# PUTTING ADAPTIVE MANAGEMENT INTO PRACTICE: INCORPORATING QUANTITATIVE METRICS INTO SUSTAINABLE GROUNDWATER MANAGEMENT

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# EXECUTIVE SUMMARY

Groundwater is a critical resource in California, serving as a reserve during droughts that are expected to be increasingly frequent and severe as climate change progresses. Adaptive management – revising management practices based on monitoring of progress toward pre-established quantitative metrics of performance – is widely viewed as an effective approach to managing water and other natural resources under conditions of uncertainty. However, linking performance metrics effectively with decision-making processes is often challenging, requiring careful consideration of institutional factors that may limit an agency's ability to act based on new information. Governance arrangements that enable adaptive management must balance the need for flexibility as conditions change with a preference among water users for stable rules.

The Sustainable Groundwater Management Act (SGMA) of 2014 – California's first statewide framework for managing groundwater – incorporates many elements of adaptive management, including requirements to manage groundwater according to quantitative metrics of performance. Under regulations guiding the development of Groundwater Sustainability Plans (GSPs), newly formed Groundwater Sustainability Agencies (GSAs) must define measurable objectives, minimum thresholds and interim milestones to eliminate six "undesirable results" by 2040 or 2042, depending upon the basin. Yet, the creation of these metrics alone will be insufficient to achieve sustainable management of California's groundwater; institutional arrangements must support their use to guide management actions.

To provide insight into the design and use of metrics as guides to decision-making, this report draws upon the experiences of four special act districts that had authority to manage groundwater prior to SGMA. These include two primarily urban water agencies, Santa Clara Valley Water District (SCVWD) and Zone 7 Water Agency (Zone 7) and two agencies with significant pumping for agricultural use, Fox Canyon Groundwater Management Agency (FCGMA) and Pajaro Valley Water Management Agency (PVWMA). This report analyzes how these agencies used quantitative metrics in their groundwater management plans prior to SGMA and identifies institutional factors that constrained or enabled the adjustment of management actions in response to changing conditions during the 2012-2016 drought. Although the metrics employed by these agencies differ from those required under GSP regulations, these agencies' experiences still offer important insights for GSAs seeking to develop metrics and integrate them into decision-making.

## Designing Effective Metrics

The metrics that these four agencies used to guide groundwater management efforts prior to SGMA took varying forms. They included metrics based on meeting a certain percentage of well-specific basin management objectives (FCGMA), outcome measures based on end-of-year projections of groundwater in storage (SCVWD), targets to meet a certain percentage of retailer needs while maintaining groundwater levels above historic lows and meeting salt management goals (Zone 7) and eliminating overdraft and halting seawater intrusion within a particular time period, with interim targets to ensure adequate progress (PVWMA).

A review of these agencies' experiences suggests the following lessons regarding the effective design of quantitative metrics:

- Metrics should be as simple as possible while remaining technically robust.
- Developing useful metrics requires considerable analysis and commitment from agency staff and stakeholders.
- Metrics related to factors over which the agency does not have full control need to be designed carefully, but can still be useful.
- Metrics should be clearly linked with a decision-making process.
- It is important to establish deadlines for achieving metrics, including a buffer when possible and clear consequences if deadlines are not met.
- To continue to be effective, metrics will need to be revised over time.

## Institutional Factors Affecting Implementation of Adaptive Management

The 2012-2016 drought impacted groundwater conditions within all four agencies to varying degrees. We analyzed their responses to these changing conditions, including whether management decisions were actually updated when thresholds were crossed. Several factors constrained or enabled their ability to adjust management actions.

Constraining factors included:

- Pressure to maintain rule stability;
- Political resistance that turned adaptive management into an excuse for delay;
- Lack of trust in data gathered to assess performance; and
- Limits on authority to implement necessary management strategies.

Enabling factors included:

- Contingency plans with pre-defined actions to be taken when thresholds were crossed;
- Strong, trusting relationships with partner agencies;
- Access to financial and personnel resources to provide rebates and other incentives; and
- Mechanisms that promote flexibility, such as trading and drought water pricing.

## Recommendations for the GSP Process

Our analysis of the experiences of these four local agencies in using performance metrics suggests important lessons for GSAs as they work to develop and implement GSPs. The regulations guiding GSP development incorporate many elements of adaptive management, including requirements to establish quantitative metrics of performance, submit annual reports and review plans every five years. However, the adoption and review of such metrics does not guarantee their effective implementation; institutional factors may constrain a GSA's ability to adjust their management actions in response to new information. Based upon our findings, we offer the following recommendations for GSAs as they develop GSPs:

- Establish a robust process for engaging agency staff and stakeholders in decisions to establish metrics and to review performance over time.
- Keep metrics as simple as possible while remaining technically robust.
- Agree in advance upon how metrics will be linked with action, including clear deadlines and steps to take if deadlines are not met.
- Balance flexibility against the need for stable rules and expectations.
- Consider including a drought contingency plan as part of the GSP.
- Take an adaptive approach to defining the metrics themselves.

# 1. INTRODUCTION

Groundwater is a crucial resource in California, accounting for about a third of the state's water supplies during normal years. That percentage increases to 60% during times of drought (DWR 2015). Yet, until recently regulation of groundwater pumping has been limited or non-existent in many areas of the state. Concerns about groundwater depletion during the historic drought of 2012-2016 triggered the passage of the Sustainable Groundwater Management Act (SGMA) in 2014, establishing California's first statewide framework for groundwater management. As climate change increases so does the likelihood of severe droughts in the future (Diffenbaugh et al. 2015), making effective management of the state's groundwater supplies critical to ensuring resilience. Climate change has also given rise to increased uncertainty about future conditions, such that water managers can no longer rely solely on historical records to plan for the future (Milly et al. 2008). It is all the more critical that water management agencies take an adaptive approach, maintaining the capacity to adjust as conditions change and information about their system improves (Pahl-Wostl 2007).

SGMA incorporates many elements of adaptive management, in particular through its requirements that groundwater basins be managed according to quantitative metrics of sustainability. Groundwater Sustainability Agencies (GSAs), which have authority to manage groundwater resources in high- and medium-priority basins across the state, must develop Groundwater Sustainability Plans (GSPs) to achieve groundwater sustainability by 2040 or 2042, depending on the basin. Regulations for the development of these plans require that quantitative objectives be defined and progress toward those goals be regularly assessed through monitoring (see Section 3). GSAs are expected to revise management actions if data suggests that objectives are not being met or progress toward them is insufficient; otherwise, the state government can intervene.

Adaptive management has long been touted as an effective approach to managing natural resources. Yet, there are often organizational or institutional barriers to its successful implementation. This paper explores how adaptive management works in practice, by analyzing the experiences of four special act districts that had authority to manage groundwater in certain areas of the state prior to passage of SGMA. In addition to examining their use of metrics in Groundwater Management Plans (GWMPs), we also analyze their responses to California's most recent drought (2012 to 2016). In particular, we address two main questions:

- **How have quantitative metrics for managing groundwater basins been defined and linked with decision-making processes?**
- **With a focus on the drought of 2012-2016, what institutional factors enabled or constrained agencies in revising management strategies based on metrics of performance?**

GSAs are currently working to develop quantitative performance metrics and establishing an adaptive approach to managing groundwater basins in California. In addition, many GSAs are operating under newly formed governance structures and will need to provide a stable set of rules to guide groundwater use, while also maintaining the flexibility to respond to changing conditions. As GSAs confront these challenges, the experiences of these special act districts in using quantitative metrics to guide management of groundwater resources can offer valuable insights.

This report is organized as follows. Section 2 provides an overview of adaptive management, and Section 3 discusses how this framework is reflected in SGMA's requirements for the development of Groundwater Sustainability Plans. Section 4 introduces four special act districts in California that used performance metrics to support groundwater management prior to SGMA's implementation. Section 5 examines how performance metrics have been defined and linked with decision-making in each of our cases, and synthesizes lessons learned through their experiences. In order to gain a better understanding of the institutional factors affecting the implementation of adaptive management, Section 6 focuses on how each agency responded to the 2012-2016 drought and draws upon their experiences to identify factors that either constrain or enable implementation of adaptive management. Section 7 summarizes key recommendations for GSAs as they approach the GSP process, and Section 8 concludes.

# 2. ADAPTIVE MANAGEMENT OF WATER RESOURCES

Among water managers in California, adaptive management is a familiar term, and is frequently referenced in state regulations and local and regional water management plans. Yet, there has been relatively little work done so far examining how adaptive management actually works in practice. This section provides a brief overview of adaptive management and the role of quantitative metrics within it, and summarizes current knowledge of the institutional challenges associated with putting adaptive management into practice.

## 2.1. Adaptive Management and the Use of Quantitative Metrics

The concept of adaptive management emerged among ecologists in the 1970s and 80s (Holling 1978, Walters 1986), but has since gained widespread acceptance as a best practice for natural resource management more generally (Garmestani and Allen 2015). The idea is a common-sense one: as policies or management actions are implemented, results should be monitored and used to improve future performance in a systematic way, in order to improve understanding and cope with uncertainty (Dreiss et al. 2017). The Delta Independent Science Board – an entity that has overseen efforts to improve management of the complex ecosystem of the California Sacramento-San Joaquin Delta – has described adaptive management as "the antithesis of dogged implementation of previously planned management actions even after it becomes apparent that they are not having the desired effects," (Delta ISB 2016, p. 4). Adaptive management is most needed when there is uncertainty surrounding the conditions of a resource and the effects of different management options (Doremus et al. 2011).

Descriptions of the process of adaptive management vary, but the three main steps described in Christian-Smith and Abhold's 2015 report *Measuring What Matters: Setting Measurable Objectives to Achieve Sustainable Groundwater Management in California* capture the key elements. These steps are: **1) plan**, including defining goals and objectives and selecting management strategies; **2) do**, which includes implementing and monitoring actions; and **3) evaluate and respond**, which involves analyzing and comparing results to objectives, communicating these results and adapting as necessary (p. 18-19).

A key element of adaptive management is the creation of quantitative metrics against which to assess performance and trigger adjustments in management strategies (Doremus et al. 2011). These metrics should be grounded in science and provide a clear technical basis for tracking progress toward management goals (Schultz and Nie 2012). Two types of metrics are particularly important: 1) quantitative targets representing achievement of a management objective, and 2) interim indicators of progress, which can provide early warning of the need to adjust management strategies (Christian-Smith and Abhold 2015). These metrics may be designed as indicators of the health or sustainability of a resource; for example, by establishing a target for the total amount of groundwater in storage. Or, metrics may relate to progress toward implementing management actions intended to improve resource conditions, for example by setting a target of a certain percentage reduction in groundwater pumping. Ultimately, though, metrics indicating the condition of the resource itself are necessary in order to achieve sustainable management.

A variety of terms have been used to describe these metrics. For example, in the context of groundwater management, Christian-Smith and Abhold (2015) use the terms "thresholds" and "targets" to refer to measures of desired end results, and "protective triggers" to refer to interim targets linked with actions to avoid reaching an undesirable outcome (p. 9). In this report, the term **quantitative or performance metrics refers to any quantifiable measure of basin conditions, or of implementation of management actions, that is used to assess progress toward effective basin management**. SGMA and its regulations require GSAs to define specific types of quantitative metrics in their GSPs, described in Section 3.

## 2.2. Institutional Barriers to Implementing Adaptive Management

Adaptive management has gained significant traction in the context of water management, particularly amidst growing recognition that extreme droughts and floods are likely to increase in frequency and duration as climate change progresses (Hoffman and Zelmer 2013). In California, the concept of adaptive management has informed the design and implementation of a range of water management policies, including management of the Delta ecosystem, statewide requirements for urban water suppliers to prepare and update Urban Water Management Plans (see Box 1), and most recently, groundwater management under SGMA. Yet, despite being so widely encouraged, implementation of adaptive management is often constrained, not just by inadequate data but by institutional factors. Christian-Smith and Abhold (2015) emphasize that institutional structures allowing for flexibility to update decisions are essential:

> Adaptive management alone will not ensure resilient and sustainable outcomes, especially if management entities are not able to incorporate new information and respond to changing conditions (Folke et al. 2005). Therefore, it is unwise to consider adaptive management as solely a scientific or technical process; it is also inherently a social process that requires institutional structures that allow for greater transparency and flexibility. (Christian-Smith and Abhold 2015, p. 16)

What characterizes "institutional structures that allow for greater transparency and flexibility"? This is an important area of on-going research for environmental governance scholars. Institutional constraints may include inadequate resources (monetary or other), insufficient flexibility within legal requirements or administrative procedures, risk aversion among managers leading to a reluctance to change existing practice, governance structures that inhibit policy change, inadequate stakeholder engagement in support of the adaptive management process and a lack of leadership (Peat et al. 2017, Allen and Gunderson 2011, Delta ISB 2016, Garmestani and Allen 2015).

An overarching challenge confronting any effort to implement adaptive management is the tension between needs for stability and flexibility. A key purpose of many institutional arrangements is to promote certainty, thereby providing a stable and predictable environment for carrying out economic activity and making investments (Hoffman and Zellmer 2013, Biber 2013, Doremus 2001). Adaptive management, on the other hand, calls for the flexibility to update decisions as new information emerges. This report contributes to our understanding of how the dual priorities of maintaining both stability and flexibility can best be achieved in the context of groundwater management.

### Box 1. Elements of adaptive management in California's requirements for Urban Water Management Plans (UWMPs).

Following a severe drought in the 1970s, the California State Legislature passed the Urban Water Management Planning Act in 1983, requiring that urban water suppliers that serve at least 3,000 urban connections or supply at least 3,000 AF annually prepare a comprehensive water management plan. The UWMP Act established statewide standards, requiring that suppliers demonstrate reliable water supplies over a 20-year timeframe and that demand management strategies be considered along with expansion of supplies. In keeping with an adaptive management approach, these plans must be updated every five years. In addition, the Act itself has been amended over the years, reflecting lessons learned and the state's evolving needs. For example, amendments have required that each UWMP include contingency plans for water shortages, discussion and reporting on recycled water use and reporting on progress toward a statewide target established in 2009 to reduce per capita water use by 20% by the year 2020 (Hanak 2010, Water Code §10610-10656 and §10608).

