Coastal Bend Regional Water Planning Area

2011 Regional Water Plan

Study 1
Evaluation of Additional Potential Regional Water Supplies for Delivery through the Mary Rhodes Pipeline, Including Gulf Coast Groundwater and Garwood Project

Prepared by:

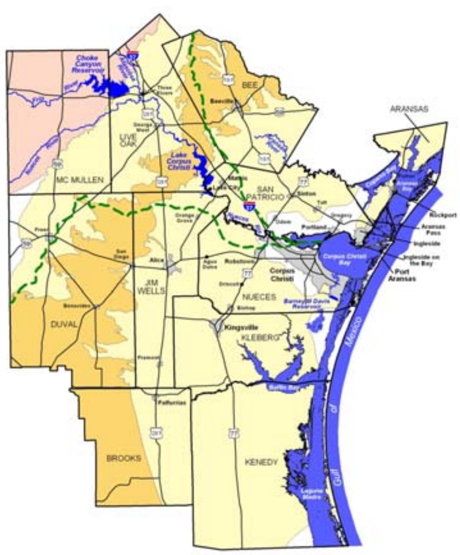
Coastal Bend Regional Water Planning Group

With administration by:

Nueces River Authority

With technical assistance by:

HDR Engineering, Inc.



April 2009

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Evaluation of Additional Potential Regional Water Supplies for Delivery through the Mary Rhodes Pipeline, including Gulf Coast Groundwater and Garwood Project
(Final)

Kristine S. Shaw, P.E.

Mark C. Graves, P.E.

Table of Contents

Section		Page
	Executive Summary	ES-1
1.0	Introduction	1
	1.1 Background	1
	1.2 Need for Study and Project Objectives	5
2.0	Description of the Study	5
3.0	Methodology and Approach	6
	3.1 Data Collection	6
	3.2 Corpus Christi Water Quality and Treatment Model	8
	3.3 Water Treatment Assumptions and Considerations	9
	3.4 Reservoir System Operations with Potential New Supplies	12
4.0	Study Results	12
	4.1 Water Quality Constituents of Interest	12
	4.1.1 UV-254	12
	4.1.2 Bromide	13
	4.2 Blending Scenarios	14
	4.3 Raw Water and Treated Water Quality Results for Blending Scenarios	15
	4.4 Water Treatment Cost Impacts with Potential Source Water Supplies	20
	4.5 Summary of Water Quality and Blending Analysis	23
	4.6 System Operations with Additional Supplies	32
5.0	Environmental Issues	37
6.0	Implementation Issues	38
7.0	Evaluation Summary	39
8.0	Texas Water Development Board Report Formalities	41

Appendices

A Summary of Raw Water Quality Statistics for Potential New Water Supply Project for Delivery through Mary Rhodes Pipeline

B TWDB Comments and Summary of the Coastal Bend RWPG Responses

List of Figures

Figure **Page**

Figure		Page
1-1	Potential Locations of Inter-Basin Transfer Projects for Coastal Bend Regional Water Supplies	4
3-1	Groundwater Data Sampling Locations Used to Estimate Water Quality for Gulf Coast Aquifer Supply Project	7
3-2	Water Quality Sampling Locations Used to Estimate Water Quality Data for the Garwood Project and Additional Lake Texana Supplies	8
3-3	O.N. Stevens WTP Schematic	11
4-1	Median Raw Water Chlorides of Water Sources	24
4-2	Median Chlorides for Groundwater Blending Scenario	24
4-3	Summary of Median Chlorides for Blending Scenarios with Groundwater, Colorado River, Lake Texana, and Nueces River Combinations	26
4-4	Median Raw Water TDS of Water Sources	26
4-5	Median TDS for Groundwater Blending Scenarios	27
4-6	Summary of Median TDS for Blending Scenarios with Groundwater, Colorado River, Lake Texana, and Nueces River Combinations	27
4-7	Summary of Relative Chemical Treatment Cost of Water Sources	29
4-8	Summary of Relative Chemical Treatment Costs for Groundwater Blending Scenarios	30
4-9	Summary of Relative Chemical Treatment Cost for Blending Scenarios	30
4-10	Comparison of Average Annual Water Supplies from the MRP and CCR/LCC System Based on Annual Demand of 175,000 acft/yr	33
4-11	Average Annual Operating and Pumping Costs for New Water Supplies	36
4-12	Project Impacts on Freshwater Inflows into the Nueces Estuary	36

List of Tables

Table		Page
3-1	Summary of Available Water Quality Data	9
4-1	Water Quality Constituents and General Impacts on Water Treatment	13
4-2	Blending Water Percentages and Quantities	16
4-3	Median Raw Water Quality of Water Sources	18
4-4	Median Raw Water Quality of Blends	19
4-5	Water Treatment Model Results for Water Sources	21
4-6	Water Treatment Model Results for Blended Water Scenarios	21
4-7	Summary of Blended Water Quality Results	28
4-8	Summary of Water Treatment Costs for Several Blended Options	31
4-9	Average Water Supply By Source to Meet an Annual Demand of 175,000 acft/yr	33
4-10	Estimated Median Raw Water Quality of CCWSM Water Supply Combinations Used to Evaluate Reservoir System Operations for a 175,000 acft/yr Supply	34

List of Acronyms

B&E	Bay and Estuary
CCR	Choke Canyon Reservoir
CCR/LCC	Choke Canyon Reservoir/Lake Corpus Christi System
CCWSM	Corpus Christi Water Supply Model
DBP	Disinfection By-Products
GMA	Groundwater Management Area
LCC	Lake Corpus Christi
LCRA	Lower Colorado River Authority
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
MRP	Mary Rhodes Memorial Pipeline
NOM	Natural Organic Matter
NTU	Nephelometric Turbidity Units
RWPG	Regional Water Planning Group
SPMWD	San Patricio Municipal Water District
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
UV-254	Ultraviolet Absorbance at 254 nanometers
WTP	Water Treatment Plant

Executive Summary

As part of a plan for future supplies, the Mary Rhodes Memorial Pipeline (MRP) was constructed to be capable of delivering up to 112,000 acft/yr, or more than twice the amount of currently contracted supplies from Lake Texana. Considering current Lake Texana supplies of up to 53,840 acft/yr, the MRP has remaining pipeline capacity of about 58,160 acft/yr (or 52% of total pipeline capacity) for future supplies. Potential future water supplies that could be transported through the pipeline include groundwater supplies from the Gulf Coast Aquifer, Garwood Project supplies from the Colorado River, or additional Lake Texana water developed by additional storage or alternative reservoir operating procedures. The City of Corpus Christi has an interbasin transfer permit with authorization to divert up to 35,000 acft/yr from the Colorado River near Bay City, hereafter referred to as the "Garwood Project". If these supplies were delivered at the maximum diversion of 35,000 acft/yr, then more than half of the current remaining MRP capacity would be used. After delivering the Garwood Project water supplies at the full permitted amount, the remaining MRP capacity would be about 23,160 acft/yr (or 21% total pipeline capacity) for additional future water supplies from groundwater or other sources.

When considering water supply projects from new sources, especially blending groundwater and surface water supplies from different river basins, it is important to consider source water chemistry and blending issues to minimize disturbances to transmission and water treatment processes and avoid unanticipated additional pretreatment needs.

This study: (1) included an evaluation of water quality of potential new supplies, (2) identified potential blending and water chemistry issues, and (3) considered reservoir system operations with possible future supplies from the Gulf Coast Aquifer, Garwood project supplies for two delivery scenarios around and through Lake Texana, and additional Lake Texana water supplies as may be available through projects being considered by the Lavaca-Navidad River Authority.

A modified version of the Corpus Christi Water Quality and Treatment Model was utilized to analyze water quality and treatment requirements when blending different water sources. The model was developed to simulate treatment processes currently utilized at the O.N. Stevens Water Treatment Plant (WTP). Five blending scenarios were evaluated. An "existing operations scenario" was used as a baseline for comparison to blending analyses with potential future MRP water supplies. Based on historical data, the "existing operations scenario" was comprised of an average supply of 41,840 acft/yr from Lake Texana (or 37% MRP capacity) with remaining supplies coming from the CCR/LCC System. Four blending scenarios were evaluated at several blended water percentage combinations, to simulate the integration of different combinations of potential future water supplies delivered through the MRP (utilizing from 61% to 95% of the pipeline capacity[1]).

The blending analysis did not indicate any large treatment issues at the O.N. Stevens WTP when blending groundwater supplies from the Gulf Coast Aquifer, surface water supplies from the Garwood Project, or additional supplies from Lake Texana with existing supplies from the Nueces River and Lake Texana. The addition of groundwater supplies from the Gulf Coast Aquifer increases median chloride levels. However, groundwater supplies limited to 20% of the total water supply would result in a blending water quality of 129 mg/L for chlorides which is well below the Secondary Drinking Water Standards of 300 mg/L. Overall, the addition of the Garwood Project water supplies would be expected to decrease chloride levels when compared to existing chloride levels for the Choke Canyon Reservoir/Lake Corpus Christi/Lake Texana (CCR/LCC/Lake Texana) System. The analysis indicated that pre-treatment or costly new treatment processes such as desalination or additional organics removal technologies will not be required with groundwater supply maintained at or below 20% of total water supply.

Higher total organic carbon and turbidity in raw water supplies requires the use of more treatment chemicals and results in higher quantities of sludge produced from the treatment process. Due to low levels of turbidity and organics in groundwater supplies from the Gulf Coast Aquifer, chemical treatment costs decrease for blending scenarios with groundwater supplies. The only blending scenarios that resulted in chemical treatment costs higher than the existing chemical costs is the scenario with the Garwood Project (Colorado River water) transferred via Lake Texana, because this scenario results in an increase in the total quantity of raw water from Lake Texana, whose water is higher in total organic carbon and turbidity concentrations.

The Corpus Christi Water Supply Model (CCWSM) was then used to evaluate various reservoir system operations and delivery scenarios with potential new supplies delivered through the MRP. In an effort to provide uniform comparisons of potential water supply projects and isolate the impacts of each water supply project, the CCWSM was simulated for an annual

[1] Although the MRP is sized to deliver 112,000 acft/yr, the current MRP *pumping* capacity is 77,000 acft. A fourth pump would need to be installed in each of the three pump stations to deliver the full Garwood Project of 35,000 acft/yr in addition to the permitted Lake Texana Supplies.

demand of 175,000 acft/yr (roughly equal to Year 2010 demand) with full utilization of permitted Lake Texana supplies.

System operations for five different combinations of existing and potential future water supplies through the MRP were simulated using the CCWSM at a fixed demand of 175,000 acft/yr. The model output was evaluated for each combination to determine average annual water supplies delivered by the MRP, annual pumping and operating costs for the pipeline, and impacts to freshwater inflows to the Nueces Bay and Estuary. The five operating scenario combinations considered current and potential future water supplies for delivery through the MRP and, on average, the amount of MRP capacity in use ranged from 47% to 100%. Essentially, as more water supplies are available for delivery through the MRP, the supplies needed from the Choke Canyon Reservoir and Lake Corpus Christi (CCR/LCC) System decreases for a fixed demand. This results in more water stored in the CCR/LCC System, which increases reservoir pass-thrus of freshwater for the Nueces Bay and Estuary according to provisions of the 2001 Agreed Order.

Based on the current MRP pumping capacity of 77,000 acft/yr, the addition of the Garwood Project supplies (up to 35,000 acft/yr) to permitted Lake Texana supplies requires installation of a fourth pump in each of the three MRP pump stations to deliver supplies for treatment. Installation of the fourth pump would be expected to increase annual pumping and operating costs for the MRP by 190% to 240%, on average, based on the amount of additional water pumped through the pipeline after adding the fourth pump.[2] The largest increase in annual pumping and operating costs is with full utilization of the MRP to deliver up to 112,000 acft/yr. Since the amount of groundwater supplies from the Gulf Coast Aquifer (up to 18,000 acft/yr) are considerably less than Garwood Project supplies, additional pumping and operating costs for the MRP are not expected to change substantially from existing costs. The costs in this study include additional annual operating and pumping costs only for the MRP, and updated capital costs to implement water management strategies will be updated during Phase II development of the 2011 Coastal Bend Regional Water Plan.

[2] The cost analysis for this study only considers average annual pumping and operating costs, as compared to pumping costs with the existing MRP pump station configuration and operations. With a fourth pump added, the amount of water capable of being transmitted through the MRP increases from 77,000 acft/yr to 112,000 acft/yr. The pumping cost per acft of water delivered would likely increase by up to 75% with the addition of new project supplies as compared to existing operating conditions.

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1.0 Introduction

The Mary Rhodes Memorial Pipeline (MRP) was completed in 1998 and began to deliver contracted raw water supplies from Lake Texana in the Lavaca-Navidad River Basin to the City of Corpus Christi (City) and their customers (Figure 1-1). Currently, the City has a raw water supply contract with the Lavaca-Navidad River Authority to receive up to 53,840 acft/yr from Lake Texana (41,840 acft/yr on a firm basis with an additional 12,000 acft/yr on an interruptible basis). The MRP delivers the majority of Lake Texana supplies called-upon by the City to the O.N. Stevens Water Treatment Plant (WTP), with a smaller amount of raw water supplies being delivered directly to the San Patricio Municipal Water District (SPMWD) for treatment and/or delivery to their manufacturing and industrial customers. At the O.N. Stevens WTP, raw water supplies from Lake Texana are added to supplies from the Choke Canyon Reservoir (CCR) and Lake Corpus Christi (LCC) system for treatment prior to distribution to the City and their customers.

As part of a plan for future supplies, the MRP was constructed to be capable of delivering up to 112,000 acft/yr, or more than twice the amount of currently contracted supplies from Lake Texana. Considering current supplies of up to 53,840 acft/yr from Lake Texana, the MRP has remaining pipeline capacity of about 58,160 acft/yr (or 52% of total pipeline capacity) for future supplies. Potential future water supplies that could be transported through the pipeline include groundwater supplies from the Gulf Coast Aquifer, Garwood Project supplies from the Colorado River, or additional Lake Texana water developed by additional storage or alternative reservoir operating procedures (Figure 1-1). The City has an interbasin transfer permit and authorization to divert up to 35,000 acft/yr from the Colorado River near Bay City, hereafter referred to as the "Garwood Project". If these supplies were delivered at the maximum diversion of 35,000 acft/yr, then more than half of the current remaining MRP capacity would be used. After delivering the Garwood Project at the full permitted amount, the remaining MRP capacity would be about 23,160 acft/yr (or 21% total pipeline capacity) for additional future water supplies from groundwater or other sources.

1.1 Background

The City and SPMWD provide water supplies to numerous entities in the Coastal Bend Region to meet a combined 85% of the municipal and industrial water demand in the region.

The City and SPMWD have considered groundwater supplies from the Gulf Coast Aquifer, as well as surface water supplies from the Colorado River (Garwood Project) to meet projected water needs of their customers. These raw water supplies, if developed, would likely be delivered via the MRP.

The SPMWD contracted with Goliad Sands, LLC to evaluate groundwater supplies from the Gulf Coast Aquifer in Bee County and negotiated an agreement with the City to conduct a preliminary groundwater quality study to evaluate opportunities for a joint project that would develop up to 18,000 acft/yr. Prior to conducting groundwater studies in Bee County, the SPMWD also considered groundwater supplies in San Patricio County. The SPMWD identified a well field study area in Bee County for further analysis, drilled three study wells in the Goliad Sands and Evangeline formation of the Gulf Coast Aquifer, and evaluated water quality for a full spectrum of water quality constituents.[1] The water quality results and well field information provided by SPMWD were used as a basis in this study to evaluate groundwater supplies from the Gulf Coast Aquifer, hereafter referred to as the "Gulf Coast Aquifer Supply Project". SPMWD's goal for the study was to identify groundwater supplies with total dissolved solids (TDS) at or below 600 mg/L for development of up to 11,000 acft/yr of groundwater supplies. The City was considering up to 7,000 acft/yr of groundwater supplies from the Gulf Coast Aquifer, in addition to surface water supplies from the Colorado River as part of the Garwood Project.

The City has entered into an agreement for the purchase of up to 35,000 acft/yr from the Garwood Irrigation Company, who holds the most significant senior water right in the Lower Colorado River Basin with a priority date of November 1, 1900. On October 7, 1998, the Texas Commission on Environmental Quality (TCEQ) approved the City's purchase and authorized the City to divert 35,000 acft/yr from the Colorado River for irrigation, municipal and industrial purpose.[2] This water source is referred to as the "Garwood Project."

In the 2006 Coastal Bend Regional Water Plan (2006 Plan), groundwater supplies from the Gulf Coast Aquifer and the Garwood Project were recommended as water management strategies to meet future water supply needs in the Coastal Bend Region. The 2006 Plan included

[1] One of the wells was abandoned during well testing due to site and drilling conditions. Two wells were drilled with water quality samples collected at multiple intervals to identify the preferred production zones based on water quality.

