INDIRECT REUSE GUIDANCE DOCUMENT

APRIL 2009

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ES. Executive Summary

Reuse of treated municipal 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, reuse of reclaimed water would supply 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. A number of reuse projects currently operate in Region C, and many others are 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 implementing indirect reuse[3] projects. This guidance document identifies technical and regulatory issues to be addressed in the planning and design of the augmentation of surface water supplies with reclaimed water. Chapters 2 and 3 consist entirely of guidance information; guidance is included in the first section of other chapters.

To serve as a case study for the guidance document, the RCWPG also developed an implementation plan for a specific, recommended indirect reuse strategy. The *2006 Region C Water Plan* recommended that the Athens Municipal Water Authority (AMWA) and the City of Athens (Athens) construct facilities to transport reclaimed water from the Athens wastewater treatment plants (WWTPs) to Lake Athens to augment the raw water supply. After blending, detention, diversion, and water treatment, the reclaimed water would be used for municipal, livestock, irrigation, and manufacturing purposes.

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[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] Indirect reuse occurs when treated wastewater effluent is discharged to a stream or reservoir and is diverted at a downstream location for reuse. The discharged water mixes with ambient water in the stream or reservoir as it travels to the point of diversion.

The next sections address regulations regarding indirect reuse in Texas, general recommendations for indirect reuse in Texas, and the following topics for the Athens indirect reuse project: receiving water body quality, receiving water body hydrology, polishing treatment of the reclaimed water, direct reuse opportunities, conceptual design of the reclaimed water conveyance system, opinions of probable cost, permitting issues, the preferred indirect reuse alternative, and the implementation plan.

ES.1. Texas Regulations Regarding Indirect Reuse

Since planned augmentation of raw water supplies with reclaimed water is relatively new in Texas, the state does not have regulations that specifically address indirect reuse. Instead, elements of an indirect reuse project are regulated by other state permits and standards, including water rights permits, Texas Pollutant Discharge Elimination System (TPDES) discharge permits, and the Texas Surface Water Quality Standards (TSWQS).[4] In addition, potable water quality is regulated by the secondary drinking water standards in the National Secondary Drinking Water Regulations[5] and the state Public Drinking Water Standards.[6,7]

ES.2. General Recommendations for Indirect Reuse in Texas

Augmentation of raw water supply with reclaimed water is becoming an accepted practice. However, since the science used to evaluate this practice is still emerging, conservative operational limits should be established to protect receiving water quality and public health. Therefore, the RCWPG recommends a multiple-barrier approach (Figure ES-1) to managing the uncertainties associated with augmenting raw water supplies with reclaimed water. The multiple barriers include advanced wastewater treatment, limits on the blend of reclaimed and natural water, requirements on the detention time in the receiving water, and advanced water treatment.

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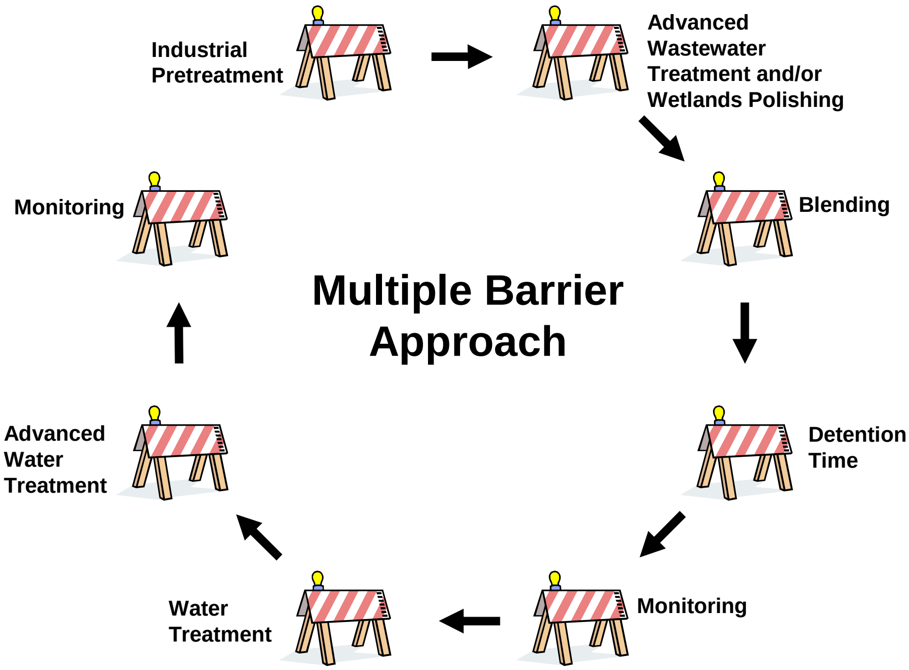
[4] Texas Administrative Code, Chapter 307.

[5] Code of Federal Regulations, Title 40, Part 143, Section 143.3

[6] Texas Administrative Code, Title 30 Chapter 290.118.

[7] The Federal secondary drinking water standard for total dissolved solids (500 mg/l) is not Federally enforceable and is intended as a guideline. The State secondary drinking water standard for TDS (1,000 mg/l) is binding, but permission to continue using water that exceeds this concentration can be obtained from the TCEQ under certain circumstances. The secondary drinking water standards could be significant for some indirect reuse projects.

Figure ES-1 Schematic Representation of the Multiple Barrier Approach



Advanced Wastewater Treatment

Based on the TSWQS for TDS, chlorides, and sulfates and based on probable future limitations on nutrient loadings to reservoirs to be implemented by the Texas Commission on Environmental Quality (TCEQ), advanced wastewater treatment for raw water supply augmentation may include processes that provide for desalination and nutrient removal. Site-specific target reclaimed water concentrations for TDS, chlorides, and sulfates should be developed based on the TSWQS and projected impacts to lake water quality. If needed or desired, advanced treatment could involve the following methods:

- Biological/chemical treatment processes at the wastewater treatment plant (WWTP),
- Treatment with a constructed treatment wetland, and/or
- Membrane filtration and advanced oxidation at the WWTP.

Blending

Blending describes the process of mixing reclaimed water with natural water in the receiving water body. Blending acts as a barrier by diluting constituents in the reclaimed water (assuming that the concentrations are lower in the natural water). For a reservoir, the blend percentage (or percent blend) is the ratio of the volume of reclaimed water stored in the reservoir to the total volume of water stored. For a stream, the blend percentage is the ratio of the volume of the reclaimed water augmentation rate to the total flow in the stream (natural and reclaimed water). Blending targets should be selected on a case-by-case basis with consideration given to site-specific conditions and the multiple barriers that are applied.

Detention Time

For a reservoir, detention time is a measure of the amount of time that water is stored prior to being withdrawn or released downstream. For a stream, the detention time is the travel time from the discharge location to the diversion location. Storage of reclaimed water for an extended period is an extremely important barrier because it provides the opportunity for natural attenuation processes (including physical, chemical, and biological processes) to act on constituents within the reclaimed water prior to subsequent reuse. A higher blend of reclaimed water warrants a longer detention time. Detention time targets should be selected on a case-by-case basis with consideration given to site-specific conditions and the multiple barriers that are applied.

Water Treatment

Water treatment provides the final treatment barrier prior to introduction of the reclaimed water to the potable water supply system. Most conventional water treatment trains provide appropriate protection for constituents that are regulated through state and federal drinking water standards. This level of treatment is generally adequate for reclaimed water augmentation programs using multiple barriers as described here. However, as with the wastewater treatment system, the appropriate water treatment system should be evaluated on a case-by-case basis to identify any specific water quality characteristics that may require special consideration. Some advanced water treatment processes include carbon filtration, biologically active carbon filtration, membrane processes, ion exchange, ozonation, and ultraviolet light (UV)/peroxide disinfection.

Monitoring

Monitoring is the process of collecting and analyzing water quality data from various components of the reclaimed water system. The monitoring and testing program should characterize the water quality of the reclaimed water; the receiving water; raw water at intakes; and treated, potable water. In addition to traditional water quality parameters, this program should consider addressing emerging microconstituents of concern, those constituents that have been identified as potential concerns with respect to potable use of reclaimed water (e.g., pharmaceuticals, endocrine disruptors, NDMA, etc.). Monitoring data can be used to evaluate treatment effectiveness and to identify any changes in water quality that may require physical or operational modifications to the reuse system. The monitoring barrier provides a feedback mechanism that allows changes within the system to be identified and evaluated before they develop into problems for the water utility.

ES.3. Athens Municipal Water Authority Indirect Reuse Project

To serve as a case study for this guidance document, an implementation plan for a specific, recommended indirect reuse strategy has been developed. The *2006 Region C Water Plan* recommended that AMWA and Athens construct facilities to transport reclaimed water from the Athens WWTPs to Lake Athens to augment the raw water supply. After blending, detention, diversion, and water treatment, the reclaimed water would be used for municipal, livestock, irrigation, and manufacturing purposes. For this study, specific targets for blend percentage, detention time, approach to treatment, and other factors have been selected based on specific considerations relevant to the AMWA project. As indicated above, targets selected for other projects should be established on a case-by-case basis.

Water Quality Evaluation for Lake Athens

Water quality data were obtained from the TCEQ for Lake Athens, from the City of Athens for treated effluent from the North WWTP and West WWTP, and from the Texas Department of Parks and Wildlife's Texas Freshwater Fisheries Center (TFFC) for effluent from TFFC operations (Table ES-1).

Currently, the City of Athens treats municipal wastewater at its North and West WWTPs. The maximum permitted annual average flowrates are 1.027 million gallons per day (mgd) at the North WWTP and 1.367 mgd at the West WWTP. As of December 2007, the annual average flowrates were approximately 0.82 mgd (or 917 ac-ft/yr) at the West WWTP and 0.50 mgd (or 565 ac-ft/yr) at the North WWTP.

Table ES-1
Summary of Lake Athens, WWTP Effluent, and TFFC Effluent Water Quality Data

Constituent	Units	Average Concentration			Target Maximum Concentrations[b]
		Lake Athens[a]	WWTP Effluent	TFFC Effluent	
Total Nitrogen[c]	mg/l	0.57			
Total Phosphorus	mg/l	<0.05	2.91	0.09	
Chlorophyll-a	μg/l	<10			
Total Dissolved Solids	mg/l	62	304		200
Chlorides	mg/l	11			50
Sulfates	mg/l	6			50
Ammonia	mg/l		0.29/0.44[d]	0.13	
Nitrate	mg/l		14.9	0.10	
Nitrite	mg/l			0.01	

[a]From TCEQ water quality data.
[b]The TCEQ does not specify numerical surface water quality standards for Lake Athens. Instead, the consultants have assumed that the target maximum concentrations will be those of the closest downstream segment (Lake Palestine) for which the TCEQ does specify numerical surface water quality standards (Texas Administrative Code, Chapter 307). These standards are applied to annual average concentrations.
[c]Estimated from sum of species concentrations. Where values were below detection limits, half of the detection limit was used in the estimate.
[d]At the North WWTP and West WWTP, respectively. All other WWTP effluent concentrations at the North WWTP.

The TFFC is a "concentrated aquatic animal production" facility.[8] The TFFC wastewater flows through two settling ponds, a 1-millimeter screen, a Parshall flume, and a rock-lined channel before being discharged to an unnamed tributary of Lake Athens a short distance upstream of the lake.

Estimation of Allowable Reclaimed Water Augmentation Rates for Lake Athens

A spreadsheet-based, monthly water balance was developed for Lake Athens to project reclaimed water blends, detention times, and TDS, chlorides, and sulfates concentrations. The water balance incorporated the following information:

[8] Texas General Permit TXG130004

- Historical inflows, outflows, and water surface elevations for 1940 through 1996;
- Projected reservoir elevation-area-volume relationships that include the effects of sedimentation;
- Projected water demands; and
- Projected reclaimed water augmentation rates.

The water balance was used to evaluate the impacts on raw water volume, yield, and quality of various reclaimed water augmentation rates under future demand and operational scenarios. Results based on the maximum blend of reclaimed water to natural water, the minimum detention time of reclaimed water, and the maximum annual average TDS concentration are summarized in Table ES-2.

Polishing Treatment of the Athens Reclaimed Water

The North WWTP and the West WWTP are activated sludge process plants operated in the extended aeration mode. Potential polishing treatment methods include a constructed treatment wetland, a combination of denitrification filters and chemical precipitation of phosphorus (DF/CP), and a combination of membrane treatment and advanced oxidation.

Constructed treatment wetlands are useful for removing nitrogen and phosphorus from WWTP effluent before introducing it as reclaimed water into a reservoir. Potential constructed treatment wetland sites are shown in Figure ES-2. Nitrogen removal can be achieved through the use of denitrification filters, and phosphorus removal can be achieved through chemical precipitation. The combination of membrane filtration and advanced oxidation removes phosphorus, nitrogen, TDS, chlorides, and sulfates; provides enhanced disinfection; and addresses emerging microconstituents of concern.

Twelve different polishing treatment scenarios were evaluated (Table ES-3), with various combinations of limiting conditions, realization of the target maximum annual average TDS concentration of 200 mg/l, and polishing treatment facilities.

Table ES-2
Summary of Various Limiting Scenarios, Feasibility, and Recommended Treatment

Limiting Condition	2060 Reclaimed Water Augmentation Rate (mgd)	Year When Demand Projected to Exceed Supply	Feasibility	Minimum Recommended Treatment
Total Reclaimed Water Supply	3.09	After 2060	Not feasible due to high percent blends and low detention times	n/a
431 Feet Minimum WSEL	2.88	After 2060	Not feasible due to low detention times	n/a
Minimum Detention Time Target	2.11	2051	Feasible	Membrane filtration and advanced oxidation of all reclaimed water for augmentation for augmentation rates where the maximum blend is projected to be greater than 50 percent. Otherwise, advanced nutrient removal from all reclaimed water for augmentation. Options for addressing potential TDS issues for augmentation rates where the maximum blend is projected to be 50 percent or less include: • Providing membrane filtration to remove TDS from a side stream of the reclaimed water used for augmentation and/or • Site-specific TSWQS for Lake Athens.[a]
50 Percent Maximum Blend Target	1.73	2046	Feasible	Advanced nutrient removal from all reclaimed water for augmentation. Options for addressing potential TDS issues include: • Providing membrane filtration to remove TDS from a side stream of the reclaimed water used for augmentation and/or • Site-specific TSWQS for Lake Athens.[a]

Table ES-2: Summary of Various Limiting Scenarios, Feasibility, and Recommended Treatment (Continued)

Limiting Condition	2060 Reclaimed Water Augmentation Rate (mgd)	Year When Demand Projected to Exceed Supply	Feasibility	Minimum Recommended Treatment
200 mg/l Maximum Annual Average TDS	1.14	2036	Feasible	Advanced nutrient removal from all reclaimed water for augmentation The target TDS limit would be met through a reduced reclaimed water augmentation rate.

[a] See discussion of TDS issues in Sections 5.6 and 9.3.

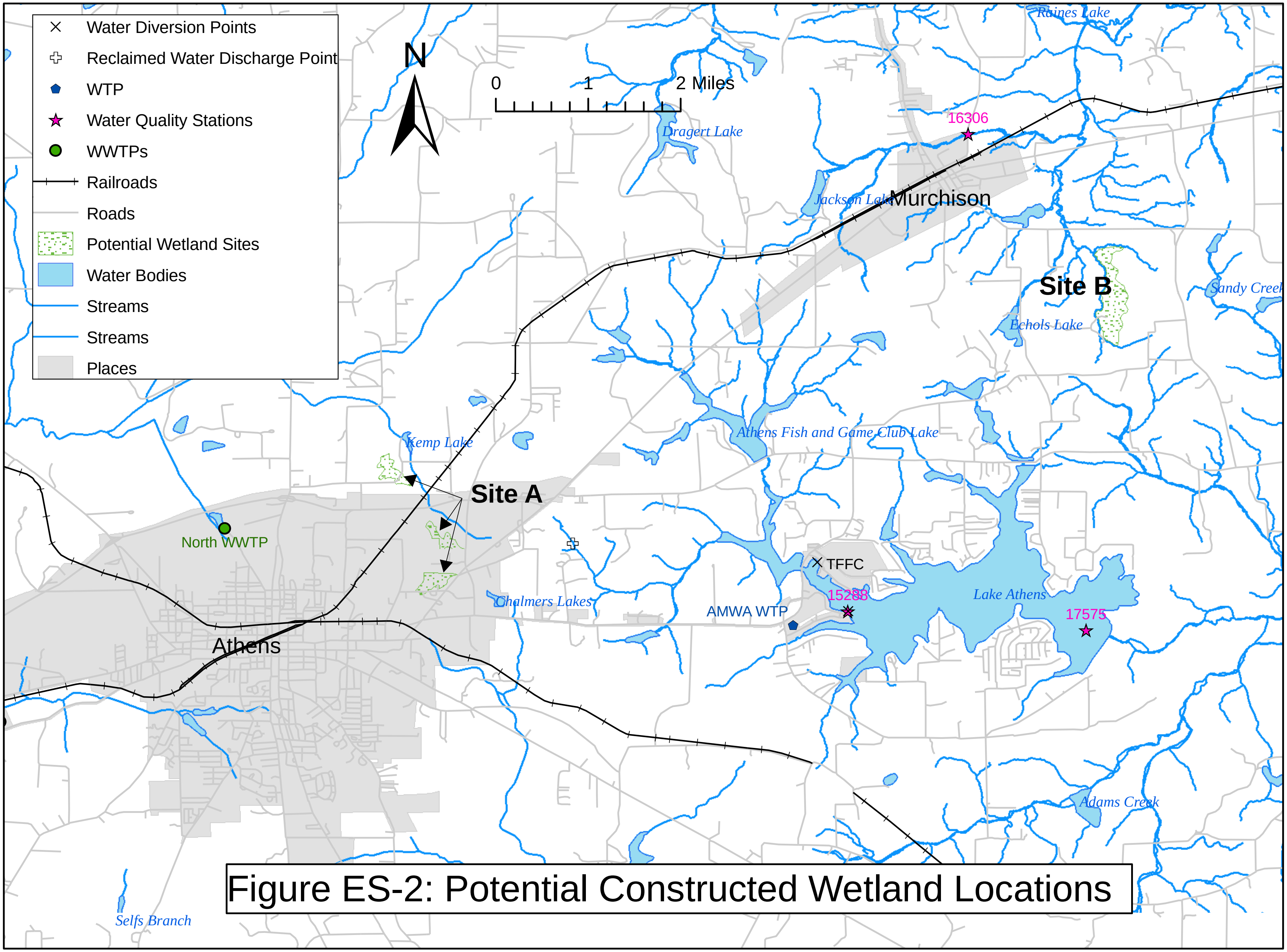


Figure ES-2: Potential Constructed Wetland Locations

Table ES-3
Polishing Treatment Scenarios

Treatment Scenario Number	Limiting Condition in Lake Athens	TDS Target 200 mg/l?	Treatment Choice	Lake Athens Augmentation Flowrate (mgd)	Comment
1	200 mg/l TDS	Yes	Denitrifying Filters/Chemical Precipitation	1.14	
2	200 mg/l TDS	Yes	Wetland Site A[a]	1.09	Augmentation flowrate limited by available size of Wetland Site A
3	200 mg/l TDS	Yes	Wetland Site B[a]	1.14	
4	200 mg/l TDS	Yes	Sidestream[b] Membrane Filtration	1.14	
5	50% Maximum Blend	No	Denitrifying Filters/Chemical Precipitation	1.73	
6	50% Maximum Blend	No	Wetland Site A	1.65	Augmentation flowrate limited by available size of Wetland Site A
7	50% Maximum Blend	No	Wetland Site B	1.73	
8	50% Maximum Blend	Yes	Sidestream Membrane Filtration	1.73	
9	50% Maximum Blend	Yes	Denitrifying Filters/Chemical Precipitation + Sidestream Membrane Filtration	1.73	
10	50% Maximum Blend	Yes	Wetland Site A + Sidestream Membrane Filtration	1.73	
11	50% Maximum Blend	Yes	Wetland Site B + Sidestream Membrane Filtration	1.73	
12	Min. Detention Time	Yes	Full Membrane Filtration + Advanced Oxidation	2.11	

[a]Wetland Site A and Wetland Site B refer to two potential sites for a constructed treatment wetland. These are discussed in detail in Chapter 6.4.

[b]Sidestream membrane filtration means that a portion of the total reclaimed water is polished with membrane filtration.

Direct Reuse Opportunities in Athens

The only obvious possibility for direct reuse within the vicinity of the pipeline route is irrigation of the Oak Lawn Cemetery. There may be potential for irrigation of agricultural land along the pipeline route, depending on the land use and the reclaimed water quality, but more advanced screening is necessary to develop this information.

Conceptual Design of Athens Reclaimed Water Conveyance System

Considerations in the design of the reclaimed water conveyance system included timing of water needs, blending and detention time in Lake Athens, and the polishing treatment alternative. Three sets of pipeline routes were identified based on these considerations.

Opinions of Probable Cost for Athens Indirect Reuse

The most cost-effective indirect reuse scenarios (Table ES-4 and Figures ES-3 and ES-4) are Scenario 5, in which denitrification filters and chemical precipitation facilities at each WWTP would remove nutrients from all wastewater, followed closely by Scenario 7, in which nutrients would be removed from the reclaimed water with a constructed treatment wetland at Wetland Site B. Both scenarios would allow augmentation of Lake Athens with up to 1.73 mgd of reclaimed water. The probable weighted unit cost[9] for each of these scenarios is $1.71 per thousand gallons. The probable unit net present values[10] for Scenarios 5 and 7 are $7.45 million per mgd and $8.02 million per mgd, respectively. The total difference in net present value between these scenarios is approximately $1 million. These costs include polishing treatment and transport of the polished reclaimed water to Lake Athens.

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[9] The probable weighted unit cost was estimated as the sum of the probable annual costs for 50 years divided by the projected total supply for the same period.

[10] The probable unit net present value was estimated as the sum of the discounted probable annual costs for 50 years divided by the augmentation rate. In consultation with AMWA, an interest rate of 0 percent per year and a discount rate of 5 percent per year were used.

Table ES-4
Opinions of Probable Cost

Treatment Scenario Number	Limiting Factor in Lake Athens	TDS Target 200 mg/l?	Treatment Choice	Lake Athens Aug. Rate (mgd)	Capital Cost[a] ($ millions)	Weighted Unit Cost[b] ($/1,000 gal)	Net Present Value ($ millions)	Unit Net Present Value[c] ($ millions /mgd)
1	200 mg/l TDS	Yes	Denitrifying Filters/Chemical Precipitation	1.14	$10.87	$2.22	$11.65	$10.22
2	200 mg/l TDS	Yes	Wetland Site A[d]	1.09	$14.32	$2.32	$12.67	$11.62
3	200 mg/l TDS	Yes	Wetland Site B[d]	1.14	$11.84	$1.92	$11.30	$9.92
4	200 mg/l TDS	Yes	Sidestream[e] Membrane Filtration	1.14	$19.31	$3.43	$21.04	$18.46
5	50% Maximum Blend	No	Denitrifying Filters/Chemical Precipitation	1.73	$11.89	$1.71	$12.88	$7.45
6	50% Maximum Blend	No	Wetland Site A	1.65	$24.07	$2.75	$16.56	$10.04
7	50% Maximum Blend	No	Wetland Site B	1.73	$14.71	$1.71	$13.88	$8.02
8	50% Maximum Blend	Yes	Sidestream Membrane Filtration	1.73	$20.24	$2.80	$23.42	$13.54
9	50% Maximum Blend	Yes	Denitrifying Filters/Chemical Precipitation + Sidestream Membrane Filtration	1.73	$22.11	$2.88	$23.54	$13.63
10	50% Maximum Blend	Yes	Wetland Site A + Sidestream Membrane Filtration	1.73	$28.23	$3.41	$25.37	$14.69
11	50% Maximum Blend	Yes	Wetland Site B + Sidestream Membrane Filtration	1.73	$24.20	$2.81	$24.09	$13.95
12	Min. Detention Time	Yes	Full Membrane Filtration + Advanced Oxidation	2.11	$26.27	$3.34	$32.51	$15.41

[a]These costs include polishing treatment of the reclaimed water and transport of the polished reclaimed water to Lake Athens. All costs are presented in second quarter 2007 dollars. Detailed opinions of probable cost are presented in Appendix G.

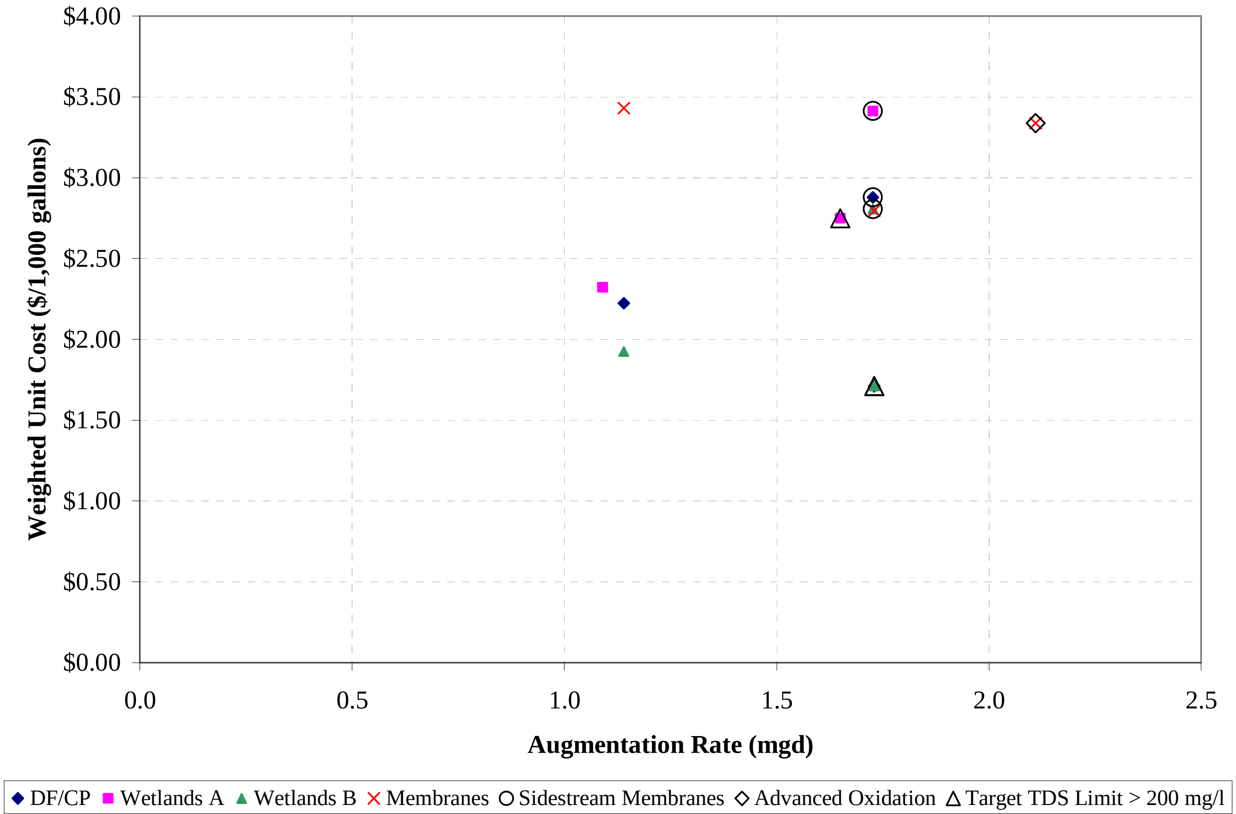
[b]The weighted unit cost represents the sum of the probable annual costs for 50 years divided by the estimated total supply volume for the same period.

[c]Net Present Value divided by the augmentation rate.

[d]Wetland Site A and Wetland Site B refer to two potential sites for a constructed treatment wetland. These are discussed in detail in Chapter 6.4.

[e]Sidestream membrane filtration means that a portion of the total reclaimed water is polished with membrane filtration.

Figure ES-3
Opinions of Probable Weighted Unit Cost



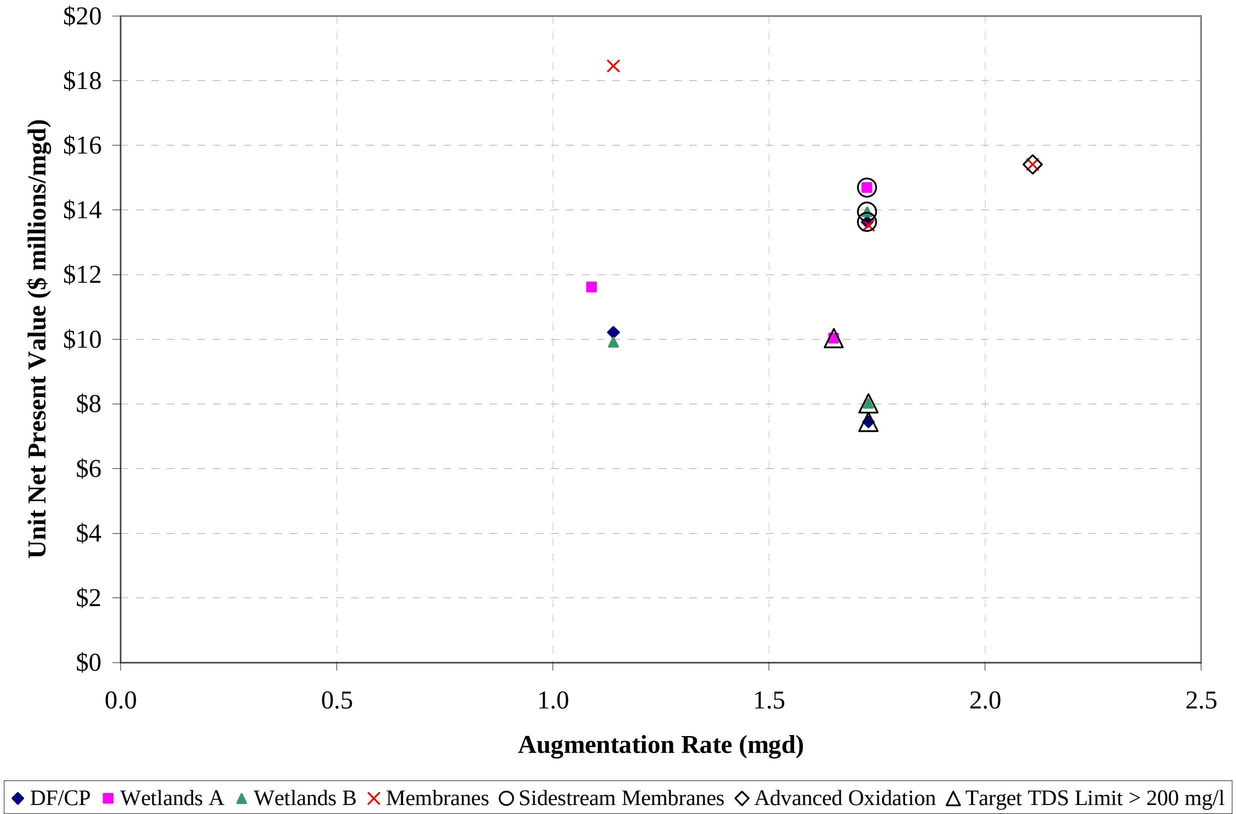
For the most cost-effective scenarios (5 and 7), a screening-level analysis suggests that the maximum annual average TDS concentration in Lake Athens during a drought-of-record situation would be approximately 259 mg/l (Table E-4).[11] Therefore, these scenarios may require one of the following actions:

- Simultaneously import raw water from another source and/or
- Develop a site-specific TSWQS limit for Lake Athens that would allow for annual average TDS concentrations greater than the target level of 200 mg/l.

The selected reclaimed water augmentation rate must comply with the TSWQS, unless there is a special situation where an amendment to the TSWQS is warranted and is granted by the TCEQ.

[11] See Chapter 5.6 for discussion of the assumptions inherent in the TDS projections.

Figure ES-4
Opinions of Probable Unit Net Present Value (Interest Rate 0%, Discount Rate 5%)



There is currently no numerical TDS standard for Lake Athens. In addition, excursions from the 200 mg/l target level are infrequent and are only projected to occur during severe drought conditions when water availability is most crucial. Finally, the projected TDS concentrations are well below the standards in the National Secondary Drinking Water Regulations[12] (500 mg/l) and the state Public Drinking Water Standards[13] (1,000 mg/l). Therefore, it may be feasible to develop a site-specific TSWQS limit for Lake Athens that would allow these scenarios. A site-specific TDS standard would have to be consistent with the intended uses of Lake Athens.

There is significant uncertainty in the screening-level projections of TDS concentrations in Lake Athens for the different Limiting Conditions. To develop a site-specific TSWQS TDS standard

[12] Code of Federal Regulations, Title 40, Part 143, Section 143.3

[13] Texas Administrative Code, Title 30 Chapter 290.105.

for Lake Athens, it would likely be necessary to monitor TDS concentrations in the reclaimed water, Lake Athens, the TFFC return flow, and tributary inflows and to construct a more detailed TDS model.

Should Scenarios 5 and 7 prove infeasible, the next most cost-effective indirect reuse scenarios are Scenarios 3 and 1, which have similar treatment facilities but a reduced augmentation rate (1.14 mgd) that is projected to achieve a projected maximum annual average TDS concentration of 200 mg/l.

Permitting Issues for the Athens Indirect Reuse Project

New or amended permits or authorizations that are potentially required for augmentation of the raw water supply in Lake Athens with reclaimed water include: an amended water right permit with a new reclaimed water discharge location, a Section 404 permit for construction of pipelines and constructed treatment wetlands, amended TPDES discharge permits that contain additional discharge locations, an underground injection control permit that allows injection of concentrated brine from a membrane filtration process into deep formations, a Chapter 210 reuse authorization that allows incorporation of direct reuse into the project, and stormwater discharge permits for construction that disturbs more than one acre. The specific permitting activity required will depend upon the reuse alternative that is implemented.

Selection of Preferred Athens Indirect Reuse Alternative

Augmentation of the Lake Athens raw water supply with reclaimed water appears to be a feasible water supply strategy. Based on evaluation of the polishing treatment processes, projected water quality impacts to Lake Athens, opinions of probable cost, and ancillary benefits, AMWA/Athens should select one of the following scenarios (Table ES-4 and Figures ES-3 and ES-4) as the preferred indirect reuse alternative:

- Scenario 5, in which denitrification filters and chemical precipitation facilities would be installed at the West and North WWTPs to remove nutrients from all wastewater at the WWTPs, or
- Scenario 7, in which nutrients would be removed from the reclaimed water with a constructed treatment wetland at Wetland Site B.

Both scenarios would allow augmentation of Lake Athens with up to 1.73 mgd of reclaimed water having a maximum total phosphorus concentration of 1 mg/l and a maximum total nitrogen concentration of 5 mg/l.

Scenario 5 is slightly less expensive on a weighted unit cost basis and would remove nutrients from all wastewater at the WWTPs, which could help the City meet more stringent effluent nutrient limits at its existing discharge locations in the future.

Scenario 7 is somewhat more expensive on a weighted unit cost basis and entails a greater capital cost, but there are ancillary, non-economic benefits that may be valuable to the stakeholders and improve public perception of recycled water use, including:

- Relatively low-tech operation,
- Relatively low energy requirements,
- Fish and wildlife habitat,
- Recreational and educational opportunities,
- Ecotourism, and
- Potential for mitigation for other projects.

AMWA/Athens should assess whether the non-economic benefits associated with constructed wetland treatment (Scenario 7) outweigh the additional cost compared to mechanical treatment at the WWTPs (Scenario 5).

Under either of these scenarios, it is projected that the maximum annual average TDS concentration in Lake Athens during a drought-of-record situation would be approximately 259 mg/l (Table E-4).[14] Therefore, either scenario may require one of the following actions:

- Simultaneously import raw water from another source and/or
- Develop a site-specific TSWQS limit for Lake Athens that would allow for annual average TDS concentrations greater than the target level of 200 mg/l.

It is recommended that AMWA/Athens should meet with the TCEQ to identify the numerical TDS standard that would be applied to Lake Athens, to discuss the proposed project, and to

[14] See Chapter 5.6 for discussion of the assumptions inherent in the TDS projections.

identify the additional information that would be required to establish a site-specific TDS standard.[15]

Should Scenarios 5 and 7 prove infeasible, the next most cost-effective indirect reuse scenarios are Scenarios 3 and 1, which have similar treatment facilities to Scenarios 5 and 7 but a reduced augmentation rate (1.14 mgd) that is projected to achieve a projected maximum annual average TDS concentration of 200 mg/l.

Implementation Plan for the Athens Indirect Reuse Project

The selected indirect reuse alternative will be implemented in two phases. Phase 1 results in polishing treatment and transport of reclaimed water from the North WWTP to Lake Athens. Phase 2 results in transport of the reclaimed water from the West WWTP to the North WWTP and additional polishing treatment facilities.

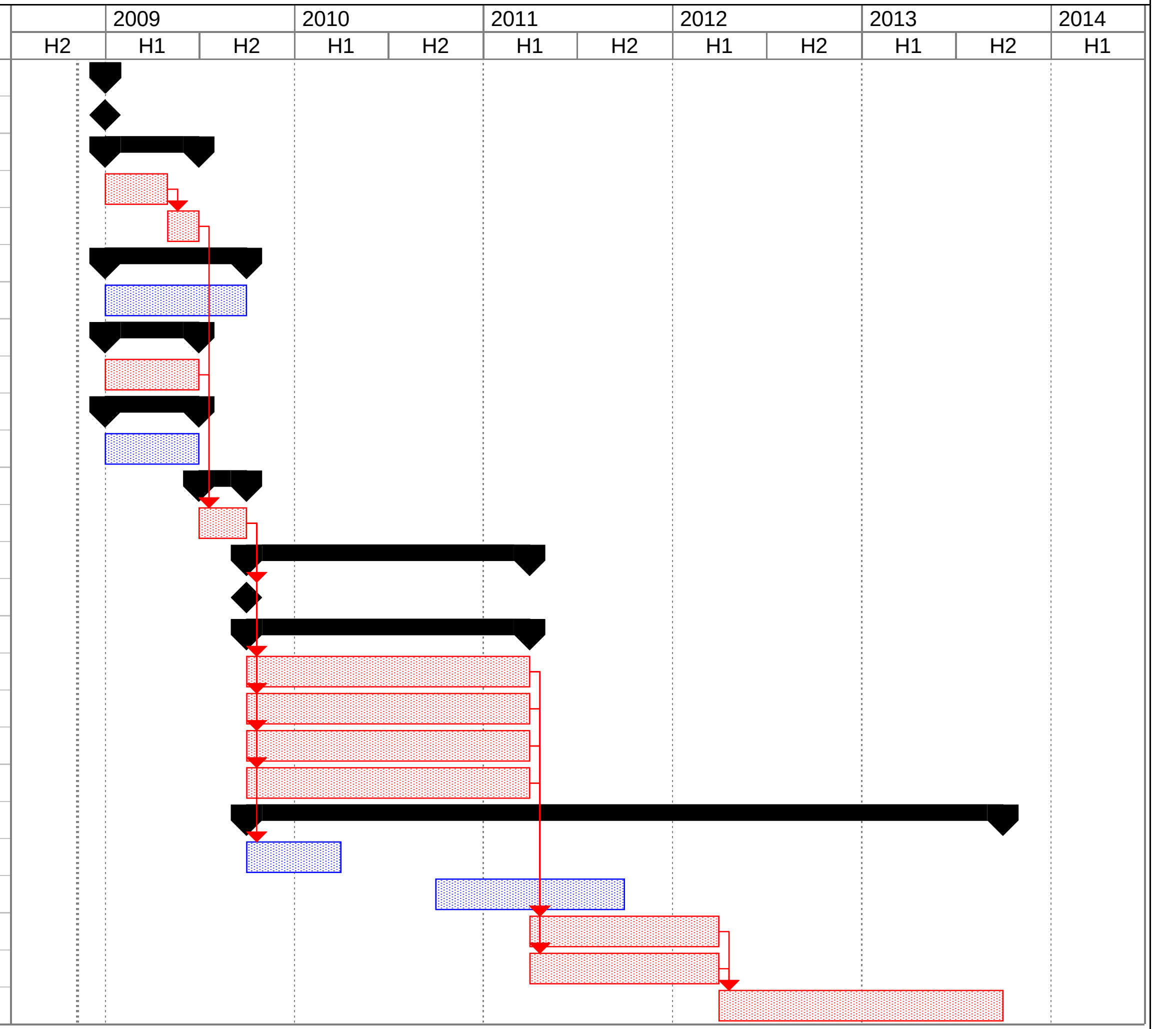
The recommended implementation plan for Phase 1 is illustrated in Figure ES-5. The proposed Phase 1 schedule of actions is as follows:

- Begin regular sampling and analysis of Lake Athens raw water, and West WWTP effluent, and North WWTP effluent for total phosphorus, total nitrogen, TDS, chlorides, and sulfates. In the short term, use these data to verify the required constructed wetland treatment area, if necessary. In the long term, use these data to track the impact of reclaimed water augmentation on Lake Athens water quality.
- Develop updated information on other potentially feasible water management strategies (Chapter 9.4) by second quarter 2009. Determine whether one or more of these strategies should be implemented instead of or simultaneously with the preferred indirect reuse alternative. The rest of this implementation plan assumes that indirect reuse will be the sole raw water supply augmentation method.

[15] Additional discussion of a site-specific TDS standard is presented in Section 9.3.

Figure ES-5
Phase 1 Indirect Reuse Implementation Plan

ID	Task Name
1	**Begin Regular Water Quality Sampling**
2	Begin Regular Water Quality Sampling
3	**Develop Information on Other Raw Water Strategies**
4	Develop Information
5	Select or Reject Other Raw Water Strategies
6	**Wetland Site B Soil Testing**
7	Wetland Site B Soil Testing (if necessary)
8	**Select Preferred Reclaimed Water Alternative**
9	Select Preferred Reclaimed Water Alternative
10	**Identify Potential Direct Reclaimed Water Customers**
11	Identify Potential Direct Reclaimed Water Customers
12	**Public Input**
13	Public Input
14	**TDS Standard for Lake Athens**
15	Develop Approach to TDS Issues
16	**Permitting**
17	Amend Certificate of Adjudication 06-3256
18	404 Permit Acquisition (Environmental/Hydraulic)
19	TCEQ Discharge Permit Amendment
20	Other Permits/Authorizations
21	**Indirect Reuse Phase I**
22	Preliminary Design
23	Wetland Land Acquisition (if necessary)
24	Pipeline Right-of-Way Acquisition
25	Design/Advertise/Bid
26	Construct Facilities



Project: Athens Indirect Reuse
Date: Thu 11/6/08

Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		Group By Summary	
Milestone		Rolled Up Progress			
Summary		Split			

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- If necessary, conduct core sampling of in-situ soils at Wetlands Site B to determine whether in-situ soils have a coefficient of permeability of $1x10^{-7}$ cm/sec or less. Conduct sampling in the first three quarters of 2009. Revise Scenario 7 opinions of probable cost as necessary.
- Assess whether the non-economic benefits associated with the constructed treatment wetland in Scenario 7 (Table ES-4 and Figures ES-3 and ES-4) outweigh the cost advantages of Scenario 5. Select the preferred indirect reuse alternative by second quarter 2009.
- Continue efforts to identify potential direct reuse customers.
- Obtain public input on the proposed plan by third quarter 2009.
- Begin developing an approach to address potential TDS issues by fourth quarter 2009. This may include discussions with the TCEQ regarding a site-specific surface water quality standard for TDS in Lake Athens. Perform additional sampling and modeling of TDS concentrations as necessary. Obtain resolution by first quarter 2011.
- Initiate efforts by fourth quarter 2009 to obtain required water right amendment, environmental and discharge permits, and direct reuse authorization. This effort includes permits necessary to implement both Phase 1 and Phase 2. Obtain necessary permits and authorizations by first quarter 2011.
- Perform preliminary design of the Phase 1 polishing treatment facilities. These will include either denitrification filters and chemical precipitation[16] at the North WWTP (Scenario 5) or a constructed treatment wetland (Scenario 7). Perform preliminary design of Phase 1 conveyance facilities (pump station and pipeline from the North WWTP to a tributary to Lake Athens) beginning in fourth quarter 2009 in support of the permit applications.
- If Scenario 7 is the preferred indirect reuse alternative, begin acquiring land for a constructed treatment wetland by third quarter 2010. Complete land acquisition by third quarter 2011.

[16] If mechanical treatment is selected as the preferred alternative, further consideration should be given during preliminary design to other processes, including biological nutrient removal within the aeration basins and/or cloth filters.

- Begin acquiring easements for conveyance facilities by second quarter 2011. Complete easement acquisition by second quarter 2012.
- Complete the final design of the Phase 1 treatment and conveyance facilities by second quarter 2012.
- Construct and place into operation the Phase 1 treatment and conveyance facilities by fourth quarter 2013.

Phase 2 treatment facilities would include either denitrification filters and chemical precipitation at the West WWTP (Scenario 5) or additional constructed treatment wetland area (Scenario 7). Phase 2 conveyance facilities would include a pump station and pipeline from the West WWTP to the North WWTP. Phase 2 facilities should be designed, constructed, and placed into operation by 2026.

1. Introduction

Reuse of treated municipal wastewater effluent[17] is becoming an increasingly important source of water in Region C and across the state of Texas. The *2006 Region C Water Plan*[18] projected that, by 2060, reuse of reclaimed water would supply 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. A number of reuse projects currently operate in Region C, and many others are in the planning and permitting process. Obviously, reuse will serve a major role in meeting future water supply requirements for the region.

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 (e.g., golf courses) and industrial uses (e.g., cooling water for steam electric power plants). Indirect reuse occurs when treated wastewater effluent is discharged to a stream or reservoir and is diverted at a downstream location 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 in addition to natural runoff. Indirect reuse can provide water supplies for municipal use, as well as irrigation and industrial supplies.

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 guidance documents for implementing indirect and direct reuse projects. This guidance document identifies technical and regulatory issues to be considered in the planning and design of the augmentation of surface water supplies with reclaimed water.

[17] Also called "reclaimed water" or "recycled water."

[18] 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.

To serve as a case study for the guidance document, an implementation plan for a specific, recommended indirect reuse strategy has been developed. The *2006 Region C Water Plan* recommended that the Athens Municipal Water Authority (AMWA) and the City of Athens (Athens) construct facilities to transport reclaimed water from the Athens wastewater treatment plants (WWTPs) to Lake Athens to augment the raw water supply. After blending, detention, diversion, and water treatment, the reclaimed water would be used for municipal, livestock, irrigation, and manufacturing purposes.

This report presents and discusses other guidance and regulations, the multiple-barrier approach to reclaimed water augmentation, proximity of the reclaimed water source to the location of use, blending and detention of reclaimed water in the receiving water, receiving water body quality, receiving water body hydrology, polishing treatment of the reclaimed water, direct reuse opportunities, the conceptual design of a reclaimed water conveyance system, opinions of probable cost, permitting issues, selection of the preferred alternative, and aspects of an implementation plan.

Chapters 2 and 3 consist entirely of guidance information. The case study, developed using the guidance information where applicable, is presented in subsequent chapters. The case study is a planned indirect reuse project, and it should be recognized that the criteria (e.g., blending percentage, detention time, etc.) were selected specifically for this example. The criteria applied to other situations should be determined on a case-by-case basis.

2. Review of Other Guidance and Regulations

The first step in consideration of an indirect reuse project is to review applicable guidance and regulations. Texas does not have regulations that specifically address indirect reuse. Instead, elements of an indirect reuse project are regulated by other state permits and standards, including water rights permits, Texas Pollutant Discharge Elimination System (TPDES) discharge permits, the Texas Surface Water Quality Standards (TSWQS),[19] and state and federal drinking water regulations. As reviewed in the following sections, the federal government and other state governments have promulgated regulations and guidelines regarding indirect reuse.

2.1. Federal Guidance

There are currently no specific federal regulations that specifically address indirect reuse. However, the U. S. Environmental Protection Agency (USEPA) has released updated guidelines for reuse.[20] These guidelines include recommendations for treatment levels, water quality, and monitoring for ground water recharge and surface water augmentation. The guidelines also recommend that the reclaimed water quality meet or exceed drinking water standards and advocate a multiple-barrier approach to potable reuse applications.

Indirect reuse can cause an increase in the concentration of total dissolved solids in the receiving water body. The National Secondary Drinking Water Regulations[21] establish a maximum TDS concentration of 500 mg/l as a secondary drinking water standard. These secondary standards are not federally enforceable but are intended as guidelines for the States.

2.2. State Regulations

Although Texas does not have regulations that specifically address indirect reuse, the state's Public Drinking Water Standards[22] establish a maximum TDS concentration of 1,000 mg/l as a

[19] Texas Administrative Code, Title 30 Chapter 307.

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

[21] Code of Federal Regulations, Title 40, Part 143, Section 143.3

[22] Texas Administrative Code, Title 30 Chapter 290.118.

secondary drinking water standard. According to the rules, “Water that does not meet the secondary constituent levels may not be used for public drinking water without written approval from the [TCEQ] executive director. When drinking water that does not meet the secondary constituent levels is accepted for use by the executive director, such acceptance is valid only until such time as water of acceptable chemical quality can be made available at reasonable cost to the area(s) in question.”[22] The secondary drinking water standard could be significant for some indirect reuse projects.

Many states have developed regulations associated with direct reuse, but only four states have regulations specifically addressing indirect potable reuse:[20] California, Florida, Hawaii, and Washington. A summary of water quality and treatment criteria for each of these states is presented in Table 2-1. In addition, a description of the regulations in each state is provided below.

California

As a result of extremely limited water supplies in many parts of the state, California has been a leader in both the implementation and regulation of indirect potable reuse projects. California’s regulations focus on groundwater spreading or injection of reclaimed water. The official regulations state that requirements will be evaluated on a case-by-case basis. However, draft regulations provide specific guidelines for water quality that are followed by the state in most cases.

California is the only state that specifies a maximum percent blend (50 percent) in its draft potable reclaimed water regulations.[23] This maximum blend is specified for groundwater recharge operations where the recharge water is inserted into the aquifer by subsurface injection. For such groundwater recharge operations, the blend is defined as the ratio of the reclaimed water volume in the recharge to the total recharge volume. The specified maximum blend is

[23] Groundwater Recharge Reuse Draft Regulation, California Department of Public Health, January 4, 2007. Available URL: http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Recharge/DraftRegulations.pdf

Table 2-1: Summary of State Regulations for Indirect Potable Reuse[a]

	California[b]			Washington		Florida				Hawaii
Type/Class	**Spreading w/ no RO**	**Spreading w/ RO**	**Injection**	**Spreading**	**Injection**	**Spreading**	**Injection (TDS>3000)**	**Injection (TDS<3000)**	**Surface Water Augmentation**	**Any**
Processes Required	Secondary, Coagulation, Chem Addition, Filtration, Nitrogen Removal, Disinfection	Secondary, Coagulation, Chem Addition, Nitrogen Removal, Filtration, Reverse Osmosis, Disinfection	Secondary, Coagulation, Chem Addition, Nitrogen Removal, Filtration, Reverse Osmosis, Disinfection	Secondary, Coagulation, Filtration, Nitrogen Removal, Disinfection	Secondary, Coagulation, Filtration, Nitrogen Removal, Reverse Osmosis, Disinfection	Secondary, Coagulation, Chem Addition, Filtration, Nitrate Removal, Disinfection	Secondary, Coagulation, Chem Addition, Filtration, Nitrogen Removal, Disinfection	Secondary, Coagulation, Chem Addition, Filtration, Reverse Osmosis[c], Nitrogen Removal, Disinfection	Secondary, Coagulation, Chem Addition, Filtration, Nitrogen Removal, Disinfection	Case-by-Case Basis
Turbidity (NTU)	2 *(24 hr avg)* 5 *(<5%)* 10 *(max)*	2 *(24 hr avg)* 5 *(<5%)* 10 *(max)*	0.2 *(<5%)* 0.5 *(max)*	2 *(1 mo. avg)* 5 *(max)*	0.1 *(1 mo. avg)* 0.5 *(max)*	N/A	N/A	N/A	N/A	
TSS (mg/L)	N/A	N/A	N/A	30 *(1 mo. avg)*	5 *(7-day avg)*	10 *(max)*	5.0 *(max)*	5.0 *(max)*	5.0 *(max)*	
BOD_5 (mg/L)	N/A	N/A	N/A	30 *(1 mo. avg)*	5 *(7-day avg)*	5 ($CBOD_5$) *(1 mo. avg)*	5 ($CBOD_5$) *(1 mo. avg)*	5 ($CBOD_5$) *(1 mo. avg)*	5 ($CBOD_5$) *(1 mo. avg)*	
TOC (mg/L)	10 *(avg)* 16 *(max)*	0.5/RWC[d]	0.5/RWC[d]	N/A	1.0 *(30-day avg)*	N/A	N/A	3 *(1 mo. avg)* 5 *(max)*	N/A	
TOX (mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2 *(mo. avg)* 0.3 *(max)*	N/A	
Total Nitrogen (mg/L)	5 *(max)*	5 *(max)*	5 *(max)*	reduced[e]	10 *(1-yr avg)*	12 (nitrate) *(max)*	10 *(1-yr avg)*	10 *(1-yr avg)*	10 *(1-yr avg)*	
Total Phosphorus (mg/L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Total Coliforms (CFU)	2.2/100mL (median) 23/100mL *(max)*	2.2/100mL (median) 23/100mL *(max)*	2.2/100mL (median) 23/100mL *(max)*	2.2/100mL (median) 23/100mL *(max)*	1/100mL (median) 5/100mL *(max)*	75% below detection 25/100mL *(max)*	75% below detection 25/100mL *(max)*	75% below detection 25/100mL *(max)*	75% below detection 25/100mL *(max)*	
Enteric Viruses	5-log reduction	5-log reduction	5-log reduction	N/A	N/A	N/A	N/A	N/A	N/A	
Disinfection - CT Number[f] (mg-min/L)	450	450	450	Cl residual of 0.5 mg/L in conveyance	Cl residual of 0.5 mg/L in conveyance	25/40/120[g]	25/40/120[g]	25/40/120[g]	25/40/120[g]	
Residence Time	6 mos.	6 mos.	12 mos.	N/A	N/A	N/A	N/A	N/A	N/A	
Recycled Water Contribution[d]	50%	50%	50%	N/A	N/A	N/A	N/A	N/A	N/A	

[a] Information obtained from Guidelines for Water Reuse, U.S. Environmental Protection Agency, EPA/625/R-04/108, September 2004.

