WHITE RIVER

MUNICIPAL WATER DISTRICT

WATER REUSE AND CONSERVATION STUDY

AUGMENTATION OF WATER SUPPLY USING RECLAIMED WATER

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FINAL REPORT

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Executive Summary

White River Municipal Water District (District) currently supplies water to the Cities of Crosbyton, Post, Ralls and Spur in a rural region located approximately 65 miles southeast of Lubbock in West Texas. The District owns and operates White River Reservoir, which provides the primary supply of water to its customers. In addition, the District operates and maintains a series of wells that can be used to supplement the surface water supply for short periods of time.

Since 1992, the region has experienced several extended periods of drought, the most recent occurring from 1999 to 2003. During this time period, the water surface elevation in White River Reservoir dropped approximately 26 feet to historically low levels. These low water levels and the associated shortage of supply have provided the impetus for the District, through a grant from the Texas Water Development Board (TWDB), to identify and evaluate supplementary sources of supply to meet the needs of its customers. As part of this effort, the District contracted with Alan Plummer Associates, Inc. (APAI) to evaluate the feasibility of augmenting the District's water supply with reclaimed water to be provided to the District by the City of Lubbock. This report provides a summary of the results of this feasibility study.

<u>Water Quality Evaluation Criteria</u>

A primary objective of this study was to address water quality issues that may be associated with reclaimed water augmentation. These issues relate to both ecological impacts on receiving waters and potential human health effects resulting from reclaimed water consumption. Efforts to minimize ecological impacts are typically focused on limiting levels of nutrients, total dissolved solids (TDS) and some specific toxic substances in the wastewater discharge stream to meet water quality standards required by regulatory agencies. These impacts must be addressed regardless of whether the wastewater discharge is utilized to augment the water supply.

With respect to human health effects, many chemical and microbial contaminants have been studied extensively and are known to be effectively removed using available water treatment technology. Contaminants known to cause harmful health effects are regulated by federal and state drinking water quality standards and are maintained at levels determined to be safe by the regulatory agencies. However, it is the group of unregulated, potential contaminants about which little or no information is currently available, that presents the greatest challenge in determining the best strategies for treatment and use of reclaimed water.

Texas currently has no specific water quality standards that pertain to indirect use of reclaimed water, although any waste discharges to waters of the state must meet the criteria in the Texas Surface Water Quality Standards. In the absence of specific water quality data for unknown and emerging contaminants, a more general water quality evaluation approach has been developed. This approach is based on the use of percent wastewater content (percent blend) and detention time as a measure of potential exposure to contaminants that may have human health impacts. The use of these indicators is based on the assumption that natural degradation and dilution are important factors in reducing the quantities of potentially harmful contaminants within the water supply. Based on experience from existing planned reuse projects, a limit on average percent blend of approximately 30%, combined with a minimum average detention time of 1 year have been adopted as general water quality criteria to be applied when evaluating exposure potential for each of the alternatives discussed in this report. These criteria have been established to provide guidance for determining upper limits on quantities of wastewater effluent that can be used to augment the supply. However, there is latitude for some variation from these criteria, particularly with the use of multiple barriers and implementation of appropriate advanced wastewater or water treatment.

Reclaimed Water Augmentation Alternatives

Three alternatives for augmentation of White River Reservoir with City of Lubbock reclaimed water were selected for further evaluation. Due to high TDS levels in the City of Lubbock wastewater effluent in comparison to the water quality standard for TDS in White River Reservoir, control of TDS levels was a major consideration in the development of the augmentation alternatives. Alternatives #1 and #2 are based on the assumption that TDS levels will be controlled such that future TDS concentration in the reservoir will not exceed historically measured levels in the reservoir. Alternative #3 is based on the assumption that the water quality standard for TDS (currently 650 mg/L) could be increased significantly to accommodate direct discharge of the Lubbock effluent into a proposed constructed wetlands upstream of the reservoir, without removal of TDS. Treatment for TDS removal would then be provided at the water treatment plant to meet drinking water standards prior to distribution to the District's customers.

In Alternative #1 (see Figure 7-1), secondary effluent from the City of Lubbock WWTP is treated with reverse osmosis (RO) on an as-needed basis to remove TDS such that historical levels of TDS are maintained in the reservoir. Following RO treatment, the effluent will be piped directly to a proposed constructed wetlands, located on a tributary to the lake. The wetlands will provide treatment for removal of nutrients, but will also provide additional "polishing" and removal of many other constituents prior to discharge into the lake. Following discharge to the wetlands system, the water flows into the reservoir, mixes with the ambient waters, and is eventually withdrawn at the District's intake for treatment at the existing water treatment plant (WTP) prior to distribution to District customers.

For Alternative #2 (see Figure 7-3), tertiary effluent from the City of Lubbock WWTP is discharged to the North Fork at the currently permitted discharge location downstream of Ransom Canyon Lake. The water then flows down the North Fork to a diversion point located at the proposed site of the future Post Reservoir. From this diversion point, the water is pumped to a proposed RO facility located at White River Reservoir. As with Alternative #1, the water is treated with RO on an as-needed basis to maintain TDS levels within the reservoir within the range of historically measured values. The remainder of Alternative #2 is identical to Alternative #1. Flow is passed through a constructed wetlands, into the reservoir and subsequently treated at the District's WTP prior to distribution to District customers. A primary disadvantage of this alternative is that stream losses are thought to be extremely high in the North Fork, particularly in the summer months. Consequently, it is unlikely that flow would be available year-round from the river. Therefore, in order to implement this alternative, diversion facilities would need to be sized to divert the required flow quantities during periods when water is available.

For Alternative #3 (see Figure 7-4), it is assumed that the TDS standard in the lake can be changed to accommodate effluent that has not undergone RO treatment prior to discharge to the proposed wetlands. Thus, secondary effluent from the Lubbock WWTP will be piped directly to a discharge point upstream of the wetlands. Effluent from the wetlands will enter the reservoir. Raw water from the reservoir is then treated at the existing District WTP. A portion of this water would then undergo RO treatment to lower TDS levels in the treated supply below those specified by drinking water standards.

<u>Selection of Preferred Alternative</u>

An evaluation of water quality and permitting issues was performed for each alternative. For initial comparisons, the evaluation was performed based on diverting 2 MGD of Lubbock effluent for augmentation purposes. This quantity is the amount required to provide for the existing District demands and to maintain adequate water levels within the reservoir over the simulated historical hydrologic period. However, up to 4 MGD of water could be diverted to the reservoir while still maintaining percent blend and detention time within the range established by the criteria discussed earlier.

In addition to the water quality and permitting evaluation, opinions of probable cost were developed for each alternative, and are summarized below for a diversion amount of 2 MGD.

Alternative	Capital Cost	Annual Cost	$/1000 gal	$/ac-ft
#1	$32,117,785	$3,015,258	$4.13	$1,346
#2	$43,565,278	$4,080,480	$5.59	$1,821
#3	$34,853,785	$3,311,905	$4.54	$1,478

Based on the evaluation of each alternative, Alternative #1 was selected as the most feasible. In addition to being slightly less costly than the other two alternatives, permitting issues are likely to be easier to address for Alternative #1. Although this alternative is feasible from a technical standpoint, ultimately the overall feasibility of this alternative will depend on the ability of the District to obtain adequate funding for the project. It should be noted, however, that although the opinion of probable cost for augmentation with reclaimed water is high, the development of any future surface water supply is likely to cost as much or more than the reclaimed water alternatives. Although the use of groundwater provides a much less costly alternative in the short-term, the long-term reliability of groundwater as a source in this region is much less certain. Conversely, reclaimed water is one of the most reliable sources of water available and, as such, would provide the District with a dependable long-term supply of water. In addition, a reclaimed water project could likely be implemented much more quickly than many other surface water development projects.

<u>Reclaimed Water Augmentation Strategy</u>

If adequate funding and support can be achieved, the following reclaimed water augmentation strategy is recommended for implementation by the District:

1. Per Alternative #1, construct a reverse osmosis (RO) treatment facility at the existing City of Lubbock wastewater treatment plant. This facility should be sized to accommodate the maximum amount of reclaimed water to be diverted to the reservoir (up to 4 MGD). However, the total capacity of the RO facility will only need to be utilized during periods of extended drought, in order to control TDS levels entering White River

Reservoir. During non-drought periods, only a portion of the effluent will require RO treatment for control of TDS.

2. Build a constructed wetlands on a tributary upstream of White River Reservoir. The wetlands will serve to remove nutrients and suspended solids, as well as other constituents, prior to discharge to the reservoir.

3. Build a conveyance pump station and pipeline to transport the reclaimed water from the Lubbock WWTP to the constructed wetlands.

4. Develop a testing program to monitor the water quality of the Lubbock wastewater, the wetlands influent and effluent, and the reservoir. This characterization would specifically address those contaminants that have been identified as potential concerns with respect to indirect use of reclaimed water (e.g. pharmaceuticals, endocrine disruptors). Following an initial sampling program, periodic monitoring should continue to track the occurrence of known contaminants and to screen for the introduction of new ones.

It is likely that pilot testing of both the RO and wetlands facilities will be necessary prior to construction of the full-scale facilities. The pilot testing will assist in the selection of treatment trains that target the specific characteristics of the Lubbock effluent. As part of the pilot testing, characterization of the water quality should be carried out, as described in item 4 above.

Implementation of the above augmentation plan will also require that the District reach an agreement with the City of Lubbock for use of the required amount of wastewater and for construction and operation of the RO facility and conveyance pump station. In addition, the required permits will need to be obtained from the state.

In order to take advantage of the total recommended diversion amount of 4 MGD, the District will need to bring more customers into its system. Potential candidates include the towns of Lorenzo and Idalou, located west of Ralls on Highway 82. Serving these towns could be cost-effective if the existing infrastructure to Ralls has enough capacity to accept the additional flows. Other potential customers include the towns of Jayton and Aspermont, located southeast of Spur.

The benefit of serving the towns along Highway 82 is that more growth is likely to occur in towns closer to Lubbock and, thus, these areas will likely experience increased water demands in the future. As the science and technology develop with respect to potable use of reclaimed water, it is possible that greater amounts of wastewater effluent than those recommended in this report can be diverted to White River Reservoir for subsequent reuse. In future years it may even become feasible to use White River Reservoir as a receptor for reclaimed water that is then subsequently reused by the City of Lubbock itself. Development of additional customers along Highway 82 would provide an initial step towards this type of regional approach to water supply and is consistent with the overall goals of the Texas Water Development Board regional planning process.

CHAPTER 1: Project Background

1.1 Project Purpose

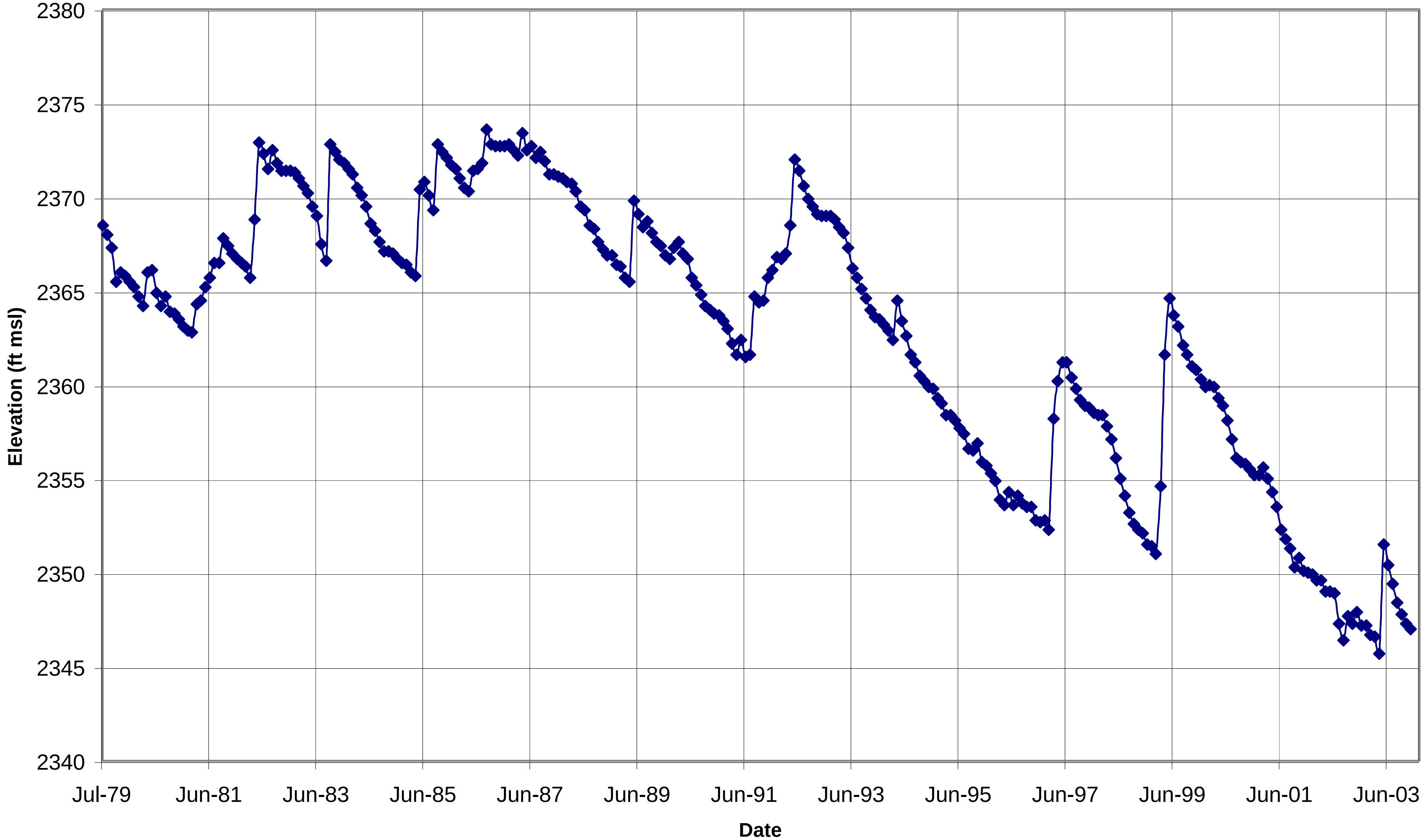
White River Municipal Water District (District) currently supplies water to the Cities of Crosbyton, Post, Ralls and Spur in a rural region located approximately 65 miles southeast of Lubbock in West Texas. The District owns and operates White River Reservoir, which provides the primary supply of water to its customers. In addition, the District operates and maintains a series of wells that can be used to supplement the surface water supply for short periods of time.

Since 1992, the region has experienced several extended periods of drought, the most recent occurring from 1999 to 2003. During this time period, the water surface elevation in White River Reservoir dropped approximately 26 feet to historically low levels, as can be seen in Figure 1-1. These low water levels and the associated shortage of supply have provided the impetus for the District, through a grant from the Texas Water Development Board (TWDB), to identify and evaluate supplementary sources of supply to meet the needs of its customers. As part of this effort, the District contracted with Alan Plummer Associates, Inc. (APAI) to evaluate the feasibility of augmenting the District's water supply with reclaimed water to be provided to the District by the City of Lubbock. This report provides a summary of the results of this feasibility study.

1.2 Study Relationship to Region O Water Plan

In 1997, the Texas Legislature enacted Senate Bill 1, which specified that short- and long-term water plans be developed for regions within the state. The Llano Estacado region, or Region O, is made up of 21 counties, including those counties served by the District. The City of Lubbock is also located in Region O.

Figure 1-1: White River Reservoir
Historical Water Surface Elevation



Projections from the Region O Water Plan (Plan), finalized in 2001, indicate that District demands are likely to decrease within the planning period (to year 2050). In addition, based on a previously calculated yield for White River Reservoir, the District is listed as having a projected surplus of water through the year 2050. Based on the current period of drought being experienced by the District, the yield of White River Reservoir appears to be significantly less than that originally projected and included in the Plan. As discussed above, water level and storage volume in the reservoir have dropped to a point that has forced the District to seek alternative sources of supply.

For areas within Region O that are projected to have water shortages in the future, a number of strategies have been identified for addressing these shortages. Use of reclaimed water is identified as both a short-term and long-term strategy in the Plan. As a short-term strategy, the emphasis is primarily on non-potable uses (e.g. irrigation, industrial). Reuse of municipal effluent for potable water supply is listed in the Plan as a long-term strategy for the municipal water user group. However, no specific recommendations for implementation of potable reuse are made within the Plan.

As this study specifically addresses the use of municipal effluent for augmentation of a potable water supply, it is consistent with the goals set forth in the Plan. Furthermore, the concept addressed in this study, whereby the City of Lubbock provides wastewater to the District for subsequent reuse, represents a regional approach to augmenting the District's supply, a strategy that is also embraced by the water planning process.

1.3 Issues Related to Potable Use of Reclaimed Water

Reclaimed water has historically been used to augment water supplies on an informal basis in many regions throughout the United States and around the world. However, as water supplies become scarcer, many water providers are initiating efforts to formally acquire rights to reclaimed water and integrate its use into their long-term water supply programs. As these efforts progress, the scientific community is beginning to take a closer look at the health implications of utilizing reclaimed water as a supplementary potable water supply.

Currently there are only a handful of studies that have attempted to document quantities and impacts of using reclaimed water as a supplementary potable water supply. Chapter 3 of this report summarizes the results of these studies. These studies have provided valuable data related to potential constituents of concern within wastewater and the effectiveness of available treatment technologies in removing these constituents. There is also a limited amount of data that provide estimates of detention times between the wastewater discharge points and raw water intake locations and percent blend of wastewater in the raw water at the intake.

These studies indicate, that to date, there are no known documented adverse health impacts associated with use of reclaimed water as a supplementary potable water source. However, there are still many constituents within the wastewater which have not been identified or about which little or no information is available as to the effectiveness of existing treatment technologies in removing them from the potable water supply. In addition, no detailed studies have been performed which address potential long-term health impacts of using reclaimed water to supplement potable water supplies. Consequently, systems using reclaimed water to supplement their potable water supplies assume some level of risk. Most systems have addressed this risk by adopting a conservative "multiple barrier" approach to the treatment and use of reclaimed water. This approach typically includes a combination of providing ample detention time and dilution between the discharge and intake points and providing various degrees of advanced treatment at the wastewater treatment plant and/or the water treatment plant.

The remainder of this report is organized as follows: water quality concerns and available treatment technologies are summarized in Chapter 2, and a summary of reuse case studies is presented in Chapter 3. Chapter 4 discusses water quality criteria and presents a proposed approach for evaluating water quality and defining appropriate treatment strategies. Chapters 5 and 6 summarize the water quality characteristics of White River Reservoir and other potential supply sources, respectively. The alternatives considered in this study are presented in Chapter 7, together with discussions of water quality, permitting issues and opinions of probable cost. Finally, Chapter 8 presents a summary of the primary conclusions and recommendations of the study.