[2] The certificate also subordinates the 35,000 acft/yr to the remaining portion of the original Garwood Irrigation water right by giving it a priority of November 2, 1900.

an analysis of drawdown impacts in Bee and San Patricio Counties associated with development of the Gulf Coast Aquifer supplies using the TWDB's Central Gulf Coast Groundwater Availability Model. According to the model simulation, pumping an additional 18,000 acft/yr of groundwater supplies (i.e., 11,000 acft/yr for the SPMWD and 7,000 acft/yr for the City) could result in an estimated 50 foot drawdown, which does not exceed drawdown criteria adopted by the planning group. The 2006 Plan recommended 11,000 acft/yr from Gulf Coast Aquifer groundwater supplies for the SPMWD beginning in Year 2010 with the additional 7,000 acft by Year 2060 to meet City of Corpus Christi needs. The Garwood Project was recommended in the 2006 Plan to provide additional water supplies for the City of Corpus Christi and their customers by Year 2030. Based on planning-level cost analysis, the groundwater supplies from the Gulf Coast Aquifer and the Garwood water supplies delivered through the MRP were considered to be cost effective future projects, with unit costs of between $500 and $600 per acft including treatment.[3]

Since the 2006 Plan, the SPMWD and City have conducted additional studies of Gulf Coast Aquifer supplies and the Garwood Project for project locations shown in Figure 1-1. As discussed earlier, the SPMWD has conducted aquifer production and water quality analyses for a well field located in Bee County. The results of their water quality analysis showed groundwater supplies in Bee County with TDS levels ranging from 671 mg/L to 851 mg/L for samples collected up to 1000 feet below ground surface.[4] At this time, the City and SPMWD are not actively pursuing implementation of the Gulf Coast Aquifer Supply Project. However, it remains a viable opportunity to provide future water supplies for the Coastal Bend Region.

The City has completed a Phase I Garwood Project study[5], which recommended three delivery options for a Phase II detailed study: Combined Facilities with LCRA/SAWS (Option 1), Garwood Town Canal to West Mustang Creek (Option 5); and Gulf Coast Furbor Canal (Option 6) to the MRP. The City is currently considering permitting and environmental issues associated with these options, including possible transmission of Garwood water supplies to West Mustang Creek to flow into Lake Texana to be pumped into the MRP for delivery.

[3] Based on 2002 U.S. Dollars and provided that groundwater supplies are of suitable water quality and do not require advanced treatment (i.e., desalination).

[4] Source: San Patricio Municipal Water District Bee County Groundwater Exploration Report. One water quality sample was collected from a deeper formation (greater than 1,000 feet below ground surface) and showed a TDS level of 1,120 mg/L.

[5] Freese and Nichols, Garwood Water Project – Phase 1 Report: Pipeline Route Screening Report, November 2004.

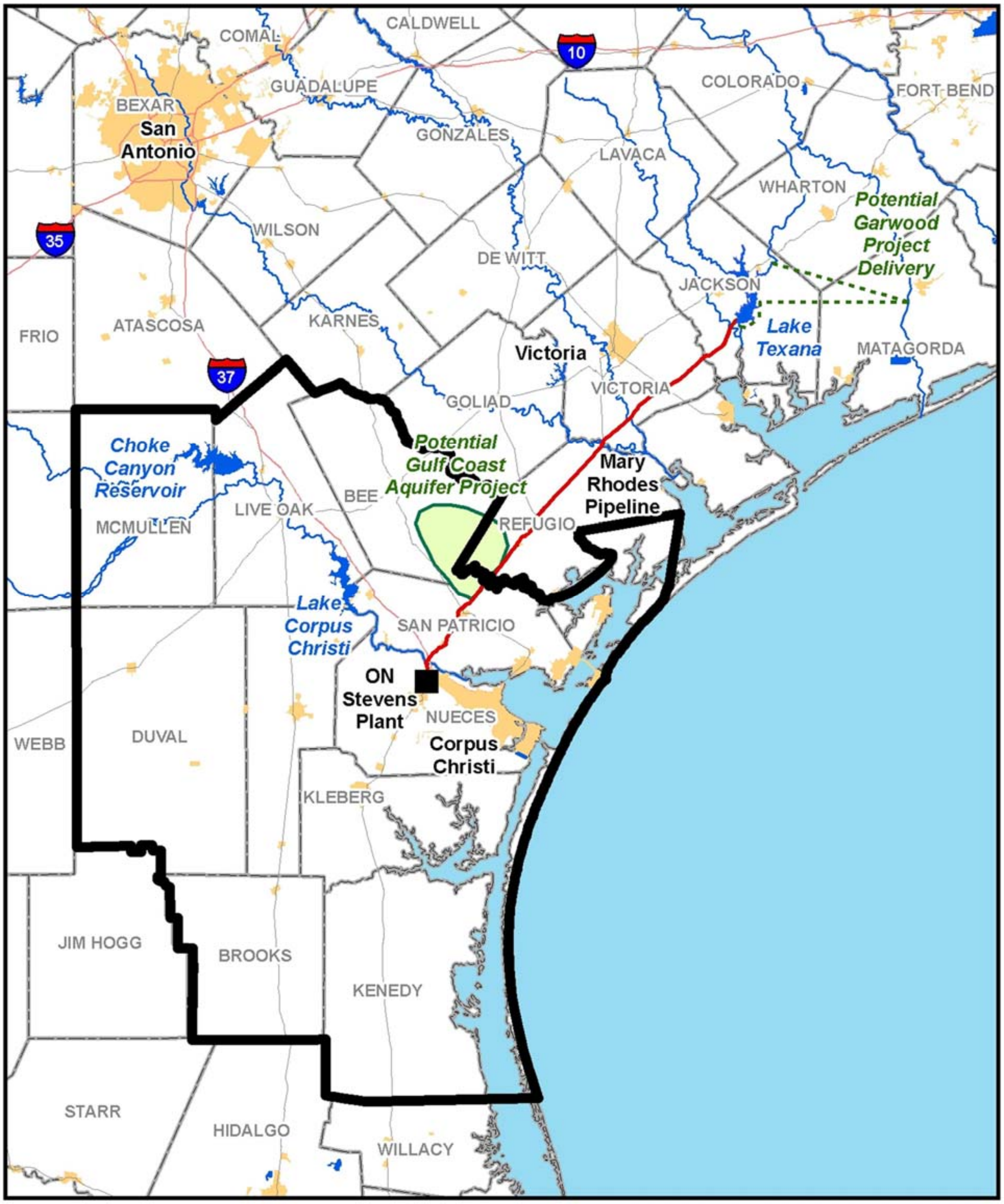


Figure 1-1. Potential Locations of Inter-Basin Transfer Projects for Coastal Bend Regional Water Supplies

The Corpus Christi Water Supply Model (CCWSM) has been updated to include operating the MRP with groundwater supplies from the Gulf Coast Aquifer and/or Garwood Project.

1.2 Need for Study and Project Objectives

While the 2006 Plan included a discussion of projects and costs for groundwater supplies from the Gulf Coast Aquifer and the Garwood Project, it did not include an analysis of integrating the supplies into the LCC/CCR/Lake Texana reservoir system. When considering water supply projects from new sources, especially blending groundwater and surface water supplies and supplies from different river basins, it is important to consider source water chemistry and blending issues to minimize disturbances to transmission and water treatment processes and identify or avoid unanticipated or additional pre-treatment needs. The objective of this study is to conduct a more detailed study of possible additional water supplies for delivery through the MRP. The study included: (1) evaluating water quality of these specific potential new supplies, (2) identifying potential blending and water chemistry issues associated with adding Gulf Coast Aquifer groundwater supplies and surface water supplies from the Garwood Project, and (3) considering LCC/CCR/Lake Texana reservoir system operations with potential supplies from the Gulf Coast Aquifer, Garwood Project, and additional supplies from Lake Texana.

2.0 Description of the Study

This study considers delivery of groundwater supplies from the Gulf Coast Aquifer in Bee County (Gulf Coast Aquifer Supply Project) and surface water supplies from the Colorado Basin (Garwood Project) through the MRP, since these projects are located near the MRP and the MRP has adequate capacity to deliver the quantities being considered. However, prior to delivering new water supplies through the MRP, groundwater and surface water quality constituents need to be evaluated to address potential blending issues or additional treatment requirements. Evaluating various operating and delivery scenarios for the Gulf Coast groundwater supplies, Garwood supplies, and additional Lake Texana supplies will help support more effective and efficient management of regional and interregional water supplies.

3.0 Methodology and Approach

3.1 Data Collection

A water quality analysis was performed to estimate source water quality for potential groundwater supplies from the Gulf Coast Aquifer. The objective of the water quality analysis was to determine source water chemistry compatibility with the existing CCR/LCC/Lake Texana system. For the Gulf Coast Aquifer Supply Project, water quality data were obtained from the Texas Water Development Board (TWDB) groundwater database and recent Bee County test well data provided by the SPMWD. The TWDB groundwater quality data were compiled on a 7 ½ minute quadrangle scale for all registered wells that pumped from the Evangeline, Goliad Sands, or Chicot/Evangeline layers located within or near the general proposed Gulf Coast Aquifer Supply Project wellfield location as shown in Figure 3-1. The SPMWD provided groundwater data for test wells drilled in Bee County in 2007, which included a comprehensive analysis of metals, radionuclides, organics, and others. The SPMWD's water quality data included several water-bearing zones that were encountered during test well drilling, since one of the objectives of their test drilling program was to identify specific zones of preferable water quality. Statistical analyses were performed to evaluate physical water quality parameters and determine concentrations of specific water quality constituents that may impact blending.

For potential surface water supplies projects (such as the Garwood Project and possible additional Lake Texana supplies), a water quality analysis was performed using Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring (SWQM) data and United States Geological Survey (USGS) data to evaluate long-term water quality trends. For the Garwood Project, two water quality scenarios were prepared based on project delivery options: (1) delivery of water supplies through a proposed pipeline around Lake Texana to tie directly in to the MRP, or (2) delivery into West Mustang Creek and ultimately Lake Texana with coordination with LCRA for operations and possible upgrade to the Garwood Pump Station and Town Canal. For the Garwood Project delivery scenario around Lake Texana, long-term water quality data were evaluated for the Colorado River near Bay City gage (TCEQ SWQM ID #12284 and USGS Gage 8162500), which was determined to be the closest proximity to the Garwood project intake. For the second delivery scenario, the Garwood Project water would be more similar to Lake Texana water quality than Colorado River water quality before being delivered through the MRP. Under the majority of circumstances, the amount of Garwood

Project water (up to 35,000 acft/yr) when added to Lake Texana, would represent a small amount of Lake Texana's stored water (with conservation storage of 153,246 acft)[6]. Therefore, even though there could be slight changes in water quality with blending of the Garwood Project supplies in Lake Texana, the water quality change is expected to be minimal assuming instant mixing of the reservoir. The water quality data for the two Lake Texana near Spillway gages (TCEQ SWQM ID #15377 and SWQM ID #13981) showed similar water chemistry characteristics and were combined to provide a larger sample set for statistical analysis. Additional water supplies from Lake Texana as may be available based on additional storage opportunities being considered by the Lavaca- Navidad River Authority or alternative reservoir operating procedures were assumed to have water quality similar to Lake Texana near Spillway gages (TCEQ SWQM ID #15377 and SWQM ID #13981) as shown in Figure 3-2.

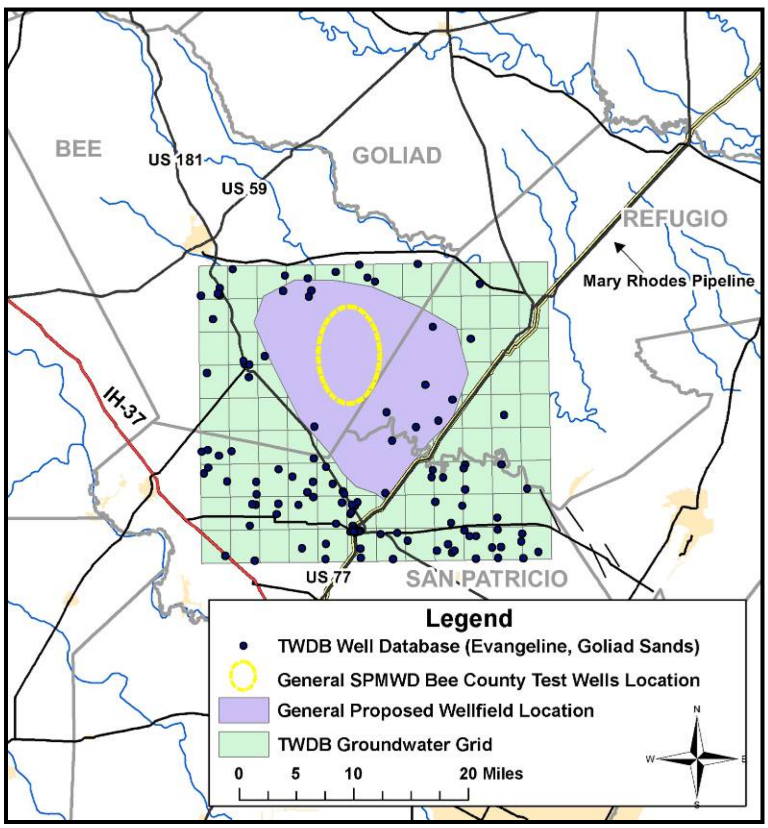


Figure 3-1. Groundwater Data Sampling Locations Used to Estimate Water Quality for Gulf Coast Aquifer Supply Project

[6] Texas Water Development Board, "Volumetric Survey of Lake Texana", April 6, 2001.

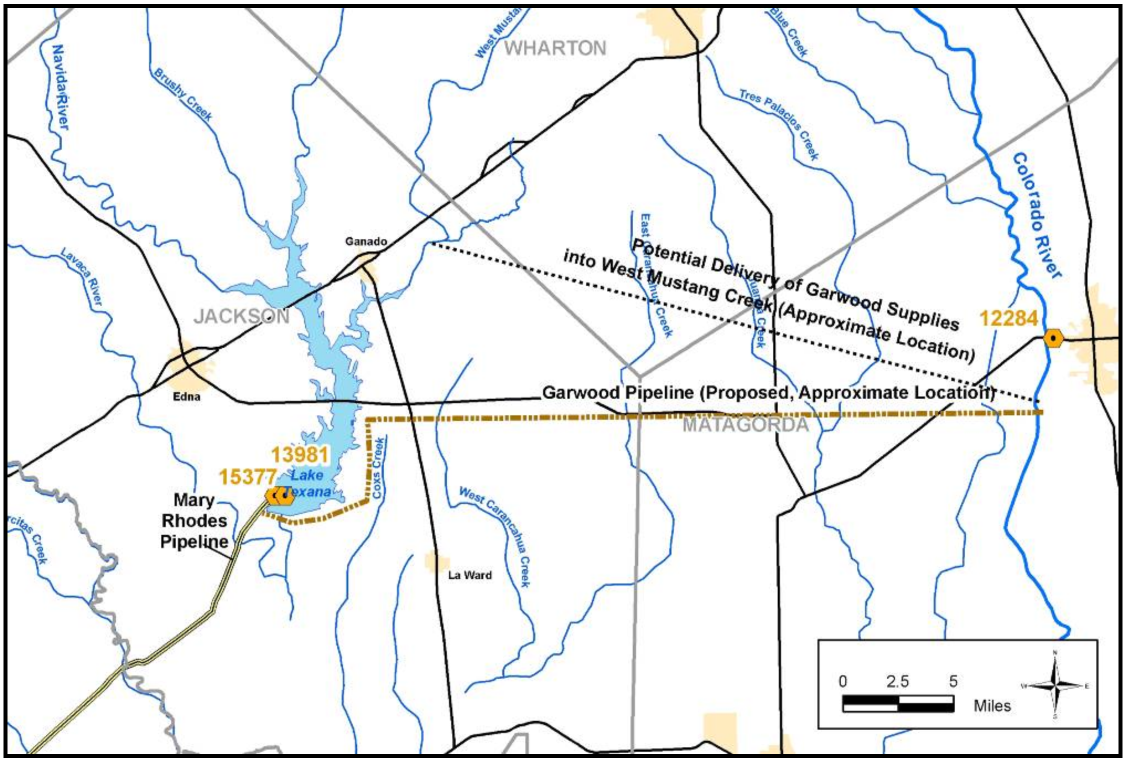


Figure 3-2. Water Quality Sampling Locations Used to Estimate Water Quality Data for the Garwood Project and Additional Lake Texana Supplies

Based on data availability, a summary of water quality constituents used for the water quality blending analysis is provided in Table 3-1. The estimated raw water quality for the Gulf Coast Aquifer Water Supply Project, Garwood Project, or additional Lake Texana supplies were then added to the Corpus Christi Water Quality and Treatment Model to simulate impacts of adding these potential new supply sources to the existing LCC/CCR/Lake Texana system and impacts on O.N. Stevens WTP facilities.

