Texas Water Development Board

Socioeconomic Impact Analysis Methodology

2021 Regional Water Plans

Economic and Demographic Analysis
Water Use, Projections and Planning Division

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1 Introduction

Texas state law requires that each regional water plan "include a quantitative description of the socioeconomic impacts of not meeting the identified water needs…" within the plan (Texas Administrative Code §357.40(a)). Though this is a requirement to be fulfilled by the individual Regional Water Planning Groups (RWPG) (TAC §357.33), the Texas Water Development Board (TWDB) has historically undertaken the task of estimating the socioeconomic impacts for each of the RWPGs at their request.

A key component in performing the analysis is determining Water User Group (WUG) specific needs, using projected water demands and supplies in the context of a one-year repeat of drought of record conditions. Six water use categories including irrigation, livestock, manufacturing, mining, municipal and steam electric power are examined, and the analysis is designed to provide a reasonable approximation to the potential economic impacts of not offsetting the projected needs in each of the anticipated planning decades. TWDB staff have identified three primary objectives: to provide an estimate which is theoretically sound, obtainable with a reasonable amount of research and effort, and comparable in approach across the various regions within the regional and state water plans and between five-year planning cycles.

1.1 Acronyms

Acronyms used within this document include the following:

- CBP: U.S. Census Bureau County Business Patterns
- EDA: Economic and Demographic Analysis department within the TWDB
- ERCOT: Electrical Reliability Council of Texas
- GDP: Gross Domestic Product
- IMPLAN: Impact Planning Model
- NAICS: North American Industry Classification System
- RWP: Regional Water Plan
- RWPA: Regional Water Planning Area
- RWPG: Regional Water Planning Group
- SWP: State Water Plan
- TAMU Agri-life: Texas A&M University, Agri-Life Extension Service
- TCEQ: Texas Commission on Environmental Quality
- TML: Texas Municipal League
- TNRIS: Texas Natural Resource Information System
- TWDB: Texas Water Development Board
- USDA: United States Department of Agriculture
- WUG: Water User Group
- WUS: Water Use Survey

2 Socioeconomic Impact Measures

Attempting to estimate drought-induced impacts at the regional level is a formidable task, and the current effort draws heavily on the methodology from past Texas state water plans, while adding some minor alterations in pursuit of more credible and robust estimates. Measures used in past state water plans as well as the current proposed plan include three types: 1) regional *economic* impacts, 2) *financial transfer* impacts, and 3) *social* impacts (Table 1). Admittedly a drought of record would impact numerous facets of the economy not portrayed in these summary measures, but data limitations, as well as constraints on time for analysis, preclude a greater level of refinement, especially in the context of a multi-decade analysis.

Table 1. Summary of socioeconomic impact measures

Economic Impacts	**Description**
1. Income losses (value-added)	The value of output less the value of intermediate consumption; it is a measure of the contribution to gross domestic product (GDP) made by an individual producer, industry, sector, or group of sectors within a year. Value-added measures used in this report have been adjusted to include the direct, indirect, and induced monetary impacts on the region.
2. Electrical power purchase costs	Proxy for income loss in the form of additional costs of power as a result of impacts of water shortages for steam-electric power category.
3. Jobs losses	Number of part-time and full-time jobs lost due to the shortage. These values have been adjusted to include the direct, indirect, and induced employment impacts on the region.
Financial Transfer Impacts	**Description**
4. Taxes on production and imports	Sales and excise taxes not collected due to the shortage, in addition to customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies. These values have been adjusted to include the direct, indirect and induced tax impacts on the region.
5. Water trucking costs	Estimated cost of shipping portable water for municipal use if shortages exceed 80% of projected demand.
6. Utility revenue losses	Foregone utility income due to not selling as much water.
7. Utility tax revenues losses	Foregone miscellaneous gross receipts tax collections.
Social Impacts	**Description**
8. Consumer surplus losses	A welfare measure of the lost value to consumers accompanying less water use. Lost consumer surplus may be defined as the amount of money required to restore the consumer to their original level of well-being which they enjoyed prior to the impact of the drought or water policy induced shortage.
9. Population losses	Population losses accompanying job losses.
10. School enrollment losses	School enrollment losses (K-12) accompanying job losses.

The primary impact measures of lost income and jobs were developed using the input-output planning model known as IMPLAN[1]. Foregone tax collections (on production and imports) were also estimated using IMPLAN output, and the remaining measures were calculated using a variety of data sources, including TWDB water use estimates and demand projections and values from other sources such as the Texas state population projections, U.S. Census Bureau statistics, USDA National Agricultural Statistical Service data, and Texas Municipal League surveys of utility prices and water use.

Impact estimates were undertaken for all WUGs that had identified water needs (potential shortages) in the following water use categories. Categories marked with a "*" in the list below relied on IMPLAN data for the income/jobs/taxes impact estimates.

- Irrigated Agriculture*
- Livestock*
- Manufacturing*
- Mining*
- Steam-Electric Power Generation
- Municipal - Residential
- Municipal – Commercial (water-intensive[2])*

3 Socioeconomic Impact Methodology

3.1 Analysis Context

The context of this socioeconomic impact analysis involves situations where there are physical shortages of water due to a recurrence of drought of record conditions. Anticipated shortages for specific water users may be nonexistent in earlier decades of the planning horizon, yet population growth or greater industrial, agricultural or other sector demands in later decades may result in greater overall demand, exceeding the existing supplies. Estimated impacts measure what would happen if water user groups experience water shortages for a period of one year if no further supplies are developed to overcome those shortages. They are independent and distinct "what if" scenarios for a particular year and water shortages are assumed to be temporary events resulting from drought of record conditions. Actual socioeconomic impacts would likely become larger as drought of record conditions persist for periods greater than a single year, especially in areas facing continued population growth.

