Getting Involved in Groundwater

A Guide to California's Groundwater Sustainability Plans

Union of Concerned Scientists

This guide is designed to help you get involved in developing a local groundwater sustainability plan, a requirement of California's Sustainable Groundwater Management Act.

Using this guide and *online toolkit*, a diverse range of people can equip themselves to effectively participate in shaping the vision and plan for their community around maintaining groundwater supplies. While technical expertise is a critical element of developing a successful groundwater sustainability plan, the community, with clarity around its values and goals, must lead the way.

Community members and other interested people are needed to actively participate in groundwater sustainability planning. The law specifically calls for the engagement of diverse voices, and your involvement will help produce the strongest plan. This guide explains what's at stake, shows you several entry points into the process, and suggests important questions to ask your Groundwater Sustainability Agency board members, technical experts, and others as you work toward a groundwater sustainability plan rooted in your community's values.

For Groundwater Sustainability Agency board members and advisory committee members, this document offers guidance for designing groundwater sustainability plans with community participation in mind. Since individual groundwater basins have different needs, this guide does not aim to be a comprehensive manual. Rather, it provides some critical questions to ask other advisory committee members and board members, stakeholders, and the technical experts with whom you'll likely be collaborating.

This guide can also help **scientists**, **technical experts**, **and consultants** understand the interplay between technical information, community values, and perceived problems and/or benefits that will guide the definition of sustainability in a groundwater sustainability plan.

Recognizing the critical need for, and the value of, effective engagement in groundwater sustainability plans, the Union of Concerned Scientists (UCS) created this guide to provide information and tools for developing community-driven, science-based plans. This guide will help you to answer the following questions:

- **What is a groundwater sustainability plan?**
- **What are the groundwater conditions in your basin?**
- **How are groundwater sustainability goals defined?**
- **How can I engage in groundwater sustainability planning?**
- **How may water budgets and models inform your plan?**
- **What is the role of technical experts in creating a plan that's based on community values and goals?**

These questions will be answered in color-coded sections, making it easy to flip to sections of the guide that most interest you and find them again later. Throughout, terms are bolded and defined when first used, and you'll find a glossary on the last page.

For additional resources, exercises, and tools to deepen your understanding, or to get more information—including referrals to experts who can help answer any technical questions—visit the UCS website at *www.ucsusa.org/CAgroundwatertoolkit*.

Cover photo: Florence Low/California DWR

An Introduction to the Sustainable Groundwater Management Act

In California, groundwater—the water found underground in the cracks and spaces in soil, sand, and rock—has long served as a "savings account" for our water supply.

In dry years, Californians rely on the water in underground **aquifers** (the layer of rock and sand that is saturated with water) more heavily. In wet years when there is ample **surface water** (rivers, lakes, and streams), the account replenishes, though this can take multiple wet years. During the state's most recent drought, more than 60 percent of our water use was supplied from underground sources, leading to declining groundwater levels in many areas. The Sustainable Groundwater Management Act (SGMA) was passed to correct our course from a race to the bottom of the aquifer to a sustainable path that we can refine over the coming decades.

The new local groundwater sustainability agencies (GSAs) must achieve sustainability by 2040 (or 2042 for lower-priority basins). Yet, there is no technical definition for sustainability—communities will define sustainability themselves. GSAs, in consultation with diverse stakeholders, will decide how much damage is acceptable and, conversely, how much repair is desired. Thus, while sustainable groundwater management has many technical aspects, determining what sustainability means at the local level is both technical and social. Sustainability will be defined by the range of community members who come forward to help develop a vision for the future. Everyone can be involved in this process, and those who engage early and often will have a greater influence over defining what sustainability means locally.

You should consider getting involved in groundwater planning if you care about one or more of the following:

- The quality of the water you drink
- Local property values
- The number of wells that have gone dry or may go dry
- The cost to drill a new well
- The amount you can pump from a well
- The health of plants and animals, especially those dependent on groundwater

What Is a Groundwater Sustainability Plan?

The Sustainable Groundwater Management Act requires that each **basin**—an aquifer or system of aquifers with reasonably well-defined boundaries—develop its own groundwater sustainability plan (GSP) to be evaluated and approved by the California Department of Water Resources. A GSP is a blueprint for the community's vision of future land and water use that preserves groundwater quantity and quality, and must contain four main components: 1) a description of the plan area and groundwater basin setting (including an assessment of current and future groundwater conditions and a water budget); 2) **the sustainability goal**, which must avoid all six **undesirable results** (see next page), such as excessive reduction of groundwater storage or contamination with saltwater; 3) projects and management actions that will achieve the community's sustainability goal; and 4) a monitoring plan that will measure progress over time.

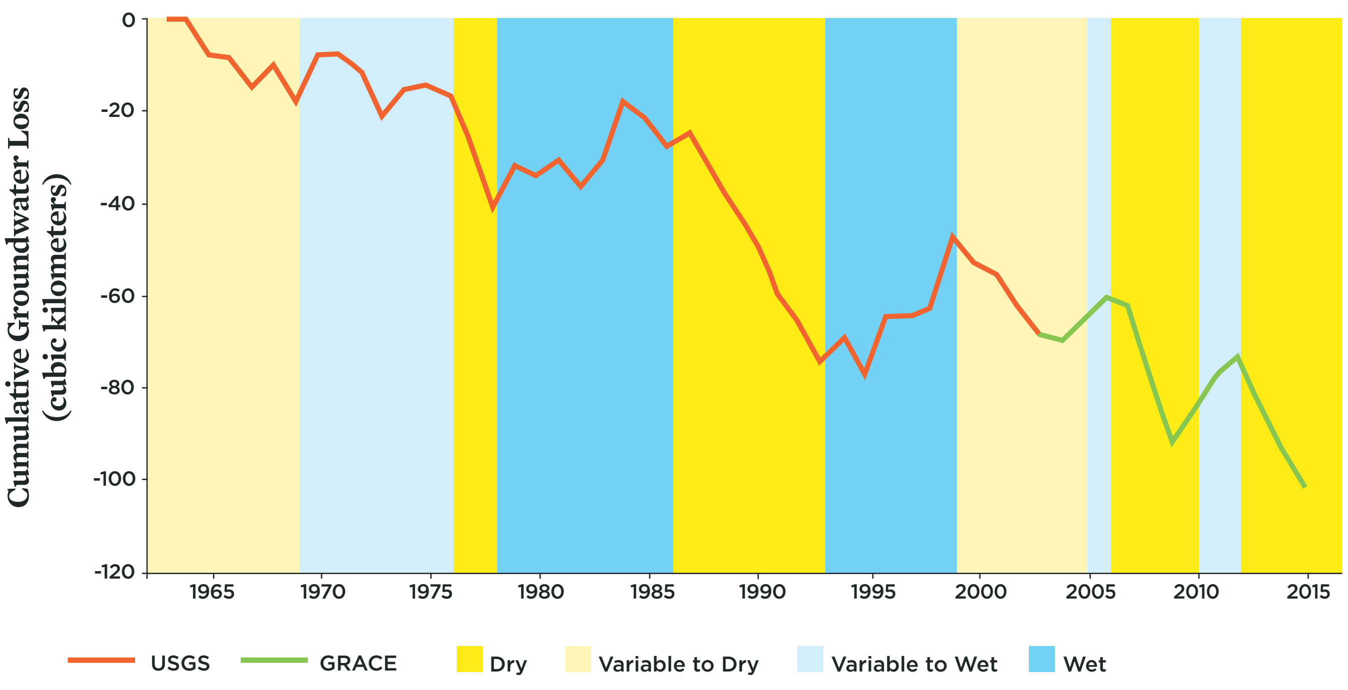
Understanding the Groundwater Conditions in Your Basin

