Texas Water Development Board

TWDB Drought Management Costing Tool

User Manual

September, 2019

Contents

1 Introduction

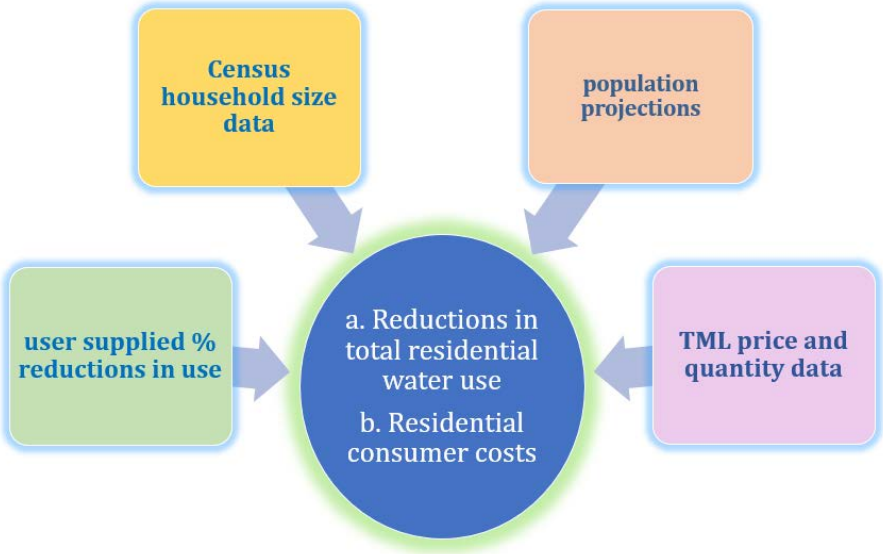
Inexpensive and readily available water is obviously a very key resource in modern society, and shortages in supplies may have adverse impacts. Measuring such impacts is a challenging task, especially in the context of a drought of record within the regional water planning effort for the State of Texas. The accompanying costing tool provides a means of estimating the possible costs to municipal water user groups (WUGs) by estimating foregone consumer surplus[1] of reduced residential water use due to drought management practices. The tool relies on household size, projected populations, WUG specific residential water use and price data, and user-determined reductions in water use to estimate cost by WUG.

This information is provided to aid the regional water planning groups (RWPGs) in evaluating the feasibility of various drought management strategies to address anticipated water needs. However, this tool does not estimate possible costs associated with drought management practices within categories of water use other than the municipal residential use.

2 Overview of the Costing Tool

The primary purpose of the tool is to provide WUG level costs and the expected household level residential water savings associated with policy-imposed restrictions or reduction on residential water use. Figure 1 depicts the data utilized by the tool to produce two major outputs: WUG level reductions in residential water use and costs to consumers. Users only need to provide the desired percent reductions in residential use.

Figure 1. Costing Data and Output



[1] Foregone consumer surplus cost estimates are not out of pocket costs, but rather are estimates of the consumer's willingness to pay to be restored back to their normal levels of water usage. Such estimates are commonly used in determining the monetary value of adverse impacts upon consumers, especially when explicit out-of-pocket costs are not incurred or are difficult to estimate.

Foregone consumer surplus per acre-foot (ac-ft) of reduced use is employed to determine estimates of consumer costs. Household level price and quantity data are also key components of the tool and are based on data from the year 2016 survey of water utilities performed by the Texas Municipal League (TML). The tool uses the TML data and resulting estimated demand functions to estimate costs per ac-ft of reduction for a given percent water use reduction at the household level. Sample estimates from year 2016 TML data are then multiplied by the number of households expected for the WUG in the decade of interest. The result is then multiplied by the anticipated quantity of water not available to the residential user based upon the year 2016 TML data of average use per household and the user provided reduction in use.

