DIRECT, NON-POTABLE REUSE GUIDANCE DOCUMENT

APRIL 2009

THE SEAL THAT ORIGINALLY APPEARED ON THIS DOCUMENT WAS AUTHORIZED BY BRIAN K. McDONALD, P.E., TEXAS NO. 83332 ON APRIL 23, 2009. ALTERATION OF A SEALED DOCUMENT WITHOUT PROPER NOTIFICATION OF THE RESPONSIBLE ENGINEER IS AN OFFENSE UNDER THE TEXAS ENGINEERING PRACTICE ACT.

Brian K. McDonald, P.E.

Prepared for:
Region C Water Planning Group

Prepared by:
Alan Plummer Associates, Inc.
Freese and Nichols, Inc.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

GLOSSARY

BAF	Biological aerated filters
BOD_5	5-day biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
Ccf	100 cubic feet
CCI	Construction Cost Index
CFU	Colony-forming unit
ENR	Engineering News-Record
EPA	U.S. Environmental Protection Agency
FWISD	Fort Worth Independent School District
GC	Golf Course
IFAS	Integrated fixed-film activated sludge system
MBBR	Moving bed biofilm reactor
MBR	Membrane bioreactor
MGD	Million gallons per day
ml	Millileter
MP	Master Plan
NTU	Nephelometric turbidity unit
PDD	Peak Day Demand
RCWPG	Region C Water Planning Group
RWPF	Reclaimed Water Production Facility
SBR	Sequencing batch reactor
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks & Wildlife Department
TRWD	Tarrant Regional Water District
TSS	Total suspended solids
TWDB	Texas Water Development Board
USACE	U.S. Army Corps of Engineers

GLOSSARY (CONTINUED)

USFWS	U.S. Fish & Wildlife Service
UV	Ultraviolet light
VCWWTP	Village Creek Wastewater Treatment Plant
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
$MM	Million dollars

ES. Executive Summary

Reuse of treated wastewater effluent[1] is becoming an increasingly important source of water in Region C and across the state of Texas. The *2006 Region C Water Plan*[2] projected that, by 2060, the reuse of reclaimed water would provide a supply of 874,417 acre-feet per year (ac-ft/yr) to Region C water user groups, or approximately 26.4 percent of the 2060 Region C water demand. There are a number of reuse projects currently operating in Region C, and many others are currently in the planning and permitting process. Obviously, reuse will serve a major role in meeting future water supply requirements for the region.

To assist in development of reuse strategies, the Texas Water Development Board (TWDB) has provided funding to the Region C Water Planning Group (RCWPG) and its consultant team to develop a guidance document for implementation of direct reuse projects. This guidance document identifies technical and regulatory issues to be addressed in the planning and design of direct, non-potable reuse projects. Chapters 2 and 3 consist entirely of guidance information. Guidance is included in the first section of other chapters, followed by case study information where applicable.

To serve as a case study for the guidance document, the RCWPG has also refined the implementation plans for two direct reuse projects for the City of Fort Worth: a Central System to serve potential customers between the Village Creek Wastewater Treatment Plant (VCWWTP) and the Central Business District and a Southern System to serve potential customers in the Southern industrial area located near the intersection of Interstate Highways 20 and 35W. These projects were recommended in the *2006 Region C Water Plan* and were included in Fort Worth's 2007 *Reclaimed Water Priority and Implementation Plan*.[3]

---

1 Also called "reclaimed water" or "recycled water."

2 Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel & Yerby, Inc., and Cooksey Communications, Inc., January 2006. *2006 Region C Water Plan*, prepared for the Region C Water Planning Group, Fort Worth.

3 Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

In the *Reclaimed Water Priority and Implementation Plan*, the Southern service area was considered in both a stand-alone Southern System alternative and in combined Central/Southern System alternatives. One of the combined Central/Southern System alternatives was preferred in the *Plan*, because it was the lowest cost alternative. However, the Southern System alternative was economically viable and could be implemented more quickly than a combined alternative to provide water to the Southern service area. It appears that the demands in the Southern service area may be more immediate than those in the Central service area, so the stand-alone Southern System concept has been refined for this report.

The next sections address Texas regulations for direct reuse, other guidance and regulations, reclaimed water supply and quality, reclaimed water demands, reclaimed water production facilities, the conceptual design of a reclaimed water production facility, the conceptual design of reclaimed water conveyance systems, costs and benefits, permitting issues, selection of preferred alternatives, and the implementation plan.

ES.1. Texas Regulations on Direct, Non-Potable Reuse

In Texas, the use of reclaimed water for beneficial purposes is regulated by the Texas Commission on Environmental Quality (TCEQ). The specific regulations are codified in Title 30, Chapter 210 of the Texas Administrative Code (30 TAC 210). Chapter 210 defines two types of direct use of reclaimed water based on the likelihood that the water would come in contact with humans. Regulations concerning the quality of the water, design of reclaimed water storage facilities, restrictions on the use of reclaimed water, and the frequency of monitoring are different for the two types of reclaimed water, Type I and Type II (Table ES-1).

ES.2. Other Guidance and Regulations

There are currently no specific federal regulations that address direct reuse. However, the U.S. Environmental Protection Agency (EPA) has released updated guidelines for reuse.[4] The EPA

[4] *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

guidelines include recommendations for treatment levels, water quality, and monitoring for direct reclaimed water uses.

Table ES-1
Texas Requirements for Type I and Type II Direct Reuse

Item	Type I	Type II
Definition	Reclaimed water use where contact with humans is likely	Reclaimed water use where contact with humans is unlikely
Examples of Uses	• Residential irrigation. • Irrigation of public parks, golf courses, and athletic fields. • Fire protection. • Irrigation of food crops. • Irrigation of pastures for milking animals. • Maintenance of impoundments or natural waterbodies where recreational activities are anticipated. • Toilet or urinal flush water. • Other activities with potential for unintentional human exposure.	• Irrigation of sod farms, silviculture, limited access and ROWs where human access is restricted or unlikely. Irrigation of food crops. 1. Remote site 2. Controlled access 3. Site not used by public when irrigating (golf courses, cemeteries, and landscaped areas surrounding commercial or industrial complexes) 4. Restricted by ordinance • Irrigation of food crops without contact with edible part or with pasteurization. • Irrigation of animal feed crops. • Maintenance of impoundments/waterbodies where direct human contact is unlikely. • Soil compaction or dust control. • Cooling tower make-up water. • Irrigation or other nonpotable uses at a WWTP.
Quality Standards (30-day averages)	• Fecal coliforms: <20 CFU/100 ml geometric mean or <75 CFU/100ml single grab • BOD_5/$CBOD_5$ = 5 mg/l • Turbidity = 3 NTU	• Fecal coliforms: <200 CFU/100 ml geometric mean or <800 CFU/100ml single grab • For a pond system, BOD_5 = 30 mg/l • For other systems, BOD_5 = 20 mg/l and $CBOD_5$ = 15 mg/l
Sampling and Analysis	Twice per week	Once per week

Some states have regulations (enforceable rules), others have guidelines (not enforceable but could be used to develop programs), some have both, and others have neither. The states with the most comprehensive regulations include Arizona, California, Florida, Hawaii, Massachusetts, Nevada, New Jersey, North Carolina, Oregon, South Dakota, Texas, Utah, and Washington.

Regulations focus either on using reclaimed water as a resource or providing an alternative to a stream discharge. The established regulations tend to be a function of the potential for human contact with the reclaimed water either through physical contact or ingestion of food – the more likely the contact, the more stringent the regulations.

ES.3. Reclaimed Water Supply and Quality

Fort Worth's minimum monthly wastewater flow during the 2002-2006 period was approximately 46 percent of the water use for the wastewater customers. Therefore, the Fort Worth reclaimed water supply was estimated to be 46 percent of the projected water demands[5] for its wastewater customers. The projected average day reclaimed water supply ranges from about 85 million gallons per day (mgd) in 2010 to 205 mgd in 2060.

Current treatment processes at the Village Creek Wastewater Treatment Plant (WWTP) consistently meet Type I requirements. The turbidity is generally an order of magnitude lower than required, and the carbonaceous biochemical oxygen demand (CBOD) stays well below the 5 mg/l limit. However, as flows increase toward the design capacity, some additional treatment facilities (such as additional filters) may be required to sustain Type I effluent quality. Additional data are shown in Chapter 4.3 for evaluation of irrigation use (chlorides) and cooling tower use (hardness and total alkalinity).

ES.4. Reclaimed Water Demands

Potential reclaimed water users were identified through analysis of Fort Worth water billing records, surveys of potential customers, meetings with potential customers, meetings with nearby cities, meetings with developers, meetings with Fort Worth Parks and Community Services Department personnel, meetings with Trinity River Vision Project staff, and review of other studies. The potential reclaimed water users were compared and ranked based on the amount of reclaimed water that could potentially be supplied to each user. Potential users were then

---

[5] Projected water demands obtained from: Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel & Yerby, Inc., and Cooksey Communications, Inc., January 2006. *2006 Region C Water Plan*, prepared for the Region C Water Planning Group, Fort Worth.

analyzed based on location to identify potential projects, or alternatives, for further analysis. The potential users and demands that have been identified are further described in this chapter.[6]

Potential reclaimed water users for the Central System and the Southern System are discussed in the following sections. Figure ES-1, taken from the *Reclaimed Water Priority and Implementation Plan*,[7] shows the general service areas for all proposed reclaimed water projects in Fort Worth.

Central System

The Central System service area extends west from the Village Creek WWTP to the downtown Fort Worth area near the IH-35W and IH-30 intersection, and as far south as Cobb Park (Figure ES-1). Potential reclaimed water uses and users in the Central System include:

- Commercial irrigation (Trinity River Vision),
- Golf course irrigation (Meadowbrook, Sycamore Creek, and Woodhaven),
- Park and recreational facilities irrigation (Gateway Park and Sycamore Park),
- Cooling tower makeup water (Harris Methodist Hospital and Central Business District), and
- Evaporative makeup water (Trinity River Vision).

Projected Central System reclaimed water demands are summarized in Table ES-2.

Southern System

The Southern System service area is an area located east of IH-35W, to the north and to the south of IH-20 (Figure ES-1). Potential reclaimed water uses and users in the Southern System include:

- Commercial irrigation (Alcon Laboratories, Miller Brewing, Federal Correctional Institution, Tarrant County Resource Connection, and Rolling Hills Tree Farm),

---

[6] Some of this analysis took place during previous studies.

[7] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

Figure ES-1
City of Fort Worth Reclaimed Water Service Areas

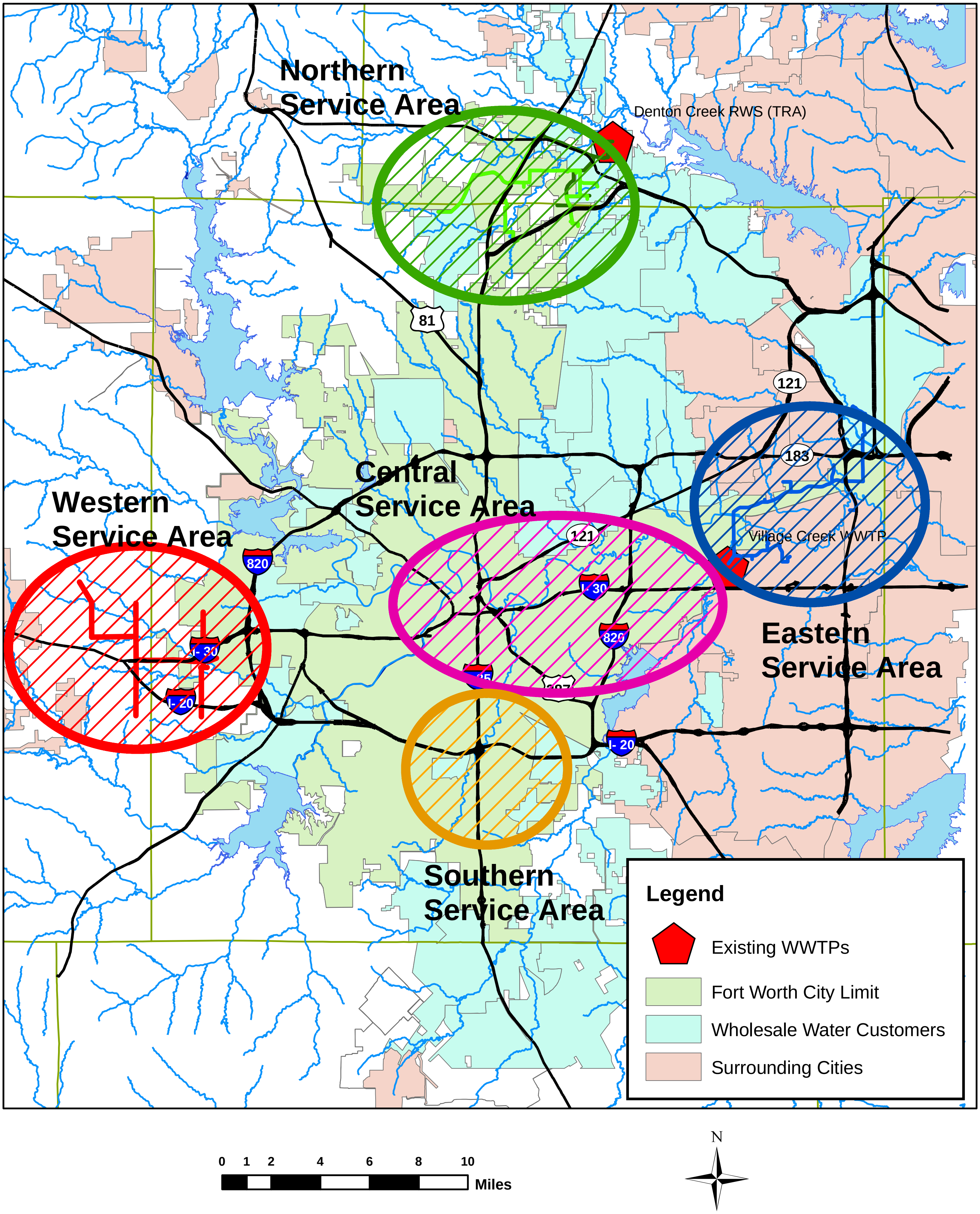


Table ES-2
Central System Projected Reclaimed Water Demands

Potential Customer	Annual Average Water Demand (mgd)	System Demand* (mgd)	Required System Pressure (psi)	Available Storage	Use	Reuse Type
Central Business District	0.49	1.23	60	No	Cooling Tower Makeup	II
Cobb Park	0.17	3.96	60	No	Park and Rec Irrigation	I
Gateway Park	0.15	3.48	60	No	Park and Rec Irrigation	I
Glen Garden GC	0.09	0.46	0	Yes	Golf Course Irrigation	II
Harris Methodist Hospital	0.05	0.13	60	No	Cooling Tower Makeup	II
Meadowbrook GC	0.06	1.73	0	Yes	Golf Course Irrigation	II
Sycamore Creek GC	0.03	0.74	0	Yes	Golf Course Irrigation	II
Sycamore Park	0.04	0.86	60	No	Park and Rec Irrigation	I
Trinity River Vision Project	0.76	2.50	17	Yes**	Evaporative Makeup, Commercial Irrigation	I
Woodhaven GC	0.09	1.16	0	Yes	Golf Course Irrigation	II
Total	**1.93**	**16.25**				

*For customers with available storage, the system demand is the peak day demand. For customers without available storage, the system demand is the peak hour demand.

**To be constructed as part of project.

- Commercial process (Ball Metal Container),
- Golf course irrigation (Glen Garden),
- Park and recreational facilities irrigation (Cobb Park, Rolling Hills Park soccer fields, Rolling Hills Park north fields, Federal Correctional Institution, Fort Worth Independent School District (FWISD) athletic fields, Tarrant County Resource Connection, and Worth Baptist Church),
- School and universities irrigation (Tarrant County College and O.D. Wyatt High School),
- Cooling tower makeup water (Miller Brewing and Mrs. Baird's Bakeries), and
- Gas well drilling.

Projected Southern System reclaimed water demands are summarized in Table ES-3.

ES.5. Site Selection for the Southern Reclaimed Water Production Facility

Three potential sites for a Southern Reclaimed Water Production Facility (RWPF) were considered (Figure ES-2). Site 3 is the recommended site for the Southern RWPF. Reasons to favor this site over the other potential sites include the following:

- Proximity to reclaimed water demands allows a less expensive conveyance system with lower pump horsepower requirements and shorter and smaller pipelines.
- Gentler topography than other sites.
- Not located adjacent to parks or residences.
- Proximity to major roads better suited for a truck filling station to accommodate demand for reclaimed water for gas well drilling.

ES.6. Conceptual Design of the Southern Reclaimed Water Production Facility

The treatment facilities recommended for the Southern RWPF include fine screens, membrane bioreactors (MBRs), and ultraviolet (UV) disinfection. MBRs were selected because of their small footprint and low turbidity in the produced reclaimed water. UV disinfection was selected because it has a small footprint, it minimizes disinfection by-products, and it reduces chlorine storage or delivery frequency. Other facilities would include odor control and reclaimed water storage.

Figure ES-2
Potential Southern RWPF Sites

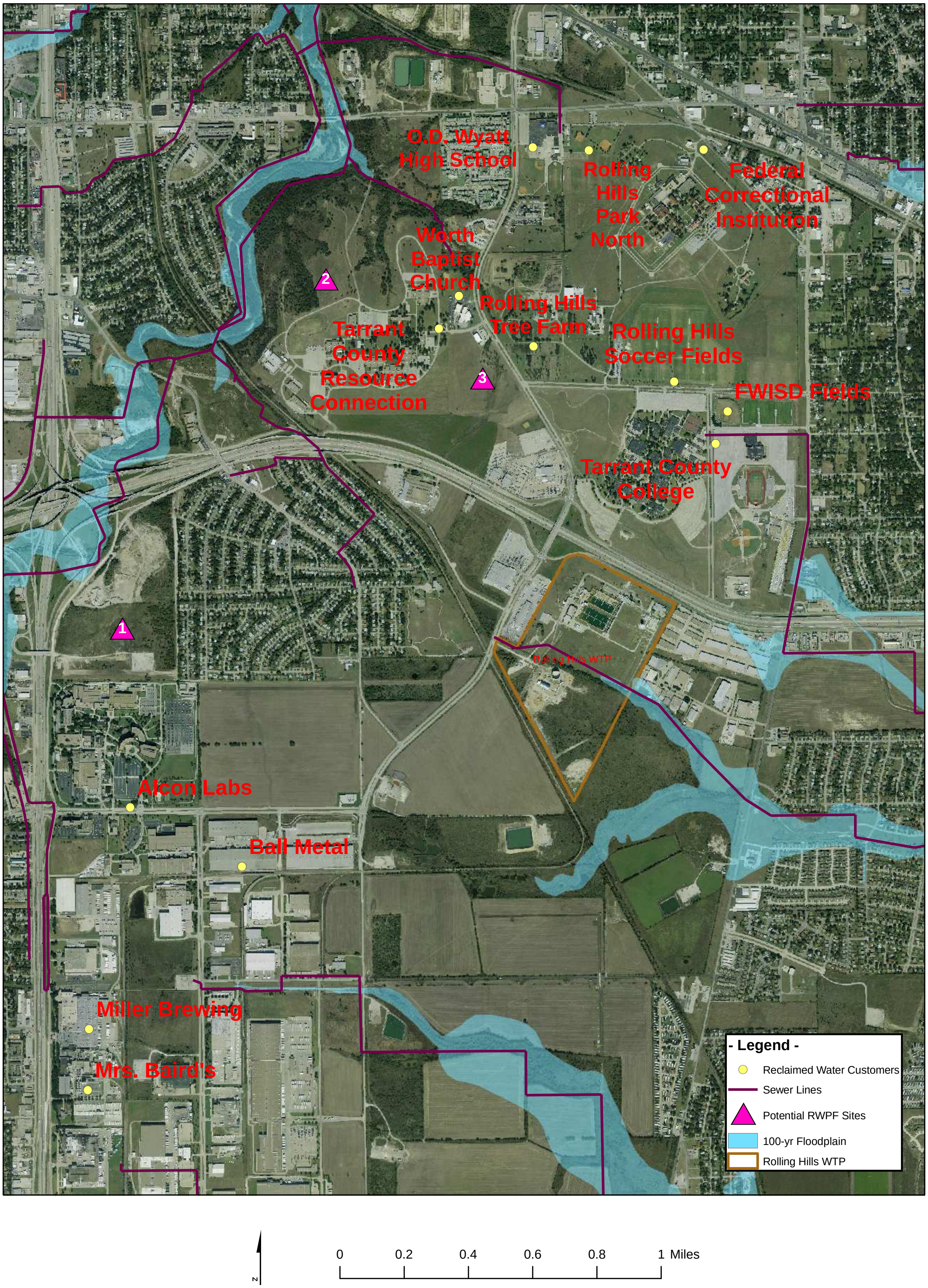


Table ES-3
Southern System Projected Reclaimed Water Demands

Potential Customer	Annual Average Water Demand (mgd)	System Demand* (mgd)	Required System Pressure (psi)	Available Storage	Use	Reuse Type
Alcon Laboratories	0.38	3.00	60	No	Commercial Irrigation	I
Ball Metal Container	0.01	0.01	60	No	Commercial Process	II
Federal Correctional Institution	0.01	0.30	60	No	Commercial Irrigation Park and Rec Irrigation	I
FWISD Athletic Fields	0.03	0.68	60	No	Park and Rec Irrigation	I
Gas Well Drilling	0.38	0.77	n/a	No	Gas Well Drilling	II
Miller Brewing Co.	0.19	0.53	60	No	Cooling Tower Makeup Commercial Irrigation	II
Mrs. Baird's Bakeries	0.10	0.25	60	No	Cooling Tower Makeup	II
O.D. Wyatt High School	0.01	0.26	60	No	School Irrigation	I
Rolling Hills Park North Fields	0.02	0.39	60	No	Park and Rec Irrigation	I
Rolling Hills Park Soccer Fields	0.15	3.65	60	No	Park and Rec Irrigation	I
Rolling Hills Tree Farm	0.02	0.38	60	No	Commercial Irrigation	II
Tarrant County College	0.01	0.31	60	No	School Irrigation	I
Tarrant County Resource Connection	0.03	0.50	60	No	Commercial Irrigation Park and Rec Irrigation	I
Worth Baptist Church	0.01	0.12	60	No	Park and Rec Irrigation	I
Total	**1.35**	**11.15**				

*System demand is the peak hour demand for each customer.

The Southern RWPF would provide a treatment capacity of 5 MGD and reclaimed water storage of 2 million gallons.[8] This treatment and storage capacity would allow the RWPF to serve the projected system demand of 11.15 MGD (Table ES-3). Based on the projected annual average demand of 1.35 MGD, the Southern RWPF would have a peak hour-to-annual average capacity ratio of 8.26. The Southern RWPF is expected to produce Type I reclaimed water.

It is anticipated that the Southern RWPF would require a minimum of 11 acres, assuming a 150-foot buffer zone between the property line and all treatment units. It is advisable to acquire a larger site to allow for expansion and/or to allow for a larger buffer area.

ES.7. Conceptual Design of the Central and Southern Reclaimed Water Conveyance Systems

The Central System would consist of about 22.4 miles of pipe ranging in diameter from 6 to 36 inches and would be constructed in six phases. The Southern System would consist of about 7.6 miles of pipe ranging in diameter from 6 to 24 inches and would be constructed in five phases. Figures ES-3 and ES-4 show maps of these systems by construction phase.

ES.8. Costs and Benefits of the Fort Worth Direct Reuse Projects

Opinions of probable cost for the Central and Southern Systems are presented in Appendix A and summarized in Table ES-4. These costs were developed using the same assumptions that were used in the *Reclaimed Water Priority and Implementation Plan*,[9] except that costs were updated from fourth quarter 2006 dollars to second quarter 2007 dollars using the Engineering News Record (ENR) Construction Cost Index (CCI).[10] Updated cost tables are presented in Appendix B.

---

[8] This is a large storage facility. Design and landscaping efforts should be made to reduce the visual impact of the reclaimed water storage.

[9] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

[10] The December 2006 ENR CCI was 7888, and the June 2007 ENR CCI was 7939, a 0.6 percent increase.

Figure ES-3
Central Reclaimed Water Conveyance System

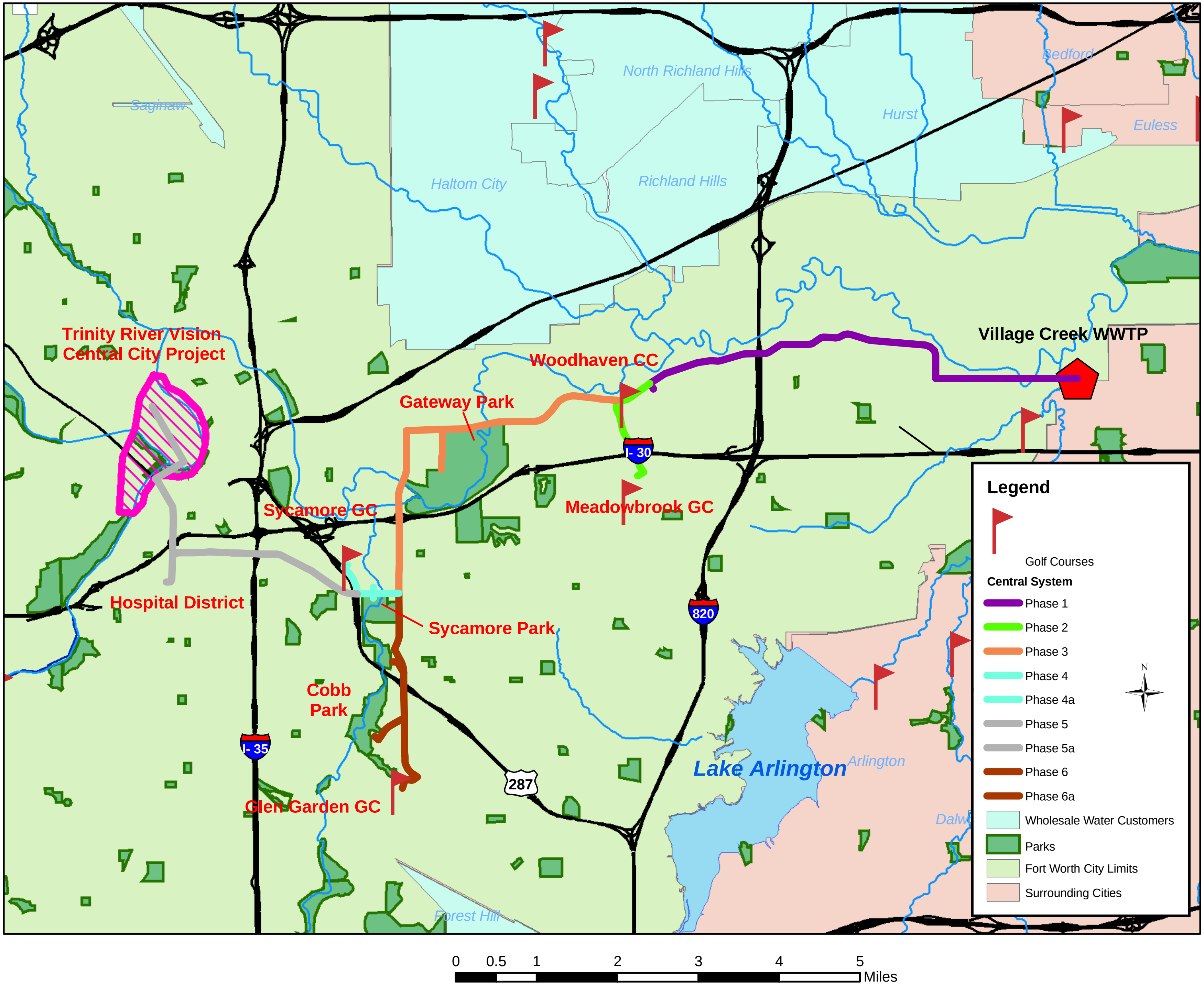


Figure ES-4
Southern Reclaimed Water Conveyance System

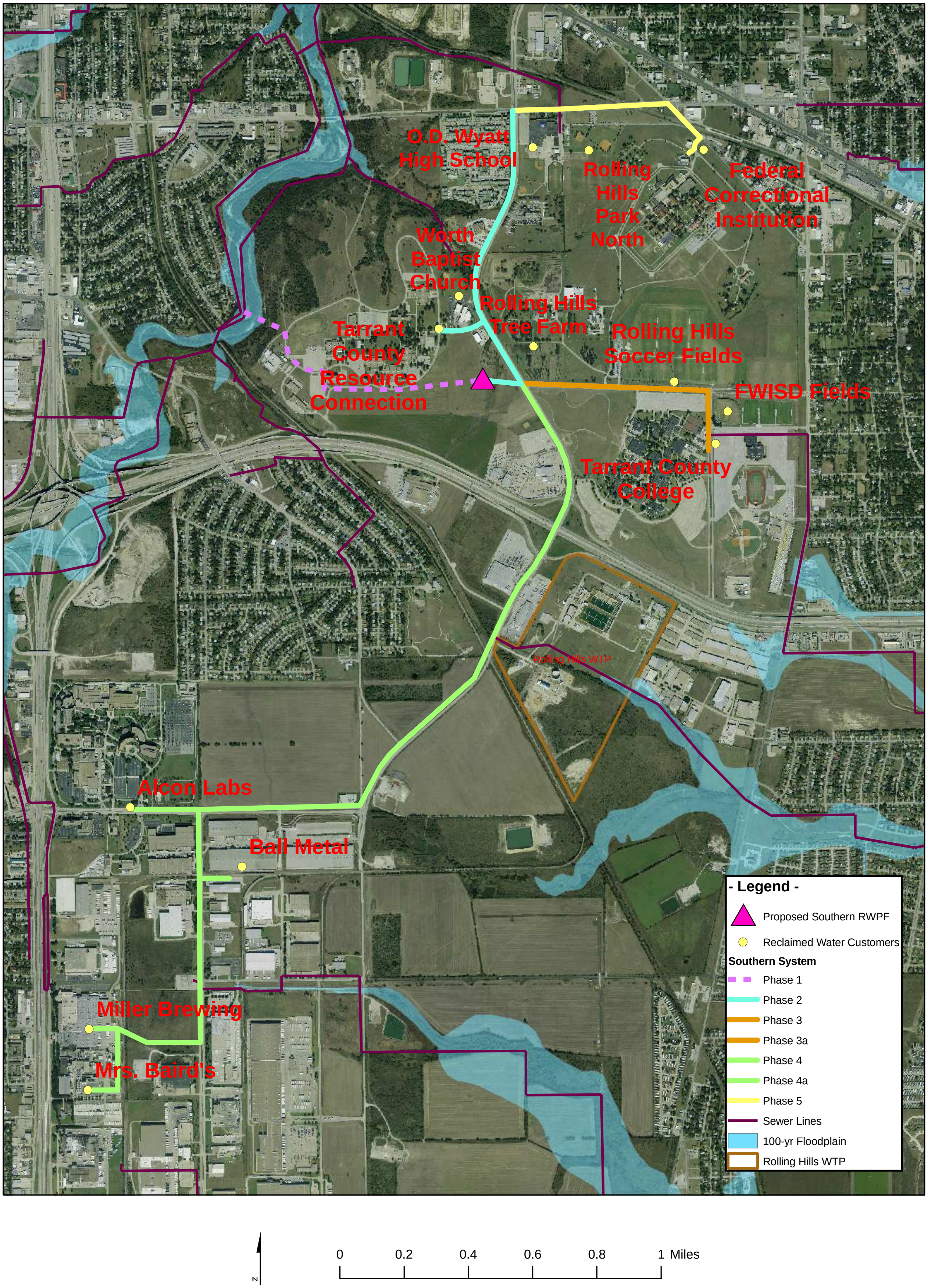


Table ES-4
Opinions of Probable Cost for Central and Southern Systems (With Indirect Benefits and Costs)

System	Annual Average Demand (MGD)	Peak System Demand (MGD)	Capital Cost ($MM)	Avoided Capital Cost[a] ($MM)	Debt Service[b] ($/yr)	Pipe and Pump Station Maintenance ($/yr)	Reclaimed Water Production Facility O&M ($/yr)	Energy ($/yr)	Probable Net Revenue Loss[c] ($/yr)	Unit Cost – First 20 Years ($/1,000 gal)	Unit Cost – After 20 Years ($/1,000 gal)	Weighted Unit Cost[d] ($/1,000 gal)
Central	1.93	16.25	$32.81	$2.76	$2,515,000	$312,000	$0	$98,000	$338,000	$4.63	$1.06	$2.49
Southern	1.35	11.15	$29.11	$1.38	$2,320,000	$167,000	$208,000	$45,000	$119,000	$5.81	$1.10	$2.98
TOTAL	3.28	27.40	$61.92	$4.14	$4,835,000	$479,000	$208,000	$143,000	$457,000	$5.12	$1.08	$2.69

[a] Credit for deferral of WTP expansions. The benefit was distributed on basis of the portion of the annual average reclaimed water demand that otherwise would have been supplied with potable water.

