A Community Guide for Evaluating Future Urban Water Demand

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INTRODUCTION

"It's tough to make predictions, especially about the future." *–Yogi Berra*

Water utilities routinely forecast water use 20 or 30 years in the future in order to plan for new water supply infrastructure, which can take many years to plan and build. Historically, water use in American cities has grown in proportion to the population and the economy. Since the 1980s, however, the water industry has seen a dramatic "decoupling." The link between water use and growth has been broken due to two major factors: (1) the uptake of indoor and outdoor water conservation and efficiency improvements in homes, businesses, and institutions; and (2) a shift from a water-intensive manufacturing to a less water-intensive service-oriented economy.

The water sector has undergone a fundamental transformation, yet the practice of demand forecasting has been slow to keep pace with these changes. In particular, water suppliers continue to routinely overestimate future water demand. Too often, forecasters overestimate population growth and economic development, underestimate the effects of water conservation and efficiency, or both. These inflated estimates of future water needs can result in unneeded water supply and treatment infrastructure, higher costs to ratepayers, and unnecessary environmental impacts.

As communities examine proposed infrastructure, it is appropriate to first ask whether there is truly a need for the project. The answer to this question depends on future water supply and demand, as well as the availability of other alternatives. The purpose of this guidebook is to provide a resource for evaluating the need for proposed water supply projects, including seawater desalination plants. It should be of use to community and environmental groups, ratepayer advocates, or anyone interested in sustainable water supply planning. Specifically, the guidebook explains how water utilities forecast long-term water demand. We review some of the approaches and methods commonly used by utilities and consultants. We also describe a set of best practices that forecasters should follow to create more accurate and robust long-range water demand forecasts.

As you read through a water demand forecast created by a water utility or a consultant, we encourage you not to be intimated by jargon, equations, or computing that you will likely encounter. As we highlight in this guidebook, long-range water demand forecasting has a fairly dismal track record. Urban water use has undergone a dramatic transformation in recent decades, and forecasts have been slow to keep pace with these changes. Even experts with impressive credentials and years of experience are vulnerable to certain blind spots. Outside reviewers have an important role to play, as it has been shown that forecasts benefit from incorporating a variety of viewpoints.

ORGANIZATION OF THIS GUIDEBOOK

This guidebook is divided into several sections. At the beginning of the guidebook, we have included a Checklist for Reviewing Water Demand Forecasts to help you evaluate a forecast and to guide you through using this resource. In the section Background on Water Demand Forecasting, we describe how water planners and managers use forecasts to plan for the future, basing important decisions and ratepayer money on these predictions. We take a brief look at the industry's track record of over-predicting future water demands and discuss why forecasting errors matter. We also give some background on how analysts create forecasts. Utility staff or consulting engineers usually develop water demand forecasts using computer programs and statistical techniques. Our goal is not to turn you into an expert forecaster, but to help you critically assess water demand forecasts and explain some of the terminology you are likely to encounter.

In the section Best Practices for Water Demand Forecasts, we describe a handful of practices that we believe result in better and more accurate forecasts. This includes taking into account the impact of increased water conservation and efficiency, as well as changing population, employment, and land use. We offer our view on how to critically evaluate these important aspects and include links to several websites and resources to compare economic and demographic forecasts with those of other authorities. In addition to these more technical aspects, we describe the importance and value of an open and transparent forecasting process that offers opportunities for concerned parties to provide input and feedback. Following an open public process is not just for good public relations; there is evidence that bringing in many points of view makes forecasting more accurate. Finally, at the end of this guidebook, we have included a short glossary of technical terms related to water supply planning and forecasting.

A Note about Terminology

Water demand – In this guidebook, we refer to water demand as the amount of water delivered by a water supplier over a certain period. In this context, it is synonymous with water use. Note that this definition is different from the one traditionally used in the field of economics. When economists refer to demand, they are usually referring to how much of something a person will purchase at a given price. To an economist, demand is not a fixed quantity, but rather a relationship between price and quantity consumed. Some utilities also use the term water production synonymously with water use. This term refers to the amount of treated water that goes into the utility's distribution system, and includes a certain quantity of water that is lost due to leaks and fire-fighting.

Water utility – We use the term water utility to refer to any entity that provides water to homes and businesses. This is synonymous with the terms water agency or water supplier, which are also frequently used.

CHECKLIST FOR REVIEWING WATER DEMAND FORECASTS

This checklist covers many elements that go into a good-quality water demand forecast. Not every forecast will (or necessarily should) contain every element in this list. As a general rule, the level of effort in a forecast should be commensurate with the decisions that will be based on it. More detailed methods are called for when potentially large investments are to be based on forecasting results. Learn more about each element by referring to the page listed. If you are attending a presentation or meeting where forecasts are being discussed, you may wish to pose some of these questions to the utility staff or consultants who prepared the forecast.

- ❑ **Is the purpose of the forecast clearly stated?**
  Is the forecast intended to justify new infrastructure or water purchases? Decision-makers should state what decisions will be based on the forecast.

- ❑ **Are major classes of water users analyzed separately?**
  Does the forecast divide customers into appropriate groups? At a minimum, the analysis should cover each sizable class of water users with similar characteristics, e.g., residential, industrial, commercial, institutional, and large landscapes. *See page 9*

- ❑ **Does the forecast use recent, up-to-date data?**
  Are the data sources clearly identified and do they come from reliable sources? Look for data that accurately reflects recent history, i.e., a mix of wet and dry years. Beware of cherry-picked data from a single year that does not reflect average conditions. For example, does the analyst rely on information from before the 2008 economic recession, which caused a slowdown in employment and new construction almost everywhere in the country? *See page 10 and page 16*

- ❑ **Has the water demand model been "validated?"**
  If the analyst is using a computer model to predict future demand, has he or she used the model to recreate observed conditions in the past? Did the model perform well? This process is referred to as model *validation* or *hindcasting*. *See page 12*

- ❑ **Does the forecaster take into account increasing water use efficiency?**
  The forecast should include the effects of "passive conservation" caused by greater uptake of efficient appliances and fixtures that are mandated by standards and codes. In addition, the forecast should consider "active conservation" programs run by the utility, such as rebates for efficient appliances. *See page 12*

- ❑ **Does the forecast take into account recent trends or developments in water use?**
  The document should include a table or chart of historical total water use and per capita water use for the region for at least the last 20 to 30 years. Such a chart can illustrate past trends, such as declining per capita water use, and allow you to see if the forecast is consistent with those trends. If the forecaster is making a projection that contradicts recent trends, it should be explained and justified with sufficient evidence. *See page 16*

- ❑ **Does the forecast reflect any structural changes in the economy or other foreseeable changes in commercial and industrial water use?**
  Does the forecaster take into consideration economic changes that are ongoing or anticipated? For example, a region that is shifting from manufacturing to a more service-oriented economy, such as office buildings or retail, may experience a decline in water use. Are local businesses and/or institutions using water more efficiently, and is this reflected in the forecast? *See page 17*

- ❑ **Does the forecast include anticipated changes in water prices, and how these may affect demand?**
  Has the cost of water for the utility increased faster than inflation in the recent past? Is it expected to do so in the future? If so, water use forecasts should include the *price elasticity* on demand, i.e., the relationship between price and consumption. *See page 19*

- ❑ **Is projected population growth realistic?**
  Is the projected population comparable with that of other planning documents in the region? Can such growth be realistically expected in the timeframe of the forecast? How do projected rates of growth compare to historic rates? Does the forecast consider factors that are likely to accelerate or slow growth? *See page 21*

- ❑ **Does the forecast include expected changes in land use or density?**
  Is your community, like many in California, seeing an increase in density in new development (i.e., homes on smaller lots and more multi-family homes)? Does the forecast consider these current development trends? Forecasts based on extrapolating existing density may overestimate water use. *See page 21*

- ❑ **Is the water demand forecast consistent with other regional planning documents?**
  Are projections of population, employment, and land use consistent with those produced by other authorities in the region? Are assumptions about the region's future, including different types of development (e.g., residential, commercial, industrial), similar to those in a city's general plan or in regional transportation plans? *See page 21*

- ❑ **Does the forecast include the effects of climate change?**
  Warming of the climate is likely to increase water use for landscapes and cooling, other things held equal. The effects of climate change should be included in detailed forecasts for those areas with significant outdoor water use. *See page 24*

- ❑ **Are drought impacts on demand included?**
  Does the forecast take into account the reductions in water use from recent droughts or drought restrictions that have been imposed? Does the forecaster assume that some of this reduction will be permanent, or present evidence there will be a fuller rebound? Are future droughts and the effect they will have on water demand anticipated? *See page 26*

- ❑ **Does the analyst incorporate uncertainty into the forecasts?**
  Modern software makes it much easier to incorporate uncertainty into the forecast, using Monte Carlo simulation or other stochastic methods. If the analyst has used one of these approaches, the forecast will show the output as a range. This may take the form of high and low estimates of future water demand, or the estimate may have error bars or "prediction intervals." *See page 27*

- ❑ **Are there multiple forecasts representing other possible future scenarios?**
  Does the forecast only represent a "business-as-usual" water demand, or are other possibilities imagined, such as "slow-growth" or "rapid-growth"? *See page 28*

- ❑ **Have the public and other stakeholders been given opportunity to give input?**
  Was stakeholder input solicited? Was a draft presented for public review and comment? Did the authors respond meaningfully to the input they received? Were meetings or workshops held to describe the forecasts and/or solicit feedback? *See page 29*

- ❑ **Has the forecast been peer reviewed?**
  Was the analysis peer reviewed or otherwise evaluated by external experts? External technical review can help spot and fix many potential errors. Further, forecasts are improved by incorporating a variety of data and viewpoints. *See page 30*

- ❑ **Does the forecaster have a conflict of interest?**
  The utility or firm producing the forecast should not stand to profit from decisions related to the forecast. For example, the forecasting firm should not be eligible to bid on design, construction, or management of a project that is justified by the forecast. *See page 30*

BACKGROUND ON WATER DEMAND FORECASTS

Water-demand forecasting is the process of making predictions about future water use. Water utilities develop forecasts for a range of different time scales, ranging from hours to decades, depending on the intended application (Billings and Jones 2008). Utilities develop short-term forecasts for the next few hours or weeks to optimize day-to-day operations. Medium-term forecasts, covering from one to several years, are used for planning system upgrades and setting water rates. Long-term forecasts—the focus of this guidebook—are developed for periods of a decade or more. This is consistent with the amount of time it takes to develop new water supply infrastructure.

Long-term forecasting of water demand presents a two-sided risk. On the one hand, overestimating demand can lead to costly investment in unneeded infrastructure and water supply sources, with higher water bills and potential environmental impacts. On the other hand, underestimating future water demand could contribute to water supply shortfalls, temporary increases in water bills, or the imposition of emergency cutbacks. Risks from under- or over-estimation can cost utilities millions of dollars, threaten consumer confidence and goodwill (a consideration for elected board members), and harm local economies.

