or decision-making—that is, the things decision-makers do in response to scientific information—is often described in a broad and undifferentiated way, and scholars rarely engage systematically with the variety of mechanisms and institutions through which law and policy take effect. Similarly, the voluminous literature on adaptive management, though it addresses continuous mutual feedback between science and policy, tends to focus on decision-making within pre-set legal structures rather than on the elements of systematic legal reform [34, 35].

Rather than treating the policy/action realm as a single, undifferentiated category, theoretical and empirical descriptions of policymaking should better reflect the complex array of processes and decision-makers. Describing '*the* science-policy interface' is a somewhat misleading oversimplification, for even a focused effort to integrate scientific knowledge into policy and law will involve multiple interfaces, each involving different recipients of and pathways for scientific knowledge. Science-policy *interfaces* is a more accurate descriptor. There are many potential target points for law and policy reform, and a successful effort to reconcile law with scientific knowledge (or to reform law for motivations unrelated to science) probably cannot target just one or two. Figure 1, below,

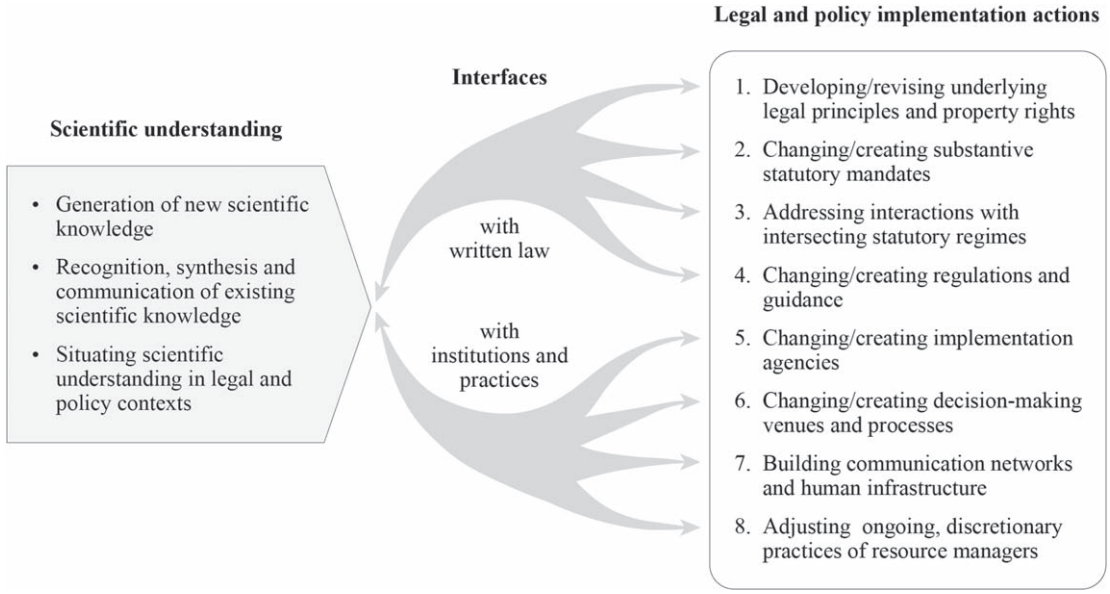


**Figure 1.** Potential interfaces between scientific knowledge and legal and policy reform. This diagram obviously is simplified, and additional feedback loops and more complex relationships, which could be described in more detailed empirical studies beyond the scope of this work, will exist within and between the boxes described here. Additionally, because governance institutions are often created and their practices are often partially controlled through written law, there will be overlap between our two general categories of interfaces.

captures the range of options. It illustrates that a legal/policy regime is made up of many different components, ranging from broad governance principles to the discretionary actions of individual resource managers.

This conceptual framework has two important implications. First, it provides an architecture for efforts to address long-entrenched laws that are inconsistent with scientific knowledge. Second, it provides a rough checklist for evaluating efforts that already are underway.

