The Economic Impacts of Water Shortages in Orange County

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Executive Summary

Estimating the economic impacts of water shortages is a critical step in identifying the potential benefits of investments that improve the reliability of water supply. As part of its reliability planning process, the Municipal Water District of Orange County (MWDOC) asked the authors of this report to estimate the economic impacts of hypothetical year-long 15% and 30% water supply reductions on each of three interested groups in Orange County: 1) Commercial and industrial businesses, 2) Residential water users, and 3) Retail water suppliers.[1] Our approach to estimating the economic impacts differs for each group depending on what method is most appropriate.

First, a survey was conducted to estimate the economic impacts of water supply reductions on businesses in Orange County. This survey asked firms to quantify how water supply reductions, of 15% and 30% for 1 year, would lead to changes in business output or employment. Based on the responses to these questions, we estimate the direct impacts of water shortages on Orange County businesses. In addition to estimating the direct impacts, we also estimate indirect and induced impacts using IMPLAN, an input-output planning model.

Based on survey responses, we estimate that a 15% reduction in water supply to businesses in Orange County would lead to a $3 billion direct reduction in business output and 19,000 lost jobs. These direct business impacts would lead to further indirect impacts amounting to output losses of $2.1 billion and indirect employment losses of over 10,700. In total, a 15% reduction in water supply to businesses would lead to a 1.9% reduction in total employment and 2% reduction in total economic output within Orange County.

A 30% reduction in water supply to businesses in Orange County would lead to a $6.5 billion reduction in business output and 43,000 lost jobs. These direct business impacts would lead to further indirect losses amounting to a reduction of $4.3 billion in business output and 22,400 lost jobs. In total, a 30% reduction in water supply to businesses would lead to a 4.2% reduction in total employment and a 4.3% reduction in output within Orange County.

[1] This report considers separately the economic consequences two distinct water shortages: First, a 15% or 30% reduction in water supply to Orange County businesses (commercial and industrial customers) and, second, a 15% or 30% reduction in water supply to residential customers in Orange County.

Second, welfare losses to residential water customers are estimated using an economic model based on demand elasticities for Orange County water utilities that have been published in peer-reviewed academic literature. Welfare losses measure how much each customer would have been willing to pay in excess of their water rates for each unit of water that they did not receive due to shortage. We estimate that on average each household of Orange County is willing to pay between $222 and $427 to avoid a 15% supply shortage for one year. This amounts to a 15% supply shortage causing a total residential welfare loss of $241 million among Orange County households. For a supply shortage of 30%, we estimate that Orange County households are willing to each pay between $744 and $1,486 to avoid a demand shortage. In total, this amounts to a residential welfare loss of $818 million for a 30% supply shortage.

Third, we calculate the revenue losses for municipal water retailers in Orange County, based on the average rates and demand levels in each district. Across all retailers in Orange County, we estimate that reductions in supply to each districts' commercial and industrial customers of 15% or 30% for a period of one year would lead to a reduction in revenues worth $37.6 million or $58.0 million respectively. A reduction in supply to each districts' single-family and multi-family residential customers of 15% or 30% for a period of one year would lead to revenue reductions of $75.1 million or $116.0 million respectively. Note that these calculations assume that districts do not impose a drought surcharge or other fees to recover these losses, in which case the losses would instead be passed onto customers in each district.

The results in this report reflect point estimates of the economic impacts of a specific level of shortage for a specific duration of time. A couple of points of caution are required in interpreting these results. First, to calculate the expected costs of a water shortage, one must multiply the cost of that shortage by the probability of such a shortage. To the extent that investments in water supply reliability can reduce the forecast probability of water shortages, the economic impacts of such reliability improvements can be calculated for each level of shortage by multiplying the estimates in this report by the expected reduction in the probability of shortage.

Second, this report describes two distinct scenarios for the residential and business sectors respectively. It is important to note that a 15% (or 30%) reduction in total water supply will not necessarily be shared equally between these two sectors. How shortages are shared among different types of customers depends on district specific policies, and will significantly influence the total economic impacts of a water shortage.

I. Introduction and Background

The Municipal Water District of Orange County (MWDOC) is a special district that acts as a wholesale water supplier and resource-planning agency in Orange County. MWDOC purchases approximately 70.2 billion gallons of imported water per year – from northern California and the Colorado River – through the Metropolitan Water District of Southern California (Metropolitan). MWDOC delivers this water to 27 member agencies who, in turn, provide retail water services to the public including 3.2 million Orange County residents. MWDOC's service area covers all of Orange County with the exception of the cities of Anaheim, Fullerton and Santa Ana, who independently purchase water from Metropolitan.[2]

Water use in Orange County is approximately evenly split between local water supplies and imported water supplies, such as those purchased from Metropolitan. Local water supplies include the Orange County Groundwater Basin, other smaller local aquifers and recycled wastewater.

Reliability planning is one of MWDOC's key roles. MWDOC must plan to have sufficient supplies to meet the needs of the county's growing population. The district must also plan for contingencies that may disrupt the county's imported and local water supplies such as droughts and earthquakes. Droughts and dry periods are frequent in the climate of Orange County and in the regions from which it imports water. A significant earthquake could potentially cut off the county from some or all of its imported water supplies and disrupt infrastructure for local distribution of water supplies. MWDOC extensively studies potential new projects to improve the reliability of water supplies. These projects can be major undertakings that require significant capital investment.

Disruptions in water supply can reduce economic activity and employment within the county, lead to hardship for local residents and pose significant economic challenges for local water agencies. Estimating the economic impacts of water shortages is a critical step in identifying the potential benefits of investments that improve the reliability of water supply. Accurately estimating the benefits of reliability helps ensure that the County does not over-invest or

[2] Note that this report estimates the economic impacts of water shortages on all Orange County residents, including those in Anaheim, Fullerton and Santa Ana, who do not purchase water through MWDOC.

under-invest in projects to ensure a reliable supply of water. Understanding the economic impacts of water shortages helps MWDOC make decisions about investments pertaining to the reliability of water supply.

Commercial, Industrial and Institutional water use in Orange County amounted about 101,400 acre-feet per year, or around 19% of all water consumed in 2020. This water is a critical input for the region's thriving economy. The economy of Orange County is worth over $255 billion, larger than either the State of Oregon or the country of New Zealand. Orange County also employs over 1.57 million full-time equivalent workers.[3] Consequently, interruptions in water supply can cause significant economic disruptions within the county. In Section II of this report, we quantify these impacts using a survey of businesses to estimate the direct impacts of water shortages on individual businesses and an economic impact model to estimate indirect spillover effects of business shortages on the wider economy.

Residential water users account for the majority of water use in Orange County. In 2020, single-family residential customers and multifamily residential customers respectively consumed around 215,900 AF and 86,600 AF of water, or around 41% and 16% of all water in Orange County. Because a substantial fraction of total residential water use is for outdoor irrigation[4], many households can modestly reduce their water use at a relatively low-cost by reducing outdoor irrigation. However, as the size of water shortages increase, households must adopt increasingly costly approaches to reducing water use, leading to increasing losses in consumer welfare. This relationship between the size of a waters shortage and the increasing cost of behaviors to curtail water use is captured in demand relationships that we estimate for each water district. In Section III, we use this approach to estimate the welfare losses to residential water customers in Orange County that would result from residential water shortages.

Retail water districts acquire water from MWDOC or other sources, which they then sell to business and residential customers in Orange County. Most of the revenue that retail water districts generate come from volumetric rates that they charge customers, however most of each district's costs do not vary significantly with the volume of water produced. During water shortages, this can lead to financial strife due to revenue shortfalls from reduced sales. In

[3] Based on numbers from Emsi (https://www.economicmodeling.com/).

[4] Outdoor irrigation accounts for around 41% of all water use in single-family residential units and 16% of water use for multifamily residential units. The remaining water use (59% and 84% respectively) is indoors.

Section IV, we estimate the revenue shortfalls to retail water districts in Orange County as a result of water shortages to both residential and business customers.[5]

Although this report considers separately 15% and 30% water shortages in each of the business (commercial and industrial) and residential sectors, it is important to note that these scenarios are distinct scenarios. A 15% or 30% reduction in total water supply will not necessarily be split equally between the residential and business sectors. Water districts in Orange County are required to produce drought management plans which describe how water shortages could be shared among different types of customers in each district. For example, because water demand is typically more elastic in the residential sector than in the business sector, a 15% reduction in total water supply will likely lead to a greater than 15% reduction in water supply among residential customers and a less than 15% reduction in water supply among business customer.[6] If shortages are distributed in this manner, it will significantly reduce the total economic impacts relative to supply reductions that are uniform across customer types.

II. Impacts of Shortages on Orange County Businesses

A. Overview of Approach

In this section, we analyze the direct and indirect economic impacts of water shortages on business output and employment in Orange County. Our approach to quantifying the business impacts of water supply reductions involves two steps. First, a survey of businesses is used to quantity the direct effects on businesses, in terms of how they would reduce output or employment in the context of water supply reductions. Those estimates are then used as an input into IMPLAN, a widely-used economic impact model to estimate the indirect impacts of the reduction in business activity on the broader economy. This approach is typical of that

[5] Note that districts sometimes choose to enact emergency drought rates or other fees during shortages in order to cover revenue losses, however these can be unpopular with customers who feel they are being punished for conserving water. In our calculations, we assume that districts do not impose a drought surcharge or other fees to recover these losses. If surcharges were imposed, then the losses estimated in this section would instead be passed onto customers in each district.

[6] A similar pattern of conservation might be expected for a 30% reduction in water supply. This memo does not address exactly how a 15% or 30% reduction in water supply might be split between these sectors.

described in academic literature[7] and has been previously used to estimate the value of reliability in other parts of California.[8]

Yet the business surveys that typically drive these economic analyses are almost thirty years old. CIC Research surveyed 619 businesses for the San Diego County Water Authority in 1993, querying firms about the impact of hypothetical water reductions ranging from 20% to 60% for two to six months.[9] MHB Consultants (1994) surveyed San Francisco Public Utilities Commission customers, querying businesses about the impact of 15% and 30% reductions in water supply.[10] Due to the age of the existing surveys, the raw data were impossible to locate and would have needed updating even if they were found. We conducted an original survey of businesses – the first on this topic in California in almost three decades – modeled on the 1994 MHB Consultants survey.

The business survey for this study asked firms to quantify how water supply reductions, of 15% and 30% for 1 year, would lead to changes in business output or employment. The survey responses were used to estimate direct impacts for firms and that direct effect was combined with an Input-Output model to calculate indirect and induced effects. The direct effect is the amount by which firms would change output or employment as a result of water supply reductions. If a firm reduces output (a direct effect), the indirect effect is the impact on that firm's suppliers, who might also reduce output due to lower demand. The induced effect includes the impact of lower employee wages or lower firm profits, which will lead to reduced demand elsewhere in the economy. We used IMPLAN, a state-of-the-art input-output model, to calculate indirect and induced impacts from the direct effects that were estimated via the business survey.

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7 See Chapter 7 of Young, R. A., & Loomis, J. B. (2014), *Determining the economic value of water: concepts and methods*, Routledge.

8 For example, see Sunding, D. and Browne, O. (2022), *Economic Impacts of Water Shortages in the EBMUD Service Area,* produced by The Brattle Group for East Bay Municipal Utility District, or,
Sunding, D. (2007), *Economic Impacts of Drought-Induced Water Shortage in the San Francisco Bay Area,* produced by The Brattle Group for San Francisco Public Utilities Commission.