The reality is that many water suppliers consistently overestimate actual water demand. Many water utilities continue to project growing water demand in the next 20 to 30 years, in spite of evidence that water demand in communities across the United States has remained steady or declined in the last few decades. This decline has occurred even while population and economies grew. Figure 1 shows four examples of such forecasts, from (a) Seattle, Washington; (b) Washington, DC; (c) San Diego, California; and (d) Phoenix, Arizona. In each case, forecasters repeatedly and incorrectly predicted that water demand would increase. Inaccurate projections are hardly limited to the water sector. In fact, forecasters in many fields—including energy, economics, demographics, and politics—have repeatedly made errors like the ones shown in Figure 1 (see e.g., Silver 2012; Tetlock and Gardner 2015). Some commentators have even started referring to graphs like these as "porcupine charts" due to their characteristic shape (Cox 2010).

Figure 1.

Water utilities consistently overestimate future water demand

a. Seattle, Washington (Flory 2012)

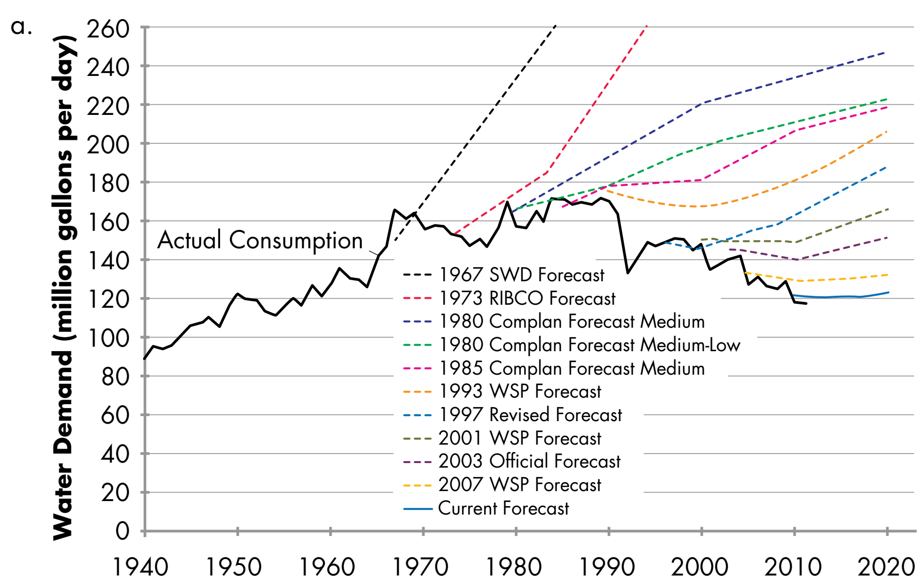


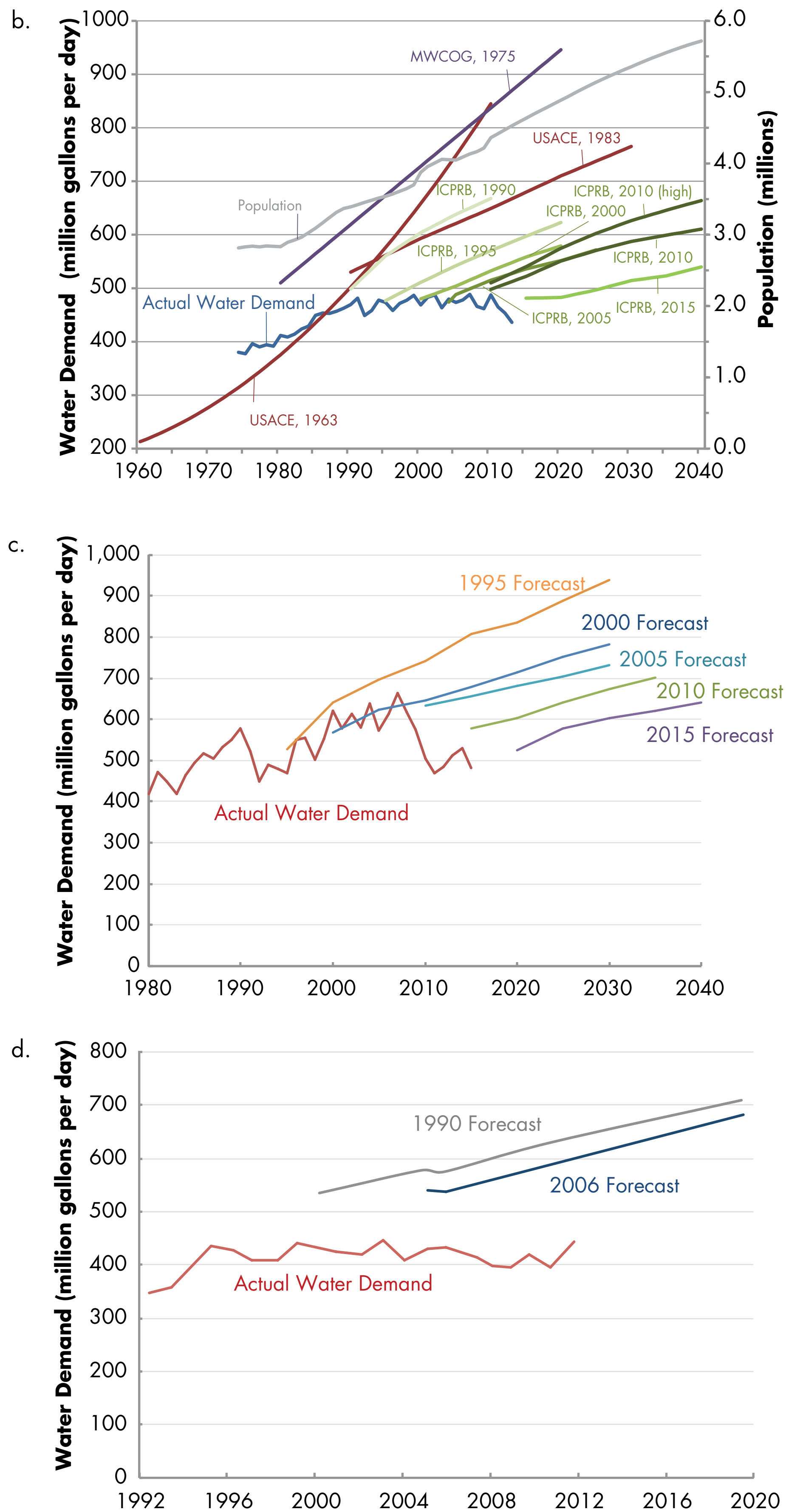
Figure 1. (continued)

Water utilities consistently overestimate future water demand

b. Washington, DC area (Ahmed, Bencala, and Schultz 2015)

c. San Diego County, compiled by the authors from San Diego County Water Authority publications and consultant reports, including the Urban Water Management Plans from 1995, 2000, 2005, 2010, and 2015 (Kiefer and Porter 2000)

d. Phoenix, Arizona (Frost 2012)



There are several reasons why forecasters so frequently and consistently overestimate future water use. First, a fundamental transformation has taken place in the urban water sector in the last few decades, and the link between water and growth has been broken in many communities. Yet, water planners have been slow to recognize that this is a lasting trend and not a temporary phenomenon. An important utility bias is the legal "duty to serve" mandated by state laws and which renders the utility legally liable when they fail to provide proper service. The duty to serve is a paramount driver for water utility managers. On the planning and design side, water utilities are largely staffed by engineers, a profession that places great importance on protecting lives and property. Engineers are accustomed to designing structures that are bigger and stronger than needed, to be on the safe side. For water supply, this conservative approach means designing pipes and treatment plants capable of handling flows greater than they are likely to encounter.

However, this design philosophy can create undesirable side effects. Here, it is important to look at what an engineering failure would look like and the risk associated with these consequences. In the water sector, when infrastructure is undersized, it could lead to low system pressures, shortages, or mandated cutbacks. While this can have a real impact on a community's economy or quality of life, these impacts can generally be avoided or managed over the long-term. An important consideration for water managers is maintaining certain flows and pressures for fire suppression. This is also an important driver for utility management in the short term. Over the long-term, expected supply shortfalls can be handled through a variety of policies and programs, such as demand management programs or water-neutral development policies.

CONSTRUCTING A DEMAND FORECAST

"To see the future is good. To prepare for it is even better." *–Anonymous*

Analysts use a variety of methods and computer models to forecast water demand. These models vary widely in their complexity, the data needs, and the amount of expertise, money, and effort needed to use them. Most long-range water demand forecasts, however, follow the same fundamental structure. To estimate future demand, forecasters multiply average per capita water use by the number of customers the utility expects to serve in the future (McMahon 1993). Beyond this basic structure, forecasters have developed a number of adjustments and refinements, some of which are discussed below.

Per capita water use is usually calculated from the utility's own records and estimates of the service area population. Water use per resident or employee is often expressed in terms of gallons per capita per day (gpcd) (see Box 1 for a simple example of this calculation). This per

Box 1.

Calculating water use per resident or employee

Total water use ÷ Number of customers = Water use per person

Example: 12,000,000 gallons/day ÷ 200,000 people = 60 gallons/(capita·day) capita estimate is sometimes called a "water use factor." The factor can represent a single year or it can be a composite of multiple years and be calculated using a simple average. The analyst may also use statistical techniques to break down water users into different groups sharing similar characteristics. In practice, forecasters typically group customers according to their pattern of water use. This allows them to create separate estimates of water use for different classes of customers in their service area. The Department of Water Resources (DWR) requires water suppliers to report past, current, and projected water use for the following customer types in their urban water management plans (DWR 2016b):

- **Single-family residential customers** are residential users in freestanding buildings containing one dwelling unit that may include a detached secondary dwelling.
- **Multi-family residential customers** are residential users in multiple dwelling units contained within one building or several buildings within one complex.
- **Commercial customers** are water users that provide or distribute a product or service.

  Industrial customers are water users that primarily manufacture or process materials, or are engaged in research and development.
- **Institutional customers** are water users dedicated to public service. This type of user includes higher education institutions, schools, courts, churches, hospitals, government facilities, and nonprofit research institutions, among others.
- **Landscape customers** are water users with a water connection supplying water solely for landscape irrigation. Such landscapes may be associated with multi-family, commercial, industrial, or institutional/governmental sites, but are considered a separate water use sector if the connection is solely for landscape irrigation.

Some forecasters may further sub-divide customer classes. For example, commercial customers can be broken into type (e.g., restaurants in their own category) or residents could be broken down by household income. Sometimes neighborhoods are divided into classes based on their density or average lot size. A water utility may add customer classes to represent special situations, for example if the service area contains major water users such as nurseries or oil refineries. Other categories can be created that represent other factors, such as land-use type or climate region. Note that for some categories, the water use factor is not necessarily "demand per capita," but might be represented as demand per account, per acre, or per employee. Land use-based water factors expressed in gallons per acre per day are sometimes called "water duty factors."

The most basic forecasts may assume no change in the per capita water use factor over time. However, this is widely recognized to lead to inaccurate forecasts, as it fails to capture the effects of increasing water use efficiency (Flory 2013; Mayer 2013; Walker 2013; Rinaudo 2015; Buck, Soldati, and Sunding 2015). To generate more accurate estimates, forecasters use different techniques to modify the water use factor or the expected number of customers, or both. This is discussed in more detail in the section Account for Water Conservation and Efficiency on *page 12*.