## 4. SGMA and California's partial integration of groundwater and surface water law

To illustrate the utility of this conceptual framework, we focus on the evolving law of groundwater and surface water in California. To provide background and a point of comparison, we begin by discussing the pre-SGMA legal regime. We then explain where SGMA closes gaps and where continuing challenges remain.

### 4.1. The pre-SGMA legal regime

Throughout the United States, groundwater law has long lagged behind surface water law [36]. California is no exception, and while the pre-SGMA legal systems that allocated California's surface water and groundwater include areas of consistency, they also created major, and deeply entrenched, gaps and conflicts.

Many of the gaps and conflicts have roots in California's traditional systems of water rights. Both surface water and groundwater rights systems include usage rights based on ownership of land adjacent to the resource (riparian or overlying rights) and usage rights based on prior appropriation of water (table 2). California's courts, agencies, and water managers have struggled to reconcile rights grounded in these different fundamental principles [37]. Even when rights share a basic operating principle—whether that principle is shared use or temporal priority—data gaps and a lack of active management inhibit effective integration of legal regimes [38].

Beyond water rights law, other state and federal statutes affect water management in California, and these laws also tended to treat the two resources separately. With relatively rare exceptions [39], federal statutes like the Clean Water Act and the Endangered Species Act (ESA) apply primarily to surface water management, as do their state-law counterparts. Regulation of groundwater extraction has not traditionally been a focus of federal or California statutory law.

The divides that traditionally separated groundwater and surface water management are institutional and procedural as well as doctrinal. For years, water rights regimes for groundwater and surface water have been implemented through separate institutions (table 2). The State Water Resources Control Board (SWRCB) is California's primary surface water regulator, and oversees both water rights and water quality protection. But until SGMA's passage, no state agency regulated groundwater use, except where groundwater was pumped from so-called 'known and definite channels' [11, 16].

**Table 2.** Summary comparison of water rights, governance institutions, and degree of state and federal oversight over decision making for surface water and groundwater in California (pre-SGMA).

| Element | | Surface water | Groundwater |
|---|---|---|---|
| Water rights | Rights based on ownership of adjacent land (correlative) | *Riparian rights:* Waterfront landowners are entitled to use a reasonable share of the natural flow from the adjacent waterway on that land. Shortages are shared equitably among riparian users. | *Overlying rights:* Owners of land overlying a groundwater basin are entitled to pump a reasonable share of the renewable groundwater for use on that land. Shortages are shared equitably among overlying users. |
| | Rights based on the prior appropriation of water (first in time = first in right) | *Appropriative rights:* Surface water that is surplus to the needs of riparian users may be diverted and put to reasonable non-riparian uses. When there is not enough water in a waterway to satisfy all appropriative users' needs, more senior appropriators (those with older rights) may take the full amount of their water right before more junior appropriators may take any water. Since late 1914, all new appropriative rights have required approval by the SWRCB. | *Appropriative rights:* Groundwater that is surplus to the needs of overlying users may be pumped and put to reasonable use on others' lands within the basin or for export outside the basin. When there is not enough groundwater available to satisfy all appropriative users' needs, more senior appropriators may take the full amount of their water right before more junior appropriators may take any water. No state approval is required for appropriative use of groundwater. |
| Management institutions | | Surface water has been managed by a range of actors including local water agencies, the California Department of Water Resources (manager of the State Water Project), the US Bureau of Reclamation (manager of the Central Valley Project), and private entities. | Groundwater has been managed primarily by local water agencies and private entities. |
| Regulatory institutions | Regulation of water rights | The SWRCB directly regulates 'post-1914' appropriative surface water rights and plays an oversight and enforcement role for all surface water rights. | Groundwater use regulation has largely been left to local governments. Counties generally require permits for well construction or modification and have sometimes imposed restrictions on groundwater extraction and use, especially out-of-area exports. A few localities have imposed pumping fees or other general restrictions. However, local regulatory activity has historically been minimal in many areas of the state. |
| | Regulation of water quality | The SWRCB implements and enforces state and federal surface water and drinking water quality requirements. | The SWRCB implements and enforces state groundwater quality and state and federal drinking water quality requirements. The US Environmental Protection Agency and the state Department of Toxic Substances Control also regulate cleanups of waste sites, many involving groundwater contamination. |
| | Other environmental regulation | State and federal wildlife agencies implement and enforce the state and federal endangered species acts and other laws that protect surface-water dependent ecosystems, species, and environmental values. | Traditionally, there are minimal intersections between federal and state habitat/wildlife protection laws and groundwater management. |
| Degree of state oversight over decision-making | | *Significant state oversight* | *Minimal state oversight* |
| Degree of federal involvement in decision-making | | *Moderate to significant federal involvement* | *Minimal federal involvement.* |


