

Texas Water Development Board



Unified Costing Model User's Guide

FINAL

VERSION 1.0

May 2013

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Prepared for:

Texas Water Development Board

Prepared by:



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CONTRACT ADMINISTRATION

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Prepared by:

HDR

**FREESE
AND
NICHOLS**

The Unified Costing Model (UCM) for Regional Water Planning is not intended to be used in lieu of professional engineering design or cost estimation procedures for water supply facilities. Results of all applications of the UCM, including those for technical evaluation of water management strategies in the regional water planning process, should be carefully reviewed by professional engineers and other knowledgeable professionals prior to use and publication. This tool was developed for the purpose of preparing regional water planning level cost estimates only. Any use of the UCM and results obtained there from will be at the User's sole risk and without liability or legal exposure to the Texas Water Development Board, HDR Engineering, Inc., and/or Freese and Nichols, Inc.

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Executive Summary

Regional water planning requires the evaluation and comparison of Water Management Strategies, including estimating costs to construct the required infrastructure. Additionally, cost estimating procedures are needed for non-infrastructure related water supply projects, such as conservation and drought management.

The Texas Water Development Board (TWDB) compiles cost estimates from all 16 planning regions and uses the information to develop the State Water Plan. Without a standardized costing method (including cost curves for infrastructure elements and assumptions), cost estimates varied across the state, region by region. The Unified Costing Model (UCM) project seeks to gain a level of consistency between cost estimates developed for the 16 Regional Water Planning Groups and their consultants.

The UCM, along with this user's guide, is intended to assist regional water planning groups and their consultants in developing consistent cost estimates across the State of Texas, so when these 16 regional plans come together to form the State Water Plan, TWDB can be assured that each water management strategy is evaluated on an even playing field with respect to cost estimates. The UCM is designed to be relatively intuitive, with individual component modules, some of which are optional, that feed information to a line item costing form, automatically when possible. Within the model, there are 11 costing modules along with some supporting data. Those modules include:

1. Quick Reference Guide
2. Project Information and Assumptions
3. Simplified Hydraulics
4. Advanced Hydraulics
5. Well Field
6. Embankment Calculations
7. Land Acquisition
8. Costing Form
9. Cost Summary
10. Conservation
11. Drought Management Risk Factor

The modules, described herein, assist the user in developing cost estimates for the most common types of water management strategies in regional water planning. Certainly, there are projects or components of projects with unique characteristics beyond the scope of what these modules are designed to evaluate, and in such cases, the user should perform an external cost estimate that may be incorporated into the UCM, where applicable. Using these procedures and methods will provide reliable and consistent preliminary configurations and cost estimates; however, results should always be reviewed and refined with application of professional judgment and experience.

0.0 Introduction and General Overview

A large volume of regional planning work consists of studying alternatives for delivering water from new water sources to demand locations and evaluating ways to optimize management of existing water supplies. Investigating these types of scenarios typically includes performing a preliminary engineering analysis of needed facilities and estimating costs to construct the required infrastructure. Other tasks may involve updating construction cost estimates of alternatives that have previously been examined. Additionally, cost estimating procedures are needed for non-infrastructure related water supply projects, such as conservation and drought management.

The Texas Water Development Board (TWDB) compiles cost estimates from all 16 planning regions and uses the information to develop the State Water Plan. Without a standardized costing method (including cost curves for infrastructure elements and assumptions), cost estimates varied across the state, region by region. With the Unified Costing Model (UCM) project, TWDB seeks to gain a level of consistency between cost estimates developed for the 16 Regional Water Planning Groups and their consultants. This, in turn, assures that cost estimates in the State Water Plan are consistent and on equal footing.

The purpose of this user's guide is to present the UCM for Regional Water Planning, which is to be used for planning-level cost estimates. Using these procedures and methods will provide reliable and consistent preliminary configurations and cost estimates; however, results should always be reviewed and refined with application of professional judgment and experience. The UCM is to be used only for strategies that do not have a detailed cost estimate based on an engineering study. Additionally, unique situations and facilities not addressed in the procedures should be evaluated on an individual basis.

The UCM contains a series of modules to aid the user in developing a cost estimate for a water management strategy under consideration in regional water plan development. Those modules, discussed in the following sections, include:

1. Quick Reference Guide
2. Project Information and Assumptions
3. Simplified Hydraulics
4. Advanced Hydraulics

-
5. Well Field
 6. Embankment Calculations
 7. Land Acquisition
 8. Costing Form
 9. Cost Summary
 10. Conservation
 11. Drought Management Risk Factor

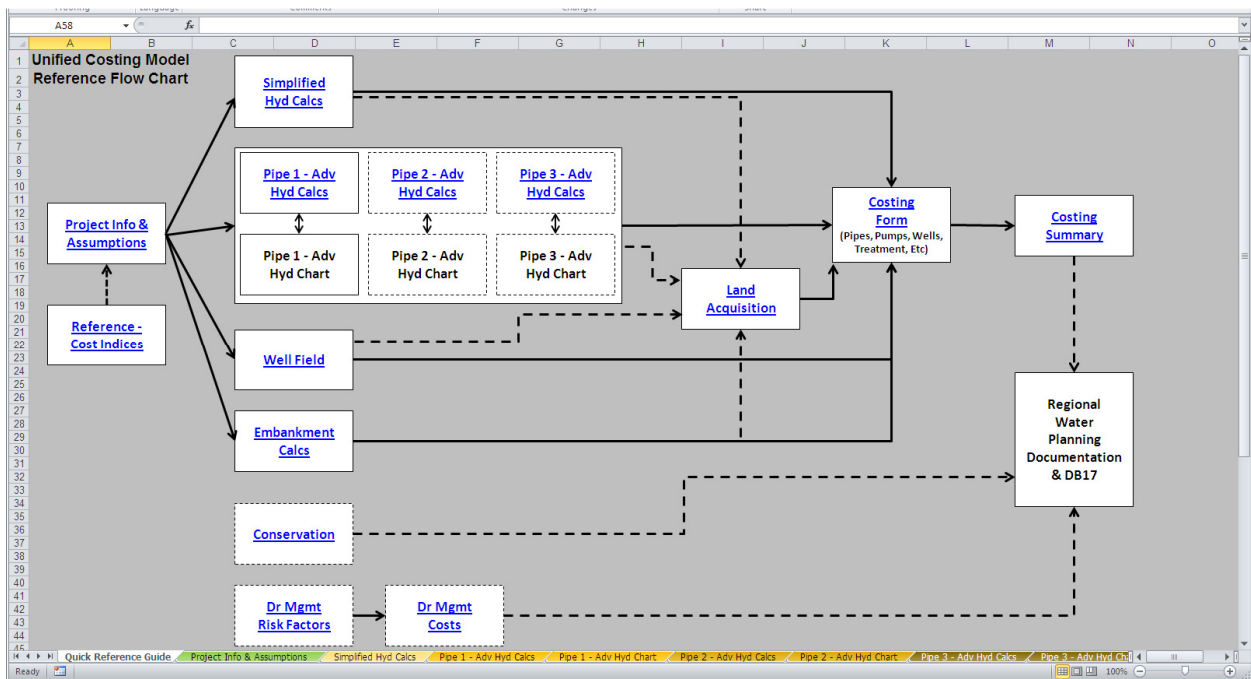
Each module has been designed to accommodate the most common types of water management strategies in regional water planning. Certainly, there are projects or components of projects with unique characteristics beyond the scope of what these modules are designed to evaluate, and in such cases, the user should perform an external cost estimate that may be incorporated into the UCM, where applicable.

1.0 Quick Reference Guide

The Quick Reference Guide module (“Quick Reference Guide” tab) of the UCM shows a flow chart to walk the user through the tool.

For a typical Water Management Strategy (WMS) that requires the construction of infrastructure, the user begins with the Project Info and Assumptions to enter details about the project. Next, the user enters data regarding the transmission of water via pipelines in one or more of the hydraulic calculations modules. If the project includes a well field or a dam, there are optional modules to assist the user in defining them. The user then enters information regarding land acquisition. The main hub of the UCM is the costing form, where data from all infrastructure-related components are either accumulated automatically or defined. This is where the cost estimate is pulled together line-item by line-item. Finally, the user can view a summary of the cost estimate in the Costing Summary, which has been designed to be easily copied and pasted into the Regional Water Plan report.

For non-infrastructure based WMSs, the UCM contains modules to assist the user in determining potential water savings and costs. The UCM includes one module for water conservation and two modules to determine drought management.



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2.0 Project Information and Assumptions

The Project Information and Assumptions module (“Project Info & Assumptions” tab) of the UCM is where basic project data and the general assumptions used throughout the costing model are entered. There are three sections in the Project Information and Assumptions module.

The first portion (Basic Info) allows the user to enter the name of the project, the Water User Group (WUG) or Wholesale Water Provider (WWP) associated with the project, and the name of the persons performing and checking the cost estimate. Additionally, the user enters the Producer Price Index¹ (PPI - used for pipelines) and the Engineering News Record Construction Cost Index² (CCI - used for all other facilities) values to establish the time basis for which the cost estimate is to be made. Historical cost indices are included in the UCM on the “Reference - Cost Indices” tab. Base cost data in the UCM are set to March 2012 dollars (a CCI of 9268 and a PPI of 184.4). At the appropriate time, the base cost data will be updated to September 2013 dollars, per the TWDB guidance for regional water planning for the 2016 Regional Water Plans. Finally, the user enters the project supply in acre-feet per year (acft/yr) and an associated peaking factor for upsizing of facilities (see Section 2.1).

The second section of the Project Information and Assumptions module allows users to enter the assumptions consistent with the TWDB guidance for regional water planning. These values have been pre-populated with the assumptions used in the 2016 regional planning cycle.

The third section of the Project Information and Assumptions module is where the user can enter assumptions pertaining to power connections and pipeline crossings. Standard values for power connections and pipeline crossings have been pre-populated.

It should be noted that cells that require user input are white in color with a blue-colored font, while default values are light green in color with blue-colored font. Default values are editable, and up to the user’s discretion.

¹ <http://www.bls.gov/ppi/>

² <http://enr.construction.com/economics/>

	A	B	C	D	E	F	G	H	I	J
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2										
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TWDB - Unified Costing Model for Regional Planning	
Project Name:	Example Pipeline Project
WUG/WWP:	Lockhart
Cost Estimator:	R Brian Perkins
Checked By:	
ENR Construction Cost Index Time Period:	March 2012
Producer Price Index Time Period:	March 2012
Available Project Yield	10,000 acft/yr
Project Peaking Factor	1.5
Average Flow	13.8 cfs
Average Flow	8.9 MGD
Peak Flow	20.7 cfs
Peak Flow	13.4 MGD
CCI Factor:	9268
PPI Factor	185.2

Basic Info	
Interest During Construction	4.00%
Rate of Return on Investments	1.00%
Construction Period	1.0 years
Engineering, Legal, & Contingencies (Pipes)	30%
Engineering, Legal, & Contingencies (All Other Facilities)	35%
Debt Service (Non-Reservoirs) Period	20 years
Debt Service (Reservoirs) Period	40 years
Annual Interest Rate (Non-Reservoirs)	5.50%
Annual Interest Rate (Reservoirs)	5.50%
Operations & Maintenance (Pipelines)	1.00%
Operations & Maintenance (Pump Stations)	2.50%
Operations & Maintenance (Dams)	1.50%
Power Costs	\$0.09 /kilowatt-hour

TWDB General Guidelines	
Power Connection Costs - Pump Stations	\$150 /HP
Recommended Crossing Length (2-Lane Roads)	115 LF
Recommended Crossing Length (4-Lane Divided Highway)	210 LF
Recommended Crossing Length (6-Lane Divided Highway)	240 LF
Recommended Crossing Length (Railways)	100 LF

Pumps & Kings	
Power Connection Costs - Pump Stations	\$150 /HP
Recommended Crossing Length (2-Lane Roads)	115 LF
Recommended Crossing Length (4-Lane Divided Highway)	210 LF
Recommended Crossing Length (6-Lane Divided Highway)	240 LF
Recommended Crossing Length (Railways)	100 LF

Key (Throughput Model):

1.5 ← User Input

1.0 ← Default Values Set, User May Adjust

8.9 ← Other colored cells are either informational or calculated values

ENR Online: <http://enr.construction.com/economics/>
PPI Online: [http://ftp.bls.gov/pub/time-series/ppc/ppc.data_13_Fabricated\(Meta\)Product](http://ftp.bls.gov/pub/time-series/ppc/ppc.data_13_Fabricated(Meta)Product)
Historical Data: [Reference - Cost Indices](#)

2.1 Water Volume and Rate of Delivery

The volume of water to be pumped and the rate at which it needs to be delivered are critical pieces of information because they are the driving components in determining pipe sizes and pump station requirements. The volume of water that will be delivered (i.e., the amount of water to be delivered over an entire year) will be determined in a separate analysis and will vary from one water management strategy to another. For example, in one strategy, the volume of water that can be delivered may depend on the yield of a reservoir, while another may depend on a predetermined amount of water to be purchased from a WWP.

After determining the volume of water for a strategy or alternative, the next piece of information needed is the desired rate of delivery. Water may be delivered at an average (uniform) rate over the entire year (i.e., the same volume of water would be pumped each day), or the rate may vary from month to month or day to day. A typical scheme where water will be delivered at varying rates is one in which more is pumped in the summer to meet “peak” demands, and then significantly lower during the winter to meet “off-peak” demands. An important point to remember is that **FACILITIES ARE TO BE SIZED BASED ON PEAK RATES OF DELIVERY**. If a variable rate is used, the transmission system will need to be examined using the low, average, and peak rates to determine system adequacy and pumping costs at each flow.

Another aspect to remember about the delivery rate is that it should be adjusted to reflect pump station downtime for maintenance activities. The UCM assumes a 5 percent pump station downtime with a uniform delivery of water. If facilities are sized for a peaking factor greater than 1.0, then maintenance downtime is assumed to be completed during the “off-peak” period.

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3.0 Simplified Hydraulics Calculations

There are two methods of performing pipeline hydraulics calculations available in the UCM. These methods are used to determine pipeline diameter(s), pump and booster sizes, and pumping energy required. The first is a simplified method presented in this section, and the other is a detailed method in which the user defines a pipeline route and uses an elevation profile (presented in Section 4.0).

The simplified method in the Simplified Hydraulics module (“Simplified Hyd Calcs” tab) allows the user to quickly determine pipeline diameter(s), pump and booster sizes, and pumping energy given a few basic pieces of information. The user inputs the beginning and ending elevations, pipeline length, water delivery amount and peaking factor, and other basic assumptions. The user chooses a pressure class for the pipe (ranging from 100 psi to 350 psi). Base pipeline costs are adjusted based on the pressure class chosen. The Simplified Hydraulics module aids the user in choosing a pipeline diameter and generates the number of pump stations required, along with their sizes and required pumping energy.

	A	B	C	D	E	F	G	H	I								
1	Pipe Sizing and Profile Plotting Spreadsheet Example Pipeline Project R Brian Perkins																
2																	
3																	
4																	
5																	
6																	
7	Hydraulics	Downtime for Maintenance (Uniform Delivery Only)					5.0%										
8		Target Flow Velocity in Pipes					5.00	ft/s									
9		Hazen-Williams C Factor (Roughness)					120										
10		Residual Head at End of Pipe						psi									
11		Maximum Pipeline Pressure						psi									
12		Pump Efficiency (Mechanical & Electrical)					0.70										
13		Total Water Conveyance (acft/yr)															
14	Peaking Factor																
15	Simplified Pipeline Hydraulics Calculations																
16																	
17																	
18										Pipeline Length (ft)	Starting Elevation (ft-msl)	Ending Elevation (ft-msl)	Computed Diameter for 5 ft/s (in)	Pipe Diameter (in)			
19													0.00				
20																	
21	Average Flow (MGD)	Peak Flow (MGD)	Peak Flow (cfs)	Velocity (ft/s)	HGL Slope (c=120) (ft/1000 ft)												
22	0.00	0.00	0.00	#DIV/0!	#DIV/0!												
23																	
24	Total Dynamic Head (ft)	Total HP Needs	Number of Pump Stations Needed	HP per Pump Station	Total Pumping Energy (kW-hr)												
25	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0												
26																	

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4.0 Advanced Hydraulics Calculations

The second method of performing pipeline hydraulics calculations available in the UCM, and used to determine pipeline diameter(s), pump and booster sizes, and pumping energy required, is through use of the Advanced Hydraulics module (“Pipe X - Adv Hyd Calcs” tab). The user supplies a pipeline profile (based on externally-selected route), including station, elevation, ground type (rock or soil), and level of development (rural or urban) along the pipeline route. The Advanced Hydraulic module allows the user to consider the pressure in the pipeline along the entire route to verify if maximum and minimum pressure parameters are met throughout the pipeline route. The user can also choose locations of booster stations and allocate a portion of the Total Dynamic Head (TDH) to each of the booster stations. Additionally, the user may specify delivery amounts and points along the pipeline route, thereby facilitating adjustment of pipe diameter for varying flowrates along the pipeline.

The user may choose up to five delivery locations along the pipeline route to deliver portions of the total water to be conveyed by the transmission system. Additionally, the user may specify up to five pump/booster stations to gain the necessary lift from the beginning of the pipeline to the end delivery point.

Finally, because water management strategies often include more than one pipeline route (for example, there may be a high-capacity diversion from a river to an off-channel reservoir and a uniform delivery of firm yield from the off-channel reservoir to a WTP), the UCM has included three (3) Advanced Hydraulics modules to allow up to three separate pipelines (transmission sub-systems) to be evaluated for one water management strategy.

4.1 Hydraulics Assumptions

The “Hydraulics” section of the Advanced Hydraulics module allows the user to input basic hydraulics information, including roughness factor, target flow velocities, type of water being transported (raw or treated water), etc. The user chooses a pressure class for the pipe (ranging from 100 psi to 350 psi). Base pipeline costs are adjusted based on the pressure class chosen.

The type of water to be transported is a consideration that may have an impact on the engineering analysis. Raw water and treated water comprise the categories that are expected to

be encountered in technical evaluation of water management strategies. Treated water is water that has been treated for some purpose; generally this would be potable water from a water treatment plant. Raw water is usually thought of as untreated, non-potable surface water that comes from a stream or reservoir. Groundwater may potentially be categorized as potable (classified as treated in the UCM) or non-potable (classified as treated in the UCM) water depending on resident levels of certain substances found in the water. It is important to be aware of the water type because minimum pipeline pressure requirements vary depending on the type and use. In the UCM, the Advanced Hydraulics module assumes a 15-psi minimum pressure for raw water and a 25-psi minimum pressure for treated water.

4.2 Water Delivery Locations

The user specifies the total water conveyance, peaking factor, delivery quantities, and locations in the “Deliveries” portion of the Advanced Hydraulics module. Some amount of water must be delivered to the end of the pipeline. The locations of the delivery points are needed in order to chart a pipeline route. Possible delivery locations include rivers, reservoirs, water treatment plants, storage tanks, and municipal distribution systems.

Pipe Sizing and Profile Plotting Spreadsheet

Example Pipeline Project
R Brian Perkins
3/21/2013

Downtime for Maintenance (Uniform Delivery Only)		Hydraulics	
Target Flow Velocity in Pipes	5.00%	ft/s	
Hazen-Williams C Factor (Roughness)	120	psi	
Residual Head at End of Pipe	25	psi	
Water Delivered (Raw or Treated)	Raw	psi	
Maximum Pipeline Pressure	150	psi	
Pump Efficiency (Mechanical & Electrical)	0.70		

Locchart: Pipeline Elevation Profile with Pressure Class Elevations

Minimum PSI = 20 psi
Maximum PSI = 114 psi

SOIL	Rural	Urban
ROCK	103.950	0
	0	0

Deliveries	
Total Water Conveyance (act/yr)	10000
Peaking Factor	1.50
Delivery Amount #1 (act/yr)	717.00
Delivery Amount #2 (act/yr)	80.00
Delivery Amount #3 (act/yr)	20.00
Delivery Amount #4 (act/yr)	1099.00
Delivery Amount #5 (act/yr)	
Station (ft):	
Station (ft):	
Station (ft):	
Station (ft):	

Advanced Pipeline Hydraulics Calculations

Segment	Pipe Diameter (in)	Average Flow (MGD)	Peak Flow (MGD)	Computed Diameter for 5 ft/s (in)	Velocity (ft/s)	HGL Slope (c=120) (ft/1000 ft)	End Station (ft)
Segment 1	36	8.93	13.39	27.56	2.93	0.874	71,700
Segment 2	18	1.79	2.68	12.33	2.34	1.302	105,950
Segment 3		0.00	0.00	0.00	#DIV/0!	#DIV/0!	
Segment 4		0.00	0.00	0.00	#DIV/0!	#DIV/0!	
Segment 5		0.00	0.00	0.00	#DIV/0!	#DIV/0!	

Pipeline Profile Data

Station (ft)	Ground Elevation (ft-msl)	Soil or Rock	Urban or Rural	Pressure: 150 psi (ft-msl)	HGL (ft-msl)	Hydraulic Calcs (psi)	Soil, Urban	Soil, Rural	Rock, Urban	Rock, Rural
0	387	Soil	Rural	733.54	823.57	102.39	0.00	50.00	0.00	0.00
50	387	Soil	Rural	733.26	823.53	102.49	0.00	50.00	0.00	0.00
100	387	Soil	Rural	733.42	823.48	102.41	0.00	100.00	0.00	0.00
150	387	Soil	Rural	733.72	823.44	102.26	0.00	150.00	0.00	0.00
200	383	Soil	Rural	734.04	823.40	102.10	0.00	200.00	0.00	0.00
250	383	Soil	Rural	734.16	823.35	102.03	0.00	250.00	0.00	0.00
300	387	Soil	Rural	733.73	823.31	102.20	0.00	300.00	0.00	0.00
350	383	Soil	Rural	732.82	823.26	102.57	0.00	350.00	0.00	0.00
400	385	Soil	Rural	731.53	823.22	103.11	0.00	400.00	0.00	0.00
450	384	Soil	Rural	730.44	823.18	103.57	0.00	450.00	0.00	0.00
500	383	Soil	Rural	729.09	823.13	104.13	0.00	500.00	0.00	0.00
550	381	Soil	Rural	727.58	823.09	104.76	0.00	550.00	0.00	0.00

4.3 Pipeline Route Selection and Profile

Generally, the first step in the Advanced Hydraulics module pipeline analysis is to determine a route. The goal is to connect the source with the destination by the most direct and logical route possible. Once a path has been selected, a two-dimensional pipeline profile can be generated from a set of points distributed along the route (Section 4.3.1). Each point represents a station (horizontal dimension), and a corresponding ground elevation (vertical dimension). The number of points and the distances between these locations needed to represent the profile adequately will vary depending on the topography along the route. The goal is to capture the general topographic features or trends while showing points of significant elevation changes (i.e., minimum and maximum points along a route segment). These data, along with the ground type (rock or soil), and level of development (rural or urban) along the pipeline route, are entered into the Pipeline Profile Data portion of the Advanced Hydraulics module.

4.3.1 Route Selection and Profile Generation Guidelines and Tasks

Pipeline routes are identified and generated using external mapping resources available. Selecting a route to be used in technical evaluation of a water management strategy is typically an exercise in professional judgment based on experience. The following guidelines and tasks should, however, be considered in any strategy evaluation:

A. Route Selection Guidelines

- Select the most direct route paralleling existing right-of-ways to the extent possible. Existing right-of-ways include roadways (preferred), pipelines, power transmission lines, and railways (least preferred).
- Limit pipeline routing across open land to the extent possible. Property division is less desirable than paralleling a boundary, except when following an existing right-of-way. In the design phase, it may be more feasible to cross open land along selected sections of a route if, during the design evaluation, the benefits outweigh the costs.
- Bypass large water bodies.

-
- Bypass cemeteries and sites **known** to be culturally significant or environmentally sensitive. An environmental and archaeological review may or may not be performed at the regional planning level, but readily available information should be used to help avoid known sensitive areas.
 - Bypass urban centers to the extent possible. Though it may result in a longer route, traversing around a city will likely result in lower construction costs.
 - Avoid rough terrain, if possible; especially bypass hills that could be higher than the hydraulic grade line of the pipeline.
 - Avoid heavily forested areas to the extent possible.
 - Avoid crossing a highway at a major interchange.
 - Avoid areas that require rock excavation if practical. Since soil conditions are usually consistent within some range, moving the pipeline is generally not expected to significantly change the ground conditions encountered. In the event that evidence shows the ground conditions would change significantly by shifting the pipeline route, the route that would result in lower construction costs should be selected.

B. Pipeline Route and Profile Generation Procedures

It is recommended that when generating a pipeline route and pipeline profile, the user use GIS technologies. Profile generation guidance can be found in Appendix B.

4.4 Pipeline Hydraulics Calculations

The user selects pipeline diameters for the transmission pipeline segments, along with pump/booster station locations and associated lift in the Advanced Pipeline Hydraulics Calculations portion of the Advanced Hydraulics module. The following sub-sections (4.4.1 through 4.4.4) briefly explain the theory behind the calculations used in the Advanced Pipeline Hydraulics Calculations portion of the UCM that guide the user in making these selections.

4.4.1 Pipe Size, Velocity, and Head Loss

The Advanced Pipeline Hydraulics Calculations portion of the Advanced Hydraulics module is used to size pipes and generate the hydraulic grade line. Using total water conveyance

and the peaking factor, the peak delivery rate is established and the process of selecting the size, velocity and head loss is as follows:

1. Estimate a pipe diameter for a corresponding velocity. A target velocity is used at this stage to help establish an appropriate size range. Equation 1 calculates the exact diameter in inches, as follows:

$$D(in) = \sqrt{\frac{Q(cfs)}{V(fps) \left(\frac{\pi}{4} \right) \left(\frac{1ft}{12in} \right)^2}} \quad (1)$$

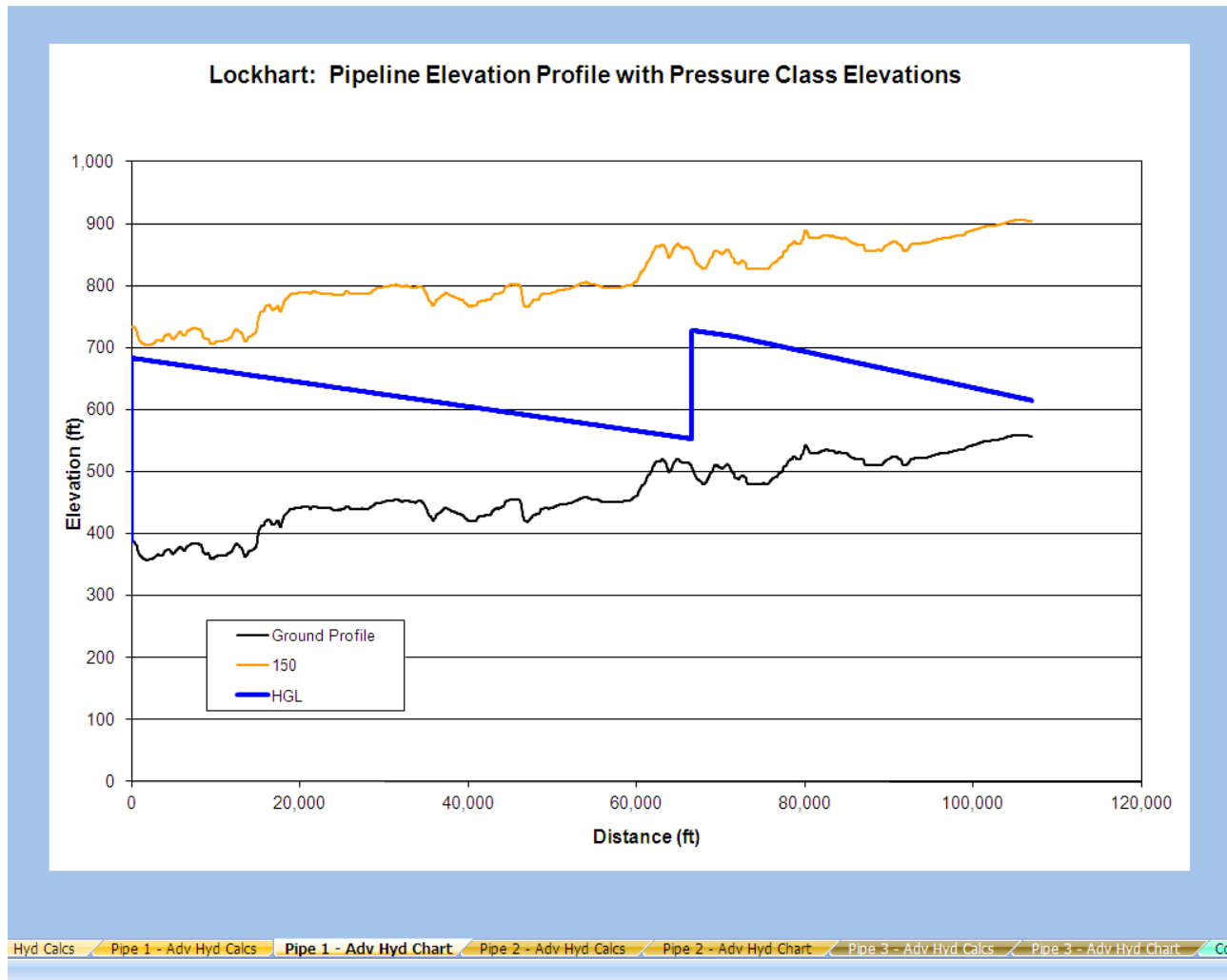
2. The user then picks a standard pipe diameter based on the diameter resulting from Equation 1. Standard pipe sizes are set in a dropdown list.
3. With the standard diameter set, the pipe velocity corresponding to the chosen pipe diameter is calculated using Equation 2. An important guideline to remember is to select pipeline diameter to maintain velocity within the 3.5-7 fps range. This range is a general guideline intended to prevent solids deposition in the pipe and to minimize energy requirements associated with friction losses experienced at high velocities.

$$V(fps) = \frac{Q(cfs)}{\left(\frac{\pi}{4} \right) \left(\frac{D(in)}{12in/ft} \right)^2} \quad (2)$$

4. Using the Hazen-Williams equation (Equation 3), the head loss in the pipe is calculated (hydraulic grade line or HGL slope) with the diameter selected in step 2 and the velocity found in step 3. The HGL will be plotted on the same graph in Advanced Hydraulic Chart (“Pipe X - Adv Hyd Chart” tab) as the ground profile using the calculated slope.