9 CIC Research, Inc. (1999), *The Economic Impact on San Diego County of Three Levels of Water Delivery: 80, 60, or 40 Percent Occurring for Two Months or Six Months,* San Diego, California: San Diego County Water Authority. (December, 28, 1993, revised December 21, 1993 and updated October 19, 1999)

10 MHB Consultants, Inc. (1994), "The Economic Impact of Water Delivery Reductions on the San Francisco Water Department's Commercial and Manufacturing Customers," Tables 13 and 14 (pp. 48, 50).

B. Survey of Businesses

1. Survey Instrument and Sample Frame

We surveyed 401 businesses in Orange County between September 2 and November 3, 2021. The survey instrument, shown in Appendix B, was modeled on the MHB Consultants survey. During spring and summer of 2021, the research team consulted with MWDOC staff and member agencies to develop and refine survey questions. Businesses were surveyed using a stratified random sampling approach within 15 industry categories, which we aggregate into eight categories. A breakdown of the number of businesses surveyed by industry and a mapping from the 15 industry to the eight industry categorization is shown in Appendix C.[11] All businesses surveyed were in Orange County, omitting firms in the Yorba Linda, Moulton Niguel, and the Irvine Ranch Water Districts at the request of those MWDOC member agencies.

The Social Science Research Center of California State University, Fullerton conducted the survey using computer assisted telephone interviewing (CATI), sampling firms within the 15 industries with a targeted balance of respondents from small firms (< 50 employees) and medium-sized firms (from 50 to 249 employees). Surveys with larger firms (>= 250 employees) were completed as possible.

The responses to questions 11b and 11c and the companion questions 12b and 12c of the survey drove the economic impact analysis. Firms were prompted at the beginning of question 11:

> *Following a hypothetical event, your business will experience recurrent shortages for a one-year period. While there is some advance notice within the first quarter, this would require you to cutback your water use to 15% less water than normal for the year.*

[11] Note that the agriculture, mining, and utilities NAICS industries were excluded due to low business presence in Orange County and that public administration was excluded in order to limit the sample to private businesses. The exclusion of these sectors is conservative, and in our analysis may lead to an underestimation of total employment impacts

To adjust to this need to reduce your water use, we would like to evaluate what the impact to your operations/business might be. Would you…

For 11b, the question asked whether firms would reduce output. For 11c, the question asked whether firms would reduce employment. If firms answered yes to either question (output or employment reductions), in both cases they were then asked to quantify the magnitude of reductions in 10 percentage point ranges from "1-10%" to "larger than 50%." A companion set of questions, questions 12b and 12c, asked the same queries for 30% water reductions for one year.

2. Analysis of Survey Data

We implement the following steps to clean the raw data. First, any firm that answered they would see an output or employment impact for a 15% water reduction but not a 30% water reduction is excluded from the analysis. We also exclude firms who answered that they would have a larger effect for a 15% water reduction than a 30% water reduction. For the question regarding output impacts, 24 firms provided inconsistent answers regarding output impacts, and 6 firms provided inconsistent answers regarding employment impacts. Three firms provided inconsistent responses for both questions. The total number of firm responses excluded from the analysis is 27, resulting in a final sample size of 374.

Second, firms that responded that they would experience an output or employment impact but answered "don't know" or "refused" when queried about the magnitude of the impact are assigned to the smallest category of that impact, "1-10%." Lastly, all impacts are converted to the mid-point of ranges (i.e. 5.5% for the "1-10%" reduction, and so on). No firms chose the open-ended "larger than 50%" response for either the 15 % or the 30 % water reduction. The results for the number of firms who answered "yes" when queried whether they would reduce output or employment, as well as the average magnitude of reduction, are shown in Table 1 and Table 2 below.

TABLE 1: NUMBER OF RESPONDENTS AND AVERAGE MAGNITUDE OF OUTPUT IMPACTS BY INDUSTRY IN ORANGE COUNTY

Industry	15% Water Supply Reduction				30% Water Supply Reduction			
	Total Respondents	Total Yes	% Yes	Average Magnitude	Total Respondents	Total Yes	% Yes	Average Magnitude
Construction	26	1	4%	1.0%	26	2	8%	1.2%
Manufacturing	71	12	17%	2.1%	71	19	27%	7.0%
Logistics, Transportation, and Warehousing	43	4	9%	1.7%	43	6	14%	2.6%
Retail and Other Services	45	3	7%	0.8%	45	10	22%	4.6%
FIRE	24	2	8%	1.7%	24	3	13%	2.4%
Professional Services, Information, and Administration	47	3	6%	1.2%	47	3	6%	1.6%
Education and Health Care	46	4	9%	0.7%	46	5	11%	1.3%
Entertainment and Tourism	72	16	22%	2.6%	72	24	33%	6.6%

Notes: Responses are aggregated by midpoint, i.e. 1%-10% is 5.5%. "Don't know" and "refused" are assumed to be the lowest impact, or 1%-10%. FIRE includes Finance, Insurance, and Real Estate. This table estimates the output impacts of a water supply reduction that requires all customers to reduce water use by 15% or 30% for one year.

TABLE 2: NUMBER OF RESPONDENTS AND AVERAGE MAGNITUDE OF EMPLOYMENT IMPACTS BY INDUSTRY IN ORANGE COUNTY

Industry	15% Water Supply Reduction				30% Water Supply Reduction			
	Total Respondents	Total Yes	% Yes	Average Magnitude	Total Respondents	Total Yes	% Yes	Average Magnitude
Construction	26	3	12%	1.4%	26	3	12%	3.7%
Manufacturing	71	12	17%	2.3%	70	18	26%	8.1%
Logistics, Transportation, and Warehousing	43	3	7%	1.5%	43	7	16%	3.5%
Retail and Other Services	45	4	9%	1.2%	45	6	13%	2.5%
FIRE	24	0	0%	0.0%	24	0	0%	0.0%
Professional Services, Information, and Administration	47	2	4%	1.7%	47	3	6%	2.1%
Education and Health Care	46	2	4%	0.7%	46	7	15%	1.9%
Entertainment and Tourism	72	12	17%	2.2%	72	22	31%	4.9%

Notes: Responses are aggregated by midpoint, i.e. 1%-10% is 5.5%. "Don't know" and "refused" are assumed to be the lowest impact, or 1%-10%. FIRE includes Finance, Insurance, and Real Estate. This table estimates the employment impacts of a water supply reduction that requires all customers to reduce water use by 15% or 30% for one year.

C. Economic Impact Calculation

The percentage changes in output and employment are used to calculate total changes in dollars for output and number of jobs for employment by multiplying the percentage impacts by industry and county totals for Orange County. We use data from Economic Modeling Specialists International (Emsi), a leader in economic and labor market information, to

determine total economic output and total employment by NAICS-coded industries in Orange County in 2020, the latest year for which data was available. Table 3 and Table 4 show direct output and employment impacts respectively.

TABLE 3: DIRECT IMPACTS TO OUTPUT BY INDUSTRY FOR 15% AND 30% WATER REDUCTIONS

Industry	Total Output ($ millions)	15% Reduction		30% Reduction	
		Direct Impact (%)	Direct Impact ($ millions)	Direct Impact (%)	Direct Impact ($ millions)
	[1]	[2]	[3]	[4]	[5]
Construction	$13,896	1.0%	$136	1.2%	$166
Manufacturing	$31,687	2.1%	$652	7.0%	$2,207
Logistics, Transportation, and Warehousing	$24,623	1.7%	$412	2.6%	$647
Retail and Other Services	$18,680	0.8%	$152	4.6%	$851
FIRE	$39,132	1.7%	$669	2.4%	$921
Professional Services, Information, and Administration	$48,508	1.2%	$583	1.6%	$790
Education and Health Care	$19,455	0.7%	$135	1.3%	$243
Entertainment and Tourism	$10,356	2.6%	$270	6.6%	$679
Total	$206,338		$3,009		$6,504

Sources and Notes:
[1]: From Emsi.
[2],[4]: From survey results. See Table 1.
[3] = [1] x [2].
[5] = [1] x [4].
This table estimates the output impacts of a water supply reduction that requires all customers to reduce water use by 15% or 30% for one year.

TABLE 4: DIRECT IMPACTS TO EMPLOYMENT BY INDUSTRY FOR 15% AND 30% WATER REDUCTIONS

Industry	Total Employed ('000s)	15% Reduction		30% Reduction	
		Direct Impact (%)	Direct Impact ('000s)	Direct Impact (%)	Direct Impact ('000s)
	[1]	[2]	[3]	[4]	[5]
Construction	103.7	1.4%	1.5	3.7%	3.9
Manufacturing	148.8	2.3%	3.5	8.1%	12.1
Logistics, Transportation, and Warehousing	100.9	1.5%	1.6	3.5%	3.5
Retail and Other Services	204.6	1.2%	2.4	2.5%	5.1
FIRE	122.8	0.0%	0.0	0.0%	0.0
Professional Services, Information, and Administration	294.8	1.7%	5.1	2.1%	6.1
Education and Health Care	227.0	0.7%	1.5	1.9%	4.4
Entertainment and Tourism	163.2	2.2%	3.5	4.9%	8.1
Total	1,365.8		19.0		43.0

Sources and Notes:
[1]: From Emsi.
[2],[4]: From survey results. See Table 2.
[3] = [1] x [2].
[5] = [1] x [4].
This table estimates the employment impacts of a water supply reduction that requires all customers to reduce water use by 15% or 30% for one year.

The data in the tables above are inputs into the IMPLAN model. We use the data, aggregated into eight industries, as inputs into IMPLAN, which calculated indirect and induced effects. We use IMPLAN's 2020 data year with the dollar year at 2022. We allow IMPLAN to populate estimates of employee compensation, proprietor income, and output when appropriate yet zero out employment when only output is affected.

IMPLAN is a highly refined data-modeling platform which builds upon the traditional input-output (I-O) modeling system and through extensive databases, economic factors, industry multipliers, and demographic statistics, provides insight into how various shocks or disruptions of earnings, employment or output in one or more industries can ripple through a local, regional, or even national economy. Effectively, the IMPLAN model measures and calculates inter-industry relationships to determine how one change in a certain industry will impact all other sectors as well as the broader local and regional economies.

These impacts are communicated as direct, indirect, and induced impacts. Direct impacts or effects are the initial estimated impacts being studied in the region – such as a large car

manufacturer opening a new plant with 500 workers in Los Angeles County. Indirect impacts are the impacts associated with business-to-business transactions indirectly caused by the direct impact or effect – such as a new car manufacturer purchasing raw materials and other inputs necessary for them to produce new vehicles. Finally, Induced impacts are economic effects stemming from household spending of labor income – such as the new 500 workers from the car manufacturing plant spending their wages and salaries on local goods and services, from local restaurants to furniture and clothing stores.

For this study, the IMPLAN model used to understand the wide-ranging effects a 15% and 30% water reduction would have on the economy in Orange County. Using the estimated direct impacts based on respondent answers by industry from the survey conducted, the average direct, indirect, induced, and total overall economic impacts for both the 15% and 30% water reduction scenarios are provided below in Table 5 and Table 6 respectively. In addition to the central estimates of economic impacts, we also provide a low and high estimates. These low and high estimates are calculated based on variation in our survey sample, as described in Appendix E, and represent roughly the 15th and 85th percentile of expected outcomes. Because the Emsi data includes industries not surveyed, such as agriculture and public administration, the impact estimates are conservative because they do not account for the effects of a water shortage on the non-surveyed industries.