2.1 TML Data

A key component of determining the economic impacts of water use restrictions or reductions for residential use lay in estimating water demand curves for WUGs in the various regional water planning areas. Annual cost and usage surveys, performed by the TML, provide the best avenue for obtaining the needed data. Table 1 portrays sample residential water use data available from the year 2016 TML survey. Variables provided include fees charged by the utility for 5,000 and 10,000 gallons of usage as well as the average usage for each household within the surveyed cities. The survey results were linked to the relevant WUGs where possible, resulting in survey data for approximately one-third of the 1,872 municipal WUGs in the state water plan. TML data was then used to determine the expected price for the average monthly water use for the WUGs. Representative price and quantity values were then developed and assigned to the remaining WUGs using average values by planning region and 3 city size classifications: large (population greater than 100,000), medium (5,000 to 99,999), and small (less than 5,000).

Table 1. Sample Output, Texas Municipal League Water Cost/Use Survey (2016, monthly)

Population group	Entity	Population	Fee (5,000 gal)	Fee (10,000 gal)	Total customers	Average use (gal/month)
More than 500,000	Houston	2,239,558	$28.62	$52.88	468,000	4,900
	Austin	912,791	$38.24	$80.85	223,164	5,600
	Fort Worth	812,238	$24.94	$44.73	238,243	6,630
	El Paso	679,036	$20.59	$33.61	205,483	NA
350,001 - 500,000	Arlington	383,204	$21.41	$35.36	101,733	2,978
Source: https://www.tml.org/Archive.aspx?AMID=40						

2.2 Demand and Consumer Surplus as a Cost Measure

Micro-economic theory deals with the notion of people's utility functions and the accompanying pleasure or value derived from using or having access to one or more goods. That is, we all derive value from inexpensive and readily available water supplies so much so that we take that resource very much for granted. This value manifests itself in so-called demand functions which may be defined as:

> **demand** = a schedule of the maximum price a consumer is willing and able to pay for various quantities of a desired good.

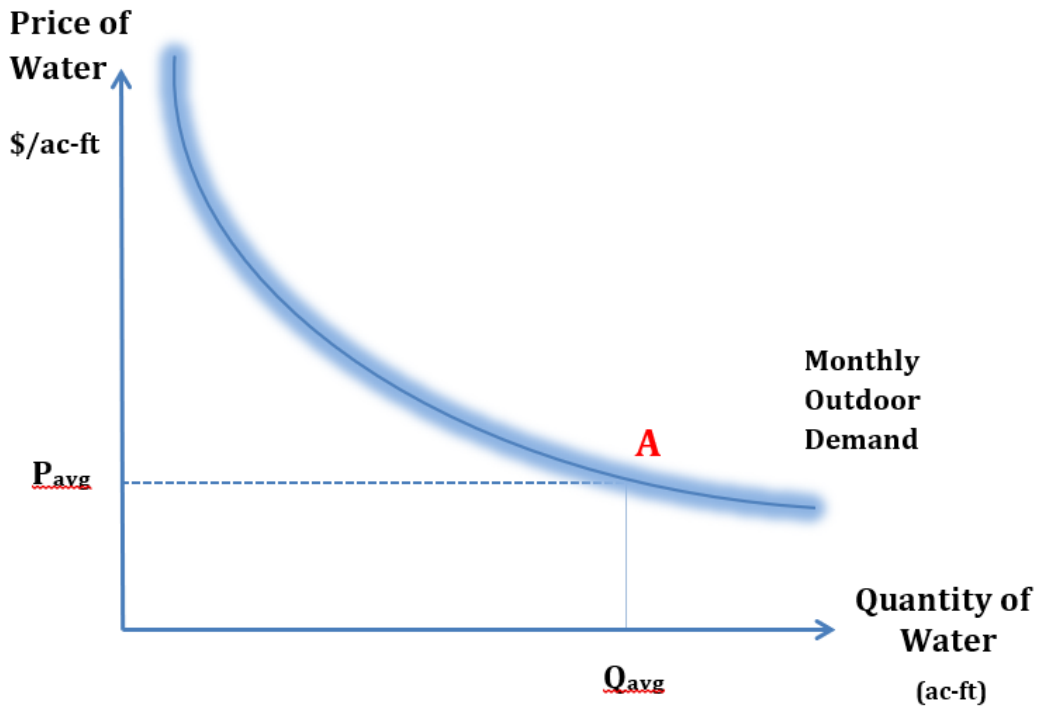
Key to this definition is the notion that the consumer is both ***willing*** (i.e., wants the good) and ***able*** (can afford it) to pay for the good. Demand curves are generally downward sloping, implying that people derive less and less benefit from additional units of the good, and are therefore less willing to trade their hard-earned dollars for more water or some other good.