(3)

$$S\left(\frac{ft}{ft}\right) = \left(\frac{V(fps)}{1.32C\left(\frac{D(in)}{4} \cdot \frac{1ft}{12in}\right)^{0.63}} \right)^{\left(\frac{1}{0.54}\right)}$$



4.4.2 Pipe Pressure

When pumps impart energy to water, or “lift” it, a pressure will be generated within the pipe. This pressure is one component of the total head. Assuming that velocity head is negligible, the pressure head can be estimated using Equation 4.

$$\text{Pressure Head} = \text{Hydraulic Grade Line Elevation} - \text{Profile Elevation.} \quad (4)$$

Pressure head can easily be converted to pressure by Equation 5. This equation can also be used to find the pressure head for a given pressure. Using a plot of the hydraulic grade line, it is possible to determine the pressure within the pipe at any point along the length.

$$\text{Pressure}(psi) = \text{Pressure Head}(ft) \left(\frac{62.4lb/ft^3 \text{ for water}}{144in^2/ft^2} \right) \quad (5)$$

Pipes are manufactured by pressure class providing a factor of safety within certain pressure ranges. A convenient tool for determining the pressure ranges in a pipeline is to plot pressure heads for various pipe pressure classes over the entire length of the pipeline profile, then inspect the grade line to see what lengths of pipe fall within a particular pressure head range.

Another guideline to keep in mind is that the HGL must clear all high profile points along the route in order to prevent formation of a vacuum within the pipeline and reduce the potential for column separation and water hammer within the pipe. It is desired to clear these points by a minimum water pressure at all times. The minimum line pressures that should be met or exceeded are 15 psi for raw water and 25 psi for treated water. This requirement should be met within all anticipated flow ranges.

4.4.3 Pump and Booster Station Locations and Total Dynamic Head

Pump/Booster station locations and sizes are dependent on the flow rate, pipe size, and corresponding head loss. A change in flow rate resulting in a change of pipe size can dramatically impact the number and sizes of pumping stations needed to convey water to the destination. Therefore the pipeline and pumping requirements must be evaluated together. Several iterations involving different combinations of pipe sizes and pumping station arrangements may be required to obtain an appropriate selection. The combination of pumping stations and pipe size selected must conform to engineering principles, comply with guidelines, and make sense economically.

Determining the size of a pump or booster station entails estimating the amount of energy, or head, needed to lift water to a sufficient level for driving water to a particular

destination. This amount of head developed by the pump is called the total dynamic head, or TDH, and is made up of the following:

- **Static Head** – The total change in elevation of the liquid from the suction level to discharge level, plus the pressure difference between suction and discharge reservoirs if different from atmospheric.
- **Pipe Friction** – The friction head loss in the suction and discharge line, elbows, and valves, and the suction pipe entrance loss.
- **Velocity Head** – the head at the end of the discharge pipe.

For study purposes, the TDH will be calculated as the difference between the calculated elevations of the HGL at the pumps and the suction source plus station losses (Equation 6).

$$\text{TDH (ft)} = \text{Final HGL Elevation at Pumping Station (ft)} - \text{Water Surface Elevation (ft)} + \text{Pumping Station Losses (ft)} \quad (6)$$

The simple approach used in the UCM for determining the TDH for sizing a pump station is one that involves starting at the destination at a predetermined elevation, creating a HGL based on the peak flow, and evaluating a number of factors back toward the source. Once a transmission system arrangement is selected for peak flows, the same factors will be evaluated to ensure that the system will function adequately for the lowest anticipated flows.

4.4.4 Pump Station Horsepower (size) and Power Requirements

Pump station sizing and power requirements involve assessment of station power needs for different operating conditions. Power is the time rate of energy transfer, with the TDH for a particular flow rate being the amount of energy to be transferred. Horsepower is the unit of power that is used in the UCM and can be calculated with Equation 7. The efficiency of the pumping station is represented by “*e*”. It is actually a “combined efficiency” that accounts for the efficiencies of the pumps and pump motors. **For regional water planning purposes, assume a combined efficiency of 0.7.** The pump station size, which is based on the greatest amount of horsepower needed, is derived using the peak flow rate and its resulting TDH.

$$HP = \frac{Q(cfs) \cdot TDH(ft)}{8.8 \cdot e} \quad (7)$$

Power consumption for estimating pumping energy costs is based on average flow rate and the headloss associated with the average flow rate. Electric energy is typically billed by the kilowatt-hour (kWh or KW-HR). “Watt” is the International System (SI) unit for power and is related to horsepower by Equation 8.

$$\begin{aligned} 1HP &= 746W \\ 1HP &= 0.746KW \\ \# \text{ of } KW &= \text{Horsepower} * \frac{0.746KW}{1HP} \end{aligned} \quad (8)$$

The estimated energy consumed in pumping is calculated by converting power back to energy for the pumping duration, based on average flow rate and the headloss associated with the average flow rate. Equation 9 illustrates this calculation.

$$\text{Annual KW - HR} = KW \cdot \text{total hours of pumping operation per year} \quad (9)$$

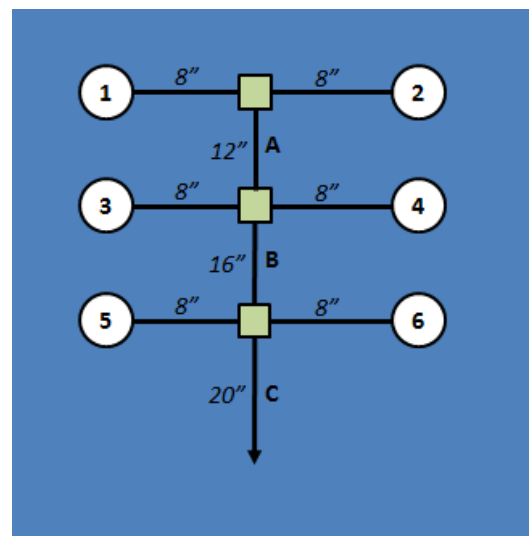
The number of hours of pumping operation is the total number of hours out of the year needed to deliver the annual water volume at a flow rate which is to be expected the majority of the time when pumping. Annual pumping energy cost is based on the annual energy consumed.

5.0 Well Fields

Wells must be constructed to extract water from below the land surface and pump it into a water delivery system. Each well can be considered an individual, or stand alone, pump station for sizing purposes and for pumping energy calculations. Size/horsepower requirements, like pump stations, are based on the flow and the total dynamic head. Total dynamic head for a well pump is the elevation difference between the hydraulic grade line and the estimated groundwater (i.e. piezometric) surface at the well during pumping conditions, plus station losses and friction losses in the casing pipe. This water surface elevation is the static water elevation below the land surface less the amount of draw down due to pumping.

The Well Field module (“Well Field” tab) allows the user to “design” the well field and collection system to help layout the facilities in order to determine costs. The user can enter basic pump and pipe information in the upper portion of the module. There is a portion dedicated to well and pipe layout, including the ability to estimate horsepower and energy necessary to support the well field and collection system.

The user lays out a well field, for example like the one on this page, and then determines the connectivity of the wells, collection pipes, and main trunk line(s). This information is then fed into the Well Field module, at which time, the flow, pipe sizes, and pumping energy is calculated.



Additionally, there is a portion at the bottom of the module designed to aid the user in selecting operational designs and capacities for reverse osmosis treatment of brackish groundwater.

Well / Pipe Number	Flow (gpm)	Peak Flow (cfs)	Computed Diameter for 5 fps (in)	Selected Diameter (in)	Velocity (fps)	Length (ft)	Begin Elevation	D/S Well/Pipe Node	Begin Elevation in D/S Well/Pipe (ft)	Elevation Delta	TDH (ft)	HP	Kw-hr	HGL Slope (ft/100ft) (c = 120)	Segment Pipe Head Loss
1	900	2.07	8.71	8	5.93	1,000	550.00	A	500.00	-50.00	0	0	0	18.72	18.72
2	900	2.07	8.71	8	5.93	1,000	500.00	A	500.00	0.00	19	6	23.805	18.72	18.72
3	900	2.07	8.71	8	5.93	1,000	549.00	B	514.00	-35.00	0	0	0	18.72	18.72
4	900	2.07	8.71	8	5.93	1,000	510.00	B	514.00	4.00	23	7	28.892	18.72	18.72
5	900	2.07	8.71	8	5.93	1,000	560.00	C	526.00	-54.00	0	0	0	18.72	18.72
6	900	2.07	8.71	8	5.93	1,000	500.00	C	526.00	26.00	45	13	56.871	18.72	18.72
7	900	2.07	8.71	8	5.93	1,000	550.00	D	568.00	8.00	27	8	33.979	18.72	18.72
8	900	2.07	8.71	8	5.93	1,000	550.00	E	586.00	28.00	47	14	59.414	18.72	18.72
9	900	2.07	8.71	8	5.93	1,000	520.00	E	591.00	71.00	90	26	114.100	18.72	18.72
10	900	2.07	8.71	8	5.93	1,000	510.00	F	591.00	81.00	100	29	126.817	18.72	18.72
11	900	2.07	8.71	8	5.93	1,000	550.00	F	541.00	-9.00	0	3	12.360	18.72	18.72
12		0.00	0.00	8	0.00		0.00		0.00	0.00	0	0	0	0.00	0.00
13		0.00	0.00	8	0.00		0.00		0.00	0.00	0	0	0	0.00	0.00
14	1,800	4.14	12.32	12	5.27	5,280	500.00	B	514.00	14.00	98	58	249.541	9.37	49.46
15	3,600	8.28	17.42	16	5.93	5,280	514.00	C	526.00	12.00	91	107	460.751	8.32	43.92
16	5,400	12.42	21.34	20	5.69	5,280	526.00	D	586.00	32.00	96	173	747.945	5.94	31.37
17	7,200	16.56	24.64	24	5.27	5,280	588.00	E	591.00	33.00	90	211	911.904	4.16	21.98
18	9,000	20.70	27.55	30	4.22	5,280	591.00	F	541.00	-50.00	35	102	440.661	2.12	11.20
19	9,900	22.77	28.90	30	4.64	5,280	541.00	G	560.00	9.00	57	184	797.590	2.53	13.36
20	9,900	22.77	28.90	30	4.64	4,000	550.00		600.00	50.00	95	307	1,325.825	2.53	10.12
TOTALS						46,680						1246	5,390.455		
flow check (wells x gpm) 93,600															
Wells	Flow (gpm)	Depth to GW Level (ft)	Pumping Drawdown (ft)	Average Well Head Elevation (ft-msl)	TDH (ft)	HP	Kw-hr	% Time Operating (Normal)							
Typical All (Well Lift Only)	900	37	50	487	109	21	92.767	0.662							
Project Info & Assumptions									Pipe 1 - Adv Hyd Calcs						
Simplified Hyd Calcs									Pipe 2 - Adv Hyd Calcs						
Pipe 3 - Adv Hyd Calcs									Pipe 4 - Adv Hyd Calcs						
Pipe 5 - Adv Hyd Calcs									Pipe 6 - Adv Hyd Calcs						
Pipe 7 - Adv Hyd Calcs									Pipe 8 - Adv Hyd Calcs						
Pipe 9 - Adv Hyd Calcs									Pipe 10 - Adv Hyd Calcs						
Pipe 11 - Adv Hyd Calcs									Pipe 12 - Adv Hyd Calcs						
Pipe 13 - Adv Hyd Calcs									Pipe 14 - Adv Hyd Calcs						
Pipe 15 - Adv Hyd Calcs									Pipe 16 - Adv Hyd Calcs						
Pipe 17 - Adv Hyd Calcs									Pipe 18 - Adv Hyd Calcs						
Pipe 19 - Adv Hyd Calcs									Pipe 20 - Adv Hyd Calcs						
Pipe 21 - Adv Hyd Calcs									Pipe 22 - Adv Hyd Calcs						
Pipe 23 - Adv Hyd Calcs									Pipe 24 - Adv Hyd Calcs						
Pipe 25 - Adv Hyd Calcs									Pipe 26 - Adv Hyd Calcs						
Pipe 27 - Adv Hyd Calcs									Pipe 28 - Adv Hyd Calcs						
Pipe 29 - Adv Hyd Calcs									Pipe 30 - Adv Hyd Calcs						
Pipe 31 - Adv Hyd Calcs									Pipe 32 - Adv Hyd Calcs						
Pipe 33 - Adv Hyd Calcs									Pipe 34 - Adv Hyd Calcs						
Pipe 35 - Adv Hyd Calcs									Pipe 36 - Adv Hyd Calcs						

Well Field Calculations: Pipes and Pump Sizing

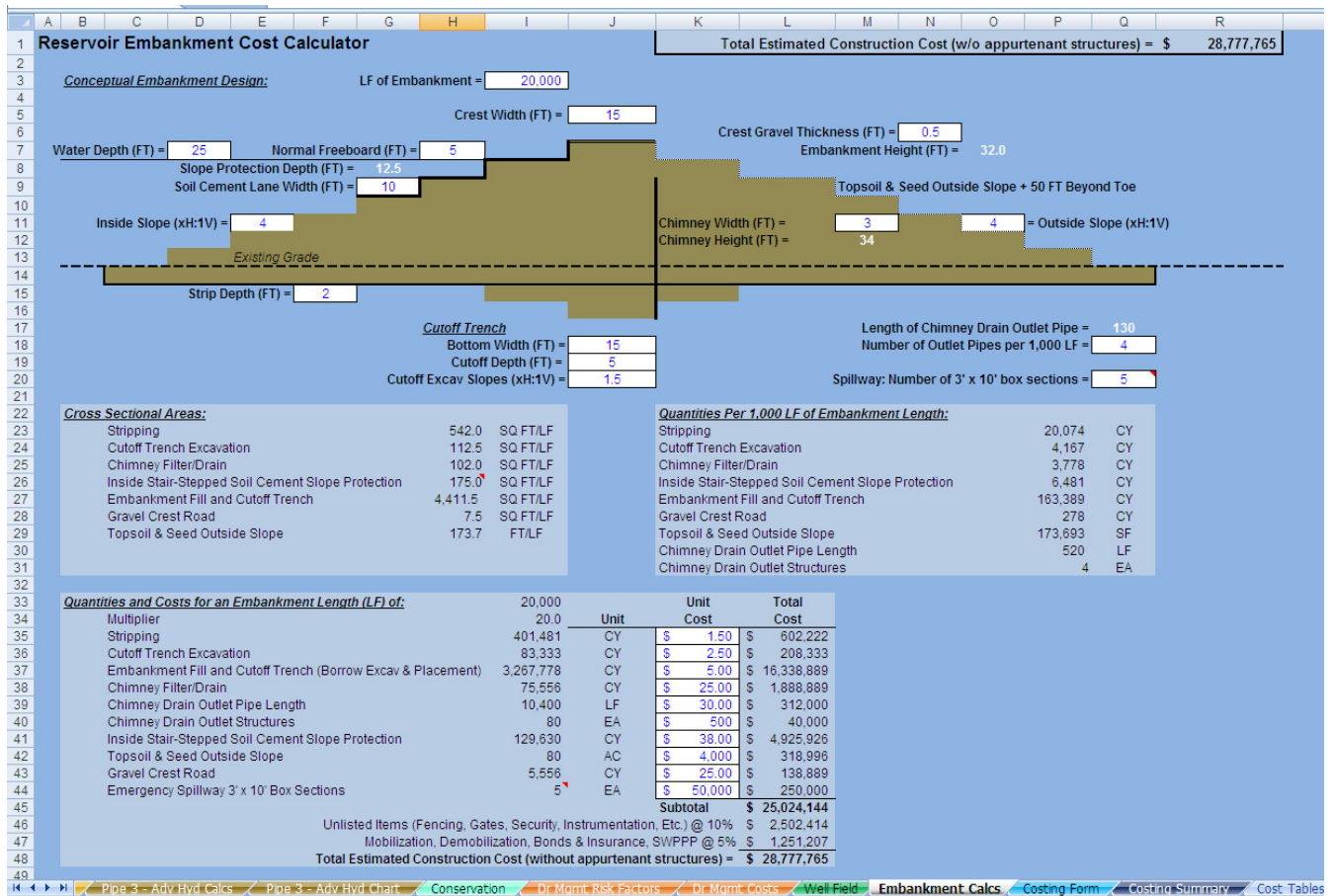
WUGMWP: Lockhart

Avg. Static Water El (ft-msl): 600
 Peak Flow Per Well (gpm): 900
 Avg. Flow Per Well (gpm): 50
 Total Water Production (act/yr): 100,000
 Avg Well Field Yield (mgd): 89.21
 Peaking Factor: 1.5
 Well Station Losses: 22
 Elevation of Delivery Point (ft-msl): 600
 C Factor: 120

Minimum Pipeline Pressure (psi): 15
 % Operating Time: 0.662
 Contingency Wells (15%): 16
 Active Wells: 104
 Peak Flow Per Well (cfs): 2.07 cfs
 Avg Well Field Yield (cfs): 1.38 cfs

6.0 Dam Embankment Estimates

A basic dam embankment quantity calculator is included in the UCM in the Embankment Calculator module (“Embankment Calcs” tab), as an alternative to using simplified cost curves (see Section 9.1.3). The user enters information regarding the cross-section of the dam and the components of the dam, along with the unit prices of various cost elements associated with the construction of a dam, such as Embankment Fill and Cutoff Trench, Emergency Spillway, etc. The embankment calculator uses this information to determine a cost estimate per linear foot for the dam, given the specifications supplied by the user.



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7.0 Land Acquisition

The Land Acquisition module (“Land Acquisition” tab) of the UCM is where the user can define land costs values (per acre) for each of the infrastructure components. Land cost vary significantly with location and economic factors. Land costs in Texas can be estimated using Rural Land Values in the Southwest published biannually by the Real Estate Center at Texas A&M University. Land values are estimated by county and land type. The user should use the Nominal Median Price per Acre when using the Real Estate Center’s land values. A link to the Real Estate Center at Texas A&M University is embedded in the Land Acquisition module of the UCM.

The screenshot displays the 'Land Acquisition' module interface. It features a spreadsheet-like layout with columns A through E. Row 2 contains a link to 'TAMU Real Estate Center' for looking up Texas Rural Land Values. Rows 5-11 list 'Pipeline Right-Of-Way Costs' with values for various parameters. Rows 15-41 list 'Land Costs for Other Facilities' with columns for 'County' and 'Land Value (\$/acre)'. An 'Information' box on the right states: 'An Internet Connection is necessary to lookup Land Values.'

Pipeline Right-Of-Way Costs			
Right-Of-Way Costing Method	Advanced		
Unit Land Cost	\$10,000	/acre	
Assumed Parcels per Mile	7	parcels/mile	
Permanent ROW Width	100	ft	
ROW Base Administrative Cost (80% of Parcels)	\$14,000	/parcel	
Condemnation Hearing Cost (10% of Parcels)	\$26,500	/parcel	
Trial Cost (10% of Parcels)	\$35,500	/parcel	

Land Costs for Other Facilities	County	Land Value (\$/acre)
Water Treatment Plant #1		
Water Treatment Plant #2		
Storage Tank		
Storage Tank		
Storage Tank		
Initial Pump Station		
Initial Pump Station		
Initial Pump Station		
Initial Pump Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Booster Station		
Well Field		
Traditional Reservoir		
Off-Channel Reservoir		
Terminal Storage		

Other sources of land values, such as county appraisal district records, may be available for use. Some judgment in the use of suggested land costs is required. For example, the land

cost estimate developed from a resource may be appropriate for general land prices but may not be appropriate for prime locations in the same area. In such a situation, the prime land value could be significantly higher than that of the surrounding lands.

Pipeline right-of-way (ROW) may be calculated by two methods: Simplified and Advanced. The simplified method simply allows the user to input a total unit cost per acre for ROW land costs. The advanced method allows the user to specify the raw land unit cost, an assumption for the number parcels crossed per mile, permanent ROW width, and information regarding administrative costs, condemnation hearings, and trials. The UCM assumes that 80 percent of the parcels will be acquired without condemnation, 10 percent acquired via a condemnation hearing, and 10 percent will go to trial.

8.0 Cost Estimating Form

A studies level cost estimate includes three major cost categories: construction costs, other project costs, and annual costs. Construction costs are the direct costs, such as those for materials, labor, and equipment, incurred in constructing facilities. These are the costs that are generally submitted by a contractor bidding on a project. “Other project costs” include additional expenses not directly associated with construction activities such as costs for engineering, land acquisition, contingencies, environmental/archaeological/cultural resources studies, and interest during construction. Capital costs and other project costs comprise the total project cost. Operation and maintenance (O&M), energy costs, and debt service payments are examples of annual costs. Major components that may be part of a preliminary cost estimate are listed in Table 1.

The Costing Form module (“Costing Form” sheet) of the UCM is the primary module for creating the cost estimate. The Costing Form module pulls information calculated in the other modules together, and allows the user to input additional data to step through the cost estimation, as summarized in Table 1. The following sub-sections briefly describe each of the elements included in creating a cost estimate in the Costing Form module.

The Costing Form contains subsections to assemble costs for pump station, pipelines, crossings, water treatment plants, dams and reservoirs, storage tanks, and well fields including wells and piping, along with project related costs such as engineering, legal, contingencies, land acquisition, environmental, archaeology studies, mitigation, and interest during construction.

Table 1. Major Project Cost Categories

Cost Elements	
Capital Costs (Structural Costs)	Other Project Costs (Non-Structural Costs)
1. Pump Stations	1. Engineering (Design, Bidding and Construction Phase Services, Geotechnical, Legal, Financing, and Contingencies)
2. Pipelines	2. Land and Easements
3. Water Treatment Plants	3. Environmental - Studies and Mitigation
4. Dams and Reservoirs	4. Interest During Construction
5. Off-Channel Reservoirs	
6. Water Storage Tanks	
7. Well Fields	
a. Public	
b. Irrigation	
c. ASR Wells	
8. Relocations	
9. Water Distribution System Improvements	
10. Other Items	
	Annual Project Costs
	1. Debt Service
	2. Operation and Maintenance (excluding pumping energy)
	3. Pumping Energy Costs
	4. Purchase Water Cost (if applicable)

8.1 Capital Costs

Cost tables have been created for the UCM and are discussed in the technical memorandum in Appendix A. The cost for a project element can be determined by applying a unit cost from the cost tables to a specific unit quantity. For example, pipeline costs can be determined by pipe diameter and linear feet of line. Cost estimates are approximate, therefore reporting costs to the dollar is not necessary. Estimates reported to the thousands of dollars are acceptable.

Throughout the Costing Form, the user has the option to override a calculated cost estimate for an element with an external cost estimate by simply filling in a value into the “External Cost Estimate” space on each line item.

The cost tables report “all-inclusive” costs to construct a particular facility. For example, the pump station cost table values include building, pump, control equipment, materials, labor,

and installation costs. Interpolation between the table values is done automatically by the UCM in order to arrive at the appropriate cost estimate. Each cost table has a reference time period for which the cost data is current. The user can adjust the time period by adjusting the CCI and PPI values on the Project Information and Assumptions module.

8.1.1 Pumping Stations

Anticipated pump and booster station costs vary according to the discharge and pumping head requirements, and structural requirements for housing the equipment and providing proper flow conditions at the pump suction intake. For studies level costing estimates the cost tables provided are based on the station size, or horsepower, for the peak flow rate. The costs include those for pumps, housing, motors, electric control, site work, and all materials needed.

The Costing Form has a section for each of the pipelines that use the Advanced Hydraulic Calculations module, each of which has a primary pump station (beginning pump station) and up to four booster stations. The primary pump station is broken into pump station cost and intake cost. The user may also wish to add a channel dam, if necessary, to this cost estimate. If the primary pump station is associated with something other than a diversion that requires an intake structure, the user can set the intake cost to zero by setting the “External Cost Estimate” to zero, thereby overriding the cost estimate. Additionally, the user enters the average flow rate associated with each booster station to establish the cost estimate for the storage tanks associated with the booster stations. The tank size is calculated using 10 percent of the daily average flow.

8.1.2 Pipeline

Pipeline construction costs are influenced by pipe materials, bedding requirements, geologic conditions, urbanization, terrain, and special crossings. Additionally, the pressure class of the pipe can affect the cost. For a studies level cost estimate, pipeline costs will be determined from unit costs based on the pipe diameter, ground type, and level of urban development. The unit costs include installed cost of the pipeline and appurtenances, such as markers, valves, thrust restraint systems, corrosion monitoring and control equipment, air and vacuum valves, blow-off valves, erosion control, revegetation of rights-of-way, fencing and gates.

Based on choices the user made on one or more of the hydraulics spreadsheets, the UCM calculates the cost associated with each pipeline segment based on the pipe diameter, soil /

urbanization condition, pipeline length, and pressure class. Base pipeline costs are adjusted based on the pressure class chosen. The factors for cost adjustment based on pressure class are based on data received from a pipe distributor in March 2013³.

Additionally, the user can input crossing information to account for various types of pipeline crossings along the route.

8.1.3 Water Treatment Plants

Construction costs for water treatment facilities are based on plant capacity for six different levels of water treatment. It is not the intent of the cost estimating methodology to establish an exact treatment process but rather to estimate the cost of a general process appropriate for bringing the source water quality to the required standard of the receiving system. The process options presented include disinfection, advanced groundwater treatment, simple filtration, conventional treatment, advanced brackish water treatment, and advanced seawater desalination. Table 2 gives a description of the processes involved in each treatment option. The water treatment plant unit costs include costs for all processes required, site work, buildings, storage tanks, sludge handling and disposal, clearwell, pumps and equipment. The costs assume pumping through and out of the plant as follows: Levels 2 through 5 treatment plants include raw water pumping into the plant for a total pumping head of 100 feet, and finished water pumping for 300 feet of total head. Levels 0 and 1 treatment includes finished water pumping only at 300 feet of head.

Table 2. Water Treatment Level Descriptions

Level 0:	Disinfection Only - This treatment process will be used for groundwater with no contaminants that exceed the regulatory limits. Assumes groundwater does not require treatment for taste and odor reduction and groundwater is stable and requires no treatment for corrosion stabilization. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.
Level 1:	Ground Water Treatment - This treatment process will be used for groundwater to lower the iron and manganese content and to disinfect. The process includes application of an oxidant and addition of phosphate to sequester iron and manganese. Chlorine disinfection as the final treatment. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.

³ Email from Ronny Huffstickler – American Ductile Iron Pipe Company, March 8, 2013.

Level 2:	Direct Filtration Treatment - This treatment process will be used for treating ground water from sources where iron, manganese, or other constituent concentrations exceed the regulatory limit and require filtration for solids removal. Assumes turbidity and taste and odor levels are low. In the direct filtration process, low doses of coagulant and polymer are used and settling basins are not required as all suspended solids are removed by filters. The process includes alum and polymer addition, rapid mix, flocculation, filtration, and disinfection. Water treatment with this process is suitable for aquifer injection or for delivery to the recharge zone.
Level 3:	Surface Water Treatment - This treatment process will be used for treating all surface water sources to be delivered to a potable water distribution system. The process includes coagulant and polymer addition, rapid mix, flocculation, settling, filtration, and disinfection with chlorine. This treatment process also applies for difficult to treat groundwater containing high concentrations of iron (greater than 3 mg/l) and manganese requiring settling before filtration.
Level 4:	Brackish Groundwater Desalination ⁴ - Note: This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of a surface water or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example: add level 3 treatment costs for a turbid surface water source). This treatment process will be used for treatment of groundwater with total dissolved solids (TDS) exceeding the regulatory limit of 1,000 mg/l. Base costs are based on reverse osmosis (RO) membrane desalination of groundwater with 3,000 mg/l of TDS to lower the treated water TDS below the regulatory limit. However, the user enters the TDS associated with the brackish water source (1,000 mg/L to 35,000 mg/L), and costs are adjusted based on the TDS. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalent addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs assume desalination concentrate will be discharged to surface water adjacent to treatment plant. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.
Level 5:	Seawater Desalination - Note: This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of a surface water or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example - For desalination of seawater with an intake located on the coast drawing turbid water, cost estimate should include Level 3 treatment plus Level 6). This treatment process will be used for treatment of seawater with total dissolved solids (TDS) exceeding the regulatory limit of 1,000 mg/l. Costs are based on reverse osmosis (RO) membrane desalination of a water with 32,000 mg/l of TDS to lower the treated water TDS below the regulatory limit. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalent addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs assume desalination concentrate will be discharged to surface water adjacent to treatment plant. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, and delivery to the recharge zone.

⁴ “Graves, M., and Choffel, K., 2004, Economic siting factors for seawater desalination projects using reverse-osmosis processes, in Texas Water Development Board Report 363, Technical Papers, Case Studies and Desalination Technology Resources.”

8.1.4 Reservoirs, Off-Channel Reservoirs, and Terminal Storage

Standard cost tables for construction costs for reservoirs, off-channel reservoirs, and terminal storage are based on reservoir capacity. The user enters the reservoir's conservation capacity and the UCM generates a cost estimate using cost curves based on bid data and engineering estimates. The standard cost curves are available to the user when there are no specific details about a surface storage facility available, outside of a storage capacity. Alternatively, the user may use the Embankment Calculations module to develop a more detailed cost estimate, when there is a specific reservoir site with specific details available.

8.1.5 Stilling Basins

If an alternative involves discharging into a water body or perhaps into a recharge structure, it may require that excess energy in the water be dissipated so that scouring and erosion do not become a problem. Energy will be dissipated with the use of stilling basins. The user enters the discharge flow in cfs, and the UCM calculates a stilling basin cost based on a cost of \$3,025 per unit flow (cfs).

