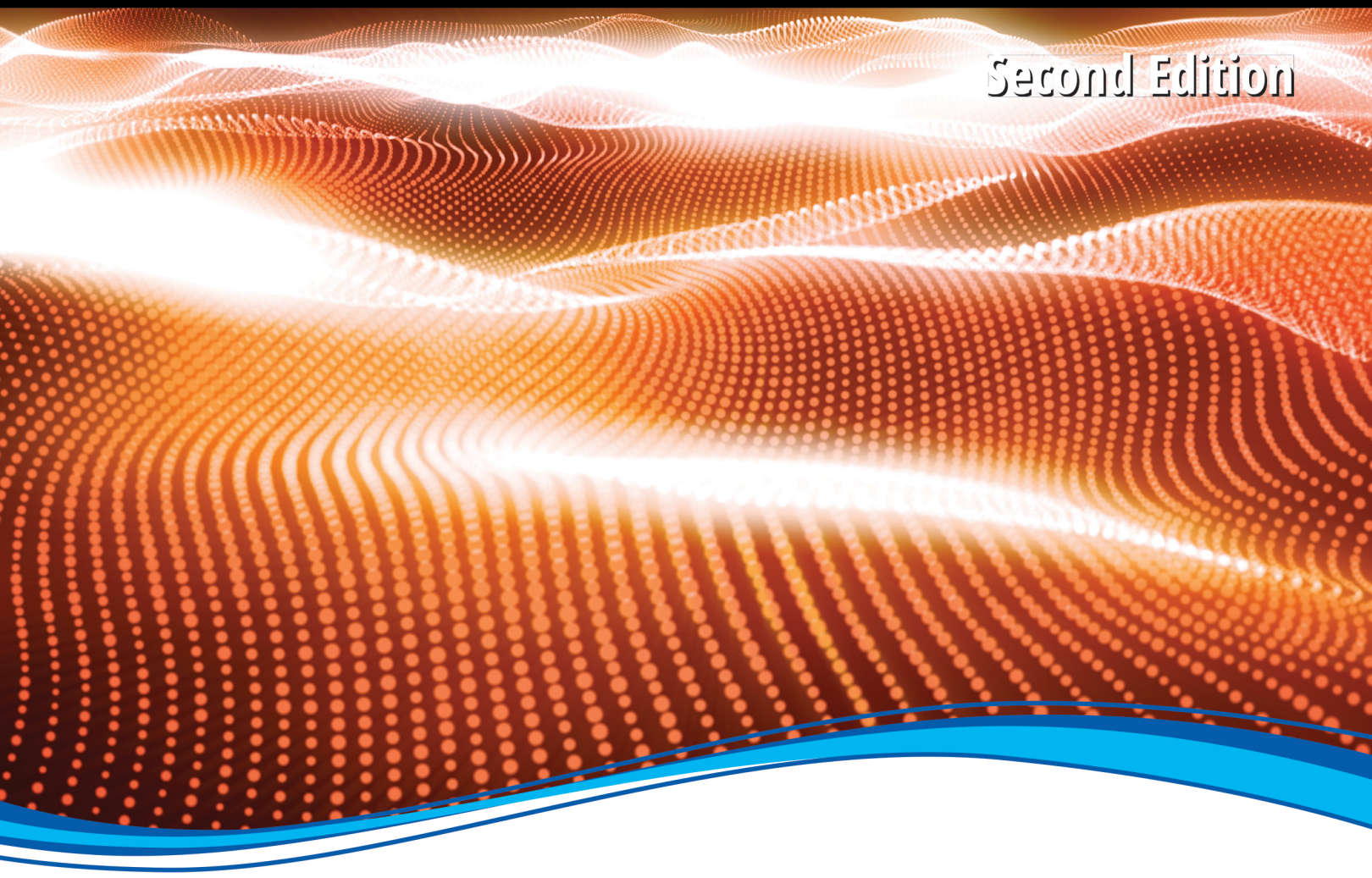
Manual of Water Supply Practices

M60

Drought Preparedness and Response

Second Edition



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Manual of Water Supply Practices—M60, Second Edition

Drought Preparedness and Response

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Introduction

The world's supply of drinkable fresh water is under increasing pressure. The United Nations (UN) estimates that water scarcity affects more than 40 percent of the global population and is projected to rise due to effects of climate change and population growth (United Nations 2015). Most people in the United States have easy access to water—it simply comes out of their taps, and it is clean and plentiful. However, increasingly, a growing number of communities are experiencing periodic water shortages. A 2014 report by the US Government Accountability Office (GAO) found that 40 out of 50 state water managers expected shortages in some part of their state under average conditions during the 10 years following their 2013 survey (GAO 2014). Some of the challenges contributing to water shortages today include the following:

- Population growth is a factor, even though citizens may be using less water per person.
- Since the 2011 edition of M60 was published, many areas of the United States have experienced their hottest and driest years on record. According to the National Oceanic and Atmospheric Administration (NOAA 2018), 2012 was the warmest year since 1895, and the four warmest years have occurred since 2012.
- Water is delivered through an increasingly complex and aging network of storage, transmission, and distribution systems.
- Water treatment processes have become more sophisticated and costly.
- Energy-related expenses, from transportation to treatment, have increased significantly.
- The environment is taxed to a critical point in numerous key waterways.
- In dry years, many areas have increased their reliance on groundwater, reducing the future availability of those supplies.
- The reliability of water deliveries has diminished as uncertainty and variability increases, as related to climate change, regulatory actions, delivery system security, and other factors.

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There are also new opportunities for reducing the impact of water shortages. Widespread use of the Internet allows for information sharing and communication at a level unimagined in previous decades. New technology allows for more efficient use of water, from commercial cooling towers to smart irrigation controllers. Regional alliances have been established to coordinate water supply and demand management efforts.

M60, *Drought Preparedness and Response*, is designed to help water managers who are facing water shortages. The manual illustrates demonstrated methods of the past as well as new tools and methods. Managing water shortages involves temporarily reducing demand and finding alternate water supplies to temporarily meet demand. Some of these actions will result in permanent changes in water use, such as the installation of efficient toilets. The primary focus of the manual is to provide a step-by-step strategy to anticipate and respond to water shortages through a structured planning process.

AWWA recognizes that the unique aspects of any particular water shortage defy the ability of even the best plans to anticipate and prepare for every contingency. This second edition includes more examples of how water suppliers dealt with multiyear droughts by implementing changes to their programs from year to year or in response to different challenges.

GETTING THE MOST OUT OF THIS MANUAL

Drought and water shortage planning is not just a best management practice for a water supplier; it is a requirement in a growing number of states and water management districts. M60 can help a water supplier meet regulatory requirements for a water shortage plan (WSP)*, but each user will need to consult the rules in his or her state or province where such requirements exist. Typically, such requirements include responding to the drought of record or other predefined challenges.