Representative demand functions for each WUG were developed assuming a given level of sensitivity to the price of water. Outdoor demand use is more price sensitive than indoor use. Within the economic demand literature, this concept is referred to as the price elasticity of demand (Ɛ). Values for Ɛ generally vary from -0.3 to -0.8 depending on the service and use type or location (i.e., water plus wastewater, water only, indoor/outdoor use, region). A representative value of -0.5 was assumed for the outdoor water demand examined here, implying that for every one percent increase in price, the quantity demanded would fall by 0.5 percent.

Figure 2 portrays a sample demand curve for water. Note that price/ac-ft is on the vertical axis and quantity of water demanded (ac-ft) is on the horizontal axis. The graph portrays the monthly demand, with point A corresponding to the price/quantity pair (P_{avg},Q_{avg}) for the average price and quantity consumed per month by the household.

Note that the representative homeowner associated with this demand curve benefitted greatly from the market price of P_{avg}. The household consumed Q_{avg} units of water, most of which they paid much less than the maximum willingness to pay price portrayed by the demand curve. This notion of a gap between the maximum willingness to pay and the actual price one has to pay introduces the concept of consumer surplus. When a consumer pays less than their maximum willingness to pay for a good, he/she experiences a benefit, either in actual dollars saved or in dollars one might spend on something else.

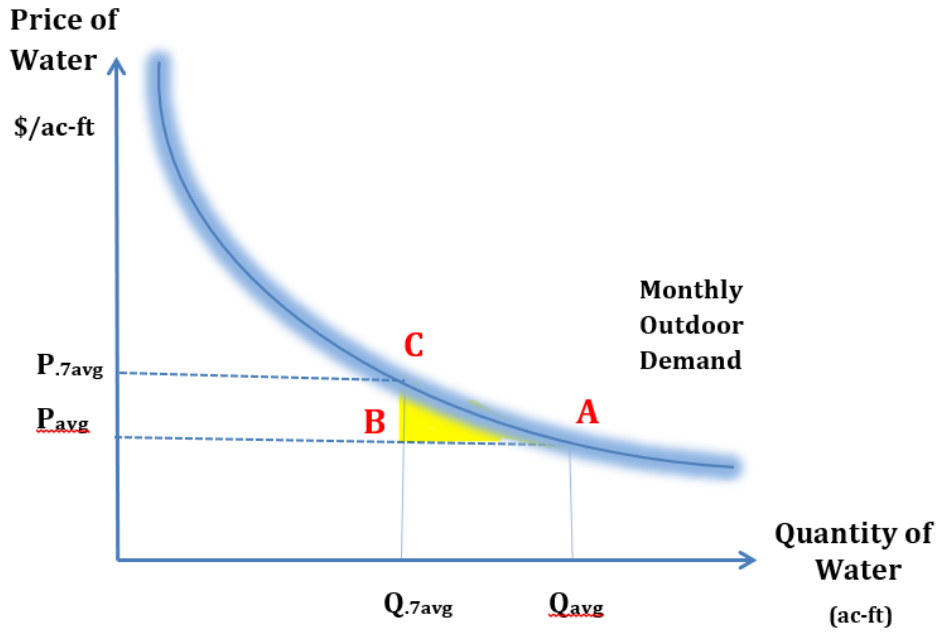
Figure 2. Sample Outdoor Water Demand Curve



Consumer surplus is then defined as the difference between how much one is willing to pay and what they actually have to pay. This measure, placed on a per ac-ft basis, places a monetary value on the adverse economic impacts due to the quantity of restrictions imposed by the utility.