3.2 Key Data Sources

Four key types of data fueled the impact estimation effort for the socioeconomic impact estimates:

- IMPLAN related output, used for the income and jobs impact estimates,

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[1] https://implan.com/
[2] IMPLAN sectors for this subcategory include the car wash, education, hospitality, laundry, meeting and recreation, food store, warehousing, and health care sectors.

- Historical water use estimates,
- Projected water needs (potential shortages), and
- Average water use price and quantity data for utilities.

Details concerning the data used appear below.

3.2.1 IMPLAN Input-Out Model

Input-Output analysis using the IMPLAN software package was the primary means of estimating the value-added, jobs, and tax related impact measures. This analysis employed regional-level models to determine key economic impacts. IMPLAN is an economic impact model, originally developed by the U.S. Forestry Service in the 1970's to model economic activity at varying geographic levels. The model is currently maintained by the Minnesota IMPLAN Group (MIG Inc.) which collects and sells county and state specific data and software. The year 2016 version of IMPLAN, employing data for all 254 Texas counties, was used in the analysis, and 16 custom IMPLAN models were developed to correspond with the 16 regional water planning areas. Each model provided estimates of value-added, jobs, and taxes on production for the economic sectors associated with the six water use categories. IMPLAN uses 536 sector-specific industry codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories[3] (irrigation, livestock, manufacturing, mining, and municipal).

Definitions of IMPLAN related terms appear below:

- *Value-added*: the value of total production within the IMPLAN sector minus the costs of producing that level of output (comparable to GDP);
- *Jobs*: the annual average of monthly jobs for the IMPLAN sector of interest;
- *Taxes*: taxes on production and imports less subsidies.

Estimates of value-added for a water use category were obtained by summing value-added estimates across the relevant IMPLAN sectors by 4-digit North American Industry Classification System (NAICS)[4] code that are associated with each water use category. These calculations were also performed for job losses as well as tax losses on production and imports. IMPLAN also provided regional level multipliers which allow one to convert the initial direct effect estimates (i.e., value added, jobs, or taxes) to their regional level counterparts. These regional level estimates

[3] An alternative income measure (non-IMPLAN based) was employed for the steam-electric power generation water use category because the steam electric power generation category is very dissimilar to the other categories considered. In general, without enough cooling water, utilities would have to throttle back plant operations, possibly forcing them to buy costly power from other providers or to generate higher cost power at other plants under their control in order to meet customer demands. Direct use of the value-added estimates from IMPLAN was deemed less indicative of the damages incurred due to a drought, and the income measure used was the expected cost of power purchased using the day-ahead market price within Texas.

[4] https://www.census.gov/eos/www/naics/

consist of the so-called total effects, and are comprised of the direct, indirect and induced effects (defined below) within the region for each IMPLAN sector.

- *Direct effects:* changes within the primary industry analyzed;
- *Indirect effects:* changes within the input supplying industries (i.e., changes as those suppliers respond to reduced demands from the directly affected industries); and,
- *Induced effects*: changes in local spending that result from reduced household income among employees in the directly and indirectly affected industry sectors.

To account for indirect and induced effects, the Type SAM (Social Accounting Matrix) multiplier from IMPLAN is applied. This multiplier is simply the ratio of the total effects proportion, divided by the direct effect. Note that, input-output models such as IMPLAN only capture backward linkages and do not include forward linkages in the economy.

3.2.2 Historical Water Use Estimates

TWDB surveys approximately 4,500 public water systems and 2,000 industrial facilities including businesses within the mining, manufacturing and steam electric power production sectors each year. The TWDB also develops annual water use estimates for irrigation and livestock using external data sets from various sources including the USDA Farm Services Administration, National Agricultural Statistical Service, Groundwater Conservations Districts, and other agencies and publications. Year 2016 water use estimates for the municipal, livestock, mining, manufacturing and steam electric power sectors were used in this analysis and aggregated by 4-digit NAICS code within each water use category. For irrigation, an average of water use from the years 2012 through 2016 was utilized due to variability in the output prices for crops and the corresponding water use across years. Water use estimates for the municipal-commercial (water-intensive) category were collected through the TWDB annual water use survey (WUS), combined with other published data.

In addition, special consideration was needed for both the manufacturing and mining water use categories. The TWDB survey data are generally available for the major water users within each category, but not all firms are surveyed or respond to the survey. This created a disconnect between the IMPLAN-source numerator in the value per acre-foot of water calculation and the denominator obtained from the TWDB water use survey. The number of entities producing the output estimated by IMPLAN did not match the number of entities actually using the water values available from the WUS.

Employing this data directly would result in inflated values per acre-foot for the water since the numerator (value added, jobs, or tax revenue) represents the total in the county of interest for the given water use category, and the denominator is total water use for a subset of the firms within the category. A reasonable remedy for the disconnect is to estimate value added, (or the other related measures) <u>per firm</u> from the relevant source, and water use per firm from the available water use survey data. U.S. Census Bureau: County Business Patterns (CBP) data, limited to those firms with fifty or more employees, was used in calculating the numerator, and the directly available number of firms surveyed in the WUS provided that value for the denominator. One may then divide those two values to determine an estimate of the value added per acre-foot for sector i in period t (Eq. 1).