Projecting future population is particularly difficult, as it is full of unknowns. Yet, there are a number of steps that forecasters can take to make forecasts more robust. According to the American Water Works Associations, population forecasts for water demand forecasts should have the following characteristics (Billings and Jones 2008):

- include high, medium, and low variants or a confidence interval;
- be based on information from sources such as birth and death records, school enrollment, and utility connections;
- be consistent with other regional and national forecasts, and should acknowledge demographic changes, such as aging of the population or projected changes in migration or birth rates;
- if the forecast does not include these above elements, it should explain why; and
- acknowledge the higher potential for variability, if the forecast is for a small area.

Many forecasts of growth made before the 2008 recession were much higher than what is observed today. For example, some cities anticipated high rates of growth in housing that no longer look likely. Practically speaking, forecasts based on population and economic growth estimates made before 2008 should be carefully scrutinized to make sure they are realistic, based on more recent trends. Alternatively, if the forecaster anticipates recent trends to reverse, she should back this claim with convincing evidence.

As we have seen, forecasters routinely overestimate water demand over the long range for a variety of reasons. In the following pages, we offer guidelines and best practices to improve the accuracy and reliability of forecasts.

WHERE TO FIND DEMAND FORECASTS

A water demand forecast may or may not exist as a stand-alone document. Frequently, forecasts are embedded in other planning documents that go by a variety of names. For example, the East Bay Municipal Utility District produced water demand forecasts as a part of its 2040 Water Supply Management Plan. The Orange County Water District publishes forecasts in its annual Engineer's Report. Sometimes, the forecast may be located in a memo or other document prepared by the water utility or by a consultant. Even if the utility posts this information on its website, it may be difficult to find. The best way to locate this information may be with a request, either by phone or in writing.

For California water utilities, the first place to look for water demand forecasts is in a water utility's Urban Water Management Plan, or UWMP, if it has published one. California enacted the Urban Water Management Plan Act (AB 797) in 1983 and has amended it several times since then. The law requires urban water suppliers serving at least 3,000 customers to publish forecasts of water demand in five-year increments over at least a 20-year future planning horizon (DWR 2016b). Most water suppliers post their UWMP on their organization's website. Additionally, the DWR website has posted completed plans at the following locations:

- **2010 UWMPs**: http://www.water.ca.gov/urbanwatermanagement/2010uwmps/
- **2015 UWMPs**: http://www.water.ca.gov/urbanwatermanagement/uwmp2015.cfm

It may be worth checking whether your water supplier met the minimum requirements for what the law says must be included in a UWMP under the California Water Code. DWR uses a checklist to verify whether water suppliers have included all the required elements, although they do not judge their quality or verify any of the calculations or assumptions. For the 2010 UWMPs, DWR determined that only 304 out of 421 plans were complete (Huff 2016).

If the document you are looking for is not readily available, you should still have access to it under state "sunshine" laws. The California Public

Records Act (California Statutes 6250–6270) allows anyone to inspect "public records," broadly defined as "any writing containing information relating to the conduct of the public's business prepared, owned, used, or retained by any state or local agency." The law covers any type of government agency but does not extend to private water or power companies, sometimes referred to as "investor-owned utilities." If agency staff are unwilling to share documents with you, your last resort would be to file a public records request, sometimes called a "FOIA request." (This term is used for public information requests, even though in some cases it would be covered under state law and not the federal government's Freedom of Information Act, or FOIA). For more information on filing a public records request, as well as sample letters, see:

- **Ballotpedia**: https://ballotpedia.org/California_FOIA_procedures
- **National Freedom of Information Coalition**: http://www.nfoic.org/california-foia-laws

BEST PRACTICES FOR DEMAND FORECASTING

"A trend is a trend is a trend. But the question is, will it bend? Will it alter its course through some unforeseen force and come to a premature end?" *–Sir Alexander Kirkland Cairncross*

Future water use depends on a variety of social, cultural, and economic factors that are notoriously difficult to predict. A great deal has been written about forecasting and forecasting failures by experts in a diversity of fields such as science and engineering, business, marketing, economics, and political science. There is no clear consensus in the professional community on what goes into a "good" forecast. Nevertheless, there are certain practices that are recommended to enhance the accuracy of forecasts and improve transparency and accountability of the forecasting process. We describe some of these practices in this section and provide a summary of the main points in a checklist beginning on page 3. It is not necessary for every forecast to follow each of these recommended practices. In general, the level of effort that goes into a forecast should be proportional with the importance of the decisions it will be used to make. Forecasts used to guide large investments call for the use of more detailed data and methods.

A general principle for improving forecasts that is often ignored is to go back and evaluate prior forecasts. Researchers have shown that forecasters get better when their performance is evaluated (Armstrong 2001; Tetlock and Gardner 2015). A group of experienced water managers writing in the *Journal of the American Water Resources Association* noted that regularly updating forecasts provides an opportunity to examine changes in demographic indicators and the rate of water use (Hagen et al. 2005). These evaluations can also help identify whether past forecasts were accurate, the cause of any inaccuracies, and whether the forecast was missing any key parameters. Despite these potential benefits, this practice is unfortunately uncommon. Ideally, forecasting should be an iterative process, with each effort building up past efforts and correcting for past mistakes. Practically speaking, you should look to see if the forecaster has included a retrospective analysis of prior forecasts and analyzed the source of any inaccuracies or omissions.

As another general rule, analysts who build mathematical or computer models of water use should take steps to ensure that these models perform well and adequately describe the real world. It is beyond the scope of this guidebook to describe the many possible pitfalls that can beset statistical analyses or computer simulation models (see e.g., Pilkey and Pilkey-Jarvis 2009). Yet, as a very basic check, whenever forecasts rely on computer models, you should try to find out whether and how the model was calibrated. Analysts "calibrate" a model by adjusting the variables or parameters of the model to make sure that it can reproduce, or "hindcast," real-world observations. A good model should be able to accurately replicate historical patterns of water use before it is used to extrapolate out into the future. While a forecaster may not include this step in the final report, even if it was done, it is a good sign when it is.

ACCOUNT FOR WATER CONSERVATION AND EFFICIENCY

One of the major causes of inaccuracy in water demand forecasting is underestimating the effects of water conservation and efficiency (Frost 2012; Mayer 2013). Every long-term water demand forecast should include the effects of water conservation and efficiency, which have the effect of reducing per capita water use rates.

California has a long history of adopting water efficiency standards and codes. In 1978, in the midst of serious drought, the legislature passed a bill requiring that all toilets sold in the state use no more than 3.5 gallons per flush. Before that, existing models used as much as 6 gallons per flush. In 1991, the state lowered the standard to 1.6 gallons and Congress followed suit in 1992, implementing national standards for toilets, urinals, faucets, and showerheads. Over time, Congress and federal agencies have adopted new standards and made their existing standards more stringent, as shown in Table 1.[1] In some cases, California's standards are stricter than federal law. The combination of state and national standards put in place over the last several decades have led to significant reductions in per capita water use. Water savings associated with standards and codes will continue to grow as more efficient appliances and fixtures are installed under existing standards and as new efficiency standards are developed and implemented (Meyers 2014).

California has been a leader in developing water efficiency standards for lawns and landscapes, beginning in 1990 with the passage of the Water Efficient Landscape Ordinance (AB 325). The current version of this law, adopted in 2006 and amended in 2015, requires cities and counties to set water-efficiency requirements for large landscapes over a certain size threshold. The ordinance discourages large areas of lawn and encourages water-efficient plants by limiting the amount of water that can be applied to the landscape based on the region's climate (DWR 2016c). It also requires water-saving measures, including high-efficiency sprinklers and pressure regulators. As more landscapes come into compliance with these requirements, it is expected to continue to reduce outdoor water use in urban areas throughout California.

Water managers sometimes make the distinction between water savings that result from standards and codes and savings that result from actions taken by the water utility. Passive conservation, or "code-based savings," refers to water savings resulting from actions and activities that do not depend on the water utility, such as the natural replacement of old devices with more efficient models when those devices wear out, as required under current standards; and the installation of efficient devices or landscapes in new buildings or during

1 The list of water-efficiency standards in Table 1 is not meant to be exhaustive, but rather to demonstrate that there has been a great deal of improvement in water use efficiency in recent years.

Table 1.

Selected state and federal water efficiency standards

Fixture/Appliance	Maximum flow rate	Law	Effective Date
Toilets	3.5 gallons per flush (gpf)	CA statutes	Jan. 1, 1978
	1.6 gpf	EPAct 1992	Jan. 1, 1994
	1.28 gpf	CA AB715 2007	Jan. 1, 2014
Showerheads	2.5 gallons per minute (gpm) at a pressure of 80 pounds per square inch (psi)	EPAct 1992	Jan. 1, 1994
	2.0 gpm at 80 psi	CEC Title 20 2015	July 1, 2016
	1.8 gpm at 80 psi	CEC Title 20 2015	July 1, 2018
Faucets	2.2 gpm at 60 psi	EPAct 1992	Jan. 1, 1994
	1.2 gpm at 60 psi	California Code of Regulations Title 20	
Residential Clothes washers	9.5 gal/cycle/ft^3 of clothing	Energy Independence and Security Act of 2007	Jan. 1, 2011
Dishwashers (regular size)	6.5 gallons/cycle	Energy Independence and Security Act of 2007	Jan. 1, 2010
Dishwashers (compact)	4.5 gallons/cycle	Energy Independence and Security Act of 2007	Jan. 1, 2010
Urinals	1.0 gpf	EPAct 1992	Jan. 1, 1994
	0.5 gpf	CA AB715 2007	Jan. 1, 2014
Commercial faucets	2.2 gpm at 60 psi	EPAct 1992	Jan. 1, 1994
Commercial faucets (public lavatory)	0.5 gpm at 60 psi	American Society of Mechanical Engineers standard	2005
Commercial pre-rinse spray valves	1.6 gpm	EPAct 2005	Jan. 1, 2006
Commercial ice makers	sliding scale, based on ice harvest rate	EPAct 2005	Jan. 1, 2010
Commercial clothes washers	9.5 gal/cycle/ft^3 of clothing	EPAct 2005	Jan. 1, 2007

Note: EPAct = Energy Policy Act; CEC = California Energy Commission; gpf = gallons per flush; gpm = gallons per minute; kWh = kilowatt hour; psi = pounds per square inch

remodeling. In addition, some communities, such as San Francisco and San Diego, have adopted "retrofit on resale" ordinances that require old, inefficient toilets to be replaced with conserving models when a home is sold (SFPUC 2016), further accelerating the uptake of efficient appliances and fixtures. Forecasters often find it difficult to predict future codes and standards. However, manufacturers continue to develop more water-efficient technologies, and these technologies are likely to become future standards. Therefore, estimates of water conservation savings based on present-day standards should be considered a low estimate of future water savings.

In contrast to passive conservation, active conservation refers to water savings resulting from utility programs. This often includes financial incentives for efficient devices, for example giveaways of faucet aerators or hose nozzles. Other utilities offer direct install programs for efficient showerheads or toilets. Active conservation could also include the adoption of water rate structures designed to encourage efficient use, such as "tiered rates," where the price of water increases with higher use. Finally, it also includes education campaigns aimed at convincing the public to use water more wisely and avoid waste. Water savings from active conservation programs has the effect of reducing per capita water use and should be included in demand forecasts. Apart from conservation programs run by a utility, emergency regulations or water conservation campaigns can help to quickly reduce water use, e.g., during a drought or other supply shortage. Some portion of water savings results from efficiency upgrades, while another portion of savings is behavioral (e.g., shorter showers, skipping the car wash). Forecasters may be hesitant to include the effects of such behavior-based conservation, as it is difficult to quantify, and often assumed to be temporary (see the discussion of "drought rebound" in the section Account for Climate Change and Drought on *page 24*).