**Figure 2.** Undesirable results to be avoided under SGMA. Source: California Department of Water Resources.

Instead, groundwater use regulation has long been left to local governments and the courts. Some local governments used their authority to create sophisticated and successful groundwater management regimes [40]. But in much of the state—particularly in the state's major agricultural regions, where groundwater use is heaviest—local regulatory activity has been minimal [41]. Similarly, while courts have adjudicated rights in some groundwater basins, few major agricultural groundwater basins have been adjudicated [42].

### 4.2. The impact of SGMA

New legislation is often a key mechanism for bringing law in line with scientific understanding. That was true with SGMA, which explicitly acknowledges groundwater-surface water interconnections and compels groundwater managers to consider these interconnections. Specifically, the statute sets a state policy of managing groundwater resources 'sustainably for long-term reliability and multiple economic, social, and environmental benefits for current and future beneficial uses' [43]. Sustainability means avoiding 'undesirable results,' including '[d]epletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water' [44] (figure 2). Regulations adopted under SGMA define 'interconnected surface water' as 'surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted' [45]. 'Beneficial uses' include supporting groundwater-dependent ecosystems as well as human consumptive and non-consumptive uses of surface water [46].

SGMA also is compelling the creation of new agencies, regulations, guidance, decision-making processes, and institutional relationships, all of which will need to address groundwater-surface water interactions (among other matters). New local groundwater sustainability agencies (GSAs) must develop and implement groundwater sustainability plans (GSPs) for groundwater basins prioritized by the California Department of Water Resources (DWR) [47]. GSPs must demonstrate how GSAs will manage groundwater to avoid undesirable depletions of surface water. SGMA also requires DWR to develop groundwater regulations, provide technical assistance, and review the sufficiency of GSPs [48]. The SWRCB is responsible for intervening, and potentially taking over management, in a groundwater basin if the two agencies deem a GSP or its implementation insufficient [49]. Both state agencies thus have significant new roles in groundwater regulation; they are no longer limited to their traditional surface water domains.

SGMA therefore takes significant action at some of the interfaces identified by our conceptual framework (figure 1). But, as explained below, the process of reconciling law with scientific understanding is just beginning.

### 4.3. Continuing challenges

While SGMA takes important steps to reconcile legal structures with hydrologic reality, many challenges remain. Drawing upon our workshops, where discussion focused on continuing challenges, and on our independent research and analysis, the discussion below summarizes the steps not yet taken toward effective integration.

We stress that our analysis is not intended as an indictment of SGMA's authors. Ambiguity is inevitable in any law of such sweeping scope, for legislators cannot foresee, let alone resolve, every complication with one bill. That is particularly true for a statute, like SGMA, that attempted to address many issues; improving management of groundwater-surface water interactions was just one of the statute's attempted reforms. Additionally, a statute providing more extensive mandates for managing groundwater-surface water interactions might not have survived the legislative process, because strong interests had evolved in reliance on the old distinctions [16]. Legislating involves compromise and political constraints, and those inherent limitations will complicate any effort to integrate scientific understanding into statutory law.

#### *4.3.1. Interfaces with written law*

As discussed above, SGMA creates new statutory mandates, and it also has generated new implementing regulations. That means it has addressed, albeit not completely, items 2 and 4 from figure 1. But our workshops and research revealed that items 1 and 3—changing underlying legal principles and addressing intersections with other statutes—remain significant challenges.