Similar calculations apply for the jobs lost per acre-foot and tax revenue lost per acre-foot of water shortage value.

$$\textbf{Eq. [1]}\ VA_{it}/(\text{ac-ft}) = (VA_{it}/\text{firmsCBP})/(\text{water use acre feet}/\text{firmsWUS})$$

Additional details concerning the water use estimates for all six categories can be found at the websites below:

- Historical Water Use and Projections Dashboard: http://www.twdb.texas.gov/waterplanning/data/dashboard/index.asp
- Historical Water Use Estimates: http://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/index.asp

3.2.3 Projected Water Needs

As part of the regional water planning process, the TWDB adopted water demand projections for WUGs with input from the planning groups, and identified potential water shortages were calculated as the difference between the existing water supplies and projected demands within each of municipal and non-municipal WUG. Socioeconomic impact estimates are then determined for all WUGs with potential shortages.

Additional information concerning the methodology used for determining WUG-specific water demand projections can be found as shown below.

- Projections Methodology: https://www.twdb.texas.gov/waterplanning/data/projections/methodology/index.asp
- Water Demand Projections http://www.twdb.texas.gov/waterplanning/data/projections/2022/demandproj.asp

3.2.4 Average Water Price and Quantity Data

Year 2016 monthly water price and quantity data from the Texas Municipal League (TML)'s annual survey[5] of residential and commercial water use (both drinking water and sewage service) was also assembled and used to estimate utility revenue losses as well as lost consumer surplus estimates.

3.3 Economic Impact Measures

Impact measures for the Economic Impacts category (Table 1) include the lost income and jobs estimates, coupled with estimates of the additional purchase costs for electrical power. Section 3.3.1, immediately following, describes the methods used for determining lost income estimates. The required steps for determining lost job impacts are totally analogous (Section 3.3.2), while methods for determining the costs of additional electrical power purchases appear in section 3.3.3.

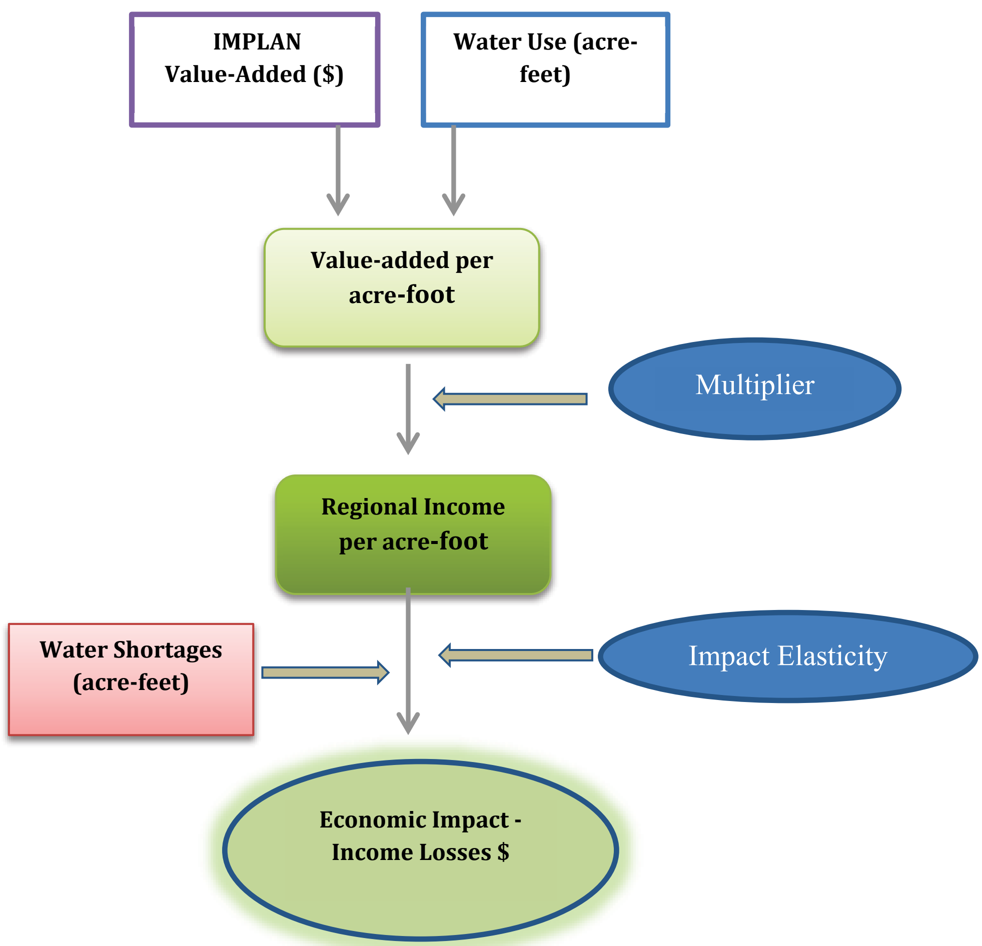
[5] https://www.tml.org/229/Water-Wastewater-Survey-Results

3.3.1 Lost Income Estimates

Numerous steps were required in determining estimates of lost income (to the region) accompanying the WUG-level water shortages within each decade of the regional water planning horizon. Figure 1 provides an overview of the process for a single IMPLAN sector, and generally consists of the following steps:

1) Bridge IMPLAN data and water use data (linking IMPLAN data to the proper TWDB water use category)
2) Estimate the baseline value of water per acre-foot of water use (value-added per acre-foot)
3) Add the indirect and induced effects (regional income per acre-foot)
4) Apply the degree of water shortage (impact elasticity)
5) Calculate income losses applying acre-feet of potential water shortages to the estimated value of water

Figure 1. Overview of IMPLAN sector lost income per acre-foot estimation



Details for each step are described in the following sections.