Forecasters typically account for conservation and efficiency by calculating the water use for different categories of customers and then applying a correction factor in the following manner:

Step 1: Forecast future water use (total or per capita). This is typically done by averaging water use from the past five or 10 years to estimate current per capita water rates, as required by the UWMP guidelines.

Step 2: Calculate conservation savings. Analysts use a variety of methods to estimate water savings, which vary in their level of detail and accuracy.

Step 3: Subtract the conservation savings from Step 2 as a correction factor to the water use estimate in Step 1. In general, water conservation savings should increase over time, as the market share of efficient devices increases. For most end uses of water, savings from water efficiency will be greater in 20 years than in 10 years, unless there is evidence that market saturation has been reached for efficient devices.

As noted for Step 2 above, forecasters use a variety of methods to estimate the effects of water conservation and efficiency. Some forecasters simply assume a percent reduction in water use will occur, such as a 10% reduction in per capita use over the next 20 years. The advantage of this approach is that it is fast and simple. However, if its basis is "expert judgment" and not observations of real-world data, the assumption may not be accurate, and more detail should be added for an important forecast.

Another way that forecasters estimate conservation savings is to compare the water use in new homes with that of older homes. New homes have the latest water-efficient devices required by law, and water use in these homes reflects what other homes are capable of once they are fully retrofitted. The forecaster assumes that water use in old homes will gradually decrease until it matches that of new homes as old devices wear out and are replaced by newer models.

A third and more detailed approach to estimating the water savings due to conservation and efficiency is referred to as "end use modeling." This technique is especially useful for estimating the water savings that will occur in the future as efficient devices are more widely adopted and gain market saturation. Using this approach, the analyst calculates how much water people use on average for toilets, showers, laundry, etc., covering all the major end uses of water. For each end use, the analyst estimates the water usage rate based on the distribution of conserving and non-conserving devices in use in their service area. For example, 45% of the toilets may be water-efficient models, while the rest are older, non-conserving models. These values can be used to estimate the water savings from the uptake of efficient models in coming years. The disadvantage of this method is that it requires more data, and the analyst usually has to make simplifying assumptions that may not be realistic (for example, dividing toilets into two categories of conserving and non-conserving, when in reality toilets with many different flow rates exist). To analyze each end use of water changes over time, the analyst creates a computer model to estimate how many efficient devices are in use in the utility's service area (see Box 2 for a description of how "stock models" are used to estimate the market share of efficient devices).

To calculate the changes in water use from conservation and efficiency, forecasters may use off-the-shelf software or develop an in-house model. An advantage of using existing software packages is that it can minimize the chance of calculation errors and take advantage of computer code developed by experts in the field. Some of these models have been approved or promoted by industry or conservation associations. These models, however, are typically "closed-source" and proprietary and may not be available for others to review, making it difficult to understand the model assumptions. Three proprietary models that you may encounter include:

- **IWR-MAIN** was one of the first water demand forecasting software packages to simulate water efficiency (Dziegielewski and Boland 1989). It appears frequently in the literature from the 1990s and early 2000s, and some utilities continue to use custom versions of it.
- **The Demand Side Management Least Cost Planning Decision Support System (DSS)** provides 30-year water demand forecasts, water conservation forecasts and benefit-cost ratios of conservation measures and programs. It was developed and is sold by the consulting firm Maddaus Water Management.
- **The Water Conservation Tracking Tool** from the Alliance for Water Efficiency (AWE) is an Excel-based tool that can be used to evaluate the water savings, costs, and benefits of urban water conservation programs. In addition to providing users a standardized methodology for water savings and benefit-cost accounting, the tool includes a library of pre-defined conservation activities from which users can construct conservation programs. The Tracking Tool can adjust a water demand forecast to account for savings achieved through active conservation programs as well as code-driven savings resulting from the natural replacement of toilets, showerheads, clothes washers and dishwashers. Although it is recommended that users enter their own demand forecast, the Tracking Tool can generate a simple baseline demand forecast if the user does not have one. The Tracking Tool is available free of charge for AWE members.

The use of one of these models is a good sign. It means that the analyst has made an effort to include efficiency in the forecast. However, it does not guarantee the conservation estimate will be complete or accurate. The analyst must also select the correct conservation measures to include in the model, enter appropriate data in the software, and calibrate the model to match local conditions. Unfortunately, it is not usually possible to check calculations that were done using proprietary software, even where a forecaster thoroughly documents all the data and assumptions.

All long-range water demand forecasts should include the effects of water conservation and efficiency. At a minimum, forecasts should evaluate future efficiency savings for toilets and clothes washers. In addition to being among the largest uses of water in most residences (Figure 2), today's models use considerably less water than older models. Moreover, studies show that there are still many inefficient devices in homes and businesses across California. For example, a study based on data collected in 2009 found that less than half of toilets in California homes were efficient models (DeOreo et al. 2011). In addition, the first national standards for residential clothes washers were not implemented until 2011 (Table 1). This suggests that many (if not the majority) of machines in use today are older, inefficient models. Finally, forecasts should also include the effect of the Model Water Efficient Landscape Ordinance (MWELO).

A useful way to visualize the effect of water efficiency in your community is to make a plot of per capita water use over time. Many forecasts will already contain such a plot. If these data are presented, consider requesting it or creating the chart on your own from information available to you. Armstrong (2001) recommends the use of graphical displays of data to "better assess patterns, to identify mistakes, and to locate unusual events." These let the reader visually interpret these data and determine at a glance whether the inputs are realistic.

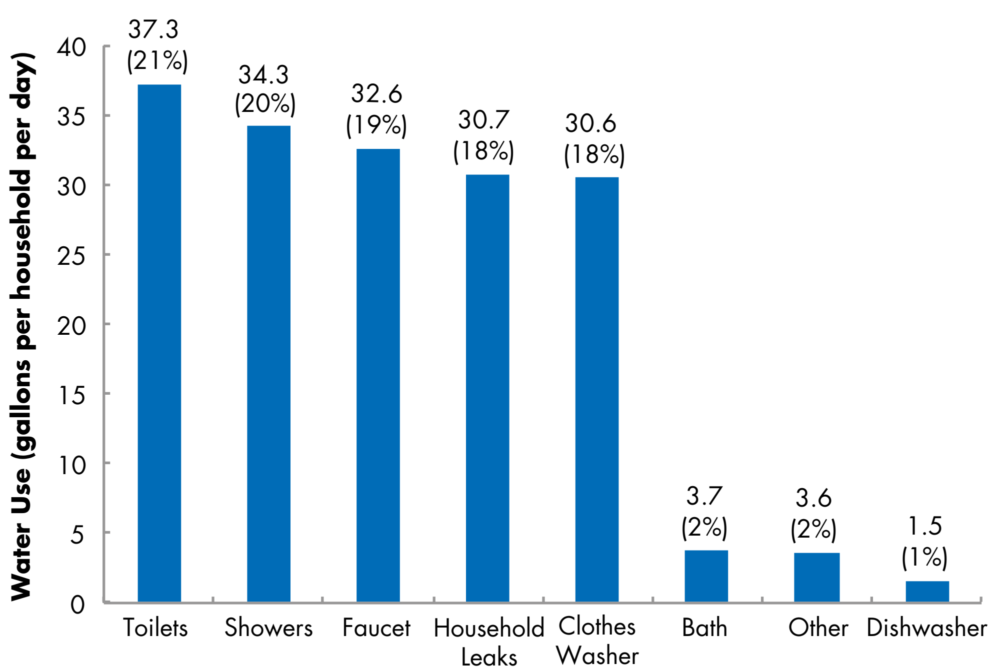
Long-term trends are important, but recent developments may be even more important, and should sometimes be given more weight. We have reviewed many recent demand forecasts and found that many of them fail to take into account recent history. The data they present show that per capita use has steadily declined for the last 10 to 15 years, and yet the forecasts tend to ignore or even reverse this trend. While it is possible that per capita use will remain steady or increase, forecasters should consider whether recent observations represent a trend that is likely to continue, rather than considering it an exception or anomaly.

Be wary if a forecaster claims that there is little remaining opportunity for improved water conservation and efficiency. International experience demonstrates that there is significant

Figure 2.

Average indoor water use in California single-family homes circa 2009

Source: Adapted from DeOreo et al. 2011



Box 2.

Estimating market saturation of water-conserving devices

Knowing the number of water-efficient appliances and fixtures in use in a community is important to accurately estimate how water use may change over time. Some utilities have used phone surveys or sampling in customers' homes to estimate the market saturation (or market penetration) of efficient devices (see e.g., Water Resources Engineering, Inc. 2002; MWD 2002). As an alternative to such studies, or to update estimates from older studies, analysts may use stock models to estimate the number of efficient devices in their service area and to estimate how it will change in the future. For example, the San Francisco Public Utility Commission recently used a stock model to estimate the number of efficient toilets, urinals, and residential washing machines (SFPUC 2016). These modeling estimates are most reliable when they are compared to real-world data from surveys or field studies (CWWA 2010).

If the demand forecast you are evaluating estimates market saturation, you should examine the analysts' results and assumptions to make sure they are realistic. Analysts often estimate a "fixture lifetime" or "failure rate" based on their "expert judgment" (i.e., best guess), because real-world data is hard to come by. In addition, there is now evidence that the "passive" turnover rate for certain fixtures, especially toilets, is not as high as is commonly assumed (DeOreo et al. 2015; DeOreo et al. 2011). The forecaster's assumption about the turnover rate can make a big difference in the estimate of conservation savings.

room for improvement, even when per capita use is low. Australians use an average of 54 gallons per person per day and Israelis use about 36 gallons per person per day (Israel Central Bureau of Statistics 2016; Turner et al. 2016). Both Australia and Israel have lowered their consumption dramatically by adopting new water-efficient technologies and water-saving habits. Forecasts should include the impact of future conservation and efficiency measures, even where per capita water use is already relatively low.

ACCOUNT FOR CHANGES IN ECONOMIC ACTIVITY

The type and scale of economic activity in a region is an important determinant of local water use. Throughout much of the 20th century in the United States, as the population and economy grew, so too did water use. Since 1980, national freshwater use began to decrease, while population continued to rise and economic activity remained strong (Donnelly and Cooley 2015). Similar trends have been seen in California and in communities across the United States (Fulton, Cooley, and Gleick 2012). This indicates that the link between economic growth and water use has been broken in many parts of the country, a phenomenon referred to as "decoupling."

A variety of factors contributed to this trend. Since the mid-20th century, the U.S. economy has shifted from one dominated by water-intensive manufacturing to a less water-intensive service-oriented economy (Short 2014; Johnston 2012; Council of Economic Advisors 2010). Additionally, state and federal policies have facilitated water-efficiency improvements among non-residential users (Cooley 2012). For example, the Clean Water Act, passed in 1973, established water-quality standards for water discharged into the environment, which encouraged dischargers to adopt more water-efficient technologies to reduce wastewater volumes and costs.