*4.3.1.1. Revising underlying legal principles*

In any legal regime, specific statutory terms are likely both to be grounded in and to interact with a set of basic legal principles, which may flow from constitutional authority or from traditional common law. That is true in California, where water law builds from several basic principles—some of which conflict. Bringing together groundwater and surface water law will require resolving some of these conflicts, yet SGMA leaves that task largely unaddressed.

Some of these basic legal principles come from the underlying property rights regime. As discussed above, California law recognizes multiple types of water usage rights, and some of those rights are grounded in temporal priority while others are grounded in geographic proximity (table 2). Reconciling groundwater and surface water management will sometimes require reconciling those competing principles. For example, overlying groundwater users and appropriative surface water users will sometimes claim the same water—particularly as climate change and regulatory limitations lead to increased scarcity and competition.

Complicating these potential conflicts is another underlying principle. Because groundwater and surface water rights are property rights, both are protected by state and federal constitutional prohibitions of 'taking' property without just compensation [36]. Consequently, when regulators attempt to reconcile competing groundwater and surface water right claims, or when they attempt to reconcile either type of claim with environmental protections, some water users may argue that their property has been taken [36].

SGMA does not address these potential conflicts. It expressly disclaims altering surface water or groundwater rights [50]. It also states that GSPs are not obliged to address undesirable results—including surface water impacts—that occurred prior to 1, January 2015 [51]. In combination, this language gives surface water users no new basis for challenging pre-2015 pumping, unless effects occur after SGMA's effective date. But the language does not eliminate the possibility of challenges under other legal theories, or of takings claims. Consequently, SGMA remains agnostic on the resolution of old conflicts between groundwater and surface water users, and legal uncertainty remains.

SGMA also leaves residual legal uncertainty about two other underlying principles of California water law. California's public trust doctrine establishes the general principle that navigable waterways should be managed, where feasible, to serve public values like environmental protection [52]. California's reasonable use doctrine provides additional authority for environmental protection [53, 54]. There are strong arguments that these laws apply to groundwater uses that deplete surface waterways [55], but SGMA says nothing explicit about the interrelationships between groundwater regulation and the public trust doctrine or reasonable use doctrine. Consequently, the exact nature of the resulting legal requirements awaits clarification through additional administrative action, legislation, or the courts.

*4.3.1.2. Addressing intersections with other statutes*

Any new statutory reform is likely to affect other preexisting laws. Continuing questions about water rights, takings doctrine, reasonable use, and the public trust doctrine exemplify this type of challenge. Our workshops and research also identified another major set of challenges deriving from other legal regimes. Federal and state laws including the ESA and the Clean Water Act protect aquatic ecosystems and water quality [56]. But the intersections between these laws and groundwater use and management remain unsettled even after SGMA's passage.

The ESA, which has been centrally important to California surface water management, exemplifies this uncertainty [13]. It prohibits actions that 'take' endangered and some threatened species, and takes can occur through habitat modifications that 'harm' species [57, 58]. Scientists understand that groundwater can be important to many threatened and endangered species [59]. The possibility of prohibited takes therefore seems obvious. But even if scientists (and lawmakers) understand that groundwater and surface water are generally interconnected, the diffuse nature of the impact means that they may not be able to link particular groundwater users' activities to particular environmental effects in surface waterways [60]. The resulting uncertainty is not unique to the ESA. Wherever laws require showing some causal connection between regulated actions and environmental harms, the scientific uncertainties surrounding groundwater management are likely to create legal risk.

SGMA says little about managing these intersections. By requiring sustainable groundwater management and by prohibiting new significant and unreasonable impacts to surface waterways and surface water users, SGMA advances environmental protection. But it establishes neither specific standards nor tailored procedures for integrating groundwater into the larger web of statutory environmental law.