8.1.6 Storage Tanks

Ground storage tanks may be used for stand-alone storage, as part of a distribution system, or as part of a pumping station. The costs for storage tanks are based on cost per million gallons of capacity. The user specifies the type of storage tank to be used (ground storage with roof, ground storage without roof, or elevated storage) and the capacity of the storage tank.

Elevated storage tanks are rarely used in water transmission systems and are typically utilized in distribution systems within a water service area. However, the UCM includes the option to include an elevated storage tank, if necessary.

8.1.7 Well Fields

The UCM contains four types of wells: public supply, irrigation, aquifer storage and recovery (ASR), and injection wells. Public supply wells are wells used by municipalities and other water suppliers to supply groundwater for consumption. Irrigation wells provide water for irrigation purposes but may also be used in scenarios involving surface and groundwater exchange. ASR is the concept of using wells to inject water into an aquifer for temporary storage and then extracting the water later when needed. ASR wells include injection wells,

recovery wells, and wells that can be used for both injection and recovery. Additionally, there are injection wells for injecting reject water from various types of projects.

Well costs have been generated for the different types of wells for pumping water from various static water level ranges and pumpage rates. The costs include complete installation of the well and pump to include drilling services, materials, pump and control equipment, valves, testing, security fencing, and a small access road. The costs do not include those for a building, surface piping connecting to a transmission/collector pipeline, or power connection costs.

8.1.8 Relocations

Large-scale projects, such as reservoirs, may require the use of lands that contain existing improvements or facilities such as homes, businesses, utilities, and roads. If the benefits outweigh the costs, the new project element may be constructed, but with the requirement that selected affected improvements or facilities be relocated. An example of a relocation is the rerouting of a highway out of the inundation area of a new reservoir. Because the type of improvements and facilities that may be candidates for relocation can vary significantly, estimating the costs for other relocation items should be handled on an individual basis.

8.1.9 Integration

The introduction of treated water to a city, or other entity, may require improvements to connect to the entity's water distribution system. A detailed analysis of a distribution system is needed to determine the system improvements required to handle the introduction of additional water supplies. The analysis would incorporate the development of a model of the entity's distribution system using a program, such as KYPIPE or EPANET, to determine what improvements are needed. This level of work is usually beyond the scope of a regional water planning analysis.

Cost estimates for distribution system improvements should be handled on an individual basis because the magnitude of improvements will vary significantly with each system. Some systems may actually require very little improvements, while others may require large-scale advancements.

8.1.10 Other Capital Cost Items

Alternatives may involve elements that are not adequately addressed by the cost tables and guidelines within this section. These additional items will require research on an individual basis to obtain appropriate cost estimates.

8.2 Other Project Costs

As previously mentioned, “other project costs” are costs incurred in a project that are not directly associated with construction activities. These include costs for engineering, legal, financing, contingencies, land, easements, environmental services, and interest during construction.

8.2.1 Engineering, Legal, Financing, and Contingencies

Some “other project” costs can be estimated by applying a percentage to the total capital cost. For studies level cost estimates we will use a percentage to calculate a combined cost that accounts for engineering, financial, and legal services, and contingencies. The contingency allowance accounts for unforeseen circumstances and for variances in design elements. The percentages to be used are 30 percent of the total construction costs for pipelines and 35 percent for all other facilities.

8.2.2 Land Acquisition

Land related costs for a project can typically be divided into two categories, land purchase costs and easement costs. Land purchase costs are those costs incurred for direct purchase of land areas not currently in the project owner’s possession. Generally, all facilities that will be part of a project, except for pipelines, will be built on land owned by the project owner. Survey and legal service costs for land transactions will be added to land and easement costs to get the total land acquisition costs. One possible exception to this is land leasing that may be used for well fields. Suggested land areas for various facility types are listed in Table 3.

Table 3. Suggested Land Area for Various Facilities

Facility	Suggested Land Area (acres)
Pump Station	5
Water Treatment Plant	0.5/MGD
Water Storage Tanks	2
Reservoirs	Inundation Area ¹
Well Fields ²	0.5 per well minimum
¹ Larger land areas may be required in order to account for flood pool, freeboard, etc. ² Larger land areas may be required in order to obtain a certain quantity of water rights.	

Pipelines may be built on lands that are, or are not, possessed by the project owner. Typically, a pipeline will start on land in the possession of the project owner that was purchased and/or dedicated for use with a specific facility, such as a pump station or water treatment plant, and then traverse cross-country. Rather than purchase land along the pipeline route, easements are usually acquired. The general definition of an easement is a right granted by the owner of a parcel of land to another party. The rights are for use of the land for a specified purpose. There are a number of easement types and methods in which they can be created. For pipelines, the process is usually similar to land purchase, with a price being paid for construction of the pipeline on the landowner's property and for future entry rights for maintenance activities. Payment for easements may be less than land purchase price since the original owner maintains title, and the land is usually restored after construction by the contractor, and used by the landowner.

Two types of easements are usually acquired for pipeline construction: temporary and permanent. Permanent easements are those, in which the pipeline will reside once constructed, and provide room for future maintenance and protect the line from other parallel underground utilities. Temporary easements provide extra working space during construction for equipment movement, material storage, and related construction activities. Once the pipeline has been installed, the grounds are restored to pre-construction conditions, and the temporary easement ceases to exist. The owner of the property may resume activities over the easements, with the right granted to the project owner allowing entry to the permanent easement for inspection,

maintenance, and repair activities. The total construction easement width shown is the sum of the permanent and temporary easements.

For more information regarding land acquisition, please see Section 7.0.

8.2.3 Surveying and Legal Fees

Surveying and legal services are required with most land transactions. For our purposes, we will estimate the fees for these services and add them to land and easement costs to get a total land acquisition cost.

Ten percent (10 percent) should be added to the total land and easement costs to account for surveying and legal fees associated with land acquisition, except for reservoirs. The surveying cost for reservoirs is estimated as \$50 per acre of inundation.

8.2.4 Environmental and Archaeology Studies, Permitting, and Mitigation

In general, most construction projects will require some type of approval by governmental agencies. Environmental permits may be required by local, state, and/or the federal agencies for projects that affect land and water resources, or generate air pollution. Of particular importance, studies for projects will be performed to determine if environmentally sensitive areas, wetlands, threatened or endangered species, and valuable archaeological/cultural resources exist on or near properties where project facilities are proposed for construction. In addition to potentially requiring permits by regulating agencies, such conditions may result in restrictions or modifications in construction, may require mitigation, and in some cases could prevent construction altogether. The definition of mitigation is to alleviate or make milder. As related to construction projects, mitigation refers to actions taken to achieve equitable compensation given for environmental impacts relative to construction and/or operation of the project. This could include purchase of land, enhancement of wildlife habitat and/or money compensation.

Environmental and archaeological studies are usually performed during the design phase of a project, though some investigations may occur during the preliminary engineering phase. In the studies level analysis of a project, it is difficult at best to determine what permits may be required and the costs for environmental studies. There will be some base fee for the initial environmental studies that will be performed on a project. More detailed environmental analysis may be required if any environmental issues are discovered, which could result in increased

environmental studies and permitting costs, and perhaps mitigation. Mitigation, if required, can vary significantly, as would the related value/cost. Costs for environmental studies, permitting, and mitigation are project dependent and should be estimated on an individual basis using information available and the judgment of qualified professionals. For all project components except pipelines, the UCM assumes the Environmental/Mitigation Costs are 100 percent of land costs. This assumption can be adjusted by the user as appropriate. The recommended value for environmental studies and mitigation costs for pipelines is \$25,000/mile of pipeline.

8.2.5 Interest During Construction

An entity generally funds construction projects by securing loans or selling bonds of some type. Typically, the entity receives the funds at the start of the construction project and pays the contractor from the funds over the duration of the construction period. Interest on the borrowed funds will be charged during the construction period as well. It is desired by the entity not to make payments on the borrowed funds or the interest until the project is complete and is generating revenue. As such, the interest during construction (IDC) is determined and treated as a cost item to be included as part of the total project cost and made part of the loan. In addition, the entity may invest part of the borrowed funds during the construction period and any gains made on the investments can be used to offset interest payments (i.e. reduce the net interest during construction).

IDC is calculated as the cost of interest on the borrowed amount less the return on the proportion of borrowed money invested.

IDC is calculated by applying the net interest rate over the construction period of the project to the average project cost (Equation 10). The net interest rate is the interest rate on borrowed funds less the return interest rate from the investment on unspent borrowed funds. The average project cost is equal to the sum of the capital costs, and all other project costs, excluding IDC, divided by two.

$$\text{IDC} = [\text{Amount Borrowed} \times \text{Annual Rate of Loan} \times \text{Construction Period (years)}] - [\text{One-Half Amount Borrowed} \times \text{Annual Rate of Return} \times \text{Construction Period (years)}] \quad (10)$$

The final total project cost is equal to all costs plus the interest during construction.

8.3 Annual Costs

The annual costs in a cost estimate are the estimated annual costs that the project owner can expect if the project is implemented. These costs include the costs for repayment of borrowed funds (debt service), operation and maintenance costs of the project facilities, pumping power costs, and possibly water purchase costs.

8.3.1 Debt Service

Debt service is the estimated annual payment that can be expected for repayment of borrowed funds based on the total project cost (present worth), the project finance rate, and the finance period in years. The UCM contains the necessary calculations to estimate annual payments based on financing period and interest rates. The financing period and interest rates are entered on the Project Information and Assumptions module.

8.3.2 Operation and Maintenance

Operation and maintenance costs for dams, pump stations, pipelines and well fields (excluding pumping power costs) include labor and materials required to maintain the project, regular repair and/or replacement of equipment. Operation and maintenance costs (O&M) are calculated as a percent of the total estimated construction cost for various types of facilities. These percentage rates are entered on the Project Information and Assumptions module by the user.

8.3.3 Pumping Energy Costs

Power costs are calculated on an annual basis using the appropriate calculated power load and a power rate. The power rate is entered on the Project Information and Assumptions module by the user.

8.3.4 Purchase of Water

The purchase cost, if applicable, should be shown if the alternative involves purchase of raw or treated water from an entity. This cost will vary by source.

9.0 Cost Summary

The Cost Summary module (“Cost Summary” sheet) pulls together common costing elements from the Costing Form module and summarizes them and their costs in a simple tabular format capable of being placed directly into a water management strategy write-up. All the fields within the module are populated automatically. The user may “condense” the summary table to eliminate elements that are not part of the current cost estimate by clicking the “Create Cost Estimate Summary for Report” button. Clicking this button will produce a summary table that only contains line items for elements that contain a cost for the cost estimate. To reset the table, the user can click the “Reset Summary” button.

	A	B	C	D	E	F	G	H	I	J	K
1		Cost Estimate Summary									
2		<i>Water Supply Project Option</i>									
3		<i>March 2012 Prices</i>									
4		<i>Lockhart - Example Pipeline Project</i>									
5		<i>Cost based on ENR CCI 9268 for March 2012 and</i>									
6		<i>a PPI of 185.2 for March 2012</i>									
7			<i>Estimated Costs</i>								
8		<i>Item</i>	<i>for Facilities</i>								
9		CAPITAL COST									
10		Dam and Reservoir (Conservation Pool acft, acres)	\$0								
11		Off-Channel Storage/Ring Dike (Conservation Pool acft, acres)	\$0								
12		Terminal Storage (Conservation Pool acft, acres)	\$0								
13		Intake Pump Stations (13.4 MGD)	\$5,336,000								
14		Transmission Pipeline (36 in dia., 20 miles)	\$14,514,000								
15		Transmission Pump Station(s) & Storage Tank(s)	\$2,240,000								
16		Well Fields (Wells, Pumps, and Piping)	\$0								
17		Storage Tanks (Other Than at Booster Pump Stations)	\$0								
18		Two Water Treatment Plants (18 MGD and 9 MGD)	\$69,136,000								
19		Integration, Relocations, & Other	\$0								
20		TOTAL COST OF FACILITIES	\$91,226,000								
21		Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	\$31,204,000								
22		Environmental & Archaeology Studies and Mitigation	\$506,000								
23		Land Acquisition and Surveying (269 acres)	\$5,488,000								
24		Interest During Construction (4% for 1 years with a 1% ROI)	\$4,495,000								
25		TOTAL COST OF PROJECT	\$132,919,000								
26		ANNUAL COST									
27		Debt Service (5.5 percent, 20 years)	\$10,932,000								
28		Reservoir Debt Service (5.5 percent, 40 years)	\$0								
29		Operation and Maintenance									
30		Intake, Pipeline, Pump Station (1% of Cost of Facilities)	\$335,000								
31		Dam and Reservoir (1.5% of Cost of Facilities)	\$0								
32		Water Treatment Plant (2.5% of Cost of Facilities)	\$14,807,000								
33		Pumping Energy Costs (19473628 kW-hr @ 0.09 \$/kW-hr)	\$1,753,000								
34		Purchase of Water (acft/yr @ \$/acft)	\$0								
35		TOTAL ANNUAL COST	\$27,827,000								
36		Available Project Yield (acft/yr), based on a Peaking Factor of 1.5	10,000								
37		Annual Cost of Water (\$ per acft)	\$2,783								
38		Annual Cost of Water (\$ per 1,000 gallons)	\$8.54								
39											

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10.0 Water Conservation

The Conservation module (“Conservation” tab) of the UCM provides the user a simplified method of calculating advanced municipal water conservation savings and associated costs. Advanced water conservation is conservation above and beyond that of the water efficiency savings that are included in the TWDB water demand projections. There are two approaches to calculating the water conservation quantities and costs in the Conservation module: Simple Approach and Detailed Approach.

Advanced Water Conservation							
Simple Approach							
<u>Municipal Water Conservation</u>							
Conservation Goal (gpcd):	140	Urban Unit Cost (\$/acft/yr):		\$600			
Rate to Achieve Goal (%/yr):	1.0%	Suburban Unit Cost (\$/acft/yr):		\$681			
Rate Once Goal Is Achieved (%/yr):	0.25%	Rural Unit Cost (\$/acft/yr):		\$770			
Location:	Urban						
WUG/WWP:	Lockhart						
Planning Year:	2010	2020	2030	2040	2050	2060	2070
Population:		124,607	130,220	132,820	133,514	130,943	126,835
Water Demand (acft/yr):		22,891	23,485	23,507	23,181	22,588	21,879
Per Capita Water Use (gpcd):	167	164	161	158	155	154	154
Base Per Capita Goal (gpcd):		151	139	135	132	129	125
Advanced Water Conservation (acft/yr):		1,810	3,258	3,386	3,455	3,720	4,055
Adv. Water Conservation Cost (\$/yr):		\$1,086,191	\$1,954,917	\$2,031,807	\$2,073,124	\$2,232,179	\$2,433,007
Detailed Approach							
WUG/WWP:	Lockhart						
Planning Year:	2010	2020	2030	2040	2050	2060	2070
Population:		124,607	130,220	132,820	133,514	130,943	126,835
Water Demand (acft/yr):		22,891	23,485	23,507	23,181	22,588	21,879
Per Capita Water Use (gpcd):	167	164	161	158	155	154	154
<u>Savings Rate</u>							
Public & School Education		2.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Water Audits		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Water Conservation Pricing		1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Landscape Design Conversion		4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Federal Clothes Washer Rules		7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Plumbing Retrofits		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Other		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
<u>Effectiveness</u>							
Public & School Education		50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Water Audits		20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Water Conservation Pricing		15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Landscape Design Conversion		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Passive Clothes Washer		10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Plumbing Retrofits		10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Other		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
<u>Costs</u>							
Public & School Education	Unit Cost	\$ 358	\$ 358	\$ 358	\$ 358	\$ 358	\$ 358
Water Audits	Unit Cost	\$ 639	\$ 639	\$ 639	\$ 639	\$ 639	\$ 639
Water Conservation Pricing	Annual Cost	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000	\$ 1,000
Landscape Design Conversion	Annual Cost	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500	\$ 500
Passive Clothes Washer	Unit Cost	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350	\$ 350
Plumbing Retrofits	Unit Cost	\$ 155	\$ 155	\$ 155	\$ 155	\$ 155	\$ 155
Other	Unit Cost	\$ 100	\$ 100	\$ 100	\$ 100	\$ 100	\$ 100
<u>Potential Water Savings (acft/yr)</u>							
Public & School Education		229	352	353	348	339	328

Simply Approach

Using the Simple Approach, the user enters the population and net water demand for a given WUG/WWP for each decade of the planning period, as well as the historical per capita water use associated with the base water use year (Year 2011 for the 2016 Regional Water Plans). The user specifies a target per capita water use as the conservation goal. The user also specifies the rate (percent per year) at which the gpcd should decrease each year until the goal is achieved and the rate of yearly gpcd decrease after the goal has been reached. If no additional conservation is to be included after the goal is met, the “Rate Once Goal Is Achieved” can be set to zero.

Finally, the user sets the unit cost of conservation by specifying the urban/suburban/rural setting of the WUG/WWP. Default unit costs of municipal water conservation were obtained from the “Quantifying the Effectiveness of Various Water Conservation Techniques in Texas”⁵ study conducted for TWDB. The user may deviate from these default unit costs if more specific cost information is available.

Detailed Approach

In the Detailed Approach, the user has the option to add conservation goals for seven categories: Public & School Education, Water Audits, Water Conservation Pricing, Landscape Design Conversion, Passive Clothes Washers, Plumbing Retrofits, and Other. Guidance is given within the UCM as comments. Additional information regarding potential savings and associated cost ranges can be found in the “Water Conservation Best Management Practices Guide⁶,” (http://www.twdb.state.tx.us/publications/reports/numbered_reports/doc/R362_BMPGuide.pdf).

The user can specify the savings rate, the effectiveness, and the costs associated with each conservation measure. The Conservation module then computes the advanced water conservation savings and the associated annual and unit cost of the strategy.

⁵ GDS Associates, “Quantifying the Effectiveness of Various Water Conservation Techniques in Texas; Appendix VI, Region L,” Texas Water Development Board, Austin, Texas, July 2003.

⁶ Water Conservation Implementation Task Force, “Water Conservation Best Management Practices Guide,” November 2004.

11.0 Drought Management Risk Factor and Cost

The Drought Management modules (there are two: “Dr Mgmt Risk Factors” and “Dr Mgmt Costs”) are used to develop estimates of municipal drought management water savings (i.e. failure to meet projected water needs) and associated costs (i.e. economic impacts of failure to meet projected water needs) for WUGs/WWPs. The calculations are rather complex, and are described in detail Appendix C, an excerpt from the 2011 South Central Texas Regional Water Plan⁷. For the UCM, an automated process has been included for quantifying drought management savings and estimating economic impacts which are converted to unit costs for direct comparison to other water management strategies.

Drought Management - Step 1: Determination of Risk Factors																	
WUG / WWP:		Lockhart															
Reference Year:		2000															
Year	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
Hist. Ann. Use (gpcd)	101	105	100	114	102	105	112	130	122	111	130	113	112	141	153	132	
5-Yr Moving Avg Use (gpcd)					104	105	107	113	114	116	121	121	118	121	130	130	
% Above (+) or Below (-) 5-year Mov. Avg.					-2.3	-0.2	5.1	15.5	6.8	-4.3	7.4	-6.8	-4.8	16.1	17.9	1.4	
Rank					17	20	26	34	27	12	28	6	11	35	36	22	
Percentile					45.9%	54.1%	70.3%	91.9%	73.0%	32.4%	75.7%	16.2%	29.7%	94.6%	97.3%	59.5%	85
% Above (+) or Below (-) Year 2000 from 5-year Mov. Avg.					9.2	11.5	17.4	29.0	19.4	6.9	20.1	4.2	6.4	29.8	31.7	13.3	
Ranked Deviation from 5-Year Moving Average ---->																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	2.70	5.41	8.11	10.81	13.51	16.22	18.92	21.62	24.32	27.03	29.73	32.43	35.14	37.84	40.54	43.24	45.94
	-9.012	0.000	0.622	1.581	1.767	4.179	4.452	4.551	5.068	6.125	6.418	6.923	7.136	7.411	7.815	8.115	8.415
	0.0	0.0	0.8	3.0	4.5	8.0	11.7	12.2	13.0	15.1	17.0	18.0	19.0	19.7	21.5	22.8	24.2
	-0.5	0.0	2.2	4.3	5.9	9.4	13.0	13.5	14.4	16.5	18.3	19.4	20.4	21.0	22.8	24.2	25.5
	-1.0	0.1	3.5	5.7	7.2	10.7	14.4	14.9	15.7	17.8	19.7	20.7	21.7	22.4	24.2	25.5	26.9
	-1.5	0.3	4.9	7.0	8.6	12.1	15.7	16.2	17.1	19.2	21.0	22.1	23.1	23.7	25.5	26.9	28.2
	-2.0	0.6	6.2	8.4	9.9	13.4	17.1	17.6	18.4	20.5	22.4	23.4	24.4	25.1	26.9	28.2	29.6
	-2.5	0.9	7.6	9.7	11.3	14.8	18.4	18.9	19.8	21.9	23.7	24.8	25.8	26.4	28.2	29.6	31.0
	-3.0	1.3	8.9	11.1	12.6	16.1	19.8	20.3	21.1	23.2	25.1	26.1	27.1	27.8	29.6	31.0	32.3
	-3.5	1.8	10.3	12.4	14.0	17.5	21.1	21.6	22.5	24.6	26.4	27.5	28.5	29.1	31.0	32.3	33.7
	-4.0	2.4	11.7	13.8	15.3	18.8	22.5	23.0	23.8	25.9	27.8	28.8	29.8	30.5	32.3	33.7	35.0
	-4.5	3.0	13.0	15.1	16.7	20.2	23.8	24.3	25.2	27.3	29.1	30.2	31.2	31.8	33.7	35.0	36.4
	-5.0	3.7	14.4	16.5	18.0	21.5	25.2	25.7	26.5	28.6	30.5	31.5	32.5	33.2	35.0	36.4	37.7
	-5.5	4.5	15.7	17.8	19.4	22.9	26.5	27.0	27.9	30.0	31.8	32.9	33.9	34.5	36.4	37.7	39.1
	-6.0	5.4	17.1	19.2	20.7	24.3	27.9	28.4	29.2	31.3	33.2	34.2	35.2	35.9	37.7	39.1	40.4
	-6.5	6.3	18.4	20.5	22.1	25.6	29.2	29.7	30.6	32.7	34.5	35.6	36.6	37.2	39.1	40.4	41.8
	-7.0	7.3	19.8	21.9	23.4	27.0	30.6	31.1	31.9	34.0	35.9	36.9	37.9	38.6	40.4	41.8	43.1
	-7.5	8.4	21.1	23.2	24.8	28.3	31.9	32.4	33.3	35.4	37.2	38.3	39.3	39.9	41.8	43.1	44.5
	-8.0	9.6	22.5	24.6	26.1	29.7	33.3	33.8	34.6	36.7	38.6	39.7	40.6	41.3	43.1	44.5	45.9
	-8.5	10.8	23.8	25.9	27.5	31.0	34.6	35.1	36.0	38.1	39.9	41.0	42.0	42.6	44.5	45.9	47.2
	-9.0	12.1	25.2	27.3	28.8	32.4	36.0	36.5	37.3	39.4	41.3	42.4	43.3	44.0	45.9	47.2	48.5
	-9.5	13.5	26.5	28.7	30.2	33.7	37.3	37.8	38.7	40.8	42.6	43.7	44.7	45.3	47.2	48.5	49.8

Note: The table to the right is used to calculate the incremental risk factor between each ranked deviation from 5-year moving average for each potential drought management reductions, via trapezoidal integration. On the far right of the table (Column AZ) sums the incremental risk factors to a total risk factor for each potential drought management reductions.

The user starts with the Drought Management Risk Factor module and enters the historical per capita water use data for each WUG/WWP and a reference year. This module calculates the risk associated with making drought management reductions at various levels. The results of this module feed the Drought Management Costs module. It should be noted that drought management water management strategies that are evaluated should take into account

⁷ South Central Texas Regional Water Planning Group, 2011 Regional Water Plan, Volume II, Technical Evaluations of Water Management Strategies, September 2010.

any previous implementation of drought management that may be embedded in historical GPCD data to avoid under-estimating impacts of annual unit costs of failure to meet projected water need (aka drought management).

The Drought Management Costs module takes results from the Drought Management Risk Factor module and calculates the amount of water saved for 5, 10, 15, and 20 percent reductions, and their associated costs. The user enters the water demand for the municipal WUG/WWP and planning year for which drought management is being considered. Additionally, the user enters the water use sector distribution (domestic/residential, commercial, and manufacturing) for the municipal WUG/WWP and the unit cost of reduction for the various sectors. This information may be obtained from TWDB upon request⁸.

Drought Management - Step 2: Cost Calculation							
<i>Water User Group:</i>		Lockhart					
<i>Water Demand (acft/yr):</i>		2,451					
<i>Planning Year:</i>		2020					
	Domestic/ Residential	Commercial	Manufacturing	Total/ Combined (\$)	Marginal Unit Cost (\$/acft/yr)	Average Unit Cost (\$/acft/yr)	Amount (acft/yr)
Share of WUG's Need Applied to Factor (%)	80%	20%	0%				
Proportional demand (acft)	1,961	490	0				
5% DM WMS Risk Factor	0.1920	#N/A	#N/A				
5% Reduction Economic Impact Factor (\$/acft)	\$ 953	\$ 35,230	\$ -				
5% DM WMS - Total Economic Impact (\$)	\$ 358,712	\$ -	\$ -	\$ 358,712			
5% DM WMS Unit Cost (\$/acft)	\$3,659	\$0	#DIV/0!	\$ 2,927	\$ 2,927	\$ 2,927	123
10% DM WMS Risk Factor	0.2502	#N/A	#N/A				
10% Reduction Economic Impact Factor (\$/acft)	\$ 1,095	\$ 35,230	\$ -				
10% DM WMS - Total Economic Impact (\$)	\$ 537,301	\$ -	\$ -	\$ 537,301			
10% DM WMS Unit Cost (\$/acft)	\$2,740	\$0	#DIV/0!	\$ 4,384	\$ 1,457	\$ 2,192	245
15% DM WMS Risk Factor	0.3135	#N/A	#N/A				
15% Reduction Economic Impact Factor (\$/acft)	\$ 1,264	\$ 35,230	\$ -				
15% DM WMS - Total Economic Impact (\$)	\$ 776,972	\$ -	\$ -	\$ 776,972			
15% DM WMS Unit Cost (\$/acft)	\$2,642	\$0	#DIV/0!	\$ 6,340	\$ 1,956	\$ 2,113	368
20% DM WMS Risk Factor	0.3719	0.1298	0.1298				
20% Reduction Economic Impact Factor (\$/acft)	\$ 1,710	\$ 35,230	\$ -				
20% DM WMS - Total Economic Impact (\$)	\$ 1,246,866	\$ 2,242,371	\$ -	\$ 3,489,237			
20% DM WMS Unit Cost (\$/acft)	\$3,179	\$22,872	#DIV/0!	\$ 28,472	\$ 22,132	\$ 7,118	490

	Demand Reduction	Unit Cost
RESIDENTIAL	5%	\$ 920
	10%	\$ 1,030
	20%	\$ 1,290
	30%	\$ 2,130
	40%	\$ 5,780
	50%	\$ 7,040
	60%	\$ 8,950
	70%	\$ 12,120
	80%	\$ 18,460
	>90%	\$ 24,070
	Commercial	\$ 35,230
	Industry	\$ -

⁸ Regional Water Planning Groups wishing to obtain such data form TWDB should provide advanced notice to TWDB.

The Drought Management Costs module processes the inputs and the resulting risk factors from the Drought Management Risk Factor module to determine the amount of water saved due to drought management and the associated economic impact of not meeting water needs.

REFERENCES

2011 Regional Water Plans, Regional Water Planning Groups, 2010

GDS Associates, “Quantifying the Effectiveness of Various Water Conservation Techniques in Texas; Appendix VI, Region L,” Texas Water Development Board, Austin, Texas, July 2003, http://www.twdb.state.tx.us/publications/reports/contracted_reports/doc/2001483390.pdf

Huffstickler, Ronny, Personal Email, American Ductile Iron Pipe Company, March 8, 2013

Water Conservation Implementation Task Force, “Water Conservation Best Management Practices Guide,” November 2004, http://www.twdb.state.tx.us/publications/reports/numbered_reports/doc/R362_BMPGuide.pdf

APPENDIX A
Unit Cost Table Development Technical Memorandum



Second Draft Technical Memorandum

To: Doug Shaw – TWDB	
From: R Brian Perkins, P.E. – HDR Rachel Ickert, P.E. – FNI	Project: Texas Water Development Board Unified Costing Model
CC:	
Date: November 30, 2012	Job No: 000172970

RE: Development of Cost Tables and Description of Modeling Tool

1. INTRODUCTION

HDR Inc. and Freese and Nichols, Inc. (FNI) were retained by the Texas Water Development Board (TWDB) to develop a costing tool to promote consistency in the regional water planning process. This technical memorandum summarizes the historical bid tab data and the methodology used to develop the unit cost tables for pipelines, booster pump stations, intake pump stations, water storage tanks, water treatment plants, desalination plants, terminal storage reservoirs, earthen dams, ring-dikes, and groundwater wells and well fields. These unit costs will be used by the regional water planning groups and their consultants. In addition, this technical memorandum outlines the costing model and how it will function.