[b] Assumes a capital recovery period of 20 years and an annual interest rate of 5.5 percent.

[c] See Section 9.3 for assumptions.

[d] Weighted unit cost is the average unit cost over 50 years.

The values shown in Table ES-4 reflect the estimated cost to construct and operate each project to serve the projected demands defined in the previous sections. For those systems that receive treated effluent from the VCWWTP, no operational cost for wastewater treatment was included. This cost was attributed to the wastewater system since this treatment would have to occur regardless of whether a reclaimed water system is developed. In addition, the cost of constructing a truck filling station at the Southern RWPF to supply gas well drilling demands was not included in Table ES-4.

Potential benefits from implementation of the Central and Southern direct reuse projects include:

- Reduction of potable water demand
    - Reduced per capita potable water use
    - Deferral of potable water treatment capacity expansion
    - Deferral of potable water distribution capacity expansion
- Deferral of additional raw water supply
- Other benefits
    - Expanded Availability of Reclaimed Water
    - Dependable supply
    - Reduction of loads to receiving streams

It is anticipated that the Southern RWPF would be permitted under the new Reclaimed Water Production Facility rules.[11] Since these rules do not permit a discharge of treated effluent from the RWPF and allow operation of the RWPF only when there is a demand for reclaimed water, downstream wastewater facilities must be designed to convey and treat the full wastewater flow.

ES.9. Permitting Issues for the Fort Worth Direct Reuse Projects

At a minimum, the new permits and/or authorizations that are potentially required for implementation of the Central and Southern direct reuse projects include: a Chapter 321 reclaimed water production facility authorization,[11] a Section 404 permit for construction of

[11] Texas Administrative Code Title 30, Chapter 321, Subchapter P, effective November 27, 2008.

pipelines, amendment of the Texas Pollutant Discharge Elimination System (TPDES) discharge permit for the Village Creek WWTP, and a stormwater discharge permit for construction that takes place over more than one acre.

ES.10. Selection of Preferred Fort Worth Direct Reuse Alternatives

The Central and Southern direct reuse alternatives recommended in the *2006 Region C Water Plan* and in the 2007 *Reclaimed Water Priority and Implementation Plan* have been refined and updated as a case study for this guidance document. Based on evaluation of potential customer demands, conceptual designs for treatment and delivery systems, permitting issues, the opinions of probable cost, and the potential benefits, both projects appear to be feasible, and it is recommended that Fort Worth proceed with implementation of the Central and Southern Systems. The City should continue to explore alternative financing approaches, including federal or state grant or loan programs, and participation from customers and/or developers.

The Central and Southern reclaimed water projects would provide significant benefits to the City by reducing per capita potable water usage, helping to achieve water conservation goals, and deferring water and wastewater system facility expansions. Implementation of these reclaimed water systems would demonstrate Fort Worth's commitment to efficient use of its water resources. This commitment is critical to the success of acquiring new water supply sources necessary to support future growth within the City.

ES.11. Implementation Plan for the Fort Worth Direct Reuse Project

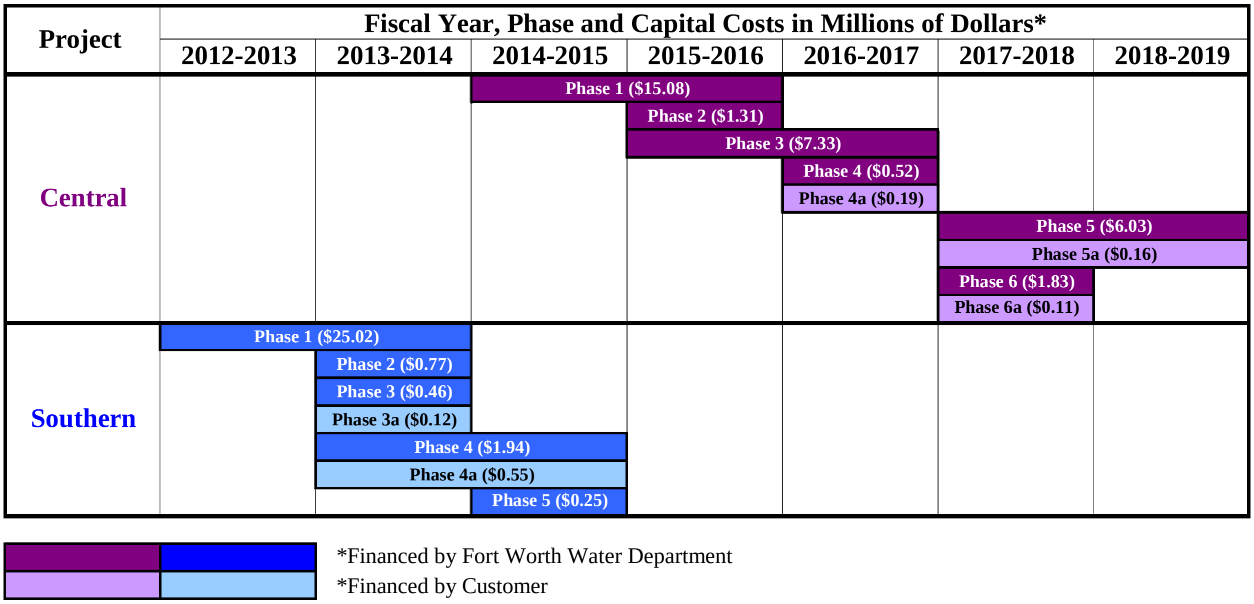
Changes to the Central and Southern Systems (*e.g.*, projected demands, pipeline routes, RWPF location, project timing, etc.) have occurred since the implementation plan presented in Fort Worth's *Reclaimed Water Priority and Implementation Plan*. The plan was quite detailed, and many of the elements of the plan remain unchanged by the results of this study, particularly administrative, testing, permitting, and marketing actions. For such matters, the plan remains unamended. Only the elements of the implementation plan that specifically concern the Central and Southern Systems are revised in this section.

The next steps for implementation are outlined in Table ES-5. A summary of the proposed construction phasing is provided in Figure ES-5, and a detailed implementation timeline is presented in Figure ES-6.

Table ES-5
Implementation Steps for Central and Southern Reclaimed Water Systems

FISCAL YEAR 2010-2011
* Perform flow monitoring to verify that 5 mgd of wastewater is available for diversion from the interceptor (M275B/290+88).
* Perform routing delineation and surveying for Southern System, Phase 1, 2, and 3 pipelines.
* Perform environmental permitting for Southern System, Phase 1, 2, and 3 pipelines.
FISCAL YEAR 2011-2012
* Begin and complete right-of-way acquisition and design for Southern System, Phase 1, 2, and 3 pipelines.
* Perform routing delineation and surveying for Southern System, Phase 4 and 5 pipelines.
* Perform environmental permitting for Southern System, Phase 4 and 5 pipelines.
FISCAL YEAR 2012-2013
* Begin and complete construction of Southern System, Phase 1, 2, and 3 pipelines.
* Begin and complete right-of-way acquisition and design for Southern System, Phase 4 and 5 pipelines.
* Perform routing delineation and surveying for Central System, Phase 1 pipeline and pump station.
* Perform environmental permitting for Central System, Phase 1 pipeline and pump station.
FISCAL YEAR 2013-2014
* Begin and complete construction of Southern System, Phase 4 and 5 pipelines.
* Begin and complete right-of-way acquisition and design for Central System, Phase 1 pipeline and pump station.
* Perform routing delineation and surveying for Central System, Phase 2, 3 and 4 pipelines.
* Perform environmental permitting for Central System, Phase 2, 3 and 4 pipelines.
FISCAL YEAR 2014-2015
* Begin construction of Central System, Phase 1 pipeline and pump station.
* Begin and complete right-of-way acquisition and design for Central System, Phase 2, 3 and 4 pipelines.
FISCAL YEAR 2015-2016
* Complete construction of Central System, Phase 1 pipeline and pump station.
* Begin and complete construction of Central System, Phase 2 pipeline.
* Begin construction of Central System, Phase 3 pipeline.
* Begin and complete construction of Central System, Phase 4 pipeline.
* Perform routing delineation and surveying for Central System, Phase 5 and 6 pipelines.
* Perform environmental permitting for Central System, Phase 5 and 6 pipelines.
FISCAL YEAR 2016-2017
* Complete construction of Central System, Phase 3 pipeline.
* Begin and complete right-of-way acquisition and design for Central System, Phase 5 pipeline.
* Begin and complete right-of-way acquisition and design for Central System, Phase 6 pipeline.
FISCAL YEAR 2017-2018
* Begin construction of Central System, Phase 5 pipeline.
* Begin and complete construction of Central System, Phase 6 pipeline.
FISCAL YEAR 2018-2019
* Complete construction of Central System, Phase 5 pipeline.

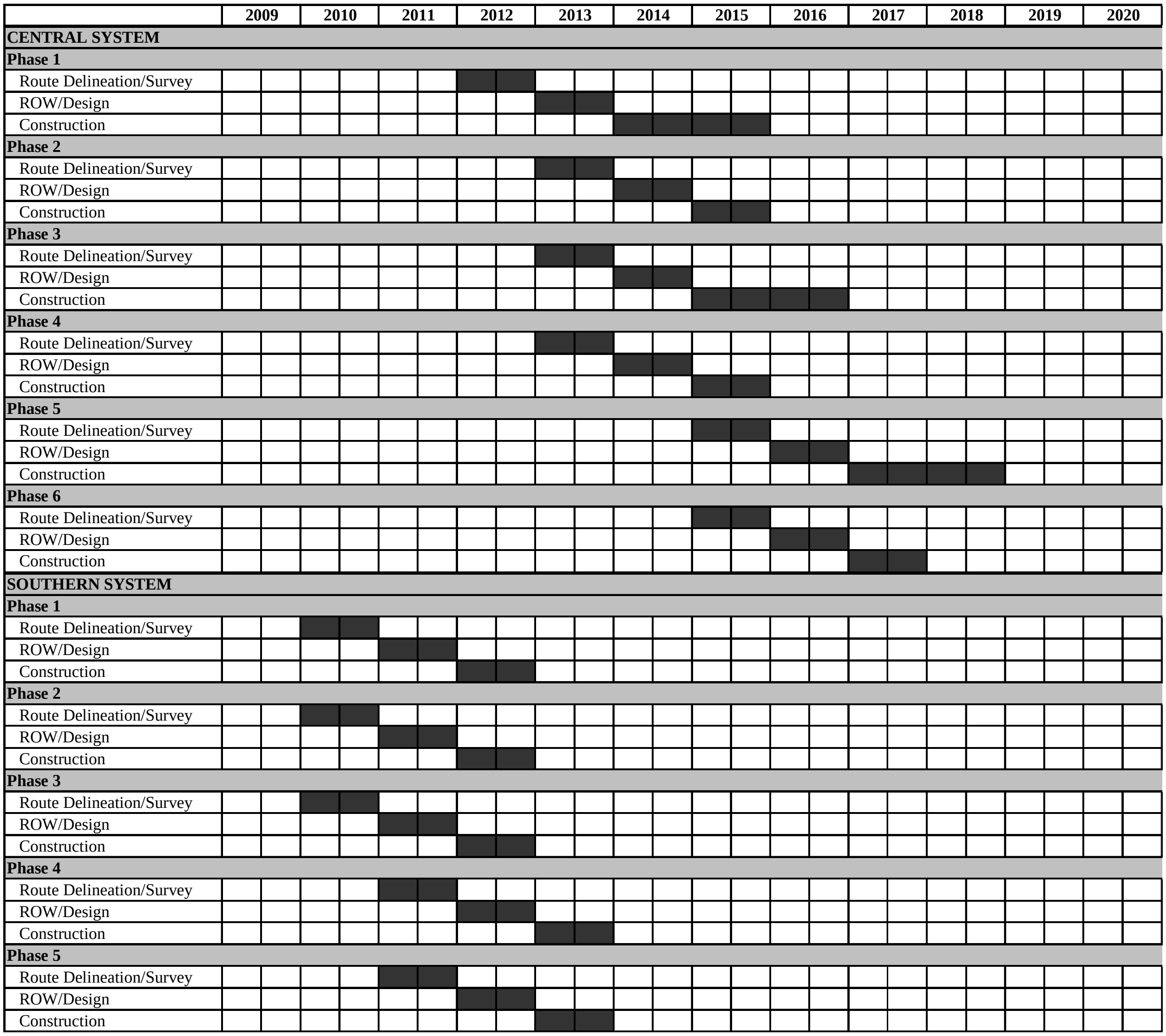
Figure ES-5
Construction Phasing for Central and Southern Reclaimed Water Systems



The recommendation to implement the proposed reclaimed water projects is based on the likelihood of customer interest and feasibility of the projects. The City should pursue further discussions with potential customers to finalize their commitment to reclaimed water use.

Figure ES-6

Detailed Implementation Timeline for Central and Southern Reclaimed Water Systems



1. Introduction

Reuse of treated wastewater effluent[12] is becoming an increasingly important source of water in Region C and across the state of Texas. The *2006 Region C Water Plan*[13] projected that, by 2060, the reuse of reclaimed water would provide a supply of 874,417 acre-feet per year (ac-ft/yr) to Region C water user groups, or approximately 26.4 percent of the 2060 Region C water demand. There are a number of reuse projects currently operating in Region C, and many others are currently in the planning and permitting process. Obviously, reuse will serve a major role in meeting future water supply requirements for the region.

1.1. Types of Reuse

There are two types of reuse: direct reuse and indirect reuse. Direct reuse occurs when treated wastewater is delivered from a wastewater treatment plant to a water user, with no intervening discharge to waters of the state. Direct reuse is most commonly used to supply water for landscape irrigation (especially golf courses) and industrial uses (especially cooling for steam electric power plants). Indirect reuse occurs when treated wastewater effluent is discharged to a stream or reservoir and is diverted downstream or out of a reservoir for reuse. The discharged water mixes with ambient water in the stream or reservoir as it travels to the point of diversion. Many of the water supplies within Region C have historically included return flows from treated wastewater effluent as well as natural runoff. Indirect reuse can provide water supplies for municipal use, as well as irrigation and industrial supplies.

1.2. Recent Fort Worth Planning

The *2006 Region C Water Plan* recommended that the City of Fort Worth (Fort Worth) construct facilities to transport reclaimed water from the Village Creek Wastewater Treatment Plant (VCWWTP) to four direct reuse projects:

---

[12] Also called “reclaimed water” or “recycled water.”

[13] Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel & Yerby, Inc., and Cooksey Communications, Inc., January 2006. *2006 Region C Water Plan*, prepared for the Region C Water Planning Group, Fort Worth.

- The Central/Southern System would serve potential customers between the VCWWTP and downtown, in the Central Business District, and in the Southern industrial area;
- The Eastern System would serve potential customers in Arlington, Euless, Centerport, and Dallas/Fort Worth International Airport; and
- The Northern System would serve potential customers in the Alliance Gateway area.
- The Western System would serve potential customers in the Mary's Creek watershed from a satellite wastewater treatment plant (WWTP).

In 2007, Fort Worth developed a *Reclaimed Water Priority and Implementation Plan*[14] that contains preliminary planning information for the projects recommended in the *2006 Region C Water Plan*.

1.3. Current Project

The Texas Water Development Board (TWDB) has provided funding to the Region C Water Planning Group (RCWPG) and its consultant team to develop guidance documents for implementing indirect and direct reuse projects. This guidance document identifies technical and regulatory issues to be addressed in the planning and design of direct, non-potable reuse projects. To serve as a case study for the guidance document, the RCWPG has also refined the implementation plans for two direct reuse projects for the City of Fort Worth: the Central System and the Southern System.

In the *Reclaimed Water Priority and Implementation Plan*, the Southern service area was considered in both a stand-alone Southern System alternative and in combined Central/Southern System alternatives. One of the combined Central/Southern System alternatives was preferred in the plan, because it was the lowest cost alternative. However, the Southern System alternative was economically viable and could be implemented more quickly than a combined alternative to provide water to the Southern service area. It appears that the demands in the Southern service

[14] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

area may be more immediate than those in the Central service area, so the stand-alone Southern System concept has been refined for this report.

In the next sections, Texas regulations for direct reuse, other guidance and regulations, projected reclaimed water supply and quality, projected reclaimed water demands, reclaimed water production facilities, water quality and treatment considerations, the conceptual design of reclaimed water conveyance systems, a feasibility evaluation, and implementation issues are presented and discussed.

Chapters 2 and 3 consist entirely of guidance information. Guidance is included in the first section of other chapters, followed by case study information where applicable.

2. Texas Regulations on Direct, Non-Potable Reuse

In Texas, the use of reclaimed water for beneficial purposes is regulated by the Texas Commission on Environmental Quality (TCEQ). The specific regulations are codified in Title 30, Chapter 210 of the Texas Administrative Code (30 TAC 210). Chapter 210 defines two types of direct reuse based on the likelihood that the water would come in contact with humans. Regulations concerning the quality of the water, design of reclaimed water storage facilities, restrictions on the use of reclaimed water, and the frequency of monitoring are different for the two types of direct reuse, Type I and Type II (Table 2-1). The following is a summary of potential reclaimed water uses regulated by reclaimed water type.

2.1. Type I Reclaimed Water

Type I reclaimed water can be used in instances where incidental contact with humans is likely to occur. The following uses are identified as Type I uses:

- Residential irrigation
- Unrestricted urban irrigation, including parks, school yards, and athletic fields
- Fire protection systems
- Direct irrigation of food crops that will be peeled, skinned, cooked, or thermally processed
- Irrigation of pastures for milking animals
- Maintenance of unrestricted recreational impoundments
- Toilet or urinal flush water
- Other similar activities where the potential for unintentional human exposure may occur

To be considered Type I Reclaimed Water, treated effluent must meet the specific quality requirements in Table 2-1; specific treatment processes are not identified or required. These parameters must be monitored twice per week and reported on a monthly basis.

Table 2-1
Texas Requirements for Type I and Type II Direct Reuse

Item	Type I	Type II
Definition	Reclaimed water use where contact with humans is likely	Reclaimed water use where contact with humans is unlikely
Examples of Uses	• Residential irrigation. • Irrigation of public parks, golf courses, and athletic fields. • Fire protection. • Irrigation of food crops. • Irrigation of pastures for milking animals. • Maintenance of impoundments or natural waterbodies where recreational activities are anticipated. • Toilet or urinal flush water. • Other activities with potential for unintentional human exposure.	• Irrigation of sod farms, silviculture, limited access and ROWs where human access is restricted or unlikely. Irrigation of food crops. 1. Remote site 2. Controlled access 3. Site not used by public when irrigating (golf courses, cemeteries, and landscaped areas surrounding commercial or industrial complexes) 4. Restricted by ordinance • Irrigation of food crops without contact with edible part or with pasteurization. • Irrigation of animal feed crops. • Maintenance of impoundments/waterbodies where direct human contact is unlikely. • Soil compaction or dust control. • Cooling tower make-up water. • Irrigation or other nonpotable uses at a WWTP.
Quality Standards (30-day averages)	• Fecal coliforms: <20 CFU/100 ml geometric mean or <75 CFU/100ml single grab • $BOD_5/CBOD_5$ = 5 mg/l • Turbidity = 3 NTU	• Fecal coliforms: <200 CFU/100 ml geometric mean or <800 CFU/100ml single grab • For a pond system, BOD_5 = 30 mg/l • For other systems, BOD_5 = 20 mg/l and $CBOD_5$ = 15 mg/l
Sampling and Analysis	Twice per week	Once per week

2.2. *Type II Reclaimed Water*

Type II reclaimed water can be used in instances where incidental contact with humans is not likely to occur. The following uses are identified as Type II uses:

- Irrigation of restricted areas, such as golf courses, sod farms, silviculture, or highway rights-of-way
- Indirect irrigation of food crops that will be peeled, skinned, cooked, or thermally processed

- Irrigation of animal feed crops other than pastures for milking animals
- Maintenance of restricted recreational impoundments
- Soil compaction or dust control in construction activities
- Cooling tower make-up water
- Nonpotable uses at wastewater treatment plants
- Other similar activities where the potential for unintentional human exposure is not likely

To be considered Type II Reclaimed Water, treated effluent must meet the specific quality requirements in Table 2-1; specific treatment processes are not identified or required. These parameters must be monitored once per week and reported on a monthly basis.

2.3. Other Reclaimed Water Uses

The Texas regulations also include an alternative approval process for uses or designs that are not specifically identified in the rules. Projects requiring an alternative approval are considered on a case-by-case basis.

2.4. Notification Requirement

Reclaimed water providers must notify the TCEQ of the proposed direct reuse project and obtain written approval to provide reclaimed water. At a minimum, the notification must include a detailed description of the intended use, a clear indication of the means for regulatory compliance, evidence of the provider's authority to terminate noncompliant reclaimed water use, an operation and maintenance plan, and a description of the reclaimed water quality.

2.5. Revision of Reclaimed Water Regulations

The rules for direct reclaimed water use have been in effect since 1997. A subcommittee of the Texas American Water Works Association Water Conservation and Reuse Division is currently reviewing them to identify rule revisions that may be needed based on implementation constraints and technological changes. There has been discussion of lowering the current Type I turbidity limit of 3 nephelometric turbidity units (NTU) to 2 NTU based on limits set by other states. An investigation into the technological and/or water quality rationale for the lower limit will be part of the subcommittee’s review process. An assessment is also being made of whether the fecal coliform limits for either type of reuse should be lowered.

Also under consideration is whether to include monitoring requirements or limits for some currently non-regulated contaminants, such as *E. coli*. The timing on the potential rule changes is unknown.

3. Other Guidance and Regulations

During the planning, design, and construction of a direct, non-potable reuse project, questions may arise that are not explicitly addressed in the Texas regulations (Chapter 2). To assist in addressing such issues, federal guidance and regulations of other states are presented in this chapter.

3.1. Federal Guidance

There are currently no specific federal regulations that address direct reuse. However, the U.S. Environmental Protection Agency (EPA) has released updated guidelines for reuse.[15] The EPA guidelines include recommendations for treatment levels, water quality, and monitoring (Table 3-1) for direct reclaimed water uses such as:

- Unrestricted urban reuse – irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments.
- Restricted urban reuse – irrigation of areas in which public access can be controlled, such as golf sources, cemeteries, and highway medians.
- Agricultural reuse on food crops – irrigation of food crops which are intended for human consumption, often further classified as to whether the food crop is to be processed or consumed raw.
- Agricultural reuse on nonfood crops – irrigation of fodder, fiber, and seed crops, pasture land, commercial nurseries, and sod farms.
- Unrestricted recreational reuse - an impoundment of reclaimed water in which no limitations are imposed on body-contact water recreation activities.
- Restricted recreational reuse – an impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.
- Environmental reuse – reclaimed water used to create manmade wetlands, enhance natural wetlands, and to sustain stream flows.

---

[15] *Guidelines for Water Reuse,* U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

Table 3-1
EPA Suggested Guidelines for Direct Reuse[16]

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Urban Reuse All types of landscape irrigation, (e.g., golf courses, parks, cemeteries) – also vehicle washing, toilet flushing, use in fire protection systems and commercial air conditioners, and other uses with similar access or exposure to the water	▪ Secondary ▪ Filtration ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 10 mg/l BOD ▪ ≤ 2 NTU[17] ▪ No detectable fecal coli/100 ml[18,19] ▪ 1 mg/l Cl_2 residual (minimum)[20]	▪ pH – weekly ▪ BOD – weekly ▪ Turbidity – continuous ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 50 ft (15 m) to potable water supply wells	▪ At controlled-access irrigation sites where design and operational measures significantly reduce the potential of public contact with reclaimed water, a lower level of treatment, e.g., secondary treatment and disinfection to achieve ≤ 14 fecal coli/100 ml, may be appropriate. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of viable pathogens. ▪ Reclaimed water should be clear and odorless. ▪ A higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ A chlorine residual of 0.5 mg/l or greater in the distribution system is recommended to reduce odors, slime, and bacterial regrowth.

---

[16] *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

[17] The recommended turbidity limit should be met prior to disinfection. The average turbidity should be basedon a 24-hour time period. The turbidity should not exceed 5 NTU at any time. If TSS is used in lieu of turbidity, the TSS should not exceed 5 mg/l.

[18] Unless otherwise noted, recommended coliform limits are median values determined from the bacteriological results of the last 7 days for which analyses have been completed. Either the membrane filter or fermentation-tube technique may be used.

[19] The number of fecal coliform organisms should not exceed 14/100 ml in any sample.

[20] Total chlorine residual should be met after a minimum contact time of 30 minutes.

Table 3-1 (Continued)
EPA Suggested Guidelines for Direct Reuse[16]

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Restricted Access Area Irrigation Sod farms, silviculture sites, and other areas where public access is prohibited, restricted or infrequent	▪ Secondary ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum)[20]	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads.
Agricultural Reuse – Food Crops Not Commercially Processed Surface or spray irrigation of any food crop, including crops eaten raw.	▪ Secondary ▪ Filtration ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 10 mg/l BOD ▪ ≤ 2 NTU[17] ▪ No detectable fecal coli/100 ml[18,19] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ Turbidity – continuous ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 50 ft (15 m) to potable water supply wells	▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of viable pathogens. ▪ A higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ High nutrient levels may adversely affect some crops during certain growth stages.

[21] The number of fecal coliform organisms should not exceed 800/100 ml in any sample.

[22] Some stabilization pond systems may be able to meet this coliform limit without disinfection.

Table 3-1 (Continued)
EPA Suggested Guidelines for Direct Reuse[16]

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Agricultural Reuse – Food Crops Commercially Processed Surface Irrigation of Orchards and Vineyards	▪ Secondary ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. ▪ High nutrient levels may adversely affect some crops during certain growth stages.
Agricultural Reuse – Nonfood Crops Pasture for milking animals; fodder, fiber, and seed crops	▪ Secondary ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to potable water supply wells ▪ 100 ft (30 m) to areas accessible to the public (if spray irrigation)	▪ If spray irrigation, TSS less than 30 mg/l may be necessary to avoid clogging of sprinkler heads. ▪ High nutrient levels may adversely affect some crops during certain growth stages. ▪ Milking animals should be prohibited from grazing for 15 days after irrigation ceases. A higher level of disinfection, e.g., to achieve ≤ 14 fecal coli/100 ml, should be provided if this waiting period is not adhered to.
Recreational Impoundments Incidental contact (e.g., fishing and boating) and full body contact with reclaimed water	▪ Secondary ▪ Filtration ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 10 mg/l BOD ▪ ≤ 2 NTU[17] ▪ No detectable fecal coli/100 ml[18,19] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ Turbidity – continuous ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed	▪ Dechlorination may be necessary to protect aquatic species of flora and fauna. ▪ Reclaimed water should be non-irritating to skin and eyes. ▪ Reclaimed water should be clear and odorless. ▪ Nutrient removal may be necessary to avoid algae growth in impoundments. ▪ Chemical (coagulant and/or polymer) addition prior to filtration may be necessary to meet water quality recommendations. ▪ The reclaimed water should not contain measurable levels of viable pathogens. ▪ A higher chlorine residual and/or a longer contact time may be necessary to assure that viruses and parasites are inactivated or destroyed. ▪ Fish caught in impoundments can be consumed.

Table 3-1 (Continued)
EPA Suggested Guidelines for Direct Reuse[16]

Types of Reuse	Treatment	Reclaimed Water Quality	Reclaimed Water Monitoring	Setback Distances	Comments
Landscape Impoundments Aesthetic impoundment where public contact with reclaimed water is not allowed	▪ Secondary ▪ Disinfection	▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 500 ft (150 m) to potable water supply wells (minimum) if bottom not sealed	▪ Nutrient removal may be necessary to avoid algae growth in impoundments. ▪ Dechlorination may be necessary to protect aquatic species of flora and fauna.
Construction Use Soil compaction, dust control, washing aggregate, making concrete	▪ Secondary ▪ Disinfection	▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous		▪ Worker contact with reclaimed water should be minimized. ▪ A higher level of disinfection, e.g., to achieve < 14 fecal coli/100 ml, should be provided when frequent work contact with reclaimed water is likely.
Industrial Use Once-through cooling	▪ Secondary ▪ Disinfection	▪ pH = 6-9 ▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to areas accessible to the public	▪ Windblown spray should not reach areas accessible to workers or the public.
Industrial Use Recirculating cooling towers	▪ Secondary ▪ Disinfection (chemical coagulation and filtration may be needed)	▪ Variable, depends on recirculation ratio ▪ pH = 6-9 ▪ ≤ 30 mg/l BOD ▪ ≤ 30 mg/l TSS ▪ ≤ 200 fecal coli/100 ml[18,21,22] ▪ 1 mg/l Cl_2 residual (minimum) [20]	▪ pH – weekly ▪ BOD – weekly ▪ TSS – daily ▪ Coliforms – daily ▪ Cl_2 residual – continuous	▪ 300 ft (90 m) to areas accessible to the public. May be reduced or eliminated if high level of disinfection is provided.	▪ Windblown spray should not reach areas accessible to workers or the public. ▪ Additional treatment by user is usually provided to prevent scaling, corrosion, biological growths, fouling and foaming.
Other Industrial Uses	Depends on site specific uses				

- Industrial reuse – reclaimed water used in industrial facilities primarily for cooling system make-up water, boiler-feed water, process water, and general washdown.

3.2. Focus of Reclaimed Water Regulations

Table 3-2 presents a summary of the number of states with regulations for various types of direct reuse. Table 3-3 lists all states and presents the distribution of reclaimed water guidelines or regulations by reuse application type. Some states have regulations (enforceable rules), others have guidelines (not enforceable but can be used to develop programs), some have both, and others have neither. The states with the most comprehensive regulations include Arizona, California, Florida, Hawaii, Massachusetts, Nevada, New Jersey, North Carolina, Oregon, South Dakota, Texas, Utah, and Washington.

Table 3-2
Number of States with Regulations or Guidelines by Reuse Type[23]

Type of Reuse[24]	Number of States
Unrestricted Urban	28
Irrigation	28
Toilet Flushing	10
Fire Protection	9
Construction	9
Landscape Irrigation	11
Street Cleaning	6
Restricted Urban	34
Agricultural (Food Crops)	21
Agricultural (Non-food Crops)	40
Unrestricted Recreational	7
Restricted Recreational	9
Environmental (Wetlands)	3
Industrial	9

[23] *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

[24] Just because a particular type of reuse is not specifically mentioned in a State's regulations does not mean that it is not allowed.

Table 3-3
Summary of State Direct, Non-Potable Reuse Regulations and Guidelines[25]

State	Regulations	Guidelines	No Regulations or Guidelines[26]	Change from 1992 Guidelines for Water Reuse[27]	Unrestricted Urban Reuse	Restricted Urban Reuse	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Industrial Reuse
Alabama		•		N		•		•			
Alaska	•			NR				•			
Arizona	•			U	•	•	•	•		•	
Arkansas		•		N	•	•	•	•			
California[28]	•			U	•	•	•	•	•	•	•
Colorado	•			GR	•	•	•	•	•	•	
Connecticut			•	N							
Delaware	•			GR	•	•		•			
Florida	•			U	•	•	•	•			•
Georgia		•		U	•	•		•			
Hawaii		•		U	•	•	•	•		•	•
Idaho	•			N	•	•	•	•			
Illinois	•			U	•	•		•			
Indiana	•			U	•	•	•	•			
Iowa	•			NR		•		•			
Kansas		•		N	•	•	•	•			
Kentucky			•	N							
Louisiana			•	N							
Maine			•	N							
Maryland		•		N		•		•			
Massachusetts		•		NG	•	•		•			
Michigan	•			N			•	•			
Minnesota			•	N							
Mississippi			•	N							
Missouri	•			N		•		•			
Montana		•		U	•	•	•	•			
Nebraska	•			GR		•		•			
Nevada	•			GR	•	•	•	•	•	•	
New Hampshire			•	N							
New Jersey		•		RG	•	•	•	•			•
New Mexico		•		N	•	•	•	•			
New York		•		N				•			
North Carolina	•			U	•	•					•
North Dakota		•		U	•	•		•			
Ohio		•		NG	•	•		•			
Oklahoma	•			GR		•	•	•			
Oregon	•			N	•	•	•	•	•	•	•
Pennsylvania		•		NG				•			
Rhode Island			•	N							
South Carolina	•			GR	•	•		•			

[25] *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

[26] Specific regulations on reuse not adopted; however, reclamation may be approved on a case-by-case basis.

[27] N - no change; GR - guidelines to regulations; NG - no guidelines or regulations to guidelines; U - updated guidelines or regulations; NR - no guidelines or regulations to regulations; RG - regulations to guidelines

[28] Has regulations for landscape irrigation excluding residential irrigation; guidelines cover all other uses.