[b] California regulations quoted here are currently in draft form.

[c] Reverse osmosis required at water supply well if direct injection occurs less than 1 mile from supply well

[d] Recycled water contribution (RWC) is the fraction of the total recharge water that is reclaimed water.

[e] "The secondary treatment process to provide oxidized wastewater shall include an additional step to reduce nitrogen prior to final discharge to groundwater" - Article 3, Section 3(2) of Washington Water Reclamation and Reuse Standards, 1997

[f] The CT number refers to the product of the chlorine residual (or equivalent) in mg/L and the contact time in minutes.

[g] CT number requirements are based on the bacterial (total coliform) content of the source water. Source waters with less than 1,000 cfu/100mL require 25 mg-min/L CT number, 1,000-10,000 cfu/100mL source waters require 40 mg-min/L, and source waters containg greater than 10,000 cfu/100mL require 120 mg-min/L.

based on the assumption that the reclaimed water has been treated with reverse osmosis (RO) and disinfection prior to recharge and that the minimum detention time in the aquifer will be 12 months.

California regulations also dictate specific treatment processes required for both spreading and groundwater injection operations, as well as disinfection requirements and effluent limits for turbidity, total suspended solids, biochemical oxygen demand, total organic carbon, total organic halides, total nitrogen, total coliforms, and enteric viruses prior to discharge to spreading basins or injection.

Florida

The State of Florida is the only state whose regulations specifically address surface water augmentation with reclaimed water. The regulations define surface water augmentation as any discharge that will reach potable drinking water supplies within 24 hours travel time. In addition, reclaimed water discharge outfalls cannot be located within 500 feet of a potable water intake. As shown in Table 2-1, groundwater injection is regulated based on total dissolved solids (TDS) concentrations in the receiving aquifer. RO is not required except in cases where the aquifer has a TDS concentration of less than 3,000 mg/L and the injection well is less than 1 mile from the water supply well.

Hawaii

In Hawaii, treatment requirements are evaluated on a case-by-case basis. The regulations state that "reclaimed water used for groundwater recharge by surface or subsurface application shall be at all times of a quality that fully protects public health." Evaluation of requirements is "based on all relevant aspects of each project including treatment provided, effluent quality and quantity, effluent or application spreading area operation, soil characteristics, hydrogeology, residence time and distance to withdrawal."

Washington

Regulations relating to indirect potable reuse in the State of Washington were modeled on California's regulations and focus primarily on groundwater spreading and injection. As with California, Washington regulations require that RO treatment be provided for any injection application into a potable supply. However, Washington’s regulations do not include criteria for reclaimed water contribution (percent blend), detention time, or virus reduction.

3. General Guidance for Indirect Reuse in Texas

Augmentation of raw water supply with reclaimed water is becoming an accepted practice. However, since the science used to evaluate this practice is still emerging, planning for indirect reuse should consider conservative operational limits to protect receiving water quality and public health. Therefore, the value of multiple barriers for managing the uncertainties associated with augmenting raw water supplies with reclaimed water should be taken into account. The following sections discuss candidate barriers and their potential benefits and provide general guidance regarding the candidate barriers. These general guidance considerations account for a number of factors, including:

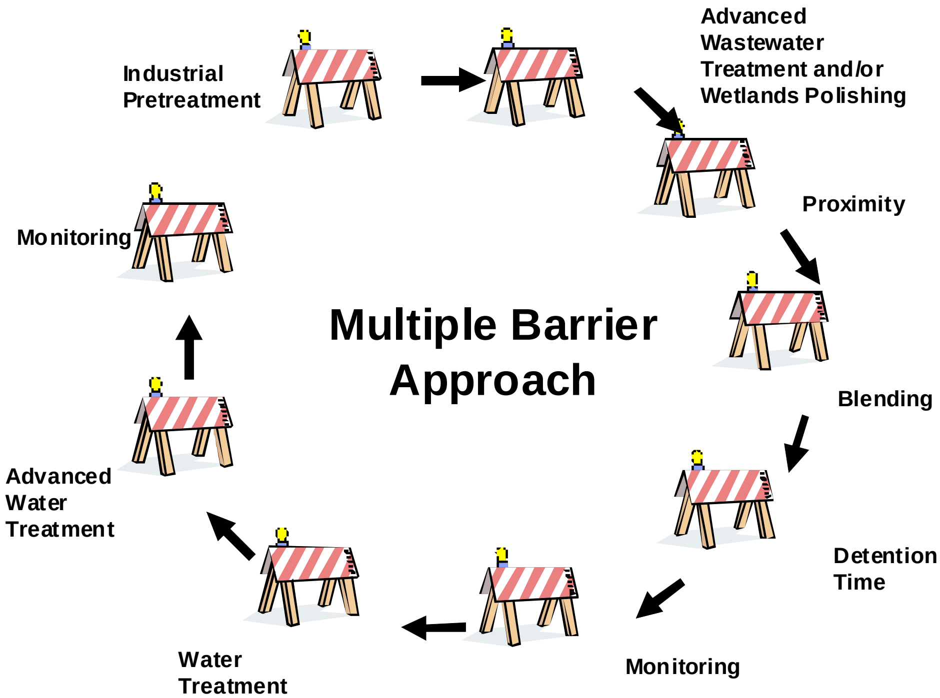
- Protection of receiving water quality and human health;
- Indirect reuse regulations in other states;
- Experiences of other planned and unplanned reclaimed water projects in the United States and abroad;
- Existing Texas Surface Water Quality Standards (TSWQS);
- Potential future nutrient/chlorophyll standards;
- Potential TPDES permitting constraints;
- Public perception and acceptance; and
- Projected cost.

The appropriate barriers should be determined on a case-by-case basis and are expected to vary from one indirect reuse project to another. Additionally, as further knowledge is gained about indirect reuse through scientific studies/research and indirect reuse project operations and as new regulations are adopted, the appropriate barriers, the barrier design parameters, and the approach to planning and implementing indirect reuse projects may change.

3.1. Multiple Barriers

Candidate barriers considered in this document are shown in Figure 3-1. Barriers may include regulated industrial pretreatment programs, conventional and/or advanced wastewater treatment

Figure 3-1 Schematic Representation of the Multiple Barrier Approach



required by relevant regulations (e.g., the TSWQS and TPDES discharge permits), proximity of the reclaimed water source to water diversion locations, the blend of reclaimed and natural water, the detention time in the receiving water, conventional and/or advanced drinking water treatment required by relevant regulations (e.g., Safe Drinking Water Act and state drinking water regulations), and a monitoring program.

With this approach, multiple mechanisms protect against potential adverse impacts of any particular constituent. For example, some constituents that are resistant to traditional wastewater treatment processes may decay quite rapidly with exposure to sunlight or when subjected to other natural processes. Thus, it is appropriate to recognize the proximity of discharge to diversion locations (i.e., distance of travel), blending, and detention time as beneficial barriers that would provide protection against certain types of constituents. Qualitatively, the multiple-barrier concept allows for some flexibility in the strength, or effectiveness, of each barrier. If the strength of one barrier is reduced, then other barriers can be strengthened to compensate, if necessary.

Industrial Pretreatment

An Industrial Pretreatment Program can be an effective method for protecting the quality of reclaimed water generated by a Publicly Owned Treatment Works (POTW) that accepts discharges from industrial and commercial users. All large POTWs (e.g., those designed to treat flow of more than five million gallons per day) and smaller POTWs with significant industrial discharges are required to implement an industrial pretreatment program pursuant to the POTW's TPDES permit.

The general pretreatment regulations for an industrial pretreatment program are established in Title 40 Code of Federal Regulations Part 430. In accordance with these regulations, POTWs shall monitor industrial and commercial dischargers and require these dischargers to treat or control pollutants in their wastewater prior to discharge to the POTW. The objectives of the program are:

- To prevent the introduction of pollutants which will interfere with the operation of a POTW;
- To prevent the introduction of pollutants which will pass through the treatment works or otherwise be incompatible with such works; and
- To improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludge.

Therefore, an initial barrier for excluding undesirable constituents that may adversely impact reclaimed water quality is a well-implemented industrial pretreatment program.

Wastewater Treatment

In Texas, current regulations establish the required treatment level, which is generally met by conventional treatment processes and/or advanced secondary treatment processes. The conventional treatment processes include various types of biological treatment followed by clarification and disinfection. The advanced secondary treatment processes generally include the conventional processes plus filtration. Additionally, the TPDES permitting process has resulted in the requirement of nutrient removal on a case-by-case basis. The discharges that are required to achieve a prescribed nutrient level generally employ a biological treatment process, which may or may not be applied in combination with chemicals.

No Texas or federal regulations require specific treatment processes for indirect reuse; therefore, any advanced treatment will be primarily determined by the treatment required to comply with TSWQS and TPDES permitting. On a case-by-case basis, the plant operator may elect to achieve certain water quality goals (e.g., provide water for specific uses of reclaimed water), which may involve specific types of treatment.

To comply with the TSWQS for TDS, chlorides, and sulfates and to comply with probable future limitations on reservoir nutrient loadings, advanced wastewater treatment for raw water supply augmentation may include processes that provide desalination and nutrient removal. An alternative to desalination treatment may be limiting the quantity of reclaimed water introduced into a water body to achieve the TSWQS. In special cases, it may also be appropriate to adjust the TSWQS.

With regard to nutrient loadings, the TCEQ has formed a Surface Water Quality Standards Advisory Work Group to consider the question of how to limit algal growth and/or nutrients (such as nitrogen and phosphorus) in Texas reservoirs. Currently, the TSWQS do not contain numerical limits on chlorophyll-a, phosphorus, or nitrogen. The recommendations of the workgroup could lead to the adoption of regulations that specify numerical limits. It is not clear how such limits would be translated into permitted discharge limits on phosphorus and nitrogen.

State and federal regulatory agencies are developing new regulations for wastewater treatment that may require one or more new or emerging advanced treatment technologies. Advanced wastewater treatment could include a variety of processes (e.g., membranes, carbon, ozone, ultraviolet light, etc.) that could be used to provide higher levels of treatment. These developments should be monitored, and adoption of regulations that require new technologies could affect the nature of the wastewater treatment barrier. As described above, the addition of advanced treatment should be considered based on regulatory requirements and on the number and effectiveness of other barriers present.

Proximity of Discharge to Water Use

The proximity of the discharge to the water use is the distance between the location where reclaimed water is discharged to a receiving water body (e.g., river) and the location where it is diverted or where it enters a water supply reservoir. The distance serves as a barrier in that physical, chemical, and biological reactions can occur that may reduce the concentration of constituents that may be of concern from a water supply perspective. The reactions and/or the reaction rates that occur in a stream are generally different from those that occur in a reservoir, which should be considered in the establishment of blending and detention time targets discussed below. Several stream characteristics can affect reaction rates, including reaeration rates and wetted perimeter. Reaeration can add oxygen to the stream, enhancing biological activity. At a given moment, a greater percentage of the water volume is exposed to the wetted perimeter in a stream than in a reservoir. Since the wetted perimeter will generally provide a greater population of organisms compared to the interior of a water body, a stream can provide beneficial treatment in a shorter period of time. Thus, with respect to proximity, consideration should be given to distance and the characteristics of the stream conveying the reuse water.

Blending

Blending describes the process of mixing reclaimed water with natural water in the receiving water body. Blending acts as a barrier by diluting constituents in the reclaimed water (assuming that the concentrations are lower in the natural water). For a reservoir, the blend percentage (or percent blend) is the ratio of the volume of reclaimed water stored in the reservoir to the total volume of water stored. For a stream, the blend percentage is the ratio of the volume of the reclaimed water augmentation rate to the total flow in the stream (natural and reclaimed water). Consideration should be given to developing an appropriate blend percentage target on a case-by-case basis taking into account the various barriers incorporated into a specific reuse project.

Furthermore, during periods of drought when the percent blend may be elevated for extended periods of time, the frequency of monitoring should be increased and, if the monitoring results suggest significant changes in water quality, additional operational or treatment steps should be considered. For example, sludge age could be increased at a WWTP, and filters at a water treatment plant (WTP) could be backwashed more frequently.

Detention Time

For a reservoir, detention time is a measure of the amount of time that water is stored prior to being withdrawn or released downstream. For a stream, the detention time is the travel time from the discharge location to the diversion location. Appropriate detention time targets may be different for reservoirs and streams, due to the difference in the physical characteristics and treatment mechanisms associated with the two types of water bodies. For instance, at a given moment, a greater percentage of the water volume is exposed to the wetted perimeter in a stream than in a reservoir. Since the wetted perimeter will generally provide a greater population of organisms compared to the interior of a water body, a stream can provide beneficial treatment in a shorter period of time.

Detention time is a beneficial barrier because it provides the opportunity for natural attenuation processes (including physical, chemical, and biological processes) to act on constituents within the reclaimed water prior to subsequent reuse. A lesser or greater blend of reclaimed water may warrant a shorter or longer detention time target, respectively.

Although water utilities or reservoir operators may have some control over detention time, it is primarily a function of the volume of storage in the reservoir (or travel time in a stream) and the rate of withdrawal or release of water from the reservoir. For a reservoir, detention time will be longer when the reservoir is full and demands are low and will be shorter when water levels are low and demands are high. Consideration should be given to developing an appropriate detention time target on a case-by-case basis taking into account the various barriers incorporated into the reuse project.

Water Treatment

Water treatment provides the final treatment barrier prior to introduction of the reclaimed water to the potable water supply system. The required treatment is established by state and federal drinking water standards. Most conventional water treatment trains provide appropriate protection for regulated constituents. This level of treatment, in conjunction with other multiple barriers, is generally adequate for reclaimed water augmentation programs. However, consideration should be given to the water treatment systems on a case-by-case basis to identify any specific water quality characteristics that may require special consideration. Advanced water treatment processes that could be considered to address identified special conditions include carbon filtration, biologically active carbon filtration, membrane processes, ion exchange, ozonation, and UV/peroxide disinfection.

It is recommended that consideration be given to a regular monitoring and testing program to provide information on any changes in raw or treated water quality. If changes in water quality are noted, adjustments to operational procedures or chemical dosages may be necessary.

Monitoring

Collecting and analyzing water quality data from various components of the reclaimed water system also serves as one of the barriers. However, it is important to recognize that there is an established federal process for developing regulations that identify which constituents need to be monitored, the acceptable analytical techniques, and what the collected data mean. Development of regulations for constituents associated with pharmaceuticals, personal care products, and other sources is dependent upon research and other investigations that are being performed. Consideration of collecting and analyzing water quality data should take into account the current regulations and developments in the understanding of what the data mean.

If an assessment of the various barriers indicates that consideration should be given to gathering water quality data, the monitoring and testing program could characterize the water quality of the reclaimed water, the receiving water, raw water at intakes, and potable water. For augmentation of surface water supplies, the USEPA recommends monitoring of the following constituents, at a minimum:[24]

- pH (daily),
- Turbidity (continuous),
- Total coliforms (daily),
- Chlorine residual (continuous),
- Drinking water standards (quarterly), and

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

- Other constituents. "Monitoring should include inorganic and organic compounds, or classes of compounds, that are known or suspected to be toxic, carcinogenic, teratogenic, or mutagenic and are not included in the drinking water standards." [25]

In addition to traditional water quality parameters, development of the monitoring program could consider addressing emerging microconstituents of concern, those constituents that have been identified as potential concerns with respect to potable use of reclaimed water (e.g., pharmaceuticals, endocrine disruptors, NDMA, etc.).

Monitoring data can be used to evaluate treatment effectiveness and to identify any changes in water quality that may require physical or operational modifications to the reuse system. The monitoring barrier provides a feedback mechanism that allows changes within the system to be identified and evaluated before they develop into problems for the water utility.

3.2. General Guidance Considerations

The following presents general guidance for assessing and considering the various facets of an indirect reuse project and for developing an implementation plan. An approach to performing a water quality assessment, which is of primary importance to determining the feasibility and operating requirements for an indirect reuse project, is outlined. Considerations are also presented that could be taken into account in assessing the interrelations between barriers. Guidance is also provided for considering the incorporation of direct nonpotable reuse into an indirect reuse project. Additionally, guidance is presented regarding the development of an implementation plan for an indirect reuse project. It is important to recognize that planning for individual indirect reuse projects will involve project-specific considerations, and the guidance provided by this manual may need to be adjusted on a case-by-case basis.

Water Quality Assessment Guidance

An assessment of water quality conditions is a key consideration in the planning and implementation of an indirect reuse project. Water quality conditions are generally managed

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

through a regulatory process that controls regulated constituents. Established limits for specific regulated constituents are included in the Texas Surface Water Quality Standards (TSWQS) and state and federal drinking water standards. Wastewater treatment plants are issued permits that are based on meeting the TSWQS. Drinking water treatment plants have the major responsibility for meeting drinking water standards. In some cases, unregulated constituents (e.g., particular situations of nutrients being discharged directly into water supply reservoirs) are controlled through general provisions in the TSWQS.

Recently laboratory analytical methods have been improved, which has allowed measurement of constituents at extremely low concentrations. Some of the constituents found are being attributed to pharmaceuticals, personal care products, and other sources. Certain endocrine-disrupting constituents have also been measured at extremely low levels. There is considerable research currently being performed to determine what impact, if any, these constituents have on water quality conditions and the use of the water. USEPA is currently assessing potential limits for these unregulated constituents. Providing multiple barriers represents an effective manner to address considerations relative to these types of unregulated constituents.

Two water quality parameters of particular interest for indirect reuse planning that should be considered to be addressed by the water quality assessment are conservative constituents (i.e., total dissolved solids, chloride, and sulfate) and nutrients (i.e., phosphorus and nitrogen). If other constituents that could adversely impact receiving water quality are known to be present in the treated wastewater effluent, these constituents should be considered as well.

The water quality assessment should characterize a full range of historical flowrates, volumes, and concentrations, using at least five years of water quality data for the receiving water body and for the reclaimed water. This water quality evaluation is an important consideration in assessing interaction of the various barriers and may influence the targets selected for certain barriers.

Treatment Guidance

A full description of treatment processes at the WWTP(s) and the WTP(s) should be developed and used to define the roles of these barriers in an indirect reuse project. As indicated above, for regulated constituents, the required treatment at WWTPs and WTPs is established by state and federal regulations. Consideration for requiring any additional treatment could involve the performance of a detailed analysis, which, if needed, would be performed during subsequent scientific and technical efforts associated with the implementation of an indirect reuse project. However, for the purpose of initial planning and performing a preliminary feasibility assessment of an indirect reuse project, consideration could be given to the potential affects of additional polishing treatment.

Polishing treatment could be of primary consideration for nutrient removal when wastewater is discharged directly to a water supply reservoir. Additionally, desalination treatment could be considered as one of the options to comply with the TSWQS for conservative constituents. Consideration could also be given to providing special treatment, if needed, at the wastewater treatment plant or drinking water treatment plant to achieve enhanced disinfection and/or to address emerging microconstituents of concern.

Nutrient removal technologies may include a combination of biological nutrient removal in aeration basins, denitrification filters, chemical precipitation of phosphorus, membrane filtration, and constructed treatment wetlands. Desalination may require one or more forms of membrane filtration, such as reverse osmosis or electrodialysis reversal. Salt levels may also be reduced by blending with low salinity water from other sources. Enhanced disinfection may include advanced oxidation technologies such as ultraviolet light and/or hydrogen peroxide. Addressing emerging microconstituents of concern may require best available technology, such as a combination of membrane filtration and advanced oxidation.

If polishing treatment alternatives are identified for consideration, the potential effectiveness of each treatment alternative should be discussed, and conceptual designs for each polishing treatment alternative should be developed. The conceptual designs for the polishing treatment alternatives will be used to develop opinions of probable cost for these facilities.

Reclaimed Water Augmentation Quantities Guidance

Assessment of the characteristics of a reuse water conveyance stream and of the reuse water receptor (e.g., reservoir) provides valuable information about the desired nature of certain barriers and the allowable raw water augmentation rate as a function of the multiple-barrier system. Performing the assessment requires developing a hydrology and water quality forecasting tool, considering proximity between discharge and location of reuse, considering blending percentage and detention time, projecting future water quality in the receiving water body, considering the levels of wastewater treatment applied to the source of the reuse water, and considering the drinking water treatment applied to the water source augmented with the reuse water.

A full description of the receiving water body should be developed, including physical dimensions, water uses, water rights, diversions, bed and banks authorizations, operating rules, operating limitations, historical yield estimates, and other items that could impact the raw water supply.

Projections of the reclaimed water available for augmentation should be developed. A WWTP may be subject to permit conditions or contractual agreements that obligate it to continue to discharge all or a portion of its treated effluent at the existing discharge location(s). In addition, as a condition of the water right required for indirect reuse, the TCEQ may impose other requirements, depending on environmental flow needs, water quality, and other environmental impacts. These issues should be incorporated into projections of the reclaimed water available for raw water supply augmentation.

For a receiving reservoir, a spreadsheet-based, monthly water balance should be developed for use in projecting reclaimed water blends, detention times, and TDS, chlorides, and sulfates concentrations. The water balance should incorporate the following information:[26]

- Historical inflows, outflows, and water surface elevations for a period that includes the drought of record;
- Projected reservoir elevation-area-volume relationships that include the effects of sedimentation;
- Projected water demands; and
- Projected reclaimed water augmentation rates.

[26] If the receiving water body is a stream, there is generally no storage capacity. In this case, the water balance will be simpler in nature, incorporating historical flows and reclaimed water augmentation rates.

Potential sources for historical hydrology information include the reservoir owner, the U. S. Army Corps of Engineers, and the U. S. Geological Survey. When measured flows and water surface elevations are not available, the best available estimates may be those used in the TCEQ's Water Availability Models (WAMs).[27]

The water balance should also be used to make projections of TDS, chlorides, and sulfates concentrations in the receiving water body and should be calibrated to historical concentrations to the extent possible. Typically, the concentrations of these constituents vary inversely with the volume of water stored in the receiving reservoir.

The water balance should then be used to evaluate the impacts on raw water volume, yield, and quality of various reclaimed water augmentation rates under future demand and operational scenarios. Parameters used in this evaluation should include the maximum blend of reclaimed water to natural water, the minimum detention time of reclaimed water, and the maximum annual average TDS concentration. Reclaimed water augmentation rates evaluated could include introduction of all available reclaimed water into the receiving water body, limited augmentation to meet a minimum detention time limit, limited augmentation to meet a selected blend limit, limited augmentation to meet the target TDS limit, or other scenarios. From this evaluation, feasible scenarios that meet case-by-case selections of blending and detention time targets and the target TDS limit will be identified, and the corresponding maximum augmentation rates will also be identified.

The TSWQS for TDS, chlorides, and sulfates may limit the allowable reclaimed water augmentation rate. The selected reclaimed water augmentation rate must comply with the TSWQS, unless there is a special situation where an amendment to the TSWQS is warranted and is granted by the TCEQ.

Finally, projections of supply and demand should be developed to show the need for additional water supply from the receiving water body and the timing of this need.

[27] Available URL: http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wam.html

The allowable reclaimed water augmentation rates will be used to develop conceptual designs for polishing treatment facilities and reclaimed water conveyance systems. The primary polishing treatment considered by this guidance document includes wastewater treatment that may be required to meet the TSWQS (e.g., total dissolved solids) or to be consistent with TPDES discharge criteria (e.g., nutrient limits applied to discharges directly into a water supply reservoir).

Direct Reuse Guidance

Although this guidance document focuses on indirect reuse through augmentation of raw water supplies with reclaimed water, it may also be feasible to provide reclaimed water for direct reuse from the pipeline that conveys reclaimed water from the WWTP(s) to the receiving water body. Reasons to consider direct reuse include revenue from sales of reclaimed water, reduced demand for potable water, and/or reduced demand for raw water (or groundwater).

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. 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 modify the design of the reclaimed water conveyance system as necessary.

State requirements for reclaimed water quality are presented in the remainder of this section. In Texas, the use of reclaimed water for beneficial purposes is regulated by the 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 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 3-1).

Type I reclaimed water can be used in instances where incidental contact with humans is likely to occur (Table 3-1). To be considered Type I Reclaimed Water, treated effluent must meet the specific quality requirements in Table 3-1; specific treatment processes are not identified or required. These parameters must be monitored twice per week and reported on a monthly basis.

Table 3-1
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
Uses	Irrigation or other uses in areas where public may be present	Irrigation or other uses in areas where the public is not present
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 water bodies where recreational activities are anticipated. • Toilet or urinal flush water. • Other activities where 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/water bodies 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 coliform: <20 CFU/100 ml geometric mean or <75 CFU/100ml single grab • BOD_5/$CBOD_5$ = 5 mg/l • Turbidity = 3 NTU	• Fecal coliform: <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

Note: These requirements do not apply to indirect reuse.

Type II reclaimed water can be used in instances where incidental contact with humans is not likely to occur (Table 3-1). To be considered Type II Reclaimed Water, treated effluent must meet the specific quality requirements in Table 3-1; specific treatment processes are not identified or required. These parameters must be monitored once per week and reported on a monthly basis.

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 and would include any indirect potable application, as well as any reuse of industrial reclaimed water.

Conveyance System Guidance

The design of the reclaimed water conveyance system depends on the choice of reclaimed water flowrate, the treatment scenario, and direct reuse opportunities. The pipeline routing, conceptual design, and opinions of probable cost are discussed in the following sections.

All requirements of a reclaimed water conveyance system should be identified. These requirements may include: WWTP location(s), delivery location(s), WTP 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.

Since the main purpose of the reclaimed water conveyance system is to deliver reclaimed water to a receiving water body for raw water supply augmentation, and assuming that the receiving water body provides ample storage to dampen peak season water demands, the system should be designed to deliver the reclaimed water at a rate close to the annual average augmentation rate. A nominal peaking factor of 1.1 is recommended for the reclaimed water conveyance system to allow for occasional maintenance down time.

It may be desirable to provide reclaimed water for direct reuse to users located close to the conveyance system. Some direct reuses, particularly irrigation, can have relatively low annual demands but relatively high peak hour demands. The demand on the conveyance system can be dampened by installing on-site storage, but the conveyance system must be designed to provide reclaimed water to the on-site storage as required to meet peak direct reuse demands.

After the requirements for a reclaimed water conveyance system have been identified, conceptual designs for the system should be developed. The conceptual designs for the reclaimed water conveyance system can be used to develop opinions of probable cost for these facilities.

Probable Cost and Start-up Issues Guidance

Opinions of probable capital costs, annual costs, unit costs, and net present values should be developed for conceptual polishing treatment and reclaimed water conveyance systems. 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. Non-economic factors associated with each alternative should be discussed, and indirect reuse alternatives should be compared to other water supply alternatives. Finally, significant construction and start-up issues should be identified and discussed.

Permitting Guidance

Permits and authorizations required to implement an indirect reuse project may include:

- Water rights permit that allows conveyance of the reclaimed water by bed and banks to the receiving water body and subsequent diversion of the reclaimed water from the receiving water body at a diversion point,
- Section 404 permit that allows discharge of dredged or fill material into waters of the United States,
- TPDES discharge permit that allows discharge of treated wastewater effluent to a receiving water body or its tributaries,
- Water treatment plant authorization,
- Underground injection control permit that allows injection of concentrated brine from a membrane filtration process into deep formations,
- Chapter 210 reuse authorization that allows direct reuse to be incorporated into the project,
- Stormwater discharge permits if construction will take place over 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.

Implementation Plan 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.

3.3. Summary

The augmentation approach described in this chapter defines a strategy for using reclaimed water to augment raw water supplies, while providing appropriate barriers that protect public health and the environment. This approach incorporates treatment barriers, natural attenuation barriers, and monitoring. The recommended barriers were established based on the current state of knowledge and technology. The approach taken for specific projects should give consideration to this proposed guidance on a case-by-case basis. Additionally, adjustments to this approach should be made as the scientific community develops further information about constituents of concern and as reclaimed water treatment technologies become more advanced.

4. Water Quality Evaluation

An initial step in evaluating a potential Athens Municipal Water Authority (AMWA) indirect reuse project is to evaluate the water quality of the receiving water body, Lake Athens, and the quality of existing and potential discharges to the receiving water body.

During development of the Lake Athens case study, the consultant team conducted three meetings with the AMWA Board to seek guidance and report progress. The Athens Director of Utilities, an ex officio member of the AMWA Board, attended each of these meetings. In addition, the City provided information on its wastewater treatment processes and had the opportunity to comment on the draft report. In these ways, coordination between Athens and AMWA was achieved for this project.

4.1. Guidance

An assessment of water quality conditions is a key consideration in the planning and implementation of an indirect reuse project. Water quality conditions are generally managed through a regulatory process that controls regulated constituents. Established limits for specific regulated constituents are included in Texas Surface Water Quality Standards and state and federal drinking water standards. The wastewater treatment plants are issued permits that are based on meeting the TSWQS. The drinking water treatment plants have the major responsibility for meeting drinking water standards. In some cases, unregulated constituents (e.g., particular situations of nutrients being discharged directly into water supply reservoirs) are controlled through general provisions in the TSWQS.

Recently laboratory analytical methods have been improved, which has allowed measuring constituents at extremely low concentrations. Some of the constituents found are being attributed to pharmaceuticals, personal care products, and other sources. Certain endocrine disrupting constituents have also been measured at extremely low levels. There is considerable research currently being performed to determine what impact, if any, these constituents have on water quality conditions and the use of the water. USEPA is currently assessing potential limits for these unregulated constituents. Providing multiple barriers represents an effective manner to address considerations relative to these types of unregulated constituents.

Two water quality parameters of particular interest for indirect reuse planning that should be considered to be addressed by the water quality assessment are conservative constituents (i.e., total dissolved solids, chloride, and sulfate) and nutrients (i.e., phosphorus and nitrogen). If other constituents that could adversely impact receiving water quality are known to be present in the treated wastewater effluent, these constituents should be considered as well.

The water quality assessment should characterize a full range of historical flowrates and concentrations, using at least five years of water quality data the receiving water body and for the treated wastewater effluent. This water quality evaluation is an important consideration in assessing interaction of the various barriers and may influence the targets selected for certain barriers.

4.2. Lake Athens Quality Data

The consultants obtained water quality data for Lake Athens from the Texas Commission on Environmental Quality Clean Rivers Program database.[28] Data were available at two lake stations: one located in the West Arm of the lake near the municipal intake and one located near the dam (Figure 4-1). The consultants also obtained water quality data for Lake Athens from the Texas Parks & Wildlife Department's Texas Freshwater Fisheries Center (TFFC), as sampled at the TFFC intake. Table 4-1 summarizes available Lake Athens water quality data for the period of record (2002 through 2007). The reported water quality data are also presented graphically in Appendix A.

4.3. Recent Municipal Treated Wastewater Effluent Flow and Quality Data

Currently, the City of Athens treats municipal wastewater at its North and West WWTPs. The maximum permitted annual average flowrates are 1.027 mgd at the North WWTP and 1.367 mgd at the West WWTP. The City discharges treated wastewater effluent from the West WWTP to a man-made ditch, flowing downstream to Walnut Creek, Cedar Creek, and the Trinity River. The

[28] Texas Commission on Environmental Quality, September 2007. Clean Rivers Program Database. Available URL: http://www.tceq.state.tx.us/compliance/monitoring/crp/data/samplequery.html

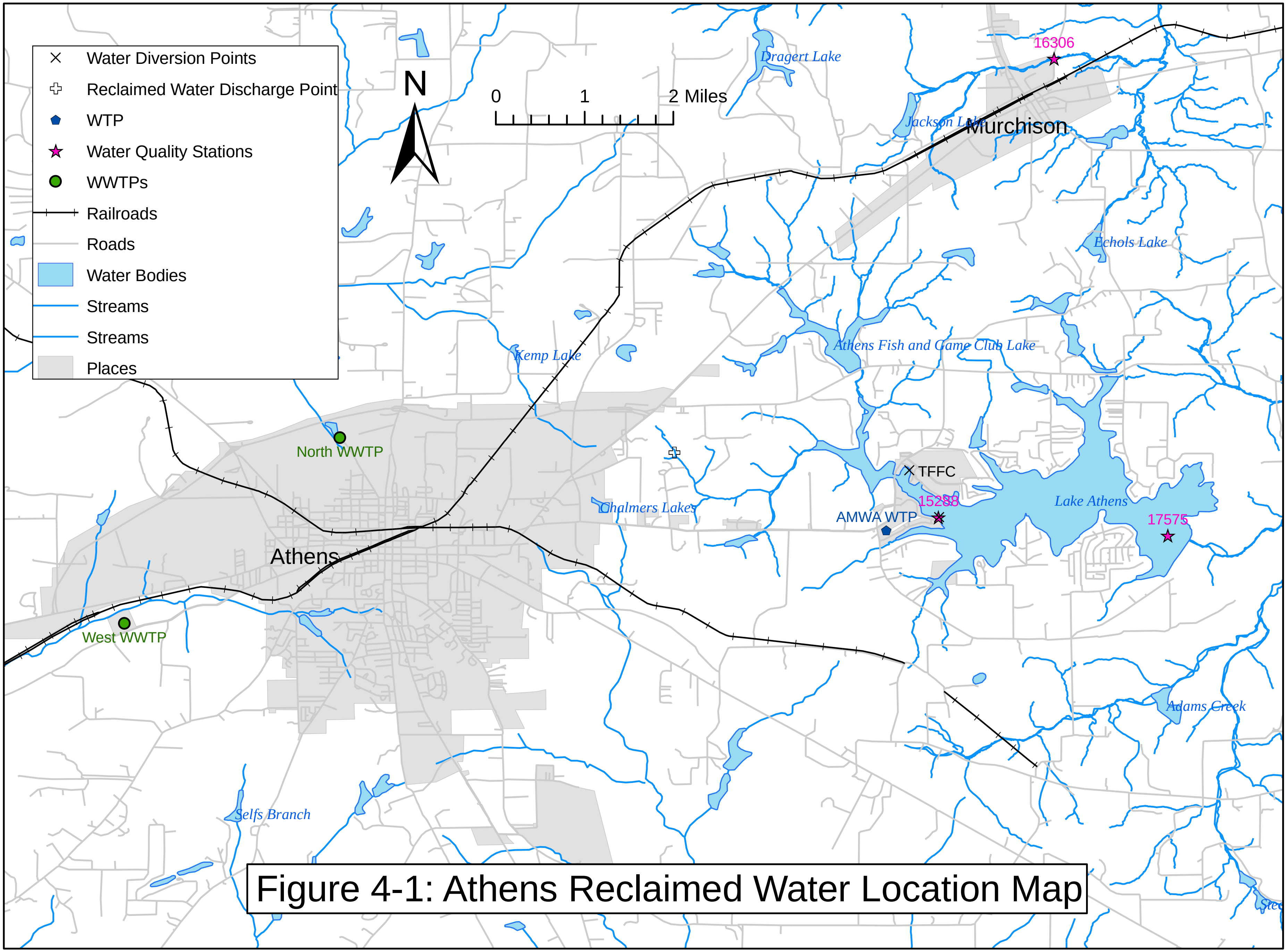


Figure 4-1: Athens Reclaimed Water Location Map

NOTE: The AMWA WTP water intake and Water Quality Station 15288 are coincident.

Table 4-1
Summary of Lake Athens Water Quality Data

Constituent	Station	Number of Samples	Units	Concentration			Target Maximum Concentrations[a]
				Minimum	Maximum	Average	
Total Nitrogen[b]	15288 West Arm	13	mg/l	0.46	0.66	0.57	n/a
	17575 Near Dam	13		0.47	0.78	0.56	
Total Phosphorus	15288 West Arm	15	mg/l	<0.05	<0.06	<0.05	n/a
	17575 Near Dam	15		<0.05	<0.06	<0.05	
	TFFC Intake	55[c]		0.02	0.62	0.07	
Chlorophyll-a	15288 West Arm	13	µg/l	<10	13.4	<10	n/a
	17575 Near Dam	13		<10	16.6	<10	
Total Dissolved Solids	15288 West Arm	15	mg/l	51	74	63	200
	17575 Near Dam	15		53	71	61	
Chlorides	15288 West Arm	15	mg/l	9	14	11	50
	17575 Near Dam	15		9	15	11	
Sulfates	15288 West Arm	15	mg/l	5	8	6	50
	17575 Near Dam	15		5	8	6	

[a]The TCEQ does not specify numerical surface water quality standards for Lake Athens. Instead, the consultants have assumed that the target maximum annual average concentrations will be those of the closest downstream segment (Lake Palestine) for which the TCEQ does specify numerical surface water quality standards (Texas Administrative Code, Chapter 307). These standards are applied to annual average concentrations. Currently, there are no numerical standards for total nitrogen, total phosphorus, or chlorophyll-a. As of May 5, 2008, the TCEQ Surface Water Quality Standards Advisory Work Group is considering nutrient criteria for Lake Palestine of 15.57 ug/l chlorophyll-a and 0.031 mg/l total phosphorus.

[b]Estimated from sum of species concentrations. Where values were below detection limits, half of the detection limit was used in the estimate.

[c]Reported monthly average concentrations.

City discharges treated wastewater effluent from the North WWTP to Onemile Creek; which flows downstream to a small, unnamed lake; Caney Creek; Forest Grove Reservoir; Caney Creek; and Cedar Creek Reservoir.

Reported treated wastewater effluent flowrates and quality from January 1998 through July 2007 are presented graphically in Appendix B. As of December 2007, the annual average flowrates were approximately 0.82 mgd (or 917 ac-ft/yr) at the West WWTP and 0.50 mgd (or 565 ac-ft/yr) at the North WWTP. Table 4-2 shows a summary of treated wastewater effluent quality for the last 5 years. Note that the average TDS concentration in the treated wastewater effluent (304 mg/l) is 242 mg/l greater than the average TDS concentration in Lake Athens (62 mg/l).

Table 4-2
City of Athens Treated Wastewater Effluent Quality, August 2002 through July 2007

Constituent	Type	WWTP	Number of Months	Concentration (mg/l)		
				Minimum	Maximum	Average
Ammonia	Average	North	65	0.04	3.41	0.29
		West	63	0.00	4.45	0.44
Total Phosphorus	Average	North	9	1.56	4.64	2.91
Total Dissolved Solids	Average	North	9	282	336	304
Total Nitrate (as NO_3)	Average	North	9	9.95	18.75	14.9

Athens does not analyze for phosphorus or nitrogen at the West WWTP. It has been assumed that the nutrient concentrations at the West WWTP are similar to those at the North WWTP. According to Athens, there is no significant difference in total suspended solids or carbonaceous biochemical oxygen demand concentrations between the plants.

4.4. Recent TFFC Treated Wastewater Effluent Flow and Quality Data

The TFFC discharges treated wastewater effluent under Texas General Permit TXG130004, which classifies the TFFC as a “concentrated aquatic animal production” facility. The TFFC wastewater flows through two settling ponds, a 1-millimeter screen, a Parshall flume, and a rock-lined channel before being discharged to an unnamed tributary of Lake Athens a short distance upstream of the lake.

Reported treated wastewater effluent flowrates and quality from January 2002 through December 2007 are presented graphically in Appendix C. In 2007, the TFFC diverted approximately 3.42

mgd (3,848 ac-ft) from Lake Athens and returned approximately 3.38 mgd (or 3,797 ac-ft/yr). It is difficult to estimate water consumption at the TFFC from these flowrates, because the return flow from the TFFC includes an unknown amount of stormwater. Table 4-3 shows a summary of treated wastewater effluent quality for the last 6 years.

Table 4-3
TFFC Treated Wastewater Effluent Quality, January 2002 through December 2007

Constituent	Type	Number of Months	Monthly Average Concentration (mg/l)		
			Minimum	Maximum	Average
Ammonia	Average	57	0.01	0.69	0.13
Phosphorus	Average	55	0.01	0.29	0.09
Nitrate	Average	55	0.02	0.34	0.10
Nitrite	Average	54	0.00	0.07	0.01

5. Estimation of Allowable Reclaimed Water Augmentation Rates

The approach to estimating the allowable raw water augmentation rate for the AMWA indirect reuse project includes developing a hydrology and water quality forecasting tool, selecting blending and detention time targets, projecting future water quality in the receiving water body, and selecting a target level of polishing treatment for the reclaimed water.

5.1. Guidance

Assessment of the characteristics of a reuse water conveyance stream and of the reuse water receptor (i.e., reservoir) provides valuable information about the desirable nature of certain barriers and the allowable raw water augmentation rate as a function of the multiple-barrier system. Performing the assessment requires developing a hydrology and water quality forecasting tool, considering proximity between discharge and location of reuse, considering blending percentage and detention time, projecting future water quality in the receiving water body, considering the levels of wastewater treatment applied to the source of the reuse water, and considering the drinking water treatment applied to the water source augmented with the reuse water.

A full description of the receiving water body should be developed, including physical dimensions, water uses, water rights, diversions, bed and banks authorizations, operating rules, operating limitations, historical yield estimates, and other items that could impact the raw water supply.

Projections of the reclaimed water available for augmentation should be developed. A WWTP may be subject to permit conditions or contractual agreements that obligate it to continue to discharge all or a portion of its treated effluent at the existing discharge location(s). In addition, as a condition of the water right required for indirect reuse, the TCEQ may impose other requirements, depending on environmental flow needs, water quality, and other environmental impacts. These issues should be incorporated into the projections of reclaimed water available for raw water supply augmentation.

For a receiving reservoir, a spreadsheet-based, monthly water balance should be developed for use in projecting reclaimed water blends, detention times, and TDS, chlorides, and sulfates concentrations. The water balance should incorporate the following information:[29]

- Historical inflows, outflows, and water surface elevations for a period that includes the drought of record;
- Projected reservoir elevation-area-volume relationships that include the effects of sedimentation;
- Projected water demands; and
- Projected reclaimed water augmentation rates.

Potential sources for historical hydrology information include the reservoir owner, the U. S. Army Corps of Engineers, and the U. S. Geological Survey. When measured flows and water surface elevations are not available, the best available estimates may be those used in the TCEQ's Water Availability Models (WAMs).[30]

The water balance should also be used to make projections of TDS, chlorides, and sulfates concentrations in the receiving water body and should be calibrated to historical concentrations to the extent possible. Typically, the concentrations of these constituents vary inversely with the volume of water stored in the receiving reservoir.

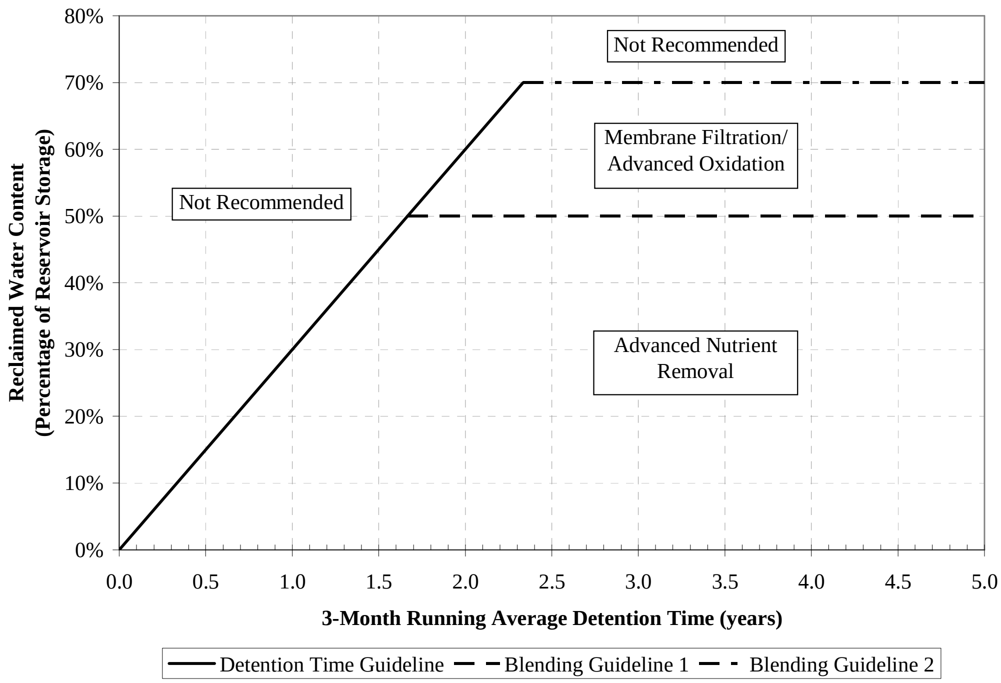
The water balance should then be used to evaluate the impacts on raw water volume, yield, and quality of various reclaimed water augmentation rates under future demand and operational scenarios. Parameters used in this evaluation should include the maximum blend of reclaimed water to natural water, the minimum detention time of reclaimed water, and the maximum annual average TDS concentration. Reclaimed water augmentation rates evaluated could include introduction of all available reclaimed water into the receiving water body, limited augmentation to meet a minimum detention time limit, limited augmentation to meet a maximum blend limit,

[29] If the receiving water body is a stream, there is generally no storage capacity. In this case, the water balance will be simpler in nature, incorporating historical flows and reclaimed water augmentation rates.

[30] Available URL: http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wam.html

limited augmentation to meet the target TDS limit, or other scenarios. For this evaluation of the AMWA project, Figure 5-1 illustrates the relationships between blend targets, detention time targets, and polishing treatment levels. From this evaluation, feasible scenarios that meet the blending and detention time targets and the target TDS limit will be identified, and the corresponding maximum augmentation rates and polishing treatment requirements will also be identified.

Figure 5-1
Summary of Blending and Detention Time Targets and Polishing Treatment Recommendations for AMWA Indirect Reuse Project



The TSWQS for TDS, chlorides and sulfates may limit the allowable reclaimed water augmentation rate. The selected reclaimed water augmentation rate must comply with the TSWQS, unless there is a special situation where an amendment to the TSWQS is warranted and is granted by the TCEQ.

Finally, projections of supply and demand should be developed to show the need for additional water supply from the receiving water body and the timing of this need.

The allowable reclaimed water augmentation rates will be used to develop conceptual designs for polishing treatment facilities and reclaimed water conveyance systems. The primary polishing treatment considered for a blend target of up to 50 percent includes wastewater treatment that may be required to meet the TSWQS (e.g., total dissolved solids) or to be consistent with TPDES discharge criteria (e.g., nutrient limits applied to discharges directly into a water supply reservoir). For a blend that exceeds the 50 percent target and is less than a 70 percent target, more advanced treatment should be considered. Identification of feasible augmentation scenarios and allowable reclaimed water augmentation rates for the Athens indirect reuse project is described below.

5.2. Description of Receiving Water Body

The Athens Municipal Water Authority (AMWA) owns and operates Lake Athens for municipal water supply, flood control, and recreational purposes. AMWA has the right[31] to perform the following actions with respect to Lake Athens (relevant locations are shown in Figure 4-1):

- Divert and use up to 5,477 ac-ft/yr from a location on the southwest shore for municipal purposes.
- Divert and use up to 3,023 ac-ft/yr from a location on the northwest shore for industrial purposes.
- Collect, treat, return, store, and reuse a maximum of 2,677.14 ac-ft/yr of treated wastewater effluent from the North and West WWTPs for augmentation of the raw water supply. The water right includes a reclaimed water discharge point on an unnamed tributary of Flat Creek (latitude 32.221º N and longitude 95.808º W).[32]
- Convey the treated wastewater effluent to the diversion points on Lake Athens using the bed and banks of an unnamed tributary to Flat Creek and Lake Athens.

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[31] Certificate of Adjudication 06-3256, as amended, is presented in Appendix D.

[32] If the reclaimed water discharge location is changed, the water right must be amended accordingly.

AMWA provides treated water from Lake Athens to the City of Athens and provides raw water to the TFFC. The intake locations are shown in Figure 4-1. In addition, Athens owns and operates three wells with a combined capacity of approximately 1.73 million gallons per day (mgd). Between 2001 and 2006, groundwater production ranged from 5.9 percent to 16.3 percent of total water production.

In the East Texas regional water plan,[33] the estimated firm yield of the raw water supply in Lake Athens for year 2000 was 6,145 ac-ft/yr. The firm yield is projected to decrease over time due to sedimentation in the lake. The conservation pool elevation for Lake Athens is 440 feet. The TFFC diverts water from the lake to TFFC through an intake with a minimum elevation of 431 feet. If the water surface elevation drops below 431 feet, the TFFC cannot obtain water using existing facilities.[34] Therefore, the minimum operational water surface elevation is 431 feet, and the corresponding operational yield of the lake is approximately 2,900 ac-ft/yr.[33]

5.3. Historical Water Balance

For Lake Athens, the estimated historical water balance for the period from January 1940 through December 1996 was extracted from the Neches River Basin WAM, placed into a spreadsheet format, and modified to allow changes in the elevation-area-volume relationship, the water demand, and the reclaimed water augmentation rate. A schematic of the Lake Athens water balance is shown in Figure 5-2.

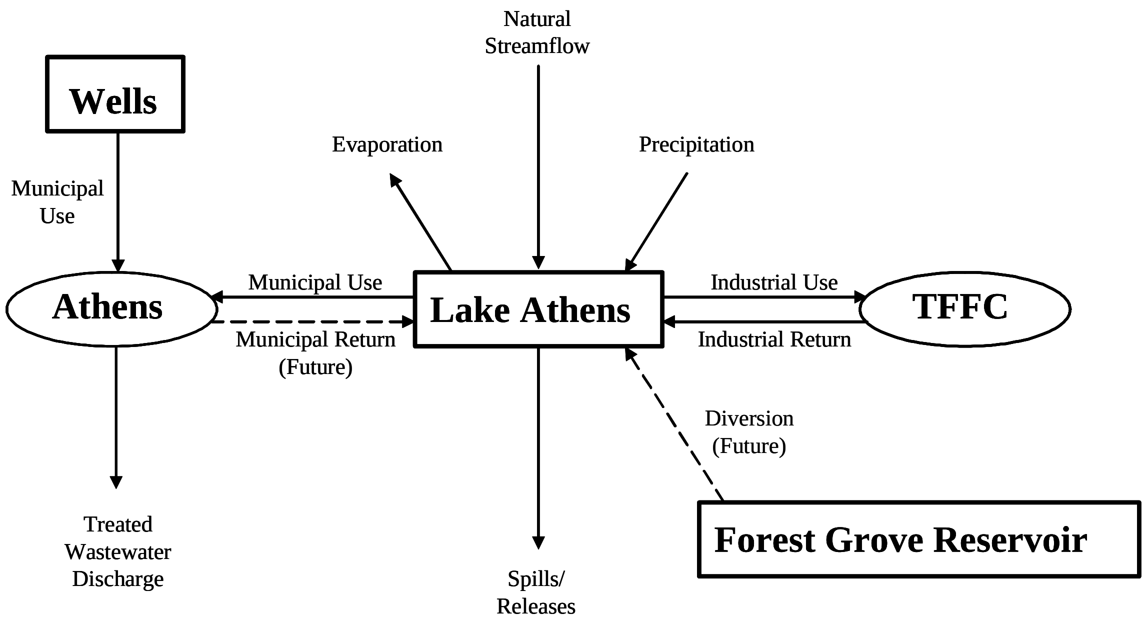
Using the elevation-area-volume relationship from the most recent lake survey[35] (conducted in 1998), the spreadsheet water balance indicates that the Lake Athens firm yield was 6,178 ac-

[33] Schaumburg & Polk, Inc. *et al*, January 2006. 2006 Water Plan East Texas Region, prepared for the East Texas Regional Water Planning Group.

[34] The *2006 Region C Water Plan* recommended that a temporary pumping strategy be used to allow the Texas Freshwater Fisheries Center to obtain water from elevations less than 431 feet until a more permanent strategy could be implemented. The temporary pumping strategy has not been considered in this analysis.