As a specific example, consider the situation portrayed in Figure 3 and assume that a drought occurs, or a drought contingency plan is implemented, and only 70% of the normal water use is possible. The individual can only consume $0.7W_{avg}$ units of water, and they lose the benefits shown in area bounded by points A, B and C. Lost consumer surplus is the area below the demand curve and above the original purchase price. One may estimate the lost consumer surplus for varying levels of reductions by simply varying the location of the left-hand side of area ABC. For linear demand functions, lost consumer surplus may be estimated as the value 0.5*(base)*(height) of the triangle ABC. Similar estimates for nonlinear demand functions require the use of integral calculus for estimating the lost consumer surplus.

Figure 3. Sample Consumer Surplus Change for 30% Reduction



Note that the functional form for the WUG specific water demand functions employed in this tool appears below:

$$[\text{Equation } 1]: \quad Q_{water} = k*P^{\varepsilon}$$

where Q_{water} = the monthly household quantity of water (ac-ft),

P = the price of water ($/ac-ft),

k = a constant to be determined using WUG specific data, and

Ɛ = the price elasticity of demand for water.

As noted earlier, the value of Ɛ is assumed to be -0.5 for the outdoor water demand functions, and integral calculus techniques are used to determine the foregone consumer surplus associated with the WUG specific water reductions.

Once the foregone consumer surplus is calculated for a given degree of water reduction, the cost per ac-ft is calculated for each municipal WUG. This is simply the foregone consumer surplus divided by the quantity of water. For example, if the consumer surplus estimate totals $2,000, and the reduction is 5 ac-ft of water, the cost/ac-ft estimate assigned to the WUG equals $400/ac-ft. These cost estimates may then be used by the RWPGs to determine potential impacts of water reductions on residents.

2.3 Analysis Assumptions

Several key assumptions accompanied the development of the drought management costing tool.

1. The relevant demand functions are only for residential outdoor water use. Historical studies have revealed that approximately 30% of residential use within the state is for outdoor water use. Therefore, this tool only allows potential reductions less than or equal to 30% of normal water use due to drought management strategies.
2. Only residential water use reductions are examined. Available data did not support similar estimates for commercial water use.
3. County-Other WUGs are not included in this costing tool.
4. Year 2010 household size data (WUG specific where possible) are employed to determine the number of households in each decade, based upon the Board-adopted projected populations. These baseline household sizes are not assumed to adjust over time.
5. Baseline data from TML for average monthly prices and quantities (per household) from the year 2016 was used in developing the demand functions for the various WUGs. Where possible, WUG specific data was used. Proxy values based upon planning region and 3 city size classifications were assigned to WUGs with no TML survey results.
6. Final cost estimates are expressed in year 2018 dollars to be consistent with the water management strategy costing requirements in the 2022 State Water Plan.

3 Use of the Costing Tool

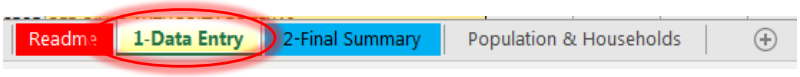
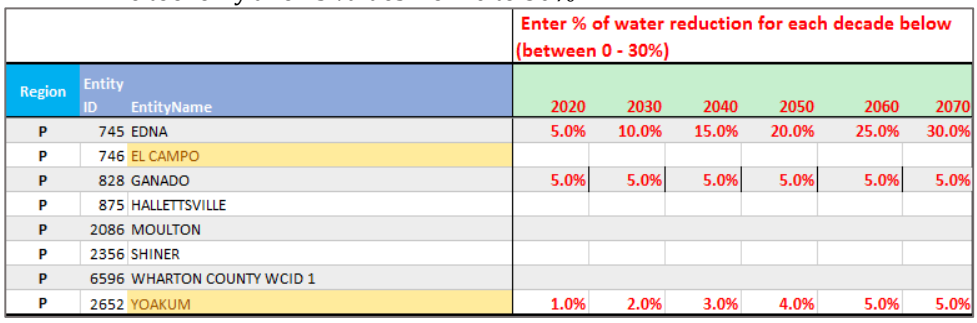
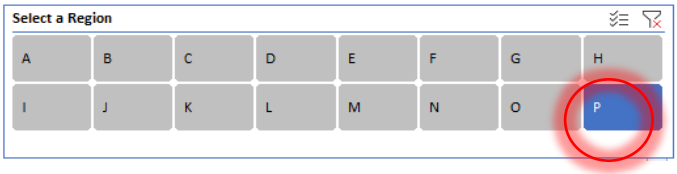
The tool consists of an Excel spreadsheet with three major components (tabs):