3.3.1.1 Bridging Water Use Categories and IMPLAN Sectors

IMPLAN uses 536 sector-specific industry codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories (irrigation, livestock, manufacturing, mining, and municipal). In addition, the IMPLAN sectors have classifications which correspond closely with the NAICS codes. Some data employed in the analysis are associated with specific 4-digit NAICS codes, which in turn must be linked to IMPLAN sector codes. Table 2 provides a sample of these relationships for the mining water use category. Note that a given NAICS code may correspond to more than one IMPLAN code. For example, NAICS code 2123 corresponds to IMPLAN codes 25, 26, and 27.

Table 2. Mining Related NAICS and IMPLAN Codes

TWDB Water Use Category	IMPLAN Sector	Description	4 Digit NAICS Code
Mining	20	Oil and gas extraction	2111
Mining	21	Coal mining	2121
Mining	22	Iron ore mining	2122
Mining	23	Copper, nickel, lead, and zinc mining	2122
Mining	24	Gold, silver, and other metal ore mining	2122
Mining	25	Stone mining and quarrying	2123
Mining	26	Sand, gravel, clay and ceramic and refractory mining and quarrying	2123
Mining	27	Other nonmetallic mineral mining and quarrying	2123
Mining	28	Drilling oil and gas wells	2131

3.3.1.2 Estimating the Baseline Economic Value of Water

Region specific estimates of the baseline value of water are estimated by summing the value-added estimates from IMPLAN across the relevant IMPLAN sectors by 4-digit NAICS code associated with that water use category for all counties in the region and then dividing by the corresponding water use, resulting in an initial estimate of the value-added per acre-foot of water use.

3.3.1.3 Applying the Regional Multiplier

Initial estimates of the value added per acre-foot of water use (Figure 1) are multiplied by the appropriate regional IMPLAN SAM multiplier to account for the regional indirect and induced effects within the region. This process yields the estimate of regional average income per acre-foot by 4-digit NAICS code within each water use category.

3.3.1.4 Applying the Impact Elasticity Function

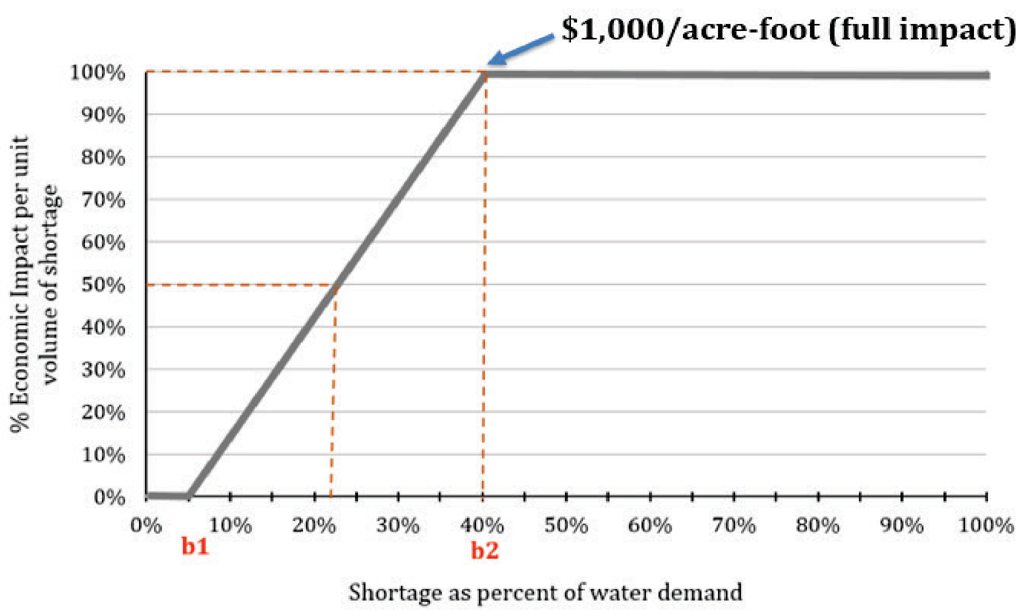
An elasticity adjustment function was incorporated into the impact estimates for several of the measures. This concept implies that consumer or producer behavior varies with the severity of the drought. Smaller shortages, 5% or less, would have no damage (0% of the calculated impact value) since water users are assumed to have some modest degree of flexibility in dealing with small water shortages. As the drought worsens, however, and the magnitude of water shortage increases, the capacity to accommodate shortages lessens, resulting in greater losses, eventually reaching the full damage estimates per acre-foot values originally calculated.

As an example, consider the following sample setting:

- If water shortages are 0 to 5 percent of total water demand, there is no corresponding impact of water shortages.
- If water shortages are between 5 percent and 40 percent of total water demand, the percent of the impact value of an acre-foot of water is increasing linearly from zero percent (with a 5 percent water shortage) and up to 100 percent (with a 40 percent water shortage).
- If water shortages are greater than 40 percent of the total water demand, the full impact value of water is used to value every acre-foot of shortage.

Figure 2 below depicts a sample impact elasticity function which reflects the setting described above, with a baseline initial lost income estimate of $1,000 per an acre-foot of water shortage. This value serves as the full impact estimate of damages per acre-foot of water shortage. The pertinent thresholds (labeled as b1 and b2 in the figure) serve as the points where damages begin to accrue and where they reach their full impact value of $1,000 per an acre-foot of water shortage.

Figure 2. Sample impact elasticity function



As an example, consider a water shortage of 22.5% (halfway between the lower threshold of 5% and the upper threshold of 40%). The final lost income per acre-foot of shortage estimate, in this case, would then be one-half (50%) of the $1,000/acre-foot baseline impact, or $500/acre-foot of water shortage. This value would be applied to all acre-feet of water shortages in determining the final impact estimate. Note that the full impact estimate of $1,000 per an acre-foot applies to every acre-foot of water shortage if the total shortages exceed 40% of normal demand.