In May 2018, Governor Brown signed AB 1668 and SB 606, further amending the UWMP Act in response to the 2012-2016 drought. Changes include a requirement that water suppliers conduct drought risk assessments that consider water shortage risks associated with a 5-year drought (previously, agencies were only required to plan for 3 years of drought), and new rules regarding the content of water shortage contingency plans and reporting to DWR on their implementation (SB 606, Water Code §§10632, 10635). The legislation also requires that urban water suppliers establish "urban water use objectives" for each year and authorizes the State Water Resources Control Board (SCWRB) to issue conservation orders for agencies that do not meet their established objectives (SB 606, Water Code §10609.20). These new requirements represent an adaptation to increasing uncertainties about the reliability of California's water supplies in the context of climate change.


Photo Credit: Michael Marfell

# 3. QUANTITATIVE METRICS IN THE CONTEXT OF SGMA

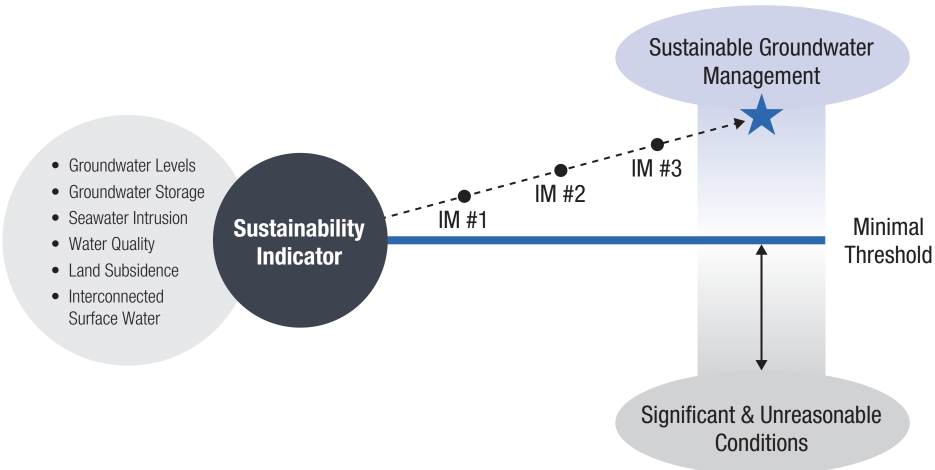
In this section, we summarize SGMA and the GSP regulation requirements that GSAs develop quantitative metrics and employ an adaptive approach to managing groundwater basins. GSAs are responsible for developing quantitative targets representing sustainable management, and if these are not met within a specified timeframe, the state government can intervene. These requirements represent a significant change from most groundwater management plans prior to SGMA, which were voluntary and lacked quantitative metrics of performance (Nelson 2011).

Prior to a deadline of June 30, 2017, more than 250 GSAs were formed in the state's high and medium priority groundwater basins, which are the focus of SGMA's requirements (Conrad et al. 2017). GSAs are responsible for developing and implementing GSPs, which must result in sustainable management by 2042, or in 21 critically overdrafted basins, by 2040. Sustainable groundwater management is defined in terms of avoiding "significant and unreasonable" impacts of six "undesirable results," which include 1) chronic lowering of groundwater levels, 2) reduction of groundwater storage, 3) seawater intrusion, 4) degraded water quality, 5) land subsidence and 6) depletions of interconnected surface water (California Water Code §10721(w)).

SGMA, along with regulations established by DWR, requires that GSPs include specific types of quantitative metrics, which together are referred to as "sustainable management criteria," (California Code of Regulations, Title 23, §354.22). DWR's draft Best Management Practices document on Sustainable Management Criteria provides more details (DWR 2017). The three types of quantitative metrics that GSAs are required to develop and use are described below. Figure 1, from DWR, illustrates how the metrics relate to one another.

- **Measurable objectives** are "specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin," (23 CCR §351(s)).
- An **interim milestone** is a "target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan." (23 CCR §351(q)).
- A **minimum threshold** is a "numeric value for each sustainability indicator used to define undesirable results," (23 CCR §351(t)). The term "sustainability indicator" refers to the six effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, are undesirable results (23 CCR §351 (ah)). For example, surface water depletion due to groundwater pumping is a sustainability indicator because it is an effect that must be monitored to determine whether it has become significant and unreasonable. Sustainability indicators become significant and unreasonable, and therefore undesirable results, when a GSA-defined combination of minimum thresholds is exceeded. Undesirable results must be eliminated within 20 years of GSP implementation.

Figure 1.
Relationship between measurable objectives, minimum thresholds and interim milestones (IM) in GSPs.




Source: DWR 2016a, *GSP Emergency Regulations Guide*, p. 14.

In keeping with principles of adaptive management, SGMA requires that each GSA submit an annual report and "periodically evaluate its groundwater sustainability plan, assess changing conditions in the basin that may warrant modification of the plan or management objectives, and may adjust components of the plan," (Water Code §10728.2). DWR must also review each GSP at least every five years to assess progress toward achieving that basin's sustainability goal (Water Code §10733.8). If GSAs within a basin fail to submit one or more GSPs covering the basin, if DWR deems that the plans do not meet GSP regulations, or if DWR finds that progress toward sustainability is inadequate, DWR can refer the basin to the State Water Resources Control Board for intervention (Water Code §10735.2).

# 4. EXAMINING THE USE OF PERFORMANCE METRICS BY SPECIAL ACT DISTRICTS PRIOR TO SGMA

Although most groundwater basins were only subject to voluntary management arrangements prior to SGMA, in some basins quantitative metrics to guide groundwater management were already in place, backed by an agency with authority to implement them. These areas include certain groundwater adjudications, where a court has determined water allocations and maintains continuing jurisdiction, as well as so-called “special act districts” (Langridge et al. 2016a, 2016b). These are local agencies whose formation was enabled through a special act of the State Legislature to address specific local needs.[1] SGMA identified 15 special act districts with groundwater management responsibilities and granted them the exclusive right to form a GSA within their jurisdiction, although they could opt out of doing so (Water Code §10723(c)(1)). Prior to SGMA, these special act districts were similar in form to a GSA, having been granted special powers by the state legislature to manage groundwater (see Langridge et al. 2016b for an overview). After SGMA was enacted, nine of these agencies, including our four cases, became GSAs prior to the June 30, 2017 deadline for GSA formation.

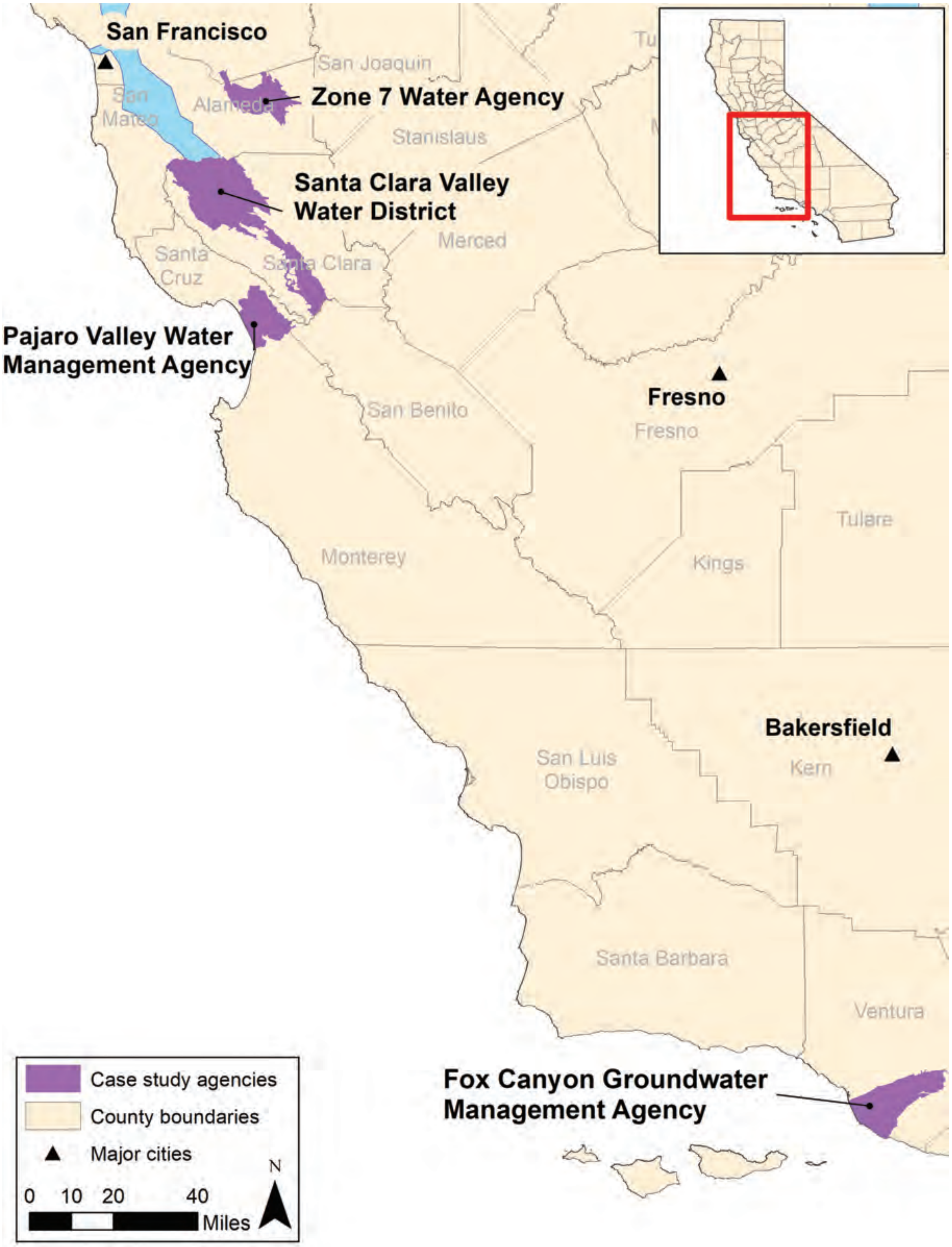
Although the metrics that these districts used to manage groundwater prior to SGMA differ from those prescribed by SGMA, their experiences offer some practical lessons in the design and use of performance metrics and related management actions. In particular, their responses to the 2012-2016 drought enable us to compare decision-making processes within the same rough timeframe and in response to similar climatic conditions, but under different institutional settings. This comparison provides insight into the institutional factors that constrain or enable responses to changing conditions.

## 4.1. Case Selection and Methods

In selecting cases, we looked for special act districts with a relatively long history (at least three decades), those in which groundwater plays a significant role in water supply and that as a group represent a mix of urban and agricultural water uses. In addition, we looked for special act districts that have long-term groundwater management plans that included quantitative metrics. Figure 2 shows the selected case studies, including two primarily urban water supply agencies: Santa Clara Valley Water District (SCVWD) and Zone 7 Water Agency (Zone 7), and two agencies with significant agricultural water use: Fox Canyon Groundwater Management Agency (FCGMA) and Pajaro Valley Water Management Agency (PVWMA). Our analysis is based upon a review of governing documents, annual reports and management plans, a detailed analysis of Board meeting minutes and video (when available) during the 2012-2016 drought and interviews with staff at the four agencies.

1 Special act districts are a type of special district, which are limited-purpose local agencies formed to perform specific services. Most special districts are formed under “principal acts,” or state legislation that enables the creation of categories of special districts. “Special act” districts are created through individualized pieces of legislation when local needs do not fit within principal acts (CSDA and CALAFCO, no date, 5).

Figure 2. Location of case study agencies.




Note: All case study agencies elected to become GSAs under SGMA. GSA boundaries obtained from DWR are used in this map.

## 4.2. Overview of Case Studies

Table 1 summarizes key features of our four case studies.[2] SCVWD, a wholesale water agency founded in 1929, is the oldest and also the largest of our case studies in terms of population, land area, amount of groundwater pumped and annual budget. SCVWD manages two groundwater basins for sustainable use through artificial recharge using local and imported surface supplies and charges fees to all groundwater users including urban water retailers and industrial, agricultural and domestic users. Most groundwater pumping is for urban purposes, but agricultural pumping still accounted for about 20% of groundwater use in 2015. Zone 7 is also a wholesale water agency that relies upon local and imported surface supplies to help recharge its groundwater basin. Groundwater pumping accounts for only a small percentage of water use each year, but the basin serves as a critical reserve in drought years. Of the four agencies, PVWMA is the most reliant on groundwater supplies, with no access to imported surface water. In 2010, agriculture accounted for 86% of groundwater pumping in PVWMA, a greater percentage than in the other three agencies. In FCGMA, a portion of the area within its jurisdiction receives some artificial recharge through surface water deliveries, and several cities rely in part upon surface water; however, the majority of agricultural water users rely primarily or solely upon groundwater.

The agencies differ in terms of their pre-SGMA authority to establish groundwater allocations; only FCGMA and Zone 7 had this authority. However, prior to SGMA, FCGMA did not have the authority to collect fees to build infrastructure for groundwater recharge; these authorities were reserved for the partner agencies that were involved in establishing FCGMA. Since it has so far been unable to charge replenishment fees and its enabling legislation places limits on extraction charges, FCGMA has by far the smallest annual operating budget of the four case studies, and the lowest fees for groundwater use (a total of $12.50/AF, compared to a maximum of $1,289 in 2018 for groundwater production in the North County portion of SCVWD). These agencies' formal authorities have changed since filing for GSA status after SGMA's passage. Under SGMA, all GSAs are granted the authority to regulate groundwater pumping and to charge replenishment fees, once a GSP is adopted (Water Code §§ 10725 et seq. and 10730.2).