CHAPTER 2: Water Quality Issues Associated with Reclaimed Water Augmentation

Water quality issues associated with augmentation of potable supplies with reclaimed water relate to both ecological impacts on receiving waters as well as human health effects resulting from increased reclaimed water consumption. Historically, efforts to minimize the ecological impacts of discharging reclaimed water to receiving water bodies have primarily focused on limiting levels of nutrients, total dissolved solids (TDS) and some specific toxic substances in the wastewater discharge stream to meet certain water quality standards required by regulatory agencies. Ecological impacts to receiving water bodies must be addressed regardless of whether the wastewater discharge is utilized to augment the water supply. However, strategies for utilizing reclaimed water may include transfer of wastewater between drainage basins in order to move the water to the location of terminal storage for the supply and optimize utilization of the reclaimed water. Consequently, these transfers can affect surface waters that would not have been impacted prior to implementation of a reclaimed water program and must be considered as part of the program evaluation.

With respect to human health effects, many chemical and microbial contaminants have been studied extensively and are known to be effectively removed using available water treatment technology. Contaminants known to cause harmful health effects are regulated by federal and state drinking water quality standards and are maintained at levels determined to be safe by the regulatory agencies. However, it is the group of unregulated, potential contaminants about which little or no information is currently available, that presents the greatest challenge in determining the best strategies for treatment and use of reclaimed water. Ecological and human health impacts of some specific constituent groups are described further in the following sections.

2.1 Chemical Contaminants

The composition of chemicals in wastewater varies depending on the type of land use and industry within the wastewater service area and the effectiveness of industrial pretreatment and source control programs. In addition, wastewater contains many inorganic chemicals and minerals that occur naturally and vary depending on the source of the potable water supply. Table 2-1 presents a general classification of chemical contaminants with examples in each category.[1]

Table 2-1: Categorization of Chemical Constituents in Wastewater

CATEGORY	EXAMPLES
Recognized Chemical Constituents	
Naturally occurring minerals and inorganic chemicals, generally at concentrations greater than 1 mg/L	Chloride, sodium, sulfate, magnesium, calcium, phosphorus, nitrogen
Chemicals of anthropogenic origin, generally at concentrations less than 1 mg/L	Regulated contaminants and priority pollutants (trace inorganic and organic chemicals)
Chemicals generated as a result of water and wastewater treatment	Known disinfection by-products, humic substances
Unknown Chemical Constituents	
Chemicals possibly present as a component of organic mixtures	Proprietary chemicals and mixtures from industrial applications and their metabolites; unidentified halogenated compounds (unknown disinfection by-products); pharmaceuticals; endocrine disruptors

2.1.1 ECOLOGICAL IMPACTS

As discussed above, efforts to minimize ecological impacts of wastewater discharges to surface waters has focused primarily on controlling nutrient and TDS levels, as well as some other recognized chemical constituents known to be harmful to aquatic life. Although ecological impacts must be addressed regardless of whether the intent is to utilize reclaimed water for potable or non-potable supply, the implementation of a reclaimed water program can contribute to additional ecological issues. Several of these issues, as they relate to nutrients and TDS are summarized briefly below.

Nutrients

As populations increase, nutrient loads (e.g. phosphorus and nitrogen) introduced to surface waters increase, both due to larger wastewater discharge quantities and non-point source increases resulting from urbanization. Agricultural practices can also have a significant impact on non-point source loads. Increased nutrient levels can lead to higher chlorophyll-a levels and

[1] Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water, National Academy Press, Washington, DC, 1998, p. 46.

eventually may lead to increased rates of eutrophication within the affected stream or lake. Aggressive efforts to augment water supplies with reclaimed water can accelerate this trend if additional wastewater is discharged or transferred to a given water body. Wastewater discharges to surface waters must comply with federal and state surface water quality standards and meet conditions specified in their discharge permits. In addition, the EPA has indicated that states must develop nutrient criteria and begin incorporating them into their water quality standards by the end of 2004. Therefore, careful consideration of potential increases in nutrient loads and their impact on surface waters must be evaluated as part of any reclaimed water program.

TDS

Allowable TDS levels in surface waters are controlled by federal and state surface water quality standards. Increased use of reclaimed water to augment surface water supplies can have a significant impact on TDS levels. TDS levels can be affected if the source water originates in a different watershed than where it is discharged and the origin watershed has significantly higher naturally occurring TDS levels. In addition, levels of dissolved solids are concentrated in wastewater as compared to the levels in the original source water. Therefore, as reclaimed water becomes a larger portion of the total supply, TDS levels will increase in the absence of additional treatment. Furthermore, surface waters serving as potable water supplies that are high in TDS may require additional treatment in order to meet drinking water standards.

In addition to the impact of nutrients and TDS, implementation of a reclaimed water program can result in other ecological impacts, many of which are not yet known or understood. Therefore, it is important to incorporate a plan for monitoring ecological health of the receiving waters into any reclaimed water program in order to identify potential problems as the program progresses.

2.1.2 HUMAN HEALTH IMPACTS

Of the categories presented in Table 2-1, the knowledge of and ability to manage and treat constituents decreases as one moves down the table. Most naturally occurring minerals and inorganic chemicals are regulated by drinking water standards. These substances typically occur at levels that can be accurately quantified in water, and established treatment processes can normally reduce their concentrations to comply with federal drinking water standards or recommended limits.

Although not as much data is available for known trace inorganics and identifiable organic contaminants (including disinfection by-products), the ability of advanced wastewater treatment processes to remove many trace chemical contaminants is well established[2]. Thus, this group of contaminants presents a manageable risk with respect to controlling levels in potable water supplies.

The last group of constituents in Table 2-1, the unknown chemical constituents, obviously presents the greatest challenge and risk with respect to any reclaimed water program. Research efforts into potential methodologies for identifying and characterizing the complex mixture of unknown chemicals are progressing. These efforts are focusing on defining general contaminant classes (such as total organic carbon (TOC)) that can be monitored and serve as indicators of levels of unknown chemical constituents. Risks can be reduced by focusing on limiting the concentrations of general contaminant classes and implementing an aggressive monitoring plan as part of any reclaimed water program.

2.2 Microbial Contaminants

Microbial contaminants in reclaimed water include enteric bacteria, enteric viruses and enteric protozoan parasites. Historically, coliforms have been used as an effective indicator for many bacterial pathogens of concern. However, protozoan and viral pathogens have caused most recognized outbreaks of waterborne disease in the United States in recent years[3]. *Giardia*, *Cryptosporidium*, and enteric viruses are the main known microorganisms of concern. In addition, wastewater may contain a number of newly recognized or emerging waterborne pathogens about which treatment effectiveness is not well known. Many pathogens are known to be highly resistant to disinfection. Membrane treatment technologies have been shown to be effective in removing pathogens, although further research is needed in order to depend entirely on them for protection (see section on treatment technologies later in this chapter). In summary, as with chemical contaminants, risks associated with potable use of reclaimed water are greatest for those microbial contaminants about which the least is known relative to potential health effects, levels of occurrence and treatment effectiveness. In order to minimize the level of risk associated with microbial contaminants, the best available treatment technologies should be utilized. In addition, a monitoring program should be implemented in order to track the

[2] *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water*, National Academy Press, Washington, DC, 1998, pp. 47-50.

[3] *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water*, National Academy Press, Washington, DC, 1998, pp. 108-109.

occurrence and concentration of specific pathogens and assess the potential health effects from these contaminants.

2.3 Current Indirect Potable Reuse Regulations

Apart from current drinking water standards, no federal regulations specifically address potable use of reclaimed water. However, the Environmental Protection Agency (EPA) has developed recommended guidelines for indirect potable reuse[4]. This document is currently being updated and it is anticipated that it will be finalized within the coming year. The EPA guidelines include recommendations for treatment levels, water quality and monitoring for ground water recharge and surface water augmentation. With respect to surface water augmentation, the EPA guidelines suggest that the wastewater treatment process provide an appropriate form of advanced treatment, which is not limited to, but includes filtration and disinfection. In addition, the guidelines recommend that the reclaimed water quality meet or exceed drinking water standards.

Currently, four states have regulations or guidelines pertaining to indirect potable reuse. These include California, Florida, Hawaii and Washington. Of these states, only Florida's regulations specifically address discharges to Class I surface waters (drinking water supplies). All of the other regulations focus on recharge of groundwater supplies with reclaimed water. A summary of the indirect potable reuse criteria for each of these states is presented in Table 2-2.

Florida's regulations state that any discharge with less than 24 hours travel time upstream from Class I waters is considered to be indirect potable reuse. Surface water discharges located more than 24 hours travel time upstream are not considered to be indirect potable reuse. The reclaimed water must meet primary and secondary drinking water standards, except for asbestos, prior to discharge. Outfalls for surface water discharges are not to be located within 500 feet of existing or approved potable water intakes. Both Florida and Washington require that pilot plant studies be performed prior to implementation of any reuse project[5].

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[4] U.S. Environmental Protection Agency, 1992, "Guidelines for Water Reuse," EPA/625/R-92/004, U.S. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, OH

Table 2-2: State Standards for Groundwater Recharge Using Reclaimed Water[1]

<table>
<tr><th></th><th>California</th><th>Florida[2]</th><th>Hawaii</th><th>Washington</th></tr>
<tr><td>Treatment</td><td rowspan="8">Case-by-case basis</td><td>Advanced treatment, filtration, and high-level disinfection</td><td rowspan="8">Case-by-case basis</td><td>Oxidized, coagulated, filtered, reverse osmosis treated, and disinfected</td></tr>
<tr><td>BOD_5</td><td>20 mg/L</td><td>5 mg/L</td></tr>
<tr><td>TSS</td><td>5 mg/L</td><td>5 mg/L</td></tr>
<tr><td>Turbidity</td><td>NS[3]</td><td>0.1 NTU (avg)
0.5 NTU (max)</td></tr>
<tr><td>Coliform</td><td>Total- All samples less than detection</td><td>Total
1/100 ml (avg)
5/100 ml (max)</td></tr>
<tr><td>Total Nitrogen</td><td>10 mg/L</td><td>10 mg/L</td></tr>
<tr><td>TOC</td><td>3 mg/L (avg)
5 mg/L (max)</td><td>1 mg/L</td></tr>
<tr><td>Primary and Secondary Standards</td><td>Compliance with most primary and secondary standards</td><td>Compliance with most primary and secondary standards</td></tr>
</table>

(1) Data in this table was taken from the DRAFT updated EPA reuse guidelines, Section 4, p. 16, received in draft form January 28, 2004

(2) Florida requirements are for the planned use of reclaimed water to augment surface water sources that will be used as a source of domestic water supply

(3) NS – Not specified by state regulations

In Texas, no regulatory water quality standards pertain specifically to indirect use of reclaimed water. Instead, reclaimed water that is discharged to a stream or reservoir is subject to Texas Pollutant Discharge Elimination System (TPDES) permitting procedures and the Texas Surface Water Quality Standards (30 TAC 307). The Texas Surface Water Quality Standards (TSWQS) include both numerical and narrative criteria to address various constituents.

[5] DRAFT Updated EPA Reuse Guidelines, Section 4, pp. 14-16, received in draft form, January 28, 2004.

2.4 Available Treatment Technologies

As discussed above, in the states with specific regulations related to indirect potable reuse, advanced levels of wastewater treatment are required to meet state water quality criteria. Advanced wastewater treatment (AWT) includes processes beyond what is considered traditional secondary treatment. The primary advanced wastewater treatment processes used for water reclamation are:

(1) Filtration- used to remove particulate matter prior to disinfection

(2) Alternative disinfection methods (e.g. UV disinfection, hydrogen peroxide)

(3) Nitrification- converts ammonia-nitrogen to nitrite- and nitrate-nitrogen; reduces levels of ammonia nitrogen in effluent

(4) Denitrification- converts nitrate-nitrogen to nitrogen gas; provides removal of total nitrogen

(5) Phosphorus removal- chemical or biological removal of phosphorus

(6) Coagulation-sedimentation- chemical coagulation with lime, alum or ferric chloride, followed by sedimentation, removes suspended solids, heavy metals, turbidity and phosphorus

(7) Carbon adsorption- effective in removing biodegradable and refractory organic constituents; may also be effective at removing some endocrine disruptors

(8) Membrane processes- microfiltration, ultrafiltration and reverse osmosis

Disinfection is the most important process for the elimination of microorganisms. UV disinfection is receiving greater attention for wastewater applications because it can be less expensive and safer than chlorine, it doesn't result in the formation of disinfection byproducts, and it is effective against *cryptosporidium*, *giardia*, and N-nitrosodimethylamine (NDMA).

Numerous studies have demonstrated the ability of AWT to remove trace chemical contaminants from the waste stream[6]. Membrane processes have become much more feasible for use in wastewater treatment in recent years and have been shown to be quite effective in removing many

[6] *Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water*, National Academy Press, Washington, DC, 1998, pp. 47-50.

known chemical constituents. Microfiltration and ultrafiltration are also capable of removing some biological contaminants and are often used to reduce fouling on downstream RO membranes. RO systems are used in cases where the removal of colloidal and/or dissolved solids is required[7].

The appropriate advanced treatment technologies to be used for any water reclamation project should be selected in light of the characteristics of the specific wastewater, the proposed use(s) of the discharge water body and any relevant federal and state regulations. As discussed earlier, there are still a number of contaminants about which little is known in terms of treatment effectiveness and potential human health impacts. Given these unknowns, a multi-barrier approach to the treatment of reclaimed water provides the most effective means of reducing the risk of human health impacts.

2.4.1 CONSTRUCTED WETLANDS

Along with advanced wastewater treatment, another type of barrier that can be utilized in reclaimed water projects is the constructed wetland. Traditionally, surface constructed wetlands have been used for removal of nutrients, total suspended solids (TSS), and bacteria. In particular, nitrate, sulfur, phosphorus, and pathogens can be greatly reduced, and these results are well documented. Wetland cells can be added at any point in the treatment train, but in reclaimed water projects, often they are used as a barrier prior to discharge into a receiving water body. The Tarrant Regional Water District's (TRWD) demonstration scale wetlands were constructed in just this manner, and the treated water will be discharged to Richland-Chambers Reservoir.

Table 2-3 displays the removal efficiencies for total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) achieved for the TRWD wetlands trains over the period 1993-2000. The TRWD wetlands are constructed with three treatment trains that operate in parallel. Each train contains three separate cells.

[7] DRAFT Updated EPA Reuse Guidelines, Section 3, pp. 42-46, received in draft form, January 28, 2004.

Table 2-3: TRWD Wetlands Removal Efficiencies[8]

MASS REMOVAL EFFICIENCIES TRWD DEMONSTRATION WETLANDS				
Parameter	**Settling Basin**	**Train 1**	**Train 2**	**Train 3**
Water Depth	4-5 feet	18 inches	12 inches	18 inches
TSS	80%	90%	17%[1]	64% - 70%
TN	10% – 20%	76% - 80%	76% - 80%	55% - 60%[2]
TP	20% - 25%	40% - 50%	66%	40% - 50%

[1]:Extreme bioturbation was experienced for short periods in Train 2. Analysis of removals excluding periods when bioturbation was present indicated mass removal efficiency for TSS was 83 percent.

[2]Vegetative cover in the last cell of Train 3 was only about 25 percent after 1995.

In addition to proven nutrient and solids removal, there is growing evidence that constructed wetlands may also provide substantial removal of organics and heavy metals under the right conditions. This group would include many of the emerging contaminants of concern for reclaimed water projects, such as pharmaceuticals, endocrine disruptors, and personal care products. Because of the large amount of biological activity that is typical of a wetlands cell, the use of the typical surrogates, total organic carbon (TOC) and dissolved organic carbon (DOC), as indicators of organics removal is not possible. As a result, only limited data is available for removal rates of specific organic contaminants. Recently, however, many studies have begun to investigate the capacity of wetlands to remove trace level contaminants, such as endocrine disruptors.

In 2000, researchers at the University of North Texas reported substantial reductions in the estrogenicity (measure of estrogen levels) of fathead minnows within the wetlands with increasing distance downstream of the influent location[9]. Other studies have shown that the "anthropogenic" character of the organic matrix found in wastewater effluents is transformed to a

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[8] Pilot Scale Wetlands Demonstration Project Summary Report, Alan Plummer Associates, Inc., 2001.

[9] Hemming, Jon M., Assessment of the Efficacy of a Constructed Wetland System to Reduce or Remove Wastewater Effluent Estrogenicity and Toxicity Using Biomarkers in Male Fathead Minnows, Doctor of Philosophy Environmental Science, University of North Texas, December 2000.

more "biological" (or natural) signature after passing through a wetlands[10]. Natural processes such as adsorption, photodegradation, oxidation/reduction, microbial activity, and plant uptake are all enhanced in a shallow, highly bioactive wetlands as compared to a reservoir. As such, there are positive signs that constructed wetlands may provide effective treatment for many types of contaminants found in wastewater, making them an even more desirable treatment option for any reclaimed water project. When combined with advanced wastewater treatment, an effective multiple barrier approach can be established.

[10] Gray, Kimberly A., et al, "Evaluation of Organic Quality in Prado Wetlands and Santa Ana River by Pyrolysis-GC/MS", Orange County Water District, 1996.

CHAPTER 3: Historical Reuse Case Studies

As mentioned earlier, indirect potable reuse has been occurring for many years on an unplanned basis throughout Texas as well as other areas of the United States and the world. No recent studies have provided estimates of the number of consumers who are provided drinking water from surface or groundwater sources that are significantly impacted by waste discharges. However, in 1980 a U.S. EPA funded study found that approximately 15 million people in the U.S. were supplied potable water from a surface water source containing more than 10 percent treated wastewater[11]. Similar levels of exposure have been identified in other studies. Indeed, some streams in the U.S. and other parts of the world, which are used as drinking water sources, consist of 100 percent treated wastewater during periods of drought[12]. Unfortunately, very little additional information has been gathered with respect to these unplanned reuse projects. Consequently, the scientific community has focused on those planned reuse projects for which significant data and experience is readily available. A selection of relevant case studies is summarized in this chapter.

3.1 Selected Domestic Case Studies

3.1.1 OCCOQUAN RESERVOIR, VIRGINIA

The Occoquan reservoir project is one of the only known planned and documented cases of indirect potable use of reclaimed water from a surface water source in the United States. The Occoquan reservoir was constructed in 1950 and expanded in 1957 to its current size to serve Fairfax and Prince William Counties, as well as parts of suburban Washington D.C. Currently, the reservoir holds approximates 30,000 acre-feet of storage with an average surface area of 2,100 acres. When the reservoir was originally built, the surrounding area was sparsely populated. However, the population in the area grew much faster than had been planned. As the population in the area increased, the community began to depend more and more on the Occoquan reservoir for its water supply. At the same time, increased discharge from secondary wastewater treatment

[11] Swayne, M. et al., Wastewater in Receiving Waters at Water Supply Abstraction Points, U.S. Environmental Protection Agency, EPA-600/2-80-044, July 1980.