Table 3-3 (Continued)
Summary of State Direct, Non-Potable Reuse Regulations and Guidelines[29]

State	Regulations	Guidelines	No Regulations or Guidelines[26]	Change from 1992 Guidelines for Water Reuse[27]	Unrestricted Urban Reuse	Restricted Urban Reuse	Agricultural Reuse Food Crops	Agricultural Reuse Non-Food Crops	Unrestricted Recreational Reuse	Restricted Recreational Reuse	Industrial Reuse
South Dakota		●		N	●	●		●			
Tennessee	●			N	●	●		●			
Texas	●			U	●	●	●	●	●	●	●
Utah	●			U	●	●	●	●	●	●	●
Vermont	●			N				●			
Virginia			●	N							
Washington		●		U	●	●	●	●	●	●	●
West Virginia	●			N			●	●			
Wisconsin	●			N				●			
Wyoming	●			U	●	●	●	●			

Regulations focus either on using reclaimed water as a resource or providing an alternative to a stream discharge. The established regulations tend to be a function of the potential for human contact with the reclaimed water either through physical contact or ingestion of food – the more likely the contact, the more stringent the regulations. Guidelines and regulations for direct, non-potable reuse are typically divided by type of use (Section 3.1).

3.3. Comparison with Texas Regulations

Reuse regulations and guidelines may specify both wastewater treatment and effluent quality limitations. Generally, the greater the opportunity for direct contact between people and the reclaimed water, either through direct contact with irrigated areas or consumption of foods irrigated with reclaimed water, the more stringent the regulations.

In this section, the ranges of effluent quality limits and wastewater treatment specifications for the six states with the most stringent reuse standards for the direct reuse applications listed in Table 3-2 are compared to the regulations in Texas.[30] The six states include Arizona, California,

---

[29] *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

[30] All material in the following sections taken from: *Guidelines for Water Reuse*, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

Florida, Hawaii, Nevada, and Washington. The most frequently limited parameters are biochemical oxygen demand (BOD), total suspended solids (TSS), turbidity, and total or fecal coliforms.

Unrestricted Urban Reuse

In the unrestricted urban reuse regulations and guidelines, several states specify secondary treatment followed by filtration and disinfection. Nevada does not require filtration. Texas does not specify treatment requirements. For the states, BOD limits range from 5 milligrams per liter (mg/l) to 30 mg/l if they are specified. Texas specifies a limit of 5 mg/l. Texas does not specify TSS limits but two states have limits of 5 and 30 mg/l. Several states limit turbidity to 2 NTU. Texas specifies a limit of 3 NTU. All states with unrestricted urban reuse regulations or guidelines limit total or fecal coliforms to non-detect or 2.2 colony-forming units (CFUs) per 100 millileters (ml) on average, with maxima of about 25 CFUs/100 ml, with the exception of Texas. Texas allows 20 CFUs/100 ml as an average with a maximum of 75 CFUs/100 ml. No other organisms are regulated in unrestricted urban reuse regulations or guidelines, but Florida requires monitoring of *Cryptosporidium* and *Giardia* downstream of disinfection, with the frequency based on treatment capacity.

Restricted Urban Reuse

Of the states specifying treatment requirements for restricted urban reuse applications, only Florida requires filtration in addition to secondary treatment and disinfection. Texas does not specify treatment requirements. BOD limits vary from 20 mg/l to 30 mg/l if they are specified. Texas specifies a limit of 20 mg/l. TSS limits are specified by two states at 5 and 30 mg/l. Two states limit turbidity to 2 NTU. Texas does not limit TSS or turbidity for this application. Four states with restricted urban reuse regulations or guidelines limit total or fecal coliforms to approximately 25 CFUs/100 ml on average with maxima ranging from 200 to 800 CFUs/100 ml. Texas and Arizona allow 200 CFUs/100 ml as an average with a maximum of 800 CFUs/100 ml. Florida maintains more stringent limits, even for restricted urban reuse. No other organisms are regulated in restricted urban reuse regulations or guidelines, but Florida requires monitoring of *Cryptosporidium* and *Giardia* downstream of disinfection, with the frequency based on treatment capacity.

Agricultural Reuse – Food Crops

All the states allowing and specifying treatment requirements for agricultural reuse on food crops require secondary treatment, filtration, and disinfection. Texas does not specify treatment requirements. BOD limits range from 5 mg/l to 30 mg/l if they are specified. Texas does not specify TSS limits, but two states specify limits of 5 and 30 mg/l. All states specifying turbidity limits have adopted 2 NTU as the standard, except Texas, which allows 3 NTU. The Texas regulations vary depending upon whether or not the crop is irrigated directly or some form of drip irrigation is used. If the crop is to be irrigated directly, Texas requires that the BOD be 5 mg/l, which is the most stringent, and that the turbidity meet a 3 NTU, which is less stringent. In addition, the crop must be skinned or pasteurized before consumption. If the crop is not directly irrigated, the BOD can be 20 mg/l, and the turbidity is not regulated.

Two states limit fecal coliforms to below detection on average with a maximum of about 25 CFUs/100 ml. Three states limit total or fecal coliforms to 2.2 CFUs/100 ml on average with maxima of about 25 CFUs/100 ml. Texas and Arizona allow fecal coliforms of 20 and 200 CFUs/100 ml, respectively, on average, with maxima of 75 and 400 CFUs/100 ml. No other organisms are restricted in agricultural reuse on food crops, but Florida requires monitoring of *Cryptosporidium* and *Giardia* downstream of disinfection with the frequency based on treatment capacity. Agricultural reuse on food crops is illegal in some states.

Agricultural Reuse – Non-Food Crops

Many states allow and encourage agricultural reuse on nonfood crops. Of the states specifying treatment requirements for agricultural reuse on nonfood crops, only Florida requires filtration in addition to secondary treatment and disinfection. Texas does not specify treatment requirements. BOD limits range from 5 mg/l to 30 mg/l if they are specified. Texas has a limit of 20 mg/l. Texas does not specify TSS limits, but two states set limits of 20 and 30 mg/l. Two states limit turbidity to 2 NTU. Texas does not have a turbidity limit for nonfood crops. Other states do not specify turbidity limits. Total or fecal coliform limits range from 2.2 to 200 CFUs/100 ml on average, with maxima ranging from 20 to 800 CFUs/100 ml. Texas requires an average of 200 CFUs/100 ml and an 800 CFUs/100 ml maximum. No other organisms are restricted.

Unrestricted Recreational Reuse

In unrestricted recreational reuse, contact with the public is likely. Of the states specifying treatment requirements for this application, only Florida requires filtration in addition to secondary treatment and disinfection. Texas does not specify treatment requirements. BOD limits range from 5 mg/l to 30 mg/l if they are specified. Texas specifies a limit of 5 mg/l. Texas does not specify TSS limits, but one state does have a limit of 30 mg/l. Two states limit turbidity to 2 NTU. Texas specifies a limit of 3 NTU. Other states do not specify turbidity limits. Three states with unrestricted recreation reuse regulations or guidelines limit total or fecal coliforms to about 2.2 CFUs/100 ml on average with maxima of about 25 CFUs/100 ml, with the exception of Texas. Texas allows 20 CFUs/100 ml as an average, with a maximum of 75 CFUs/100 ml. No other organisms are restricted in restricted urban reuse regulations or guidelines, but Florida requires monitoring of *Cryptosporidium* and *Giardia* downstream of disinfection, with the frequency based on treatment capacity.

Restricted Recreational Reuse

Of the states specifying treatment requirements for restricted recreation reuse applications, only Florida and Hawaii require filtration in addition to secondary treatment and disinfection. Texas does not specify treatment requirements. BOD limits range from 20 mg/l to 30 mg/l if they are specified. Texas specifies a limit of 20 mg/l. Only Washington specifies TSS limits at 30 mg/l. Other states do not. Three states limit turbidity to 2 NTU. Texas does not specify turbidity limits. Four states with restricted urban reuse regulations or guidelines limit total or fecal coliforms to about 2.2 CFUs/100 ml or non-detect on average, with maxima of about 25 CFUs/100 ml. Texas allows 200 CFUs/100 ml as an average, with a maximum of 800 CFUs/100 ml. No other organisms are restricted in restricted recreational reuse.

Industrial Reuse

Several states have regulations for industrial reuse applications, including Texas. Regulations vary as a function of the use of the reclaimed water. Texas limits BOD to 20 mg/l, turbidity to 3 NTU, and fecal coliforms to 200 CFUs/100 ml on average, with a maximum of 800 CFUs/100 ml.

3.4. *Other Requirements and Guidelines*

In addition to wastewater treatment and effluent requirements, state regulations and guidelines may also address some or all of the following:

- Water quality monitoring - Parameters and frequency vary greatly between states and projects. The Texas requirements are shown in Table 2-1. The most frequently monitored parameters are those covered in the regulations and guidelines although others may be required at specific projects. Treatment facility reliability requirements vary greatly from state to state. Requirements may include redundancy, alarms, or sizes of units.
- Minimum storage requirements[31] - These are set to minimize opportunities for surface discharge rather than the seasonal irrigation limitations. Requirements are highly dependent upon geographic location and climatic conditions.
- Application rates - These are frequently based on the hydraulic capacity of the system and are set to maximize the volume of water that can be disposed. Texas requires "reasonable control" of applications rates to prevent "surface runoff or excessive percolation below the root zone" and to prevent "wet grass" conditions in unrestricted areas.[32] Some states limit the nutrient loadings, particularly nitrogen.
- Groundwater monitoring[31] - Many states require groundwater monitoring in areas where reclaimed water is being used for irrigation. Typical requirements are at least one monitoring well up-gradient of the reuse site and two or more down-gradient. The parameters and frequency of monitoring are generally on a case-by-case basis.
- Setback distances for irrigation - These are established to provide a buffer zone between reclaimed water irrigation sites and facilities such as potable water supply wells, property lines, residential areas, and roadways. These vary based on the quality of reclaimed water and the method of application. The Texas regulations do not include numerical setback distances but focus on access to the irrigated property. Type I reclaimed water quality is required for irrigation in areas with public access, and Type II reclaimed water quality is

---

[31] Texas does not have regulations associated with this topic.

[32] Texas Administrative Code, Title 30, Chapter 210.24

required in areas with restricted public access. An area with restricted public access may be “remote” or located a “sufficient distance” from the irrigation.[33]

[33] Texas Administrative Code, Title 30, Chapter 210.32

4. Reclaimed Water Supply and Quality

The first step in evaluating the potential amount of direct reuse is to determine the quantity and the quality of the available reclaimed water. The projected reclaimed water supply and quality for Fort Worth is discussed in the sections that follow.

4.1. Guidance

To characterize the full range of historical flowrates and concentrations, at least five years of water quality data should be evaluated for the treated wastewater effluent. At a minimum, the water quality evaluation should include parameters regulated in 30 TAC Chapter 210, such as carbonaceous biochemical oxygen demand (CBOD), fecal coliforms, and turbidity. Other parameters will depend on the projected uses. Examples include:

- Irrigation uses (nitrogen, phosphorus, total dissolved solids, sodium, magnesium, calcium, carbonate, bicarbonate, boron, selenium, pH, and others)
- Cooling water (total dissolved solids (TDS), total hardness and total alkalinity)
- Evaporative makeup water (bacteria and viruses).

Other parameters are shown by type of use in Table 3-1.

The water supply evaluation should be used to ensure that sufficient supply is available to meet projected reclaimed water demands. The water quality evaluation should be used to determine recommended treatment processes at a reclaimed water production facility (RWPF). The reclaimed water supply and quality evaluation for Fort Worth is described below.

4.2. Projected Reclaimed Water Supply

Fort Worth provides wastewater treatment at the Village Creek Wastewater Treatment Plant (VCWWTP) for its residents and for 23 wholesale customers. The VCWWTP is currently permitted to treat up to 166 million gallons per day (mgd) on an annual average basis. Currently, the annual average flowrate is approximately 120 mgd. Fort Worth already provides reclaimed water from the VCWWTP for golf course irrigation at the nearby Waterchase Golf Club. The

VCWWTP would be a source of additional reclaimed water for direct reuse. Table 4-1 shows the projected population for Fort Worth and its wholesale customers.

Table 4-2 shows the projected water demand for Fort Worth's wholesale wastewater customers. Over the long term, it appears that a return flow of 60 percent of the water demand for the wholesale wastewater customers matches recent monthly average flowrates at the VCWWTP reasonably well (Figure 4-1). Actual flowrates at the VCWWTP depend on the amount of infiltration and inflow of stormwater to the collection system. In dry years, the annual average flowrate will be less than in wet years. To better assure that the reclaimed water would be available during dry months, a 46 percent return flow was used to project the reclaimed water supply through 2060 (Figure 4-1).

The *2005 Fort Worth Water Master Plan* projected faster population growth for Fort Worth, suggesting that the reclaimed water supply may grow faster than shown in Figure 4-1. At this time, no attempt has been made to reconcile these projections, because there is sufficient reclaimed water available for all reuse projects that Fort Worth is currently considering. Reclaimed water demands for the Central System and Southern System are projected in Chapter 5.

4.3. Reclaimed Water Quality

The VCWWTP currently employs conventional liquids treatment processes consisting of screening, primary clarification, biological treatment, final clarification, filtration, and disinfection. Unless otherwise noted, it is anticipated that future reclaimed water quality will be similar to recent reclaimed water quality.

Comparison to Type I Requirements

Current treatment processes consistently meet Type I requirements. The turbidity is generally an order of magnitude lower than required, and the CBOD stays well below the 5 mg/l limit. However, as flows increase toward the design capacity, some additional treatment capacity (such as additional filters) may be required to sustain Type I effluent quality. Figure 4-2 shows VCWWTP effluent quality data for the relevant reuse parameters for 2006.

Table 4-1
TWDB Population Projections for Fort Worth Wholesale Wastewater Customers

Entity	2000	2010	2020	2030	2040	2050	2060
Benbrook	20,208	21,000	25,000	30,000	36,000	43,000	51,000
Blue Mound	2,388	2,500	2,500	2,500	2,500	2,500	2,500
Burleson	3,462	4,885	6,218	7,589	9,035	10,770	12,820
Crowley	7,467	9,000	11,000	14,000	19,000	23,000	25,000
Dalworthington Gardens	2,186	2,467	2,650	2,771	2,850	2,902	2,935
Edgecliff Village	2,550	2,550	2,550	2,550	2,550	2,550	2,550
Everman	5,836	6,500	7,100	7,700	8,300	8,900	9,000
Forest Hill	12,949	14,339	15,641	16,980	18,392	20,000	21,000
Fort Worth	534,694	632,940	786,306	953,237	1,168,901	1,477,264	1,848,759
Haltom City	39,018	44,855	50,322	53,058	54,428	55,113	55,456
Hurst	36,273	38,829	41,224	42,841	43,932	44,669	45,167
Kennedale	5,850	7,509	9,064	10,114	10,824	11,303	11,626
Lake Worth	4,618	4,854	5,400	6,000	6,600	7,200	7,500
North Richland Hills	55,635	64,861	73,503	79,341	83,286	85,951	87,751
Pantego	2,318	2,318	2,318	2,318	2,318	2,318	2,318
Richland Hills	8,132	8,400	9,000	9,600	10,300	10,700	10,850
River Oaks	6,985	7,100	7,100	7,100	7,100	7,100	7,100
Saginaw	12,374	15,995	19,387	21,859	23,660	24,973	25,930
Sansom Park	4,181	4,376	4,527	4,644	4,734	4,804	4,857
Tarrant County MUD #1[34]	5,789	5,735	5,751	5,767	5,783	5,799	5,815
Watauga	21,908	23,423	24,632	25,596	26,365	26,979	27,468
Westover Hills	658	658	658	658	658	658	658
Westworth Village	2,124	2,250	2,375	2,525	2,700	2,900	3,200
White Settlement	14,831	15,800	17,000	18,500	19,000	20,500	22,000
TOTAL	**812,434**	**943,144**	**1,131,226**	**1,327,248**	**1,569,216**	**1,901,853**	**2,293,260**

[34] Through 2020, the projections for Tarrant County MUD #1 are taken from the 1999 North Central Texas Council of Governments Water Quality Management Plan. A uniform growth rate was applied for later decades.

Table 4-2
Water Demand Projections for Fort Worth Wholesale Wastewater Customers (ac-ft)

Entity	2000	2010	2020	2030	2040	2050	2060
Benbrook	4,776	4,893	5,685	6,721	7,984	9,489	11,254
Blue Mound	259	297	300	294	286	283	283
Burleson	3,525	4,119	4,741	5,430	6,159	7,099	8,293
Crowley	1,179	1,361	1,614	2,023	2,703	3,246	3,528
Dalworthington Gardens	693	771	816	847	862	874	884
Edgecliff Village	451	460	451	443	434	428	428
Everman	699	808	859	906	948	1,007	1,018
Forest Hill	1,508	1,783	1,892	1,997	2,122	2,285	2,399
Fort Worth	128,771	149,596	182,321	218,891	265,795	334,259	418,317
Haltom City	6,381	7,135	7,835	8,142	8,231	8,272	8,324
Hurst	7,151	7,524	7,850	8,014	8,070	8,156	8,247
Kennedale	1,081	1,346	1,594	1,756	1,867	1,937	1,992
Lake Worth	859	930	1,010	1,102	1,190	1,290	1,344
North Richland Hills	10,158	12,496	13,832	14,753	15,300	15,693	16,022
Pantego	657	649	641	634	626	621	621
Richland Hills	1,120	1,327	1,381	1,441	1,511	1,558	1,580
River Oaks	1,025	1,010	986	954	931	923	923
Saginaw	2,107	2,885	3,540	3,942	4,240	4,448	4,618
Sansom Park	576	603	609	609	605	608	615
Tarrant County MUD #1[35]	216	214	215	215	216	216	217
Watauga	2,920	3,437	3,532	3,584	3,603	3,657	3,723
Westover Hills	279	276	274	272	270	268	268
Westworth Village	183	244	287	297	308	328	362
White Settlement	2,425	2,531	2,647	2,818	2,831	3,031	3,253
TOTAL	**178,999**	**206,695**	**244,912**	**286,085**	**337,092**	**409,976**	**498,513**
60 Percent Return Flow (mgd)	**95.9**	**110.7**	**131.2**	**153.2**	**180.6**	**219.6**	**267.0**
46 Percent Return Flow (mgd)	**73.5**	**84.9**	**100.6**	**117.5**	**138.4**	**168.4**	**204.7**

[35] 2006 Region C Water Plan for 2000 then uniform per capita use

Figure 4-1
Projected Reclaimed Water Supply

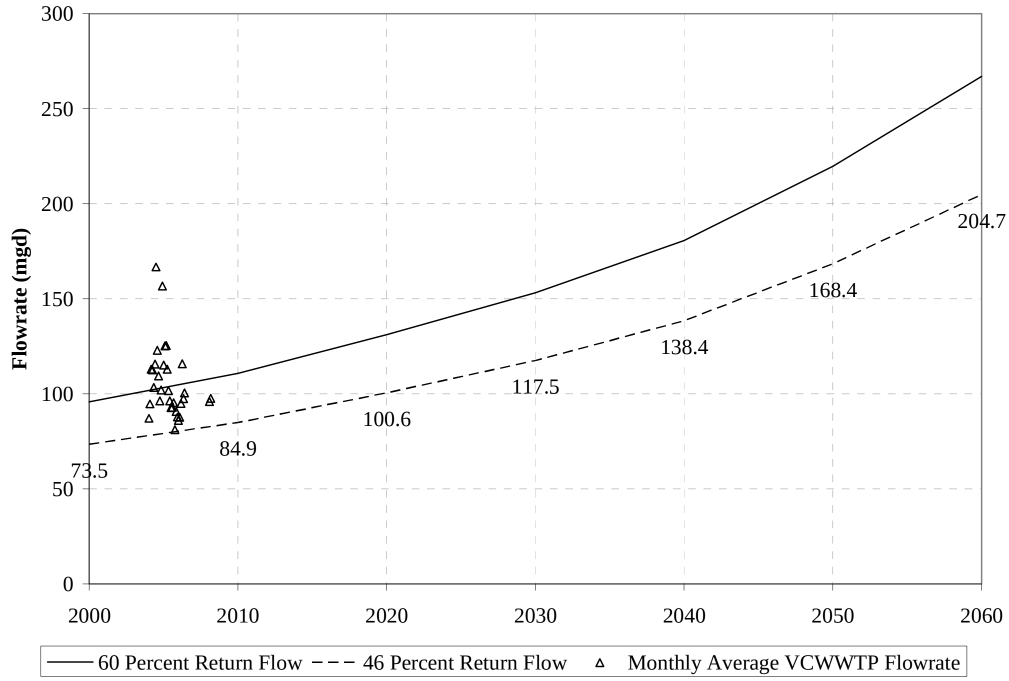
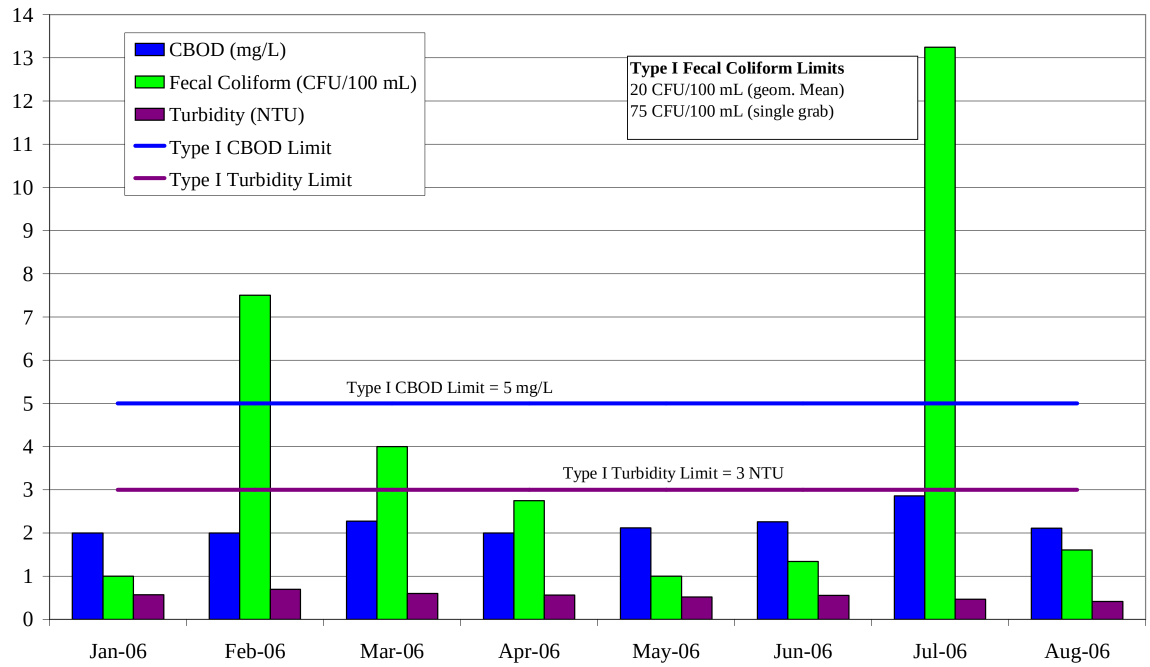


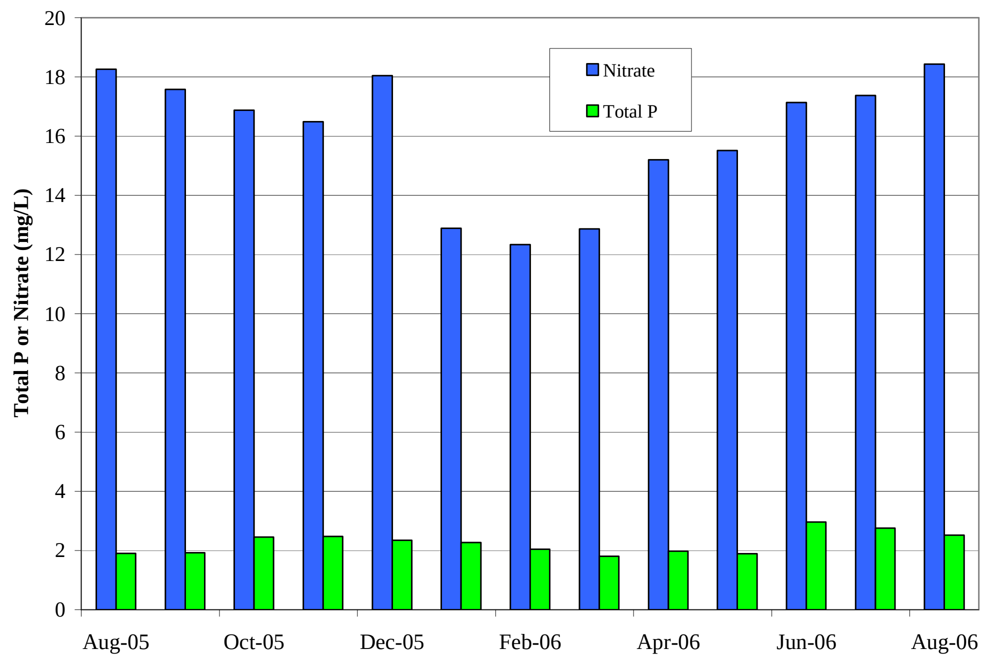
Figure 4-2
Village Creek WWTP Effluent Quality for Regulated Reuse Constituents



Irrigation Parameters

Many reuse applications involve using reclaimed water for irrigation. In these applications, it is beneficial and desirable for the effluent to contain nutrients (such as nitrogen and phosphorous) that contribute positively to the health of lawns and green spaces. Figure 4-3 shows the concentrations of total phosphorus and nitrate in the VCWWTP effluent.

Figure 4-3
Village Creek WWTP Effluent Quality for Nutrients



In high concentrations, total dissolved solids (TDS) have adverse effects on vegetation. Dissolved solids can inhibit the uptake of water in plants or contribute to the inadvertent uptake of high concentrations of salts, which damage plant tissues. A commonly used surrogate for TDS is chloride, which can begin to adversely affect the health of plants at levels approximating the 200 to 300 mg/l range. VCWWTP data, not shown here, indicate that average chloride concentrations reach only 100 mg/l. Because of the concerns surrounding solids and salts, restrictions may be placed on golf course irrigation water when TDS concentrations exceed 450 mg/l. At concentrations greater than 2,000 mg/l, use of reclaimed water may be discontinued altogether until the levels of solids are reduced.

Other parameters (*e.g.*, sodium, magnesium, calcium, carbonate, bicarbonate, boron, selenium, pH, and others) may also be important to specific irrigation uses.

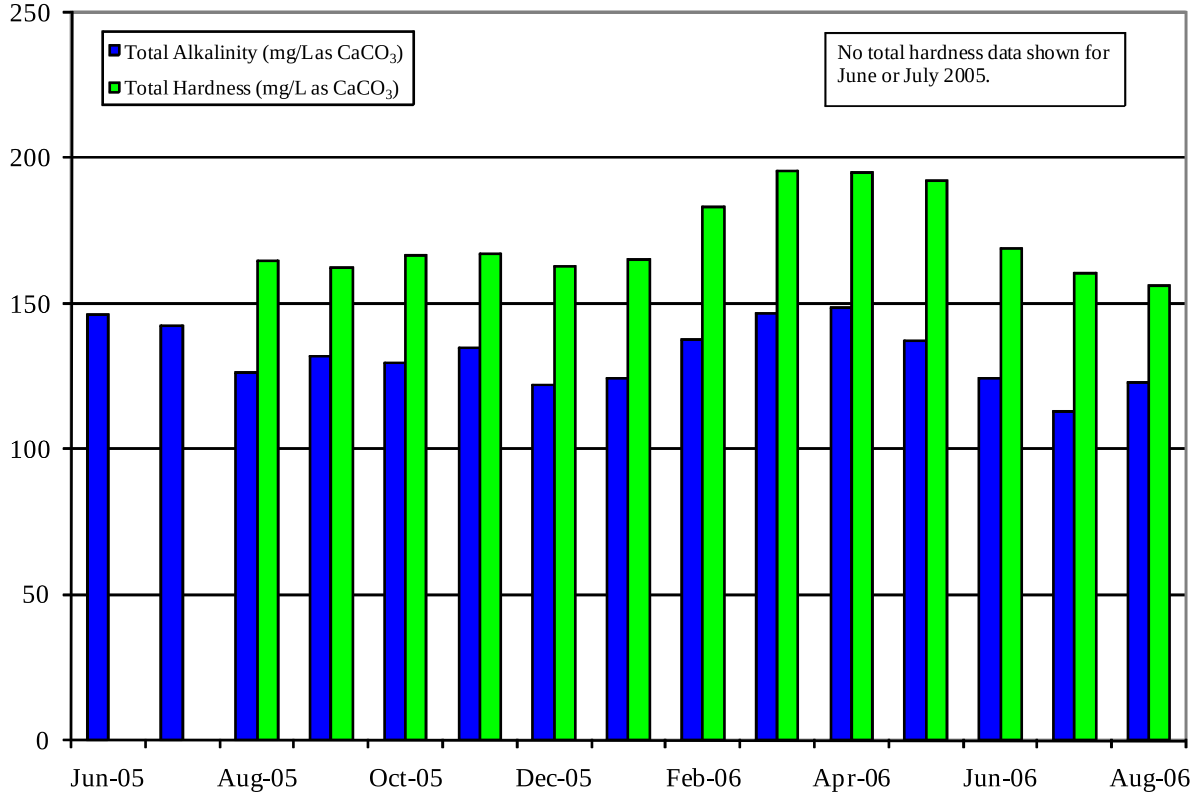
Cooling Tower Parameters

For use in industrial cooling towers, it may be necessary to provide polishing treatment of the reclaimed water from the VCWWTP. Dissolved solids can precipitate and result in clogging or corrosion of pipes. Often, membrane filtration is a prerequisite for making reuse water attractive to industry for these purposes. One of the more critical parameters for industrial reuse applications is total hardness, a function of the calcium and magnesium concentrations, because it often dictates the extent to which deposits are formed in cooling tower piping. The average total hardness of the Village Creek effluent in 2005 was approximately 165 mg/l as $CaCO_3$; for 2006 it was slightly higher at 176 mg/l as $CaCO_3$. Industries may have on-site softening systems that can treat the reclaimed water to acceptable levels. Other cations should not be present in significant quantities, as the alkalinity of the water was comparable to the hardness levels: 133 mg/l as $CaCO_3$ and 132 mg/l as $CaCO_3$ for 2005 and 2006, respectively. For other metals, such as copper and zinc, acceptable levels should be determined by individual industrial customers, but these elements were not present at concentrations that are hazardous to aquatic or human life. Again, it is likely that specific testing will be necessary, depending on the reclaimed water customer and the reclaimed water use. Figure 4-4 shows the total alkalinity and hardness for VCWWTP effluent.

Evaporative Makeup Water Parameters

Another application of Type I reclaimed water is the augmentation of recreational impoundments and aesthetic water features such as park fountains. Because of the high potential for human exposure in recreational waters, additional testing for bacteria or viruses (*e.g., E. coli*) or more frequent testing may be warranted. In addition, polishing treatment to remove nutrients may be necessary to minimize algae growth in ponds or lakes.

Figure 4-4
Village Creek WWTP Effluent Total Alkalinity and Total Hardness



Potential Future Requirements

It is difficult to predict what new federal or state requirements may be applied to discharge permits in the future. As entities develop more reclaimed water projects, total dissolved solids (TDS) levels may become an issue; some existing Texas Pollutant Discharge Elimination System (TPDES) permits limit TDS concentrations. The EPA has also required all states to incorporate some form of nutrient standards into surface water quality standards. Thus, future discharge permits will likely include a phosphorous limit and possibly a nitrogen limit; however, this has a greater impact on conventional discharges than on most reuse applications. As these regulations are implemented, several types of treatment technologies, such as denitrification filters, will be more readily available.

Direct reuse programs reduce the nutrient loading to receiving streams. Therefore, even with the possible tightening of effluent permit limits, reuse could help reduce the impact that more stringent permitting requirements would have on the VCWWTP with regard to the requisite treatment process alterations to meet future limits.

5. Reclaimed Water Demands

Fort Worth's 2007 *Reclaimed Water Priority and Implementation Plan* identified potential reclaimed water uses, service areas, reclaimed water users, and projected reclaimed water demands for the Central System and the Southern System. These have been reviewed and expanded and are summarized in the following sections.

5.1. Guidance

Existing and future water uses should be screened to identify potential direct reuse opportunities. The screening process may include review of known large water users, well records, aerial photographs, and other information. Potential reclaimed water uses include:

- Commercial irrigation,
- Commercial process use,
- Golf course irrigation,
- Park and recreational facility irrigation,
- Public facility irrigation,
- Residential irrigation,
- Schools and university irrigation,
- Cooling tower makeup water,
- Gas well drilling use,
- Evaporative makeup water,
- Dust control, and
- Other uses.

Once a potential user has been identified, additional information must be developed, including the location of use, the type of water use, reclaimed water quality requirements, annual demand, and peak demand. This information should be used to design the capacity and treatment facilities at reclaimed water production facilities and to design the reclaimed water conveyance system.

5.2. Potential Reclaimed Water Uses

Potential reclaimed water uses in Fort Worth include commercial irrigation, commercial process use, golf course irrigation, park and recreational facility irrigation, public facility irrigation, residential irrigation, schools and university irrigation, cooling tower makeup water, gas well drilling use, and evaporative makeup water. Each category has different water use characteristics such as seasonal variation and frequency of use, as described below. These characteristics were used to help define monthly, daily, and hourly peaking factors that are necessary in design of transmission facilities.

Definitions

The following definitions are used to quantify demands:

Annual Demand: Total annual water demand divided by 365 days. This is the average demand throughout a year.