When water utilities forecast future demand for the commercial, industrial, and institutional sectors, they must first try to predict the type and size of economic activity likely to occur in their service area. Growth in water-intensive sectors, such as nurseries or food processing, could increase overall water use, while the addition of new office workers might result in only modest increases or none at all, given increasing residential and commercial water efficiency. Economic factors may come into play if the overall socio-economic status of a region is in transition. For example, a forecaster may also posit that water use will increase if the population becomes wealthier and residents purchase or build bigger houses with pools and larger landscapes.

In addition to growth or contraction of a sector, the way each sector uses water also affects total demand. Improvements in conservation and efficiency, in particular, can reduce the amount of water used per employee or per unit of product. It is important for the analyst to carefully consider water use for important industries in the service area as well as how it is likely to change in the future. A water utility often develops water factors for different industrial sectors using data from its service area, although compilations of such data are also available (Dziegielewski et al. 2000). While some authorities suggest that commercial and industrial water use has changed over time, trends are not well-understood or documented, and this is an ongoing area of research (Kiefer, Krentz, and Dziegielewski 2015; Brendle Group In Progress).

One of the common ways that forecasters incorporate economic changes is to focus on employment.[2] Using this approach, the forecaster estimates the number of future workers in different sectors of the economy. Many forecasters describe business sectors using the North American Industry Classification System (NAICS) codes (US Census Bureau 2016a). In other cases, forecasting may differentiate businesses according to similarities in water use patterns, such as solar manufacturing or fast-food restaurants.

After dividing businesses into groups, the analyst then estimates the rate of water use for each, often based on utility records and billing data or from water use factors in the literature (Kiefer, Krentz, and Dziegielewski 2015). These factors are typically expressed in gallons per employee per day, or sometimes gallons per account per day. These unit demands are then multiplied by the forecasted number of employees or accounts in a given sector. Typically, the forecasted number of employees is based on estimates from local planning organizations or the industries themselves, rather than being calculated in-house by the utility.

Economic forecasts are notoriously difficult to make and are rarely accurate in the long-term. Water utilities typically obtain these forecasts from another organization involved with regional economic planning, but this may not guarantee their quality or accuracy. The same organizations

2 While it would be more accurate to estimate water use based on production, e.g., the number of meals served or of the amount of steel produced, production data are not readily available. Employment data are often available from government or other sources, and thus it has become the standard practice to forecast commercial, industrial, and institutional water demand based on employment.

often play a role in promoting economic growth and jobs and may have an incentive to create overly optimistic forecasts of job growth. Consequently, it is worth comparing economic and employment forecasts from multiple authorities. Large differences in the forecast rate of change in employment or economic activity could be the sign of an unrealistic forecast. Another thing to look for is a forecast of economic growth that is significantly different from the historic average. If the forecaster is positing that growth will be much greater than what has occurred in the past, he should provide ample evidence for why this might be the case. Resources for finding other economic forecasts for California include:

- **California's Employment Development Department** provides county-level projections for employment by industry sector. "Long-term" projections are 10-year projections: http://www.labormarketinfo.edd.ca.gov/data/employment-projections.html
- **CalTrans** conducts periodic economic forecasts through its Office of Transportation Economics, Division of Transportation Planning. Current forecasts extend through 2040. http://www.dot.ca.gov/hq/tpp/offices/eab/socio_economic.html

In addition to verifying that rates of economic growth rate are realistic, you may wish to look at how the forecaster handles issues of economic downturns and recessions, which can have large effects on water use. Economists theorize that recessions are an inevitable and recurring feature of modern economies, but even experts cannot reliably predict when a recession will occur, how deep it will be, or how long it will last. Forecasts may be rendered obsolete by an economic disruption and should be regularly updated with new information. For example, a recent study by the Water Research Foundation found that, for the four utilities they examined, the most recent recession beginning in 2007 resulted in statistically significant reductions in regional water demand (Kiefer et al. 2016). The authors conclude that "it would be remiss to ignore the effects of the economy and the potential consequences of periodic business cycles in formulating future water demand scenarios." In practice, this means that assuming steady, uninterrupted economic growth over the next 20 to 30 years is probably not realistic, as it is sure to be punctuated by periods of decline or slower growth.

ACCOUNT FOR CHANGES IN WATER PRICE

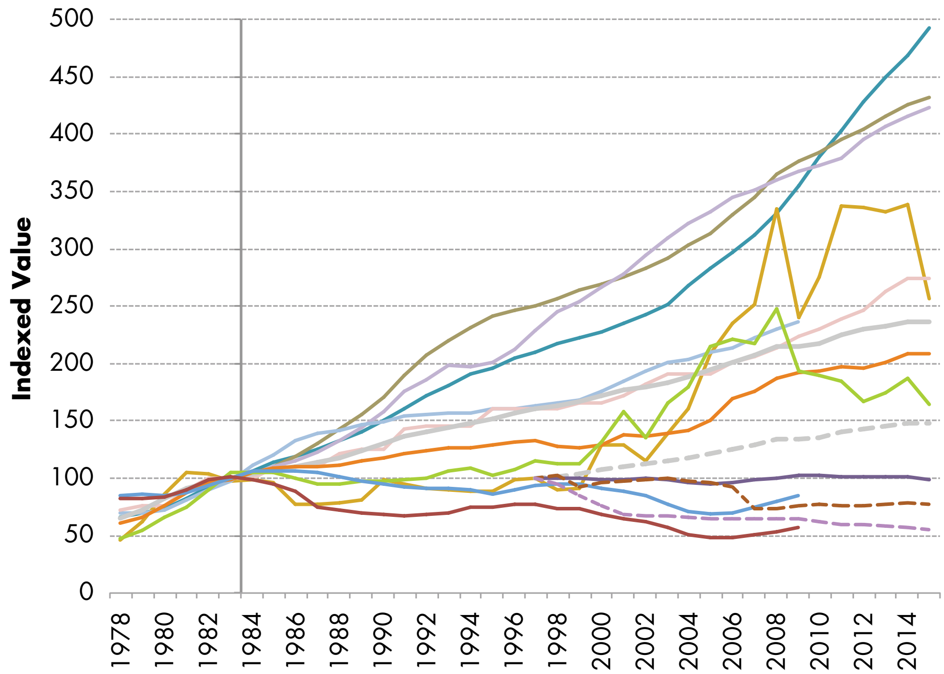
Most long-term forecasts should consider how water demand will change in response to price, especially where there is a reasonable expectation that water prices will increase faster than overall inflation. Over the last three decades, the price of water and sewer service has risen at twice the rate of inflation (Figure 3).[3] Somewhat paradoxically, expensive new water sources built to meet projected demand can lead to higher water prices, thereby reducing water use.

In economics, price elasticity refers to the relationship between the demand for a good or service and its price. If a good is elastic, a change in its price will have a large effect on the quantity of a good demanded; conversely, if a good is inelastic, changes in price will not have a large effect on demand. Price elasticities are almost always negative, meaning that as price goes up, demand goes down (or vice versa). A typical price elasticity for residential water service might be –0.3 (Taylor, McKean, and Young 2004). This means that if water prices increase by 10%, then the amount of water purchased would decrease by 3% (–0.3 times 10%). The assumption that per capita water demand will

3 Despite this increase, water is a relatively small part of the household budget for most Americans.

Figure 3.

Long-term trends in consumer prices for utilities



Note: The index is set to 100 for 1982-1984 except for telephone and wireless services, where the index is set to 100 for 1997. Year (*) indicates start of series.

Source: Beecher (2015)

remain constant in the future implies zero price response, which is hardly ever the case (Chesnutt et al. 2012). Outdoor water use is typically more responsive to price than indoor demand because it contains a larger "discretionary" component, such as landscape watering and pools, which customers are more likely to cut due to higher prices (Olmstead and Stavins 2009).

Note that price response and conservation are linked phenomena: customers respond to higher prices by altering their behavior (e.g., shorter showers, reducing lawn watering) or by investing in water efficient devices (e.g., low-flow showerheads, water-efficient landscapes). Because of this, some analysts believe that including both price elasticity and conservation in a forecast could result in "double counting" of the future water savings (see e.g., Rodrigo 2016). For example, in its forecasts, the Metropolitan Water District of Southern California calculated "price-effect conservation." They assumed that water demand will not respond strongly to price in the future because "much of the easily obtained water use efficiencies will be achieved by 2020." Yet they did not substantiate this claim beyond citing "professional judgment" (Metropolitan Water District of Southern California 2016).

When considering whether the forecast has adequately accounted for the effects of rising water prices on demand, it is important to look at recent history. If the price of water paid by customers has risen faster than inflation in the recent past, experience shows that many customers will reduce their water use as a result. If the trend toward increased water prices is expected to continue in the future (for example, to fund infrastructure upgrades), it is likely to drive down future per capita water demand. In some cases, forecasters will lump conservation and price effects together in a single analysis. It is especially important for the forecaster to consider the effects of price elasticity on water demand when price effects have not already been considered as a part of the analysis of conservation.

CHECK FOR CONSISTENCY WITH OTHER RELEVANT PLANNING DOCUMENTS

It may be useful to seek out other regional planning documents for your region to see whether the water forecast is consistent with other plans, for example for housing and transportation. As we have noted, water demand forecasters typically rely on information developed by other regional planning organizations, such as for projected population and employment. It is worth looking at whether the projected growth rates are similar across plans. Here are a few specific questions to have in mind as you review other planning documents: How do the projected rates of population and economic growth compare to other regional plans? Are there different assumptions about the size and style of future homes and buildings?

In California, large water suppliers are required to publish Urban Water Management Plans (UWMPs), which must contain a water demand forecast for the utility's service area for the next 20 years. The state requires that population estimates "be based upon data from the state, regional, or local service agency population projections within the service area of the urban water supplier" (California Water Code Section 10631). In addition, UWMP guidance "strongly encourages" the use of other planning processes and documents (DWR 2016b). In other words, water planners are encouraged to harmonize their planning with other agencies, but it is not a requirement.

As you review a demand forecast, you should assess whether the data and assumptions are consistent with those in other planning documents for the area. If there are important differences, you should press the water agency to consider how these different assumptions might affect forecasted water demand. Other relevant planning documents to examine might include: city and county general plans, water master plans, recycled water master plans, integrated resource plans, integrated regional water management plans, and groundwater management plans. These are listed, along with a short description, in Box 3.

Another reason to review these documents is to understand whether other agencies share a similar vision of the region's future. Other agencies' plans may represent a different vision of the future that is no less likely, such as a lower rate of growth or different patterns of economic development. Other agencies' plans will not necessarily be more accurate or less biased. Regional planning organizations often also play a role in promoting economic growth and jobs. Since they are also "boosters," they have an incentive to create rosy forecasts of job growth that may end up being too high. When looking at another agency's population or employment projections, if possible, find out first whether their past predictions have been accurate. In other words, how did their forecast rates of growth compare to observed growth in the region?