[35] *Volumetric Survey of Lake Athens*, prepared for the Athens Municipal Water Authority by the Texas Water Development Board, March 10, 2003.

Figure 5-2
Lake Athens Water Balance Schematic



ft/yr. This compares favorably with the WAM firm yield of 6,177 ac-ft/yr. Future elevation-area-volume relationships were estimated from the 1998 survey and a sedimentation rate of 1.109 acre-feet per square mile per year (ac-ft/sq mi/yr).[36] With this sedimentation rate, the Lake Athens yield is projected to decrease over time, as shown in Table 5-1.

From summer 2005 through spring 2007, Lake Athens experienced a significant drought, with a minimum water surface elevation of 435.09 feet (Figure 5-3). The historical water balance was used to assess whether this drought was more severe than the previous drought of record, which occurred between 1951 and 1957. Using 2007 water demands and historical climatological conditions, it is projected that the water surface elevation would reach 432.03 feet if the drought

[36] *Volumetric Survey of Lake Athens* reports an estimated sedimentation rate of 4.263 ac-ft/sq mi/yr. However, it also says, "Please note that this [sedimentation rate] is just a mathematical estimate based on the difference between the original survey and the current survey. In reality, the calculated value is unreasonable and should not be used. An error in the original volume is more likely the reason there is such a large difference in storage over the 36 years of operation." Therefore, it was assumed that the sedimentation rate in Lake Athens is the average of the estimated sedimentation rates for the following nearby reservoirs: Lake Palestine (1.439 ac-ft/sq mi/yr), Cedar Creek Reservoir (1.025 ac-ft/sq mi/yr), and Lake Striker (0.862 ac-ft/sq mi/yr).

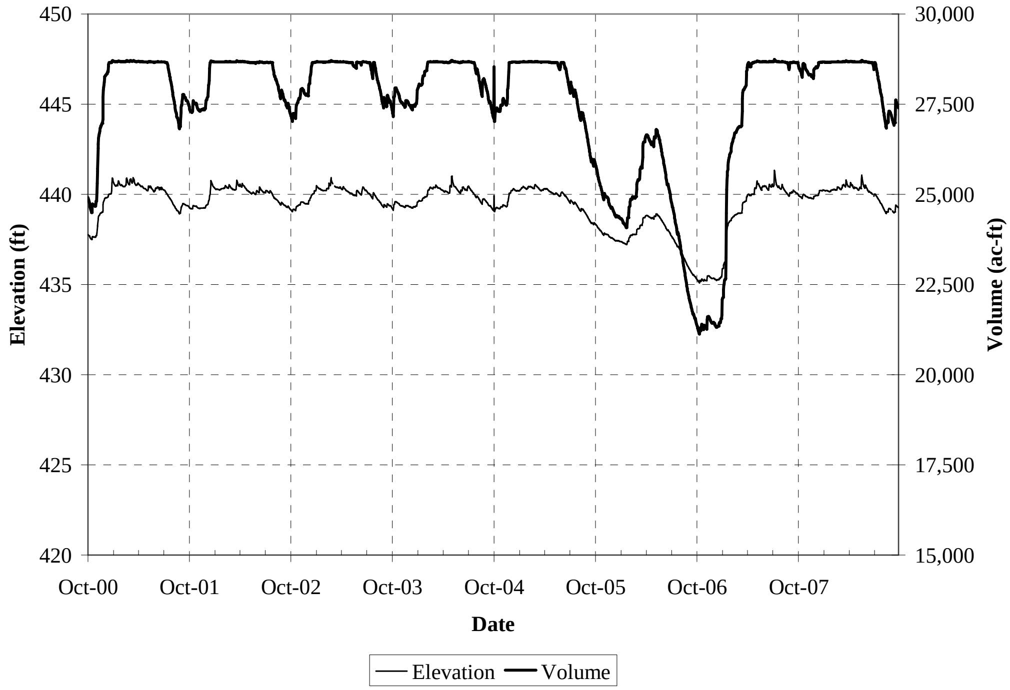
Table 5-1
Projected Lake Athens Yield Without Reclaimed Water Augmentation[a]

Yield	1998	2000	2010	2020	2030	2040	2050	2060
Firm Yield (ac-ft/yr)	6,178	6,172	6,147	6,123	6,092	6,075	6,055	6,036
Operational Yield[b] (ac-ft/yr)	2,782	2,779	2,769	2,760	2,729	2,743	2,748	2,758

[a]Calculated using spreadsheet-based, monthly flow balance.

[b]Assumes that minimum lake elevation is 431 feet msl. These amounts are projected to be available for consumption without return flow to the lake.

Figure 5-3
Lake Athens Water Surface Elevation and Volume, 2000-Present



conditions of 1951-1957 reoccurred today. Based on this analysis, the 2005-2007 drought appears to have been less severe than the drought of record. Therefore, the historical water balance is sufficient for analysis of firm yields and potential water quality impacts.

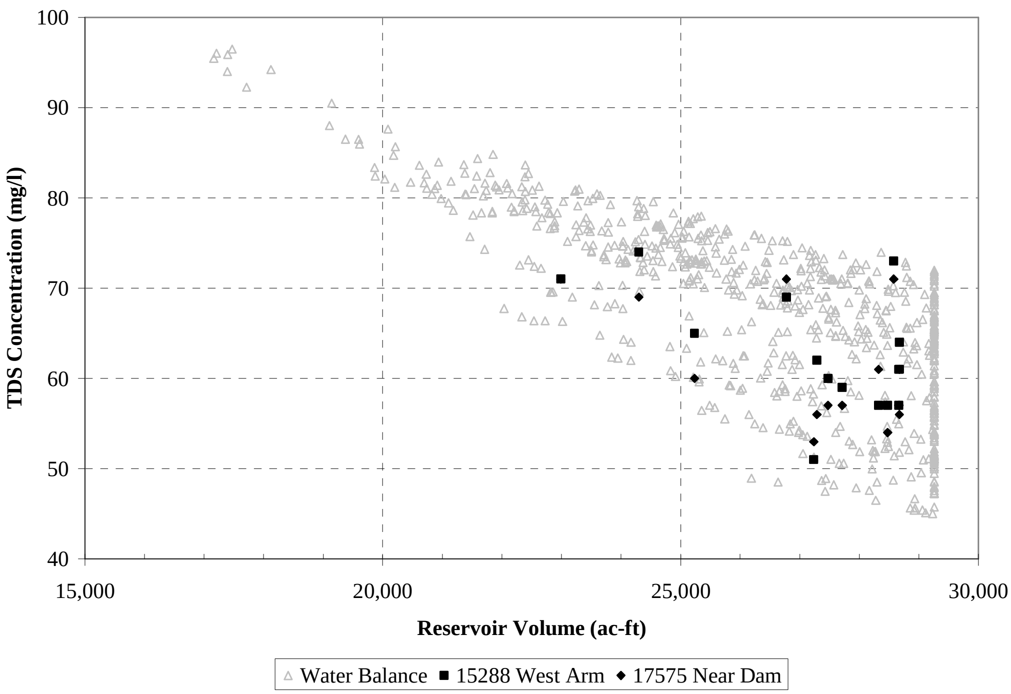
5.4. *Water Quality*

The water balance spreadsheet model described above was used to make projections of TDS, chlorides, and sulfates concentrations in Lake Athens.[37] The water balance is based on hydrologic and climatic conditions that occurred from 1940 to 1996, but raw water quality data for these constituents are only available from 2002 on. Therefore, graphs of constituent concentration versus lake volume were used to calibrate a single representative concentration (for each constituent) in the tributary inflows to Lake Athens. For each constituent, the tributary inflow concentration was varied until the projected relationship between the lake concentration

[37] Projected concentrations are based on the assumption that the lake is well-mixed and that there is no short-circuiting of reclaimed water from the discharge point to the water intakes.

and the lake volume from the water balance was similar to the historical relationship based on measured concentrations and volumes. Based on the calibrations shown in Figures 5-4 through 5-6, it has been assumed that the tributary inflow water quality can be represented by the following concentrations: 44 mg/l TDS, 8 mg/l chlorides, and 4 mg/l sulfates.[38]

Figure 5-4
Calibration of Tributary TDS Concentration



The other source of TDS, chlorides, and sulfates for the reservoir is the reclaimed water augmentation. The reclaimed water originates from raw water, but municipal use increases the TDS, chlorides, and sulfates concentrations relative to the concentrations in the raw water. As discussed in Chapter 4, the average TDS concentration in the treated wastewater effluent (304 mg/l) is 242 mg/l greater than the average TDS concentration in Lake Athens (62 mg/l). No chlorides or sulfates concentrations were available for the treated wastewater effluent.

[38] The calibration assumes that TFFC does not add TDS to the water that it returns to Lake Athens. Sampling should be conducted to verify this assumption.

Figure 5-5
Calibration of Tributary Chlorides Concentration

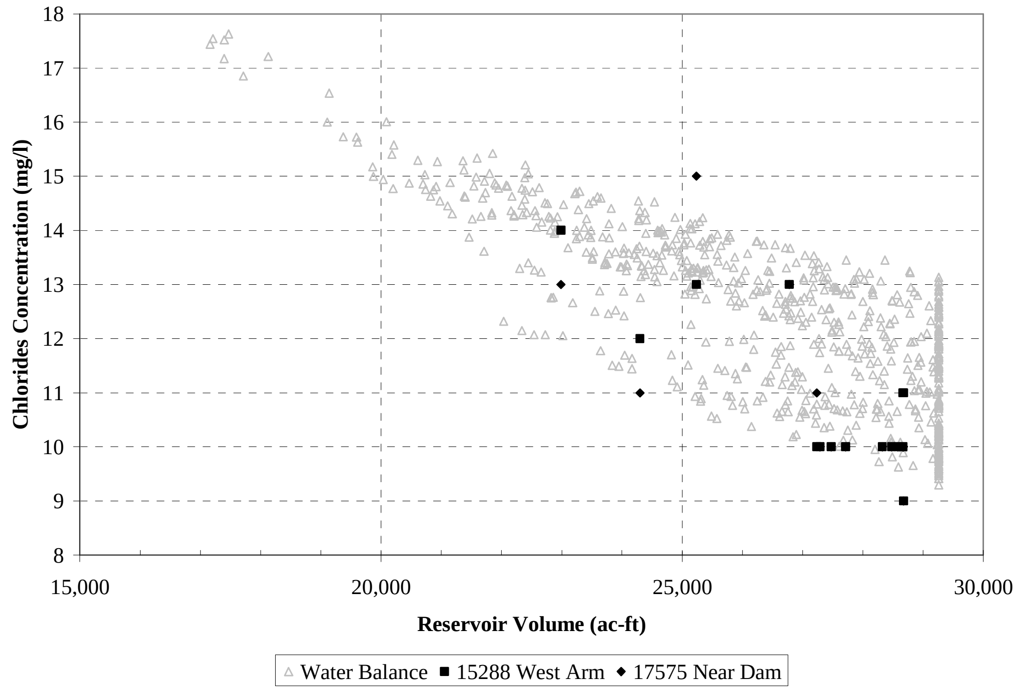
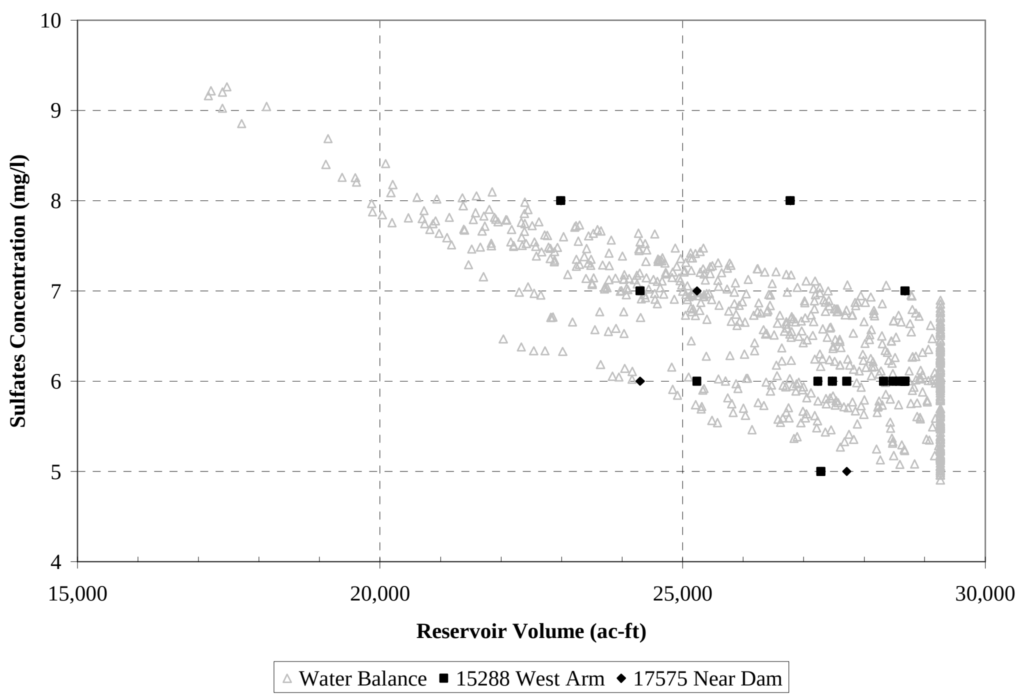


Figure 5-6
Calibration of Tributary Sulfates Concentration



Based on the difference between TDS in the raw water and TDS in the Athens treated wastewater effluent and based on experience with other projects, it has been assumed that the reclaimed water will have concentrations greater than the raw water concentrations in the lake by the following amounts: 250 mg/l for TDS, 40 mg/l for chlorides, and 50 mg/l for sulfates.

5.5. Projected Water Supply and Water Quality

The following assumptions were used in developing the water balance for use in estimating the maximum allowable reclaimed water augmentation rate under future conditions:

- TFFC will divert 3,023 ac-ft/yr (the amount of AMWA's industrial water right) from Lake Athens and will return 90 percent of this amount to Lake Athens.
- AMWA water demands are taken from the *2006 Region C Water Plan*.
- Athens will obtain 444 ac-ft/yr from wells, as in the *2006 Region C Water Plan*.

These assumptions are summarized in Table 5-2. The water demand from Lake Athens (after the TFFC return flow) is projected to exceed the operational yield (from Table 5-1) by about 2009.[39]

Finally, additional assumptions were made regarding the reclaimed water augmentation:

- Athens will return to Lake Athens up to 52.8 percent of its total water demand as reclaimed water. This is the average return flow percentage for the period 2002-2006.
- The municipal reclaimed water retains its identity when diverted from Lake Athens, passed through the TFFC facility, and returned to Lake Athens. In other words, for purposes of estimating the reclaimed water blend percentage, the portion of the TFFC discharge that originated from municipal reclaimed water is still counted as municipal reclaimed water when it is returned to the lake from the TFFC.

[39] This means that a water shortage is projected for "drought of record" hydrologic conditions but not necessarily for other hydrologic conditions. Athens could boost its groundwater production to extend the time until the water demand from Lake Athens exceeds the operational yield, although no analysis has been conducted to determine how long this could be forestalled.

Table 5-2
Projected AMWA Water Demand and Supply (ac-ft/yr)

Demand	2010	2020	2030	2040	2050	2060
Athens[a]	2,326	2,832	3,431	4,111	5,003	6,108
Irrigation	159	164	169	174	179	185
Livestock (TFFC)	3,023	3,023	3,023	3,023	3,023	3,023
Manufacturing	66	71	80	91	103	117
Subtotal	*5,574*	*6,090*	*6,703*	*7,399*	*8,308*	*9,433*
Demand Reduction through Water Conservation	24	190	346	467	606	783
Total Water Demand[b]	***5,550***	***5,900***	***6,357***	***6,932***	***7,702***	***8,650***
TFFC Return Flow	2,716	2,716	2,716	2,716	2,716	2,716
Net Water Demand After TFFC Return Flow[c]	*2,834*	*3,184*	*3,641*	*4,216*	*4,986*	*5,934*
Lake Athens Operational Yield[d]	2,769	2,760	2,729	2,743	2,760	2,758
Projected Shortage	*65*	*424*	*912*	*1,473*	*2,226*	*3,176*

[a] Does not include the portion of Athens' water demand to be satisfied with groundwater (assumed to be 444 ac-ft/yr).

[b] Before TFFC return flow. TFFC returns a substantial portion (assumed to be 90 percent) of its diversion to the lake after use.

[c] Projected demand for water by entities that, historically, have not returned flow to the lake.

[d] The *2006 Region C Water Plan* recommended that a temporary pumping strategy be used to allow the Texas Freshwater Fisheries Center to obtain water from elevations less than 431 feet until a more permanent strategy could be implemented. Although the temporary pumping strategy is not considered in this analysis, the *2006 Region C Water Plan* projects that it could supply up to an additional 1,500 acre-feet per year from Lake Athens.

The consultants evaluated several limiting conditions to identify feasible reclaimed water augmentation rates and the corresponding polishing treatment requirements (Table 5-3). Each successive Limiting Condition restricts reclaimed water augmentation rates more than the previous Limiting Condition. The results of the evaluation of the Limiting Conditions are presented in the following sections. Tables showing projected reclaimed water augmentation rates and projected lake conditions for each Limiting Condition are presented in Appendix E.

Table 5-3
Limiting Conditions for Reclaimed Water Augmentation Evaluation

Limiting Condition Number	Description
1	All Available Reclaimed Water Supply
2	Minimum Water Surface Elevation of 431 Feet
3	Minimum Detention Time and Minimum Water Surface Elevation of 431 Feet
4	50 Percent Maximum Blend and Minimum Water Surface Elevation of 431 Feet
5	200 mg/l Maximum Annual Average TDS and Minimum Water Surface Elevation of 431 Feet

Limiting Condition 1: All Available Reclaimed Water Supply

If AMWA augments Lake Athens with all available reclaimed water and if AMWA demands water from Lake Athens according to Table 5-2, the maximum blend of reclaimed water to natural water by decade is projected to range from 35.4 percent to 70.5 percent (Table E-1). Under Limiting Condition 1, the total water available to AMWA would be sufficient to meet projected demand until after 2060. However, the projected maximum blend and minimum detention time (Figure 5-7) do not meet the blending and detention time targets established for the AMWA project, so reclaimed water augmentation rates under Limiting Condition 1 are not feasible.

Limiting Condition 2: 431 Feet Minimum Water Surface Elevation

With its current infrastructure, the TFFC cannot withdraw water if the water surface elevation in Lake Athens is less than 431 feet. Limiting the minimum water surface elevation (WSEL) to 431 feet does not limit the reclaimed water augmentation rate until after 2050 (Table E-2). Under Limiting Condition 2, the total water available to AMWA would be sufficient to meet projected demand until after 2060. However, the projected minimum detention time does not meet the detention time target established for the AMWA project (Figure 5-8), so reclaimed water augmentation rates under Limiting Condition 2 are not feasible.

Figure 5-7
Projected 2060 Monthly Blends and Detention Times for Limiting Condition 1

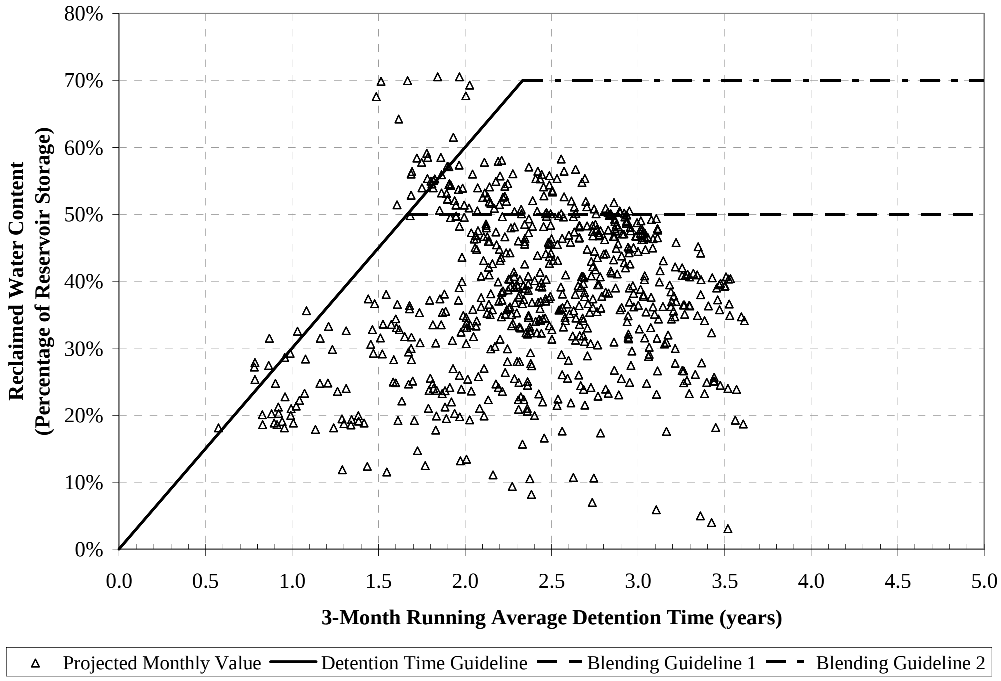
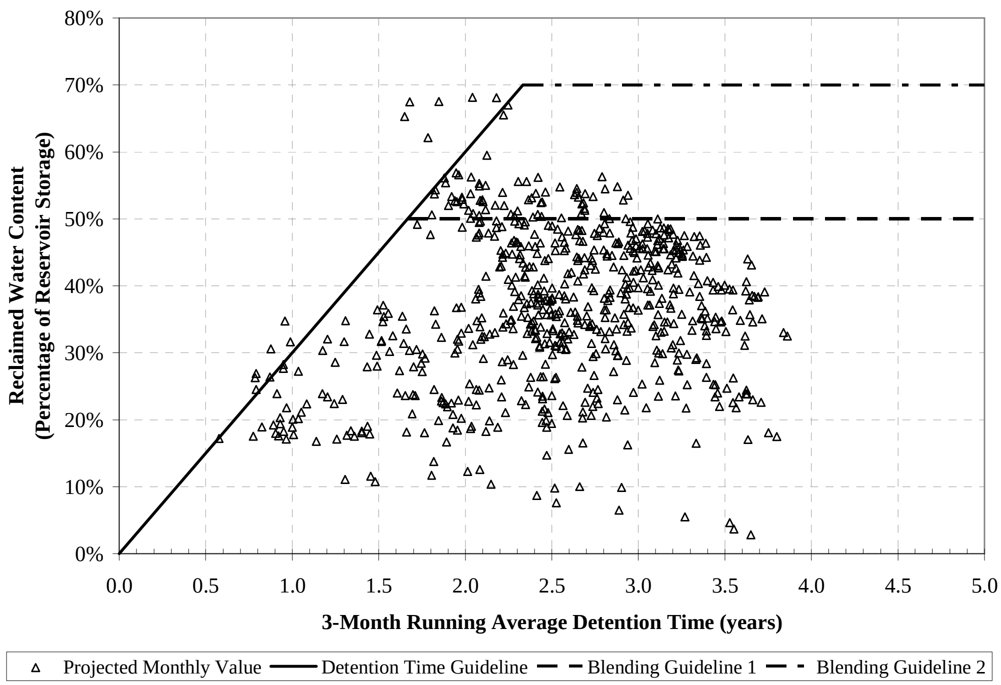


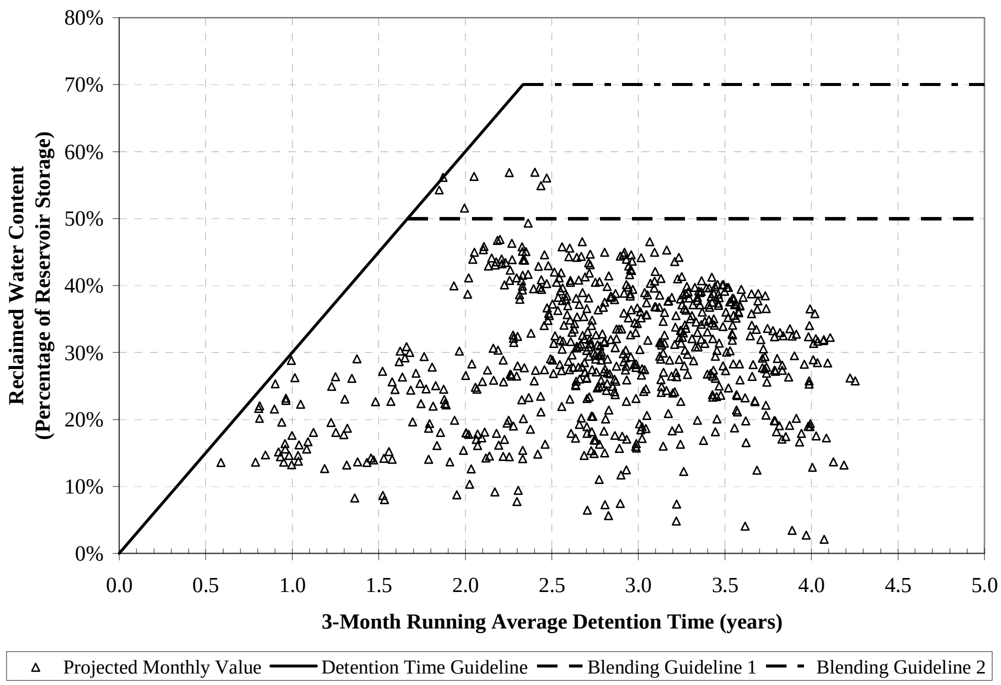
Figure 5-8
Projected 2060 Monthly Blends and Detention Times for Limiting Condition 2



Limiting Condition 3: Minimum Detention Time

Reducing the reclaimed water augmentation rates to meet the detention time target established for the AMWA project and limiting the minimum WSEL to 431 feet (Limiting Condition 3) limits the reclaimed water augmentation rate after 2030 (Table E-3 and Figure 5-9). Under Limiting Condition 3, the total water available to AMWA would be sufficient to meet projected demand until about 2050. More advanced treatment that addresses emerging microconstituents of concern would be recommended when the projected maximum blend exceeds 50 percent. The reclaimed water augmentation rates under Limiting Condition 3 (as much as 2.11 mgd by 2060) are feasible because they meet the blending and detention time targets established for the AMWA project.

Figure 5-9
Projected 2060 Monthly Blends and Detention Times for Limiting Condition 3



Membrane filtration treatment would be required to reduce the projected maximum annual average TDS concentration to meet a target concentration of 200 mg/l.[40] Some of the water that enters membrane filtration is rejected from the process as concentrated brine, which would reduce the amount available for augmentation in some decades. The projected impact of membrane filtration treatment is shown in Table E-3.[41] By 2020, it is projected that approximately 21.5 percent of the available reclaimed water would required membrane filtration to reduce the maximum annual average TDS concentration to the target concentration of 200 mg/l. By 2040, essentially all of the reclaimed water should be treated with membrane filtration because the maximum blend is projected to exceed 50 percent.

Limiting Condition 4: 50 Percent Maximum Blend

If the reclaimed water is polished only with advanced nutrient removal, then the recommended maximum reclaimed water blend in Lake Athens is approximately 30 percent during most hydrologic conditions and approximately 50 percent during drought periods. Reducing the reclaimed water augmentation rates to meet the blending target established for the AMWA project and limiting the minimum WSEL to 431 feet (Limiting Condition 4) limits the reclaimed water augmentation rate after 2020 (Table E-4 and Figure 5-10). Under Limiting Condition 4, the total water available to AMWA would be sufficient to meet projected demand until about 2046. The reclaimed water augmentation rates under Limiting Condition 4 (as much as 1.73 mgd by 2060) are feasible because they meet the blending and detention time targets established for the AMWA project.

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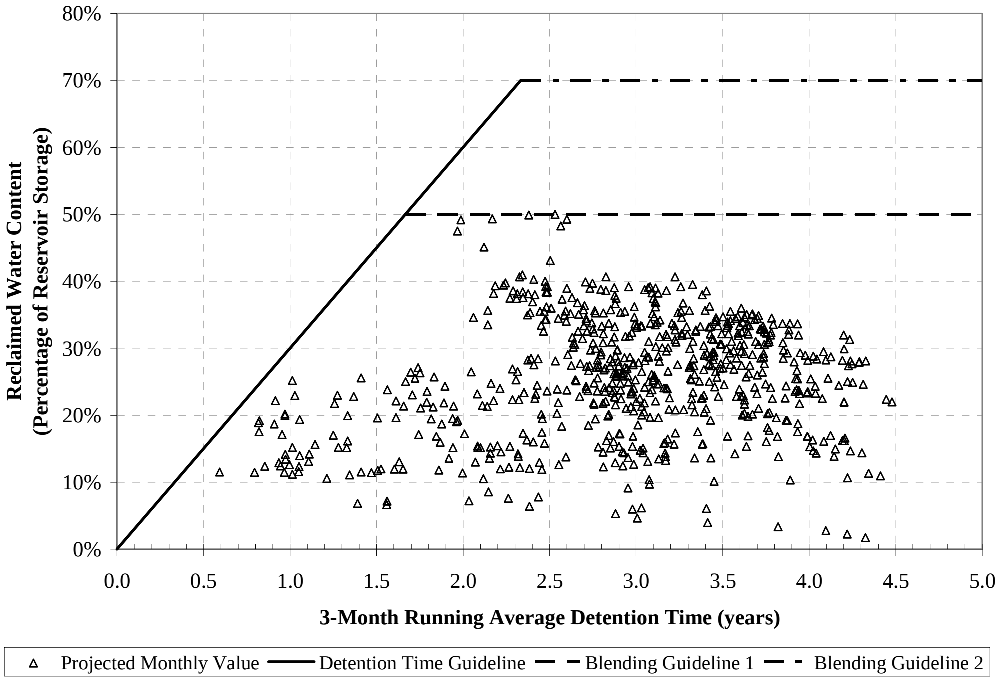
[40] There are similar issues with chlorides and sulfates, but they are less severe than the TDS issue. All of the methods to reduce TDS concentrations (e.g., desalination, reduced reclaimed water augmentation rates, etc.) will also reduce the chlorides and sulfates concentrations. Therefore, chlorides and sulfates will not be discussed further.

[41] Based on the following assumptions about membrane filtration:

- 80 percent of the reclaimed water introduced to the membrane filtration process (the feed water) will be recovered as permeate and will be used for water supply augmentation (20 percent will be rejected as concentrate).
- The permeate TDS concentration will be 6 percent of the feed water TDS concentration.
- For desalination treatment, membrane filtration facilities will be sized to treat a relatively small percentage (or side stream) of the reclaimed water used for augmentation. The remaining reclaimed water will bypass the membrane filtration process. After membrane filtration, the permeate will be recombined with the bypass water and will be used for water supply augmentation.

Figure 5-10
Projected 2060 Monthly Blends and Detention Times for Limiting Condition 4

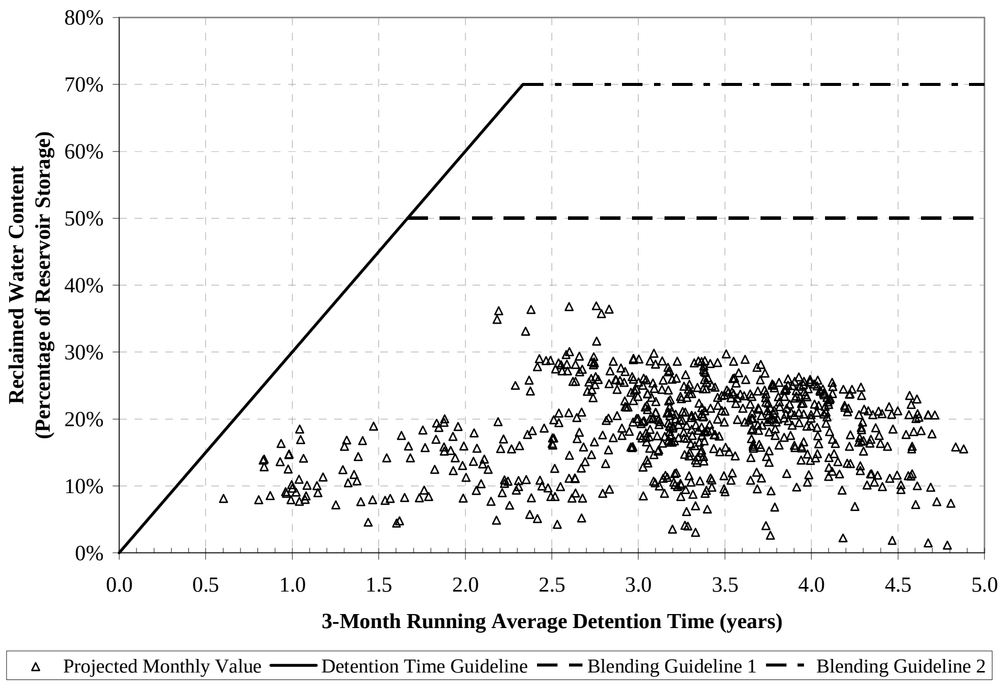


Membrane filtration treatment would be required to reduce the projected maximum annual average TDS concentration to meet the target concentration of 200 mg/l. Some of the water that enters membrane filtration is rejected from the process as concentrated brine, which would reduce the amount available for augmentation in some decades. The projected impact of membrane filtration treatment is shown in Table E-4.[41] By 2030, it is projected that approximately 29.9 percent of the available reclaimed water would required membrane filtration to reduce the maximum annual average TDS concentration to the target concentration of 200 mg/l.

Limiting Condition 5: 200 mg/l Maximum Annual Average TDS

Limiting Conditions 1 through 4 require membrane filtration treatment to reduce the projected maximum annual average TDS concentration to the target concentration of 200 mg/l. Membrane filtration treatment would be provided for a side stream of the reclaimed water prior to augmentation. If membrane filtration treatment is not provided, another approach is to reduce the reclaimed water augmentation rate to limit the maximum annual average TDS concentration to 200 mg/l (Limiting Condition 5). If the minimum WSEL is also limited to 431 feet, then the allowable reclaimed water augmentation rate is limited in every decade (Table E-5). Under Limiting Condition 5, the total water available to AMWA would be sufficient to meet projected demand until about 2036. The reclaimed water augmentation rates under Limiting Condition 5 (as much as 1.14 mgd by 2060) are feasible because they meet the blending and detention time targets established for the AMWA project. Projected monthly reclaimed water blends and detention times are shown in Figure 5-11.

Figure 5-11
Projected 2060 Monthly Blends and Detention Times for Limiting Condition 5



Importing raw water to Lake Athens from another source could provide further dilution of the reclaimed water[42] and could allow greater reclaimed water augmentation rates, lower maximum blends, and more water for municipal supply than shown for many of the Limiting Conditions. At this time, any future augmentation of Lake Athens with raw water is speculative and would have unknown water quality. Therefore, no analysis of importing additional raw water to Lake Athens has been conducted.

[42] Note that an import of raw water from Forest Grove Reservoir may contain a substantial portion of reclaimed water, since the existing North WWTP discharge ultimately flows to Forest Grove Reservoir.

5.6. Feasibility and Minimum Required Polishing Treatment

Limiting Conditions 1 and 2 are not feasible according to the maximum percent blends and minimum detention times selected for the Athens indirect reuse project (Figure 5-1).

The projected allowable reclaimed water augmentation rates, maximum TDS concentrations, compliance with the target TDS limit, and comparisons of Athens demands and supplies from Lake Athens are shown graphically by decade for the limiting scenarios discussed in Chapter 5.5 (Figures 5-12 through 5-15).

When the projected maximum blend exceeds 50 percent, it is recommended that membrane filtration/advanced oxidation treatment be provided for all reclaimed water used for water supply augmentation. The projected maximum percent blend for Limiting Condition 3 (Minimum Detention Time Target and 431 Feet Minimum WSEL) scenario does not exceed 50 percent until about 2026. Because about 20 percent of the reclaimed water that is treated with membrane filtration is wasted as concentrated brine and because the available reclaimed water is limited to that produced within the City, applying membrane treatment reduces the feasible augmentation rate and reduces the projected maximum percent blend. Therefore, under Limiting Condition 3, it is not until after 2040 that all of the reclaimed water used for water supply augmentation should be treated with membrane filtration (Table E-3). Due to this limitation, using membrane filtration with the Limiting Condition 3 will not produce a greater recommended augmentation rate than Limiting Condition 4 until after 2040 (Figure 5-13).

The TSWQS do not contain a numerical TDS standard for Lake Athens. In such a case, a screening-level analysis should consider the TDS standard for the "nearest appropriate segment."[43] The consultants have assumed that the target TDS limit for Lake Athens (an unclassified lake) is the same as that for Lake Palestine (the nearest downstream classified lake):

[43] Texas Commission on Environmental Quality, January 2003. *Procedures to Implement the Texas Surface Water Quality Standards*, Publication RG-194 (Revised).

Table 5-4
Summary of Various Limiting Scenarios, Feasibility, and Recommended Treatment

	Limiting Condition	2060 Reclaimed Water Augmentation Rate (mgd)	Year When Demand Projected to Exceed Supply	Feasibility	Minimum Recommended Treatment
1	All Available Reclaimed Water Supply	3.09	After 2060	Not feasible due to high percent blends and low detention times	n/a
2	431 Feet Minimum WSEL	2.88	After 2060	Not feasible due to low detention times	n/a
3	Minimum Detention Time Target and 431 Feet Minimum WSEL	2.11	2051	Feasible	Membrane filtration and advanced oxidation of all reclaimed water for augmentation for augmentation rates where the maximum blend is projected to be greater than 50 percent. Otherwise, advanced nutrient removal from all reclaimed water for augmentation. Options for achieving the target maximum annual average TDS concentration of 200 mg/l for augmentation rates where the maximum blend is projected to be 50 percent or less include: ▪ Providing membrane filtration to remove TDS from a side stream of the reclaimed water used for augmentation and/or ▪ Site-specific TSWQS for Lake Athens.[a]
4	50 Percent Maximum Blend Target and 431 Feet Minimum WSEL	1.73	2046	Feasible	Advanced nutrient removal from all reclaimed water for augmentation. Options for achieving the target maximum annual average TDS concentration of 200 mg/l include: ▪ Providing membrane filtration to remove TDS from a side stream of the reclaimed water used for augmentation and/or ▪ Site-specific TSWQS for Lake Athens.[a]

Table 5-4: Summary of Various Limiting Scenarios, Feasibility, and Recommended Treatment (Continued)

Limiting Condition		2060 Reclaimed Water Augmentation Rate (mgd)	Year When Demand Projected to Exceed Supply	Feasibility	Minimum Recommended Treatment
5	200 mg/l Maximum Annual Average TDS and 431 Feet Minimum WSEL	1.14	2036	Feasible	Advanced nutrient removal from all reclaimed water for augmentation The target TDS limit would be met through a reduced reclaimed water augmentation rate.

[a] See discussion of TDS issues in Sections 5.6 and 9.3.

Figure 5-12
Comparison of Allowable Reclaimed Water Augmentation Rates for Various Limiting Conditions (Without Membrane Filtration)

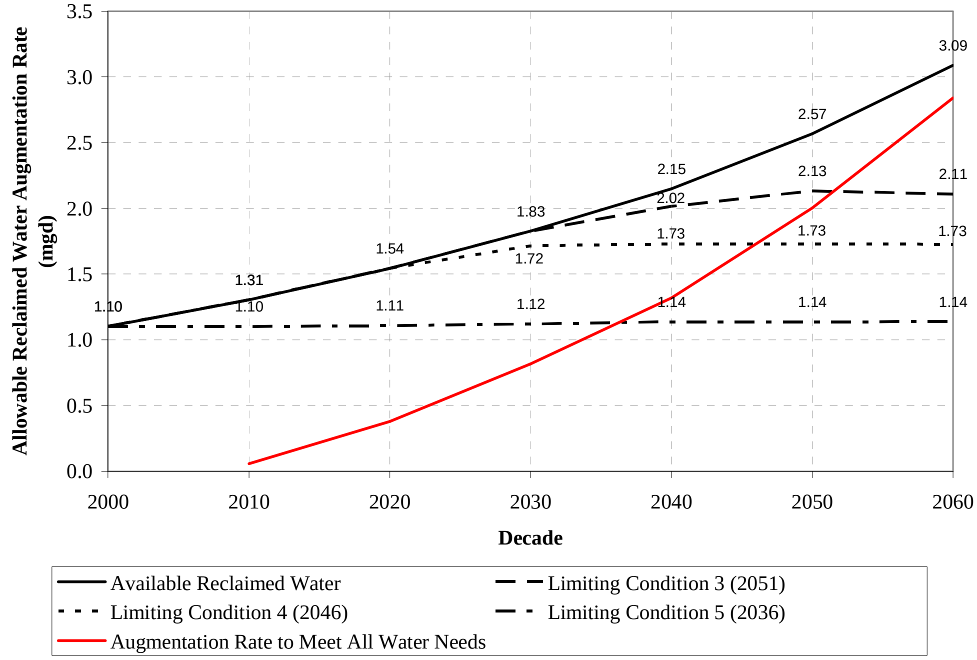


Figure 5-13
Comparison of Allowable Reclaimed Water Augmentation Rates for Various Limiting Conditions (With Membrane Filtration)

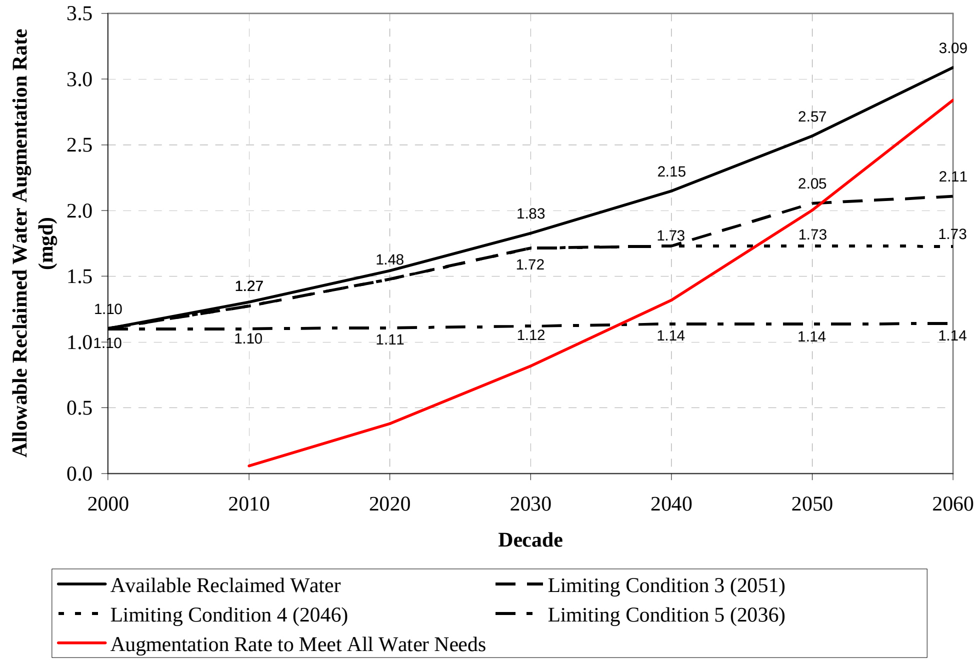


Figure 5-14
Projected 2060 Annual Average TDS Concentrations for Various Limiting Conditions (Without Membrane Filtration)

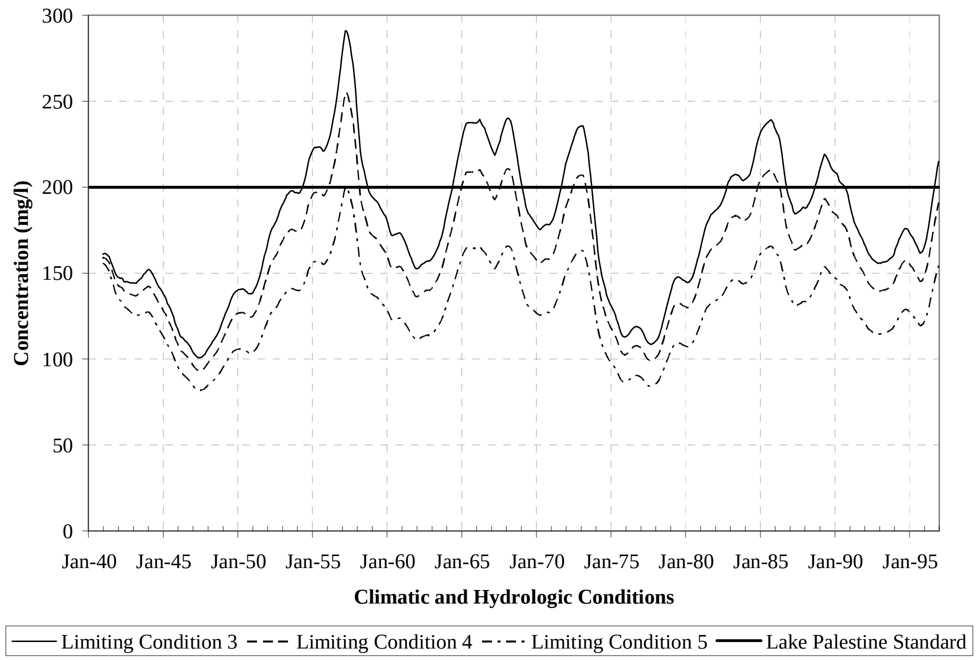
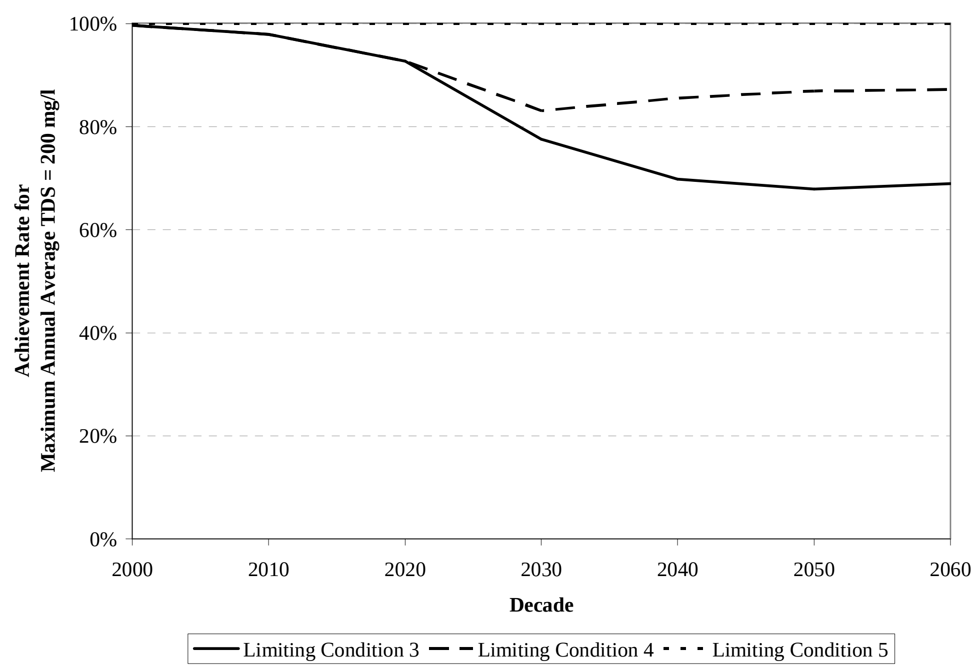


Figure 5-15
Projected Compliance with Target TDS Limit for Various Limiting Conditions (Without Membrane Filtration)



a maximum annual average of 200 mg/l. AMWA could address potential TDS issues through one of the following actions:

- Provide desalination treatment for all or part of the reclaimed water,
- Reduce the reclaimed water augmentation rate to that shown under Limiting Condition 5,
- Import raw water to Lake Athens from another source, and/or
- Develop site-specific TSWQS for Lake Athens.

Figure 5-14 summarizes projected TDS concentrations in Lake Athens for different reclaimed water augmentation rates. There is significant uncertainty in the projected TDS concentrations. Sources of uncertainty include the following:

- Available TDS concentration data for reclaimed water were limited.
- No data were available regarding how much TDS is added to the flow diverted to TFFC and returned to Lake Athens.
- The actual location where the target TDS limit would be applied is unclear.
- It was assumed that the lake is well-mixed (at a given time, TDS concentrations are the same at all locations in the lake).

For Limiting Conditions 3 and 4, the screening-level analysis suggests that excursions from the target TDS concentration would be infrequent and would be limited to severe drought conditions when water availability is most crucial.

To develop a site-specific TSWQS TDS standard for Lake Athens, it would likely be necessary to monitor TDS concentrations in the reclaimed water, Lake Athens, the TFFC return flow, and tributary inflows and to construct a more detailed TDS model. In addition, a site-specific TDS standard would have to be consistent with the intended uses of Lake Athens.

6. Polishing Treatment of the Reclaimed Water

As mentioned in Chapter 5, polishing treatment of the reclaimed water is recommended prior to augmentation of the raw water supply in Lake Athens. This chapter reviews existing treatment processes at the WWTPs and the water treatment plant (WTP) and discusses alternatives for polishing wastewater treatment.

6.1. Guidance

A full description of treatment processes at the WWTP(s) and the WTP(s) should be developed and used to define the roles of these barriers in an indirect reuse project. As indicated above, for regulated constituents, the required treatment at WWTPs and WTPs is established by state and federal regulations. Consideration for requiring any additional treatment could involve the performance of a detailed analysis, which, if needed, would be performed during subsequent scientific and technical efforts associated with the implementation of an indirect reuse project. However, for the purpose of initial planning and performing a preliminary feasibility assessment of an indirect reuse project, consideration could be given to the potential effects of additional polishing treatment.

Polishing treatment could be of primary consideration for nutrient removal when wastewater is discharged directly to a water supply reservoir. Additionally, desalination, treatment could be considered as one of the options to comply with TSWQS for conservative constituents. Consideration could also be given to providing special treatment, if needed, at the wastewater treatment plant or drinking water treatment plant to achieve enhanced disinfection and/or to address emerging microconstituents of concern.

If feasible polishing treatment alternatives have been identified, the potential effectiveness of each treatment alternative should be discussed, and conceptual designs for each polishing treatment alternative should be developed. The conceptual designs for the polishing treatment alternatives will be used to develop opinions of probable cost for these facilities. For the Athens indirect reuse project, a description of existing treatment processes and conceptual design information for feasible polishing treatment alternatives are presented below.

6.2. Description of Wastewater Treatment at Existing WWTPs

The North WWTP and the West WWTP are activated sludge process plants operated in the extended aeration mode. Treatment units are each plant are shown in Table 6-1.

Table 6-1
Treatment Units at Athens WWTPs

Facility	North WWTP	West WWTP
Bar screen	X	
Comminutor		X
Grit chamber	X	
Grit separators		X
Imhoff tanks	X	
Primary clarifiers		X
Trickling filters	X	X
Aeration basin	X	X
Final clarifiers	X	X
Sludge digester		X
Chlorine contact chambers	X	X
Dechlorination chamber	X	X

6.3. Description of Water Treatment at Existing Water Treatment Plant

Water is pumped from Lake Athens to the AMWA WTP. During the treatment process, the flow passes through solids contact clarifiers, gravity dual media filters, a wet well, and two clearwells before being pumped into the distribution system.

6.4. Conceptual Design of Polishing Wastewater Treatment

Potential polishing treatment methods include constructed treatment wetlands, denitrification filters and chemical precipitation of phosphorus (DF/CP), and a combination of membrane treatment and advanced oxidation. Each of these methods is evaluated below.

Twelve different polishing treatment scenarios were evaluated (Table 6-2), with various combinations of Limiting Conditions, realization of the target maximum annual average TDS concentration of 200 mg/l, and polishing treatment facilities. These polishing treatment scenarios and the polishing treatment facilities are discussed in the next sections.

Table 6-2
Polishing Treatment Scenarios

Treatment Scenario Number	Limiting Factor in Lake Athens	TDS Target 200 mg/l?	Treatment Choice	Lake Athens Augmentation Flowrate (mgd)	Comment
1	200 mg/l TDS	Yes	Denitrifying Filters/Chemical Precipitation	1.14	
2	200 mg/l TDS	Yes	Wetland Site A[a]	1.09	Augmentation flowrate limited by available size of Wetland Site A
3	200 mg/l TDS	Yes	Wetland Site B[a]	1.14	
4	200 mg/l TDS	Yes	Sidestream[b] Membrane Filtration	1.14	
5	50% Maximum Blend	No	Denitrifying Filters/Chemical Precipitation	1.73	
6	50% Maximum Blend	No	Wetland Site A	1.65	Augmentation flowrate limited by available size of Wetland Site A
7	50% Maximum Blend	No	Wetland Site B	1.73	
8	50% Maximum Blend	Yes	Sidestream Membrane Filtration	1.73	
9	50% Maximum Blend	Yes	Denitrifying Filters/Chemical Precipitation + Sidestream Membrane Filtration	1.73	
10	50% Maximum Blend	Yes	Wetland Site A + Sidestream Membrane Filtration	1.73	
11	50% Maximum Blend	Yes	Wetland Site B + Sidestream Membrane Filtration	1.73	
12	Min. Detention Time	Yes	Full Membrane Filtration + Advanced Oxidation	2.11	

[a]Wetland Site A and Wetland Site B refer to two potential sites for a constructed treatment wetland. These are discussed in detail in Chapter 6.4.