2. HISTORICAL BID TABULATIONS

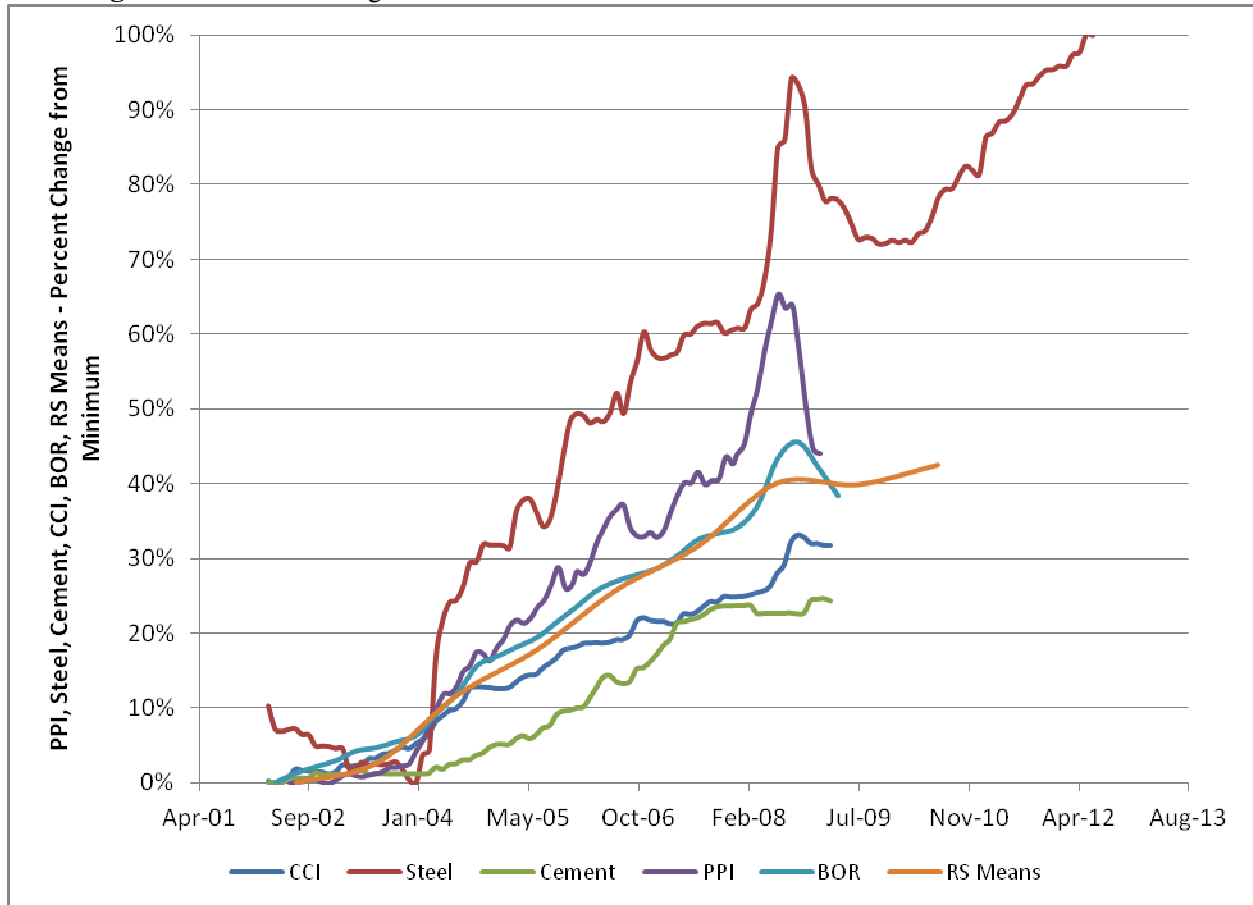
METHODOLOGY

Unit costs were developed in Microsoft Excel using historical bid tab information from HDR, Freese and Nichols Inc (FNI), and AMTEK. AMTEK is a database clearinghouse that contains recent bid information for water projects throughout Texas. All unit costs include the contractors' mobilization, overhead, and profit. The unit costs do not include engineering, contingency, financial and legal services, costs for land and right-of-ways, permits, environmental and archeological studies, or mitigation. The costs for these items are determined separately in the cost tables. Attachment A includes the bid data used to develop the unit costs.

Indexing Unit Costs

The historical bid tab costs were normalized based on two cost indices. The booster pump stations, intake pump stations, water storage tanks, water treatment plants, terminal storage reservoirs, and groundwater wells and well fields were indexed using Engineering News-Record's (ENR) Construction Cost Index (CCI). The pipeline bid tabs were indexed using the U.S. Bureau of Labor Statistics Producer Price Index (PPI). A separate index was used for pipeline projects because pipeline projects are particularly dependent upon the cost of steel. The PPI reflects the changes in steel prices more closely than the CCI. Several indices were considered before deciding upon the CCI and PPI. Other indices considered include the RS Means, Bureau of Reclamation Construction Cost Trends (BOR), cement prices and steel prices. The References section of this memo includes information on where each of these indices can be found. The index selection process considered the availability of each index, the frequency with which the indices were updated, and the accurateness of following costing trends of each index. **Figure 1** shows each of the indices considered as a function of the percent change from the minimum index value since March 2002.

Figure 1. Percent Change from Minimum for PPI, Steel, Cement, BOR, RS Means, and CCI



The CCI is updated monthly, and the index history is available at ENR.com for an annual or monthly fee. The bid tab costs were normalized using the monthly index value. If only the year of the bid was provided and not the month then the annual average was used to index the cost.

The PPI is updated monthly and is available free of charge at bls.gov/ppi. The index selected to index the pipeline costs was the “inputs to construction industries.”

3. UNIT COST TABLES AND CURVES

The unit costs provided in this memorandum are March 2012 costs. Unit costs will be adjusted using the CCI and PPI indices for September 2013 when those indices are available.

Unit costs were developed by plotting the normalized bid costs for each project type. Outliers were removed (typically no more than two points, if any). Incomplete data was also removed, i.e. no indication if the tank had a roof, no identification of booster versus intake pump station, etc. Trendlines were then added to the plotted data, and the data were analyzed for trends. Unit costs were developed based on the trendlines as a starting point for the analysis. However, the trendlines typically did not fit the data well for the highest and lowest data points. Therefore, the cost curves were adjusted until the curves fit the available data and were logical (continuously increasing, urban costs higher than rural costs, etc.). The data was analyzed to determine if there were differences in construction costs based on geographical zones. No regional differences were discernible from the data. For large-scale water supply projects in Texas, a select group of contractors and manufacturing facilities are typically involved in projects all over the state. Project cost variations appear to most often be tied to material cost variations.

SPECIFIC CONSIDERATIONS FOR UNIT COST DEVELOPMENT

Pipeline Unit Costs

Charts were developed by plotting bid data for rural and urban pipelines in soil and rock terrains. Cost per linear foot is on the y-axis, and the pipeline diameter is on the x-axis (**Figures 2 and 3**). The plotted data includes pipelines ranging in diameter from 6 inches to 108 inches.

A curve for pipeline costs in rural settings in soil was developed with a total of 43 data points. There were limited data for pipelines in rural settings in rock so based on the limited rural-rock data, a factor of 1.2 was used to relate the costs to the rural-soil pipelines. Similarly, bid data for pipelines in urban settings for rock and soil were limited. Therefore, a factor of 1.4 was used to relate the urban-soil costs to rural-soil pipelines. No bid data were available for pipelines in urban settings installed in rock. Consistent with pricing for the rural-rock pipeline, a factor of 1.2 was applied to the urban-soil pipeline costs to develop the urban-rock costs. Pipeline costs are presented in **Table 1**. In Figure 3, the cost curves for the urban pipelines are higher than the bid data for the larger pipe diameters because of the constant factor, based on rural pipeline line costs, that was used to develop the urban pipeline costs. The rural pipeline cost curves better match the bid data and more bid data was available to develop the rural cost curves.

The pipeline cost data were analyzed for cost differences between pipelines of different pressure classes, and cost differences could not be determined from the data. For regional water planning purposes, it is typically reasonable to assume one pressure class rating. However, in cases where it is known that higher pressure class pipe will be required, unit costs can be adjusted based on the percent increase in steel cylinder thickness.

Figure 2. Bid Data and Cost Curves for Rural Pipelines

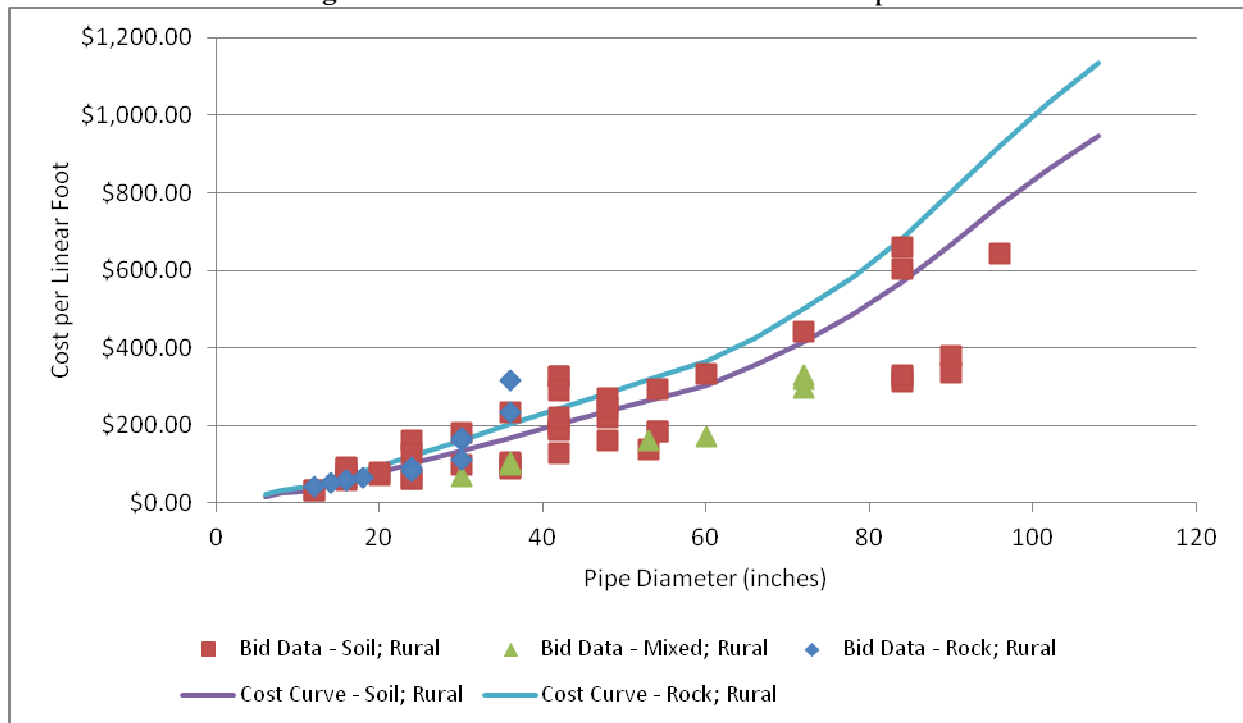


Figure 3. Bid Data and Cost Curves for Urban Pipelines

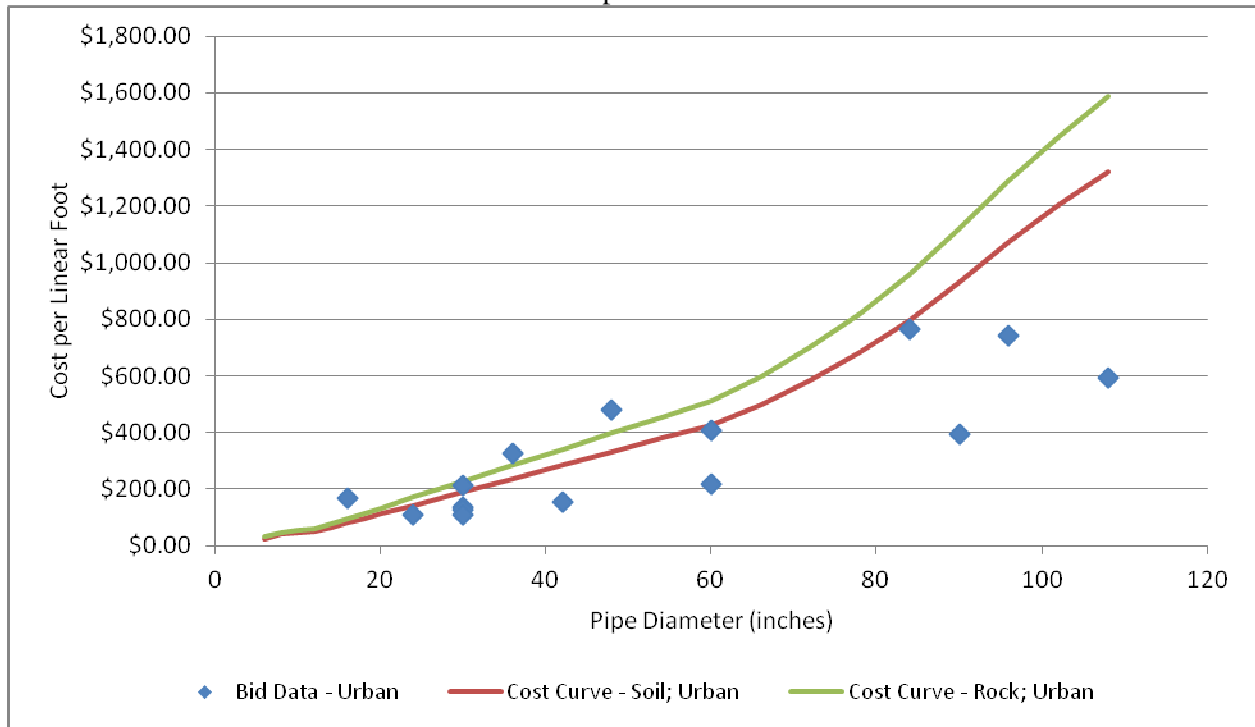


Table 1. Unit Costs for Pipelines (Does not include right-of-way)

Diameter	Rural Cost with Appurtenances - Soil	Rural Cost with Appurtenances - Rock	Urban Cost with Appurtenances - Soil	Urban Cost with Appurtenances - Rock
(inches)	(\$/Foot)	(\$/Foot)	(\$/Foot)	(\$/Foot)
6	\$18	\$22	\$25	\$30
8	\$28	\$34	\$39	\$47
10	\$31	\$38	\$44	\$53
12	\$35	\$41	\$48	\$58
14	\$46	\$55	\$64	\$77
16	\$57	\$68	\$80	\$96
18	\$68	\$82	\$96	\$115
20	\$80	\$95	\$111	\$134
24	\$102	\$122	\$143	\$171
30	\$136	\$163	\$190	\$228
36	\$169	\$203	\$237	\$285
42	\$203	\$244	\$284	\$341
48	\$237	\$284	\$332	\$398
54	\$271	\$325	\$379	\$454
60	\$304	\$365	\$426	\$511
66	\$356	\$427	\$498	\$598
72	\$416	\$500	\$583	\$700
78	\$487	\$585	\$682	\$819
84	\$570	\$684	\$798	\$958
90	\$667	\$800	\$934	\$1,121
96	\$767	\$921	\$1,074	\$1,289
102	\$859	\$1,031	\$1,203	\$1,443
108	\$945	\$1,134	\$1,323	\$1,588
114	\$1,040	\$1,247	\$1,455	\$1,746
120	\$1,144	\$1,372	\$1,601	\$1,921
132	\$1,315	\$1,578	\$1,841	\$2,209
144	\$1,512	\$1,815	\$2,117	\$2,541

Pump Station Unit Costs

Intake and booster pump station costs were developed based on horsepower. Pump stations should be sized for peak pumping capacity. Bid data for 15 intake pump stations was plotted, and unit costs were developed directly from the bid data. The bid data ranged from 200 horsepower to 20,000 horsepower. Twelve bid data points were used to develop reservoir intake pump station unit costs. The intake pump station costs listed in **Table 2** can be used for reservoir or river intake pump station costs. These costs for intake pump stations include the intake structure and the pump station facilities. However, intake structure costs can vary depending on site conditions, so site-specific cost estimates may be necessary in some instances.

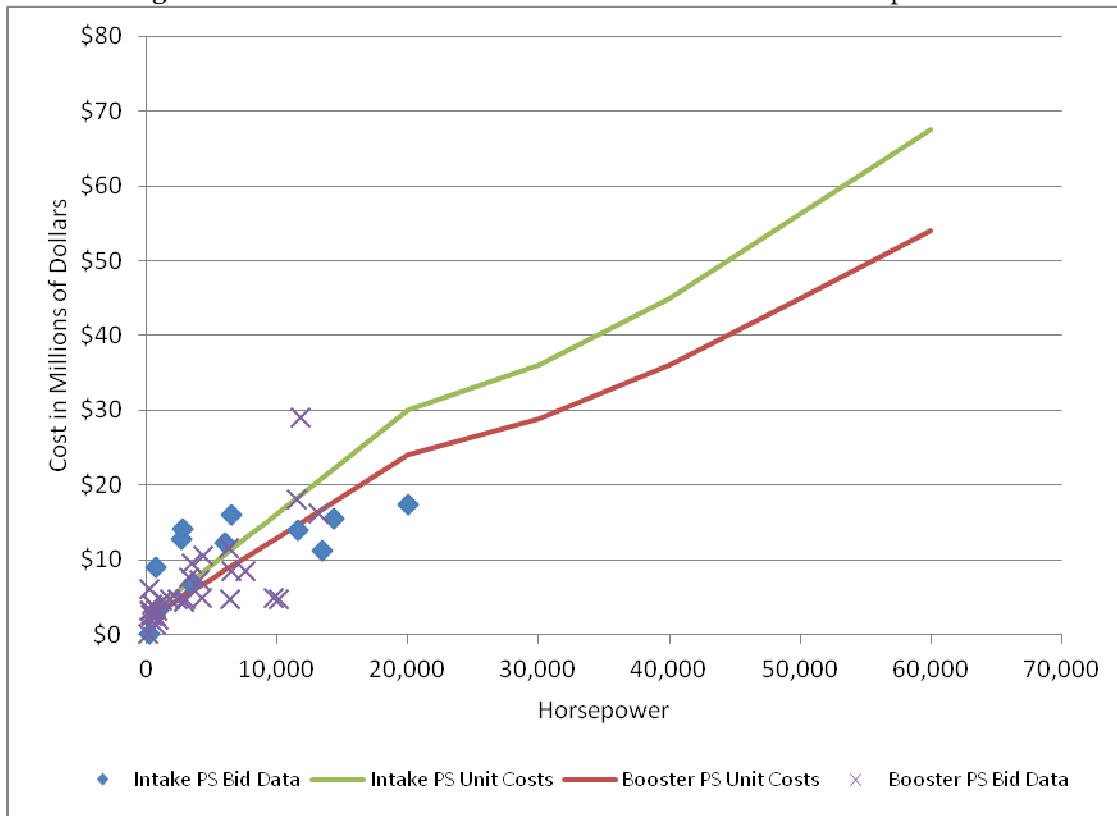
Booster pump station costs were developed based on bid data for 31 pump stations ranging from 80 horsepower to 13,400 horsepower. Costs for booster pump stations include only the pump station facilities. Trendlines were used to determine the unit costs for the higher horsepower capacities where bid data was not available. The bid data and cost curves are plotted in **Figure 4**.

Note that the scope of work states that water intake structures will be costed at 50% of the pump station cost (to be re-evaluated). There is sufficient data to develop cost curves for intake pump stations, and the costs include both the pump station and the intake structure. Therefore, the process of costing intake structures as a percentage of pump station costs was not used.

Table 2. Unit Costs for Booster and Reservoir Intake Pump Stations

Horsepower	Booster Pump Station Costs	Intake Pump Station Costs
5	\$602,000	
10	\$662,000	
20	\$695,000	
25	\$730,000	
50	\$766,000	
100	\$804,000	
200	\$1,616,000	\$2,000,000
300	\$1,778,000	\$2,500,000
400	\$2,254,000	\$3,000,000
500	\$2,318,000	\$3,500,000
600	\$2,381,000	\$4,000,000
700	\$2,445,000	\$4,500,000
800	\$2,880,000	\$5,000,000
900	\$2,990,000	\$5,500,000
1,000	\$3,100,000	\$6,000,000
2,000	\$4,201,000	\$8,400,000
3,000	\$5,301,000	\$9,700,000
4,000	\$6,401,000	\$11,000,000
5,000	\$7,501,000	\$12,000,000
6,000	\$8,602,000	\$13,000,000
7,000	\$9,702,000	\$14,000,000
8,000	\$10,802,000	\$15,000,000
9,000	\$11,902,000	\$16,000,000
10,000	\$13,003,000	\$17,000,000
20,000	\$24,005,000	\$28,000,000
30,000	\$28,806,000	\$37,000,000
40,000	\$36,008,000	\$47,000,000
50,000	\$45,009,000	\$56,000,000
60,000	\$54,011,000	\$65,000,000

Figure 4. Bid Data and Cost Curves for Booster and Intake Pump Stations



Tank Unit Costs

Unit costs for tanks were developed by evaluating bid data for 35 projects. The costs were broken down by elevated versus ground storage tanks. The ground storage tanks costs were further broken down into open or roofed tanks. The bid data for elevated storage tanks ranged in size from 0.3 to 2.7 million gallons of storage. The bid data for ground storage tanks, with no roofs, ranged from 6 to 14 million gallons. The bid data for covered ground storage tanks ranged from 0.3 to 10 million gallons. **Figure 5** includes the bid data and cost curves for elevated storage tanks. **Figure 6** shows the bid data and cost curves for the ground storage tanks. The final unit costs were based on the bid data. **Tables 3** and **4** include the unit costs for elevated and ground storage tanks, respectively.

Figure 5. Cost Curve and Bid Data for Elevated Storage Tanks

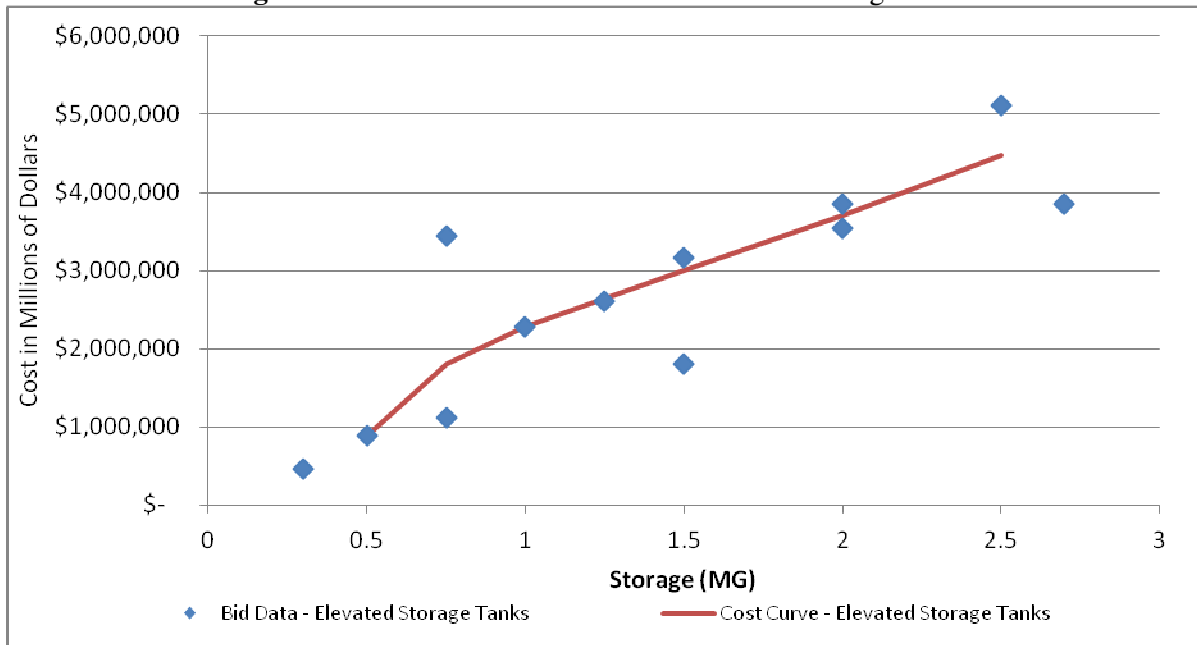


Table 3. Elevated Storage Tank Unit Costs

Size (MG)	Cost
0.5	\$894,000
0.75	\$1,800,000
1	\$2,274,000
1.5	\$3,000,000
2	\$3,699,000
2.5	\$4,482,000

Figure 6. Cost Curve and Bid Data for Ground Storage Tanks

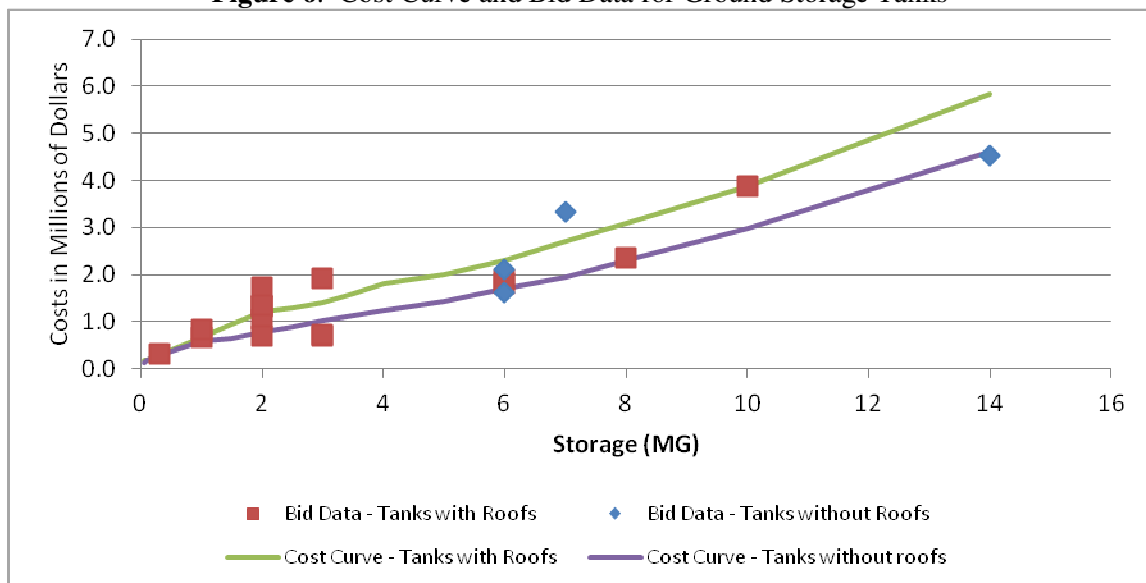


Table 4. Ground Storage Tank Unit Costs

Size (MG)	With Roof	Without Roof
0.05	\$173,000	\$115,000
0.1	\$187,000	\$169,000
0.5	\$400,000	\$363,000
1	\$678,000	\$600,000
1.5	\$939,000	\$654,000
2	\$1,200,000	\$780,000
2.5	\$1,300,000	\$895,000
3	\$1,400,000	\$1,010,000
3.5	\$1,600,000	\$1,120,000
4	\$1,800,000	\$1,230,000
5	\$2,000,000	\$1,420,000
6	\$2,300,000	\$1,700,000
7	\$2,700,000	\$1,950,000
8	\$3,100,000	\$2,300,000
10	\$3,879,000	\$2,980,000
12	\$4,848,750	\$3,800,000
14	\$5,842,000	\$4,600,000

Water Treatment Plant Unit Costs

Water treatment plants are to be sized for peak day capacity. A peaking factor of 2 is recommended if no specific data are available. For the TWDB costing study, a total of 48 water treatment plants were evaluated based on treatment level, size and cost. The treatment levels for regional costing include:

- Level 0 – Disinfection Only
- Level 1 – Iron & Manganese removal for groundwater
- Level 2 – Advanced groundwater treatment
- Level 3 – Conventional Treatment and groundwater nitrate removal
- Level 4 – Brackish Water Treatment
- Level 5 – Saline Water Desalination Treatment

It is recommended that Level 0 costs be added to public water supply well costs. These costs should also be considered for projects which may need to boost disinfection or re-disinfect after storage. A description of the treatment levels is included below. Unit costs are included in **Table 5**. Expansion costs have also been developed from available data for Level 3 – Conventional Treatment and are included in Table 5. Expansion costs for other WTP levels will be developed as the cost difference between the original capacity and the expanded capacity:

$$\text{Expansion cost (B - A mgd)} = \text{WTP Cost at new size (A mgd)} - \text{WTP Cost at original size (B mgd)}$$

Table 5. Unit Costs for Water Treatment Plants

Capacity (MGD)	New Level 0	New Level 1	New Level 2	New Level 3	Expansion Level 3	New Level 4	New Level 5
0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
0.1	\$17,414	\$217,675	\$1,000,000	\$1,334,000	\$1,332,895	\$1,500,000	\$2,137,155
1	\$67,044	\$873,601	\$3,500,000	\$4,700,000	\$4,700,000	\$8,000,000	\$14,300,000
10	\$427,600	\$3,635,603	\$18,500,000	\$32,000,000	\$18,000,000	\$39,900,000	\$95,683,276
50	\$2,138,000	\$10,558,964	\$70,000,000	\$142,282,302	\$65,000,000	\$199,900,000	\$361,273,225
75	\$3,207,000	\$15,234,181	\$102,333,333	\$210,843,105	\$103,335,736	\$299,900,000	\$504,892,722
100	\$4,276,000	\$18,664,589	\$134,666,667	\$278,708,349	\$125,257,305	\$399,900,000	\$640,230,025
150	\$6,414,000	\$28,562,983	\$199,333,333	\$413,008,034	\$187,882,925	\$599,900,000	\$894,745,189
200	\$8,552,000	\$32,890,501	\$264,000,000	\$545,945,228	\$231,722,072	\$799,900,000	\$1,134,583,070

Level 0. Disinfection Only - This treatment process will be used for groundwater with no contaminants that exceed the regulatory limits. Assumes groundwater does not require treatment for taste and odor reduction and groundwater is stable and requires no treatment for corrosion stabilization. With this treatment, the ground water is suitable for public water system distribution, aquifer injection, or artificial recharge. These costs should be used with caution for treatment plants greater than 50 MGD as bid data was limited above this capacity.

Level 1. Iron and Manganese Removal - This treatment process will be used for groundwater to lower the iron and manganese content and to disinfect. The process includes application of an oxidant and addition of phosphate to sequester iron and manganese and chlorine disinfection as the final treatment. These costs should be used with caution for treatment plants greater than 50 MGD as bid data was limited above this capacity.