The lower (b1) and upper bound (b2) thresholds employed in the analysis are shown, by water use category, in Table 3 and are based on very limited available literature, consultant input, and professional experience and judgement that included a stakeholder preview. The livestock sector is more sensitive to shortages since feed supplies are quickly impacted in a drought of record, and producers often have to liquidate all or a portion of their inventory.

Table 3. Economic impact elasticity function threshold parameters

Water Use Category	Impact Elasticity Parameters b1(lower bound)	b2 (upper bound)
Irrigated Agriculture	5%	40%
Mining	5%	40%
Manufacturing	5%	40%
Livestock	5%	10%
Municipal-Commercial (water intensive)	5%	40%

Impact elasticity functions were also used to adjust the estimates of job and tax losses for impact estimates in the five water use categories.

3.3.1.5 Final Estimates of Income Loss for the Water Use Category

The estimate of lost income for the IMPLAN sectors at 4-digit NAICS level was obtained by multiplying the acre-feet of potential water shortages and then by applying the impact elasticity.

In practice, multiple IMPLAN sectors comprise a single TWDB water use category (i.e., mining, livestock, etc.). The process portrayed in Figure 1 is for a single 4-digit NAICS of the many which constitute a TWDB water use category, and the calculation is repeated for all IMPLAN sectors within the water use category. The final lost income estimate for the water use category is obtained by summing each 4-digit NAICS level impact estimate making up a portion of the water use category. For example, one would sum the individual estimates for the sand, gravel, oil, and gas sectors for the mining water use category.

3.3.1.6 Characteristics of the Final Income Impact Estimates

Estimation of the final income impact estimates involved a large amount and sets of data, many data manipulations, and many calculations all of which requires a great deal of effort and time. The final results have several characteristics worth noting.

Each estimate:

- varies with the WUG specific **degree of shortage** (impact elasticity),
- varies with the **composition of water use/economic activity** within each county by 4-digit NAICS code,
- employs region specific **multipliers** to reflect impacts on that region, and
- results in monetary values expressed in year **2018 $** (compatible with Water Management Strategy cost estimates).

The second item within the list merits additional discussion. Table 4 below summarizes a sample calculation of lost income for the mining sector. Impact estimates are shown for two representative counties with a varying composition of historical water use and economic activity. Sand and gravel production are more prominent in terms of water use for county A, while oil exploration is the major water user in county B. Suppose that there is a 1,000 acre-foot shortage in mining in each county. Lost income for county A is $600,000, while the higher valued and larger proportion of water use for oil exploration in county B results in a lost income estimate of $1 million. Average lost income per acre-foot of water shortage is smaller for county A ($500/acre-foot vs. $1,000/acre-foot of water shortage) due to the higher proportion of lower valued sand and gravel production. Use of the impact measure estimation procedures described above thus allowed the final impact estimates to reflect the variability in economic activity across counties within each planning region.

Table 4. County level lost income impact calculation example

	County A		County B	
	sand and gravel (NAICS 2123)	oil exploration (NAICS 2111)	sand and gravel (NAICS 2123)	oil exploration (NAICS 2111)
Income/acre-foot of water	$ 500	$ 1,000	$ 500	$ 1,000
Water use proportion	80%	20%	20%	80%
Acre-feet of water shortages[a]	800	200	200	800
Lost income by 4-digit NAICS	$400,000	$200,000	$100,000	$900,000
Mining total lost income	**$600,000**		**$1,000,000**	

[a] Assumes a shortage of 1,000 acre-feet in each county

3.3.2 Lost Job Estimates

The procedures outlined in the entirety of section 3.3.1 also apply for the analysis estimates of lost job impacts. IMPLAN output estimates for employment/jobs in each IMPLAN sector are divided by the associated water use, and the procedures noted in the earlier discussion result in analogous estimates for the job related impacts.

3.3.3 Electrical Power Purchase Costs

Use of IMPLAN-related output was not employed for this specialized water use category. Instead, the dollar impact was calculated as the cost of purchasing additional power during peak demand periods to compensate for lost generating capacity due to water shortage. The majority of the state is connected via a network overseen by the Electrical Reliability Council of Texas (ERCOT)[6], and water shortages at one location and the associated lost electrical power generation may be offset with purchases of electrical power from other providers. The average day-ahead market price from ERCOT of 5.6 cents/kWh (year 2011) was employed in estimating the additional cost of purchasing power. The 2011 value represents a reasonable value for a drought impacted year. County-level estimates of water use and historical power generation data (U.S. Energy Information Administration[7]) were used to generate estimates of the required power purchases for each

[6] http://www.ercot.com/
[7] https://www.eia.gov/electricity/data/eia860/

county-specific acre-feet of potential water shortages. Total power purchase costs were estimated as the product of the average day-ahead price and the required additional kWh of power accompanying the water shortages.

3.4 Financial Transfer and Social Impact Measures

Financial transfer measures involve both winners and losers. As an example, reductions in economic output in the manufacturing sector result in reduced tax collections by local and state government, but consumers and other entities also pay less taxes since those goods were not purchased. The social impact measures relate to other facets impacting society which would accompany a drought. Calculation details for each of these remaining measures appear below.

3.4.1 Taxes on Production and Imports

Impact estimates for taxes on production and imports, while a member of the financial transfer category, rely on estimation procedures identical to that of both the income loss estimates and the job loss estimates (sections 3.3. IMPLAN output, water use data, and water shortage data are all combined using the same procedures to determine WUG-specific impact estimates.) As noted above, some parties win (paying less taxes), while other parties lose (collect fewer taxes) in response to drought induced reductions in water use.