Peak Month: The month with the greatest water demand.

Peak Month Demand: Total water demand for the Peak Month divided by the number of days in the month. This is the average demand during the Peak Month.

Peak Month Factor: Peak Month Demand divided by the Annual Average Demand.

Peak Day: The day in the Peak Month with the greatest water demand.

Peak Day Demand: Total water demand for the Peak Day divided by 24 hours. This is the average demand on the Peak Day.

Peak Day Factor: Peak Day Demand divided by the Peak Month Demand.

Peak Hour: The hour in the Peak Day with the greatest water demand.

Peak Hour Demand: Total water demand for the Peak Hour divided by one hour. This is the average demand during the Peak Hour.

Peak Hour Factor: Peak Hour Demand divided by Peak Day Demand.

System Demand: For customers with available storage, the system demand is the peak day demand. For customers without available storage, the system demand is the peak hour demand.

These definitions can also be written in equation form:

Peak Month Demand = Peak Month Factor * Annual Demand

Peak Day Demand = Peak Day Factor * Peak Month Demand
= Peak Day Factor * Peak Month Factor * Annual Average Demand

Peak Hour Demand = Peak Hour Factor * Peak Day Demand
= Peak Hour Factor * Peak Day Factor * Peak Month Factor
* Annual Average Demand

Impact of Storage

The peaking factors described in the previous section were defined based on projected reclaimed water demands. These peaking factors will be used to design transmission facilities to convey reclaimed water to meet the peak demands. If reclaimed water storage is available, the peak demands on the transmission system can be reduced, and the facilities can be designed to convey lesser flowrates. Storage does not affect the demand for water, only the timing with which the water is provided.

Consider an irrigation user with a Peak Day Demand of *PDD*. If this user does not have available storage and runs the irrigation system for *N* hours per day, then the Peak Hour Factor is 24/*N*, and the transmission system must be designed to meet a Peak Hour Demand of 24**PDD*/*N*. If this user can store reclaimed water, then the transmission system can be designed to meet a lesser Peak Hour Demand. The Peak Hour Demand *on the transmission system* can be reduced to *PDD* with a storage volume of at least (24-*N*) hours times *PDD*.

As a numerical example, assume that the Peak Day Demand is 0.5 mgd and that the user runs the irrigation system for 6 hours per day. Without storage, the Peak Hour Factor is 4.0 (24 hours/6 hours), and the transmission system must be designed to meet a Peak Hour Demand of 2.0 mgd (4*0.5 mgd). If the user can provide 375,000 gallons of storage [(2 mgd – 0.5 mgd)*6 hours], the transmission system can be designed to meet a Peak Hour Demand of 0.5 mgd (in this situation, the Peak Hour Demand *on the transmission system* is the same as the Peak Day Demand).

Storage can also be placed at key points in a reclaimed water distribution system to reduce the required pipe sizes and pumping capacities in portions of the system. As future peak hour demands increase, storage and pumping capacity could be added to the system to maximize the system capacity.

Demand Seasonality (Peak Month Factor)

Irrigation use typically peaks during the months of June through September, and may sometimes include May and October as well. The volume of water used for irrigation during the Peak Month is projected to be 22 percent of the Annual Demand volume. Thus, the Peak Month Factor for irrigation uses is assumed to be 2.64, unless user-specific data are available. This Peak Month Factor is consistent with previous studies prepared for Fort Worth. Most of the reclaimed water uses considered in this report are irrigation uses; the exceptions are commercial processes, cooling tower makeup, gas well drilling uses, and evaporative makeup water.

Commercial Processes

For most commercial processes, water demand is expected to remain relatively constant throughout the year. Therefore, the Peak Month Factor for commercial process use is assumed to be 1.0.

Cooling Tower Makeup Water

Demand for cooling tower makeup water is seasonal and depends on the wet bulb temperature, the cooling tower capacity, and the number of cooling towers. It was assumed that the Peak Month Factor for cooling tower makeup water is 2.0.

Gas Well Drilling

Gas well drilling takes place year-round. Since there is no apparent seasonality in water demand, it was assumed that the Peak Month Factor for gas well drilling demand is 1.0.

Evaporative Makeup Water

The purpose of evaporative makeup water is to replace water lost to evaporation from large water features. Since evaporative losses depend on air temperature, they are highly seasonal and highly dependent on geographic location. Analysis of TWDB net evaporation (evaporation minus precipitation) data[36] suggests that an appropriate average Peak Month Factor for Tarrant County is 3.06.

Distribution of Peak Month Demands (Peak Day and Peak Hour Factors)

Peak day and peak hour demands may be greater than peak month demands, depending on the demand characteristics of individual users, design of irrigation systems, and other factors. Peak Day and Peak Hour Factors are discussed below for each anticipated reclaimed water use.

Commercial Irrigation

Business or commercial enterprises utilize water for irrigation purposes. All customers identified in the commercial irrigation category were assumed to irrigate on a daily basis for a period of 4 hours per day, unless specific information was available. This results in a Peak Day Factor of 1.0[37] and a Peak Hour Factor of 6.0.

Commercial Processes

Business or commercial enterprises also use water in their processes. All customers identified in the commercial processes category were assumed to use water at a constant rate, regardless of the time of year or time of day, unless user-specific data were available. For commercial process use, the Peak Day Factor is 1.0, and the Peak Hour Factor is 1.0.

---

[36] Texas Water Development Board, "Texas Evaporation/Precipitation." Available URL: http://midgewater.twdb.state.tx.us/Evaporation/evap.html

[37] With a Peak Day Factor of 1.0, the irrigator still has some discretion regarding the distribution of the irrigation water. For example, the irrigator could distribute one day's supply over the entire irrigated area, could distribute two days' supply over one-half the irrigated area, etc.

This consistent demand will help to ensure continuous operation of the system and reduce the need for flushing operations. However, many of the commercial process demands identified were small in comparison to the larger users in other categories.

Golf Course Irrigation

Golf courses are typically ideal places to initiate reclaimed water practices. Golf courses tend to be large water users due to heavy irrigation. Many of the courses have water features, or ponds, that can be used as storage facilities for reclaimed water. If existing ponds were to be used for reclaimed water storage, then the peaking factor for the reclaimed water system would be reduced. However, many courses will not allow significant variations in the water surface elevation of these ponds, as this could affect the aesthetics of the course. For this reason, ponds are not considered for storage in this analysis, and it was assumed that golf courses would be irrigated on a daily basis for 12 hours per day, unless specified otherwise. This assumption results in a Peak Day Factor of 1.0 and Peak Hour Factor of 2.0. If it is determined by the City and the respective golf course, that its water features could be used as temporary storage, then the peaking factors should be adjusted, resulting in a more economical design.

Parks and Recreational Facilities

This category includes public and private parks and recreational areas such as sports complexes. These areas usually have substantial green space that requires irrigation to maintain public areas and sports fields. Parks and recreational areas, similar to golf courses, are usually excellent locations to implement reclaimed water projects. Parks and recreational areas were assumed to irrigate once every three days for a period of 8 hours, unless specific information was available. This results in a Peak Day Factor of 3.0, and a Peak Hour Factor of 3.0.

Public Facilities

Public facilities are government-owned facilities, such as public libraries or courthouses. This category does not include City-owned parks or golf courses, which are included in separate categories. Public facilities were assumed to irrigate once every three days for a period of 8 hours, unless specific information was available. This schedule is similar to the parks and recreational areas, but the annual average water demand is typically much less. This results in a Peak Day Factor of 3.0, and Peak Hour Factor of 3.0.

Residential Irrigation

Installation of a reclaimed water system in a previously developed residential area would be a costly endeavor. However, installing a dual water system during initial development could be feasible. The City has had previous discussions with developers in the Mary's Creek Basin (not located in the Central or Southern service areas) regarding installation of a dual water system during development. In these areas, the residential irrigation demand was estimated based on the total acreage of residential areas. Residential areas were assumed to irrigate on a daily basis for a period of 4 hours per day, unless specific information was available. This results in a Peak Day Factor of 1.0, and Peak Hour Factor of 6.0.

These assumptions are made based on considering the entire residential area as a whole rather than considering individual homes. In the absence of regulations, individual homeowners will irrigate on different days and at different times.

Schools and Universities

Potential reclaimed water customers also include schools and universities, where reclaimed water could be used for irrigation purposes. Schools were assumed to irrigate once every three days for a period of 8 hours, unless specific information was available. This results in a Peak Day Factor of 3.0, and a Peak Hour Factor of 3.0.

Cooling Tower Makeup Water

Cooling towers remove heat from air-conditioning systems or industrial processes by evaporating water and discharge (or blowdown) additional water to maintain target maximum dissolved solids concentrations. Reclaimed water can be provided to replace the water that is evaporated and blown down.

Demand for cooling tower makeup water is seasonal and depends on the wet bulb temperature, the cooling tower capacity, and the number of cooling towers. It was assumed that the Peak Month Factor is 2.0, the Peak Day Factor is 1.25, and the Peak Hour Factor is 1.0.

Gas Well Drilling

Recent advances in gas drilling technology have allowed the natural gas industry to mine gas deposits in the Barnett Shale formation, located in Tarrant County and several surrounding counties. As part of the drilling operations, water is used to fracture the formation so that the deposits of natural gas are released. The water used for this process, referred to as “frac water,” can be non-potable. Both the Texas Railroad Commission and the TCEQ have approved use of reclaimed water for hydraulic fracturing. Approximately 3 to 4 million gallons of water are required during the fracturing process for each well. Frac water is typically stored in “frac ponds” on site.

It is possible that several drillers will want water at the same time, but it is not possible to predict the timing of gas well drilling demands, and it is not economical to design for a high peaking factor. Therefore, it was assumed that the Peak Day Factor is 2.0, and the Peak Hour Factor is 1.0.

Evaporative Makeup Water

Large water features generally have sufficient storage to dampen out the differences between peak hour and peak month demands. Therefore, a Peak Day Factor of 1.0 and a Peak Hour Factor of 1.0 were assumed for evaporative makeup water.

Summary of Peaking Factors

The typical peaking factors for monthly, daily, and hourly water demands are summarized in Table 5-1. These peaking factors are used unless specific information is available for a particular customer.

5.3. Potential Reclaimed Water Service Areas, Users, and Demands

Potential reclaimed water users were identified through analysis of Fort Worth water billing records, surveys of potential customers, meetings with potential customers, meetings with nearby cities, meetings with developers, meetings with Fort Worth Parks and Community Services Department personnel, meetings with Trinity River Vision Project staff, and review of other

Table 5-1
Typical Peaking Factors

Category	Peak Month Factor	Peak Day Factor	Peak Hour Factor
Commercial Irrigation	2.64	1.00	6.0
Commercial Process	1.00	1.00	1.0
Golf Course Irrigation	2.64	1.00	2.0
Parks and Rec Irrigation	2.64	3.00	3.0
Public Facility Irrigation	2.64	3.00	3.0
Residential Irrigation	2.64	1.00	6.0
School Irrigation	2.64	3.00	3.0
Cooling Tower Makeup	2.00	1.25	1.0
Gas Well Drilling	1.00	2.00	1.0
Evaporative Makeup	3.06*	1.00	1.0

*For Tarrant County. This factor should be reevaluated for other geographic locations.

studies. The potential reclaimed water users were compared and ranked based on the amount of reclaimed water that could potentially be supplied to each user. Potential users were then analyzed based on location to identify potential projects, or alternatives, for further analysis. The potential users and demands that have been identified are further described in this chapter.

Potential reclaimed water users for the Central System and the Southern System are discussed in the following sections. Figure 5-1, taken from the *Reclaimed Water Priority and Implementation Plan*,[38] shows the general service areas for all proposed reclaimed water projects in Fort Worth.

Central System

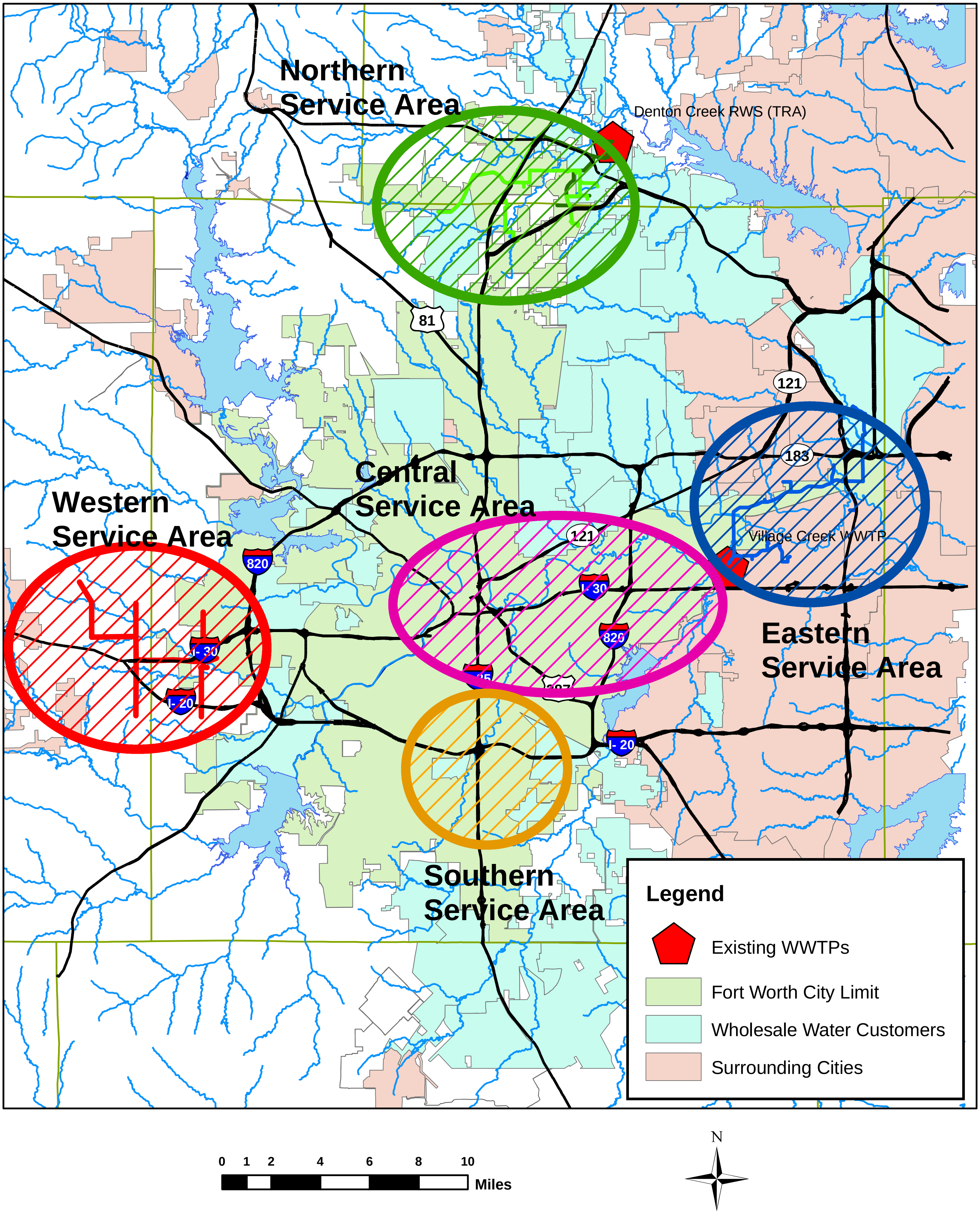
The Central System service area extends west from the Village Creek WWTP to the downtown Fort Worth area near the IH-35W and IH-30 intersection, and as far south as Cobb Park (Figure 5-1). Potential reclaimed water uses and users in the Central System include:

- Commercial irrigation (Trinity River Vision),
- Golf course irrigation (Meadowbrook, Sycamore Creek, and Woodhaven),
- Park and recreational facilities irrigation (Gateway Park, and Sycamore Park),

---

[38] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

Figure 5-1
City of Fort Worth Reclaimed Water Service Areas



- Cooling tower makeup water (Harris Methodist Hospital and Central Business District), and
- Evaporative makeup water (Trinity River Vision).

Projected reclaimed water demands are summarized in Table 5-2. The largest potential single use for the Central System is the Trinity River Vision Project, a major flood control project in downtown Fort Worth, which is scheduled to be completed by about 2015. The Project will isolate a portion of the current river and establish an urban lake to be used for a variety of boating and water activities. Preliminary information provided by Project staff indicates that the Project could require the following reclaimed water supplies to offset evaporative losses from the urban lake or other water features and to provide commercial irrigation water:

- 0.76 mgd annual average
- 2.50 mgd peak month (and peak day)
- 7.50 mgd peak hour

As shown in Table 5-2, storage and pumping capacity would be provided to limit the peak hour demand on the reclaimed water system to 2.5 mgd.

The Gateway Park demand has been increased from the amount shown in the *Reclaimed Water Priority and Implementation Plan*,[39] because the latest planning information for Gateway Park shows 20 new soccer fields, 2 new baseball fields, and 2 new softball fields.

The demand for cooling tower makeup water was estimated from the current square footage of Class A (4,913,805 square feet) and Class B (3,155,854 square feet) office space in the Fort Worth Central Business District.[40] Assumptions included 1 ton of cooling capacity per 350

---

[39] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

[40] Fort Worth Chamber of Commerce, "General Market Statistics," January 2008. Available URL: http://www.fortworthchamber.com/eco/docs/GeneralMarketStatistics_000.pdf. There are 7 Class A office buildings in the Central Business District: the D.R. Horton Tower (City Center), the Wells Fargo Tower (City Center), Burnett Plaza, Carter & Burgess Plaza, the JP Morgan Chase Bank Building, the Pier 1 Imports headquarters, and the Radio Shack campus (recently purchased by Tarrant County College). There are 37 Class B office buildings in the Central Business District.

Table 5-2
Central System Projected Reclaimed Water Demands

Potential Customer	Annual Average Water Demand (mgd)	System Demand* (mgd)	Required System Pressure (psi)	Available Storage	Use	Reuse Type
Central Business District	0.49	1.23	60	No	Cooling Tower Makeup	II
Cobb Park	0.17	3.96	60	No	Park and Rec Irrigation	I
Gateway Park	0.15	3.48	60	No	Park and Rec Irrigation	I
Glen Garden GC	0.09	0.46	0	Yes	Golf Course Irrigation	II
Harris Methodist Hospital	0.05	0.13	60	No	Cooling Tower Makeup	II
Meadowbrook GC	0.06	1.73	0	Yes	Golf Course Irrigation	II
Sycamore Creek GC	0.03	0.74	0	Yes	Golf Course Irrigation	II
Sycamore Park	0.04	0.86	60	No	Park and Rec Irrigation	I
Trinity River Vision Project	0.76	2.50	17	Yes**	Evaporative Makeup, Commercial Irrigation	I
Woodhaven GC	0.09	1.16	0	Yes	Golf Course Irrigation	II
Total	**1.93**	**16.25**				

*For customers with available storage, the system demand is the peak day demand. For customers without available storage, the system demand is the peak hour demand.

**To be constructed as part of project.

square feet, annual average load factor of 40 percent, 1.44 gallons of water evaporated per ton-hour, and 3 cycles of concentration.

Fort Worth has had some initial discussions with gas well drillers regarding the use of reclaimed water for their operations. Fort Worth has constructed a truck filling station at the Village Creek WWTP from which trucks can obtain reclaimed water for use in fracturing operations. The Central System has been designed to accommodate the demands from Table 5-2 and has not been designed with additional capacity to meet gas well drilling water demands. Should there be unused capacity in the Central System after implementation, it may be possible to supply water for gas well drilling through the Central System on a temporary basis. Fort Worth could potentially serve more demand from the Central System if users provide on-site storage.

Other projected demands were taken from the *Reclaimed Water Priority and Implementation Plan*.

Southern System

The Southern System service area is an area located east of IH-35W, to the north and to the south of IH-20 (Figure 5-1). Potential reclaimed water uses and users in the Southern System include:

- Commercial irrigation (Alcon Laboratories, Miller Brewing, Federal Correctional Institution, Tarrant County Resource Connection, and Rolling Hills Tree Farm),
- Commercial process (Ball Metal Container),
- Golf course irrigation (Glen Garden),
- Park and recreational facilities irrigation (Cobb Park, Rolling Hills Park soccer fields, Rolling Hills Park north fields, Federal Correctional Institution, Fort Worth Independent School District (FWISD) athletic fields, Tarrant County Resource Connection, and Worth Baptist Church),
- School and universities irrigation (Tarrant County College and O.D. Wyatt High School),
- Cooling tower makeup water (Miller Brewing and Mrs. Baird's Bakeries), and
- Gas well drilling.

Projected reclaimed water demands for the Southern System are summarized in Table 5-3.

Table 5-3
Southern System Projected Reclaimed Water Demands

Potential Customer	Annual Average Water Demand (mgd)	System Demand* (mgd)	Required System Pressure (psi)	Available Storage	Use	Reuse Type
Alcon Laboratories	0.38	3.00	60	No	Commercial Irrigation	I
Ball Metal Container	0.01	0.01	60	No	Commercial Process	II
Federal Correctional Institution	0.01	0.30	60	No	Commercial Irrigation Park and Rec Irrigation	I
FWISD Athletic Fields	0.03	0.68	60	No	Park and Rec Irrigation	I
Gas Well Drilling	0.38	0.77	n/a	No	Gas Well Drilling	II
Miller Brewing Co.	0.19	0.53	60	No	Commercial Irrigation, Cooling Water Makeup	II
Mrs. Baird’s Bakeries	0.10	0.25	60	No	Cooling Water Makeup	II
O.D. Wyatt High School	0.01	0.26	60	No	School Irrigation	I
Rolling Hills Park North Fields	0.02	0.39	60	No	Park and Rec Irrigation	I
Rolling Hills Park Soccer Fields	0.15	3.65	60	No	Park and Rec Irrigation	I
Rolling Hills Tree Farm	0.02	0.38	60	No	Commercial Irrigation	II
Tarrant County College	0.01	0.31	60	No	School Irrigation	I
Tarrant County Resource Connection	0.03	0.50	60	No	Commercial Irrigation Park and Rec Irrigation	I
Worth Baptist Church	0.01	0.12	60	No	Park and Rec Irrigation	I
Total	**1.35**	**11.15**				

*System demand is the peak hour demand for each customer.

The largest potential single peak use for this system is for irrigation of the 19 soccer fields at Rolling Hills Park. Planning information provided by Fort Worth indicates that the annual average demand for these fields is 0.15 mgd, with a peak hour demand of approximately 3.65 mgd.

Gas well drilling demands were estimated using several assumptions:

- Water would be supplied to drillers' trucks at a filling station located at the RWPF;
- Cost-effective trucking distance of 30 miles;[41]
- Horizontal well length of 3,000 feet;
- 3 million gallons water demand for each well;
- 75 percent of area within this radius is accessible to drillers;
- 8 percent of potential wells have already been drilled; and
- Fort Worth will serve 10 percent of the gas well drilling water demand within this radius.

The potential gas well drilling demands were distributed in time taking into account the following information:

- Historical well completions,
- Projected maximum completion rate of 360 wells per year,
- Total potential wells in the radius, and
- A 60-year development period.

With these assumptions, the potential gas well drilling water demand is projected to reach a maximum annual average rate of 0.85 mgd during the period 2010-2014. After this time, the potential gas well drilling demand is projected to decline to a steady rate of 0.38 mgd for the period 2021 through 2067. The demand shown in Table 5-3 is the later, steady rate. Additional analysis should be performed to determine whether it is cost-effective for Fort Worth to design infrastructure to meet more of the projected demand. Peak demands for gas well drillers depend on whether drillers are fracturing multiple wells at the same time. A Peak Month Factor of 1.0

[41] Some of the demand within the 30-mile radius could be met with reclaimed water from the VCWWTP.

and a Peak Day Factor of 2.0 have been assumed for gas well drilling water demand, but additional analysis may be necessary to refine these assumptions.

The reclaimed water conveyance portion of the Southern System has been designed to accommodate the demands from Table 5-3 and has not been designed with additional capacity to meet gas well drilling water demands. Should there be unused capacity in the Southern conveyance system after implementation, it may be possible to supply water for gas well drilling through the Southern conveyance system on a temporary basis. Fort Worth could potentially serve more demand from the Southern conveyance system if users provide on-site storage.

Irrigation demands at the Federal Correctional Institution, the FWISD Fields, the Rolling Hills Tree Farm, the Tarrant County Resource Connection, and Worth Baptist Church were based on estimated irrigated acreage and an annual irrigation rate of 30 inches per year. Other projected demands were taken from the *Reclaimed Water Priority and Implementation Plan*.

6. Site Selection for a Reclaimed Water Production Facility

Rather than pumping reclaimed water from the VCWWTP to various reclaimed water demand locations, it may be more economical to construct a reclaimed water production facility (RWPF) closer to the reclaimed water demands. RWPFs are small treatment facilities located near an existing trunk sewer that can treat a portion of the flow in the line and deliver it to a nearby reclaimed water user. Solids generated at an RWPF would be returned to the collection system and handled at the main WWTP. RWPFs can have several advantages, including:

- RWPFs can be located close to the point of service;
- RWPFs can treat only the flow needed for reclaimed water sales;

6.1. Guidance

Guidance for site selection criteria and discussion of the new TCEQ rules for Reclaimed Water Production Facilities are presented in this section.

RWPF Site Selection Criteria

Factors that should be considered when selecting an RWPF site are listed in Table 6-1 and summarized in the following sections.

Acreage for Treatment Units, Storage, Conveyance Facilities, and Buffers

An RWPF site should have sufficient acreage for planned wastewater treatment units, reclaimed water storage, reclaimed water conveyance facilities, and required buffer distances. The size of the treatment units, storage, and conveyance facilities will depend on the wastewater and reclaimed water design flowrates. The following buffer distances apply:[42]

[42] Texas Administrative Code Title 30, Chapter 309

Table 6-1
Reclaimed Water Production Facility Site Selection Criteria

Criterion	Criterion Type			
	Engineering	Environmental	Public Acceptance	Regulatory/ Permitting
Acreage for Treatment Units, Storage, Conveyance Facilities, and Buffers	x			x
Acreage for Future Expansion	x			
Minimum Distance from Wells, Potable Water Storage, and WTPs		x		x
Proximity to Wastewater Collection System Infrastructure with Sufficient Wastewater Supply	x			
Proximity to Reclaimed Water Demands	x			
Gently Sloping Terrain	x			
Proximity to Existing Roadways	x			
Proximity to Power Supply	x			
Proximity to Permissible Effluent Discharge Location*	x			x
Percentage of Undeveloped Acreage			x	
Distance from Developed Areas/Property			x	
Potential for USACE 404 Permitting Issues (Floodplain, Wetlands, Endangered Species, Cultural Resources)	x	x		x
Potential for Other Adverse Environmental Conditions		x		x
Predominant Wind Direction	x		x	
Desirability of Site for Other Uses			x	
Relative Land Costs				
Minimal Number of Highway and River Crossings	x	x		
Relative Elevations of Site and Wastewater Interceptor	x			
Minimal Number of Property Owners			x	

*If the RWPF is to be permitted as a Reclaimed Water Production Facility under TCEQ rules (Chapter 321, Subchapter P), no discharge of effluent is allowed, and this criterion should not be considered. Discharge of effluent would require an individual domestic wastewater permit.

- Wastewater treatment units must be located:
  - Outside the 100-year floodplain.[43]
  - At least 150 feet from a property line. Additional requirements may apply to RWPFs; see Chapter 6.1 for discussion of the RWPF rules.
  - At least 500 feet from a public water well, spring, or similar source of public drinking water.
  - At least 250 feet from a private water well.
  - At least 500 feet from an elevated or ground potable-water storage tank.
  - At least 500 feet from a surface water treatment plant.
- A wet well or pump station at a wastewater treatment facility must be located at least 300 feet from a public water well, spring, or similar source of public drinking water.
- Lagoons with anaerobic activity may not be located within 500 feet of a property line.

In addition, other requirements may apply.

Acreage for Future Expansion

An ideal RWPF site should have sufficient acreage for future expansions to meet projected future demands.

Proximity to Wastewater Collection System with Sufficient Wastewater Supply

An ideal RWPF site would be located adjacent to existing wastewater collection system infrastructure, either an interceptor or a lift station, which has a sufficient supply of wastewater to meet projected reclaimed water demands. The further the RWPF site is from such a location, the more expensive it would be to convey the raw wastewater to the RWPF.

---

[43] If any treatment facilities are to be located within the 100-year floodplain, they must be protected from inundation, typically by levees. Construction within the 100-year floodplain is subject to review by the U. S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act if the land is determined to be within USACE jurisdiction. Construction of levees in the 100-year floodplain would effectively reduce the available valley storage. The USACE will accept no loss of valley storage within the 100-year floodplain, unless that loss is mitigated. In addition, it must be demonstrated that the final project configuration will not increase the 100-year flood water surface elevation. See more discussion on Section 404 permitting in Section 7.A.19.

Proximity to Reclaimed Water Demands

An ideal RWPF site would be located close to reclaimed water demands. The further the RWPF site is from the reclaimed water demands, the more expensive it would be to convey the reclaimed water to the users.

Gently Sloping Terrain

An ideal RWPF site would have gently sloping terrain that is conducive to plant construction and overall hydraulic operation of the plant. Sites where more grading would be necessary to prepare the site would be more expensive.

Proximity to Existing Roadways

An ideal RWPF site would be adjacent to existing roadways with the capacity to allow trucks and construction equipment access to the site. The further the RWPF site from existing road access, the more expensive it would be to provide this road access.

Proximity to Power Supply

An ideal RWPF site would be located adjacent to a three-phase power supply line with adequate supply. The further the RWPF site is from such a location, the more expensive it would be to convey power to the RWPF.

Proximity to Permissible Effluent Discharge Location

If a wastewater treatment facility is to be permitted with an individual domestic wastewater permit, an ideal site would be located adjacent to a stream that is a permissible effluent discharge location. There may be times when the treated effluent from the treatment facility exceeds the demand for reclaimed water and/or storage capacity. In such situations, it may be desirable to discharge the treated effluent to a nearby stream. To receive an effluent discharge permit, Fort Worth would have to show that dissolved oxygen concentrations in the stream will meet the

Texas Surface Water Quality Standards.[44] The further the site is from a permissible discharge location, the more expensive it would be to convey treated effluent to such a location.

If the wastewater treatment facility is to be permitted as a Reclaimed Water Production Facility under TCEQ rules (Chapter 321, Subchapter P), as contemplated for the Southern System, no discharge of effluent is allowed, and this criterion should not be considered in selecting a site for an RWPF.

Percentage of Undeveloped Acreage

An ideal RWPF site would be completely undeveloped. Public acceptance issues may arise if all or part of the site is already developed.

Distance from Developed Areas/Property

An ideal RWPF site would be distant from developed areas or property, particularly residences. Unfortunately, such a site may also be distant from reclaimed water demands. The distance from developed areas must be balanced with the distance to reclaimed water demands.

Potential for USACE 404 Permitting Issues

An ideal RWPF site would not impact waters of the United States, threatened or endangered species, or cultural resources. The implications of such impacts are discussed below.

<u>Impacts to Waters of the United States (Including Wetlands)</u>

Under Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers (USACE) is responsible for regulating dredged and fill activities which impact waters of the United States, including wetlands. Typically, excavation activities do not require authorization by a Section 404 permit. However, projects that involve excavation activities with associated fill activities would be reviewed for total impacts. The permitting options include general permits (both nationwide and regional) and individual permits. The USACE-recommended sequencing is: avoidance of impacts where practicable, minimization of unavoidable impacts, and then development of

[44] Texas Administrative Code Title 30, Chapter 307

compensatory mitigation to replace the functions of the impacted jurisdictional area. Efforts to avoid and minimize impacts to delineated jurisdictional areas may facilitate permitting the proposed project under a general permit.

On-site investigation is necessary to delineate jurisdictional waters of the U.S. Submittal to the USACE of a preliminary determination of jurisdictional waters of the U.S., as well as proposed project plans, quantification of impacts to jurisdictional areas as a result of the proposed project, analysis of practicable alternatives for the proposed project, and a proposed compensatory mitigation plan for unavoidable impacts to jurisdictional areas is required for a Section 404 permit application. Determination of the impacts of the proposed facilities to floodplain and valley storage will be required by the USACE prior to issuance of a Section 404 permit.

Impacts to Threatened or Endangered Species

An evaluation of potential impacts to species listed as endangered or threatened under the Endangered Species Act or to designated critical habitat will also be required as part of the Section 404 permit application review. The State of Texas is also included in the 404 permit review process and maintains a list of protected species that includes the Federally-listed species but also contains other State-listed species of concern. An on-site survey for habitat or observation of protected species can be coordinated with the on-site investigation for delineation of jurisdictional waters. Copies of coordination correspondence with the U.S. Fish and Wildlife Service (USFWS) and the Texas Parks and Wildlife Department (TPWD) should be included with the 404 permit application submittal to the USACE.

In the event that a 404 permit review is not required, disturbance of more than 5 acres of a project site also triggers the requirement for an on-site survey for protected species and correspondence with the USFWS and TPWD for assessment of potential impacts.