The manual was written by water professionals experienced with droughts and contains an abundance of information that will help users to write and amend plans to respond to unique and changing circumstances. Finally, while the goal of planning is to anticipate and prepare for future events, experience has shown that the unanticipated can derail a plan's implementation. This manual provides numerous examples of how water suppliers implemented and changed their plans to fit their unique circumstances in instances in which changes to drought measures or stages were required during a drought.

DEFINITION OF A DROUGHT AND WATER SHORTAGES

In the most general sense, *drought* is a deficiency of precipitation over an extended period of time, resulting in a *water shortage* for some activity, group, or environmental purpose. A water shortage occurs when supply is reduced to a level that cannot support existing demands. Natural forces, system component failure or interruption, or regulatory actions may cause these water shortages. Such conditions could last two to three months or extend over many years.

WATER SHORTAGE PLANNING

Providing a reliable supply of water, which is the primary goal of all water suppliers, requires being prepared for water shortages of varying degree and duration.

* Water shortage plans are required planning documents in many states and provinces and are known under different titles such as "drought response plan," "drought management plan," "water shortage contingency plan," or "water shortage response plan." For ease of reading, we use the term *water shortage plan*, or the abbreviation *WSP*, in this manual.

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Proper planning before a shortage occurs allows for the selection of appropriate responses consistent with the varying severity of shortages. Plans are most effective when water suppliers start demand-reduction measures before a severe shortage develops.

If demand-reduction measures are delayed, reserve supplies may be depleted early in an extended shortage, causing unnecessary social and economic harm to the community. A WSP enables a water supplier to assess the risks and reduce the vulnerability of a community to water shortage impacts and to establish priorities that will provide water for public health and safety and minimize impacts on economic activity, environmental resources, and the region's lifestyle.

DROUGHT-RELATED REGULATIONS AND PLANNING REQUIREMENTS

In many states and provinces, there are regulations that water suppliers must follow when declaring a water shortage emergency that also provide them with authority to enforce emergency measures. Frequently, water suppliers are required to develop and periodically update WSPs as part of their overall water management planning process.

WSPs typically include the following components:

- the policy and legislative intent of the plan, authority for the plan, and public involvement;
- an estimate of supply and demand for five or more consecutive dry years;
- a description of the stages of action to take in response to water shortages;
- a plan for dealing with a catastrophic supply interruption;
- a list of the prohibitions, penalties, and consumption reduction methods used;
- an analysis of expected revenue effects of reduced sales during shortages and proposed measures to overcome those effects; and
- a system to monitor and document water reductions.

SEVEN-STEP PLANNING AND IMPLEMENTATION PROCESS

Water shortage planning is a dynamic process. It evolves as conditions change and new information becomes available. The WSP includes specific mandatory requirements and penalties that become effective when certain shortage conditions or triggers occur. The chapters of this manual describe a seven-step planning process designed to assist water suppliers facing water shortages. Each chapter includes examples and suggestions for communicating the results of the planning step to the public.

The seven steps discussed in this manual are as follows.

Step 1: Form a water shortage response team.
Step 2: Forecast supply in relation to demand.
Step 3: Balance supply and demand and assess mitigation options.
Step 4: Establish triggering levels.
Step 5: Develop a staged demand-reduction program.
Step 6: Adopt the plan.
Step 7: Implement the plan.

Appendix A: Water Shortage Planning Checklist provides an overview of the entire planning cycle as a way to track the tasks in each step. Some of the tasks can be performed simultaneously and are not necessarily in the order that a particular water supplier will follow.

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The checklist, combined with the information provided in this manual's seven steps, can help form the foundation of a water supplier's WSP and actions or can be used to update an existing plan.

Appendix B: Additional Sources of Weather and Climate Information provides a list of useful federal and state resources on climate and weather that should be consulted as needed to both prepare and implement the WSP.

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Step 1

Form a Water Shortage Response Team

SELECTING THE WATER SHORTAGE RESPONSE TEAM

The first step in effective water shortage planning and implementation requires a water supplier to

- designate a water shortage response team leader;
- establish a water shortage response team of staff with decision-making authority representing all departments, clearly defining the roles and responsibilities of each team member; and
- provide the water shortage response team with funding and appropriate level of staff.

Selecting a water shortage response team leader is critical. The designated team leader will spearhead the effort and involve every unit in the organization. The team leader is someone who the water supplier's board of directors and general manager trust to speak for the supplier with the press, lead meetings that hundreds of customers attend, and organize and manage a multiyear shortage response program. This person is someone who is able to work with and motivate all staff and communicate the importance of working together to the staff and community. The team leader should be able to handle several complex situations at one time, deal with the public calmly and consistently, and gain the support of local businesses and groups.

It is the team leader's responsibility to oversee the response team. In selecting team members, management needs to find individuals from numerous disciplines to develop a specific, detailed water shortage plan (WSP). Developing the WSP requires collecting and analyzing water supply and water demand data and understanding the water supplier's

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sources of supply, operational constraints, critical customers, demand-reduction measures (including estimated savings), community outreach protocols, budget, costs, and sources of income. These elements must be revisited and updated in response to actual conditions, such as when the weather forecasts and water supply conditions indicate the WSP may be implemented within a year.

Every department of the water supplier will be involved in developing the specific WSP and in implementing the plan. For instance, the billing department may need to change the billing format so that customers can compare their monthly water use with the targeted reduction. Meter readers may need to read meters more frequently (i.e., once monthly instead of every two months), and computer programmers may need to develop new account databases to track customer penalty charges and rebate program participation. For suppliers who use advanced metering infrastructure (AMI), increases in the types and frequency of customer reminders and alerts for excessive water use are in order. Rebate programs may need to be started or expanded. Human resources may need to hire temporary staff, and engineering may need to deepen wells, install new water treatment devices, or design system interconnections. Operations may need to accelerate capital improvements or add leakage repair crews as drying soils create more stress on pipes. If the supplier has water conservation staff, they will be essential in many of these actions. However, the implementation of a water shortage response plan will probably affect every staff member's responsibilities. All staff members will be viewed by the community as informal sources of information and should receive sufficient and regular briefings so that they are able to answer basic questions.

Smaller water suppliers may have only one or two people to do all the work. In medium to large organizations, the water shortage response team will probably include more members, some of whom will be more heavily engaged and some of whom will be brought in to work on specific components of the plan or its implementation. The following list shows the types of roles people on the Drought Response Team can play. Larger utilities create teams with many or even all of the following actors.