[b]Sidestream membrane filtration means that a portion of the total reclaimed water is polished with membrane filtration.

Conceptual Design of Constructed Treatment Wetlands

Constructed treatment wetlands are useful for removing nitrogen and phosphorus from WWTP effluent before introducing the treated effluent as reclaimed water into a reservoir. Initial studies indicate that constructed treatment wetlands also have potential benefits in reducing concentrations of emerging microconstituents of concern (EMCs). Research on this topic is ongoing. At this time, it is difficult to quantify the effectiveness of constructed treatment wetlands in addressing EMCs.

Constructed treatment wetlands do not remove conservative constituents such as TDS, chlorides, or sulfates. Concentrations of these substances may be increased or reduced in treatment wetlands depending on whether evaporation exceeds precipitation (concentration effect) or whether precipitation exceeds evaporation (dilution effect). Depending on the flowrate and the target TDS concentration, additional polishing treatment (such as membrane filtration) may be necessary to reduce TDS, chlorides, and sulfates concentrations in the reclaimed water before nutrient removal in a constructed wetland. This additional polishing will also reduce the total phosphorus concentration in the reclaimed water and decrease the required size of the constructed wetland.

To design a constructed wetland, it is necessary to identify the wetland influent quality and the target wetland effluent quality. Available total phosphorus and nitrate data with which to characterize the reclaimed water are limited (Table 4-2). Based on the average concentrations in the treated wastewater effluent, it has been assumed that the reclaimed water influent to the constructed wetland will have a total phosphorus concentration of 3 mg/l and a total nitrogen concentration of 15.2 mg/l.[44]

[44] AMWA/Athens should begin regular sampling and analysis of Lake Athens raw water, and West WWTP effluent, and North WWTP effluent for total phosphorus, total nitrogen, TDS, chlorides, and sulfates. In the short term, these data should be used to verify the required minimum constructed wetland treatment area, as discussed in the next section. In the long term, these data should be used to track the impact of reclaimed water augmentation on Lake Athens water quality.

Minimum Treatment Area

The consultants estimated the minimum wetland treatment area required to achieve a total nitrogen concentration of 5 mg/l and a total phosphorus concentration of 1 mg/l[45] using equations that represent stirred tank reactors in series. The basic equation is:[46]

$$C_j – C^* = [C_{j-1} – C^*]/[1 + 0.002927*kA/N/Q]$$

where:

the index j represents outflows from the jth wetland cell,
the index j-1 represents inflows to the jth wetland cell,
C = concentration (mg/l),
C^* = lowest achievable concentration that will occur in a treatment wetland (mg/l).
k = rate constant (m/yr), and
A = constructed wetland treatment area (acres),
N = number of equally-sized wetland cells in series (assumed to be 4),
Q = flowrate (mgd),

The equations for flow and concentration were modified to consider evapotranspiration, precipitation, and infiltration. These equations are:

$$Q_j = Q_{j-1} – ((ET – P)/13,450.63 – I*923.67)\ A/N$$

$$C_j = [C_{j-1} + (kC^* * 0.002927 + PC_p/13,450.63)*A/N/Q_{j-1}]/[1 + (k*0.002927 - I*923.67)*A/N/Q_j]$$

where:

ET = evapotranspiration rate (in/yr),
P = precipitation rate (in/yr),
I = infiltration rate (cm/sec),
C_p = concentration in the rainfall.

[45] The consultants predict that the design total phosphorus concentration of 1.0 mg/l is the maximum concentration that will be acceptable to the TCEQ. The design concentration should be confirmed during the preliminary design stage.

[46] Kadlec, R. H., and R. L. Knight, Treatment Wetlands, Lewis Publishers, 1996.

Given the concentration for the wetland influent, the target flowrate, the target concentration for the wetland effluent, and the number of wetland cells, these equations can be solved iteratively to estimate the minimum required constructed wetland treatment area.

The consultants used k = 22 m/yr and C^* = 1.5 mg/l to model removal of total nitrogen and k = 11.5 m/yr and C^* = 0.02 mg/l to model removal of total phosphorus. These are conservative values that are appropriate for planning-level design of constructed wetlands in Texas. With these parameter choices, the phosphorus target controls the required wetland treatment area.

The minimum required total area was estimated for the polishing treatment scenarios in Table 6-2 that use constructed wetland (Table 6-3). Estimated minimum acreages ranged from 51.6 acres to 82.0 acres, depending on the scenario.

Table 6-3
Estimated Minimum Acreage Required to Provide Polishing Treatment of Reclaimed Water

Polishing Treatment Scenario	Wetland Influent Flowrate[47] (mgd)	Wetland Effluent Flowrate (mgd)	Influent Total Phosphorus Concentration (mg/l)	Minimum Required Treatment Area (ac)	Additional Area for Facilities[a] (ac)	Minimum Required Total Area (ac)
2	1.15	1.09	3.00	44.9	6.7	51.6
3	1.20	1.14	3.00	47.0	7.0	54.0
6	1.74	1.65	3.00	68.0	10.2	78.2
10, 11	1.80	1.73	2.33[b]	52.6	7.9	60.5
7	1.83	1.73	3.00	71.3	10.7	82.0

[a] Added 15 percent additional area for facilities. No additional wetland treatment area was added to allow for redundancy or operational shutdowns.
[b] Reduced from 3 mg/l through membrane filtration of a portion of the flow.

[47] The design influent flowrates to the wetlands are based on 56.5 inches per year (in/yr) of evapotranspiration, 39.5 in/yr of precipitation, and a recharge rate of 10^{-7} centimeters per second (cm/sec). The evapotranspiration and precipitation rates were chosen such that the difference (17 inches per year) is the 75th percentile value, based on historical data obtained from the TWDB for the Lake Athens area, available URL: http://midgewater.twdb.state.tx.us/Evaporation/evap.html.

Potential Sites

The consultants reviewed soil types and topography between the North WWTP and Lake Athens and in the vicinity of Lake Athens. Most of the native soils are relatively permeable and are not naturally suitable for constructed wetlands. Initial screening identified one soil type that warranted further investigation: the Lufkin-Raino soil complex. These soils are located on "nearly level, moundy, uplands" and are characterized by slopes ranging from 0 to 1 percent and very slow permeability.[48] The complex consists of Lufkin (40 to 55 percent), Raino (30 to 40 percent), and other soil types. Lufkin soils are located between mounds, and Raino soils are located on the mounds. The mounds of Raino soils range from 25 to 100 feet in diameter and are 1 to 3 feet higher than the surrounding soils. Individual mounds are spaced from 25 to 500 feet apart.

Constructed treatment wetlands are regulated by the TCEQ's design criteria for constructed wetlands.[49] The proposed guidelines state that, "treatment units shall be constructed with a liner which is as restrictive as, or more restrictive than, material with a coefficient of permeability of $1x10^{-7}$ centimeters per second [cm/sec] with a thickness of 2 feet…"[49]

Unmodified in-situ soils can be used in place of a liner if they are shown to have properties equivalent to or better than the liner requirements. To demonstrate these properties, at least one core sample per 0.25 acres of constructed wetland bottom area shall be taken. These samples must demonstrate the following characteristics:[49]

- Coefficient of permeability less than or equal to 10^{-7} cm/sec
- More than 30% passing a number 200 mesh sieve;
- Liquid limit greater than 30%; and
- Plastic index greater than 15.

[48] United States Department of Agriculture Soil Conservation Service in cooperation with Texas Agricultural Experiment Station, Soil Survey of Henderson County, Texas, November 1979.

[49] Texas Administrative Code, Title 30, Chapter §217.209.

Selected physical and engineering properties of the Lufkin and Raino soils are shown in Table 6-4. Favorable soil properties are shown in bold, italicized text.

Lufkin-Raino soils in the vicinity were identified from Natural Resource Conservation Service (NRCS) data. Using 2005 aerial photographs (the latest available), United States Geological Survey (USGS) topographic maps, and National Hydrography Data, these areas were adjusted to exclude existing buildings, roads, railroads, steep slopes, and land located within 50 feet of a creek. From the remaining parcels, a total of four were selected to comprise two potential sites for constructed wetlands. These are identified as Wetland Site A and Wetland Site B in Figures 6-1 through 6-3.

The lowest permeability shown in Table 6-4 is "less than 0.06 inches per hour" (or $4.2x10^{-5}$ cm/sec). Sampling of in-situ soils will be necessary to determine whether the actual coefficient of permeability for Wetland Sites A and B is $1x10^{-7}$ cm/sec or less.

Due to the limited availability of locations with favorable soil properties, Site A consists of tracts A1 (27.7 acres), A2 (23.9 acres), and A3 (26.7 acres), for a total area of 78.3 acres (Figure 6-2). The available total acreage limits the potential augmentation rates slightly in polishing treatment scenarios 2 and 6.

Each tract in Site A is located adjacent to existing development. Tract A3 includes some of the most desirable commercial land in Athens. It is adjacent to State Highway 31 frontage, and a 10-acre portion of A3 is listed for sale at $8.50 per square foot ($370,260 per acre). Tract A2 is located in an area that is reserved for industrial development. It may be difficult to obtain this tract and obtain the proper zoning. The advantages of industrial development in this area may outweigh the advantages of a constructed treatment wetland.

It is anticipated that the constructed wetland would consist of one or more sedimentation basins, followed by multiple parallel trains of up to 4 wetland cells connected in series. The precise layout for these basins and cells would be determined during preliminary design.

Table 6-4
Physical and Engineering Properties of Lufkin and Raino Soils[a]

Soil Type	Soil Depth (in)	Description	Permeability (in/hr)	Percentage Passing #200 Seive	Liquid Limit (%)	Plasticity Index[b]
Lufkin, ***0 to 1 percent slope***	0-10	Loam	0.6-2.0	***40-85***	< 30	NP-10
	10-44	Clay, clay loam, silty clay loam	***< 0.06***	***70-95***	***45-67***	***30-45***
	44-60	Clay, clay loam, sandy clay loam	***< 0.06***	***44-90***	***45-86***	***25-55***
Raino, ***0 to 1 percent slope***	0-29	Loam	0.6-2.0	***40-80***	< 30	NP-10
	29-35	Loam, sandy clay loam, clay loam	0.6-2.0	***40-70***	20-40	5-20
	35-72	Clay, sandy clay, silty clay	***< 0.06***	***55-90***	***46-74***	***24-45***

[a]Favorable soil properties are shown in bold, italicized text. Properties taken from United States Department of Agriculture Soil Conservation Service in cooperation with Texas Agricultural Experiment Station, Soil Survey of Henderson County, Texas, November 1979.
[b]NP means "non-plastic"

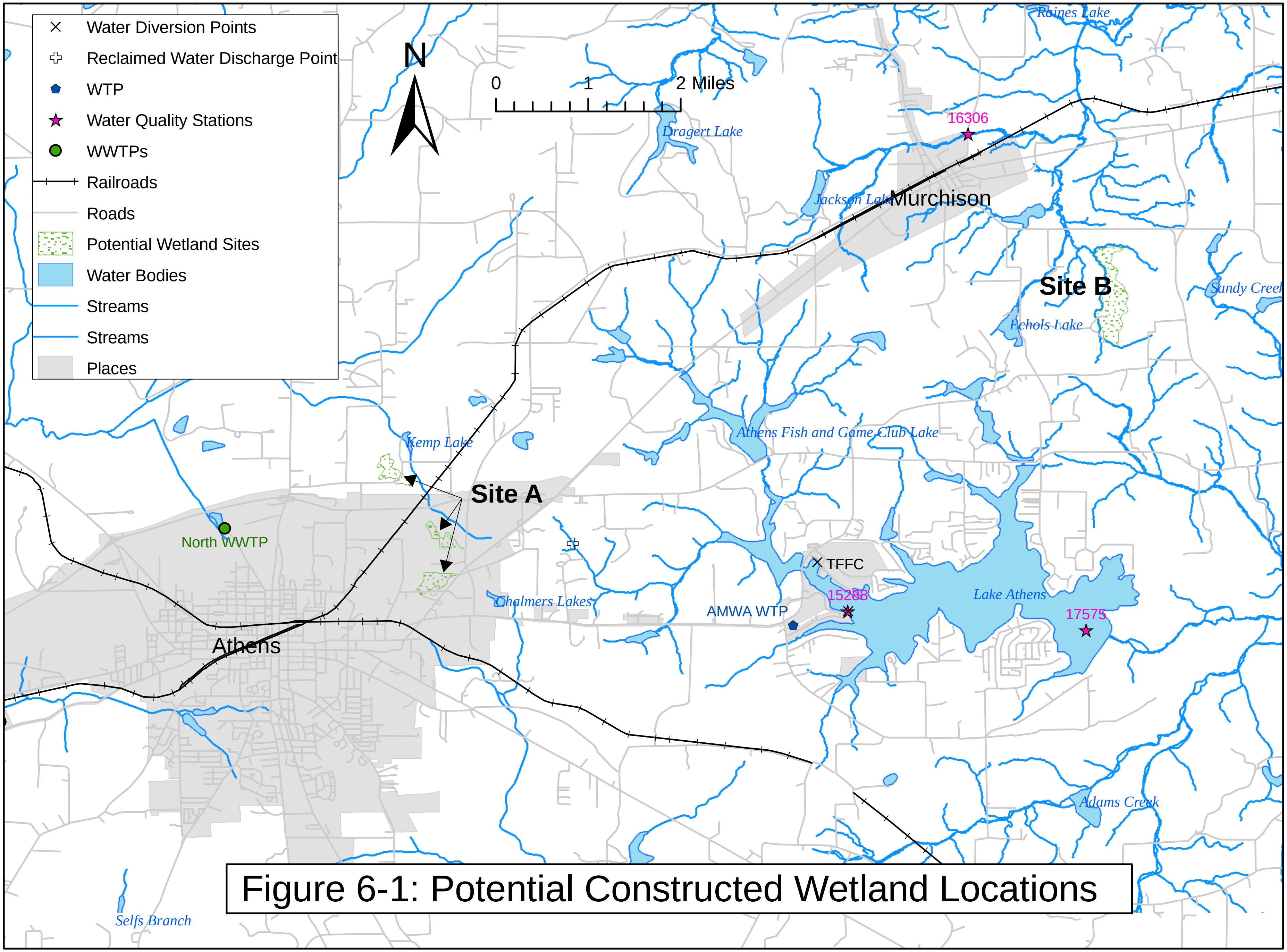


Figure 6-1: Potential Constructed Wetland Locations

Figure 6-2: Constructed Wetland Site A

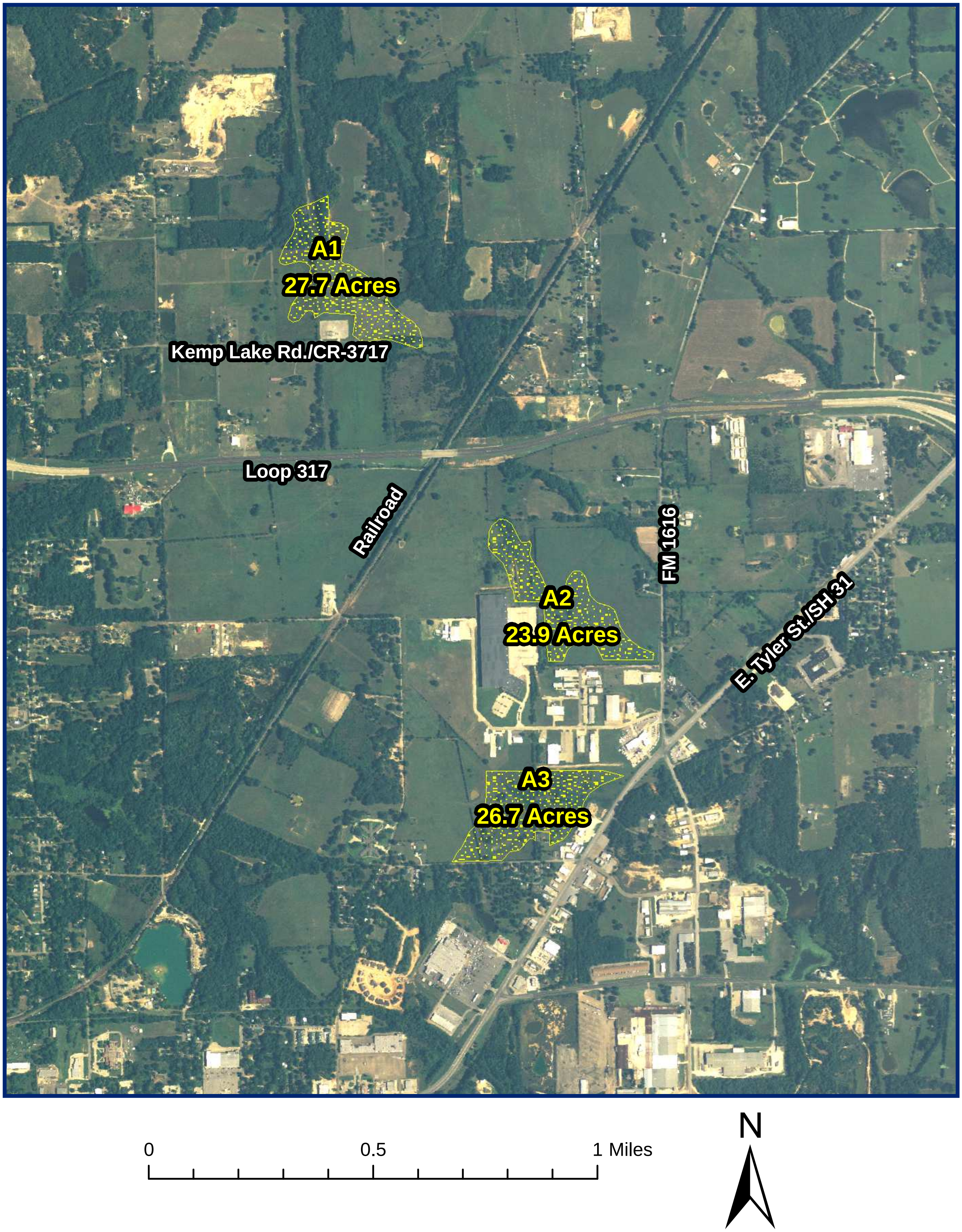
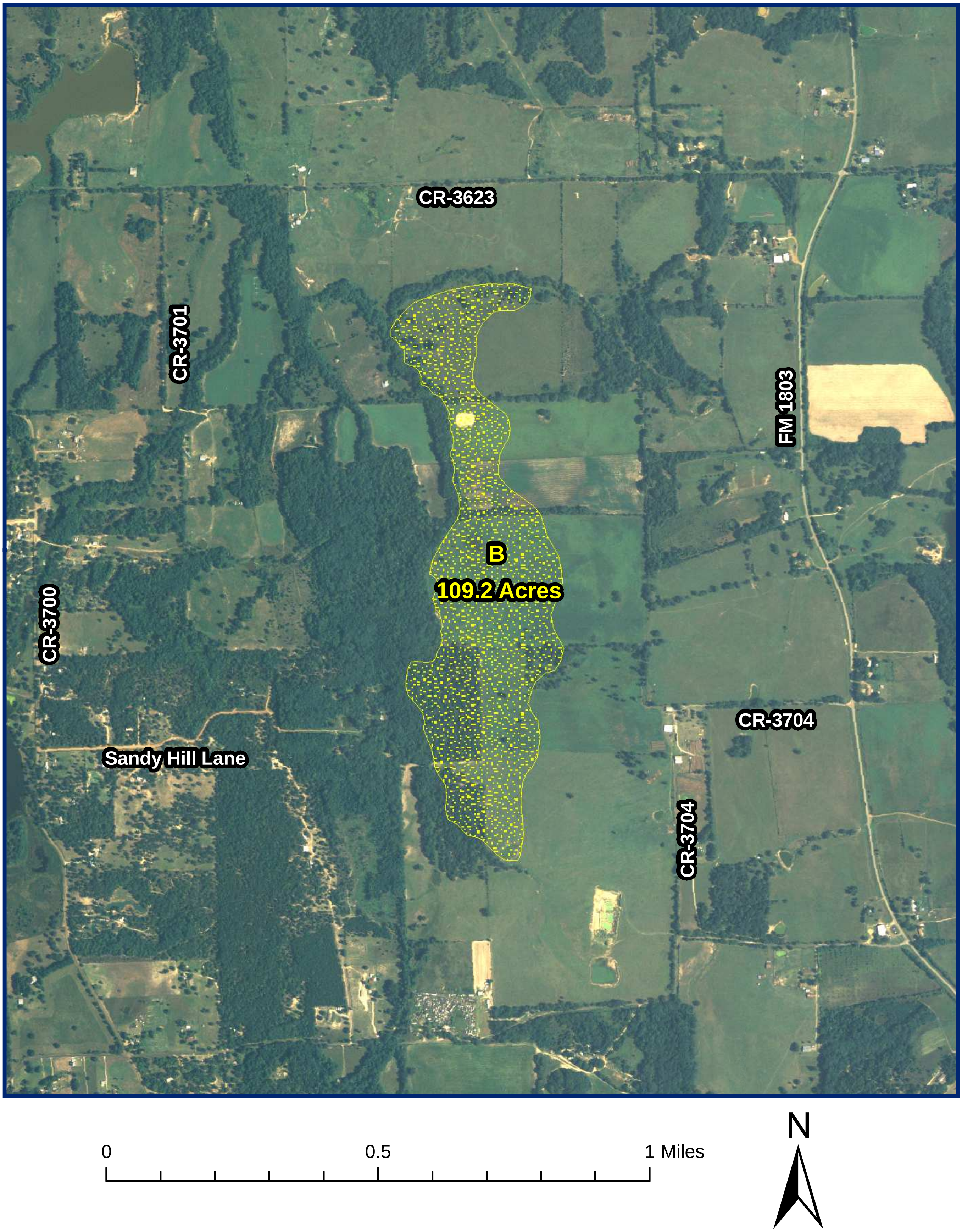


Figure 6-3: Constructed Wetland Site B



Conceptual Design of Denitrification Filters and Chemical Precipitation of Phosphorus

Nitrogen removal can be achieved through the use of denitrification filters, and phosphorus removal can be achieved through chemical precipitation. Design considerations for each of these processes are presented below.

Denitrification Filters

Because ammonia is an oxygen-demanding substance contained in raw wastewater and because most wastewater discharge permits contain limits on oxygen-demanding substances, WWTPs generally contain processes that convert ammonia to nitrate (nitrification) prior to discharge. These processes do not remove nitrogen from the wastewater; they merely convert it to a preferred form. To completely remove nitrogen, it is necessary to follow the nitrification process with denitrification (the conversion of nitrate to nitrogen gas), which releases nitrogen gas to the atmosphere.

Denitrification filters are biologically active filters with an empty bed contact time of 20 to 30 minutes. To maintain growth of the denitrifying bacteria, a supplemental carbon source (e.g., methanol or acetic acid) is usually provided to the process. Denitrification filters can be designed to consistently meet total nitrogen limits of 5 mg/l or less.

Design aspects of a denitrification filter include:

- Flow-paced carbon feed system
- Filter media bed volume based on empty bed contact time, water temperature, nitrate loading, and target nitrate concentration.
- Start-up time, loading rate, and carbon feed related to establishing and maintaining a healthy population of denitrifying microorganisms.
- Monitoring of microbe growth in the process.
- Monitoring of carbon and nitrate concentrations in the effluent.
- Backwash characteristics such as frequency, duration, air rate, water rate, sequencing, and the need for oxidants to control or limit the biological growth.

At the North WWTP, effluent from the final clarifiers would be piped to two denitrification filters located to the west of the existing facilities. Effluent from the denitrification filters would be piped to a lift station that would lift the flow to the chlorine contact chamber. Methanol would be added to the flow to maintain the population of denitrifying microorganisms in the denitrification filters, requiring methanol storage and feed facilities. Similar facilities would be constructed at the West WWTP.

Chemical Precipitation of Phosphorus

Chemical phosphorus removal is achieved by the precipitation of phosphorus with lime, aluminum salts, or iron salts. The chemicals can be added into a primary clarifier, an aeration basin, or a final clarifier. Very low concentrations of total phosphorus (less than 0.5 mg/l) can be achieved using chemical precipitation.

At the North WWTP, alum storage and chemical feed facilities would be constructed that would allow addition of alum ahead of the denitrification filters and ahead of the final clarifiers. Similar facilities would be constructed at the West WWTP.

Conceptual Design of Membrane Filtration/Advanced Oxidation

The combination of membrane filtration and advanced oxidation removes phosphorus, nitrogen, TDS, chlorides, and sulfates; provides enhanced disinfection; and addresses emerging microconstituents of concern (EMCs). Research at facilities that employ these processes has demonstrated effective reduction of many EMCs. Research to determine the extent to which these processes reduce EMCs and to identify appropriate standards for EMCs is ongoing.

Membrane filtration can be used for nutrient removal, desalination (TDS removal), and removal of other constituents. Table 6-5 shows the primary and ancillary uses of membrane filtration and advanced oxidation for each polishing treatment scenario.

The conceptual design consists of treating all or part of the combined reclaimed water flow from the West and North WWTPs with integrated membrane treatment (ultrafiltration and reverse osmosis) followed by advanced oxidation (ultraviolet light (UV) and hydrogen peroxide), as outlined in Table 6-5. The treatment processes would be located at the North WWTP and would be located downstream of the existing dechlorination processes. In addition to the permeate stream (the filtered water that would be used to augment the water supply in Lake Athens),

Table 6-5
Membrane Filtration and Advanced Oxidation in Polishing Treatment Scenarios

Scenario Number	Treatment Choice	Primary Purpose	Ancillary Benefits	Required Facility Size (mgd)	Projected Maximum Brine Flowrate (mgd)
4	Sidestream[a] Membrane Filtration	Nutrient Removal	Other Constituent Removal Desalination	1.00	0.20
8	Sidestream Membrane Filtration	Nutrient Removal Desalination	Other Constituent Removal	1.52	0.30
9	Denitrifying Filters/Chemical Precipitation + Sidestream Membrane Filtration	Desalination	Nutrient Removal Other Constituent Removal	0.51	0.10
10	Wetland Site A + Sidestream Membrane Filtration	Desalination	Nutrient Removal Other Constituent Removal	0.54	0.11
11	Wetland Site B + Sidestream Membrane Filtration	Desalination	Nutrient Removal Other Constituent Removal	0.54	0.11
12	Full Membrane Filtration + Advanced Oxidation	Nutrient Removal Desalination Other Constituent Removal Enhanced Disinfection		2.64[50]	0.53

[a]Sidestream membrane filtration means that a portion of the total reclaimed water is polished with membrane filtration.

[50] This flowrate is greater than the combined permitted capacities of the West and North WWTP (2.394 mgd). For purposes of this report, it has been assumed that the WWTPs will be expanded as necessary to provide wastewater treatment.

membrane filtration also produces a waste stream of concentrated brine. It is anticipated that the concentrate would be disposed of using deep-well injection.

The following assumptions have been made for the conceptual design:

- 80 percent of the reclaimed water introduced to the membrane filtration process (the feed water) will be recovered as permeate and will be used for water supply augmentation
- 20 percent of the reclaimed water introduced to the membrane filtration process will be rejected as concentrate.
- The permeate TDS concentration will be 6 percent of the influent TDS concentration.
- For desalination treatment (polishing treatment scenarios 9 through 11), membrane filtration facilities would be sized to treat a relatively small percentage (or sidestream) of the reclaimed water used for augmentation. The remaining reclaimed water will bypass the membrane filtration process. After membrane filtration, the permeate will be recombined with the bypass water and will be used for water supply augmentation.

Membrane filtration, advanced oxidation, and concentrate disposal processes are discussed in more detail in the following sections.

Membrane Filtration

Membrane filtration is a pressure- or vacuum-driven separation process in which the membranes act as barriers to suspended, colloidal, or dissolved contaminants. Membrane systems such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) are generally classified by the pore size of the membrane element.

MF and UF are low-pressure systems intended for particulate removal and operate by a size exclusion mechanism in which particulate matter larger than the membrane pore size is rejected (Figures 6-4 and 6-5). Highly uniform membrane pore sizes allow for very high removal of a targeted particle size or microorganism.

NF and RO membranes require higher operating pressures and are intended not for particle removal but for removal of dissolved contaminants. The removal of dissolved contaminants is

Figure 6-4
Membrane Separation Mechanism

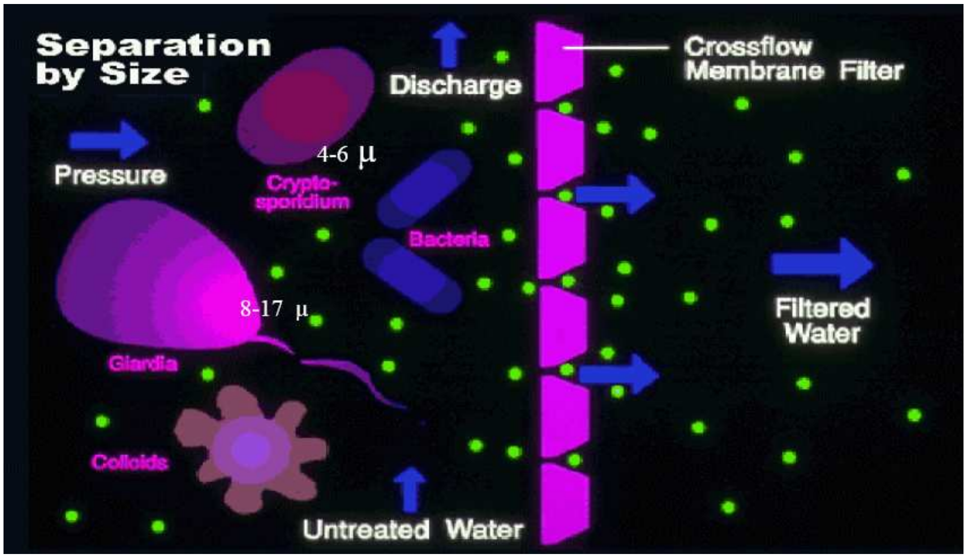
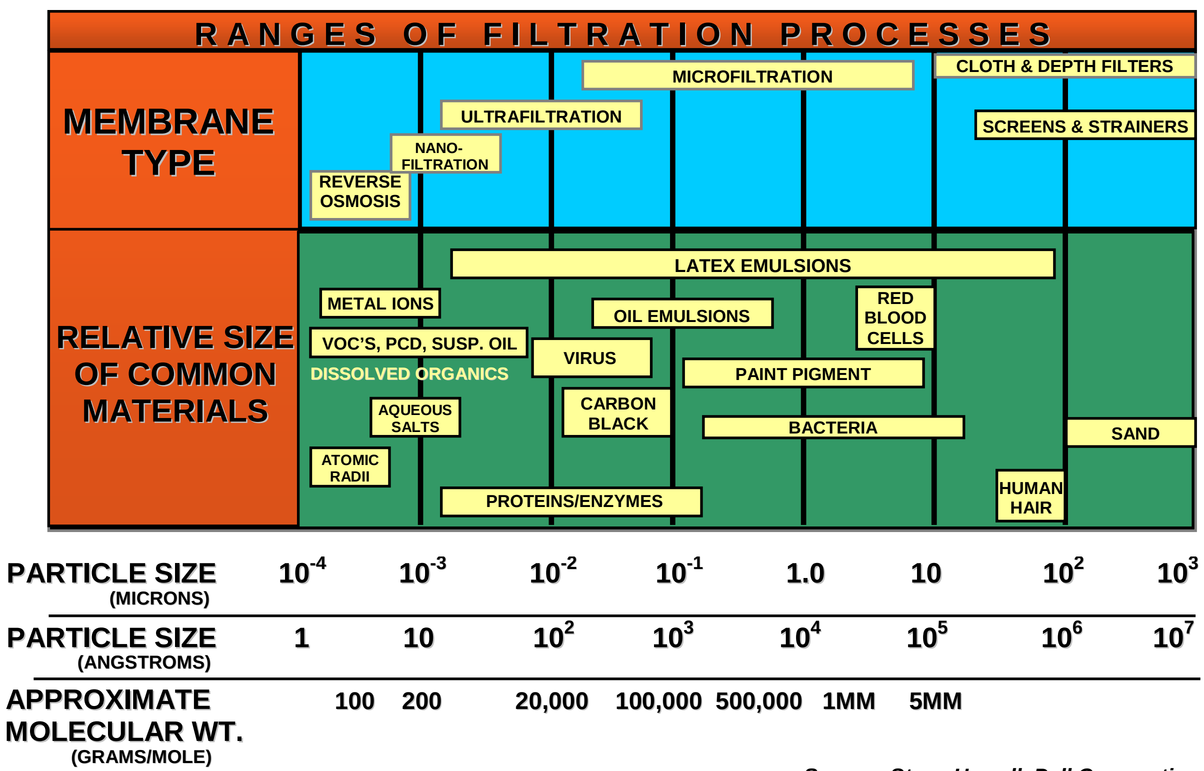


Figure 6-5
Membrane Removal and Particle Size Range



Source: *Steve Howell, Pall Corporation* primarily achieved through charge repulsion and diffusion mechanisms. Contaminants that can be removed by RO treatment include organic compounds, hardness, metals, nitrates, dissolved solids, suspended solids, bacteria, cysts, and viruses.

Membranes are susceptible to fouling, which occurs when particles, organic matter, and microorganisms accumulate on the membrane surface as water passes through the membrane. Fouling reduces the amount of water that can be treated by the membranes over time. Fouling can be reversible or irreversible. Reversible fouling can be controlled by improving the quality of the membrane feed water, backwashing, and chemical cleaning of the membranes. As irreversible fouling sets in, membranes must be replaced.

An RO system for the treatment of tertiary effluent would likely require MF or UF pretreatment to increase the efficiency of the RO system and reduce fouling of the RO membranes. Because UF membranes remove some organic compounds, UF membranes can potentially provide better protection to the RO membranes than can MF membranes.

UF membranes generally operate at high recoveries, with more than 90 percent of the feed water recovered as membrane filtrate. Because UF membranes primarily remove particulate matter, the reject water from UF membranes can be recycled to the head of the treatment process, and the net recovery can be 99 percent or more. RO membranes generally operate at lower recoveries, typically around 80 percent of the RO feed water. For planning purposes, it has been assumed that recovery from a combined UF/RO system would be 80 percent.

UF systems are available in two configurations: pressurized and vacuum. RO systems are pressurized. Pressurized systems utilize feed pumps and membranes installed in containers with sealed ends. The containers or modules are mounted to pipe headers or manifolds which make up a rack or skid. Typical operating pressures for low pressure systems (e.g., MF/UF) range from 3 to 40 pounds per square inch (psi). Operating pressures for high pressure systems (e.g., RO) range from 100 to 400 psi.

Vacuum-type membrane systems are usually immersed in a basin and filtrate is drawn into the membrane by pump suction. A low pressure immersed membrane system (e.g., MF/UF) operates under a vacuum ranging from -12 to -3 psi. Pilot testing would be necessary to determine site-specific operating conditions and the recommended UF system configuration.

Both pressurized and vacuum membranes are modular. This allows additional capacity to be installed in small increments, potentially reducing the initial investment. In both configurations, strainers to protect the membranes precede the membrane skids. The diameter and length of membrane modules vary by manufacturer, as does the configuration of the modules and headers.

In addition to the membrane modules, equipment requirements for a UF/RO system include feed or filtrate pumps; strainers; backwash pumps; air blowers; air compressors and dryers; variable frequency drives (VFDs) and/or motor starters for feed pumps, backwash pumps, blowers, and clean-in-place (CIP) pumps; CIP system; chemical feed pumps for chemically enhanced backwash; pilot scale skid assembly; and filtrate storage tank.

Advanced Oxidation

Advanced oxidation with UV and hydrogen peroxide is a process used for simultaneous enhanced disinfection and environmental contaminant reduction. UV light can break chemical bonds in some compounds and can inactivate *Cryptosporidium*, *Giardia lamblia*, and some viruses. The irradiation of hydrogen peroxide by UV light creates strong oxidizing radicals that reduce contaminants in water into elemental compounds by breaking the bonds between the molecules. UV/peroxide can be used for the treatment of compounds of small molecular size that can pass through RO membranes such as NDMA,[51] pharmaceuticals, personal care products, hormone compounds, and organic compounds. UV/peroxide has been used for the oxidation of petrochemical byproducts and pesticides since the mid-1980s. The combination of membrane treatment and UV/peroxide provides powerful, multiple-barrier treatment of the recycled water.

The UV/peroxide system would consist of two UV reactor trains and a hydrogen peroxide delivery system that includes a bulk storage tank and chemical feed pumps. The hydrogen peroxide would be injected upstream of the UV reactors. The size of the UV/peroxide system largely depends on the UV transmittance of the water being treated. Larger systems are required

[51] N-nitrosodimethylamine, a chloramination by-product.

for treatment of water with low transmittance. The UV reactors would be placed downstream of the membranes and would treat the RO permeate, the recycled water with the highest transmittance.

Chlorine may be needed to quench residual peroxide in the treated effluent. During preliminary design, the peroxide dosage will be evaluated, and the capacity of the existing chlorine system will be further investigated. For the planning-level analysis, it has been assumed that no additional chlorine facilities will be needed.

Concentrate Disposal

It has been assumed that UF reject water would be recycled to the head of the North WWTP, that 20 percent of the water treated with RO would be rejected as concentrate, and that the concentrate would be disposed of by deep-well injection. It is anticipated that the TDS concentration in the injected waste stream would range from 221 mg/l to 1,024 mg/l, depending on the augmentation scenario and Lake Athens water quality (Tables E-3 through E-5).

It is anticipated that concentrate would be injected into the Woodbine sand formation, located at a depth between 3,950 feet and 4,650 feet.[52] The Woodbine formation has a favorable combination of porosity (30 to 40 percent), permeability (300 to 600 millidarcies), formation pressure, water chemistry,[53] a seal layers on top (Eagleford shale), and a seal layer on the bottom (Maness shale).[52] Although no injection rates for Henderson County were identified, the median injection rate in the Woodbine formation in Gregg and Rusk Counties is approximately 0.66 mgd.[54] Based on this information, it has been assumed that the projected injection rates for the various polishing treatment scenarios (0.10 mgd to 0.53 mgd) will be achievable and that the well depth will be 4,150 feet. Should concentrate disposal be required for the selected polishing

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[52] Personal communication with W.C. "Chip" Perryman, President, Athens Municipal Water Authority.

[53] Water in the Woodbine sand formation in Henderson County is highly saline (total dissolved solids concentration greater than 3,000 mg/l) and non-potable. Reference: Baker, B., Duffin, G., and R. Flores, January 1990. *Evaluation of Water Resources in Part of North-Central Texas*, Texas Development Board Report 318, January 1990

[54] Nicot, J. P. and A. H. Chowdhury, 2005. "Disposal of brackish water concentrate into depleted oil and gas fields: a Texas study," Desalination, Vol. 181, pp. 64-75. Available URL: http://www.desline.com/articoli/6377.pdf.

treatment alternative, selection of an appropriate site for a disposal well and development of site-specific design information should take place during preliminary design.

7. Direct Reuse Opportunities

Although this guidance document focuses on indirect reuse through augmentation of raw water supplies with reclaimed water, it may also be feasible to provide reclaimed water for direct reuse from the pipeline that conveys reclaimed water from the WWTP(s) to the receiving water body. Reasons to consider direct reuse include revenue from sales of reclaimed water, reduced demand for potable water, and/or reduced demand for raw water (or groundwater).

7.1. 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. 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 modify the design of the reclaimed water conveyance system as necessary.

State requirements for reclaimed water quality are presented in the remainder of this section. In subsequent sections, a review of reclaimed water quality and screening of potential direct reuse opportunities are presented for the Athens indirect reuse project.

In Texas, the direct reuse of reclaimed water for beneficial purposes is regulated by the 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 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 7-1).

Type I reclaimed water can be used in instances where incidental contact with humans is likely to occur (Table 7-1). To be considered Type I Reclaimed Water, treated effluent must meet the specific quality requirements in Table 7-1; specific treatment processes are not identified or required. These parameters must be monitored twice per week and reported on a monthly basis.

Table 7-1
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
Uses	Irrigation or other uses in areas where public may be present	Irrigation or other uses in areas where the public is not present
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 water bodies where recreational activities are anticipated. • Toilet or urinal flush water. • Other activities where 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/water bodies 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 coliform: <20 CFU/100 ml geometric mean or <75 CFU/100ml single grab • BOD$_5$/CBOD$_5$ = 5 mg/l • Turbidity = 3 NTU	• Fecal coliform: <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

Note: These requirements do not apply to indirect reuse.

Type II reclaimed water can be used in instances where incidental contact with humans is not likely to occur (Table 7-1). To be considered Type II Reclaimed Water, treated effluent must meet the specific quality requirements in Table 7-1; specific treatment processes are not identified or required. These parameters must be monitored once per week and reported on a monthly basis.

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 and would include any indirect potable application, as well as any reuse of industrial reclaimed water.

7.2. Athens Reclaimed Water Quality

The BOD effluent concentration at each WWTP (Figure B-5) occasionally exceeds the 5 mg/l limit for Type I reclaimed water. Therefore, without further treatment, it appears that the WWTPs produce Type II reclaimed water. Two of the polishing treatment alternatives (denitrification filters/chemical precipitation or membrane filtration/advanced oxidation) would result in additional treatment facilities located at the North WWTP. Implementation of these types of polishing treatment might improve the reclaimed water quality to Type I.

7.3. Screening for Potential Direct Reuse Customers

To identify potential direct reclaimed water users, the consultants reviewed top commercial water customers, data for wells located near the pipeline route, and aerial photographs of the pipeline route. Each of these reviews is discussed below.

The 10 commercial water customers that purchased the most water from the City of Athens from June 2007 through May 2008 are shown in Table 7-2 and Figure 7-1. In general, these customers are not located within one-half mile of the potential pipeline routes, and it is not clear how much of this potable water use could be replaced with reclaimed water. Given the low usages compared to the proposed augmentation rates, it is unlikely that changing the pipeline route to accommodate any of these customers would be cost-effective.

Wells within one-half mile of the potential pipeline routes (Table 7-3) were identified from TWDB groundwater data. Many of these wells are used for public water supply, and direct use of reclaimed water is not considered to be suitable for this purpose, given the current state of knowledge and technology. Of the remaining wells, no data are available regarding how much water is used for non-potable purposes.

Table 7-2
Top 10 Commercial Water Users in Athens, June 2007 through May 2008

Name	Water Use (gal)
East Texas Medical Center	20,180,800
Best Western Motel	12,476,100
Green Oaks Nursing Home	9,372,500
South Place Nursing Home	7,260,000
Henderson County Justice Center	7,140,700
Fairview Apartments	5,520,600
Athens City Cemetery	4,286,200
Cain Center	4,254,500
Athens Country Club	3,921,100
Trinity Valley Community College	4,769,700

Table 7-3
Wells within One-Half Mile of Potential Pipeline Routes

State Well Number	Owner	Well Type	Primary Purpose of Use
34-49-602	Walter Lee Hampton	Water	Domestic, Stock
34-49-604	A. C. Rasco	Water	Domestic, Stock
34-50-110	Dal-High WS	Spring	Public Supply
34-50-111		Spring	
34-50-205		Water	Domestic
34-50-206	Henderson County Fair Board Association	Water	Stock
34-50-303	Damon Douglas	Water	Domestic
34-50-304	Athens Fish & Game Club	Water	Unused
34-50-307	Bethel-Ash WSC Hall Well	Water	Public Supply
34-50-308		Spring	
34-51-104	Lone Star M V Camp	Water	Public Supply
34-51-107	Bethel-Ash WSC (Douglas)	Water	Public Supply
34-51-108	Lone Star Camp	Water	Public Supply
34-51-109	Camp Lone Star	Water	Public Supply

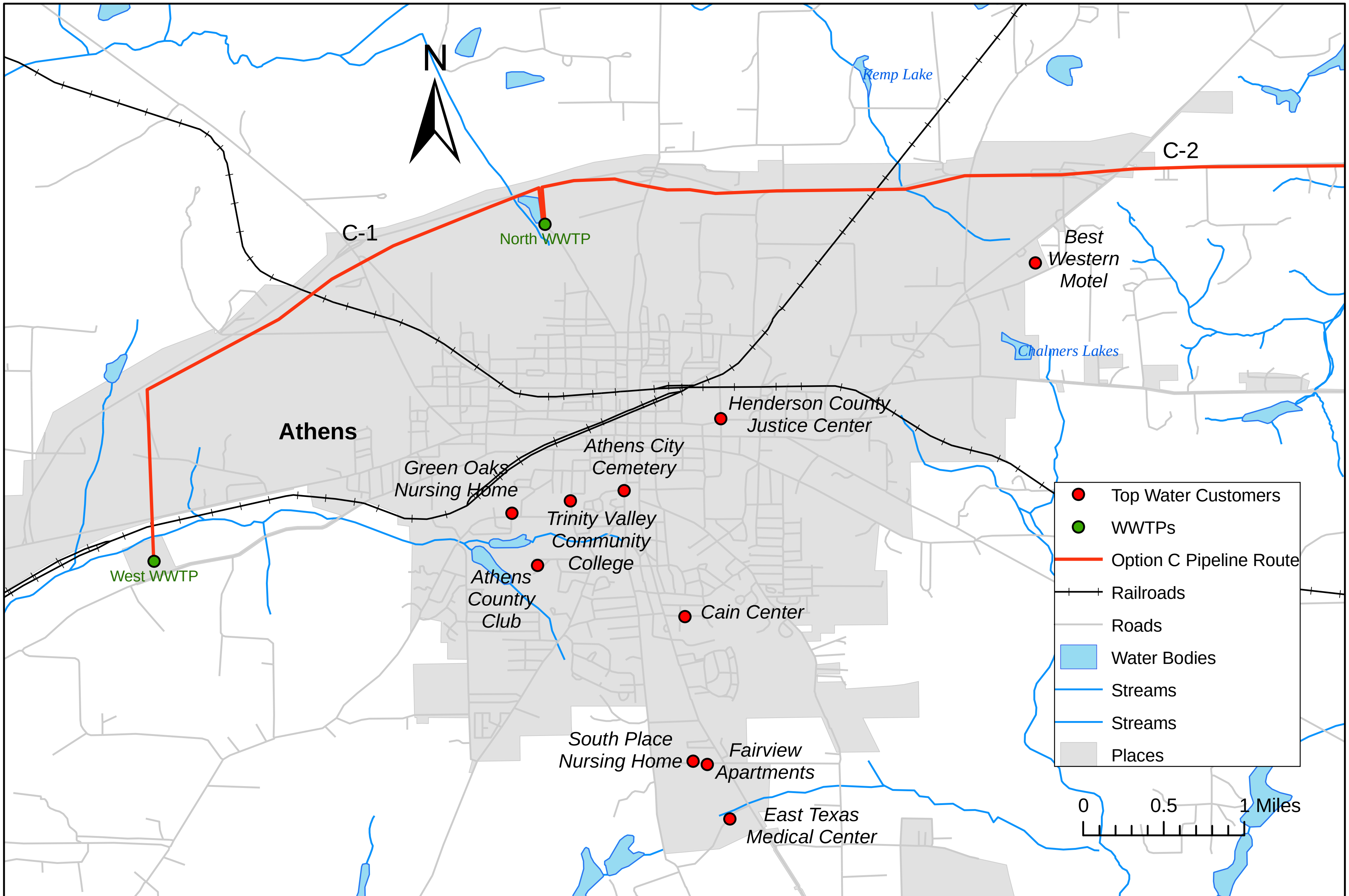


Figure 7-1: Athens Top 10 Commercial Water Customers
June 2007 Through May 2008

Finally, aerial photographs of potential pipeline routes were reviewed. The only obvious possibility for direct reclaimed water use within the vicinity of the pipeline route is irrigation of the Oak Lawn Cemetery. There may be potential for irrigation of agricultural land along the pipeline route, depending on the land use and the reclaimed water quality, but more advanced screening is necessary to develop this information.

To summarize, only one potential direct reuse opportunity was identified: irrigation at the Oak Lawn Cemetery. It is unknown whether the Oak Lawn Cemetery is currently irrigated, and the source of their irrigation water has not been identified.

The following assumptions were made in estimating water demand at the Oak Lawn Cemetery:

- Irrigated area of 15 acres
- Peak demand:
  - Peak demand of one inch per week (15 acres * 1 inch/week = 407,314 gallons per week)
  - Irrigation of entire area twice per week (407,314 gallons per week/2 rounds of irrigation per week = 203,657 gallons per round of irrigation)
  - Three irrigation zones (203,657 gallons per round of irrigation/3 irrigation zones per round of irrigation= 67,886 gallons per round of irrigation per zone)
  - One zone irrigated per day (67,886 gallons per zone * 1 zone/day = 67,886 gallons per day)
- Annual demand of 20 inches (15 acres * 20 inches per year = 8.146 million gallons per year)

The City should continue to identify additional direct reclaimed water customers and integrate them into the design of the reclaimed water conveyance system during the preliminary design phase.

8. Conceptual Design of Reclaimed Water Conveyance System

The design of the reclaimed water conveyance system depends on the choice of reclaimed water flowrate, the polishing treatment scenario, and direct reuse opportunities. The pipeline routing, conceptual design, and opinions of probable cost are discussed in the following sections.

8.1. Guidance

All requirements for a reclaimed water conveyance system should be identified. These requirements may include: WWTP 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.

Since the main purpose of the reclaimed water conveyance system is to deliver reclaimed water to a receiving water body for raw water supply augmentation, and assuming that the receiving water body provides ample storage to dampen peak season water demands, the system should be designed to deliver the reclaimed water at a rate close to the annual average augmentation rate. A nominal peaking factor of 1.1 is recommended for the reclaimed water conveyance system to allow for occasional maintenance down time.

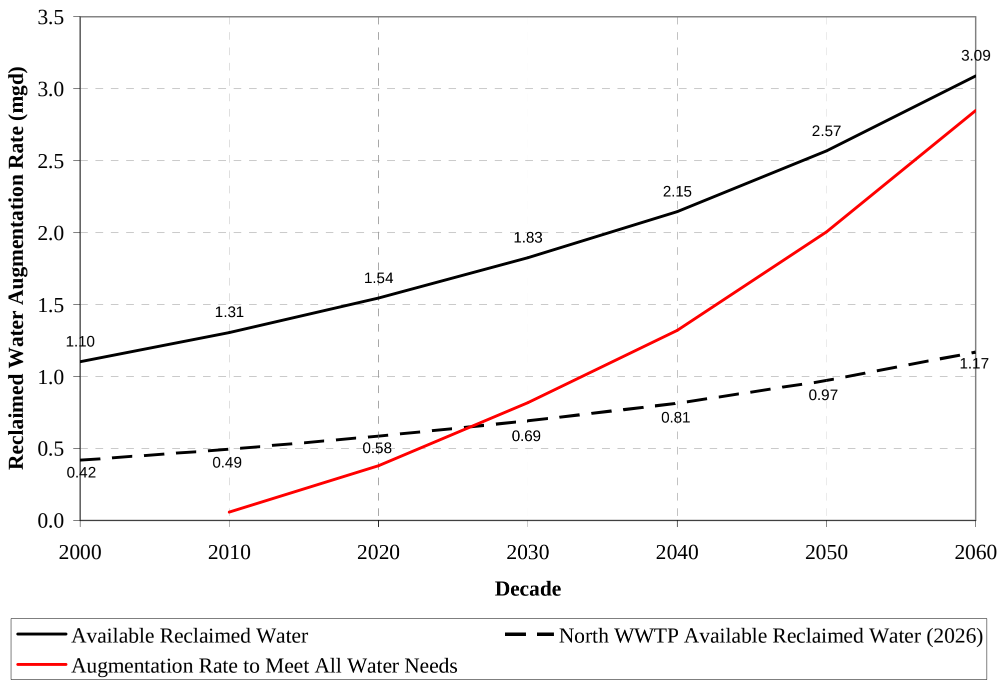
It may be desirable to provide reclaimed water for direct reuse to users located close to the conveyance system. Some direct reuses, particularly irrigation, can have relatively low annual demands but relatively high peak hour demands. The demand on the conveyance system can be dampened by installing on-site storage, but the conveyance system must be designed to provide reclaimed water to the on-site storage as required to meet peak direct reuse demands.

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 Athens indirect reuse project, the pipeline routing evaluation and the conceptual design of the reclaimed water conveyance system are presented below.

8.2. Pipeline Routing Evaluation

The reclaimed water conveyance system must convey reclaimed water from the West and North WWTPs to the polishing treatment location and to Lake Athens. Initially the North WWTP can provide all of the reclaimed water necessary to meet AMWA's water needs through water supply augmentation (Figure 8-1). By 2026, the reclaimed water from the North WWTP must be supplemented with reclaimed water from the West WWTP to meet AMWA's water needs. Therefore, to avoid duplication of pipes, the conveyance system should be designed to convey reclaimed water directly from the West WWTP to the North WWTP. In addition, this would allow construction of membrane filtration and advanced oxidation facilities at a single location (the North WWTP), should those facilities be selected for polishing treatment.