3.4.2 Water Trucking Costs

Potable water was assumed to be trucked into any municipal WUG for water shortages above the 80% shortage level. A staff survey of numerous trucking firms throughout the state produced in an estimated delivery cost of $35,000/acre-foot which assumes a 60-mile round trip haul. The 80% shortage threshold was assumed to represent the deepest shortage before shipping would be required in order to meet minimal sanitary and drinking water requirements that was assumed to be 20% of total municipal demand.

3.4.3 Water and Wastewater Utility Revenue Losses

Average price data from the year 2016 TML survey for both drinking water and sewage service was collected and used to estimate municipal WUG-specific utility lost sales revenue due to potential water shortages. Water shortages were multiplied by the average water retail price to estimate lost utility revenue accompanying the reduced sales of water and sewage service during the drought.

3.4.4 Water Utility Tax Revenue Losses

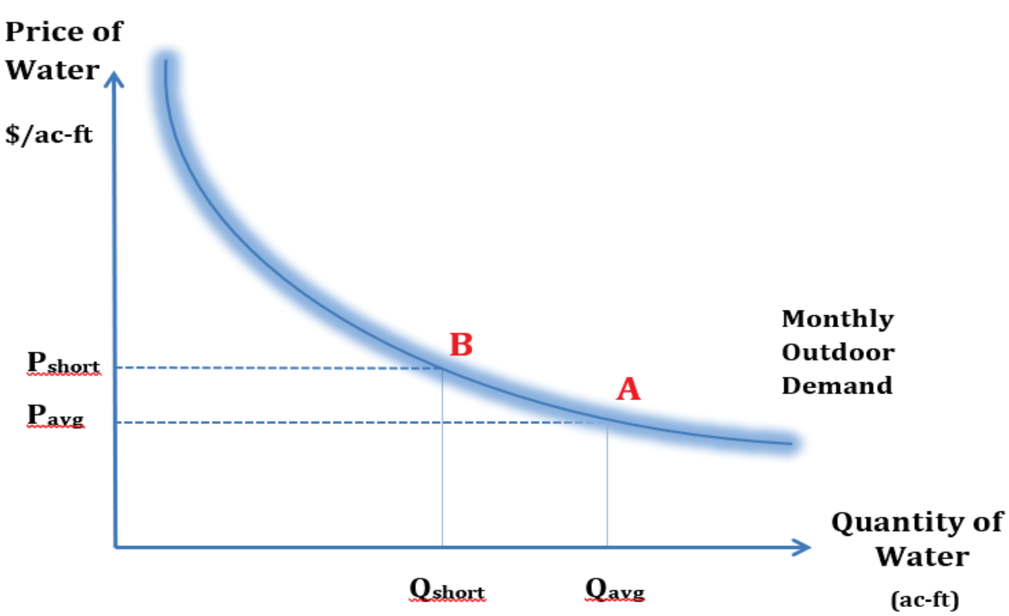
The State of Texas collects the miscellaneous gross receipts tax on water utility revenues[8]. Tax rates (2016), which vary by city size, were applied to the utility revenue losses for each WUG to determine the lost tax revenue to the state due to the reduced sales of water and sewage service.

[8] https://comptroller.texas.gov/taxes/misc-gross-receipts/faq.php

3.4.5 Consumer Surplus Losses

Changes in consumer surplus are a measure of the impact on consumer well-being accompanying a change in economic conditions or policy. In the case of a drought and the loss of access to water, it may be defined as the monetary value that would be required to restore consumers to their original level of well-being prior to the drought. Average water price and quantity per household data from the TML year 2016 survey was used to estimate demand functions similar to the one shown in Figure 3 below. Demand within this context is defined as the schedule of retail prices per household which a consumer is willing and able to spend for various quantities of water. In this case, price is on the vertical axis and quantity of water on the horizontal axis.

Figure 3. Sample household level water demand function



Variables shown in Figure 3 are defined as follows:

P_{avg} : average price of water under normal conditions

P_{short} : price of water accompanying reduced demand during drought

Q_{avg}: quantity of water consumed under normal conditions

Q_{short}: quantity of water consumed during the drought

Under drought conditions, cities may impose use restrictions, prompting water use to fall from Q_{avg} down to Q_{short} acre-feet/month, and the lost consumer surplus impact measure provides a monetary estimate of the loss of use of this water for each household.

Equation [2] below shows the relationship between water demand W (1,000 gallons/month), P (price per 1,000 gallons), and an assumed elasticity of demand epsilon (ε) for an individual household.

$$\textbf{Eq. [2]} \quad W = kP^{\varepsilon}$$

The elasticity of demand ε represents the percent change in quantity demanded for every one percent change in price P, and the variable k represents a constant to be estimated based upon the demand and price data for the individual city. Two families of curves were estimated using average price and quantity data for the available TML data: one for indoor water demand, and a second for outdoor water demand. Outdoor demand was assumed to consist of thirty percent of total demand[9]. Price elasticities (-0.30 for indoor water use and -0.50 for outdoor use) used within the analysis are based on the study by Bell and Griffin.[10] The negative sign implies that price and quantity demanded move in opposite directions. I.e., if price increases by 1%, then quantity demanded will decrease by .3% for the indoor demand curve.

If one solves Equation [2] for the constant k, Equation [3] results with an estimate of the value of k as:

$$\textbf{Eq. [3]} \quad k = (W/P^{\varepsilon})$$

Once the WUG-specific demand functions were obtained, welfare economics techniques and calculus were employed to estimate lost consumer surplus accompanying the WUG-specific degrees of water shortage for both indoor and outdoor water use. Lost consumer surplus was not estimated for shortages exceeding 80% of normal water demand due to poor estimation performance of the estimated demand functions for those high degrees of shortages. Details on the use of consumer surplus as a measure of benefits or adverse impacts upon consumers, appear in the paper by Griffin and Bell, cited earlier, and a related web article[11].