Impacts to Cultural Resources

A review for potential impacts to cultural resources protected under the National Historic Preservation Act must be coordinated with the Section 404 permitting. A search for sites previously recorded for the area should be conducted as a minimum indication of the potential for archaeological sites within the project site. A pedestrian survey by a qualified archeologist or a more intensive survey could be required.

Potential for Other Adverse Environmental Conditions

An ideal RWPF site would be free of other adverse environmental conditions, such as contaminated soil, contaminated groundwater, buildings with asbestos, etc.

Predominant Wind Direction

Predominant winds at an ideal RWPF site would blow away from developed areas, particularly residences. This would help reduce odor complaints and help address public acceptance concerns. If the predominant wind direction is unfavorable at an otherwise-suitable RWPF site, odor control facilities may be necessary.

Desirability of Site for Other Uses

An ideal RWPF site would be relatively undesirable for other uses but still suitable under other site criteria. Examples could include sites with nearby overhead power lines, gas wells, or significant industrial development.

Relative Land Costs

An ideal RWPF site would be inexpensive compared to other potential sites.

Minimal Number of Highway and River Crossings

An ideal RWPF site would require no highway or river crossings to convey wastewater from the collection system to the site and to convey reclaimed water from the site to the users. The more highway and river crossings, the more expensive the wastewater and reclaimed water conveyance facilities would be.

Relative Elevations of Site and Wastewater Interceptor

An ideal RWPF site would have a minimal difference in elevation between the site and the wastewater source. The higher the site elevation relative to the wastewater source, the more expensive it would be to convey wastewater to the site.

Minimal Number of Property Owners

An ideal RWPF site would be owned by only one owner. It is more convenient for a utility to negotiate with one owner than with several owners and may speed property acquisition.

Based on the site evaluation criteria shown in Table 6-1, several potential sites should be selected for further analysis. A preferred site should be selected after consideration of other site-specific factors (including relative land costs and the impact of the site choice on conveyance system pumping requirements and costs).

The TCEQ has recently enacted new rules for "reclaimed water production facilities". The rules and site selection criteria are discussed below.

Rules for Reclaimed Water Production Facilities

Historically, domestic wastewater permittees were required to apply for an individual domestic wastewater permit to construct and operate Reclaimed Water Production Facilities (or RWPFs). The review and approval process for an individual domestic wastewater permit is expensive and time-consuming for both the applicant and the TCEQ. The TCEQ has enacted new rules[45] allowing a streamlined authorization process for Reclaimed Water Production Facilities at locations other than the permitted wastewater treatment facility. Under the rules, WWTP owners that have an individual domestic wastewater permit and a Chapter 210 reuse authorization[46] can obtain an authorization to construct and operate a Reclaimed Water Production Facility.

The following restrictions would apply to Reclaimed Water Production Facilities:[45]

- "A reclaimed water production facility may not discharge wastewater or pollutants into [waters of the state].
- The hydraulic capacity of the reclaimed water production facilities may not individually nor collectively exceed the permitted hydraulic capacity of the associated domestic wastewater treatment facility.

---

[45] Texas Administrative Code Title 30, Chapter 321, Subchapter P, effective November 27, 2008.

[46] Texas Administrative Code Title 30, Chapter 210

- A reclaimed water production facility may not be authorized at a flow rate that could cause interference with the operation of the domestic wastewater treatment facility or a violation of the domestic wastewater treatment facility's permit.
- A reclaimed water production facility may not treat or dispose of sludge. All sludge must be conveyed through the collection system to the permitted domestic wastewater treatment facility, treated, and disposed of in accordance with the facility's permit and all applicable rules.
- The owner may not accept trucked or hauled wastes at a reclaimed water production facility."

The new rules offer two alternatives for meeting buffer zone requirements:

- Treatment units must be located at least 150 feet from the nearest property line, or
- The RWPF must meet an alternative "enhanced" buffer zone designation that requires one of the following: "(1) a treatment unit not located in a building may not be located closer than 300 feet to the nearest property line; (2) a treatment unit located within an enclosed building that is not equipped with exhaust air systems and odor control technology may not be located closer than 150 feet of the nearest property line; or (3) a treatment unit located within an enclosed building equipped with exhaust air systems and odor control technology may not be located closer than 50 feet of the nearest property line."

The TCEQ adopted the RWPF rules on November 5, 2008, and the rules became effective November 27, 2008.

In the sections below, potential Southern RWPF sites are described, and the recommended Southern RWPF site is presented.

6.2. Potential RWPF Sites for Southern System

In previous planning, it was assumed that the Southern System would be supplied from the VCWWTP. However, it may be more economical to construct an RWPF near the Southern

System demands. Using the site selection criteria discussed above, three potential RWPF sites are shown in Figure 6-1.

Site 1

Site 1 is located near the southeast corner of the intersection of I-20 and I-35W. The property is 54.6 acres in size and is mostly undeveloped, with the exception of a gas well in the southwest quadrant. The center of Site 1 is located within about 1,200 feet of sewer main M-275C, which is anticipated to have sufficient flow to support a Southern RWPF.[47] Site 1 is owned by Golden Investments. Surrounding land use includes single-family residential to the east, Alcon Laboratories to the south, I-35W to the west, and sand and gravel mining to the north.

Site 2

Site 2 is located north of I-20 near Carter Park on the north side of the Tarrant County Resource Connection. The property is 39.9 acres in size and is undeveloped. The center of Site 2 is located within about 1,700 feet of sewer main M-275B, which is anticipated to have sufficient flow to support a Southern RWPF.[47] Site 2 is owned by Tarrant County. Adjacent parcels are owned by Tarrant County and the City of Fort Worth. Surrounding land use includes park/open space to the east, north, and west, and the Tarrant County Resource Connection to the south.

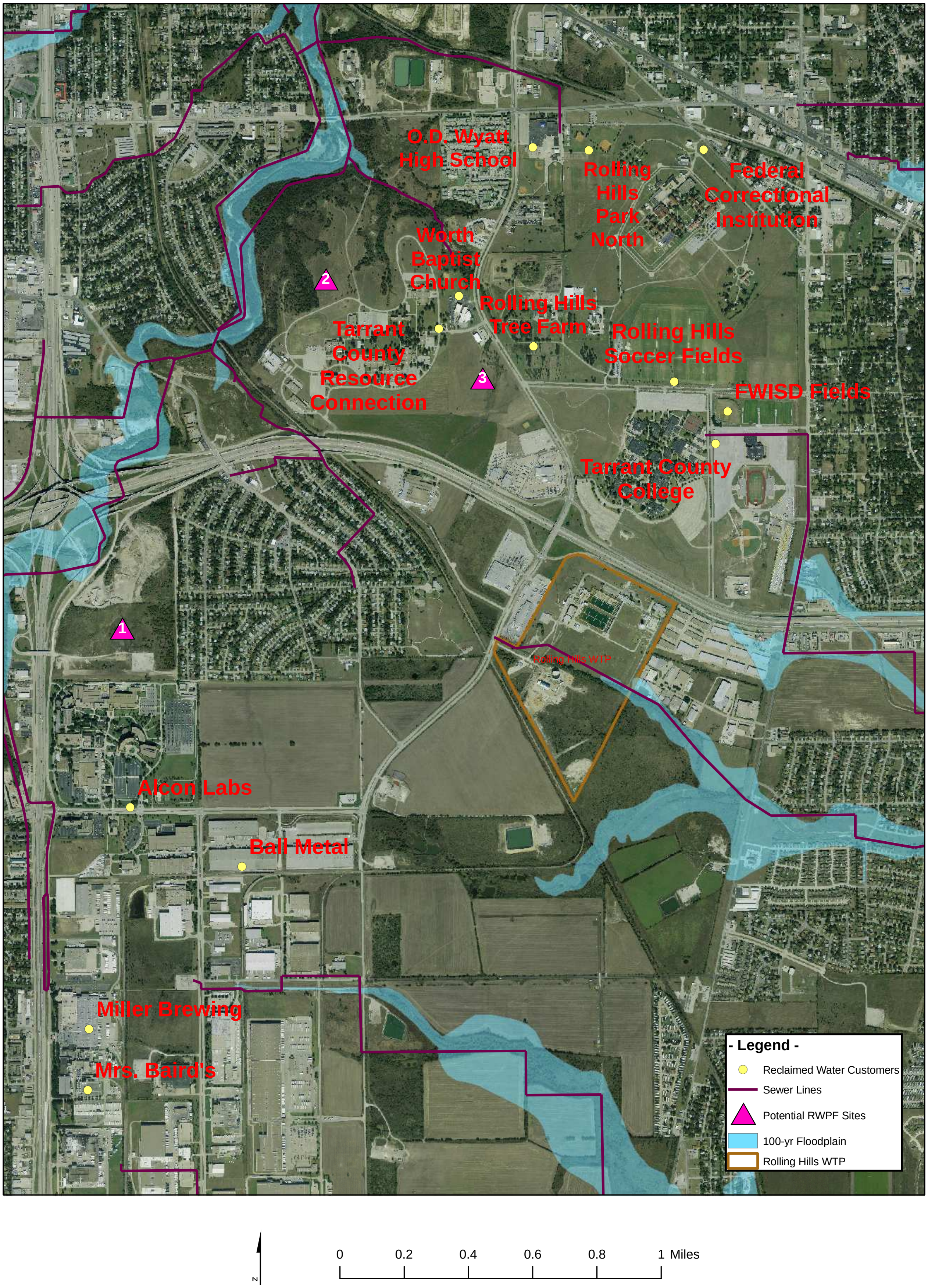
Site 3

Site 3 is located north of I-20, along Campus Drive and south of Circle Drive, on the southeast side of the Tarrant County Resource Connection. The property is 25.469 acres in size and is undeveloped. The center of Site 3 is located within about 5,200 feet of sewer main M-275B,[48] which is anticipated to have sufficient flow to support a Southern RWPF.[47] Site 3 is owned by Tarrant County. The ownership and land use for adjacent parcels are listed below:

[47] Fort Worth's calibrated dry-weather flow under 2000 conditions indicates the following flows in the sewer interceptors: approximately 6.8 mgd near Site 1 and approximately 7.3 mgd near Sites 2 and 3. Since the contributing population has grown significantly since 2000, existing dry-weather flows are expected to be greater.

[48] Assuming that the wastewater diversion pipeline would follow Circle Drive.

Figure 6-1
Potential Southern RWPF Sites



- Tarrant County owns the parcels to the west and to the southeast of the site. These parcels are undeveloped. Beyond the west parcel is the Tarrant County Resource Connection.
- Tarrant Appraisal District records list “Marbur Dev-Museum Dist” as the owner of a parcel on the north side of the site (5000 Campus Drive). This property contains the Tarrant County Campus Dialysis center.
- Worth Baptist Church owns another parcel to the north of the site. This parcel is used for church and athletic activities.
- The City of Fort Worth owns the parcel to the east (across Campus Drive). Fort Worth operates the Rolling Hills Tree Farm on this parcel.
- Tarrant Appraisal District records show that the remaining parcels to the east and south of the site are owned by Fossil Creek Realty, Inc.; Moorman Meador Estate; and D & K Family. The majority of this area is undeveloped, but there are parking lots covering the southern portions of two parcels. Two automobile dealerships and Interstate Highway 20 are located further to the south.

6.3. Recommended Site for Southern RWPF

Site 3 is the recommended site for the Southern RWPF. Reasons to favor this site over the other potential sites include the following:

- Proximity to reclaimed water demands allows a less expensive conveyance system with lower pump horsepower requirements and shorter and smaller pipelines.
- Gentler topography than other sites.
- Not located adjacent to parks or residences.
- Proximity to major roads better suited for a truck filling station to accommodate demand for reclaimed water for gas well drilling.

However, for some of the same reasons, this land will likely be more expensive to acquire than the other sites.[49]

[49] Tarrant Appraisal District data indicate that the appraised value of Site1 is $8,712 per acre, the appaised value of Site 2 is $10,000 per acre, and the appraised value of Site 3 is $32,670 per acre.

7. Conceptual Design of a Reclaimed Water Production Facility

In this chapter, reclaimed water quality requirements, advanced treatment technologies, and a conceptual design for the Southern RWPF are discussed and presented.

7.1. Guidance

The water quality required for each potential reclaimed water use should be identified, using site-specific information where it is available. The available reclaimed water quality should be compared to the water quality requirements to determine whether additional polishing treatment is necessary. In addition, advanced wastewater treatment technologies that minimize the required treatment footprint and produce the required water quality should be considered for new RWPFs. Finally, conceptual designs should be developed for WWTP/RWPF improvements or for new RWPFs based on the projected reclaimed water demands and quality requirements.

For the Fort Worth direct reuse project, reclaimed water quality requirements are described, existing wastewater treatment processes are identified, potential advanced treatment technologies for an RWPF are discussed, and a conceptual design for the Southern RWPF is presented in the following sections.

7.2. Reclaimed Water Quality Requirements

Texas Administrative Code Title 30, Chapter 210 requires limits on turbidity, fecal coliforms, and BOD for Type I and Type II reclaimed water, respectively (Table 2-1). Each potential reclaimed water demand has been classified as Type I or Type II (Tables 5-2 and 5-3). It has been assumed that reclaimed water users with site-specific water quality requirements will be responsible for on-site polishing treatment of the reclaimed water prior to use.

7.3. Description of Existing Wastewater Treatment Processes

The VCWWTP currently employs conventional liquids treatment processes consisting of screening, primary clarification, biological treatment, final clarification, filtration, and disinfection. Unless otherwise noted, it is anticipated that future reclaimed water quality from the

VCWWTP will be similar to recent reclaimed water quality. Recent reclaimed water quality is discussed in Section 4.3.

Current treatment processes consistently meet Type I requirements. The turbidity is generally an order of magnitude lower than required, and the CBOD stays well below the 5 mg/l limit. However, as flows increase toward the design capacity, some additional treatment facilities (such as additional filters) may be required to sustain Type I effluent quality.

7.4. Advanced Treatment Technologies for an RWPF

Selection of treatment technologies for an RWPF must consider aesthetics, reclaimed water quality requirements, space requirements, life-cycle costs, potential for odor, and operation and maintenance issues. Advanced treatment technologies that should be considered for oxidation and clarification at an RWPF include: biological aerated filters, integrated fixed-film activated sludge systems, moving bed biofilm reactors, sequencing batch reactors, and membrane bioreactors. Disinfection through ultraviolet light should also be considered. A summary of these processes and the conventional facilities that they enhance or replace is shown in Table 7-1, and a summary of the treatment efficiencies relative to conventional facilities is shown in Table 7-2.

Oxidation and Clarification

Each advanced oxidation and/or clarification process is discussed in detail below.

Biological Aerated Filters (BAF)

Biological aerated filters are attached-growth processes that can remove suspended solids and organics with high efficiency. Nitrification, denitrification, and phosphate removal are also possible with such systems. They combine aerobic biological treatment and biomass solids separation by depth filtration. Biological aerated filters have a smaller footprint than for conventional aeration basins and do not require a secondary clarifier. They also have low operating costs, convenient operation, and are resistant to shock loadings. The main disadvantages include a more complex instrumentation and controls system and a higher capital cost than activated sludge treatment.

Table 7-1
Installation of Advanced Treatment Technologies With Respect to Conventional Facilities

Technology	Technology Installed by Insertion into Conventional Facilities			Technology Replaces Conventional Facilities		
	Aeration Basins	Secondary Clarifiers	Disinfection	Aeration Basins	Secondary Clarifiers	Disinfection
Biological Aerated Filters				X	X	
Integrated Fixed-Film Activated Sludge Systems	X					
Moving Bed Biofilm Reactor	X					
Sequencing Batch Reactors				X	X	
Membrane Bioreactors					X	
Ultraviolet Light						X

Table 7-2
Treatment Efficiency[a] of Advanced Wastewater Treatment Technologies Relative to Conventional Technology

Process	BAF[b]	IFAS[b]	MBBR[b]	SBR[b]	MBR[b]	UV[c]
Oxidation and Clarification	greater	greater	greater	greater	greater	n/a
Denitrification	greater	greater	greater	greater	same	n/a
Phosphorus Removal	same or greater	same or greater	same or greater	same or greater	same or greater	n/a
Organics Removal	same or greater	same or greater	same or greater	same or greater	same or greater	n/a
Disinfection	n/a	n/a	n/a	n/a	n/a	same

[a] A process has "greater" efficiency if it can provide the same level of treatment with a smaller footprint. For some processes, the relative efficiency depends on the design; such cases are denoted "same or greater."
[b] Compared to aeration basins followed by clarifiers.
[c] Compared to chlorination.

Integrated Fixed-Film Activated Sludge Systems (IFAS)

This process incorporates a fixed-film system into the conventional activated sludge process. The fixed-film is placed in the aerobic zone of an aeration basin, providing a large surface area for microorganism growth. The IFAS system results in additional biomass, increasing the treatment capacity for a given aeration basin size. Volumetric nitrification rates can be improved by these systems, and denitrification is also possible. The capital cost for aeration basins with IFAS is typically 20 to 25 percent greater than for aeration basins alone, and the operating costs are similar to those for conventional treatment. Finally, aeration basins with IFAS media are more resistant to shock loadings.

Types of fixed-film media include structured sheet or knitted fabric. Free-floating media retained by screens in the aerobic zone, such as sponge cubes and other types of plastic sections, are also used. Designs for IFAS systems are largely empirical due to a limited understanding of the complex issues related to the biofilm.

Moving Bed Biofilm Reactor (MBBR)

Like the IFAS process, the Moving Bed Biofilm Reactor process is based on the aerobic biofilm principle. Small polyethylene cylinders are added to an aeration basin to promote biofilm growth. The MBBR process is similar to an IFAS system, but there is no return activated sludge. Instead, all of the microbiological treatment takes place in the biofilm. The MBBR process results in additional biomass, increasing the treatment capacity for a given aeration basin size. The capital cost for aeration basins with MBBR is typically 20 to 25 percent greater than for aeration basins alone, and the operating costs are similar to those for conventional treatment.

Sequencing Batch Reactors (SBRs)

Sequencing batch reactors are activated sludge processes that have multiple processes occurring in a single basin in a batch process. Wastewater is added to a batch reactor, and the processes of equalization, aeration and mixing, and settling take place for a given time. At the end of the time period, the treated supernatant is decanted from the reactor and conveyed to the filtration and/or disinfection processes. SBRs have a smaller footprint than conventional treatment facilities. In addition to oxidation and nitrification, SBRs can be used for denitrification and phosphorus removal by modifying the length of the aeration cycle. Should regulations change to include nutrient limits, SBRs would be a feasible treatment technology. The capital cost for SBRs is similar to the capital cost for comparable conventional facilities, and operating costs are similar to those for conventional treatment. However, SBRs require a sophisticated instrumentation and controls system.

Membrane Bioreactors (MBRs)

MBRs can achieve advanced organic and suspended solids removal rates via a combination of membrane filtration and biological activated sludge processes. Their ability to fit well into small sites makes them an excellent treatment choice for RWPFs. Enhanced nutrient removal is also possible. Compared to conventional treatment facilities, the MBR process allows for smaller aeration basins and replaces secondary clarifiers. The absence of a clarifier results in high mixed liquor concentrations (between 8,000 to 15,000 mg/l). MBRs have higher solids retention times than conventional facilities and produce less sludge.

Wastewater flows into grit removal and screening chambers before the biological process. A mesh screen (1 to 3 mm) removes debris. An aerated basin maintains the solids in suspension and provides oxygen for the microorganisms. If denitrification is necessary, an anoxic zone can be created within the basin. Biomass is retained by submerged membranes with flat-sheet or hollow fiber configurations. Also, breakdown of a wider range of carbon sources is possible, as many enzymes and soluble oxidants are retained by the membranes, making for a more active biological mix. A return activated sludge line recycles concentrated mixed liquor back to the aeration basin.

The MBR process produces a high quality effluent suitable for reclaimed water applications with biochemical oxygen demands (BOD) and total suspended solids concentrations less than 2 mg/l. Easy automation, reduced odor generation, and reduced susceptibility to upsets due to flow variations are some of the other benefits of using MBRs.

The main disadvantage is the relatively high cost of an MBR unit. Aeration increases the energy costs, and membranes are susceptible to fouling, which may require cleaning. Skilled personnel are often required for operation and maintenance. Currently, there is no standard configuration; all manufacturers have a proprietary design.

Disinfection

A disinfection unit must succeed each of the advanced oxidation and clarification technologies discussed in the previous section. Ultraviolet light (UV) is an advanced disinfection technology that can be used in place of chlorination. A small chlorine system would be necessary to maintain a chlorine residual in the reclaimed water.

Advantages of UV disinfection over chlorination include a smaller footprint, minimization of disinfection by-products, and reduced chlorine storage or delivery frequency. However, a UV disinfection system is more costly to install and operate.

The advantages and disadvantages of the advanced wastewater treatment technologies discussed in this section are summarized in Table 7-3.

Table 7-3
Advantages and Disadvantages of Advanced Wastewater Treatment Technologies

Advanced Treatment Technology	Advantages	Disadvantages
Biological Aerated Filter (BAF)	• Small footprint • No secondary clarifier required • Shock-load resistance • Nitrogen and phosphorus removal possible • Low operating costs	• More complex instrumentation and control • Higher capital costs than conventional activated sludge process • Mainly used for industrial processes

Table 7-3 (Continued)
Advantages and Disadvantages of Advanced Wastewater Treatment Technologies

Advanced Treatment Technology	Advantages	Disadvantages
Integrated Fixed-Film Activated Sludge System (IFAS)	• Increased treatment capacity due to additional biomass • Can achieve higher organic loadings with smaller basin volumes • Shock-load resistance • Longer sludge age results in improved nitrification rates • Denitrification possible • Decreased clarifier solids loading	• Empirical design due to limited understanding of complex issues related to the biofilm • Media can become clogged due to biomass overgrowth • Fixed media can impede proper mixing in the basin • 20 to 25 percent greater capital costs for aeration basins
Moving Bed Biofilm Reactor (MBBR)	• Increased treatment capacity due to additional biomass • Can achieve higher organic loadings with smaller basin volumes • Shock-load resistance • Longer sludge age results in improved nitrification rates • No sludge return	• Empirical design due to limited understanding of complex issues related to the biofilm • Media can become clogged due to biomass overgrowth • Mainly used for industrial processes • 20 to 25 percent greater capital costs for aeration basins
Sequencing Batch Reactor (SBR)	• Oxidation and clarification processes take place in a single reactor • Can be used for denitrification and phosphorus removal • Smaller footprint • Process flexibility to control filamentous bulking	• Sophisticated instrumentation and controls • Requires a high level of operator training, process efficiency dependant on operation • Shock-load resistance

Table 7-3 (Continued)
Advantages and Disadvantages of Advanced Wastewater Treatment Technologies

Advanced Treatment Technology	Advantages	Disadvantages
Membrane Bioreactor (MBR)	• Combines a bioreactor and microfiltration as one unit process. • Can replace or supplement secondary clarification and effluent filtration. • Achieve higher volumetric loading rates and shorter reactor hydraulic retention times • Longer sludge retention times resulting in less sludge production • Operation at low DO concentrations with potential for simultaneous nitrification-denitrification in long sludge retention time designs • Phosphorus removal • High-quality effluent in terms of low turbidity, bacteria, TSS, and BOD • Small footprint making it very suitable for RWPFs • Less odor generated	• Higher capital and operating costs • Increased energy costs • Membranes are subject to fouling. Maintenance and cleaning of membrane is expensive and time-consuming. • Requires significant pre-treatment to protect the membranes (grit removal, etc.) • Requires skilled personnel for operation and maintenance
UV Disinfection	• Small footprint • Minimization of disinfection by-products • Reduced chlorine storage or delivery frequency	• Chlorine addition necessary to maintain residual in treated water • More costly to install and operate

7.5. Conceptual Design of the Southern RWPF

The treatment facilities recommended for the Southern RWPF include fine screens, membrane bioreactors (MBRs), and ultraviolet (UV) disinfection. MBRs were selected because of their small footprint and low turbidity in the produced reclaimed water. UV disinfection was selected because it has a small footprint, it minimizes disinfection by-products, and it reduces chlorine storage or delivery frequency. Other facilities would include odor control and reclaimed water storage.

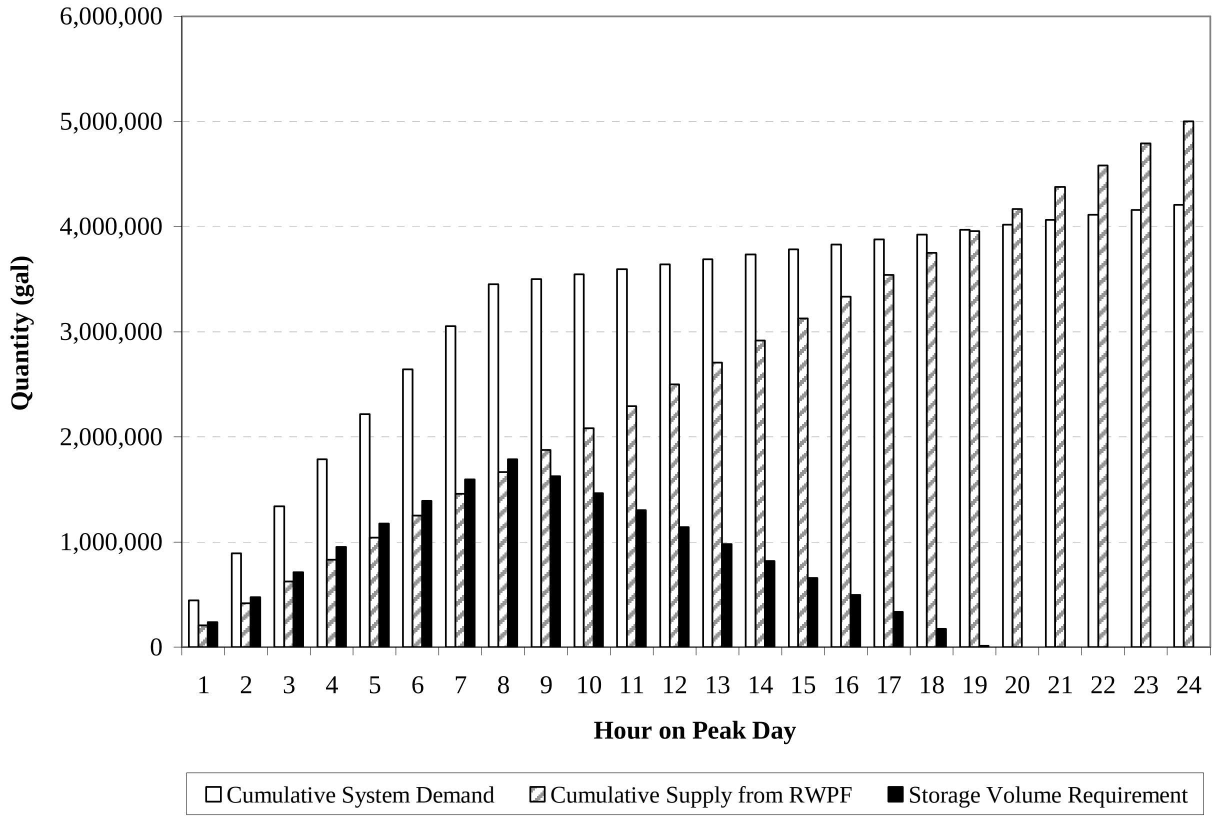
The Southern RWPF would provide a peak-day treatment capacity of 5 MGD and reclaimed water storage of 2 million gallons.[50] This treatment and storage capacity would allow the RWPF to serve the projected peak hour demand of 10.72 MGD (Table 5-3 and Figure 7-1). Based on the projected annual average demand of 1.35 MGD, the Southern RWPF would have a peak day-to-annual average capacity ratio of 3.71. The Southern RWPF is expected to produce Type I reclaimed water.

It is anticipated that the Southern RWPF would require a minimum of 11 acres, assuming a 150-foot buffer zone between the property line and all treatment units.[51] It is advisable to acquire a larger site to allow for expansion and/or to allow for a larger buffer area.

[50] This is a large storage facility. Design and landscaping efforts should be made to reduce the visual impact of the reclaimed water storage.

[51] Texas Administrative Code Title 30, Chapter 321, Subchapter P, effective November 27, 2008.

Figure 7-1
Southern RWPF Storage Requirement



8. Conceptual Design of the Reclaimed Water Conveyance Systems

In this chapter, pipeline routing considerations are discussed, and the conceptual designs for the reclaimed water conveyance systems are presented.

8.1. Guidance

All requirements of a reclaimed water conveyance system should be identified. These requirements may include: WWTP/RWPF location(s), delivery location(s), polishing treatment location(s), phasing of the system to reflect the timing of water needs or water availability, existing easements, availability of additional easements, cost minimization, pumping requirements, reclaimed water blending requirements, and other requirements.

The reclaimed water conveyance system should be designed to meet peak demands, as determined in Chapter 5. Some direct reuses, particularly irrigation, can have relatively low annual demands but relatively high peak hour demands. Where it is cost-effective, storage should be included to reduce system costs and/or increase operational flexibility.

After the requirements for a reclaimed water conveyance system have been identified, conceptual designs for the system should be developed. As discussed in Chapter 9, the conceptual designs for the reclaimed water conveyance system will be used to develop opinions of probable cost for these facilities. For the Fort Worth direct reuse project, the pipeline routing evaluation and the conceptual design of the reclaimed water conveyance system are presented below.

8.2. Pipeline Routing Considerations

The reclaimed water conveyance systems must convey reclaimed water from the VCWWTP to the customers for the Central System and from the Southern RWPF to the customers for the Southern System. To minimize system costs, the selected pipeline routes were as direct as possible and minimize the number of highway and stream crossings.

8.3. *Conceptual Design of Reclaimed Water Conveyance Systems*

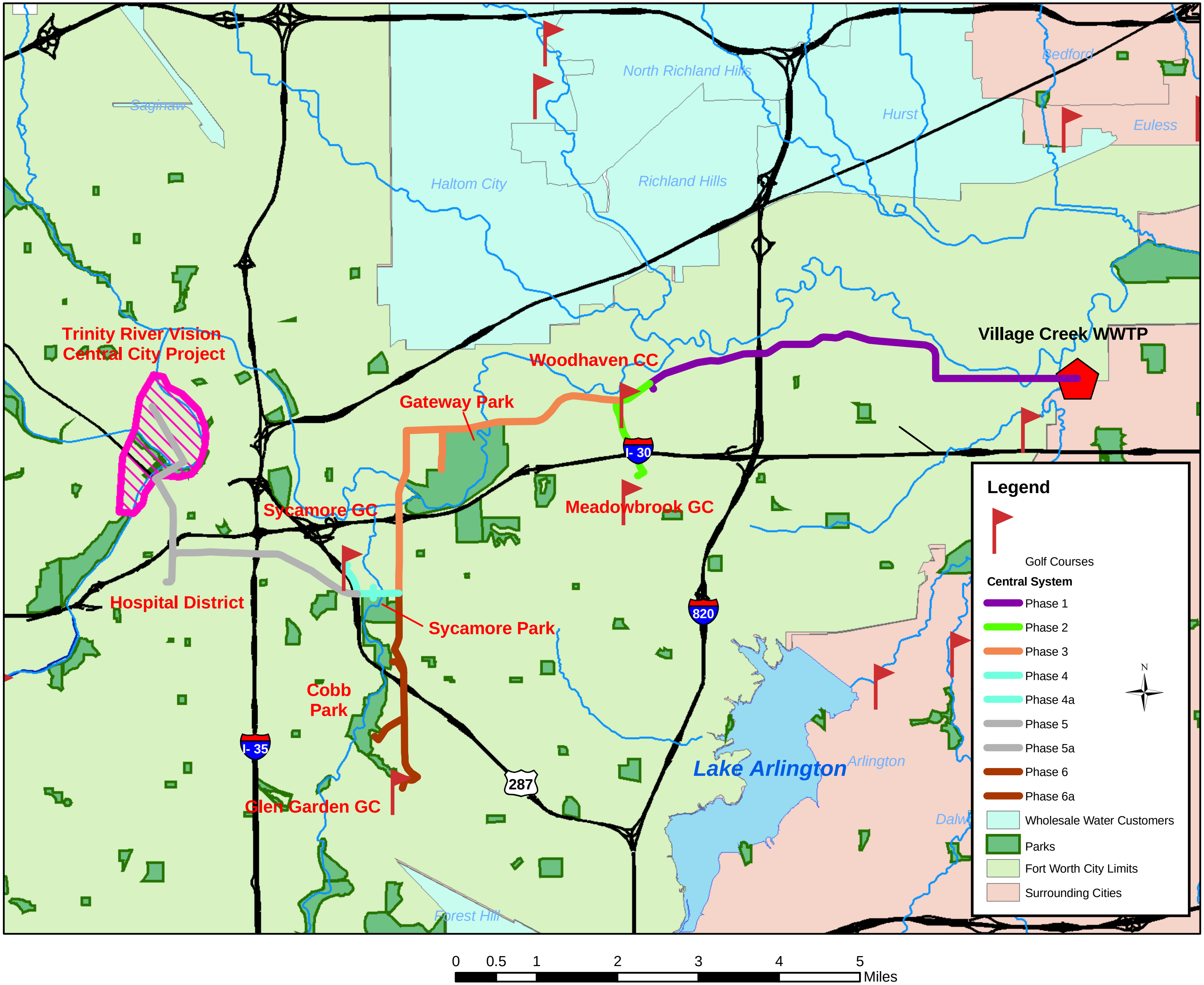
This section describes the planned facilities and proposed project phasing for the Central System and Southern System service areas. Construction to be completed by the City has been separated into phases denoted by a number (i.e. Phase 1, 2, etc.). Pipelines to be constructed by a customer are included as separate phases denoted by a number and character (i.e. Phase 4a, 5a, etc.).