Figure 8-1
Comparison of Available Reclaimed Water and Projected Water Needs



A second consideration involves blending and detention time in Lake Athens. As discussed in Chapter 3, blending and detention time are two of the multiple barriers (Figure 3-1) recommended for managing the uncertainties associated with augmenting raw water supplies with reclaimed water. The least expensive pipeline would convey the reclaimed water as far as the westernmost drainage of Lake Athens. This is consistent with the discharge location in

AMWA's existing water right[55] (Figure 4-1). However, with this discharge point, the reclaimed water would pass the AMWA and TFFC water intakes before flowing into the main body of the lake. To maximize blending and detention time, the reclaimed water should be introduced to Lake Athens at a location close to the dam.

The third consideration involves the selection of the polishing treatment alternative. Under two of the alternatives (denitrifying filters/chemical precipitation and membrane filtration/advanced oxidation), polishing treatment is provided at one or both of the WWTPs. However, polishing treatment with a constructed wetland must be achieved at Wetland Site A or Wetland Site B (Figure 6-1). Therefore, the conveyance system for the wetland polishing treatment scenarios must be designed to transport the reclaimed water to the wetland site and convey the polished reclaimed water from the wetland site to Lake Athens. Finally, pipeline routes should be as direct as is feasible to minimize system costs.

Based on the considerations discussed above, three sets of pipeline routes were identified:

- Option A (Figure 8-2) conveys reclaimed water from the West WWTP to the North WWTP, from the North WWTP to Wetland Site A, and from Wetland Site A to a tributary to Lake Athens.
- Option B (Figure 8-3) conveys reclaimed water from the West WWTP to the North WWTP, from the North WWTP to Wetland Site B, and from Wetland Site B to a tributary to Lake Athens.
- Option C (Figure 8-4) conveys reclaimed water from the West WWTP to the North WWTP and from the North WWTP to a tributary to Lake Athens.

8.3. Conceptual Design of Reuse Water Conveyance System

Given the flow rates under consideration, preliminary evaluation indicates that it is most cost-effective to size the pipelines to carry the full design flow. In other words, it is not cost-effective

[55] Certificate of Adjudication 06-3256, as amended.

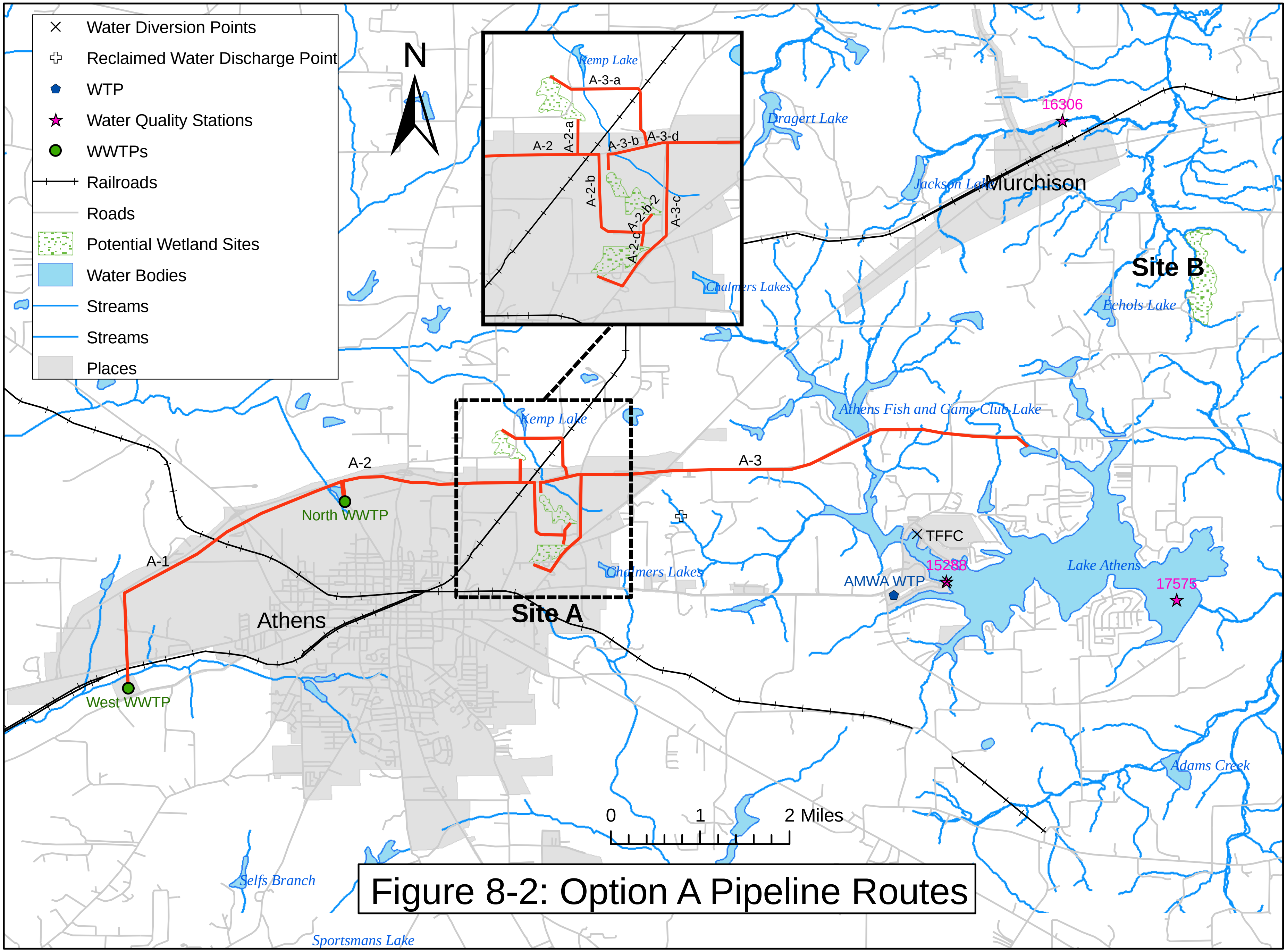


Figure 8-2: Option A Pipeline Routes

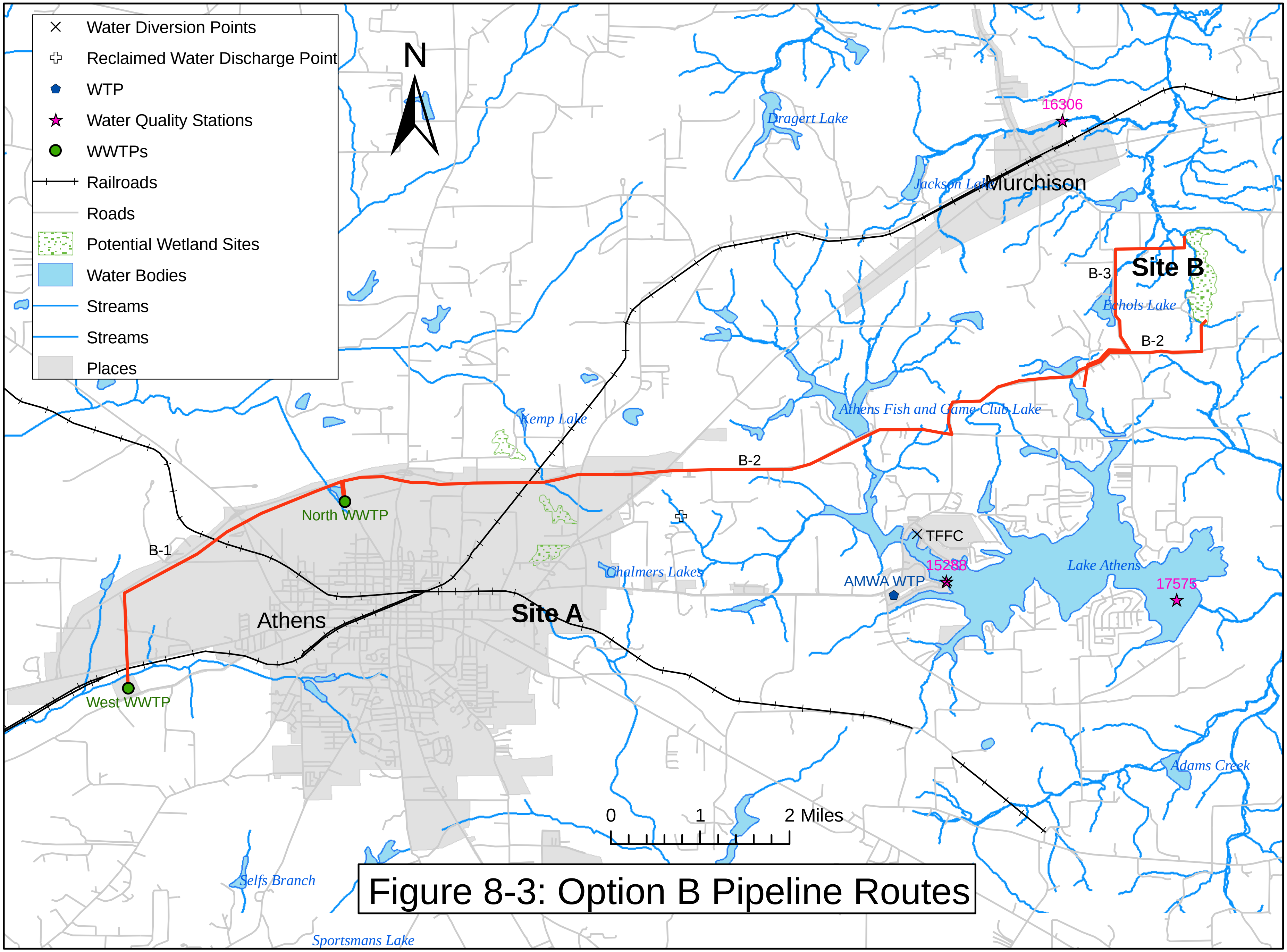


Figure 8-3: Option B Pipeline Routes

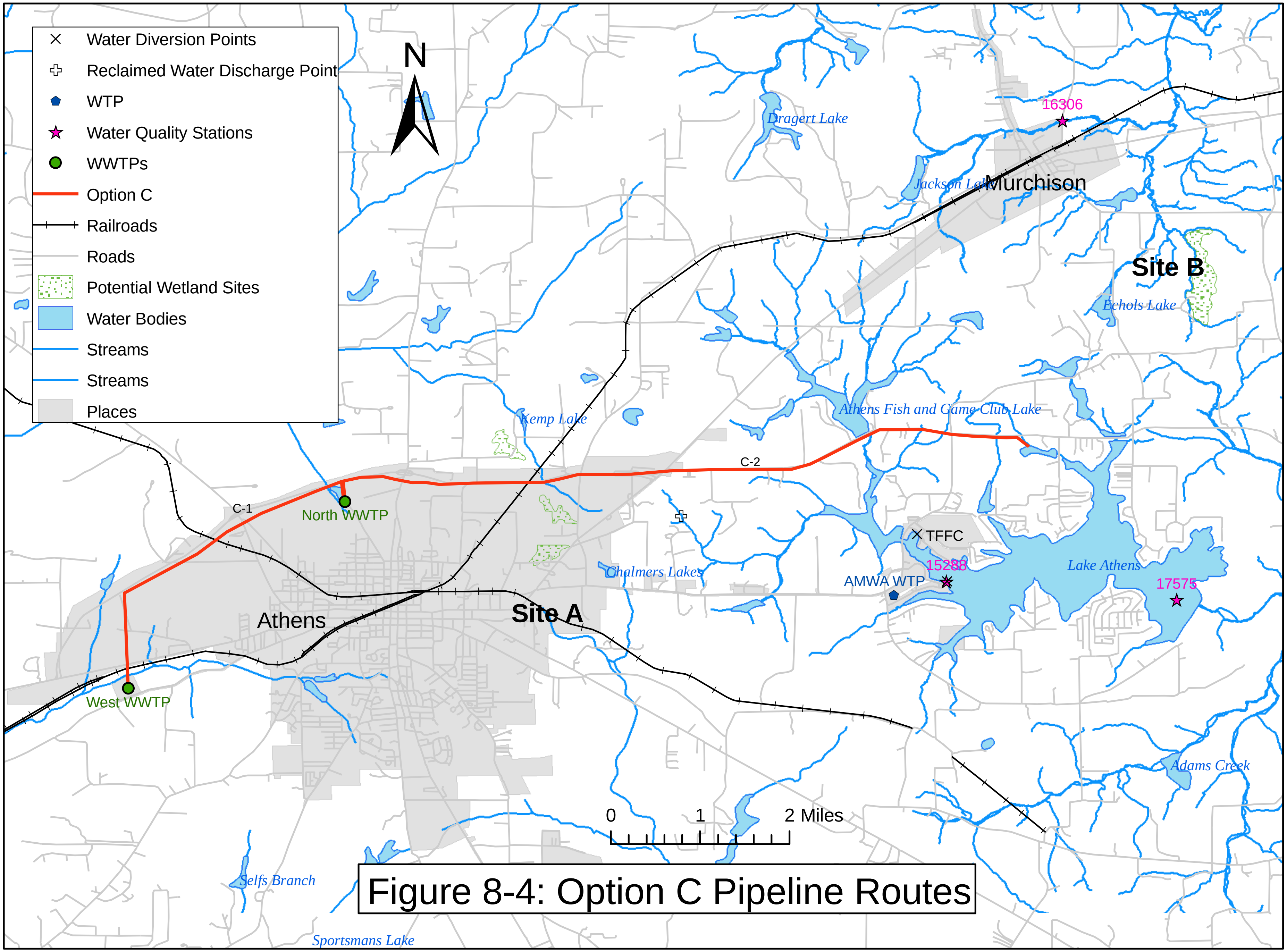


Figure 8-4: Option C Pipeline Routes

to construct smaller, parallel pipelines. Design pipe sizes and pump station capacities depend on the polishing treatment scenario (Table 6-2). The design sizes and capacities are listed in the detailed opinions of probable cost that are discussed in Chapter 9 and presented in Appendix G. These conceptual designs do not include direct reuse at the Oak Lawn Cemetery (Chapter 7).

9. Opinions of Probable Cost

Guidance on developing opinions of probable cost and the opinions of probable cost for the Athens indirect reuse project are presented below.

9.1. Guidance

Opinions of probable capital costs, annual costs, unit costs, and net present values should be developed for conceptual polishing treatment and reclaimed water conveyance systems discussed in Chapters 6 and 7. 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. Non-economic factors associated with each alternative should be discussed, and indirect reuse alternatives should be compared to other water supply alternatives. Finally, significant construction and startup issues should be identified and discussed.

Cost assumptions and opinions of probable cost are presented below for the Athens indirect reuse project.

9.2. Cost Assumptions

Cost tables used in developing opinions of probable cost are presented in Appendix F. Methods used to develop the opinions of probable cost for each polishing treatment/conveyance scenario are generally consistent with those used in the *2006 Region C Water Plan* (with the exceptions described in Appendix F) but unit costs were updated to reflect second quarter 2007 costs. The opinions of cost for polishing treatment focus on advanced wastewater treatment (Chapter 6.4) and do not include improvements necessary to maintain or expand existing wastewater treatment facilities.

Detailed opinions of probable cost for each polishing treatment/conveyance scenario are included in Appendix G and summarized in Table 9-1 and Figures 9-1 and 9-2. Comparison of the opinions of probable costs for the indirect reuse alternatives and comparison with other raw water supply alternatives are discussed below. In addition, the opinion of cost for direct reuse at the Oak Lawn Cemetery is discussed separately below.

9.3. Comparison of Indirect Reuse Scenarios

In this section, the scenarios are compared on a cost basis, and ancillary benefits are discussed.

Cost Comparison

Two methods were used to compare the opinions of probable cost for each scenario: a weighted unit cost method and a net present value method. The results from each method are discussed below.

Weighted Unit Cost

The weighted unit cost was estimated as the sum of the probable annual costs for 50 years divided by the projected total supply volume for the same period. Weighted unit costs for each indirect reuse scenario are shown in Table 9-1 and Figure 9-1.[56]

On a weighted unit cost basis, the most cost-effective indirect reuse scenarios are Scenario 5, where denitrification filters and chemical precipitation facilities at each WWTP would remove nutrients from all wastewater, and Scenario 7, where nutrients would be removed from the reclaimed water with a constructed treatment wetland at Wetland Site B. Both scenarios would allow augmentation of Lake Athens with up to 1.73 mgd of reclaimed water. The probably weighted unit cost for each of these scenarios is $1.71 per thousand gallons. These costs include polishing treatment and transport of the polished reclaimed water to Lake Athens.

These weighted unit costs are greater than the weighted unit costs from the *2006 Region C Water Plan* for the Tarrant Regional Water District (TRWD) East Texas Third Pipeline and Reuse project ($0.75 per thousand gallons) and for the North Texas Municipal Water District (NTMWD) East Fork Reuse project ($0.64 per thousand gallons). Factors contributing to the difference in costs include:

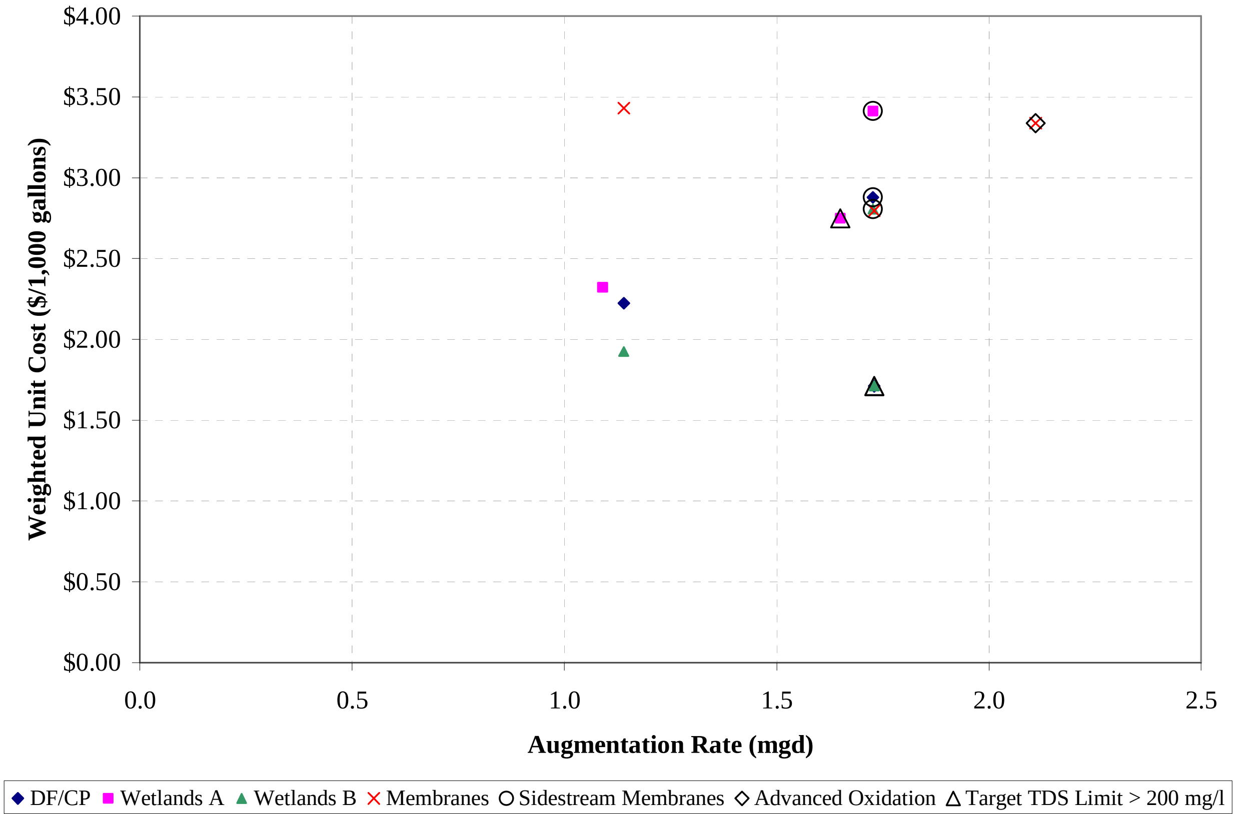
[56] These costs do not include facilities needed to provide reclaimed water for direct reuse (see Section 9.5 for more discussion of direct reuse facilities).

Table 9-1
Opinions of Probable Cost

Treatment Scenario Number	Limiting Factor in Lake Athens	TDS Target 200 mg/l?	Treatment Choice	Lake Athens Aug. Rate (mgd)	Capital Cost[a] ($ millions)	Weighted Unit Cost[b] ($/1,000 gal)	Net Present Value ($ millions)	Unit Net Present Value[c] ($ millions /mgd)
1	200 mg/l TDS	Yes	Denitrifying Filters/Chemical Precipitation	1.14	$10.87	$2.22	$11.65	$10.22
2	200 mg/l TDS	Yes	Wetland Site A[d]	1.09	$14.32	$2.32	$12.67	$11.62
3	200 mg/l TDS	Yes	Wetland Site B[d]	1.14	$11.84	$1.92	$11.30	$9.92
4	200 mg/l TDS	Yes	Sidestream[e] Membrane Filtration	1.14	$19.31	$3.43	$21.04	$18.46
5	50% Maximum Blend	No	Denitrifying Filters/Chemical Precipitation	1.73	$11.89	$1.71	$12.88	$7.45
6	50% Maximum Blend	No	Wetland Site A	1.65	$24.07	$2.75	$16.56	$10.04
7	50% Maximum Blend	No	Wetland Site B	1.73	$14.71	$1.71	$13.88	$8.02
8	50% Maximum Blend	Yes	Sidestream Membrane Filtration	1.73	$20.24	$2.80	$23.42	$13.54
9	50% Maximum Blend	Yes	Denitrifying Filters/Chemical Precipitation + Sidestream Membrane Filtration	1.73	$22.11	$2.88	$23.54	$13.63
10	50% Maximum Blend	Yes	Wetland Site A + Sidestream Membrane Filtration	1.73	$28.23	$3.41	$25.37	$14.69
11	50% Maximum Blend	Yes	Wetland Site B + Sidestream Membrane Filtration	1.73	$24.20	$2.81	$24.09	$13.95
12	Min. Detention Time	Yes	Full Membrane Filtration + Advanced Oxidation	2.11	$26.27	$3.34	$32.51	$15.41

[a]These costs include polishing treatment of the reclaimed water and transport of the polished reclaimed water to Lake Athens. All costs are presented in second quarter 2007 dollars. Detailed opinions of probable cost are presented in Appendix G.
[b]The weighted unit cost represents the sum of the probable annual costs for 50 years divided by the estimated total supply volume for the same period.
[c]Net Present Value divided by the augmentation rate.
[d]Wetland Site A and Wetland Site B refer to two potential sites for a constructed treatment wetland. These are discussed in detail in Chapter 6.4.
[e]Sidestream membrane filtration means that a portion of the total reclaimed water is polished with membrane filtration.

Figure 9-1
Opinions of Probable Weighted Unit Cost

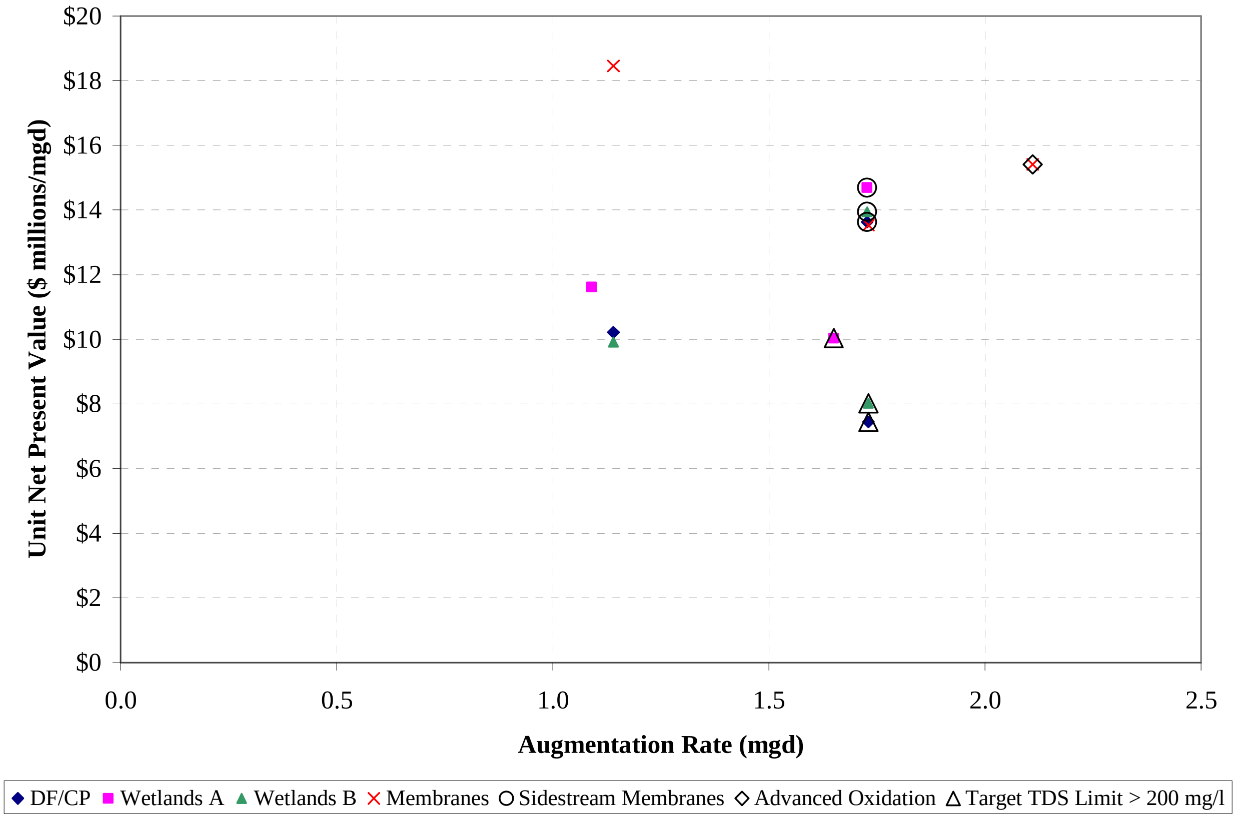


- The costs in the *2006 Region C Water Plan* are based on second quarter 2002 dollars. Material, construction, and power costs have increased significantly since 2002.
- The TRWD and NTMWD projects are very large and benefit from the economy of scale. The TRWD project supplies 188,765 acre-feet per year (168.4 mgd), and the NTMWD project supplies 102,000 acre-feet per year (91.0 mgd).

Net Present Value

The unit net present value was estimated as the sum of 50 years of discounted probable annual costs divided by the augmentation rate. Net present values are shown in Table 9-1 and Figure 9-2. In consultation with AMWA, an inflation rate of 0 percent per year and a discount rate of 5 percent per year were used in the analysis.

Figure 9-2
Opinions of Probable Unit Net Present Value (Interest Rate 0%, Discount Rate 5%)



On a unit net present value basis, Scenario 5 is the most cost-effective scenario, followed closely by Scenario 7. The probable unit net present values for Scenarios 5 and 7 are $7.45 million per mgd and $8.02 million per mgd, respectively. The total difference in net present value between these scenarios is approximately $1 million.

Sensitivity Analysis

In the opinions of probable cost, there is significant uncertainty in the costs for constructed treatment wetlands and for concentrate disposal wells. The costs used are planning-level costs, but actual costs will be highly dependent on site conditions. To address the uncertainty, these costs were varied to show the impact on the weighted unit cost.

In Scenario 7, the construction cost for Wetland Site B was assumed to be $30,000 per acre. A change to this cost of $5,000 per acre results in a corresponding change in the weighted unit cost of about $0.05 per thousand gallons.

Reducing the assumed cost for concentrate disposal wells and associated pumping by half would reduce the weighted unit cost for scenarios that include concentrate disposal wells by $0.24 to $0.36 per thousand gallons. The scenarios with membrane filtration facilities do not appear to be cost-effective, even taking into account the uncertainty in the concentrate disposal well costs.

TDS Issues

For the most cost-effective scenarios (5 and 7), a screening-level analysis suggests that the maximum annual average TDS concentration in Lake Athens during a drought-of-record situation would be approximately 259 mg/l (Table E-4).[57] Therefore, these scenarios may require one of the following actions:

- Simultaneously import raw water from another source and/or
- Develop a site-specific TSWQS limit for Lake Athens that would allow for annual average TDS concentrations greater than the target level of 200 mg/l.

The selected reclaimed water augmentation rate must comply with the TSWQS, unless there is a special situation where an amendment to the TSWQS is warranted and is granted by the TCEQ. There is currently no numerical TDS standard for Lake Athens. In addition, excursions from the 200 mg/l target level are infrequent and are only projected to occur during severe drought conditions when water availability is most crucial (Figure 5-14). Finally, the projected TDS concentrations are well below the standards in the National Secondary Drinking Water Regulations[58] (500 mg/l) and the state Public Drinking Water Standards[59] (1,000 mg/l). Therefore, it may be feasible to develop a site-specific TSWQS limit for Lake Athens that would allow these scenarios. A site-specific TDS standard would have to be consistent with the intended uses of Lake Athens.

There is significant uncertainty in the screening-level projections of TDS concentrations in Lake Athens for the different Limiting Conditions. To develop a site-specific TSWQS TDS standard

[57] See Chapter 5.6 for discussion of the assumptions inherent in the TDS projections.

[58] Code of Federal Regulations, Title 40, Part 143, Section 143.3

[59] Texas Administrative Code, Title 30 Chapter 290.105.

for Lake Athens, it would likely be necessary to monitor TDS concentrations in the reclaimed water, Lake Athens, the TFFC return flow, and tributary inflows and to construct a more detailed TDS model.

Should Scenarios 5 and 7 prove infeasible, the next most cost-effective indirect reuse scenarios are Scenarios 3 and 1, which have similar treatment facilities but a reduced augmentation rate (1.14 mgd) that is projected to achieve a maximum annual average TDS concentration of 200 mg/l.

Discussion of Other Factors

Each of the scenarios has ancillary benefits that are not captured in the comparison of weighted unit costs. An ancillary benefit from Scenarios 1 and 5 (denitrification filters/chemical precipitation) is that nutrients would be removed from the entire wastewater flow, which could help the City meet more stringent effluent nutrient limits at its existing discharge locations in the future.

An ancillary benefit from the membrane filtration/advanced oxidation scenarios is that this choice of polishing treatment provides desalination, provides enhanced disinfection, and provides maximum practicable protection against emerging microconstituents of concern.

As a natural system, a constructed treatment wetland may provide significant non-economic benefits that can improve public perception of reclaimed water use, including:

- Fish and wildlife habitat,
- Recreational and educational opportunities,
- Ecotourism, and
- Potential for mitigation for other projects.[60]

A constructed treatment wetland is also a relatively low-tech operation with relatively low energy requirements.

[60] If the wetlands are designated as permanent “jurisdictional” wetlands rather than temporary “treatment wetlands,” it may be possible to create a wetlands mitigation bank that would allow AMWA to mitigate for other projects that cause loss of wetlands or to sell mitigation credits to owners of other projects that cause loss of wetlands.

However, for reasons discussed in Chapter 6.4, it may be difficult to obtain support for a constructed wetland located at Site A, particularly for Tracts A2 and A3.

9.4. Comparison With Other Raw Water Supply Alternatives

Opinions of probable cost for other potentially feasible water management strategies are presented in Appendix U of the *2006 Region C Water Plan*. These strategies include augmentation of the raw water supply in Lake Athens by obtaining water from Forest Grove Reservoir, purchasing Lake Palestine water from the Upper Neches River Municipal Water Authority, and purchasing Lake Palestine water from Dallas Water Utilities. The latter strategy would include a partnership with Dallas Water Utilities in a conveyance pipeline.

Table 9-2 shows the opinions of probable cost for these potentially feasible water management strategies, after updating these costs to second quarter 2007 costs using the tables in Appendix F. Each of these strategies appears to yield more raw water and cost less than any of the indirect reuse scenarios. This is only a cursory comparison of other raw water supply alternatives with the indirect reuse scenarios. There may be other factors or changed conditions that cause these alternatives to be less feasible and not preferred. No recommendations will be made in this regard.

9.5. Direct Reuse

As discussed in Chapter 7.3, one potential direct reuse opportunity was identified: irrigation of Oak Lawn Cemetery. Serving this property with reclaimed water would involve tapping the pipeline from the North WWTP, installing a 70,000 gallon storage tank at the cemetery, and increasing the pumping capacity of the North WWTP lift station. These items could be added to any of the indirect reuse alternatives in Table 9-1. Based on the supply assumptions in Chapter 7.3 and the costs presented below, the probable marginal cost for this direct reuse is approximately $3.07 to $3.19 per thousand gallons (Table 9-3).

Table 9-2
Opinions of Probable Cost for Other Potentially Feasible Water Management Strategies

Strategy[a]	Lake Athens Aug. Rate (mgd)	Capital Cost ($ millions)	Weighted Unit Cost[b] ($/1,000 gal)
Obtain Water from Forest Grove Reservoir	4.02	$9.12	$0.43
Purchase Water from Lake Palestine (UNRMWA)	3.57	$14.50	$0.85
Purchase Water from Lake Palestine (DWU)[c]	3.57	$2.11	$0.50

[a]Each strategy involves pumping raw water to Lake Athens. Costs were updated from those presented in the *2006 Region C Water Plan* to second quarter 2007 costs using the cost assumptions in Appendix F.
[b]The weighted unit cost represents the sum of probable annual costs for 50 years divided by the estimated total supply for the same period. This calculation accounts for phasing of each scenario.
[c]Assumes partnership in DWU pipeline from Lake Palestine.

Table 9-3
Opinion of Probable Marginal Cost for Direct Reuse at Oak Lawn Cemetery

Item	Scenario 1	Scenario 5
Increase in probable annual cost	$25,000	$26,000
Annual supply (mg)	8.146	8.146
Probable unit cost for direct reuse ($/1,000 gal)	$3.07	$3.19

9.6. Construction and Startup Issues

No significant construction and startup issues were identified for the Athens indirect reuse project.

10. Permitting Issues

Guidance on permitting issues and permitting issues for the Athens indirect reuse project are presented below.

10.1. Guidance

Permits and authorizations required to implement an indirect reuse project may include:

- Water rights permit that allows conveyance of the reclaimed water by bed and banks to the receiving water body and subsequent diversion of the reclaimed water from the receiving water body at a diversion point,
- Section 404 permit that allows discharge of dredged or fill material into waters of the United States,
- TPDES discharge permit that allows discharge of treated wastewater effluent to a receiving water body or its tributaries,
- Underground injection control permit that allows injection of concentrated brine from a membrane filtration process into deep formations,
- 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.

New or amended permits or authorizations that are potentially required for augmentation of the raw water supply in Lake Athens with reclaimed water are discussed below.

10.2. Water Right Permit

AMWA has the right[61] to collect, treat, return, store, and reuse a maximum of 2,677.14 ac-ft/yr of treated wastewater effluent from the North and West WWTPs for augmentation of the raw water supply. The water right includes a reclaimed water discharge point on an unnamed tributary of Flat Creek (Figure 4-1) and authority to convey the treated wastewater effluent to the diversion points on Lake Athens using the bed and banks of an unnamed tributary to Flat Creek and Lake Athens. However, as discussed in Chapter 8.2, it is desirable to discharge the reclaimed water to a location closer to the dam (Figures 8-2 through 8-4). The change in discharge location will require an amendment to Certificate of Adjudication 06-3256 related to discharge location and bed and banks conveyance authority.

It has been assumed that the change in discharge location will not affect the permitted reuse amount (2,677.14 ac-ft/yr) and will not result in an obligation for Athens to continue discharging treated effluent at its existing discharge locations.

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 a treatment wetland for the recommended project will probably require a Section 404 permit from the USACE.

Under Section 401 of the Clean Water Act, certification by the TCEQ (known as a 401 Water Quality Certification) of compliance with state water quality standards is required for any discharge of pollutants into waters of the United States. Activities conducted under a Section 404 Permit must not violate established Texas Surface Water Quality Standards. This certification review is done in conjunction with the USACE Section 404 Permit review.

It is not clear whether the USACE would consider a polishing treatment wetland to be a wastewater treatment unit or a jurisdictional wetland ("waters of the United States"). A

[61] Certificate of Adjudication 06-3256, as amended, is presented in Appendix D.

wastewater treatment unit can be discontinued if it is no longer useful; however, a jurisdictional wetland must be maintained under the Clean Water Act. If a constructed wetland is considered for polishing treatment, AMWA/Athens should resolve this uncertainty through discussions with the USACE.

10.4. TPDES Discharge Permit

The City discharges treated wastewater effluent from the West WWTP (TPDES Permit No. 10143-003) to a man-made ditch, which flows downstream to Walnut Creek, Cedar Creek, and the Trinity River. The City discharges treated wastewater effluent from the North WWTP (TPDES Permit No. 10143-001) to Onemile Creek; which flows downstream to a small, unnamed lake; Caney Creek; Forest Grove Reservoir; Caney Creek; and Cedar Creek Reservoir. To discharge the treated wastewater effluent to a tributary of Lake Athens will require amending the existing TPDES discharge permits to include new discharge locations.

In addition, augmentation of the raw water supply in Lake Athens with reclaimed water could cause the maximum annual average TDS concentration to exceed the target TDS concentration of 200 mg/l during severe droughts, depending on the choice of augmentation flowrate and polishing treatment. Approaches to address the TDS issue are discussed in Chapter 9.3.

10.5. Underground Injection Control Permit

Use of membrane filtration would produce a waste stream of concentrated brine. It is anticipated that the concentrate would be disposed of using deep-well injection. Construction and operation of a Class I injection well requires an underground injection control permit from the TCEQ. Standards for Class I injection wells are regulated by Texas Administrative Code Title 30 Chapter 331 Subchapter D. The Texas Railroad Commission also reviews and comments on applications for Class I injection wells. The applicant will be required to show that the waste stream will be injected into a formation below the lowermost formation that is an underground source of drinking water (USDW) and that the formations are hydraulically isolated to prevent contamination of the USDW.

10.6. Chapter 210 Reuse Authorization

If direct reuse customers are to be served from the reclaimed water conveyance system, the City must obtain a Chapter 210[62] reuse authorization from the TCEQ. To obtain this authorization, the City must demonstrate that it meets the general requirements, quality criteria, design, and operational requirements that Chapter 210 requires for direct reuse projects.

10.7. 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, the AMWA/Athens 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.

10.8. 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.

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[62] Texas Administrative Code Title 30 Chapter 210 “Use of Reclaimed Water.”

11. Selection of Preferred Indirect Reuse Alternative

Guidance on selecting the preferred indirect reuse alternative and selection of the preferred alternative for the Athens indirect reuse project are presented below.

11.1. Guidance

From the various indirect reuse alternatives that have been evaluated to this point, the preferred alternative 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.

Although protection of public health and protection of receiving water quality are not explicitly listed above, each of the alternatives must meet these criteria to be considered feasible.

Selection of the preferred indirect reuse alternative for AMWA/Athens is discussed below.

11.2. Selection of Preferred Indirect Reuse Alternative for Athens

Augmentation of the Lake Athens raw water supply with reclaimed water appears to be a feasible water supply strategy. Based on evaluation of the polishing treatment processes, projected water quality impacts to Lake Athens, opinions of probable cost, and ancillary benefits, AMWA/Athens should select one of the following scenarios (Table 9-1 and Figures 9-1 and 9-2) as the preferred indirect reuse alternative:

- Scenario 5, in which denitrification filters and chemical precipitation facilities would be installed at the West and North WWTPs to remove nutrients from all wastewater at the WWTPs, or
- Scenario 7, in which nutrients would be removed from the reclaimed water with a constructed treatment wetland at Wetland Site B.

Both scenarios would allow augmentation of Lake Athens with up to 1.73 mgd of reclaimed water having a maximum total phosphorus concentration of 1 mg/l and a maximum total nitrogen concentration of 5 mg/l.

Scenario 5 is slightly less expensive on a weighted unit cost basis and would remove nutrients from all wastewater at the WWTPs, which could help the City meet more stringent effluent nutrient limits at its existing discharge locations in the future.

Scenario 7 is about 8 percent more expensive on a weighted unit cost basis and entails a greater capital cost, but there are ancillary, non-economic benefits (Chapter 9.3) that may be valuable to the stakeholders and improve public perception of recycled water use, including:

- Relatively low-tech operation,
- Relatively low energy requirements,
- Fish and wildlife habitat,
- Recreational and educational opportunities,
- Ecotourism, and
- Potential for mitigation for other projects.

AMWA/Athens should assess whether the non-economic benefits associated with constructed wetland treatment (Scenario 7) outweigh the additional cost compared to mechanical treatment at the WWTPs (Scenario 5).

Under either of these scenarios, a screening-level analysis suggests that the maximum annual average TDS concentration in Lake Athens during a drought-of-record situation would be approximately 259 mg/l (Table E-4).[63] Therefore, either scenario may require one of the following actions:

- Simultaneously import raw water from another source and/or
- Develop a site-specific TSWQS limit for Lake Athens that would allow for annual average TDS concentrations greater than the target level of 200 mg/l

It is recommended that AMWA/Athens should meet with the TCEQ to identify the numerical TDS standard that would be applied to Lake Athens, to discuss the proposed project, and to identify the additional information that would be required to establish a site-specific TDS standard.[64]

Should Scenarios 5 and 7 prove infeasible, the next most cost-effective indirect reuse scenarios are Scenarios 3 and 1, which have similar treatment facilities to Scenarios 5 and 7 but a reduced augmentation rate (1.14 mgd) that is projected to achieve a projected maximum annual average TDS concentration of 200 mg/l.

[63] See Chapter 5.6 for discussion of the assumptions inherent in the TDS projections.

[64] Additional discussion of a site-specific TDS standard is presented in Section 9.3.

12. Implementation Plan

Guidance on developing an implementation plan and the implementation plan for the Athens indirect reuse project are presented 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.

The implementation plan for the Athens indirect reuse project is discussed below.

12.2. Schedule of Actions

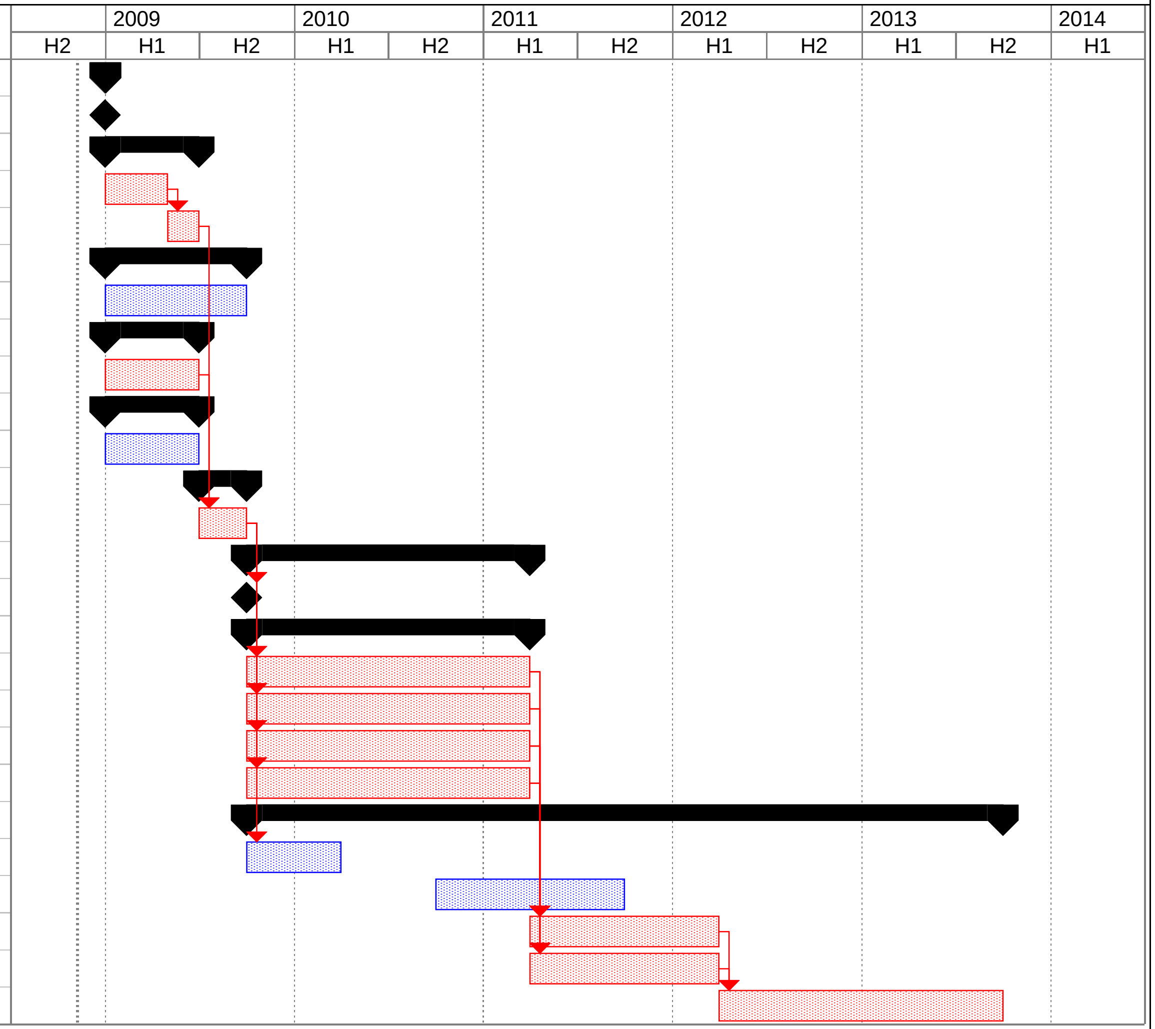
The selected indirect reuse alternative will be implemented in two phases. Phase 1 results in polishing treatment and transport of reclaimed water from the North WWTP to Lake Athens. Phase 2 results in transport of the reclaimed water from the West WWTP to the North WWTP and additional polishing treatment facilities.

The recommended implementation plan for Phase 1 is illustrated in Figure 12-1. The proposed Phase 1 schedule of actions is as follows:

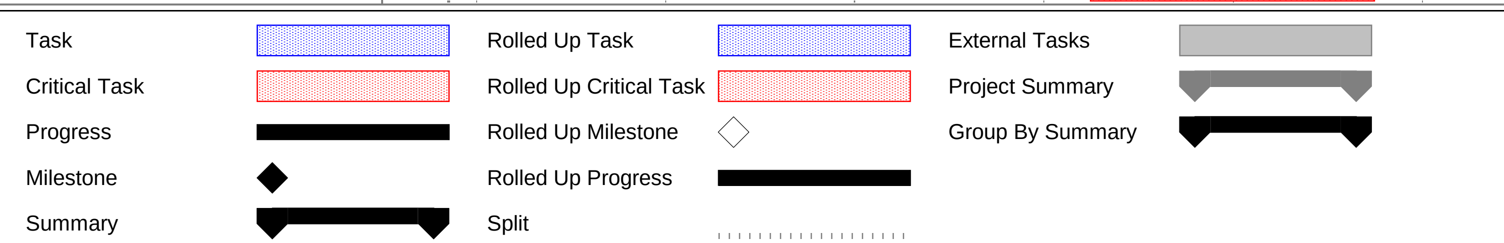
- Begin regular sampling and analysis of Lake Athens raw water, and West WWTP effluent, and North WWTP effluent for total phosphorus, total nitrogen, TDS, chlorides, and sulfates. In the short term, use these data to verify the required constructed wetland treatment area, if necessary. In the long term, use these data to track the impact of reclaimed water augmentation on Lake Athens water quality.
- Develop updated information on other potentially feasible water management strategies (Chapter 9.4) by second quarter 2009. Determine whether one or more of these strategies should be implemented instead of or simultaneously with the preferred indirect reuse alternative. The rest of this implementation plan assumes that indirect reuse will be the sole raw water supply augmentation method.

Figure 12-1
Phase 1 Indirect Reuse Implementation Plan

ID	Task Name
1	**Begin Regular Water Quality Sampling**
2	Begin Regular Water Quality Sampling
3	**Develop Information on Other Raw Water Strategies**
4	Develop Information
5	Select or Reject Other Raw Water Strategies
6	**Wetland Site B Soil Testing**
7	Wetland Site B Soil Testing (if necessary)
8	**Select Preferred Reclaimed Water Alternative**
9	Select Preferred Reclaimed Water Alternative
10	**Identify Potential Direct Reclaimed Water Customers**
11	Identify Potential Direct Reclaimed Water Customers
12	**Public Input**
13	Public Input
14	**TDS Standard for Lake Athens**
15	Develop Approach to TDS Issues
16	**Permitting**
17	Amend Certificate of Adjudication 06-3256
18	404 Permit Acquisition (Environmental/Hydraulic)
19	TCEQ Discharge Permit Amendment
20	Other Permits/Authorizations
21	**Indirect Reuse Phase I**
22	Preliminary Design
23	Wetland Land Acquisition (if necessary)
24	Pipeline Right-of-Way Acquisition
25	Design/Advertise/Bid
26	Construct Facilities



Project: Athens Indirect Reuse
Date: Thu 11/6/08



Thu 11/6/08 8:30 AM

- If necessary, conduct core sampling of in-situ soils at Wetlands Site B to determine whether in-situ soils have a coefficient of permeability of $1x10^{-7}$ cm/sec or less. Conduct sampling in the first three quarters of 2009. Revise Scenario 7 opinions of probable cost as necessary.
- Assess whether the non-economic benefits associated with the constructed treatment wetland in Scenario 7 (Table 9-1 and Figures 9-1 and 9-2) outweigh the cost advantages of Scenario 5. Select the preferred indirect reuse alternative by second quarter 2009.
- Continue efforts to identify potential direct reuse customers.
- Obtain public input on the proposed plan by third quarter 2009.
- Begin developing an approach to address potential TDS issues by fourth quarter 2009. This may include discussions with the TCEQ regarding a site-specific surface water quality standard for TDS in Lake Athens. Perform additional sampling and modeling of TDS concentrations as necessary. Obtain resolution by first quarter 2011.
- Initiate efforts by fourth quarter 2009 to obtain the required water right amendment, environmental and discharge permits, and direct reuse authorization. This effort includes permits necessary to implement both Phase 1 and Phase 2. Obtain necessary permits and authorizations by first quarter 2011.
- Perform preliminary design of the Phase 1 polishing treatment facilities. These will include either denitrification filters and chemical precipitation[65] at the North WWTP (Scenario 5) or a constructed treatment wetland (Scenario 7). Perform preliminary design of Phase 1 conveyance facilities (pump station and pipeline from the North WWTP to a tributary to Lake Athens) beginning in fourth quarter 2009 in support of the permit applications.
- If Scenario 7 is the preferred indirect reuse alternative, begin acquiring land for a constructed treatment wetland by third quarter 2010. Complete land acquisition by third quarter 2011.
- Begin acquiring easements for conveyance facilities by second quarter 2011. Complete easement acquisition by second quarter 2012.

[65] If mechanical treatment is selected as the preferred alternative, further consideration should be given during preliminary design to other processes, including biological nutrient removal within the aeration basins and/or cloth filters.

- Complete the final design of the Phase 1 treatment and conveyance facilities by second quarter 2012.
- Construct and place into operation the Phase 1 treatment and conveyance facilities by fourth quarter 2013.

Phase 2 treatment facilities would include either denitrification filters and chemical precipitation at the West WWTP (Scenario 5) or additional constructed treatment wetland area at Wetland Site B (Scenario 7). Phase 2 conveyance facilities would include a pump station and pipeline from the West WWTP to the North WWTP. Phase 2 facilities should be designed, constructed, and placed into operation by 2026 (based on projections shown in Figure 8-1).

12.3. Schedule of Capital Expenditures

The recommended implementation plan results in the projected schedule of capital expenditures shown in Table 12-1 for Scenario 5 (polishing treatment with denitrification filters/chemical precipitation) and Table 12-2 for Scenario 7 (polishing treatment with a constructed wetland).

Table 12-1
Projected Schedule of Capital Expenditures, Scenario 5

Expenditure	Opinion of Probable Capital Costs[a] ($ Million)										
	2009	**2010**	**2011**	**2012**	**2013**	**… …**	**2022**	**2023**	**2024**	**2025**	**Total**
Permitting/TDS Approach	$0.029	$0.114	$0.029								$0.173
Indirect Reuse Phase 1											
- Design Engineering	$0.045	$0.045	$0.169	$0.337							$0.594
- Construction, etc.				$2.203	$4.406						$6.609
Indirect Reuse Phase 2											
- Design Engineering							$0.030	$0.143	$0.228		$0.401
- Construction, etc.									$1.370	$2.742	$4.112
TOTAL	$0.074	$0.159	$0.198	$2.539	$4.406		$0.030	$0.143	$1.598	$2.742	$11.888

[a]Capital costs in second quarter 2007 dollars. Where applicable, expenditure shown in first year of construction.