A ribbon cutting ceremony of the first advanced metering infrastructure installation in Fox Canyon in [2018].

2 For further details about the four agencies discussed in this report, see Langridge et al. 2016b.

## Table 1. Overview of case studies

| | FCGMA | PVWMA | SCVWD | Zone 7 Water Agency |
|---|---|---|---|---|
| Year established | 1983 | 1984 | 1929 | 1957 |
| Population (2010) | 700,000 | 114,282 | 1.78 million | 220,000 |
| Land area | 183 sq. mi | 110 sq. mi | 1,304 sq. mi | 109 sq. mi (basin area) |
| Number of Bulletin 118 groundwater basins covered | 4 (partial coverage) | 1 (entire basin) | 2 (entire basins) | 1 (entire basin) |
| Percent of water use accounted for by groundwater | 65% (Ventura County, 2010) | 92% (2015) | 34% in North County, 94% in South County (2015) | 6% (2015) |
| Total annual groundwater pumping (2015) | 142,039 AF | 51,400 AF | 120,000 AF | 9,600 AF |
| % pumping for agriculture use | 77% (2015) | 86% (2010) | 22% (2015) | 6% (2015) |
| Pre-SGMA authority to limit extractions or establish allocations? | Yes | Limited/uncertain | No | Yes |
| Pre-SGMA authority to build/manage infrastructure? | No | Yes | Yes | Yes |
| Agency holds rights to surface water? | No | No | Yes (70% of groundwater pumped is managed recharge) | Yes (significant groundwater recharge) |
| Annual operating budget (2015) | $1.07 million | $18 million | $277 million (2015-16) | $75.2 million (2015-16) |
| Groundwater pumping fees (2018-2019) | $6/AF extraction charge for M&I and agricultural pumpers; $6.50/AF "sustainability" charge | $231 - $309/AF, depending on zone | $1,289/AF for urban/industrial, $27.02 for agricultural (North County) | Normally, no fee to retailers for their own pumping; replenishment fee of $839/AF if retailers exceed quota |

**Data sources:** Langridge et al. 2016b; SCVWD Act (2009 update); FCGMA Act (1983, updates in 1991, 2005 and 2014); SCVWD 2016 Groundwater Management Plan; SCVWD Protection and Augmentation of Supplies 2016-17; FCGMA Annual Reports 2010, 2015; Zone 7 Water Agency Annual Report 2015; PVWMA Annual Report 2015; *DWR, 2010 CASGEM Basin Prioritizations Results*; *Zone 7 Water Agency Fiscal Year 2015-16 Budget*; FCGMA Extraction Fees and Statements; *SCVWD 2015-16 Budget News Release*; *Zone 7 Water Agency Resolution 15-95, 2015*.

# 5. EXPERIENCES AND LESSONS IN DEFINING QUANTITATIVE PERFORMANCE METRICS

In the context of adaptive management, quantitative metrics form the basis for management decisions. This section captures lessons related to the design of performance metrics, based upon experiences using them in our case study agencies. In Section 5.1, we provide an overview of each agency's approach to quantitative metrics in their pre-SGMA groundwater management plans. Section 5.2 summarizes lessons learned and their relevance to GSAs.

## 5.1. Overview of Quantitative Metrics Used in Case Study Groundwater Management Plans.

This analysis focuses primarily on Groundwater Management Plans (GWMPs) adopted and implemented by our case study agencies prior to SGMA.[3] Some metrics are also contained in other plans that have been implemented in coordination with GWMPs, including Urban Water Management Plans (UWMPs), and Salt and Nutrient Management Plans (SNMPs). Where relevant, metrics from these plans are also considered here. Table 2 summarizes some of the key metrics used by each agency to track groundwater levels and storage.

Table 2. Pre-SGMA performance metrics for groundwater levels and storage in four pre-SGMA groundwater management plans

| | FCGMA (2007 plan) | PVWMA (2014 plan) | SCVWD (2012 plan) | Zone 7 (2005 plan) |
|---|---|---|---|---|
| Objectives | Eliminate overdraft and seawater intrusion (by 2010 according to Act) | Eliminate overdraft and seawater intrusion | Ensure supply reliability and avoid significant land subsidence | Ensure supply reliability and avoid significant land subsidence |
| Quantitative thresholds | • Groundwater level BMOs defined at 16 wells across 5 basins<br>• Meet at least 50% of all 52 BMOs (includes water quality BMOs) at any given time<br>• In Forebay: maintain at least 85,000 AF storage | Reduce annual pumping by 12,100 AFY to reach safe yield:<br>• 5,000 AFY through water conservation<br>• 7,100 AFY through supplemental supply projects | Maintain projected end-of-year basin storage of at least 300,000 AF | • Remain above historic lows in key wells<br>• Maintain basin at 75% full storage (operational goal) |

3 Prior to SGMA, AB 3030 (1992), SB 1938 (2002) and SB 359 (2011) established guidelines for local agencies to develop groundwater management plans (GWMPs). Beginning in 2002, local agencies were required to file a GWMP in order to be eligible for certain grant funding from the state. Guidelines for developing GWMPs did not require establishing quantitative management objectives.

Table 2, continued

| | FCGMA (2007 plan) | PVWMA (2014 plan) | SCVWD (2012 plan) | Zone 7 (2005 plan) |
|---|---|---|---|---|
| Link with decision-making | Report card presented annually to Board | Board to review progress in 2023 and 2025:<br>• By 2023, achieve 75% of conservation target<br>• By 2025, achieve 100% of conservation target and complete all but 500 AF of supply projects | Board reviews status on a quarterly basis | • Annual supply planning presented to Board<br>• Monthly monitoring informs operations |
| Types of actions triggered if threshold is exceeded | • No specific actions identified, except for pumping reductions when Forebay threshold is exceeded<br>• Declining levels spark discussion of reduced pumping allocations | • Revise water conservation program in 2023<br>• Consider additional supply projects in 2025 | • Implement recommended water use reductions as defined in WSCP<br>• Shift production to different wells to avoid subsidence | • Pro-actively shift production to different wells to avoid historic lows<br>• Adjust local pumping and access other supplies as needed<br>• Increase monitoring frequency from monthly to weekly |

**Data sources:** FCGMA 2007, PVWMA 2014, SCVWD 2012 and Zone 7 Water Agency 2005.

PVWMA, SCVWD and Zone 7 have submitted alternative plans to DWR, largely based on the plans discussed here. If approved, these plans will guide these agencies' efforts to manage groundwater under SGMA.[4] FCGMA, on the other hand, has developed draft GSPs for groundwater basins within its jurisdiction, and in doing so has significantly revised the metrics it will use to guide management decisions moving forward. We analyze the agency's 2007 plan here because it offers important lessons, but it is important to note that FCGMA is developing new plans under SGMA.

### 5.1.1. Fox Canyon Groundwater Management Agency

The act that established FCGMA in 1983 included quantitative metrics, with the intent of halting further seawater intrusion in order to reduce pumping to within safe yield in the upper aquifer system by the year 2000, and in the Lower Aquifer System by 2010 (§121-601, §121-1102). A schedule was established to reduce pumping by 5% every five years, in order to achieve a 25% reduction by 2010. In 2007, a review of the agency's previous plan found that while groundwater extractions had decreased significantly (from 164,700 AF in 1987 to just under 128,700 in 2002), seawater intrusion was still occurring in both the upper and lower aquifer systems (FCGMA 2007). Modeling conducted for the 2007 plan indicated that the safe yield was about 100,000 AFY, considerably lower than the 1985 estimate of 125,000 AFY.

4 SGMA allowed agencies that were already managing groundwater to submit an existing plan as an alternative to developing a GSP. These plans had to meet certain requirements and be submitted to DWR by January 1, 2017 for review and approval. If DWR deems an alternative plan to be inadequate, this agency will be required to prepare a GSP instead (Water Code §10733.6). At the time of publication, the evaluation of alternative plans had not yet been released.

The 2007 GWMP established a new approach to track performance moving forward. It identified 52 Basin Management Objectives (BMOs), which are quantitative targets of groundwater levels and water quality at 26 different wells located in the five main groundwater basins for which FCGMA has responsibility. Groundwater level BMOs are specified at 16 of the wells located in coastal basins, and for all wells, BMOs related to seawater intrusion and water quality are also specified (chloride concentrations, total dissolved solids or TDS and nitrates). The plan set a goal of meeting 50% of these BMOs, with the aim of achieving a balance between avoiding significant problems and continuing to allow as much pumping as possible. The plan states, "meeting BMOs all the time is a more conservative approach, but requires much larger and more expensive strategies and does not take into account the natural climatic variations in groundwater levels that occurred even before the basin was pumped extensively," (FCGMA 2007, p. 38). Given the agency's limited staff and resources, the plan's BMOs and measures of success were developed primarily by a consultant, with relatively limited involvement from FCGMA staff or stakeholders.

While the 2007 plan identified a range of projects that FCGMA would undertake to reach safe yield, it did not lay out a process for updating management strategies if progress was inadequate. However, since 2012 FCGMA staff has presented a "BMO scorecard" annually to the Board, using color-coding and maps to communicate the status of the groundwater basins within the agency's jurisdiction. In addition, staff presentations have compared overall pumping to the estimated annual safe yield of 100,000 AF. In 2014, declining trends in groundwater levels at BMO wells raised concerns among Board members, and ultimately helped trigger the enactment of Emergency Ordinance E (see discussion in Section 6.1.2).

### 5.1.2. Pajaro Valley Water Management Agency

PVWMA's 2014 update of its Basin Management Plan (BMP) took place following years of contention over the legality of increases in pumping charges imposed by the agency in order to manage the basin. PVWMA's 2002 BMP laid out a set of management strategies necessary to eliminate basin overdraft, then estimated at about 16,000 AFY (PVWMA 2002). However, the rate structure established to implement the plan was overturned by a California Court of Appeals decision in 2007, and as result the agency was forced to refund almost $12 million to its customers. PVWMA then worked with groundwater pumpers to agree upon a new rate structure, which was approved in 2010 for a period of five years. An ad-hoc basin management planning committee was established, composed of 21 stakeholders and technical experts who were deeply involved in guiding the development of a BMP update that was ultimately adopted in 2014. The agency also began using a new hydrologic model developed in collaboration with the United States Geological Survey (USGS) instead of an earlier proprietary model, and encouraged active stakeholder engagement in this process. As a result, the technical basis for the 2014 plan was much more transparent than for the 2002 plan. A representative of PVWMA commented that, "Our motto was 'local folks developing local solutions'."

The 2014 BMP's quantitative target is to eliminate overdraft, currently estimated at 12,100 AFY (PVWMA 2014, ES-6). The committee decided to aim for balancing the water budget rather than establishing a sustainable yield because they believed the water budget was less subjective. According to a PVWMA representative, sustainable yield "really depended on the interpretations of what is sustainable…However, we could use the model to develop the water budget by analyzing the inflows and outflows. Of course, there are assumptions that go into any model, but it's the best tool we have, right now."

The 2014 BMP update defines metrics related to implementation of management actions in order to track progress toward their target. With input from a University of California extension specialist, the committee established a goal of 5,000 AF in voluntary agricultural water conservation. In order to come up with the remaining 7,100 AFY, the committee then identified projects to add new supply and optimize existing supplies. Under the plan, PVWMA is scheduled to eliminate all but 500 AFY of overdraft by 2025. Interim targets were established to measure progress. For example, by 2020, PVWMA plans to achieve 75% of its water conservation goal, and if not, make changes to this program. A PVWMA representative described the committee's thinking: "If we weren't meeting conservation goals, we were going to have to revisit the BMP…We knew we were going to need some time to do that before 2025." The interim targets relate to program implementation, but in 2025, the agency will review basin conditions, with a target of eliminating 80% of overdraft and reducing the rate of seawater intrusion by 90% (PVWMA 2014, 78). With regard to water quality, PVWMA's 2016 Salt and Nutrient Management Plan (SNMP) defines targets in terms of the "assimilative capacity" for contaminants in two different subareas. The conservation efforts and water supply projects in the 2014 BMP are also intended to help address these water quality targets. For example, irrigating crops with nitrate-rich groundwater pumped out of the basin and recharging the basin with higher quality water sources helps result in improved groundwater quality (PVWMA 2016, 90, 96).

PVWMA staff provide BMP implementation updates to the Board on a monthly basis. Staff monitor basin conditions and groundwater extractions and provide this information to the Board through annual reports. The BMP specifies that progress toward water conservation will be reviewed in 2023, and basin conditions in 2025. If targets for basin conditions are not met, then PVWMA plans to consider undertaking additional, pre-identified water supply projects (PVWMA 2014, 78).

### 5.1.3. Santa Clara Valley Water District

As the oldest of the four agencies in this study, SCVWD has had considerably more time than the others to refine its approach to evaluating performance. The agency's first comprehensive set of quantitative metrics appear in its 2012 GWMP, but metrics related to land subsidence – one of the original reasons for forming the agency in 1929 – were in place far earlier. The 2012 GWMP articulates the agency's goals in two BMOs: maintaining water supply reliability and avoiding land subsidence (BMO 1) and maintaining water quality (BMO 2). Each BMO is associated with specific "Outcome Measures," which are quantitative indicators that reflect success in achieving these results. For example, the two Outcome Measures associated with BMO 1 are to maintain a projected end-of-year groundwater storage level of 300,000 AF or more[5], and to ensure that subsidence is no more than 0.01 ft/year at all subsidence index wells. Over the years, the agency has obtained input on these metrics from water retailers and agricultural stakeholders through various standing committees. The land subsidence target has been particularly well-vetted.