3.2 Corpus Christi Water Quality and Treatment Model

A modified version of a model previously developed for the City of Corpus Christi[7] was utilized to analyze water quality and treatment requirements when blending various combinations of the four water sources: Gulf Coast Aquifer groundwater supplies from Bee County, Colorado River at Bay City (for Garwood Project supplies delivered around Lake Texana), Lake Texana (also representative of Garwood Project supplies delivered through

[7] HDR Engineering, Inc. , Technical Memorandum "Corpus Christi Water Quality and Treatment Model, Project No. 09079-009-036, Water Treatment Model Development", February 2001.

Mustang Creek and Lake Texana), and Nueces River at O.N. Stevens WTP intake. A combination of several pre-existing models and treatment equations were utilized to develop the City of Corpus Christi Water Quality and Treatment model to estimate blended raw water quality, projected treated water quality, and relative chemical treatment costs when these waters are blended. The basis for most of the model was the “Water Treatment Plant Simulation Program, Version 1.21” developed for the USEPA.

Table 3-1.
Summary of Available Water Quality Data

	Surface Water		Groundwater	
Water Quality Parameters	**Lake Texana**	**Colorado River near Bay City**	**County Test Well Data**	**TWDB Well Database (near wellfield area)**
Total Dissolved Solids	✓	-	✓	✓
Chloride	✓	✓	✓	✓
Bromide	-	-	-	✓
Turbidity	✓	✓	✓	-
Temperature	✓	✓	✓	✓
Alkalinity	✓	✓	✓	✓
Hardness	✓	✓	✓	✓
pH	✓	✓	✓	✓
Total Organic Carbon	✓	✓	✓	-
Radium	-	-	✓	-
Gross Alpha	-	-	✓	-
Radon	-	-	✓	-
Uranium	✓	-	-	-
Arsenic	✓	-	✓	✓
Manganese	✓	-	✓	✓
Iron	✓	-	✓	✓

3.3 Water Treatment Assumptions and Considerations

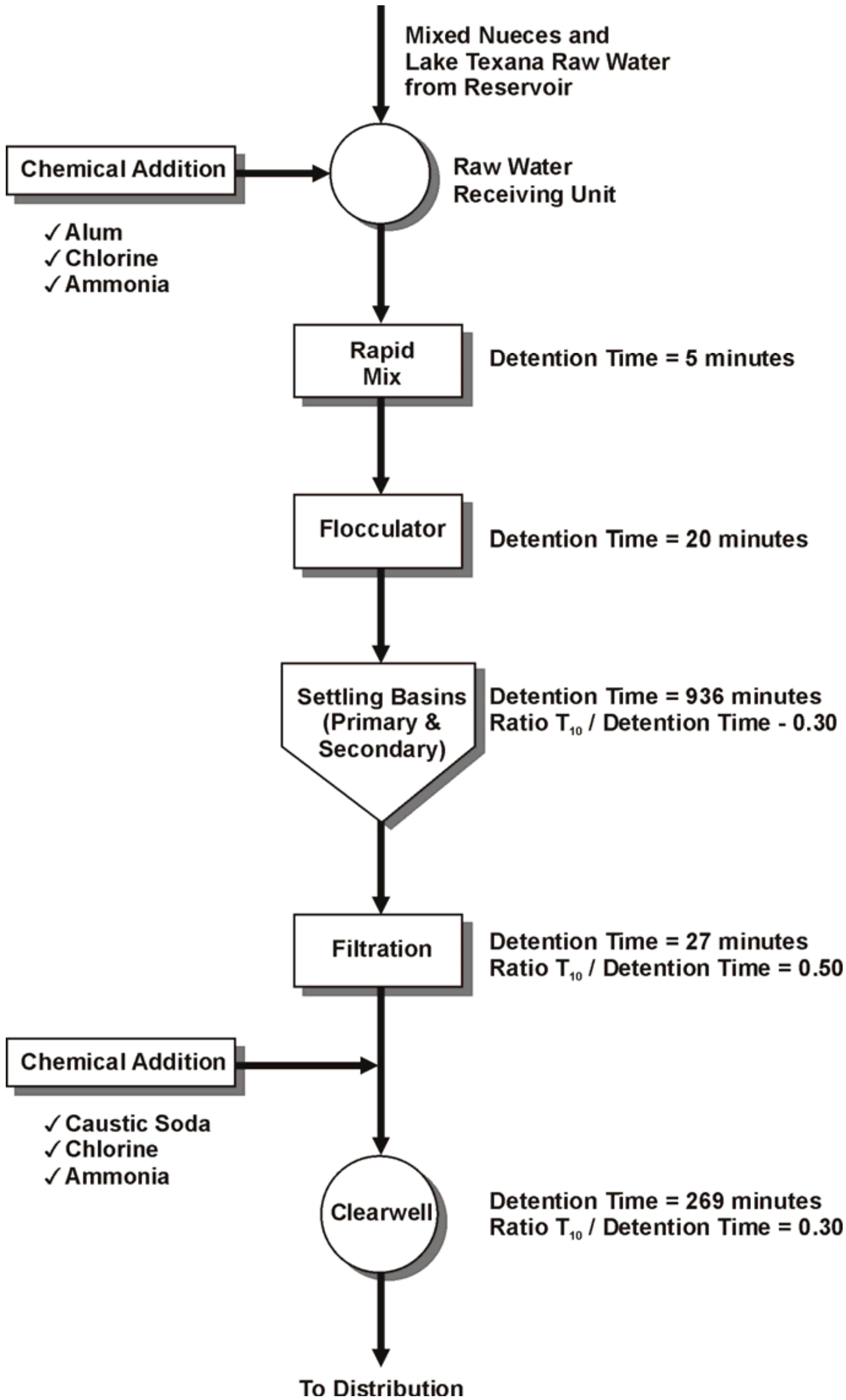
Water quality information from the four water sources were organized into median, minimum, and maximum values (water quality data and analysis methods discussed previously). Median water quality values were input into the model to calculate the resulting blended water quality for a wide range of possible combinations of the four water sources. The calculated blended water quality parameters were then input into a series of calculations to determine approximate optimum coagulant dose, Total Organic Carbon (TOC) removal with calculated coagulant dose, turbidity removal, resultant pH and alkalinity after application of the calculated coagulant dose, the Total Trihalomethanes (TTHM) formation potential, chloramines decay, and caustic dose for stabilization. The TTHM concentration is defined in this analysis as an indicator of the formation potential of all disinfection by-products (DBPs) of concern when utilizing chlorine or chloramines for disinfection. The model was developed to simulate the treatment processes currently utilized at the O.N. Stevens WTP.

The treatment chemical dosages calculated by the model were used to develop relative treatment costs of treating different water blends. Currently, the source water fed into the O.N. Stevens WTP is a blend of approximately 50% Nueces and 50% Texana raw water.[8] Information from previous City budgets and operator experience was used to approximate chemical dosages over the last several years. These current chemical dosages were used as a baseline to compare treatment costs for different raw water blend combinations.

Turbidity of the blended raw water will affect the quantity of sludge produced, filter run times and backwash requirements. However, the amount of sludge produced is not considered a significant cost factor because the O.N. Stevens WTP currently utilizes large ponds for sludge disposal and no significant transfer or costs are incurred from sludge handling. The pond capacity available is assumed to be sufficient to allow sludge disposal from any of the blended water possibilities without significant difference in the procedures or cost of sludge disposal.

A simplified schematic of the O.N. Stevens WTP was developed for use in the model calculations. Detention times used in the model were based on an average treated water flow of 75 mgd. Figure 3-3 shows the simplified schematic utilized with detention times indicated. Only those portions of the water treatment plant that would be expected to fluctuate in cost with different raw water blends were included in the schematic and considered in the cost comparisons.

[8] Based on information provided by the City of Corpus Christi on August 8, 2008. The provided spreadsheet included flows from the Nueces River and Lake Texana supplies into the O.N. Stevens WTP from January 2004 to July 2008 which was then used to calculated average source water blend ratios.



T_{10} = Detention time at which 90% of the water passing through the reservoir is retained in the reservoir. Generally determined by tracer studies.
Ratio T_{10}/Detention Time = The ratio between T_{10} and the theoretical detention time calculated as volume/flow rate.

Figure 3-3. O.N Stevens WTP Schematic[9]

[9] HDR Engineering, Inc. , Technical Memorandum "Corpus Christi Water Quality and Treatment Model, Project No. 09079-009-036, Water Treatment Model Development", February 2001.

3.4 Reservoir System Operations with Potential New Supplies

After evaluating the results of blended water quality with possible new projects, the CCWSM was used to simulate reservoir system operations with additional water supplies that may be delivered through the MRP from the Gulf Coast Aquifer Supply Project, Garwood Project from the Colorado River, and/or additional Lake Texana water developed by additional storage or alternative reservoir operating procedures. In an effort to provide a uniform comparison of potential water supply projects and isolate the impacts of each water supply project, the CCWSM was simulated for an annual demand of 175,000 acft/yr (or about Year 2010 projected demands) with full utilization of permitted Lake Texana supplies. Five combinations of existing and potential future water supplies through the MRP were simulated using the CCWSM. Model output was evaluated for each combination to determine average annual water supplies delivered by the MRP, annual pumping and operating costs for the pipeline, and impacts to freshwater inflows to the Nueces Bay and Estuary (Nueces B&E). The five scenario combinations considered current and potential future water supplies for delivery through the MRP and on average. The amount of MRP capacity in use ranged from 47% to 100%.

4.0 Study Results

4.1 Water Quality Constituents of Interest

The water quality constituents of interest for blended water qualities and treatment requirements are shown in Table 4-1. For some of the water quality constituents, there was not enough information available for calculations in the Corpus Christi Water Quality and Treatment model. In cases where water quality information was deficient, the required information for the treatment model was estimated from relationships between the missing constituent and other available constituents or from general relationships between constituents in other natural waters.

4.1.1 UV-254

There was not adequate information on UV-254 for any of the water sources. Therefore, UV-254 was estimated from the relationship between UV-254 and TOC. A strong correlation between UV-254 and TOC concentration has been observed for most natural waters. A general relationship between TOC and UV-254 developed from water quality data collected from 16 sites throughout the US was reported in an article by K. Bell-Auy Et Al[10]. The R^2 value for the correlation between TOC and UV-254 data presented in K. Bell-Auy et al. (2000) was 0.98. The relationship developed was utilized to estimate UV-254 for all source waters and is as follows.

$$UV254 = 0.0022*(TOC^2) + 0.04 * TOC + 0.0036$$

Table 4-1.
Water Quality Constituents
and General Impacts on Water Treatment

Water Quality Constituent	General Impact on Treatment
Temperature	DBP formation, disinfection requirements, disinfectant decay
Turbidity	Coagulant demand, filter run times, filtered turbidity, sludge production
TOC	Oxidant demand, coagulant demand, DBP formation
Ultraviolet absorbance at 254 nm (UV-254)	Coagulant demand, DBP formation
pH	Caustic dose, coagulant demand, DBP formation
Alkalinity	Caustic dose, enhanced coagulation requirements, corrosion chemistry
Calcium Hardness	Corrosion chemistry
Total Hardness	Corrosion chemistry
Total Dissolved Solids (TDS)	Finished water quality
Chloride	Finished water quality
Bromide	Disinfection byproduct formation
Iron	Oxidant demand, groundwater treatment requirements
Manganese	Oxidant demand, groundwater treatment requirements

4.1.2 Bromide

There was bromide information available only for Bee County groundwater. However, there was substantial chloride information available for all water sources. There is generally a strong correlation between chloride concentration and bromide concentration. The R^2 value for the correlation between chloride and bromide data available for the Nueces River has been

[10] Bell-Auy, Kimberly, et al, "Conventional and Optimized Coagulation for NOM Removal", Journal AWWA Vol. 92 October 2000.

calculated at 0.90. Therefore, a relationship was developed between chloride and bromide and used to calculate bromide concentrations for the other water sources.

$$Bromide\ (mg/L) = 0.0025 * Chloride\ (mg/L) + 0.0907$$

4.2 Blending Scenarios

The composition of raw water supplies treated at the O.N. Stevens WTP has historically averaged 50% Nueces River and 50% Lake Texana water. As mentioned earlier, the City has a contract with the Lavaca-Navidad River Authority to divert 41,840 acft/yr on a firm basis and up to 12,000 acft/yr on an interruptible basis from Lake Texana (up to 53,840 acft/yr). Based on the raw water source data provided by the City, interruptible supplies have varied from 0 to 2,300 acft/yr over the past few years based on need and water availability. For the blending scenarios, the firm supply of Nueces River and Lake Texana water currently treated at O.N. Stevens WTP (41,840 acft/yr of each supply[11]) was assumed to continue at the current rate while additional supplies are added. However, based on current use, this "existing operations" scenario requires about 37% of the MRP capacity to deliver an average supply of 41,840 acft/yr from Lake Texana with remaining supplies coming from the CCR/LCC System. Four blending scenarios were evaluated at several blended water percentage combinations, to simulate the integration of different combinations of potential future supplies to be delivered through the MRP (utilizing from 61% to 95% of the pipeline capacity[12]). The blending scenarios are:

(1) Addition of Gulf Coast Aquifer groundwater supplies from Bee County.

(2) Addition of Garwood Project supplies from the Colorado River – delivered via pipeline around Lake Texana that connects directly into the MRP.

(3) Addition of Garwood Project supplies from the Colorado River – delivered via canal or pipeline into West Mustang Creek and ultimately Lake Texana. These raw water supplies would then be withdrawn from Lake Texana and transported through the MRP (water quality of additional supply is essentially the same as Lake Texana).

(4) Addition of both the Gulf Coast Aquifer groundwater and Garwood Project supplies from the Colorado River (piped from the Colorado river directly into the MRP).

For Scenario # 3, the much larger quantity of water in Lake Texana will greatly dilute the new supply from the Colorado River. Therefore, the new Colorado River water supply being

[11] Data provided by City of Corpus Christi on August 8, 2008.
[12] Although the MRP is sized to deliver 112,000 acft/yr, the current MRP *pumping* capacity is 77,000 acft. A fourth pump would need to be installed in each of the three pump stations to deliver the full Garwood Project of 35,000 acft/yr in addition to the permitted Lake Texana Supplies.

diverted through Lake Texana is assumed to have a raw water quality that is the same as the existing Lake Texana water quality.

Table 4-2 shows the blending ratios evaluated and quantity of each water source in the blended water supply. Based on the 2006 Plan water demand projections and Year 2000 billing data provided by the City, the projected future water demand from O.N. Stevens WTP is anticipated to increase from about 90,000 acft/yr in 2010 to 131,000 acft/yr in 2060. The blended water scenario with all four water supply sources (Scenario # 4) include groundwater supplies from 10-20% of total supply in addition to an option based on existing operations and contract maximums, for a supply up to 160,680 acft/yr. Scenario # 4 *does not include additional Lake Texana supplies beyond contracted supplies*. For a supply scenario of 160,680 acft/yr with blending of all four supplies based on contract maximums, the amount estimated to be delivered through the MRP is 106,840 acft/yr, on average, or 95% of the pipeline capacity.

The City has an interbasin permit for up to 35,000 acft/yr diversion from the Colorado River for the Garwood Project. With full project utilization, the scenario would be most similar to Scenario # 2 "existing with 30% Colorado" combination. As discussed earlier, most blending scenarios were based on the "existing operations" scenario and do not include interruptible Lake Texana supplies. The Scenario 4 "blend all four based on existing operations and contract maximums" includes Lake Texana firm and interruptible supplies in addition to full project utilization of the Garwood Project and Gulf Coast Aquifer Supply Project.

4.3 Raw Water and Treated Water Quality Results for Blending Scenarios

The median raw water quality for each of the four water sources is shown in Table 4-3. A complete summary of water quality data and associated statistical analyses by source water are included in Appendix A. The groundwater concentrations of iron and manganese are below the regulatory levels of 0.3 mg/L for iron and 0.05 mg/L for manganese, therefore, additional treatment will not be required to remove iron and manganese from the groundwater. Therefore, the iron and manganese concentrations are not considered in the following evaluation of blended raw and treated water quality. Similarly, the temperature of all water sources is within the normal range of existing supplies so temperature is not considered in the following evaluation of blended raw and treated water quality.