[12] Kavanaugh, M.C., Unregulated and Emerging Chemical Contaminants: Technical and Institutional Challenges, Water Environment Federation, 2003.

plants (WWTPs) began to significantly affect the water quality. By 1969 the reservoir became highly eutrophic giving the area's drinking water frequent problems with taste and odor. Active viruses were also found in the reservoir and its tributaries. Since the area's attempts to improve water quality by limiting population growth had been unsuccessful, a new approach was necessary. The region was forced to pick one of two alternatives 1) export WWTP secondary effluent out of the watershed or 2) provide the highest level of treatment technology and discharge into the Occoquan reservoir. Since the area needed the effluent for its raw water supply it chose the latter. In the summer of 1978 a new advanced wastewater treatment plant was brought online to replace the 11 existing WWTPs.

The Upper Occoquan Sewage Authority's (UOSA) Water Reclamation Plant (WRP) treats an average of approximately 54 MGD of wastewater from within the Occoquan watershed, less than 2% of which is from industrial users. The wastewater is first treated with conventional secondary treatment. Calcium hydroxide is added to the secondary effluent to raise the pH to 11.3. The precipitate is flocculated with polymer and settled. Flow is sent to recarbonation basins where the pH is lowered to 9.5-10.0 with CO_2 to remove carbonates. The pH is then further reduced to 7.0. Phosphorous and organics are reduced by multimedia pressure filtration. The flow then moves on to activated carbon filters with a 30-minute empty bed detention time. Ammonia ions are removed as the flow passes through an ion exchange system. Chlorine is added to the breakpoint to remove any additional ammonia that gets through the ion exchanger system, and sulfur dioxide is added to remove the chlorine before it is discharged back into the reservoir via Bull Run Creek. The UOSA WRP has at least one backup for each mechanical and electrical system. Effluent from the WRP represents 15% of the total reservoir inflow, on average, although that number greatly increases during dry periods. The reservoir has an average detention time of approximately one month.

Since the UOSA WRP was brought online in 1978 the amount of nutrients being discharged into the reservoir has been dramatically reduced. Consequently, the overall water quality of the reservoir has improved since the WRP began operation.

3.1.2 ORANGE COUNTY, CALIFORNIA- WATER FACTORY 21

The Orange County Water District (OCWD) initiated pilot studies in 1965 to evaluate the feasibility of injecting effluent from an advanced wastewater treatment (AWT) facility into potable water supply aquifers. Operation of a 15 MGD AWT facility, known as Water Factory 21, began in 1976. Raw water for Water Factory 21 is provided by an adjacent wastewater treatment facility which produces biologically treated secondary effluent. Advanced treatment processes include lime sedimentation, recarbonation, multimedia filtration, activated carbon absorption, reverse osmosis and disinfection. Originally disinfection was performed with chlorination, but the plant recently switched to UV light and hydrogen peroxide, due to its effectiveness in removing N-nitrosodimethylamine (NDMA).

Prior to injection, the product water is blended 2:1 with deep well water from an aquifer not subject to contamination. Depending on the hydrologic conditions, the injected water flows toward the ocean to create a seawater barrier, or inland to augment the potable groundwater supply. More than half of the injected groundwater flows inland to replenish the groundwater supply. However, it is estimated that no more than 5% of the water supply for area residents is made up of reclaimed water.

Planning is currently underway to expand the program with a new Groundwater Replenishment System in 2007. For this project, a new treatment plant will allow the District to inject up to 64 MGD into the injection wells, thus providing the region with a drought-proof source of water for the future.[13]

3.2 Selected International Case Studies

3.2.1 WINDHOEK, NAMIBIA

In 1968, Namibia's capitol of Windhoek began developing a system for reclaiming potable water from domestic wastewater to supplement the potable water supply via direct reuse. Since this time, the system has been producing acceptable potable water to the City as part of a larger program to manage and conserve water. The reclamation plant operates on an intermittent basis during periods of drought to supplement the supply during peak demand periods or during emergencies. On average, the treated effluent has contributed about 10% to the water supply, although this fraction can be as high as 30% during drought periods.

The most recent facility was opened in 2002 and accepts secondary effluent from the Gammans wastewater treatment plant. The new Goreangab water reclamation plant has a capacity of 5.5 MGD and uses a multi-barrier treatment process. The treatment train includes oxidation and pre-ozonation, coagulation/flocculation, dissolved air flotation, dual media filtration, and ozonation.

[13] Orange County Water District, (http://www.ocwd.com)

The water is then further treated with biological activated carbon filters, granular activated carbon filters and dosed with powdered activated carbon. Finally, the water is sent through ultrafiltration. Chlorine is added for final disinfection and stabilization prior to blending with other waters and pumping to the distribution system.

3.2.2 SINGAPORE NEWATER

Following a very extensive testing program and public relations campaign, Singapore initiated a water reclamation program in which reclaimed water (or "NEWater") is discharged to the City's water supply reservoirs to augment supply. Currently, 2 MGD of NEWater is discharged to the reservoirs, which corresponds to about 1% of Singapore's daily water consumption. This percentage is anticipated to increase to 2.5% by 2011. Additional NEWater is used directly for industrial purposes. The advanced treatment process includes microfiltration, reverse osmosis and UV disinfection.

Singapore undertook a very extensive testing program in which approximately 190 parameters were tested and evaluated, including bacteria, viruses, hormones, carcinogens, and pharmaceuticals. In all cases, the water met the drinking water standards of both the US EPA and the World Health Organization. In addition, animal studies were performed in which fish lived in concentrated NEWater and mice drank pure NEWater for a two-year period, both showing no signs of any adverse health effects. [14,15]

[14] US Water News Online, February 2003: http://www.uswaternews.com/archives/arcglobal/3sinpum2.html

[15] The Straits Times, February 22, 2003: http://www.ecologyasia.com/NewsArchives/feb2003/straitstimes_030222_3.htm

CHAPTER 4: Water Quality Criteria for Indirect Potable Use of Reclaimed Water

As discussed earlier, Texas currently has no specific water quality standards that pertain to indirect use of reclaimed water. Any waste discharges to waters of the state must meet the criteria in the Texas Surface Water Quality Standards (TSWQS), as described in 30 TAC 307.

Since there are currently no specific federal or state criteria that address indirect potable reuse in Texas, the decision to proceed with a planned indirect reuse project must be based on a case-by-case evaluation of the particular project, the associated risks and available data and experience of other reuse efforts within and outside Texas. Based on review of the EPA guidelines, other state regulations and case studies (Chapter 3) and experience with other reuse projects in Texas, APAI has developed a proposed approach for evaluating the feasibility of augmenting White River Reservoir with reclaimed water. It should be emphasized that there are still numerous questions that remain with respect to reuse within the scientific community. Therefore, there is some level of risk associated with any project that proposes to use reclaimed wastewater for potable purposes. The goal of this evaluation approach is to provide a rational methodology for evaluation of the potential level of exposure to constituents in the wastewater, and to identify methods of reducing this exposure potential, based on the current state of knowledge.

4.1 Proposed Water Quality Evaluation Approach

4.1.1 REGULATED CONSTITUENTS

With respect to those constituents addressed in the state surface water quality standards, specified in Table 4-1, the evaluation approach is very similar to that for any wastewater discharge into waters of the state. Nutrient levels must be maintained below a level that will cause excessive eutrophication or reduce dissolved oxygen levels below the state standard. In addition, discharges must not increase the levels of chlorides, sulfates and TDS beyond the limits specified in Table 4-1. The methodology for evaluation of these constituents, while not trivial, has been established by the state and carried out for numerous waste dischargers throughout the state. The methodology typically includes the application of a water quality model to determine what permit limits are required to meet state standards.

Table 4-1: Site-specific Water Quality Criteria for White River Reservoir (Segment 1240)

Parameter	Cl^{-1} (mg/L)	SO_4^{-2} (mg/L)	TDS (mg/L)	Dissolved Oxygen (mg/L)	PH Range (SU)	Indicator Bacteria (#/100 ml)	Temperature (F)
Criteria	150	100	650	5.0	6.5-9.0	126/200	89

With respect to chloride (and indirectly, TDS), it is possible that a review of the standards by the TCEQ may result in a higher standard for the lake. Since the available data indicate that current concentrations of chloride, sulfate and TDS exceed the standard, any discharge to the lake that further increases these levels is not likely to be permitted by the TCEQ.

While application of a detailed water quality model of White River Reservoir is beyond the scope of this study, a preliminary evaluation of potential water quality issues related to those parameters listed in Table 4-1 was performed and will be discussed in Chapter 7 with respect to each proposed alternative.

In addition to those constituents addressed in the surface water quality standards, there are a number of constituents included in the drinking water standards for which monitoring and testing protocols are well established. While discharge permits are not contingent upon meeting these standards, it is APAI's recommendation that a comprehensive testing and monitoring program be established to evaluate the quality of any proposed discharge with respect to parameters included in the drinking water standards, prior to implementation of any reuse project. Such a program can identify any potential parameters of concern and may influence any decision to provide advanced treatment at either the wastewater treatment plant or the water treatment plant.

4.1.2 OTHER CONSTITUENTS

As discussed in Chapter 2, it is the emerging and unknown contaminants that present the greatest risk for reclaimed water projects. Monitoring and testing programs can be carried out for known emerging contaminants (e.g. pharmaceuticals and endocrine disruptors) to determine their levels and evaluate potential concerns. However, there is currently no data available for this group of contaminants in the Lubbock wastewater or in White River Reservoir and the science and knowledge associated with this group of contaminants is still in the early stages of development.

In the absence of specific water quality data for identified, unknown and emerging contaminants, a more general water quality evaluation approach has been identified. This approach provides a basis for comparison with other reuse projects and allows for a relative comparison of exposure potential to these unknown and emerging contaminants. The approach is based on the use of percent wastewater content and detention time as a measure of potential exposure to contaminants that may have human health impacts. Qualitatively, larger wastewater contents and shorter detention times are associated with a higher level of exposure potential. Conversely, lower wastewater content and longer detention times are associated with a lower level of exposure potential. The use of these indicators is based on the assumption that natural degradation and dilution are important factors in reducing the quantities of potentially harmful contaminants within the water supply. Although there are no standards with respect to these indicators, there are some data available, which provide a range of values for existing planned reuse projects as well as some unplanned projects. These are summarized in Table 4-2.

Table 4-2: Estimated Percent Wastewater Content and Detention Time for Selected Potable Reuse Projects

PROJECT	WASTEWATER CONTENT	DETENTION TIME (MONTHS)
Upper Occoquan Sewage Authority (1)	7%-90%	1-2
Windhoek, Namibia (direct reuse) (2)	10%-30%	n/a
Singapore (3)	1%	unknown
Unplanned Indirect Potable Reuse Projects	Up to 100% (4)	unknown

(1) DRAFT Updated EPA Reuse Guidelines, Section 2, p. 48, received in draft form, January 28, 2004

(2) Martin Creamer's Engineering News Online:

http://www.engineeringnews.co.za/eng/features/water/?show=7566

(3) US Water News Online, February 2003: http://www.uswaternews.com/archives/arcglobal/3sinpum2.html

(4) Kavanaugh, M.C., Unregulated and Emerging Chemical Contaminants: Technical and Institutional Challenges, Water Environment Federation, 2003.

As discussed in Chapter 3, the level of treatment for each of the projects listed in Table 4-2 varies. For the planned projects, some form of advanced wastewater treatment is used in all the cases listed. For unplanned projects, treatment is typically limited to standard secondary treatment, although some advanced treatment for nutrient removal may be used in some cases. Table 4-2 indicates that there has been a wide range of percent wastewater content and detention time values observed. For the planned projects, average values are in the range of 10-30%, with some much higher values occurring during drought conditions. For unplanned projects, data is more difficult to obtain; values are likely to be in a similar range, but with a lower level of treatment. With respect to detention times, the Upper Occoquan Sewage Authority project has typical detention times on the order of 1-2 months, whereas a City of San Diego pilot project proposed using detention times on the order of 6-12 months. The Windhoek, Namibia project has detention times on the order of hours or days, since it is a direct reuse application.

Given the many uncertainties associated with the use of reclaimed water for augmentation of potable water supplies, and based on the very limited experience of existing planned projects, a limit on average percent wastewater content (percent blend) of approximately 30%, combined with a minimum average detention time of 1 year have been adopted as general water quality criteria to be applied when evaluating exposure potential for each of the alternatives discussed later in this report. These criteria have been established to provide guidance for determining upper limits on quantities of wastewater effluent that can be used to augment the supply. However, there is latitude for some variation from these criteria, particularly with the use of multiple barriers and implementation of appropriate advanced wastewater treatment.

CHAPTER 5: Water Quality Evaluation of White River Reservoir

By their very nature, lakes and reservoirs collect the constituents that enter these water bodies from various sources. The sources of these constituents can include storm water runoff from various land uses, wastewater discharges, interbasin transfers of water, and groundwater sources. Storm water runoff is generally the largest contributor of water to lakes. The land uses that contribute this runoff can include undeveloped land, agricultural land, urban land, recreation areas, and other land uses in the watershed. The constituents that enter a lake can include oxygen demanding substances, salts, nutrients, suspended solids, naturally occurring substances, and man-made chemicals. Some of these substances leave the lake with the released water, some substances settle to the lake bottom, some substances are recycled during lake turnovers in the fall, some substances are converted to other forms, and some substances are involved in complex interactions with the aquatic life cycle.

5.1 Texas Surface Water Quality Standards

As large lakes get older, the concentrations of the contributed constituents tend to increase in the lake waters. To protect the water quality of Texas lakes, the Texas Commission on Environmental Quality (TCEQ), the Environmental Protection Agency (EPA), and other agencies have established limits for various substances in lake waters. The TCEQ's Texas Surface Water Quality Standards (TSWQS), which are revised every three years, set forth limits for many substances in lakes. A water quality standard is the combination of a designated use (e.g. Contact Recreation, High Aquatic Life, Public Water Supply) and the criteria necessary to maintain that use. White River Reservoir is a classified segment (segment 1240) of the Brazos River basin and, as such, has specific water quality standards, previously defined in Table 4-1. Any discharge to this segment must not result in the violation of these standards. Concentration limits for many other substances are listed in the TSWQS for Texas waters for Aquatic Life Protection and Human Health Protection. The TCEQ also publishes standards that limit the concentrations of various substances for public water supply sources.

5.2 Texas Water Quality Inventory and 303(d) List

The TCEQ frequently reviews the water quality of Texas Lakes. Every two years, the Commission is required by the EPA to publish the Texas Water Quality Inventory (known as the 305(b) Report) and the 303(d) List. These reports are required by Sections 305(b) and 303(d) of the federal Clean Water Act. The Water Quality Inventory provides a summary of water body uses that are supported (achieved), water body uses that are not supported, and water quality concerns. Water body uses can include Aquatic Life Use, Contact Recreation Use, General Use, Fish Consumption Use, and Public Water Supply Use. Water body concerns can include Nutrient Enrichment Concern, Algal Growth Concern, Sediment Contaminants Concern, Fish Tissue Contaminant Concern, and Public Water Supply Concern. The 303(d) List identifies impaired water bodies for which effluent limitations (or other source limitations) are not stringent enough to maintain water quality standards.

5.3 Nutrient Criteria

There are currently no numerical criteria for nutrients in the TSWQS. The TCEQ does currently consider nutrient controls by 1) applying narrative criteria to address nutrient loadings at sites of concern, 2) developing watershed rules which require additional treatment of wastewater discharges in or near specified water bodies, and 3) employing TCEQ's antidegradation considerations for increases in discharge loads. TCEQ also screens ammonia, nitrite plus nitrate, ortho-phosphorus, total phosphorus, and chlorophyll-*a* monitoring data as a preliminary indication of areas of possible concern for the Water Quality Inventory and 303(d) listings of impaired water bodies. The nutrient screening criteria for Texas lakes are shown in Table 5-1. If the screening level is exceeded for greater than 25 percent of the measured values at a particular sampling site, then this parameter is labeled a "concern". Generally, the TCEQ utilizes approximately five years worth of data with ten samples or more.

Table 5-1: Nutrient and Chlorophyll Screening Criteria

PARAMETER	CONCENTRATION
Ammonia (NH_3-N)	0.106 mg/L
Nitrite plus Nitrate (NO_2 + NO_3)	0.32 mg/L
Ortho-Phosphorus (OP)	0.05 mg/L
Total Phosphorus (TP)	0.18 mg/L
Chlorophyll *a* (Chl *a*)	21.4 ug/L

The EPA has indicated that states must develop nutrient criteria and begin incorporating them into their water quality standards by the end of 2004. The TCEQ has stated that they will develop and evaluate criteria to address nutrients and eutrophication as well as complementary approaches towards controlling nutrients. The TCEQ will also develop procedures to implement the application of criteria to permitting. The effort will be staged over several years. Preliminary criteria development will focus on major reservoirs. Criteria for streams and rivers, estuaries, and wetlands will subsequently be evaluated.

The TCEQ is exploring different strategies to develop nutrient criteria. Some of the strategies now being investigated include: 1) basing criteria on direct concentrations of nutrients; 2) basing criteria on direct indicators of eutrophication - such as chlorophyll-*a*; 3) developing "translator" procedures that relate concentrations of nitrogen and phosphorus to direct indicators of eutrophication; 4) relating criteria to protecting water-quality related uses, and 5) basing criteria on various percentiles of ambient concentrations of nutrients and chlorophyll *a* as outlined in the EPA's guidance documents.

5.4 Water Quality Characteristics of White River Reservoir

The TCEQ makes available surface water quality monitoring data collected from surface waters in Texas. These data are used by the TCEQ to establish management policies related to Texas surface water resources. The surface water quality monitoring program is intended to provide the means to evaluate the physical, chemical and biological characteristics of aquatic systems in relation to their intended uses and include measurements of a wide range of parameters.

Historical data for several key parameters in White River Reservoir are shown in Figures 5-1 through 5-5 for the period between 1999 and 2003. With respect to chloride, sulfate and TDS (Figures 5-1, 5-2 and 5-3), the data show a steady increase in concentration since 1999. In fact, these data suggest that ambient concentrations of all of these parameters currently exceed the surface water quality criteria listed in Table 4-1 for this segment. These increasing concentrations are likely attributable at least in part to the hydrologic conditions during this period. As mentioned in Chapter 1, this area has received very little precipitation since 1999 and lake levels have dropped significantly during this time (see Figure 1-1). Consequently, it is to be expected that concentrations of dissolved solids would have increased during this period.

Historical measurements of dissolved oxygen (DO), nitrate and phosphorus are shown in Figures 5-4 through 5-6. The DO measurements are presented as vertical profiles, and as expected, there is strong seasonal variation in DO concentrations in the lake. Comparison to the TSWQS for DO is made to measurements taken in the epilimnion (upper layer). The data indicate that measured DO levels in the epilimnion are well above the standard of 5.0 mg/L, even during the summer months. Measured concentrations of nitrate and phosphorus indicate that there are currently no significant problems with elevated levels in the reservoir.