- 1-Data Entry: User data entry form for decade specific desired reductions in water use by region and WUG
- 2-Final Summary: A summary of the key parameters and final cost and water savings estimates
- Population & Households: Reference tab with background information on the number of households based on the 2010 Census data and the Board-adopted 2020-2070 WUG and region level population projections.

When using the tool, the user employs the 1-Data Entry tab to enter the desired percent reductions in water use, and then may view or export the summary input data and output via the 2-Final Summary tab. Step-by-step instructions are provided in Section 3.1 Step-by-Step Instructions for Use of the Tool

Table 2 below provides detailed step-by-step instructions for using the tool and exporting results.

Table 2. Specific Steps for Using the Tool, Data Entry and Output Export

Step	Action
1	**Open** the Drought Management Costing Tool Excel file
2	**Respond** yes or ok to any prompts for permission to accept macros or enable editing
3	**Select** the tab labeled **1-Data Entry (Figure 4)** 
4	**Click** on the region of interest within the dashboard at the top of the page. The entry form will filter to display only municipal WUGs within the selected region. 
5	**Enter** the decade specific desired reductions in household water use for the WUG/region of interest. – • One may copy and paste entries from one cell to another, or use the drag cell operation to copy the % reduction entry from a parent cell to fill in the same value to multiple cells. • The tool only allows values from 0 to 30%. 
6	**Check** all entries for accuracy. (All calculations are updated continuously as one enters the desired reduction percentages.)
7	To view the output summary, **click** on the tab **2-Final Summary** 
8	**Select** the region of interest from the dashboard at the top of the page.  Drought Management Costing Summary

Enter % of water reduction for each decade below (between 0 - 30%)

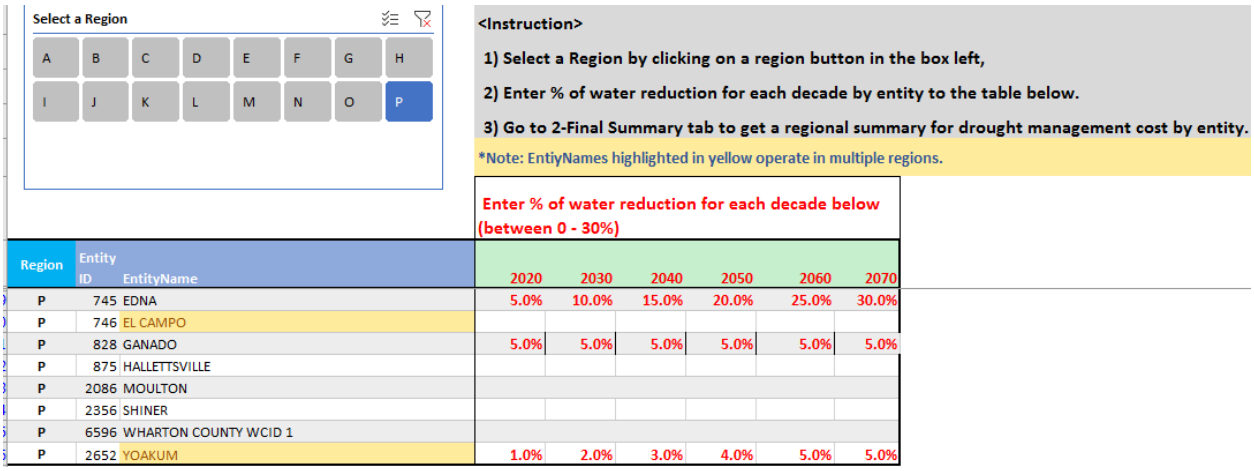
Region	Entity ID	EntityName	2020	2030	2040	2050	2060	2070
P	745	EDNA	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%
P	746	EL CAMPO						
P	828	GANADO	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
P	875	HALLETTSVILLE						
P	2086	MOULTON						
P	2356	SHINER						
P	6596	WHARTON COUNTY WCID 1						
P	2652	YOAKUM	1.0%	2.0%	3.0%	4.0%	5.0%	5.0%