TABLE 5: TOTAL ECONOMIC IMPACTS ASSOCIATED WITH A 15% REDUCTION IN WATER

Impact		Employment ('000s)	Labor Income ($ millions)	Value Added ($ millions)	Output ($ millions)
1 - Direct Impacts	[1]	19.0 [15.0 - 23.1]	$1,042 [$830 - $1,254]	$1,754 [$1,392 - $2,115]	$3,009 [$2,407 - $3,611]
2 - Indirect Impacts	[2]	5.2 [4.1 - 6.3]	$431 [$343 - $519]	$718 [$570 - $867]	$1,152 [$914 - $1,390]
3 - Induced Impacts	[3]	5.5 [4.4 - 6.7]	$364 [$290 - $438]	$595 [$474 - $717]	$947 [$753 - $1,140]
Total	[4]	29.7 [23.5 - 36.0]	$1,837 [$1,463 - $2,212]	$3,068 [$2,436 - $3,699]	$5,108 [$4,074 - $6,142]
% of County Total	[5]	1.9% [1.5% - 2.3%]			2.0% [1.6% - 2.4%]

Sources and Notes:
Low and high IMPLAN estimates in brackets.
[1]: Employment and output are calculated from survey results. See Table 4 and Table 3 respectively. Labor Income and Value Added are from IMPLAN.
[2],[3]: From IMPLAN.

[4] = [1] + [2] + [3].
[5] = [4] / county total.

TABLE 6: TOTAL ECONOMIC IMPACTS ASSOCIATED WITH A 30% REDUCTION IN WATER

Impact		Employment ('000s)	Labor Income ($ millions)	Value Added ($ millions)	Output ($ millions)
1 - Direct Impacts	[1]	43.0	$2,265	$3,667	$6,504
		[36.3 - 49.8]	[$1,913 - $2,618]	[$3,095 - $4,239]	[$5,529 - $7,478]
2 - Indirect Impacts	[2]	10.5	$886	$1,460	$2,342
		[8.8 - 12.1]	[$749 - $1,023]	[$1,231 - $1,688]	[$1,976 - $2,709]
3 - Induced Impacts	[3]	11.9	$778	$1,272	$2,022
		[10.0 - 13.7]	[$656 - $899]	[$1,073 - $1,470]	[$1,706 - $2,338]
Total	[4]	65.4	$3,929	$6,399	$10,868
		[55.1 - 75.6]	[$3,318 - $4,541]	[$5,399 - $7,398]	[$9,211 - $12,525]
% of County Total	[5]	4.2%			4.3%
		[3.5% - 4.8%]			[3.6% - 4.9%]

Sources and Notes:
Low and high IMPLAN estimates in brackets.
[1]: Employment and output are calculated from survey results. See Table 4 and Table 3 respectively. Labor Income and Value Added are from IMPLAN.
[2],[3]: From IMPLAN.
[4] = [1] + [2] + [3].
[5] = [4] / county total.

III. Impacts of Shortages on Residential Water Users

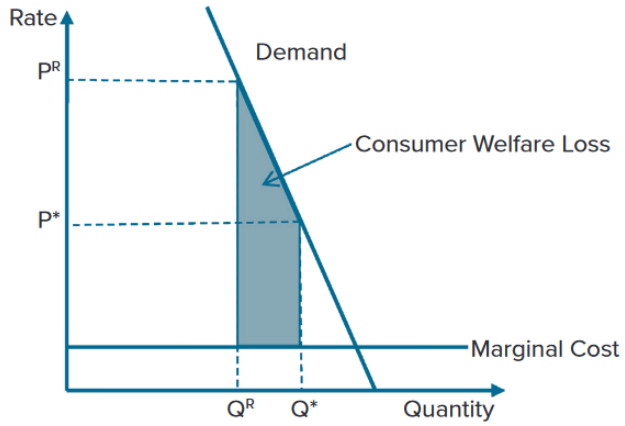
A. Overview of Approach

In this section, we analyze the welfare impacts of water supply reductions on residential water customers in Orange County. As in the previous section, this analysis considers a hypothetical shortage in which customers in the service area are required to reduce their water use by either 15% or 30% for the period of one year. However, in this section we consider residential customers (both single- and multi-family) rather than businesses (commercial and industrial customers).

Welfare losses measure how much each customer would have been willing to pay (WTP) in excess of their water rates for each unit of water that they did not receive due to water reductions. Residential water customers are typically willing to pay the most for the first units of water that they consumer, which may be used for necessary health and sanitation purposes. However, customers are willing to pay increasingly less for each subsequent unit of water which they put to increasingly lower value uses, such as longer periods of turf irrigation. To estimate the welfare losses associated with water supply reductions, The Brattle Group adopted a well-established methodology that is published in peer-reviewed journals, which uses a measure of consumers' willingness to pay to avoid water supply restriction.[12]

For each study area, we calibrate a demand curve that specifies the relationship between customers' rates and the quantity of water demanded. During a water reduction, we can estimate the customer welfare losses by calculating the area between this demand curve and the utility's cost curve. This area is illustrated in Figure 1.

FIGURE 1: DEPICTION OF WELFARE LOSSES UNDER LINEAR DEMAND, NON-MARGINAL PRICING, AND A FLAT MARGINAL COST CURVE



Source: Nemati, M., Buck, S., & Sunding, D. (2018), "Cost of California's 2015 drought water conservation mandate," *ARE Update*, *21*(4), 9-11.

To simplify the interpretation of our results, we have aggregated residential water suppliers in Orange County into three study areas based on their primary water sources: Brea and La Habra,

[12] Brozović, N., Sunding, D. L., & Zilberman, D. (2007), "Estimating business and residential water supply interruption losses from catastrophic events," *Water resources research*, *43*(8).

Buck, S., Auffhammer, M., Hamilton, S., & Sunding, D. (2016), "Measuring welfare losses from urban water supply disruptions," *Journal of the Association of Environmental and Resource Economists*, *3*(3), 743-778.

Buck, S., Nemati, M., & Sunding, D. (2021), "Consumer welfare consequences of the California drought conservation mandate," *Applied Economic Perspectives and Policy*.

Orange County Basin, and South Orange County.[13] The boundary of these three regions are shown in Figure 2. For each of these study areas, we calibrate an iso-elastic demand curve. Iso-elastic demand curves are commonly used in the economic literature, and are based on the assumption that at any level of demand, a one percentage reduction in the quantity of water available will always lead to the same percentage increase in the willingness to pay for water. We collected data to calibrate a separate demand curves for each study area. Three pieces of information are required to calibrate these demand curves: total residential water demand, average residential water rates, and the price elasticity of demand for water.[14] The assumptions that we adopt are summarized in Table 7 and are described below:

1. Total residential water demand is estimated in each region for the year 2019 by adding up the residential water consumption that each utility is required to report to the Department of Water Resources (DWR).[15]
2. Average residential water rates are calculated on a population-weighted average basis using the median rate tier for single-family household customers.[16] Where rate data from 2019 is not available, rate data from the closest available year are used and adjusted for inflation.
3. Price Elasticity of Demand estimates are taken from Table 5 of Buck et. al. (2016).[17] This paper reports price elasticity estimates for water utilities throughout California, including Anaheim, Fullerton, Santa Ana and MWDOC. We calculate a demand-weighted average

[13] The cities of Brea and La Habra primarily rely on source water from the Main San Gabriel Groundwater Basin, supplemented by imported water from MWDOC; the OC Basin Agencies primarily rely on source water from the Orange County Groundwater Basin, and supplemented by imported water from MWDOC; and the South Orange County Agencies rely almost entirely on imported water from MWDOC. Irvine Ranch Water District's (IRWD) service area includes portions of the South Orange County and OC Basin study areas. MWDOC assumes 30% of IRWD lies in the South Orange County study area. Likewise, we apportion 30% of IRWD's residential water demand and welfare loss to South Orange County.

[14] Demand curves are calibrated using equation 10 from Buck et al. (2016): $A_i = P_i / Q_i^{\frac{1}{\varepsilon_i}}$

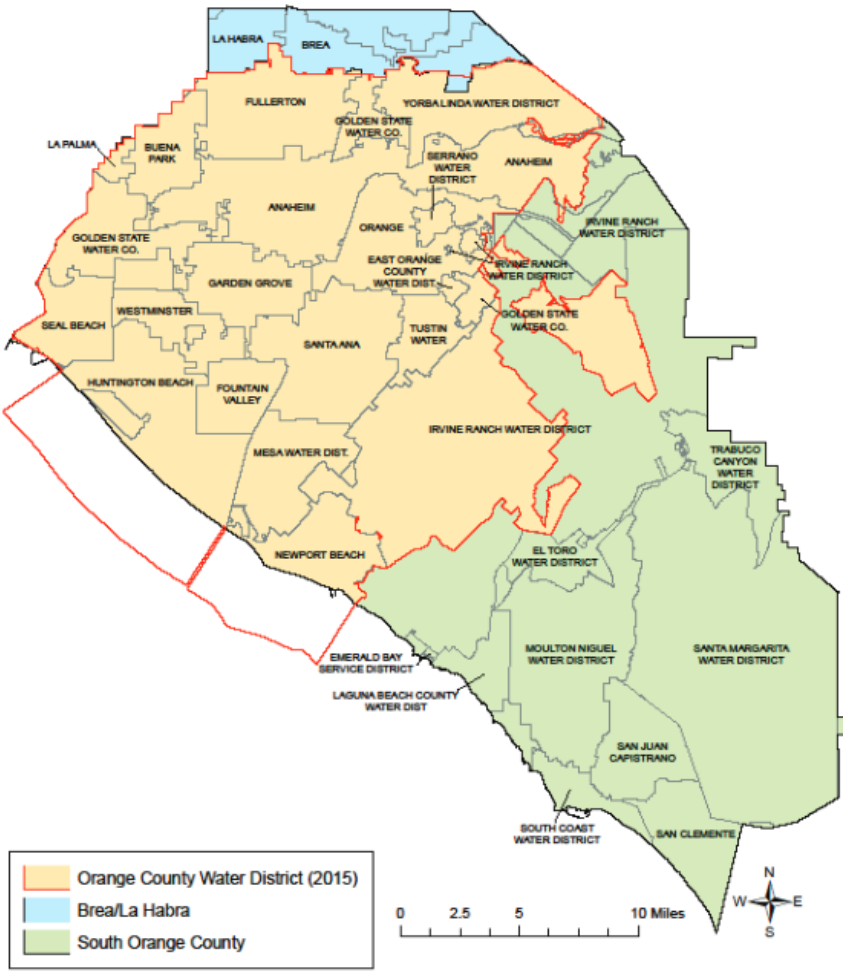
[15] Note that we chose to rely on demand data from 2019 rather than 2020 or 2021 to avoid complications caused by the impact of the COVID-19 pandemic on residential water demand. For some districts where 2019 data is not available, we rely instead on data from 2018 or 2020. Data for Emerald Bay Service District and Serrano Water district were obtained from their websites as they did not report data to the DWR.

[16] We obtain rate data from the websites of each water utility.

[17] Buck et.al. (2016).

elasticity for each study area based on these estimates. An elasticity of -0.162 indicates that a 10% increase in rates would result in a 1.62% reduction in water usage.[18,19]

FIGURE 2: THREE STUDY REGIONS IN ORANGE COUNTY BASED ON MIX OF LOCAL AND IMPORTED WATER SOURCES



Source: Figure 1 from "Orange County Water Reliability Study," MWDOC (2016).