- Board of Directors or City Council—responsible for approving water shortage–related actions, which often includes adopting a water shortage declaration at various stages of the plan (unless such authority has been delegated to the General Manager), approving implementation of water rate surcharges, adopting updated plans and codes, and approving contracts; a governing body representative may serve as a liaison to a community advisory committee and on a water shortage response team or otherwise be engaged with the General Manager and staff
- General Manager or Director of Utilities—responsible for overall direction for the response
- Water Shortage Response Team Leader—responsible for leadership, management, coordination, information gathering and dissemination, key support staff assignments, role clarification, and communication with a broad array of interested parties
- Water Quality and Treatment Manager—responsible for overall guidance on drinking water quality and operations, issues related to potential alternative supplies, and opportunities for use of nonpotable water
- Water Supply Manager—responsible for estimating and managing long-term water supplies
- Finance Manager—responsible for cost estimates for operational changes, supply alternatives, and demand-reduction measures; customer database improvements and bill format changes; expected lost revenue estimates; recommended rate changes; and use of the revenue stabilization fund

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- Conservation Manager—responsible for water use reduction measures management, cost estimates to achieve demand reductions, and liaison with green industry and large water users (residential and commercial, industrial, and institutional customers); this person may serve in the role of Water Shortage Response Team Leader
- Communications Director (wholesale and large retail agencies)—responsible for messaging, customer relations, media relations, press releases, and coordination with wholesale customers
- Planning and Engineering Manager—responsible for new connection water use projections, new and expanded supply infrastructure, interconnection planning, and water quality treatment improvements
- Distribution System Operations Manager—responsible for overseeing frequency and intensity of leakage management, system water loss audits, and meter accuracy testing
- Customer Service—responsible for customer contact, current information about the state of the program, and increasing frequency of customer meter reading
- Administrative Staff—hires staff, purchases equipment, and negotiates union contract adjustments
- Legal Staff—reviews legality of program, rate changes, interagency agreements, and contracts
- Environmental Review (wholesale and large retail agencies)—reviews supplemental supply projects and prepares environmental documentation

Tuolumne Utilities District (TUD) Water Shortage Response Team

In 2013, following the August–October Rim Fire in the Stanislaus National Forest and a long-range weather forecast that predicted historically low precipitation, TUD convened its water shortage response team. The team consisted of the General Manager, who was the team leader, the District Engineer, the Water Operations Manager, and the Public Relations Manager and evaluated drought conditions, explored water management and supply options, formulated recommendations to the Board, and implemented all aspects of the drought response.

In addition to ongoing communication, the team met at a designated time weekly. The team brought in other staff as necessary for tactical planning and implementation and provided monthly updates to the Board. The team kept all customer service staff fully and regularly informed of drought conditions, current status, and mandatory conservation measures. All other water supply staff were briefed in case they encountered customers during their daily work duties. Engaging this core team ensured all staff and departments were moving in the same direction, created opportunities for brainstorming innovative solutions, and provided a unified message to the public (USEPA 2018).

Be aware that other governmental agencies, stakeholders, or groups may need to be consulted in developing the WSP and notified when the plan is implemented. For example, the water supplier may need to engage with state or province regulators if plans are required by state law or regulation. Are there other water suppliers or regional authorities with which a WSP may overlap? If the utility received water from a wholesale supplier, a utility representative should be part of the wholesaler's drought response team as well. Are there other local government agencies that may be affected by actions required in the WSP or that may be able to assist in implementing actions? Are there key industries or other large water users (e.g., universities) that should also be engaged in the planning process?

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SETTING PRIORITIES

Most water suppliers have a general water shortage response plan that is connected to its water supply or emergency response planning efforts. As these plans are developed or reviewed, it is critical that the utility work with the community in setting priority actions. This will help move towards quick responses when water shortages loom and is critical when facing a drought that may exceed the drought of record. When dry conditions first emerge, it is a signal that the WSP may need to be implemented and should be reviewed carefully and revised as needed to fit the specific conditions of the current drought. The information needing review includes the following.

- Supply: reliability may change from year to year or when triggered by changes in system operational conditions
- Demand: may increase due to unexpected growth or decrease due to efficiency programs
- Revenue: may have changed due to new rates or the depletion of the shortage contingency fund
- Infrastructure: areas in need of repair or subject to pipe breaks may aggravate shortage

Traditionally, water suppliers have focused demand-reduction measures on curtailing customer consumption. Given clear, timely, and specific information on supply conditions and the necessary actions to delay increased reductions, customers prefer the opportunity to meet targeted demand-reduction levels through voluntary measures. The decision to move to mandatory restrictions is more acceptable if the voluntary approach has been tried first but has not resulted in enough demand reduction to ensure public health, safety, and environmental protection through the projected duration of the shortage.

Priorities for use of available water in a community, while varying in order from place to place, may be established as follows:

1. Health and Safety—protect public health and firefighting capabilities
2. Commercial, Industrial, and Institutional—maintain economic base, protect jobs
3. Environment—reduce losses to natural resources
4. Permanent Crops—protect since it takes five to ten years to replace
5. Annual Crops—protect jobs
6. Landscaping—protect jobs, maintain established trees and shrubs
7. New Demand—generally, two years of construction projects are already approved

While reducing customer consumption is important during a water shortage, the water supplier must also focus on the efficiency of its own operations, particularly optimized leakage control. In a fundamental way, leakage—both in the supplier's distribution piping systems and the customer's service connection piping and internal plumbing—are high priorities in a water shortage situation because

- unlike most customer consumption, which runs intermittently, leakage runs continuously and will only increase until detected and abated and
- leakage provides no benefit whatsoever and wastes water and energy resources in extraction, treatment, and delivery.

While it is important for a water supplier to have an ongoing leakage loss reduction program (see M36, *Water Audits and Loss Control Programs*, 4th ed.), it is especially worthwhile for the water supplier to target excessive leakage losses as a priority in a water shortage situation. Traditional customer demand-reduction measures focus on providing

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customers with programs and knowledge that help them to reduce their use while still allowing them flexibility and choice in how water is used. The amount of public support and cooperation is likely to be greater if actions are equitable; that is, all water users are experiencing a similar service level and degree of involvement or sacrifice. The water supplier should set a positive example by "taking care of its own house" and communicate to the public the work it is doing to manage and minimize water loss and other operational improvements being made to help respond to the water shortage.

Denver Water Drought Response Plan (2016)

In 2002, the Board of Water Commissioners originally adopted a policy stating that Denver Water's goal for drought response is to preserve the quality of public life and economic activity to the extent possible in the face of a water shortage. Denver Water regularly updates its Drought Response Plan (2016), which outlines specific measures designed to maximize available water supplies and minimize water use. Because every drought is different, the Board can adjust and refine drought response measures based on actual conditions.