With regard to its water supply reliability objective, SCVWD is required to develop Water Shortage Contingency Plans (WSCPs) as part of its UWMP, including "stages" that correspond to different degrees of water shortage (see Box 1). SCVWD's stages are based upon projected end-of-year groundwater in storage. Stage 1 refers to normal conditions, when projected end-of-year groundwater in storage is 300,000 AF or more, while Stages 2 through 5 range from "alert" through "emergency" stages, with an emergency corresponding to less than 150,000 AF projected groundwater in storage. This simple approach to measuring the severity of a water shortage makes it easy to evaluate whether or not these triggers have been met. Furthermore, since each stage is associated with a specific target for reducing water use, this facilitates decision-making about what actions to take in response.

Water quality outcome measures were first introduced in the 2012 GWMP. Meeting these targets is challenging because the agency does not hold regulatory authority over many of the land use-related drivers of this problem. For example, one water quality outcome measure requires that water quality standards be met at 95% of all water supply wells, but in 2013, only 79% of wells met the standards, primarily due to nitrate contamination in domestic wells (2013 Annual Groundwater Report, iv).

Agency staff prepare annual groundwater reports, as well as quarterly updates for outcome measures, although progress on water quality is measured annually due to the data analysis involved. Whenever an outcome measure is not met, the staff provides a related action plan.

5 This total is broken down into specific targets for each groundwater management area: 278,000 AF in Santa Clara Plain, 5,000 AF in Coyote Valley and 17,000 AF in the Llagas subbasin (SCVWD 2012, 6-1).

### 5.1.4. Zone 7 Water Agency

As a wholesale water supplier primarily serving urban water users, maintaining water supply reliability is a core objective for Zone 7. In its 2012 Water Supply Reliability Policy, the agency established the target of meeting 100% of retailer water needs 90% of the time, and 85% of their water demands 99% of the time, during normal, average and drought years. When the agency is experiencing unplanned infrastructure outages lasting for a week or more, Zone 7's target is to meet 80% of retailers' demands (Zone 7 2012, 1). Meeting its water supply reliability goals involves balancing a number of factors related to estimated surface water deliveries, access to water stored remotely in groundwater banks in Kern County, groundwater storage levels, facility outages and water quality indicators.

The agency's 2016 Alternative Groundwater Sustainability Plan, and previously the 2005 GWMP (updated annually), lays out its overall approach to managing the basin. A key target is to ensure that groundwater levels at key wells throughout the basin are maintained above historic lows experienced in the 1960s, representing about 128,000 AF of groundwater in storage (Zone 7 2005, 3-7 to 3-8). Operationally, the agency's target is to maintain its "operational storage" (the amount above 128,000 AF) at 75-80%, a level chosen to both ensure adequate reserves while also minimizing impacts of high groundwater levels on gravel mining operations. The estimated operational storage is used to inform decisions such as whether the agency should access some of its water stored remotely in groundwater banks in Kern County. The agency monitors groundwater levels semi-annually through a combination of private wells and key wells maintained by Zone 7, supplemented by monthly monitoring of Zone 7's wells. This monitoring informs estimates of groundwater in storage and helps to identify localized lows. When these come close to historic lows in a given well, Zone 7 staff will seek to move pumping elsewhere in the basin to avoid risk of land subsidence (Zone 7 2015, 5-1 to 5-2).

Similar to SCVWD, Zone 7 has a Water Shortage Contingency Plan, but the stages in this plan are primarily based on its access to surface water supplies rather than groundwater levels. Zone 7's 2010 WSCP contained two stages, one associated with a partial loss of supply, and second stage involving a "catastrophic loss of a major supply" (Zone 7 2010, 13-2 to 13-3). After the 2012-2016 drought, Zone 7 revised its WSCP to include more stages, defined in terms of circumstances that indicate "a reasonable probability" that water supplies may be insufficient in the "next few years," (Stage 1), "current or upcoming year (Stage 2), or "in the current year," (Stages 3 and 4). Stages are further distinguished based on the status of State Water Project allocations and groundwater storage (Zone 7 2016a, 8-2). Declaration of a statewide drought emergency could also trigger these stages.

The agency's Salt and Nutrient Management Plans (2004, 2015) set water quality goals, and established quantitative targets for TDS, nitrates and chromium VI according to secondary and primary maximum contaminant levels (MCLs). In addition, Zone 7 has established a target for boron, which can affect irrigated crops and golf course turf (Zone 7 2016b, 6-1). The status of water quality indicators influences decisions about groundwater pumping. For example, Zone 7 has TDS targets for groundwater stored in the basin. When TDS levels are too high, the most effective strategy for reducing salts is to increase groundwater pumping.

Once a year in April, Zone 7 staff present to the Board an "annual review of water supply sustainability," in which they review current conditions, project supply and demand over the next five years, and recommend groundwater pumping levels for the coming year. This annual review provides a framework in which the Board reviews and updates its water supply decisions.

## 5.2. Lessons Learned Regarding the Design of Performance Metrics

In this section, we synthesize key lessons learned through the experiences of our case study agencies. Although our case study agencies did not define metrics in the same manner as in the GSP regulations, their experiences still provide valuable insights for newly formed GSAs. For each of the six broad lessons discussed below, we summarize key points that GSAs may wish to consider as they develop GSPs.

### 5.2.1. Metrics Should be as Simple as Possible While Remaining Technically Robust

Our review of the experiences of these four agencies suggests that when performance metrics are simpler, they are easier to evaluate, communicate and act upon. SCVWD's target of maintaining a total of 300,000 AF of projected end-of-year groundwater storage is one example. It serves as a single indicator of the status of integrated management of surface and groundwater supplies, providing, according to one SCVWD staff member, "the final, balancing number of the whole picture." Because the metric is specific to water supply, it directly informs decisions about conservation and pumping. Finally, having a standard procedure for projecting end-of-year storage makes it relatively easy to assess whether or not the target has been met. Similarly, PVWMA's targets of addressing 80% of overdraft and reducing the rate of seawater intrusion by 90% by 2025 are relatively simple, and there is a robust and mutually-agreed model and process for evaluating progress. Simplicity does not have to mean using a single number as a target. Zone 7's approach involves multiple factors, but the ultimate target – meeting nearly 100% of retailer needs, except when surface water supplies are significantly disrupted – is straightforward and clearly defined. Of course, technical robustness should not be sacrificed in creating simple metrics.

In contrast, FCGMA's 2007 plan's guideline of meeting 50% of 52 BMOs seems simple, but leaves room for uncertainty. Because some BMOs relate to groundwater levels and others to water quality, this measure of success is quite general; determining whether or not to act requires a more specific look at which BMOs have been exceeded. The plan also provided no specifics on the timeframe over which to evaluate progress. As one FCGMA representative described it, "There's always an argument that you used the wrong time period or you don't have enough data, or I interpret it differently than you…Optically, it looks good to a regulator if you just take a quick look at it, but practically, if you start lifting the hood and playing with the engine, well, you may want to think about it." In practice, the agency never made decisions based on whether or not 50% of BMOs were met, although downward trends in groundwater levels at coastal wells did help inform the Board's efforts to respond to the drought, as discussed in Section 6. Several staff members commented that they have learned through these experiences the value of hard targets, which the agency is developing for its GSPs under SGMA.

As GSAs work through the process of developing measurable objectives and minimum thresholds for each undesirable result, it is important to keep in mind the value of simplicity and ease of evaluation. This clarity will help promote effective communication and transparency. In some cases, for example, it may be appropriate for GSAs to establish a set of groundwater level measurements as a proxy for multiple sustainability indicators. However, modeling and other technical analyses are essential to ensure that the relationship between these indicators and the occurrence of undesirable results is adequately understood.

### 5.2.2. Developing Good Metrics Requires Considerable Data, Analysis and Engagement from Agency Staff and Stakeholders

All four agencies conducted extensive technical analyses and engaged stakeholders in the process of developing performance metrics to guide decision-making. As large wholesale urban suppliers that have been in operation for many decades (since 1929 and 1957 respectively), SCVWD and Zone 7 have had easier access to the resources needed to maintain strong technical expertise on staff, and to conduct outreach and engagement in the development of metrics. Their technical expertise and long track records have helped them develop high credibility and trust among key stakeholders. Although PVWMA's resources are not nearly as great, following the lawsuits over rates under its 2002 BMP, staff made a significant investment in engaging stakeholders on technical issues in the development of the 2014 plan. Consultants were hired only after the stakeholder committee had worked extensively with the groundwater model and on determining priorities.

The stakeholder engagement process appears to have been more limited in the case of the 2007 FCGMA plan, and the technical expertise upon which the metrics were based was largely external to the agency. Interviews revealed that for many years, FCGMA lacked adequate technical expertise on staff, which limited their ability to engage in developing the 2007 plan. FCGMA has since expanded the depth and range of expertise of its staff, who have been substantively engaged, along with stakeholders, in the GSP development process.

> Many new GSAs have limited resources and are facing enormous technical and organizational challenges in developing GSPs that meet SGMA and GSP regulation requirements. In many basins, consultants will play an essential role in providing expertise for technical studies and the plan development process, which must move quickly. However, GSAs should also make a longer-term commitment to build the capacity of their staff, to enable them to work effectively with consultants and to support meaningful stakeholder engagement in agreeing upon metrics of performance. Both are critical in developing metrics that are technically sound and have credibility and support among stakeholders.

### 5.2.3. Metrics Related to Factors Over Which the Agency does not Have Full Control Need to be Designed Carefully, but Can Still be Useful

Our case study agencies have authority over some but not all aspects of groundwater management. This is particularly true in the case of water quality. Each agency's plan includes groundwater quality targets, mostly based on primary and secondary maximum contaminant levels (MCLs) established by the state. However, the agencies themselves do not have direct control over land use, which is a key driver of many water quality problems. During interviews, staff at FCGMA and SCVWD acknowledged that these targets are difficult to achieve due to this lack in authority. In the case of FCGMA, its powers prior to SGMA were mainly restricted to establishing pumping allocations, leaving the Board with few opportunities to address these problems.

GSAs may find it useful to track metrics that fall outside of their authorities. Doing so may encourage GSAs to collaborate with other agencies, programs, or partners with the necessary authorities to meet their goals. In addition, such metrics, and accompanying monitoring efforts, may help other agencies, NGOs and researchers understand groundwater conditions in a more complete manner. SCVWD has found it useful to establish metrics for water quality, even though the agency lacks authority over land use. Staff did not anticipate reaching these targets in the near future – particularly around nitrates, which are related to the use of fertilizer in agriculture – but the Board felt it was nonetheless important to have goals to work toward. As a staff member commented, "I think the intent is to just keep our focus on it, do what we can do in terms of any programs for our attempts to influence land use decisions and actions by the regional boards to try to address the problem." Recognizing that these are long-term goals, however, staff have also considered revising their outcome measures in the future in a way that allows them to demonstrate some progress: "We want to push ourselves…and shoot for great conditions. [But] it also needs to be something that we can measure and have some success along the way." Setting up interim targets to be met within a particular timeframe is one possible approach.

> There are instances in which GSAs lack authority over the drivers of a particular undesirable result, such as in the case of water quality problems stemming from land use decisions. Establishing metrics in these circumstances can serve to clarify goals and encourage focus on developing the relationships with land use agencies, an understanding of the issues and the commitment necessary to ultimately achieve them. The process of establishing measurable objectives and interim milestones for a GSP may provide a foundation for partnering with land use agencies, and setting up agreements such that when milestones are not met, the GSA and other entities jointly undertake specific actions.

### 5.2.4. Metrics Should be Clearly Linked With a Decision-Making Process

The value of quantitative metrics in the context of adaptive management lies in an agency's ability to evaluate progress toward targets and, if certain thresholds are crossed, to adjust management actions. However, research on the implementation of adaptive management suggests that this link between performance metrics and the decision process is often deficient (Williams and Brown 2014).

The clearest examples of effective linkages are found the Water Shortage Contingency Plans of the two urban water agencies in our study, in which specific actions are associated with each "stage" of drought. One reason why the linkage between targets and action is so clear in WSCPs is that the state's UWMP legislation and DWR guidance require this; in fact, the UWMP Act refers to these as "stages of action," (Water Code §10632(a)(1)). Interviews suggested that specifying these reduction levels in advance was helpful. As one SCVWD staff member put it, "It won't be viewed as arbitrary. When we call on citizens to use less water…[it's] not like somebody just sitting in an office and just, 'Oh, 20 percent sounds like a good number.'…There is a basis to it, and then the projected groundwater storage level is that technical support behind this 20 percent." PVWMA's plan also explicitly linked interim targets with considering specific actions, such as increased investment in water conservation and undertaking additional water projects.

In some cases, this linkage is an internal, operational one. For example, Zone 7 has an operational goal of maintaining its basin at approximately 75-80% full, so as to ensure adequate storage while avoiding costs to aggregate mining companies incurred when the basin is completely full. This practice is embedded in agreements with mining companies, such that if groundwater levels exceed certain thresholds in key wells, companies do not need to pay certain groundwater recharge fees. In another example of an operational linkage between metrics and action, staff at Zone 7 have taken steps to shift pumping away from particular wells when water levels get close to a defined threshold, a practice enabled by monthly monitoring (or even weekly, during certain drought periods). Defining routine patterns of action at this operational level is critical because they can increase the agency's ability to respond quickly and pro-actively, rather than waiting until a Board meeting occurs before acting. Implementing this requires strong relationships with partners involved.

> In addition to establishing minimum thresholds and interim milestones, GSAs should also discuss and agree ahead of time upon the actions that they plan to consider if thresholds are crossed or milestones are not reached. It is also important to define the process for making decisions. For example, it may be useful to allow agency staff to make certain adjustments as soon as new monitoring information becomes available, while other types of changes may need to be reviewed by the GSA's board of directors.