Table 12-2
Projected Schedule of Capital Expenditures, Scenario 7

Expenditure	Opinion of Probable Capital Costs[a] ($ Million)										
	2009	**2010**	**2011**	**2012**	**2013**	**… …**	**2022**	**2023**	**2024**	**2025**	**Total**
Permitting/TDS Approach	$0.044	$0.172	$0.044								$0.261
Indirect Reuse Phase 1											
- Design Engineering	$0.058	$0.058	$0.221	$0.441							$0.778
- Construction, etc.				$2.884	$5.768						$8.652
Indirect Reuse Phase 2											
- Design Engineering							$0.033	$0.159	$0.254		$0.446
- Construction, etc.									$1.525	$3.051	$4.576
TOTAL	$0.103	$0.231	$0.265	$3.325	$5.768		$0.033	$0.159	$1.779	$3.051	$14.713

[a]Capital costs in second quarter 2007 dollars. Where applicable, expenditure shown in first year of construction.

Appendix A: Lake Athens Water Quality Data

Figure A-1: Lake Athens Estimated Total Nitrogen Concentrations

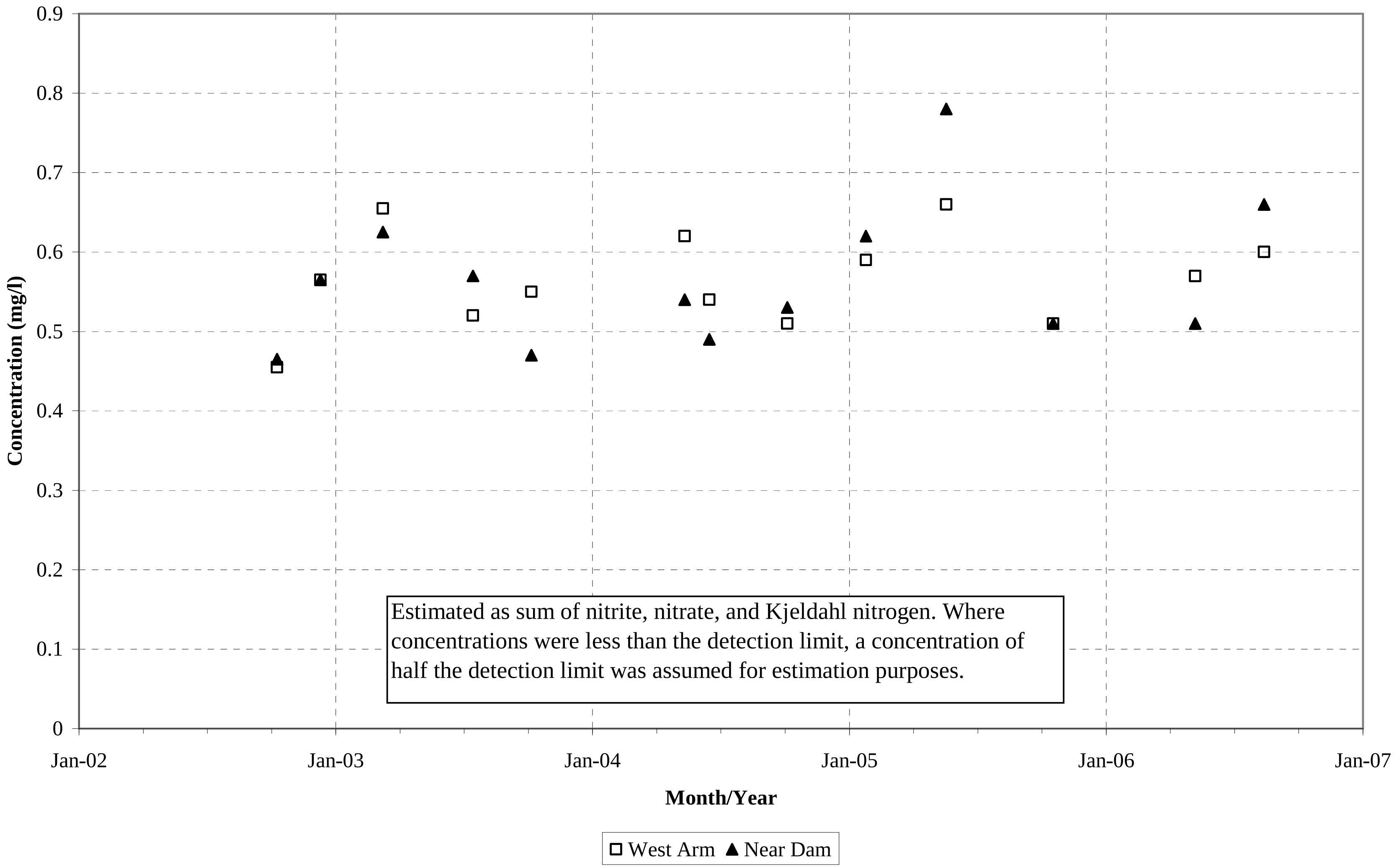


Figure A-2: Lake Athens Total Phosphorus Concentrations

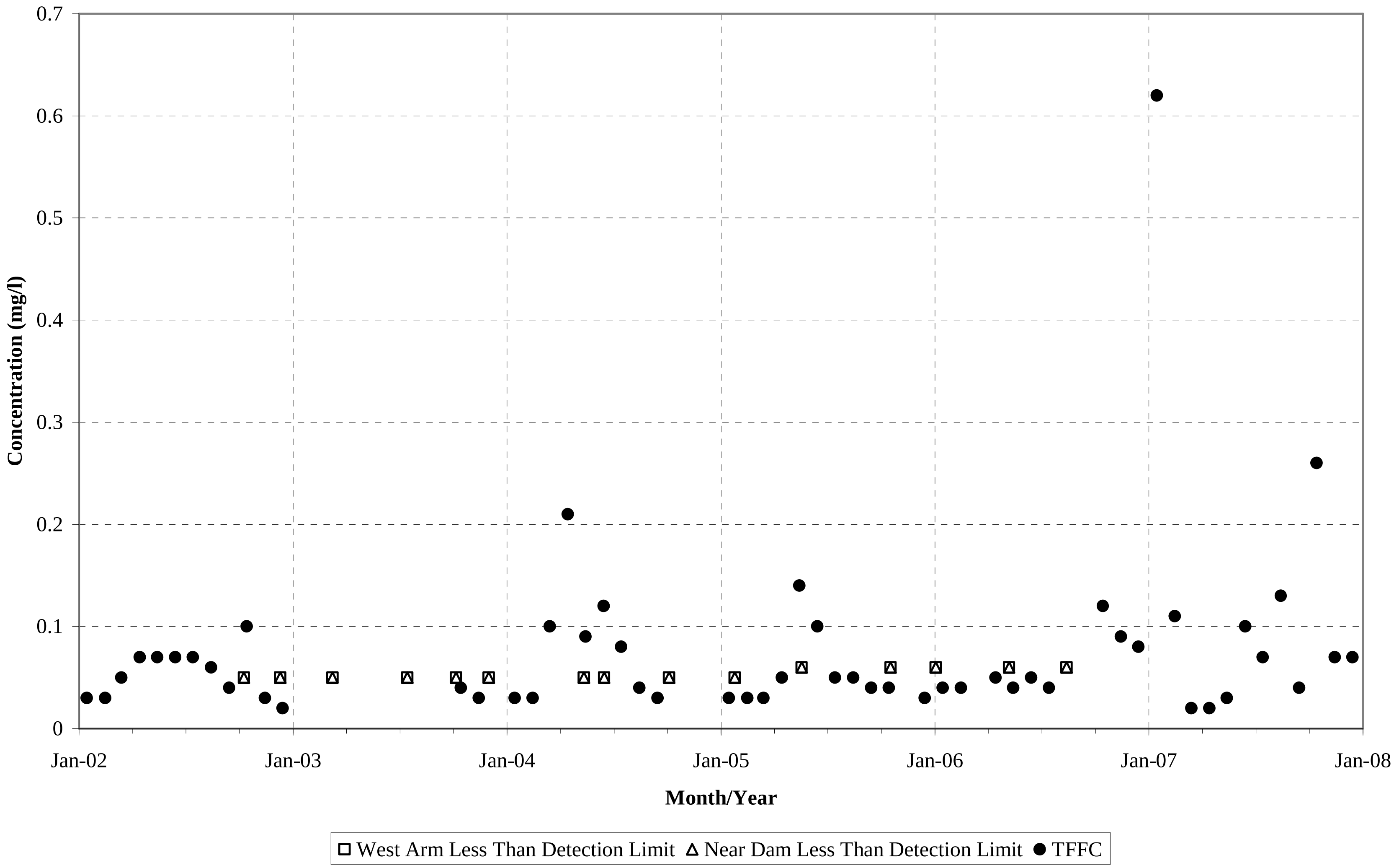


Figure A-3: Lake Athens Chlorophyll-a Concentrations

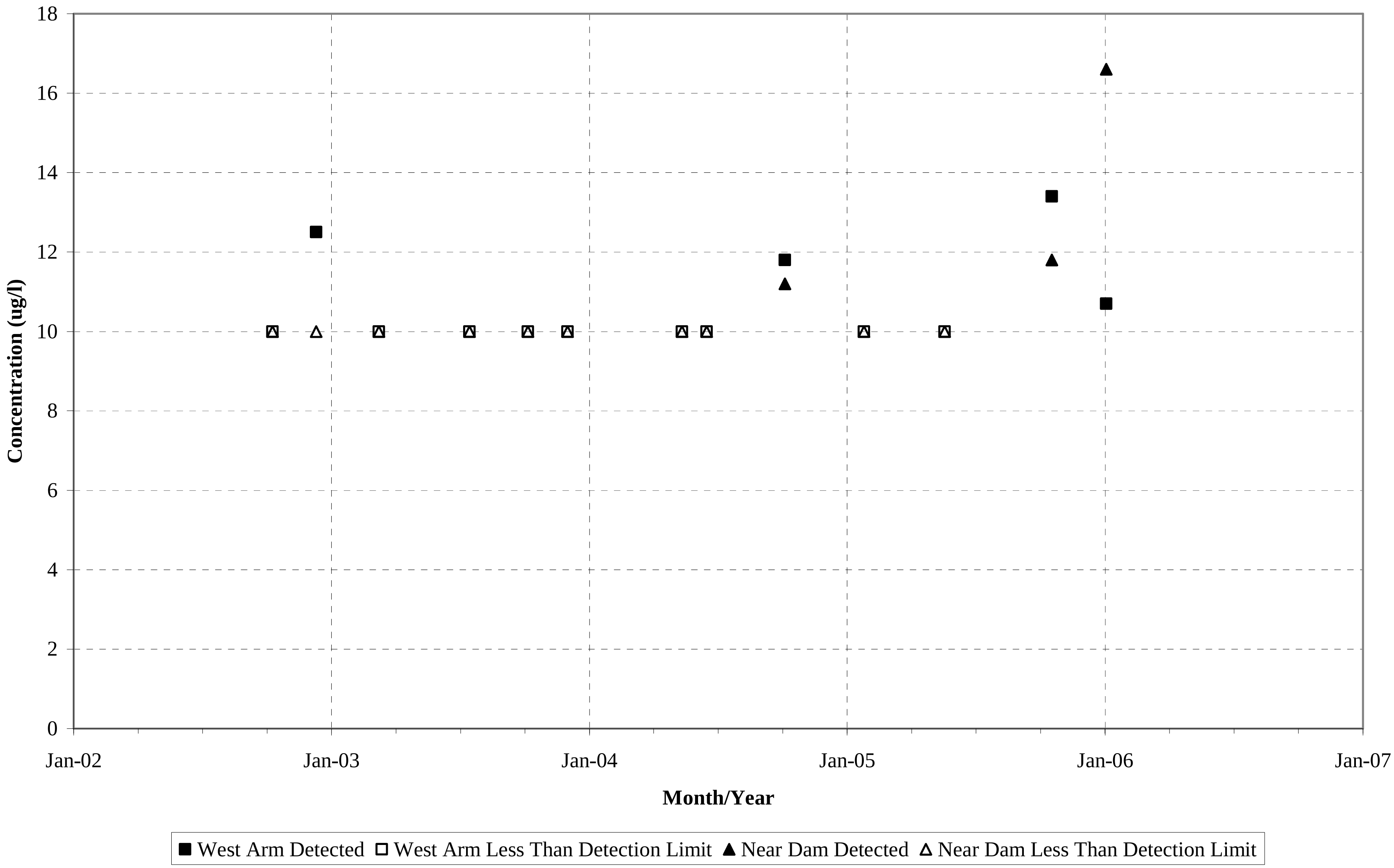


Figure A-4: Lake Athens Total Dissolved Solids Concentrations

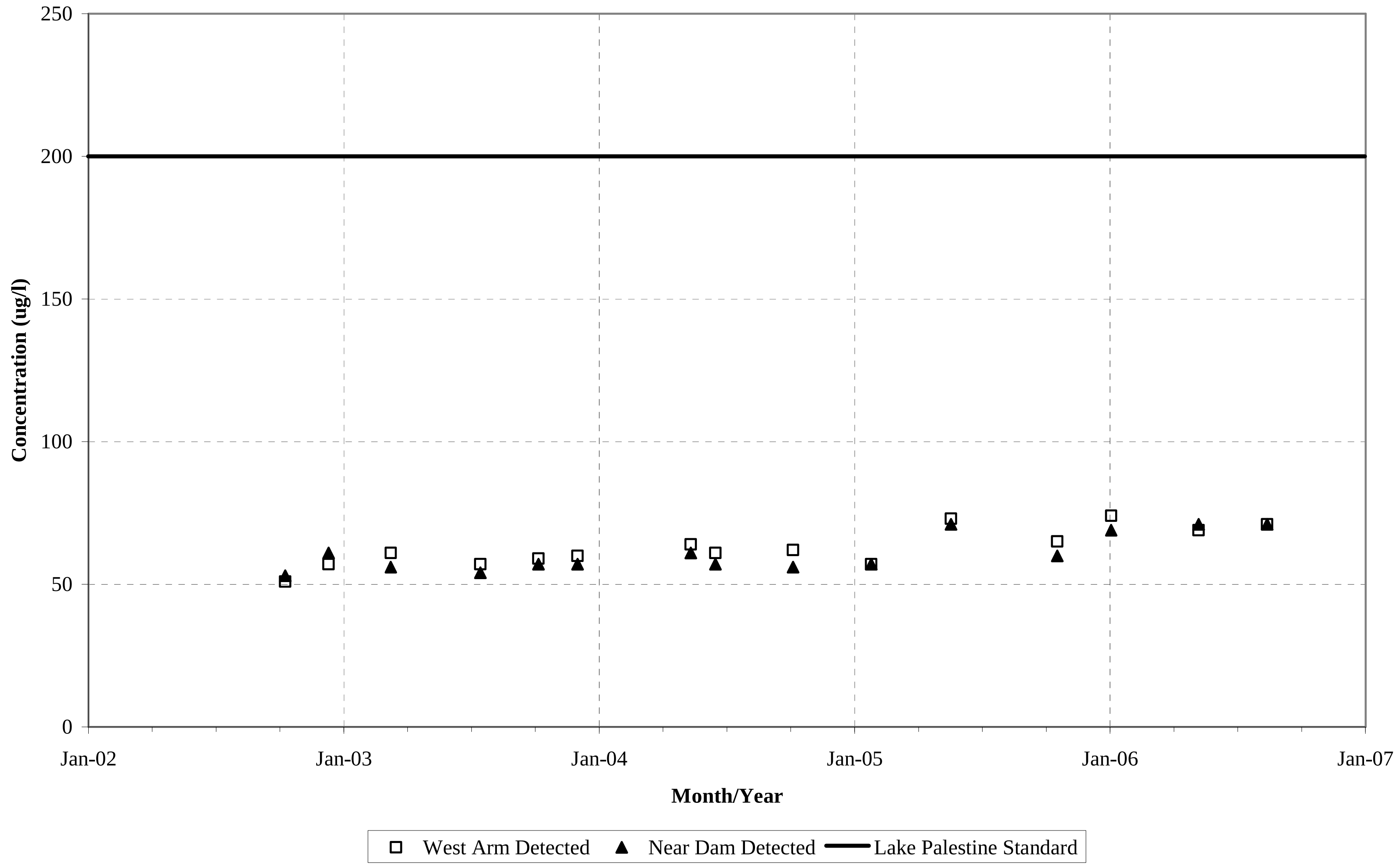


Figure A-5: Lake Athens Chlorides Concentrations

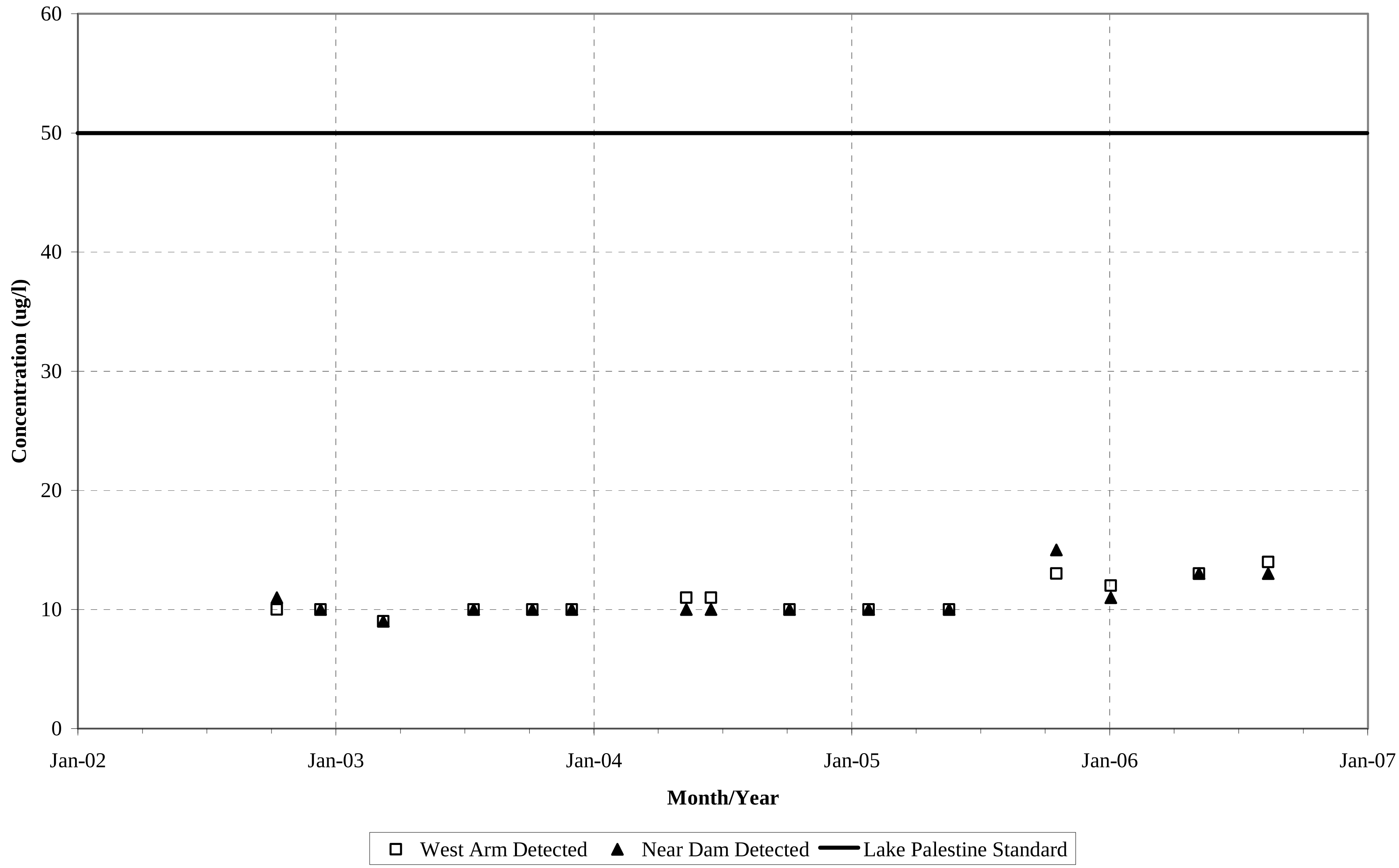
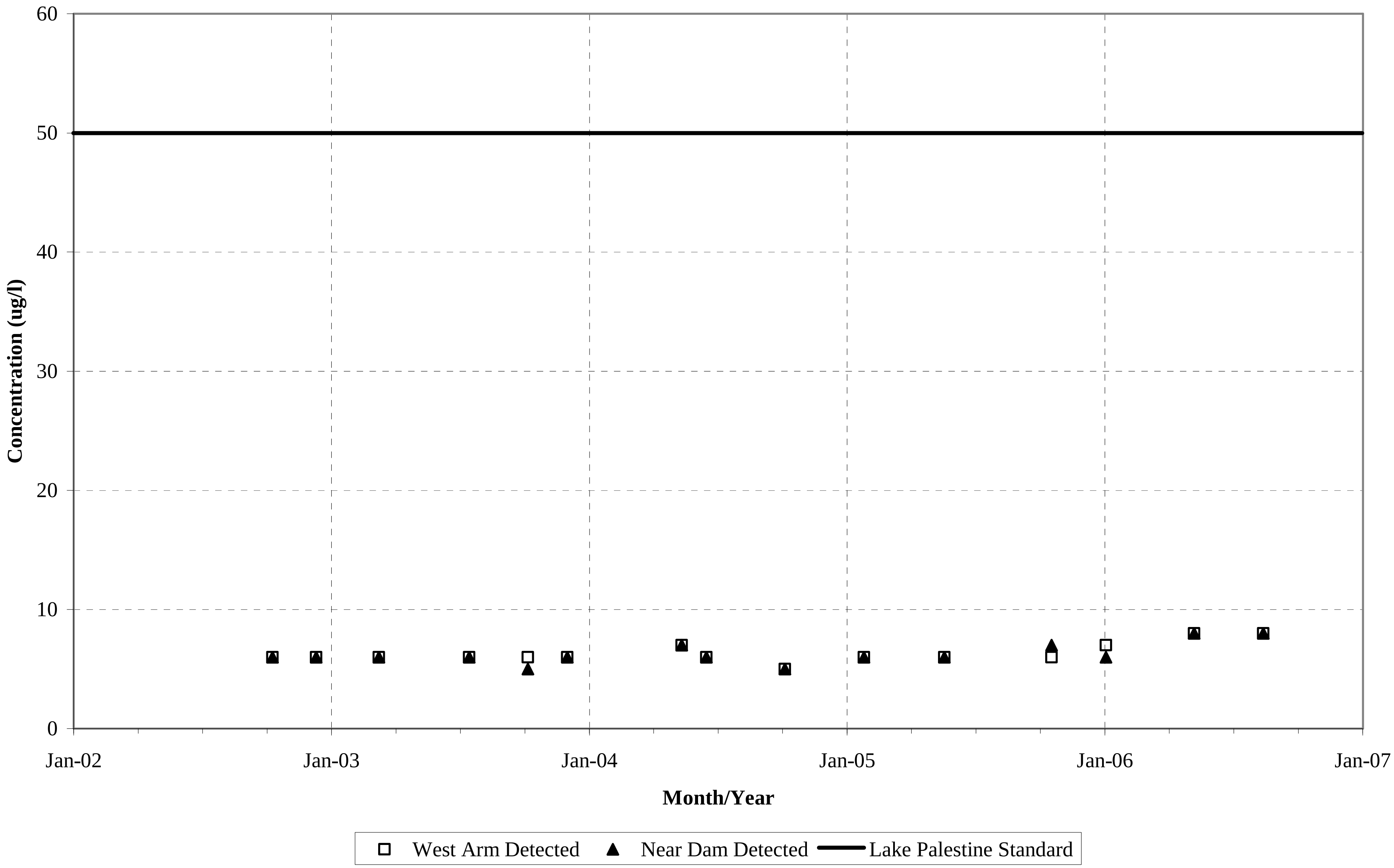


Figure A-6: Lake Athens Sulfates Concentrations



Appendix B: Athens Reclaimed Water Flowrates and Quality Data

Figure B-1: City of Athens Monthly Average Total Phosphorus in Reclaimed Water

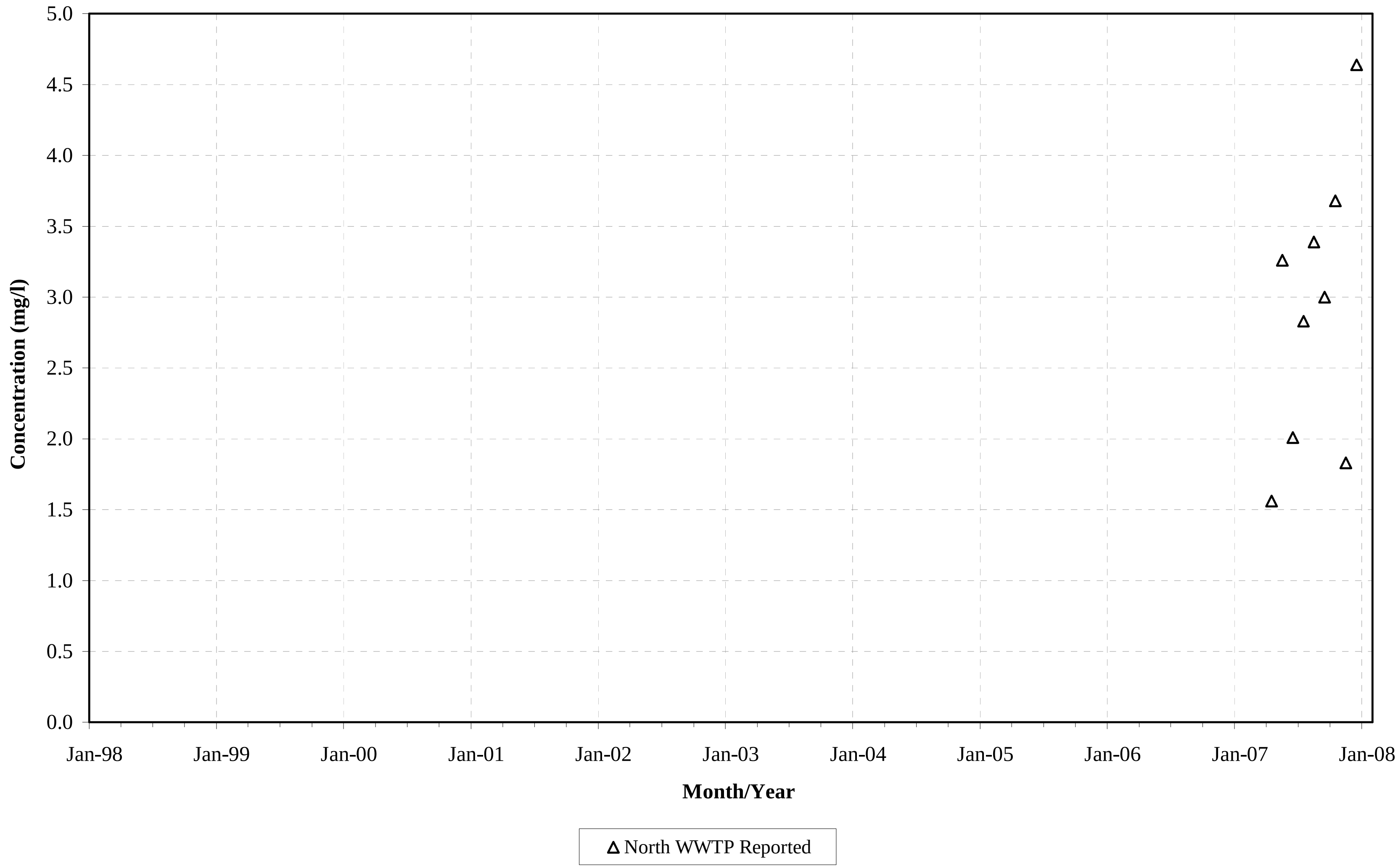


Figure B-2: City of Athens Monthly Average Ammonia in Reclaimed Water

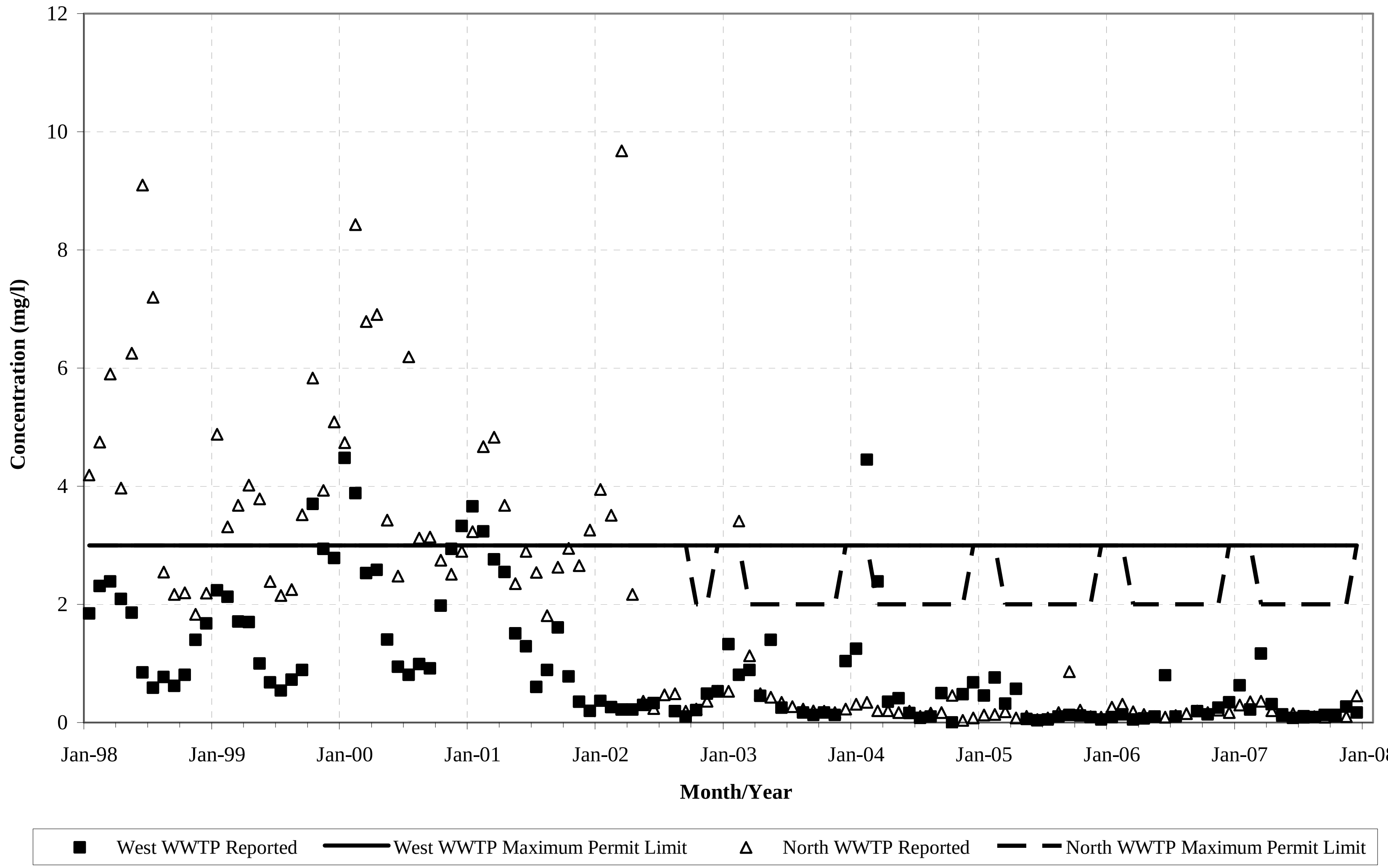


Figure B-3: City of Athens Monthly Average Total Nitrate in Reclaimed Water

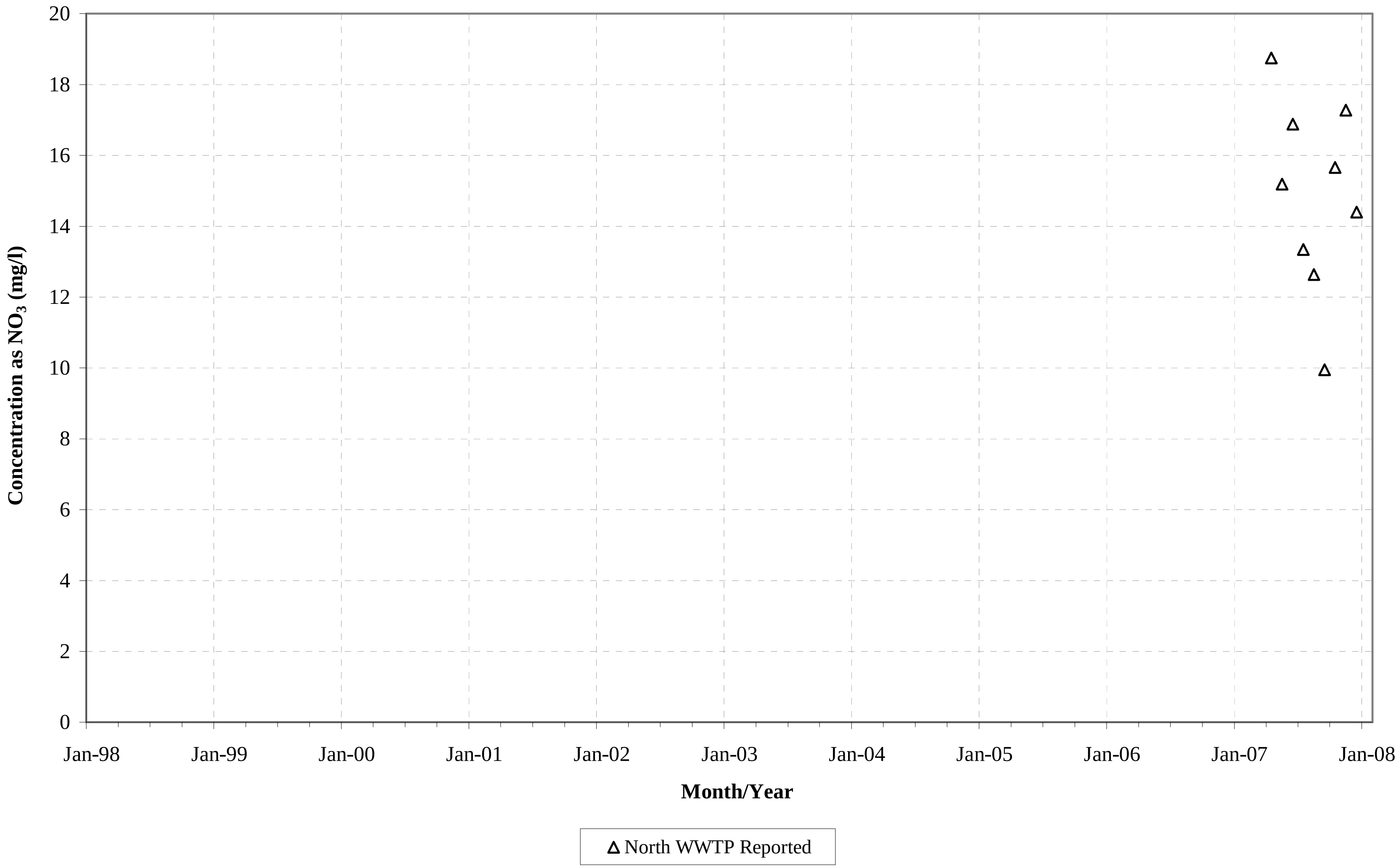


Figure B-4: City of Athens Monthly Average Total Suspended Solids in Reclaimed Water

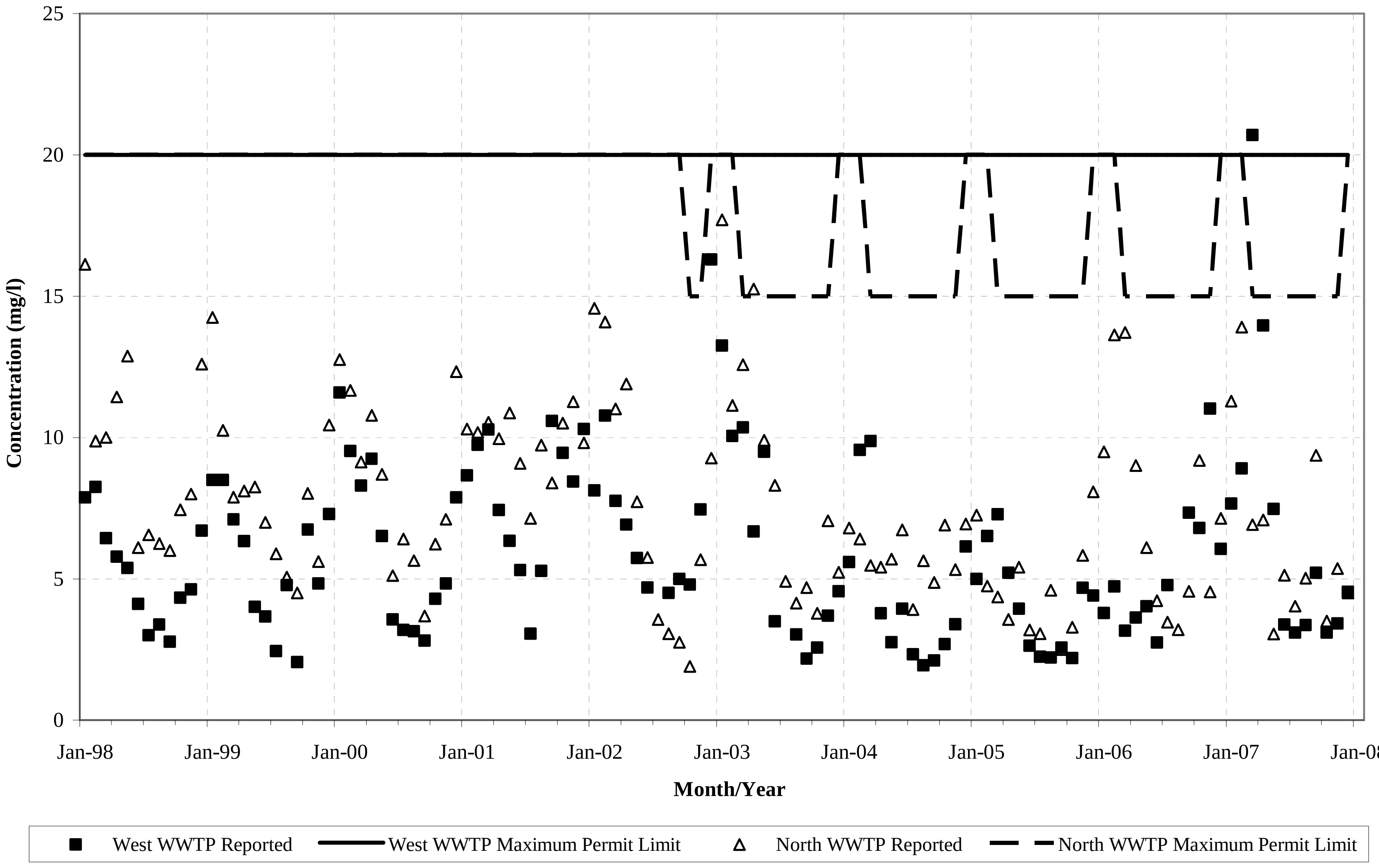


Figure B-5: City of Athens Monthly Average BOD in Reclaimed Water

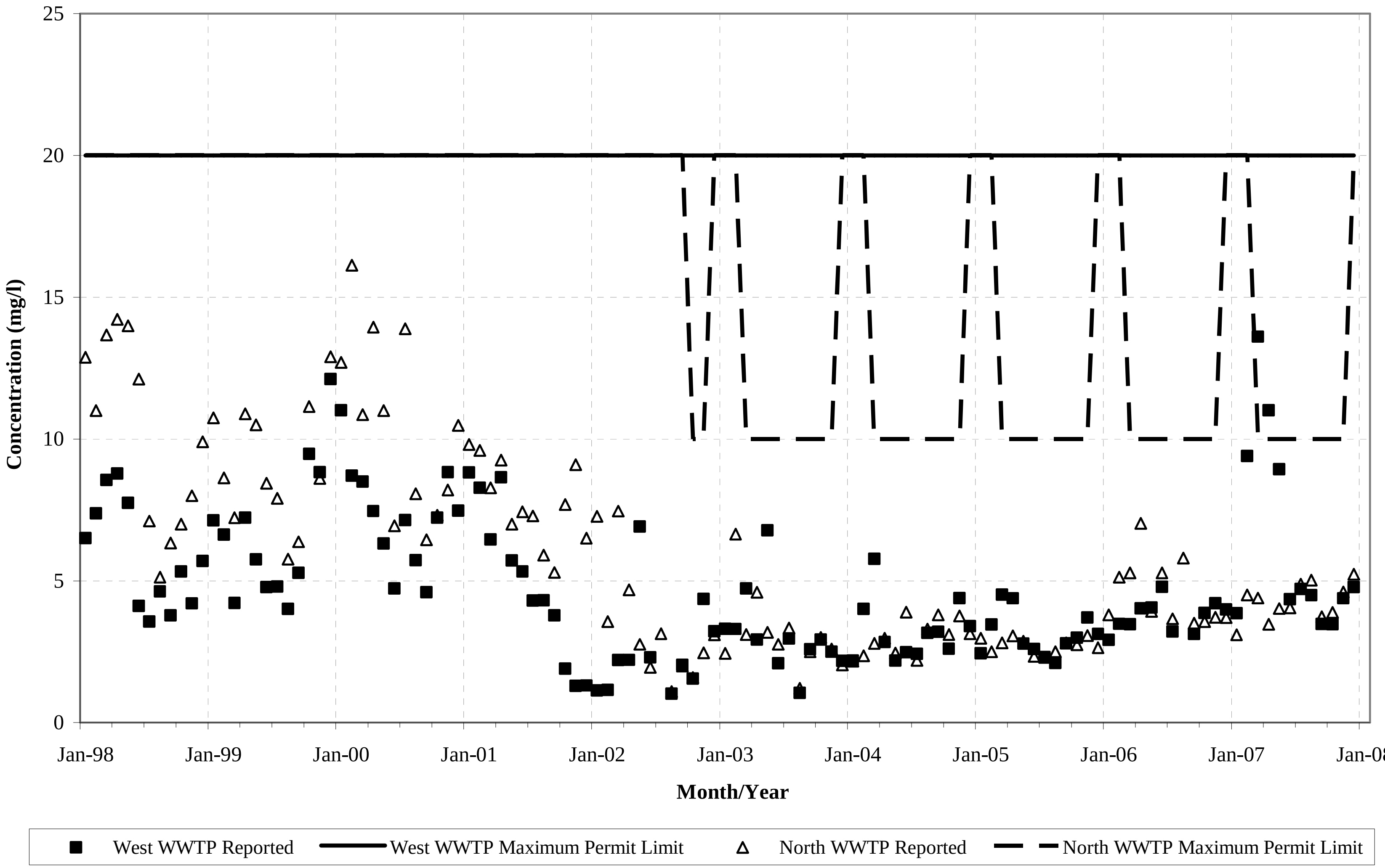


Figure B-6: City of Athens Monthly Average Total Dissolved Solids in Reclaimed Water

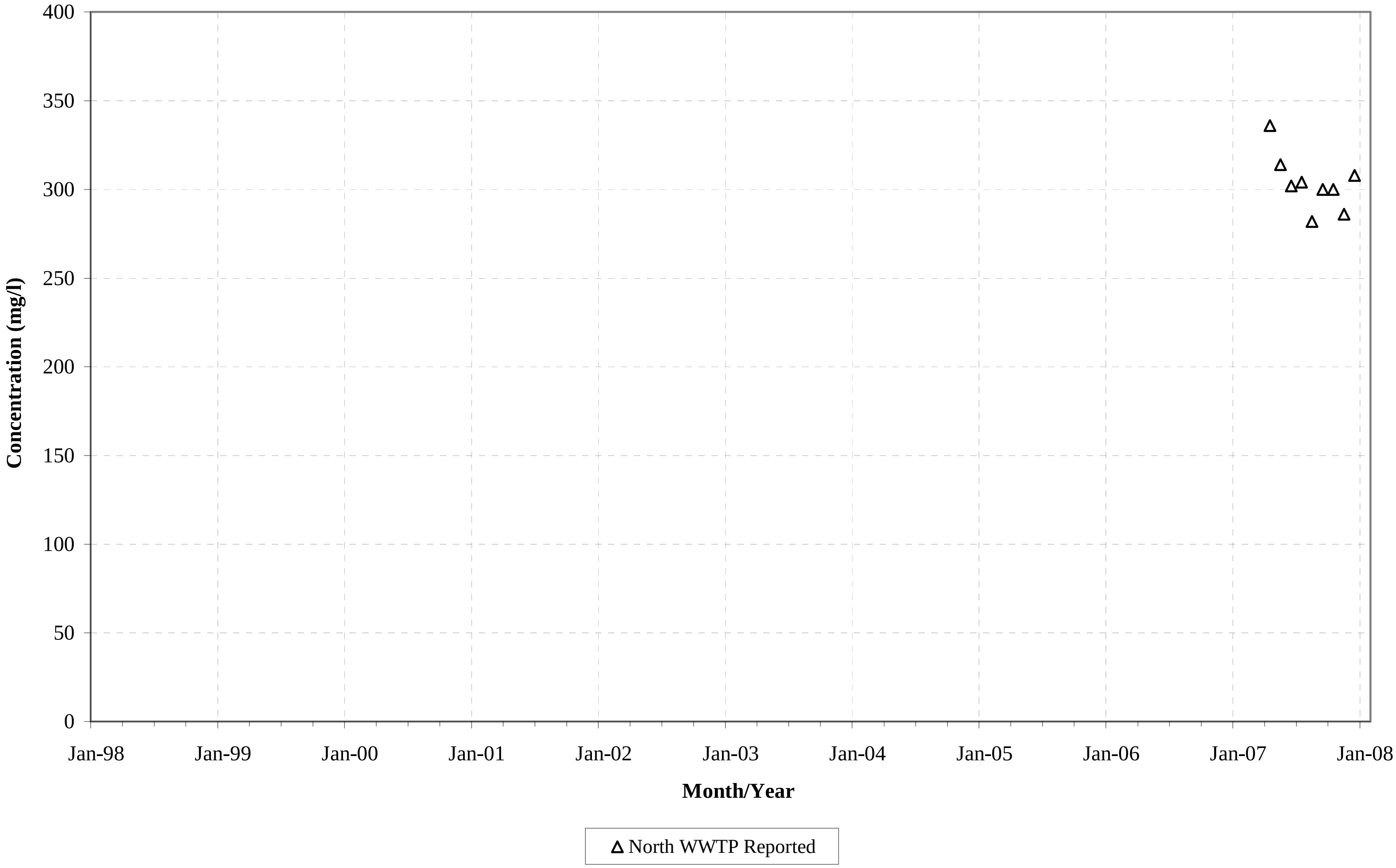
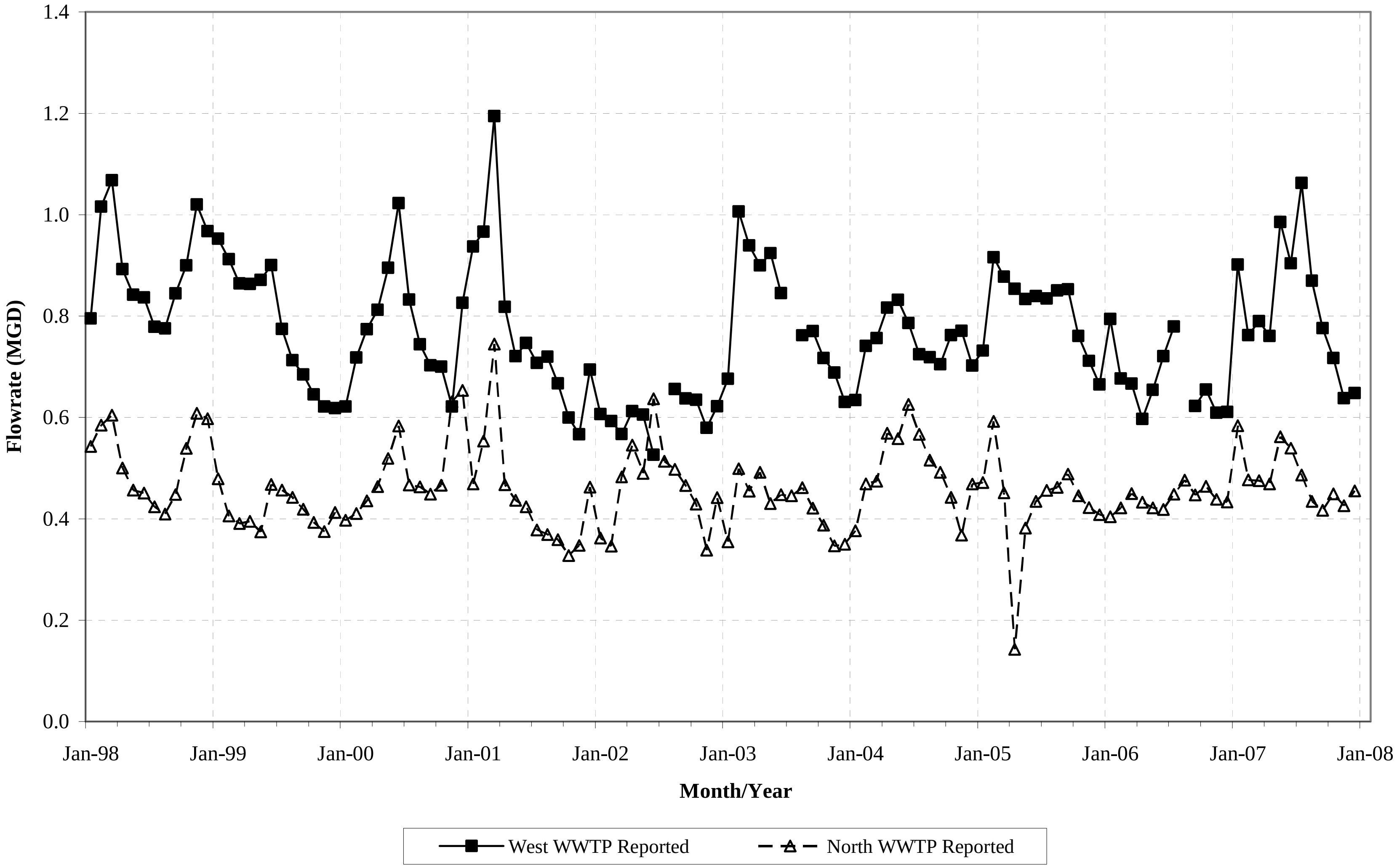


Figure B-7: City of Athens Monthly Average Flowrate of Reclaimed Water



Appendix C: Texas Freshwater Fisheries Center Influent and Effluent Flowrates and Quality Data