Denver Water's guidelines are designed to "maintain the health, safety and economic vitality of the community; to avoid adverse impacts to public activity and quality of life for the community; and to consider individual customer needs as much as possible." The water-use restrictions imposed during the 2002–2003 drought indicated that no single "silver bullet" was effective at encouraging all customers to reduce water use. Instead, a "basket of programs"—restrictions, surcharges, enforcement, incentives, and monitoring and evaluation—is recommended to create an overall atmosphere that encourages water savings.

With respect to setting restrictions, Denver Water adheres to the following principles as much as possible.

- Avoid irretrievable loss of natural resources.
- Restrict less essential uses before essential uses.
- Affect individuals in small groups before affecting large groups or the public as a whole, allowing as much public activity as possible to be unaffected.
- Minimize adverse financial effects.
- Implement extensive public information and media relations programs.

ESTABLISHING SCHEDULES AND MAINTAINING MOMENTUM

Depending on the level of preparedness, implementing a WSP will typically require two to six months of advanced planning and dedicated effort. For instance, if rationing is planned to take effect on May 1, the water shortage response team would need to begin work by November 1 of the previous year, or by February or March of the current year at the very latest if there is not ready capability in the existing billing system. Most rationing schemes require custom computer programming to execute.

Step 7 includes a list of essential elements associated with developing the WSP. Table 1-1 contains an example of a planning timeline—any individual timeline will depend on the level of review and activities required by the water supplier to adopt and implement a plan.

COORDINATION, COOPERATION, AND COMMUNICATION

The development of a good WSP is contingent upon effective coordination, cooperation, and communication within the water supplier; with the community; and among local, regional, and state agencies. Following are some strategies for the water shortage response team to consider.

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- Establish a community advisory committee. If the water supplier will be asking the public to carry out voluntary water reductions, this group may be able to help develop messages that will resonate with the public. It may also help in building support for water use reductions. Some water suppliers have used a community "ambassador"-type role for these committee members.
- If the water supplier is a city or county, include departments such as parks, fire, health, and the office of emergency services. It will be important for these departments to understand where they place among the priorities for receiving service and how they will be affected under escalating shortage stages. A number of states and provinces, including California, Georgia, Texas, and others, have priority water uses written into code. Water suppliers should check their state or province regulations to be sure their priorities follow applicable law.
- Organize meetings and create partnerships with sanitary districts, local cities, counties, Native American tribes, other water suppliers, regional heath and water quality boards, etc., to facilitate water shortage response coordination.
- Establish a regional public communication program. This is particularly important if the water supplier is in an area with multiple water suppliers and overlapping media markets.
- If others use the same water sources, establish a joint operations liaison between water suppliers or, depending on the complexity, convene a committee to coordinate withdrawals and pumping—quantity and timing.

Effective communication is particularly essential to the success of any WSP in achieving the desired water use reductions. All customers need to be adequately informed about water supply conditions, understand the need to conserve, and know what actions they are being asked or required to take to mitigate the shortage. Even before formal declaration

Table 1-1 Example planning timeline

24 Nov	Staff member reviews water supplier's drought trigger dashboard and the National Oceanic and Atmospheric Administration (NOAA 2019) Drought Outlook forecast and sees potential for initiation of drought conditions within the next 6–8 months.
26 Nov	Staff member begins to research and draft an updated plan.
10 Dec	Draft plan is ready for staff review. General Manager and team review plan and suggest changes. The plan is modified and expanded to include implementation procedures.
17 Dec	Essential staff members review the draft plan, comment on how it affects their functions, and ensure that it is workable.
3 Jan	Board subcommittee reviews the draft plan, suggests changes, and sends the plan to the Board for review and action.
January–March	Public hearings announced. Plan released for public review.
Feb–Mar	Public hearings result in public pressure to revise specific elements of the plan.
End of March	Full Board reviews the draft plan and schedules public hearings.
31 Mar	The Board declares a Water Shortage Warning, requests 10% reduction (*rainy season is almost over*) and adopts Plan.
April	Customers are notified by direct mail that mandatory rationing has been adopted and how the plan will affect them.
mid-Apr	Customers receive individual letter with their allotment, description of rationing plan and appeal procedures, general rationing/information brochure, and conservation information on how to reduce use (efficient toilets, showerheads, and landscaping, meter reading, leak repair, etc.).
1 May	Board declares a Water Shortage Emergency, Stage 1 *(rainy season is over)*.

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of a water shortage occurs, a public information and media program should be activated to provide customers with as much notice as possible. The more severe the shortage, the more vigorous the public information campaign will need to be. Droughts can be prolonged events that evolve slowly over time. Plan to provide public information using a variety of methods at regular intervals, repeated often and updated frequently. Public information efforts should always strive to be clear, professional, consistent, straightforward, reasoned, and honest to build trust and community support.

Step 7 includes a section that highlights important considerations in developing a public information and media program that should accompany a robust WSP.

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Step 2

Forecast Supply in Relation to Demand

Supply and demand data are needed as a basis for planning and estimating how much water of acceptable quality will be available under various shortage conditions, including multiyear shortages. Pumping and pipeline capacity also are considered in this step. Calculating projected demand, including increases because of growth and less precipitation, will be balanced against projected supply. The best time to initiate this process is before a shortage occurs.

Water shortage planning includes a process of defining possible responses to an array of "what-if?" scenarios. Good planning backed by accurate data produces wise decisions when faced with specific situations.

Information about both historical and current conditions is necessary. Historical data can be used to generate a reasonably accurate description of normal versus drought water supply conditions. Depending upon the state or regional governance, the drought of record or some specific guidance may exist that a water supplier must consider when defining a water shortage. A review of the current supply is used to estimate how much water of acceptable quality will probably be available. Historical and current data, along with projected weather and climate data, are used to create water shortage scenarios. These scenarios account for shortage periods exceeding the drought of record by one or more years. This step reviews the data needed to assess possible water shortage scenarios and provides the calculations necessary for interpreting the data. Figures 2-1 and 2-2 are satellite images of Folsom Reservoir taken before, during, and after the California drought of 2014–2017 that illustrate the effects of drought on a reservoir and the surrounding landscape.