Table 4-2.
Blended Water Percentages and Quantities

Scenario	***Existing***	***Scenario 1 – Gulf Coast Aquifer Supply Project in Bee County***		
Water Source	50% Nueces 50% Texana	Existing with 10% Groundwater	Existing with 15% Groundwater	Existing with 20% Groundwater
	Blended Water Percentages (%)			
Nueces River	50%	45%	42.5%	40%
Lake Texana	50%	45%	42.5%	40%
Colorado River	0%	0%	0%	0%
Groundwater	0%	10%	15%	20%
Total Percentage	100%	100%	100%	100%
	Water Quantity (acft/yr)			
Nueces River	41,840	41,840	41,840	41,840
Lake Texana	41,840	41,840	41,840	41,840
Colorado River				
Groundwater		9,000	15,000	21,000
Total Quantity	**83,680**	**92,680**	**98,680**	**104,680**

Scenario	***Scenario 2 - Garwood Project delivery via pipeline around Lake Texana***			***Scenario 3 – Garwood Project via Lake Texana***
Water Source	Existing with 10% Colorado	Existing with 20% Colorado	Existing with 30% Colorado	Garwood via Texana 40% Nueces 60% Texana[1]
	Blended Water Percentages (%)			
Nueces River	45%	40%	35%	40%
Lake Texana	45%	40%	35%	60%
Colorado River	10%	20%	30%	0%
Groundwater	0%	0%	0%	0%
Total Percentage	100%	100%	100%	100%
	Water Quantity (acft/yr)			
Nueces River	41,840	41,840	41,840	41,840
Lake Texana	41,840	41,840	41,840	41,840
Colorado River	9,000	21,000	35,000	21,000
Groundwater				
Total Quantity	**92,680**	**104,680**	**118,680**	**104,680**

[1] Scenario 3 assumes the 20% contribution from the Colorado River has the same raw water quality as Lake Texana. Therefore, the Colorado River portion of the blended water for water quality analysis is shown as 0%.

Table 4-2.
Blended Water Percentages and Quantities (Concluded)

Scenario	***Scenario 4 - Blend all four***			
Water Source	Blend All Four 10% Groundwater	Blend All Four 15% Groundwater	Blend All Four 20% Groundwater	Blend All Four Based on Existing Operations and Contract Maximums
	Blended Water Percentages (%)			
Nueces River	32%	30%	28%	33.5%
Lake Texana	32%	30%	28%	33.5%
Colorado River	26%	25%	24%	22%
Groundwater	10%	15%	20%	11%
Total Percentage	100%	100%	100%	100%
	Water Quantity (acft/yr)			
Nueces River	41,840	41,840	41,840	53,840
Lake Texana	41,840	41,840	41,840	53,840
Colorado River	35,000	35,000	35,000	35,000
Groundwater	13,200	21,000	30,000	18,000
Total Quantity	**131,880**	**139,680**	**148,680**	**160,680**

Table 4-3.
Median Raw Water Quality of Water Sources

Label					
Constituent	***Units***	***Nueces***	***Texana***	***Colorado (Garwood Project)***	***Gulf Coast Aquifer Groundwater***
Temperature	^oF	68	71	77	79
Turbidity	NTU	25	89	30	0
Total Organic Carbon (TOC)	mg/L	5.7	9.5	4.0	0.6
UV 254	1/cm	0.30	0.58	0.20	0.03
pH		8.0	7.8	8.2	7.8
Alkalinity	mg/L as CaCO3	164	68	177	284
Calcium Hardness	mg/L as CaCO3	200	62	180	210
Total Hardness	mg/L as CaCO3	230	77	246	263
Total Dissolved Solids (TDS)	mg/L	483	121	425	945
Chloride	mg/L	146	14	58	325
Bromide	mg/L	0.46	0.13	0.24	1.00
Iron	mg/L	Not Applicable	Not Applicable	Not Applicable	0.05
Manganese	mg/L	Not Applicable	Not Applicable	Not Applicable	0.014

Table 4-4 shows the median raw water quality of the blends considered. Conventional water treatment as practiced at the O.N. Stevens WTP generally will not significantly change the concentration of the dissolved constituents such as TDS and chloride. Therefore, TDS and chloride concentrations shown in Table 4-4 are representative of the anticipated median finished water quality. At concentrations below the regulatory limits of 300 mg/L for chlorides and 1,000 mg/L for TDS, the concentration of TDS and chloride will not directly impact chemical treatment costs at a conventional WTP.

Table 4-4.
Median Raw Water Quality of Blends

Scenario	***Units***	***Existing***	***Scenario 1 - Gulf Coast Aquifer Supply Project in Bee County***		
Label		50% Nueces 50% Texana	Existing with 10% Groundwater	Existing with 15% Groundwater	Existing with 20% Groundwater
Raw Water Constituents					
Turbidity	NTU	57	51	48	46
TOC	mg/L	7.6	6.9	6.5	6.2
UV 254	1/cm	0.44	0.40	0.38	0.36
pH		7.9	7.9	7.9	7.9
Alkalinity	mg/L as CaCO3	116	133	141	150
Calcium Hardness	mg/L as CaCO3	131	139	143	147
Total Hardness	mg/L as CaCO3	154	165	170	175
TDS	mg/L	302	366	398	431
Chloride	mg/L	80	105	117	129
Bromide	mg/L	0.30	0.37	0.40	0.44

Scenario	***Units***	***Scenario 2 - Garwood Project delivery via pipeline around Lake Texana***			***Scenario 3 - Garwood Project via Lake Texana***
Label		Existing with 10% Colorado	Existing with 20% Colorado	Existing with 30% Colorado	Garwood via Texana 40% Nueces 60% Texana
Raw Water Constituents					
Turbidity	NTU	54	52	49	63
TOC	mg/L	7.2	6.9	6.5	8.0
UV 254	1/cm	0.42	0.39	0.37	0.47
pH		8.0	8.0	8.0	7.9
Alkalinity	mg/L as CaCO3	122	128	134	106
Calcium Hardness	mg/L as CaCO3	136	141	146	117
Total Hardness	mg/L as CaCO3	163	172	181	138
TDS	mg/L	310	327	340	266
Chloride	mg/L	78	76	74	67
Bromide	mg/L	0.29	0.28	0.28	0.26

Table 4-4.
Median Raw Water Quality of Blends (Concluded)

Scenario	***Units***	***Scenario 4 - Blend all four***			
Label		Blend All Four 10% Groundwater	Blend All Four 15% Groundwater	Blend All Four 20% Groundwater	Blend All Four Based on Existing Operations and Contract Maximums
Raw Water Constituents					
Turbidity	NTU	44	42	39	45
Total Organic Carbon	mg/L	5.9	5.6	5.3	6.0
UV 254	1/cm	0.34	0.32	0.30	0.34
pH		8.0	7.9	7.9	8.0
Alkalinity	mg/L as CaCO3	149	157	164	148
Calcium Hardness	mg/L as CaCO3	152	155	159	151
Total Hardness	mg/L as CaCO3	189	193	197	185
TDS	mg/L	400	430	461	401
Chloride	mg/L	100	111	124	103
Bromide	mg/L	0.35	0.39	0.42	0.36

4.4 Water Treatment Cost Impacts with Potential Source Water Supplies

A summary of the Corpus Christi Water Quality and Treatment model results by treating each of the four water sources at 100% are shown in Table 4-5 and the results for the blended water scenarios are shown in Table 4-6. The relative total treatment costs were determined using the existing treatment costs of treating 50% Nueces and 50% Texana raw water at the O.N. Stevens WTP as a baseline for comparison. Similarly, the specific values calculated by the treatment model such as the coagulant dose and the TTHM concentrations should only be considered as rough estimates of the relative value of these treatment results for each blended water relative to the others. For example as shown in Table 4-6, if specific treatment and disinfection processes used for treating the existing raw water (50% Nueces and 50% Texana) results in finished TTHM water concentrations that are in the range of 67 ug/l then it is likely that the same treatment processes used to treat a blended water consisting of 40% Nueces, 40% Texana, and 20% groundwater from Gulf Coast Aquifer Water Supply Project in Bee County (Scenario # 1"Existing with 20% Groundwater") will result in DBP concentrations that are around 79 ug/l or roughly 15% greater than those observed when treating existing water.

Table 4-5.
Water Treatment Model Results for Water Sources

Label					
Parameter	***Units***	***Nueces***	***Texana***	***Colorado (Garwood Project)***	***Gulf Coast Aquifer Groundwater***
Cost Difference from Baseline (50:50 Nueces River and Lake Texana)	%	-27	33	-45	-83
TOC Removal Required	%	25	40	15	0
TTHM formed (40 hours)	ug/l	76	52	51	1
Sludge Produced	lb/year	20,000	67,000	23,000	6
Alum Dose	mg/L	34	80	28	0
Caustic Dose	mg/L	7	18	5	3
Treated Alkalinity	mg/L as CaCO3	164	70	176	288
Treated TOC	mg/L	3.6	3.7	2.7	0.6

Table 4-6.
Water Treatment Model Results for Blended Water Scenarios

Scenario	***Units***	***Existing***	***Scenario 1 - Gulf Coast Aquifer Supply Project in Bee County***		
Label		50% Nueces 50% Texana	Existing with 10% Groundwater	Existing with 15% Groundwater	Existing with 20% Groundwater
Parameter					
Cost Difference from Baseline	%	0	-10	-16	-19
TOC Removal Required	%	35	25	25	25
TTHM formed (40 hours)	ug/l	67	73	76	79
Sludge Produced	lb/year	43,000	38,000	36,000	33,000
Alum Dose	mg/L	52	44	40	36
Caustic Dose	mg/L	11	10	9	9
Treated Alkalinity	mg/L as CaCO3	117	134	142	152
Treated TOC	mg/L	4.0	3.9	3.8	3.8

Table 4-6.
Water Treatment Model Results for Blended Water Scenarios (Concluded)

Scenario	***Units***	***Scenario 2 - Garwood Project delivery via pipeline around Lake Texana***			***Scenario 3 – Garwood Project via Lake Texana***
Label		Existing with 10% Colorado	Existing with 20% Colorado	Existing with 30% Colorado	Garwood via Texana 40% Nueces 60% Texana
Parameter					
Cost Difference from Baseline	%	-6	-11	-15	7
TOC Removal Required	%	25	25	25	35
TTHM formed (40 hours)	ug/l	66	65	64	65
Sludge Produced	lb/year	41,000	39,000	37,000	47,000
Alum Dose	mg/L	48	46	44	56
Caustic Dose	mg/L	10	9	9	13
Treated Alkalinity	mg/L as CaCO3	122	128	134	109
Treated TOC	mg/L	3.9	3.8	3.7	4.0

Scenario	***Units***	***Scenario 4 - Blend all four***			
Label		Blend All Four 10% Groundwater	Blend All Four 15% Groundwater	Blend All Four 20% Groundwater	Blend All Four Based on Existing Operations and Contract Maximums
Parameter					
Cost Difference from Baseline	%	-25	-26	-31	-22
TOC Removal Required	%	25	25	25	25
TTHM formed (40 hours)	ug/l	70	72	74	71
Sludge Produced	lb/year	33,000	31,000	29,000	33,000
Alum Dose	mg/L	36	34	32	38
Caustic Dose	mg/L	7	8	7	8
Treated Alkalinity	mg/L as CaCO3	149	158	165	149
Treated TOC	mg/L	3.6	3.5	3.4	3.6

These relative treatment chemical cost estimates and DBP formation potentials can be used to compare differences between the blended water qualities, but the actual treatment costs and concentrations of DBPs that form for each water quality will be highly dependant on the specific treatment and disinfection processes used.

4.5 Summary of Water Quality and Blending Analysis

The blending analysis did not indicate any large treatment issues when blending Nueces River, Lake Texana, Gulf Coast Aquifer Supply Project, and Colorado River water (Garwood Project) in the ratios being considered. The existing treatment processes at the O.N. Stevens WTP are capable of treating any of the blends evaluated to produce finished water that meets all regulatory requirements and is non-corrosive to the distribution system.

One of the key differences between the water sources that could have triggered costly additional treatment is higher dissolved constituents (total dissolved solids and/or chlorides) that could require the addition of desalination treatment. However, as shown in Figure 4-1 the chloride concentrations of all the water sources except the groundwater (GW) are well below the Secondary Maximum Contaminant Level (MCL) of 300 mg/L for chlorides. Blending the groundwater at up to 20% of the total water supply will maintain a blended water chloride concentration of 129 mg/L that is still much lower than the Secondary MCL as shown in Figure 4-2. Based on the reported median chloride concentrations of each water source, groundwater supplies at up to 50% of the total water supply could result in a total blended water supply having chloride concentrations of less than 210 mg/L.

There is considerable variability in the chloride concentration for Gulf Coast Aquifer groundwater in Bee County with maximum chloride levels for some wells considerably higher than the median. Based on this water quality variability, a higher level of groundwater supplies (i.e. 50%) was not considered in order to provide a sufficient margin of safety for treatment. However, even at the maximum groundwater chloride concentration, the blended water chloride concentration would be less than the chloride secondary MCL of 300 mg/L if the groundwater is less than 20% of the total water supply. Therefore, limiting the groundwater to 20% of total supply is a reasonable goal to ensure regulatory limits are met during fluctuating water quality and to provide a relatively consistent water quality to customers.

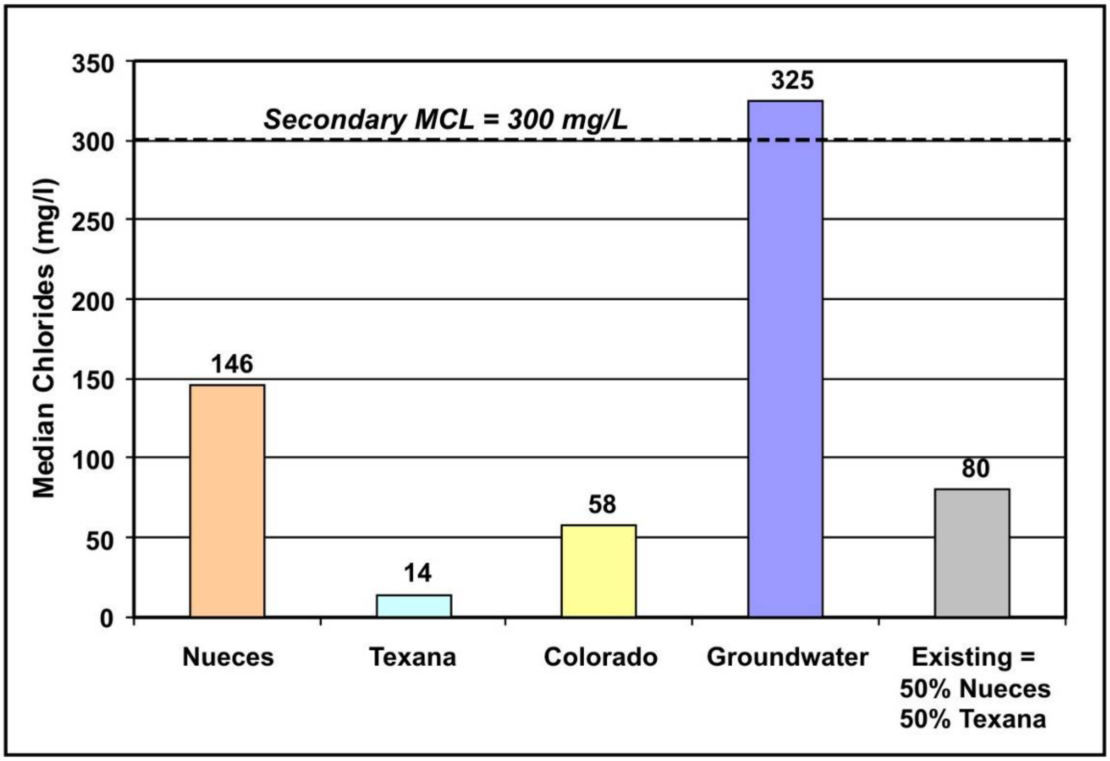


Figure 4-1. Median Raw Water Chlorides of Water Sources

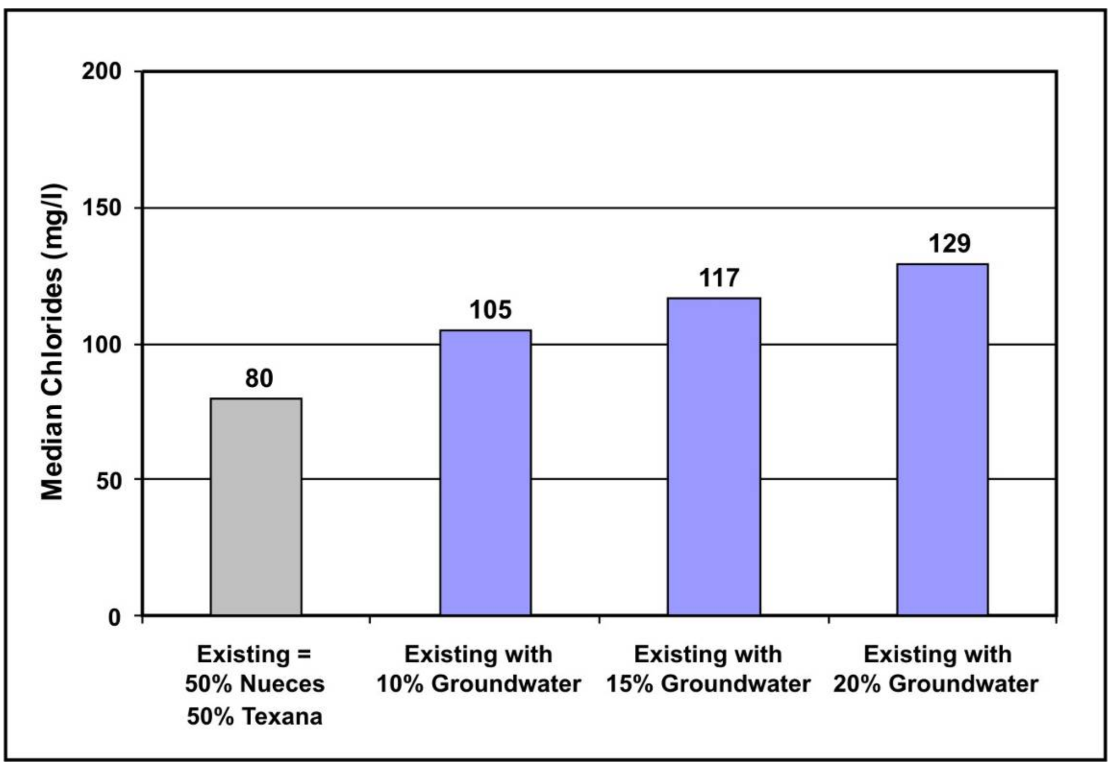


Figure 4-2. Median Chlorides for Groundwater Blending Scenarios

Lake Texana and the Colorado River water have much lower chloride concentrations and therefore blending these two water sources with the higher chloride supplies of Nueces River and groundwater supplies from the Gulf Coast Aquifer result in lower blended water chloride concentrations as shown in Figure 4-3. Figures 4-4, 4-5, and 4-6 show that the concentration of TDS has a similar relationship as concentration of chlorides for each water source and for the blending scenarios considered and that TDS is less than half the Secondary MCL for all blending scenarios considered.