[18] Buck et.al. (2016) estimate that the average elasticities for San Francisco Bay Area Utilities and Southern California Utilities (which includes MWDOC, Anaheim, Fullerton, and Santa Ana) are -0.158 and -0.193 respectively. San Francisco households are more inelastic, or price insensitive, while Southern California households are relatively more elastic, or sensitive to changes in prices. At average elasticities ranging from -0.162 to -0.172, MWDOC households are somewhere in between, but could be characterized as relatively inelastic compared to the Southern California average.

[19] Note that these elasticities were estimated based on data from 1996 to 2009. It is widely expected that demand will become increasingly inelastic as the penetration of water efficient appliances, irrigation, and other water conservation technologies increases among residential households. Once water efficient technologies are adopted, then households will find it increasingly costly to generate additional savings to respond to future shortage. This would lead the residential welfare losses associated with shortages to be even larger than those estimated in this report.

TABLE 7: KEY ASSUMPTIONS FOR ECONOMIC IMPACT ANALYSIS

		Brea and La Habra	Orange County Basin	South Orange County	Total
Total Residential Population	[1]	106,446	2,423,159	636,082	3,165,687
Total Residential Water Demand (mgd)	[2]	10	193	47	250
Average Persons per Household	[3]	3.0	3.2	2.7	
Average Residential Water Rates ($ / mgd)	[4]	$6,033	$3,787	$4,718	
Price Elasticity of Demand	[5]	-0.16	-0.17	-0.16	

Sources and Notes:

[1],[2]: From Residential Water Suppliers in Orange County. When 2019 data was not available, values from 2020 or 2018 were substituted.

[3]: Center for Demographic Research, January 2020.

[4]: From Residential Water Suppliers in Orange County. When 2019 data was not available, inflation-adjusted values from 2020 or 2021 were substituted.

[5]: Table 5 of Buck et. al. (2016). The MWDOC elasticity is used for Brea and La Habra and South Orange County. A residential demand-weighted average elasticity is calculated for Orange County Basin using the elasticities for Anaheim, Fullerton, Santa Ana, and MWDOC.

B. Results

We calculate the average welfare loss (in $ / million gallons) and total annual welfare loss (in $ millions) for each service area.[20] Table 8 summarizes the per-household welfare loss and the total welfare loss for the 15% shortage and 30% water supply reduction scenarios. Figure 3 shows how estimated welfare losses increase as the extent of demand rationing increases from 0% to 50%.

We estimate that a shortage that requires all residential customers to reduce water use by 15% for one year causes average welfare losses of 2,413 - 4,215 $ / million gallons.[21] Across all three regions, we estimate total residential welfare losses from a 15% water shortage to be $241 million per year. The per household WTP ranges from $222 to $427 per household-year, meaning a household of approximately three people would be willing to pay $222-$427 per year to avoid reducing their water consumption by 15%.

[20] The average welfare loss is calculated using equation 13 from Buck et al. (2016): $\frac{L_i}{Q_i^* r_{it}} = \frac{\varepsilon_i}{1+\varepsilon_i} P_i^* \frac{1-(1-r_{it})^{\frac{1+\varepsilon_i}{\varepsilon_i}}}{r_{it}} - c_i$. Where $r_{it} = \frac{Q^* - Q^R}{Q^*}$. The total welfare loss is calculated by multiplying the average welfare loss by total daily residential water demand and by 365 days per year.

[21] This corresponds to an average welfare loss of $786 – 1,373 per acre-foot.

A shortage that requires all residential customers to reduce water use by 30% for one year causes average welfare losses of 8,080 - 14,682 $ / million gallons.[22] Across all three regions, we estimate the total residential welfare losses from a 30% water shortage to be $818 million per year. The average WTP is $744 to $1,486, meaning a household would be willing to pay between $744 and $1,486 per year to avoid reducing their water consumption by 30%.

The differences in per-household welfare losses between the three basins reflect differences in the value of water to households, their willingness-to-pay, and not the differences in the costs of providing wholesale water supply to the different basins. The differences in these estimates between basins arise from differences between basins in the average residential rates and the price elasticities of demand.

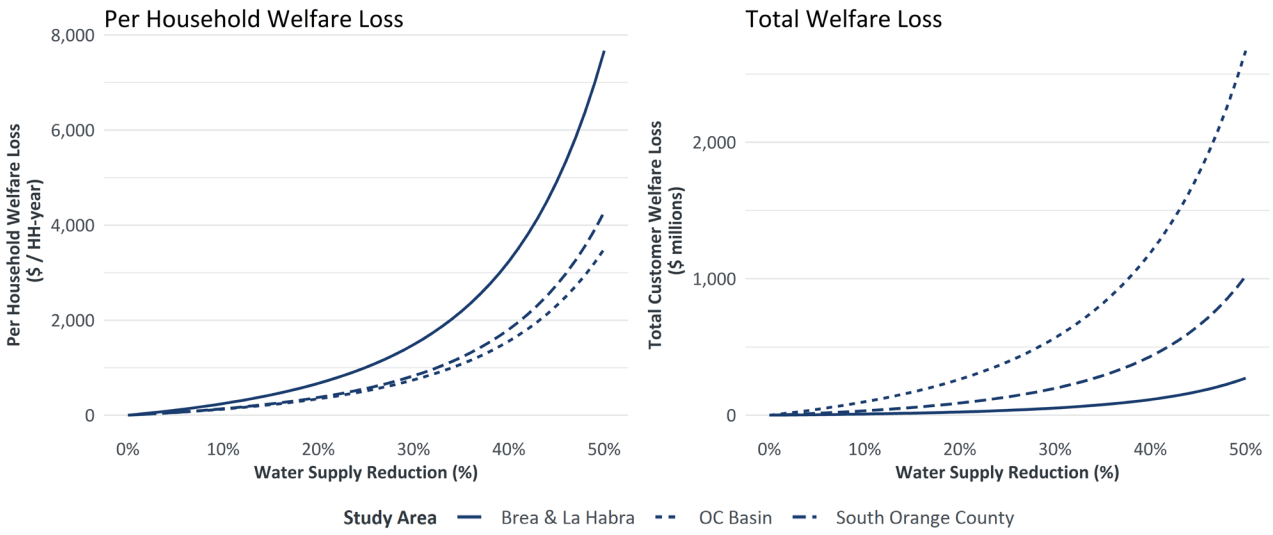
TABLE 8. ECONOMIC IMPACT OF WATER SUPPLY REDUCTIONS ON RESIDENTIAL CUSTOMER WELFARE

		Brea and La Habra	Orange County Basin	South Orange County	Total
			15% Reduction		
Per Household Welfare Loss ($ / HH-year)	[1]	$427	$222	$238	
Total Welfare Loss ($ millions / year)	[2]	$15	$170	$57	$241
			30% Reduction		
Per Household Welfare Loss ($ / HH-year)	[3]	$1,486	$744	$829	
Total Welfare Loss ($ millions / year)	[4]	$53	$568	$198	$818

Notes:
This table estimates the economic impacts of a shortage that requires all customers to reduce water use by 15% or 30%.
[1],[3]: Total Welfare Loss / Population x Persons per Household.
[2],[4]: Average Welfare Loss x Total Daily Residential Water Demand / 365 days per year. Average Welfare Loss is calculated using equation 13 from Buck et.al. (2016).

[22] This corresponds to an average welfare loss of $2,633 – 4,784 per acre-foot.

FIGURE 3. PER HOUSEHOLD AND TOTAL RESIDENTIAL CUSTOMER WELFARE LOSSES UNDER WATER SUPPLY REDUCTIONS



Source: Brattle Calculations.

IV. Impact of Water Shortages on the Water District Revenues

In this section, we calculate the revenue lost to retail water districts in Orange County that would be associated with 15% and 30% water supply reductions. Note that retail water districts sometimes choose to enact emergency drought rates or other fees during shortages in order to cover revenue losses. However, these can be unpopular with customers who feel they are being punished for conserving water. In our calculations, we assume that districts do not impose a drought surcharge or other fees to recover these losses. If surcharges were imposed, then the losses estimated in this section would instead be passed onto customers in each district.

To calculate revenue loss, we multiply overall demand times the percent shortage times the water rate by member district for the residential and commercial, industrial, and institutional (CII) sectors, then sum by study area. Total demand by sector is estimated in each region for the year 2019 by adding up the water consumption that each utility is required to report to the Department of Water Resources (DWR).[23] Residential water rates are calculated using the

[23] Note that we chose to rely on demand data from 2019 rather than 2020 or 2021 to avoid complications caused by the impact of the COVID-19 pandemic on residential water demand. For some districts where 2019 data is

median rate tier for single-family household customers.[24] CII water rates are calculated using the median rate tier for CII customers. In instances where the sector is not specified, the residential and CII rates are the same. Where rate data from 2019 is not available, rate data from the closest available year are used and adjusted for inflation. These calculations assume that districts do not impose a drought surcharge or other fees to recover these losses, in which case the losses would instead be imposed on customers.

Table 9 shows the total revenue loss for the CII and residential sectors that MWDOC member agencies would face given the 15% and 30% water supply reduction scenarios. Across all three regions, we estimate that revenue losses are $37.6 million from CII customers and $58.0 million from residential customers for a total of $95.6 million given a 15% reduction in water consumption. For a 30% reduction in water consumption, we estimate revenue losses of $75.1 million from CII and $116.0 million from residential customers, for a total of $191.1 million.

Note that the revenue losses reported in Table 9 are substantially smaller than the welfare losses reported in Table 8. Each additional unit of shortage leads to a similar revenue loss for water retailers (depending on their specific rate and cost structure), whilst for households, each additional unit of shortage is increasingly costly, as households must take increasingly extreme measures to reduce water use.

TABLE 9: ORANGE COUNTY WATER RETAILERS ANNUAL REVENUE LOSS ($ MILLIONS)

Water Supply Reduction		Brea and La Habra	Orange County Basin	South Orange County	Total
		Commercial, Industrial, and Institutional			
15% Reduction	[1]	$1.6	$32.4	$3.6	$37.6
30% Reduction	[2]	$3.1	$64.9	$7.1	$75.1
		Residential			
15% Reduction	[3]	$3.3	$41.1	$13.6	$58.0
30% Reduction	[4]	$6.5	$82.2	$27.3	$116.0

Sources and Notes:
This table estimates the economic impacts of a shortage that requires all customers to reduce water use by 15% or 30%.
Revenue loss is calculated by agency as demand x shortage x water rate.

not available, we rely instead on data from 2018 or 2020. Data for Emerald Bay Service District and Serrano Water district were obtained from their websites as they did not report data to the DWR.

[24] We obtain rate data from the websites of each water utility.

CII demand data is from residential water suppliers in Orange County. When 2019 data was not available, values from the closest year were substituted.
Commercial and industrial water rate data is from residential water suppliers in Orange County. When 2019 data was not available, inflation-adjusted values from 2020 or 2021 were substituted. When CII-specific water rates were not available, residential rates were substituted.

Appendix A: Business Water Reliability Survey Technical Report

SOCIAL SCIENCE RESEARCH CENTER
CALIFORNIA STATE UNIVERSITY
FULLERTON™

Municipal Water District of Orange County
Business Water Reliability Survey
Technical Report

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Social Science Research Center

INTRODUCTION

Orange County faces two vastly different kinds of potential water disruptions – periodic drought, typical of the region's climate, and larger, potentially catastrophic disruptions in water availability. A drought scenario is better understood as it is experienced more frequently. In dry periods, residents may face voluntary water use reductions, price increases, and, in more extreme circumstances, water rationing that in the past have yielded reductions in water use from 10 to 35 percent. Businesses, being high-value water users responsible for the local job base, are often shielded from water rationing efforts. A more extreme event could require reductions in water supply of 50 percent or more, for possibly weeks or months, and it would likely not be possible to shield businesses from supply reductions in the case of a catastrophic event. The most commonly discussed source of extreme interruptions would be earthquake damage to water treatment or major distribution systems, such as the potential for an earthquake to damage the Robert B. Diemer water treatment plant in North Orange County.