*4.3.2. Interfaces with institutions and practices*

Even if the doctrinal quandaries described above were resolved, integrating groundwater and surface water management would still raise major institutional and procedural challenges. While SGMA takes steps toward addressing these challenges—to use figure 1's framework, it creates new agencies (5) and new decision-making venues and procedures (6) and is beginning to forge new networks (7) and facilitate institutional learning (8)—significant challenges remain.

As mentioned above, management institutions for groundwater and surface water have evolved in

**Table 3.** Pre-SGMA assignment of responsibility for activities related to groundwater-surface water interactions.

| Responsibility (Pre-SGMA) | | Local agencies | State agencies | Federal agencies | Other |
|---|---|---|---|---|---|
| Groundwater rights and regulation | Regulating groundwater use | X | | | Common law and the courts |
| Surface water rights and regulation | Allocating and regulating surface water rights | | X | | Pre-1914 and riparian rights allocated by common law |
| | Supplying surface water | X | X | X | Private water suppliers |
| Environmental laws | Implementing the public trust doctrine | | X | | |
| | Implementing statutory environmental laws | | X | X | |

disparate ways. In California, groundwater regulation and management have been championed as local prerogatives, while surface water regulation is handled primarily by the SWRCB (table 3). Similarly, while a state agency—DWR—is one of California's largest surface water suppliers, no state agency supplies groundwater.

These traditional responsibilities have consequences for managerial networks and experience. For surface water, significant interactions of the SWRCB and DWR with wildlife agencies are common. For groundwater, analogous interactions have been relatively rare. SGMA changes this status quo by giving the state explicit oversight and intervention authority over local groundwater management and by expanding the responsibilities of local managers. Nevertheless, the old institutional arrangements have legacy effects that will complicate implementation of the new. Indeed, much of the discussion in our workshops focused on the challenges and opportunities created by the shifting institutional landscape.

One key legacy effect involves the distribution of expertize. Because no state agency previously asserted authority to manage or regulate groundwater-surface water interactions, there is no state entity with experience doing so. Instead, DWR and the SWRCB will need to develop expertize and translate technical knowledge into effective oversight and intervention programs. For local governments, the challenges could be even greater. Many GSAs are forming in areas where local governments have never regulated water use (beyond straightforward well permitting). And local governments often face challenges funding governance of any kind [61]. Consequently, the institutional capacity necessary for managing groundwater-surface water interactions must be built from the ground up at multiple levels, sometimes under severe funding and resource constraints [62].

A related challenge is the lack of established human networks and relationships. Effective regulation typically requires discretion, communication, diplomacy, negotiation, trust, and improvisation [63]. Effective regulators often rely on relationships with other agencies, advocacy groups, and regulated entities to navigate technical and resource challenges. In an established arena like surface water management, those networks are often well-developed. When groundwater-surface water challenges arise, however, both regulators and those they regulate may not know where to begin or whom to contact. And while key SGMA deadlines require quick action, processes for responding to these challenges are still under development.

### 4.4. Remaining gaps

In summary, reconciling California law with the reality of groundwater-surface water interconnection is a complex, multifaceted process, and removing the legacies of traditional legal divides will require intervention at many levels of law- and policy-making. Table 4 illustrates this complexity, comparing SGMA's reforms and the remaining gaps and challenges to the conceptual framework introduced in Part 3.

## 5. Drawing broader lessons from SGMA

California water law and management are distinctive, and the specific challenges would differ for other attempts to address gaps between law and science. Another reform statute might be clear on underlying principles but vague on specific substantive mandates. Or the substantive mandates might be clear while decision-making processes and agency responsibilities are left undefined. The only near-universal gap is likely to be the challenge of creating institutional memory. Nevertheless, the presence of legacy effects and the need for a multilayered response are likely to arise anywhere policymakers seek to reconcile law with science. The basic evaluative framework presented here can help scholars understand what has been accomplished and where major work remains, and help policymakers plot courses forward.