Understanding the current groundwater conditions in your basin will help you to collaborate to create the best sustainability plan. In California, there are currently 515 groundwater basins or subbasins. While some basins' boundaries follow city or county lines, most boundaries are based on the hydrogeology of the area. A groundwater basin is typically bound on all sides by features that affect the water's flow, such as impermeable rock, a seismic fault, or the ocean.

Undesirable Results

California's groundwater basins are vulnerable to six types of undesirable results (explained in Figures 1–6), which the sustainability plan aims to avoid. You will want to know whether your basin is currently experiencing any of these undesirable results or if it's likely that it could in the future.

FIGURE 1. Significant and Unreasonable Reduction of Groundwater Storage

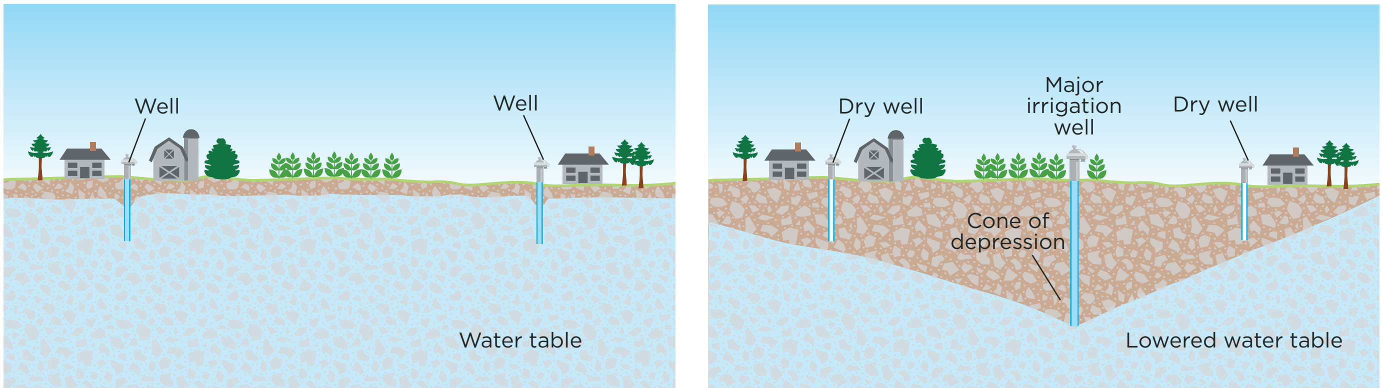


During the drought from 2012 to 2016, California got 60 percent of its water supply from groundwater. However, this drought only compounded an old problem: consistent ***overdraft*** *of groundwater—when more is taken out than is replaced—has been occurring in California's Central Valley over the last 50 years. Drawing down our groundwater storage puts natural areas and communities at great risk. During the drought, many residents' wells dried up. Reduction of groundwater could mean that there may not be enough groundwater during dry times to meet our needs, or it may become more difficult to access.*

Note: The red line shows data from groundwater model simulations calibrated by the US Geological Survey (USGS) from 1962 to 2003. The green line shows Gravity Recovery and Climate Experiment (GRACE) satellite-based estimates of groundwater storage losses. Background colors represent different water years.

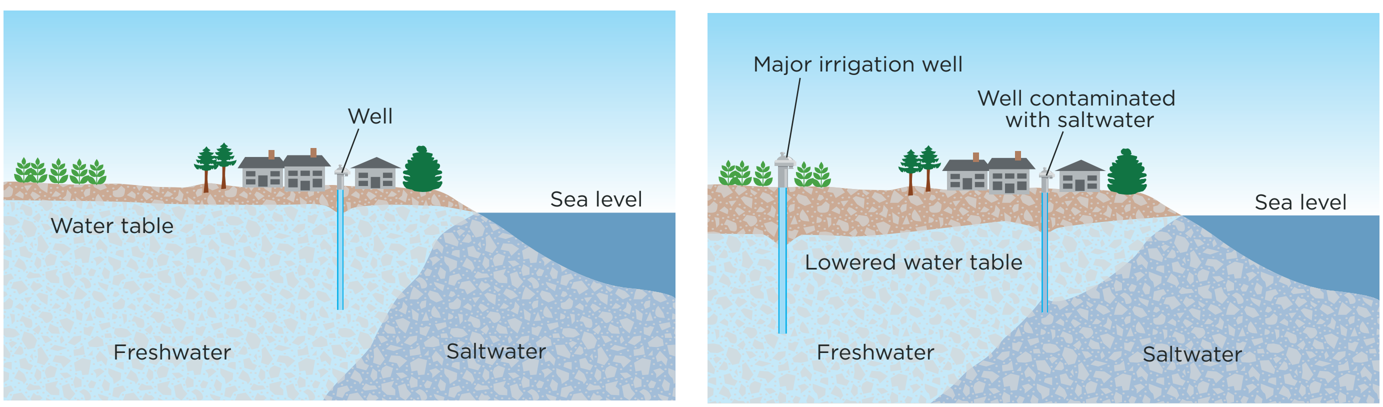
SOURCE: ADAPTED FROM FAMIGLIETTI ET AL. 2014.

FIGURE 2. Significant and Unreasonable Lowering of Groundwater Levels



Regardless of your basin's total volume, the level—its distance from the surface—matters, too. Groundwater is often available to those with the deepest well. With deeper and deeper wells going in, shallower drinking water wells are drying up. While this is related, of course, to the reduction in overall quantity of water, it may also be caused or exacerbated locally by a ***cone of depression*** *(a lowering of the water table that develops around pumped wells), shown above. If your neighbor puts in a deep well next door, that's going to have a bigger impact on your well than if someone at a distance across the basin does.*