Central System

The main trunk line of the Central System is an 11.1-mile long, 36/30/24-inch diameter transmission main constructed primarily within existing City easements and right-of-way (ROW). The Central System is proposed to be constructed in six phases. Figure 8-1 shows a map of the construction phasing for the Central System Service Area.

- Phase 1 includes a 1,785-hp pump station constructed at the Village Creek WWTP, 5.8 miles of 36-inch transmission main along Randol Mill Road, and a 10-inch pipeline to the Woodhaven Golf Course.
- Phase 2 includes a 0.5-mile long, 30-inch diameter extension of the transmission main along Randol Mill Road, and a 10-inch pipeline to the Meadowbrook Golf Course.
- Phase 3 includes 2.3 miles of 30-inch transmission main, 2.5 miles of 24-inch transmission main along 1st Street and Beach/Mitchell Street, and a 16-inch pipeline to provide reclaimed water to Gateway Park.
- Phase 4 includes a 0.5-mile long, 18-inch transmission main along Vickery Blvd.
    - Phase 4A includes 8-inch pipelines, to be constructed by others, to distribute reclaimed water to Sycamore Park and the Sycamore Golf Course.
- Phase 5 includes construction of a 2.4-mile long, 16-inch transmission main along Vickery Blvd, and a 2.3-mile long, 16-inch pipeline along Henderson Street and Main Street to provide reclaimed water to the Trinity River Vision project corridor. A 2-MG ground storage tank and 7.5-MGD booster pump station will be constructed at the Trinity River Vision project location. Construction of a ground storage tank will allow for a decreased pumping and pipeline capacity from VCWWTP. The savings in reduced pipeline and pumping costs was determined to more than compensate for the additional cost of a ground storage tank and booster pump station.

Figure 8-1
Central Reclaimed Water Conveyance System



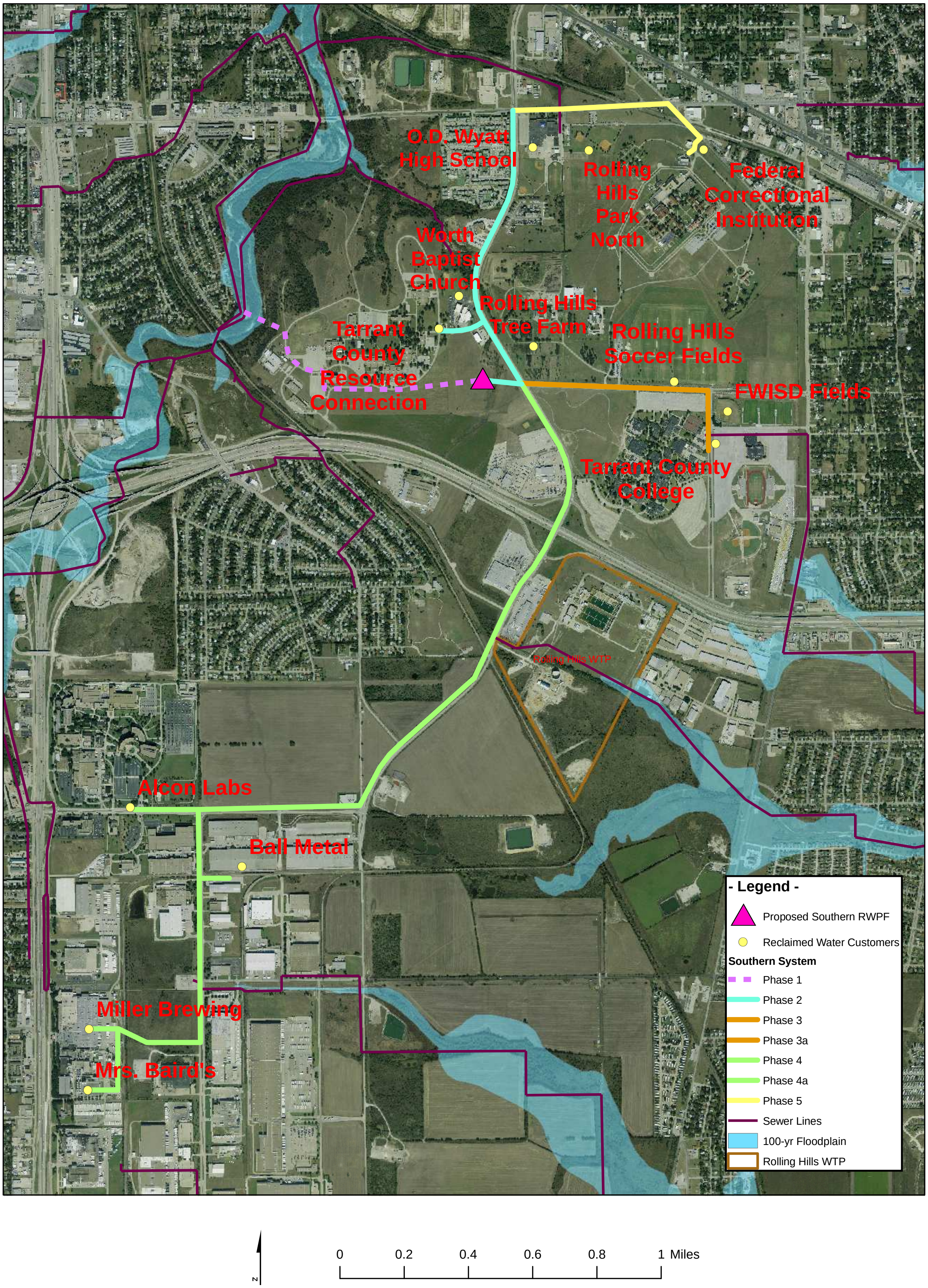
    - Phase 5A, to be constructed by Harris Methodist Hospital, is a 6-inch pipeline from the Phase 5 pipeline to the Harris Methodist Hospital on Pennsylvania Road.
- Phase 6 includes a 16-inch pipeline to Cobb Park along Berry Street.
    - Phase 6A, to be constructed by the Glen Garden Golf Course, includes a 6-inch pipeline to supply reclaimed water to the Glen Garden Golf Course.

Southern System

The Southern System is proposed to be constructed in five phases. Figure 8-2 shows a map of the construction phasing for the Southern System Service Area.

- Phase 1 includes a 105-hp pump station and 0.9 miles of 16-inch diameter force main to convey wastewater from interceptor M275B to the RWPF; a 5-MGD RWPF located along Campus Drive south of Circle Drive (Site 3); 2 million gallons of reclaimed water storage; a 604-hp pump station to supply the reclaimed water conveyance system; and a truck filling station to accommodate demand for reclaimed water for gas well drilling.
- Phase 2 includes 0.1 miles of 30-inch diameter transmission main proceeding east from the RWPF to Campus Drive, 0.9 miles of 10-inch diameter transmission main proceeding north on Campus Drive, and 0.3 miles of 6-inch diameter transmission main to serve the Tarrant County Resource Connection. Phase 2 will also serve O.D. Wyatt High School, Worth Baptist Church, and Rolling Hills Tree Farm.
- Phase 3 includes 0.5 miles of 18-inch diameter transmission main proceeding east along Joe B. Rushing Road to serve the Rolling Hills Park soccer fields.
    - Phase 3A, to be constructed by Tarrant County College and the Fort Worth Independent School District (FWISD), includes an 8-inch pipeline along C. A. Robertson Boulevard to supply Tarrant County College and FWISD athletic fields.
- Phase 4 includes 2.1 miles of 16-inch transmission main and 0.2 miles of 14-inch transmission main south along Campus Drive to Alcon Laboratories.
    - Phase 4A, to be constructed by others, includes 6-inch pipelines to supply reclaimed water to Ball Metal Container Corporation, Miller Brewery, and Mrs. Baird’s Bakery.

Figure 8-2
Southern Reclaimed Water Conveyance System



- Phase 5 includes 0.5 miles of 8-inch and 0.2 miles of 6-inch diameter transmission main proceeding east along East Seminary Drive to serve the Rolling Hills Park North Fields and the Federal Correction Institution.

9. Costs and Benefits

This chapter presents a summary of probable construction and operation and maintenance costs for each system and an evaluation of potential benefits of the reclaimed water systems.

9.1. Guidance

To assess the feasibility of a potential direct reuse project, project costs and benefits should be considered. Opinions of probable capital, annual, and unit costs should be developed for the conceptual treatment and reclaimed water conveyance system designs discussed in Chapters 7 and 8. The costs that are included and excluded should be stated, the assumptions used in developing the costs should be stated, detailed opinions of cost should be presented, and a basis for comparing costs for different alternatives should be established.

Additional costs and benefits that can be evaluated include:

- Deferral of capital costs
  - Water system capacity expansion,
  - Wastewater system capacity expansion, and
  - Raw water supplies.
- Avoidance of operating expenses
  - Purchase of treated water
  - Purchase of raw water
  - Water treatment expenses
- Loss of revenue from potable water sales

The value of deferring capital costs can be estimated as the present value of the difference in debt service payments with and without deferral. The value of avoided operating expenses can be estimated as a unit cost multiplied by all or part of the projected reclaimed water demand, as appropriate.

Opinions of probable costs and benefits are described below for the Fort Worth direct reuse project.

9.2. Opinions of Probable Cost

Opinions of probable cost for the Central and Southern Systems are presented in Appendix A and summarized in Table 9-1. These costs were developed using the same assumptions that were used in the 2007 *Reclaimed Water Priority and Implementation Plan*,[52] except that costs were updated from fourth quarter 2006 dollars to second quarter 2007 dollars using the Engineering News Record (ENR) Construction Cost Index (CCI).[53] Updated cost tables are presented in Appendix B.

The values shown in Table 9-1 reflect the estimated cost to construct and operate each project to serve the projected demands defined in Chapter 5. No operational cost for wastewater treatment was included for the Central System. This cost was attributed to the wastewater system since this treatment would have to occur regardless of whether a reclaimed water system is developed. In addition, the cost of constructing a truck filling station at the Southern RWPF to supply gas well drilling demands was not included in Table 9-1.

The Central System is similar to Alternative C1 in the 2007 *Reclaimed Water Priority and Implementation Plan*,[52] except that it would provide cooling tower makeup water in the Central Business District, would serve additional demands in Gateway Park, and would serve the Glen Garden Golf Course (Table 5-2). Although the capital cost for the Central System is slightly greater than for Alternative C1, the annual average demand is much greater, resulting in a weighted unit cost that is approximately 33 percent lower.

The Southern System is similar to Alternative S1 in the 2007 *Reclaimed Water Priority and Implementation Plan*,[52] except that it does not serve Cobb Park or Glen Garden Golf Course and does serve several additional customers in the vicinity of the RWPF (Table 5-3). Although the capital cost for the Southern System is greater than for Alternative S1, the annual average demand is also greater, resulting in a weighted unit cost that is slightly lower.

---

[52] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

[53] The December 2006 ENR CCI was 7888, and the June 2007 ENR CCI was 7939, a 0.6 percent increase.

Table 9-1
Opinions of Probable Cost for Central and Southern Systems

System	Annual Average Demand (MGD)	Peak System Demand (MGD)	Capital Cost ($MM)	Debt Service[a] ($/yr)	Pipe and Pump Station Maintenance ($/yr)	Reclaimed Water Production Facility O&M ($/yr)	Energy ($/yr)	Unit Cost – First 20 Years ($/1,000 gal)	Unit Cost – After 20 Years ($/1,000 gal)	Weighted Unit Cost[b] ($/1,000 gal)
Central	1.93	16.25	$32.81	$2,746,000	$312,000	$0	$98,000	$4.48	$0.58	$2.14
Southern	1.35	11.15	$29.11	$2,435,000	$167,000	$208,000	$45,000	$5.80	$0.85	$2.83
TOTAL	3.28	27.40	$61.92	$5,181,000	$479,000	$208,000	$143,000	$5.02	$0.69	$2.42

[a]Assumes a capital recovery period of 20 years and an annual interest rate of 5.5 percent.
[b]Weighted unit cost is the average unit cost over 50 years

9.3. *Indirect Benefits and Costs*

As new water resources become more costly and difficult to obtain, the benefits of using reclaimed water are becoming widely recognized by cities and utilities around the world. Although negative public perception of reclaimed water use can sometimes hinder or delay efforts to implement reclaimed water programs, these perceptions are often alleviated with public education and information programs that emphasize safety and the benefits of reclaimed water use to the community. The following sections describe some of the potential benefits to the City of Fort Worth and its current and future water supply requirements. The monetary value of these benefits was not estimated.

Reduction of Potable Water Demand

A leading driver for the implementation of reuse projects is the reduction of potable water demand. Potable water can be replaced by reuse water for irrigation of crops, parks, golf courses, and other green spaces. This is particularly relevant in states such as Texas, when summer usage can be significantly greater than that of winter consumption due to irrigation demands. Water reuse has also been identified as a Best Management Practice for water conservation by the Water Conservation Implementation Task Force established by the 78th Texas Legislature. Reducing the potable water demand would help the City conserve its potable water supply, defer expansion of water treatment plants, and defer expansion of the water distribution system. These topics are discussed in the next sections.

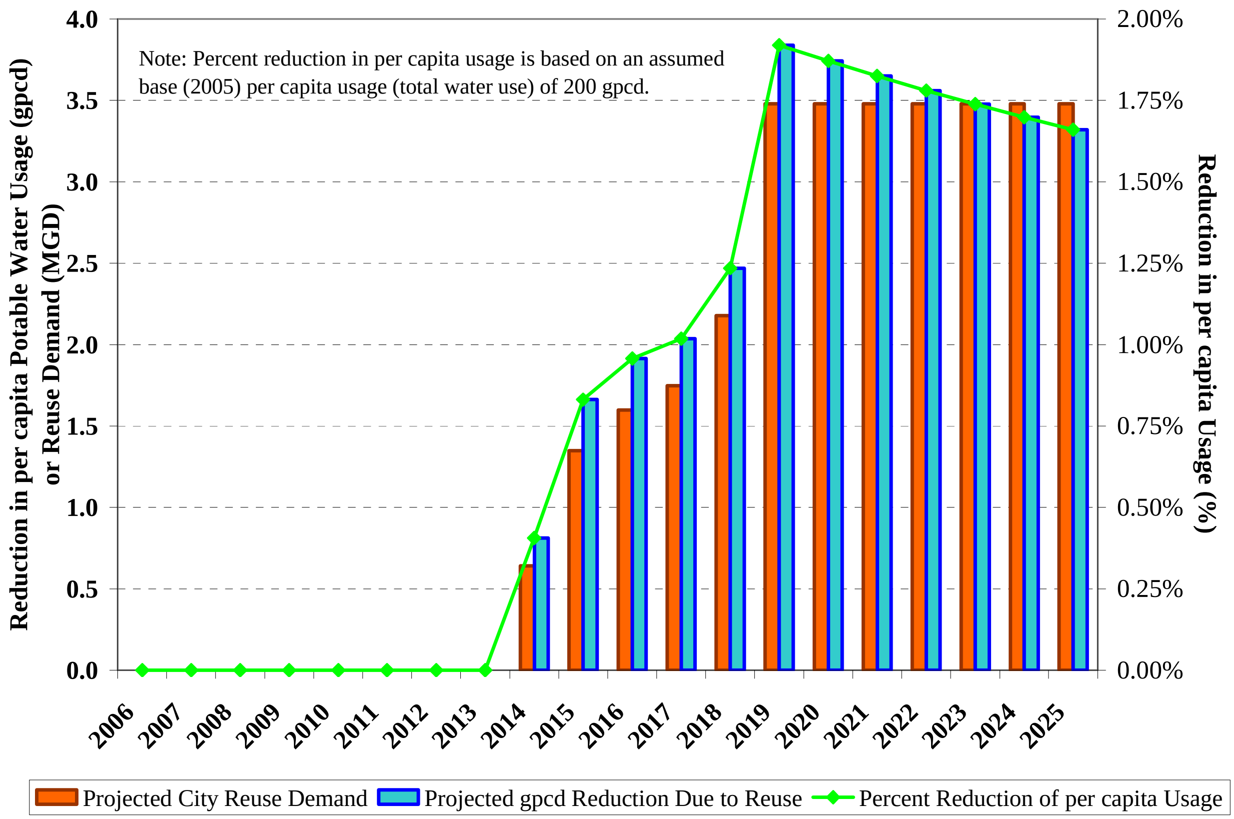
Reduced Per Capita Potable Water Use

Reduction of potable water demand is critical to acquiring permits for future water supplies, particularly those that would require an interbasin transfer. To obtain interbasin transfer authorization, applicants must demonstrate that they have "developed and implemented a water conservation plan that will result in the highest practicable levels of water conservation and efficiency achievable within the jurisdiction of the applicant."[54] Implementation of the reclaimed water system would demonstrate the City's commitment to efficient use of its water resources

[54] Texas Administrative Code, Title 30, Chapter 297.18(d)(2).

and could put the City and/or its raw water supplier, Tarrant Regional Water District (TRWD), in a position to obtain grants or low-interest-rate funding from the TWDB. Therefore, in addition to other water conservation efforts, development of a water reuse program will provide for efficient use of the City's water resources and will assist the TRWD in securing necessary future water supplies to meet anticipated growth within the City of Fort Worth and surrounding areas. Figure 9-1 shows projections of the per capita reduction in potable demand (3 to 4 gallons per capita per day after full implementation) that would result from development of Central and Southern Systems.

Figure 9-1
Projected Reduction in Per Capita Potable Water Usage Due to Reuse



Deferral of Potable Water Treatment Capacity Expansion

The reduction in potable water demand has implications for the potential improvements needed at Fort Worth water treatment plants. The North Holly Water Treatment Plant (WTP) has no space for further expansion and space at the South Holly WTP is limited. The 2005 Water

Master Plan predicts that several expansion projects or new facilities will be needed in the next two decades.

Figure 9-2 shows projected potable water demand by pressure plane through the planning year 2025. The required water treatment capacity of Fort Worth WTPs, as determined by the 2005 Water Master Plan (MP), is denoted by the red line; the capacity needed after implementation of the Central and Southern Systems is shown in gray. As can be seen, there is a difference between the capacity required with and without the reclaimed water system. Some of the required capacity expansions can be delayed by approximately two years. It was assumed that all reclaimed water supplied to meet the demands in Tables 5-2 and 5-3 would replace potable water supplied from Fort Worth WTPs, with the exception of gas well drilling demands.

Deferral of WTP improvements results in deferral of costs that would otherwise be incurred by the City of Fort Worth. Based on costs presented in the *2005 Fort Worth Water Master Plan*, the benefit to the City of deferring the WTP improvements identified above was determined to be approximately $4.14 million in 2007 dollars. Details of this benefit calculation are provided in Appendix C.

Deferral of Potable Water Distribution Capacity Expansion

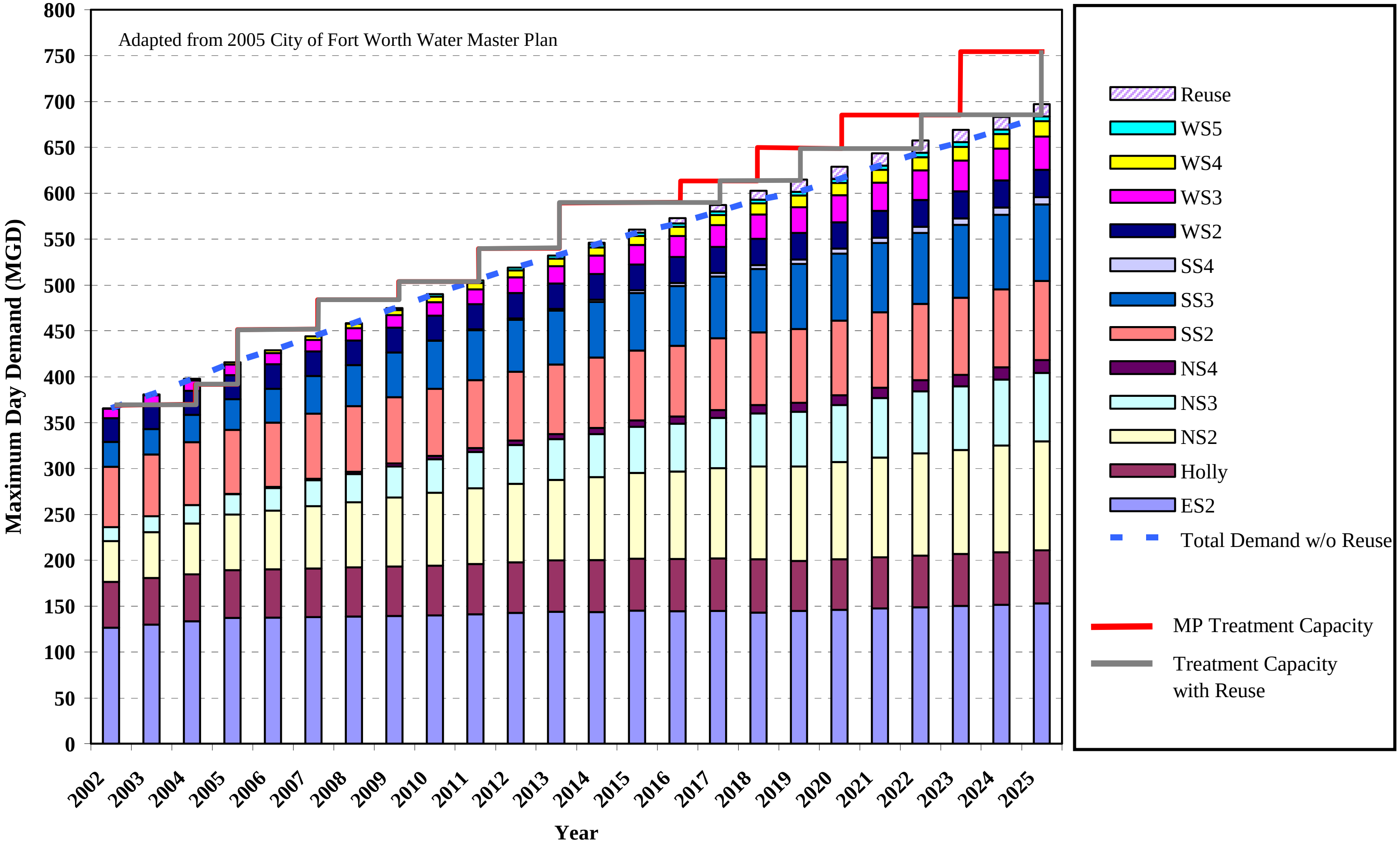
Additionally, improvements needed for potable water storage and pumping facilities, piping, and other water distribution system facilities benefit from a reduced potable demand, particularly when this demand is reduced during peak usage periods. Due to the difficulty of identifying specific facility deferrals within the water distribution system, and their relatively low anticipated value, no quantitative evaluation of deferring these facilities was performed.

Deferral of Wastewater System Capacity Expansion

It has been assumed throughout this document that the Southern RWPF would be permitted under the new Reclaimed Water Production Facility rules.[55] Since these rules do not permit a discharge of treated effluent from the RWPF and allow operation of the RWPF only when there

[55] Texas Administrative Code Title 30, Chapter 321, Subchapter P, effective November 27, 2008.

Figure 9-2
City of Fort Worth Projected Water Treatment Needs With and Without Reuse Projects



is a demand for reclaimed water, downstream wastewater facilities must be designed to convey and treat the full wastewater flow. Therefore, no deferral of wastewater system capacity expansion is projected due to the Southern RWPF.

However, if Fort Worth were to obtain a TPDES discharge permit for the Southern RWPF, some deferral of wastewater system capacity expansion may be possible.

Deferral of Additional Raw Water Supply

In addition to replacing potable water demands with reclaimed water, reuse projects can defer the need for new raw water supplies. The *2006 Region C Water Plan* projects that Fort Worth will obtain additional raw water from TRWD and that TRWD will obtain additional water with the water management strategies shown in Table 9-2. Deferral of these raw water supply strategies would reduce costs for TRWD as a whole and also benefit Fort Worth indirectly.

Table 9-2
Projected Future TRWD Capital Costs for Additional Raw Water Supply

Strategy	Development Dates	Quantity for TRWD (ac-ft/yr)	TRWD Share of the Capital Cost ($MM)
Third East Texas Pipeline and Reuse	2010, 2018	188,765	$626.35
Marvin Nichols Reservoir	2030, 2050	280,000	$1,482.17
Toledo Bend Reservoir	2050, after 2060	200,000	$1,035.19
Oklahoma Water	2060	50,000	$287.35

However, the Fort Worth Central and Southern Systems are projected to provide relatively small amounts of water (approximately 3,677 ac-ft/yr) compared to the strategies in Table 9-2. Therefore, it appears unlikely that any of these large projects, many of which would be developed in partnership with other regional water providers, would be delayed based on implementation of the Fort Worth Central and Southern reuse projects, and no estimates of the benefit of deferral of additional raw water supply are presented.

Other Benefits

Other benefits include the expanded availability of reclaimed water, the dependability of the reclaimed water supply, and reduction of loads to receiving streams. These benefits are discussed in the following sections.

Expanded Availability of Reclaimed Water

The proposed Central and Southern Systems would establish reclaimed water infrastructure that could make reclaimed water available and attractive to new customers that have not been considered in this analysis. Sales of additional reclaimed water to new customers would help defray the system cost and result in additional potable water savings. In addition, the Central and Southern Systems would establish multiple public examples of irrigation with reclaimed water and other reuse applications. This could raise the profile of direct reuse, provide public education opportunities, and attract new customers.

Dependable Supply

Reuse water provides a new water supply source that should be compared on an equal basis to other potential surface and groundwater sources, including new reservoirs. As a water supply source, reclaimed water is particularly attractive because the supply is relatively consistent, even during periods of drought, and actually increases as population increases.

Reduction of Load to Receiving Streams

Direct reuse projects reduce loads of BOD and other constituents to receiving streams. In addition, the reduction in load is likely to be greatest during dry weather when irrigation demands are high, flow in the receiving stream is low, and the assimilative capacity of the stream is at its minimum. This load reduction can have permitting implications for dischargers, who may be able to defer future permit requirements that are more stringent. The impact is particularly important in light of the EPA's current effort to begin incorporating nutrient criteria into surface water quality standards. Although the TCEQ is still exploring different strategies for the development of nutrient criteria, it is likely that these criteria will be established within the next several years.

For irrigation uses, elevated nutrient levels are typically desirable and can decrease the amount of required fertilization. Therefore, even with more stringent requirements for receiving streams, it is likely that nutrient reduction would not be necessary for reclaimed water primarily used for irrigation, potentially resulting in reduced treatment costs in the future.

Net Loss of Potable Water Revenue

Since direct reuse projects reduce potable water use, they also reduce revenue from the sale of potable water. The lost revenue would be partially offset by reduced raw water purchase, raw water treatment, and potable water distribution costs. After full implementation of the Central and Southern Systems, the probable net annual loss of potable water revenue is approximately $472,000, based on the following assumptions:

- Potable water rate of $1.80 per 100 cubic feet (ccf) for industrial users.
- Potable water rate of $2.15 per ccf for commercial users.
- Potable water rate of $0.00 per ccf for City usage. It is assumed that payment from one City department to another does not truly represent revenue.
- Rate of $1.00 per ccf to purchase raw water, treat raw water, and distribute treated water.
- Cobb Park and Rolling Hills North not currently irrigated.
- Gas well drillers and Trinity River Vision not currently using potable water.
- Net loss of revenue based on a mix of actual historical use and projected demands.

Summary of Indirect Benefits and Costs

As discussed in the previous section, a number of benefits can be attributed to the development of reclaimed water systems. Many of these benefits do not have a direct monetary value and are difficult to quantify in terms of a cost savings to the City. However, as referenced above, deferral of WTP facility expansions and net loss of potable water revenue are quantifiable and can be included in the cost of the reclaimed water system. Table 9-3 provides a summary of the net opinion of probable cost with these indirect benefits and costs included.

With indirect benefits and costs, the systemwide weighted-average unit cost of the reclaimed water is approximately $2.69 per thousand gallons based on full utilization of the projected demands.

Table 9-3
Opinions of Probable Cost for Central and Southern Systems (With Indirect Benefits and Costs)

System	Annual Average Demand (MGD)	Peak System Demand (MGD)	Capital Cost ($MM)	Avoided Capital Cost[a] ($MM)	Debt Service[b] ($/yr)	Pipe and Pump Station Maintenance ($/yr)	Reclaimed Water Production Facility O&M ($/yr)	Energy ($/yr)	Probable Net Revenue Loss[c] ($/yr)	Unit Cost – First 20 Years ($/1,000 gal)	Unit Cost – After 20 Years ($/1,000 gal)	Weighted Unit Cost[d] ($/1,000 gal)
Central	1.93	16.25	$32.81	$2.76	$2,515,000	$312,000	$0	$98,000	$338,000	$4.63	$1.06	$2.49
Southern	1.35	11.15	$29.11	$1.38	$2,320,000	$167,000	$208,000	$45,000	$119,000	$5.81	$1.10	$2.98
TOTAL	3.28	27.40	$61.92	$4.14	$4,835,000	$479,000	$208,000	$143,000	$457,000	$5.12	$1.08	$2.69

[a] Credit for deferral of WTP expansions. The benefit was distributed on basis of the portion of the annual average reclaimed water demand that otherwise would have been supplied with potable water.

[b] Assumes a capital recovery period of 20 years and an annual interest rate of 5.5 percent.

[c] See Section 9.3 for assumptions.

[d] Weighted unit cost is the average unit cost over 50 years.

10. Permitting Issues

General guidance on permitting issues for direct reuse and a discussion of specific permitting issues for the Fort Worth direct reuse project are presented below.

10.1. Guidance

Permits and authorizations required to implement a direct reuse project may include:

- Chapter 321 reclaimed water production facility authorization,
- Section 404 permit that allows discharge of dredged or fill material into waters of the United States,
- Chapter 210 reuse authorization that allows direct reuse to be incorporated into the project,
- Stormwater discharge permits if construction will disturb more than one acre, and
- Other permits and authorizations.

The reasons for each of these permits and authorizations should be discussed, and any particular difficulties should be identified.

Permits or authorizations that are potentially required for the Fort Worth direct reuse project are discussed below.

10.2. Chapter 321 Reclaimed Water Production Facility Authorization

Fort Worth must obtain a Chapter 321 authorization[56] from the TCEQ to construct an RWPF. To do so, the City must demonstrate that it will meet the general, design, and buffer zone requirements and restrictions that the rules require.

[56] Texas Administrative Code Title 30, Chapter 321.

10.3. Section 404 Permit

Under Section 404 of the Clean Water Act, the U.S. Army Corps of Engineers (USACE) has jurisdiction over discharge of dredged or fill material into waters of the United States. Construction of pipelines and an RWPF for the recommended project will probably require a Section 404 permit from the USACE.

10.4. TPDES Discharge Permit

The City discharges treated wastewater effluent from the Village Creek WWTP (TPDES Permit No. 10494-013) to the West Fork Trinity River. Use of reclaimed water as evaporative makeup water for the Trinity River Vision Project would constitute a second discharge of treated effluent. Therefore, the TPDES discharge permit for the Village Creek WWTP would have to be amended to include the additional discharge location.

Although it has been assumed throughout this document that the Southern RWPF would be permitted according to the TCEQ's RWPF rules (Section 10.2), it may be possible to obtain a TPDES discharge permit for the Southern RWPF. This would add flexibility by allowing the MBR to maintain more consistent operation during low demand periods and could allow flushing of remote lines if two or more outfalls are designated

10.5. Chapter 210 Reuse Authorization

Fort Worth has obtained a Chapter 210[57] reuse authorization from the TCEQ that would allow direct reuse from the Central and Southern Systems. To obtain this authorization, Fort Worth demonstrated that it would meet the general requirements, quality criteria, design, and operational requirements that Chapter 210 requires for direct reuse projects.

[57] Texas Administrative Code Title 30 Chapter 210 "Use of Reclaimed Water."

10.6. Stormwater Discharge Permit

If construction is required over an area greater than one acre, a stormwater permit will be needed from the TCEQ. It is likely that the project would be covered under General Permit No. TXR150000. To obtain this coverage, Fort Worth would need to file a notice of intent to begin construction, prepare pollution prevention plans and materials, and notify TCEQ staff upon completion of construction.

10.7. Miscellaneous Authorizations

There may be other miscellaneous approvals required from the TCEQ before pursuing construction of any facilities. For instance, the City would need to obtain approval for the design of any wastewater treatment facilities contemplated by these options. The wastewater treatment design requirements are located in Title 30 Texas Administrative Code Chapter 217. There may also be permits associated with obtaining rights-of-way for conveyance pipelines. These and other authorizations would need to be fully addressed in the preliminary design report for the project.