Figure C-1: TFFC Influent Characteristics

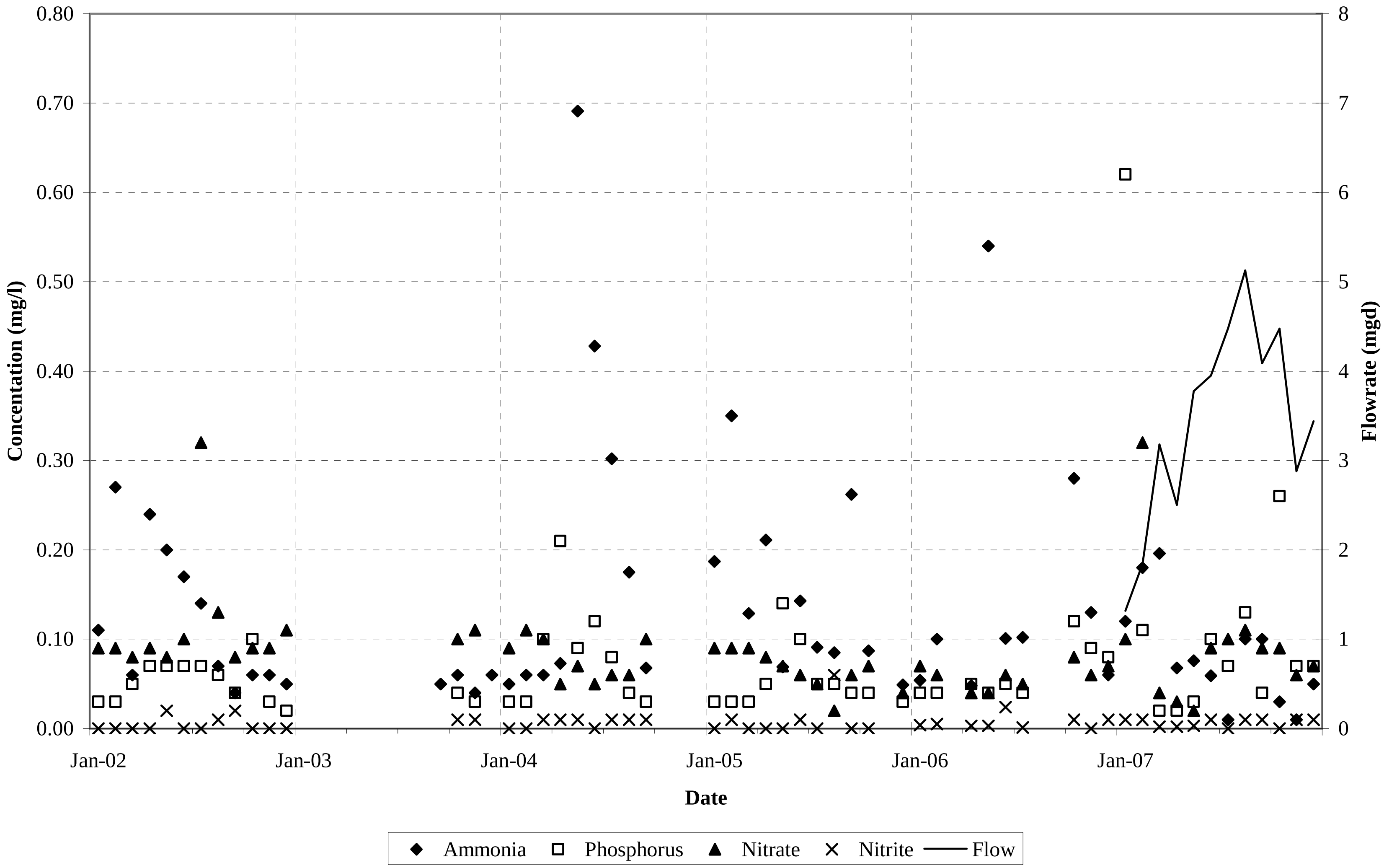
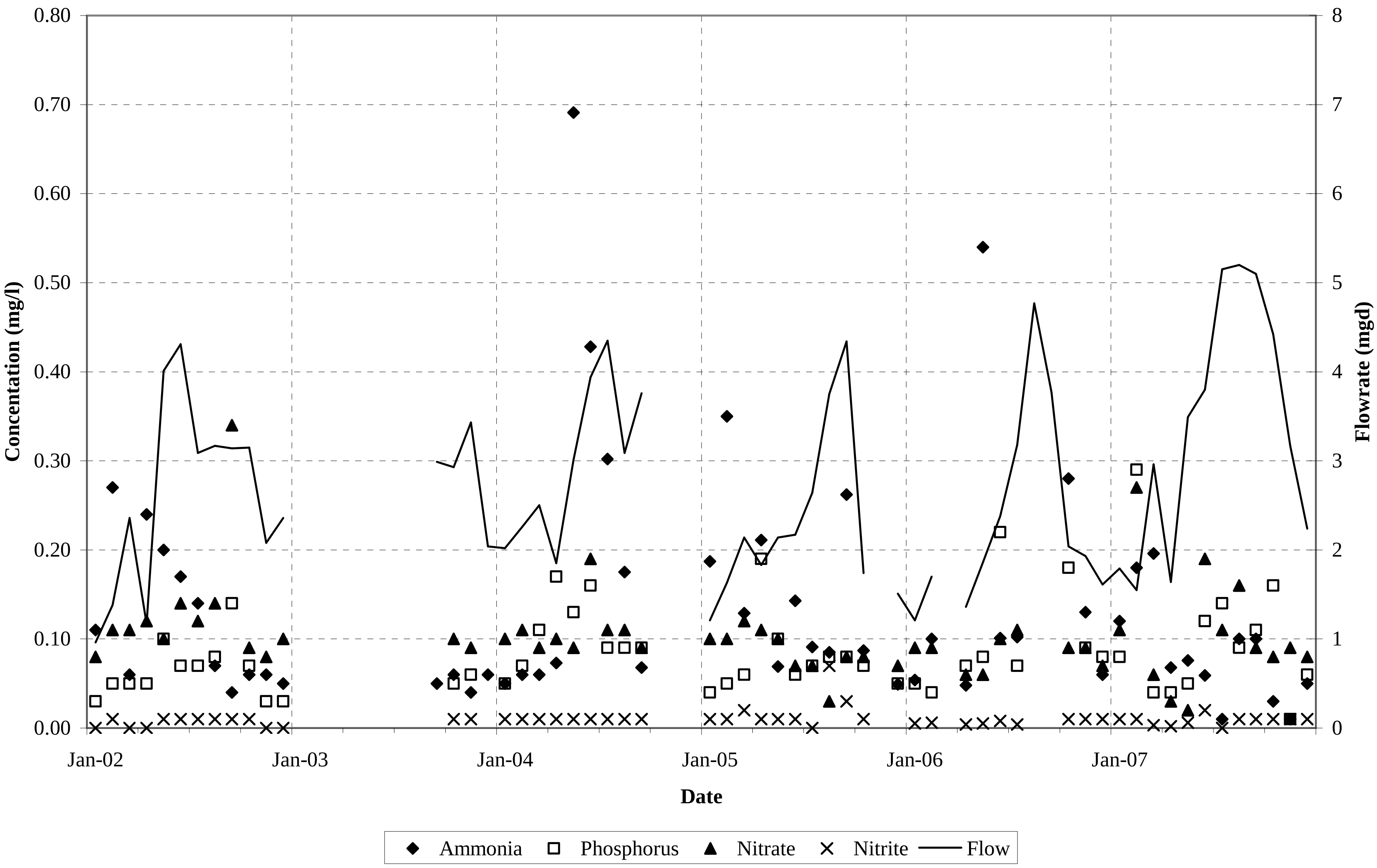


Figure C-2: TFFC Effluent Characteristics



Appendix D: Amendment to Certificate of Adjudication 06-3256B

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

AMENDMENT TO CERTIFICATE OF ADJUDICATION

Application No. 06-3256B	Certificate No. 06-3256B	Type:	§§ 11.122, 11.046, 11.042 & 11.085
Owner:	Athens Municipal Water Authority	Address	508 Tyler Street Athens, Texas 75751
Filed:	August 6, 2003	Granted:	MAY 26 2004
Purpose:	Municipal & Industrial	County:	Henderson
Watercourse:	Flat Creek, tributary of the Neches River	Watershed:	Neches River Basin & Trinity River Basin

WHEREAS, Certificate of Adjudication No. 06-3256 authorizes the Athens Municipal Water Authority (Athens MWA or Owner) to impound, with a time priority of January 17, 1955, not to exceed 32,840 acre-feet of water in Lake Athens on Flat Creek, tributary of the Neches River, Neches River Basin, Henderson County; and

WHEREAS, Certificate of Adjudication No. 06-3256 further authorizes the Athens MWA to divert and use, with a time priority of January 17, 1955, not to exceed 5,477 acre-feet of water per annum for municipal purposes and not to exceed 3,023 acre-feet of water per annum for industrial purposes within the service area of the Athens MWA; and

WHEREAS, pursuant to an interbasin transfer exempt under Texas Water Code section 11.085, the water authorized by Certificate of Adjudication No. 06-3256 may be diverted from Lake Athens in the Neches River Basin for use within the service area of the City of Athens in the Trinity River Basin; and

WHEREAS, the Athens MWA is ~~authorized to divert the~~ water authorized at a maximum rate of not to exceed 5 cfs (2,250 gpm) with a time priority of January 17, 1955, from a point on the southwest shore of Lake Athens in the A.M. Butler Survey, Abstract 94, for municipal purposes and at a maximum rate of 11 cfs (5,000 gpm) with a time priority of May 16, 1994, for industrial purposes from a point on the northwest shore of Lake Athens in the same survey; and

WHEREAS, the City of Athens operates two wastewater treatment plants (WWTPs), the North WWTP and the West WWTP, and seeks to amend Certificate of Adjudication No. 06-3256 to collect, treat, return, and reuse a combined maximum of 2,677.14 acre-feet of treated effluent per year (2.39 million gallons per day) from both WWTPs to augment the raw water source in Lake Athens; and

WHEREAS, Applicant seeks authorization to use the bed and banks of an unnamed tributary of Flat Creek and Lake Athens to convey up to 2,677.14 acre-feet per year of treated effluent from the City of Athens' West and North WWTPs in the Trinity River Basin to Athens WMA's authorized diversion points on Lake Athens in the Neches River Basin; and

WHEREAS, treated effluent from the West WWTP will be piped to the North WWTP, at which point treated effluent streams from both plants will be combined and piped to the unnamed tributary of Flat Creek for conveyance to Lake Athens; and

WHEREAS, the impoundment of the treated effluent will not increase the authorized storage capacity of Lake Athens and will be used to augment the 8,500 acre-feet of water per year authorized for diversion from Lake Athens pursuant to Certificate of Adjudication No. 06-3256 for municipal and industrial use by the Athens MWA ; and

WHEREAS, the discharge point on the unnamed tributary of Flat Creek will be located at Latitude 32.221°N and Longitude 95.808°W; and

WHEREAS, Applicant does not seek to increase the total diversion amount of 8,500 acre-feet of water per annum authorized by Certificate of Adjudication No. 06-3256; and

WHEREAS, the Texas Commission on Environmental Quality finds that jurisdiction over the application is established; and

WHEREAS, the Executive Director has determined that in order to protect existing water rights, a special condition should be included in the permit limiting diversions to the actual discharges of treated effluent less carriage losses; and

WHEREAS, no person protested the granting of this amendment; and

WHEREAS, the Commission has complied with the requirements of the Texas Water Code and Rules of the Texas Commission on Environmental Quality in issuing this amendment;

NOW, THEREFORE, this amendment to Certificate of Adjudication No. 06-3256, designated as Certificate of Adjudication 06-3256B, is issued to the Athens Municipal Water Authority, subject to the following terms and conditions:

1. IMPOUNDMENT

Within the authorized storage capacity of Lake Athens, the Athens Municipal Water Authority is authorized to store a maximum of 2,677.14 acre-feet of treated effluent water per year.

2. USE

The Athens Municipal Water Authority is authorized to reuse a maximum of 2,677.14 acre-feet of treated wastewater treatment plant effluent per year (2.39 million gallons per day) to augment the raw water source in Lake Athens authorized by Certificate of Adjudication No. 06-3256.

3. TIME PRIORITY

The time priority for the bed and banks conveyance, storage, and use of the water authorized herein shall be August 6, 2003.

4. CONSERVATION

Owners shall implement water conservation plans that provide for the utilization of those practices, techniques, and technologies that reduce or maintain the consumption of water, prevent or reduce the loss or waste of water, maintain or improve the efficiency in the use of water, increase the recycling and reuse of water, or prevent the pollution of water, so that a water supply is made available for future or alternative uses.

5. SPECIAL CONDITIONS

In addition to the Special Conditions contained in Certificate of Adjudication No. 06-3256 which remain in effect:

A. Athens Municipal Water Authority is authorized to discharge treated effluent into an unnamed tributary of Flat Creek at a point located at Latitude 32.221°N and Longitude 95.808°W., and to use approximately 2 miles of the bed and banks of the unnamed tributary and Lake Athens to convey a maximum of 2,677.14 acre-feet per year (2.39 million-gallons per day) of treated effluent from the City of Athens' West and North WWTPs in the Trinity River Basin to the diversion points on Lake Athens in the Neches River Basin for diversion and reuse within the service area of the Athens MWD in the Trinity River Basin.

B. Athens MWD is authorized to convey the treated effluent from the Trinity River Basin to Lake Athens in the Neches River Basin.

C. Athens MWA may not divert from Lake Athens any more than the amount of water authorized for diversion by Certificate of Adjudication No. 06-3256, including treated effluent.

D. Prior to the discharge and diversion of the water authorized herein, Athens MWA shall install and maintain a measuring device(s), capable of measuring within plus-or-minus 5% accuracy, to record the amount of treated effluent discharged into the unnamed tributary of Flat Creek and conveyed to the reservoir for storage to augment the raw water source in Lake Athens.

E Athens MWA shall maintain electronic records (in spreadsheet or database format) of the discharge and diversion of the water authorized herein and shall submit the records to the Executive Director upon request.

This amendment is issued subject to all terms, conditions and provisions contained in Certificate of Adjudication No. 06-3256 except as amended herein.

This amendment is issued subject to all superior and senior water rights in the Neches and Trinity River Basins.

Certificate owner agrees to be bound by the terms, conditions and provisions contained herein and such agreement is a condition precedent to the granting of this amendment.

All other matters requested in the application which. are not specifically granted by this amendment are denied.

This amendment is issued subject to the Rules of the Texas Commission on Environmental Quality and to the right of continuing supervision of State water resources exercised by the Commission.

TEXAS COMMISSION ON
ENVIRONMENTAL QUALITY

For the Commission

Date Issued: MAY 26 2004

Appendix E: Detailed Reclaimed Water Augmentation Evaluation Results

Table E-1: Reclaimed Water Augmentation in Lake Athens – All Available Reclaimed Water Supply (Limiting Condition 1)

Quantity	Units	2000	2010	2020	2030	2040	2050	2060
Without Membrane Filtration:								
Augmentation Rate	ac-ft/yr	1,237	1,464	1,731	2,047	2,407	2,878	3,462
Augmentation Rate	mgd	1.10	1.31	1.54	1.83	2.15	2.57	3.09
Return Flow	%	52.8	52.8	52.8	52.8	52.8	52.8	52.8
Maximum Blend	%	35.4	40.6	46.1	52.2	57.9	64.2	70.5
Maximum Annual Average TDS Concentration	mg/l	200	220	242	270	299	336	382
Annual Average TDS <= 200 mg/l	%	99.7	97.9	92.7	77.6	62.6	47.0	35.5
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.25	0.18	0.07	-0.05	-0.17	-0.82
Minimum Water Surface Elevation	ft	434.85	434.60	434.30	433.91	433.51	432.14	430.17
Total Water Available[a]	ac-ft/yr	6,727	6,942	7,199	7,483	7,854	8,328	8,916

[a]Minimum WSEL of 431 feet. Compare to the total water demand in Table 5-2.

Table E-2: Reclaimed Water Augmentation in Lake Athens Limited by 431 Feet Minimum WSEL (Limiting Condition 2)

Quantity	Units	2000	2010	2020	2030	2040	2050	2060
Without Membrane Filtration:								
Augmentation Rate	ac-ft/yr	1,237	1,464	1,731	2,047	2,407	2,878	3,224
Augmentation Rate	mgd	1.10	1.31	1.54	1.83	2.15	2.57	2.88
Return Flow	%	52.8	52.8	52.8	52.8	52.8	52.8	52.8
Maximum Blend	%	35.4	40.6	46.1	52.2	57.9	64.2	68.1
Maximum Annual Average TDS Concentration	mg/l	200	220	242	270	299	336	363
Annual Average TDS <= 200 mg/l	%	99.7	97.9	92.7	77.6	62.6	47.0	39.8
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.25	0.18	0.07	-0.05	-0.17	-0.57
Minimum Water Surface Elevation	ft	434.85	434.60	434.30	433.91	433.51	432.14	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,727	6,942	7,199	7,483	7,854	8,328	8,680

[a]Minimum WSEL of 431 feet.
Bold, italicized font shows values that limit the reclaimed water augmentation rate.

Table E-3: Reclaimed Water Augmentation in Lake Athens Limited by Detention Time Target and 431 Feet Minimum WSEL (Limiting Condition 3)

Quantity	Units	2000	2010	2020	2030	2040	2050	2060
Without Membrane Filtration:								
Augmentation Rate	ac-ft/yr	1,237	1,464	1,731	2,047	2,259	2,391	2,363
Augmentation Rate	mgd	1.10	1.31	1.54	1.83	2.02	2.13	2.11
Return Flow	%	52.8	52.8	52.8	52.8	49.6	43.9	45.0
Maximum Blend	%	35.4	40.6	46.1	52.2	55.5	57.3	56.9
Maximum Annual Average TDS Concentration	mg/l	200	220	242	270	286	293	291
Annual Average TDS <= 200 mg/l	%	99.7	97.9	92.7	77.6	69.8	67.9	68.9
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.25	0.18	0.07	***0.00***	***0.00***	***0.00***
Minimum Water Surface Elevation	ft	434.85	434.60	434.30	433.91	433.07	***431.00***	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,727	6,942	7,199	7,483	7,707	7,844	7,826
With Membrane Filtration:								
Reclaimed Water to Membrane Filtration	ac-ft/yr	***1,237***	***1,464***	***1,731***	***2,047***	***2,407***	***2,878***	2,954
Reclaimed Water to Membrane Filtration	mgd	***1.10***	***1.31***	***1.54***	***1.83***	***2.15***	***2.57***	2.64
Reclaimed Water Requiring Membrane Filtration	%	0.2	11.9	21.5	30.4	97.3	100.0	100.0
Average Membrane Filtration Capacity	mgd	0.0023	0.16	0.33	0.55	2.09	2.57	2.64
Average Concentrate Flowrate	mgd	0.00046	0.03	0.07	0.11	0.42	0.51	0.53
Maximum Concentrate TDS	mg/l	1,017	1,017	1,018	1,014	716	714	714
Minimum Concentrate TDS	mg/l	369	369	369	368	233	222	221
Return Flow	%	52.8	52.8	52.8	52.8	52.8	52.8	45.1
Maximum Blend	%	35.4	38.9	44.7	50.0	50.0	56.0	56.9
Augmentation Rate	mgd	1.10	1.27	1.48	1.72	1.73	2.05	2.11
Maximum Annual Average TDS Concentration	mg/l	200	200	200	199	146	144	144
Annual Average TDS <= 200 mg/l	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.26	0.21	0.11	0.12	0.06	***0.00***
Minimum Water Surface Elevation	ft	434.85	434.56	434.23	433.78	431.98	***431.00***	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,737	6,918	7,135	7,359	7,392	7,756	7,826

[a]Minimum WSEL of 431 feet.
Bold, italicized font shows values that limit the reclaimed water augmentation rate.

Table E-4: Reclaimed Water Augmentation in Lake Athens Limited by 50 Percent Maximum Blend and 431 Feet Minimum WSEL (Limiting Condition 4)

Quantity	Units	2000	2010	2020	2030	2040	2050	2060
Without Membrane Filtration:								
Augmentation Rate	ac-ft/yr	1,237	1,464	1,731	1,923	1,938	1,938	1,936
Augmentation Rate	mgd	1.10	1.31	1.54	1.72	1.73	1.73	1.73
Return Flow	%	52.8	52.8	52.8	49.6	42.5	35.6	29.5
Maximum Blend	%	35.4	40.6	46.1	***50.0***	***50.0***	***50.0***	***50.0***
Maximum Annual Average TDS Concentration	mg/l	200	220	242	259	257	255	255
Annual Average TDS <= 200 mg/l	%	99.7	97.9	92.7	83.1	85.6	86.9	87.2
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.25	0.18	0.11	0.12	0.18	0.17
Minimum Water Surface Elevation	ft	434.85	434.60	434.30	433.78	431.98	***431.00***	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,727	6,942	7,199	7,379	7,388	7,394	7,401
With Membrane Filtration:								
Reclaimed Water to Membrane Filtration	ac-ft/yr	***1,237***	***1,464***	***1,731***	2,045	2,055	2,052	2,049
Reclaimed Water to Membrane Filtration	mgd	***1.10***	***1.31***	***1.54***	1.82	1.83	1.83	1.83
Reclaimed Water Requiring Membrane Filtration	%	0.2	11.9	21.5	29.9	28.4	27.7	27.6
Average Membrane Filtration Capacity	mgd	0.0023	0.16	0.33	0.54	0.52	0.51	0.50
Average Concentrate Flowrate	mgd	0.00046	0.03	0.07	0.11	0.10	0.10	0.10
Maximum Concentrate TDS	mg/l	1,017	1,017	1,018	1,019	1,022	1,024	1,024
Minimum Concentrate TDS	mg/l	369	369	369	369	370	369	368
Return Flow	%	52.8	52.8	52.8	52.7	45.1	37.6	31.3
Maximum Blend	%	35.4	39.8	44.7	50.0	50.0	50.0	50.0
Augmentation Rate	mgd	1.10	1.27	1.48	1.72	1.73	1.73	1.73
Maximum Annual Average TDS Concentration	mg/l	200	200	200	200	200	200	200
Annual Average TDS <= 200 mg/l	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.26	0.21	0.11	0.12	0.18	0.17
Minimum Water Surface Elevation	Ft	434.85	434.56	434.23	433.78	431.98	***431.00***	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,737	6,918	7,135	7,359	7,392	7,394	7,401

[a]Minimum WSEL of 431 feet.
Bold, italicized font shows values that limit the reclaimed water augmentation rate.

Table E-5: Reclaimed Water Augmentation in Lake Athens Limited by 200 mg/l Maximum Annual Average TDS Concentration and 431 Feet Minimum WSEL (Limiting Condition 5)

Quantity	Units	2000	2010	2020	2030	2040	2050	2060
Without Membrane Filtration:								
Reclaimed Water Augmentation	ac-ft/yr	1,234	1,234	1,242	1,256	1,276	1,276	1,278
Reclaimed Water Augmentation	mgd	1.10	1.10	1.11	1.12	1.14	1.14	1.14
Return Flow	%	52.7	44.5	37.9	32.4	28.0	23.4	19.5
Maximum Blend	%	35.4	35.5	35.8	36.3	36.8	36.8	36.9
Maximum Annual Average TDS Concentration	mg/l	***200***	***200***	***200***	***200***	***200***	***200***	***200***
Annual Average TDS <= 200 mg/l	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Exceedance of Minimum Detention Time Recommendation	yrs	0.31	0.34	0.35	0.35	0.34	0.33	0.33
Minimum Water Surface Elevation	ft	434.85	434.38	433.82	431.93	***431.00***	***431.00***	***431.00***
Water Available for Municipal and Industrial Supply[a]	ac-ft/yr	6,723	6,714	6,712	6,695	6,729	6,735	6,746

[a]Minimum WSEL of 431 feet.
Bold, italicized font shows values that limit the reclaimed water augmentation rate.

Appendix F: Cost Estimating for SB1 Projects

Assumptions Used to Develop Opinions of Probable Cost

Assumptions used in developing opinions of probable cost are presented in this appendix. Development of the opinions of probable cost for each polishing treatment/conveyance scenario was consistent with methods used in the *2006 Region C Water Plan*, but unit costs were updated to reflect second quarter 2007 costs. Project-specific cost assumptions are shown below, followed by a memorandum entitled “Cost Estimating for SB1 Projects” and dated September 4, 2008.

Constructed Treatment Wetlands

Construction costs for constructed treatment wetlands were assumed to be $30,000 per acre for Wetland Site B and $35,000 per acre for Wetland Site A. The following land costs were assumed:

- Site A1: $7,000 per acre
- Site A2: $87,120 per acre
- Site A3: 10 acres at $370,260 per acre, 6 acres at $196,020 per acre, and 10.7 acres at $43,560 per acre.
- Site B: $5,000 per acre

Permitting and mitigation for a constructed treatment wetland were assumed to cost 3 percent of the total construction cost. Operation and maintenance costs for constructed treatment wetlands were assumed to be $1,000 per acre per year.

Denitrification Filters/Chemical Precipitation

Site-specific opinions of probable construction cost were developed for denitrification filter and chemical precipitation facilites at the West and North WWTPs. These estimates were $1.645 million and $1.520 million, respectively. These facilities were sized to treat all wastewater at each WWTP.

Operation and maintenance costs for denitrification filters/chemical precipitation were assumed to be $0.25 per thousand gallons.

Membrane Filtration/Advanced Oxidation

Construction costs for membrane filtration and advanced oxidation facilities were estimated from Tables F-1 and F-2.

Operation and maintenance costs for membrane filtration and advanced oxidation were assumed to be $0.82 and $0.083 per thousand gallons, respectively.

Table F-1: Construction Costs for Membrane Filtration Facilities

Influent to Process (mgd)	Construction Cost
0.25	$2,313,000
0.50	$3,424,000
0.75	$4,336,000
1.00	$5,178,000
1.25	$5,225,000
1.50	$4,927,000
1.75	$5,415,000
2.00	$5,936,000
2.25	$6,390,000
2.50	$6,849,000
2.75	$7,223,000

Table F-2: Construction Costs for Advanced Oxidation Facilities

Influent to Process (mgd)	Construction Cost
0.25	$896,000
0.50	$949,000
0.75	$1,096,000
1.00	$1,157,500
1.25	$1,179,000
1.50	$1,485,500
1.75	$1,510,500
2.00	$1,563,500
2.25	$1,578,500
2.50	$1,625,000
2.75	$1,640,000

Deep Well Injection

Deep well injection costs were calculated using the following formula:[66]

$$\text{Construction Cost} = [-288{,}000 + 145{,}900*\text{Diam} + 754*\text{Depth} - 203{,}896*\ln(\text{Depth}) + 957{,}872]*\text{ENR}_{\text{June 2007}}/\text{ENR}_{\text{Sept 2001}}$$

where:

Diam = tube diameter in inches,
Depth = total depth of the well in feet,
$\text{ENR}_{\text{Sept 2001}}$ = Engineering News Record construction cost index for September 2001 (6931), and
$\text{ENR}_{\text{June 2007}}$ = ENR construction cost index for June 2007 (7939).

This formula includes the costs of logging, testing and surveying, installing the casing, installing the grouting, installing the injection tube, installing the packer, and mobilization/demobilization but does not include a monitoring well or pump facilities. Engineering, contingency, construction management, financial and legal costs are to be estimated at 35 percent of the construction cost of the concentrate disposal facilities. This formula is intended for development of preliminary opinions of probable cost; a detailed cost estimate should be developed during preliminary design.[66]

Operation and maintenance costs for an injection well were assumed to be 1 percent of the well construction cost and $0.11 per thousand gallons for chemicals.

It was assumed that it will cost $100,000 to apply for a deep-well injection permit, perform engineering studies, conduct site testing, and develop other data required for a successful permit application. Costs for this permit are highly variable. It has been assumed that the permit application will face only limited opposition.

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[66] Modified from Mickley, M.C., Membrane Concentrate Disposal: Practices and Regulation, Report No. 69, U.S. Department of Interior, Bureau of Reclamation, September 2001.

No monitoring wells or pretreatment have been considered for the deep-well injection of the concentrated brine resulting from membrane filtration. The TCEQ may require these facilities as a condition of an underground injection control permit.

Discharge Structures

Construction costs for discharge structures were estimated from Table F-3.

Table F-3: Construction Costs for Advanced Oxidation Facilities

Influent to Process (mgd)	Construction Cost
0.50	$30,000
1.00	$31,000
2.00	$34,000
5.00	$40,000
10.00	$50,000
60.00	$130,000
80.00	$150,000
120.00	$220,000

Other Permitting

It was assumed that it will cost $100,000 to apply for amended water right and TPDES discharge permits, perform engineering studies, and develop other data required for successful permit applications. Costs for these permit are highly variable. It has been assumed that the permit applications will face only limited opposition.

Right-of-Way Costs

Costs for pipeline rights-of-way were assumed to be $10,000 within the Athens city limits and $5,000 per acre outside the Athens city limits.

Power Costs

Power costs for this project were estimated using a rate of $0.105 per kilowatt-hour.

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MEMORANDUM

TO: File, NTD07286

FROM: Simone Kiel, Rachel Ickert

SUBJECT: Cost Estimating for SB1 Projects

DATE: September 4, 2008

Introduction

1. The evaluation of water management strategies requires developing cost estimates. Guidance for cost estimates may be found in the TWDB's "General Guidelines for Regional Water Plan Development (2007-2012)", Section 4.1.2. Costs are to be reported in second quarter 2007 dollars.

2. All cost estimates should be checked by construction services and discipline leaders in the appropriate areas, including Environmental Science.

3. We have developed standard unit costs for installed pipe, pump stations and standard treatment facilities developed from experience with similar projects throughout the State of Texas. These estimates are to be used for all SB1 projects, unless more detailed costing is available. All unit costs include the contractors' mobilization, overhead and profit. The unit costs **do not** include engineering, contingency, financial and legal services, costs for land and rights-of-way, permits, environmental and archeological studies, or mitigation.

4. The information presented in this memorandum is intended to be 'rule-of-thumb' guidance. Specific situations may call for alteration of the procedures and costs. Note that the costs in this memorandum provide a planning level estimate for comparison purposes.

5. It is important that when comparing alternatives that the cost estimates be similar and include similar items. If an existing reliable cost estimate is available for a project it should be used where appropriate. All cost estimates must meet the requirements set forth in the TWDB's "General Guidelines for Regional Water Plan Development (2007-2012)".

6. The cost estimates have two components:

   - Initial capital costs, including engineering and construction costs, and

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- Average annual costs, including annual operation and maintenance costs and debt service.

TWDB does not require the consultant to determine life cycle or present value analysis. In general, unless you are putting together a complex scenario with phased implementation or are planning on using State funding, annual costs are sufficient for comparison purposes and a life-cycle analysis is not required.

ASSUMPTIONS FOR CAPITAL COSTS:

Conveyance Systems

Standard pipeline costs used for these cost estimates are shown in Table 1. Pump station costs are based on required Horsepower capacity and are listed in Table 2. The power capacity is to be determined from the hydraulic analyses conducted from a planning level hydraulic grade line evaluation (or detailed analysis if available). Pipelines and pump stations are to be sized for peak pumping capacity.

- Pump efficiency is assumed to be 75 percent.
- Peaking factor of 2 times the average demand for strategies when the water is pumped directly to a water treatment plant. (or historical peaking factor, if available)
- Peaking factor of 1.2 to 1.5 is to be used if there are additional water sources and/or the water is transported to a terminal storage facility.
- Ground storage is to be provided at each booster pump station along the transmission line.
- Ground storage tanks should provide sufficient storage for 2.5 to 4 hours of pumping at peak capacity. Costs for ground storage are shown in Table 3. Covered storage tanks are used for all strategies transporting treated water.
- Costs for elevated storage tanks are shown in Table 3A.

Water Treatment Plants

Water treatment plants are to be sized for peak day capacity (assume peaking factor of 2 if no specific data is available). Costs estimated for new conventional surface water treatment facilities and expansions of existing facilities are listed in Table 4. Conventional treatment does not include advanced technologies, such as ozone or UV treatment. **All treatment plants are to be sized for finished water capacity**.

- For reverse osmosis plants for surface water, increase construction costs shown on Table 4 by the amount shown on Table 5 for the appropriate size plant that will be used for RO. If groundwater is the raw water source, use only the costs in Table 5. These costs were based on actual cost estimates of similar facilities.
- The amount of reject water generated by reverse osmosis treatment is dependent

upon the incoming quality of the raw water. Final treatment goals should be between 600 and 800 mg/l of TDS. (This provides a safety margin in meeting secondary treatment standards.) For reverse osmosis treatment of brackish water (1,000 – 3,000 mg/l of TDS), assume that 20 percent of the raw water treated with membranes is discharged as reject water, unless project-specific data is available. For brackish water with TDS concentrations between 3,000 and 10,000 mg/l, assume 30% reject water. Desalination of seawater or very high TDS water will have a higher percent of reject water (50 to 60%). Minimal losses are assumed for conventional treatment facilities.

- Costs for ion exchange facilities are shown on Table 6. For these facilities it is assumed that 2 to 3 percent of the raw water would be discharged as reject water.

New Groundwater Wells

The per-linear-foot costs for new water wells shown in Table 7 are based on a price per square foot of casing material. The costs for public water supply and industrial wells were developed using $130 to $150 per square foot of casing material. It is assumed that the cost of irrigation wells is approximately 60% of the cost for municipal and industrial wells. Well depth will be estimated by county and aquifer.

For expansion of existing well fields for municipal water providers, an additional $150,000 per well for connection to the existing distribution system is assumed. Connection costs and conveyance systems for new well fields will be determined on a case-by-case basis.

New Reservoirs

Site-specific cost estimates will be made for reservoir sites. The elements required for reservoir sites are included in Table 8. Lake intake structures for new reservoirs will be determined on a case-by-case basis. Generally, costs for construction of such facilities prior to filling of the reservoir will be less than shown on Table 2.

Other Costs

- Engineering, contingency, construction management, financial and legal costs are to be estimated at 30 percent of construction cost for pipelines and 35 percent of construction costs for pump stations, treatment facilities and reservoir projects. (Exhibit B)
- Permitting and mitigation for transmission and treatment projects are to be estimated at 1 percent of the total construction costs. For reservoirs, mitigation and permitting costs are assumed equal to twice the land purchase cost, unless site specific data is available.

- Right-of-way costs for transmission lines are estimated per acre of ROW using the unit costs in Table 9. If a small pipeline follows existing right-of-ways (such as highways), no additional right-of-way cost is assumed. Large pipelines will require ROW costs regardless of routing.
- The costs for property acquisition for reservoirs are to be based on previous cost estimates, if available. A minimum of $3,500 per acre is assumed if no site specific data is available.

Interest during construction is the total of interest accrued at the end of the construction period using a 6 percent annual interest rate on total borrowed funds, less a 4 percent rate of return on investment of unspent funds. This is 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. These factors were used in cost estimating and are presented in Table 10.

ASSUMPTIONS FOR ANNUAL COSTS:

Annual costs are to be estimated using the following assumptions:

- Debt service for all transmission and treatment facilities is to be annualized over 30 years, but not longer than the life of the project. Debt service for reservoirs is to be annualized over 30 years. [Note: uniform amortization periods should be used when evaluating similar projects for an entity.]
- Annual interest rate for debt service is 6 percent.
- Water purchase costs are to be based on wholesale rates reported by the selling entity when possible. In lieu of known rates, a typical regional cost for treated water and raw water will be developed.
- Operation and Maintenance costs are to be calculated based on the construction cost of the capital improvement. Engineering, permitting, etc. should not be included as a basis for this calculation. However, a 20% allowance for construction contingencies should be included for all O&M calculations. Per the "General Guidelines for Regional Water Plan Development (2007-2012)", O&M should be calculated at:
    - 1 percent of the construction costs for pipelines
    - 1.5 percent for dams
    - 2.5 percent of the construction costs for pump stations, storage tanks, meters and SCADA systems

  - Assume O&M costs for treatment facilities are included in the treatment cost

- Surface water treatment costs are estimated at $0.65 per 1,000 gallons for conventional plants and $1.15 per 1,000 gallons of finished water for surface water plants with reverse osmosis. Assume cost for treatment of groundwater by reverse osmosis is $0.60 per 1,000 gallons. If only a portion of the water will be treated with RO, apply costs proportionately. Treatment for nitrates is estimated at $0.35 per 1,000 gallons. Treatment for groundwater (assuming chlorination only) is estimated at $0.25 per 1,000 gallons. These costs include chemicals, labor and electricity and should be applied to amount of finished water receiving the treatment.

- Reject water disposal for treatment of brackish water is to be estimated on a case-by-case basis depending on disposal method. If no method is defined, assume a cost of $0.30 per 1,000 gallons of reject water. [This value represents a moderate cost estimate. If the water were returned to a brackish surface water source, the costs would be negligible. If evaporation beds or deep well injection were used, the costs could be much higher.]

- Pumping costs are to be estimated using an electricity rate of $0.09 per Kilowatt Hour. If local data is available, this can be used.

Table 1

Pipeline Costs (does not include ROW)

Diameter	**Base Installed Cost**	**Rural Cost with Appurtenances**	**Urban Cost with Appurtenances**	**Assumed ROW Width**	**Assumed Temporary Easement Width**
(Inches)	($/Foot)	($/Foot)	($/Foot)	(Feet)	(Feet)
6	22	24	36	15	50
8	29	32	48	15	50
10	36	40	60	20	60
12	44	48	72	20	60
14	51	56	84	20	60
16	58	64	96	20	60
18	65	72	108	20	60
20	76	84	126	20	60
24	98	108	162	20	60
30	123	135	200	20	60
36	155	171	257	20	60
42	182	200	300	30	70
48	227	250	348	30	70
54	268	295	405	30	70
60	309	340	460	30	70
66	373	410	550	30	70
72	436	480	648	30	70
78	500	550	743	40	80
84	573	630	850	40	80
90	655	720	972	40	80
96	727	800	1,080	40	80
102	809	890	1,200	40	80
108	909	1,000	1,350	40	80
114	1,000	1,100	1,485	50	100
120	1,127	1,240	1,675	50	100
132	1,364	1,500	2,025	50	100
144	1,609	1,770	2,390	50	100

Notes:
- a Costs are based on PVC class 150 pipe for the smaller long, rural pipelines.
- b Appurtenances assumed to be 10% of installed pipe costs.
- c For urban pipelines, costs were increased by 35% for cost with appurtenances. For pipes 42"and smaller, additional costs were added.
- d Adjust costs for obstacles (rock, forested areas) and easy conditions (soft soil in flat country).

Table 2
Pump Station Costs for Transmission Systems

Horsepower	Booster PS Costs	Lake PS with Intake Costs
5	$480,000	
10	$500,000	
20	$525,000	
25	$550,000	
50	$600,000	
100	$690,000	
200	$1,040,000	$1,380,000
300	$1,340,000	$1,780,000
400	$1,670,000	$2,220,000
500	$1,890,000	$2,510,000
600	$2,000,000	$2,660,000
700	$2,110,000	$2,810,000
800	$2,340,000	$3,110,000
900	$2,450,000	$3,260,000
1,000	$2,670,000	$3,551,000
2,000	$3,890,000	$5,174,000
3,000	$4,670,000	$6,211,000
4,000	$5,670,000	$7,541,000
5,000	$6,500,000	$8,645,000
6,000	$7,500,000	$9,975,000
7,000	$8,300,000	$11,039,000
8,000	$9,200,000	$12,236,000
9,000	$10,200,000	$13,566,000
10,000	$11,400,000	$15,162,000
20,000	$19,000,000	$25,270,000
30,000	$25,000,000	$33,250,000
40,000	$31,000,000	$41,230,000
50,000	$36,000,000	$47,880,000
60,000	$41,000,000	$54,530,000
70,000	$46,000,000	$61,180,000

Note:
1. Lake PS with intake costs include intake and pump station.
2. Adjust pump station costs upward if the pump station is designed to move large quantities of water at a low head (i.e. low horsepower). See Rusty Gibson for appropriate factor.
3. Assumed multiple pump setup for all pump stations.

Table 3
Ground Storage Tanks

Size (MG)	With Roof	Without Roof
0.05	$116,000	$99,000
0.1	$170,000	$145,000
0.5	$407,000	$310,000
1.0	$590,000	$436,000
1.5	$740,000	$550,000
2.0	$890,000	$664,000
2.5	$1,010,000	$764,000
3.0	$1,130,000	$863,000
3.5	$1,260,000	$952,000
4.0	$1,400,000	$1,040,000
5.0	$1,600,000	$1,212,000
6.0	$1,930,000	$1,400,000
7.0	$2,275,000	$1,619,000
8.0	$2,625,000	$1,925,000
10.0	$3,485,000	$2,560,000
14.0	$5,205,000	$3,800,000

Note: Costs assume steel tanks smaller than 1 MG, concrete tanks 1 MG and larger.

Table 3A
Elevated Storage Tanks

Size (MG)	Cost
0.5	$1,240,000
0.75	$1,430,000
1.0	$1,620,000
1.5	$2,140,000
2.0	$2,670,000
2.5	$3,140,000

Table 4
Conventional Water Treatment Plant Costs

Plant Capacity (MGD)	New Conventional Plants	Conventional Plant Expansions
1	$5,400,000	$2,700,000
3	$9,900,000	$6,900,000
7	$16,300,000	$12,000,000
10	$20,800,000	$14,900,000
15	$27,100,000	$19,400,000
20	$32,900,000	$24,300,000
30	$44,300,000	$33,200,000
40	$55,800,000	$42,300,000
50	$67,500,000	$50,600,000
60	$79,000,000	$59,100,000
70	$89,900,000	$67,200,000
80	$100,400,000	$75,700,000
90	$110,200,000	$84,200,000
100	$121,100,000	$93,200,000

Note: Plant is sized for finished peak day capacity.

Table 5
Additional Cost for Reverse Osmosis Treatment

Plant Capacity (MGD)	Reverse Osmosis Facilities Cost
0.5	$1,200,000
1	$1,500,000
3	$3,000,000
7	$6,700,000
10	$9,100,000
15	$13,200,000
20	$17,000,000
30	$23,700,000
40	$29,200,000
50	$34,000,000
60	$37,900,000

Note: Plant is sized for finished water capacity.

Table 6
Groundwater Nitrate Treatment

Treatment Capacity (MGD)	Ion Exchange Plant Cost
0.25	$700,000
1.0	$1,600,000
3.0	$3,600,000

Note: Plant is sized for finished water capacity.

Table 7
Cost Elements for Water Wells

Well Diameter (inches)	Typical Production Range (gpm)	Estimated Cost per LF a=1 for PWS/Industrial or 0.6 for Irrigation
6	50-100	$210a
8	100-250	$280a
10	250-400	$370a
12	400-500	$470a
15	500-600	$560a

Table 8
Cost Elements for Reservoir Sites

Capital Costs	Studies and Permitting
Embankment	Environmental and archeological studies
Spillway	Permitting
Outlet works	Terrestrial mitigation tracts
Site work	Engineering and contingencies
Land	Construction management
Administrative facilities	
Supplemental pumping facilities	
Flood protection	

Table 9
Pipeline Easement Costs

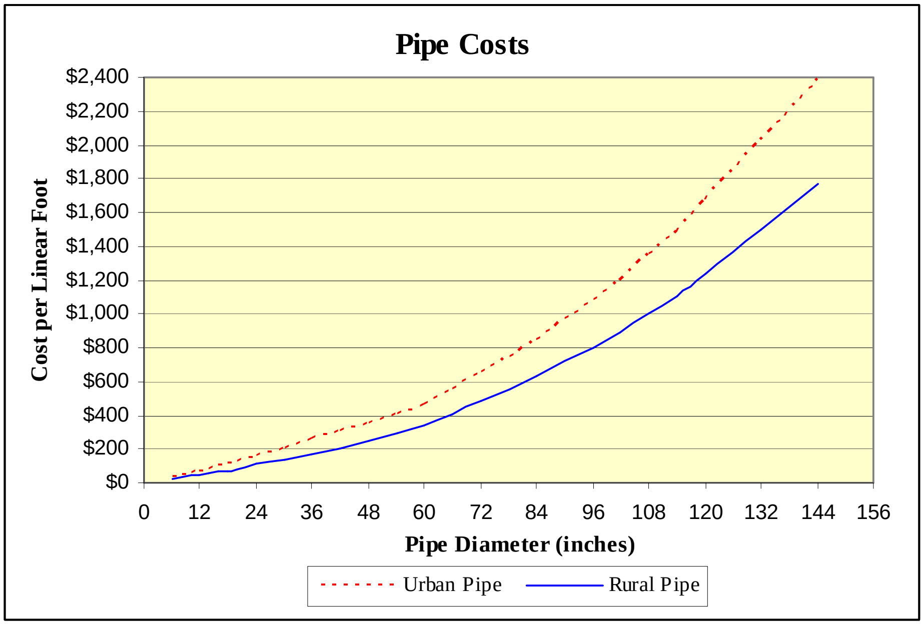
Description of Land	Cost per Acre
Rural County	$ 10,000
Suburban County	$ 25,000
Urban County	$ 60,000
Highly Urbanized Area	Evaluate on a case-by-case basis

Note: Suburban County is defined as a county immediately bordering the Dallas/Fort Worth Metroplex.

Table 10
Factors for Interest During Construction

Construction Period	Factor
6 months	0.02167
12 months	0.04167
18 months	0.06167
24 months	0.08167
36 month construction	0.12167

Figure 1



Appendix G: Detailed Opinions of Probable Cost by Polishing Treatment Scenario

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	1
Lake Athens Limiting Factor:	200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice:	Denitrification Filters/Chemical Precipitation

					Total Project	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Annual Supply (ac-ft/yr)					1,277	764	513			
CONSTRUCTION COSTS										
RECLAIMED WATER TREATMENT FACILITIES										
Denitrification Filters/Chemical Precip.		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP Facilities		1.37	mgd		$ 1,645,000		$ 1,645,000			
North WWTP Facilities		1.03	mgd		$ 1,520,000	$ 1,520,000				
Land		0	acres	$ 10,000	$ -					
Engineering and Contingencies		35%			$ 1,108,000	$ 532,000	$ 576,000	$ -	$ -	
Subtotal of DF/CP					**$ 4,273,000**	**$ 2,052,000**	**$ 2,221,000**	**$ -**	**$ -**	
TRANSMISSION FACILITIES										
Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
8" Water Line	C-1									
Pipeline		19,395	ft	$ 48	$ 931,000		$ 931,000			
ROW		6.7	ac	$ 10,000	$ 67,000		$ 67,000			
12" Water Line	C-2-a									
Pipeline		17,000	ft	$ 72	$ 1,224,000	$ 1,224,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
12" Water Line	C-2-b									
Pipeline		19,383	ft	$ 48	$ 930,000	$ 930,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		1.14	mgd		$ 31,000	$ 31,000				
Engineering and Contingencies		30%			$ 656,000	$ 656,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 3,961,000**	**$ 2,963,000**	**$ 998,000**	**$ -**	**$ -**	
Pump Station(s)		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP										
Pump, Building, & Appurtenances		16	hp		$ 515,000		$ 515,000			
North WWTP										
Pump, Building, & Appurtenances		60	hp		$ 618,000	$ 618,000				
Storage Tank		190,000	gal		$ 223,000	$ 223,000				
Engineering and Contingencies		35%			$ 475,000	$ 294,000	$ 180,000	$ -	$ -	
Subtotal of Pump Station(s)					**$ 1,831,000**	**$ 1,135,000**	**$ 695,000**	**$ -**	**$ -**	
PERMITTING AND MITIGATION										
Pipelines and Pump Stations		1%			$ 69,000	$ 43,000	$ 26,000	$ -	$ -	
Water Rights and TPDES Discharge					$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation					**$ 169,000**	**$ 143,000**	**$ 26,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL					**$ 10,234,000**	**$ 6,293,000**	**$ 3,940,000**	**$ -**	**$ -**	
Interest During Construction			(18 months)		**$ 631,000**	**$ 388,000**	**$ 243,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST					**$ 10,865,000**	**$ 6,681,000**	**$ 4,183,000**	**$ -**	**$ -**	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	1
Lake Athens Limiting Factor:	200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice:	Denitrification Filters/Chemical Precipitation

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 789,000	$ 485,000	$ 304,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
West WWTP DF/CP	498,955	1,000 gal	$ 0.25	$ 125,000	$ -	$ 125,000			
North WWTP DF/CP	374,855	1,000 gal	$ 0.25	$ 94,000	$ 94,000	$ 94,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 26,000	$ 26,000	$ -	$ -	$ -	
Pump Station	2.50%			$ 41,000	$ 25,000	$ 15,000	$ -	$ -	
Power	67	hp	$ 0.105	$ 46,000	$ 36,000	$ 5,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 1,121,000**	**$ 666,000**	**$ 543,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 332,000**	**$ 181,000**	**$ 239,000**	**$ -**	**$ -**	

UNIT COSTS	
Cost per Acre-Foot	**Full Project**
First 30 Years	$878
After 30 Years	$260
50-Year Weighting (Includes Phasing)	$725
Cost per 1,000 Gallons	
First 30 Years	$2.69
After 30 Years	$0.80
50-Year Weighting (Includes Phasing)	$2.22

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 2
Lake Athens Limiting Factor: 200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice: Wetlands A

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,221	656	108	457		

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Wetlands A	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	51.6	acres	$ 35,000	$ 1,806,000	$ 970,000	$ 836,000			
Land	51.6	acres	$ 44,100	$ 2,276,000	$ 194,000	$ 2,082,000			
Engineering and Contingencies	35%			$ 632,000	$ 340,000	$ 293,000	$ -	$ -	
Subtotal of Wetlands A				**$ 4,714,000**	**$ 1,504,000**	**$ 3,211,000**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
8" Water Line	A-1									
Pipeline		19,395	ea	$ 48	$ 931,000			$ 931,000		
ROW		6.7	ac	$ 10,000	$ 67,000			$ 67,000		
12" Water Line	A-2									
Pipeline		9,963	ft	$ 72	$ 717,000	$ 717,000				
ROW		4.6	ac	$ 10,000	$ 46,000	$ 46,000				
10" Water Line	A-2-a									
Pipeline		1,400	ft	$ 60	$ 84,000	$ 84,000				
ROW		0.6	ac	$ 10,000	$ 6,000	$ 6,000				
10" Water Line	A-2-b									
Pipeline		5,109	ea	$ 60	$ 307,000		$ 307,000			
ROW		2.3	ac	$ 10,000	$ 23,000		$ 23,000			
10" Water Line	A-2-b-2									
Pipeline		835	ft	$ 60	$ 50,000		$ 50,000			
ROW		0.4	ac	$ 10,000	$ 4,000		$ 4,000			
10" Water Line	A-3-a									
Pipeline		5,541	ea	$ 60	$ 332,000	$ 332,000				
ROW		2.5	ac	$ 10,000	$ 25,000	$ 25,000				
10" Water Line	A-3-b									
Pipeline		2,012	ft	$ 60	$ 121,000		$ 121,000			
ROW		0.9	ac	$ 10,000	$ 9,000		$ 9,000			
12" Water Line	A-3-d									
Pipeline		719	ft	$ 72	$ 52,000	$ 52,000				
ROW		0.3	ac	$ 10,000	$ 3,000	$ 3,000				
12" Water Line	A-3									
Pipeline		23,266	ft	$ 48	$ 1,117,000	$ 1,117,000				
ROW		10.7	ac	$ 5,000	$ 53,000	$ 53,000				
Discharge Structure		1.09	mgd		$ 31,000	$ 31,000				
Engineering and Contingencies		30%			$ 1,123,000	$ 700,000	$ 143,000	$ 279,000	$ -	
Subtotal of Pipeline(s)					**$ 5,101,000**	**$ 3,166,000**	**$ 657,000**	**$ 1,277,000**	**$ -**	

Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	2
Lake Athens Limiting Factor:	200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice:	Wetlands A

	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Pump, Building, & Appurtenances	16	hp		$ 515,000			$ 515,000		
North WWTP									
Pump, Building, & Appurtenances	38	hp		$ 576,000	$ 576,000				
Storage Tank	190,000	gal		$ 223,000	$ 223,000				
Wetlands A-North									
Pump, Building, & Appurtenances	21	hp		$ 530,000	$ 530,000				
Wetlands A-Central									
Pump, Building, & Appurtenances	15	hp		$ 513,000		$ 513,000			
Engineering and Contingencies	35%			$ 825,000	$ 465,000	$ 180,000	$ 180,000	$ -	
Subtotal of Pump Station(s)				**$ 3,182,000**	**$ 1,794,000**	**$ 693,000**	**$ 695,000**	**$ -**	
PERMITTING AND MITIGATION									
Pipelines and Pump Stations	1%			$ 73,000	$ 44,000	$ 12,000	$ 17,000	$ -	
Wetlands	3%			$ 65,000	$ 35,000	$ 30,000	$ -	$ -	
Water Rights and TPDES Discharge				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation				**$ 238,000**	**$ 179,000**	**$ 42,000**	**$ 17,000**	**$ -**	
CONSTRUCTION TOTAL				**$ 13,235,000**	**$ 6,643,000**	**$ 4,603,000**	**$ 1,989,000**	**$ -**	
Interest During Construction	(24 months)			**$ 1,081,000**	**$ 543,000**	**$ 376,000**	**$ 162,000**	**$ -**	
TOTAL CAPITAL COST				**$ 14,316,000**	**$ 7,186,000**	**$ 4,979,000**	**$ 2,151,000**	**$ -**	

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,040,000	$ 522,000	$ 362,000	$ 156,000	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
Wetlands A	51.6	acres	$ 1,000	$ 52,000	$ 28,000	$ 24,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 45,000	$ 28,000	$ 6,000	$ 11,000	$ -	
Pump Station	2.50%			$ 71,000	$ 40,000	$ 15,000	$ 15,000	$ -	
Power	80	hp	$ 0.105	$ 55,000	$ 36,000	$ 9,000	$ 10,000		
TOTAL ANNUAL COST (First 30 Years)				**$ 1,263,000**	**$ 654,000**	**$ 416,000**	**$ 192,000**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 223,000**	**$ 132,000**	**$ 54,000**	**$ 36,000**	**$ -**	

UNIT COSTS	
Cost per Acre-Foot	**Full Project**
First 30 Years	$1,034
After 30 Years	$183
50-Year Weighting (Includes Phasing)	$756
Cost per 1,000 Gallons	
First 30 Years	$3.17
After 30 Years	$0.56
50-Year Weighting (Includes Phasing)	$2.32

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	3
Lake Athens Limiting Factor:	200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice:	Wetlands B