### 5.2.5. It is Important to Establish Deadlines for Achieving Metrics, Including a Buffer When Possible and Clear Consequences if Deadlines are Not Met

Meaningful metrics must have clearly defined timelines associated with them. Establishing these is not always straightforward, particularly for a variable resource like groundwater. The water level in a given well may fall below a target value for a certain period of time but rise again during the rainy season. FCGMA's 2007 plan lacked this specificity. In addition, FCGMA's experience illustrates the need for real consequences of not meeting a deadline. The agency's original legislation established a goal of achieving safe yield by 2010, but as a FCGMA representative put it, "That flew by and there were no repercussions…it didn't seem real to people. The potential consequence was that the state steps in, but for the state to really stick to those deadlines is very important if they want it to make a difference, you know. They can't allow the deadlines to slip like they did with the [FCGMA] Act."

Whenever possible, it also is helpful to establish interim targets that include a buffer for fixing problems before a threshold is ultimately crossed and consequences ensue. PVWMA has established such buffers in its 2014 plan by setting a deadline to achieve 75% of its water conservation goal by 2020 and 100% in 2023, well before the end of the plan's 30-year period. Setting an earlier deadline for achieving water conservation made sense because these water savings are more uncertain than those of supplemental water supply projects; if the target is not met, there is still time to adjust.

SGMA sets a timeline for achieving sustainability and establishes the consequence of state intervention if deadlines aren't met. To help ensure state intervention is avoided, GSAs are required to set interim milestones to achieve the sustainability goal for the basin prior to the 2040 (or 2042) deadline, allowing time to alter management strategies if milestones are not met.

### 5.2.6. To Continue to be Effective, Metrics Will Need to be Revised Over Time

SCVWD, by far the oldest of our four case study agencies, has refined its approach over time, as analyses of basin conditions have improved. As one long-serving former staff member and current board member commented:

> We should continue to ask ourselves, 'Are these the right things to measure, and is this the right way to measure them? How can we make them better?'…I worked for this organization for many, many years starting in the 1970s...staff, just based on gut feeling, [would say] oh, 15 percent, that sounds like a good number. [Now], it's nothing like that. There is a rational, logical and technical approach to it.

The process of reviewing metrics can also include considering the validity and reliability of the data used to assess progress toward specified targets. For example, within FCGMA groundwater wells have been metered for decades. Yet, the self-reported metering data has proved unreliable, and the agency is in the process of shifting to automated metering. FCGMA is undertaking the process of developing GSPs fully anticipating that further changes will be needed along the way.

One undesirable result for which all GSAs will need to take an adaptive approach is depletions of interconnected surface water. SGMA is the first statewide law to recognize the connection between groundwater and surface water, and none of our four case study agencies had included this in their pre-SGMA plans objectives or metrics. As a result, there is limited data and considerable uncertainty surrounding the nature and scale of these interactions (Cantor et al. 2018).

Many GSAs are starting out with limited data and modeling. As their understanding of their basin improves and more monitoring data becomes available, they will need to revise measurable objectives, thresholds and milestones. Developing measurable objectives and thresholds to address depletions of interconnected surface water will be particularly challenging, since data about this undesirable result is currently so limited. In this context, taking an adaptive approach will be especially important.

# 6. PUTTING PERFORMANCE METRICS INTO PRACTICE: EXPERIENCES FROM THE 2012-2016 DROUGHT

Droughts are a regular feature of California's hydrology. Groundwater has long served as a critical reserve during dry periods, with groundwater levels typically expected to decline during drought and recuperate when wetter conditions return. However, as droughts become increasingly frequent and severe under climate change (Diffenbaugh et al. 2015), the assumption that groundwater levels will always recover as they have after previous droughts may no longer be valid. Since the 2012-2016 drought some basins are already back at pre-drought levels, but many have been slower to recover, particularly overdrafted basins (Harter and Brewster 2018).

As discussed in Section 3, SGMA and GSP regulations require GSAs to report groundwater extraction, total water use and other information about the groundwater basin annually. The regulations also require GSAs to periodically evaluate GSPs to determine whether the plan is meeting management objectives and meeting its sustainability goal. There is no prescribed timeframe accompanying this portion of the requirement (Water Code§ 10728.4). However, since GSPs will be evaluated by DWR at five-year intervals to ensure adequate progress toward the basin's sustainability goal, GSAs will likely assess their own progress at least that often. However, groundwater managers may need to undertake more frequent assessments of their basin to respond more quickly during a drought and avoid long-term impacts to the groundwater basin.

This section examines how each of our four case study agencies responded to changing conditions during the 2012-2016 drought, and the role that quantitative metrics played in the decision process. Drawing upon these experiences, we identify institutional factors that constrained or enabled these agencies as they sought to update their management strategies when quantitative targets were not met.

The 2012-2016 drought affected access to water for agricultural and urban use and had significant economic and health and safety impacts. In 2015 alone, land fallowing and higher water costs in the agricultural sector cost over $2 billion and led to the loss of about 10,000 farming jobs statewide. While most urban areas weathered the drought fairly well through aggressive conservation measures, many rural communities struggled with water access, and over 2,000 domestic wells ran dry (Hanak et al. 2016). The drought triggered a range of state-level actions to conserve water, summarized in Box 2, which had a significant influence on how local agencies responded to the drought, particularly in urban areas.

## Box 2. State-level actions in response to the 2012-2016 drought

State agencies in California undertook a range of actions to mitigate impacts during this historic drought. Under the guidance of an interagency Drought Task Force established in 2013, various agencies implemented programs to monitor drought conditions and impacts, expedite voluntary water transfers, provide emergency water and food supplies and institute restrictions where needed to protect water quality and endangered species. The state also instituted targets for reductions in urban water use. In his January 2014 executive order (B-17-2014), Governor Brown proclaimed a drought emergency, requesting urban water suppliers to voluntarily reduce their use by 20% and directing them to implement their Water Shortage Contingency Plans. When this did not result in significant water savings, the Governor issued another executive order in April 2015 (B-29-15), mandating a 25% reduction in urban water use statewide. This was the first time the state government had ordered mandatory water use reductions. In order to achieve this, the State Water Resources Control Board (SWRCB)'s emergency regulations established specific percentage reductions for each urban supplier, assigning lower percent reductions to suppliers that were already using water more efficiently (SWRCB 2015a). Urban suppliers largely met these standards; for example, in July 2015, suppliers achieved reductions of 31% statewide compared to July 2013 (SWRCB 2015b). After water conditions improved, the Governor lifted the drought emergency in April 2017 in all but four counties (Executive Order B-40-17).[6] However, in May 2018, Governor Brown signed legislation (AB 1668 and SB 606) to establish permanent targets for urban water use, tailored to water agencies' particular circumstances, with the threat of state-imposed fines if targets are exceeded.

While most of the state's conservation orders focused on reducing urban water use, surface water supplies for some agricultural water users were also restricted; for example, deliveries through the State Water Project and the Central Valley Project declined sharply. As a result, growers who were able to do so switched to groundwater. State agencies took several actions intended to promote more efficient agricultural water use. For example, Governor Brown's April 2015 order expanded the requirement to submit Agricultural Water Management Plans (AWMPs) from suppliers delivering water to at least 25,000 acres to those delivering water to 10,000 acres or more. AWMPs must discuss use of efficient irrigation practices, and after the April 2015 executive order, must also include a drought response plan (DWR et al., 2017).

6 For an overview of conservation-related executive orders and proclamations during the drought, see *https://www.waterboards.ca.gov/water_issues/programs/conservation_portal/executive_orders.html*.

## 6.1. Overview of Drought Responses

Table 3 provides an overview of the drought response strategies of the four case studies. While all four set quantitative targets for reducing water use, they vary in the degree to which these metrics were used to evaluate progress, whether decisions were adjusted in an effort to meet targets, and ultimately, whether targets were met.

Table 3. Drought response policies (2012-2016) in four case studies

| | FCGMA | PVWMA | SCVWD | Zone 7 |
|---|---|---|---|---|
| Drought response policy | • Emergency Ordinance E: reduce M&I and agricultural pumping by 20% | • Emergency declaration and voluntary conservation target<br>• Continued implementation of BMP, including agricultural water conservation goal | • Implementation of Water Supply Contingency Plan<br>• Compliance with statewide conservation requirements | • Implementation of Water Supply Contingency Plan<br>• Compliance with statewide conservation requirements |
| Date initiated | April 2014 | February 2014 | January 2014 | February 2014 |
| Quantitative targets/triggers | • Overall: reduce pumping by 20% within 18 months<br>• M&I: hard cap at 20% reduction, triggers at 10 and 15% at 6-month intervals<br>• Ag: use of "irrigation allowance index" to determine allocations | • Voluntary conservation target of 20%<br>• BMP: conserve 5,000 AFY of agricultural water by 2025 (75% by 2020) | • Voluntary reduction targets from 10 – 30% for retailers, depending on stage of WSCP<br>• Policies applied to agricultural pumping as well, but emphasis was on urban reductions | • Voluntary reduction targets of 20-25%<br>• Policies applied to agricultural pumping as well, but emphasis was on urban reductions |
| Link between metrics and decision-making | • Board scheduled to review data and consider changes on Feb. 1 and Aug. 1, 2015 | • No review of progress toward voluntary 10% reduction target<br>• Quarterly updates on BMP implementation, quantitative conservation target conservation in 2020 | • Board reviewed data and considered changes monthly | • Board reviewed data and considered changes monthly<br>• Staff had authority to make adjustments based on monitoring |
| Targets met? | M&I – yes<br>Agricultural - no | Unknown | M&I: Nearly (27% reduction)<br>Ag: no | M&I: yes<br>Ag: no (but nearly in 2014) |
| Changes made based on performance? | No | No review conducted | Yes – moved target from 10 to 20 to 30% reductions | Yes – moved target from 20 to 25% reductions |

**Data sources:** Ordinances, resolutions, Board meeting minutes and accompanying staff memos.

### 6.1.1. Pajaro Valley Water Management Agency

Of the four agencies, PVWMA's actions in response to the drought were the most limited. Following the Governor's declaration of a state of emergency in January 2014, PVWMA declared a local drought emergency and requested water users to voluntarily reduce use by 20%. Watsonville, the main city within PVWMA, was later required to establish targets and track progress toward water use reduction under the Governor's executive order of April 2015. PVWMA focused its efforts on promoting agricultural water conservation. In response to the drought, in July 2014 the agency initiated early implementation of its Water Conservation Program, which had previously been scheduled to start one year later as part of implementing the BMP Update. This included conservation outreach, development and implementation of voluntary irrigation efficiency programs and financial and technical assistance. The Water Conservation Program's goal is to conserve 5,000 AFY by 2023, and the agency intends to review this in 2020 to determine whether there has been adequate progress toward this goal - at least 75% of the conservation target has been met; if not, changes will be made to the program. Staff do not attempt to report progress on an annual basis because a large number of variables, such as temperature, rainfall and farming practices that vary from season to season, can affect how much irrigation water is used.

One reason why PVWMA made few changes to its management strategies is that even during normal years, groundwater pumping accounts for nearly all water use within PVWMA, and water use would not be expected to change significantly as a result of the drought. According to a PVWMA representative, "In our valley, the drought really didn't impact the production of crops at all… Folks were pumping groundwater, as normal. It's not like in the Central Valley where all of a sudden your [Central Valley Project] allotment is down to five or zero percent and you're not getting any water and your crops are dying. Here, it was…just still pumping, as usual." However, pumping did increase somewhat in PVWMA during the drought because the availability of recycled water from Watsonville declined as the city's use decreased to meet the state's conservation targets and some businesses closed prior to the drought. In addition, some agricultural users increased their pumping to make up for the lack of rainfall, the increased evapotranspiration and to help flush salts and nutrients from the soil.

PVWMA's annual reports indicate that basin conditions deteriorated during the drought. One metric tracked in these reports is acres of land where groundwater levels are below sea level. In the fall of 2011 approximately 26,300 acres west of the San Andreas Fault Zone had groundwater levels below sea level, but by the fall of 2015 that figure was 45,100 acres (PVWMA 2011, 8 and 2015, 8). It is difficult to determine whether this indicates a faster rate of seawater intrusion than would have occurred under normal conditions; by 2017, this indicator had returned to pre-drought levels. The agency chose to address deteriorating conditions during the drought through voluntary measures rather than mandatory cutbacks. The potential socio-economic impacts of mandatory cutbacks on communities heavily invested in agriculture were a significant consideration. Discussion of mandatory reductions has also been deterred by uncertainty over the agency's authority to require pumping reductions, and concerns about whether such actions might lead some landowners to take legal action to adjudicate the basin. As a PVWMA representative described it, "Some legal interpretations of the Agency Act suggest we do have that authority, but most people that we've talked to seem to think that if the agency were to ever try to use that power, it would trigger an adjudication of the Valley, which is really something that everyone has been working to avoid."