10.8. Other Regulatory Issues

As discussed elsewhere in this document, implementation of direct reuse projects could help Fort Worth (or its wholesale supplier) obtain an interbasin transfer authorization for future raw water supplies (Chapter 9.3) and could potentially help defer more stringent future TPDES effluent quality requirements (Chapter 9.3).

In addition, new TCEQ rules (discussed in Chapter 6.1) allow a streamlined authorization process for Reclaimed Water Production Facilities at locations other than the permitted wastewater treatment facility for WWTP owners that have an individual domestic wastewater permit and a Chapter 210 reuse authorization.

11. Selection of Preferred Alternatives

Guidance on selecting the preferred direct reuse alternatives and selection of the preferred alternatives for the Fort Worth direct reuse project are presented below.

11.1. Guidance

From the various direct reuse alternatives that have been evaluated to this point, the preferred alternative(s) should be selected, based on considerations such as:

- Opinions of probable cost,
- Ancillary benefits,
- Anticipated treatment performance,
- Ease of operation and maintenance,
- Probability of public acceptance,
- Implementation timing,
- Legal/institutional considerations,
- Uncertainties (in projected water quality, opinions of probable cost, permitting, etc.), and
- Other considerations.

Selection of the preferred direct reuse alternatives for Fort Worth is discussed below.

11.2. Selection of the Preferred Direct Reuse Alternatives for Fort Worth

The Central and Southern direct reuse alternatives recommended in the *2006 Region C Water Plan* and in the 2007 *Reclaimed Water Priority and Implementation Plan* have been refined and updated as a case study for this document. Based on evaluation of potential customer demands, conceptual designs for treatment and delivery systems, permitting issues, the opinions of probable cost, and the potential benefits, both projects appear to be feasible, and it is recommended that Fort Worth proceed with implementation of the Central and Southern Systems. The City should continue to explore alternative financing approaches, including federal or state grant or loan programs, and participation from customers and/or developers.

The Central and Southern reclaimed water projects would provide significant benefits to the City by reducing per capita potable water usage, helping to achieve water conservation goals, and deferring water and wastewater system facility expansions. Implementation of these reclaimed water systems would demonstrate Fort Worth's commitment to efficient use of its water resources. This commitment is critical to the success of acquiring new water supply sources necessary to support future growth within the City and in other communities within TRWD's service area.

The cost analysis presented in Chapter 9 was based on the projected demands presented in Chapter 5. Experience with other established reclaimed water systems suggests that once facilities are in place, demand for reclaimed water often exceeds projected values. Although the "if we build it, they will come" strategy is not without risk, most reclaimed water systems must, to some extent, rely on uncommitted future demands to justify initial implementation.

12. Implementation Plan

Guidance on developing an implementation plan and the implementation plan for the Fort Worth direct reuse project are discussed below.

12.1. Guidance

The implementation plan should consist of a schedule of actions to be taken and an associated schedule of capital expenditures. Implementation actions should be scheduled in a logical order and should show the critical path and any decision points.

When a direct reuse project includes customers across multiple cities and/or CCNs, there are significant permitting and cost-sharing issues that must be resolved prior to implementation. Consider an example where City A is the reclaimed water producer and the potential users are located in City A and City B. City A would provide reclaimed water to retail customers (within City A) and a wholesale customer (City B). City B would resell the reclaimed water to its retail customers (within City B). In this case, both Cities A and B would have to obtain authorizations for direct reuse of reclaimed water under Chapter 210. In addition, issues such as sharing of capital costs, system ownership, and reclaimed water rates must be resolved.

12.2. Implementation Plan for Fort Worth

Changes in the Central and Southern Systems (*e.g.*, projected demands, pipeline routes, RWPF location, project timing, etc.) have occurred since the implementation plan presented in Fort Worth's *Reclaimed Water Priority and Implementation Plan*.[58] The plan was quite detailed, and many of the elements of the plan remain unchanged by the results of this study, particularly administrative, testing, permitting, and marketing actions. For such matters, the plan remains unamended. Only the elements of the implementation plan that specifically concern the Central and Southern Systems are revised in this section.

---

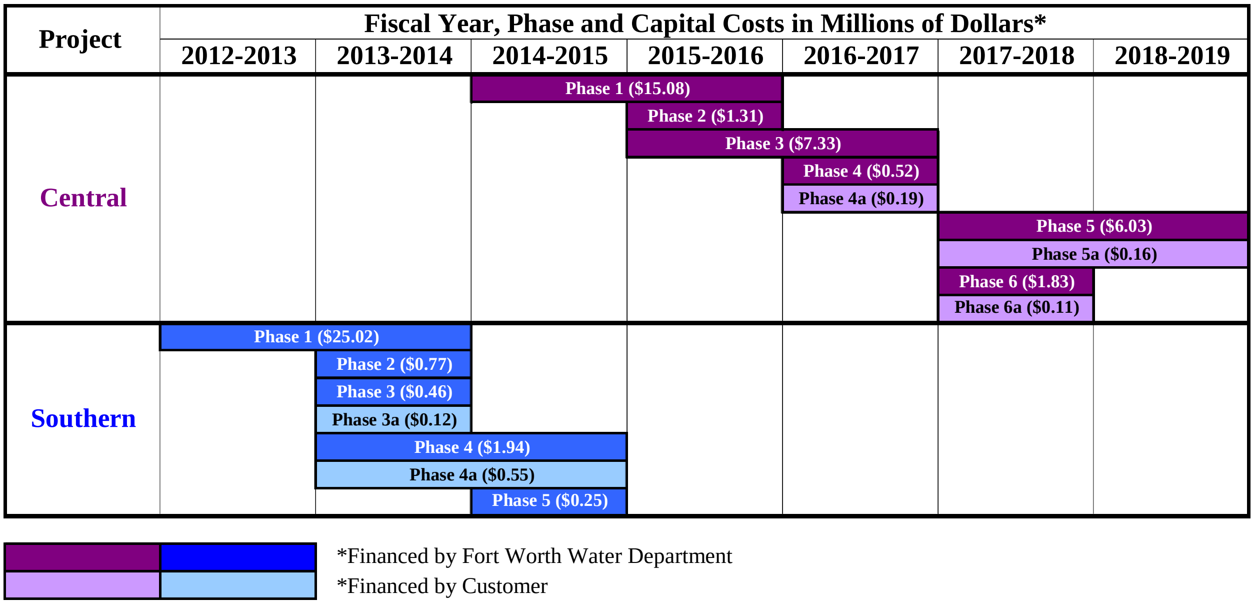
[58] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

The next steps for implementation are outlined in Table 12-1. A summary of the proposed construction phasing is provided in Figure 12-1, and a detailed implementation timeline is presented in Figure 12-2.

Table 12-1
Implementation Steps for Central and Southern Reclaimed Water Systems

FISCAL YEAR 2010-2011
* Perform flow monitoring to verify that 5 mgd of wastewater is available for diversion from the interceptor (M275B/290+88).
* Perform routing delineation and surveying for Southern System, Phase 1, 2, and 3 pipelines.
* Perform environmental permitting for Southern System, Phase 1, 2, and 3 pipelines.
FISCAL YEAR 2011-2012
* Begin and complete right-of-way acquisition and design for Southern System, Phase 1, 2, and 3 pipelines.
* Perform routing delineation and surveying for Southern System, Phase 4 and 5 pipelines.
* Perform environmental permitting for Southern System, Phase 4 and 5 pipelines.
FISCAL YEAR 2012-2013
* Begin and complete construction of Southern System, Phase 1, 2, and 3 pipelines.
* Begin and complete right-of-way acquisition and design for Southern System, Phase 4 and 5 pipelines.
* Perform routing delineation and surveying for Central System, Phase 1 pipeline and pump station.
* Perform environmental permitting for Central System, Phase 1 pipeline and pump station.
FISCAL YEAR 2013-2014
* Begin and complete construction of Southern System, Phase 4 and 5 pipelines.
* Begin and complete right-of-way acquisition and design for Central System, Phase 1 pipeline and pump station.
* Perform routing delineation and surveying for Central System, Phase 2, 3 and 4 pipelines.
* Perform environmental permitting for Central System, Phase 2, 3 and 4 pipelines.
FISCAL YEAR 2014-2015
* Begin construction of Central System, Phase 1 pipeline and pump station.
* Begin and complete right-of-way acquisition and design for Central System, Phase 2, 3 and 4 pipelines.
FISCAL YEAR 2015-2016
* Complete construction of Central System, Phase 1 pipeline and pump station.
* Begin and complete construction of Central System, Phase 2 pipeline.
* Begin construction of Central System, Phase 3 pipeline.
* Begin and complete construction of Central System, Phase 4 pipeline.
* Perform routing delineation and surveying for Central System, Phase 5 and 6 pipelines.
* Perform environmental permitting for Central System, Phase 5 and 6 pipelines.
FISCAL YEAR 2016-2017
* Complete construction of Central System, Phase 3 pipeline.
* Begin and complete right-of-way acquisition and design for Central System, Phase 5 pipeline.
* Begin and complete right-of-way acquisition and design for Central System, Phase 6 pipeline.
FISCAL YEAR 2017-2018
* Begin construction of Central System, Phase 5 pipeline.
* Begin and complete construction of Central System, Phase 6 pipeline.
FISCAL YEAR 2018-2019
* Complete construction of Central System, Phase 5 pipeline.

Figure 12-1
Construction Phasing for Central and Southern Reclaimed Water Systems

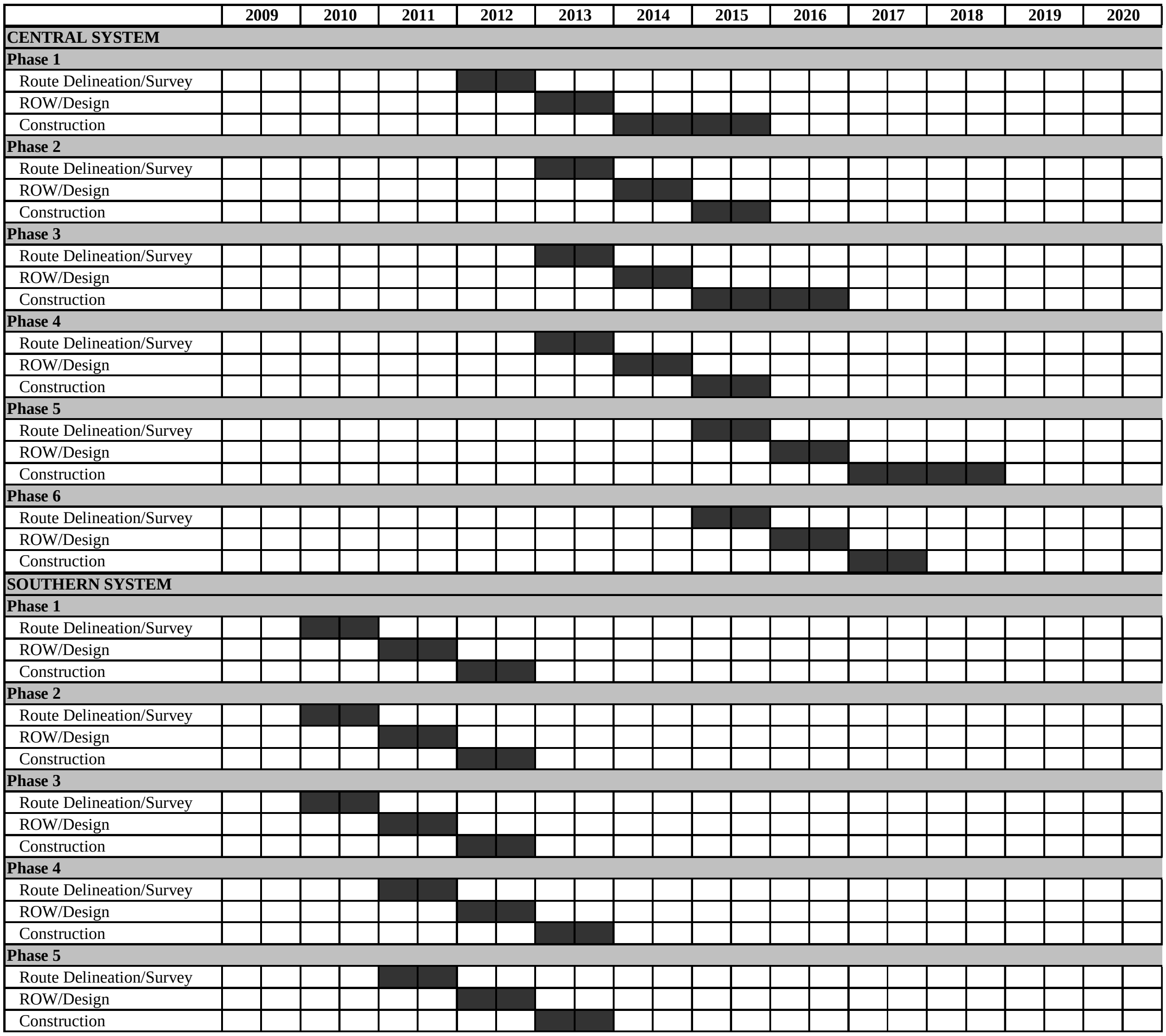


The recommendation to implement the proposed reclaimed water projects is based on the likelihood of customer interest and feasibility of the projects. The City should pursue further discussions with potential customers to finalize their commitment to reclaimed water use. Other potential customers identified in this report should also be contacted directly to confirm their interest, needs, and expectations.

12.3. Construction and Startup Issues

No significant construction or startup issues were identified for the Central and Southern Systems.

Figure 12-2
Detailed Implementation Timeline for Central and Southern Reclaimed Water Systems



Appendix A: Opinions of Probable Cost for Central and Southern Systems

Hydraulic Evaluation and Opinions of Probable Cost

Fort Worth Central Reclaimed Water System

Pipe Sizing and Estimated Cost

Velocity: 5 ft/sec; C = 130

ID #	From	To	Phase	Annual Avg. Demand (mgd)	Peak Demand (mgd)	Design Capacity (mgd)	Calculated Diameter[1] (in)	Design Diameter (in)	Pipeline: Distance (mile)	Pipeline: Length (ft)	Pipeline: Unit Cost[2]	Pipeline: Cost	ROW (ft)	Land: Area[3] (acre)	Land: Unit Cost	Land: Cost	Total Pipeline Cost	Pipeline Maintenance Costs[4]	Start Elevation (ft)	End Elevation (ft)	Static Head (ft)	Max. Cap. Velocity (mgd)	Head Loss (ft)	Req. Pressure Head (ft)	TDH
1	VCWWTP	1	1	1.93	16.25	16.25	30.4	36	5.80	30,600	$ 231.49	$7,084,000	0	0.0	$30,000	$0	$7,084,000	$78,000	472	496	24	3.6	32.7	0	57
2	1	2	2	1.84	15.09	15.09	29.3	30	0.49	2,600	$ 201.29	$523,000	0	0.0	$30,000	$0	$523,000	$6,000	496	499	3	4.8	5.9	0	9
3	2	3	3	1.78	13.36	13.36	27.5	30	2.31	12,200	$ 201.29	$2,456,000	0	0.0	$30,000	$0	$2,456,000	$27,000	499	506	7	4.2	22.1	0	29
4	3	4	3	1.63	9.88	9.88	23.7	24	2.52	13,300	$ 171.10	$2,276,000	20	6.1	$30,000	$183,000	$2,459,000	$25,000	506	576	70	4.9	40.8	0	111
5	4	5	6	0.26	4.42	4.42	15.8	16	1.02	5,400	$ 104.67	$565,000	20	2.5	$30,000	$75,000	$640,000	$6,000	576	575	-1	4.9	26.9	0	26
6	4	6	4	1.37	5.46	5.46	17.6	18	0.34	1,800	$ 124.80	$225,000	20	0.8	$30,000	$24,000	$249,000	$2,000	576	530	-46	4.8	7.5	0	-39
7	6	7	4	1.33	4.60	4.60	16.1	18	0.19	1,000	$ 124.80	$125,000	20	0.5	$30,000	$15,000	$140,000	$1,000	530	563	33	4.0	3.0	0	36
8	7	8	5	1.30	3.86	3.86	14.8	16	2.42	12,800	$ 104.67	$1,340,000	20	5.9	$30,000	$177,000	$1,517,000	$15,000	563	620	57	4.3	49.5	0	107
9	1	Woodhaven GC	1	0.09	1.16	1.16	8.1	10	0.08	400	$ 67.43	$27,000	0	0.0	$30,000	$0	$27,000	$0	496	510	14	3.3	1.7	0	16
10	2	Meadowbrook GC	2	0.06	1.73	1.73	9.9	10	1.08	5,700	$ 67.43	$384,000	20	2.6	$30,000	$78,000	$462,000	$4,000	499	530	31	4.9	49.3	26	106
11	3	Gateway Park	3	0.15	3.48	3.48	14.1	16	0.57	3,000	$ 104.67	$314,000	0	0.0	$30,000	$0	$314,000	$3,000	506	522	16	3.9	9.6	138	164
12	5	Cobb Park (A)	6	0.17	3.96	3.96	15.0	16	0.15	800	$ 104.67	$84,000	20	0.4	$30,000	$12,000	$96,000	$1,000	575	552	-23	4.4	3.3	138	118
13	20	Cobb Park (B)	6	0.17	3.96	3.96	15.0	16	0.45	2,400	$ 104.67	$251,000	20	1.1	$30,000	$33,000	$284,000	$3,000	642	630	-12	4.4	9.8	138	136
14	6	Sycamore GC (A)	4A	0.03	0.74	0.74	6.5	8	0.08	400	$ 45.29	$18,000	0	0.0	$30,000	$0	$18,000	$0	530	525	-5	3.3	2.1	0	-3
15	7	Sycamore GC (B)	4A	0.03	0.74	0.74	6.5	8	0.44	2,300	$ 45.29	$104,000	0	0.0	$30,000	$0	$104,000	$1,000	563	555	-8	3.3	12.2	4	8
16	6	Sycamore Park	4A	0.04	0.86	0.86	7.0	8	0.08	400	$ 45.29	$18,000	0	0.0	$30,000	$0	$18,000	$0	530	532	2	3.8	2.8	138	143
17	8	Harris Meth. Hosp.	5A	0.05	0.13	0.13	2.7	6	0.45	2,400	$ 39.25	$94,000	15	0.8	$30,000	$24,000	$118,000	$1,000	620	640	20	1.0	1.9	138	160
18	8	TRV/CBD	5	1.25	3.73	3.73	14.5	16	2.27	12,000	$ 104.67	$1,256,000	20	5.5	$30,000	$165,000	$1,421,000	$14,000	620	529	-91	4.1	43.7	40	-7
19	21	Glen Garden GC	6A	0.09	0.46	0.46	5.1	6	0.30	1,600	$ 39.25	$63,000	15	0.6	$30,000	$18,000	$81,000	$1,000	625	640	15	3.6	14.3	4	33
20	5	20	6	0.26	4.42	4.42	15.8	16	0.59	3,100	$ 104.67	$324,000	20	1.4	$30,000	$42,000	$366,000	$4,000	575	642	67	4.9	15.5	0	82
21	20	21	6A	0.09	0.46	0.46	5.1	6	0.78	4,100	$ 39.25	$161,000	15	1.4	$30,000	$42,000	$203,000	$2,000	642	625	-17	3.6	36.8	0	20
										118,300		$17,692,000		29.6		$888,000	$18,580,000	$194,000							

Pump Station CapitalCost / Pump Station Annual Operation and Maintenance Cost

ID #	Pump Station No.	Name		Capacity (mgd)	Design Diameter (in)	Max. Cap. Velocity (mgd)	Headloss (mgd)	Static Head (ft)	Req. Pressure Head (ft)	TDH (ft)	Required Power[5] (hp)	Required Power[5] (kW)	Pump Station Cost[6]	Annual Av.Demand (mgd)	Pipe Length (ft)	Design Diameter (in)	Average Velocity (ft/sec)	Headloss (ft)	Static Head (ft)	TDH (ft)	Required Power[5] (hp)	Required Power[5] (kW)	Unit Power Cost ($/kWh)	Annual Power Cost	Annual Maint. Cost[7]
		WRC		**0.0**																					
	0	TRV Pump Station		7.50			0	0	40	40	70	52	$513,000	0.76				0.00	0	40	7	5	$0.10	$5,000	$15,000
	1g	VCWWTP to Harris Methodist		16.25			163	168	138	469	1785	1331	$3,432,000	1.93				10.58	168	317	143	107	$0.10	$93,000	$103,000
1		VCWWTP	1	16.25	36	3.6	32.7	24.0		412.7				1.93	30600	36	0.42	0.63	24.0						
2		1	2	15.09	30	4.8	5.9	3.0		403.8				1.84	2600	30	0.58	0.12	3.0						
3		2	3	13.36	30	4.2	22.1	7.0		374.7				1.78	12200	30	0.56	0.53	7.0						
4		3	4	9.88	24	4.9	40.8	70.0		263.9				1.63	13300	24	0.80	1.45	70.0						
6		4	6	5.46	18	4.8	7.5	-46.0		302.5				1.37	1800	18	1.20	0.58	-46.0						
7		6	7	4.60	18	4.0	3.0	33.0		266.5				1.33	1000	18	1.16	0.30	33.0						
8		7	8	3.86	16	4.3	49.5	57.0		159.9				1.30	12800	16	1.44	6.62	57.0						
17		8	Harris Meth. Hosp.	0.13	6	1.0	1.9	20.0		138.0				0.05	2400	6	0.39	0.35	20.0						
		TRV Storage		2.00									$845,000												
												Total:	**$4,790,000**										**Total:**	**$98,000**	**$118,000**

Hydraulic Evaluation and Opinions of Probable Cost

Fort Worth Central Reclaimed Water System

Summary of Estimated Cost

ID #	From	To	Design Capacity	Capital Cost									Annual Operation and Maintenance Cost				
				WRC Cost	Pump Station & Storage Tank	Storage	Pipeline	Land	Contingency & Fees	Permitting & Mitigation	Interest During Construction	Total Capital Cost	Debt Service	Energy Cost	Pipe Maint.	PS Equip. Maint.	Total Annual (First Years)
1	VCWWTP	1	16.25		$3,432,000	$0	$7,084,000	$0	$3,326,000	$105,000	$1,093,000	$15,040,000	$1,259,000	$93,000	$78,000	$103,000	$1,533,000
2	1	2	15.09				$523,000	$0	$157,000	$5,000	$26,000	$711,000	$59,000		$6,000		$65,000
3	2	3	13.36				$2,456,000	$0	$737,000	$25,000	$252,000	$3,470,000	$290,000		$27,000		$317,000
4	3	4	9.88				$2,276,000	$183,000	$683,000	$23,000	$248,000	$3,413,000	$286,000		$25,000		$311,000
5	4	5	4.42				$565,000	$75,000	$170,000	$6,000	$31,000	$847,000	$71,000		$6,000		$77,000
6	4	6	5.46				$225,000	$24,000	$68,000	$2,000	$12,000	$331,000	$28,000		$2,000		$30,000
7	6	7	4.60				$125,000	$15,000	$38,000	$1,000	$7,000	$186,000	$16,000		$1,000		$17,000
8	7	8	3.86				$1,340,000	$177,000	$402,000	$13,000	$151,000	$2,083,000	$174,000		$15,000		$189,000
9	1	Woodhaven GC	1.16				$27,000	$0	$8,000	$0	$3,000	$38,000	$3,000		$0		$3,000
10	2	Meadowbrook GC	1.73				$384,000	$78,000	$115,000	$4,000	$22,000	$603,000	$50,000		$4,000		$54,000
11	3	Gateway Park	3.48				$314,000	$0	$94,000	$3,000	$32,000	$443,000	$37,000		$3,000		$40,000
12	5	Cobb Park (A)	3.96				$84,000	$12,000	$25,000	$1,000	$5,000	$127,000	$11,000		$1,000		$12,000
13	20	Cobb Park (B)	3.96			$0	$251,000	$33,000	$75,000	$3,000	$14,000	$376,000	$31,000		$3,000		$34,000
14	6	Sycamore GC (A)	0.74				$18,000	$0	$5,000	$0	$1,000	$24,000	$2,000		$0		$2,000
15	7	Sycamore GC (B)	0.74				$104,000	$0	$31,000	$1,000	$5,000	$141,000	$12,000		$1,000		$13,000
16	6	Sycamore Park	0.86				$18,000	$0	$5,000	$0	$1,000	$24,000	$2,000		$0		$2,000
17	8	Harris Meth. Hosp.	0.13				$94,000	$24,000	$28,000	$1,000	$12,000	$159,000	$13,000		$1,000		$14,000
18	8	TRV/CBD	3.73		$513,000	$845,000	$1,256,000	$165,000	$852,000	$26,000	$286,000	$3,943,000	$330,000	$5,000	$14,000	$15,000	$364,000
19	21	Glen Garden GC	0.46			$0	$63,000	$18,000	$19,000	$1,000	$4,000	$105,000	$9,000		$1,000		$10,000
20	5	20	4.42				$324,000	$42,000	$97,000	$3,000	$18,000	$484,000	$41,000		$4,000		$45,000
21	20	21	0.46				$161,000	$42,000	$48,000	$2,000	$10,000	$263,000	$22,000		$2,000		$24,000
				$0	$3,945,000	$845,000	$17,692,000	$888,000	$6,983,000	$225,000	$2,233,000	$32,811,000	$2,746,000	$98,000	$194,000	$118,000	$3,156,000

Annual and Unit Cost Summary

Years	Amortized Capital Costs, 20 Yrs @ 5.5%	Annual Power Cost ($)	Annual O&M Cost (Excluding Power)	Total Annual ($)	Unit Cost ($/1,000 gal)
1-20	$2,746,000	$98,000	$312,000	$63,120,000	$4.48
20-50	0	$98,000	$312,000	$12,300,000	$0.58
TOTAL			**Total =**	$75,420,000	
AVERAGE				$1,508,000	$2.14
			Average Cost =	$1,508,000	Per Year
			Average Cost =	$2.14	Per 1000 Gallons

Assumptions:
1. Maximum pipeline velocity is 5 ft/s.
2. Pipeline costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
3. Land costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
4. Pipeline maintenance costs assumed 1% of construction cost.
5. Power based upon pump wire to water efficiency of 75%.
6. Pump station costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
7. PS equipment maintenance costs 2.5% of PS construction costs.

Hydraulic Evaluation and Opinions of Probable Cost
Fort Worth Southern Reclaimed Water System

Pipe Sizing and Estimated Cost

Velocity: 5 ft/sec; C = 130

ID #	From	To	Phase	Annual Avg. Demand (mgd)	Peak Demand (mgd)	Design Capacity (mgd)	Calculated Diameter[1] (in)	Design Diameter (in)	Pipeline: Distance (mile)	Pipeline: Length (ft)	Pipeline: Unit Cost[2]	Pipeline: Cost	ROW (ft)	Land: Area[3] (acre)	Land: Unit Cost	Land: Cost	Total Pipeline Cost	Pipeline Maintenance Costs[4]	Start Elevation (ft)	End Elevation (ft)	Static Head (ft)	Max. Cap. Velocity (mgd)	Head Loss (ft)	Req. Pressure Head (ft)	TDH
2	4	2	5	0.03	0.69	0.69	6.3	8	0.49	2,600	$ 45.29	$118,000	15	0.9	$30,000	$27,000	$145,000	$1,000	680	675	-5	3.1	12.2		7
4	30	4	2	0.07	1.45	1.45	9.1	10	0.91	4,800	$ 67.43	$324,000	20	2.2	$30,000	$66,000	$390,000	$4,000	672	680	8	4.1	30.0	138	176
5	30	5	4	0.68	3.79	3.79	14.7	16	2.08	11,000	$ 104.67	$1,151,000	20	5.1	$30,000	$153,000	$1,304,000	$13,000	672	707	35	4.2	41.2		76
6	5	6	4A	0.30	0.79	0.79	6.7	8	0.23	1,200	$ 45.29	$54,000	15	0.4	$30,000	$12,000	$66,000	$1,000	707	705	-2	3.5	7.2		5
7	6	7	4A	0.29	0.78	0.78	6.6	8	0.78	4,100	$ 45.29	$186,000	15	1.4	$30,000	$42,000	$228,000	$2,000	705	710	5	3.5	24.0		29
8	2	Correctional Facility	5	0.01	0.30	0.30	4.1	6	0.21	1,100	$ 39.25	$43,000	0	0.0	$30,000	$0	$43,000	$0	675	685	10	2.4	4.5	138	152
11	30	11	3	0.19	4.64	4.64	16.2	18	0.47	2,500	$ 124.80	$312,000	20	1.1	$30,000	$33,000	$345,000	$3,000	672	668	-4	4.1	7.7	138	142
12	11	TCC/FWISD Fields	3A	0.04	0.99	0.99	7.5	8	0.30	1,600	$ 45.29	$72,000	15	0.6	$30,000	$18,000	$90,000	$1,000	668	665	-3	4.4	14.6	138	150
13	5	Alcon Laboratories	4	0.38	3.00	3.00	13.0	14	0.21	1,100	$ 85.55	$94,000	20	0.5	$30,000	$15,000	$109,000	$1,000	707	710	3	4.3	5.1	138	146
14	6	Ball Metal	4A	0.01	0.01	0.01	0.8	6	0.09	500	$ 39.25	$20,000	0	0.0	$30,000	$0	$20,000	$0	705	700	-5	0.1	0.0	138	133
15	7	Miller Brewery	4A	0.19	0.53	0.53	5.5	6	0.09	500	$ 39.25	$20,000	0	0.0	$30,000	$0	$20,000	$0	710	711	1	4.2	5.8	138	145
16	7	16	4A	0.10	0.25	0.25	3.8	6	0.28	1,500	$ 39.25	$59,000	15	0.5	$30,000	$15,000	$74,000	$1,000	710	711	1	2.0	4.3		5
28	30	Tarrant Co. Resource Connection	2	0.03	0.50	0.50	5.3	6	0.15	800	$ 39.25	$31,000	15	0.3	$30,000	$9,000	$40,000	$0	665	681	16	3.9	8.4	138	162
30	WRC	30	2	0.97	10.38	10.38	24.3	30	0.13	700	$ 201.29	$141,000	20	0.3	$30,000	$9,000	$150,000	$2,000	671	672	1	3.3	0.8		2
32	Sewer	WRC	1	1.35	4.20	4.20	15.4	16	0.89	4,700	$ 104.67	$492,000	20	2.2	$30,000	$66,000	$558,000	$5,000	600	671	71	4.7	21.3	8	100
										72,000		$3,117,000		15.5		$465,000	$3,582,000	$34,000							

Pump Station CapitalCost / **Pump Station Annual Operation and Maintenance Cost**

ID #	Pump Station No.	Name		Capacity (mgd)	Design Diameter (in)	Max. Cap. Velocity (mgd)	Headloss (mgd)	Static Head (ft)	Req. Pressure Head (ft)	TDH (ft)	Required Power[5] (hp)	Required Power[5] (kW)	Pump Station Cost[6]	Annual Av.Demand (mgd)	Pipe Length (ft)	Design Diameter (in)	Average Velocity (ft/sec)	Headloss (ft)	Static Head (ft)	TDH (ft)	Required Power[5] (hp)	Required Power[5] (kW)	Unit Power Cost ($/kWh)	Annual Power Cost	Annual Maint. Cost[7]
		WRC		**5.0**																					
	0	Sewer to WRC		4.20			21	71	8	100	99	74	$643,000	1.35				2.60	71	82	26	19	$0.10	$17,000	$19,000
32		Sewer	WRC	4.20	16	4.7	21.3	71.0		8.0				1.35	4700	16	1.49	2.60	71.0						
	1i	WRC to Miller		10.38			79	40	138	257	624	466	$1,919,000	0.97				7.64	40	186	42	31	$0.10	$28,000	$58,000
30		WRC	30	10.38	30	3.3	0.8	1.0		255.2				0.97	700	30	0.31	0.01	1.0						
5		30	5	3.79	16	4.2	41.2	35.0		179.0				0.68	11000	16	0.75	1.71	35.0						
6		5	6	0.79	8	3.5	7.2	-2.0		173.8				0.30	1200	8	1.33	1.20	-2.0						
7		6	7	0.78	8	3.5	24.0	5.0		144.8				0.29	4100	8	1.29	3.85	5.0						
15		7	Miller Brewery	0.53	6	4.2	5.8	1.0		138.0				0.19	500	6	1.50	0.87	1.0						
		Additional WRC Storage		2.00									$845,000												
												Total:	**$3,407,000**										**Total:**	**$45,000**	**$77,000**

Hydraulic Evaluation and Opinions of Probable Cost

Fort Worth Southern Reclaimed Water System

Summary of Estimated Cost

ID #	From	To	Design Capacity	Capital Cost									Annual Operation and Maintenance Cost				
				WRC Cost	Pump Station & Storage Tank	Storage	Pipeline	Land	Contingency & Fees	Permitting & Mitigation	Interest During Construction	Total Capital Cost	Debt Service	Energy Cost	Pipe Maint.	PS Equip. Maint.	Total Annual (First Years)
2	4	2	0.69				$118,000	$27,000	$35,000	$1,000	$7,000	$188,000	$16,000		$1,000		$17,000
4	30	4	1.45				$324,000	$66,000	$97,000	$3,000	$19,000	$509,000	$43,000	$236,000	$4,000	$114,000	$397,000
5	30	5	3.79				$1,151,000	$153,000	$345,000	$12,000	$130,000	$1,791,000	$150,000		$13,000		$163,000
6	5	6	0.79				$54,000	$12,000	$16,000	$1,000	$7,000	$90,000	$8,000		$1,000		$9,000
7	6	7	0.78				$186,000	$42,000	$56,000	$2,000	$22,000	$308,000	$26,000		$2,000		$28,000
8	2	Correctional Facility	0.30				$43,000	$0	$13,000	$0	$2,000	$58,000	$5,000		$0		$5,000
11	30	11	4.64				$312,000	$33,000	$94,000	$3,000	$17,000	$459,000	$38,000		$3,000		$41,000
12	11	TCC/FWISD Fields	0.99				$72,000	$18,000	$22,000	$1,000	$4,000	$117,000	$10,000		$1,000		$11,000
13	5	Alcon Laboratories	3.00				$94,000	$15,000	$28,000	$1,000	$11,000	$149,000	$12,000		$1,000		$13,000
14	6	Ball Metal	0.01				$20,000	$0	$6,000	$0	$2,000	$28,000	$2,000		$0		$2,000
15	7	Miller Brewery	0.53			$0	$20,000	$0	$6,000	$0	$2,000	$28,000	$2,000		$0		$2,000
28	30	Tarrant Co. Resource Connection	0.50				$31,000	$9,000	$9,000	$0	$2,000	$51,000	$4,000		$0		$4,000
30	WRC	30	10.38				$141,000	$9,000	$42,000	$1,000	$15,000	$208,000	$17,000		$2,000		$19,000
32	Sewer	WRC	4.20	$12,889,000	$2,562,000	$845,000	$492,000	$396,000	$5,851,000	$168,000	$1,818,000	$25,021,000	$2,094,000	$17,000	$5,000	$19,000	$2,135,000
16	7	16	0.25				$59,000	$15,000	$18,000	$1,000	$7,000	$100,000	$8,000		$1,000		$9,000
				$12,889,000	$2,562,000	$845,000	$3,117,000	$795,000	$6,638,000	$194,000	$2,065,000	$29,105,000	$2,435,000	$253,000	$34,000	$133,000	$2,855,000

Annual and Unit Cost Summary

Years	Amortized Capital Costs, 20 Yrs @ 5.5%	Annual Power Cost ($)	Annual O&M Cost (Excluding Power)	Total Annual ($)	Unit Cost ($/1,000 gal)
1-20	$2,435,000	$253,000	$167,000	$57,100,000	$5.80
20-50	0	$253,000	$167,000	$12,600,000	$0.85
TOTAL			Total =	$69,700,000	
AVERAGE				$1,394,000	$2.83
			Average Cost =	$1,394,000	Per Year
			Average Cost =	$2.83	Per 1000 Gallons

Assumptions:
1. Maximum pipeline velocity is 5 ft/s.
2. Pipeline costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
3. Land costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
4. Pipeline maintenance costs assumed 1% of construction cost.
5. Power based upon pump wire to water efficiency of 75%.
6. Pump station costs from Reclaimed Water Priority and Implementation Plan, adjusted to 2nd quarter 2007 with ENR CCI.
7. PS equipment maintenance costs 2.5% of PS construction costs.