					Total Project	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Annual Supply (ac-ft/yr)					1,277	764	513			
CONSTRUCTION COSTS										
RECLAIMED WATER TREATMENT FACILITIES										
Wetlands B		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities		54.0	acres	$ 30,000	$ 1,620,000	$ 969,000	$ 651,000			
Land		54.0	acres	$ 5,000	$ 270,000	$ 162,000	$ 108,000			
Engineering and Contingencies		35%			$ 567,000	$ 339,000	$ 228,000	$ -	$ -	
Subtotal of Wetlands B					**$ 2,457,000**	**$ 1,470,000**	**$ 987,000**	**$ -**	**$ -**	
TRANSMISSION FACILITIES										
Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
8" Water Line	B-1									
Pipeline		19,395	ea	$ 48	$ 931,000		$ 931,000			
ROW		6.7	ac	$ 10,000	$ 67,000		$ 67,000			
12" Water Line	B-2-a									
Pipeline		17,000	ea	$ 72	$ 1,224,000	$ 1,224,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
12" Water Line	B-2-b									
Pipeline		32,643	ft	$ 48	$ 1,567,000	$ 1,567,000				
ROW		15.0	ac	$ 5,000	$ 75,000	$ 75,000				
12" Water Line	B-3									
Pipeline		14,128	ea	$ 48	$ 678,000	$ 678,000				
ROW		6.5	ac	$ 5,000	$ 32,000	$ 32,000				
Discharge Structure		1.14	mgd		$ 31,000	$ 31,000				
Engineering and Contingencies		30%			$ 962,000	$ 683,000	$ 279,000	$ -	$ -	
Subtotal of Pipeline(s)					**$ 5,645,000**	**$ 4,368,000**	**$ 1,277,000**	**$ -**	**$ -**	
Pump Station(s)		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP										
Pump, Building, & Appurtenances		16	hp		$ 515,000		$ 515,000			
North WWTP										
Pump, Building, & Appurtenances		72	hp		$ 640,000	$ 640,000				
Storage Tank		200,000	gal		$ 229,000	$ 229,000				
Wetlands B										
Pump, Building, & Appurtenances		31	hp		$ 562,000	$ 562,000				
Engineering and Contingencies		35%			$ 681,000	$ 501,000	$ 180,000	$ -	$ -	
Subtotal of Pump Station(s)					**$ 2,627,000**	**$ 1,932,000**	**$ 695,000**	**$ -**	**$ -**	
PERMITTING AND MITIGATION										
Pipelines and Pump Stations		1%			$ 61,000	$ 44,000	$ 17,000	$ -	$ -	
Wetlands		3%			$ 58,000	$ 35,000	$ 23,000	$ -	$ -	
Water Rights and TPDES Discharge					$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation					**$ 219,000**	**$ 179,000**	**$ 40,000**	**$ -**	**$ -**	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 3
Lake Athens Limiting Factor: 200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice: Wetlands B

					Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
CONSTRUCTION TOTAL					**$ 10,948,000**	**$ 7,949,000**	**$ 2,999,000**	**$ -**	**$ -**	
Interest During Construction		(24 months)			**$ 894,000**	**$ 649,000**	**$ 245,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST					**$ 11,842,000**	**$ 8,598,000**	**$ 3,244,000**	**$ -**	**$ -**	
ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**		**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service					$ 860,000	$ 625,000	$ 236,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs										
Wetlands B	54	acres	$ 1,000		$ 54,000	$ 32,000	$ 22,000			
Transmission Facilities O&M Costs										
Pipeline	1%				$ 38,000	$ 27,000	$ 11,000	$ -	$ -	
Pump Station	2.50%				$ 58,000	$ 43,000	$ 15,000	$ -	$ -	
Power	103	hp	$ 0.105		$ 71,000	$ 61,000	$ 10,000			
TOTAL ANNUAL COST (First 30 Years)					**$ 1,081,000**	**$ 788,000**	**$ 294,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)					**$ 221,000**	**$ 163,000**	**$ 58,000**	**$ -**	**$ -**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$847
After 30 Years	$173
50-Year Weighting (Includes Phasing)	$627
Cost per 1,000 Gallons	
First 30 Years	$2.60
After 30 Years	$0.53
50-Year Weighting (Includes Phasing)	$1.92

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 4
Lake Athens Limiting Factor: 200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice: Sidestream Membranes

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,277	764	513			

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Membranes	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Facilities	1.00	mgd		$ 5,179,000	$ 5,179,000				
Land	0	acres	$ 10,000	$ -					
Engineering and Contingencies	35%			$ 1,813,000	$ 1,813,000	$ -	$ -	$ -	
Subtotal of Membranes				**$ 6,992,000**	**$ 6,992,000**	**$ -**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
8" Water Line	C-1									
Pipeline		19,395	ft	$ 48	$ 931,000		$ 931,000			
ROW		6.7	ac	$ 10,000	$ 67,000		$ 67,000			
12" Water Line	C-2-a									
Pipeline		17,000	ft	$ 72	$ 1,224,000	$ 1,224,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
12" Water Line	C-2-b									
Pipeline		19,383	ft	$ 48	$ 930,000	$ 930,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		1.14	mgd		$ 31,000	$ 31,000				
Engineering and Contingencies		30%			$ 656,000	$ 656,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 3,961,000**	**$ 2,963,000**	**$ 998,000**	**$ -**	**$ -**	

Pump Station(s)	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
West WWTP									
Pump, Building, & Appurtenances	16	hp		$ 515,000		$ 515,000			
North WWTP									
Pump, Building, & Appurtenances	60	hp		$ 618,000	$ 618,000				
Storage Tank	190,000	gal		$ 223,000	$ 223,000				
Engineering and Contingencies	35%			$ 475,000	$ 294,000	$ 180,000	$ -	$ -	
Subtotal of Pump Station(s)				**$ 1,831,000**	**$ 1,135,000**	**$ 695,000**	**$ -**	**$ -**	

BRINE DISPOSAL FACILITIES

Injection Well(s)	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
3" Tube Diameter	4,150	ft		$ 3,153,000	$ 3,153,000				
Pumping	53	hp		$ 605,000	$ 605,000				
Engineering and Contingencies	35%			$ 1,315,000	$ 1,315,000	$ -	$ -	$ -	
Subtotal of Injection Well(s)				**$ 5,073,000**	**$ 5,073,000**	**$ -**	**$ -**	**$ -**	

PERMITTING AND MITIGATION

	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Pipelines and Pump Stations	1%			$ 131,000	$ 125,000	$ 6,000	$ -	$ -	
Water Rights and TPDES Discharge				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 4
Lake Athens Limiting Factor: 200 mg/l TDS (Limiting Condition 5)
Polishing Treatment Choice: Sidestream Membranes

Subtotal of Permitting and Mitigation					**$**	**331,000**	**$**	**325,000**	**$**	**6,000**	**$**	**-**	**$**	**-**	
CONSTRUCTION TOTAL					**$**	**18,188,000**	**$**	**16,488,000**	**$**	**1,699,000**	**$**	**-**	**$**	**-**	
Interest During Construction		(18 months)			**$**	**1,122,000**	**$**	**1,017,000**	**$**	**105,000**	**$**	**-**	**$**	**-**	
TOTAL CAPITAL COST					**$**	**19,310,000**	**$**	**17,505,000**	**$**	**1,804,000**	**$**	**-**	**$**	**-**	
ANNUAL COSTS	**Qty.**	**Units**		**Unit Cost**		**Total Cost**		**Phase 1**		**Phase 2**		**Phase 3**		**Phase 4**	**Comment**
Debt Service					$	1,403,000	$	1,272,000	$	131,000	$	-	$	-	assume 6% over 30 years
Treatment Facilities O&M Costs															
Membranes	366,629	1000 gal	$	0.82	$	301,000	$	180,000	$	121,000					
Transmission Facilities O&M Costs															
Pipeline	1%				$	26,000	$	26,000	$	-	$	-	$	-	
Pump Station	2.50%				$	41,000	$	25,000	$	15,000	$	-	$	-	
Power	67	hp	$	0.105	$	46,000	$	36,000	$	10,000					
Brine Disposal Facilities O&M Costs															
Well	1.00%				$	38,000	$	38,000							
Chemicals	73,326	1000 gal	$	0.11	$	8,000	$	8,000							
Power	41	hp	$	0.09	$	24,000	$	24,000							
TOTAL ANNUAL COST (First 30 Years)					**$**	**1,887,000**	**$**	**1,609,000**	**$**	**277,000**	**$**	**-**	**$**	**-**	
TOTAL ANNUAL COST (After 30 Years)					**$**	**484,000**	**$**	**337,000**	**$**	**146,000**	**$**	**-**	**$**	**-**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$1,478
After 30 Years	$379
50-Year Weighting (Includes Phasing)	$1,118

Cost per 1,000 Gallons	
First 30 Years	$4.53
After 30 Years	$1.16
50-Year Weighting (Includes Phasing)	$3.43

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 5
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Denitrification Filters/Chemical Precipitation

					Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)					1,938	764	1,174			
CONSTRUCTION COSTS										
RECLAIMED WATER TREATMENT FACILITIES										
Denitrification Filters/Chemical Precip.		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP Facilities		1.37	mgd		$ 1,645,000		$ 1,645,000			
North WWTP Facilities		1.03	mgd		$ 1,520,000	$ 1,520,000				
Land		0	acres	$ 10,000	$ -					
Engineering and Contingencies		35%			$ 1,108,000	$ 532,000	$ 576,000	$ -	$ -	
Subtotal of DF/CP					**$ 4,273,000**	**$ 2,052,000**	**$ 2,221,000**	**$ -**	**$ -**	
TRANSMISSION FACILITIES										
Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	C-1									
Pipeline		19,395	ft	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	C-2-a									
Pipeline		17,000	ft	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	C-2-b									
Pipeline		19,383	ft	$ 56	$ 1,085,000	$ 1,085,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies		30%			$ 764,000	$ 764,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 4,685,000**	**$ 3,432,000**	**$ 1,253,000**	**$ -**	**$ -**	
Pump Station(s)		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP										
Pump, Building, & Appurtenances		37	hp		$ 574,000		$ 574,000			
North WWTP										
Pump, Building, & Appurtenances		91	hp		$ 674,000	$ 674,000				
Storage Tank		290,000	gal		$ 283,000	$ 283,000				
Engineering and Contingencies		35%			$ 536,000	$ 335,000	$ 201,000	$ -	$ -	
Subtotal of Pump Station(s)					**$ 2,067,000**	**$ 1,292,000**	**$ 775,000**	**$ -**	**$ -**	
PERMITTING AND MITIGATION										
Pipelines and Pump Stations		1%			$ 73,000	$ 47,000	$ 27,000	$ -	$ -	
Water Rights and TPDES Discharge					$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation					**$ 173,000**	**$ 147,000**	**$ 27,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL					**$ 11,198,000**	**$ 6,923,000**	**$ 4,276,000**	**$ -**	**$ -**	
Interest During Construction			(18 months)		**$ 691,000**	**$ 427,000**	**$ 264,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST					**$ 11,889,000**	**$ 7,350,000**	**$ 4,540,000**	**$ -**	**$ -**	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 5
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Denitrification Filters/Chemical Precipitation

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 864,000	$ 534,000	$ 330,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
West WWTP DF/CP	498,955	1,000 gal	$ 0.25	$ 125,000	$ -	$ 125,000			
North WWTP DF/CP	374,855	1,000 gal	$ 0.25	$ 94,000	$ 94,000	$ 94,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 30,000	$ 30,000	$ -	$ -	$ -	
Pump Station	2.50%			$ 46,000	$ 29,000	$ 17,000	$ -	$ -	
Power	113	hp	$ 0.105	$ 78,000	$ 55,000	$ 23,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 1,237,000**	**$ 742,000**	**$ 589,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 373,000**	**$ 208,000**	**$ 259,000**	**$ -**	**$ -**	

UNIT COSTS	
Cost per Acre-Foot	**Full Project**
First 30 Years	$638
After 30 Years	$192
50-Year Weighting (Includes Phasing)	$557
Cost per 1,000 Gallons	
First 30 Years	$1.96
After 30 Years	$0.59
50-Year Weighting (Includes Phasing)	$1.711

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	6
Lake Athens Limiting Factor:	50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice:	Wetlands A

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,848	656	108	454	630	

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Wetlands A	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	78.3	acres	$ 35,000	$ 2,741,000	$ 970,000	$ 836,000	$ -	$ 935,000	
Land	78.3	acres	$ 97,300	$ 7,619,000	$ 194,000	$ 2,082,000	$ -	$ 5,343,000	
Engineering and Contingencies	35%			$ 959,000	$ 340,000	$ 293,000	$ -	$ 327,000	
Subtotal of Wetlands A				**$ 11,319,000**	**$ 1,504,000**	**$ 3,211,000**	**$ -**	**$ 6,605,000**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	A-1									
Pipeline		19,395	ea	$ 60	$ 1,164,000			$ 1,164,000		
ROW		8.9	ac	$ 10,000	$ 89,000			$ 89,000		
14" Water Line	A-2									
Pipeline		9,963	ft	$ 84	$ 837,000	$ 837,000				
ROW		4.6	ac	$ 10,000	$ 46,000	$ 46,000				
10" Water Line	A-2-a									
Pipeline		1,400	ft	$ 60	$ 84,000	$ 84,000				
ROW		0.6	ac	$ 10,000	$ 6,000	$ 6,000				
12" Water Line	A-2-b									
Pipeline		5,109	ea	$ 72	$ 368,000		$ 368,000			
ROW		2.3	ac	$ 10,000	$ 23,000		$ 23,000			
10" Water Line	A-2-b-2									
Pipeline		835	ft	$ 60	$ 50,000		$ 50,000			
ROW		0.4	ac	$ 10,000	$ 4,000		$ 4,000			
10" Water Line	A-2-c									
Pipeline		560	ft	$ 60	$ 34,000				$ 34,000	
ROW		0.3	ac	$ 10,000	$ 3,000				$ 3,000	
10" Water Line	A-3-a									
Pipeline		5,541	ea	$ 60	$ 332,000	$ 332,000				
ROW		2.5	ac	$ 10,000	$ 25,000	$ 25,000				
10" Water Line	A-3-b									
Pipeline		2,012	ft	$ 60	$ 121,000		$ 121,000			
ROW		0.9	ac	$ 10,000	$ 9,000		$ 9,000			
10" Water Line	A-3-c									
Pipeline		7,175	ft	$ 60	$ 430,000				$ 430,000	
ROW		3.3	ac	$ 10,000	$ 33,000				$ 33,000	
12" Water Line	A-3-d									
Pipeline		719	ft	$ 72	$ 52,000	$ 52,000				
ROW		0.3	ac	$ 10,000	$ 3,000	$ 3,000				
14" Water Line	A-3									
Pipeline		23,266	ft	$ 56	$ 1,303,000	$ 1,303,000				
ROW		10.7	ac	$ 5,000	$ 53,000	$ 53,000				

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 6
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands A

	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Discharge Structure	1.65	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies	30%			$ 1,442,000	$ 792,000	$ 162,000	$ 349,000	$ 139,000	
Subtotal of Pipeline(s)				**$ 6,544,000**	**$ 3,566,000**	**$ 737,000**	**$ 1,602,000**	**$ 639,000**	
Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	37	hp		$ 574,000			$ 574,000		
North WWTP									
Pump, Building, & Appurtenances	57	hp		$ 613,000	$ 613,000				
Storage Tank	290,000	gal		$ 283,000	$ 283,000				
Wetlands A-North									
Pump, Building, & Appurtenances	21	hp		$ 530,000	$ 530,000				
Wetlands A-Central									
Pump, Building, & Appurtenances	15	hp		$ 513,000		$ 513,000			
Wetlands A-South									
Pump, Building, & Appurtenances	18	hp		$ 520,000				$ 520,000	
Engineering and Contingencies	35%			$ 1,062,000	$ 499,000	$ 180,000	$ 201,000	$ 182,000	
Subtotal of Pump Station(s)				**$ 4,095,000**	**$ 1,925,000**	**$ 693,000**	**$ 775,000**	**$ 702,000**	
PERMITTING AND MITIGATION									
Pipelines and Pump Stations	1%			$ 94,000	$ 48,000	$ 13,000	$ 21,000	$ 12,000	
Wetlands	3%			$ 99,000	$ 35,000	$ 30,000	$ -	$ 34,000	
Water Rights and TPDES Discharge				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation				**$ 293,000**	**$ 183,000**	**$ 43,000**	**$ 21,000**	**$ 46,000**	
CONSTRUCTION TOTAL				**$ 22,251,000**	**$ 7,178,000**	**$ 4,684,000**	**$ 2,398,000**	**$ 7,992,000**	
Interest During Construction		(24 months)		**$ 1,817,000**	**$ 586,000**	**$ 383,000**	**$ 196,000**	**$ 653,000**	
TOTAL CAPITAL COST				**$ 24,068,000**	**$ 7,764,000**	**$ 5,067,000**	**$ 2,594,000**	**$ 8,645,000**	
ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,749,000	$ 564,000	$ 368,000	$ 188,000	$ 628,000	assume 6% over 30 years
Treatment Facilities O&M Costs									
Wetlands A	78.3	acres	$ 1,000	$ 78,000	$ 28,000	$ 24,000	$ -	$ 26,000	
Transmission Facilities O&M Costs									
Pipeline	1%			$ 57,000	$ 31,000	$ 6,000	$ 14,000	$ 6,000	
Pump Station	2.50%			$ 91,000	$ 43,000	$ 15,000	$ 17,000	$ 16,000	
Power	133	hp	$ 0.105	$ 91,000	$ 48,000	$ 9,000	$ 23,000	$ 11,000	
TOTAL ANNUAL COST (First 30 Years)				**$ 2,066,000**	**$ 714,000**	**$ 422,000**	**$ 242,000**	**$ 687,000**	
TOTAL ANNUAL COST (After 30 Years)				**$ 317,000**	**$ 150,000**	**$ 54,000**	**$ 54,000**	**$ 59,000**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$1,118

Treatment Scenario Number:	6
Lake Athens Limiting Factor:	50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice:	Wetlands A

After 30 Years	$172
50-Year Weighting (Includes Phasing)	$896
Cost per 1,000 Gallons	
First 30 Years	$3.43
After 30 Years	$0.53
50-Year Weighting (Includes Phasing)	$2.75

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 7
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands B

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,938	764	1,174			

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Wetlands B	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	82.0	acres	$ 30,000	$ 2,460,000	$ 970,000	$ 1,490,000			
Land	82.0	acres	$ 5,000	$ 410,000	$ 162,000	$ 248,000			
Engineering and Contingencies	35%			$ 861,000	$ 340,000	$ 522,000	$ -	$ -	
Subtotal of Wetlands B				**$ 3,731,000**	**$ 1,472,000**	**$ 2,260,000**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	B-1									
Pipeline		19,395	ea	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	B-2-a									
Pipeline		17,000	ea	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	B-2-b									
Pipeline		32,643	ft	$ 56	$ 1,828,000	$ 1,828,000				
ROW		15.0	ac	$ 5,000	$ 75,000	$ 75,000				
14" Water Line	B-3									
Pipeline		14,128	ea	$ 56	$ 791,000	$ 791,000				
ROW		6.5	ac	$ 5,000	$ 32,000	$ 32,000				
Discharge Structure		1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies		30%			$ 1,145,000	$ 796,000	$ 349,000	$ -	$ -	
Subtotal of Pipeline(s)					**$ 6,663,000**	**$ 5,061,000**	**$ 1,602,000**	**$ -**	**$ -**	

Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	37	hp		$ 574,000		$ 574,000			
North WWTP									
Pump, Building, & Appurtenances	110	hp		$ 725,000	$ 725,000				
Storage Tank	300,000	gal		$ 289,000	$ 289,000				
Wetlands B									
Pump, Building, & Appurtenances	47	hp		$ 594,000	$ 594,000				
Engineering and Contingencies	35%			$ 764,000	$ 563,000	$ 201,000	$ -	$ -	
Subtotal of Pump Station(s)				**$ 2,946,000**	**$ 2,171,000**	**$ 775,000**	**$ -**	**$ -**	

PERMITTING AND MITIGATION

	Qty.	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Pipelines and Pump Stations	1%	$ 72,000	$ 51,000	$ 21,000	$ -	$ -	
Wetlands	3%	$ 89,000	$ 35,000	$ 54,000	$ -	$ -	
Water Rights and TPDES Discharge		$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection		$ -	$ -	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation		**$ 261,000**	**$ 186,000**	**$ 75,000**	**$ -**	**$ -**	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 7
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands B

CONSTRUCTION TOTAL				**$**	**13,601,000**	**$ 8,890,000**	**$ 4,712,000**	**$ -**	**$ -**	
Interest During Construction	(24 months)			**$**	**1,111,000**	**$ 726,000**	**$ 385,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST				**$**	**14,712,000**	**$ 9,616,000**	**$ 5,097,000**	**$ -**	**$ -**	
ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**		**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$	1,069,000	$ 699,000	$ 370,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs										
Wetlands B	82	acres	$ 1,000	$	82,000	$ 32,000	$ 50,000			
Transmission Facilities O&M Costs										
Pipeline	1%			$	45,000	$ 31,000	$ 14,000	$ -	$ -	
Pump Station	2.50%			$	65,000	$ 48,000	$ 17,000	$ -	$ -	
Power	168	hp	$ 0.105	$	115,000	$ 93,000	$ 22,000			
TOTAL ANNUAL COST (First 30 Years)				**$**	**1,376,000**	**$ 903,000**	**$ 473,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$**	**307,000**	**$ 204,000**	**$ 103,000**	**$ -**	**$ -**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$710
After 30 Years	$158
50-Year Weighting (Includes Phasing)	$558
Cost per 1,000 Gallons	
First 30 Years	$2.18
After 30 Years	$0.49
50-Year Weighting (Includes Phasing)	$1.712

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 8
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Sidestream Membranes

					Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)					1,938	764	1,174			
CONSTRUCTION COSTS										
RECLAIMED WATER TREATMENT FACILITIES										
Membranes		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities		1.52	mgd		$ 4,974,000	$ 4,974,000				
Land		0	acres	$ 10,000	$ -					
Engineering and Contingencies		35%			$ 1,741,000	$ 1,741,000	$ -	$ -	$ -	
Subtotal of Membranes					**$ 6,715,000**	**$ 6,715,000**	**$ -**	**$ -**	**$ -**	
TRANSMISSION FACILITIES										
Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	C-1									
Pipeline		19,395	ft	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	C-2-a									
Pipeline		17,000	ft	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	C-2-b									
Pipeline		19,383	ft	$ 56	$ 1,085,000	$ 1,085,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies		30%			$ 764,000	$ 764,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 4,685,000**	**$ 3,432,000**	**$ 1,253,000**	**$ -**	**$ -**	
Pump Station(s)		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP										
Pump, Building, & Appurtenances		37	hp		$ 574,000		$ 574,000			
North WWTP										
Pump, Building, & Appurtenances		91	hp		$ 674,000	$ 674,000				
Storage Tank		290,000	gal		$ 283,000	$ 283,000				
Engineering and Contingencies		35%			$ 536,000	$ 335,000	$ 201,000	$ -	$ -	
Subtotal of Pump Station(s)					**$ 2,067,000**	**$ 1,292,000**	**$ 775,000**	**$ -**	**$ -**	
BRINE DISPOSAL FACILITIES										
Injection Well(s)		**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
3" Tube Diameter		4,150	ft		$ 3,153,000	$ 3,153,000				
Pumping		115	hp		$ 743,000	$ 743,000				
Engineering and Contingencies		35%			$ 1,364,000	$ 1,364,000	$ -	$ -	$ -	
Subtotal of Injection Well(s)					**$ 5,260,000**	**$ 5,260,000**	**$ -**	**$ -**	**$ -**	
PERMITTING AND MITIGATION										
Pipelines and Pump Stations		1%			$ 133,000	$ 126,000	$ 7,000	$ -	$ -	
Water Rights and TPDES Discharge					$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection					$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 8
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Sidestream Membranes

	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Subtotal of Permitting and Mitigation				**$ 333,000**	**$ 326,000**	**$ 7,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL				**$ 19,060,000**	**$ 17,025,000**	**$ 2,035,000**	**$ -**	**$ -**	
Interest During Construction		(18 months)		**$ 1,175,000**	**$ 1,050,000**	**$ 125,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST				**$ 20,235,000**	**$ 18,075,000**	**$ 2,160,000**	**$ -**	**$ -**	
ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,470,000	$ 1,313,000	$ 157,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
Membranes	556,376	1000 gal	$ 0.82	$ 457,000	$ 180,000	$ 277,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 30,000	$ 30,000	$ -	$ -	$ -	
Pump Station	2.50%			$ 46,000	$ 29,000	$ 17,000	$ -	$ -	
Power	113	hp	$ 0.105	$ 78,000	$ 55,000	$ 23,000			
Brine Disposal Facilities O&M Costs									
Well	1.00%			$ 38,000	$ 38,000				
Chemicals	111,275	1000 gal	$ 0.11	$ 12,000	$ 5,000	$ 7,000			
Power	87	hp	$ 0.09	$ 51,000	$ 20,000	$ 31,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 2,182,000**	**$ 1,670,000**	**$ 512,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 712,000**	**$ 357,000**	**$ 355,000**	**$ -**	**$ -**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$1,126
After 30 Years	$367
50-Year Weighting (Includes Phasing)	$911
Cost per 1,000 Gallons	
First 30 Years	$3.46
After 30 Years	$1.13
50-Year Weighting (Includes Phasing)	$2.80

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	9
Lake Athens Limiting Factor:	50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice:	Denitrification Filters/Chemical Precipitation + Sidestream Membranes

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,935	764	1,171			

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Denitrification Filters/Chemical Precip.	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP Facilities	1.37	mgd		$ 1,645,000		$ 1,645,000			
North WWTP Facilities	1.03	mgd		$ 1,520,000	$ 1,520,000				
Land	0	acres	$ 10,000	$ -					
Engineering and Contingencies	35%			$ 1,108,000	$ 532,000	$ 576,000	$ -	$ -	
Subtotal of DF/CP				**$ 4,273,000**	**$ 2,052,000**	**$ 2,221,000**	**$ -**	**$ -**	

Membranes	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	0.51	mgd		$ 3,452,000	$ 3,452,000				
Land	0	acres	$ 10,000	$ -	$ -				
Engineering and Contingencies	35%			$ 1,208,000	$ 1,208,000	$ -	$ -	$ -	
Subtotal of Membranes				**$ 4,660,000**	**$ 4,660,000**	**$ -**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	C-1									
Pipeline		19,395	ft	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	C-2-a									
Pipeline		17,000	ft	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	C-2-b									
Pipeline		19,383	ft	$ 56	$ 1,085,000	$ 1,085,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies		30%			$ 764,000	$ 764,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 4,685,000**	**$ 3,432,000**	**$ 1,253,000**	**$ -**	**$ -**	

Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	37	hp		$ 574,000		$ 574,000			
North WWTP									
Pump, Building, & Appurtenances	91	hp		$ 674,000	$ 674,000				
Storage Tank	290,000	gal		$ 283,000	$ 283,000				
Engineering and Contingencies	35%			$ 536,000	$ 335,000	$ 201,000	$ -	$ -	
Subtotal of Pump Station(s)				**$ 2,067,000**	**$ 1,292,000**	**$ 775,000**	**$ -**	**$ -**	

BRINE DISPOSAL FACILITIES

Injection Well(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
2" Tube Diameter	4,150	ft		$ 2,972,000	$ 2,972,000				
Pumping	37	hp		$ 574,000	$ 574,000				

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 9
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Denitrification Filters/Chemical Precipitation + Sidestream Membranes

			Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Engineering and Contingencies	35%		$ 1,241,000	$ 1,241,000	$ -	$ -	$ -	
Subtotal of Injection Well(s)			**$ 4,787,000**	**$ 4,787,000**	**$ -**	**$ -**	**$ -**	
PERMITTING AND MITIGATION								
Pipelines and Pump Stations	1%		$ 151,000	$ 124,000	$ 27,000	$ -	$ -	
Water Rights and TPDES Discharge			$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection			$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation			**$ 351,000**	**$ 324,000**	**$ 27,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL			**$ 20,823,000**	**$ 16,547,000**	**$ 4,276,000**	**$ -**	**$ -**	
Interest During Construction		(18 months)	**$ 1,284,000**	**$ 1,020,000**	**$ 264,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST			**$ 22,107,000**	**$ 17,567,000**	**$ 4,540,000**	**$ -**	**$ -**	

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,606,000	$ 1,276,000	$ 330,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
West WWTP DF/CP	498,955	1,000 gal	$ 0.25	$ 125,000	$ -	$ 125,000			
North WWTP DF/CP	374,855	1,000 gal	$ 0.25	$ 94,000	$ 94,000	$ 94,000			
Membranes	185,303	1000 gal	$ 0.82	$ 152,000	$ 60,000	$ 92,000	$ -		
Transmission Facilities O&M Costs									
Pipeline	1%			$ 30,000	$ 30,000	$ -	$ -	$ -	
Pump Station	2.50%			$ 46,000	$ 29,000	$ 17,000	$ -	$ -	
Power	113	hp	$ 0.105	$ 78,000	$ 55,000	$ 23,000			
Brine Disposal Facilities O&M Costs									
Well	1.00%			$ 36,000	$ 36,000				
Chemicals	36,817	1000 gal	$ 0.11	$ 4,000	$ 2,000	$ 2,000			
Power	28	hp	$ 0.09	$ 16,000	$ 6,000	$ 10,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 2,187,000**	**$ 1,588,000**	**$ 693,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 581,000**	**$ 312,000**	**$ 363,000**	**$ -**	**$ -**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$1,130
After 30 Years	$300
50-Year Weighting (Includes Phasing)	$938
Cost per 1,000 Gallons	
First 30 Years	$3.47
After 30 Years	$0.92
50-Year Weighting (Includes Phasing)	$2.88

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 10
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands A + Sidestream Membranes

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,935	656	108	454	717	

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Wetlands A	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	60.5	acres	$ 35,000	$ 2,118,000	$ 750,000	$ 646,000	$ -	$ 722,000	
Land	60.5	acres	$ 44,000	$ 2,662,000	$ 194,000	$ 2,082,000	$ -	$ 386,000	
Engineering and Contingencies	35%			$ 741,000	$ 263,000	$ 226,000	$ -	$ 253,000	
Subtotal of Wetlands A				**$ 5,521,000**	**$ 1,207,000**	**$ 2,954,000**	**$ -**	**$ 1,361,000**	

Membranes	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	0.53	mgd		$ 3,536,000	$ 3,536,000				
Land	0	acres	$ 10,000	$ -	$ -				
Engineering and Contingencies	35%			$ 1,238,000	$ 1,238,000	$ -	$ -	$ -	
Subtotal of Membranes				**$ 4,774,000**	**$ 4,774,000**	**$ -**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	A-1									
Pipeline		19,395	ea	$ 60	$ 1,164,000			$ 1,164,000		
ROW		8.9	ac	$ 10,000	$ 89,000			$ 89,000		
14" Water Line	A-2									
Pipeline		9,963	ft	$ 84	$ 837,000	$ 837,000				
ROW		4.6	ac	$ 10,000	$ 46,000	$ 46,000				
10" Water Line	A-2-a									
Pipeline		1,400	ft	$ 60	$ 84,000	$ 84,000				
ROW		0.6	ac	$ 10,000	$ 6,000	$ 6,000				
12" Water Line	A-2-b									
Pipeline		5,109	ea	$ 72	$ 368,000		$ 368,000			
ROW		2.3	ac	$ 10,000	$ 23,000		$ 23,000			
10" Water Line	A-2-b-2									
Pipeline		835	ft	$ 60	$ 50,000		$ 50,000			
ROW		0.4	ac	$ 10,000	$ 4,000		$ 4,000			
8" Water Line	A-2-c									
Pipeline		560	ft	$ 48	$ 27,000				$ 27,000	
ROW		0.2	ac	$ 10,000	$ 2,000				$ 2,000	
10" Water Line	A-3-a									
Pipeline		5,541	ea	$ 60	$ 332,000	$ 332,000				
ROW		2.5	ac	$ 10,000	$ 25,000	$ 25,000				
10" Water Line	A-3-b									
Pipeline		2,012	ft	$ 60	$ 121,000		$ 121,000			
ROW		0.9	ac	$ 10,000	$ 9,000		$ 9,000			
8" Water Line	A-3-c									
Pipeline		7,175	ft	$ 48	$ 344,000				$ 344,000	
ROW		2.5	ac	$ 10,000	$ 25,000				$ 25,000	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 10
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands A + Sidestream Membranes

	Qty.	Units	Unit Cost	Total Cost	Phase 1	Phase 2	Phase 3	Phase 4	Comment
12" Water Line A-3-d									
Pipeline	719	ft	$ 72	$ 52,000	$ 52,000				
ROW	0.3	ac	$ 10,000	$ 3,000	$ 3,000				
14" Water Line A-3									
Pipeline	23,266	ft	$ 56	$ 1,303,000	$ 1,303,000				
ROW	10.7	ac	$ 5,000	$ 53,000	$ 53,000				
Discharge Structure	1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies	30%			$ 1,415,000	$ 792,000	$ 162,000	$ 349,000	$ 111,000	
Subtotal of Pipeline(s)				**$ 6,415,000**	**$ 3,566,000**	**$ 737,000**	**$ 1,602,000**	**$ 509,000**	
Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	37	hp		$ 574,000			$ 574,000		
North WWTP									
Pump, Building, & Appurtenances	60	hp		$ 618,000	$ 618,000				
Storage Tank	300,000	gal		$ 289,000	$ 289,000				
Wetlands A-North									
Pump, Building, & Appurtenances	30	hp		$ 560,000	$ 560,000				
Wetlands A-Central									
Pump, Building, & Appurtenances	21	hp		$ 530,000		$ 530,000			
Wetlands A-South									
Pump, Building, & Appurtenances	8	hp		$ 492,000				$ 492,000	
Engineering and Contingencies	35%			$ 1,072,000	$ 513,000	$ 186,000	$ 201,000	$ 172,000	
Subtotal of Pump Station(s)				**$ 4,135,000**	**$ 1,980,000**	**$ 716,000**	**$ 775,000**	**$ 664,000**	
BRINE DISPOSAL FACILITIES									
Injection Well(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
2" Tube Diameter	4,150	ft		$ 2,972,000	$ 2,972,000				
Pumping	43	hp		$ 586,000	$ 586,000				
Engineering and Contingencies	35%			$ 1,245,000	$ 1,245,000	$ -	$ -	$ -	
Subtotal of Injection Well(s)				**$ 4,803,000**	**$ 4,803,000**	**$ -**	**$ -**	**$ -**	
PERMITTING AND MITIGATION									
Pipelines and Pump Stations	1%			$ 171,000	$ 127,000	$ 13,000	$ 21,000	$ 10,000	
Wetlands	3%			$ 76,000	$ 27,000	$ 23,000	$ -	$ 26,000	
Water Rights and TPDES Discharge				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation				**$ 447,000**	**$ 354,000**	**$ 36,000**	**$ 21,000**	**$ 36,000**	
CONSTRUCTION TOTAL				**$ 26,095,000**	**$ 16,684,000**	**$ 4,443,000**	**$ 2,398,000**	**$ 2,570,000**	
Interest During Construction		(24 months)		**$ 2,131,000**	**$ 1,363,000**	**$ 363,000**	**$ 196,000**	**$ 210,000**	
TOTAL CAPITAL COST				**$ 28,226,000**	**$ 18,047,000**	**$ 4,806,000**	**$ 2,594,000**	**$ 2,780,000**	
ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 10
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands A + Sidestream Membranes

Debt Service				$ 2,051,000	$ 1,311,000	$ 349,000	$ 188,000	$ 202,000	assume 6% over 30 years
Treatment Facilities O&M Costs									
Wetlands A	60.5	acres	$ 1,000	$ 61,000	$ 22,000	$ 19,000	$ -	$ 20,000	
Membranes	193,749	1000 gal	$ 0.82	$ 159,000	$ 54,000	$ -	$ 105,000		
Transmission Facilities O&M Costs									
Pipeline	1%			$ 56,000	$ 31,000	$ 6,000	$ 14,000	$ 4,000	
Pump Station	2.50%			$ 92,000	$ 44,000	$ 16,000	$ 17,000	$ 15,000	
Power	140	hp	$ 0.105	$ 96,000	$ 55,000	$ 13,000	$ 23,000	$ 5,000	
Brine Disposal Facilities O&M Costs									
Well	1.00%			$ 36,000	$ 36,000				
Chemicals	38,750	1000 gal	$ 0.11	$ 4,000	$ 1,000	$ -	$ 3,000		
Power	32	hp	$ 0.09	$ 19,000	$ 6,000	$ -	$ 13,000		
TOTAL ANNUAL COST (First 30 Years)				**$ 2,574,000**	**$ 1,560,000**	**$ 403,000**	**$ 363,000**	**$ 246,000**	
TOTAL ANNUAL COST (After 30 Years)				**$ 523,000**	**$ 249,000**	**$ 54,000**	**$ 175,000**	**$ 44,000**	

UNIT COSTS

Cost per Acre-Foot	**Full Project**
First 30 Years	$1,331
After 30 Years	$270
50-Year Weighting (Includes Phasing)	$1,112

Cost per 1,000 Gallons	
First 30 Years	$4.08
After 30 Years	$0.83
50-Year Weighting (Includes Phasing)	$3.41

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 11
Lake Athens Limiting Factor: 50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice: Wetlands B + Sidestream Membranes

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	1,935	764	1,171			

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Wetlands B	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	60.5	acres	$ 30,000	$ 1,815,000	$ 717,000	$ 1,098,000			
Land	60.5	acres	$ 5,000	$ 303,000	$ 120,000	$ 183,000			
Engineering and Contingencies	35%			$ 635,000	$ 251,000	$ 384,000	$ -	$ -	
Subtotal of Wetlands B				**$ 2,753,000**	**$ 1,088,000**	**$ 1,665,000**	**$ -**	**$ -**	

Membranes	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	0.53	mgd		$ 3,549,000	$ 3,549,000				
Land	0	acres	$ 10,000	$ -	$ -				
Engineering and Contingencies	35%			$ 1,242,000	$ 1,242,000	$ -	$ -	$ -	
Subtotal of Membranes				**$ 4,791,000**	**$ 4,791,000**	**$ -**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	B-1									
Pipeline		19,395	ea	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	B-2-a									
Pipeline		17,000	ea	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	B-2-b									
Pipeline		32,643	ft	$ 56	$ 1,828,000	$ 1,828,000				
ROW		15.0	ac	$ 5,000	$ 75,000	$ 75,000				
14" Water Line	B-3									
Pipeline		14,128	ea	$ 56	$ 791,000	$ 791,000				
ROW		6.5	ac	$ 5,000	$ 32,000	$ 32,000				
Discharge Structure		1.73	mgd		$ 33,000	$ 33,000				
Engineering and Contingencies		30%			$ 1,145,000	$ 796,000	$ 349,000	$ -	$ -	
Subtotal of Pipeline(s)					**$ 6,663,000**	**$ 5,061,000**	**$ 1,602,000**	**$ -**	**$ -**	

Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	37	hp		$ 574,000		$ 574,000			
North WWTP									
Pump, Building, & Appurtenances	110	hp		$ 725,000	$ 725,000				
Storage Tank	300,000	gal		$ 289,000	$ 289,000				
Wetlands B									
Pump, Building, & Appurtenances	47	hp		$ 594,000	$ 594,000				
Engineering and Contingencies	35%			$ 764,000	$ 563,000	$ 201,000	$ -	$ -	
Subtotal of Pump Station(s)				**$ 2,946,000**	**$ 2,171,000**	**$ 775,000**	**$ -**	**$ -**	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	11
Lake Athens Limiting Factor:	50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice:	Wetlands B + Sidestream Membranes

BRINE DISPOSAL FACILITIES									
Injection Well(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
2" Tube Diameter	4,150	ft		$ 2,972,000	$ 2,972,000				
Pumping	43	hp		$ 586,000	$ 586,000				
Engineering and Contingencies	35%			$ 1,245,000	$ 1,245,000	$ -	$ -	$ -	
Subtotal of Injection Well(s)				**$ 4,803,000**	**$ 4,803,000**	**$ -**	**$ -**	**$ -**	
PERMITTING AND MITIGATION									
Pipelines and Pump Stations	1%			$ 150,000	$ 129,000	$ 21,000	$ -	$ -	
Wetlands	3%			$ 65,000	$ 26,000	$ 40,000	$ -	$ -	
Water Rights and TPDES Discharge				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection				$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation				**$ 415,000**	**$ 355,000**	**$ 61,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL				**$ 22,371,000**	**$ 18,269,000**	**$ 4,103,000**	**$ -**	**$ -**	
Interest During Construction		(24 months)		**$ 1,827,000**	**$ 1,492,000**	**$ 335,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST				**$ 24,198,000**	**$ 19,761,000**	**$ 4,438,000**	**$ -**	**$ -**	

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,758,000	$ 1,436,000	$ 322,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
Wetlands B	61	acres	$ 1,000	$ 61,000	$ 24,000	$ 37,000			
Membranes	195,018	1000 gal	$ 0.82	$ 160,000	$ 63,000	$ 97,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 45,000	$ 31,000	$ 14,000	$ -	$ -	
Pump Station	2.50%			$ 65,000	$ 48,000	$ 17,000	$ -	$ -	
Power	168	hp	$ 0.105	$ 115,000	$ 93,000	$ 22,000			
Brine Disposal Facilities O&M Costs									
Well	1.00%			$ 36,000	$ 36,000				
Chemicals	38,750	1000 gal	$ 0.11	$ 4,000	$ 2,000	$ 2,000			
Power	32	hp	$ 0.09	$ 19,000	$ 8,000	$ 11,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 2,263,000**	**$ 1,741,000**	**$ 522,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 505,000**	**$ 305,000**	**$ 200,000**	**$ -**	**$ -**	

UNIT COSTS	
Cost per Acre-Foot	**Full Project**
First 30 Years	$1,170
After 30 Years	$261
50-Year Weighting (Includes Phasing)	$914
Cost per 1,000 Gallons	
First 30 Years	$3.59
After 30 Years	$0.80

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	11
Lake Athens Limiting Factor:	50% Maximum Blend (Limiting Condition 4)
Polishing Treatment Choice:	Wetlands B + Sidestream Membranes

50-Year Weighting (Includes Phasing)	$2.81

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number:	12
Lake Athens Limiting Factor:	Minimum Detention Time (Limiting Condition 3)
Polishing Treatment Choice:	Membranes + Advanced Oxidation

	Total Project	Phase 1	Phase 2	Phase 3	Phase 4	Comment
Annual Supply (ac-ft/yr)	2,364	764	1,600			

CONSTRUCTION COSTS

RECLAIMED WATER TREATMENT FACILITIES

Membranes	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	2.64	mgd		$ 7,055,000	$ 7,055,000				
Land	0	acres	$ 10,000	$ -	$ -				
Engineering and Contingencies	35%			$ 2,469,000	$ 2,469,000	$ -	$ -	$ -	
Subtotal of Membranes				**$ 9,524,000**	**$ 9,524,000**	**$ -**	**$ -**	**$ -**	

Advanced Oxidation	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Facilities	2.11	mgd		$ 1,570,000	$ 1,570,000				
Land	0	acres	$ 10,000	$ -	$ -				
Engineering and Contingencies	35%			$ 550,000	$ 550,000	$ -	$ -	$ -	
Subtotal of Advanced Oxidation				**$ 2,120,000**	**$ 2,120,000**	**$ -**	**$ -**	**$ -**	

TRANSMISSION FACILITIES

Pipeline(s)	**Name**	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
10" Water Line	C-1									
Pipeline		19,395	ft	$ 60	$ 1,164,000		$ 1,164,000			
ROW		8.9	ac	$ 10,000	$ 89,000		$ 89,000			
14" Water Line	C-2-a									
Pipeline		17,000	ft	$ 84	$ 1,428,000	$ 1,428,000				
ROW		7.8	ac	$ 10,000	$ 78,000	$ 78,000				
14" Water Line	C-2-b									
Pipeline		19,383	ft	$ 56	$ 1,085,000	$ 1,085,000				
ROW		8.9	ac	$ 5,000	$ 44,000	$ 44,000				
Discharge Structure		2.11	mgd		$ 34,000	$ 34,000				
Engineering and Contingencies		30%			$ 764,000	$ 764,000	$ -	$ -	$ -	
Subtotal of Pipeline(s)					**$ 4,686,000**	**$ 3,433,000**	**$ 1,253,000**	**$ -**	**$ -**	

Pump Station(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
West WWTP									
Pump, Building, & Appurtenances	44	hp		$ 588,000		$ 588,000			
North WWTP									
Pump, Building, & Appurtenances	126	hp		$ 781,000	$ 781,000				
Storage Tank	350,000	gal		$ 318,000	$ 318,000				
Engineering and Contingencies	35%			$ 590,000	$ 385,000	$ 206,000	$ -	$ -	
Subtotal of Pump Station(s)				**$ 2,277,000**	**$ 1,484,000**	**$ 794,000**	**$ -**	**$ -**	

BRINE DISPOSAL FACILITIES

Injection Well(s)	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
4" Tube Diameter	4,150	ft		$ 3,334,000	$ 3,334,000				
Pumping	168	hp		$ 928,000	$ 928,000				
Engineering and Contingencies	35%			$ 1,492,000	$ 1,492,000	$ -	$ -	$ -	

Augmentation of Lake Athens with Reclaimed Water
Athens Municipal Water Authority

Treatment Scenario Number: 12
Lake Athens Limiting Factor: Minimum Detention Time (Limiting Condition 3)
Polishing Treatment Choice: Membranes + Advanced Oxidation

Subtotal of Injection Well(s)			**$ 5,754,000**	**$ 5,754,000**	**$ -**	**$ -**	**$ -**	
PERMITTING AND MITIGATION								
Pipelines and Pump Stations	1%		$ 181,000	$ 174,000	$ 7,000	$ -	$ -	
Water Rights and TPDES Discharge			$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Deep Well Injection			$ 100,000	$ 100,000	$ -	$ -	$ -	highly variable
Subtotal of Permitting and Mitigation			**$ 381,000**	**$ 374,000**	**$ 7,000**	**$ -**	**$ -**	
CONSTRUCTION TOTAL			**$ 24,742,000**	**$ 22,689,000**	**$ 2,054,000**	**$ -**	**$ -**	
Interest During Construction	(18 months)		**$ 1,526,000**	**$ 1,399,000**	**$ 127,000**	**$ -**	**$ -**	
TOTAL CAPITAL COST			**$ 26,268,000**	**$ 24,088,000**	**$ 2,181,000**	**$ -**	**$ -**	

ANNUAL COSTS	**Qty.**	**Units**	**Unit Cost**	**Total Cost**	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Comment**
Debt Service				$ 1,908,000	$ 1,750,000	$ 158,000	$ -	$ -	assume 6% over 30 years
Treatment Facilities O&M Costs									
Membranes	962,688	1000 gal	$ 0.82	$ 791,000	$ 256,000	$ 535,000			
UV/Oxidation	770,150	1000 gal	$ 0.08	$ 64,000	$ 21,000	$ 43,000			
Transmission Facilities O&M Costs									
Pipeline	1%			$ 30,000	$ 30,000	$ -	$ -	$ -	
Pump Station	2.50%			$ 51,000	$ 33,000	$ 18,000	$ -	$ -	
Power	145	hp	$ 0.105	$ 100,000	$ 74,000	$ 26,000			
Brine Disposal Facilities O&M Costs									
Well	1.00%			$ 40,000	$ 40,000				
Chemicals	192,538	1000 gal	$ 0.11	$ 22,000	$ 7,000	$ 15,000			
Power	128	hp	$ 0.09	$ 75,000	$ 24,000	$ 51,000			
TOTAL ANNUAL COST (First 30 Years)				**$ 3,081,000**	**$ 2,235,000**	**$ 846,000**	**$ -**	**$ -**	
TOTAL ANNUAL COST (After 30 Years)				**$ 1,173,000**	**$ 485,000**	**$ 688,000**	**$ -**	**$ -**	

UNIT COSTS

	Full Project
Cost per Acre-Foot	
First 30 Years	$1,304
After 30 Years	$496
50-Year Weighting (Includes Phasing)	$1,087
Cost per 1,000 Gallons	
First 30 Years	$4.00
After 30 Years	$1.52
50-Year Weighting (Includes Phasing)	$3.34

Appendix H: Response to Comments on Draft Indirect Potable Reuse Guidance Document

Response to Comments on Draft Indirect Potable Reuse Guidance Document

The Region C Water Planning Group received two sets of comments regarding the draft Indirect Potable Reuse Guidance Document: written comments from the Texas Water Development Board (TWDB) and verbal comments from a member of the Region C Water Planning Group (RCWPG).

<u>Response to Texas Water Development Board Comments</u>

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 1, Item F requires a planning level analysis of the detention time in Lake Athens that would be associated with two discharge quantities being discharged into Lake Athens at up to three discharge locations. It does not appear that the draft report addresses this requirement. Please include this analysis in the final report.*

   A spreadsheet-based, monthly water balance was developed to project monthly detention times for reclaimed water in Lake Athens under various operating conditions. In Sections 5.5 and 5.6, monthly detention times were projected for Lake Athens based on the five reclaimed water flowrates associated with the Limiting Condition scenarios.

   One of the assumptions inherent in the water balance is that the lake is well-mixed (Footnote 37 on Page 5-8), meaning that the projected concentrations, detention times, etc. do not depend on the location where reclaimed water is discharged. This assumption is consistent with a "planning-level" analysis. The presented analysis presented meets the Scope of Work requirement. Five discharge quantities is more than the required two, and one discharge location satisfies the requirement of "up to" three locations.

The potential for short-circuiting of reclaimed water was considered qualitatively with respect to reclaimed water discharge locations for Lake Athens (Page 8-2):

> "The least expensive pipeline would convey the reclaimed water as far as the westernmost drainage of Lake Athens. This is consistent with the discharge location in AMWA's existing water right (Figure 4-1). However, with this discharge point, the reclaimed water would pass the AMWA and TFFC water intakes before flowing into the main body of the lake. To maximize blending and detention time, the reclaimed water should be introduced to Lake Athens at a location close to the dam."

During meetings with the Athens Municipal Water Authority, other potential discharge locations were discussed and rejected using the same logic. Therefore, multiple Lake Athens discharge locations were considered during the planning process.

No changes have been made to the report as a result of this comment.

d. *Scope of Work Task 2, Item P states that the study will achieve coordination between Athens Municipal Water Authority and City of Athens to develop a consensus about the recommended options and the implementation plan. The report does not discuss this coordination. Please include a discussion of the coordination between the entities in the final report.*

During development of the Lake Athens case study, the consultant team conducted three meetings with the AMWA Board to seek guidance and report progress. The Athens Director of Utilities, an *ex officio* member of the AMWA Board, attended each of these meetings. In addition, the City had the opportunity to comment on the draft report. In these ways, coordination between Athens and AMWA was achieved for this project.

This information was added to the introduction of Chapter 4.

e. *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 H-1 shows projected 2060 reuse supplies obtained from the *2006 Region C Water Plan*. The *Plan* recommends development of 795,466 acre-feet per year (ac-ft/yr) of new Region C reuse supplies by 2060.[67] 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.[68] 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 H-1: Projected 2060 Reuse Supply Used in Region C

Item	**Quantity (ac-ft/yr)**	**Calculation**
Recommended Reuse Projects in Region C[67]		
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[68]	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.

[67] 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.

[68] *2006 Region C Water Plan*, Table 3.1, Page 3.2.

f. *Chapter 5, Figures 5-4 to 5-6 are not clear. Please consider an alternative way to present this information or include additional information in the final report to clarify these figures.*

   Additional explanatory text has been added to Section 5.4, which contains Figures 5-4 through 5-6.

g. *Chapter 6, Page 6-16 states that membrane filtration involves size exclusion as a mechanism. However, membrane filtration is also achieved by a combination of different mechanisms, including sieving, hindered transport through the narrow membrane pores and other specific interactions between the components and the membrane material (such as adsorption or electrical interactions). Please consider including this information in the final report.*

   Explanatory text has been added to the description of membrane filtration beginning on Page 6-16 to acknowledge other filtration mechanisms.

h. *Appendix B, Figures B-3 and B-6 are confusing because the figures list the 'West WWTP Maximum Permit Limit', 'North WWTP Maximum Permit Limit', and 'West WWTP Reported' in the legend; however, there are no values present in the figure for these parameters. If the values of these parameters are zero, please indicate so in the Figures.*

   Figures B-1, B-3, B-6, and B-7 were modified to remove extraneous information.

<u>Response to Region C Water Planning Group Member Comment</u>

A member of the Region C Water Planning Group commented that the guidance for blending, detention time, total phosphorus, and total nitrogen concentrations in the reclaimed water should not include numerical targets to be applied statewide. Instead, the guidance should focus on the factors that should be considered in developing numerical targets on a case-by-case basis.

Numerous changes were made to the guidance portion of the document to address these comments.

No changes were made to the Athens Municipal Water Authority/City of Athens case study as a result of this comment.

Other Changes

Although no other comments were received, the following additional changes have been made:

- Reorganization of the Chapter 3 General Guidance for Indirect Reuse in Texas
- Guidance regarding the following elements in the multiple-barrier approach to managing the uncertainties associated with augmenting raw water supplies with reclaimed water: industrial pretreatment and the proximity of the reclaimed water discharge to the water use.
- Expanded guidance in several other sections.