3.4.6 Population and School Enrollment Losses

Once the estimated job losses for each sector and region are calculated, data from the U.S. Census Bureau, Texas Demographic Center, and results from a recent applied economic study were used to estimate expected population and school enrollment loss values. The latter involved a study of job layoffs and the resulting adjustment of the labor market, including the change in population. The study[12] utilized Bureau of Labor Statistics data regarding layoffs between 1996 and 2013, as well as Internal Revenue Service regarding migration, to model an estimate of the change in the population as the result of a job layoff event. Layoffs impact both out-migration, as well as in-migration into an

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[9] https://www.twdb.texas.gov/publications/reports/technical_notes/doc/SeasonalWaterUseReport-final.pdf

[10] Bell, D.R. and Griffin, R.C. "*Community Water Demand in Texas as a Century is Turned*." Research contract report prepared for the Texas Water Development Board. May 2006.

[11] https://www.investopedia.com/terms/c/consumer_surplus.asp

[12] Foote, Andrew, Grosz, Michel, Stevens, Ann. "Locate Your Nearest Exit: Mass Layoffs and Local Labor Market Response." University of California, Davis. April 2015. http://paa2015.princeton.edu/uploads/150194

area; both of which can negatively affect the population of an area. In addition, the study found that a majority of those who did move following a layoff moved to another labor market rather than to an adjacent county.

Based on this work, a simplified ratio of lost jobs and net population lost was calculated for the state as a whole: for every 100 jobs lost, 18.36 people were assumed to move out of the area. A statewide average proportion of the population (19.13%; Texas Demographic Center, 2016), which are in grades K through 12, was multiplied by the population losses to estimate school enrollment losses.

3.5 Assumptions and Limitations of the Analysis

The modeling of complex systems requires making many assumptions and acknowledging the model's uncertainty and limitations. This is particularly true when attempting to estimate a wide range of socioeconomic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of this methodology include:

1. The foundation for estimating the socioeconomic impacts of water shortages resulting from a drought are the potential water shortages that were identified by RWPGs as part of the regional water planning process. These water shortages have some uncertainty associated with them but serve as a reasonable basis for evaluating the potential impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshots for years in which potential water shortages were identified (i.e., 2020, 2030, 2040, 2050, 2060, and 2070). The estimates are independent and distinct "what if" scenarios for each particular year, and water shortages are assumed to be temporary events resulting from a single year recurrence of drought of record conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

3. Input-output models such as IMPLAN rely on a static profile of the structure of the economy as it appears today. This presumes that the relative contributions of all sectors of the economy would remain the same, regardless of changes in technology, availability of limited resources, and other structural changes to the economy that may occur in the future. Changes in water use efficiency will undoubtedly take place in the future as supplies become more stressed. Use of the static IMPLAN structure was a significant assumption and simplification considering the 50-year time period examined in this analysis. To presume an alternative future economic makeup, however, would entail positing many other major assumptions that would very likely generate as much or more error.

4. This is not a form of cost-benefit analysis. That approach to evaluating the economic feasibility of a specific policy or project employs discounting future benefits and costs to their present value dollars using some assumed discount rate. The methodology employed in this effort to estimate the economic impacts of future water shortages did not use any discounting methods to weigh future costs differently through time.

5. All monetary values originally based upon year 2016 IMPLAN and other sources are reported in constant year 2018 dollars to be consistent with the water management strategy requirements in the State Water Plan.

6. IMPLAN based loss estimates (income-value-added, jobs, and taxes on production and imports) are calculated only for those IMPLAN sectors for which the TWDB's Water Use Survey (WUS) data was available and deemed reliable. Every effort is made in the annual WUS effort to capture all relevant firms who are significant water users. Lack of response to the WUS, or omission of relevant firms, impacts the loss estimates.

7. Impacts are annual estimates. The socioeconomic analysis does not reflect the full extent of impacts that might occur as a result of persistent water shortages occurring over an extended duration. The drought of record in most regions of Texas lasted several years.

8. Value-added estimates are the primary estimate of the economic impacts within this report. One may be tempted to add consumer surplus impacts to obtain an estimate of total adverse economic impacts to the region, but the consumer surplus measure represents the change to the well-being of households (and other water users), not an actual change in the flow of dollars through the economy. The two measures (value-added and consumer surplus) are both valid impacts but ideally should not be summed.

9. The value-added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects to capture backward linkages in the economy described in Section 3.2.1. Population and school enrollment losses also indirectly include such effects as they are based on the associated losses in employment. The remaining measures (consumer surplus, utility revenue, utility taxes, additional electrical power purchase costs, and potable water trucking costs), however, do not include any induced or indirect effects.

10. The majority of impacts estimated in this analysis may be more conservative (i.e., smaller) than those that might actually occur under drought of record conditions due to not including impacts in the forward linkages in the economy. Input-output models such as IMPLAN only capture backward linkages on suppliers (including households that supply labor to directly affected industries). While this is a common limitation in this type of economic modeling effort, it is important to note that forward linkages on the industries that use the outputs of the directly affected industries can also be very important. A good example is impacts on livestock operators. Livestock producers tend to suffer substantially during droughts, not because there is not enough water for their stock, but because reductions in available pasture and higher

prices for purchased hay have significant economic effects on their operations. Food processors could be in a similar situation if they cannot get the grains or other inputs that they need. These effects are not captured in IMPLAN, resulting in conservative impact estimates.