What once was considered a good prediction based on historical data now has a new level of uncertainty. In today's world, water managers can no longer assume *stationarity*. That is, the raw data upon which projections have been based in the past are no longer stationary but vary considerably over time and cannot alone be used to project future

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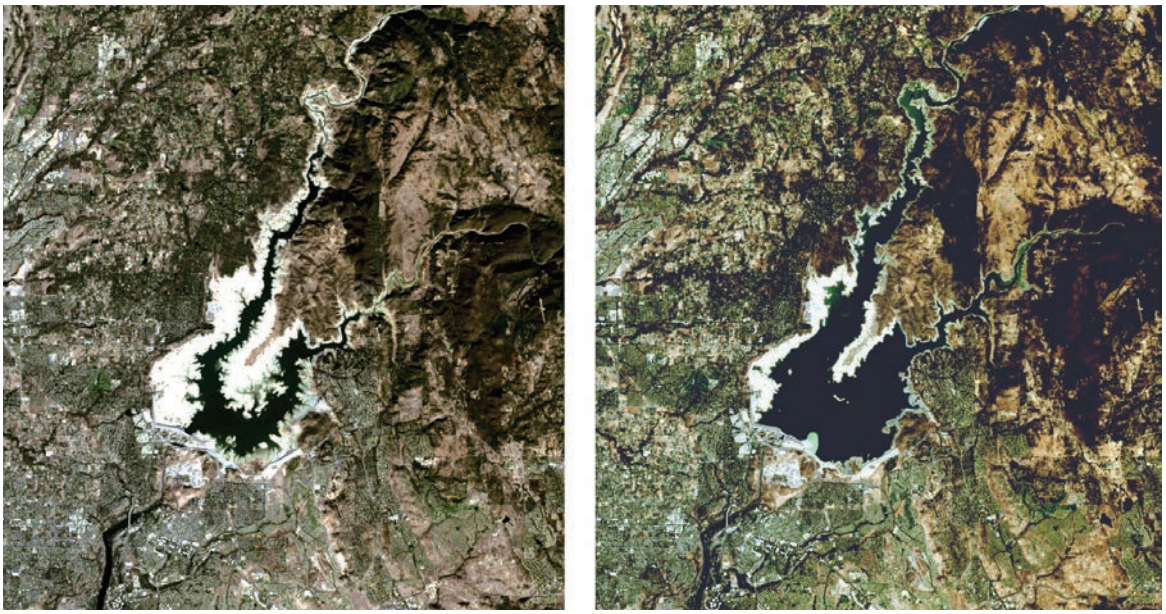
Source: US Geological Survey

Figure 2-1 Folsom Reservoir, California, 2010 (top left) and 2013 (top right) before drought and 2014 (bottom) during drought

conditions. The new reality is the increased variability of precipitation. More suppliers are considering the potential effect of climate change when determining the reliability of their water supply.

Water suppliers will want to incorporate increased uncertainty when implementing the following procedure. To best account for uncertainty, it is essential that planners consider droughts with varying intensities and durations instead of basing planning solely on the drought of record. In order to be aware of drought conditions and forecasts, utilities should routinely check the US Drought Monitor, US Drought Outlook, and other early warning systems.

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Source: US Geological Survey

Figure 2-2 Folsom Reservoir, California, 2015 (left) during drought and 2016 (right) near end of drought

DATA COLLECTION

Data concerning permitted water resource allocations, water purchase agreements, available water supply, treatment flexibility, distribution system, customer characteristics, and seasonal demand profiles are compiled and used for building a shortage-planning database.

Weather and Climate Data

General categories of weather and climate information include

- precipitation records and forecasts (rainfall and snowpack),
- stream flow,
- soil moisture, and
- drought indices (e.g., Palmer drought index).

Both historical and forward-looking weather and climate data will be important to review, the former for consideration of the potential impacts of drought and the latter to help inform triggers that will help to determine when a water shortage plan (WSP) needs to be implemented.

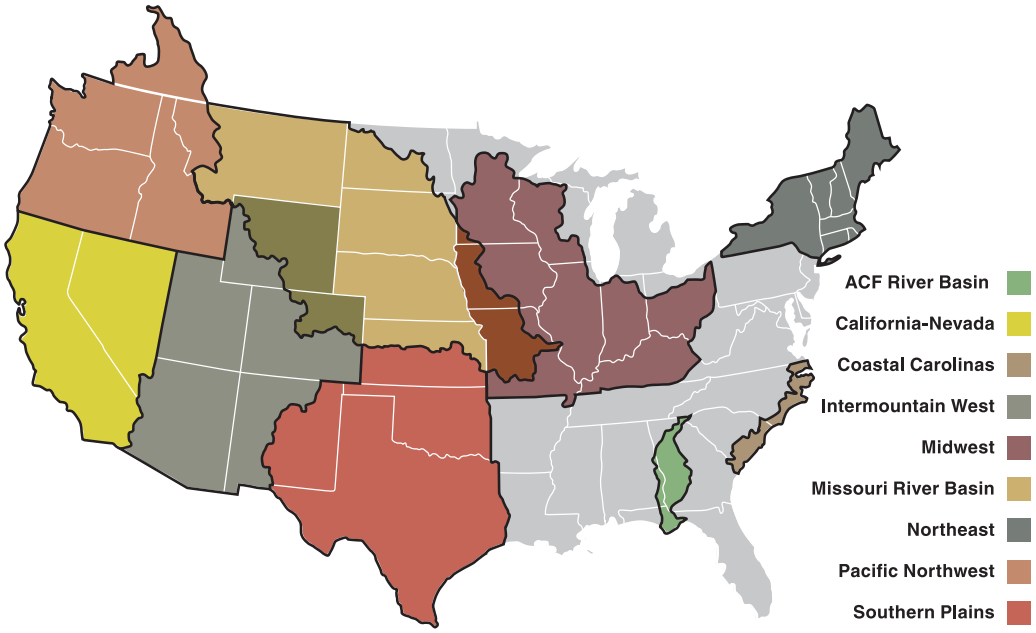
A number of federal agencies collaborate to provide a National Integrated Drought Information System (NIDIS), which includes the US Drought Monitor and provides information on the Palmer drought index, weekly and monthly changes in drought conditions, outlooks and forecasts of drought conditions and their impacts, various other water supply and climatological data resources, and regional drought monitoring information. Additional data can be found on the National Weather Service and US Geological Survey websites, and several states have resources specific to their areas. Information about NIDIS and related programs are provided on the following three pages.

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Platforms to Help Monitor for Drought

Since the first edition of M60 was released in 2011, additional tools and resources have been released that will help water managers better prepare for drought conditions by monitoring weather and climate. Many of these new tools are available due to improvements in federal interagency collaboration efforts that also bring in state and local government and non-government partners to improve understanding of weather and climate conditions. The **National Integrated Drought Information System (NIDIS)** managed by the National Oceanic and Atmospheric Administration (NOAA) is the primary hub of federal collaboration to provide information to the user community. NIDIS oversees the US Drought Monitor described on the next page. NIDIS has expanded its offerings over the past several years and has many resources that can help decision makers stay on top of the climate outlook for their region.