In both circumstances – whether a drought or a catastrophic disruption – residents and businesses could experience a reduction in available water supply. Efforts to mitigate those reductions require the County have a credible estimate of the value of water supply reliability to ensure the avoidance of over-investing or under-investing in water supply projects. How much would residents and businesses be willing to pay to avoid reductions or interruptions in water supply? How would this compare to mitigation costs to avoid shortages?

The most recent study to quantify the value of water supply reliability in Orange County was conducted almost two decades ago (Orange County Business Council, 2003). Since then, little work has been done to illuminate how residents and businesses would be economically harmed if water supply is reduced or interrupted. Water agencies occasionally conduct customer surveys or opinion polls, and those surveys are useful for assessing customer satisfaction in qualitative terms. But opinion and satisfaction surveys cannot give insight into how residents and businesses value a reliable water supply, nor can satisfaction or opinion surveys give a quantified estimate of the value of a secure water supply. Similarly, satisfaction or opinion surveys cannot illuminate how persons and firms would be willing to pay for investments to increase the reliability of water supply.

The Municipal Water District of Orange County (MWDOC) detailed an economic study to quantify how the Orange County community values water supply reliability. The purpose of this study is to quantify measures of benefits that would accrue to the County from reducing small (e.g. drought) and large (e.g. catastrophic event) reductions in water availability. To this end, MWDOC, through Tech Coast Consulting Group, LLC, contracted with the Social Science Research Center (SSRC) at California State University, Fullerton to administer a telephone survey to a sample of businesses operating in Orange County, California. The purpose of this study was to measure the value businesses place on various water-related aspects, the extent to which they had ever been impacted by previous droughts and would be impacted by future calls for water conservation, as well as how their business practices might be impacted by a hypothetical water shortage requiring them to cutback on their water consumption.

Between September 2 and November 3, 2021, the SSRC completed a total of 401 surveys with representatives of businesses operating in Orange County. Importantly, businesses serviced by the Irvine Ranch, Moulton Niguel, and Yorba Linda Water Districts were omitted from the current study, as these districts did not want their constituents surveyed. Although surveys were available in Spanish, all surveys were conducted in English. The overall margin of error for the total survey sample is plus or minus 4.89 percentage points with a confidence level of 95%. [1]

The instrument for the administration of this survey was comprised of approximately 46 items, used to document the impact of a hypothetical water shortage on the business practices of those operating in Orange County. The survey instrument was drafted by MWDOC staff and later refined by the SSRC to improve flow, clarity, and ease of administration. The survey instrument is reproduced in Appendix A.

Once a final survey instrument has been agreed upon, the SSRC must obtain approval from California State University's Institutional Review Board (IRB), a university committee appointed by the CSUF President to protect the rights and welfare of human subjects recruited to participate in research activities. IRBs help mitigate potential risks to participants, including risks to their physical and psychological well-being, confidentiality and privacy, and autonomy, among others. The process to request approval entails completing an application, having that application reviewed by an IRB committee, and receiving a formal approval notice. Research cannot begin until the IRB has reviewed and approved research undertakings. The study protocol received approval from CSUF IRB on August 18, 2021. Surveys were only administered to individuals who provided verbal consent to participate in the current study.

A training/pilot study was conducted on September 1, prior to full-scale survey administration. During this pilot training, staff were familiarized with the background of the study, read through the survey instrument, engaged in roleplaying with other interviewers, and practiced with the CATI software before administering surveys to live respondents. The purpose of the pilot study was to provide telephone interviewers with project information and familiarity and to determine whether full-scale data collection could be initiated. A limited number of surveys were collected during the pilot to identify potential problems or difficulties with the survey or the data collection process.

On the evening of the pilot, after data collection concluded, a debriefing session was conducted in which call center staff and management discussed any issues experienced, as well as solutions to the those issues. All issues were compiled and brought to the attention of the Tech Coast Consulting Group, along with recommendation for edits to the survey.

Midway through data collection, the SSRC made the survey available online for business

[1] Margin of error calculated based on population of total employer establishments from the 2018 American Community Survey (ACS) 1-year estimate (99,577 employer establishments).

representatives resistant to completing the survey by phone but willing to complete the survey online.

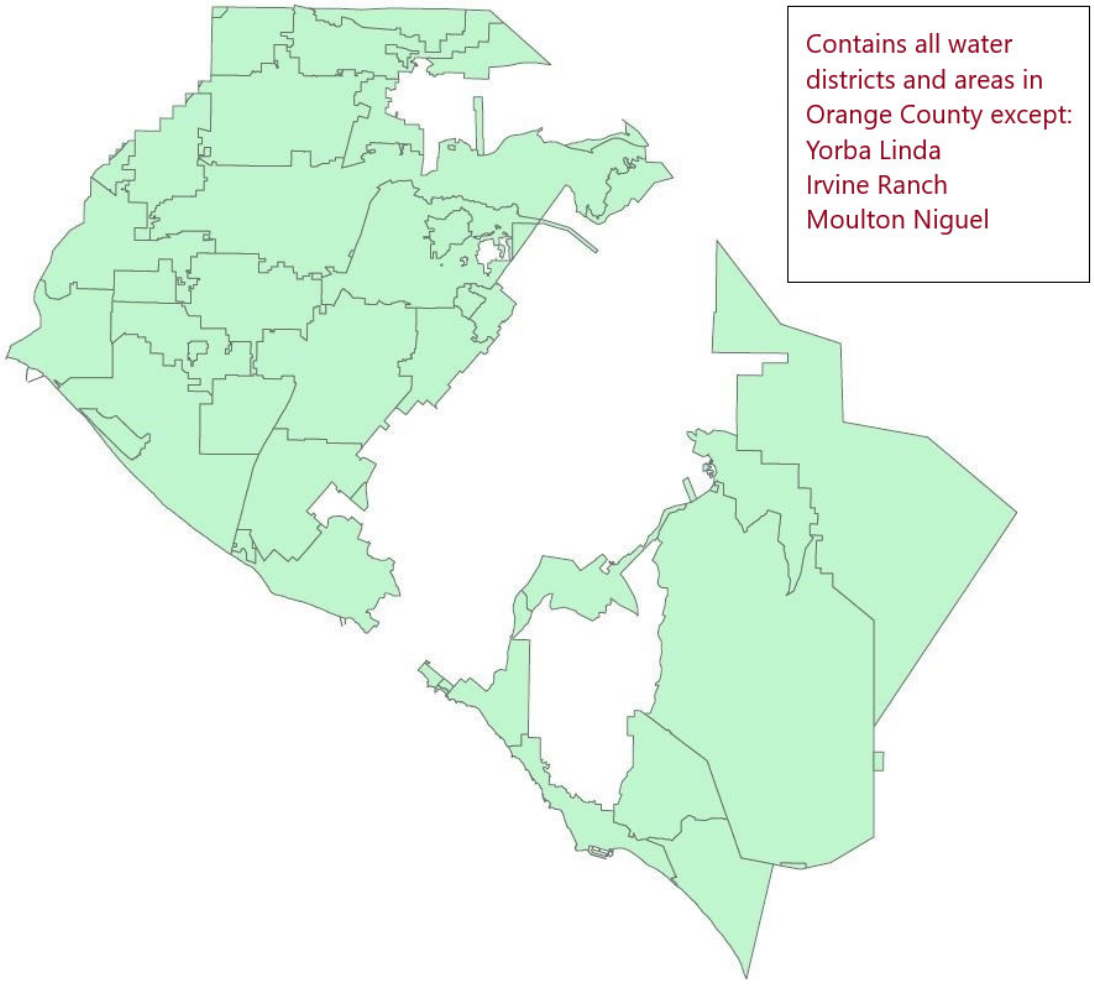
Interviews were conducted between 9:00 AM and 5:00 PM, Monday through Friday. The length of time required to complete each telephone interview ranged from 9 minutes (*n* = 2; 0.50%) to 77 minutes (*n* = 1; 0.25%). The mean survey administration time was 23 minutes and 47 seconds, and the median time was 22 minutes.

SAMPLE SELECTION

The population of inference for the current study is all businesses operating in Orange County, omitting those serviced by Yorba Linda, Moulton Niguel, and the Irvine Ranch Water districts. A map depicting the geographic area of study is presented in Figure 1. The SSRC contracted with Scientific Telephone Samples (STS), one of the premier vendors of statistically sound telephone samples, to obtain a list of businesses operating in Orange County, along with corresponding telephone numbers. To improve the efficiency of the sample, businesses were originally included in the sampling frame if located in a census block containing 90% or more of its landmass in the sampling area. Over time, however, this strategy was relaxed as the 90% criteria did not produce an adequate number of records in the sampling frame to reach the target number of survey completions. To achieve the 401 survey completions, the final sampling frame utilized contained businesses operating in census blocks with 30% or more of their land mass within the sampling area.

STS provided the SSRC with a list of 5,011 telephone numbers. In order to ensure representation of business size, quotas were originally set to ensure a third of surveys were completed with "small" businesses (less than 50 employees on site), another third with "medium" ones (50 to 249 employees on site), and a final third were completed with "large-sized" businesses (250 or more employees on site). However, as only 41 (<1%) records in the sampling frame were designated as large businesses, study quotas were reconfigured such that half of survey completions came from small businesses and the other half from medium businesses. Surveys were completed with large businesses as possible.

Figure 1. Geographic Area of Study



TECHNICAL APPROACH TO DATA COLLECTION

The SSRC implements Computer Assisted Telephone Interviewing (CATI) through WinCATI® software to facilitate the control of the sample, track scheduled call-backs, and monitor progress regarding the completion of sample design quotas. Programming is carried out using Sensus software, which allows for the randomization of questions and question sets within a survey to eliminate response order biases, response range limits to reduce recording errors, and complex interview navigation commands to ensure the proper administration of survey items.

Survey questions and response options appear on a computer screen while the interviewer is speaking to the respondent. Data are entered directly into the system to reduce coding or keying errors. SSRC supervisors are present during all interviewing shifts, and call-monitoring is routinely performed to verify the accuracy of the data. All SSRC supervisors previously worked as a telephone interviewer, and receive extensive training in telephone interviewing techniques and methodological considerations.

The CATI system includes a sophisticated call tracking and call-back scheduling procedure. This system assigns sample records to interviewing stations based on user configurable rules, which include a randomization element and also consider call history and interviewer capability/training. An attempt history is maintained for each sample record, which can be used to calculate productivity and other process-related statistics. If no contact is made, the call record will note the time of day and the interviewer who attempted the call. The call will then be automatically reassigned at a later time based upon an algorithm that reduces the probability the call will come up again on the same day and time. When a contact is made but the interview is not completed, call information is recorded that includes whether a call-back has been scheduled, who the interviewer spoke with, who they should talk to if the eligible respondent is not present, and the current disposition of the call (for example, immediate refusal, answering machine, mid- interview termination, etc.). In addition, the time of each call, the number of times the record has been called, and any interviewer-generated notes are recorded.