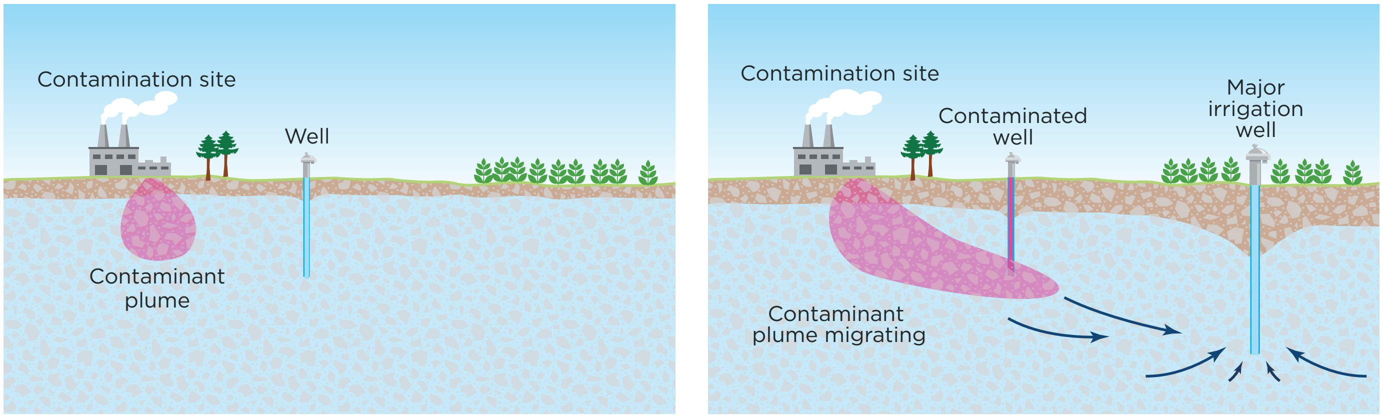
FIGURE 3. Significant and Unreasonable Seawater Intrusion



Freshwater is less dense than saltwater, and therefore floats on top of saltwater in an aquifer. When freshwater is pumped out of the aquifer, its weight on the saltwater is diminished, letting the saltwater rise and flow toward the source of the pumping. This can result in ***saltwater intrusion*** *into drinking water and agricultural water supplies.*

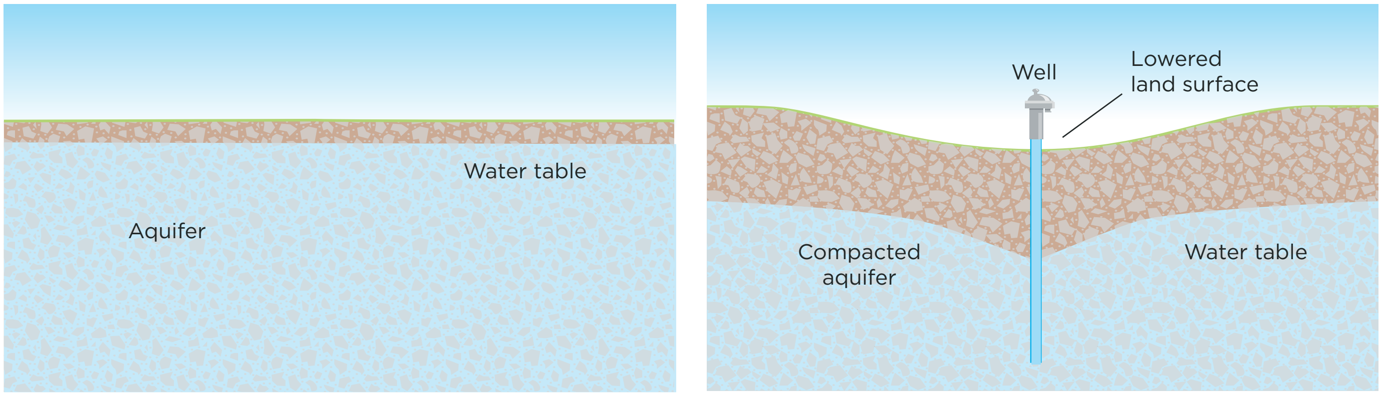
> ***Deep wells, such as major irrigation wells, can have adverse effects on neighboring shallower wells, causing them to run dry or become contaminated.***

FIGURE 4. Significant and Unreasonable Degraded Water Quality



Contaminant plumes *are a mixture of waste chemicals and groundwater that exist in the aquifer near the sites where they are produced. Groundwater pumping can pull a plume from its current location toward nearby wells, putting them at risk of contamination.*

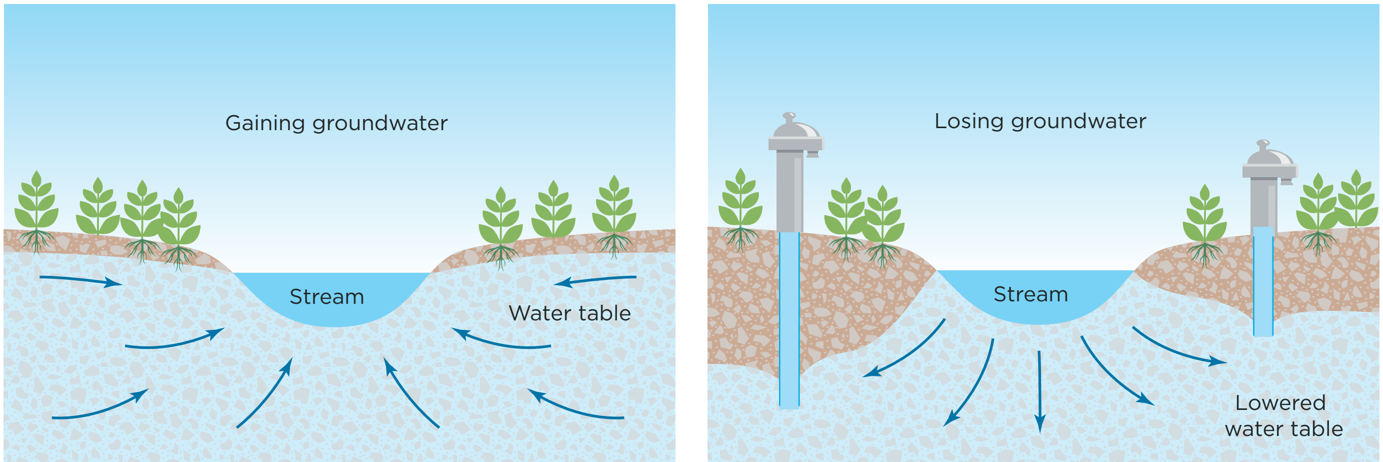
FIGURE 5. Significant and Unreasonable Land Subsidence



Chronic overdraft of an aquifer can lead to major problems by causing ***land subsidence****, the settling or sinking of land. The rapid rate at which land is sinking in California puts infrastructure such as canals, pipelines, roads, and buildings at risk. This land loss is often irreversible. Recent US Geological Survey data show extraordinary land subsidence in the Central Valley, cracking a major water delivery canal and threatening to make it unusable (Sneed, Brandt, and Solt 2013).*

[***Overdrafting water can cause the land around a well to become unstable and sink, a condition that is often irreversible.***]

FIGURE 6. Significant and Unreasonable Depletions of Interconnected Surface Water



Surface water, such as rivers and streams, and groundwater are interconnected. Groundwater and rivers and streams can actively feed one another, as seen in Figure 6. In fact, the primary source of many streams in the United States is groundwater. Surface water supplies can gain or lose groundwater, depending on the elevation of the water table below. The pumping of groundwater from an aquifer can deplete the supply that would otherwise feed a stream or other surface water, and can turn a "gaining stream" into a "losing stream." By affecting the quantity of water exchanged between the two bodies, pumping can affect the quality of the water and the transport of contaminants between them.