Level 2. Direct Filtration Treatment - This treatment process will be used for treating ground water from sources where iron, manganese, or other constituent concentrations exceed the regulatory limit and require filtration for solids removal. Assumes turbidity and taste and odor levels are low. In the direct filtration process, low doses of coagulant and polymer are used and settling basins are not required as all suspended solids are removed by filters. The process includes alum and polymer addition, rapid mix, flocculation, filtration, and disinfection.

Level 3. Conventional Treatment - This treatment process will be used for treating typical surface water sources to be delivered to a potable water distribution system. The process includes coagulant and polymer addition, rapid mix, flocculation, settling, filtration, and disinfection with chlorine. This treatment process also applies for difficult to treat groundwater containing high concentrations of iron (greater than 3 mg/l) and manganese requiring settling before filtration. This cost curve is also recommended for nitrate removal from groundwater.

Level 4. Brackish Water Desalination - This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of a surface water or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example: add level 3 treatment costs for a turbid surface water source). This treatment process will be used for treatment of groundwater with total dissolved solids (TDS) exceeding 1,000 mg/l. Costs are based on reverse osmosis (RO) membrane desalination of a groundwater with 5,000 mg/l of TDS to lower the treated water TDS below 1,000 mg/l. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalant addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs

do not include disposal of desalination concentrate. Facilities necessary for disposal of concentrate require specific costs developed based on method of disposal and local geography/geology.

Level 5. Saline Water Desalination - This treatment cost does not include pretreatment for solids removal prior to RO membranes. For desalination of seawater or groundwater containing high solids concentrations, additional solids removal treatment should be included in addition to desalination. (Example - For desalination of seawater with an intake located on the coast drawing turbid water, cost estimate should include Level 3 treatment plus Level 5). This treatment process will be used for treatment of saline water with total dissolved solids (TDS) exceeding 10,000 mg/l. Costs are based on reverse osmosis (RO) membrane desalination of a water with 32,000 mg/l of TDS to lower the treated water TDS below regulatory limits. The desalination concept includes minimal pretreatment (cartridge filtration, antiscalent addition, acid addition), reverse osmosis membrane system, and disinfection with chlorine. Costs do not include disposal of desalination concentrate and should be cost in the same method as transmission pipelines.

At this time there are no constructed seawater desalination plants in Texas. However, Brownsville Public Water Utilities and Laguna Madre have developed costs for pilot projects. The TWDB compiled data from these studies and separated costs for just the water treatment plant construction.

Well Unit Costs

Costs for public water supply wells were developed based on available bid data and statistical analysis. HDR used cost estimates from Wellspec Company from a September 1999 report “Typical New Well Field Cost for a Public Water Utility – Carrizo and Gulf Coast Aquifer” to identify key costing attributes. The Wellspec report included costs for 67 wells with varying depth, pumping capacity, casing and screen diameters. The analysis indicates that well depth and pumping capacity correlate to 81% and 67% of the variability in costs.

A total of 8 data points with bid tabs, total depth and pumping capacity were used to develop cost curves. Well costs include mobilization, materials and installation for the well, development, testing, security and road access and other miscellaneous items associated with the well. Unit cost tables have been developed using well depth and pumping capacity. Cost curves for 100 gpm, 175 gpm, 350 gpm, 700 gpm 1,000 gpm and 1,800 gpm are shown in Figure 7 with the bid data.

Costs shown in Table 6 are for complete installation of well and pump and include drilling services, materials, pump and control equipment, valves, testing, security fencing and small access road.

Figure 7. Well Bid Data and Various Cost Estimating Methods

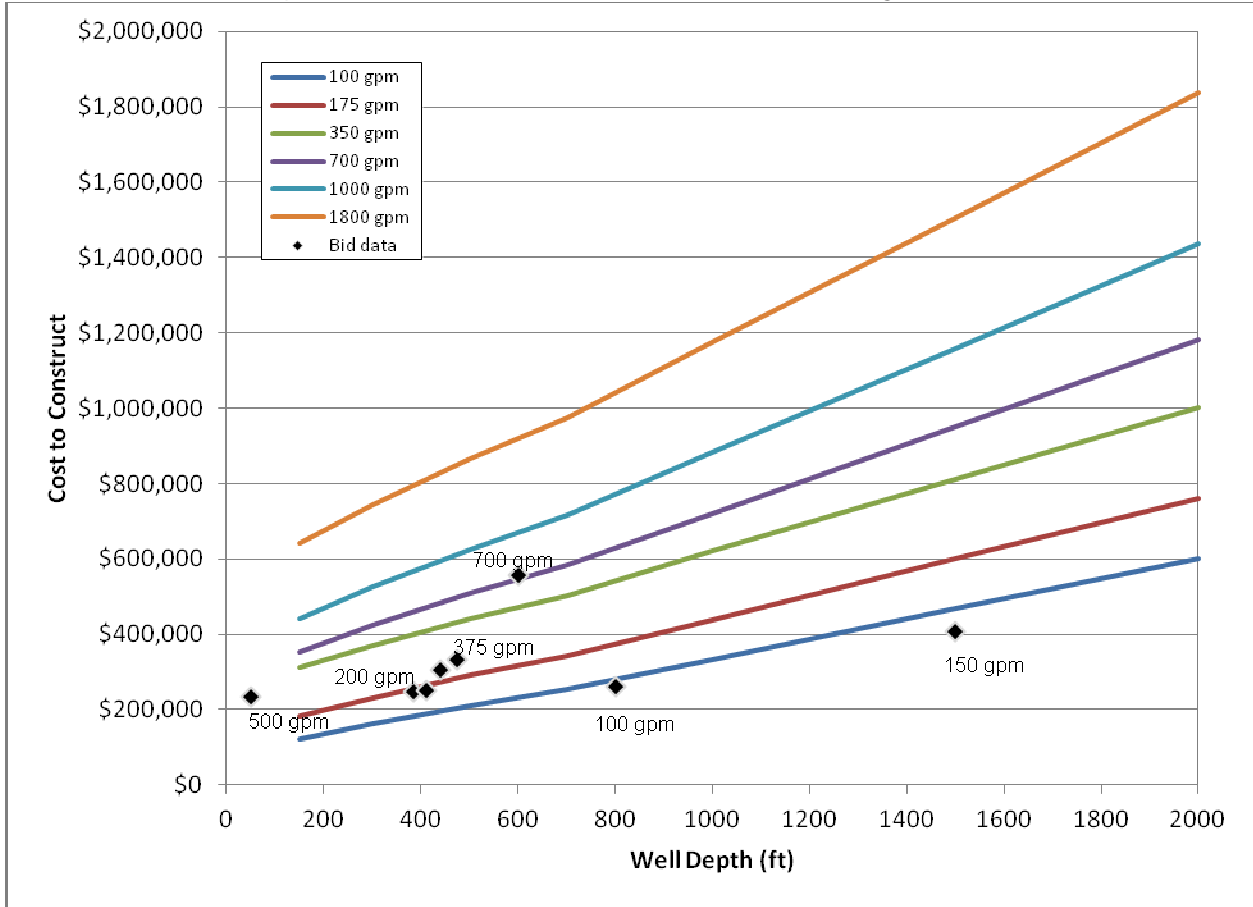


Table 6. Unit Costs for Public Water Supply Wells

Well Depth	Well Capacity (gpm)					
	100	175	350	700	1,000	1,800
150	\$120,447	\$182,847	\$312,000	\$352,633	\$439,703	\$642,866
300	\$162,530	\$232,186	\$371,498	\$425,191	\$525,322	\$744,447
500	\$210,419	\$290,233	\$441,154	\$507,908	\$625,452	\$866,345
700	\$253,954	\$342,475	\$503,554	\$583,368	\$715,424	\$973,731
1,000	\$333,768	\$438,252	\$619,647	\$721,229	\$882,308	\$1,173,992
1,500	\$467,275	\$599,331	\$811,201	\$951,964	\$1,158,029	\$1,504,858
2,000	\$600,782	\$758,959	\$1,002,755	\$1,182,699	\$1,435,202	\$1,837,174

Irrigation well costs can range from between 55 percent and 70 percent of the cost of a public supply well¹, due to the use of carbon steel screens (as opposed to stainless steel), no cementing in of casings, no gravel packing, and no TCEQ permitting requirements. Costs in Table 7 were developed using 60 percent of the cost of the public supply wells.

Table 7. Unit Costs for Irrigation Wells

Well Depth	Well Capacity (gpm)					
	100	175	350	700	1,000	1,800
150	\$66,754	\$103,033	\$175,591	\$201,712	\$255,405	\$368,596
300	\$88,521	\$132,056	\$214,772	\$253,954	\$322,159	\$449,861
500	\$110,289	\$165,433	\$256,856	\$310,549	\$394,717	\$544,187
700	\$127,702	\$190,103	\$293,135	\$358,438	\$458,568	\$625,452
1,000	\$166,884	\$245,247	\$368,596	\$457,117	\$584,819	\$785,080
1,500	\$233,638	\$339,573	\$493,396	\$621,098	\$793,787	\$1,049,192
2,000	\$298,940	\$430,996	\$618,196	\$783,629	\$1,004,206	\$1,314,755

No new bid data was available for ASR wells. **Table 8** unit costs range from 2% to 16% greater in cost than a public water supply well depending on the depth and capacity. The increase in price is primarily due to more elaborate plumbing required, larger casing size, and more SCADA and valves for control.

Table 8. Unit Costs for ASR Wells

Well Depth	Well Capacity (gpm)					
	100	175	350	700	1,000	1,800
150	\$133,507	\$206,065	\$358,438	\$404,875	\$505,005	\$744,447
300	\$175,591	\$255,405	\$417,935	\$477,433	\$590,624	\$847,480
500	\$223,479	\$314,903	\$487,591	\$560,150	\$692,206	\$967,927
700	\$268,465	\$367,145	\$551,443	\$635,610	\$780,727	\$1,076,764
1,000	\$346,828	\$462,922	\$666,085	\$773,471	\$947,611	\$1,275,574
1,500	\$481,787	\$622,550	\$857,638	\$1,004,206	\$1,223,332	\$1,606,439
2,000	\$613,843	\$782,178	\$1,049,192	\$1,234,941	\$1,500,504	\$1,938,756

Dam Unit Costs

Because of the large number of factors that influence costs, site specific cost estimates should be used for new dams and reservoirs whenever possible. These costs should be used for screening purposes only. Unit costs were developed for earthen dams with storage up to 70,000 acre-feet. Data for reservoirs constructed prior to 1940 were removed from the analysis because the construction practices were somewhat different prior to this timeframe. The costs for the earthen dams were initially developed based on a polynomial trendline and then refined by manual adjustments to better reflect the bid data. The bid data included reservoirs ranging from 42 acre-feet of normal storage to 72,800 acre-feet of normal storage. A cost curve

¹ Based on data from Wellspec Company, September 1999.

and the bid data are shown in **Figure 8**. The costs developed for the earthen embankments are included in **Table 9** and apply under the following conditions/assumptions:

- On-site borrow
- No spillway gates
- Includes an overflow spillway and/or an excavated emergency spillway
- Includes upstream slope protection such as soil cement or rock riprap. Includes grass as downstream slope protection.
- Includes an internal drainage system
- Infrastructure relocations are not included
- Does not include the cost to purchase land

The elements required for reservoir sites are included in **Table 12**.

Figure 8. Cost Curve and Bid Data for Earthen Embankment Reservoirs

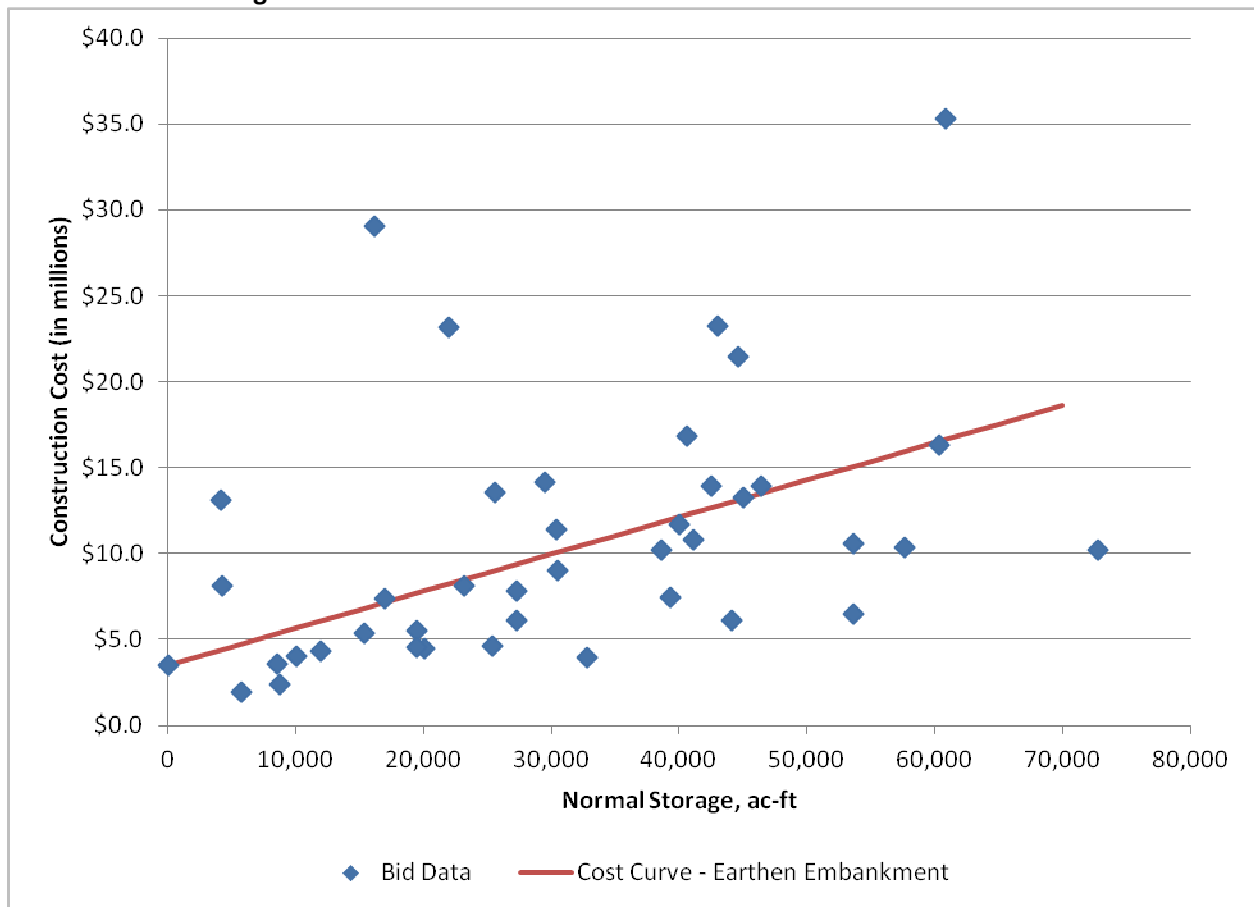


Table 9. Unit Costs for Earthen Dams

Earthen Dams	
Storage (ac-ft)	Cost
50	\$3,511,000
1,000	\$3,716,000
5,000	\$4,579,000
10,000	\$5,657,000
15,000	\$6,736,000
20,000	\$7,814,000
25,000	\$8,893,000
30,000	\$9,972,000
35,000	\$11,050,000
40,000	\$12,129,000
45,000	\$13,207,000
50,000	\$14,286,000
55,000	\$15,365,000
60,000	\$16,443,000
65,000	\$17,522,000
70,000	\$18,600,000

Terminal Storage Unit Costs

There were limited data available for terminal storage reservoirs. The terminal storage costs were based on six construction costs ranging in size from 61 acre-feet of normal storage to 506 acre-feet of normal storage. The more recent data point indicated significantly higher costs than the data points from years prior to 2008. Therefore, the costs were adjusted to better reflect current costs seen in the bidding process. Several recent opinion of probable construction cost (OPCC) estimates are plotted in **Figure 9** showing the expected higher construction costs. The cost curve and bid data are included in **Figure 9**. The terminal storage costs are listed in **Table 11** and include the elements listed in Table 12 as well as the assumptions below:

- No internal drainage system
- HDPE and soil cement liners
- Inlet/Outlet pipes of 84-inches or less and no valves on the pipes
- Balanced cut and fill
- No site work (such as fencing, roads, landscaping)
- No instrumentation
- No lighting/security

Figure 9. Cost Curve and Bid Data for Terminal Storage Reservoirs

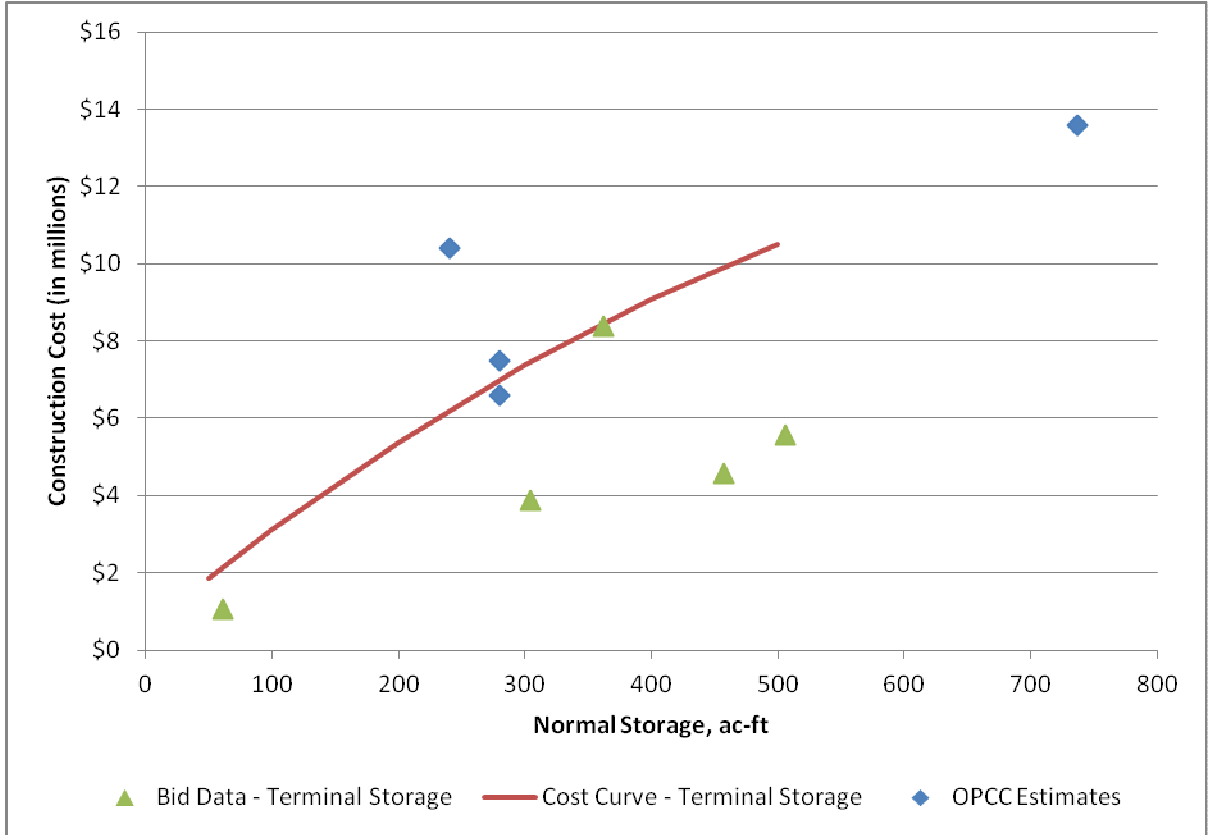


Table 11. Unit Costs for Terminal Storage Reservoirs

Terminal Storage Reservoirs	
Storage (ac-ft)	Cost
50	\$1,863,000
100	\$3,107,000
200	\$5,384,000
300	\$7,378,000
400	\$9,087,000
500	\$10,514,000

Table 12. Cost Elements for Dams

Capital Costs
Embankment
Spillway
Outlet works
Site work
Land
Administrative facilities
Supplemental pumping facilities
Flood protection

Large Ring-Dike Unit Costs

No bid data were available for large ring-dike costs, so costs were based on recent OPCCs. The unit costs are included in **Table 13**. The following assumptions were used to develop the unit costs for the off-channel ring-dikes:

- Water Depth of 20 ft.
- Normal Freeboard of 5 ft.
- A Crest Width of 15 ft.
- Crest Gravel Thickness of 0.5 ft.
- An Embankment Height of 27 ft.
- Slope Protection Depth of 7.5 ft.
- Soil Cement Lane Width of 10 ft.
- An Inside Slope of 4:1 (H:V)
- A Strip Depth of 2 ft.
- Cutoff Trench Bottom Width of 15 ft.
- A Cutoff Depth of 5 ft.
- A Cutoff Excavation Slope of 1.5:1 (H:V)
- A Chimney Width of 3 ft.
- Chimney Height of 24 ft.
- Chimney Drain Outlet Pipe Length of 90 ft.
- 4 Outlet Pipes per 1,000 Lf
- 5 Emergency Spillway 3' x 10' box sections
- The Unit Cost of Stripping is \$1.50 per cubic yard
- The Unit Cost for Cutoff Trench Excavation is \$2.50 per cubic yard
- The Unit Cost for the Embankment Fill and Cutoff Trench (Borrow Excavation & Placement) is \$5.00 per cubic yard
- The Unit Cost for a Chimney Filter/Drain is \$25.00 per cubic yard
- The Unit Cost for the Chimney Drain Outlet Pipe is \$30.00 per linear foot
- The Unit Cost of Chimney Drain Outlet Structures is \$500 each
- The Unit Cost of the Inside Stair-Stepped Soil Cement Slope Protection is \$38.00 per cubic yard
- The Unit Cost for the Topsoil and Seed for the Outside Slope is \$4,000 per acre
- The Unit Cost for the Gravel Crest Road is \$25.00 per cubic yard
- The Unit Cost for the Emergency Spillway 3' x 10' Box Sections is \$50,000 each

Table 13. Unit Costs for Large Ring-Dikes

Storage Volume (ac-ft)	Capital Cost
500	\$4,192,000
1,000	\$5,870,000
2,500	\$9,198,000
4,000	\$11,596,000
5,000	\$12,948,000
10,000	\$18,252,000
12,500	\$20,390,000
15,000	\$22,322,000
17,500	\$24,099,000
19,000	\$25,105,000
20,000	\$25,753,000
22,000	\$27,003,000
25,000	\$28,776,000

Other costs that will be included in the costing model that are not detailed in this memorandum include operation and maintenance costs for WTP, crossing costs for pipeline installations, injection wells, and WWTP improvements for reuse projects.

4. DESCRIPTION OF COSTING TOOL MODEL

The costing tool model will be based in MS Excel and include Visual Basic for Applications functions designed to assist the user in calculating the capital, project, annual, and unit costs for a water management strategy. The Excel spreadsheet will consist of six worksheets: Assumptions/Project, Pipeline Hydraulics Calculations, Pipeline Hydraulic Plot, Costing Form, Costing Summary, and Costing Tables. Each of these worksheets is briefly described below.

Assumptions/Project

The Assumptions/Project page is used to define the project characteristics and list all the assumptions used in the cost analysis. Default values for the costing assumptions will be consistent with TWDB guidelines for regional planning, but can be modified if necessary based on the specific project. This page will act as the inputs for many of the other pages (values filled in on this page will propagate to other

Pipeline Hydraulics Calculations

This Hydraulics page will be used to calculate the pipe size and pump station(s) size for large transmission pipelines. There will be a simplified calculation option in which the user can specify pipe length, elevation change, and flow rate to determine pipe and pump sizes. Additionally, there will be an option to specify a pipeline route and profile so the user can perform a more detailed analysis. This option will taken into account the elevation change along the pipeline route, the soil/rock topography, the urban/rural setting, and help the user select booster pump locations (if necessary).

Pipeline Hydraulic Plot

When using the more detailed pipeline hydraulics tool, this page will plot up the hydraulic gradeline and pipeline profile along the pipeline route. This will aid in the selection of pump station size(s), booster pump location(s), and pipe sizes.

Costing Form

The Costing Form will be the comprehensive line-item form used to select and cost out each element of the project. In addition to capital cost items, there will be line items calculating associated project costs (mitigation, contingencies, land costs, interests during construction, etc), as well as annual and unit costs.

Costing Summary

The Costing Summary tab will simplify the line-item costs from the Costing Form by lumping associated costs together into groups, and create a table that is easily exported for use in reports.

Costing Tables

The Costing Tables page will be the brains behind the costing tool. This is where cost tables for major elements will be maintained and referenced when determining the line-item costs in the Costing Form.

5. REFERENCES

Engineering News-Record (ENR). (2012). Historical Indices. Retrieved February 2012, from ENR.com Economics:http://enr.construction.com/economics/historical_indices/

RS Means - Reed Construction Data. (2012). Means Online Store. Retrieved February 2012, from <http://rsmeans.reedconstructiondata.com/>

U.S. Bureau of Labor Statistics. (2012). Producer Proce Indexes. Retrieved February 2012, from PPI Databases: <http://www.bls.gov/ppi/data.htm>

U.S. Bureau of Reclamation. (2012). Construction Cost Trends. Retrieved February 2012, from http://www.usbr.gov/pmts/estimate/cost_trend.html

Attachment A

County	Region	Capacity (mgd)	Construction Cost (in millions)	Index	Normalized Cost (in millions)	Normalized Cost	Year Built	New/Expansion	Source Water	Treatment Process	Comments
Jefferson	northwest	14	\$11.00	7115	\$14.33	\$14,328,601.55	2004	expansion	Lawson's Canal/Neches River	Conventional coagulation, sedimentation, filtration	Excludes New HSPs, Clearwell and Chemical Storage and Feed in separate projects. Includes new filter complex for total 50 MGD capacity
Tarrant	northwest	35	\$43.50	7751	\$32.01	\$32,013,675.65	2006	expansion	Eagle Mountain Lake	Conventional coagulation, sedimentation, filtration w/pre-ozonation	Expansion from 70 to 105 mgd. Ultimate capacity: 140 mgd
Hill	northwest	3	\$5.75	7966	\$6.69	\$6,689,806.68	2007	expansion	Lake Aquilla	Conventional coagulation, sedimentation, filtration	Expansion from 6 to 9
Tarrant	northwest	32.5	\$28.80	8310	\$32.12	\$32,120,144.40	2008	expansion	Richland-Chambers Res./Cedar Creek Lake	Conventional coagulation, sedimentation, filtration w/pre- and intermediate ozonation	Expansion from 65 to 97.5 mgd. Ultimate capacity: 130 mgd
Brown	northwest	7.5	\$11.33	8570	\$12.25	\$12,252,793.47	2009	expansion	Lake Brownwood	Direct MF Membrane Filtration (Pa II)	Excludes Rehab of existing facilities
Eastland	northwest	2	\$3.50	9070	\$3.58	\$3,576,405.73	2011	Expansion	Lake Cisco	Conventional Pretreatment, MF Membrane Filtration (Pa I)	Some existing plant systems used, existing filtration system replaced with MF
Johnson	northwest	5	\$7.40	9070	\$7.56	\$7,561,543.55	2011	expansion	Lake Pat Cleburne	Conventional coagulation, sedimentation, filtration	Expansion from 15 to 20 mgd
Williamson	southeast	7.5	\$17.30	7751	\$20.69	\$20,685,898.59	2006	expansion	Lake Granger	Conventional coagulation, sedimentation, filtration	Excludes Terminal Storage Reservoir cost. Includes New HSPs and Chemical Storage and Feed
Willacy	southeast	0.3	\$3.30	9070	\$3.37	\$3,372,039.69	2011	Expansion	Rio Grande River	Package conventional treatment (Roberts)	Includes rehab of raw water and solids dewatering system improvements
Llano	southwest	4	\$10	7446	\$12.45	\$12,446,951.38	2005	Expansion	Lake LBJ	Conv Pretreat (existing), MF Membrane	Ultimate cap of 8 mgd
Kimble	southwest	2	\$4	8310	\$4.46	\$4,461,131.17	2008	Expansion	South Llano River	Package Pretreat (existing), MF Membrane	Existing high service pump station and clearwell
Grayson	northeast	1	\$1.50	5920	\$2.35	\$2,348,310.81	1998	New	Lake Texoma	Package conventional (US Filter)	Two plants constructed in one contract
Ellis	northeast	6	\$18.00	9268	\$18.00	\$18,000,000.00	2013	new	Richland-Chambers Res./Cedar Creek Lake	Conventional Pretreatment, MF Membrane Filtration (Siemens)	In construction
Wichita	northwest	1	\$1.50	5920	\$2.35	\$2,348,310.81	1998	New	Lake Arrowhead	Package conventional (US Filter)	Two plants constructed in one contract
Bosque	northwest	1	\$3	6343	\$4.38	\$4,383,414.79	2001	New	North Bosque River	Package conventional (US Filter)	Included channel dam
Denton	northwest	20	\$36.80	6538	\$52.17	\$52,166,167.02	2002	new	Lake Ray Roberts	Conventional coagulation, sedimentation, filtration w/pre- and intermediate ozonation	Ultimate capacity: 50 mgd
Runnels	northwest	2.5	\$4.40	7446	\$5.48	\$5,476,658.61	2005	New	Lake Ballinger, OH I've Reservoir	Conventional Pretreat, Dual-Media Filtration	
Shackelford	northwest	2.5	\$6	8802	\$6.32	\$6,317,655.08	2010	New	Hubbard Creek Reservoir	Conventional Pretreat, UF Membrane (GE)	
Somervell	northwest	2.5	\$8.68	9070	\$8.87	\$8,869,486.22	2011	new	Paluxy river/Wheeler Branch Reservoir	Direct MF Membrane Filtration (Pa I)	
Williamson	southeast	6	\$10	5620	\$16.49	\$16,491,103.20	1997	New	Lake Georgetown	Conventional coagulation, sedimentation, filtration	
Williamson	southeast	4	\$16	6343	\$23.38	\$23,378,212.20	2001	New	Lake Travis	Package conventional (Roberts)	Ultimate cap of 12 mgd
Fort Bend	southeast	10	\$32	9070	\$32.70	\$32,698,566.70	2011	New	Brazos River	Plate settler-pretreat, MF Membrane	Included raw water reservoir. In const.
Burnet	southwest	3	\$6.20	7751	\$7.41	\$7,413,443.43	2006	New	Lake LBJ	Conventional Pretreat, MF Membrane	Original bid: \$7.5 M, negotiated scope to reduce