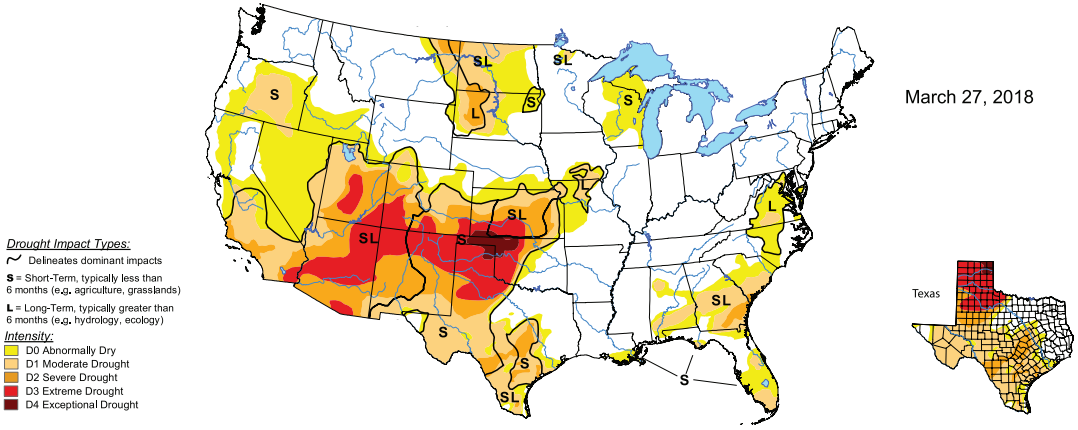
More recently, NIDIS has established several **Drought Early Warning Systems (DEWS)** across the country. The DEWS use new and existing networks of federal, tribal, state, local, and academic partners to make climate and drought science accessible and useful for decision makers and to improve the capacity of stakeholders to monitor, forecast, plan for, and cope with the impacts of drought. The DEWS offer a wealth of information that is specific to the states and basins in which they operate. Many provide periodic briefings via webinar to provide the user community with current information. The DEWS are very interested in responding to the needs of users in their networks, and there are good opportunities for water utilities to become more engaged. Learn more about the DEWS at https://www.drought.gov/drought/regions/dews.



ACF: Apalachicola-Chattahoochee-Flint

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Background	U.S. Drought Monitor	Process
The US Drought Monitor, established in 1999, is a weekly map of drought conditions produced jointly by the National Oceanic and Atmospheric Administration, the US Department of Agriculture, and the National Drought Mitigation Center at the University of Nebraska–Lincoln. The US Drought Monitor website is hosted and maintained by the drought center.	www.drought.gov	The weekly maps are released at 8:30 a.m. Eastern Standard Time each Thursday and are assessments of past conditions based on data through 7 a.m. Eastern time (8 a.m. Eastern Daylight Time) the preceding Tuesday. The map is based on measurements of climatic, hydrologic, and soil conditions as well as reported impacts and observations from more than 350 contributors around the country.



March 27, 2018

Drought Classification	Other Resources	General Contact Information
The Drought Monitor summary map identifies general areas of drought and labels them by intensity. D1 is the least intense level and D4 the most intense. Drought is defined as a moisture deficit bad enough to have social, environmental, or economic effects. D0 areas are not in drought but are experiencing abnormally dry conditions that could turn into drought or are recovering from drought but are not yet back to normal.	National Drought Mitigation Center: http://drought.unl.edu National Integrated Drought Information System: https://www.drought.gov/drought US Department of Agriculture: https://www.usda.gov National Oceanic and Atmospheric Administration: http://www.noaa.gov The National Drought Mitigation Center's website includes a collection of state drought monitoring and planning resources; click "Info by State" on the "Planning" tab.	DroughtMonitor@unl.edu US Drought Monitor National Drought Mitigation Center University of Nebraska–Lincoln P.O. Box 830988 Lincoln, NE 68583-0988 Phone: (402) 472-6707 Fax: (402) 472-2946

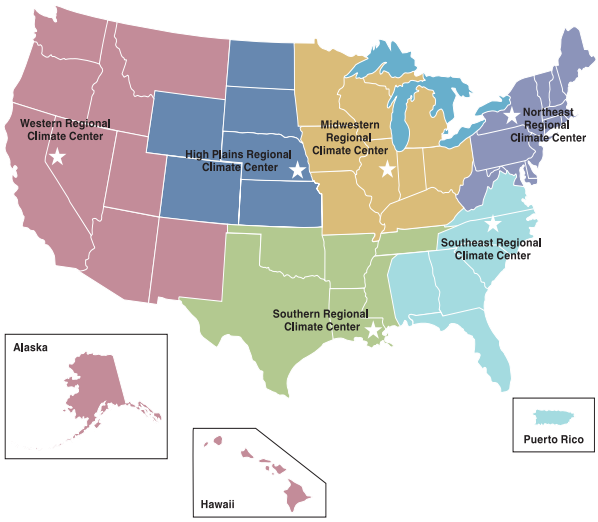
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NOAA also oversees the **Regional Climate Centers** (RCCs), another more recent federal-state cooperative effort that is focused on providing climate data, information, and knowledge for decision makers and other users. Many of the RCCs are amplifying and building on tools that have been developed through NIDIS. For example, the Western Regional Climate Center (https://wrcc.dri.edu/) has tools that provide historic atmospheric and precipitation data, current atmospheric and precipitation time series data plots, links to various types of current weather observation data resources, and links to drought monitoring resources and data.

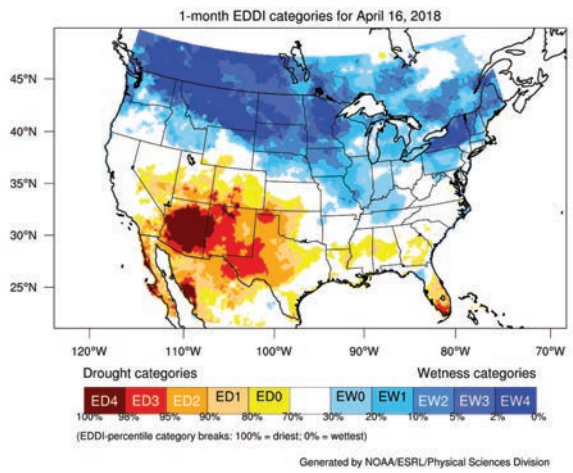
Regional Climate Centers



https://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers

Although not explicitly focused on weather impacts, the **USGS Climate Science Centers** may also offer resources to better understand impacts of drought in an area. Eight regional centers address regional impacts of climate change by offering support and research. https://nccwsc.usgs.gov/

The NOAA **Regional Integrated Sciences and Assessments (RISA)** Program also focuses on research projects that address climate sensitive issues. Some, like the Western Water Assessment (https://wwa.colorado.edu/), are very focused on monitoring drought. https://cpo.noaa.gov/Meet-the-Divisions/Climate-and-Societal-Interactions/RISA



Emerging Tools

A newer resource that will continue to improve in the next several years is the **Evaporative Demand Drought Index** (EDDI). Still in the experimental stages, EDDI assesses the "thirst of the atmosphere" and can offer early warning of drought and fire-weather risk. Because it captures signals of water stress at weekly to monthly timescales, it may prove to be a strong tool in preparing for flash droughts and ongoing droughts. https://www.esrl.noaa.gov/psd/eddi/

Supply Data

Some of the resources referenced in the previous weather and climate section also maintain information on water supplies, including reservoir levels and groundwater elevations. As geographic information systems are more widely adopted, many states are developing online data dashboards that allow for easy access to water data. For example, the Texas Water Development Board and the California Water Resources department maintain websites

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(https://waterdatafortexas.org/reservoirs/statewide; https://water.ca.gov/News/Current-Conditions) that include a wealth of information on the status of supplies in each state.