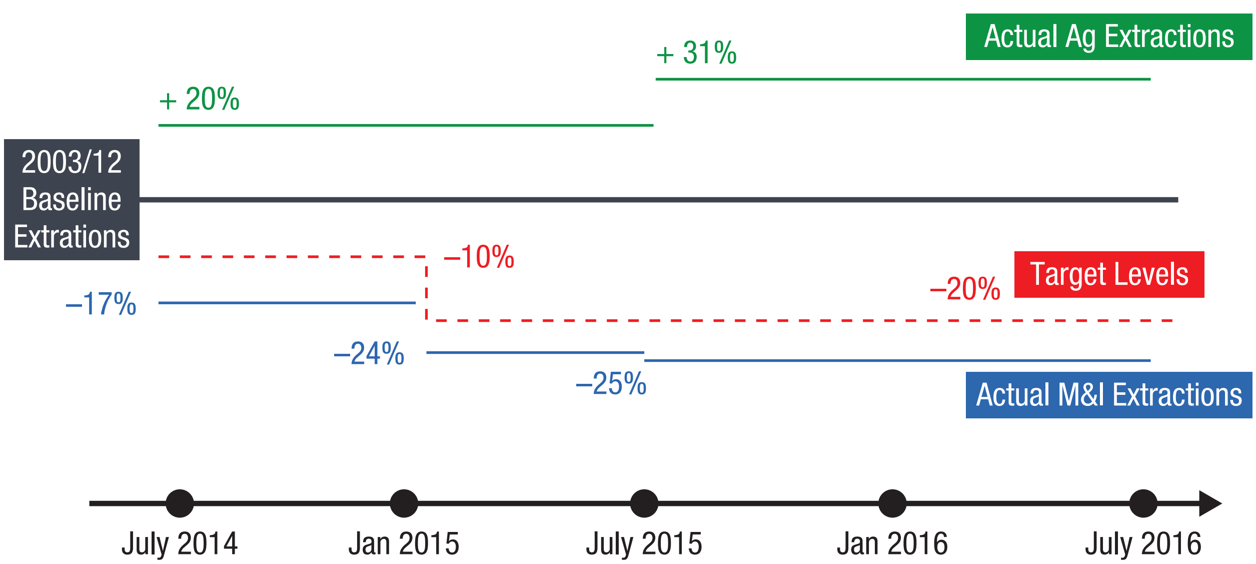
### 6.1.2. Fox Canyon Groundwater Management Agency

In contrast to PVWMA's experience, the impact of the drought was quite evident on the groundwater basins managed by FCGMA. In 2012, 25 out of 52 BMOs (48%) were met, but by 2015 only 15 out of 52 were being met (29%) (FCGMA 2012, 2015). Of particular concern were BMOs representing declining groundwater levels in the Oxnard Plain and Las Posas basins and the advance of seawater intrusion. The lack of rain was leading to increased extractions of around 130,000 AF in 2014, far above the 2007 estimated safe yield of 100,000 AF (FCGMA Board meeting minutes, March 14, 2014, 2-3). At the same time, the agency was facing the potential loss of approximately 8-10,000 AFY of surface water from the Freeman Diversion due to concerns about steelhead trout, listed under the Endangered Species Act. The agency's 2007 groundwater management plan did not outline specific steps to be taken when BMOs were not met. However, the anticipated loss of surface water diversions, along with declining trends in groundwater level BMOs, provided the impetus for the Board to begin discussing policy options in January 2014, leading to the enactment of Emergency Ordinance E in April 2014.

The goal of Emergency Ordinance E was to reduce groundwater pumping by 20% within 18 months of implementation, using 2002-2013 pumping as a baseline. While both urban and agricultural users were subject to the ordinance, urban users faced a hard cap on pumping while agricultural users did not. Urban areas were given an allocation for the first six months of implementation (July 2014 – January 2015) of 10% below their baseline pumping. This was reduced by an additional 5% beginning in January 2015 and by another 5% in July 2015. Agricultural users, on the other hand, were allocated water based on the estimated water requirements of their crops. These estimates came from an index, called the Irrigation Allowance Index (IAI), which takes into account crop and soil type, degree of ground shading and evapotranspiration rates (which vary according to precipitation rates). Under the ordinance, farmers' allocations were based on a 25% reduction in the IAI, which agency staff believed would be sufficient to achieve an interim target of 10% reduction in agricultural pumping by February 2015, and a 20% reduction by August 2015. The ordinance specified that the Board would review progress in February and August 2015, and could further adjust the IAI if needed. In addition, water users are not allowed to accrue or use credits while the ordinance is in effect.

Emergency Ordinance E included clear, quantitative targets, as well as defined interim targets to provide early warning if progress was not adequate. As shown in Figure 3, these targets were met by urban water users, but not by agricultural water users, whose pumping had increased. During the first year of implementation, agricultural pumping was up by 20%, and during the second year, by 31%. A key reason for this increase was that the method chosen to reach the target of 20% pumping reductions for agriculture did not impose a hard cap on pumping. In fact, pumping increases occurred despite the fact that 95% of agricultural pumpers had remained within their allocations. This was possible because when precipitation is low – as it was during the drought – the IAI's estimates of crop water requirements increase due to higher evapotranspiration. As a result, although farmers' allocations were based on a 25% reduction in the IAI, water allocations themselves increased during the drought.

## Figure 3. Comparison of FCGMA's water use reduction targets and actual water use reductions under Emergency Ordinance E




**Data sources:** FCGMA board meeting minutes, staff memos and supplemental documents.

Although the ordinance provided the opportunity for the Board to review progress, no changes were made to Emergency Ordinance E, even though targets for agricultural pumping reductions were not met. During the first scheduled review of performance (February and March 2015), the Board decided to wait until a full crop year had been completed (July 2014 to July 2015) before taking action. These data were not available until January 2016. By that time, municipal operators had more than met their reduction requirements, while agricultural extractions had increased rather than decreased, and groundwater levels had declined compared to 2002 levels (staff memo to FCGMA Board of Directors, January 27, 2016). Nonetheless, the staff's recommendation to the Board was to make no changes to the ordinance, and instead to take additional steps to improve data collection and reporting, increase enforcement for lack of reporting, raise surcharges for extractions in excess of allocations and set a timeframe for coming up with a new allocation system for the long-term (January 27, 2016 staff memo, 5). This approach, ultimately approved by the Board, emerged out of a series of meetings between staff and agricultural representatives regarding the extraction results.

Ordinance E remained unchanged for several reasons. Some growers in the Oxnard and Pleasant Valley basins received reduced surface water deliveries from United Water Conservation District, and increased their extractions as a result. In addition, growers did not favor changes to the requirements under Ordinance E because they were already working to develop an allocation methodology as part of a Groundwater Sustainability Plan (GSP), which at that time, the agency anticipated adopting by the end of 2017. If changes were made to the ordinance, growers would have to adjust their practices yet again when the GSP is adopted. Yet another factor was concern among Board members and staff that some pumping was being under-reported. The agency had been working on establishing Automated Metering Infrastructure (AMI), which would automatically report extractions to the agency, improving both reliability and the timeliness of extraction data. However, the AMI project was not yet complete, and growers, as well as staff and Board members, wanted to wait until the automated system was functional before changing allocations again, this time with better data.

FCGMA was hampered also by its limited resources and its lack of authority to implement a full range of management strategies. Sufficient funds were not available to promote additional monitoring, conduct extensive outreach or provide rebates that might support compliance. Furthermore, the restriction in FCGMA's enabling legislation against building or managing water infrastructure has meant that the agency had fewer management options that it could implement directly, rather than relying upon individual member agencies. As a GSA, FCGMA will gain the authority to undertake many of these activities and to charge replenishment fees once it adopts a GSP.

### 6.1.3. Santa Clara Valley Water District

First initiated in January 2014, SCVWD's drought response effort was guided by the Water Shortage Contingency Plan (WSCP), contained in its 2010 UWMP. As described in Box 3, the WSCP is a required UWMP element, which must include, among other things, "stages of action" to respond to shortages. The SCVWD's five stages are distinguished based on the projected-end-of-year groundwater storage. For example, "normal" conditions are defined as at least 300,000 AF in projected end-of-year storage, while between 250,000 – 300,000 AF represents "stage 2" or the "alert" stage in the WSCP, which triggers a 0-10% reduction in water use. A projected 200,000 – 250,000 AF of storage is associated with a "severe" stage and triggers a 10-20% reduction (SCVWD, 2010). Once its drought response strategy had been initiated, the Board reviewed current projections of end-of-year groundwater storage every month, and would determine whether the target for water use reduction should be revised, based on the stages in the WSCP. Table 4 shows the percentage reductions over time. These targets applied to both urban and agricultural pumping, but the agency's efforts were primarily on reducing urban water use.

Table 4. Timeline of reduction targets under SCVWD's Drought Response Strategy

| Date | SCVWD Water Use Reduction Targets (%, compared to 2013) |
|---|---|
| January 2014 | 10 |
| February 2014 | 20 |
| March 2015 | 30 (with recommendation that retailers make reductions mandatory) |
| June 2016 | 20 (with recommendation that retailers make reductions mandatory) |
| January 2017 | 20 (removed recommendation for mandatory reductions) |

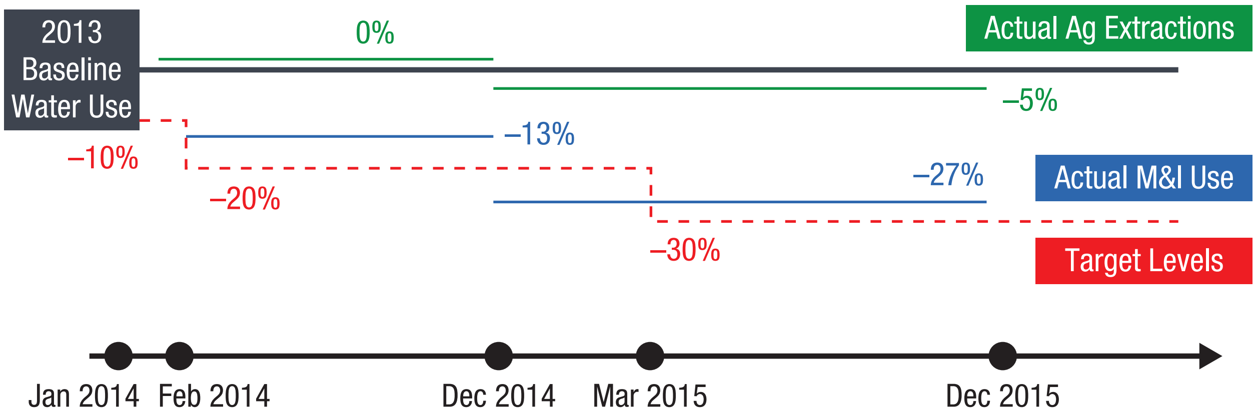
**Data sources:** Board meeting minutes, staff memos and accompanying documents.

### Box 3. Drought planning requirements in Urban Water Management Plans

The requirement to include a Water Shortage Contingency Plan (WSCP) in UWMPs was added during a drought in the early 1990s (Hanak 2010). The required elements of WSCPs have evolved over time, but for the 2010 plans in place during the recent drought, water suppliers were required to identify "stages of action" associated with specific potential water supply conditions, one of which must include a loss of 50% reduction in water supplies, as well as actions associated with each stage. Agencies were also required to assess how water use reductions would affect revenues and expenditures, and how these impacts would be mitigated, such as through the development of drought reserves or rate adjustments (DWR 2010). Legislation enacted in 2018 (AB 1668 and SB 606) expanded WSCP requirements, including mandating that plans include six stages of action, conduct an annual review of water reliability and a number of other requirements (Water Code §10632). In addition, this legislation requires that UWMPs include a "drought risk assessment" that assesses resilience to a 5-year drought, rather than the 3-year dry period that urban suppliers were previously required to consider (Water Code §10635).

In addition to these voluntary targets, the retailers purchasing water from SCVWD had targets of their own, first voluntary and then mandatory reductions under Governor Brown's executive orders. SCVWD's target reductions did not always match these, and in most cases exceeded them. For example, following the Governor's April 2015 executive order B-29-15 (see Box 2), San Jose Water Company had a mandatory conservation target of 20% compared to 2013, whereas SCVWD had already instituted a voluntary reduction target of 30%. In order to encourage retailers to meet these higher targets, agency staff held regular meetings with retail water agencies, provided support for outreach efforts and implemented extensive rebate programs. Figure 4 compares the water use reduction targets set over time with available data about actual reduction levels for urban and agricultural water use. Overall, the targets for water use reductions set under the drought response strategy were met in urban areas, but not in agricultural areas.

Figure 4. Comparison of Santa Clara Valley Water District's water use reduction targets and actual water use reductions




**Data sources:** SCVWD board meeting minutes, staff memos and supplemental documents.

SCVWD utilized data about progress toward these targets to adjust their drought response plans, following the stages outlined in their WSCP. For example, during the March 2015 Board meeting, staff presented data showing that only a 13% reduction was achieved in urban areas between February to December 2013, below the target of 20%. These data about actual conservation rates were factored into the projection of the end-of-year storage. The 2016 Protection and Augmentation of Water Supplies report prepared by SCVWD noted, "Due to the ongoing drought and the community not reaching the 20 percent target in 2014, groundwater storage at the beginning of 2015 was in the "Alert" stage of our Water Shortage Contingency Plan," (SCVWD 2016, 10). Based on this, the Board decided to increase the conservation target to 30%.

While agricultural pumping was technically covered by the reduction targets, it was not the primary target of SCVWD's drought response efforts. The District partnered with a local resource conservation district to promote irrigation efficiency, but outreach efforts were not extensive. According to interviews, achieving reductions in urban areas, particularly through rebates to replace lawns with drought-tolerant landscaping, represented "low-hanging fruit" compared to achieving agricultural reductions among pumpers who depend upon groundwater for their livelihoods.

During 2015, urban reductions averaged 27%, close to the 30% target. Considerable resources were brought to bear in order to achieve this, particularly through the agency's landscape rebate program. By June 2016, the agency's rebates had led to over 7.7 million square feet of turf conversion since early 2014, at a cost of $22.8 million (June 14, 2016 Board meeting, Item 2.3 supplemental memo, 4). By January 2017, the agency had spent over $46 million on drought response activities overall (January 24, 2017 Board meeting, agenda item 5.1 supplemental memo, 4). SCVWD has over 700 people on staff, and during the drought, many were shifted out of their regular roles to contribute to the drought effort. On an organizational level, SCVWD had both the human and financial resources available to respond quickly and effectively.

Although SCVWD lacked formal authority to require reductions, strong informal relationships between agency staff appear to have been effective in encouraging compliance among water retailers to meet voluntary targets that sometimes exceeded state requirements. According to interviews with agency staff, regular communication with retailers to understand the constraints they were facing and how SCVWD could best support them were critical to success. In at least one instance, SCVWD staff utilized these informal relationships to avoid exceeding an Outcome Measure. When regular monitoring of subsidence index wells revealed a concern that subsidence thresholds may be violated, SCVWD worked with the San Jose Water Company to shift their pumping to another area of the basin to ensure that the groundwater level targets related to the Outcome Measure would not be exceeded. In response to falling groundwater levels and storage, SCVWD also encouraged water retailers to use more treated water rather than groundwater, thereby supporting groundwater recovery even during the drought.