Location	Depth, ft	Capacity, gpm	Diameter, in	Year	Cost	Index	Normalized Cost
Van Alstyne	2400	325		2003	\$415,192	6694	\$574,843
Bells	800			2007	\$223,575	7966	\$260,117
Anna	1500	150		2003	\$293,453	6694	\$406,293
Southmayd				2000	\$225,914	6221	\$336,565
Canyon	475			10/20/2011	\$402,005	9147	\$407,323
McAllen				9/15/2011	\$1,746,700	9153	\$1,768,646
Tronillo				8/10/2011		9088	\$0
EPWU				7/12/2011		9080	\$0
Devine	400			5/3/2011	\$246,300	9035	\$252,652
Bastrop Co	500			3/3/2011	\$720,070	9011	\$740,607
Lockhart	600			2/22/2011	\$764,800	8998	\$787,749
Kerrville	830			12/16/2010	\$971,700	8952	\$1,006,000
Canyon	2870			8/26/2010	\$1,502,539	8858	\$1,572,085
X	2200			4/13/2010	\$1,045,500	8677	\$1,116,710
Dimmitt	930			11/17/2009	\$913,066	8592	\$984,904
Bastrop	50			4/9/2009	\$807,358	8528	\$877,415

Name	County	Region	Bid Date	Total Bid Amount	Tank Size (MG)	Elevated /Ground	Material	Open/Roof	Bid Day CCI Index	Percent Increase	Present Day Cost
Pal Anderson	Anderson	northeast	5/24/2010	\$ 2,150,000	1	elevated			8761	1.05787	\$ 2,274,421
Pro Collin	Collin	northeast	5/31/2007	\$ 2,717,000.00	1.5	Elevated			7942	1.16696	\$ 3,170,632
SE Kaufman	Kaufman	northeast	9/16/2010	\$ 1,728,000	1.5	Elevated			8836	1.048891	\$ 1,812,483
Mt. V Tarrant	Tarrant	northwest	1998	\$ 300,000	0.3	elevated			5920	1.565541	\$ 469,662
Bro Brown	Brown	northwest	2000	\$ 600,000	0.5	elevated			6221	1.489793	\$ 893,876
Bur Tarrant	Tarrant	northwest	1998	\$ 2,200,000	0.75	elevated			5920	1.565541	\$ 3,444,189
Bro Brown	Brown	northwest	2000	\$ 750,000	0.75	elevated			6221	1.489793	\$ 1,117,344
SA Tom Green	Tom Green	northwest	2000	\$ 1,750,000	1.25	elevated			6221	1.489793	\$ 2,607,137
Ele Tarrant	Tarrant	northwest	2002	\$ 2,500,000	2	elevated			6538	1.417559	\$ 3,543,897
Joint Use Tarrant	Tarrant	northwest	2001	\$ 3,500,000	2.5	Elevated			6343	1.461138	\$ 5,113,984
RR Travis	Travis	southeast	Jun-08	\$ 3,403,012	2	Elevated			8185	1.132315	\$ 3,853,282
Barton Hill Travis	Travis	southeast	Mar-03	\$ 2,753,000	2.7	Elevated			6627	1.398521	\$ 3,850,129
TWSP Hunt	Hunt	northeast	7/19/2006	\$ 1,750,000	6	Ground		Open	7721	1.200363	\$ 2,100,635
LAH Garza	Garza	northwest	2009	\$ 1,500,000	6	Ground		Open	8570	1.081447	\$ 1,622,170
RH Tarrant	Tarrant	northwest	2006	\$ 2,784,000	7	Ground		Open	7751	1.195717	\$ 3,328,875
BB Tarrant	Tarrant	northwest	2006	\$ 3,795,000	14	Ground		Open	7751	1.195717	\$ 4,537,745
Dog Collin	Collin	northeast	12/18/2007	\$ 1,500,000	2	Ground		Roof	8089	1.145753	\$ 1,718,630
Sys Collin	Collin	northeast	4/5/2006	\$ 1,595,000	3	Ground		Roof	7695	1.204418	\$ 1,921,047
Fla Dallas	Dallas	northeast	2004	\$ 1,800,000	8	Ground		Roof	7115	1.3026	\$ 2,344,680
Mou Tarrant	Tarrant	northwest	1998	\$ 200,000	0.3	Ground	Steel	Roof	5920	1.565541	\$ 313,108
Bro Brown	Brown	northwest	1995	\$ 400,000	1	Ground	Steel	Roof	5471	1.694023	\$ 677,609
Cit Erath	Erath	northwest	Sep-01	\$ 564,500	1	ground		Roof	6391	1.450164	\$ 818,618
TPS Ward	Ward	northwest	2011	\$ 1,300,000	2	Ground	Concrete	Roof	9070	1.02183	\$ 1,328,379
WFPS Ward	Ward	northwest	2011	\$ 1,300,000	2	Ground	Concrete	Roof	9070	1.02183	\$ 1,328,379
Bet Tarrant	Tarrant	northwest	2004	\$ 800,000	2	Ground	Steel	Roof	7115	1.3026	\$ 1,042,080
Bur Tarrant	Tarrant	northwest	2003	\$ 500,000	2	Ground	Steel	Roof	6694	1.384523	\$ 692,262
Tro Denton	Denton	northwest	1995	\$ 800,000	2	Ground	Steel	Roof	5471	1.694023	\$ 1,355,218
Mi Taylor	Taylor	northwest	2003	\$ 1,372,990	6	Ground	Concrete	Roof	6694	1.384523	\$ 1,900,937
RR WTP Denton	Denton	northwest	2003	\$ 1,300,000	6	Ground	Concrete	Roof	6694	1.384523	\$ 1,799,880
Mi Taylor	Taylor	northwest	2003	\$ 2,801,370	10	Ground	Concrete	Roof	6694	1.384523	\$ 3,878,562
Dom Brazos	Brazos	southeast	2002	\$ 500,000	3	Ground	Steel	Roof	6538	1.417559	\$ 708,779
Joh			2001	\$ 500,000	3	Ground	Steel	Roof	6343	1.461138	\$ 730,569
AM McLennan	McLennan	northeast	4/22/2010	\$ 419,500	0.75	Ground			8677	1.068111	\$ 448,073
AM Bastrop	Bastrop	southeast	3/3/2011	\$ 152,000	0.05	Ground			9011	1.028521	\$ 156,335
AM Travis	Travis	southeast	10/6/2010	\$ 280,000	0.25	Ground			8921	1.038897	\$ 290,891

Region	Bid Date	Pump Station Bid	Initial HP	Ultimate HP	Lake/River/Booster	CCI Bid Day Index	Percent Increase	Present Day Cost
northeast	9/28/2011	\$4,697,170	2400		Booster	9153	1.012564	\$4,756,185.85
Northeast	12/18/2007	\$2,854,400.00	800		Booster	8089	1.145753	\$3,270,438.77
Northeast	6/11/2008	\$2,855,000.00	200		Booster	8185	1.132315	\$3,232,759.93
northeast	7/19/2006	\$8,723,595.00	4300		Booster	7721	1.200363	\$10,471,477.59
northeast	6/15/2006	\$5,082,826	200	500	Booster	7700	1.203636	\$6,117,874.20
Northeast	4/5/2006	\$3,428,220	400		Booster	7695	1.204418	\$4,129,011.43
northeast	9/18/2001	\$11,219,955	13200		Booster	6391	1.450164	\$16,270,778.12
northeast	1990	\$1,592,479.00	300		Booster	4732	1.95858	\$3,118,997.33
northeast	1985	\$628,098	700		Booster	4195	2.209297	\$1,387,654.89
northeast	1990	\$1,031,468	900		Booster	4732	1.95858	\$2,020,212.47
Northeast	1987	\$4,000,000	6500		Booster	4406	2.103495	\$8,413,980.94
northwest	1993	\$2,652,521	10100		Booster	5210	1.778887	\$4,718,534.48
northwest	7/6/2011	\$3,708,200	600		Booster	9080	1.020705	\$3,784,977.71
northwest	2006	\$24,230,665	11800		Booster	7751	1.195717	\$28,973,010.35
Northwest	2006	\$15,164,527	11450		Booster	7751	1.195717	\$18,132,477.90
northwest	2/5/2004	\$5,391,000	4000	8750	Booster	6862	1.350627	\$7,281,228.21
northwest	1993	\$2,651,312	1800		Booster	5210	1.778887	\$4,716,383.80
northwest	6/28/2001	\$3,007,094	2900	3750	Booster	6318	1.46692	\$4,411,165.33
northwest	1993	\$2,642,887	3000		Booster	5210	1.778887	\$4,701,396.68
northwest	1999	\$4,968,117.00	3300		Booster	6059	1.529625	\$7,599,357.71
northwest	1993	\$2,706,706	4200		Booster	5210	1.778887	\$4,814,923.46
northwest	1993	\$2,625,259	6400		Booster	5210	1.778887	\$4,670,038.47
northwest	1999	\$5,568,854	7600		Booster	6059	1.529625	\$8,518,260.25
northwest	1993	\$2,721,831	9700		Booster	5210	1.778887	\$4,841,829.12
northwest	Sep-01	\$1,751,000.00	460		Booster	6391	1.450164	\$2,539,237.68
northwest	Apr-10	\$8,907,000	3414		Booster	8677	1.068111	\$9,513,665.55
northwest	Apr-10	\$10,867,000	6315		Booster	8677	1.068111	\$11,607,163.31
southeast	Mar-07	\$3,842,000	1250		Booster	7856	1.179735	\$4,532,542.77
	Apr-04	\$130,000.00	80		Booster	7017	1.320792	\$171,703.01
	Mar-08	\$2,304,000.00	300		Booster	8109	1.142928	\$2,633,305.22
	Apr-04	\$1,887,000	750		Booster	7017	1.320792	\$2,492,335.19

Project	County	Region	Bid Date	Pump Station Bid	Initial HP	Lake/River/Booster	CCI Bid Day Index	Percent Increase	Present Day Cost
Raw PS	Somervell	northwest	3/30/2006	\$4,055,000.00	2200	River	7692	1.204888	\$4,885,821.63
EFDPS	Kaufman	northeast	9/18/2006	\$22,464,685.00	1500	River	7763	1.193868	\$26,819,876.41
TWSPPLS	hunt	northeast	7/19/2006	\$10,146,578.00	6000	Intake	7721	1.200363	\$12,179,573.23
Raw Water No. 4	Collin	northeast	1994	\$7,463,784	2700	Intake	5408	1.713757	\$12,791,115.04
AI	Taylor	northwest	6/28/2001	\$9,592,906.50	2800	Intake	6318	1.46692	\$14,072,025.55
B	Tarrant	northwest	1997	\$10,051,288	6500	Intake	5826	1.5908	\$15,989,587.57
CL	Delta	northeast	1989	\$6,941,783	11600	Intake	4615	2.008234	\$13,940,725.26
PS1	Runnels	northwest	1993	\$6,347,000	13400	Intake	5210	1.778887	\$11,290,594.24
T	Grayson	northeast	1987	\$7,340,658	14300	Intake	4406	2.103495	\$15,441,039.12
RCL	Navarro	northeast	1987	\$8,254,113	20000	Intake	4406	2.103495	\$17,362,488.15
0630B			6/30/2011	\$8,774,941	700	Intake	9053	1.023749	\$8,983,337.37
AM0119A	Travis	Southeast	1/19/2009	\$154,764	200	Intake	8549	1.084103	\$167,780.18
San Marcos Raw Water Capacity Expansion Project - GBRA	Hays	Southeast	Mar-07	\$5,704,000	3500	Intake	7856	1.179735	\$6,729,209.78
APS	Hill	northeast	2/20/2000	\$2,205,270.00	900	Intake	6160	1.504545	\$3,317,928.95

Rural Costs										
Bid Date	Pipe Type	Pipe I.D.	Pipe Length	Time Adjustment		Present Day Unit Costs		Rural vs. Urban	Terrain Type	Region East/West
				Bid Day PPI Index	Percent Increase	Total Cost / LF	Pipe Cost / LF			
5/12/1988	Conc	72	52,822	105.6	2.006	\$366.54	\$328.54	Rural	mixed	east
11/10/1988	Conc	72	56,397	107.7	1.967	\$333.28	\$298.21	Rural	mixed	east
5/1/1989	Steel	72	31,452	111.4	1.901	\$355.46	\$319.05	Rural	mixed	east
5/21/1998	Conc	30	59,100	133.6	1.585	\$88.84	\$68.17	Rural	mixed	east
4/2/1992	Conc	53	285,035	116.6	1.816	\$170.51	\$161.63	Rural	mixed	west
4/2/1992	Conc	60	252,154	116.6	1.816	\$184.29	\$170.29	Rural	mixed	west
6/28/2001	Conc	36	270,851	140.6	1.506	\$114.30	\$99.72	Rural	mixed	west
10/22/1986	Conc	36	102,004	99.5	2.129	\$118.49	\$105.38	rural	mixed	
4/27/2004		36		150	1.412		\$317.70	rural	rock	
10/7/2004		30		156.6	1.352490421		\$163.11	rural	rock	
10/7/2004		30		156.6	1.352490421		\$168.52	rural	rock	
10/7/2004		36		156.6	1.352490421		\$233.98	rural	rock	
10/7/2004		16		156.6	1.352490421		\$60.56	rural	rock	
10/7/2004		24		156.6	1.352490421		\$93.28	rural	rock	
10/7/2004		24		156.6	1.352490421		\$83.36	rural	rock	
10/7/2004		30		156.6	1.352490421		\$110.63	rural	rock	
1/5/2005		12		157.4	1.345616264		\$41.37	rural	rock	
1/5/2005		14		157.4	1.345616264		\$51.76	rural	rock	
1/5/2005		16		157.4	1.345616264		\$60.10	rural	rock	
1/5/2005		18		157.4	1.345616264		\$65.54	rural	rock	
10/2/1986	Conc	90	95,825	99.5	2.129	\$414.34	\$334.94	rural	soil	east
5/27/1987	Conc	90	96,056	100.8	2.101	\$454.38	\$379.26	rural	soil	east
3/8/1990	Conc	36	27,352	112.5	1.883	\$113.21	\$88.92	Rural	soil	east
11/8/1990	Conc	30	39,838	115	1.842	\$122.91	\$97.49	Rural	soil	east
7/11/1991	Conc	24	62,649	115.3	1.837	\$71.13	\$61.70	Rural	soil	east
8/26/1992	Steel	84	58,475	116.8	1.813	\$376.68	\$323.92	Rural	soil	east
5/6/1993	Conc	84	72,831	121.6	1.742	\$340.06	\$313.37	Rural	soil	east
4/7/1994	Conc	84	76,094	123.8	1.711	\$357.05	\$328.78	Rural	soil	east
1/20/2000	Conc	24	164,430	138	1.535	\$83.93	\$61.39	Rural	soil	east
10/31/2000	Conc	36	102,553	139	1.524	\$133.95	\$91.23	Rural	soil	east
1/9/2001	Conc	36	80,440	138.6	1.528	\$136.62	\$100.76	Rural	soil	east
3/14/2002	Steel	54	39,495	137.9	1.536	\$238.28	\$184.83	Rural	soil	east
11/13/2008		16		194.3	1.090066907		\$74.97	rural	soil	east
11/13/2008		16		194.3	1.090066907		\$74.97	rural	soil	east
2/11/2010	Steel	42	30,280	192.7	1.099	\$287.85	\$189.74	Rural	Soil	east
2/11/2010	Steel	42	37,785	192.7	1.099	\$240.36	\$199.68	Rural	Soil	east
10/14/2010	Steel	96	28,436	198	1.070	\$822.95	\$641.99	Rural	Soil	east
4/2/1992	Conc	53	285,601	116.6	1.816	\$149.87	\$138.74	Rural	soil	west
12/17/2009	Conc	42	115,301	190.3	1.113	\$160.48	\$129.88	Rural	soil	west
12/17/2009		42		190.3	1.112979506		\$186.98	rural	soil	west
9/8/2010	Conc	48	72,204	197.2	1.074	\$261.78	\$221.40	Rural	Soil	west
1/12/2012	Steel	48	89,135	211.8	1.000	\$280.00	\$270.64	Rural	Soil	west
1/12/2012	Steel	42	76,139	211.8	1	\$358.50	\$220.00	Rural	Soil	west
1/12/2012	Steel	48	32,180	211.8	1	\$848.22	\$246.71	Rural	Soil	west
9/9/1999	Conc	54	188,877	137.2	1.544	\$201.04	\$184.18	Rural	soil	
12/3/2003		42		142.5	1.486315789		\$326.00	Rural	soil	
12/3/2003		42		142.5	1.486315789		\$326.00	Rural	soil	
12/14/2006		16		175.9	1.204093235		\$59.67	rural	soil	
12/14/2006		20		175.9	1.204093235		\$72.28	rural	soil	
12/14/2006		16		175.9	1.204093235		\$63.52	rural	soil	
12/14/2006		20		175.9	1.204093235		\$78.11	rural	soil	
12/24/2006		12		175.9	1.204093235		\$32.51	rural	soil	east
12/24/2006		12		175.9	1.204093235		\$32.51	rural	soil	east
4/3/2007		16		180.9	1.170812604		\$88.53	rural	soil	
4/3/2007		16		180.9	1.170812604		\$92.65	rural	soil	
4/21/2009	Conc	48	67,081	186.6	1.135	\$191.43	\$161.85	Rural	soil	
10/1/2009		24		188.8	1.121822034		\$161.54	rural	soil	east
5/1/2010		24		198.6	1.066465257		\$127.98	rural	soil	
3/1/2011		30		208.7	1.014853857		\$180.77	rural	soil	
3/1/2011		36		208.7	1.014853857		\$234.45	rural	soil	
3/1/2011		42		208.7	1.014853857		\$290.65	rural	soil	
10/9/2003	Conc	36	35,790	142.4	1.487	\$17.00	\$106.30	Rural	soil	east
5/16/2006	Steel	72	32,026	176.5	1.200	\$487.10	\$442.80	Rural	soil	east
6/20/2006	Steel	84	57,474	177.8	1.191	\$824.68	\$660.10	Rural	soil	east
8/17/2006	Steel	84	67,423	179.4	1.181	\$731.93	\$602.50	Rural	soil	east
11/2/2006	Conc	60	50,690	175.4	1.208	\$412.50	\$334.36	Rural	soil	east
11/15/2006	Conc	54	38,662	175.4	1.208	\$352.18	\$294.76	Rural	soil	east

Urban Costs										
Bid Date	Pipe Type	Pipe I.D.	Pipe Length	Time Adjustment		Present Day Unit Costs		Rural vs. Urban	Terrain Type	Region East/West
				Bid Day PPI Index	Percent Increase	Total Cost / LF	Pipe Cost / LF			
5/28/1987	Steel	108	30,977	100.8	2.101	\$656.18	\$593.84	Urban	mixed	east
12/5/1996	Conc	90	39,026	132.5	1.598	\$686.53	\$394.41	Urban	mixed	east
10/8/1998	Conc	60	64,021	133.5	1.587	\$282.91	\$215.77	Urban		east
9/15/2004	Conc	42	35,659	155.4	1.000	\$219.50	\$154.70	urban		east
12/14/2004	FBGL	60	29,037	155.5	1.362	\$448.95	\$405.89	Urban		east
6/28/2005	Conc	30	41,986	162.4	1.304	\$237.69	\$136.94	Urban	Soil	east
4/28/2006	Steel	96	55,528	174.8	1.212	\$954.13	\$740.35	Urban	mixed	east
6/29/2006	Steel	84	47,025	177.8	1.191	\$1,056.79	\$763.71	Urban	soil	east
6/27/2007	PVC	30	27,638	182.3	1.162	\$234.53	\$128.96	Urban		east
10/1/2009	PVC	30	40,333	188.8	1.122	\$191.73	\$109.96	Urban		east
4/19/2005		36		161.7	1.309833024		\$326.18	urban	soil	
2/28/2007		16		176.8	1.197963801		\$166.02	urban	soil	
2/28/2007		30		176.8	1.197963801		\$214.04	urban	soil	
4/12/2010		24		197.4	1.072948328		\$110.51	urban	soil	east
11/2/2010		48		199	1.064321608		\$478.63	urban	soil	west

Project	Organization	Normal Storage (ac-ft)	Bid Year	Bid Amount	CCI Cost Index	Percent Change	Normalized Amount	Cost per Acre-foot	Comments	County	Nearest Town	Distance from Nearest Town (miles)
Alan Henry	Lubbock	11,5937	1991	\$29,317,871	4835	1.91855256		\$0.00		Garza, Kent	Wichita Falls	10
Arrowhead Lake	City of Wichita Falls	262,100	1965	\$12,500,000	5971	9.54799176		\$0.00		Clay	Wichita Falls	13
Atkins, Lake	Atkins Municipal Water Authority	32,790	1961	\$361,000	5897	10.92428876	\$3,950,115.70	\$120.47		Henderson	Atkins	8
Bonham, Lake	Bonham Municipal Water Authority, City of Bonham	12,000	1967	\$500,000	\$1,074	8.62942719	\$4,314,711.36	\$359.56		Fannin	Bonham	5
Brady Creek Reservoir	City of Brady	30,430	1961	\$1,004,277	5847	10.94214876	\$11,426,634.28	\$375.51		McCulloch	Brady	3
Brandy Branch Cooling Pond	AEP-Southwestern Electric Power Company	29,513	1981	\$5,407,659	\$1,535	2.621782178	\$14,177,703.99	\$480.39		Harrison	Hallsville	10
Brazoria Reservoir	Dow Chemical	21,970	1953	\$1,500,000	5600	15.44666667	\$23,170,000.00	\$1,054.62		Brazoria	Brazoria	1
Caddo Lake	Northeast Texas Municipal Water District	129,000	1968	\$3,172,609	\$5,826	1.902798963	\$3,503,421.18	\$0.00		Caddo Parish (LA)	Shreveport, LA	19
Capp Smith Park	Watauga	42	1997	\$2,202,300	\$5,826	1.902798963	\$3,503,421.18	\$0.00		Tarrant	Watauga	0
Champion Creek Reservoir	Luminant Generation Company LLC dba Luminant Power	42,500	1958	\$1,142,830	5759	12.21086369	\$13,954,872.78	\$328.35		Mitchell	Colorado City	7
Cherokee, Lake	Cherokee Water Company	45,016	1948	\$658,182	\$461	20.10412148	\$13,232,170.88	\$293.94		Gregg, Rusk	Longview	12
Clyde, Lake	City of Clyde	5,748	1969	\$270,000	\$1,269	7.303388495	\$1,971,914.89	\$431.06		Callahan	Clyde	6
Coleman, Lake	City of Coleman	40,000	1965	\$1,227,648	5971	9.54799176	\$11,717,653.62	\$292.94		Coleman	Coleman	14
Cypress Springs, Lake	Franklin Co Water District	72,800	1968	\$1,270,000	\$1,155	8.024242424	\$10,190,787.88	\$139.98		Franklin	Mount Vernon	8
Graham, Lake (Edleman)	City of Graham	53,680	1928	\$237,100	\$207	44.77294686	\$10,615,665.70	\$197.76		Young	Graham	2.2 miles NW
Graham, Lake	City of Graham	53,680	1956	\$486,490	5692	13.39306358	\$6,515,931.50	\$121.38		Young	Graham	2.2 miles NW
Greenbelt Lake	Greenbelt MWDA	60,400	1966	\$1,795,514	\$1,019	9.095191364	\$16,330,443.43	\$270.37		Donley	Clarendon	5
Houston County Lake	Houston Co WICID No 1	19,500	1966	\$500,000	\$1,019	9.095191364	\$4,547,995.68	\$233.21		Houston	Crockett	10
Hubert H Moss Lake	City of Gainesville	23,210	1964	\$820,760	5936	9.10709402	\$8,126,927.01	\$350.15		Cooke	Gainesville	10
J.B. Thomas, Lake	Colorado River Municipal Water District	203,600	1951	\$1,452,877	5943	17.06819996	\$9,040,317.92	\$0.00		Scurry	Snyder	16
Jacksonville, Lake	City of Jacksonville	30,500	1956	\$675,000	5692	13.39306358	\$3,988,434.31	\$94.89		Cherokee	Jacksonville	5
Johnson Creek Reservoir	AEP-Southwestern Electric Power Company	10,100	1960	\$354,604	\$824	11.24757282	\$3,994,341.31	\$394.89		Marion	Jefferson	13
Kickapoo, Lake	City of Wichita Falls	106,000	1945	\$3,500,000	\$308	30.09090909	\$1,794,541.19	\$0.00		Archer	Archer City	10
Kurtz, Lake	Abitibi Consolidated Industries	16,200	1959	\$2,500,000	\$797	11.62860728	\$29,071,518.19	\$1,794.54		Angelina	Lufkin	8
Lake Amon G Carter	City of Bowie	20050	1955	\$320,046	\$669	14.04242424	\$4,494,271.71	\$224.15		Montague	Bowie	6
Lake Arlington	City of Arlington	45,710	1956	\$3,883,700	\$692	13.39306358	\$51,345,121.79	\$1,123.28		Tarrant	Arlington	7
Lake Inocna	North Montague Co WSD	25,400	1953	\$395,005	\$797	11.62860728	\$4,593,358.02	\$180.84		Montague	Inocna	8
Leon, Lake	Eastland County Water Supply District	27,290	1996	\$396,392	\$600	15.44666667	\$6,122,935.09	\$224.37		Eastland	Ranger	7 miles S
Liberty Flood Control Levee, Ph I				\$1,629,480	\$5,620	1.64911032		#DIV/0!				
Liberty Flood Control Levee, Ph II				\$1,057,954	\$5,920	1.565540541		#DIV/0!				
Mackenzie Municipal Water Authority Reservoir	Mackenzie Municipal Water Authority	46,450	1972	\$2,636,390	\$1,753	5.28693668	\$13,938,426.99	\$300.07		Briscoe	Silverton	9 miles NW
Millers Creek Reservoir	North Cent. Tex. MWA Et Al	25,520	1972	\$1,204,960	\$1,753	5.28693668	\$7,848,713.32	\$287.84		Byelor & Throckmold	Goree	9 miles SE
Mitchell County Reservoir	Colorado River Municipal Water District	27,266	1991	\$4,094,315	\$4,835	1.91856256	\$7,848,713.32	\$287.84		Mitchell	Coahoma	10 miles SW
Munual, Lake	Paola County Fresh Water, SD #1	44,650	1956	\$1,600,000	\$692	13.39306358	\$21,438,901.73	\$479.93		Paola	Carthage	10 miles SW
Nacogdoches, Lake	City of Nacogdoches	41,140	1977	\$2,992,915	\$3,576	3.597826687	\$10,767,887.66	\$261.74		Nacogdoches	Nacogdoches	10 miles W
New Terrell City Lake	City of Terrell	8,772	1955	\$169,900	\$660	14.04242424	\$2,385,807.88	\$273.85		Kaufman	Terrell	6 miles E
North Fork Buffalo Creek Reservoir	City of Iowa Park	15,400	1964	\$542,880	5996	9.10709402	\$5,375,440.00	\$349.05		Wichita	Iowa Park	5 miles NW
North Lake	Luminant Generation Company LLC dba Luminant Power	17,000	1950	\$550,000	5692	13.39306358	\$7,366,184.97	\$433.30		Dallas	Coppell	2 miles SE
Oak Creek Reservoir	City of Sweetwater	39,360	1950	\$411,113	\$510	18.17254902	\$7,470,971.15	\$189.81		Dallas	Coppell	2 miles SE
Palentine, Lake	Upper Neches River Municipal Water Authority	411,844	1960	\$1,950,000	\$824	11.24757282	\$38,287,925.38	\$759.47		Anderson, Cherokee	Frankston	4 miles W
Palo Duro Reservoir	Palo Duro River Authority	60,897	1988	\$17,200,100	\$4,519	2.050896216	\$5,114,205.55	\$138.44		Hansford	Spearsman	12 miles N
Palo Pinto, Lake	Palo Pinto County MWD No. 1	44,100	1963	\$594,400	\$901	10.2863485	\$6,114,205.55	\$539.95		Palo Pinto	Mineral Wells	15 miles SW
Pat Cleburne, Lake	City of Cleburne	25,580	1963	\$1,316,600	\$901	10.2863485	\$13,543,006.44	\$539.95		Johnson	Cleburne	4 miles SW
Raw Water Storage Reservoir	Durant, OK	4278	1991	\$4,224,191	\$4,835	1.91856256	\$8,097,166.18	\$1,892.75		Bryan	Durant, OK	8 miles SW
Red Draw Reservoir	Colorado River Municipal Water District	8,538	1941	\$1,997,948	\$4,146	2.23407622	\$3,572,065.14	\$418.37		Howard	Big Spring	5 miles E
Stamford, Lake	City of Stamford	57,630	1994	\$289,365	\$258	35.92248062	\$10,394,708.60	\$180.37		Haskell	Haskell	10 miles SE
Tawakoni, Lake	Sabine River Authority of Texas	916,200	1958	\$4,301,200	\$759	12.21086369	\$5,408,000.00	\$0.00		Reins, Van Zandt, H	Wills Point	9 miles NE
Terminal Storage	CRMW		1994		\$5,408	1.713757396		#DIV/0!				
Twin Buttes Reservoir	Bureau of Reclamation - USDOI	186,200	1960	\$1,186,626	824	11.24757282	\$23,234,059.95	\$540.33		Tom Green	San Angelo	8 miles SW
Tyler, Lake	City of Tyler	43,000	1949	\$1,195,797	\$477	19.42976959	\$16,836,388.50	\$414.69		Smith	Tyler	12 miles SE
Tyler East, Lake	City of Tyler	40,600	1967	\$1,951,033	\$1,074	8.62942719	\$5,541,915.78	\$284.04		Smith	Tyler	12 miles SE
Upper Neches, Lake	Zavala Dimmitt Counties, WID No. 1	17,590	1956	\$225,900	\$692	13.39306358	\$5,541,915.78	\$284.04		Zavala	Crystal	6 miles E
Weatherford Lake	City of Weatherford	19,470	1956	\$2,428,460	\$746	1.244695138	\$13,142,699.87	\$3,191.52		Parker	Weatherford	7 miles N
Welsh Reservoir	AEP-Southwestern Electric Power Company	23,587	2005	\$10,558,971	\$7,446	1.244695138	\$13,142,699.87	\$3,191.52		Thus	Cason	7 miles E
Wheeler Branch Dam	White River Municipal Water District	38,600	1962	\$960,062	\$872	10.62844037	\$10,203,961.72	\$264.35		Somerville	Glen Rose	16 miles SE
White River Lake	City of Wichita Falls	14,000	1900	\$350,000	#DIV/0!		\$10,203,961.72	\$0.00		Crosby	Wichita Falls	6 miles SW

APPENDIX B
Pipeline Route and Profile Generation Procedures

Using the pipeline route selection guidelines, a route can be defined, and then a corresponding profile generated. These tasks have typically been accomplished by manual methods in the past. The manual process entails drawing a route on a topographic map, setting points that define the ground profile, and measuring the stations and recording the corresponding ground elevations. Performing these tasks, especially recording the profile data, can be very tedious and time consuming. Advancements in computer technology and the growth of Geographic Information Systems (GIS) have resulted in mapping tools that can accelerate this process significantly. The definition of GIS is as follows:

Geographic Information Systems (GIS) – an organized collection of computer hardware, software, geographic data, and personnel, designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced data.