ACCOUNT FOR EXPECTED LAND USE CHANGES

Many communities are building denser residential developments, including more multi-family homes and detached, single-family homes on smaller lots. Researchers have predicted a continuing trend towards multi-family residential housing in California's coastal areas (Matkins and UCLA Anderson Forecast 2016; Hanak and Davis 2006). Indeed, statewide there are now more multi-family housing units being built, with their numbers of units surpassing new single-family homes since 2011 (US Census Bureau 2016b; CIRB 2016). This trend is linked to shifting tastes and development policies, and it accelerated after the most recent

Box 3.

Relevant local and regional planning documents

Plans and forecasts are created by a number of different agencies. As described above, it may be useful to compare projected changes in the economy, population, and demographics with these plans.

- **General Plans**: A planning document prepared by a local government. State law has required cities and counties to prepare plans since the 1920s, but only since 1971 has state law required that they actually be followed or implemented. Unfortunately, a water element is not a required part of any local government's General Plan.
- **Specific Plans**: Cities and counties may publish a specific plan for an area within their community to guide its development. Some are quite broad, containing simple statements of policy goals, while others are specific about their community's development plans and guidelines. In California, all specific plans must be consistent with the general plan for the jurisdiction within which it is located. These documents, or ones with similar purposes, are sometimes referred to as Community Plans or Area Plans.
- **Transportation Plans**: A local or regional agency may have prepared a transportation plan covering the same area served by your water supplier. Because this may have been prepared by a different group, with a different goals and legal requirements, it may offer a different perspective. These plans are usually created by one of California's 18 Metropolitan Planning Organizations (MPOs) and 26 Regional Transportation Planning Agencies (RTPAs). To find the transportation planning agencies in California, view the listings and map at http://www.dot.ca.gov/transplanning/orip/agencies.html.

In addition, other state and local agencies may have information pertinent to your demand forecast. These include:

- **The California Department of Finance** annually publishes population projections for counties. See http://www.dof.ca.gov/research/demographic/reports/projections/P-3/.
- **The Local Agency Formation Commissions (LAFCOs)**: Each county has its own LAFCO, which are agencies formed by the California legislature to oversee the boundaries of cities and special districts. Their mission is to prevent urban sprawl and "prepare studies to independently assess the relationship between service demands and community needs." To find your LAFCO, do a web search for "county name + LAFCO."
- **Regional Councils of Government**: At a regional scale, these councils publish their own projections, which may be more detailed than the state's projections. There are 37 of these regional government agencies that participate in "planning and program implementation on a wide variety of issues, including transportation, housing, the economy, energy, and the environment." For more information, and to find your local agency, see www.calcog.org.

Continued on next page.

Box 3. (continued)

Relevant local and regional planning documents

- Some cities may also have their own forecasts that they have created for other purposes. It may be worth inquiring with a city's Planning Department.
- Many universities have centers for demographic or economic research, for example:
  - **University of Southern California**, Pop Dynamics. http://popdynamics.usc.edu/
  - **University of California, Berkeley**, The Department of Demography, http://demog.berkeley.edu/
  - **University of California, Los Angeles**, California Center for Population Research, https://ccpr.ucla.edu/
  - **California State University, Fullerton**, Center for Demographic Research (focuses on Orange County), http://www.fullerton.edu/cdr/

economic downturn. The net result of this trend is smaller homes with less landscaping and lower outdoor water use, pushing down per capita rates of water use in new homes.

In reviewing a long-range water demand forecast, you should examine whether projections for development and housing reflect current plans or trends for housing density. Forecasts based on existing density may overestimate water use. The best source for information on anticipated changes to land use is the General Plan. For nearly 100 years, cities and counties have prepared General Plans that guide the physical development of their community and describe the policies that dictate land use decisions. DWR, in its guidance for creating Urban Water Management Plans, encourages water suppliers to collect relevant information from other local agencies, but warns them not to rely on information that may be out out-of-date, for example housing projections in General Plans that no longer represent current tastes and trends. Specifically, DWR notes that "growth in many communities reflects a trend to smaller lots with larger homes than the existing customer base. A General Plan completed prior to 2005 likely reflected the trend toward larger lots and rapid build-out—matching conditions of the late 1990s. Today, however, land-use agencies are promoting trends to more dense residential developments, mixed uses, and slower growth" (DWR 2016b).

A forecaster will usually incorporate land use changes into water demand forecasts by examining the how water use varies for different types of land use and buildings in the utility's service area. Factors influencing water use can include, for example, the number of bedrooms, presence of a garden, and the size of the landscaped area or parcel (Fox, McIntosh, and Jeffrey 2009; DeOreo et al. 2015). The analyst typically calculates the average water factor for different types or buildings and land uses, usually in terms of gallons per day per building unit or acre. The analyst may modify the water factor based on anticipated changes in future water use. These water factors are then multiplied by the projected number of units or acres, which the analyst usually obtains from other local planning agencies. The City of Santa Cruz, for example, categorized residential customers according to whether they live in either a single-family or multi-family unit. This enabled the city to incorporate known differences in how customers in each category respond to drought, price, weather, and income. The city further divided customers by location (i.e., inside and outside the city). This allowed them to account for the faster growth in multi-family homes compared to single-family homes inside the city, while the reverse is true outside the city (Mitchell 2015).

You may come across demand forecasts that estimate water use for a "built-out" service area. In this case, you should ask whether this assumption is realistic over the time span of the forecast. Buildout refers to "the state of maximum development as permitted by a plan or regulations." This can be informative as it provides an upper bound for estimates of future water use. However, there are two reasons why it may not be realistic. First, in many areas, existing development is at a lower density than what is theoretically possible under the zoning laws for that area. This is particularly a concern where the analyst has conducted an "ultimate" buildout analysis, which assumes that all areas are developed to their fullest possible extent. This would mean that in areas that are already developed, structures would have to be torn down to make room for newer, higher-density development. This may or may not be likely. Second, even if an area could achieve build-out, it may not occur during the time horizon of even long-term water demand forecasts (typically 20-30 years). If the forecaster is predicting a much faster rate of development than the region has seen historically, he may over-predict future water use.

You should also evaluate whether the projected growth in housing is realistic. One way to do this is to compare the projected number of new homes built per year to current and historic rates of housing development, sometimes referred to as "housing starts." The United States Census Bureau publishes data on housing construction:

- **US Census Bureau Building Permits Survey**: https://www.census.gov/construction/bps/

These data on housing construction are available monthly, year-to-date. It is also available at a variety of geographic scales: e.g., for states and for selected metropolitan areas. The latter is probably the most useful, as it is the smallest, most local scale. The Census Bureau does not report data strictly within city boundaries, but for larger geographic areas referred to as Metropolitan Statistical Areas. These areas typically cover an entire county, or occasionally multiple counties.[4]

ACCOUNT FOR CLIMATE CHANGE AND DROUGHT

It is now broadly recognized that climate change will have widespread effects on freshwater resources. Climate models disagree as to whether future precipitation is likely to increase or decrease in California (Berg and Hall 2015). Nevertheless, there is a broad consensus among climate scientists that temperatures will increase (Davidson et al. 2014; Moser, Ekstrom, and Franco 2012). Figure 4 shows projected increases in statewide annual temperatures in three 30-year periods under different emissions scenarios produced using state-of-the-art climate models. These models predict that average temperature in California will increase by 1.5 to 5°F by mid-century, with further increases expected in the following decades.

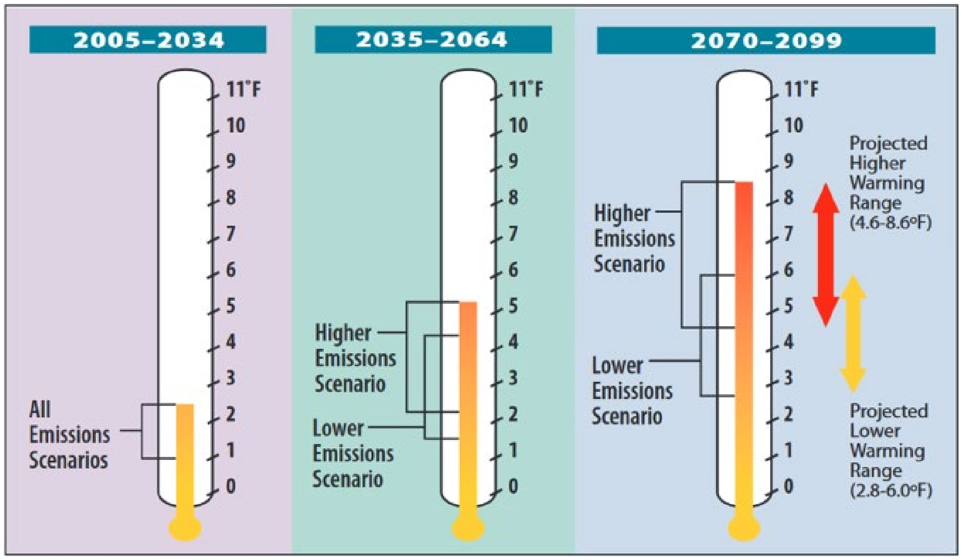
Warmer temperatures have a direct effect on outdoor water use. In California, as in much of the

4 Metropolitan statistical area maps can be found at https://www.census.gov/population/metro/data/maps.html.

Figure 4.

Projected average temperatures in California with warming due to climate change

Source: Reprinted from *Our Changing Climate 2012*, a report by the California Climate Change Center (Moser, Ekstrom, and Franco 2012)



West, more than half of the water used in urban areas is used outdoors (Heberger, Cooley, and Gleick 2014). Some of this is for washing cars or sidewalks, or for filling pools and spas; however, the vast majority is for landscape irrigation. Recent research has shown that, holding other things equal, warmer temperatures would increase California's landscape water demand by 10% to 15% by the year 2050 (CCTC 2007; Grundstein 2009; Lutz, van Wagtendonk, and Franklin 2010). These studies also provide evidence that the effects of climate change are already driving changes in landscape water consumption. Measured and estimated temperature, evaporation, and crop water use are already slightly higher than they were in preceding decades.

Water requirements for cooling buildings are also likely to be affected by warmer temperatures. Cooling towers are widely used in California high rises, shopping malls, and schools, and they use large amounts of water. For example, Los Angeles estimated that cooling towers use 2.5 billion gallons per year in the city (Smith 2016). While evaporative cooling systems are less common in the residential sector, some homes use similar devices for cooling, referred to as "swamp coolers." While there is little research or practical guidance on how evaporative cooling will change, warming is expected to cause an increase in water use, other things being held equal.

The effects of climate change should be included in long-range demand forecasts, especially for those areas with significant outdoor water use. According to DWR, areas where demand during the summer is more than 50% higher than in the winter should do so. In addition, DWR recommends that utilities include climate change in their long-term demand forecasts if their water use for industrial, residential, or commercial cooling is significant (DWR 2016b). Until recently, there was little practical guidance available for water planners and managers about how to incorporate climate change into water demand forecasts. However, recent studies have contributed data and analytical methods to better predict how climate change will affect future landscape water use (Christian-Smith, Heberger, and Allen 2012; Kiefer et al. 2013).