5.4.1 WATER QUALITY INVENTORY AND 303 (d) LIST

White River Lake has been identified as a threatened water body in the General Use category on the 2004 draft 303(d) list due to elevated levels of chloride. Aquatic Life, Contact Recreation and Public Water Supply uses are listed as fully supported. Fish Consumption use was not assessed. With respect to the general use category, the TCEQ has assigned chloride to category 5b, indicating that "a review of the water quality standards for this water body will be conducted before a TMDL is scheduled". No other concerns were identified in the water quality inventory, which has not been updated since 2002.

Figure 5-1: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
TDS

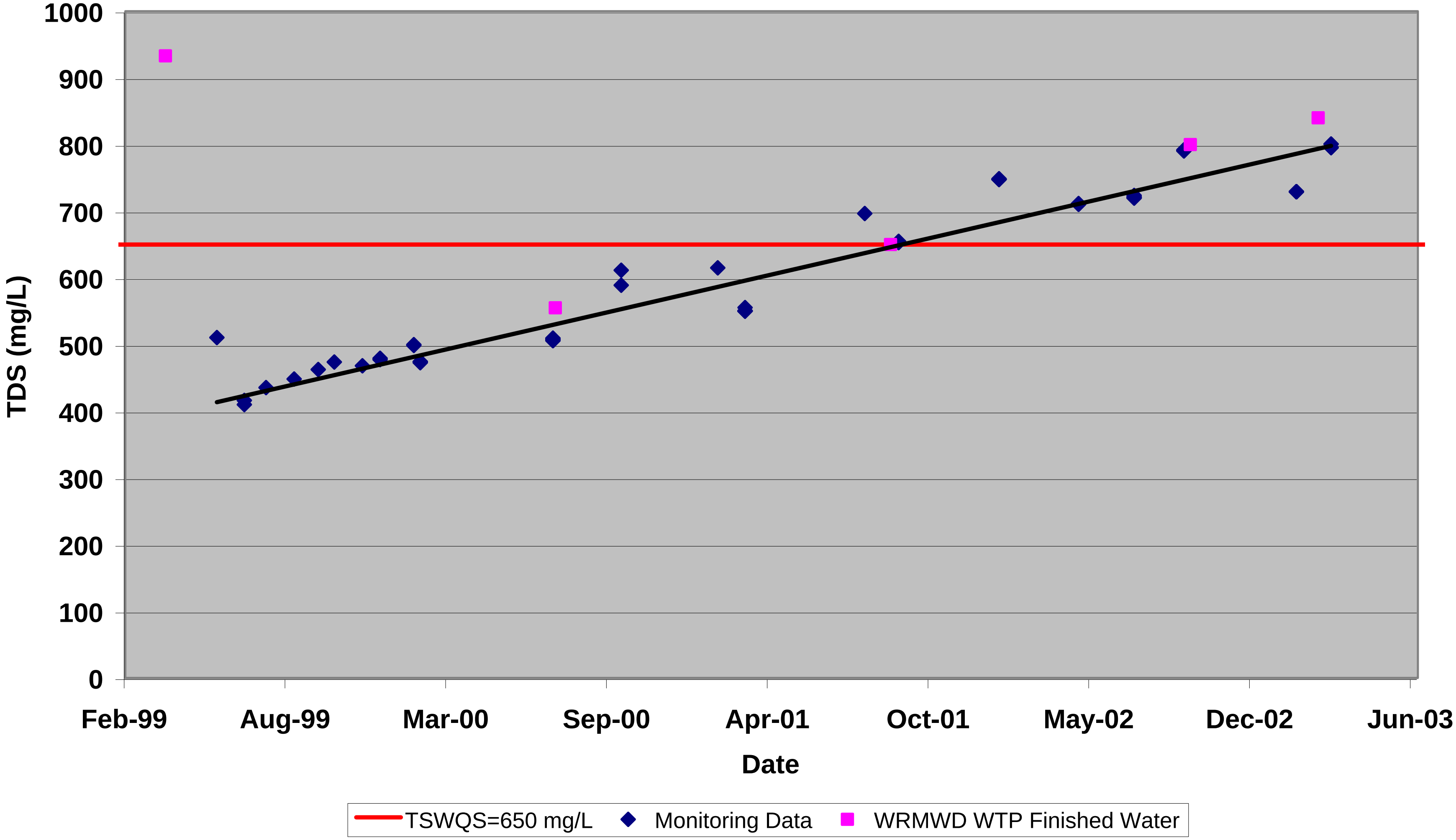


Figure 5-2: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
Chloride

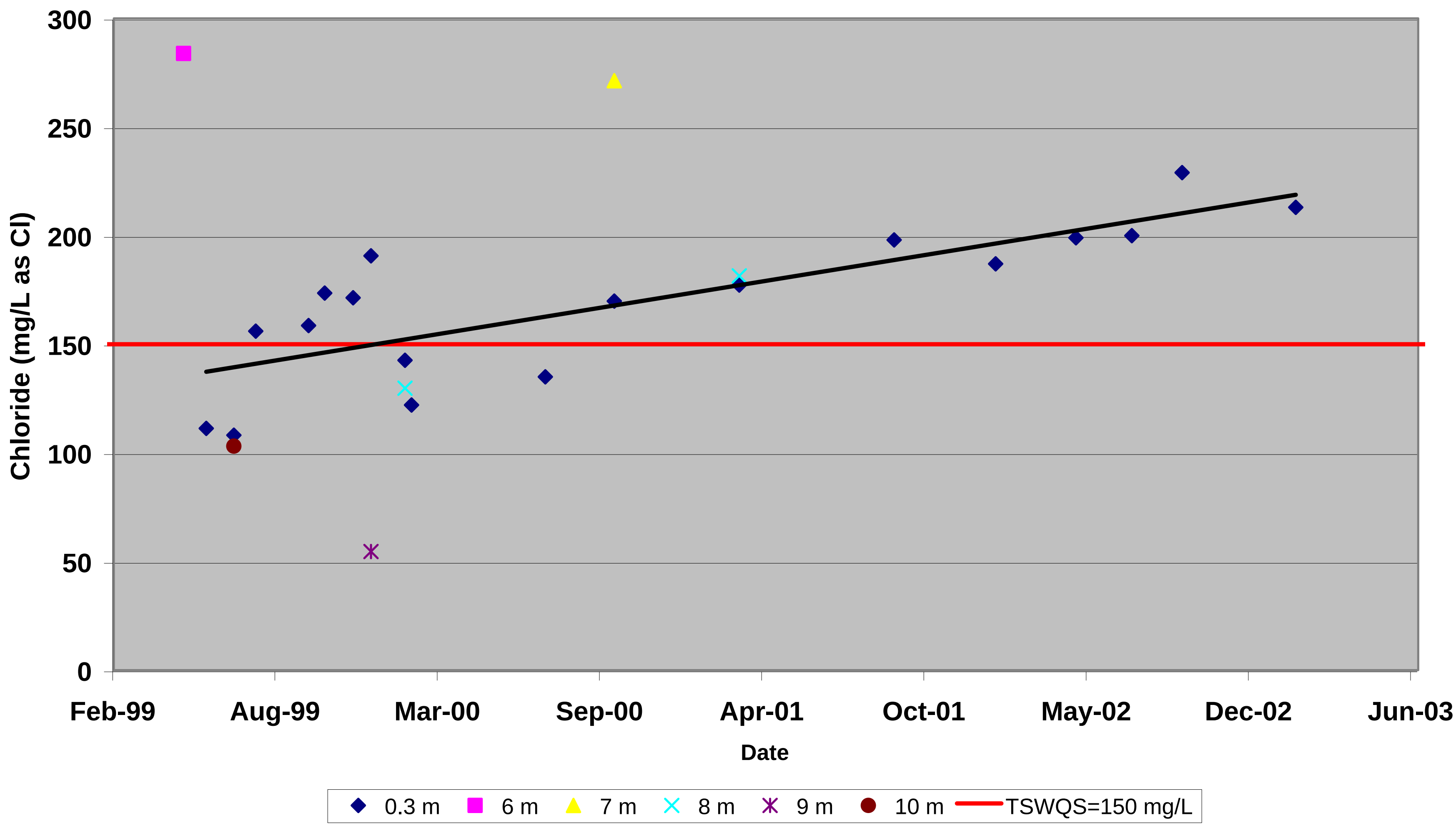


Figure 5-3: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
Sulfate

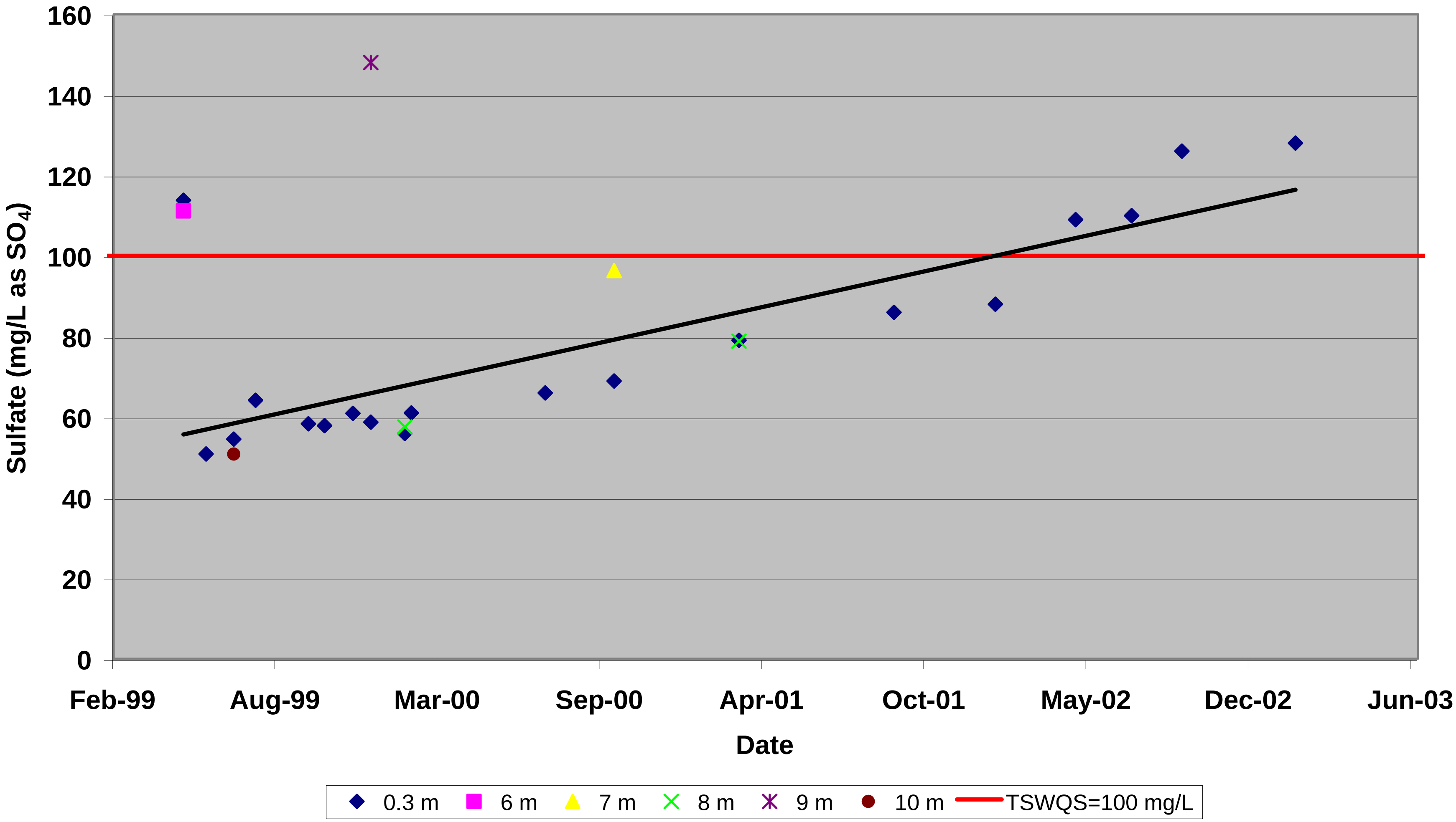


Figure 5-4: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
Dissolved Oxygen

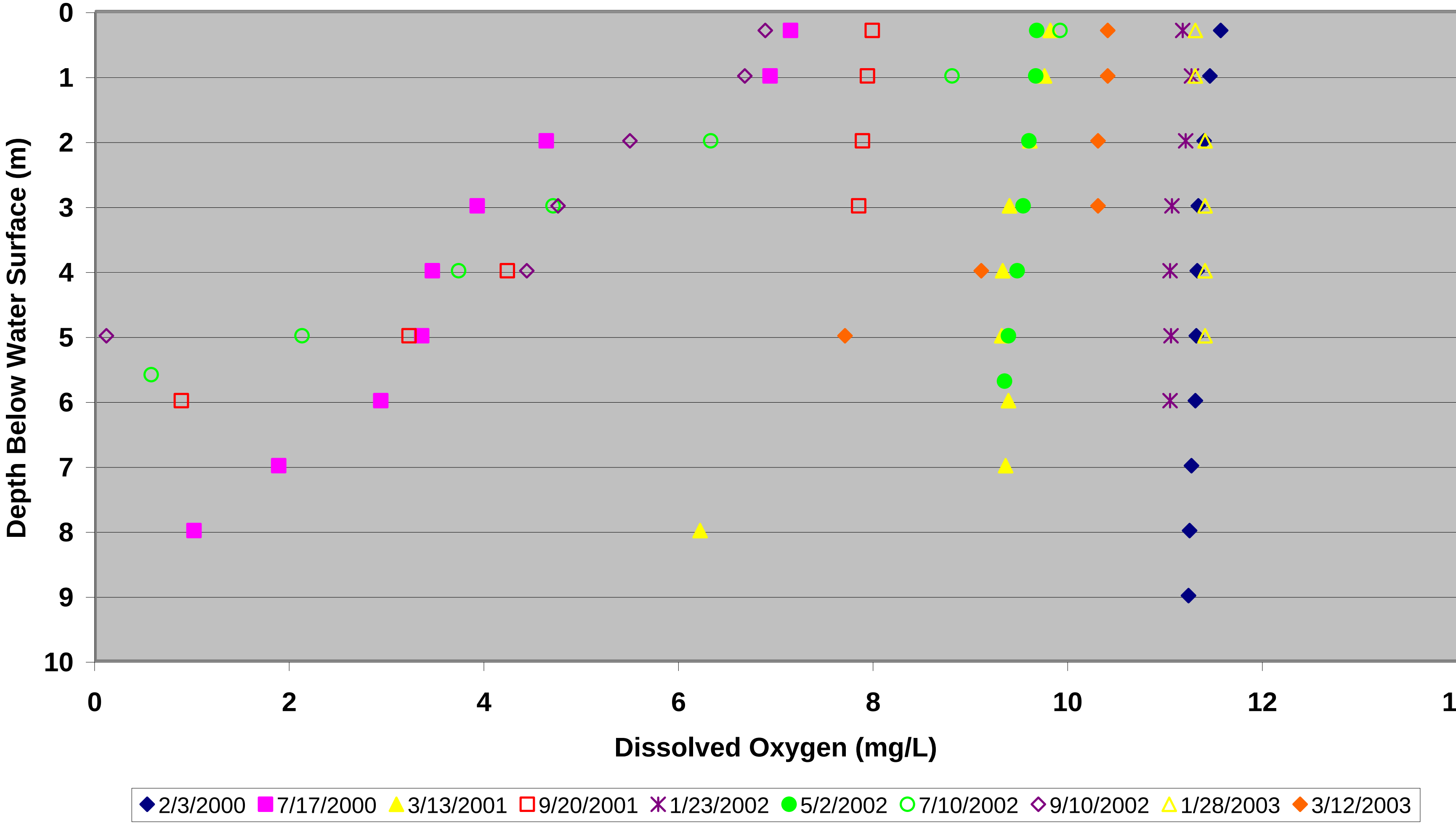


Figure 5-5: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
Nitrate Nitrogen