For study planning purposes, the definition may be summarized as follows:

Geographic Information Systems (GIS) – a system for utilizing data that is linked spatially to a geographic reference.

GIS should be used to the greatest extent practical as the means for laying out a pipeline route and “capturing” the profile information because it offers increased efficiency and speed in performing these tasks. An appropriate set of tools useful in determining pipeline routes and profiles consists of the following:

- **ArcGIS** – This is a mapping and GIS software package created by ESRI⁹. It has capabilities for creating maps, adding features (such as pipeline routes) to existing maps, and for readily integrating multiple geographically referenced databases.
- **Digital Elevation Model (DEM)** – DEMs are files that have ground elevation data located at regularly spaced intervals in a geographic area. These files provide elevation data only.
- **United States Geological Survey (USGS) Topographic Maps** - USGS topographic maps are available in electronic format locally through the Texas Natural Resources Information System (TNRIS).

⁹ <http://www.esri.com/>

- **Topologically Integrated Geographic Encoding and Referencing (TIGER) Maps**
 - These are mapping files prepared by the United States Census Bureau. TIGER maps show many of the items that are shown on USGS topographic maps, such as rivers, lakes, roadways, railroads, and urban centers. It does not, however, provide information on ground elevation data and vegetation conditions. Data such as population counts and political boundaries may be spatially linked to the map. Though void of ground elevation data, these maps can be very useful for determining a pipeline alignment.
- **Texas Department of Transportation (TxDOT) Highway Maps** - County highway maps are available in electronic format.
- **Model Builder Profile Tool** –This is a custom built tool within the ArcGIS software to extract the station and elevation data along a specified route and save it to an exportable data file.
- **Aerial Photography** – Current aerial photography, that can be accessed online or via various agencies, that are useful to determine urban development along the specified route.

Because of the time reduction that GIS can offer in route selection and profile generation, using GIS is clearly the preferred method for technical evaluation of water management strategies considered in the regional water planning process. If there is a reason that GIS can not be used, the manual approach previously summarized should be followed. The steps for laying out a pipeline and profile generation using GIS are as follows:

5. Consult with a GIS specialist.
6. Using the ArcGIS package, lay out a pipeline route on a topographic, current aerial photography, TIGER, or highway map that is overlaid on a corresponding DEM. Define and draw a route on the map following the route selection guidelines. If a TIGER or TxDOT map is used to layout a route, it is a good idea to check the pipeline alignment on a USGS topographic map or current aerial photography to identify potentially undesirable land features along the pipeline. For example, make sure that the route is not traversing

extremely rough terrain or that it is not going over a high peak when there is relatively flat ground close by. Additionally, USGS maps may provide more details regarding features that need to be accounted for such as stream crossings along the pipeline route. Once created, the pipeline route can easily be placed on different types of map files, with the location on each being determined using latitude and longitude coordinates (i.e. geo-referenced).

7. Extract profile data using the Profiler tool¹⁰. The station interval distance can be specified with the software, and should be such that the general land features are recorded while capturing points of significant elevation changes. Begin stationing at the water source for consistency. Save the profile data to an electronic file.
8. Generate a plot of the ground profile using a spreadsheet. The data saved in step three will probably have to be “delimited” so that it can be read directly into columns of a spreadsheet. The plot will have elevations on the vertical axis and stations on the horizontal axis (see Figure 1). Treat the ground profile as if it were the pipeline profile for regional planning purposes, therefore, no adjustments to the elevation data will need to be made for pipe burial. In an actual pipeline design project the ground profile would be plotted along with a profile of the pipeline beneath the ground surface by a specified amount of ground cover.

¹⁰ Profiler Tool is part of ESRI's 3D Spatial Analyst Package

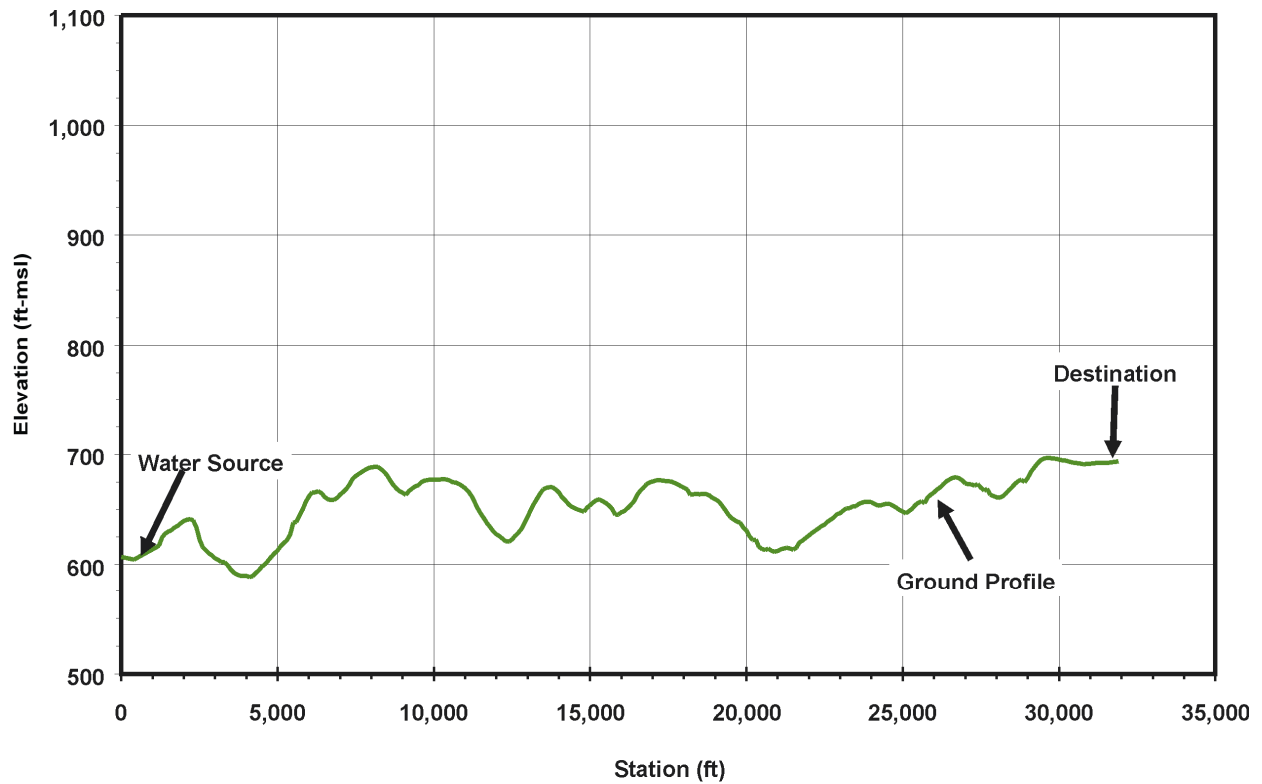


Figure 1. Typical Ground Profile Plot

In addition to generating a profile, there are several tasks that must be performed after the pipeline route is established. These tasks include determining the number and length of pipeline crossings that are likely to require special installations utilizing trenchless technology construction techniques. Such crossings may include streams, roads, railways, and major rivers. In addition, the soil conditions along the route should be categorized utilizing available information. This information is needed in order to prepare the construction cost estimate.

APPENDIX C
Drought Management Methodology
(Excerpt from the 2011 South Central Texas Regional Water Plan)

4C.2 Drought Management

4C.2.1 Description of Water Management Strategy

Texas Administrative Code (TAC), Chapter 357 Regional Water Planning Guidelines, states that “Regional water plan development shall include an evaluation of all water management strategies the regional water planning group determines to be potentially feasible, including drought management measures including water demand management [357.7(a)(7)(B)].” As defined here, drought management means the periodic activation of approved drought contingency plans resulting in short-term demand reduction. This reduction in demand is then considered a “supply” source. Using this approach, an entity may make the conscious decision not to develop firm water supplies greater than or equal to projected water demands with the understanding that demands will have to be reduced or go unmet during times of drought. Using this rationale, an economic impact of not meeting projected water demands can be estimated and compared with the costs of other potentially feasible water management strategies in terms of annual unit costs.

Figure 4C.2-1 shows how water supply planning was done in the 2007 State Water Plan and 2006 Regional Water Plans. For each Water User Group (WUG) with an identified shortage or need during the planning period, a future water supply plan was developed consisting of one or more water management strategies. In each case, the planned future water supply was greater than the projected dry weather demand to allow for drought more severe than the drought of record, uncertainty in water demand projections, and/or available supply from recommended water management strategies. This difference between planned water supply and projected dry weather demand is called management supply in Region L.

Figure 4C.2-2 illustrates how a drought management water management strategy (WMS) could alter the planning paradigm for WUGs with projected needs. Instead of identifying water management strategies to meet the projected need, planned water supply remains below the projected dry weather water demand. The difference between these two lines represents the drought management WMS. Under this concept, a WUG’s water demand would be reduced by activating a drought contingency plan to reduce demands, resulting in unmet needs. This strategy of demand reduction could negate the need for water management strategies to meet the full projected need of the WUG. Basically, using this approach,

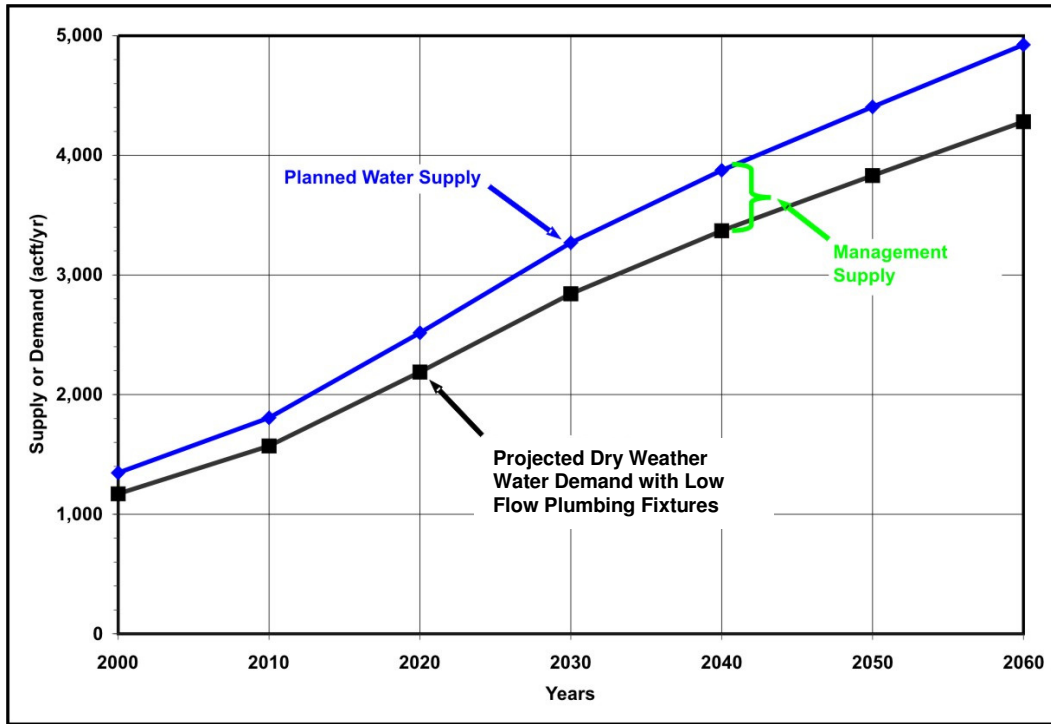


Figure 4C.2-1. Typical Planning in 2006 Regional Water Plan

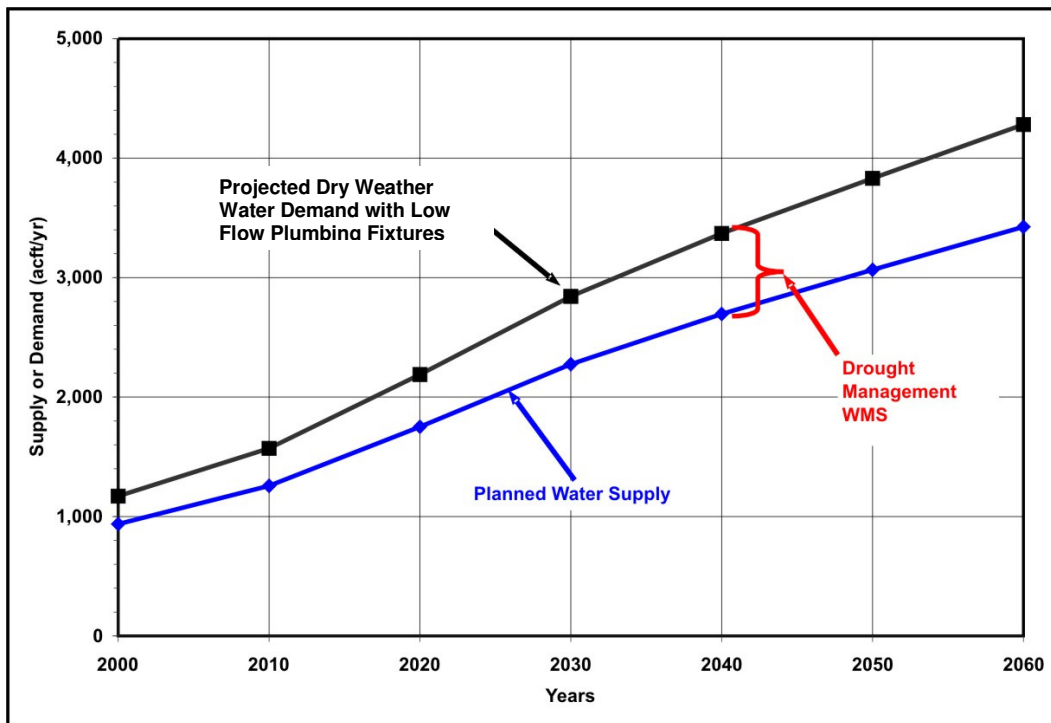


Figure 4C.2-2. Planning with Drought Management Water Management Strategy

the WUG is planning to manage water shortages through drought contingency plan activation. This concept is more fully illustrated in Figure 4C.2-3, which shows that, in any given year, the actual demand may be above or below the planned supply. During times in which the demand exceeds supply, the WUG would experience shortages and incur associated economic impacts.

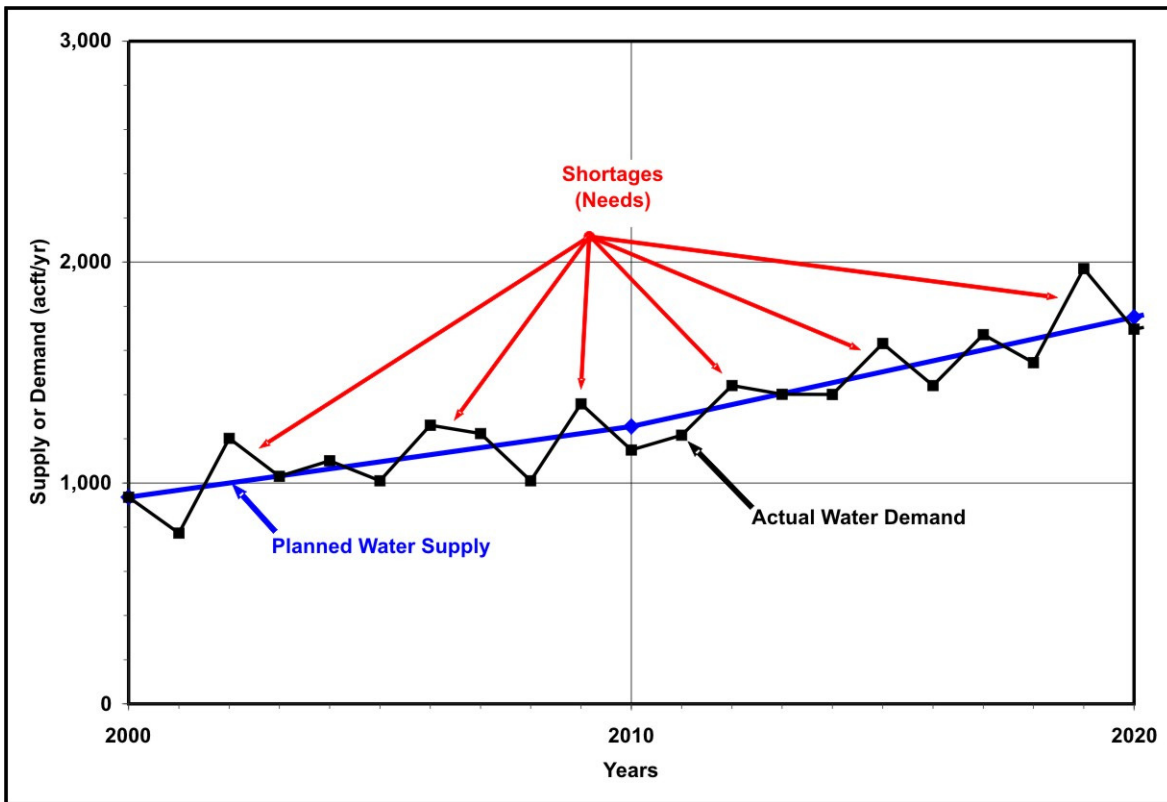


Figure 4C.2-3. Example Drought Management Water Management Strategy

4C.2.2 Drought Management Strategy Methodology

As shown in Figure 4C.2-4, there are a number of incremental steps to calculating a unit cost for this strategy so that it can be compared to other strategies. The first step in the process is to calculate a risk factor for the 5% reduction, 10% reduction, 15% reduction, and 20% reduction cases. Figure 4C.2-5 illustrates the 5% reduction scenario. The risk factor is defined as the integrated chance of occurrence of potential annual demands in excess of planned supply based on historical per capita variations for each entity. A 5% Drought Management WMS, for example, equates to planned supply that is 95% of projected demand.

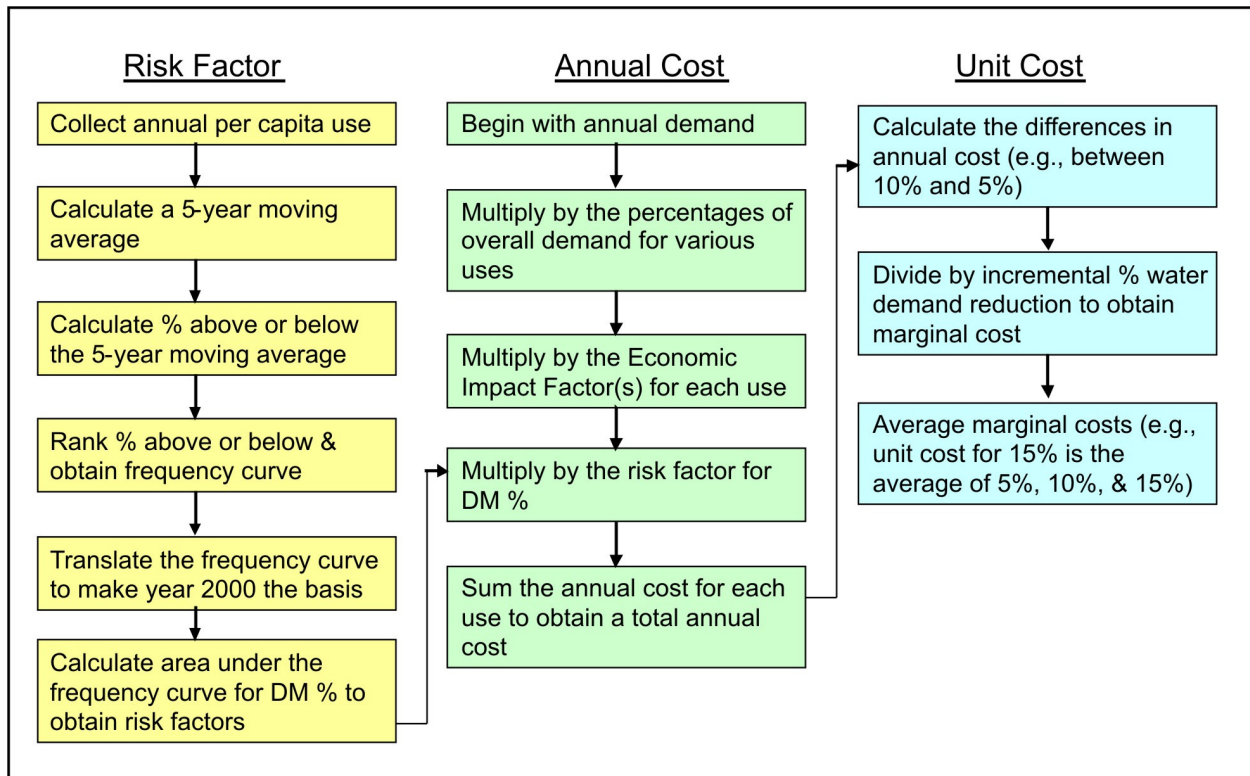


Figure 4C.2-4. Methodology Flowchart

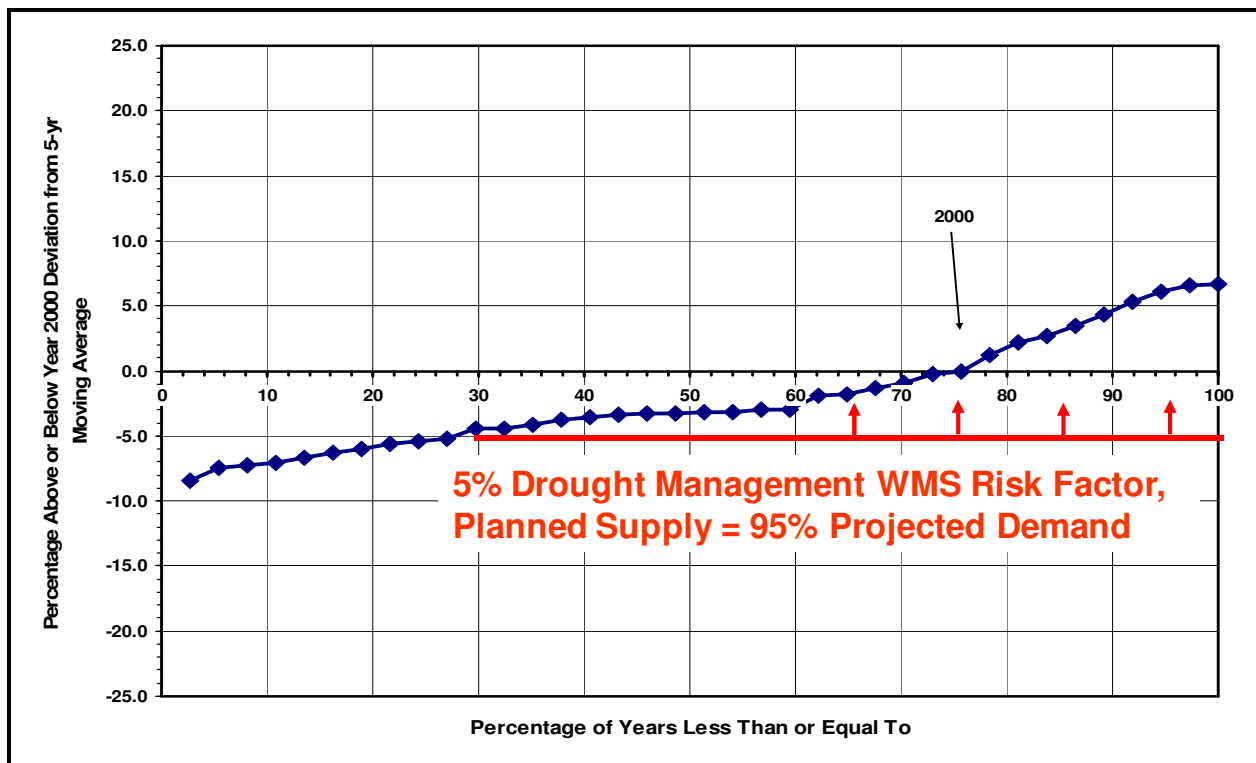


Figure 4C.2-5. Frequency of Per Capita Water Use Variations Adjusted to Basis of Demand Projections

The first step in determining the risk factors was to obtain historical annual per capita water use values. These data were obtained from the TWDB for the period 1964 to 2004, if available. From these data, a 5-year moving per capita water use average was calculated in order to limit the effects of trends in per capita water use rates. Next, an annual percentage above or below the 5-year moving average was calculated. These values were then ranked lowest to highest. A frequency curve was then developed using these data with the percentage above or below the 5-year moving average on the y-axis and the percentage of years less than or equal to that value on the x-axis. Finally, this curve was translated so that the year 2000 value was placed at 0 on the y-axis (Figure 4C.2-5) because year 2000 was used by the TWDB as the basis for demand projections in the 2011 regional water plans. From a plot like Figure 4C.2-5, the integrated area under the frequency curve was calculated as the risk factor. Using formulas developed in Excel, a chart of risk factors was developed for each WUG for each ½% reduction in water use. Using data supplied by the TWDB which shows the % of water use for each WUG that is considered to be residential/domestic, the % reduction in this use type was determined for each of the determined drought management levels (5%, 10%, 15%, and 20%). In other words, reductions in use were focused on residential use first. In this case, all reductions in residential use are attributed to outdoor water use and no reductions in indoor residential water use were assumed to occur. For example, a 10% reduction in overall water use for a WUG may reflect a 12% reduction in residential water use, depending on the amount of water used for other purposes. Using the chart developed above, the risk factor associated with a 12% reduction in use (10% overall) was determined. If an overall 20% reduction in water use could be obtained without exceeding a 25% reduction in residential use, the use for other water users was not affected. If however, for certain WUGs (Kyle, New Braunfels, BMWD, and SAWS) this was not the case. For these WUG, residential water use was reduced by 25% with the remaining reduction being split evenly between commercial and industrial use.

After risk factors for each scenario were calculated, an annual cost was then calculated using the following formula:

$$(\text{Demand}) \times (\% \text{Demand}) \times (\text{Risk Factor}) \times (\$ \text{Impact Factor}) = \text{DM WMS Annual Cost}$$

where:

- Demand (acft/yr) = Projected “dry year” demand from TWDB based on year 2000 per capita use rate (projected demand in year 2010 was used);

- % Demand = Proportion of water demand associated with various use types (i.e., residential, commercial, and manufacturing);
- Risk Factor = Integrated chance of occurrence of potential annual demands in excess of planned supply based on historical per capita use variations for each entity;
- \$ Impact Factor (\$/acft) = Economic impact factors used by TWDB (see Table 4C.2-1) to calculate economic impacts of not meeting needs. TWDB factors used include (a) lost sales for water-intensive commercial users; (b) costs to non-water-intensive commercial businesses and households; and (c) lost sales for manufacturing; and
- DM WMS Annual Cost (\$/yr) = Typical annual economic impacts of adhering to the Drought Management WMS for that water use type. The annual cost for each use type (i.e., domestic, commercial, and manufacturing) were then summed to obtain a total annual cost.

The final step in this process was to convert the annual cost to a unit cost so that this strategy could be compared to other potentially feasible water management strategies. In order to do this, the difference between the annual cost for each scenario were first calculated (i.e., between 10% and 5%). This value was then divided by a 5% water demand reduction from the year 2010 demand to obtain a marginal cost. Finally, the marginal cost values were averaged to obtain a unit cost (i.e., the unit cost for 15% is the average of 5%, 10%, and 15%).