Step	Action
9	**Examine** the results. (See **Section 3.2** for more details concerning the tool output) • Final total water volumes and cost estimates are displayed under "***Total annual water reduction in ac-ft***" and "***Total annual cost (in 2018 $)***"
10	**Select** the headings and output and then copy and paste them into a new spreadsheet.
11	**Save and close** the Costing Tool.

3.1 Details: Data Entry Tab

Figure 4 depicts the data entry form where the user inputs the decade specific desired reduction in water use percentages by WUG and region. Several WUGs occupy multiple regions, necessitating this greater degree of detail. WUG/region combinations fitting this category are highlighted in yellow within the entry form, and the associated costs and water use reductions are calculated using WUG/region specific population projections. For example, the El Campo WUG shown below in Figure 4 also has service area in Region K. RWPGs may be interested in the costs for all residences in a particular WUG, regardless of the planning region. In that case, the tool should be used to provide cost and water reduction estimates for all affected regions.

Figure 4. Data Entry Tab



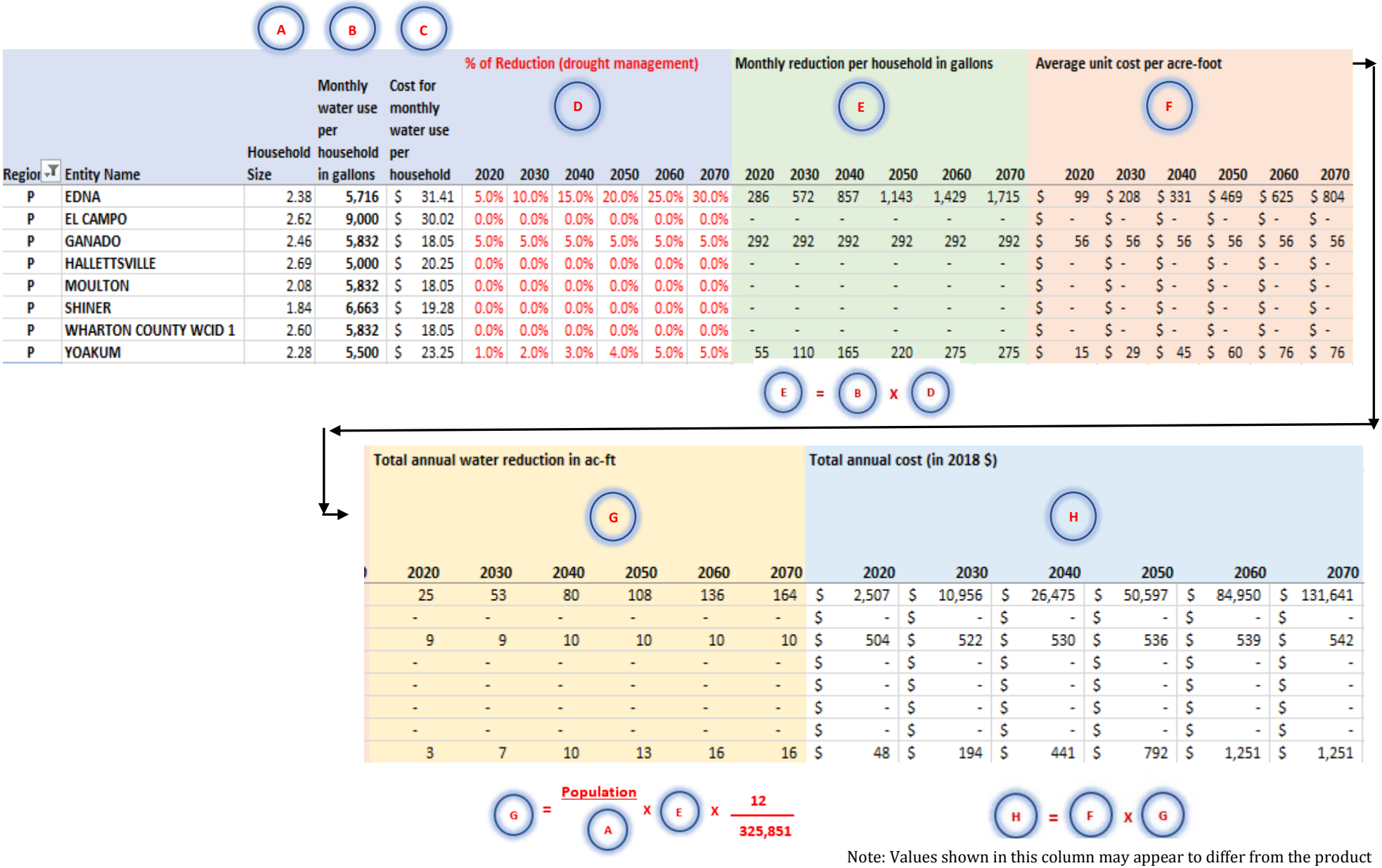
3.2 Details: Final Summary Tab

The 2-Final Summary tab within the cost tool summarizes the user input desired reductions as well as key output data such as total volume of water saved and the associated costs by decade. Information for understanding the data on this tab appears below, both in text form (Table 3) and pictorially (Figure 5). Both the table and the figure make use of a shorthand single letter name for each data/section type within the summary tab. The shorthand letter names (shown in a blue halo) appear within the section headings within Figure 5, with details of the calculation procedures shown below the sections where appropriate. All cost values are expressed in year 2018 dollars.

Table 3. Final Summary Tab Components (See also Figure 5)

Shorthand Letter Name	Item	Description and or Use	Source/Calculation (units)