The framework also has utility for researchers seeking to understand environmental science-policy-law interfaces. By integrating the notion of a multifaceted set of science-policy interfaces into discussions of science, policy, and law, it can help scholars and practitioners think beyond a myopic focus on legislative change as they work to reconcile law with science. For researchers who are concerned with the

**Table 4.** SGMA's role in reforming regulation and management of groundwater-surface water interconnections.

| Potential elements of reform | | SGMA's role | Remaining gaps |
|---|---|---|---|
| Written law | 1. Changing/creating fundamental principles | – Acknowledges the interconnection of groundwater and surface water systems and management | – SGMA does not change/integrate the groundwater and surface water rights systems |
| | 2. Changing/creating specific statutory mandates | – Requires groundwater managers to avoid depletions of surface water that have 'significant and unreasonable' impacts on surface water users, where those impacts occur after 1, January 2015 | – SGMA leaves conflicts arising from past impacts to be resolved under other laws<br>– SGMA does not require surface water managers to avoid significant and unreasonable impacts to groundwater users |
| | 3. Addressing interactions with intersecting legal regimes | – Acknowledges water rights law, exempts GSPs from state environmental review, and requires consistency with local land-use planning by cities and counties | – SGMA is largely silent with respect the public trust doctrine, takings doctrine, and statutory environmental laws and does not fully address water rights law |
| | 4. Changing/creating regulations and guidance | – Assigns DWR responsibility for creating implementing regulations and guidance | – SGMA, its implementing regulations, and related guidance documents do not address the gaps identified above and below |
| Institutions and practices | 5. Changing/creating implementing agencies | – Mandates the creation of GSAs<br>– Assigns new groundwater management oversight responsibilities to the SWRCB, DWR | – SGMA does not address the groundwater management responsibilities of other local, state, or federal agencies |
| | 6. Changing/creating decision-making venues and processes | – Makes GSPs and DWR and SWRCB processes the venues for key decisions<br>– Creates GSP development as a key planning process | – SGMA allows but does not compel surface water managers, land-use regulators, and federal resource agencies to participate in GSP creation and implementation. |
| | 7. Building communication networks and human infrastructure | – Authorizes DWR to support local capacity-building<br>– Compels some communication between GSAs, DWR, and the SWRCB<br>– Compels some communication among nearby GSAs<br>– Compels some communication between GSAs and local land-use authorities (cities and counties) | – SGMA does not compel communication between GSAs or state agencies and surface water managers or federal resource agencies. |
| | 8. Adjusting ongoing, discretionary practices of resource managers | – Creates new responsibilities, which will spur learning. | – SGMA does not (and could not) instantly create institutional memory for managing groundwater-surface water interactions |

effectiveness of science-policy communication systems, differentiating among interfaces will matter, because communication systems that work for one decision-making body, such as a legislature, may not work for others such as agencies or courts. For researchers focused on the appropriate degree of engagement between scientists and political sphere [33], the different interfaces again matter, because some policymaking entities are more political than others. And for researchers focused on adaptive management, the differentiation again matters, because some forms of policymaking will be more adaptive than others. In short, while engaging with the complexity of law- and policy-making realms will complicate analyses of science-policy interfaces, it also can make those analyses richer and more valuable.

## 6. Conclusion

For California water management, SGMA's acknowledgment of groundwater-surface water interconnections is like the Berlin Wall coming down. After over a century, the most important and frequently-criticized boundary in California water law is crumbling. But just as the Berlin Wall's fall set in motion a long and difficult integration process, California too will need

years to reconcile legal and management systems that spent decades in artificial separation.

This article has emphasized the challenges facing legal and management systems that attempt to move past such artificial legal distinctions. Using the case of water management in California, we have demonstrated that many levels of reform will be necessary for overcoming the challenges arising from gaps between scientific knowledge and policy, and we have created a framework for assessing which of those levels a particular reform effort addresses and where the greatest continuing challenges remain. While the gaps faced by other reform efforts will be different, identifying them will be central to the process of moving past the legacy effects of legal fictions and towards policy that better reflects scientific reality.

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