CRITICAL QUESTIONS

- **What are the biggest groundwater challenges in our groundwater basin? Which undesirable results are already occurring, and to what extent are they problematic in the eyes of the community?**
  - For many basins, there are obvious signs that groundwater is not being managed sustainably, like subsidence, dry wells, or poor water quality. Identifying these as priorities early on will guide the community's process to address them more completely.
- **Are the basin's boundaries physical or are they drawn along city or county lines?**
  - If there is no physical boundary but rather a human-designed one, people in neighboring basins will need to agree on how to characterize their share of the shared groundwater resource.
- **Where do undesirable results occur and who are they affecting?**
  - Are the impacts of undesirable results well understood? There may be more work needed to accurately characterize the extent of the problems before your community can define its sustainability goals.
- **Do future projections for the undesirable results affecting your basin account for changing conditions, including population growth, land use change, and climate change?**
  - These factors can change water demand immensely and are critical to account for in the planning process. Previous plans and policies, such as your county's general plans and integrated regional water management plans, may include projections of this sort.

Defining Your Basin's Sustainability Goals

A sustainable groundwater basin is one operating within its **sustainable yield**—the maximum quantity of water that can be withdrawn without causing an undesirable result. Therefore, achieving sustainability means avoiding undesirable results, and each basin must define specific sustainability goals to that end.

Sustainability Is (Mostly) Subjective

As previously mentioned, there is no technical definition for sustainability. It is not simply the presence or absence of a result like land subsidence that is in itself undesirable; rather, it is the extent to which the result is undesirable. For each undesirable result, the local community will decide *how much* damage is acceptable, or conversely, *how much* repair is desired. Despite the flexibility around local sustainability goals, there are a couple of clear boundaries that limit the interpretation of sustainability. The California Water Code, first, says that one basin's definition of sustainability cannot threaten others' ability to achieve their sustainability goals (Section 10733(c)), and, second, indicates that both continued overdraft and significant depletion of interconnected surface waters are unacceptable long-term strategies (Section 10735.2(a)(5)).

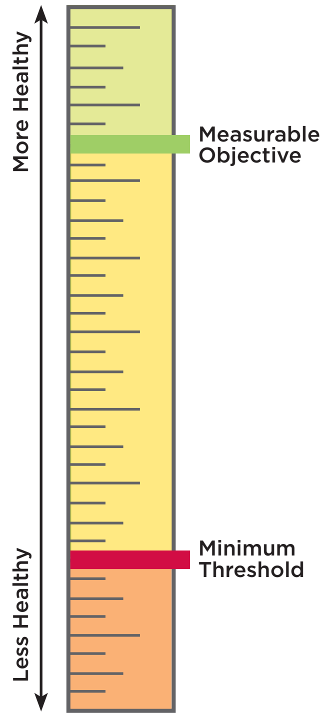
Minimum Thresholds and Measurable Objectives

While there are several components of sustainability, here we focus on the concept of **minimum thresholds**, or failure points—numeric values that basins will use to define undesirable results. Minimum thresholds may vary across time and space.

An example of a minimum threshold varying in time is a groundwater level threshold that is lower in the summer than the winter. A minimum threshold varying across space could be land subsidence that threatens major public infrastructure, but only in populated areas of the basin. In this basin, the minimum threshold for subsidence will likely be more conservative in the populated areas than unpopulated areas.

Once a GSA has set minimum thresholds, it will need quantitative measures of success. **Measurable objectives** are more forward-looking goals that may not be achieved until 2040 (2042 for lower-priority basins). Here, then, we focus on minimum thresholds and refer you to our previous publication *Measuring What Matters: Setting Measurable Objectives to Achieve Sustainable Groundwater Management* by J. Christian-Smith and K. Abhold (2015) via *www.ucsusa.org/CAgroundwatertoolkit*, if you are interested in learning more about measurable objectives, specifically.

FIGURE 7. Setting Goals for Undesirable Results



Measurable objectives and minimum thresholds must be determined for each undesirable result:

- Significant and Unreasonable Reduction of Groundwater Storage
- Significant and Unreasonable Lowering of Groundwater Levels
- Significant and Unreasonable Seawater Intrusion
- Significant and Unreasonable Degraded Water Quality
- Significant and Unreasonable Land Subsidence
- Significant and Unreasonable Depletions of Interconnected Surface Water

For each of the undesirable results, the GSA must establish a measurable objective, or goal, and a minimum threshold, or lowest acceptable measurement. The measurable objectives and minimum thresholds for each result are interrelated, and determining them is a complex process.

CRITICAL QUESTIONS

- **Does the minimum threshold exceed an existing federal, state, or local standard?**
  - Where there are existing standards, these standards have the force of law and cannot be weakened by SGMA. (See the *online toolkit*, which summarizes existing policies and case law related to each undesirable result.) In some cases, standards and regulatory processes may exist that can guide your basin's threshold-setting process.
- **Was the threshold developed through a transparent public process?**
  - SGMA has numerous procedural requirements to ensure that the public can participate in decisions. Were these requirements followed?
  - SGMA requires the active engagement of diverse stakeholders. How were their views and concerns incorporated into your basin's planning process?
- **Does the threshold violate the threshold of neighboring basins?**
  - Neighboring basins can affect each other's groundwater balances. The law states that a GSP may be found inadequate if it adversely affects a neighbor's ability to comply. Therefore, it is important to understand how your basin's management may affect neigboring basins.
- **Does the threshold allow negative impacts to continue or worsen?**
  - For example, minimum thresholds may allow lowering groundwater levels, land subsidence, and seawater intrusion to continue or even worsen. In such cases, who or what would be affected? A **vulnerability analysis**, which looks at who and what will be affected by certain threats, may be needed to answer this question.
  - Are the negative impacts reversible?
  - Is it possible to mitigate these negative impacts through an agreement with the affected communities? For example, if groundwater levels continue to drop and dry out drinking water wells, is there a plan to provide alternate water sources?
- **For any of the proposed management actions, are levels of uncertainty particularly high?**
  - Any long-term planning process inherently involves uncertainty, and it is critical that such uncertainty be acknowledged. In cases in which there are few data points, a long time lag between an action and its consequence, or little ability to forecast future conditions, it is wise to develop more conservative thresholds.
- **Does a given threshold conflict with thresholds for other undesirable results?**
  - Undesirable results interact with each other; therefore, after thresholds are chosen for each undesirable result, it will be critical to ensure that none of the thresholds have negative effects on the others. For instance, the threshold for chronic overdraft of an aquifer may allow seasonal fluctuations in groundwater levels dramatic enough to increase land subsidence during certain times of the year.
- **How will we know when we have crossed a minimum threshold?**
  - Before finalizing a threshold, make sure that the monitoring network has the necessary accuracy and speed. It needs to provide measurements with enough accuracy to alert you when you are approaching a threshold and do so without undue delay, enabling you to take appropriate management actions in time.