### 6.1.4. Zone 7 Water Agency

Although Zone 7 maintains significant groundwater reserves, both locally and in remote water storage banks, and has access to surface water through the State Water Project, the agency initially faced somewhat of a crisis at the time of Governor Brown's drought emergency declaration in January 2014. DWR indicated that it might need to stop all deliveries through the State Water Project, which would have meant that Zone 7 would not receive its surface water allocation, nor would it be able to access the groundwater it had stored in the Cawelo and Semitropic water storage banks in Kern County (since the agency uses SWP infrastructure to deliver this water from the Delta via exchange). The agency had not factored in this possibility in developing its contingency plans. In response, the Board took the initial step of declaring a local drought emergency and establishing a voluntary target of 20% reduction in water use. This was consistent with the Governor's request for 20% reductions, but the Board anticipated that this would be adjusted as new information emerged (Board meeting minutes, Jan. 29, 2014).

During the Annual Water Supply Sustainability Review in April 2014, staff indicated that they expected no additional supplies from contracts to be available in 2014, and projected that the agency could meet only 77% of expected demand that year, and only 75% in 2015. Based on this updated analysis, the Board approved a 25% reduction in water use as described under Stage 2 of the 2010 WSCP. Stage 2 is associated with an "extended, unplanned outage" in Zone 7's ability to deliver water, and adjusts the target for water deliveries to 75% of customer demands. To achieve this 25% reduction, Zone 7's 2010 WSCP recommended that indoor water use be reduced by 5% and outdoor water use by 50-60%. A number of water use practices were also prohibited by Zone 7, including specific restrictions on outdoor watering (Item 8, April 16, 2014 Board Packet).

Later in 2014, DWR determined that it would be able to make some SWP deliveries, enabling Zone 7 to receive some of the water it had stored in Kern County water banks. In order to maximize groundwater in storage, during 2015 and 2016 Zone 7 minimized local groundwater pumping and relied as much as possible on these delivered and banked water supplies. The 25% reduction target remained in place until the next annual review of water supply sustainability in April 2015. However, the drought emergency was not lifted until June 2016. Although initial water conservation efforts failed to meet the voluntary 20% target, ultimately, retailers more than met the 25% target, with an average reduction of 29% in 2014 and of 37% in 2015, compared to 2013 values (2016 Annual Review of Sustainable Water Supply, April 20, 2016). Similar to SCVWD, regular communication with retail suppliers helped to facilitate this. Zone 7 also adjusted its own pumping when its monitoring indicated that certain wells were approaching historic lows.

Zone 7 invested significant resources in its drought response, and this, combined with reduced water sales, impacted Zone 7's budget. Zone 7 made use of the drought contingency reserve it had already established in response to requirements that WSCPs address the financial impacts of droughts. The board discussed the possibility of instituting an additional drought surcharge in 2014, but ultimately refrained from doing so because retailers were reluctant to increase rates just as their customers were making substantial efforts to save water. Later that year, they discussed increasing regular water rates by up to 7% to maintain reserves. However, retailers again opposed this, and the Board decided instead upon a 2-year rate increase of 3%, pegged to the Consumer Price Index (Board meeting minutes, October 1 and October 15, 2014) and lowered funding for capital investments by $3.5M for one year. Ultimately, however, the agency had to find a way to recoup the significant financial losses it experienced during the drought, and in October 2015, the Board approved a temporary surcharge as well as a 3% rate increase for 2016-18 (Resolution 15-95, Oct. 21, 2015).

## 6.2. Institutional Factors that Constrain or Enable Adaptive Management

Drawing upon evidence from the drought experiences of our four case studies, this section discusses factors that have served to constrain or enable updating management strategies when pre-defined quantitative thresholds were crossed.

### 6.2.1. Constraints

#### *6.2.1.1. Pressure to Maintain Rule Stability*

In a 2001 article reviewing the institutional challenges of adaptive management in the context of the Endangered Species Act, legal scholar Holly Doremus commented:

> …[O]ur institutions must perform a difficult balancing act, affording agencies the flexibility needed to manage adaptively while maintaining some degree of closure to our decisions and facilitating the public oversight needed to ensure that our societal goals are met. (Doremus 2001, 52)

These tensions between the need for flexibility and stability are apparent in our case studies. In the case of FCGMA, discussions leading up to the approval of Emergency Ordinance E were tense, with some urging immediate action to reduce pumping and others cautioning against a sudden shift in direction. Concern over an uncertain regulatory environment was a common theme in public comments from urban and agricultural stakeholders. A representative of the City of Camarillo noted, "We are trying to develop a desalter…But we have to spend $50 million, and if you keep changing the rules on us, we're hesitant to invest," (FCGMA Board meeting, Feb. 26, 2014). A FCGMA Board member who represents agricultural interests commented that for farming operations, "banks need to be paid, there's commitments in place, there's businesses." He also emphasized that farmers benefit from stability to support investment in new water supplies: "Businesses and municipalities need certainty, so they are willing to invest that money…[FCGMA] needs to try to have consistent, certain rules, so that everybody knows the playbook…[If we have] certainty to get projects built, you're going to find the agricultural community ready to get on board," (FCGMA Board meeting, February 26, 2014).

Discussions between FCGMA and its urban and agricultural stakeholders ultimately led to changes in the draft ordinance, including shifting away from a hard cap and toward efficiency allocations for agricultural pumping and introducing a more gradual timeline for achieving pumping reductions. When it became clear that agricultural pumping was not declining as they had hoped, agricultural stakeholders again argued against changing the rules, emphasizing the impacts this would have on their ability to plant that season. Groundwater pumpers also faced additional uncertainty about future rules due to on-going discussions about a new allocation scheme to be implemented as part of a GSP. The fact that the rules were about to change again under the GSP process made FCGMA Board members more hesitant to institute changes to Emergency Ordinance E.

For urban water agencies, the need to implement incremental reductions in water use in response to a drought must be balanced against retailers' and rate payers' concerns about stable water rates. Zone 7's drought experience illustrates some of these challenges. Its policy to reduce water use by 25% during the drought meant a 25% reduction in water sales, but it encountered resistance in trying to recoup these losses and the funds expended from reserves. For example, during discussions about rate increases and drought surcharges in 2014, a city council member from Pleasanton appealed for a more modest increase in water rates, commenting that the city needed "credibility to continue to get the constituents to conserve, and to ask them to keep conserving and accept a 7% increase hurts that credibility," (Zone 7 Board meeting minutes, Oct. 1, 2014). Zone 7 did not impose a drought surcharge in 2014, but implemented temporary surcharges in 2016 and 2017 (in addition to rate increases 3% per year) to recoup the $26 million in reserves the agency used during the drought. In 2017, Zone 7 also restructured its 100% volume-based treated water rates to include some fixed charges. Although unpopular with local retail agencies, the fixed component of the rates helps to insulate the agency's finances from future impacts of droughts and to stabilize long-term rates.

### *6.2.1.2. Political Resistance that Turned Adaptive Management into an Excuse for Delay*

Decision-making processes are inevitably subject to pressures from those who will be impacted by a particular decision. Depending upon how those interests are represented in an agency's governance structure, such pressures can have a significant influence on outcomes. Since adaptive management involves taking incremental steps in the face of uncertainty, each of these steps provides an opportunity for the exercise of political resistance to change (Doremus 2001). In some cases, rather than helping to avoid paralysis, adaptive management can become an excuse for delaying action, particularly when action may have significant negative implications for particular stakeholders.

FCGMA's Board faced significant resistance to Emergency Ordinance E, which influenced its design and implementation. The initial draft of the ordinance imposed incremental reductions in pumping for both agricultural and municipal uses, increasing by 5% every six months. However, in response to concerns in the agricultural community, the requirements for agricultural pumping were changed from a hard cap to an efficiency allocation based on a 25% reduction in the Irrigation Allowance Index. This was expected to generate reductions in pumping, but there was uncertainty about how much and how long it would take. In order to address this uncertainty, targets were established, and the ordinance provided the Board with an opportunity to make adjustments if targets were not met within a specific timeframe. During the Board meeting when the final version was approved, the ordinance was described by the Board as "an adaptive approach and subject to periodic review," (Board meeting minutes, April 11, 2014). A key selling point was that it would allow an opportunity for agricultural pumpers to provide input on changes to the ordinance. A Board member commented that the Irrigation Allowance Index was not a moving target: "We are not changing those numbers until they are studied and presented, and everyone will have a chance to argue over them."

Ultimately, agricultural pumping increased rather than decreased under the ordinance. When the Board reviewed progress as scheduled under the ordinance, agricultural representatives argued that more time was needed to see results. As one representative commented, "Listen to these farmers come forward and ask for some kind of certainty in the leases they had in place and the plants that they had ordered and all the rest of it. The least we should do is see this through a full cycle and not make a decision based on a short run of data," (FCGMA Board Meeting minutes, March 25, 2015). The Board decided not to make any changes and to wait for additional data. When progress was reviewed again January 2016, pumping had continued to increase instead of decrease. Stakeholders once again argued that introducing changes would be counter-productive, especially since a new approach would be introduced soon under the GSP process.

Pumping restrictions posed substantial challenges for agricultural pumpers within FCGMA, as well as in other parts of the state. For example, many growers make purchases for agricultural inputs a year or even more in advance, and an unexpected loss of water supply can spell serious financial trouble. These concerns need to be carefully considered in developing plans to cope with drought. However, in this instance, periodic reviews based on previously agreed upon metrics of performance became a series of opportunities to argue for delay, despite a lack of progress. Part of the challenge involves overcoming the attitude that the drought will end, the basin will quickly recover, and the problem will be over. One interviewee described the prevailing attitude as follows: "If you just wait six more months, we've got this other plan that will work…And all the time, they're hoping it's going to rain and everything is going to be better." As climate change brings increasingly frequent and intense droughts, the assumption that after the drought, pumping practices can return to "normal" is becoming less and less tenable.

### *6.2.1.3. Lack of Trust in Data Gathered to Assess Performance*

Effective adaptive management depends not only upon access to adequate monitoring data, but also upon the degree to which these data are trusted by decision-makers and stakeholders. A lack of trust in groundwater extraction data was another important reason why the FCGMA board did not make to changes Emergency Ordinance E despite evidence of increased pumping. FCGMA has required metering of groundwater pumping for decades, and these data are self-reported each year. However, the Board, staff and some members of the agricultural community all acknowledged that some pumpers were not reporting their pumping accurately. Under the ordinance, all agricultural pumpers had to report how much of their efficiency allocation they were using, and if they exceeded their allocation, they would face steep fines of over $1,000 per acre feet. Perhaps not surprisingly, very few have reported any exceedances, and some have reported water uses that are suspiciously low.

The FCGMA had been already been discussing the need to implement automated metering to eliminate this data reliability problem, and the experience under Emergency Ordinance E made the need for this even more clear. When the Board reviewed progress under the ordinance and decided for the second time not to make changes to allocations, part of the rationale for this was to allow time for automated metering systems to be installed.

#### *6.2.1.4. Limits on Authority to Implement Needed Management Strategies*

Prior to SGMA, each of our case studies held a different set of authorities to manage groundwater. During the drought, limits on the authority of PVWMA and FCGMA appear to have constrained their options for responding. PVWMA clearly had the authority to establish augmentation pumping charges and implement projects to access supplemental supplies; this was the primary basis for their 2014 plan to eliminate overdraft. However, there has been uncertainty and tension around whether or not the agency held the authority to place restrictions on groundwater pumping. PVWMA was originally formed to ensure local groundwater supplies were "managed toward the avoidance and eventual prevention of conditions of long-term overdraft, land subsidence, and water quality degradation" (PVWMA Charter Section 102(a)). However, as a PVWMA representative pointed out, part of PVWMA's purpose is also to preserve agriculture in the region. For growers, pumping restrictions, especially if imposed with little advance notice, can cause significant difficulties, both operationally and financially. At the same time, preserving agriculture also requires sustained access to groundwater, and this would not be possible if seawater intrusion were to significantly expand. Farmers in the Pajaro Valley groundwater basin experienced fewer impacts of the drought because they were already largely dependent on groundwater. Had conditions been severe enough, it is unclear whether PVWMA could have acted to impose restrictions. Even though such restrictions would meet strong opposition, having such authority may be important, since if implemented, pumping reductions are likely to have a more immediate effect on basin conditions compared to supply-oriented projects, which often take years to implement.

In contrast, FCGMA had the authority to establish groundwater allocations and impose high penalties for exceeding them, with the practical effect of restricting pumping. However, the agency did not have the authority to implement supply-driven solutions, and instead had to rely upon other agencies to build infrastructure for groundwater recharge. The agency's lack of ability to charge replenishment fees has also limited the resources it has available to incentivize pumping reductions. Given the significant difficulties the agency encountered in achieving agricultural pumping reductions under Emergency Ordinance E, incentives might have been useful. Neither Zone 7 nor SCVWD had the authority to require their retail agencies to reduce water use, yet through collaboration and the use of incentives such as rebate programs and discounts for recycled water for landscape irrigation, they were able to achieve substantial reductions, at least for urban water use. More work is needed to understand how incentives can best help achieve agricultural pumping reductions, as discussed below.

### 6.2.2. Enabling Factors

#### *6.2.2.1. Contingency Plans with Pre-defined Actions to be Taken When Thresholds are Crossed*

The experiences of the two urban water suppliers, SCVWD and Zone 7, show the benefits of establishing a pre-defined set of actions to be considered when a particular threshold is crossed. As the drought continued, both agencies saw conditions cross into higher alert stages described in their state-mandated Water Supply Contingency Plans, and both agencies took the actions that had been identified for each stage. According to SCVWD and Zone 7 staff, having these stages in place with pre-defined actions associated with each helped to ensure that stakeholders did not view the decision-making process as arbitrary. The importance of establishing contingency plans is well-documented in the context of adaptive management (Biber 2013, Doremus et al. 2011), as well as in the public administration and disaster management literature, although of course, even with the best planning negative outcomes cannot always be averted (Eriksson and McConnell 2011).