	Region	Regional water planning area	
	EntityName	Water user group (WUG) name	
A	Household Size	Persons per household	Year 2010 Census
B	Monthly water use per household in gallons	Average monthly billed household water use in gallons.	TML data, 2016 (gallons/household/mo)
C	Cost for monthly water use per household	Average monthly utility billed cost for household water use	TML data, 2016 ($/mo)
D	% of Reduction (drought management)	Percent reductions in average use specified by the tool user for each decade to attain the desired level of water use reductions. Tool multiplies these percentages by the average water use per household to determine average reductions in water use per household in gallons.	User supplied via the 1-Data Entry tab (%, by decade)
E	Monthly reduction per household in gallons	Estimated reductions in household monthly water use imposed by the drought management based on % of reduction entered by users. Calculated as the average monthly use multiplied by the percent reduction.	B*D (gal/mo)
F	Average unit cost per acre-foot **(in 2018 $)**	WUG and % reduction specific estimate of foregone consumer surplus, divided by the corresponding reduction in average monthly water use due to drought management .	Area beneath WUG level demand function and above the average price, divided by the ac-ft of reduction in use. ($/ac-ft)
G	**Total annual water reduction in ac-ft**	Total annual reduction in ac-ft of all household water use due to drought management plan implementation based on % of reduction entered by users. Calculated as the number of households * 12 months * monthly household reduction in use, then converted to acre-feet.	[(population/A)*12* E]/ 325,851 gal/ac-ft) (ac-ft/year)
H	**Total annual cost (in 2018 $)**	Total annual costs for foregone water use. Calculated as total annual water reduction * average unit cost per ac-ft. (Note: values shown in this column may appear to differ from the product (F * G) due to rounding of the component parts F and G)	F * G ($/year)