Analysts can simulate the effects of climate change on landscape water use by using computer models originally developed for croplands. Agronomists and hydrologists estimate crop water demand, or theoretical irrigation requirements, using the concept of evapotranspiration. Evapotranspiration, or ET, is a combination of evaporation of water from the soil and plant surfaces, and transpiration, which is water lost by the plant. Evapotranspiration is affected by hydro-climatic factors, including air temperature, wind speed, humidity, solar radiation, and cloud cover. ET is anticipated to increase along with rising temperatures due to climate change.

In addition to the warming climate, future droughts are likely to have a major impact on water supplies and demands. Droughts are a natural occurrence in California, and climate change is expected to make droughts more frequent and intense (Moser, Ekstrom, and Franco 2012). Since 1900, California has experienced drought an average of 2 years out of 10 (DWR 2016a).[5] Based on this history, it is extremely likely that California cities will experience one or more droughts in the next few decades.

Droughts can have two opposing effects on urban water use. Dry conditions increase demand for landscape irrigation. A report by the state Legislative Analyst's Office noted that urban use tends to increase by up to 10% during dry years due to increased landscape water use (Freeman 2008). On the other hand, prolonged drought can prompt state and local authorities to call for water conservation, driving water use down. Although it is common for utilities to plan for drought-induced supply shortages, they too often fail to consider how drought may affect demand.

Forecasts should consider the likelihood of more frequent and intense droughts in the future. The state already requires a simple analysis of how drought could affect water supply and demand in Urban Water Management Plans. Utilities are required to describe how demand can vary during a normal year, a single dry year, or over three or more consecutive dry years. In May 2016, Governor Jerry Brown issued an executive order requiring analysis of longer droughts in the future. Among other things, the order directs water suppliers to plan not only for more frequent droughts but for droughts that are at least 5 years in duration in their Water Shortage Contingency Plans, a required element of UWMPs (Brown Jr. 2016). However, experience and research shows that California has experienced droughts that last much longer than three years. Moreover, prolonged and more severe droughts may be more common in the future (Diffenbaugh, Swain, and Touma 2015; Mao, Nijssen, and Lettenmaier 2015; Williams et al. 2015). Therefore, forecasts should examine the impact of longer, more severe drought on local demand.

Some forecasters assume water use will return to "normal" levels following a drought; however, this is not realistic.[6] Experience in cities throughout the West shows that drought-induced water-use reductions often persist, even after the drought ends (Cohen 2011). This happens for two reasons. First, many residents respond to drought conditions by installing water-conserving appliances or replacing their lawns with less-water intensive landscaping, actions that have long-term impacts. Second, drought can cause a permanent

5 According to DWR, the state experienced serious droughts from 1928–34, 1976–77, 1987–92, 2007–2009, and 2012-2015; i.e., since 1900, California has experience drought in 22 out of the last 115 years, or 19% of years. If we assume that the past is a reliable guide to the future, we can estimate that there is a 98.5% chance that there will be one or more drought years in the next 20 years and a 55% chance that there will be four or more drought years.

6 It is difficult to determine exactly how much urban water use in California rebounded from past droughts. Detailed measurements of urban water use were not available until recently. It was only in July 2014 that the State Water Resources Control Board began requiring urban water suppliers to report monthly water production (Brown 2015).

shift in peoples' attitudes and behaviors related to water use. In Australia, for example, it has been well-documented that per capita water use, which fell dramatically during the Millennium Drought, has remained low even though the drought has ended (Beal, Makki, and Stewart 2014).[7] If a forecast includes rebound, it should also include a careful analysis of the conservation and efficiency measures that were implemented during the drought, measures that may be sustained even after the drought ends.

ACCOUNT FOR UNCERTAINTY

The further into the future we project, the more that random occurrences and unforeseen events make our predictions less accurate. As we have seen, when making long-range predictions, a forecaster has to make many assumptions about future changes to technology, laws, and the economy, which are notoriously difficult to predict. Forecasters should acknowledge the uncertainty in the data and methods they use, and reflect this in their forecast. While psychologists have found that "people tend to find uncertainty disturbing" (Tetlock and Gardner 2015, 68), we should not confuse uncertainty with a lack of rigor. Rather, acknowledging uncertainty is a way of being honest about the limitations of a forecast.

However, forecasting can still be a useful activity when it feeds into a flexible decision-making process, especially when forecasts are honest about the range of possible futures. It is attractive for water utilities to develop plans based on a single estimate of future water demand. It provides a clear and concrete goal on which to base investment decisions. A drawback of such point estimates is that "external parties can perceive them as if they are entirely accurate and certain" (Kiefer and Porter 2000). Replacing this paradigm with one that incorporates uncertainty and risk may be uncomfortable. Nevertheless, decision-makers should be aware of uncertainties and their magnitudes and should take them into account when making judgments about the future. It is more useful when forecasters show a range of realistic possibilities, and where possible, assign probabilities to different outcomes.

Uncertainty is familiar to most of us from the "margin of error" we see reported with political polls. Error bars are a mathematical way to represent the extent of unavoidable errors in data collection and analysis. Uncertainty can be modeled in a variety of ways. In the following section, we describe some of the most common ways that forecasters incorporate uncertainty into future projections.

Monte Carlo Simulation

One way that forecasters incorporate uncertainty into mathematical models is to use a technique called Monte Carlo simulation. This falls under a class of stochastic (or random) methods used by scientists and engineers. This is a computerized method for running simulation models many times, using a different (but realistic) set of input parameters each time.

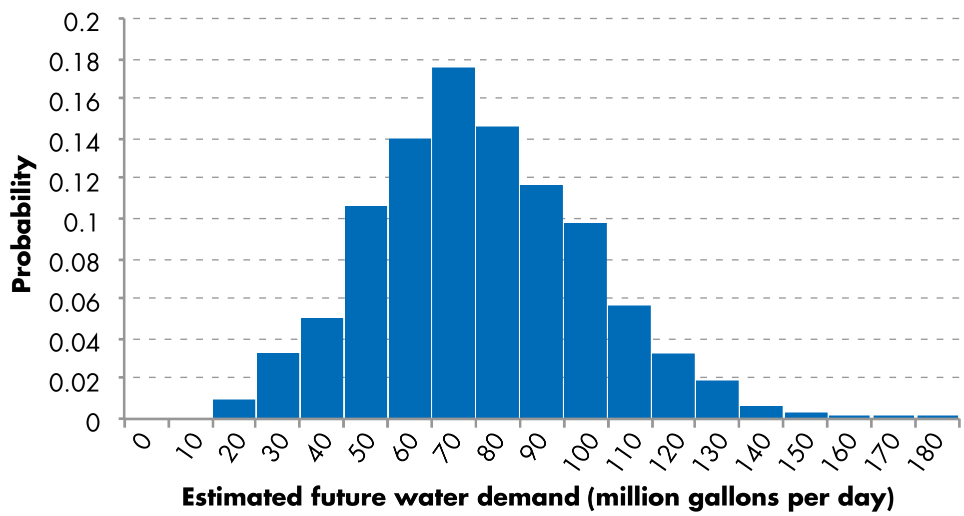
Figure 5 shows an example of output from a Monte Carlo style simulation of future water demand. These are the results of running a water demand simulation model 1,000 times. The plot is a histogram representing the frequency of the

7 This study demonstrates that while Australian cities experienced some rebound in water use when the drought ended, residents made large and permanent reductions in their water use. Pre-drought consumption in Southeast Queensland was 80 gallons per capita per day (gpcd), which declined to 32–37 gpcd during the drought and increased to 47 gpcd in 2012 after the drought ended. This indicates that there was a permanent change in water use, most likely driven by changes in both technology and behavior.

Figure 5.

Example output from a Monte Carlo style forecast of water demand

Source: After Billings and Jones 2008



water use predicted by a model. Here, the most frequent result was between 70 and 80 million gallons per day (mgd), which occurred in about 17% of the simulations. There were also results as low as 20 mgd and as high as 160 mgd, although these extremes occurred with far less frequency.

Monte Carlo simulation allows us to express our forecast probabilistically. We can make statements like, "according to our model, there is a 5% chance that water demand will exceed 120 mgd in the next 30 years" or, "there is a 75% probability that water use will be between 60 mgd and 90 mgd." Replacing a single prediction about the future with statements of probability, we can make more nuanced statements about possible futures and better evaluate risks. Suppose for instance, that during a drought, the safe yield of our water system is 100 mgd. Water managers may be willing to tolerate a 10% chance of exceeding this threshold. Then again, if there were a 90% chance that demand will exceed 100 mgd, it would probably change the utility's decision-making dramatically.

Scenario-Based Planning

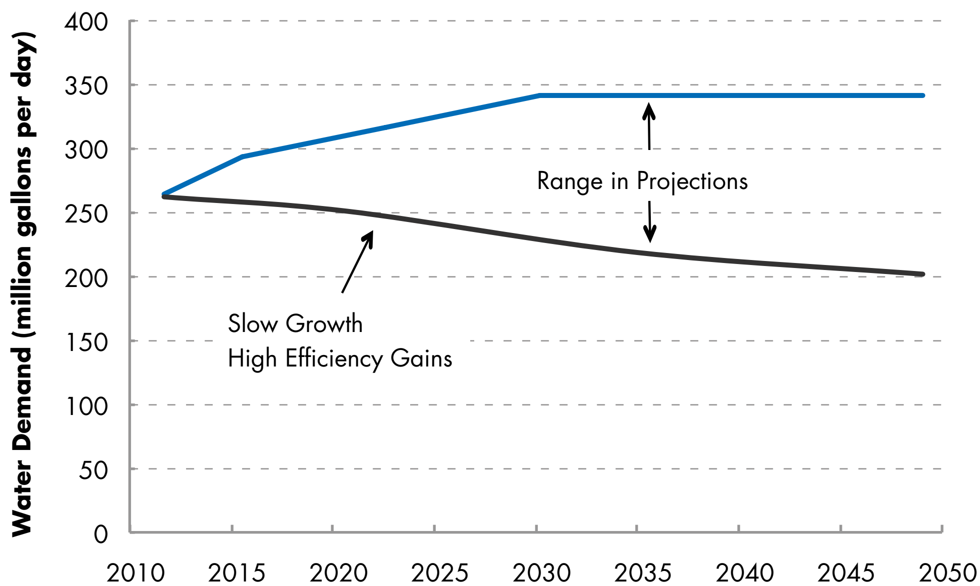
Another way to create a forecast that addresses future uncertainty is through scenario building. Scenario-based planning is premised on the idea that, while we cannot predict the future, we can nonetheless gain valuable insight by comparing different possible paths to the future. In this way of thinking, a forecast does not need to be accurate in order to be useful. Rather, the analysis describes the consequences of choices or policies on a wide range of plausible future conditions (Gleick et al. 2003). For these reasons, DWR now issues multiple scenarios of water supply and demand in the California Water Plan, rather than a single forecast (see Gleick 1995).

Figure 6 shows an example of scenario-based forecast from the city of Phoenix, Arizona (Frost 2012). According to the city's chief water planner, Doug Frost, it is "difficult to predict long-term technological demographic and economic trends." So instead of trying to develop a single forecast of future water use, his department endeavored "to provide a range of realistic possibilities to assist with planning." The city's water department created three scenarios, representing different assumptions about growth and water efficiency. The range in projections in Figure 6 shows that by 2040, the difference between the high and low scenarios is more than 100 mgd. Each of the scenarios might be considered a "storyline" describing different programs and policies. The

Figure 6.