A summary of blended water quality results in Table 4-7 shows that the addition of groundwater supplies from the Gulf Coast Aquifer could increase median chloride levels from 31 to 61% as compared to existing chloride levels for the CCR/LCC/Lake Texana System depending on the amount of groundwater supplies added as percent of total supply. Overall, the addition of Garwood Project water supplies would be expected to decrease chloride levels as compared with existing chloride levels for the CCR/LCC/Lake Texana System with the largest decrease in chloride levels of 17% with Garwood supplies delivered through Lake Texana prior to transmission by the MRP to treatment facilities. Blended water quality results for TDS have a similar relationship as chloride concentrations.

Modifications to the existing treatment requirements may be required if blending additional water sources leads to significant increases in the formation of DBPs such as TTHM forming in the plant and distribution system. An estimation of the TTHM formation potential for each water source and the blended water scenarios indicated that, while there is some potential for increased DBP formation with some blending scenarios, utilizing the existing treatment scheme at the O.N. Stevens WTP with chloramines as primary and secondary disinfectant is not likely to produce DBP concentrations that exceed the regulatory levels for any of the blending scenarios. The highest TTHM formation potential results occurred for the scenarios where surface water with high organics is blended with a groundwater that has high bromide concentrations. These scenarios result in higher DBP concentrations in the treated water due to the formation of brominated DBPs that are heavier.

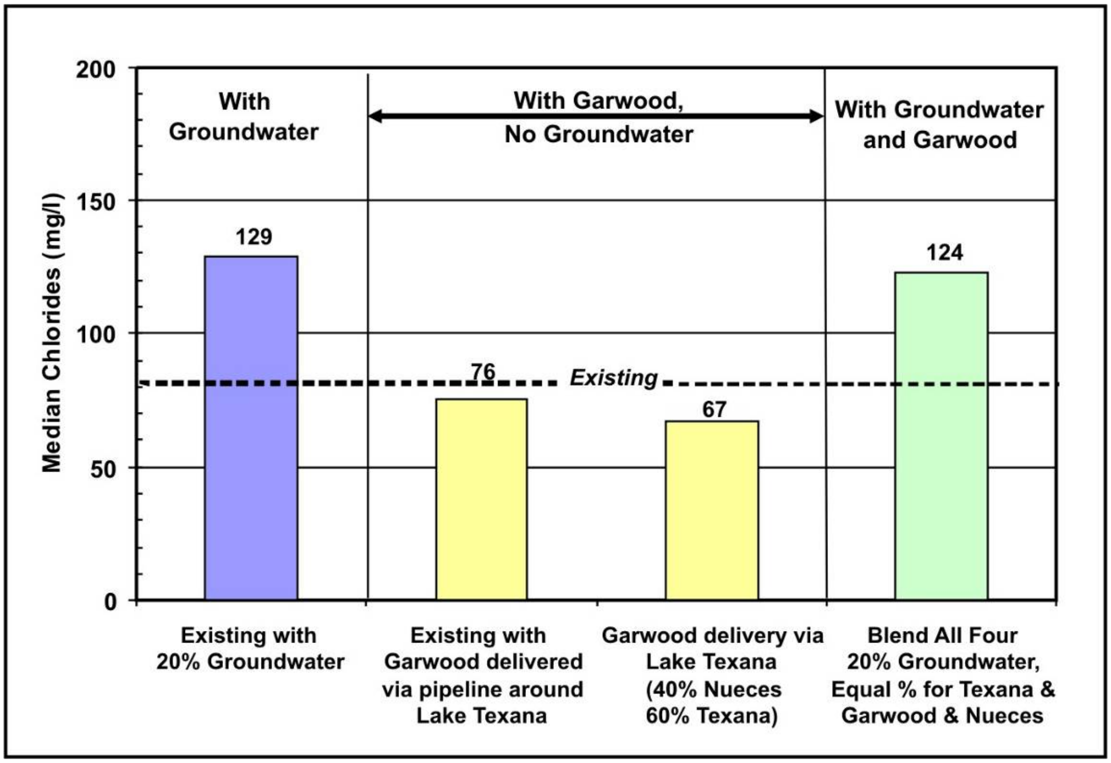


Figure 4-3. Summary of Median Chlorides for Blending Scenarios with Groundwater, Colorado River, Lake Texana, and Nueces River Combinations

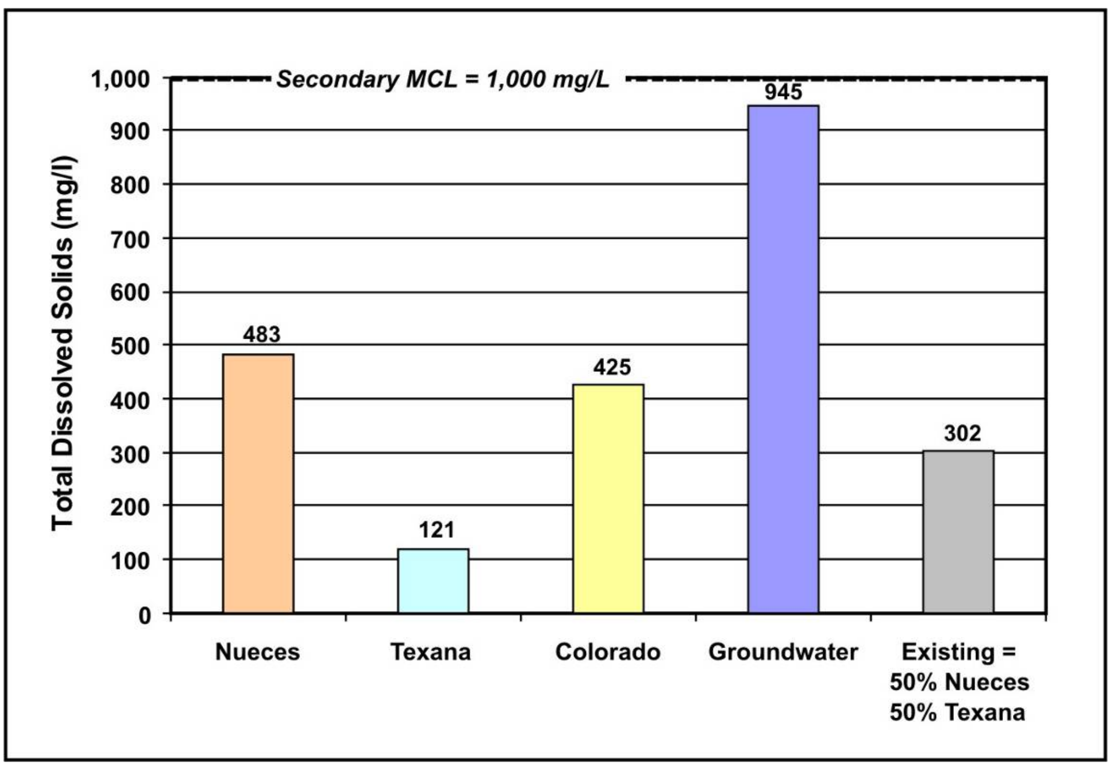


Figure 4-4. Median Raw Water TDS of Water Sources

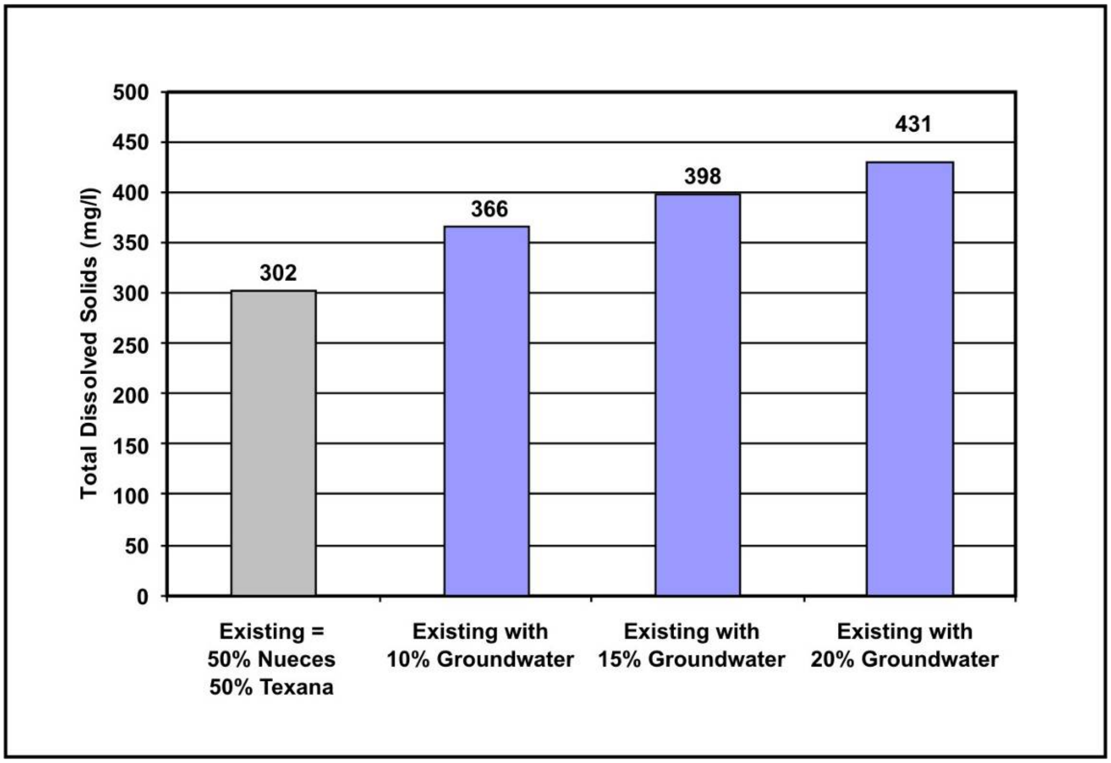


Figure 4-5. Median TDS for Groundwater Blending Scenarios

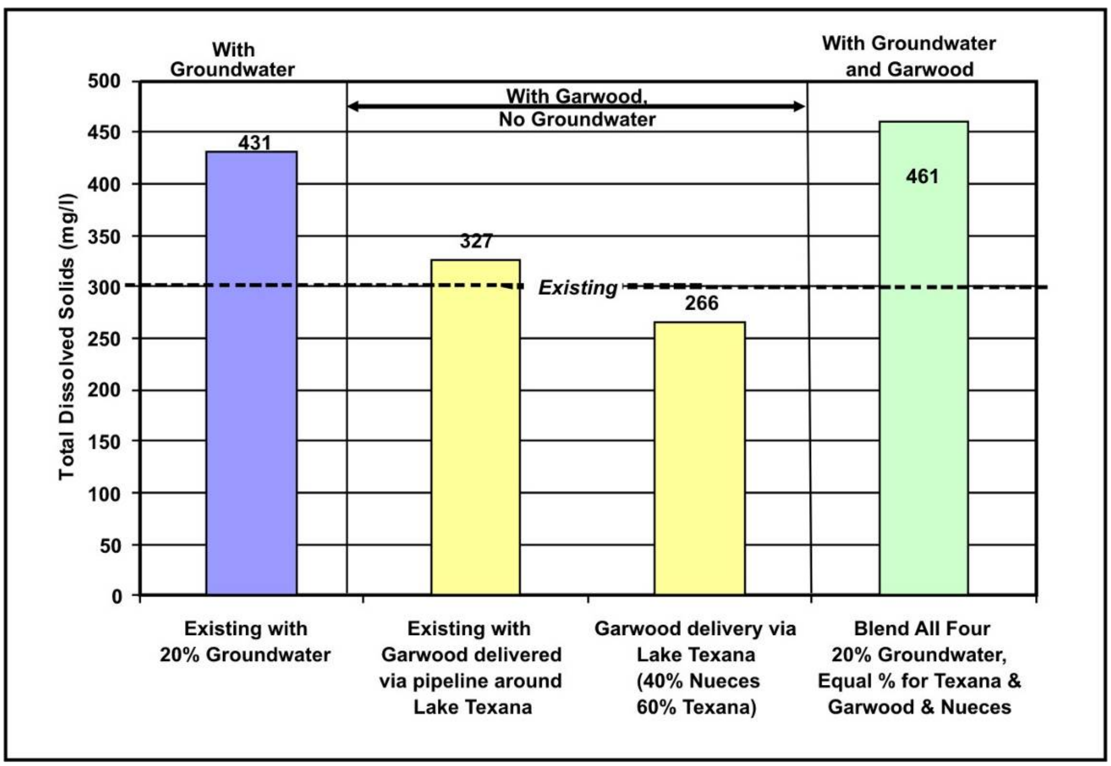


Figure 4-6. Summary of Median TDS for Blending Scenarios with Groundwater, Colorado River, Lake Texana, and Nueces River Combinations

Table 4-7.
Summary of Blended Water Quality Results

Supply Scenarios	Median Chlorides (mg/L)	% Change in Chlorides from Existing Supply	Median TDS (mg/L)	% Change in TDS from Existing Supply
Existing Supply				
Lake Texana and Nueces River (50:50 blend)	80	-	302	-
Blended Options (with New Supply Sources)				
Groundwater Supplies- 10% total supply	105	31%	366	21%
Groundwater Supplies- 20% total supply	129	61%	431	43%
Garwood Supplies- deliver around Lake Texana	76	-6%	327	8%
Garwood Supplies- deliver through Lake Texana	67	-17%	266	-12%
Groundwater (20%) and Garwood added	124	55%	461	53%

For the two potential new water sources (Gulf Coast Aquifer Supply Project in Bee County and Garwood Project- Colorado River supplies), the median values for pH, alkalinity, and hardness indicate that these waters will be stable and non-corrosive in a distribution system. Blending these new water sources with the existing water supplies from the Nueces River and Lake Texana will result in alkalinity and hardness concentrations that are about the same as the current median concentrations in the distribution system.