Appendix B: Cost Estimation for Recycled Water Alternatives

Cost Estimation for Recycled Water Alternatives

Opinions of probable cost for the Central and Southern Systems were developed using the same assumptions that were used in the *Reclaimed Water Priority and Implementation Plan*,[59] except that costs were updated from fourth quarter 2006 dollars to second quarter 2007 dollars using the Engineering News Record (ENR) Construction Cost Index (CCI).[60]

A copy of the technical memorandum that describes the development of opinions of probable cost for the *Reclaimed Water Priority and Implementation Plan* is attached.[61]

---

[59] Alan Plummer Associates, Inc. and Chiang, Patel & Yerby, Inc., May 2007. *Reclaimed Water Priority and Implementation Plan*, prepared for the Fort Worth Water Department, Fort Worth.

[60] The December 2006 ENR CCI was 7888, and the June 2007 ENR CCI was 7939, a 0.6 percent increase.

[61] The attached technical memorandum is Appendix F in the *Reclaimed Water Priority and Implementation Plan*.

TECHNICAL MEMORANDUM 1

COST PROJECTIONS FOR RECYCLED WATER ALTERNATIVES

CITY OF FORT WORTH – WATER REUSE PRIORITY AND IMPLEMENTATION PLAN

TO: **Alan Plummer Associates, Inc. (APAI)**

FROM: **Chiang, Patel & Yerby, Inc. (CP&Y)**

This document is issued for interim review only under the authority of Richard L. Shaffer, P.E.

Date: **February 26, 2007**

TABLE OF CONTENTS

1 INTRODUCTION

1. Evaluation of water reuse alternatives required development of cost projections. Costs were projected in fourth quarter 2006 dollars.
2. All cost projections were reviewed by construction services and division leaders of CP&Y.
3. The cost projection procedure used to evaluate the alternatives is generally consistent with the cost estimating procedure used by Region C for evaluating water supply alternatives. Unit costs may have been adjusted to reflect updated estimates.
4. All unit costs include the contractor's mobilization, overhead and profit. The unit costs do not include engineering, contingency, financial and legal services, costs for land and rights-of-way, permits, environmental and archeological studies, or mitigation.
5. The cost estimates have two components:
   a. Initial capital costs, including engineering and construction costs, and
   b. Average annual costs, including annual operation and maintenance costs and debt service.

2 ASSUMPTIONS FOR CAPITAL COSTS

Conveyance Systems

Standard pipeline costs used for these cost projections are shown in Table TM1-1. Pump station costs were based on required horsepower capacity and are listed in Table TM1-2. The power capacity was determined from the hydraulic analyses conducted from a planning level hydraulic grade line evaluation.

Pipelines and pump stations were sized for peak pumping capacity. It was assumed that conveyance systems would convey the peak month demand for users with available storage and peak hour demand for users without any available storage. Golf course ponds are not considered available storage, since the golf course operators would not likely permit pond levels to significantly fluctuate.

- Maximum pipeline velocity for design was 5 feet per second.
- Pump efficiency was assumed to be 75%.
- Peaking factors:
  - Peak Month Factor = 2.64, unless more site specific data was available. This assumption was intended to be consistent with the City of Fort Worth's (COFW) *Draft Feasibility Study – Mary's Creek Water Recycling Center*.
  - Peak Day Factor was based on the number of days recycled water would be utilized – "1" for everyday use, "2" for every other day use, "3" for use every third day, etc., unless more site specific data was available.
  - Peak Hour Factor was based on the number of hours during the day that recycled water would be utilized – "1" for 24 hours per day use, "2" for 12 hours per day use, "3" for 8 hours per day use, "6" for 4 hours per day use, etc., unless more site specific data was available.

Water Reclamation Centers / Satellite Wastewater Treatment Plants

Water reclamation centers (WRCs) were sized for the peak day capacity. The WRC facility was assumed to be a highly compact facility designed to treat base loads with minimal peaking factors and minimal redundant equipment. Since wet weather flows continue through the collection system to the regional treatment facility, this configuration differs from typical wastewater treatment plants that are designed to treat significant peak flows. Since peaking flows and high levels of redundancy were not critical to the design, significant construction cost savings were achieved. Probable cost projections for new water reclamation centers are listed in Table TM1-3.

Other Costs

Additional costs, associated with the development and construction of alternatives, are described below. Except for the amount of annual interest accrued on unspent funds during construction, these costs are consistent with the Region C cost estimating procedure. The annual interest rate included for each alternative is based on data provided by the COFW.

- Engineering, contingency, construction management, financial and legal costs were estimated at 30 percent of construction costs for pipelines and 35 percent of construction costs for pump stations, storage tanks and water reclamation centers.

- Permitting and mitigation for transmission and treatment projects were estimated at 1 percent of the total construction costs.
- Right-of-way costs for transmission pipelines were estimated at $3,000 per acre of ROW for rural pipelines and $30,000 per acre of ROW for urban pipelines. If a small pipeline follows existing right-of ways (such as highways), no additional right-of-way cost was assumed. Large pipelines required ROW costs regardless of routing.
- Interest during construction was the total of interest accrued at the end of the construction period, using a 5.5 percent annual interest rate on total borrowed funds, less a 4 percent rate of return on investment of unspent funds. This was calculated assuming that the total estimated project cost (excluding interest during construction) would be drawn down at a constant rate per month during the construction period. Factors were determined for different lengths of time for project construction, and are presented in Table TM1-4.

3 ASSUMPTIONS FOR ANNUAL COSTS

Annual costs were projected using the following assumptions:

- Debt service for all transmission and treatment facilities was annualized over 20 years, but not longer than the life of the project. If state participation was used to fund a portion of the project, then debt service for all, or a portion, of the transmission and treatment facilities may be annualized over a period of 34 years, in accordance with state participation guidelines.
- Annual interest rate for debt service was assumed to be 5.5 percent, based on COFW data.
- Operation and Maintenance costs were calculated based on the construction costs of the capital improvement. Engineering, permitting, etc. was not included as a basis for this calculation. However, a 20% allowance for construction contingencies was included for all O&M calculations. O&M was calculated at:
  - 1 percent of the construction costs for pipelines and storage tanks,
  - 2.5 percent of the construction costs for pump stations, and
  - O&M for water reclamation centers should be based on unit costs as shown in Table TM1-3.
- Pumping costs were projected using an electricity rate of $0.10 per Kilowatt Hour. This rate is greater than the rate included in the Region C cost estimating procedure, however, is more consistent with local electricity rates.

Table TM1-1

Pipeline Costs (does not include ROW)

Diameter (Inches)	Base Installed Cost ($/Foot)	Rural Cost with Appurtenances ($/Foot)	Urban Cost with Appurtenances ($/Foot)	Assumed ROW Width (Feet)
6	$ 30.00	$ 33.00	$ 39.00	15
8	$ 34.00	$ 38.00	$ 45.00	15
10	$ 51.50	$ 57.00	$ 67.00	20
12	$ 62.00	$ 69.00	$ 81.00	20
14	$ 65.00	$ 72.00	$ 85.00	20
16	$ 80.00	$ 88.00	$ 104.00	20
18	$ 95.00	$ 105.00	$ 124.00	20
20	$ 107.00	$ 118.00	$ 140.00	20
24	$ 130.50	$ 144.00	$ 170.00	20
30	$ 153.50	$ 169.00	$ 200.00	20
36	$ 176.50	$ 195.00	$ 230.00	20
42	$ 241.00	$ 266.00	$ 314.00	30
48	$ 270.00	$ 297.00	$ 351.00	30

Notes:

1. Pipeline costs developed by CP&Y were based on cost data from pipeline suppliers
2. Pipeline material and depth are as follows:
   a. 6" - 12" C900 - PVC DR-18, 5' to 6' depth of cover
   b. 14" - 24" C905 - PVC DR-25, 6' to 7' depth of cover
   c. 30" - 48" RCCP, 6' to 7' depth of cover
3. Appurtenances assumed to be 10% of installed pipe costs
4. 15% Contractor's OH&P included in Base Cost

Table TM1-2

Pump Station Costs for Transmission Systems

25	$261,000
50	$418,000
100	$648,000
200	$972,000
300	$1,254,000
400	$1,568,000
500	$1,777,000
600	$1,881,000
700	$1,986,000
800	$2,195,000
900	$2,299,000
1,000	$2,508,000
2,000	$3,658,000
3,000	$4,389,000
4,000	$5,330,000
5,000	$6,061,000
6,000	$6,897,000
7,000	$7,524,000
8,000	$8,151,000
9,000	$8,883,000
10,000	$9,405,000

Note: Pump Station costs were based on Region C cost projections and have been adjusted for inflation

Table TM1-3

Costs for Satellite WRC

WRC Flowrate	mgd	1.0	2.0	3.0	4.0	5.0
	gpm	694	1,389	2,083	2,778	3,472
Screen		$240,000	$320,000	$400,000	$480,000	$560,000
MBR		$1,767,000	$3,131,000	$4,501,000	$5,849,000	$7,196,000
UV Disinfection		$160,000	$220,000	$280,000	$340,000	$400,000
Electrical		$250,000	$443,000	$635,000	$828,000	$1,020,000
Building		$135,000	$175,000	$205,000	$235,000	$255,000
SCADA		$125,000	$222,000	$318,000	$414,000	$510,000
Lift Station		$350,000	$668,000	$975,000	$1,250,000	$1,500,000
Storage Tank	Size (gal)	500,000	1,000,000	1,500,000	2,000,000	2,500,000
	Cost	$380,000	$500,000	$680,000	$840,000	$990,000
Odor Control		$100,000	$180,000	$255,000	$320,000	$375,000
Capital Cost		**$3,507,000**	**$5,859,000**	**$8,249,000**	**$10,556,000**	**$12,806,000**
Annual Maint. ($/1000gal)		$0.24	$0.18	$0.15	$0.13	$0.11
Annual O&M ($/year)		$87,000	$134,000	$160,000	$186,000	$206,000
Annual Energy ($/1000gal)		$0.56	$0.51	$0.47	$0.44	$0.42
Annual Energy ($/year)		$204,000	$372,000	$514,000	$640,000	$764,000
Total Annual O&M		**$291,000**	**$506,000**	**$674,000**	**$826,000**	**$970,000**

Note: Cost projections for WRC facilities were developed by CP&Y, and are based on data received from process equipment suppliers.

Table TM1-3 (cont.)

Costs for Satellite WRC

WRC Flowrate	mgd	8.0	10.0	12.0	15.0
	gpm	5,556	6,944	8,333	10,417
Screen		$800,000	$960,000	$1,152,000	$1,440,000
MBR		$10,761,000	$13,142,000	$15,709,000	$19,560,000
UV Disinfection		$592,000	$720,000	$864,000	$1,080,000
Electrical		$1,548,000	$1,900,000	$2,280,000	$2,850,000
Building		$295,000	$320,000	$345,000	$385,000
SCADA		$774,000	$950,000	$1,140,000	$1,425,000
Lift Station		$2,160,000	$2,500,000	$2,760,000	$3,000,000
Storage Tank	Size (gal)	4,000,000	4,500,000	4,750,000	5,000,000
	Cost	$1,740,000	$2,020,000	$2,170,000	$2,310,000
Odor Control		$480,000	$500,000	$600,000	$750,000
Capital Cost		**$19,150,000**	**$23,012,000**	**$27,020,000**	**$32,800,000**
Annual Maint. ($/1000gal)		$0.11	$0.11	$0.11	$0.11
Annual O&M ($/year)		$317,000	$392,000	$466,000	$577,000
Annual Energy ($/1000gal)		$0.42	$0.42	$0.42	$0.42
Annual Energy ($/year)		$1,220,000	$1,523,000	$1,827,000	$2,282,000
Total Annual O&M		**$1,537,000**	**$1,915,000**	**$2,293,000**	**$2,859,000**

Table TM1-4

Factors for Interest During Construction

Construction Period	Factor
6 months	0.018333
12 months	0.038333
18 months	0.058333
24 months	0.078333
36 months	0.118333
48 months	0.158333

Appendix C: Deferral of Potable Water Distribution Capacity Expansion

Inflation Rate	4.0%
Financing Period (years)	20
Loan/bond Interest Rate	5.5%
Investment Return Rate	5.0%

	Southwest WTP				
	Capital Cost	**2016 Debt Service**	**2017 Debt Service**	**Benefit of Deferral**	**2007 Benefit of Deferral**
2005	$42,702,000				
2006	$44,410,080				
2007	$46,186,483				
2008	$48,033,943				
2009	$49,955,300				
2010	$51,953,512				
2011	$54,031,653				
2012	$56,192,919				
2013	$58,440,636				
2014	$60,778,261				
2015	$63,209,391				
2016	$65,737,767	$5,500,892		$5,500,892	$3,545,924
2017	$68,367,278	$5,500,892	$5,720,928	($220,036)	($135,083)
2018	$71,101,969	$5,500,892	$5,720,928	($220,036)	($128,650)
2019		$5,500,892	$5,720,928	($220,036)	($122,524)
2020		$5,500,892	$5,720,928	($220,036)	($116,690)
2021		$5,500,892	$5,720,928	($220,036)	($111,133)
2022		$5,500,892	$5,720,928	($220,036)	($105,841)
2023		$5,500,892	$5,720,928	($220,036)	($100,801)
2024		$5,500,892	$5,720,928	($220,036)	($96,001)
2025		$5,500,892	$5,720,928	($220,036)	($91,429)
2026		$5,500,892	$5,720,928	($220,036)	($87,076)
2027		$5,500,892	$5,720,928	($220,036)	($82,929)
2028		$5,500,892	$5,720,928	($220,036)	($78,980)
2029		$5,500,892	$5,720,928	($220,036)	($75,219)
2030		$5,500,892	$5,720,928	($220,036)	($71,637)
2031		$5,500,892	$5,720,928	($220,036)	($68,226)
2032		$5,500,892	$5,720,928	($220,036)	($64,977)
2033		$5,500,892	$5,720,928	($220,036)	($61,883)
2034		$5,500,892	$5,720,928	($220,036)	($58,936)
2035		$5,500,892	$5,720,928	($220,036)	($56,130)
2036			$5,720,928	($5,720,928)	($1,389,878)
2037				$0	$0
2040				$0	$0
2041				$0	$0
2042				$0	$0
2043				$0	$0
2044				$0	$0
2045				$0	$0
2046				$0	$0
TOTAL		$110,017,846	$114,418,560	($4,400,714)	$441,901

Inflation Rate	4.0%
Financing Period (years)	20
Loan/bond Interest Rate	5.5%
Investment Return Rate	5.0%

	Eagle Mountain WTP Expansion; Expand High Service PS 1				
	Capital Cost	**2018 Debt Service**	**2019 Debt Service**	**Benefit of Deferral**	**2007 Benefit of Deferral**
2005	$56,160,000				
2006	$58,406,400				
2007	$60,742,656				
2008	$63,172,362				
2009	$65,699,257				
2010	$68,327,227				
2011	$71,060,316				
2012	$73,902,729				
2013	$76,858,838				
2014	$79,933,191				
2015	$83,130,519				
2016	$86,455,740				
2017	$89,913,969				
2018	$93,510,528	$7,824,898		$7,824,898	$4,575,056
2019	$97,250,949	$7,824,898	$8,137,894	($312,996)	($174,288)
2020	$101,140,987	$7,824,898	$8,137,894	($312,996)	($165,988)
2021	$105,186,627	$7,824,898	$8,137,894	($312,996)	($158,084)
2022		$7,824,898	$8,137,894	($312,996)	($150,556)
2023		$7,824,898	$8,137,894	($312,996)	($143,387)
2024		$7,824,898	$8,137,894	($312,996)	($136,559)
2025		$7,824,898	$8,137,894	($312,996)	($130,056)
2026		$7,824,898	$8,137,894	($312,996)	($123,863)
2027		$7,824,898	$8,137,894	($312,996)	($117,965)
2028		$7,824,898	$8,137,894	($312,996)	($112,348)
2029		$7,824,898	$8,137,894	($312,996)	($106,998)
2030		$7,824,898	$8,137,894	($312,996)	($101,902)
2031		$7,824,898	$8,137,894	($312,996)	($97,050)
2032		$7,824,898	$8,137,894	($312,996)	($92,429)
2033		$7,824,898	$8,137,894	($312,996)	($88,027)
2034		$7,824,898	$8,137,894	($312,996)	($83,835)
2035		$7,824,898	$8,137,894	($312,996)	($79,843)
2036		$7,824,898	$8,137,894	($312,996)	($76,041)
2037		$7,824,898	$8,137,894	($312,996)	($72,420)
2040				$0	$0
2041				$0	$0
2042				$0	$0
2043				$0	$0
2044				$0	$0
2045				$0	$0
2046				$0	$0
TOTAL		$156,497,967	$162,757,886	($6,259,919)	$570,153

Inflation Rate	4.0%
Financing Period (years)	20
Loan/bond Interest Rate	5.5%
Investment Return Rate	5.0%

	Expand Northwest WTP and High Service PS				
	Capital Cost	**2020 Debt Service**	**2022 Debt Service**	**Benefit of Deferral**	**2007 Benefit of Deferral**
2005	$51,246,000				
2006	$53,295,840				
2007	$55,427,674				
2008	$57,644,781				
2009	$59,950,572				
2010	$62,348,595				
2011	$64,842,538				
2012	$67,436,240				
2013	$70,133,690				
2014	$72,939,037				
2015	$75,856,599				
2016	$78,890,863				
2017	$82,046,497				
2018	$85,328,357				
2019	$88,741,491				
2020	$92,291,151	$7,722,862		$7,722,862	$4,095,598
2021	$95,982,797	$7,722,862		$7,722,862	$3,900,570
2022	$99,822,109	$7,722,862	$8,353,047	($630,186)	($303,130)
2023	$103,814,993	$7,722,862	$8,353,047	($630,186)	($288,695)
2024	$107,967,593	$7,722,862	$8,353,047	($630,186)	($274,948)
2025		$7,722,862	$8,353,047	($630,186)	($261,855)
2026		$7,722,862	$8,353,047	($630,186)	($249,386)
2027		$7,722,862	$8,353,047	($630,186)	($237,510)
2028		$7,722,862	$8,353,047	($630,186)	($226,200)
2029		$7,722,862	$8,353,047	($630,186)	($215,429)
2030		$7,722,862	$8,353,047	($630,186)	($205,170)
2031		$7,722,862	$8,353,047	($630,186)	($195,400)
2032		$7,722,862	$8,353,047	($630,186)	($186,096)
2033		$7,722,862	$8,353,047	($630,186)	($177,234)
2034		$7,722,862	$8,353,047	($630,186)	($168,794)
2035		$7,722,862	$8,353,047	($630,186)	($160,756)
2036		$7,722,862	$8,353,047	($630,186)	($153,101)
2037		$7,722,862	$8,353,047	($630,186)	($145,811)
2040			$8,353,047	($8,353,047)	($1,669,545)
2041			$8,353,047	($8,353,047)	($1,590,043)
2042				$0	$0
2043				$0	$0
2044				$0	$0
2045				$0	$0
2046				$0	$0
TOTAL		$154,457,233	$167,060,944	($12,603,710)	$1,015,943

Inflation Rate	4.0%
Financing Period (years)	20
Loan/bond Interest Rate	5.5%
Investment Return Rate	5.0%

	Eagle Mountain WTP Expansion; Expand High Service PS 2				
	Capital Cost	**2023 Debt Service**	**2025 Debt Service**	**Benefit of Deferral**	**2007 Benefit of Deferral**
2005	$109,512,000				
2006	$113,892,480				
2007	$118,448,179				
2008	$123,186,106				
2009	$128,113,551				
2010	$133,238,093				
2011	$138,567,616				
2012	$144,110,321				
2013	$149,874,734				
2014	$155,869,723				
2015	$162,104,512				
2016	$168,588,693				
2017	$175,332,240				
2018	$182,345,530				
2019	$189,639,351				
2020	$197,224,925				
2021	$205,113,922				
2022	$213,318,479				
2023	$221,851,218	$18,564,361		$18,564,361	$8,504,548
2024	$230,725,267	$18,564,361		$18,564,361	$8,099,569
2025	$239,954,278	$18,564,361	$20,079,213	($1,514,852)	($629,452)
2026	$249,552,449	$18,564,361	$20,079,213	($1,514,852)	($599,478)
2027	$259,534,547	$18,564,361	$20,079,213	($1,514,852)	($570,932)
2028		$18,564,361	$20,079,213	($1,514,852)	($543,745)
2029		$18,564,361	$20,079,213	($1,514,852)	($517,852)
2030		$18,564,361	$20,079,213	($1,514,852)	($493,192)
2031		$18,564,361	$20,079,213	($1,514,852)	($469,707)
2032		$18,564,361	$20,079,213	($1,514,852)	($447,340)
2033		$18,564,361	$20,079,213	($1,514,852)	($426,038)
2034		$18,564,361	$20,079,213	($1,514,852)	($405,751)
2035		$18,564,361	$20,079,213	($1,514,852)	($386,429)
2036		$18,564,361	$20,079,213	($1,514,852)	($368,028)
2037		$18,564,361	$20,079,213	($1,514,852)	($350,503)
2040		$18,564,361	$20,079,213	($1,514,852)	($302,777)
2041		$18,564,361	$20,079,213	($1,514,852)	($288,359)
2042		$18,564,361	$20,079,213	($1,514,852)	($274,628)
2043			$20,079,213	($20,079,213)	($3,466,825)
2044			$20,079,213	($20,079,213)	($3,301,738)
2045				$0	$0
2046				$0	$0
TOTAL		$371,287,226	$401,584,264	($30,297,038)	$2,109,615

Inflation Rate	4.0%
Financing Period (years)	20
Loan/bond Interest Rate	5.5%
Investment Return Rate	5.0%

	Summary of All Projects				
	Capital Cost	**2023 Debt Service**	**2025 Debt Service**	**Benefit of Deferral**	**2007 Benefit of Deferral**
2005	$259,620,000				
2006	$270,004,800				
2007	$280,804,992				
2008	$292,037,192				
2009	$303,718,679				
2010	$315,867,427				
2011	$328,502,124				
2012	$341,642,209				
2013	$355,307,897				
2014	$369,520,213				
2015	$384,301,021				
2016	$399,673,062	$5,500,892		$5,500,892	$3,545,924
2017	$415,659,985	$5,500,892	$5,720,928	($220,036)	($135,083)
2018	$432,286,384	$13,325,791	$5,720,928	$7,604,863	$4,446,406
2019	$375,631,792	$13,325,791	$13,858,822	($533,032)	($296,812)
2020	$390,657,063	$21,048,652	$13,858,822	$7,189,830	$3,812,920
2021	$406,283,346	$21,048,652	$13,858,822	$7,189,830	$3,631,353
2022	$313,140,588	$21,048,652	$22,211,869	($1,163,217)	($559,527)
2023	$325,666,211	$39,613,014	$22,211,869	$17,401,144	$7,971,665
2024	$338,692,860	$39,613,014	$22,211,869	$17,401,144	$7,592,062
2025	$239,954,278	$39,613,014	$42,291,083	($2,678,069)	($1,112,793)
2026	$249,552,449	$39,613,014	$42,291,083	($2,678,069)	($1,059,803)
2027	$259,534,547	$39,613,014	$42,291,083	($2,678,069)	($1,009,336)
2028		$39,613,014	$42,291,083	($2,678,069)	($961,272)
2029		$39,613,014	$42,291,083	($2,678,069)	($915,498)
2030		$39,613,014	$42,291,083	($2,678,069)	($871,902)
2031		$39,613,014	$42,291,083	($2,678,069)	($830,383)
2032		$39,613,014	$42,291,083	($2,678,069)	($790,841)
2033		$39,613,014	$42,291,083	($2,678,069)	($753,182)
2034		$39,613,014	$42,291,083	($2,678,069)	($717,316)
2035		$39,613,014	$42,291,083	($2,678,069)	($683,158)
2036		$34,112,121	$42,291,083	($8,178,961)	($1,987,049)
2037		$34,112,121	$36,570,155	($2,458,033)	($568,733)
2040		$18,564,361	$28,432,260	($9,867,899)	($1,972,322)
2041		$18,564,361	$28,432,260	($9,867,899)	($1,878,402)
2042		$18,564,361	$20,079,213	($1,514,852)	($274,628)
2043			$20,079,213	($20,079,213)	($3,466,825)
2044			$20,079,213	($20,079,213)	($3,301,738)
2045				$0	$0
2046				$0	$0
TOTAL		$792,260,273	$845,821,653	($53,561,380)	$4,137,612

Appendix D: Response to TWDB Comments on Direct, Non-Potable Reuse Guidance Document

Response to TWDB Comments on Draft Direct, Non-Potable Reuse Guidance Document

The Region C Water Planning Group (RCWPG) received written comments from the Texas Water Development Board (TWDB). Each TWDB comment is listed in italicized text below and followed with the RCWPG response.

a. *In addition to submitting an electronic copy of the final report, please submit electronic copies of all appendices as well as all figures in the report, as required by the contract between TWDB and Region C.*

   Electronic copies of all materials in the final report will be submitted to the TWDB.

b. *Blank pages are present throughout the report. Please remove the blank pages in the final report.*

   All blank pages have been removed in the final report.

c. *Scope of Work Task 2 Item D states that the study will gather and analyze data required to determine the cost avoidance/deferment associated with each of the benefits identified for the selected Water Reuse projects. The report did not appear to address this requirement. Please include this analysis in the final report.*

   Additional cost avoidance/deferral information has been added to Section 9.3 and Appendix C.

d. *Page ES-1 of the Executive Summary and Page 1-1 of the Introduction state that the 2006 Region C Water Plan projects that reuse of reclaimed water will supply 874,417 acre-feet/year in 2060. However, the Region C Water Plan states on page 4B.20 that the volume of reuse recommended in Region C is 795,466 acre-feet/year in 2060. Please clarify this discrepancy in the final report.*

Table D-1 shows projected 2060 reuse supplies obtained from the *2006 Region C Water Plan*. The 2006 Plan recommends development of 795,466 acre-feet per year (ac-ft/yr) of new Region C reuse supplies by 2060.[62] Of this amount, approximately 770,998 ac-ft/yr would be used in Region C, with the remainder being used in other regions. The projected 2060 Region C supply from currently available reuse sources is 103,429 ac-ft/yr.[63] Therefore, the total projected 2060 reuse supply to be used in Region C, from currently available and recommended new sources, is 874,417 ac-ft/yr.

Table D-1: Projected 2060 Reuse Supply for Region C

Item	Quantity (ac-ft/yr)	Calculation
Recommended Water Reuse Projects in Region C[62]		
Total Reuse Projects in Region C	795,466	[A]
Total Amount Used in Region C	770,998	[B]
Currently Available Reuse Supplies Used in Region C[63]	103,429	[C]
Total Projected Reuse Supply Used in Region C	874,417	[B]+[C]

The text on pages ES-1 and 1-1 has been modified to clarify that the 874,417 ac-ft/yr would be supplied to Region C water user groups.

e. *In Chapter 4 on Page 4-7 and 4-8, the most common unit used for expressing hardness and alkalinity is mg/L as CaCO3. However, instead of reporting the hardness values in mg/L as CaCO3, the report expressed the values in mg/L. Please clarify the constituent being reported for total hardness.*

The units for total hardness and total alkalinity have been changed from mg/l to mg/l as $CaCO_3$.

---

[62] Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel & Yerby, Inc., and Cooksey Communications, Inc., January 2006. *2006 Region C Water Plan*, prepared for the Region C Water Planning Group, Fort Worth. Table 4B.6, Page 4B.20.

[63] *2006 Region C Water Plan*, Table 3.1, Page 3.2.

f. *In Chapter 4, according to Figure 4-4, the values of hardness were greater than 150 mg/L from Jun-05 to Jun-06. However, for Jul-06 and Aug-06, the values of hardness were zero. Please review the figure to confirm the results shown or clarify the results in the text.*

   Figure 4-4 has been corrected, and explanatory text has been added to the figure.

g. *In Chapter 7, beginning on Page 7-2, within the discussion and comparison of the different advanced treatment technologies and conventional treatment technologies, it is important to know whether the advanced technologies and conventional technologies have the same treatment capacities. During the discussion of BAF, IFAS, MBBR, SBRs, MBRs, and UV light disinfection, please consider including a comparison of the capacities of these technologies with the capacities of conventional technologies.*

   Verbal clarification of this comment indicates that it is addressed toward the relative treatment efficiencies of the various treatment technologies. In Section 7.4, the text describes various advanced treatment technologies as having a smaller footprint or not requiring a clarifier. These are indications that the advanced treatment technology has greater efficiency than conventional facilities with respect to the space required for the facilities. Using this definition of efficiency, the efficiency of the advanced treatment technologies relative to conventional technology are summarized in a qualitative fashion in Table 7-2.

h. *In Chapter 7, beginning on Page 7-2, the report compares the cost of BAFs, MBRs, and UV light disinfection with the cost of conventional treatment technologies. However, the cost of IFAs, MBBRs, and SBRs were not compared with the cost of conventional treatment technologies. Please consider including a comparison of the costs of IFAs, MBBRs, and SBRs with the cost of conventional treatment technologies in the final report.*

   Additional text has been added to Section 7.4 to compare the costs of IFAS, MMBRs, and SBRs with conventional treatment technologies.

i. *Table 7-1 has a table heading titled, “Insert into Conventional Facilities”. The Title is confusing. Please clarify or reconsider the title of this heading.*

Column headings for Table 7-1 have been changed for clarity.

j. *In Chapter 7, it would be useful to include a table that summarizes the advantages and disadvantages of the different advanced treatment technologies. Please consider adding a Table in Section 7.4 with this information in the final report.*

Table 7-3, which summarizes the advantages and disadvantages of the advanced wastewater treatment technologies, has been added to Section 7.4.