The CATI system allows the researcher to set the number of times a sample record is to be called before it is retired. SSRC standard operating procedure dictates 21 attempts per record. If contact is not established after 21 calls, the number is transferred to a holding queue. Exceptions are made to this procedure in two cases. First, if the 21st call attempt yields a scheduled callback, then a 22nd call attempt will be made as scheduled. Second, when a respondent begins a survey and cannot complete it at that time but indicates they will complete the survey at a later date, an indefinite number of call attempts are made to complete with that individual.

The survey was also programmed into Qualtrics, a widely used and sophisticated software package for constructing web-based surveys. SSRC staff extensively tested the survey for errors before emailing the survey link to a business representative who requested a link to the survey instrument while on the phone with a telephone interviewer. Utilization of the online survey began halfway through the data collection period, when it was realized making the survey available online might increase the survey response rate. This approach ensured representation of all types of businesses, regardless of an inability to complete by phone due to busy schedules or other barriers.

A total of 14,351 call attempts were made to complete 401 surveys, with an average of 3.29 calls per completed survey.

DATA COLLECTION OUTCOMES

Overall, 381 (95.01%) of the 401 total surveys were conducted by phone, while the remaining 4.98% (*n* = 20) were completed online. Of the 401 completed interviews, the largest proportion (*n* = 68; 17.00%) were conducted by businesses located in the area serviced by the Anaheim Water District and the Santa Ana Water District (*n* = 53; 13.21%). The service areas of the remaining 280 businesses in the survey sample are depicted in Table 1. As shown in Table 2, the largest proportion of survey completers represented businesses in the manufacturing sector (*n* = 76; 19.00%), followed by accommodation and food services (*n* = 71; 17.71%), and some "other" industry (*n* = 35; 8.7%). Examples of "other" industries reported by survey respondents include "diagnostics software," "biotech," "aerospace software and engineering," and "exporting of recyclables." The remainder of the distribution is shown in Table 2.

Looking at the number of employees at the location of the business surveyed, 253 (63.10%) surveys were conducted with small businesses, 145 (36.20%) were completed with medium-sized businesses, and three (0.75%) were done with large businesses. This is true despite the fact survey quotas initially designated 50% of completions should come from both small- and medium-sized businesses. That survey quotas were not met is indicative of the level of difficulty experienced in obtaining cooperation from medium-sized businesses.

Table 1. Service Area of Businesses Contained in Study Sample

Area	Count	%
Anaheim	68	17.00
Brea	12	3.00
Buena Park	12	3.00
El Toro Water District	12	3.00
Fountain Valley	19	4.74
Fullerton	23	5.74
Garden Grove	12	3.00
Golden State Water	18	4.49
Huntington Beach	28	6.98
La Habra	10	2.49
Laguna Beach County Water District	5	1.25
Mesa Water District	34	8.48
Newport Beach	14	3.50
Orange	37	9.23
San Clemente	8	2.00
San Juan Capistrano	7	1.75
Santa Ana	53	13.22
Santa Margarita Water District	10	2.50
Tustin	6	1.50
Westminster	12	3.00
Total	**401**	**100.00**

Table 2. Industries of Businesses Represented in the Survey Sample

Industry	Count	%
Manufacturing	76	18.95
Accommodations and Food Service	71	17.71
Other	35	8.73
Retail	34	8.48
Construction	31	7.73
Medical	31	7.73
Service (Other)	24	5.99
Finance/Real Estate	17	4.24
Arts, Entertainment, and Recreation	17	4.24
Distributor	12	3.00
Agriculture	9	2.24
Nonprofit	8	2.00
Residential	8	2.00
Tourism	7	1.75
Transportation	5	1.25
Total	**401**	**100.00**

Table 3 presents the number of attempts required to complete each interview. As the table shows, approximately two thirds of the surveys (*n* = 268, 66.83%) were completed in the first three call attempts. The SSRC calculates survey response rates using the American Association for Public Opinion Research (AAPOR) Response Rate Calculation Method 3 (RR3), which includes an estimate of eligibility among unscreened sample records based on the eligibility rate among respondents for whom a final determination could be made.

Table 3. Number of Attempts per Completed Interview

Number of Attempts	Completed Interviews	% of all Completes
1	73	18.20
2	99	24.69
3	96	23.94
4	51	12.72
5	34	08.48
More than 5	48	11.97
Total	**401**	**100.00**

The RR3 formula is:

$$Rate = \frac{C}{(C+I)+(R+N)+eU}$$

Where *C*= complete interviews, *I*= incomplete interviews, *R*= eligible refusals, *N*= other eligible non-complete records, *e*= estimate of eligibility, and *U*= records with unknown eligibility.

In addition to the Response Rate, a Cooperation Rate was also calculated for the study. This rate is the proportion of interviews completed of all eligible units. The SSRC uses Cooperation Rate Method 3 (COOP3), which counts completed interviews, partial interviews, and refusals as eligible units.

The Response Rate for the sample was 10.40%, but the Cooperation Rate was 33.20%. In all, completed surveys comprised 8.24% (*n* = 401) of all records attempted (*N* = 4,869). The largest proportion of all records attempted were answering machines (*n* = 1,828, 37.54%). Table 5 depicts the outcomes of all 4,869 attempted records.

Table 5. Disposition of All Attempted Records

Disposition	Count	%
Answering Machine	1,828	37.54
Call Blocking/Technical Barrier	305	6.26
Hang Up	269	5.53
Soft Refusal	423	8.69
Non-Working/Disconnected	448	9.20
Busy Signal	93	1.91
Complete	401	8.24
Online Link Requested	152	3.12
No Answer	351	7.21
Callback	221	4.54
Temporarily Out of Service	33	<0.10
Final Refusal	102	2.10
Number Changed	36	<0.10
Not a Business	69	1.42
Language Problem	6	<0.10
Partial	13	<0.10
Fax/Data Line	13	<0.10
Ineligible	100	2.10
Incoherent / Lost Connection	6	<0.10
Total	**4,869**	**100%**

Appendix B: Business Water Reliability Survey Instrument

MWDOC Value of Water Supply Reliability Business/Industry Survey Instrument

INTRO Hi, my name is _____, and I'm calling from the Social Science Research Center at Cal State University on behalf of the Municipal Water District of Orange County (MWDOC). We are conducting a survey of Orange County businesses. This brief survey, which will take about five minutes to complete, addresses how potential water supply interruptions might affect your business practices. The data collected through this survey will help inform decision makers plan for and invest in long term water reliability for Orange County - and are in no way indicative of future restrictions, shortages, or disruptions.

Are you the person at your business who would have details on the company's water usage, or is that someone else?

1. CORRECT PERSON [SKIP TO START]
2. SOMEONE ELSE

OTHP Is the person who would have information on water usage available now?

1. YES [SKIP TO INTROA]
2. NO

OTHW When can I call back to reach them?
[RECORD TIME AND DATE; END]

INTROA Hi, my name is _____, and I'm calling from the Social Science Research Center at Cal State University on behalf of the Municipal Water District of Orange County (MWDOC). We are conducting a survey of Orange County businesses. This brief survey, which will take about five minutes to complete, addresses how potential water supply interruptions might affect your business practices. The data collected through this survey will help inform decision makers plan for and invest in additional long term water reliability for Orange County - and are in no way indicative of future restrictions, shortages, or disruptions.

START Is it okay to ask you these questions now?

1. CONTINUE
2. CALLBACK
3. REFUSED

ELIG First, to make sure you are eligible to participate in the following study, which water district services your businesses? [INTERVIEWER, CODE CORRECT RESPONSE. ONLY READ OPTIONS IF RESPONDENT DOES NOT KNOW]

1. YORBA LINDA WATER DISTRICT [SKIP TO INELGIBLE]
2. MOULTON NIGUEL WATER DISTRICT [SKIP TO INELGIBLE]
3. IRVINE RANCH WATER DISTRICT [SKIP TO INELGIBLE]
4. CITY OF ANAHEIM
5. CITY OF FULLERTON
6. CITY OF HUNTINGTON BEACH
7. CITY OF SANTA ANA
8. EAST ORANGE COUNTY WATER
9. El TORO WATER
10. EMERALD BAY SERVICE DISTRICT
11. GOLDEN STATE WATER CO
12. LAGUNA BEACH COUNTY WATER
13. LAGUNA BEACH WATER
14. MESA WATER DISTRICT
15. SANTA MARGARITA WATER DISTRICT
16. SERRANO WATER
17. SOUTH COAST WATER DISTRICT
18. TRABUCO CANYON WATER
19. TUSTIN WATER
20. OTHER SPECIFY>

ICONSENT Before we continue, I need to read you some information about your rights as a research participant. Participation in this study is completely voluntary, and you are free to decline to answer any survey question, to decline to participate entirely, or to stop participating at any time. Your identity and your responses will remain confidential to the extent permitted by law. None of our staff have any financial interest in the results of this study.

These data are being collected to inform local decision-making and will not be sold to a third party. Nor will these data be used at a later date to sell you something. Lastly, this call will be recorded for quality control and to ensure fair treatment of all participants. If you have questions about your rights as a research participant or general questions about the study, I have some numbers I can provide you. [IF REQUESTED]: You may contact the California State University, Fullerton Institutional Review Board at (657) 278-7719. For any other questions about the study, contact Laura Gil-Trejo at 657-278-7691.

Now that you have this information, are you willing to participate in the study?

1. YES
2. NO [END]

INTRO To help us understand how important a reliable water supply is for your business, please answer the following questions to the best of your ability.

Q1. What industry sector would you classify your business as?

1. Agriculture (NAICS 11)
2. Manufacturing (NAICS 31)
3. Arts, Entertainment & Recreation (NAICS 71)
4. Accommodations & Food Services (NAICS 72)
5. Tourism (NAICS NN002)
6. Some other Industry, SPECIFY>
7. DON'T KNOW
9. REFUSED

Q2. How long has your business been located in Orange County?

1. SPECIFY IN YEARS> _____
2. SPECIFY IN MONTHS
7. DON'T KNOW
9. REFUSED

Q3. Is your business based/headquartered in Orange County?

1. YES [SKIP TO Q4]
2. NO
7. Don't know
9. REFUSED

Q3a. Where is your business headquartered?

1. SPECIFY CITY> _____
   SPECIFY STATE> _____
7. DON'T KNOW
9. REFUSED

Q4. Does your business have multiple locations within Orange County?

1. YES
2. NO [SKIP TO Q5]
7. DON'T KNOW [SKIP TO Q5]
9. REFUSED [SKIP TO Q5]

Q4a. How many locations are within Orange County?

1. SPECIFY NUMBER> _____
7. DON'T KNOW
9. REFUSED

Q4b. How many total locations are there (including those within and outside Orange County)?

1. SPECIFY NUMBER> _____
7. DON'T KNOW
9. REFUSED

TRANS2 The next few questions are about your business and its interaction with water use.

Q5. Where would you say water is used **most** within your business?

1. Operations/Manufacturing (including sterilization, operation related rising, boilers/chillers)
2. Cleaning/Sanitation
3. Building Cooling/HVAC
4. Landscape
5. OTHER, SPECIFY> _____
7. DON'T KNOW
9. REFUSED

Q6. Does your business location or campus have a sizable landscape area (such as lawns, or gardens areas beyond parking strips)?

1. YES
2. NO
7. DON'T KNOW
9. REFUSED

Q7. Rate the importance of the following water related aspects to your business or operations:

a. The **amount** of water your business uses.
b. The overall **cost** of water.
c. Water use **efficiency**.
d. The reliability of water **quality**.