The blending analysis indicated that the existing treatment processes at O.N. Stevens WTP will be adequate to treat the raw water resulting from any of the blending scenarios without large modifications. Thus, costly new treatment processes such as desalination or additional organics removal technologies will not be required. However, there will be significant differences in the treatment costs that result from the quantity of chemicals required to treat each blended raw water quality. In general, higher TOC and turbidity in the raw water will require the use of more treatment chemicals and will result in higher quantities of sludge produced from the treatment process. The relative chemical cost for treating each of the water sources is shown in Figure 4-7. Higher treatment costs for the Lake Texana water are the result of higher total organic carbon and turbidity concentrations in the Lake Texana water. In contrast, the Colorado River raw water quality data for the Garwood Project indicates that the TOC and turbidity concentrations will be lower in the Colorado River than for either of the existing water supplies resulting in lower treatment costs. The lowest treatment costs are for the Gulf Coast Aquifer

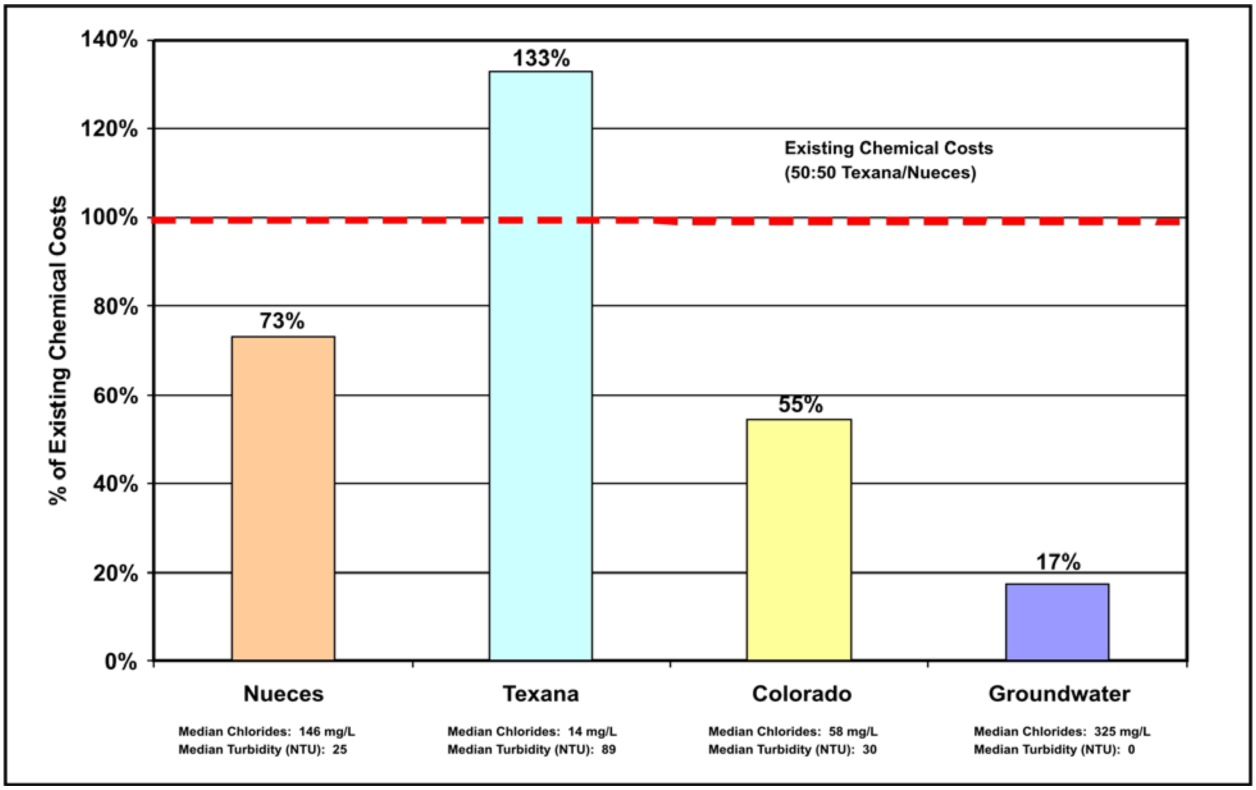


Figure 4-7. Summary of Relative Chemical Treatment Cost of Water Sources

Supply Project in Bee County due to the very low levels of turbidity and organics in the groundwater. Consequently, as shown in Figure 4-8, chemical treatment costs decrease for blending scenarios with increasing portions of groundwater supplies from the Gulf Coast Aquifer. Similarly, chemical treatment costs decrease for all blending scenarios that have less than the baseline 50% portion of the total water supply coming from Lake Texana as shown in Figure 4-9. Due to higher TOC and turbidity of Lake Texana source waters, the treatment costs are higher for scenarios with larger percent contributions from Lake Texana. For example, the water supply contribution from Lake Texana is 40% for the Scenario #1 “existing with 20% groundwater” option and has higher treatment costs than Scenario #4 with all four supplies blended (Lake Texana, Nueces River, Garwood Project, and 20% groundwater) which has a water supply from Lake Texana of 28%. The only blending scenario that resulted in chemical

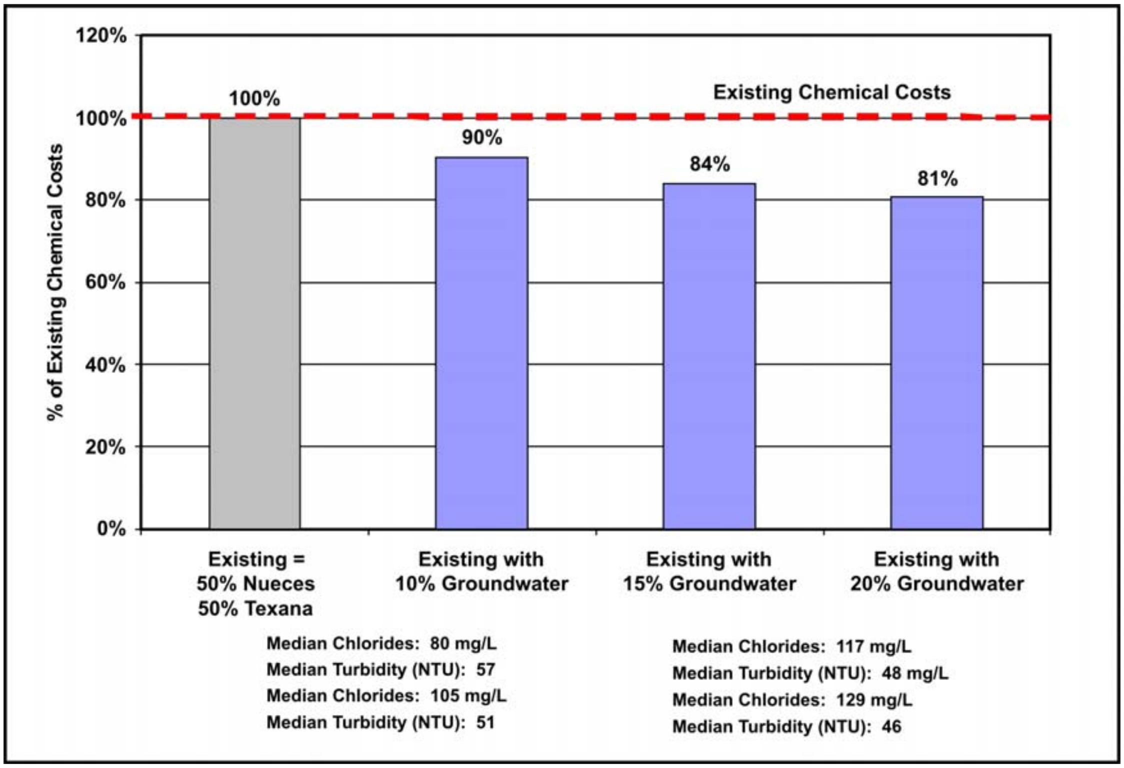


Figure 4-8. Summary of Relative Chemical Treatment Costs for Groundwater Blending Scenarios

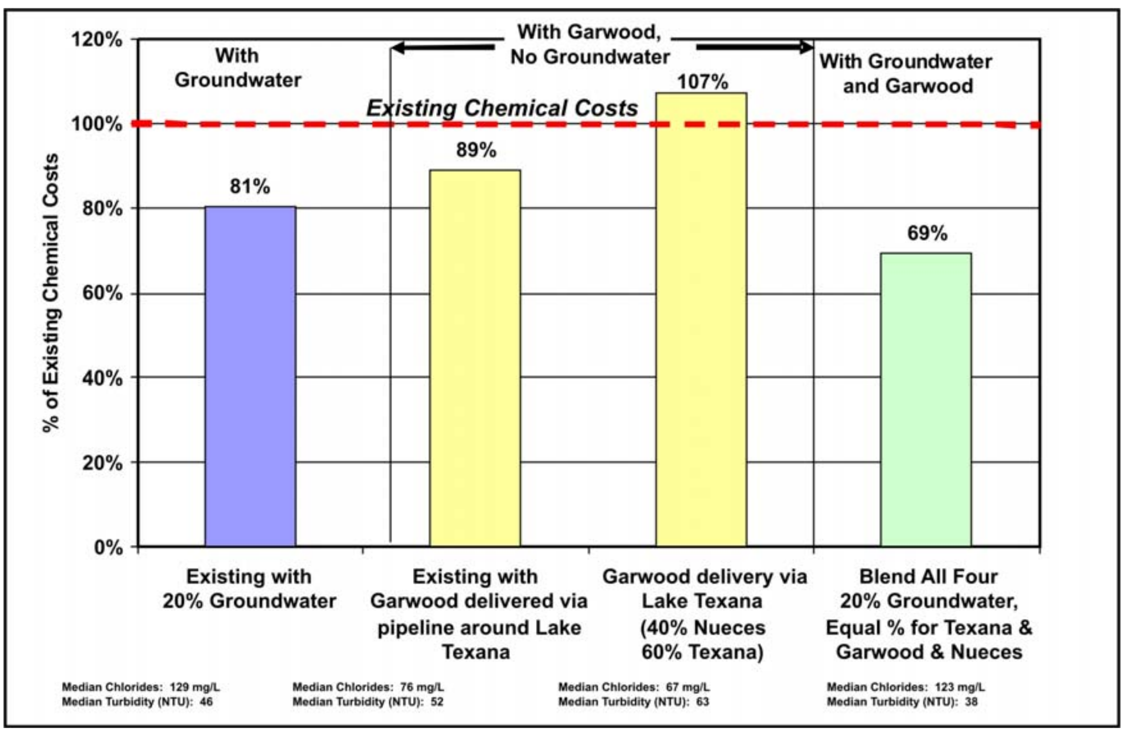


Figure 4-9. Summary of Relative Chemical Treatment Cost for Blending Scenarios

treatment costs higher than the existing chemical costs is the scenario where Colorado River water is transferred via Lake Texana, because this scenario effectively results in an increase of the total raw water supply that is made up of raw water with the quality of Lake Texana.

A summary of water treatment costs is provided in Table 4-8 and shows that turbidity levels impact the cost of water treatment. While blending groundwater supplies increases chloride levels, it decreases treatment costs by as much as 20% as compared to the existing treatment of CCR/LCC/Lake Texana supplies because of the lower turbidity in the groundwater supplies. Adding Garwood Project water delivered through Lake Texana would be expected to increase treatment costs by about 7% as compared to the existing CCR/LCC/Lake Texana system, with the assumption that blending of Garwood water in Lake Texana does not lower the median turbidity of the water withdrawn. Obviously, such blending would lower turbidity to some extent, thus treatment costs could be increased somewhat less than 7%.

Table 4-8.
Summary of Water Treatment Costs for Several Blended Options

Supply Scenarios	***Median Chlorides (mg/L)***	***Median Total Hardness (mg/L as CaCO3)***	***Median Turbidity (NTU)***	***Estimated % Change in Treatment Costs from Existing Supply***
Existing Supply				
Lake Texana and Nueces River (50:50 blend)	80	154	57	-
Blended Options (with New Supply Sources)				
Groundwater Supplies- 10% total supply	105	165	51	-10%
Groundwater Supplies- 20% total supply	129	175	46	-19%
Garwood Supplies (20%) - deliver around Lake Texana	76	172	52	-11%
Garwood Supplies (20%)- deliver through Lake Texana	67	138	63	7%
Groundwater (20%) and Garwood added	124	197	39	-31%

The blending analysis and resulting water treatment estimates are based on the median water quality for each water supply. The quantities of chemicals used and sludge produced will vary if water quality of any of the raw water sources changes considerably throughout the year or from year to year. However, based on the range of historical water quality for each water source as summarized in Appendix A at the blending ratios considered, the water quality of all the evaluated water sources vary within ranges that can successfully be treated at the O.N. Stevens WTP with existing treatment methods.

4.6 System Operations with Additional Supplies

The CCWSM was then used to evaluate system operations with additional supplies delivered through the MRP for the following five water supply combinations at an annual demand of 175,000 acft/yr:

1: Baseline (Lake Texana and CCR/LCC Supplies)
2: Baseline + Gulf Coast Aquifer Supply Project (18,000 acft/yr)
3: Baseline + Garwood Project Supplies (35,000 acft/yr)
4: Baseline + Gulf Coast Aquifer Supplies (18,000 acft/yr) + Garwood Project (35,000 acft/yr)
5: Baseline + Gulf Coast Aquifer Supplies + Garwood Project + additional Lake Texana supplies or other surface water from the Lavaca-Navidad River Basin for Maximum Delivery of up to 112,000 acft/yr through the MRP

For the baseline evaluation without additional supplies, the CCWSM prioritizes Lake Texana supplies of up to 53,840 acft/yr (or 48% MRP capacity) to be used first to meet annual water demands with the remaining supplies coming from the CCR/LCC System. For each simulation of an additional supply project (i.e. Gulf Coast Aquifer groundwater supplies or Garwood Project), the model would continue to prioritize Lake Texana supplies, then the additional supply project, with remaining supplies to meet the 175,000 acft/yr demand coming from the CCR/LCC System. Essentially as more water supplies are available through projects for delivery through the MRP, then supplies needed from CCR/LCC System to meet water demands decreases as shown in Figure 4-10. Model Scenarios # 2 through # 5 simulate future potential water sources delivered through the MRP with average pipeline utilization ranging from 61% (# 2) to 100% (# 5) MRP capacity. The average amount of water from various sources for an annual demand of 175,000 acft/yr based on a 70 year simulated hydrologic period from 1934 to 2003 is shown in Table 4-9.

Based on previous water quality blending analyses, these five combinations would be expected to have median raw water quality comparable to raw water quality blends presented earlier, as shown in Table 4-10.

The water source prioritization of the model and pipeline constraints strongly impact average water supply by source. For example, when interruptible supplies from Lake Texana are

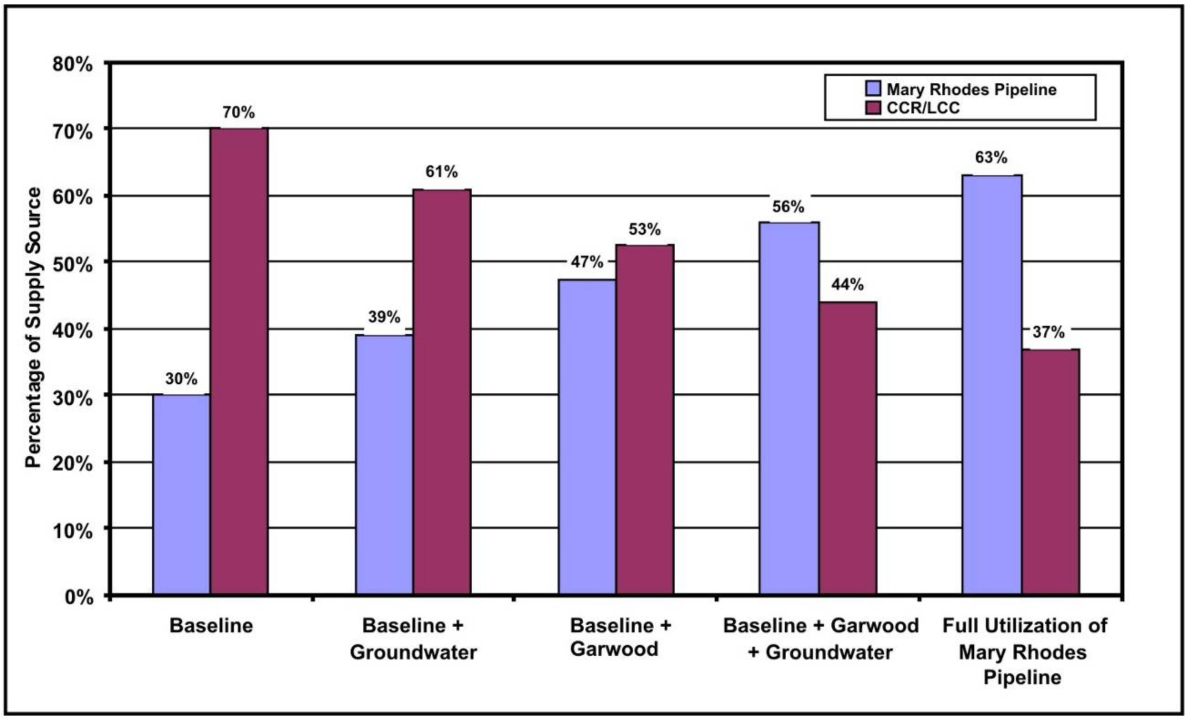


Figure 4-10. Comparison of Average Annual Water Supplies from the MRP and CCR/LCC System Based on Annual Demand of 175,000 acft/yr

Table 4-9.
Average Water Supply By Source to Meet an Annual Demand of 175,000 acft/yr

Water Supply Source	*1. Baseline (Lake Texana and CCR/LCC Supplies)**	*2. Baseline + Gulf Coast Aquifer groundwater*	*3. Baseline + Garwood Project*	*4. Baseline + Gulf Coast Aquifer groundwater + Garwood Project*	*5. Baseline + Groundwater + Garwood + additional Lake Texana*
Nueces River (acft)	122,590	106,550	91,910	77,140	64,660
Lake Texana[1]	52,410	52,410	52,410	52,410	52,410
Colorado River[2]	-	-	30,680	30,680	30,680
Groundwater	-	16,040	-	14,770[3]	16,040
Additional Lake Texana or other Lavaca-Navidad supplies	-	-	-	-	11,210
Total Average Annual Supply (acft)	175,000	175,000	175,000	175,000	175,000

[1] Based on contract for Lake Texana supplies of 41,840 acft/yr and interruptible supplies of 12,000 acft/yr (maximum 53,840 acft/yr).

[2] Based on Garwood Project permit for up to 35,000 acft/yr.