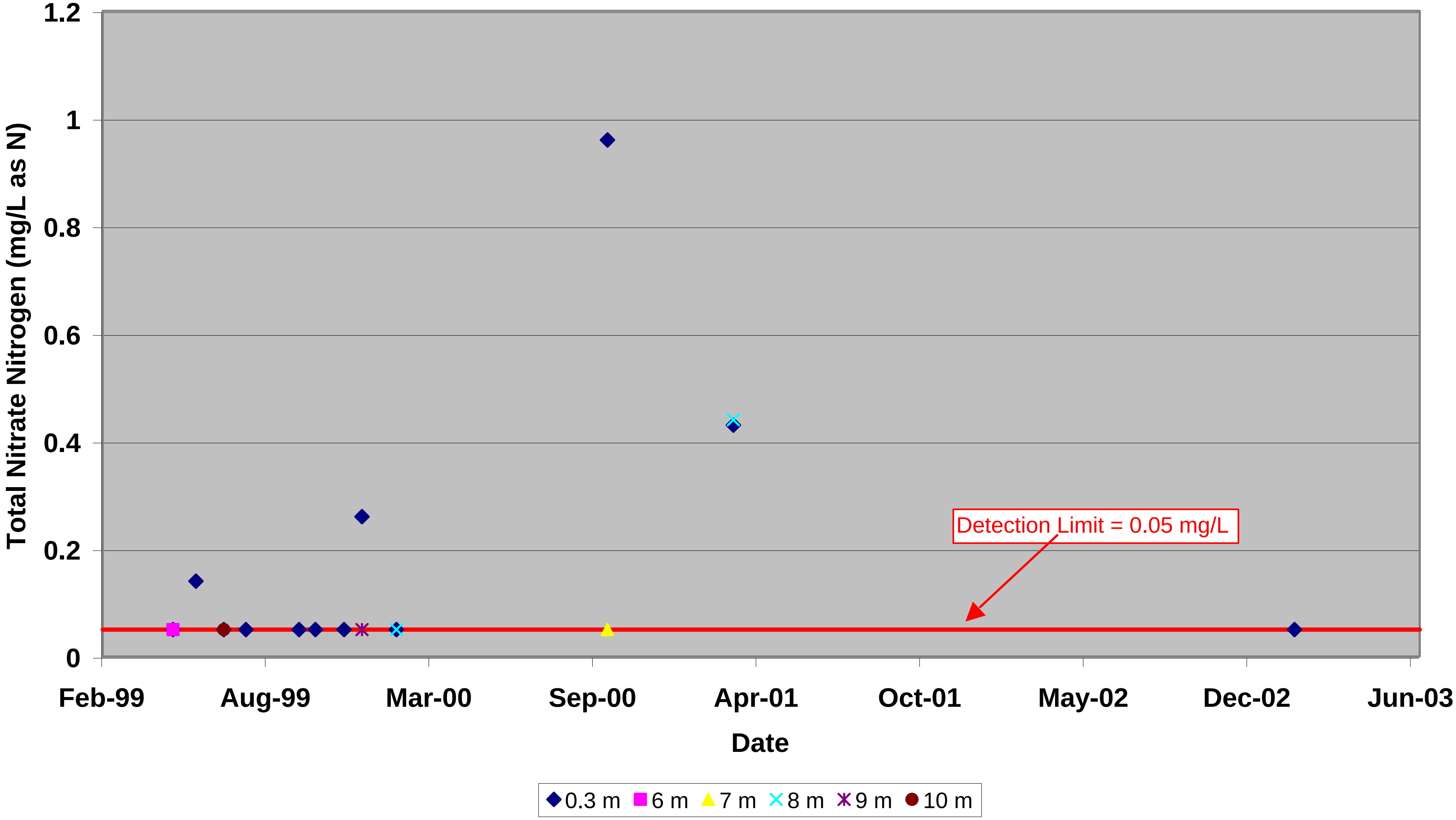
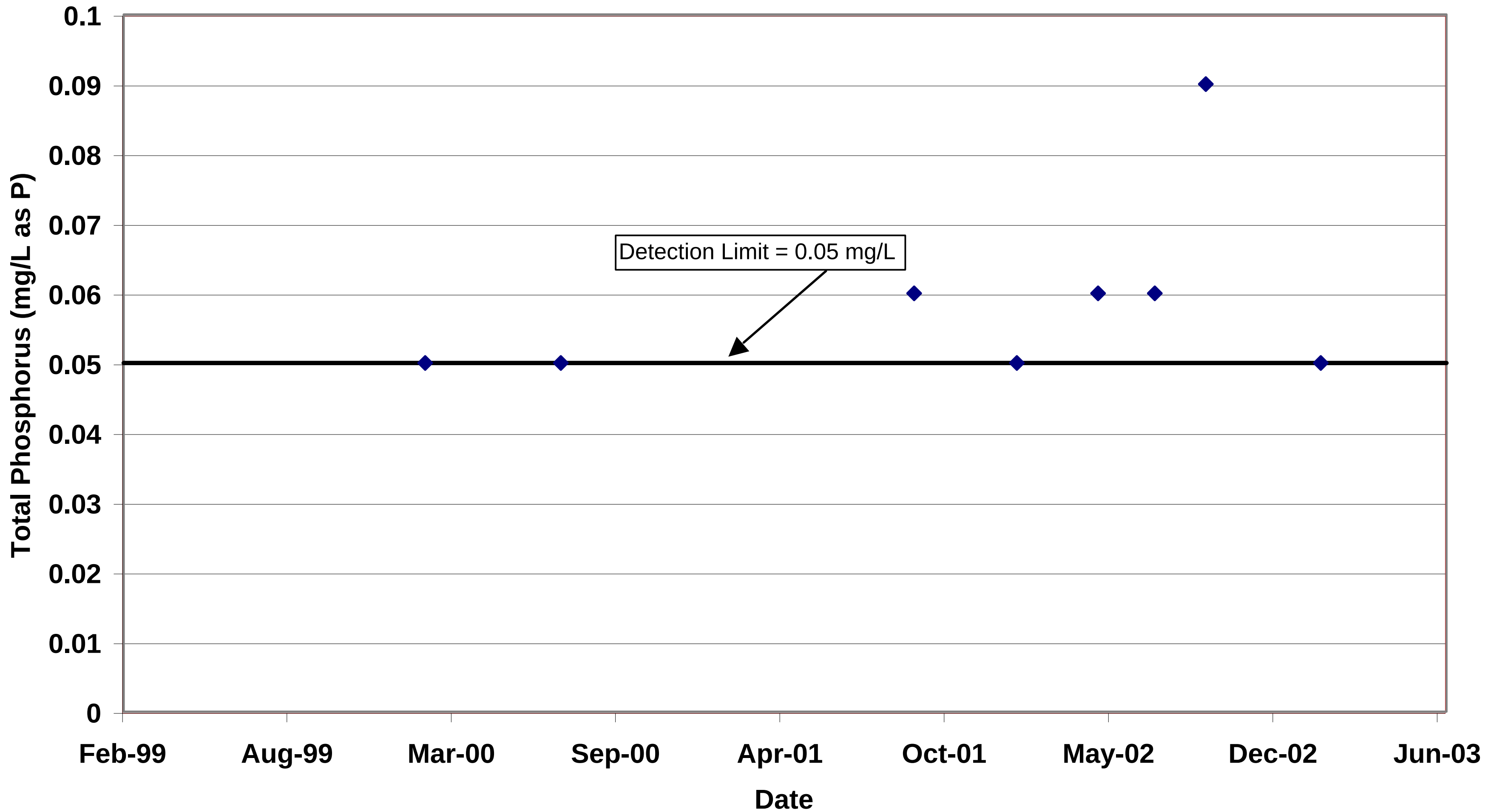


Figure 5-6: White River Municipal Water District
White River Reservoir Surface Water Quality Monitoring Data, 1999-2003
Total Phosphorus



CHAPTER 6: Water Quality Characteristics of Potential Water Supply Sources

6.1 North Fork Double Mountain Fork Brazos River

Since the City of Lubbock currently has a permit to discharge wastewater to the North Fork of the Double Mountain Fork of the Brazos River (North Fork), diversion of water from this stream segment has been considered in one of the alternatives addressed later in this report. The District has collected water quality data at various sampling locations on the North Fork over the past twenty years. Much of these data were collected in the late 1980s, though a small amount of data were also collected more recently in 2001. Table 6-1 provides a summary of these data. The data indicate that TDS concentrations within the North Fork are significantly greater than the surface water quality standard of 650 mg/L in White River Reservoir. This issue is discussed in detail with respect to the augmentation alternatives presented in Chapter 7.

Table 6-1: Summary of Water Quality Data for All Stations on the North Fork Double Mountain Fork (1986-2001)

	TDS (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Na^+ (mg/L)	Total Hardness (mg/L)
Average	1177	384	255	258	475
Median	1358	410	270	273	564
Minimum	296	53	44	34	67
Maximum	1839	600	375	533	640
Standard Deviation	474	147	80	110	184

6.2 City of Lubbock Wastewater

The water quality characteristics of the City of Lubbock wastewater, Pump Station #1, are summarized in Table 6-2 and plots of the data are presented in Figure 6-1 through 6-4. These data represent water quality characteristics of the City's wastewater that undergoes tertiary treatment and is discharged to the North Fork. It should be noted that the City has a program that utilizes land application of wastewater. The wastewater used for land application is not treated to the same level as the wastewater discharged to the North Fork from Pump Station #1. Again, as for the North Fork, TDS concentrations are significantly greater than the water quality standard of 650 mg/L in White River Reservoir. This issue will be discussed in detail in Chapter 7.

Table 6-2: Summary of Water Quality Data from Pump Station #1, City of Lubbock WWTP (Apr 2003-July 2003)

	pH	BOD_5 (mg/L)	TSS (mg/L)	NO_3-N (mg/L)	NH_3-N (mg/L)	Total P (mg/L)	TDS (mg/L)	TKN (mg/L)	Total N (mg/L)	Cl_2 (mg/L)	DO (mg/L)
Minimum	7.10	2	3	6.9	0.23	3.80	1220	1.16	14.8	0.06	3.4
Average	7.42	6	9	17.4	1.08	4.56	1436	2.34	20.3	2.48	5.6
Maximum	7.90	25	46	29.2	5.24	5.52	1600	6.10	31.2	41.0	7.2
Median	7.42	4	6	16.9	0.49	4.67	1440	1.93	18.9	0.23	5.9

Figure 6-1: White River Municipal Water District
City of Lubbock WWTP Discharge Data, Pump Station #1
TDS

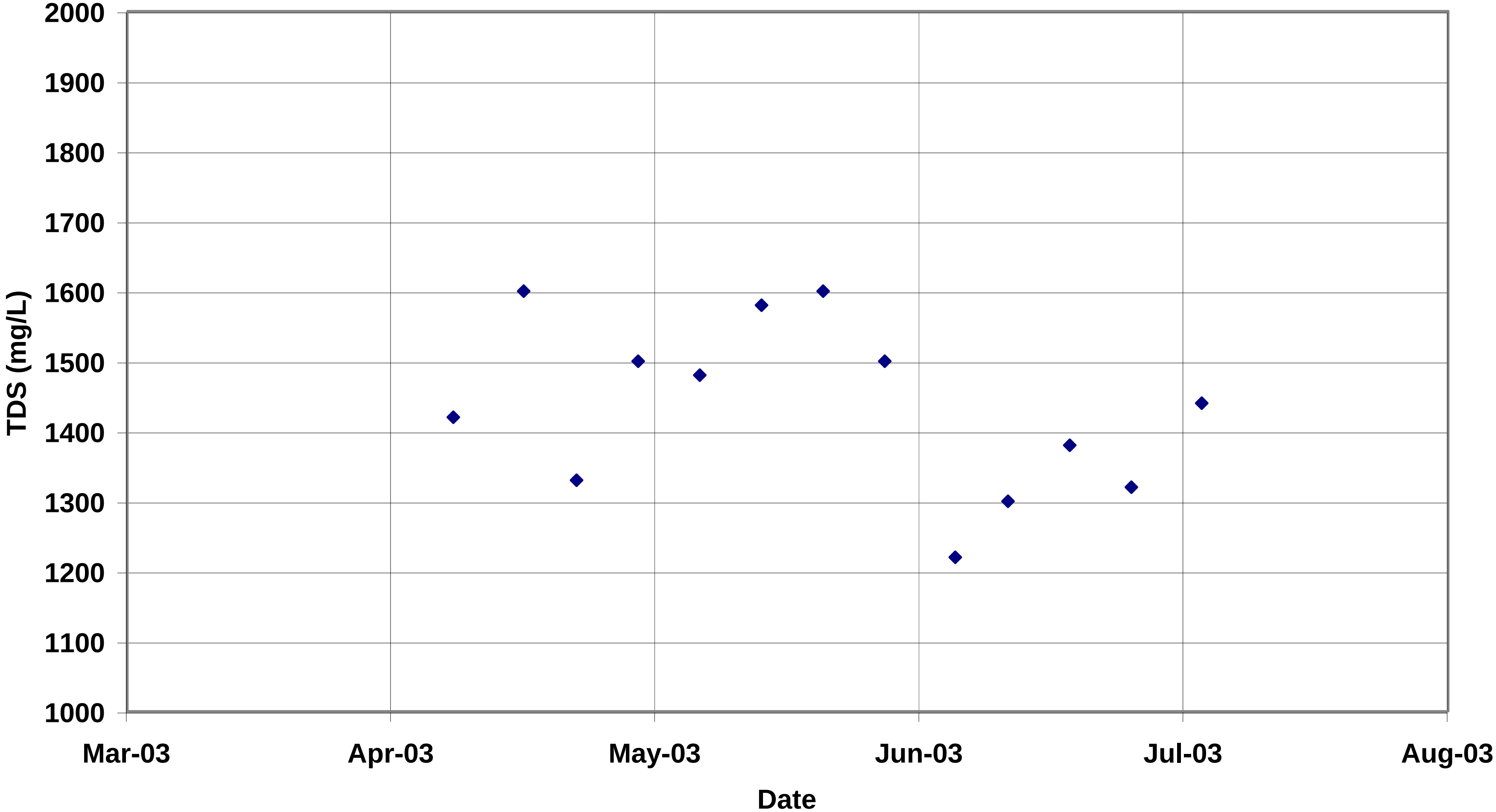


**Figure 6-2: White River Municipal Water District
City of Lubbock WWTP Discharge Data, Pump Station #1
Dissolved Oxygen**

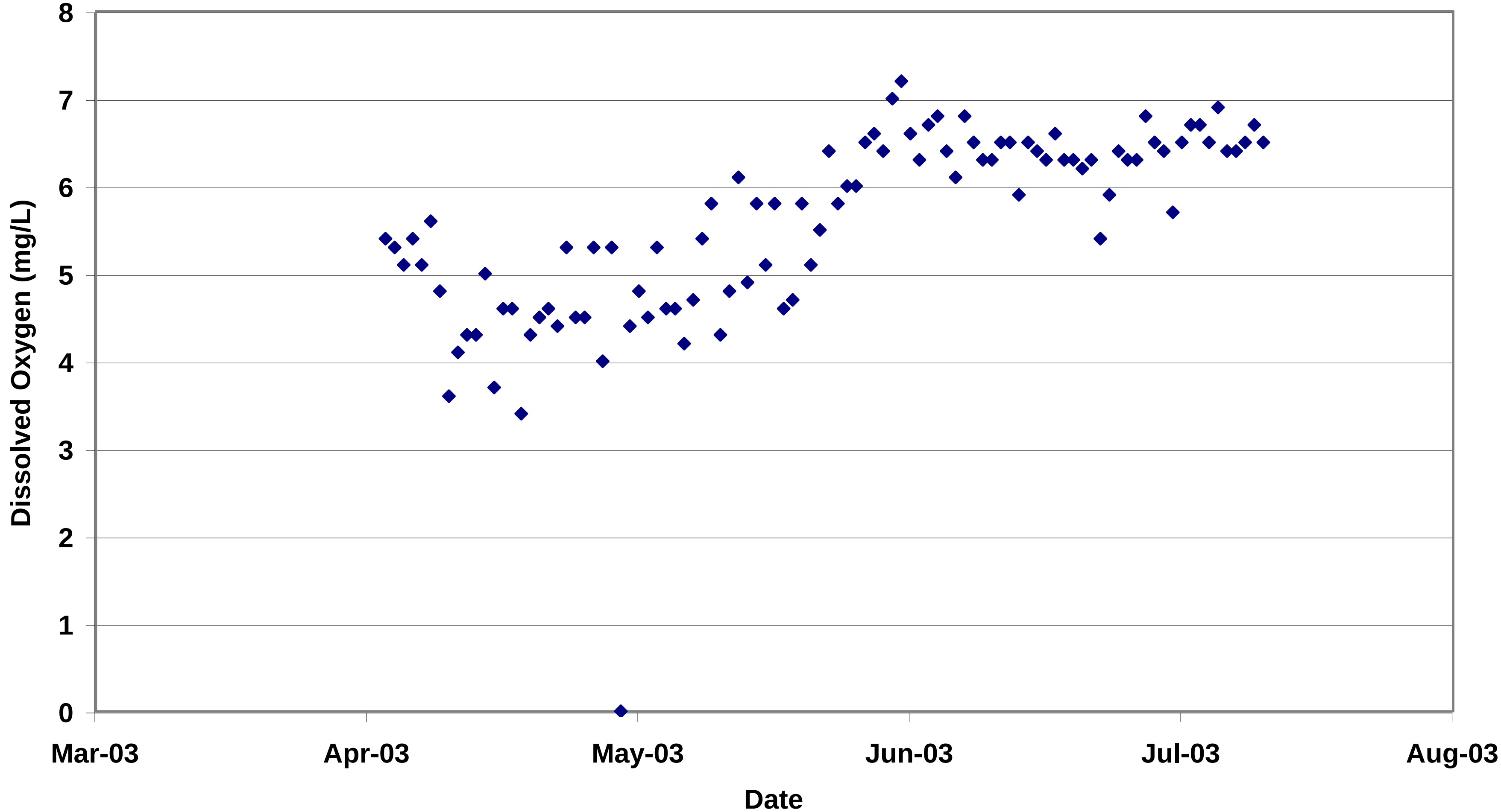


Figure 6-3: White River Municipal Water District
City of Lubbock WWTP Discharge Data, Pump Station #1
Nitrogen