General categories of supply-related information include the following:

- Supply
  - Local supply status
  - Supply allocation and forecast from water wholesalers and other sources
  - Production records (minimum of five years) and forecasts
  - Surface water elevations and quality by elevation
  - Groundwater table or aquifer levels and quality by elevation
  - Reservoir levels
- Assets
  - Facilities data: maximum sustained pumping rates, pipeline capacities, etc.
  - Contingency agreements for supplemental supplies from regional water agencies or neighboring water suppliers
  - Water rights available for lease

Maintaining detailed records of the state of the infrastructure necessary to store and transport water is essential in accurately determining the amount of water that is available for consumption minus any physical losses due to leakage. This information is also helpful in identifying infrastructure that could be repaired and replaced to reduce leakage and increase supplies. Water audits of the transmission and distribution systems should be routinely performed to ensure accurate calculations of supply and demand.

Supply data should be collected for the past five years or longer, for the drought or droughts of record, and for years when there were diminished supplies due to unforeseen circumstances such as in the aftermath of disasters. The amount of projected water supplies for future years that includes the addition of any new supplies such as the construction of reservoirs, the acquisition of additional water rights, etc., should also be determined.

Regularly review agreements that give the water supplier the ability to provide or receive supplemental supplies during a water shortage. These agreements may need to change if areas experience greater demand due to population growth. If no agreements are in place, determine whether sharing agreements would be beneficial for water suppliers in the region.

Demand Data

Water use data that detail how much water was used by each customer in each sector is needed by month (or as often as is available) for at least the last five years. The amount of water lost due to leakage should be included in the total demand. Projected changes in the population as well as changes in commercial, industrial, and agricultural uses as a result of new development or land use changes should be obtained to determine the future projected demand. Potential increases in water losses due to aging infrastructure should also be considered. These data are used to assess demand for individual customers and customer class and the average use by month, by season, and by year. The following data are needed to assess demand. If the agency does not have access to all of the items on the list, gather what is available, and expand data collection efforts for future potential water shortages.

- Annual volume of water supplied as input to the water distribution system, for at least five years, as well as forecasts for future water delivery
- Billed customer consumption records for at least the five most recent years
- Service area population and growth projections

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- Customer class characteristics
  - The average number of residents per single-family residence
  - The average number of residents per multifamily unit
  - The number of units per multifamily connection
  - The number of businesses served by each commercial meter and the number of employees at each business
  - Peak to average residential demand
  - Peak day to winter residential demand
- The number of acres irrigated by each landscape irrigation meter
- The number of acres irrigated by each agricultural meter
- The annual volume of nonrevenue water quantified into apparent (nonphysical) losses and real (physical) losses, which are largely leakage; the cost impact of these losses should also be tabulated
- Attributes of the customer meter population: the number breakdown of meters by age, make, model, and size of meter

DATA ANALYSIS

Much of this information is routinely collected and analyzed as part of periodic updates to water master plans, wastewater master plans, local urban water management plans, and general plan updates or through other agencies for their specific purposes. For example, local business licensing entities may provide the information the water supplier needs regarding the identification of industrial customers through the US Census Bureau's North American Industry Classification System, https://www.census.gov/eos/www/naics/ (2019). Likewise, the county agricultural commissioner, university extension, and resource conservation district may have the irrigated acreage information needed for this analysis.

Coordination of the development of a drought-planning database with ongoing data collection and analysis programs will be beneficial in the long run. If not previously determined in other studies, analysis of the raw data may be required to illuminate certain drought period trends, such as the relation of landscape water use to irrigated acreage and precipitation.

Supply Data Analysis (Projected Dry-Year Supply Without Augmentation)

First, the reliable yield for each source should be determined for the next 5, 10, and 15 or more years. Evaluate what the expected supply would be under various percentage reductions in the overall supplies over varying time periods. For a worst-case scenario, assume a repeat of the worst historical drought in the region or a duration similar to the Millennium Drought in Australia (~13.5 years) to account for longer dryer periods or back-to-back droughts with short wet intervals. Many states and provinces have specific guidelines for the type of analyses. Water suppliers need to check with the agency responsible for regulating water rights or water resource planning in their state for guidance.

For purchased water sources, the contracted allocation should not be used. Instead, the water wholesaler or other source can provide estimates of how much water will likely be available during each of the next five or more years. Active participation in the wholesaler's process is critical to developing the allocation method for short supplies.

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Megadroughts and Anticipatory Water Modeling

The possibility and impact of prolonged drought periods—also referred to as megadroughts, which last for two decades or longer and do not allow time to replenish regular and emergency supplies—should be considered. The additional analysis that needs to be performed and the accompanying mitigation and planning strategies for these types of droughts are fundamentally different than the standard drought planning procedures described in this manual. However, it is recommended that water suppliers and government entities go through the exercise of determining the resulting impacts to supply and demand from this type of drought and what the long-term drought management, water supply, water use, and related policies would need to be in order to yield sustainable supplies.

Arizona State University (Gober et al. 2016) evaluated the sustainability of groundwater resources during a 50-year megadrought in the Phoenix area. An anticipatory water policy and planning model was used across a broad range of policies that included population growth management, water conservation, water banking, direct use of reclaimed water, and water augmentation. This analysis not only accounted for weather- or climate-induced megadroughts but also those associated with rapid population growth, overuse, and antiquated management. The analysis showed that continued population growth coupled with no change in per capita demand and current management strategies resulted in unsustainable groundwater supplies even under conditions when there is no megadrought. However, results also showed that moderate reductions in growth along with the implementation of conservation, reuse, banking, and augmentation before the occurrence of extreme drought periods would allow for the achievement of a sustainable supply for many years during and after a megadrought.

