Forecasting Future Demand for a Water Utility: An Overview of Best Practices and Common Pitfalls

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INTRODUCTION

Accurately forecasting future demand for water is imperative for utilities dealing with scarce groundwater, environmental constraints, more restrictive permit conditions, and legal challenges. Utilities, water managers, and planners often expend significant time and resources forecasting water demand, but often overlook common pitfalls undermining the accuracy and defensibility of forecasts. Although issues vary with each utility's data and sometimes require complex solutions, the overview presented in this paper will increase awareness of common pitfalls and the best practices to avoid them.

Estimating Current and Historic Population Served by the Utility

Accurate estimation of current and historic served population is the starting point for projecting water demand, yet it is often taken for granted. These population estimates serve as a starting point for population projections and as the basis for calculating historic per capita water use. Per capita calculations coupled with population projections typically serve as the basis for water demand forecasting.

For per capita calculations, estimates are generally required for the past completed year and some number of prior years. Using an average of multiple historical years helps offset fluctuations in annual rainfall and other factors influencing water use. Water management districts often request data on average annual served population over the past five years as a basis for water use permitting projections. Although a five-year average may be an adequate proxy for future per capita use, this is not always the case. Served population must be estimated accurately and consistently throughout the historical period, and shorter or longer historical periods or other adjustments may be required to address certain recent changes, including:

- extreme rainfall or drought conditions so atypical that they abnormally skew the average
- changes in water rates, conservation measures, and irrigation restrictions
- changes in the sources of water that affect consumption (e.g., reuse provided at a lower cost per gallon may encourage inefficient irrigation)
- changes in treatment processes that result in a higher or lower proportion of water lost
- new growth that is different from historical customers based on income, density of development, and the percentage of customers with irrigation systems or private irrigation wells

Figure 1. Projected dwelling units per acre at build-out in St. Augustine. High density is in red, moderate in orange, and low in yellow.

The estimation and projection of served populations based on political boundaries can result in significant errors, because service areas and city boundaries rarely coincide, and large self-supplied populations (those with private wells) may reside within a utility's potable service area. The common assumption that all population within a utility's potable service area is served or that the self-supplied population is negligible is often incorrect. Self-supplied population in a service area is typically between 5% and 20% of the total population, but can be as high as 70%. Including the self-supplied population in the served population estimates will result in projections of served population that are too high, but estimates of historic per capita use that are too low. However, these errors do not typically offset. If the common assumption that all future growth within a utility service area will be served is used, the demand projections will be lower (due to the inaccurate per capita data) despite the higher population. Including the population of an enclosed private utility would have the same effect.

In a recent project for a large utility requiring the geocoding of customer data (locating customers on a digital map), the utility was surprised that 22% of the service area population was self-supplied. Had that work not been performed, the utility would have likely projected a future per capita use that is 22% too low. Because both the water management district and the utility assumed that all future growth in the service area would be served by the utility, and because the projected population growth was agreed to by both parties, the water demand projected for future growth served by the utility would also have been 22% too low.

Typically the best data source for estimating current and historic served units is the utility's billing data. Querying billing data for

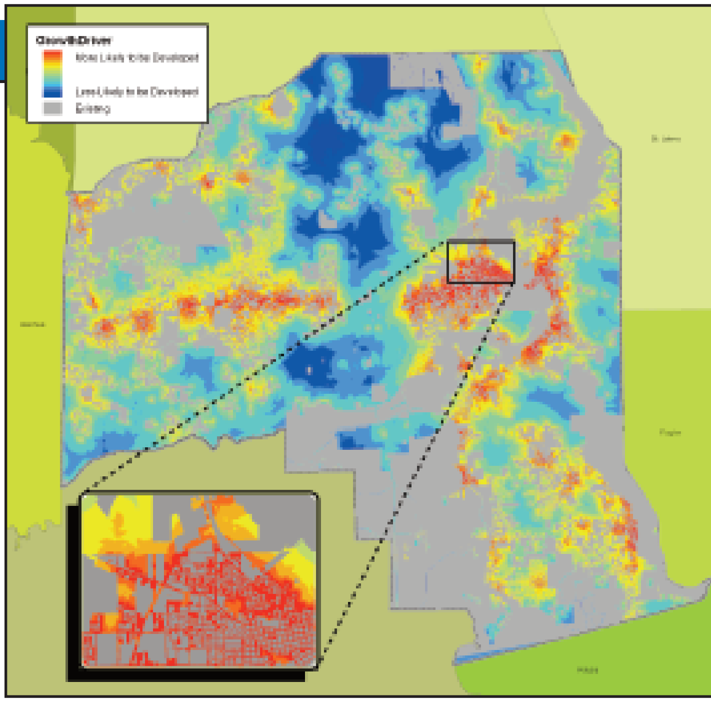

Figure 2. Growth Drivers Model, Putnam County. High growth probability is in red, moderate in yellow and low in blue.