Scenario planning to project alternative water use futures in Phoenix, Arizona

Source: Redrawn from Frost (2012)



point is that any one of these futures is possible, and that the policies we choose will determine which path becomes reality. Despite this, when the authors are the ones who decide which scenarios to analyze, it may invite bias into the analysis. Therefore, forecasters should seek input on the range of possible scenarios from individuals and groups with a range of perspectives and viewpoints, as discussed in the following section.

We have presented two methods that are commonly used by forecasters to better portray future uncertainty. Stochastic methods, such as Monte Carlo simulations, are mathematical methods that develop a set of outputs with their associated probabilities. Scenario-based planning is a method for incorporating qualitative information, developing different forecasts based on different pathways that are likely. Decisionmakers will benefit from using one or both of the techniques described here to better understand the range of possible futures. When this feeds into a flexible process, it will help in crafting plans that minimize costs to ratepayers and invest in infrastructure at the time it is really needed. If your utility is not already practicing one or more of these methods, you should urge them to do so.

ENSURE TRANSPARENCY, STAKEHOLDER ENGAGEMENT, AND REVIEW

In the preceding sections, we discussed the importance of using good data and methods to produce forecasts. Equally important, the entity conducting the forecast should follow an open and transparent process. This means including ample opportunity for interested citizens and other stakeholders to review forecasting data, models, and assumptions. Technical and peer review is vital for forecasts that will be used as the basis for important decisions or large investments. Such a process will not only help to increase the public's trust and acceptance but can also help make forecasts better. In the following section, we provide suggestions for improving the demand forecasting process.

Transparency means that the public has the right and the means to examine decision-making processes. This means, at a minimum, that water utility meetings should be open to the public, and important decisions are open to discussion. Utilities can further promote transparency by following a process for publishing the forecast that allows interested parties to participate and provide feedback. Methods should be clearly described, such that others can audit the forecasting methods and replicate them. Allowing full access to forecast data via a website allows others to replicate the forecast, or to re-analyze them using different methods (Armstrong 2001, 28).

Another important consideration related to transparency is that the utility conducting the forecast should clearly state the purpose of the forecast. Forecasters should be upfront about the intended use of the forecast and the decisions that might be affected by it (Armstrong 2001). Given the uncertainty inherent in long-term forecasting, utilities must disclose when the forecast is used to make expensive, long-term decisions.

Further, the utility should be careful to avoid conflicts of interest. In particular, the engineers or consultants who are developing the forecast should not be involved in or allowed to bid on the planning, designing, or construction of water supply projects. This would create an obvious incentive to overstate future demand. Forecasting expert J. Scott Armstrong recommends that the forecasting process should be separate from the planning process: "Separating these functions could lead to different reports such as ones showing forecasts for alternative plans. This principle is sensible and important, yet it is often ignored" (Armstrong 2001).

In addition, periodic stakeholder engagement is important throughout the forecast development process. The forecast should be discussed at a public meeting, with enough notice and opportunity for the public to take part.[8] In addition, the public should be allowed sufficient time and opportunity to review the materials and provide feedback. Transparency helps the utility build good relationships with its customers, but this is not its only use. Transparency can improve forecasting by providing an opportunity for stakeholders to provide critiques that will often improve the forecast. Indeed, research shows that forecasting is more accurate when forecasters are open to outside viewpoints. Philip Tetlock, a political scientist and the University of Pennsylvania, has found that the best forecasters are not necessarily those with the most expertise; rather, the best forecasters are those who seek to incorporate a range of viewpoints, perspectives, and data, even when these contradict their own beliefs (Tetlock and Gardner 2015).[9] Likewise, water supply planners would be wise to invite critique from a range of perspectives and should welcome outside input.

Even though peer review is standard practice in many fields of science and engineering, it is not widely implemented for water resources planning and decision-making. Independent peer review by qualified experts can be accomplished in a number of ways. Experts can be recruited to critique the structure of the forecaster's model and the model inputs. Seattle, for example, used a peer-review process for their water demand forecast, enlisting university researchers to conduct an independent review. Reviewers scrutinized the mathematical modeling and assumptions and made several recommendations for how it could be improved (Palmer et al. 2006).

8 California state law governs how legislative bodies must conduct their business in order to ensure transparency and public engagement. For more information about the requirements of this law, known as the Brown Act, please see the reports from the California Attorney General's Office (2003) or the League of California Cities (2010).

9 Tetlock has studied the performance of expert forecasters since the 1980s. He and his team have found that many experts rarely scored better than chance would dictate. In other words, flipping a coin would have given equally accurate forecasts. Additionally, they found that the more frequently an expert appeared on television, or the more credentials an expert held, the less accurate were his or her forecasts.

Aside from a formal peer review, technical review can also help catch errors that would be difficult or impossible to spot by reading a report. When data and statistics are involved, mistakes and errors in reasoning are surprisingly common, even among working scientists and engineers (Reinhart 2015). Many, if not most, forecasts are calculated with spreadsheets like Microsoft Excel. Raymond Panko, a professor at the University of Hawaii and perhaps the world's leading experts on spreadsheet errors, wrote that, "fifteen years of research studies have concluded unanimously that spreadsheet errors are both common and non-trivial" (Panko 2000). Unsurprisingly, the larger and more complex the spreadsheet, the more errors it contained. In addition to helping improve the model's structure and parameters, independent reviews can help catch unintended errors.

This is not to say that analysis is less prone to error when it uses off-the-shelf commercial software. Scientists from the University of Wyoming and the US Geological Survey (Parker et al. 1995) studied examined how water utilities use IWR-MAIN, a water demand forecasting model popular in the 1990s and early 2000s. They found that many users did not understand the software's conceptual model of how the world worked. Nor, they found, did many users take sufficient care to set it up properly with appropriate input values.[10] Regardless of the software or methods being used, whenever forecasting involves complex calculations or large data sets, they should be audited by a qualified expert.

10 Early versions of the software included "defaults" for many of the model variables. While this is useful for an analyst with limited time and a limited budget, these defaults might not represent the local reality.

CONCLUSION

"The best way to predict your future is to create it." *–Abraham Lincoln*

Historically, many water utilities forecasted water demand by simply extrapolating historical water use based on population and economic growth. From the 1950s to the mid-1980s, water use in many cities and suburbs grew roughly in proportion with growth. However, a fundamental transformation has taken place in the urban water sector in the last few decades, and the link between water use and growth has been broken in many places. Demand forecasting has been slow to keep pace with these changes, with water suppliers routinely overestimating future water demand. Overestimating future demand can result in unneeded water supply and treatment infrastructure, higher water bills, and greater environmental impact.

The purpose of this guidebook is to provide a resource for community groups and others to evaluate the need for new or expanded water-supply projects. We focus on long-range forecasts of future water demand. However, forecasting future demand is only one-half of water supply planning. The question of alternatives is equally important. If we are confident that water demand will likely exceed the supply, before proceeding with expensive infrastructure projects, we should ask whether other alternatives have been properly considered. Utilities should thoroughly analyze alternative water sources which may have a lower cost or lower environmental impact. A utility should also consider whether it can maintain reliable water service through demand management programs to reduce water use.

If you were motivated enough to read this far, you have something important to contribute to helping water utilities make better forecasts. There is ample evidence that forecasts are improved by incorporating a diversity of viewpoints and that decision-making is improved by considering all the outcomes that are likely. Better forecasting will drive better management and investment decisions, saving ratepayers' money, preserving water, and protecting the environment.

Glossary

Accuracy	Accuracy refers to how closely the prediction agrees with the actual outcome.
Active conservation	Water savings that occur as a result of programs run by a water utility.
Build out	Refers to "the state of maximum development as permitted by a plan or regulations." Water demand forecasting often refers to planning documents to predict how much development and what kind of development there will be in the future to help predict how much water will be needed.
Census	Counting up all of something. Contrast with a sample, which means examining part of a population to understand what the whole is like. The United States Census, mandated by the Constitution, attempts to count all of the people in the country, and also gathers information about demographics, housing, and utilities.
Demographics	Characteristics of a population, often referring to statistics on race, income, gender, age, education, and housing.
Econometric	A term often used by economists to refer to the use of linear regression. This is a statistical method used to see how different variables are correlated, or related to one another. For example, an econometric analysis may seek to determine how water demand is related to the price paid by the customer.
End use	In urban water management, refers to the type of water use inside a home or business, for example, shower, toilet, faucet, etc.
Gap analysis	An analysis of likely future water supply and demand. The projected shortfall is the "gap" that needs to be filled by either through "supply augmentation" or "demand management."
gpcd	Gallons per capita per day
mgd	Million gallons per day

Monte Carlo simulation A computerized method for running simulation models many times, and during each iteration or realization, setting the inputs or parameters to random values sampled from a distribution. For example, rather than setting population growth rate at 2%, we may decide we do not know the true value, and allow this value to float from 1% to 3%. The computer program will pick a random value within that interval every time we run our simulation.

Natural replacement A term used by water analysts to describe the replacement of old water-using appliances and fixtures with newer models. Natural replacement refers to units that are independently replaced by their owners, e.g., during a remodel or when the old one wears out, and not as a result of a program run by the water utility.

Passive conservation Passive conservation refers to water savings resulting from actions and activities that do not depend on direct financial assistance or educational programs from the district. These savings result primarily from (1) the natural replacement of existing plumbing fixtures with water-efficient models required under current plumbing code standards, and (2) the installation of water-efficient fixtures and equipment in new buildings and retrofits, as required under CALGreen Building Code Standards.

Price elasticity Refers to the relationship between the demand for a good or service and its price.

Rebound effect Used to describe the increase in water use following the lifting of drought restrictions or an economic downturn. In the past, it was often assumed that rates of water use would fully return to “normal” pre-drought levels. However, data show that some of the water-use cutbacks are more lasting, as residents install efficient fixtures and landscapes, and permanently alter some behaviors.

Stochastic Random. When forecasters refer to a stochastic model, it refers to a model where the parameters, or inputs, are not given a single value. Rather, inputs are described by a range, or distribution, of values and set to a random value within that distribution each time the model is run. See also Monte Carlo simulation.

Time-series data A time series is a sequence of data points plotted versus time. For example, a water manager may analyze measurements of monthly water use taken over several years for patterns and trends.

Uncertainty A state of imperfect or unknown information. In forecasting, we refer to the uncertainty in an outcome to mean that some part of what happens in the future is subject to randomness and chance, and therefore impossible to predict.

Water duty factor A way of expressing the amount of water used for different land uses, usually expressed in units of gallons per day per acre (DWR 2016b).

Water-neutral growth Policy requiring that new development not result in a net increase in water use in a community. This is usually accomplished by requiring the developer to fund "offsets," for example, by paying for water efficiency projects elsewhere in the community. A recent article found 13 communities in the US with such a policy (Dickinson 2015).

Zoning Zoning is the primary way that local governments in California (and elsewhere in most of the US) regulate land use and building. Cities publish zoning maps that show the boundaries for areas with different designated uses, such as residential, commercial, industrial, and agricultural. Zoning can cover a range of topics, like the style, height, and density of buildings. Water and environmental concerns may also be addressed through zoning ordinances, for example by requiring water-efficient landscaping.

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