Engaging in Your Groundwater Sustainability Plan Process

The new law is important not only because it is the first statewide requirement for groundwater management, but also because it includes unprecedented requirements for stakeholder engagement in water planning. GSAs are required to encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin (see the *online toolkit* for a list of engagement requirements).

Every GSA must develop a list of interested parties to contact regarding plan preparation, meeting announcements, and availability of draft plans, maps, and other documents. In addition, the GSA must explain how it will take into account these parties' interests and those of all beneficial uses and users of groundwater. Figure 8 includes a list of parties who should be involved according to the law.

There are several entry points into the planning process depending on your interests and concerns. Engage early and often! Here are some prime opportunities:

- **Put your name on the "interested parties" list.** Contact your GSA and be added to its list, and you will receive information about meetings and the planning process.
- **Attend public meetings.** GSAs are required to hold public meetings that offer time for community members to share their questions, perspectives, and concerns. Public meetings are one opportunity to ask the "critical questions" suggested throughout this guide. Don't be shy; your questions will help to shape the process. Make sure the answers you receive are understandable.

Community Water Center

Getting engaged often starts with learning more about your groundwater basin, as these community members are doing. Check out the online version of this toolkit *for more learning and technical assistance resources.*

FIGURE 8. Whose Interests Must Be Considered in Groundwater Sustainability Planning?


Kelly M. Grow/California DWR

Interested parties include:

- General public
- Agricultural users
- Domestic well owners
- Municipal well operators
- Public water systems
- Local land-use planning agencies
- Environmental interests
- Surface water users
- The federal government
- California Native American tribes
- Disadvantaged communities

There are many groups whose interests must be considered in order to create an effective and equitable groundwater sustainability plan that qualifies for state approval. Everyone has an opportunity to engage, but at varying levels, including as board members, committee members, or audience members. Take a look around your GSA meetings and take note of how different groups are being represented.

- **Chime in during public comment periods.** Public comment periods will be opened after a GSP has been submitted to the state. Here you'll have an opportunity to describe how your critical questions were addressed (or ignored) and provide additional feedback.
- **Take part in the five-year updates.** At least every five years, GSAs must update their plans. These updates will offer many of the same opportunities for your involvement.
- **Join the groundwater sustainability agency's board.** Among many other responsibilities, GSA board members will vote whether to approve a GSP for submission to the state.
  - Even if you are not on the GSA board, you may want to engage with board members to discuss your interests and concerns.
- **Join an advisory committee.** Advisory committees, such as technical advisory committees or stakeholder outreach committees, may be consulted in the development of GSPs.

Process for Adopting a GSP

There is a three-step process for GSP approval:

1. The plan must be approved by the GSA board at a public meeting. This is required to follow an open process, which includes public meetings, comment periods, and stakeholder outreach.
2. The plan must be submitted to the California Department of Water Resources. The deadline for submitting a plan in **critically overdrafted basins** is January 31, 2020, and for medium and high-priority basins is January 31, 2022 (see Department of Water Resources Bulletin 118 via *www.ucsusa.org/CAgroundwatertoolkit* for more information about basin boundaries and characteristics), after which they will be posted online and available for public comment. The department has up to two years to evaluate each plan and the public comments in order to determine whether the plan is: 1) adequate, 2) conditionally adequate (has minor deficiencies that may be corrected within 180 days), or 3) inadequate.

3. If the plan is found to be inadequate, the State Water Resources Control Board may categorize the groundwater basin as "probationary," which would allow the State Water Resources Control Board to take over the responsibility of developing a GSP for the groundwater basin, collect fees to that end, and enforce management actions.

Plans will be evaluated by the state every five years to assess progress and recommend corrective actions up to and including state takeover of the management and planning of the basin.

CRITICAL QUESTIONS

- **How many GSAs are in your groundwater basin? Are they coordinating, and how?**
  - For examples of different approaches to forming GSAs, see the Water Education Foundation publication *Know Your Options: A Guide to Forming Groundwater Sustainability Agencies* by V. Kincaid and R. Stager (2016) and the California Department of Water Resources publication *Groundwater Sustainability Plan Emergency Regulations Guide* (2016), both available via *www.ucsusa.org/CAgroundwatertoolkit*.
- **What are the neighboring basins? Are they coordinating, and how?**
  - For information about GSA formation in neighboring basins see *To Consolidate or Coordinate: Status of the Formation of Groundwater Sustainability Agencies in California* by E. Conrad et al. (2016), via *www.ucsusa.org/CAgroundwatertoolkit*.
- **What is your GSA's governance structure and voting process?**
  - Who are the members of your GSA?
  - Who has voting power?
  - How are votes weighted, and what threshold is needed to pass different types of resolutions?
- **When and where do the GSA board and advisory committees meet?**
  - Check out the Department of Water Resources' SGMA portal for your GSA's point of contact, who can give you more information: *http://sgma.water.ca.gov/portal/#GSA*.
- **Who is involved in the GSP planning process?**
  - While the GSA board ultimately votes on the plan, many people may be involved through other channels, such as serving on advisory committees, providing public comment, meeting with board members and other stakeholders, and engaging in other ways. Which interests in Figure 8 are well represented? Which interests are missing? In what ways are different interests participating?
  - How will the concerns of interested parties and groundwater users be considered, as required by the law? You may want to ask about the process for documenting and addressing concerns raised in public comment, for example.
- **What plans and concerns already exist within your basin boundaries that precede and may affect the GSP?**
  - Existing plans and policies may include county general plans, integrated regional water management plans, and previous groundwater plans.
- **What resources are available to support your basin's planning process? Are there facilitation services?**
  - The Department of Water Resources makes facilitation services and money for this process available through its website: *www.water.ca.gov/groundwater/sgm/facilitation_services.cfm*.

Understanding Water Budgets and Models

Water budgets and models are tools that will help you understand your basin's groundwater conditions, set sustainability goals, implement your plan, and measure progress.

Water Budgets

The **water budget** is a critical element of a GSP. Water budgets track a variety of important pieces of information and can be used to help estimate a groundwater basin's sustainable yield, the amount of water that can be drawn out without causing an undesirable result. This section does not review any specific water budget, but will help you understand what a water budget can and cannot tell you, the degree of certainty associated with the data, and how a water budget can help you choose potential management actions.

A water budget is like a household budget. It accounts for all the water that enters and leaves your groundwater basin, by category. Your sources of income are **inflows** and your expenses are **outflows** (quantified in **acre-feet**, or the amount of water it takes to cover one acre of land one foot deep, which equals 43,560 cubic feet). Just as your household budget categories may differ from those of your friends, there are many ways to characterize the inflows and outflows in a water budget. (Check out the *online toolkit* for a list of commonly used water budget terms.)

BOX 1.