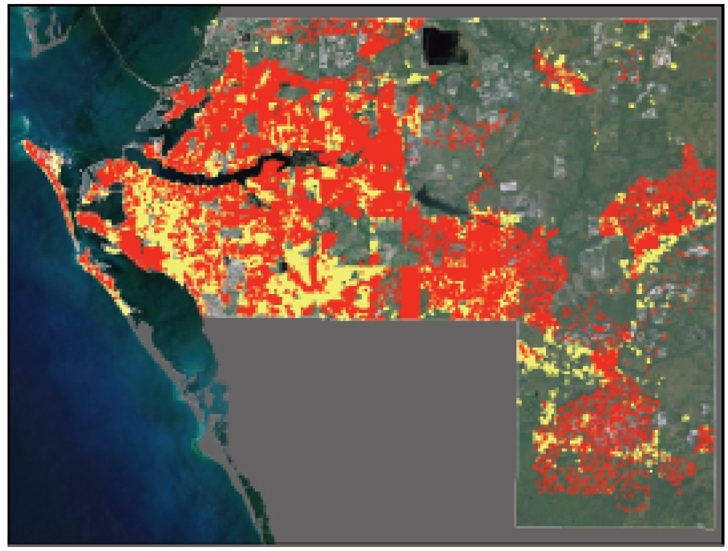

Figure 3. Population forecast dot density map of Manatee County. The 2008 base year population is in yellow, and the 2008-2030 population growth is in red.

residential customers can sometimes be complicated by outdated or poorly designed databases, databases with multi-family customers grouped with commercial, etc.; however, billing data are still normally the best source for estimating currently served residential units. Any master metered connections must be translated to the number of residential units they serve using one or more of the following: property appraiser data, census data, electric meters, or the billing data itself. Using an average number of residential units served over the year mitigates any seasonal fluctuations in population and may be the most appropriate number to apply to annual water use for calculating average per capita use.

Once current and historical estimates of average dwelling units served by year are derived, these can be converted to population by multiplying the units by the average persons per household for that area. The county average persons per household is often used, but this can be significantly different from the average persons per household for the service area, and population in group quarters must also be taken into account (either separately or added into the persons per household). The latest census data at the block level (the smallest level of census geography) are typically the best source of household size and group quarters data. Block-level metrics can then be applied to parcel-based models, such as those favored by a growing number of utilities and water management districts; however, a population-weighted average across the service area may also be used to derive the most appropriate multipliers to apply to served units.

Population forecasts for utilities are developed using a variety of methods and models. Some may be appropriate for some utilities but inadequate for others, so it is important to have a good understanding of the pros and cons of a desired method before implementing it.

GIS-based models and tools can be used to efficiently develop reliable and defensible forecasts. These models can calculate historical growth rates using census and parcel data and factor in the historic influence of growth drivers, including roads and interchanges, certain existing commercial uses, existing residential development, and surface water. They can exclude non-developable lands, including wetlands, conservation areas, inappropriate land uses, and areas that are "built out." In addition to projections of permanent residents, forecasts can include seasonal residents, tourists, and commuters. These projections are typically distributed to the property parcel level and then summarized by utility service area (requiring an accurate service area map) or other boundaries [city, traffic analysis zone (TAZ), basin, etc.]

Some models constrain the projections of permanent residents at the county level to the county projections made by the University of Florida's Bureau of Economic and Business Research (BEBR). BEBR makes low, medium, and high projections for each county in Florida, but the medium projections are considered their most likely forecasts (Smith and Rayer, 2011). BEBR provides the official forecasts for the State of Florida, and constraining small area projections to the county-level BEBR forecast is the ideal way to develop utility projections consistent with BEBR. However, accurately projecting water demand for water utilities requires a much smaller geographic unit than the county. Also, using county growth rates for all utilities within that county is not advisable, as utilities grow at different rates.