[3] The total average supply from MRP is 97,890 acft/yr. Since these multiple water supplies through the MRP are operated as a system, it is difficult to specifically isolate contribution from each project. The groundwater contribution was calculated after assuming Lake Texana and Colorado River supplies based on previous scenarios.

Table 4-10.
Estimated Median Raw Water Quality of CCWSM Water Supply Combinations Used to Evaluate Reservoir System Operations for a 175,000 acft/yr Supply

CCWSM Scenario	1. Baseline (Lake Texana and CCR/LCC Supplies)*	2. Baseline + Gulf Coast Aquifer groundwater	3. Baseline + Garwood Project	4. Baseline + Gulf Coast Aquifer groundwater + Garwood Project	5. Baseline + Groundwater + Garwood + additional Lake Texana
Similar Water Quality Analysis (As compared to Table 4-4 labels)	50% Nueces 50% Texana	Existing with 20% Groundwater	Existing with 30% Colorado	Blend All Four 15% Groundwater	Blend All Four Based on Existing Operations and Contract Maximums
Turbidity (NTU)	57	46	49	42	45
TOC (mg/L)	7.6	6.2	6.5	5.6	6.0
UV 254 (1/cm)	0.44	0.36	0.37	0.32	0.34
pH	7.9	7.9	8.0	7.9	8.0
Alkalinity (mg/L as CaCO3)	116	150	134	157	148
Calcium Hardness (mg/L as CaCO3)	131	147	146	155	151
Total Hardness (mg/L as CaCO3)	154	175	181	193	185
TDS (mg/L)	302	431	340	430	401
Chloride (mg/L)	80	129	74	111	103
Bromide (mg/L)	0.30	0.44	0.28	0.39	0.36

* Note: Water quality for Baseline simulation would be expected to have slightly higher chlorides and dissolved solids than indicated, since Lake Texana supplies would account for 30% of the total demand (based on contract limits of 51,840 acft/yr from Lake Texana) rather than the 50% from Lake Texana from previous analyses.

available then the model will simulate delivery of up to 4,000 acft/mo for the first three months (i.e., 12,000 acft/yr) in addition to the base permit of 3,487 acft/mo (i.e., 41,840 acft/yr divided by 12) from Lake Texana, for a total of 7,487 acft/mo (80% pipeline capacity). The MRP capacity of 112,000 acft/yr is simulated in the model by delivering up to 9,333 acft/mo (i.e., 112,000 acft/yr divided by 12). When Lake Texana supplies are fully utilized, there are a few months when the MRP capacity is limited to 1,846 acft/mo (or 20% pipeline capacity) for additional water supplies. Based on pipeline capacity constraints and model operations, the average Garwood Project supply shown in Table 4-9 is 30,680 acft/yr of the 35,000 acft/yr permit. These results should not be confused with the firm yield of the Garwood Project, which based on previous analyses has been found to be roughly equivalent to the permitted supply of 35,000 acft/yr when operated with the LCC/CCR/Lake Texana System. If groundwater, additional Lake Texana, or other Lavaca-Navidad supplies are not fully utilized as indicated in Scenario # 5 (Table 4-9), then additional supplies from the Garwood Project up to 35,000 acft/yr permit (contingent on water availability) would be able to be delivered through the MRP.

Currently, there are no facilities in place to convey Garwood Project supplies from the Colorado River to the MRP.

The CCWSM simulates average annual operating and pumping costs associated with supplies being delivered through the MRP. As expected, pumping costs increase with delivery of additional supplies through the MRP. Based on the current MRP pumping capacity of 77,000 acft, a fourth pump would need to be installed in each of the three pump stations to deliver the full Garwood Project of 35,000 acft/yr in addition to the permitted Lake Texana Supplies. Installation of the fourth pump results in an increased pumping cost of 190 – 240% as shown in Figure 4-11, on average, based on the amount of additional water pumped through the pipeline after adding the fourth pump.[13] The largest increase in annual pumping and operating costs is with full utilization of the MRP to deliver up to 112,000 acft/yr. These costs only include additional annual operating and pumping costs for the MRP, and do not include the capital costs to implement projects, well field costs, or infrastructure to deliver to the MRP. The costs to implement the Gulf Coast Aquifer Supply Project and Garwood Project will be updated during Phase II development of the 2011 Plan, to September 2008 U.S. Dollars per TWDB guidelines.

As expected, with more water supplies delivered through the MRP, less water would be used from the CCR/LCC system for water supply at a fixed annual water demand. This results in more water being stored in LCC and CCR, which causes increases in freshwater inflows to the Nueces B&E from the reservoir system according to provisions of the 2001 Agreed Order. As shown in Figure 4-12, full utilization of the MRP (112,000 acft/yr) would increase median freshwater inflows to the Nueces B&E by 49,700 acft (or 15%) as compared to current conditions. With only the Gulf Coast Aquifer Water Supply Project, the increase in median freshwater inflows to the Nueces B&E is negligible (<1%), simply because the average annual quantity of groundwater is about 16,040 acft/yr compared to an average annual quantity of 30,680 acft/yr with the Garwood Project. With the Garwood Project, the increase in median freshwater inflows to the Nueces B&E is about 7% as compared to current conditions.

[13] The cost analysis for this study only considers average annual pumping and operating costs, as compared to pumping costs with the existing MRP pump station configuration and operations. With a fourth pump added, the amount of water capable of being transmitted through the MRP increases from 77,000 acft/yr to 112,000 acft/yr. The pumping cost per acft of water delivered would likely increase by up to 75% with the addition of new project supplies as compared to existing operating conditions.

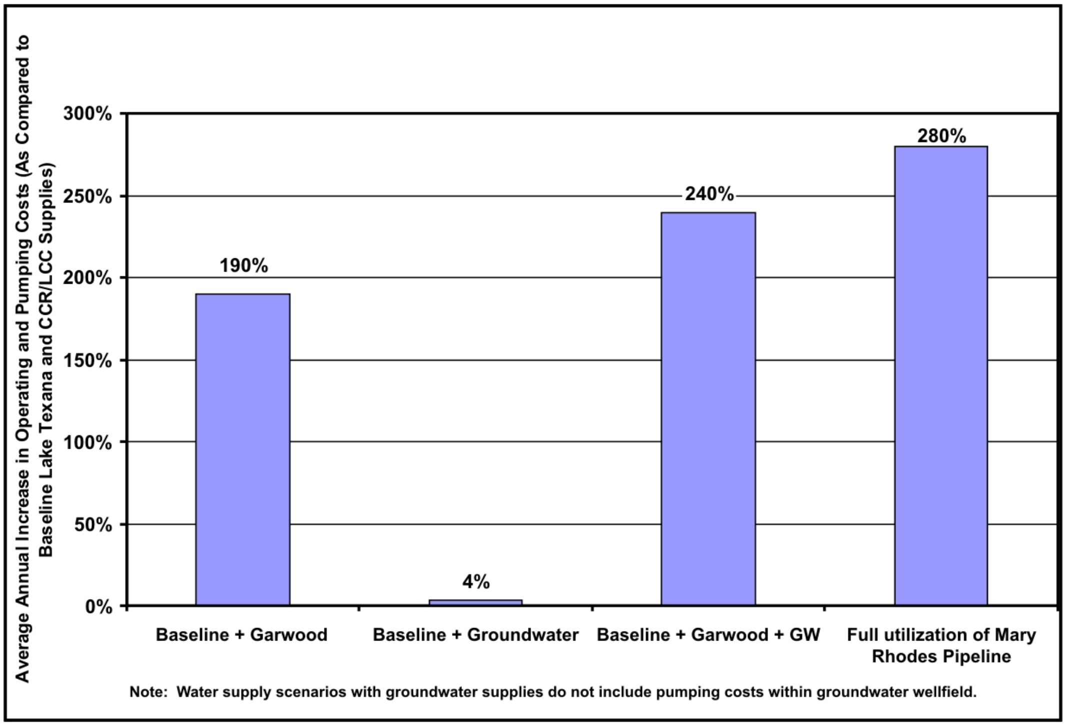


Figure 4-11. Average Annual Operating and Pumping Costs for New Water Supplies

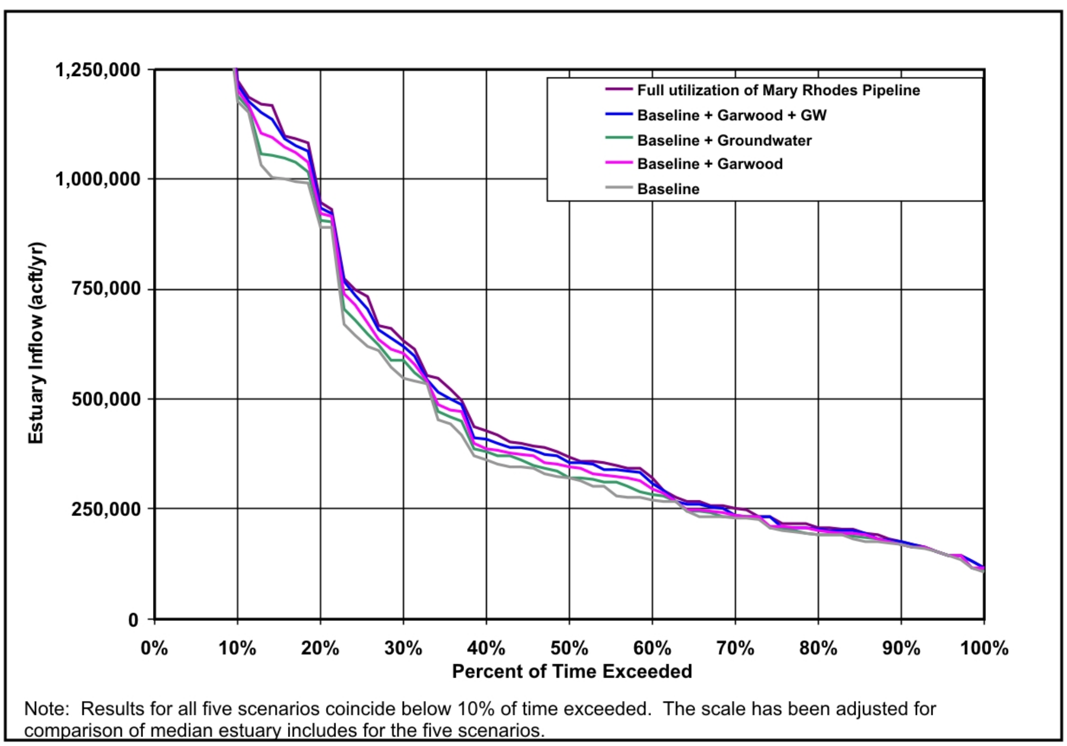


Figure 4-12. Project Impacts on Freshwater Inflows into the Nueces Estuary

5.0 Environmental Issues

The potential environmental issues related to delivery of water from new water supply projects through the MRP vary according to supply source and locations of connecting pipelines and pumping facilities. With judicious pipeline alignment, environmental impacts associated with routing of connecting pipelines can be minimized. The 2006 Plan includes detailed descriptions of environmental issues for the Garwood Project (Strategy N-14) and Gulf Coast Aquifer Supplies (Strategy N-7).

The pumping of groundwater from the Gulf Coast Aquifer could have a very slight negative impact on baseflow in the downstream reaches of streams near the project area in Bee, San Patricio, or Refugio Counties. However, many of the streams have minimal or no flow most of the time; thus, no measurable impact on wildlife along the streams is expected. Based on limiting groundwater supplies from the Gulf Coast Aquifer at 20% of total supplies, desalination and brine disposal will not be necessary. Habitat studies and surveys for protected species will need to be conducted at well field sites and along well field collection pipeline corridors prior to project implementation. Wetland impacts and primary pipeline stream crossings can be minimized by selecting pipeline routes with the least environmental disturbance and using appropriate construction methods, including erosion controls and revegetation procedures.

The City of Corpus Christi is currently studying several alternative delivery options to deliver Garwood Project supplies to the MRP. Prior to project implementation, a detailed environmental assessment and cultural resources survey will be needed to identify site-specific environmental considerations. In summary, the following environmental issues would need to be considered for the Garwood Project based on delivery option:

- Effects to the Colorado River downstream from the diversion, including the Lavaca-Colorado Estuary;
- For Garwood Project delivery around Lake Texana, the effects along the pipeline right-of-way from the diversion point on the Colorado River to the delivery point at the MRP pumping station;
- For Garwood Project delivery into West Mustang Creek and Lake Texana, the impacts of transferring source water from one basin to another including identifying and preventing transfer of any undesirable species.

6.0 Implementation Issues

Implementation of groundwater projects in Bee County are subject to rules and management plans of the Bee Groundwater Conservation District, which limits annual well production to 4 acft of water supply per acre. Based on the model simulations conducted for the 2006 Plan for 18,000 acft/yr of Gulf Coast Aquifer groundwater supplies in the vicinity of southeast Bee County using the Central Gulf Coast Groundwater Availability Model, the drawdown associated with the project was significantly less than drawdown criteria developed by the Coastal Bend Regional Water Planning Group.[14] Bee County is split between Groundwater Management Area (GMA) 15 and GMA 16, which are both in the process of preparing desired future conditions. These desired future conditions will then be used to determine groundwater available for permitting in Bee County, after which, the Gulf Coast Aquifer Groundwater Supply Project may be subject to county-wide production limits and require well field production permits from Bee Groundwater Conservation District. The SPMWD has conducted test drilling and aquifer water quality testing to evaluate the project feasibility and water quality concerns. Prior to implementing the Gulf Coast Aquifer Water Supply Project, capital and operation and maintenance costs should be evaluated in greater detail.

Implementation issues associated with the Garwood Project supplies are described in detail in the 2006 Plan. Delivery of the Garwood Project at a uniform annual rate to the MRP offer a significant benefit to the operations of the O.N. Stevens WTP by providing water quality consistency. Based on results of this study and those from previous studies by the City, adding Garwood Project to the MRP is anticipated to have minimal impacts on WTP operations other than potential increases in chemical costs for WTP and sludge disposal depending on delivery method of Garwood Project supplies.

The following permits will need to be obtained for interbasin transfer of Garwood Project supplies to the MRP and will require more detailed environmental impacts analysis as part of the permitting process:

[14] The Central Gulf Coast GAM used to simulate the Gulf Coast Groundwater Project pumping in the confined portion of the Evangeline aquifer, showed a maximum drawdown of about 50 feet. The CBRWPG adopted the following acceptable drawdown criteria for the 2006 Plan for confined aquifers: (a) water level declines limited to no more than 250 feet below predevelopment levels; and water level declines not exceeding 62.5% of the elevation difference between predevelopment flow heads and the top of the aquifer.

- Coastal Coordinating Council review;
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit;
- General Land Office Sand and Gravel Removal permit;
- U.S. Army Corps of Engineers (USACE) Section 10 and 404 dredge and fill permits for stream crossings;
- General Land Office easement if pipeline crosses any state owned riverbeds;
- Run-of-river and easement acquisition;
- Agency approval for crossing highways and railroads, creeks or rivers.

7.0 Evaluation Summary

The water quality blending analysis did not indicate any large treatment issues when blending groundwater supplies from the Gulf Coast Aquifer, surface water supplies from the Garwood Project, or additional supplies from Lake Texana with existing supplies from the Nueces River and Lake Texana. The analysis indicated that pre-treatment or costly new treatment processes such as desalination or additional organics removal technologies will not be required if groundwater supply is maintained at or below 20% of total water supply. The addition of groundwater supplies from the Gulf Coast Aquifer increases median chloride levels. However, groundwater supplies limited to 20% of the total water supply would result in a blended water quality of 129 mg/L which is well below Secondary Drinking Water Standards of 300 mg/L for chlorides. Overall, the addition of Garwood Project water supplies would be expected to decrease chloride levels as compared to existing chloride levels for the CCR/LCC/Lake Texana System.

Higher total organic carbon and turbidity in raw water supplies requires the use of more treatment chemicals and results in higher quantities or sludge produced from the treatment process. Due to low levels of turbidity and organics in groundwater supplies from the Gulf Coast Aquifer, chemical treatment costs decrease for blending scenarios with groundwater supplies. The only blending scenarios that resulted in chemical treatment costs higher than the existing chemical costs is the scenario with the Garwood Project (Colorado River water) transferred via Lake Texana, because this scenario results in an increase of total raw water supply that is made up of Lake Texana water quality which is higher in total organic carbon and turbidity concentrations.

In an effort to provide uniform comparisons of potential water supply projects and isolate the impacts of each water supply project, the CCWSM was used to evaluate reservoir system operations with potential new supplies delivered through the MRP for an annual demand of 175,000 acft/yr (roughly equal to Year 2010 demands) with full utilization of permitted Lake Texana supplies. Five combinations of existing and potential future water supplies through the MRP were simulated and the model output was evaluated for each combination to determine average annual water supplies delivered by the MRP, annual pumping and operating costs for the pipeline, and impacts to freshwater inflows to the Nueces B&E. The five scenario combinations considered current and potential future water supplies for delivery through the MRP and on average, the amount of MRP capacity utilized ranged from 47% to 100%. Essentially, as more water supplies are available for delivery through the MRP, the supplies needed from the CCR/LCC System decreases for a fixed water demand. This results in more water stored in the CCR/LCC System which increases quantities of reservoir pass-thrus of freshwater which then flows to the Nueces B&E according to provisions of the 2001 Agreed Order. With full utilization of the MRP (112,000 acft/yr), median freshwater inflows to the Nueces B&E would be expected to increase by about 49,700 acft (or 15%) as compared to current LCC/CCR/Lake Texana system operations.