For the past several decades, urban water suppliers have operated under statewide policies that require them to develop such plans. Indeed, experiences during a serious drought in the 1980s triggered the passage of the Urban Water Management Act to require water supply reliability analysis and contingency planning that includes defined stages of alert and associated actions. Agricultural water suppliers, on the other hand, have not faced such requirements. In most parts of the state, reductions in agricultural water use during droughts are determined by seniority in water rights, and by the decisions of state and federal agencies regarding how much water to deliver through the State and Central Valley Water Projects. When surface water supplies are decreased, agricultural water users often turn to groundwater, and in most areas of the state, they faced few limitations on pumping prior to SGMA.

However, the 2012-2016 drought brought increased attention to the need for drought planning among agricultural suppliers. In 2015, Executive Order B-29-15 added drought planning requirements to Agricultural Water Management Plans, which agricultural water suppliers must periodically submit to the state. The order also expanded the set of agencies required to submit these plans from those serving 25,000 acres or more to those serving 10,000 acres or more. AWMPs must now include a drought management plan that describes the agency's policies for water allocations during shortages. DWR's guidance encourages, but does not require, suppliers to include more specific elements, including stages of alert, adjustments to supply operations as well as demand management actions to be taken during a shortage (DWR 2016, 35-36).

#### *6.2.2.2. Strong, Trusting Relationships with Partner Agencies*

During the drought, SCVWD and Zone 7 both relied upon strong formal and informal relationships developed over the years with retail agencies, their core stakeholders and these were crucial to enabling SCVWD and Zone 7 to gain cooperation to meet water use reduction targets, despite their lack of formal authority to require these reductions. For SCVWD, it initially took some time to develop a consistent message and implementation across all retailers, in part because some retailers who also received supplies from the San Francisco Public Utilities Commission were facing different targets. SCVWD staff held regular meetings with retailers and attending City Council meetings to emphasize the seriousness of the drought, and encouraging adoption of SCVWD. Ultimately, nearly all retailers did so. Once this happened, SCVWD was able to establish a consistent message across its entire service area to encourage water conservation. In addition, staff members were able to work informally with retailers to change pumping practices when a well was getting close to a threshold or storage levels were declining significantly. Similarly, Zone 7 staff worked closely with retailers to encourage water conservation that ultimately exceeded its 25% target. Of course, the retail water agencies in both of these cases also faced state requirements to reduce water use, which undoubtedly facilitated these efforts.

For FCGMA and PVWMA, where the majority of groundwater pumping is for agriculture, there were no state requirements in the background to encourage informal collaboration. PVWMA undertook voluntary water conservation efforts in response to the drought, beginning the agricultural water conservation program planned for its BMP 2014 update a year early. The agency made a significant investment in building strong stakeholder involvement in the plan; these relationships, as well as the program design, will be tested when it comes time to evaluate progress toward water conservation goals in 2020. FCGMA encouraged significant stakeholder participation in the development and implementation of Emergency Ordinance E. Some of these interactions were contentious, particularly during Board meetings. However, both urban and agricultural stakeholders met separately with staff on numerous occasions, and these meetings were critical to reaching agreement upon both the final version of the ordinance, and in its implementation. Overall, the experiences in our case studies suggest that strong, formal and informal relationships grounded in trust are critical to enabling a coordinated response to changing conditions.

*6.2.2.3. Access to Financial and Personnel Resources to Offer Rebates and Other Incentives*

One significant contrast between our urban and agricultural-oriented case studies is the availability and use of resources to respond to the drought. For example, by June 2016, SCVWD had invested over $22 million in its landscape rebate program; in contrast, FCGMA's total budget in 2014 was just $1.1 million. This difference is explained by the fact that rates for municipal water use tend to be much higher than for agriculture, and because experience with rebate programs shows that they can result in significant water savings.

Finding resources to support outreach and incentives to reduce water use in agricultural regions, either as part of short-term drought response or long-term conservation, is more challenging. PVWMA has invested about $1 million in conservation outreach programs in order to achieve its goal of 5,000 AFY of agricultural water conservation by 2023. The agency also recently started piloting a land fallowing incentive program, and is working with UC Santa Cruz to develop a program to offer rebates to landowners who use their land for groundwater recharge (Kiparsky et al. 2018). GSAs across the state will have much to learn from PVWMA's efforts and other similar programs.

*6.2.2.4. Mechanisms that Promote Flexibility, such as Trading and Drought Water Pricing*

Restricting groundwater extractions is probably the least preferred among all options open to water agencies involved in groundwater management. This is particularly true for agricultural groundwater pumpers, for whom water access plays a critical role in determining a farming operation's activities and income in a given year. For municipal water suppliers, water use reductions can also have a significant impact on the agency's finances. Yet, pumping reductions are sometimes necessary in order to reach management objectives, and this option will need to be considered by many GSAs, especially those governing basins in critical overdraft. Our four case studies, as well as experiences in some basins governed by adjudications prior to SGMA, suggest that it is easier to achieve reductions when they are accompanied by mechanisms that offer some flexibility to agencies and groundwater pumpers in coping with the impacts of reductions.

Water trading is one such mechanism. FCGMA has been working to enable growers in the Oxnard and Oxnard Forebay basins to buy and sell water. The agency's investments in automated metering of groundwater extractions are helping to make it possible to establish a market for groundwater (Hersko 2017). PVWMA's pilot to pay farmers to recharge groundwater is another example of a mechanism to enhance flexibility. Water markets have been beneficial in other settings, such as in the Mojave groundwater adjudication where trading provided water rights holders with the option to sell their rights if the cost of purchasing enough water became too high as "free pumping allowances" were reduced. Several recent studies have highlighted the potential benefits of groundwater rights trading, while also emphasizing that the right institutional conditions need to be in place for these markets to work effectively (Green Nylen et al. 2017, Babbitt et al. 2017).

For urban water suppliers, maintaining financial stability while implementing water conservation efforts depends upon effective water pricing and the creation of contingency reserves. Zone 7 relied upon a drought contingency fund during the 2012-2016 drought to help cover costs while selling 25% less water. Proposals to introduce a drought surcharge or additional rate increases were met with resistance, but ultimately, these had to be imposed in order to recoup these losses. In this instance, the need for stable rules and expectations is in tension with water agency efforts to respond to an on-going drought (see Section 6.2.1). In the wake of the drought, Zone 7 introduced fixed fees as a portion of their rates to improve their financial resilience. In 2017, SCVWD established a drought contingency fund, and is also considering introducing fixed fees as a portion of their water rates. A recent report by the Public Policy Institute of California synthesizing lessons from the drought for cities and suburbs in California recommends that water agencies establish rate structures with pre-approved rate adjustment mechanisms that would be triggered during droughts (Mitchell et al. 2017, 46).

# 7. RECOMMENDATIONS FOR THE GSP PROCESS

The state's regulations for GSP development offer a strong foundation for GSAs to take an adaptive approach to managing groundwater. The regulations require several types of quantitative performance metrics, including measurable objectives to work toward, minimum thresholds to avoid crossing and interim milestones to track progress over time. However, as argued throughout this report, the mere creation of these metrics does not guarantee their effective implementation. In practice, a range of institutional factors may constrain a local water agency's ability to act in response to information about the effectiveness of existing management efforts, or to changing conditions, such as droughts, that affect their ability to reach their objectives. By examining the experiences of four special act districts in California that had authority to manage groundwater prior to SGMA, we have identified a number of lessons learned regarding how metrics can be designed most effectively and what actions local agencies can take to help overcome constraints to implementing an adaptive management approach.

Here, we summarize some of the implications of our findings for GSAs to consider in developing GSPs. While the metrics used in our case studies differ somewhat from those that GSAs will need to develop for their GSPs, many of these lessons are still relevant.

1. **Establish a robust process for engaging key stakeholders in decisions to establish metrics and to review performance over time.** Adaptive management is only effective when decisions are grounded in robust technical analysis that is broadly understood and accepted by the stakeholders involved. If technical information is not adequately vetted and trusted, adaptive management can become a hollow process in which thresholds are crossed and deadlines come and go without action. GSAs must invest in building adequate capacity among staff members to coordinate meaningful engagement by interested parties in determining the technical basis for establishing metrics and evaluating performance. PVWMA has laid the groundwork for this through its ad hoc planning committee, which was deeply engaged in developing its 2014 plan. Similarly, FCGMA has strongly encouraged stakeholders to take an active role in developing new allocation schemes for the GSPs it is developing. The benefits of these investments in a robust engagement process are likely to be evident as both agencies evaluate their performance against the benchmarks established in their plans.

2. **Agree upon how metrics are linked with action.** Regulations require that GSPs identify measurable objectives, minimum thresholds and interim milestones for each sustainability indicator to avoid undesirable results. Experiences in our case studies show that it is critically important to identify in advance the steps the agency will consider taking if progress is inadequate, and the timeframes on which these steps will be considered. This core element of contingency planning has been a part of the requirements for California urban water suppliers in planning for water shortages for decades, and would likely help facilitate effective GSP implementation.

3. **Balance flexibility against the need for stable rules and expectations.** One of the most significant barriers to implementing adaptive management is that water users seek stability in the rules they must follow. This should be taken into account in the design of metrics, and in how metrics are linked to action. Pre-defining the set of actions that may be taken when specific thresholds are crossed, as suggested above, can help achieve this balance. In addition, mechanisms that improve flexibility, such as markets and drought contingency funds, can help ensure that when the time comes, stakeholders are willing and able to follow through on the agreed-upon plan of action. Resistance to change stemming from concerns about rule stability represents a real potential barrier to sustaining progress toward sustainability goals. GSAs will need to establish clear plans for what they will do when metrics are not met. They will also need to consider what level of financial risk is acceptable to their rate payers and the region with respect to emergencies and drought contingency plans.

4. **Consider including a drought contingency plan as part of the GSP.** Climate change is likely to bring increasingly severe and frequent droughts to California. The historic 2012-2016 drought served as a wake-up call that the state's groundwater resources are not infinite, and pro-active management strategies are necessary to ensure that groundwater is available as a reserve during times of shortage. While groundwater levels will decline during dry periods and recuperate during wet periods, it is no longer a safe assumption that water levels will always recover as they have in the past. Instead of waiting it out until the rains come again, it may be necessary to take short-term actions during a drought to avoid veering too far off course on the road to sustainability. Urban water suppliers have been required to have drought contingency plans for decades, and many agricultural water suppliers are now also required to develop drought response plans as part of their Agricultural Water Management Plans. Agreeing ahead of time on a plan will help ensure a GSA is able to respond effectively to the next severe drought, including measures to promote an effective "rebound" after the drought.

5. **Take an adaptive approach to developing metrics themselves.** In many groundwater basins, considerable uncertainty exists regarding numerous physical characteristics, such as a basin's storage capacity, the location of promising sites for groundwater recharge and connections between groundwater and surface water. In some basins, there is even considerable uncertainty about how much groundwater is being extracted each year. Initial definitions of measurable objectives and minimum thresholds may prove inadequate as data is collected and modeling improves. Adaptive management provides an appropriate framework for approaching this. Metrics themselves will need to be reviewed and revised based on experience and new information. Under the GSP regulations, DWR will review annual reports and plans every five years; this should involve a thorough assessment of whether the chosen metrics are providing adequate information upon which to base management decisions.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# 8. CONCLUSION

Given California's highly variable climate – which is becoming even more variable as climate change progresses – and the current limitations of our understanding of groundwater conditions in many parts of the state, adaptive management will be critical to reaching groundwater sustainability within the 20-year timeframe established under SGMA. The new law incorporates many elements of adaptive management, in particular by requiring GSAs to develop and use quantitative metrics to guide their efforts to achieve sustainable management and requiring regular progress reviews. Yet, as our analysis of the experiences of four special act districts that managed groundwater prior to SGMA, defining these metrics is only the first step. Careful thinking is needed about how metrics will be used to inform decision-making. Has the technical basis of a particular threshold and its relationship to sustainability been vetted with stakeholders? Once a threshold is crossed, what actions will be considered? What decision-making process will be followed? Our case studies suggest that thinking through these questions ahead of time and pre-defining actions associated with crossing certain thresholds is helpful for balancing the need for flexibility when conditions change with the need for a stable rule environment for water users.

Statewide policies play an important role in establishing an overall institutional framework that supports the creation of metrics linked with decision-making. For decades, urban water agencies have had urban water management plans that include a water shortage contingency plan defining actions to be taken to cope with droughts and other shortages. Recently enacted legislation takes this a step further by setting statewide standards for per capita urban water use, in addition to even more specific requirements for drought contingency planning. Agricultural water users, while they face uncertainty each year with regard to surface water access, have not been required to operate within quantitative targets with respect to groundwater. Under SGMA, statewide standards now require setting such targets for the first time, for both agricultural and urban uses. Given the considerable uncertainties involved, climatic and otherwise, GSAs must have the capacity and processes in place to adjust strategies during GSP implementation based on data about progress toward meeting their objectives. As argued in this report, this will require robust stakeholder engagement in defining metrics as well as the actions to be undertaken when thresholds are crossed. This is a critical first step toward the development of institutional arrangements that will enable a GSA to make course corrections later on.

Ultimately, the implementation of GSPs in groundwater basins across California will be an important opportunity to learn about the practice of adaptive management. However, GSAs do not need to start from scratch. There is already much to learn from the experiences of agencies that took adaptive approaches to managing groundwater prior to SGMA, and it is hoped that the lessons identified in this report will be useful to GSAs in the challenging tasks ahead.

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