[IF 4 OR 5: "What aspect(s) of operations is it "important/very important" to?"
SPECIFY RESPONSE>]

1. Very unimportant
2. Unimportant
3. Neither important nor unimportant
4. Important
5. Very important
7. DON'T KNOW
9. REFUSED

TRANS3 Note: The general approach to water management planning is to minimize impacts to businesses to the greatest extent possible in support of the economy.

The following questions refer to <u>previous or hypothetical cases</u> and are aimed at quantifying potential impacts of various levels of water supply shortages. Please note, these questions **<u>DO NOT</u>** imply that water shortages are pending **<u>and DO NOT imply</u>** that any changes to current water management strategies are being contemplated.

Q8. Was your operations/business impacted during the last **<u>major drought</u>** (2014 to 2016, which included the Governor's 2015 call for water use reduction)?

1. YES
2. NO [SKIP TO Q9]
7. DON'T KNOW [SKIP TO Q9]
9. REFUSED [SKIP TO Q9]

Q8a. Describe the impact this had on your business.

1. SPECIFY> _____
7. DON'T KNOW
9. REFUSED

Q8b. Did this impact result in revenue reduction?

1. YES
2. NO [SKIP TO Q9]
7. DON'T KNOW [SKIP TO Q9]
9. REFUSED [SKIP TO Q9]

Q8c_1. As a result, did you make any changes to reduce your water use?

1. YES
2. NO [SKIP TO Q9]
7. DON'T KNOW [SKIP TO Q9]
9. REFUSED [SKIP TO Q9]

Q8c_2 Were these changes short- or long-term?

1. SHORT-TERM
2. LONG-TERM
7. DON'T KNOW
9. REFUSED

Q9. Thinking about a hypothetical future drought, would a drought related call for water use reductions (conservation) have an impact to your operations/business?

1. YES
2. NO
7. DON'T KNOW
9. REFUSED

Q10. Has your business ever been impacted by water supply disruptions in the past?

1. YES
2. NO [SKIP TO TRANS4]
7. DON'T KNOW [SKIP TO TRANS4]
9. REFUSED [SKIP TO TRANS4]

Q10b. Describe the impact these disruptions had on your business.

1. SPECIFY> _____
7. DON'T KNOW
9. REFUSED

Q10c. And how long did this water supply disruption last?

1. SPECIFY IN DAYS>
2. SPECIFY IN WEEKS>
3. SPECIFY IN MONTHS>
7. DON'T KNOW
9. REFUSED

Q10d. Did the impact of these disruptions result in revenue reduction?

1. YES
2. NO
7. DON'T KNOW
9. REFUSED

Q10e_1. As a result, did you make any changes to reduce your water use?

1. YES
2. NO [SKIP TO TRANS4]
7. DON'T KNOW [SKIP TO TRANS4]
9. REFUSED [SKIP TO TRANS4]

Q10e_2 Were these changes short- or long-term?

1. SHORT-TERM
2. LONG-TERM
7. DON'T KNOW
9. REFUSED]

TRANS4 The following questions will ask how likely it is that your operation/business might be impacted as a result of <u>hypothetical</u> examples.

Q11. Following a hypothetical event, your business will experience recurrent shortages **<u>for a one-year period</u>**. While there is some advance notice within the first quarter, this would require you to cutback your water use to **<u>15% less water than normal for the year</u>**.

To adjust to this need to reduce your water use, we would like to evaluate what the **<u>impact to your operations/business</u>** might be. Would you…

[NOTE TO INTERVIEWER: IF YES, PROBE TO DESCRIBE WHAT KIND OF CHANGES]

Q11a. Make **<u>changes</u>** to operational practices? (Such as implement new technology or practices; see note above)

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

Q11b. **<u>Decrease</u>** production output?

1. YES, please explain>_____
2. NO [SKIP TO Q11c]
7. DON'T KNOW [SKIP TO Q11c]
9. REFUSED [SKIP TO Q11c]

Q11b.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q11c. Lower employment?

1. YES, please explain>_____
2. NO [SKIP TO Q11d]
7. DON'T KNOW [SKIP TO Q11d]
9. REFUSED [SKIP TO Q11d]

Q11c.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q11d. Experience income and cash flow reductions?

1. YES, please explain>_____
2. NO [SKIP TO Q11e]
7. DON'T KNOW [SKIP TO Q11e]
9. REFUSED [SKIP TO Q11e]

Q11d.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q11e. If this resulted in an increased cost, would you **pass increased costs through** to your customers?

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

Q11f. Begin to consider relocation?

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

Q12. Following a hypothetical event, your business will experience recurrent shortages **for a one-year period**. While there is some advance notice within the first quarter, this would require you to cutback your water use to **30% less water than normal for the year**.

To adjust to this need to reduce your water use, we would like to evaluate what the **impact to your operations/business might be**.

[Note to interviewer: if yes, probe to describe what kind of changes]

Q12a. Make **changes** to operational practices? (Such as implement new technology or practices; see note above)

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

Q12b. **Decrease** production output?

1. YES, please explain>_____
2. NO [SKIP TO Q12c]
7. DON'T KNOW [SKIP TO Q12c]
9. REFUSED [SKIP TO Q12c]

Q12b.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q12c. Lower employment?

1. YES, please explain>_____
2. NO [SKIP TO Q12d]
7. DON'T KNOW [SKIP TO Q12d]
9. REFUSED [SKIP TO Q12d]

Q12c.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q12d. Experience income and cash flow reductions?

1. YES, please explain>_____
2. NO [SKIP TO Q12e]
7. DON'T KNOW [SKIP TO Q12e]
9. REFUSED [SKIP TO Q12e]

Q12d.1. By what estimated percentage range?

1. 1-10%
2. 11-20%
3. 21-30%
4. 31-40%
5. 41-50%
6. More than 50%
7. DON'T KNOW
9. REFUSED

Q12e. If this resulted in an increased cost, would you **pass increased costs through** to your customers?

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

Q12f. Begin to consider relocation?

1. YES, please explain>_____
2. NO
7. DON'T KNOW
9. REFUSED

TRANS5 The following questions will focus on your business's considerations for location and/or expansion of your business within Orange County.

Q13. What are the top three reasons your business is based here (meaning reasons you would **not** consider relocation)?

1. Geographic location
2. You have invested too much capital
3. Local skilled workforce
4. Complementary industry access
5. Regulations in the area
6. Other, SPECIFY>_____
7. DON'T KNOW
9. REFUSED

Q14. What are the top three reasons your business might consider not expanding in Orange County?

1. SPECIFY #1>_____
   SPECIFY #2>_____
   SPECIFY #3>_____
7. DON' KNOW
9. REFUSED

Q15. Rate the likelihood that any of the following water related reasons could result in consideration for future expansions decisions:

a. Intermittent calls for small reductions in water use.
b. Less often, but greater reduction amounts when calls for water use reduction occur.
c. Intermittent small changes to water quality (yet still meeting all drinking water standards)
d. Albeit less often, greater water quality changes (yet still meeting all drinking water standards)
e. Increased water cost
f. Any other water related reasons, SPECIFY>_____

1. Very unlikely
2. Unlikely
3. Neither likely nor unlikely
4. Likely
5. Very likely
7. DON'T KNOW
9. REFUSED

Q16. Rate the importance of the following to future expansion decisions:

a. Water reliability
b. Water quality
c. Water cost
d. Any other water related reasons, SPECIFY>_____

1. Not at all Important
2. Unimportant
3. Neither important nor unimportant
4. Important
5. Very important
7. DON'T KNOW
9. REFUSED

Q17. Do you have additional water related comments you would like to share?

1. YES, SPECIFY>_____
2. NO
7. DON'T KNOW
9. REFUSED

INELIGIBLE **I am sorry, you are ineligible to participate in this survey. Thank you for your time.**

CONCL **Thank you for your feedback!**

This information will only be used to help inform decision makers as they continue to plan for and invest in long term water reliability for Orange County and are in NO WAY indicative of future restrictions, shortages, or disruptions.

Appendix C: Survey Respondents by Industry and Aggregation Method

We surveyed 401 businesses in Orange County using a stratified random sampling approach within 15 industry categories categorized by the North American Industry Classification System (NAICS). Table C1 shows the number and share of businesses surveyed by 15-industry categorization. In order to improve the quality of the survey analysis, survey results in peer or similar industry sectors were aggregated together to form eight broader industry categories. Table C1 also highlights which of the 15 industry categories are included in the eight categories analyzed.

TABLE C1: EIGHT-CATEGORY INDUSTRY BREAKDOWN AND COUNT OF SURVEY RESPONDENTS

NAICS Code	15-Industry Category	8-Industry Category	Count	Percent of Total
31-33	Manufacturing	Manufacturing	73	18%
72	Accomodation and Food Services	Entertainment and Tourism	61	15%
44-45	Retail Trade	Retail and Other Services	43	11%
62	Health Care and Social Assistance	Education and Health Care	39	10%
42	Wholesale Trade	Logistics, Transportation, Warehousing	30	7%
23	Construction	Construction	28	7%
54	Professional, Scientific, and Technical Services	Professional Services, Information, and Administration	26	6%
53	Real Estate Rental and Leasing	Finance, Insurance, and Real Estate (FIRE)	17	4%
56	Administrative and Support and Waste Management and Remediation Services	Professional Services, Information, and Administration	15	4%
71	Arts, Entertainment, and Recreation	Entertainment and Tourism	15	4%
48-49	Transportation and Warehousing	Logistics, Transportation, Warehousing	14	3%
52	Finance and Insurance	Finance, Insurance, and Real Estate (FIRE)	11	3%
61	Eduational Services	Education and Health Care	11	3%
51	Information	Professional Services, Information, and Administration	10	2%
81	Other Services	Retail and Other Services	8	2%
Total			401	100%

Sources and Notes:
Includes responses that were dropped in analysis due to inconsistencies.

Appendix D: Eight-Category Economic Impacts

D.1 Economic Impacts for a 15% Water Reduction Scenario

Table D1 shows the economic impacts from IMPLAN for each of the eight industry categories for a 15% water reduction scenario, as well as the total impact's share of the Orange County employment and output for that industry. The Orange County employment and output data come from Emsi.