The addition of Garwood Project supplies (up to 35,000 acft/yr) to permitted Lake Texana supplies requires installation of a fourth pump in each of the three MRP pump stations to deliver supplies for treatment, which would be expected to increase pumping and operating costs for the MRP by 190 to 240%, on average, based on the amount of additional water pumped through the pipeline after adding the fourth pump.[15] Since the amount of groundwater supplies from the Gulf Coast Aquifer (up to 18,000 acft/yr) are considerably less than Garwood Project supplies and over a shorter distance, additional pumping and operating costs for the MRP are not expected to change substantially from existing costs. During Phase II development of the 2011 Plan, costs to implement proposed water management strategies for delivery through the MRP will be updated including groundwater supplies from the Gulf Coast Aquifer and the Garwood Project.

[15] The cost analysis for this study only considers average annual pumping and operating costs, as compared to pumping costs with the existing MRP pump station configuration and operations. With a fourth pump added, the amount of water capable of being transmitted through the MRP increases from 77,000 acft/yr to 112,000 acft/yr. The pumping cost per acft of water delivered would likely increase by up to 75% with the addition of new project supplies as compared to existing operating conditions.

8.0 Texas Water Development Board Report Formalities

This report was prepared in accordance with the approved Scope of Work pursuant to TWDB Contract No. 0704830699. The preliminary draft report was posted in October 2008 on the Nueces River Authority website for Regional Water Planning Group and public comment. All draft report comments were addressed. The draft report was approved by the Coastal Bend RWPG on November 13, 2008 and submitted to the TWDB on December 23, 2008.

The TWDB provided comments on the draft report in March 2009. The Coastal Bend RWPG approved responses to the TWDB comments on March 12, 2009. A copy of TWDB comments on the draft study report and written summary of how this final report addresses these comments is provided in Appendix B.

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Appendix A
Summary of Raw Water Quality Statistics for Potential New Water Supply Projects Delivered through Mary Rhodes Pipeline

Colorado River nr Bay City (GARWOOD, SW SUPPLY, MAX 35,000 acft/yr)

Station ID	Description	USGS Gage	POR
12284	Colorado River @ SH35 Bridge at Bay City	8162500	2/9/84 - 6/6/07

SW Parameter	# of Samples	Min	Max	Median	Average	Normal Condition 35th to 65th percentile		Worst Condition 80th to 95th percentile	
ALKALINITY, TOTAL (MG/L AS CACO3)	**182**	**69**	**256**	**177**	**174**	**162**	**191**	**205**	**239**
CARBON, TOTAL ORGANIC, NPOC (TOC), MG/L	**179**	**1.0**	**12.1**	**4.0**	**4.3**	**3.6**	**4.3**	**5.0**	**7.0**
CHLORIDE (MG/L AS CL)	**176**	**1.5**	**158**	**58**	**61**	**49**	**66**	**79**	**114**
CHLORIDE, DISSOLVED (MG/L)	4	49.1	60.8	53	54	50	55	57	60
HARDNESS, TOTAL (MG/L AS CACO3)	**3**	**134**	**243**	**200**	**192**	**180**	**213**	**226**	**239**
PH (STANDARD UNITS)	**424**	**6.8**	**8.9**	**8.2**	**8.2**	**8.1**	**8.3**	**8.5**	**8.7**
TEMPERATURE, WATER (DEGREES CENTIGRADE)	428	6.5	32.9	25	23	21	28	30	31
TEMPERATURE, WATER (DEGREES FAHRENHEIT)	72	43.7	88.52	73	72	68	84	85	88
TOTAL ORGANIC CARBON,NPOC(TOC), SED DRY WT,MG/KG	3	1500	17900	6,260	8,553	4832	9752	13244	16736
TURBIDITY,FIELD NEPHELOMETRIC TURBIDITY UNITS, NTU	37	9.15	1000	26	97	23	44	73	411
TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	20	4	292	51	76	23	84	118	205
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU	**13**	**5.77**	**112**	**30**	**40**	**20**	**45**	**59**	**101**

*** Note: Bolded water quality parameters are referenced in Table 4-3.**

Lake Texana (MAX CURRENT WITH BASE + INTERRUPTIBLE 53,840 acft/yr), and Garwood Supplies Delivered through Lake Texana

Station ID 15377	Lake Texana Near Spillway	POR: 1/16/96 - 8/14/07
Station ID 13981	Lake Texana Near Spillway	POR: 2/2/93 - 7/12/06

SW Parameter	**# of Samples**	**Min**	**Max**	**Median**	**Average**	**Normal Condition 35th to 65th percentile**		**Worst Condition 80th to 95th percentile**	
ALKALINITY, FILTERED SAMPLE AS CACO3 MG/L	44	33	107	67	65	54	75	79	88
ALKALINITY, TOTAL (MG/L AS CACO3)	**61**	**10**	**295**	**68**	**68**	**54**	**74**	**84**	**95**
ALKALNITY,WATER,DISS,INCR TIT,FIELD,ASCACO3,MG/L	34	40	96	65	65	57	68	76	93
ARSENIC, DISSOLVED (UG/L AS AS)	80	1	29	2	4	2	3	4	15
CARBON, TOTAL ORGANIC, NPOC (TOC), MG/L	**60**	**2.7**	**23.2**	**9.5**	**9.9**	**7.0**	**10.5**	**13.1**	**21.4**
CHLORIDE (MG/L AS CL)	**148**	**3**	**36**	**14**	**16**	**12**	**18**	**23**	**28**
CHLORIDE, DISSOLVED (MG/L)	4	29	32	30	30	30	30	30	31
HARDNESS, TOTAL (MG/L AS CACO3)	**87**	**20**	**135**	**77**	**77**	**70**	**87**	**97**	**105**
IRON, DISSOLVED (UG/L)	98	3	2,721	19	158	11	29	51	1,264
MANGANESE, TOTAL (UG/L AS MN)	102	0	4,674	4	239	2	16	155	1,462
PH (STANDARD UNITS)	**1794**	**6.0**	**9.5**	**7.8**	**7.7**	**7.6**	**7.9**	**8.0**	**8.2**
SOLIDS, DISSOLVED-SUM OF CONSTITUENTS (MG/L)	**23**	**70**	**167**	**121**	**124**	**110**	**142**	**154**	**162**
TEMPERATURE, WATER (DEGREES CENTIGRADE)	1793	9	32	22	21	18	26	28	29
TEMPERATURE, WATER (Fahrenheit converted)		**47**	**89**	**71**	**70**	**65**	**78**	**82**	**85**
TURBIDITY, (JACKSON CANDLE UNITS)	14	14	190	53	64	35	55	72	184
TURBIDITY,FIELD NEPHELOMETRIC TURBIDITY UNITS, NTU	**6**	**6**	**98**	**89**	**69**	**75**	**91**	**95**	**97**
TURBIDITY,HACH TURBIDIMETER (FORMAZIN TURB UNIT)	20	21	110	57	62	49	72	90	101
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU	48	15	121	43	53	38	61	73	105
URANIUM, NATURAL, DISSOLVED	54	0.06	1.00	0.20	0.36	0.13	0.28	1.00	1.00

*** Note: Bolded water quality parameters are referenced in Table 4-3.**

Evangeline, Goliad Sands, and Chicot/Evangeline WQ

Water Quality Parameter	# Samples	Min	Max	Median	Avg	40th to 60th percentile	
TDS, mg/L	**54**	**594**	**2,548**	**945**	**1,081**	**911**	**982**
SO_4, mg/L	54	2	272	57	61	47	61
Cl^-, mg/L	**54**	**147**	**1,200**	**325**	**418**	**285**	**369**
pH	**54**	**6.9**	**8.6**	**7.8**	**7.8**	**7.7**	**7.9**
Total Alk, mg/L $CaCO_3$	**54**	**160**	**408**	**284**	**281**	**268**	**296**
Total Hardness, mg/L $CaCO_3$	**54**	**5**	**1,280**	**263**	**305**	**212**	**328**
Specific Cond (umhos/cm)	47	1,063	5,460	1,705	2,005	1,627	1,831
TEMPERATURE, WATER (DEGREES CENTIGRADE)	9	24	29	26	26	25	26
Temperature (converted to Fahrenheit)		**75**	**85**	**79**	**79**	**78**	**79**
ARSENIC, DISSOLVED (UG/L AS AS)	11	2	19	10	9	10	10
IRON, DISSOLVED (UG/L)	**12**	**15**	**149**	**51**	**52**	**32**	**51**
MANGANESE, DISSOLVED (UG/L AS MN)	**11**	**1**	**23**	**14**	**11**	**6**	**14**
ALKALNITY,WATER,DISS,INCR TIT,FIELD,ASCACO3,MG/L	11	238	315	279	276	260	292
BROMIDE (MG/L AS BR)	**11**	**0.5**	**2.6**	**1.0**	**1.2**	**0.9**	**1.1**

*** Note: Bolded water quality parameters are referenced in Table 4-3.**

San Patricio Municipal Water District- Bee County Groundwater Exploration Report (Groundwater Samples)														
			GS01			**GS03**								
			(694.5 - 724.5 ft bgs)	**(409.5 - 439.5 ft bgs)**		**(1024.5 - 1054.5 ft bgs)**		**(869.5 - 909.5 ft bgs)**		**(829.5 - 859.5 ft bgs)**				**(479.5 - 499.5 ft bgs)**
Water Quality Constituent	**Method**	**Units**	**Zone 1**	**Zone 2**		**Zone 1**		**Zone 2**		**Zone 3**				**Zone 4**
			GS01-2007-705	GS01-2007-420		GS03-2007-1035		GS03-2007-884		GS03-2007-840		GS03-DUP1		GS03-2007-490
Specific Conductivity	120.1	umhos/c	1280	1200		2330		1370		1230		1220		1410
Turbidity	**180.1Rev**	**NTU**						**2**		**1.38**		**1.91**		
Alkalinity	2320B	mg/L	283	256		290		297		326		311		630
Bicarbonate (HC03)	2320B	mg/L	283	256		283		290		307		299		236
Carbonate (CO3)	2320B	mg/L	1.14	1.14		7.7		11.5		19.2		11.5		393
Hardness	**2340C**	**mg/L**	**114**	**180**		**18**		**18**		**14**		**16**		**196**
Total Dissolved Solids	2540C	mg/L	**736**	**671**		**1120**		**719**		**746**		**726**		**851**
Total Cyanide	335.4	mg/L	0.000617[a]	0.000617[a]		0.000617[a]		0.000617[a]		0.000617[a]		0.000617[a]		0.000617[a]
Nitrate	353.2	mg/L	0.035	0.127		0.015		0.03		0.014		0.016		0.023
pH	4500	pH	7.75	7.72		8.46		8.51		8.43		8.45		6.27
Total Organic Carbon	5310	mg/L	0.26	0.211		1.31		0.471		0.682		0.406		0.718
Nitrite	8507	mg/L	0.008	0.0035		0.0035		0.0035		0.0035		0.0035		0.009
Antimony	6010B	mg/L	0.0063	0.0063		0.0063		0.0063		0.0063		0.0063		0.0063
Arsenic	6010B	mg/L	0.00428	0.00789		0.0031		0.0031		0.0031		0.0034		0.00375
Barium	6010B	mg/L	0.09	0.089		0.174		0.156		0.109		0.106		0.0919
Beryllium	6010B	mg/L	0.00036	0.00036		0.00036		0.00036		0.00036		0.00036		0.00036
Cadmium	6010B	mg/L	0.0019	0.0019		0.0019		0.0019		0.0019		0.0019		0.0019
Calcium	6010B	mg/L	25.5	37.6		4.28		4.12		4.22		4.33		44.4
Chromium	6010B	mg/L	0.00155	0.00155		0.00155		0.00155		0.00155		0.00155		0.00155
Copper	6010B	mg/L	0.00145	0.00145		0.00491		0.00145		0.00145		0.00145		0.00531
Iron	6010B	mg/L	0.666	0.705		0.08656		0.184		0.197		0.18		0.965
Lead	6010B	mg/L	0.0021	0.0021		0.00461		0.0021		0.0021		0.0021		0.0021
Manganese	6010B	mg/L	0.0128	0.0501		0.00378		0.00609		0.00752		0.00831		0.0601
Selenium	6010B	mg/L	0.00239	0.00399		0.00203		0.0021		0.00203		0.00203		0.00203
Sodium	6010B	mg/L	220	180		418		259		238		236		255
Thallium	6010B	mg/L	0.00784	0.00784		0.00784		0.00784		0.00784		0.00784		0.00784

San Patricio Municipal Water District- Bee County Groundwater Exploration Report (Groundwater Samples)(continued)														
			GS01			GS03								
			(694.5 - 724.5 ft bgs)	(409.5 - 439.5 ft bgs)		(1024.5 - 1054.5 ft bgs)		(869.5 - 909.5 ft bgs)		(829.5 - 859.5 ft bgs)				(479.5 - 499.5 ft bgs)
Water Quality Constituent	**Method**	**Units**	**Zone 1**	**Zone 2**		**Zone 1**		**Zone 2**		**Zone 3**				**Zone 4**
Mercury	7470A	ug/L	0.053	0.053		0.053		0.053		0.053		0.053		0.053
Total Coliform	9222B	cfu/100 mL	Present	Present		20		Present		Present		Present		Present
Chloride	**300Rev2**	**mg/L**	**203**	**173**		**489**		**180**		**133**		**134**		**266**
Fluoride	300Rev2	mg/L	0.883	0.571		1.03		0.792		0.472		0.472		0.568
Sulfate	300Rev2	mg/L	50	50.9		1.02		48.9		52.2		52.9		68.8
Asbestos	100.2		ND	ND		ND		ND		0.26		0.26		1.32
Silicon	200.7	ppm	10	11.619		7		7.02		7.47		7.37		10.5
Arsenic Speciation (III) by ASV	SW846 70	ug/L	5.8	11.4		ND		ND						7.6
Atrazine	8270C	ug/L	ND	ND		ND		ND				ND		ND
Photon Radioactivity/Beta Photon Emitters (CS-137)	901.1			NDALC		NDALC		NDALC				NDALC		NDALC
Gross Alpha	900			NDALC		NDALC		NDALC				NDALC		NDALC
Gross Beta	900	pCi/L		6.98	+/- 1.32	NDALC		8.7	+/- 2.86			NDALC		5.99
Radium 226	903.1			NDALC		NDALC						Result Below RL		Result Below RL
Radium 228	904			NDALC		1.02[b]	+/- 0.376[b]					NDALC		Result Below RL
Rn 222		pCi/L		100	+/- 23.2	257	+/- 35.9	203	+/- 29.3	1300	+/- 129	1280	+/- 126	

[a] converted to milligrams/liter from micrograms/liter

[b] duplicate. Original showed NDALC.

NDALC- not detected above limiting criteria

Note: gw samples collected on August 2 and 9, 2007 at test well GS01

Source of Data: San Patricio Municipal Water District

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Appendix B
TWDB Comments and
Summary of the Coastal Bend RWPG Responses

TWDB Contract No. 0704830699

Region N, Region-Specific Study 1:

<u>TWDB Comments on Draft Final Region-Specific Study Reports:</u>

1) **Evaluation of Additional Potential Regional Water Supplies for Delivery through the Mary Rhodes Pipeline, Including Gulf Coast Groundwater and Garwood Project**

Region-Specific Study 1: Evaluation of Additional Potential Regional Water Supplies for Delivery through the Mary Rhodes Pipeline, Including Gulf Coast Groundwater and Garwood Project

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1. ES-2: The executive summary and report body does not provide a summary that includes all of the following: total existing Mary Rhodes pipeline volume capacity; share of that current capacity already associated with existing supplies; remaining share of pipeline capacity; share of remaining capacity that would be required to transmit the existing Garwood water right held by Corpus Christi; and the share of pipeline capacity that would be required to support the scenarios that were modeled as part of this study. Please consider presenting a concise summary of how the Mary Rhodes pipeline capacity would be utilized under the scenarios and comment on whether or not there is capacity to transfer the full Garwood water right along with all the options that were considered in this study.

   Response: The requested information regarding MRP capacity with existing and potential future supplies as evaluated for blending water quality and modeled system operations has been added to the report body sections (1.0, 3.4, 4.2, 4.6, and 7.0). This information has also been summarized in the executive summary. Section 4.6 has been updated to include a brief summary on how the MRP capacity could be utilized under the modeled scenarios, in addition to a brief discussion of the ability of the MRP to transfer the permitted Garwood Project supply.

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