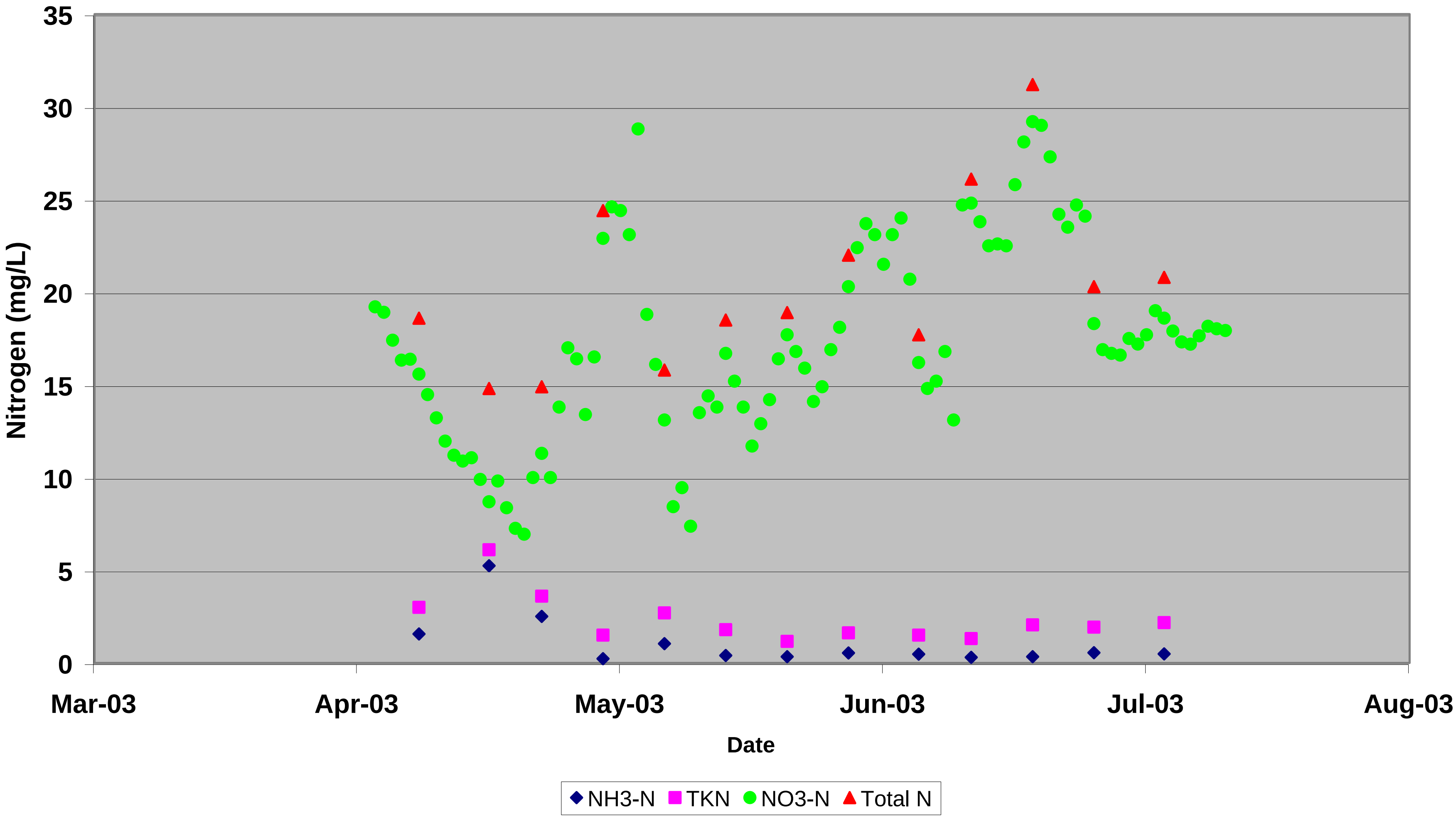
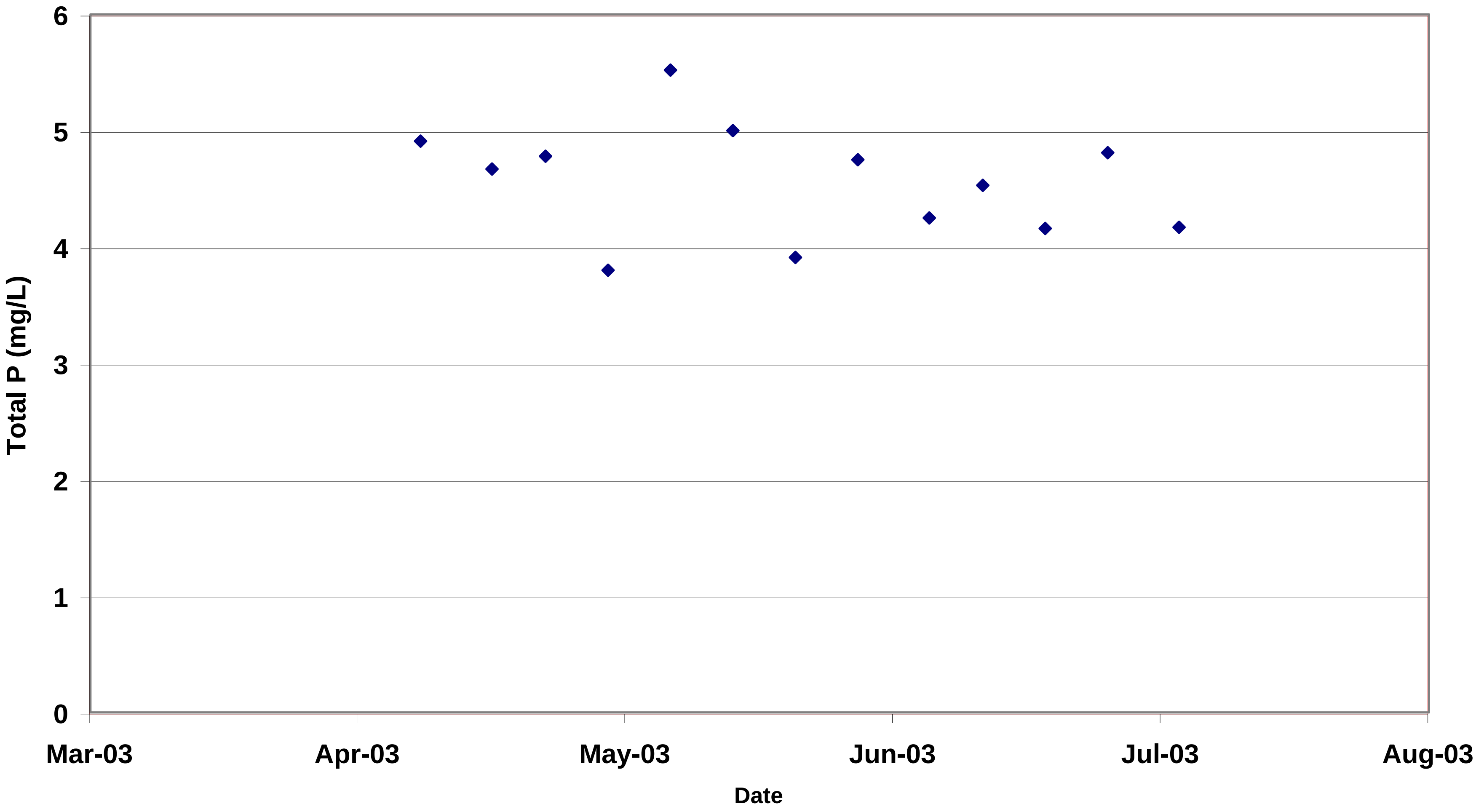


Figure 6-4: White River Municipal Water District City of Lubbock WWTP Discharge Data, Pump Station #1 Total Phosphorus



CHAPTER 7: Alternatives for Augmentation of White River Reservoir with Reclaimed Water

7.1 Definition of Alternatives

Three alternatives for augmentation of White River Reservoir with City of Lubbock reclaimed water were selected for further evaluation. Each of these alternatives will be defined in this section. Following presentation of the augmentation alternatives, an evaluation of water quality will be presented, as well as a discussion of relevant permitting and legal issues associated with each alternative. Finally, opinions of probable cost will be presented for each alternative.

As will be discussed in detail in a later section, due to high TDS levels in the City of Lubbock wastewater effluent in comparison to the TDS standard in White River Reservoir, control of TDS levels was a major consideration in the development of the augmentation alternatives. Two of the alternatives are based on the assumption that TDS levels will be controlled such that future TDS concentrations in the reservoir will not exceed historically measured levels in the reservoir (as shown in Figure 5-1). The third alternative is based on the assumption that the water quality standard for TDS (currently 650 mg/L) could be increased significantly to accommodate direct discharge of the Lubbock effluent into a proposed constructed wetlands upstream of the reservoir without removal of TDS. Treatment for TDS removal would then be provided at the water treatment plant to meet drinking water standards prior to distribution to the District's customers. The feasibility of each alternative with respect to regulatory and economic considerations will be discussed in later sections of this chapter.

7.1.1 ALTERNATIVE #1: REVERSE OSMOSIS TREATMENT AT LUBBOCK WWTP AND DIRECT PIPELINE TO WETLAND/WHITE RIVER RESERVOIR

A schematic representation of Alternative #1 is presented in Figure 7-1. In addition, Figure 7-2 provides a map of the region, with preliminary routing of pipelines shown for each alternative. In Alternative #1, secondary effluent from the City of Lubbock WWTP is treated with reverse osmosis (RO) on an as-needed basis to remove TDS such that historical levels of TDS are maintained in the reservoir. As will be discussed in a later section, during drought periods, there are times during which 100% of the wastewater must be treated with RO in order to maintain historical levels in the lake. Therefore, the RO units must be sized to accommodate all of the proposed discharge to the reservoir.

Figure 7-1
White River Municipal Water District Reuse Augmentation Study
System Schematic – Alternative #1

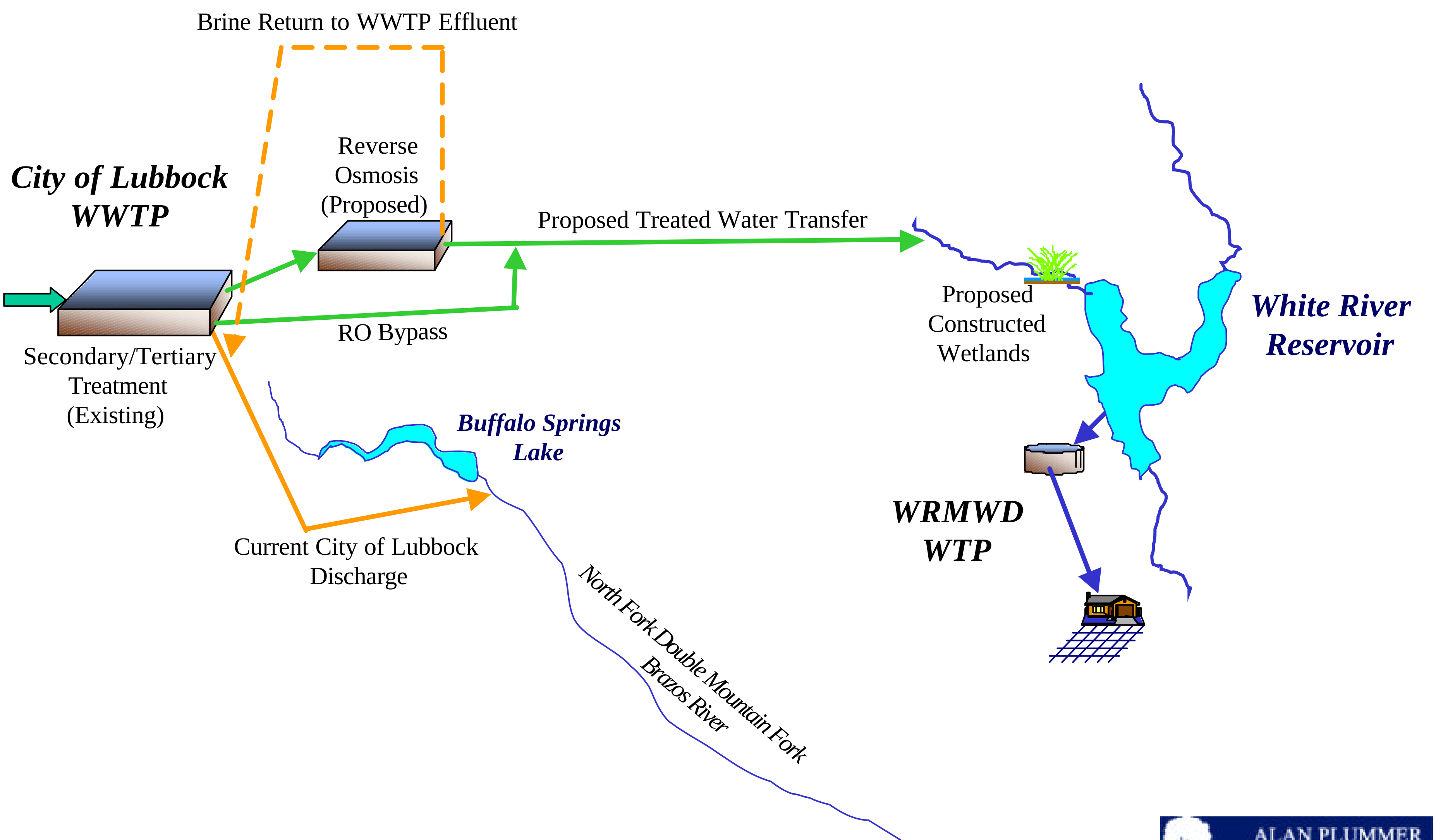


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Figure 7-2: Map of District Service Area and Preliminary Pipeline Routings

Please refer to map in pocket at back of report.

Following RO treatment, the effluent will be piped directly to a proposed constructed wetlands, located on a tributary to White River Reservoir. The wetlands will provide treatment for removal of nutrients from the effluent, but also provides additional “polishing” and removal of many other constituents prior to discharge into the reservoir. Although much of the research is currently ongoing, several studies have shown that natural processes occurring in wetlands systems degrade a number of potential contaminants that may be present in wastewater (see Section 2.3.2). Thus, in addition to nutrient removal, the wetlands system provides an additional treatment barrier to other unknown constituents that may be present in the wastewater effluent.

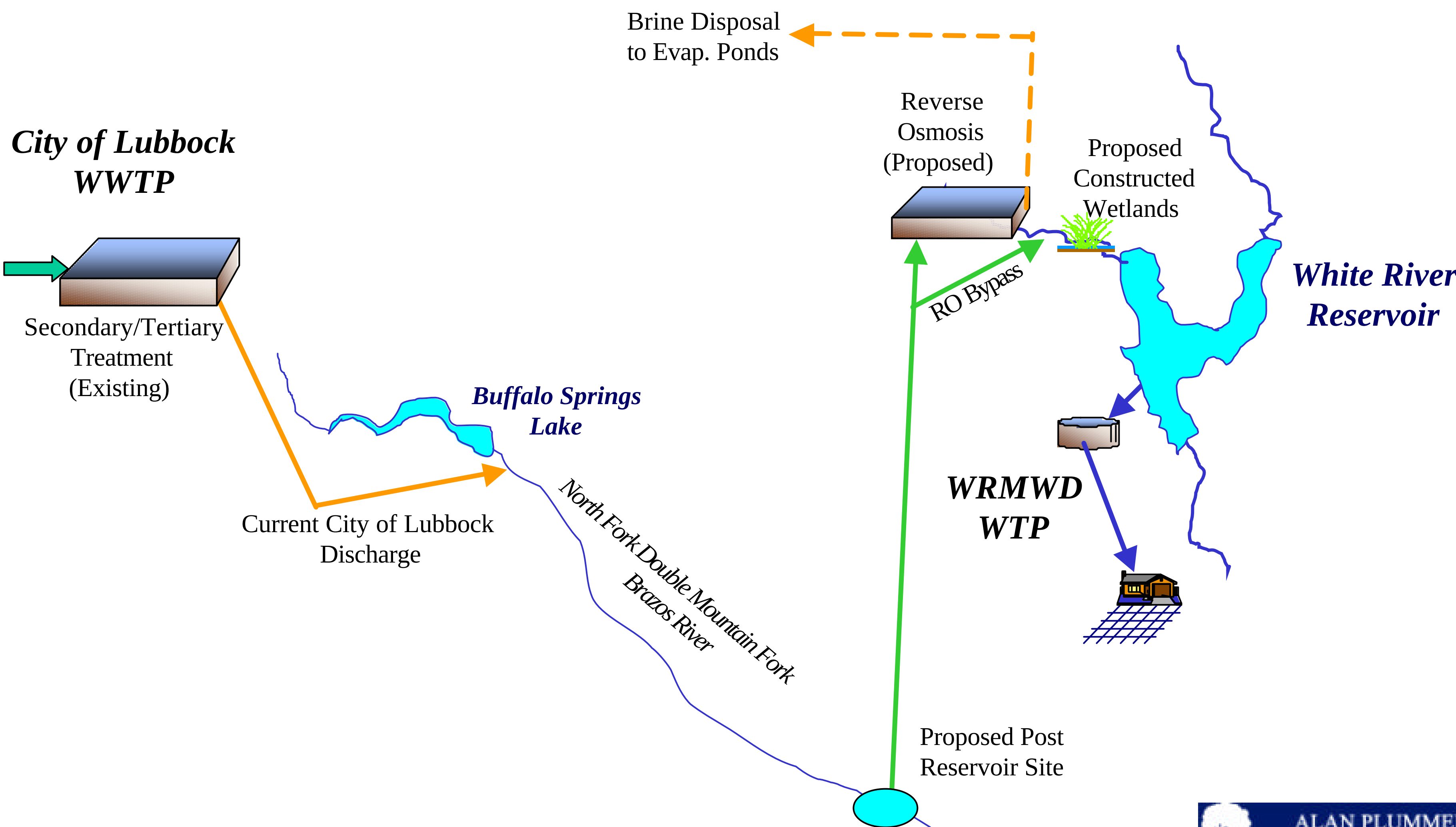
Following discharge to the wetlands system, the water flows into the reservoir, mixes with the ambient waters, and is eventually withdrawn at the District’s intake for treatment at the existing water treatment plant (WTP) prior to distribution to District customers.

For this alternative, it is assumed that the required permits can be obtained to discharge the brine reject stream from the RO treatment process to the North Fork Double Mountain Fork (North Fork) at the location currently permitted for the City of Lubbock wastewater discharge. However, implementation of this alternative would require a more detailed evaluation of water quality and permitting issues associated with this assumption. If discharge to the North Fork is not allowed, additional brine disposal costs would need to be considered for this alternative.

7.1.2 ALTERNATIVE #2: DISCHARGE TO NORTH FORK OF DOUBLE MOUNTAIN FORK AND DOWNSTREAM DIVERSION FROM FUTURE POST RESERVOIR SITE

A schematic representation of Alternative #2 is shown in Figure 7-3. For this alternative, tertiary effluent from the City of Lubbock WWTP is discharged to the North Fork at the currently permitted discharge location downstream of Ransom Canyon Lake. The water then flows down the North Fork to a diversion point located at the proposed site of the future Post Reservoir. From this diversion point, the water is pumped to a proposed RO facility located at White River Reservoir. As with Alternative #1, the water is treated with RO on an as-needed basis to maintain TDS levels within the reservoir within the range of historically measured values. The remainder of Alternative #2 is identical to Alternative #1. Flow is passed through a constructed wetlands, into the reservoir and subsequently treated at the District’s WTP prior to distribution to District customers.

Figure 7-3
White River Municipal Water District Reuse Augmentation Study
System Schematic – Alternative #2



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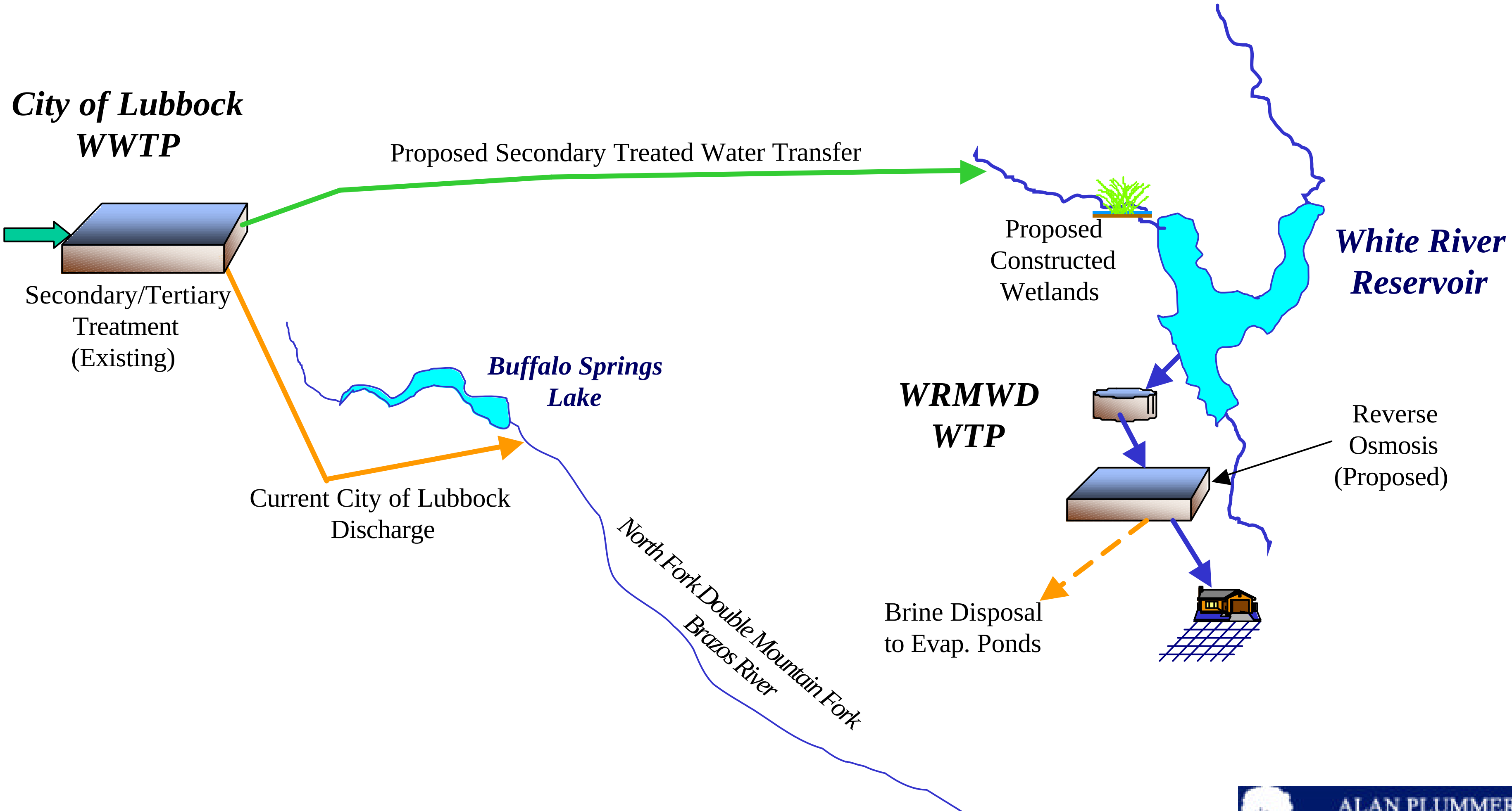
This alternative was initially selected because it was thought that there could be some water quality benefit associated with blending the Lubbock wastewater discharge with natural flows in the North Fork as well as with natural attenuation processes resulting from the travel time between the discharge and diversion locations. However, further evaluation of conditions in the North Fork suggests that it may be difficult to take advantage of these potential benefits. As discussed in Chapter VI, TDS concentrations in the North Fork are very similar to those measured in the City of Lubbock wastewater effluent. Therefore, little to no dilution of TDS would be expected as a result of mixing with ambient waters.