TABLE D1: ECONOMIC IMPACTS OF A 15% WATER REDUCTION SCENARIO BY INDUSTRY
PANEL A: CONSTRUCTION

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	1,456	$60,023,396	$81,592,762	$136,287,747
2 - Indirect	187	$13,534,177	$21,807,195	$34,989,082
3 - Induced	280	$18,365,319	$30,044,450	$47,764,864
Total	1,924	$91,922,891	$133,444,408	$219,041,692
% County Total	1.9%			1.6%

PANEL B: MANUFACTURING

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	3,479	$161,145,936	$288,236,431	$651,584,966
2 - Indirect	802	$73,932,346	$114,570,105	$185,233,073
3 - Induced	867	$56,902,552	$93,057,228	$147,939,701
Total	5,148	$291,980,834	$495,863,765	$984,757,740
% County Total	3.5%			3.1%

PANEL C: LOGISTICS, TRANSPORTATION, AND WAREHOUSING

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	1,561	$133,998,046	$253,558,110	$412,293,122
2 - Indirect	787	$67,694,104	$108,697,973	$172,551,547
3 - Induced	755	$49,524,087	$81,007,416	$128,785,004
Total	3,103	$251,216,237	$443,263,499	$713,629,673
% County Total	3.1%			2.9%

PANEL D: RETAIL AND OTHER SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	2,364	$77,422,897	$100,229,130	$151,516,763
2 - Indirect	239	$19,839,754	$33,703,016	$53,948,219
3 - Induced	374	$24,561,601	$40,185,286	$63,887,262
Total	2,977	$121,824,251	$174,117,433	$269,352,244
% County Total	1.5%			1.4%

PANEL E: FIRE

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	0	$142,622,842	$409,899,808	$668,505,788
2 - Indirect	1,296	$103,387,613	$199,783,803	$322,256,544
3 - Induced	946	$62,075,126	$101,558,769	$161,459,627
Total	2,243	$308,085,581	$711,242,380	$1,152,221,960
% County Total	1.8%			2.9%

PANEL F: PROFESSIONAL, INFORMATION, AND ADMINISTRATIVE SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	5,080	$268,229,699	$369,097,340	$583,133,989
2 - Indirect	1,188	$96,409,245	$148,624,916	$237,090,012
3 - Induced	1,383	$90,704,720	$148,365,355	$235,869,968
Total	7,651	$455,343,664	$666,087,611	$1,056,093,970
% County Total	2.6%			2.2%

PANEL G: EDUCATION AND HEALTHCARE SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	1,529	$80,258,171	$90,110,374	$135,342,410
2 - Indirect	214	$16,901,249	$28,722,860	$46,081,840
3 - Induced	360	$23,648,195	$38,678,324	$61,490,162
Total	2,104	$120,807,616	$157,511,559	$242,914,413
% County Total	0.9%			1.2%

PANEL H: ENTERTAINMENT AND TOURISM

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	3,536	$118,543,497	$161,057,138	$270,401,574
2 - Indirect	467	$39,162,410	$62,535,865	$99,806,050
3 - Induced	583	$38,223,882	$62,519,814	$99,393,167
Total	4,586	$195,929,789	$286,112,817	$469,600,791
% County Total	2.8%			4.5%

D.2 Economic Impacts for a 30% Water Reduction Scenario

Table D2 shows the economic impacts from IMPLAN for each of the eight industry categories for a 30% water reduction scenario, as well as the total impact's share of the Orange County employment and output for that industry. The Orange County employment and output data come from Emsi.

TABLE D2: ECONOMIC IMPACTS OF A 30% WATER REDUCTION SCENARIO BY INDUSTRY

PANEL A: CONSTRUCTION

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	3,851	$72,969,618	$99,191,201	$165,683,143
2 - Indirect	228	$16,453,313	$26,510,708	$42,535,746
3 - Induced	340	$22,326,466	$36,524,625	$58,067,089
Total	4,419	$111,749,397	$162,226,535	$266,285,979
% County Total	4.3%			1.9%

PANEL B: MANUFACTURING

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	12,095	$545,799,079	$976,252,844	$2,206,909,355
2 - Indirect	2,715	$250,407,843	$388,047,378	$627,381,881
3 - Induced	2,938	$192,728,164	$315,183,556	$501,069,741
Total	17,748	$988,935,086	$1,679,483,778	$3,335,360,976
% County Total	11.9%			10.5%

PANEL C: LOGISTICS, TRANSPORTATION, AND WAREHOUSING

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	3,486	$210,302,489	$397,945,368	$647,071,149
2 - Indirect	1,236	$106,242,135	$170,595,429	$270,810,067
3 - Induced	1,185	$77,725,303	$127,136,638	$202,120,910
Total	5,906	$394,269,927	$695,677,435	$1,120,002,126
% County Total	5.9%			4.5%

PANEL D: RETAIL AND OTHER SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	5,137	$434,840,928	$562,930,731	$850,984,560
2 - Indirect	1,342	$111,428,755	$189,290,914	$302,996,846
3 - Induced	2,103	$137,948,715	$225,698,184	$358,818,870
Total	8,582	$684,218,398	$977,919,829	$1,512,800,277
% County Total	4.2%			8.1%

PANEL E: FIRE

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	0	$196,541,234	$564,861,930	$921,233,587
2 - Indirect	1,787	$142,473,174	$275,311,826	$444,085,238
3 - Induced	1,304	$85,542,551	$139,952,938	$222,499,242
Total	3,091	$424,556,960	$980,126,694	$1,587,818,066
% County Total	2.5%			4.1%

PANEL F: PROFESSIONAL, INFORMATION, AND ADMINISTRATIVE SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	6,053	$363,178,264	$499,751,265	$789,553,101
2 - Indirect	1,609	$130,536,412	$201,235,505	$321,015,680
3 - Induced	1,872	$122,812,586	$200,884,065	$319,363,763
Total	9,533	$616,527,262	$901,870,836	$1,429,932,543
% County Total	3.2%			2.9%

PANEL G: EDUCATION AND HEALTHCARE SERVICES

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	4,366	$144,213,902	$161,917,079	$243,193,393
2 - Indirect	385	$30,369,432	$51,611,389	$82,803,307
3 - Induced	648	$42,492,851	$69,500,114	$110,490,135
Total	5,399	$217,076,184	$283,028,582	$436,486,835
% County Total	2.4%			2.2%

PANEL H: ENTERTAINMENT AND TOURISM

Impact	Employment	Labor Income	Value Added	Output
1 - Direct	8,057	$297,619,845	$404,356,219	$678,880,547
2 - Indirect	1,173	$98,322,647	$157,004,938	$250,576,890
3 - Induced	1,463	$95,966,341	$156,964,638	$249,540,292
Total	10,694	$491,908,833	$718,325,796	$1,178,997,729
% County Total	6.6%			11.4%

Appendix E: Calculation of Low and High Impact Estimates

Business impact analyses sometimes give one estimate. We go beyond that. The business survey was high quality, with 374 firm respondents, giving the best information on business impacts in almost three decades and providing the only survey results drawn completely from businesses operating in Orange County. The results reported in Table 5 and Table 6 and in the body of the report are the central tendency, which are the most likely impacts. Below the most likely impacts, in brackets, are low and high estimates. Here we describe the method for obtaining those low and high estimates based on an analysis of survey sampling error ranges.

We account for survey sampling error by calculating survey sample errors and using those to quantify low and high direct impacts. Those low and high direct impacts were then input into IMPLAN to obtain low and high indirect, induced, and total impacts. (Recall that the total impact is the sum of direct, indirect, and induced impacts.) Due to the sample size, the low/high analysis was only conducted for the full Orange County economy and not disaggregated by industry.

We use the same eight categories described in the body of the report. Standard errors for the sample mean impact in each of the eight categories were calculated as

$$se_{\mu} = \frac{se}{\sqrt{n}}$$

Where se_{μ} = standard error of the sample mean impact in the category

se = standard error of the mean impact in the category

n = valid survey respondents within the category

We take the low/high impact values to be one standard error of the sample mean below and above the mean impact in each category. Individually, each category would experience impacts outside the +/- one standard error value with probabilities approximately equal to 0.33. (In other words, in each of the eight categories, the likelihood that an impact would be outside the low/high range would be approximately 0.33, or one-third.) Yet each category will not move identically due to sampling error. It is highly unlikely that sampling error would cause each category to have only low or high values. We assume that the sampling error across the categories are independent – a very reasonable assumption. Note that we are not assuming that impacts within industries are independent across categories, rather we are assuming that the survey sampling error is independent across industry categories.

Given that assumption, the economy wide sampling error would be the sum of $\frac{1}{\sqrt{8}}$ multiplied by each of the eight values for se_{μ}. A short illustration is provided below.

For the eight industry sectors, let the variance of the sample mean = var(x_i) and the variance of the economy-wide sample mean = var(x). (Note we are using "i" to index the eight industry categories.) If cov(x_i,x_j) for any two sectors "i" and "j" = 0, the variance of the economy-wide sample mean is:

$$var(x) = \sum_{i=1}^{8} var(x_i)$$

Implying:

$$se(x)^2 = \sum_{i=1}^{8} se(x_i)^2$$

Normalize var(x) = 1 and assume for simplicity that each se(x_i) has the same value. Then

$$se(x_i) = \frac{1}{\sqrt{8}}$$

We use $\frac{1}{\sqrt{8}}$ of each of the eight industry sample standard errors to calculate low and high values for impacts from the 15 percent and 30 percent water reductions. Each of the eight-industry sector's output and employment reductions are moved to $\frac{1}{\sqrt{8}}$ of the sector's sampling standard error above the sample mean for high impacts and $\frac{1}{\sqrt{8}}$ of the sector's sampling standard error below the mean for low impacts. The resulting values are input into IMPLAN to calculate high and low total impacts. This adjusts for the inherent uncertainty in the survey results. The likelihood that a realized impact would be lower than the low values due to survey sampling error would be approximately 16 percent, and similarly the likelihood that an impact would be larger than the high value would be approximately 16 percent.

Within each of those eight categories, we report below in Table E1 the number of valid respondents (firms replying to the yes/no question about whether they would experience output impacts), the standard error of the mean impact within each category, and the industry sample standard error. Table E2 shows the same for the employment impact question.

TABLE E1: OUTPUT IMPACT SAMPLING STANDARD ERRORS FOR EIGHT INDUSTRY CATEGORIES

Industry	15% Reduction			30% Reduction		
	Total Respondents	Standard Error of the Mean	Economy-Wide Standard Error	Total Respondents	Standard Error of the Mean	Economy-Wide Standard Error
	[1]	[2]	[3]	[4]	[5]	[6]
Construction	26	0.98	0.35	26	1.00	0.35
Manufacturing	71	0.66	0.23	71	1.90	0.67
Logistics, Transportation, and Warehousing	43	0.96	0.34	43	1.28	0.45
Retail and Other Services	45	0.49	0.17	45	1.97	0.70
FIRE	24	1.22	0.43	24	1.34	0.48
Professional Services, Information, and Administration	47	0.82	0.29	47	1.06	0.37
Education and Health Care	46	0.39	0.14	46	0.66	0.23
Entertainment and Tourism	72	0.78	0.28	72	1.58	0.56

Sources and Notes:
[1],[4]: Excludes respondents with inconsistent responses for output and employment questions.
[2] = sample standard deviation / sqrt([1]).
[3] = [2] / sqrt(8).
[5] = sample standard deviation / sqrt([4]).
[6] = [5] / sqrt(8).

TABLE E2: EMPLOYMENT IMPACT SAMPLING STANDARD ERRORS FOR EIGHT INDUSTRY CATEGORIES

Industry	15% Reduction			30% Reduction		
	Total Respondents	Standard Error of the Mean	Economy-Wide Standard Error	Total Respondents	Standard Error of the Mean	Economy-Wide Standard Error
	[1]	[2]	[3]	[4]	[5]	[6]
Construction	26	0.84	0.30	26	2.94	1.04
Manufacturing	71	0.73	0.26	70	2.13	0.75
Logistics, Transportation, and Warehousing	43	0.95	0.34	43	1.41	0.50
Retail and Other Services	45	0.67	0.24	45	1.27	0.45
FIRE	24	0.00	0.00	24	0.00	0.00
Professional Services, Information, and Administration	47	1.61	0.57	47	1.63	0.58
Education and Health Care	46	0.56	0.20	46	0.96	0.34
Entertainment and Tourism	72	0.70	0.25	72	1.16	0.41

Sources and Notes:
[1],[4]: Excludes respondents with inconsistent responses for output and employment questions.
[2] = sample standard deviation / sqrt([1]).
[3] = [2] / sqrt(8).
[5] = sample standard deviation / sqrt([4]).
[6] = [5] / sqrt(8).