Capabilities and Limitations of Water Budgets

A water budget is useful for understanding information about a whole basin, but undesirable results can be localized to just one part of a basin.

Water Budgets Alone CAN:	Water Budgets Alone CANNOT:
Provide information about your basin as a whole	Provide information about specific places within the basin
Determine safe yield	Determine sustainable yield
Describe the past	Project into the future
Report on overdraft	Report on undesirable results

Safe Yield vs. Sustainable Yield

It is important to distinguish between safe yield and sustainable yield: GSAs are tasked with determining their sustainable yield. **Safe yield** simply ensures that inflows are equal to or greater than outflows, avoiding a reduction in groundwater storage. Sustainable yield, on the other hand, is the amount of pumping you can have without causing *any* of the six undesirable results, not just a reduction in groundwater storage. To go back to our budget analogy, you could attain safe yield by not spending more than your income, but if you can't afford rent on that budget, it's not sustainable. Undesirable results are like housing, food, and clothing—they are necessary to address through your budget process to maintain quality of life. A GSA may determine that sustainable yield is less than the safe yield in order to avoid the other five undesirable results.

Hydrologic Models

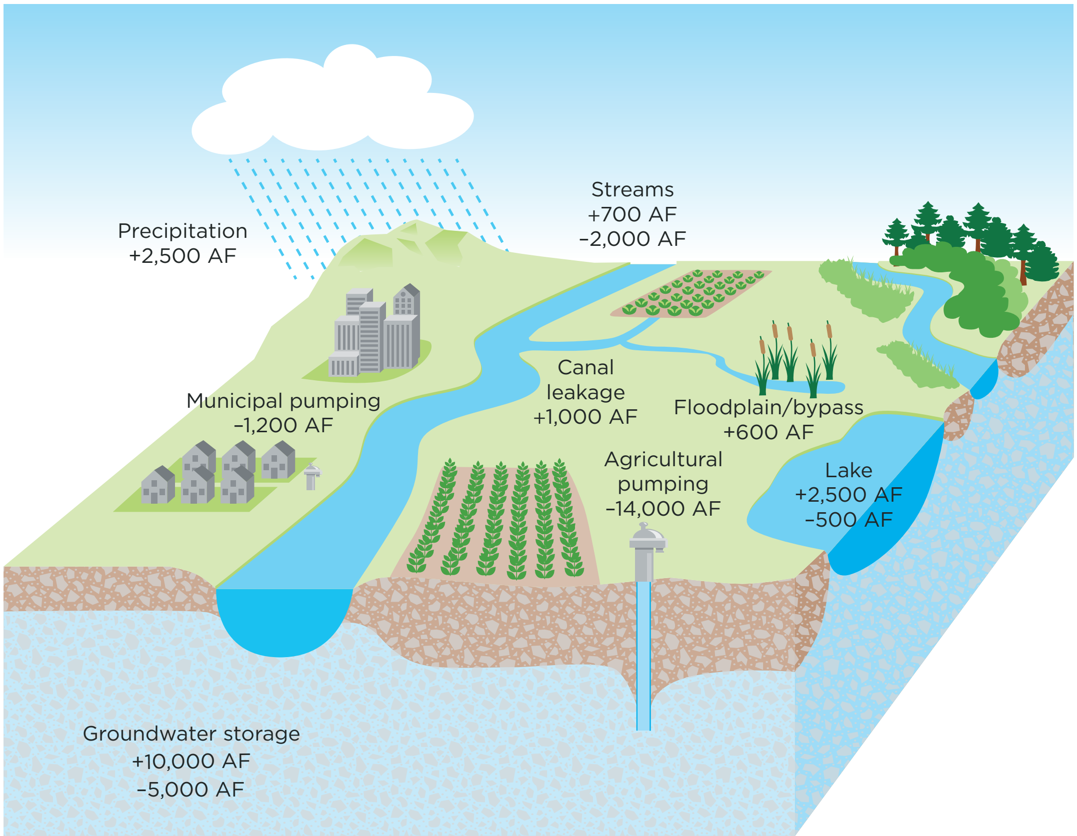
If a water budget tells you what is happening, then a **hydrologic model** tells you where, when, and why it's happening. Because most undesirable results will require some sort of spatial analysis, most basins will use a hydrologic model, which can show three-dimensional information that is geographically specific within your basin. If you think about a groundwater basin as being broken into hundreds of smaller units, a groundwater model is essentially calculating all of the water budget components within each unit for each month of each year. A groundwater model can both look backward and project forward.

It can be checked against historical data to ensure that its results roughly match past experience, and it can simulate how things may change in the future with population change, land use change, and climate change. Importantly, groundwater models allow you to test "if . . . then" scenarios to consider the impacts of different possible management actions.

If a new model is developed for a GSP, the model must consist of **public domain, open-source software**. Open-source software makes its code, or the computer calculations that it is based on, public and freely available, whereas **proprietary software** often requires costly user licenses to access. While the use of a model is not *explicitly* required by the law, the state has thus far provided no examples of an acceptable equally effective method. (See the *online toolkit* for more information about models' legal requirements.)

Models can play a critical role in translating your sustainability goals into your groundwater sustainability plan's minimum thresholds. Because groundwater models enable users to explore the effects of different management actions on groundwater levels in a basin, these models commonly serve as the basis for groundwater management decisions. For example, if a GSA establishes a minimum threshold for groundwater levels in the basin, a model can help convert that threshold into the amount of groundwater pumping that can be sustained or the amount of artificial **recharge** (replenishment) needed.

FIGURE 9. Conceptual Water Budget for One Month in a Hypothetical Basin



Here, a hypothetical basin's water budget for a single month is represented in a visual way, referred to as a conceptual water budget. Inflows to the aquifer are labeled with a plus sign (+) and the total volume of water, measured in acre-feet (AF). Outflows are labeled with a minus (-) sign. This basin's largest source of groundwater this month is groundwater storage, or the water that flows within the aquifer across the basin boundary (10,000 AF). The largest outflow is agricultural pumping (14,000 AF). To calculate whether a basin is overdrafting, subtract the total of all outflows from the total of all inflows. If the number is negative, the basin is in a state of overdraft. In this example, the basin's total inflows amount to 17,300 AF. The outflows total 22,700, meaning the basin has overdrafted by 5,400 AF this month.

A model can also be used to conduct vulnerability analysis that explores who and what could be negatively affected by different thresholds and management actions.

Assumptions and Uncertainty

A water budget and a hydrologic model are only as reliable as the data they utilize. When it comes to groundwater, we suffer from a lack of data in many places. Even where there are data, the data may rely on estimates rather than direct measurements. Therefore, it is important to understand the data and assumptions that go into a model in order to trust the results.

For instance, in some places, agricultural groundwater pumping is physically measured using meters or other measurement devices, while in others, this pumping is estimated using crop acreage and estimates of how much water the crop type typically consumes (referred to as **evapotranspiration**). Model results can be inaccurate if the crop acreage numbers are out of date or if the estimate of water usage assumes historical temperatures rather than the rising temperatures accompanying climate change.