In addition, stream losses within the North Fork can be quite large, particularly in the summer months. Observations made during August 2003 by APAI in the North Fork indicated that there was no flow in the river at the FM 207 crossing north of Post. Very rough estimates of flow just downstream of the Lubbock discharge location (downstream of Ransom Canyon Reservoir) indicated that the flow at this point was approximately 2 to 3 MGD. Similar observations were made in February 2004 when the flow was estimated to be between 4 to 5 MGD immediately downstream of the Lubbock discharge and 2 to 3 MGD at the FM 207 crossing. Based on these observations, it is likely that very little flow would be available for diversion during the warmer months. With larger discharges to the North Fork by Lubbock, some water may reach the proposed diversion location, but a more detailed evaluation of stream flows under these conditions is necessary in order to make this determination. For purposes of this study, it was assumed that diversion of the required augmentation quantity would need to occur over a 6-month period, i.e. enough flow would be available for diversion only during 6 months of the year. Thus, pumping, transmission and RO treatment facilities, as well as the constructed wetlands, were sized to convey and treat twice the quantity required for augmentation on an annual average basis.

7.1.3 ALTERNATIVE #3: DIRECT PIPELINE TO WETLAND/WHITE RIVER RESERVOIR; REVERSE OSMOSIS TREATMENT AT WHITE RIVER WTP

A schematic representation of Alternative #3 is shown in Figure 7-4. For this alternative, it is assumed that the TDS standard in the lake can be changed to accommodate effluent that has not undergone RO treatment prior to discharge to the proposed wetlands. Thus, secondary effluent from the Lubbock WWTP will be piped directly to a discharge point upstream of the wetlands. Effluent from the wetlands will enter the reservoir. Raw water from the reservoir is then treated at the existing District WTP. A portion of this water would then undergo RO treatment to lower TDS levels in the treated supply below those specified by drinking water standards.

Figure 7-4
White River Municipal Water District Reuse Augmentation Study
System Schematic – Alternative #3



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Modification of the surface water quality standards to accommodate significantly higher TDS levels in the lake is likely to be a major obstacle to implementation of this alternative. Although there are some lakes with much higher TDS standards in Texas (e.g. Possum Kingdom Lake, 3500 mg/L TDS standard, Lake Granbury, 2500 mg/L), it is unlikely that the TCEQ would raise the standard on a lake to accommodate high TDS levels resulting from import of waters for purposes of augmenting the supply. This issue and others associated with this alternative will be discussed in greater detail later in this chapter.

7.2 Water Quality Evaluation of Augmentation Alternatives

7.2.1 METHODOLOGY AND ASSUMPTIONS

In order to evaluate each of the augmentation alternatives, APAI developed a water balance model that can be used to evaluate water quality in the reservoir. Initially, input to the model consisted of historical data, in order to simulate historical water quality conditions in the lake over the time period from July 1979 to December 2002. The District provided monthly data for lake level and raw water intake flow quantities over this period, while historical precipitation and evaporation rates were taken from published Texas Water Development Board (TWDB) data. Historical natural inflows were then back-calculated on a monthly basis from these data.

For the purpose of calculating relevant water quality parameters such as the wastewater percent blend and reservoir detention time, complete mixing in the reservoir was assumed. In addition, for future scenarios, spills were assumed to take place at elevations greater than 2374 feet above mean sea level (msl).

For future scenarios, unlike the historical water balance model, a range of assumptions must be made regarding model input and lake operation rules in order to estimate water quality parameters. For instance, since specific hydrology cannot be known for a given year in the future, the spreadsheet model examines the impact of new source quantities (e.g. reclaimed water) as they are superimposed on historical hydrologic conditions occurring from 1979-2002. Since populations (and demands) in the current service area are anticipated to decline (based on projections in the Region O Water Plan), future year scenario demands for the District's existing customers were assumed to be equal, on a monthly basis, to those that occurred in 2001.

The elevation-area-capacity curve used to calculate lake elevations and surface areas from end-of-month storage volumes was taken from the 1993 Volumetric Survey of White River Lake, published by the TWDB. A constant sedimentation rate of 100 acre-feet per year was also incorporated into the storage volume calculation.

Lastly, the model was calibrated to recent TDS data taken by the District in order to estimate the average TDS content of incoming natural runoff. Based on a fit of the available data, the model assumes natural runoff TDS concentrations to be constant at 120 mg/L for all results presented in this report.

7.2.2 RESERVOIR DETENTION TIMES

Detention time calculations are performed based on total outflow from the reservoir. For the complete mixing assumption, the detention time for the lake can be calculated using the following formula:

$$DT = \frac{V}{Q_{out}}$$

where DT is the detention time in White River Reservoir assuming complete mixing, V is the current end-of-month storage volume, and Q_{out} is the total outflow for a given month, which is comprised of spills, raw water demand, and evaporation.

An average detention time is computed for each month in the simulation. Computed detention times can be highly variable on a monthly basis, particularly following periods of large inflows that result in modeled spills (and consequently, large outflows). In order to smooth out some of this variability, a three-month running average was used for presentation of the detention time values. The three-month running average generally maintains the magnitude of the detention time trend, but eliminates the extreme valleys associated with large storm events.

7.2.3 SIMULATED WASTEWATER PERCENT BLEND

Along with calculation of detention times, a primary goal of the water balance model is to estimate the percentage of wastewater contained in the reservoir over the course of the modeled time period. This quantity is referred to as the "percent blend" and has been identified in previous chapters as an important evaluation parameter in indirect potable reuse projects. The model calculates the percent blend by tracking the contents of the reservoir by inflow type (e.g. natural inflow, precipitation, reclaimed water) under the complete mixing assumption (i.e. all points in the reservoir are characterized by equal percent blends at any given time). As such, all outflows from the reservoir have the same quality and percent blend, with the exception of evaporation. Because evaporation leaves all or most of the constituents that may impact the environment or human health behind, evaporation quantities are assumed to contain no wastewater.

For Alternatives #1 and #2, the model simulates percent removal of constituents (and in particular, TDS) associated with reverse osmosis (RO) treatment of incoming raw water or wastewater streams, whether diverted from the North Fork Double Mountain Fork or piped directly from the City of Lubbock WWTP. The model is configured to allow RO treatment to be modeled with or without a bypass stream comprised of any portion of the influent water. In the results presented below, the RO treatment simulation is set up to only provide treatment on that portion of the diverted water that is necessary to maintain a user-specified quality of water in White River Reservoir. However, in reporting percent blend, no distinction is made between the RO permeate and any bypass stream comprised of secondary effluent, i.e. RO treated effluent is given no percent blend "credit" in the model.

7.2.4 TOTAL DISSOLVED SOLIDS

As discussed previously, total dissolved solids (TDS) have been shown to be of particular concern in White River Reservoir. Due to the relatively high TDS content of both the North Fork Double Mountain Fork Brazos River (North Fork) and the City of Lubbock's wastewater (see Chapter 6), any reuse project relying on these sources to augment supplies in White River Reservoir will result in increased lake TDS levels without treatment for removal of TDS. A solids balance was used to calculate TDS concentrations on a monthly basis for both the historical and simulated cases. In the model, the TDS of the City of Lubbock wastewater effluent and North Fork water were assumed to have a constant value of 1400 mg/L. Natural runoff into White River Reservoir was assumed to have a constant TDS concentration of 120 mg/L, as discussed in Section 7.2.1.

As mentioned, the ability to apply reverse osmosis (RO) to the reclaimed water stream has been incorporated into the model. For purposes of calculating TDS concentrations, the simulation of RO treatment was assumed to operate at 95% efficiency (i.e. 95% of the TDS is removed from the waste stream) and 85% recovery (85% of the flow is recovered- the remaining 15% is lost to the brine reject stream or other losses). The portion of the influent water treated varied with the previous month's lake TDS level. As TDS levels in the lake approach the annual average standard of 650 mg/L, a larger portion of the influent stream is passed through RO. At 95% efficiency, the TDS content of the RO permeate stream is 70 mg/L (=0.05 x 1400 mg/L).

7.2.5 HISTORICAL SIMULATION RESULTS

As discussed previously, analysis of simulated historical conditions in White River Reservoir was performed to estimate historical TDS levels in the lake, and also to calibrate the model by adjusting the TDS content of natural inflow, for which no data were available. A plot of historical lake elevation was provided in Chapter 1 (Figure 1-1). Calculated historical TDS concentrations are displayed in Figure 7-5.

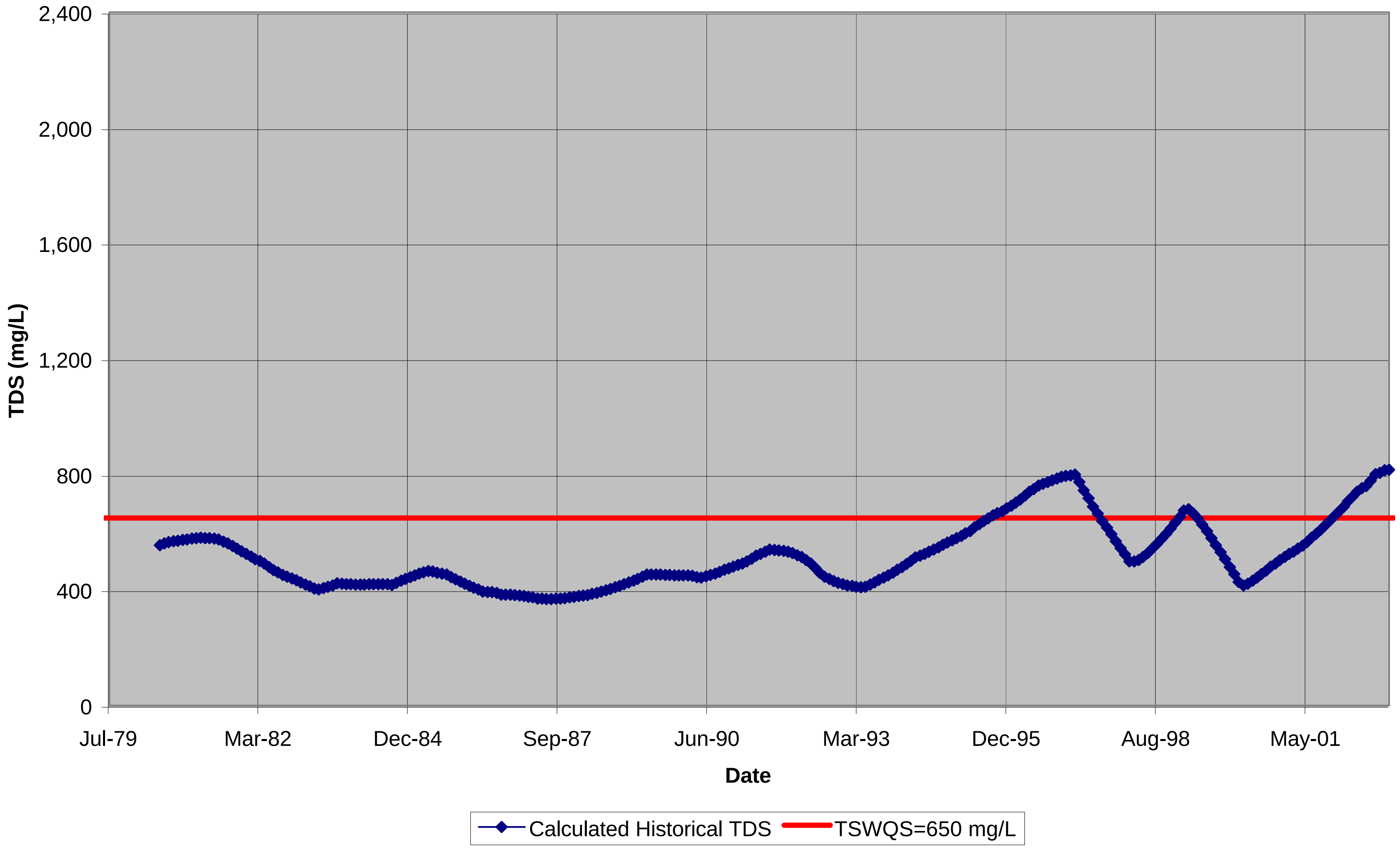
7.2.6 SIMULATED AUGMENTATION SCENARIO RESULTS

For modeling purposes, Alternatives #1 and #2 are assumed equivalent in terms of their impact on the water quality in White River Reservoir. This assumption implies that both the North Fork Double Mountain Fork and the City of Lubbock wastewater can be assumed to be of similar quality. From a TDS standpoint, the data support the use of an average of 1400 mg/L TDS for both sources. Due to low rainfall totals in the region, the North Fork Double Mountain Fork is likely comprised of nearly all wastewater over much of the year. As a result, the model assumes all diversions are 100% wastewater. It should be noted that this assumption is conservative in that it likely overestimates the percent blends to be expected in White River Reservoir for Alternative #2. If Post Reservoir is constructed, and some storage is established at the diversion site, the water quality of the diversion could be significantly better than 100% wastewater. Even if no reservoir is constructed, diversions occurring during storm events will result in slightly lower average percent blends than computed in the model. Alternative #3 was modeled by applying no reverse osmosis treatment to the Lubbock effluent. Diversions from the Lubbock WWTP in this alternative are assumed to contain 100% secondary effluent, with no removal in TDS prior to discharge to the proposed constructed wetlands.

Since treated water demands for existing District customers are expected to remain constant or decrease slightly within the next 50 years (as noted in the Region O Water Plan), historical monthly demands from 2001[16] (annual average demand of 1.95 MGD) were used to establish a base scenario for the Alternative #1/#2 and Alternative #3 cases. The base scenarios assume that 2.0 MGD of Lubbock wastewater is used to augment the supply in White River Reservoir.

[16] Monthly demands were computed from metered treated water pumped flows provided by the District.

Figure 7-5: White River Reservoir
Calculated Historical Total Dissolved Solids - 1-yr Running Average



Subsequent scenarios were created by increasing wastewater flows incrementally by 1.0 MGD for each alternative and determining the maximum annual average demand that could be supplied while maintaining a minimum lake elevation of 2358 ft msl for the modeled hydrologic period of record. Percent blends, detention times, and TDS concentrations in the reservoir were calculated for each scenario. A statistical summary of all modeled scenario results is presented in Table 7-1 (Alt. #1/#2) and in Table 7-2 (Alt. #3). In addition, more detailed results for each of the Base 2001 scenarios are discussed separately below.

Alternative #1/#2 Base Scenario Results

Results of the base scenario (Scenario 1a) for Alternative #1/#2 are shown in Figures 7-6 through 7-9. Figure 7-6 shows calculated water levels in the reservoir based on the use of 2.0 MGD of Lubbock wastewater effluent to augment supply. At the end of the simulation period, the modeled water surface elevation is approximately 12 feet higher than the historical level under these conditions. Calculated 1-year average TDS levels are shown in Figure 7-7 in comparison to calculated historical values. As discussed earlier, RO treatment is used to control the TDS concentrations in the lake such that they are maintained within the range of the calculated historical values. Due to significant evaporation losses and drought conditions with limited natural inflows, there are periods during which all of the Lubbock wastewater (or North Fork diversion water) must undergo RO treatment in order to control TDS levels within the lake.

Calculated percent blend of wastewater within the lake for Scenario 1a is shown in Figure 7-8. Since the historical drought of record is currently on-going, the maximum percent blend occurs at the end of the simulation period and is approximately 25%. Figure 7-8 also indicates that during this period of drought, a large percentage of the wastewater content within the lake has undergone RO treatment as a result of the need to control TDS levels. Calculated three-month running average detention times for Scenario 1a are presented in Figure 7-9. Since calculated detention times are computed based on outflow from the lake, they exhibit a strongly seasonal pattern associated with seasonal variations in lake outflow. Calculated three-month average detention times range from 1-1.5 years in the summer months to values greater than 5 years during some winter periods. Overall, the average detention time during the entire simulation period is approximately 2.7 years.