11. The model does not reflect dynamic economic responses to water shortages as they might occur, nor does the model reflect economic impacts associated with a recovery from a drought of record including:
    a. The likely significant economic rebound to some industries immediately following a drought, such as landscaping;
    b. The cost and time to rebuild liquidated livestock herds (a major capital investment in that industry);
    c. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
    d. Impacts of negative publicity on Texas' ability to attract population and business in the event that it was not able to provide adequate water supplies for the existing economy.

12. Estimates for job losses and the associated population and school enrollment changes may exceed what would actually occur. In practice, firms may be hesitant to lay off employees, even in difficult economic times. Estimates of population and school enrollment changes are based on regional evaluations and therefore do not necessarily reflect what might occur on a statewide basis.

13. **The results must be interpreted carefully. It is the general and relative magnitudes of impacts as well as the changes of these impacts over time that should be the focus rather than the absolute numbers.** Analyses of this type are much better at predicting relative percent differences brought about by a shock to a complex system (i.e., a water shortage) than the precise size of an impact. To illustrate, assuming that the estimated economic impacts of a drought of record on the manufacturing and mining water user categories are $2 and $1 million, respectively, one should be more confident that the economic impacts on manufacturing are twice as large as those on mining and that these impacts will likely be in the millions of dollars. But one should have less confidence that the actual total economic impact experienced would be $3 million.

14. The methodology does not capture "spillover" effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

15. The methodology that the TWDB has developed for estimating the economic impacts of potential water shortages, and the assumptions and models used in the analysis, are specifically designed to estimate potential economic effects at the regional and county levels. Although it may be tempting to add the regional impacts together in an effort to produce a statewide result, the TWDB cautions against that approach for a number of reasons. The IMPLAN modeling (and corresponding economic multipliers) are all derived from regional models – a statewide model of Texas would produce somewhat different multipliers. As noted in point 14 within this section, the regional modeling used by TWDB does not capture spillover

losses that could result in other regions from potential water shortages in the region analyzed, or potential spillover gains if decreased production in one region leads to increases in production elsewhere. The assumed drought of record may also not occur in every region of Texas at the same time, or to the same degree.

In addition to the caveats noted above, potential users of the impact estimates should note the following:

Projected impacts provided in the regional impact reports pertain to the decade specific water shortages of individual WUGs developed in each RWP. Impact estimates therefore are not well suited for determining the potential value of water when estimating the possible benefits of a given water management strategy. This caution applies at two levels:

1. The WUG-specific percent of need mitigated by the proposed water management strategy will very likely not correspond to the level of water shortage used to develop the original impact estimate, and
2. Aggregated lost income impacts (i.e., regional level lost income estimates, divided by the associated regional-level water shortages and multiplied by the acre-feet of water supplied by the water management strategy), will not be a good estimate of the WUG-specific lost income avoided by implementation of the strategy. The per acre-foot value of water implicit within the aggregated estimates contains many varied levels of water shortage for numerous WUGS, and therefore is not representative of an individual WUG's possible lost income avoided by implementation of a particular water management strategy.

3.6 Other Data Sources

Numerous data sources were employed in developing the socioeconomic impact analysis. Table 5 summarizes the various types and sources of relevant data.

Table 5. Data source summary

Data Type	Sources
Irrigated Agriculture	IMPLAN; TWDB Water Use Survey (WUS), USDA Farm Service Agency; USDA: National Agricultural Statistics Service; USDA Cropscape Cropland Data Layer (CDL); TAMU Agri-life; Texas Commission on Environmental Quality (TCEQ)
Manufacturing	IMPLAN; WUS; U.S. Census Bureau: County Business Patterns
Mining	IMPLAN; WUS; University of Texas: Bureau of Economic Geology; Frac-Focus Oil & Gas Water Use Estimates
Livestock	IMPLAN; WUS; USDA-National Agricultural Statistics Service; TAMU Agri-life; Texas State Soil and Water Conservation Board; TCEQ
Municipal: Commercial, Water-Intensive	IMPLAN; WUS; Census Bureau: County Business Patterns; U.S. Census Bureau; Texas Municipal League; Texas Demographic Center; Office of the Texas Comptroller

Steam Electric Power Generation	WUS; Electrical Reliability Council of Texas (ERCOT); U.S. Energy Information Administration; TCEQ; Texas Public Utilities Commission (PUC); University of Texas: Bureau of Economic Geology: Steam Electric Report
Municipal: Residential	WUS; Texas Demographic Center; U.S. Census Bureau; Texas Municipal League; Office of the Texas Comptroller of Public Accounts
Municipal: non water-intensive	WUS; Texas Demographic Center; U.S. Census Bureau; Texas Municipal League; Office of the Texas Comptroller of Public Accounts
Miscellaneous Reports and Data	Texas Water Resources Institute; Pacific Institute; University of California at Davis; BBC Consulting Firm Peer Review; Lawrence Berkeley National Laboratory
Additional TWDB Sources	Texas Water Service Boundary Viewer; Texas Natural Resources Information System (TNRIS); Various TWDB Technical Reports

4 Additional Resources

The TWDB has developed a socioeconomic impact analysis website in order to provide greater detail and easier access to topics related to the analysis. For more information visit the website:

http://www.twdb.texas.gov/waterplanning/data/analysis/index.asp.

Features included on the website consist of the following:

- An Interactive Dashboard for viewing region and county level impact results
- Socio Economic Impact Reports for the 16 Regional Water Planning Groups for the 2021 Regional Water Plans and previous water plans
- Frequently Asked Questions (FAQs)
- Summary of Socioeconomic Impact Assessment Methodology
- Contact: EDA@twdb.texas.gov