While uncertainty is inherent in any long-term planning process, a model can describe where uncertainty lies and provide a range of possible future scenarios. **Scenario-based planning** examines management options under a range of possible future conditions in order to develop solutions that would work well across the range.

Boundary conditions reflect the flows between neighboring basins and they are likely to be one of the more controversial aspects of groundwater modeling. It is critical that different models *within* a basin have matching boundary conditions, and it is also important for different models *between* basins to have similar boundary conditions. The Department of Water Resources will be using its public domain, open-source code called Integrated Water Flow Model (IWFM) or California Central Valley Simulation Model (C2VSIM) to evaluate GSPs; therefore, it would be wise to compare against these models, specifically.

BOX 2.

Capabilities and Limitations of Water Models

There are many ways models can be useful, if designed and shared effectively. For information about models see *Projecting Forward: A Framework for Groundwater Model Development Under the Sustainable Groundwater Management Act* by T. Moran (2016), via *www.ucsusa.org/CAgroundwatertoolkit*. However, there is one key goal of SGMA that a model alone cannot accomplish, and that is to determine community values—a model alone cannot define when a groundwater condition becomes an undesirable result, nor can it define a community's sustainability goals. Model development and community values need to be integrated: stakeholder values inform the model, defining its limits and objectives, and the model informs the stakeholders about the ability of different management actions to meet their goals.

Models CAN:

- Test management actions to determine whether they allow a community to meet its sustainability goals
- Forecast the effects of groundwater management actions
- Collect, synthesize, and coordinate data
- Quantify projected water budgets
- Engage board members and stakeholders
- Be used to evaluate a GSP

Models CANNOT:

- Develop management actions and make decisions
- Decide what is a significant and unreasonable undesirable result
- Define sustainability goals

> ***A water budget and a hydrologic model are only as reliable as the data they utilize. Therefore, it is important to understand the data and assumptions that go into a model in order to trust the results.***

CRITICAL QUESTIONS

- **What are the major categories of inflows and outflows?**
  - To describe inflows and outflows the water budget/model uses both straightforward terms, such as precipitation or stream flow, and other, potentially confusing terms, such as **diversion recoverable loss**, which simply means canal leakage. Ask for definitions of any terms you don't know.
- **What are the biggest groundwater gains and losses in your basin?**
  - This can be a very informative exercise to do yourself or ask a technical expert to provide. In many basins, boundary inflows represent the largest gain of groundwater and agricultural pumping represents the largest loss of groundwater.
- **Are the data sources for water budgets and models clearly identified, and do they come from reliable sources?**
  - As described above, it is important to understand how various aspects of the underlying water budget data are measured or estimated. Are the data sources clearly identified, and are they based on direct measurements or estimates?
- **Does the model describe uncertainty explicitly?**
  - If the model tracks uncertainty, model outputs will be displayed as a range.
  - Management actions should be tested across the full range of possible future conditions in order to decrease the risk that they don't address the basins' issues.
- **Is the model based on open source software?**
  - Models developed in support of a GSP after June 1, 2016, are required to rely on public domain, open-source software. If the model were to use proprietary software, it would likely require expensive user licenses to run.
- **What is the *spatial* extent of the model (e.g., basin-wide or localized)?**
  - If the model is more localized, how were the boundary conditions calculated? The boundary conditions of a localized model should roughly match the flows into and out of the model's area as defined by larger-scale basin models (such as IWFM or C2VSIM).
- **What is the *temporal* extent of the water budget and/or model?**
  - Look for data that accurately reflect recent history. Beware of data only representing exceptionally wet or dry conditions, especially if this period is meant to serve as a base case against which proposed management actions will be measured.
- **Does the model account for recent trends in land and water use and reflect existing planning documents?**
  - Land and water uses have been changing rapidly over the last decade in California due to a series of economic and regulatory drivers, including high commodity prices for permanent crops like almonds, mandatory urban water conservation measures, and increased outdoor water demands due to hotter temperatures. Are future land uses assumed by the model consistent with these changes and other regional planning documents (such as county general plans)?
- **How does the model include the projected effects of climate change?**
  - The effects of climate change should be modeled over the 50-year **planning horizon**.
  - Different global climate models can be used (for example, hot/dry, cool/wet, middle of the road), and different emissions scenarios can be relied upon (low or high). If the model relies on a middle-of-the-road scenario, it is

important to capture the uncertainty of future climate changes by running scenarios that are more extreme.

- **Can the model be used to perform a vulnerability analysis?**
  - The model may have data about human and ecological communities that may be affected by management decisions, such as domestic well depths, groundwater-dependent ecosystem locations, or endangered species habitat. The model should be used to provide information about the consequences of different management options, including who and what will be affected by the different choices.

Kate Cullen/UCS

Data visualization can help stakeholders better understand technical information. At this Community Water Leaders Network training, participants fill out a conceptual water budget for their groundwater basin using historical data.

Collaborating with Technical Experts

This guide does not assume that you will learn how to construct water budgets or run hydrologic models; rather, it is designed to equip you with a basic knowledge of what they are and what they can and cannot do.

In most cases, water budgets and models will be produced by technical experts used by the GSA, whether hired as members of the staff or external consultants. These experts should use sustainability goals and community values to inform the models' assumptions and parameters. In the best case, technical experts can help to create a shared understanding of basin conditions and clarify the choices and trade-offs between different management actions.

Importantly, experts should be partners in this process. While they do not drive the group's decisionmaking, they can inform it and help to clarify the consequences of different options. Experts should be asked about how they will communicate with the GSA and stakeholders to ensure that everyone understands the process and the desired results. Experts should be asked about how they will integrate social values and preferences into technical tools and what information they will consider in constructing a series of future scenarios for stakeholders and the GSA to consider. Finally, GSAs that hire external experts should consider how to ensure that the GSA retains access to and control over the data and models that are developed for its basin, as both will need to be updated continually.

California DWR

Unlike these geologists in Gridley, California, you don't have to know how to inspect a monitoring well to participate in groundwater sustainability planning. Experts and the local groundwater sustainability agency should work collaboratively with the public and other stakeholders to design and implement an effective and equitable sustainability plan.