Water Quality Data Analysis

Treated water quality by source should be established for constituents regulated by the Safe Drinking Water Act (PL 93-523) and other state, province, or local codes. Comparison of this information with raw water data gives insights into the seasonal variability of the supply and the ability of the treatment system to respond to changes in raw water quality. Data should be developed on how the water quality of each source may vary with the planning cycle use projections. The ability to adequately treat water of degraded quality during drought will be critical if the water supplier plans to use all possible sources. Identify process or chemical changes needed to respond to reduced raw water quality and new supply sources.

Water suppliers that blend water from various sources will need to examine the ability of the treatment system to meet water quality standards when lesser quality water is delivered from one or more sources. Also, certain commercial or industrial customers may need advanced notification if the water quality characteristics will be significantly different during drought periods.

To stay informed of drought-induced water quality issues, a water supplier may decide to temporarily expand its routine water quality–monitoring program. This information may also be useful in alleviating customer concerns if aesthetic differences in water quality, such as chlorides, hardness, and odor, occur during a drought. Increased testing will also provide data on possible impacts of varying water quality on the water supplier and customer distribution systems.

Water Demand Data Analysis (Projected Dry-Year Demand Without Demand-Reduction Programs)

The more information that is known about how customers use water, the better the demand projections and selection of appropriate demand-reduction measures will be. At a minimum, customer type and their seasonal demands should be identified. Standard

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water supplier customer types include: single-family residential, multifamily residential, commercial, industrial, institutional, landscape, recycled, agricultural, and wholesale.

From a review of water use records, specific water use factors can be determined for each user type on an average monthly, seasonal, and annual basis. Knowledge of user characteristics will be helpful when assessing the demand-reduction impacts of restrictions and rationing allocation methods and estimating revenue generation from pricing changes and water shortage surcharges. Common units of water use measurement are as follows:

- Gallons per capita per day (gpcd)
- Gallons per day per dwelling unit (gpdd)
- Gallons per day per connection (gpdc)

For large landscapes and dedicated irrigation meters:

- Gallons per day per irrigated acre (gpda) by crop, irrigation, and soil type

For some commercial institutional and industrial customers:

- Gallons per day per employee (gpde)
- Gallons per day per square foot (gpdf)

Further analysis of a given category, such as determining individual subarea factors or correlating customer classes with land use designations, may be useful. This is especially important if a large proportion of the overall demand is generated by one or two customer class types.

Water use records should be analyzed on a seasonal basis. Again, conducting this analysis by customer type is essential. Winter residential use compared with summer residential use provides a good indication of indoor versus outdoor usage. The same analysis of seasonal water use among industrial customers may be indicative of process changes or landscape irrigation. Overall, indoor use may be best determined based on inflows, with winter data based on periods when there wasn't any precipitation (to avoid stormwater inflow impacts).

In a dry year, demand for water usually increases over normal demand. More water is needed for landscape irrigation because of less than normal precipitation during the spring and fall, and soil tends to not be as moist. Drought year demand will increase the most in areas such as inland valleys and desert areas that ordinarily use a high percentage of water for landscape irrigation. Some agencies have reported unexpected demand from previously unserved people requesting water service because of failing private wells or for the use of reservoirs for firefighting purposes.

To forecast drought-year demand, it may be helpful to plot normal-year consumption in the service area and overlay that with demand from drier years. Comparing average demand with dry-year demand may provide a multiplier (e.g., 107 percent) to use for predicting the dry-year demand of increased future demand because of growth or other factors. The actual years used will vary based on the region and the quality of data available. Water suppliers may be able to plot full supply periods against data from a historic drought period. Project the dry-year increase for each customer type for future years. If the dry-year demand data is from years where drought restrictions or programs were in place, the dry-year demand information will reflect those, and the multiplier may need to be adjusted to reflect demand in the absence of demand-reduction measures. More rigorous statistical analysis can be performed to identify the factors that impact demand such as rainfall, temperature, season, economy, and the presence of conservation programs. M50, *Water Resources Planning*, and M52, *Water Conservation Programs: A Planning Manual*, provide additional information on water demand analysis and forecasting.

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While shortages will vary by year, as population increases and demand grows, additional supplies that could have been accessed during shortage conditions may no longer be available because the water is supplying the new demand.

One concern expressed by some water managers in terms of demand management is commonly referred to as *demand hardening*. This refers to a situation in which most of the waste and low-value uses have been eliminated from the system, so when shortages do occur, their impacts—in terms of damages caused to customers, the environment, and economy—may be greater than in cases where only some of the waste and low-value uses had been eliminated. That is, in a community where most of the toilets and washing machines have been replaced with high-efficiency models and very little water is dedicated to landscape irrigation, there would be less opportunity for significant savings from drought-induced demand management measures. However, in the California drought of 2015 when across-the-board reductions were imposed, even communities with active water conservation programs and diligent water users were able to effectively further reduce per capita water use to very low levels and achieve additional savings. The additional savings were generated by a combination of increased rebate programs for indoor and outdoor water conservation equipment and changes in behavior by customers. Coverage in the media and statewide and local messaging all contributed to the heightened awareness and willingness of customers to change their behaviors. In most communities, demand hardening is not prevalent, and it requires careful analysis of the specific characteristics of the individual system to determine whether or not it is a real problem.

IS THERE A PREDICTED SHORTAGE?

A supplier's projected supply for five or more years, when compared with projected demand for the same period, provides data on the yearly (or monthly) supply and demand balance. Additional scenarios should be developed to account for uncertainty and variability in precipitation. In addition to consideration of the supply and demand over the last five years, scenarios that would occur during a millennium-length drought (as discussed previously) in relation to demand could also be evaluated to determine what the shortages would be under those conditions. Scenarios can also adjust supply and demand for future conditions that include the acquisition of additional supply sources and changes in demand. By adjusting various percentage reductions or increases in supply and demand based upon those scenarios, a supplier can assess what the potential shortages may be. In some cases, these projections may show that the supplies will be adequate for some conditions. It is more likely that during significant dry periods, suppliers will find the supply deficit will vary year to year but gradually increase as reserve supplies dwindle. The predicted, unmitigated annual supply deficit is then countered with supplemental supplies and demand-reduction measures that can be designed for various climate and drought scenarios. A combination of supplemental supplies and reduced demand is used to balance supply and demand.

A *mitigated supply* is the normal dry year supplies plus emergency supplies. *Mitigated customer demand* is the projected dry year demand minus reductions resulting from demand-reduction measures. The combination of emergency supplies and reduced demand is used to balance supply and demand.

Progressive water suppliers are entering into regional, county, and local agreements to improve water supply management, share the cost of emergency supplies, and improve demand-reduction media messages and program costs. The discussion of factors considered in setting drought triggers in Step 4 of this manual is closely related to the evaluation of supply and demand discussed here.

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