BEBR projections also do not include most seasonal residents, tourists or commuters. Seasonal resident population can be estimated using data from the census, other surveys, emergency room admissions for particular age groups (comparing winter v. summer), or a combination [as used by the Southwest Florida Water Management District (SWFWMD)]. Tourist population can be estimated using lodging room data from the Florida Department of Business and Professional Regulation, with average occupancy and party size data applied (typically at the county level). Commuter population can be estimated using census data. Projections for seasonal and commuter population can be made by applying historical ratios of each to permanent population and applying those ratios to future population projections. To project tourist population, analyses performed by SWFWMD indicate that a simple extrapolation of the linear trend (least squares method) of historical room data more accurately predicted known years than increasing tourists in proportion to permanent population (Doty, 2009).

Because non-permanent population cohorts typically use less water than permanent residents, these cohorts should be "functionalized" when making calculations of per capita use. This is

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the conversion of a non-permanent resident to some fraction of a permanent resident based on anticipated water use characteristics. Functionalization of seasonal residents requires estimating the proportion of the year they are in residence and estimating outdoor irrigation use when they are not in residence. Tourists can be functionalized with estimated unit occupancy and party size ratios. Commuters are functionalized by applying the net change in commuter population (referred to as net commuters) to the typical numbers of working hours per day and the days worked per week (SWFWMD, 2009).

A forecast for total "functional" population can then be calculated by adding projections of permanent population to functionalized seasonal, tourist, and net commuter population. Adding the growth in all of these population groups (or cohorts) to the current served population is necessary to account for all forecasted growth and to accurately determine forecasted per capita demand. Many utilities simplify this process by only projecting permanent population, but this can significantly impact the demand forecast. Regardless, estimates and projections should use functionalized or permanent population consistently.

Forecasting Future Water Demands

The first step in many approaches to forecasting water demand is to apply historic per capita use to projected served population. Some projections use a historic gross per capita use, calculated by dividing total water use by served population. Typically an average of recent years is used, such as the five year period used by many water management districts. Applying this historic average gross per capita use to the forecasts of future served population will result in total demand projections that are consistent with the water use characteristics of the historic years used as the basis for the per capita calculations. If these characteristics are expected to change in the future (reducing or increasing per capita use), the per capitas should be adjusted accordingly. For example, significant changes in water rates, conservation measures, income levels, population densities, and the percentage of customers with irrigation systems or private irrigation wells may require adjustments to historic per capita average to make it a reasonable proxy for future per capita use. This gross per capita method presumes that non-residential uses will increase roughly in proportion to population, an assumption made by many utilities and water managers. This assumption allows for projections to be made quickly and easily, but it would not be accurate in cases where non-residential uses are expected to change in the future at a different rate than population. For water use permitting, these projections will only serve at a starting point, as water managers typically scrutinize the utility for opportunities to reduce demands, including conservation, reuse, etc.

Other utilities develop separate projections for each category of water use (residential, commercial/industrial/institutional, irrigation, water utility use, unaccounted for water, etc.). These utilities (which are often larger utilities) typically use a residential (or household) per capita use for their residential use projections. As with gross per capita calculations, typically an average of recent years is used at least as a starting point, and that can be adjusted for future years due to changing water use characteristics such as those cited previously. Applying this historic average residential per capita use to the forecasts of future served population will result in residential demand projections that are consistent with the water use characteristics of the historic years used as the basis for the per capita calculations. The other use categories may be projected in proportion to the change in residential demand (like the gross per capita method), but they may also use different methods, such as mathematical extrapolations of historic data, analyses based on available future land use, etc. Unaccounted for water is typically calculated as a percentage of total use, and if this is high (especially above 10%); water use regulators may require strategies to reduce this over the course of the permit.

Conclusion

Forecasting future demand for a water utility can be tricky business, with a myriad of potential pitfalls that can compromise the validity and defensibility of the resulting forecast. Population projections should take into account land uses and availability, parcel information, growth drivers, all population cohorts, and self-supplied population, in addition to the historic growth trends typically used for small-area forecasting. Limiting small-area projections to BEBR's county-level forecasts provides consistency with other projections made by state and local governments while providing the spatial precision needed for water permitting and planning. Water demand projections should take into account historic per capita use, but also anticipated future changes in per capita use. With ever-changing population dynamics, the increasing scarcity of groundwater, fierce competition among utilities over scarce resources, and a growing number of expensive legal challenges, it is imperative to develop realistic and defensible forecasts of population and water demand and update them regularly.

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