CRITICAL QUESTIONS

- **What are the pros and cons of developing internal GSA capacity versus hiring external technical experts?**
  - There will likely be differences in terms of cost, access to data and the model's code, frequency of model runs, and variety of scenarios.
  - If the GSA uses an internal expert, it will need to identify someone to oversee him or her.
- **Does the technical expert have any possible conflicts of interest?**
  - Conflicts of interest could include everything from nepotism to financial gain from a certain outcome. They should be avoided. At a minimum, engineers or consultants who are helping develop the GSP should not be involved in or allowed to bid on the planning, designing, or construction of water projects, as this would create an obvious incentive to state or embed a preference for particular outcomes.
- **How will the expert ensure meaningful stakeholder input informs sustainability goal setting?**
  - The role of a technical expert is to integrate community values into technical tools and provide information about the potential consequences of different management actions. To do either effectively, the expert must have nuanced information from stakeholders about community values and preferences.
- **How will the expert share the differing assumptions that drive different scenarios and their results?**
  - Experts should be prepared to provide a number of different future scenarios, not just one result, as this is what will help a community decide between different management options.
- **How will the expert communicate to ensure that the GSA and stakeholders have the necessary information to understand the project process and results?**
  - At a minimum, technical experts should comply with the GSA's communications plan for interacting with stakeholders. Ideally, the GSA and expert should develop a specific plan for communicating technical issues, and the expert should have the willingness and skills to discuss complex, technical information with non-experts.
- **Is the expert working with other groundwater basins, particularly neighboring groundwater basins?**
  - If working with neighboring basins, how would he or she help to ensure that all use *the same* data and assumptions?
  - If not working with neighboring basins, how would he or she ensure that both use *consistent* data and assumptions?
- **Is the expert familiar with integrated surface water-groundwater models?**
  - If yes, you may consider asking them to describe how they used them in past projects, and whether they accounted for future projections of land use, climate change, population growth, etc.
  - If no, what kind of tools would they use that would be considered equivalent to an integrated surface water-groundwater model?
  - As the state has not identified any equivalent tool to a model, you may consider asking them how they can ensure your basin will comply with the law.

continued

CRITICAL QUESTIONS *(continued)*

- **Does the expert use public domain, open-source software or proprietary software?**
  - If the expert uses proprietary software, ensure that the expert provides publicly available supporting documentation and calibration data and proof that the model was developed before January 1, 2016, to comply with the law.
  - If the expert uses proprietary software, ensure that there are user licenses available for the GSA and stakeholders to understand and access the model's code. Consider requiring a lifetime license, so that license costs do not become untenable over time.
  - In either case, consider how the GSA will retain control over the data and model through 2040 (2042 for medium- and high-priority basins). Regular updates will be necessary for the purposes of annual reporting and the five-year GSP updates.
- **How will the expert help to ensure data coordination and sharing?**
  - Within basins, all GSAs must rely on the same information and have a coordination agreement that describes how data will be collected and shared for seven water budget components:
    - Groundwater elevation
    - Groundwater extraction
    - Surface water supply
    - Total water use
    - Change in groundwater storage
    - Water budget
    - Sustainable yield
  - Between basins, a coordination agreement is not required; however, it is very beneficial to have agreement around boundary conditions and a shared understanding of the impacts of your basin's management actions on your neighboring basin's ability to reach its sustainability goals.
- **How will the technical expert share data sources and model assumptions?**
  - Information about data sources and uncertainty around individual water budget components needs to be communicated with the GSA and stakeholders so that you may understand and assess the information and assumptions that inform model outcomes.
- **How will the technical expert share results?**
  - Model results can be complex, and having some kind of visualization platform can be very useful for communication purposes. Models like C2VSIM can be visualized using mapping software.
- **Who owns the intellectual property contained in model data, processing, and outputs?**
  - It will be important to ensure that your GSA—not experts or consultants—owns the intellectual property so that it can update, expand, and improve your basin's data over SGMA's 20-year timeline.

California Department of Fish and Wildlife

Sustainable groundwater management will help ensure there's enough safe, clean water for both people and the environment. Get involved in your local planning process—without you, it may not happen.

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[GLOSSARY]

Acre-foot (AF). The volume of water required to cover one acre of land (43,560 square feet) to a depth of one foot. Equal to 325,851 gallons or 1,233 cubic meters.

Aquifer. Underground layers of rock or sand that can store and transmit water.

Basin. An aquifer or system of aquifers that has reasonably well-defined boundaries.

Boundary condition. Description of the flows at the edges of the area analyzed by a model.

Cone of depression. A lowering of the water table when groundwater is pumped from a well, especially in the immediate circle around the pumping.

Critically overdrafted basin. A groundwater basin in which the continuation of present practices of withdrawing water would likely result in significant negative environmental, social, or economic impacts.

Diversion recoverable loss. Canal leakage.

Evapotranspiration. The quantity of water released by plants, retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Groundwater. Water stored underground in pore spaces of soil, in fractures, and in joints formed in hard rocks.

Hydrologic model. A conceptual representation of part of the water cycle that uses three-dimensional information that is geographically specific.

Inflow. Water that moves into a basin.

Land subsidence. Lowering or sinking of the land surface due to a number of factors, including the overdraft of a groundwater basin over the long term or a decline in groundwater levels year by year.

Measurable objectives. Specific measures used to determine whether the GSA of a basin is successful in achieving its sustainability goal and avoiding undesirable results.

Minimum thresholds. Numeric values used to define undesirable results. The minimum threshold is the lowest level of the metric that should not be crossed, regardless of fluctuations in dry and wet years.

Outflow. Water that leaves a basin.

Overdraft. A situation that occurs when more water is pumped from a groundwater basin than is replaced from all sources, not measured annually but rather over a period of years.

Planning horizon. The length of time into the future that is accounted for in a particular plan.

Plume. A body of one fluid moving through another, often used to refer to the presence of contaminated water in—or its migration into—an aquifer.

Proprietary software. Software that is owned by an individual or company and usually has major restrictions on its use by other people.

Public domain, open-source software. Software that is in the public domain and usually is freely available for anyone's use.

Recharge. The practice of increasing the amount of water flowing into a groundwater basin.

Safe yield. The maximum quantity of water that can be withdrawn from a groundwater basin at a given time without overdraft.

Saltwater/seawater intrusion. The movement of saltwater into freshwater aquifers, which can lead to contamination of drinking water sources and other consequences.

Scenario-based planning. An approach that examines management options under a range of possible future conditions in order to develop solutions that would work well across the range.

Surface water. Water that is on Earth's surface in rivers, lakes, reservoirs, or oceans.

Sustainable yield. The maximum quantity of water that can be withdrawn annually from a groundwater supply without causing an undesirable result.

Sustainability goal. The objective of operating a basin within its sustainable yield.

Undesirable result. One of six groundwater conditions that must be avoided in order to comply with the Sustainable Groundwater Management Act: significant and unreasonable reduction of groundwater storage, significant and unreasonable lowering of groundwater levels, significant and unreasonable seawater intrusion, significant and unreasonable degraded water quality, significant and unreasonable land subsidence, and significant and unreasonable depletions of interconnected surface water.

Vulnerability analysis. The process of identifying, quantifying, and prioritizing (or ranking) the potential threats to people, infrastructure, and other assets within a system.

Water budget. An accounting of the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored.

[NOTES]

Getting Involved in Groundwater

A Guide to California's Groundwater Sustainability Plans

California's Sustainable Groundwater Management Act is ambitious, with unprecedented opportunities for stakeholder involvement. This guide will help you locate key points in the planning process where you can become involved and identify key questions for you to ask.

Jennifer Sharp/iStock

Union of Concerned Scientists

FIND THIS DOCUMENT ONLINE: www.ucsusa.org/CAgroundwatertoolkit

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