An example cost calculation for the City of Uvalde is provided in Tables 4C.2-2 and 4C.2-3. Using data supplied by the TWDB (Table 4C.2-1), the “Share of WUG’s Need Applied to Factor” row is populated. In this case, 80% of the demand is applied to Domestic/Residential use and 20% to Commercial use. There is no demand associated with Manufacturing for the City of Uvalde. Next, the demand associated with each water use is determined by multiplying the total year 2010 demand times the percentage associated with each use type (i.e., 6,087 acft x .80 = 4,870 acft for domestic/residential demand). Using the methodology described above, the risk factor was determined for each scenario. Next, the economic impact factor was determined for each use type using the data supplied by the TWDB and shown in Table 4C.2-1. These factors are constant from one drought management scenario to the next, with the exception of the factors for Domestic/Residential which were determined by interpolating between the values

Table 4C.2-2.
5% Drought Management Scenario (City of Uvalde)

	Domestic/ Residential	Com- mercial	Manu- facturing	Total/ Combined
Share of WUG's Need Applied to Factor (%)	80%	20%	0%	
Proportional Demand (acft)	4,870	1,217	0	
5% DM WMS Risk Factor	0.0007	0.0000	0.0000	
5% Reduction Economic Impact Factor (\$/acft)	\$949	\$52,120	-	
5% DM WMS - Total Economic Impact (\$)	\$3,375	\$0		\$3,375

Table 4C.2-3.
10% Drought Management Scenario (City of Uvalde)

	Domestic/ Residential	Com- mercial	Manu- facturing	Total/ Combined
Share of WUG's Need Applied to Factor (%)	80%	20%	0%	
Proportional Demand (acft)	4,870	1,217	0	
10% DM WMS Risk Factor	0.0038	0.0000	0.0000	
10% Reduction Economic Impact Factor (\$/acft)	\$1,095	\$52,120	-	
10% DM WMS - Total Economic Impact (\$)	\$20,363	\$0		\$20,363

supplied by the TWDB for the risk factor associated with scenario. For example, for the 5% drought management scenario (a 6.3% reduction in residential/domestic use) for the City of Uvalde, the associated economic impact factor for domestic/residential is \$949; however, for the 10% reduction scenario (a 12.5% reduction in residential/domestic use), the economic impact factor is \$1,095. Next the total economic impact for each use type is calculated by multiplying the proportional demand times the risk factor times the economic impact factor (i.e., 4,870 acft x 0.0038 x \$1,095/acft = \$20,363 for the residential sector with a 10% reduction). This same formula was used to determine the economic impact for each use type. Note, that the only WUGs for which commercial and manufacturing water use was reduced are Kyle, New Braunfels, BMWD, and SAWS, and only for the 20% reduction scenario. Next, the economic impacts for each use type were summed to obtain a total economic impact (in this case and most cases just for domestic/residential). This type of process was used to determine the total economic impact for each of the drought management scenarios.

To determine the unit cost for the 10% drought management scenario for Uvalde, the following steps were completed. First, marginal costs for both the 5% and 10% scenarios were calculated. For the 5% scenario, this is simply the total economic impact divided by 5% of the total year 2010 demand (i.e., $\$3,375 / 304 \text{ acft} = \$11/\text{acft}$). For the 10% scenario, a marginal cost must first be calculated. This is calculated as the difference in total economic impact between the 10% and 5% drought management scenarios, divided by 5% of the total year 2010 demand (i.e., $(\$20,263 - \$3,375) / 304 \text{ acft} = \$56/\text{acft}$). To calculate the unit cost for the 10% drought management scenario, the marginal costs of the 5% and the 10% scenario are averaged (i.e., $(\$11 + \$56) / 2 = \$33/\text{acft}$).

4C.2.3 Yield from Drought Management Strategy

The yield associated with drought management is simply the year 2010 projected demand times the appropriate percentage depending upon which scenario is used (5%, 10%, 15% or 20%). These values are summarized below in Table 4C.2-4.

4C.2.4 Drought Management Strategy Costs

For each selected WUG, risk factors for 5%, 10%, 15%, and 20% drought management scenario reductions were calculated (Table 4C.2-5). For the 5% reduction scenario, the risk factors ranged from 0.0005 for the City of Point Comfort, indicating there is very little risk of a higher per capita use rate occurring than what occurred in the year 2000, to 0.1652 for the City of Castroville, indicating a much greater risk of demand being greater than supply. For the 20% scenario, the risk factors ranged from a low of 0.0136 for the City of Point Comfort to a high of 0.3113 for Atascosa Rural WSC. The risk factors associated with the commercial and manufacturing uses in Kyle, New Braunfels, BMWD, and SAWA are 0.0713, 0.0170, 0.1730, and 0.0820 respectively.

As described above, these risk factors were then used to determine an annual cost for a planned supply less than demand for the year 2010 (Table 4C.2-6). For the 5% reduction scenario, the annual cost ranged from \$106 for the City of Point Comfort to a cost of almost \$5.7 million for SAWS. For the 20% reduction scenario, the annual cost ranged from \$4,979 for the

**Table 4C.2-4.
Drought Management Yield**

Entity	Yield (acft)			
	5%	10%	15%	20%
Alamo Heights	104	207	311	414
Aqua WSC	13	27	40	53
Atascosa Rural WSC	47	94	141	188
Castle Hills	41	82	123	164
Castroville	34	68	102	136
County Line WSC	58	115	173	230
East Medina SUD	44	88	132	176
Garden Ridge	28	57	85	113
Hill Country Village	42	84	126	168
Hollywood Park	116	231	347	463
Hondo	89	178	268	357
Jourdanton	40	80	120	160
Kirby	50	101	151	201
Kyle	137	274	411	548
La Coste	10	21	31	41
Lockhart	123	245	368	490
Luling	53	107	160	213
Lytle	24	48	72	96
Martindale	6	13	19	25
Martindale WSC	9	19	28	38
Natalia	17	33	50	66
New Braunfels	525	1,051	1,576	2,102
Point Comfort	11	22	34	45
Sabinal	20	41	61	81
San Antonio (BMWD)	1,233	2,465	3,698	4,931
San Antonio (SAWS)	9,883	19,767	29,650	39,534
Shavano Park	41	82	123	164
SS WSC	78	156	234	313
Universal City	130	261	391	522
Uvalde	304	609	913	1,217
Water Services, Inc.	48	95	143	190
Woodcreek	12	25	37	49

**Table 4C.2-5.
Risk Factors**

Entity	Risk Factors			
	5%	10%	15%	20%
Alamo Heights	0.1254	0.1765	0.2280	0.2853
Aqua WSC	0.1439	0.1918	0.2445	0.2924
Atascosa Rural WSC	0.1620	0.2100	0.2631	0.3113
Castle Hills	0.0939	0.1465	0.1976	0.2551
Castroville	0.1652	0.2088	0.2569	0.3090
County Line WSC	0.0077	0.0121	0.0175	0.0287
East Medina SUD	0.0785	0.1245	0.1762	0.2293
Garden Ridge	0.0202	0.0365	0.0573	0.0933
Hill Country Village	0.0162	0.0236	0.0325	0.0462
Hollywood Park	0.0145	0.0250	0.0422	0.0727
Hondo	0.1242	0.1724	0.2250	0.2785
Jourdanton	0.0833	0.1157	0.1519	0.1916
Kirby	0.0473	0.0886	0.1419	0.1990
Kyle	0.0820	0.1332	0.1867	0.2328
La Coste	0.0299	0.0589	0.1077	0.1531
Lockhart	0.1143	0.1711	0.2342	0.2926
Luling	0.0338	0.0632	0.1049	0.1541
Lytle	0.0308	0.0597	0.1024	0.1473
Martindale	0.0229	0.0461	0.0829	0.1237
Martindale WSC	0.0475	0.0780	0.1136	0.1528
Natalia	0.0832	0.1162	0.1535	0.1950
New Braunfels	0.0233	0.0653	0.1243	0.1730
Point Comfort	0.0005	.0..17	0.0067	0.0136
Sabinal	0.0397	0.0574	0.0813	0.1146
San Antonio (BMWD)	0.1449	0.2199	0.2902	0.3089
San Antonio (SAWS)	0.0530	0.1307	0.2037	0.2231
Shavano Park	0.0188	0.0364	0.0650	0.1032
SS WSC	0.0600	0.1048	0.1498	0.1948
Universal City	0.0592	0.1133	0.1762	0.2342
Uvalde	0.0007	0.0038	0.0184	0.0458
Water Services, Inc.	0.0214	0.0491	0.0884	0.1358
Woodcreek	0.0468	0.0863	0.1302	0.1756

**Table 4C.2-6.
Total Annual Cost**

Entity	Total Annual Cost			
	5%	10%	15%	20%
Alamo Heights	\$207,467	\$334,603	\$492,848	\$795,557
Aqua WSC	\$39,415	\$60,714	\$88,873	\$127,948
Atascosa Rural WSC	\$134,283	\$195,817	\$277,718	\$384,550
Castle Hills	\$71,926	\$131,986	\$206,066	\$363,087
Castroville	\$110,122	\$162,132	\$234,565	\$353,656
County Line WSC	\$9,453	\$17,170	\$31,834	\$95,670
East Medina SUD	\$58,052	\$104,559	\$172,803	\$268,225
Garden Ridge	\$11,735	\$24,473	\$44,092	\$86,421
Hill Country Village	\$13,281	\$22,545	\$36,933	\$65,164
Hollywood Park	\$32,969	\$65,928	\$135,465	\$283,804
Hondo	\$186,065	\$293,119	\$444,307	\$659,526
Jourdanton	\$65,394	\$105,840	\$164,152	\$258,230
Kirby	\$37,944	\$85,364	\$148,882	\$269,313
Kyle	\$161,234	\$305,472	\$495,428	\$4,106,244
La Coste	\$6,279	\$14,324	\$30,044	\$51,436
Lockhart	\$212,699	\$367,325	\$578,264	\$981,151
Luling	\$30,282	\$64,242	\$126,289	\$218,304
Lytle	\$14,479	\$34,571	\$70,064	\$126,262
Martindale	\$2,943	\$6,839	\$14,099	\$25,334
Martindale WSC	\$9,615	\$18,122	\$33,911	\$83,733
Natalia	\$29,368	\$47,150	\$80,054	\$186,586
New Braunfels	\$176,029	\$574,252	\$1,264,094	\$6,174,754
Point Comfort	\$106	\$445	\$2,042	\$4,979
Sabinal	\$16,587	\$27,700	\$45,067	\$76,464
San Antonio (BMWD)	\$2,272,791	\$4,122,408	\$7,207,795	\$132,531,960
San Antonio (SAWS)	\$5,681,497	\$17,092,861	\$33,833,350	\$627,263,236
Shavano Park	\$15,091	\$34,067	\$73,354	\$142,175
SS WSC	\$86,255	\$168,677	\$301,988	\$648,445
Universal City	\$117,148	\$258,925	\$462,754	\$835,451
Uvalde	\$3,375	\$20,363	\$112,875	\$186,182
Water Services, Inc.	\$21,809	\$57,433	\$132,763	\$374,501
Woodcreek	\$12,309	\$26,109	\$50,588	\$125,279

City of Point Comfort to a cost of almost \$627.3 million for SAWS. The two most important factors driving the annual cost are the risk factor and whether or not that WUG supplies water for commercial and manufacturing purposes (at the 20% reduction level), as these uses have high impact factors.

Finally, the annual cost data were used to calculate a unit cost so that comparisons could be made with other potentially feasible water management strategies (Table 4C.2-7). For the 5% scenario (supply equal to 95% of dry condition demand), the unit costs ranged from \$9/acft/yr for the City of Point Comfort to a high of \$3,239/acft/yr for the City of Castroville. For the 20% scenario (supply equal to 80% of dry condition demand), the unit costs ranged from \$111 for the City of Point Comfort to a high of \$26,878 for BMWD. Again, the high unit costs for BMWD are primarily due to the high risk factors (i.e., the year 2000 per capita was lower than in many previous years) and the high economic impact factors associated with commercial and manufacturing uses.

The SCTRWPG has found, and the San Antonio Water System (SAWS) has demonstrated, that water user groups having sufficient flexibility to focus on discretionary outdoor water use first and avoid water use reductions in the commercial and manufacturing use sectors may find some degrees of drought management to be economically viable and cost-competitive with other water management strategies. Recognizing that implementation of appropriate water management strategies is a matter of local choice, the SCTRWPG recommends due consideration of economically viable drought management as an interim strategy to meet near-term needs through demand reduction until such time as economically viable long-term water supplies can be developed. Hence, new demand reductions associated with the 5 percent drought management scenario are shown as recommended at year 2010 for each municipal water user group with projected needs for additional water supply at year 2010¹.

¹ In accordance with the SAWS 2009 Water Management Plan Update, 37,622 acft/yr is the drought management supply (demand reduction) shown for SAWS in year 2010. This quantity is between the 15 and 20 percent drought management scenarios presented in Table 4C.2-4.

**Table 4C.2-7.
Average Unit Cost**

Entity	Average Unit Cost			
	5%	10%	15%	20%
Alamo Heights	\$2,004	\$1,616	\$1,587	\$1,921
Aqua WSC	\$2,952	\$2,274	\$2,219	\$2,396
Atascosa Rural WSC	\$2,854	\$2,081	\$1,968	\$2,043
Castle Hills	\$1,754	\$1,610	\$1,675	\$2,214
Castroville	\$3,239	\$2,384	\$2,300	\$2,600
County Line WSC	\$164	\$149	\$184	\$416
East Medina SUD	\$1,318	\$1,187	\$1,308	\$1,522
Garden Ridge	\$415	\$433	\$520	\$765
Hill Country Village	\$317	\$269	\$294	\$389
Hollywood Park	\$285	\$285	\$390	\$613
Hondo	\$2,086	\$1,643	\$1,660	\$1,848
Jourdanton	\$1,633	\$1,321	\$1,366	\$1,612
Kirby	\$755	\$849	\$988	\$1,340
Kyle	\$1,177	\$1,115	\$1,205	\$7,493
La Coste	\$613	\$699	\$977	\$1,255
Lockhart	\$1,736	\$1,499	\$1,573	\$2,002
Luling	\$568	\$602	\$789	\$1,023
Lytle	\$605	\$722	\$975	\$1,318
Martindale	\$471	\$547	\$752	\$1,013
Martindale WSC	\$1,017	\$959	\$1,196	\$2,215
Natalia	\$1,780	\$1,429	\$1,617	\$2,827
New Braunfels	\$335	\$546	\$802	\$2,938
Point Comfort	\$9	\$20	\$61	\$111
Sabinal	\$815	\$681	\$738	\$939
San Antonio (BMWD)	\$1,844	\$1,672	\$1,949	\$26,878
San Antonio (SAWS)	\$575	\$865	\$1,141	\$15,867
Shavano Park	\$369	\$416	\$597	\$868
SS WSC	\$1,104	\$1,079	\$1,288	\$2,074
Universal City	\$898	\$993	\$1,183	\$1,602
Uvalde	\$11	\$33	\$124	\$153
Water Services, Inc.	\$459	\$604	\$931	\$1,969
Woodcreek	\$1,001	\$1,061	\$1,371	\$2,546

APPENDIX D
Scope of Work and Response to TWDB Comments

In order to promote consistency in the regional water planning process, the TWDB has contracted HDR Inc. to create a unified costing tool to be made available to regional water planning groups and their consultants.

Task 1 - Unit Cost Data/Tables – Development of Empirical and Unit Costs

Empirical costing data will be used to develop the costs of project facilities using bid tabulations from previous capital construction projects. HDR and FNI will draw on each firm's previous design and construction experience to identify recent projects that have been competitively bid, awarded, and constructed within the State. In addition, the HDR Team will access data from available databases, most notably the AMTEK database clearinghouse, which contain recent bid information from throughout Texas, to increase the pool of bid tabs used in the analyses. The HDR Team will meet with TWDB staff to ensure that costing elements necessary for all water management strategies recommended in regional water plans are represented in the costing curves and tables.

Unit cost tables will be developed, in Microsoft Excel and will be reproduced in the user manual, primarily for pipelines, pump stations, water intakes, water storage tanks, water treatment plants, and groundwater wells and well fields, relocation of existing infrastructure such as roads and utilities, and any other significant construction costs identified by each planning group. The electronic tables in Excel will be used as a lookup source, so that when the user enters a pipeline diameter, the unit cost per foot for that specific pipe diameter will be taken from the table. Costs will be reviewed to remove additional items that should not be included; however, the resulting unit cost will be comprehensive for the type of project, for example, including costs for material, equipment, installation and profit. The HDR Team will develop cost tables to take into account regional differences in construction costs of facilities, where appropriate. In analyzing the bid tab data available along with the bids from the database, HDR and FNI will evaluate the data to observe any differences based on geography. If there is such a cost difference, geographical zones will be created.

A brief explanation of the components to be included:

- Pipeline costs will be classified into groups based on diameter, pressure class, type of pipe, terrain, level of urban development, and distance, to the extent feasible using available data.
- Pump station and booster station costs will be based on total horsepower of the pump/booster station required to meet flow and head requirements, to the extent feasible using available data.
- Water treatment plant costs will reflect the treatment level required (disinfection to advanced treatment) and will be sized for finished water quantity, to the extent feasible using available data.
- Groundwater well costs will be based on diameter, depth, production capacity and type of well (municipal, irrigation, ASR) , to the extent feasible using available data.
- Storage tank costs will be based on size and type of storage (elevated or ground storage) , to the extent feasible using available data.
- Well field costs will be based on the number of wells necessary to meet peak demand plus backup wells, along with collection pipelines, and necessary land acquisition, to the extent feasible using available data.
- Water intake costs will be costed at 50% of the pump station cost, however HDR will re-examine this and possibly include costing mechanisms for coastal, river and lake intakes, to the extent feasible using available data.
- Reservoir and dams will be costed in several manners. Generic cost curves will be developed for off-channel type reservoirs based on landscape. In addition, HDR will provide an embankment/dam calculation sheet for instances where a defined reservoirs site is available, to the extent feasible using available data.
- Offshore desalination concentrate disposal pipelines will be costed in the same methodology as transmission pipelines. However, HDR will further analyze these methods.
- Desalination Plants

- Existing facility data along with supplier data for specific technologies will be used to define a cost curve for desalination facilities. These facilities will be grouped by source water and levels of TDS.

Task 2 - Unit Cost Data/Tables – Develop flexible data structure customizable for location/time

The unit costs tables will be developed to be customizable based on regions defined by Task 1 and easily updated with new information.

Because construction costs for infrastructure projects change from year to year and are based on market conditions reflected in the cost of materials, cost of labor, and cost of equipment, the historical bids will be updated to a common timeframe, with the ability to use an indexing feature to update the cost to September 2013 costs as per TWDB Guidance at the appropriate time. The HDR Team will attempt to index costs appropriately based on material cost inflation and/or labor cost inflation. One method is to use information gathered and published as a construction cost index (CCI) (ENR, RS Means) which can be used to adjust costs to a specified quarter or month and year. This procedure will be used so that previous competitively bid, awarded, and constructed projects over recent years can be normalized to be used in the development of the cost curves and tables.

Deliverables

- A Technical Memorandum will be submitted to the TWDB describing the development and analysis of the cost curves and tables, and the procedure for updating these curves and tables for each planning cycle. The memorandum will include:
 - Unit cost tables and cost curves.
 - Description of historical bid tabulations used and methodology for normalizing estimates.
 - Initial description of how tool/model developed in Tasks 3, 4 and 5 will function/look.

The HDR Team will then meet with TWDB staff to summarize the work performed under Tasks 1 and 2, as well as to present the proposed model format and structure to be developed

under Tasks 3, 4 and 5 and to discuss modifications and content, and confirm the information to be presented in the cost summary table that will make its way into the regional water plans.

Task 3 – Costing Model – Develop tool to estimate costs for water development strategies

HDR will work with FNI to develop a Microsoft Excel spreadsheet model to be used to prepare planning level cost estimates for the water management strategies. The model will be automated to the extent it can incorporate background assumptions and calculations and reduce human errors in compiling costing information.

The layout of the information in the costing model will create a consistent description of the project costs in both detailed and summarized form which will be useful for comparison of water management strategies. The costing model output will allow modification of formats in accordance with TWDB guidelines (July 2011). A summary table of the cost components will be produced by the costing model that, in addition to providing a total cost estimate, provides pertinent line-item cost information and can be readily inserted into the regional water planning documentation and TWDB's Water Planning Database.

The model will incorporate tools for hydraulic analysis for determining pipeline and pump stations capacities, designing well field layouts and off-channel reservoirs. The model will be capable of sizing a project for peaking or for base load purposes in accordance with state requirements. Project costs will be developed using the unit costs developed in Task 1 and assumptions for other capital costs such as river and utility crossing costs, relocation, power connection costs, land acquisitions and easements by infrastructure component. The model will incorporate TWDB's costing guidance where appropriate. Strategies involving reservoirs generally include previous cost estimates performed by engineering firms that can be indexed to the common date.

In addition to capital costs, other project costs assumptions consistent with TWDB guidance (TWDB, July 2011) will be included such as engineering and legal costs, contingencies, surveying costs, environmental and archeology studies, mitigation costs, and interest during construction. Other project costs will generally be developed using common percentages of the

capital costs. The costing model will calculate annual costs based on assumptions for operation and maintenance, debt service, energy costs, purchase of water and any other associated fees or annual costs, in accordance with TWDB rules and guidelines for regional water plans.

Task 4 – Costing Model – Develop tool components to estimate cost of conservation and drought management strategies

Conservation and drought management strategy costing tools will be designed to estimate the direct costs and probable economic costs, as appropriate, in a way that allows regional water planning groups to make reasonable comparisons to the alternative financial costs of developing water projects and will incorporate methodologies from previous TWDB-funded research and regional water planning studies.

Task 5 – Costing Model – Develop comparison component

Develop a tool to facilitate apples-to-apples comparisons of water management strategies by providing discounted present value unit cost estimates of project water supplies to normalize for variable project start dates and annual costs and other relevant investment and/or time-related factors. These will be based on a 50-year planning horizon.

Deliverables

- Costing Tool
- The HDR Team will meet with TWDB staff to ensure that the User's Guide conveys key information in a way that will support the successful use of the costing model by Regional Water Planning Groups and their consultants.

Task 6 – User's Guide

A User's Guide will be developed to illustrate the costing methodology, background assumptions of the costing model, and provide practical explanation of how to use the costing model. Expected chapters are expected to include:

- I. An introduction explaining overall context and purpose of the costing tool

II. General Project Components

- a. A section on pipelines with guidance on route selection, profile determination and pipe sizing.
- b. A section on pumps and booster station calculations that describes the methodology of determining pump/booster station location, Total Dynamic Head, horsepower, and power requirements.
- c. A section on well field layout with guidance on how to determine well characteristics, spacing, and collection pipeline sizes.
- d. A section on water intake
- e. A section on off-channel reservoirs with information on calculating the materials and costs. With some guidance for on-channel reservoirs.
- f. A section that describes the calculations necessary for determining conservation cost estimates and how these can be used in making cost comparisons.
- g. A section that describes the calculations necessary for determining drought management estimates and how these can be used in making cost comparisons.

III. A section that walks the user through the major elements of the detailed costing sheet and its assumptions, as well as how the summary project cost sheet can be presented in a regional water plan, including, but not limited to:

- a. Data and Cost Curves
- b. Assumptions
- c. Developing cost estimates
- d. Presentation of costs
- e. Comparisons of costs
- f. Maintenance of data model
- g. Assumption sheet?

IV. A separate Quick Reference Guide

Deliverables

- User's Guide
- Quick Reference Guide
- Training Session (with TWDB staff or with Consultants)

Attachment I
HDR Engineering, Inc.
Research and Planning Study – Unified Costing Model for Regional Water Planning
TWDB Contract No. 1148321307 Draft Report Review Comments

HDR Responses in Bold & Red

General

1. As required by item 3 of Article III of the contract, please include a one page executive summary in the final report.

An Executive Summary has been included.

2. Task 6 of the Scope of Work identifies a separate “Quick Reference Guide” as a deliverable. This has not been included in what was delivered to the TWDB. Please include with the final report.

A Quick Reference Guide is included in the UCM.

3. Please add language similar to that found below prior to the last sentence of the disclaimer found on the page preceding the Table of Contents:
 - a. *“This tool was developed for the purpose of preparing regional water planning level cost estimates only.”*

Language included.

The Costing Tool

1. Task 1 of the Scope of Work states: “Existing facility data along with supplier data for specific technologies will be used to define a cost curve for desalination facilities.” The desalination aspect of the tool should be based a cost curve that, at least, takes into account the TDS of the water being desalinated. Currently in the draft costing tool, the cost of water with a TDS 5,001 is considered the same as seawater at 35,000 TDS which is not realistic for planning purposes. Please consult additional sources of information, such as the one below, and revise the final costing tool and associated documents to better reflect anticipated desalination costs associated with varying TDS.

- a. Additional source of information:

http://www.twdb.texas.gov/innovativewater/desal/doc/Cost_of_Desalination_in_Texas_rev.pdf

The UCM has been revised to include costs for brackish desalination as a function of TDS.

2. Please ensure all the underlying assumptions built into the first sheet of the module are noted in the final output summary sheet generated by the tool.

Assumptions included in the Cost Summary.

3. Please ensure that all cost categories (below) are clearly listed in the final cost table, so that anyone reading a single estimate will know what costs are included.

- a. *“engineering and feasibility studies , legal assistance, financing, bond counsel, and contingencies (engineering, contingencies, financial, and legal services”*

Incorporated.

4. Please remove the ‘life-cycle’ cost calculation entirely from the tool and related documentation.

It has been removed.

5. It appears that the methodology used for the drought management strategy portion of the tool implicitly assumes that all variation embodied in historical calculation for gpcd is due to weather variability. However, changing demographics or economic conditions also impact gpcd. Please ensure, within the final Technical Memorandum, User’s Guide and within the tool, that uncertainty due to other factors such as population related usage, commercial usage, recreational usage, regional economic conditions, water pricing etc. are acknowledged.

Incorporated.

6. The conservation component of the costing tool does not appear to allow for stages of conservation based on various programs like toilet replacement. Please consider incorporating (e.g. other quantified conservation costing methods used in previous Regional Water Plans) in the final costing tool and associated documents.

The Conservation Module has been rebuilt to incorporate stages of conservation, in addition to the simplified approach.

7. The input cells for pipeline and pump station land acquisition unit costs are included in the Project Info & Assumptions tab, however land acquisition cost inputs for the remaining infrastructure items (such as well fields) are included in the Costing Form. Please consider including all land cost elements into a single module or tab location to prevent user error.

A Land Acquisition Module has been developed and included

8. Please consider including some kind of auto-flag that shows up on the final costing sheet if at least one “cost override” was entered in the final costing tool.

Incorporated.

9. Please consider differentiating (possibly through color coding) between a) the input cells that are required values from the user and; b) recommended default values that can be changed by the user but that aren't necessarily required, in the final costing tool.

A color-code system has been incorporated and a key included on the Project Information and Assumptions Module.

10. Please consider reordering tabs in the tool so that infrastructure related modules are grouped together and non-infrastructure modules are grouped last in the application.

The tabs have been reordered. In addition, the sections of User's Manual have been reordered accordingly.

The User's Guide

1. Section 1.0., the introduction, describes the purpose of the tool is to provide an estimate of infrastructure costs for water supply projects. However, the tool includes modules to estimate drought management and conservation activities. Please include these 'non-infrastructure' related water supply projects in the discussion of the purpose of the tool in the final User's Guide.

Language about non-Infrastructure components has been incorporated.

2. Please include more context for this research to the introduction section of the final User's Guide.

The Introduction section has been re-written to provide additional context.

3. As stated in Task 6 of the Scope of Work, please include in the final User's Guide a summary "how to" section, that walks the user through the major elements of the detailed costing sheet and its assumptions, as well as how the summary project cost sheet can be presented in a regional water plan.
 - a. For Example: a) "first you make sure the assumptions are correct on tab 1; b) then you confirm that you are using the right cost year (e.g., indices); c) then you work through the sheets; d) print out the final result/paste into a document; and e) document the estimate by, for example, saving the tab or entire spreadsheet...." Discussion should also explain how the user could include several components in one estimate and how that is accomplished.

Language has been included in the Quick Reference Guide section to address this.

4. Page 3, first paragraph, last sentence: replace "costs" with "cost estimates".

Changed.

5. Page 3, second paragraph, should insert 'water' between 'regional' and 'planning'.

Changed.

6. Page 3, second paragraph, second line replace "study-level" with "planning-level".

Changed.

7. Page 5, second paragraph, should include a reference footnote, at least, that refers to the need to update the cost indices to TWDB planning guidance for each planning round "(e.g., to September of 2013 for the 2016 RWPlans)."

Changed.

8. Section 6.0 – please incorporate the full material explaining the methodology similar in content (including graphics) to what is contained in Volume II of the 2011 Region L Regional Water Plan, Section 4C.2. This may be included as an appendix.

Incorporated.

9. Section 6.0 – since the methodology is based on historical GPCD, this section should include a note that drought management WMSs being evaluated may need to take into account any previous implementation of drought management that may be embedded in the historical GPCD to avoid double-counting potential savings from this WMS.

Language has been added to note the embedded conservation/drought management in the data.

10. Page 23, last sentence: Should read: "This information may be obtained from TWDB upon request. [1]" Also, please include a footnote at the end of that sentence stating that RWPGs wishing to obtain such data from TWDB should provide advanced notice to TWDB.

Incorporated

11. Please consider including a simple module 'map' that shows how/which tabs feed into which tabs so the user can quickly see how the costing tool sheets fit together to generate a total cost.

The Quick Reference Guide now demonstrates this.

12. Section 7.0 – please consider including a simple well-field schematic in the final User’s Guide illustrating what the zones/nodes are (A, B C etc) to assist the user in utilizing the tool properly.

Incorporated.

Technical Memorandum

1. In section 3 of the Technical Memorandum where pipeline costs are discussed, the following statement is made: “However, in cases where it is known that higher pressure class pipe will be required, unit costs can be adjusted based on the percent increase in steel cylinder thickness.” Please explain how this adjustment can be made, in the final User’s Guide.

The ability to choose higher pressure class pipe is now incorporated into the model and explained.

2. Page 11, paragraph 1, regarding level 5 desalination treatment, it states “Costs do not include disposal of desalination concentrate.” However, Task 1 of the Scope of Work states that offshore disposal pipelines will be costed in the same manner as transmission pipelines, unless a more accurate method is found upon further investigation by HDR. Please confirm whether this is a capability of the final tool and clarify this in the associated documents including the final User’s Guide.

Incorporated.

3. Page 13 states that irrigation wells can cost between 55 and 70 percent of the cost of a public supply well and that ASR wells can cost from 2 to 16 percent more than public supply wells. Please explain the basis fo this statement in the final memorandum.

An explanation is incorporated.