Figure 5. Final Summary Tab Components



		A	B	C	% of Reduction (drought management) D						Monthly reduction per household in gallons E						Average unit cost per acre-foot F					
Regior	Entity Name	Household Size	Monthly water use per household in gallons	Cost for monthly water use per household	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
P	EDNA	2.38	5,716	$ 31.41	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%	286	572	857	1,143	1,429	1,715	$ 99	$ 208	$ 331	$ 469	$ 625	$ 804
P	EL CAMPO	2.62	9,000	$ 30.02	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
P	GANADO	2.46	5,832	$ 18.05	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	292	292	292	292	292	292	$ 56	$ 56	$ 56	$ 56	$ 56	$ 56
P	HALLETTSVILLE	2.69	5,000	$ 20.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
P	MOULTON	2.08	5,832	$ 18.05	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
P	SHINER	1.84	6,663	$ 19.28	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
P	WHARTON COUNTY WCID 1	2.60	5,832	$ 18.05	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
P	YOAKUM	2.28	5,500	$ 23.25	1.0%	2.0%	3.0%	4.0%	5.0%	5.0%	55	110	165	220	275	275	$ 15	$ 29	$ 45	$ 60	$ 76	$ 76

E = B X D

Total annual water reduction in ac-ft G						Total annual cost (in 2018 $) H					
2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
25	53	80	108	136	164	$ 2,507	$ 10,956	$ 26,475	$ 50,597	$ 84,950	$ 131,641
-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
9	9	10	10	10	10	$ 504	$ 522	$ 530	$ 536	$ 539	$ 542
-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
3	7	10	13	16	16	$ 48	$ 194	$ 441	$ 792	$ 1,251	$ 1,251

G = Population / A X E X 12 / 325,851

H = F X G

Note: Values shown in this column may appear to differ from the product (F * G) due to rounding of the component parts F and G.

3.3 Details: Population and Households

The Population and Households tab (Table 4) is included as a convenient data reference source for users and includes household size, number of households, and the TWDB projected population values for each WUG/region combination. The number of households parameter is calculated simply as the decade specific population projection, divided by the household size.

Table 4. Sample Data, Population and Households Tab

				Number of Households						Projected Population					
Region	EntityId	Entity Name	Household Size	2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
P	745	EDNA	2.382	2,413	2,497	2,533	2,563	2,582	2,593	5,747	5,949	6,034	6,105	6,150	6,177
P	746	EL CAMPO	2.621	4,615	4,830	5,002	5,151	5,289	5,411	12,096	12,660	13,111	13,502	13,863	14,183
P	828	GANADO	2.463	844	874	887	897	903	908	2,080	2,153	2,184	2,209	2,224	2,236
P	875	HALLETTSVILLE	2.693	1,047	1,047	1,047	1,047	1,047	1,047	2,820	2,820	2,820	2,820	2,820	2,820
P	2086	MOULTON	2.083	420	420	420	420	420	420	874	874	874	874	874	874
P	2356	SHINER	1.835	1,119	1,119	1,119	1,119	1,119	1,119	2,054	2,054	2,054	2,054	2,054	2,054
P	6596	WHARTON COUNTY WCID 1	2.603	413	440	461	479	497	511	1,076	1,146	1,201	1,248	1,293	1,331
P	2652	YOAKUM	2.275	1,627	1,627	1,627	1,626	1,627	1,627	3,701	3,701	3,701	3,700	3,701	3,701

4 Limitations

The enclosed tool provides reasonable estimates of the costs for residential consumers faced with water reduction for outdoor water use due to drought management. Cost estimates directly from the tool may be used as the adverse monetary impacts of possible restrictions on water use for the residential water user, and those estimates are acceptable for use as the estimated costs within regional water plans. However, RWPGs using this tool should understand the limitations to the costs calculated by the tool, and know that other factors may also be appropriate for consideration if the local data is available. Such factors include the following:

1. Reduced incomes to the utility due to smaller sales of water;
2. Increased enforcement and monitoring costs of implementation while also considering any collected fees for non-compliance;
3. Positive effects of reduced water treatment costs for not sold water;
4. Cash flow considerations due to smaller water sales;
5. Potential price changes to incentivize reduced water use; or
6. The tool's focus on household water use without considering delivery losses and other non-billed water quantities.

5 Contact Information

Additional questions may be directed to:

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