Table 7-1: Summary of Alternative #1/#2 Model Results (Variable RO Treatment)

Model Scenario	WW Inflow (MGD)	Max Demand* (MGD)	Avg % Blend**	Max % Blend**	Avg DT (yrs)	Avg TDS (mg/L)	Max 1-yr TDS (mg/L)	Max TDS (mg/L)
Scenario 1a (base)	2.00	1.95	15%	25%	2.70	609	817	891
Scenario 1b	3.00	2.87	21%	34%	2.42	647	867	953
Scenario 1c	4.00	3.70	26%	42%	2.22	668	891	984
Scenario 1d	5.00	4.54	30%	48%	2.05	686	918	1018
Scenario 1e	6.00	5.37	34%	53%	1.91	697	936	1043
Scenario 1f	7.00	6.20	38%	58%	1.79	708	956	1069
Scenario 1g	8.00	7.03	41%	61%	1.68	719	976	1097
Scenario 1h	9.00	7.86	44%	65%	1.59	726	985	1112
Scenario 1i	10.00	8.70	46%	67%	1.50	733	1008	1142

* to maintain 2358 ft elevation, except in the case of Base 2001 run which utilizes historical 2001 demands
**% blend calculations do not distinguish between RO permeate and secondary wastewater

Table 7-2: Statistical Summary of Alternative #3 Model Results (No RO Treatment)

Model Scenario	WW Inflow (MGD)	Max Demand* (MGD)	Avg % Blend	Max % Blend	Avg DT (yrs)	Avg TDS (mg/L)	Max 1-yr TDS (mg/L)	Max TDS (mg/L)
Scenario 3a (base)	2.00	1.95	16%	28%	2.73	1017	1988	2188
Scenario 3b	3.00	3.28	23%	38%	2.32	1447	3010	3365
Scenario 3c	4.00	4.27	29%	46%	2.10	1813	3850	4328
Scenario 3d	5.00	5.25	33%	53%	1.93	2176	4673	5277
Scenario 3e	6.00	6.23	38%	58%	1.79	2537	5484	6221
Scenario 3f	7.00	7.21	41%	62%	1.66	2899	6292	7170
Scenario 3g	8.00	8.19	45%	66%	1.55	3260	7087	8110
Scenario 3h	9.00	9.17	48%	69%	1.46	3621	7873	9048
Scenario 3i	10.00	10.15	50%	72%	1.37	3981	8654	9988

* to maintain 2358 ft elevation, except in the case of Base 2001 run which utilizes historical 2001 demands

**Figure 7-6: White River Reservoir
Calculated Water Surface Elevation
Scenario 1a**

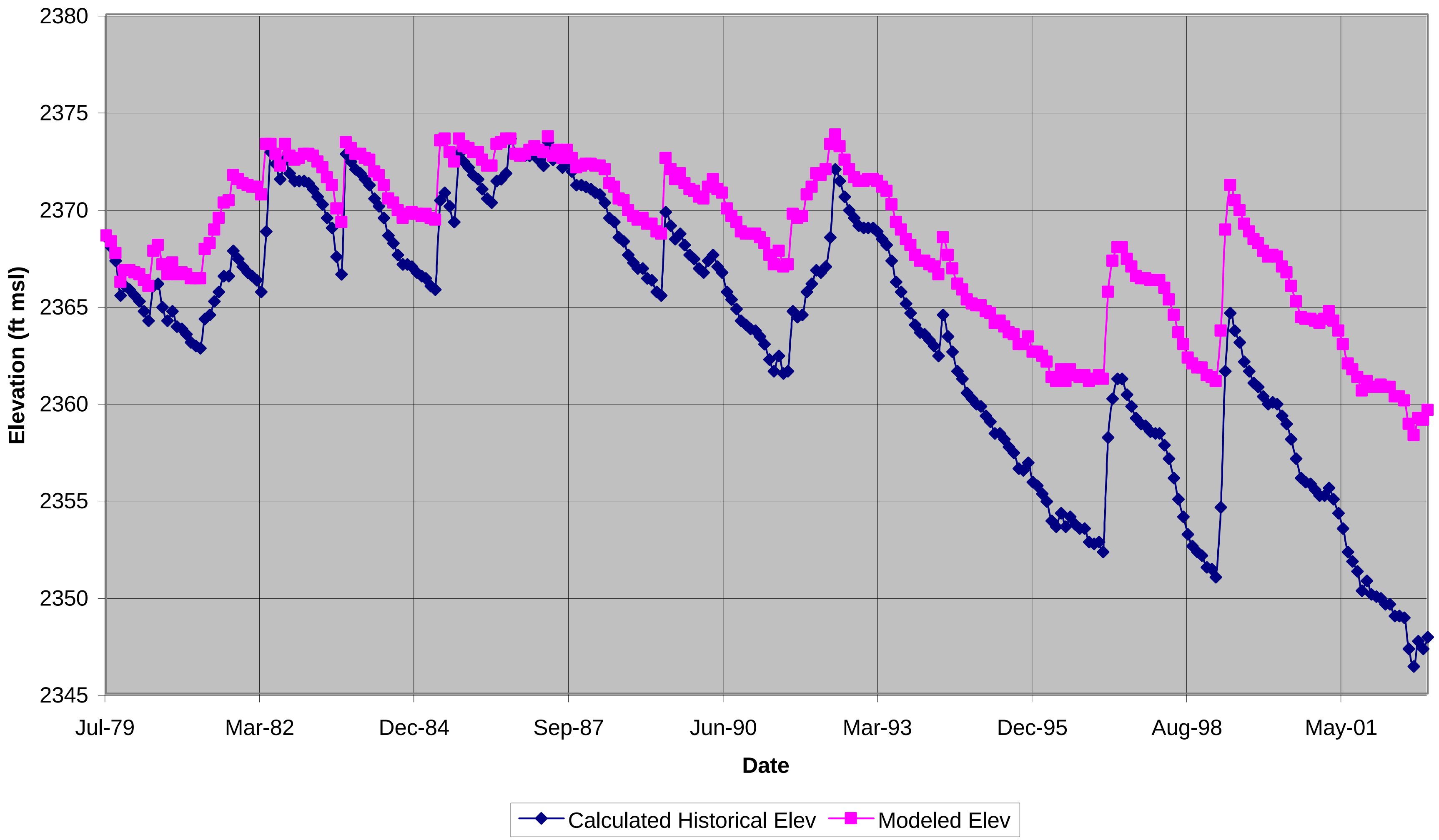


Figure 7-7: White River Reservoir
Calculated Total Dissolved Solids - 1-yr Running Average
Scenario 1a

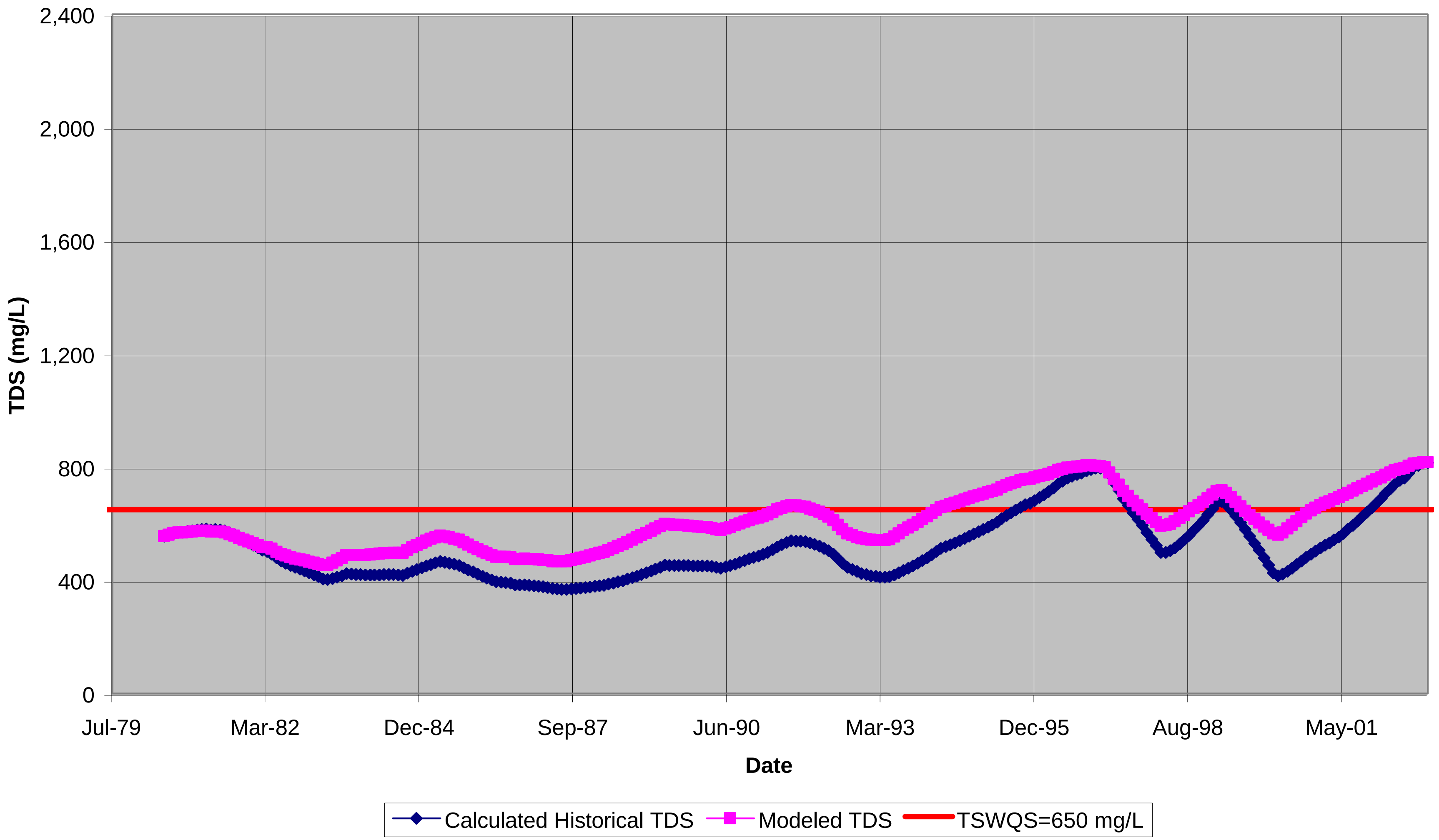


Figure 7-8: White River Reservoir
Modeled Percent Wastewater
Scenario 1a

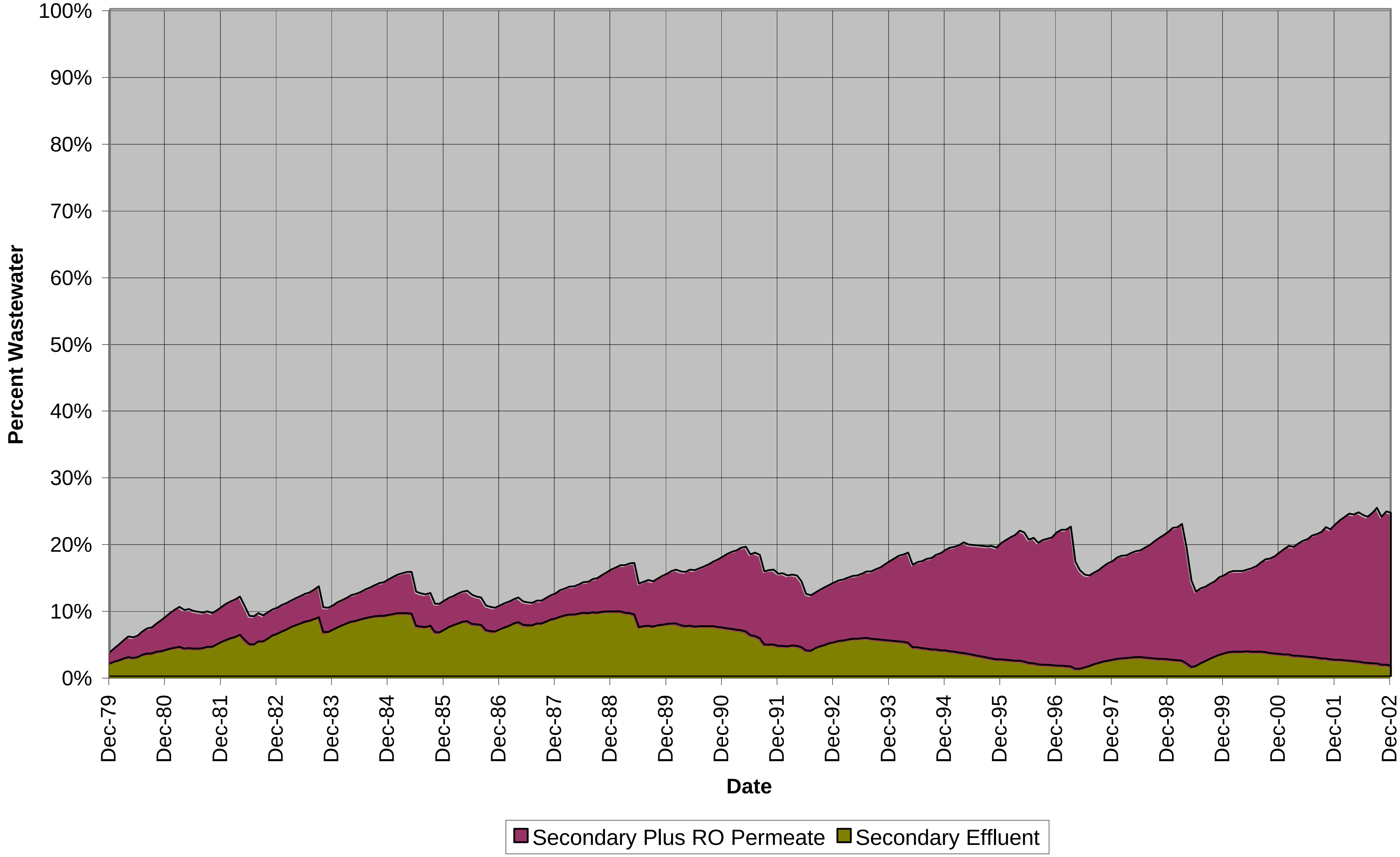
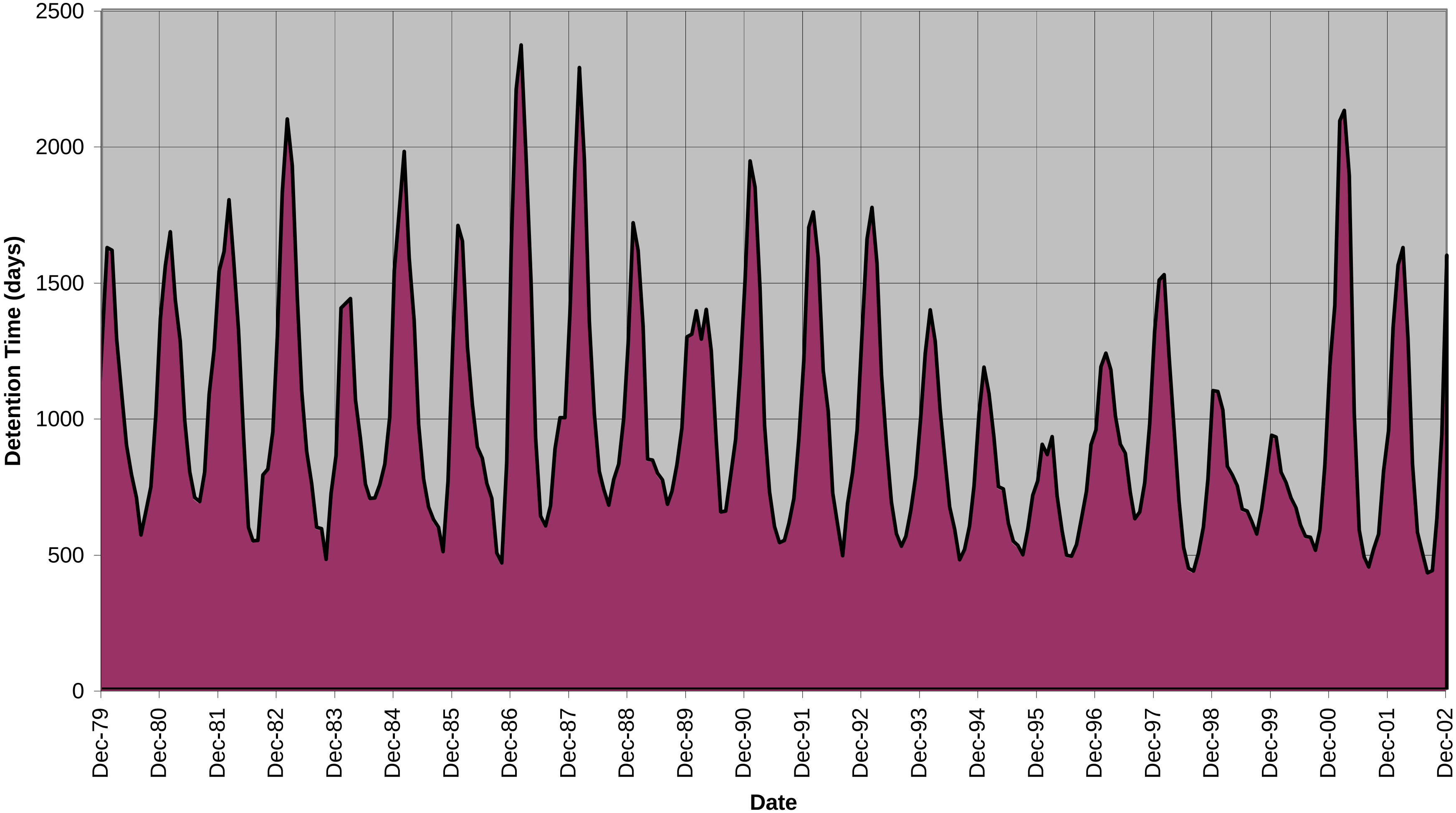


Figure 7-9: White River Reservoir
3-month Running Average Detention Time
Scenario 1a



Alternative #3 Base Scenario Results

Results of the base scenario for Alternative #3 (Scenario 3a) are shown in Figures 7-10 through 7-12. As expected, water levels are maintained within a similar range to those for Alternatives #1 and #2, as indicated in Figure 7-10. However, since Alternative #3 does not provide for any removal of TDS with RO treatment prior to discharge of effluent into the wetlands/reservoir system, calculated TDS concentrations in the reservoir for this alternative increase to nearly 2000 mg/L during the simulation period, as shown in Figure 7-11. Percent blends are in a similar range to those computed for Alternatives #1 and #2; however since none of the wastewater has undergone RO treatment, there is no "barrier" effect of RO associated with these percent blends. Calculated detention times are very similar to those shown for the Alternative #1/#2 case and are not shown again here.

Results for Wastewater Diversions greater than 2 MGD

As shown in Tables 7-1 and 7-2, increasing the amount of wastewater effluent that is diverted to White River Reservoir increases the percent blend and TDS while decreasing the detention time. As discussed in Chapter 4, a goal of maintaining average percent blends below approximately 30% and average detention times greater than 1 year has been set in order to minimize the potential exposure to constituents in the wastewater. Based on these criteria, the maximum amount of wastewater that could be diverted is approximately 4 to 5 MGD, as indicated by Scenarios 1c and 1d in Table 7-1 and 3c and 3d in Table 7-2. For the 5 MGD case, however, the maximum monthly percent blend approaches 50% for Alternatives #1/#2 (Scenario 1d) and exceeds 50% for Alternative #3 (Scenario 3d). Given that this blend could persist for several months during a period of drought, it is recommended that the diversion be capped at 4 MGD. However, as the state of knowledge progresses in this field, it is possible that this quantity could be increased in the future. For a diversion of 4 MGD, the annual average demand that can be supported is about 3.7 MGD for Scenario 1c and 4.3 MGD for Scenario 3c. Alternative #3 supports more demand due to the assumption of no RO treatment on the wastewater and no losses to a brine reject stream.

Figure 7-10: White River Reservoir
Calculated Water Surface Elevation
Scenario 3a

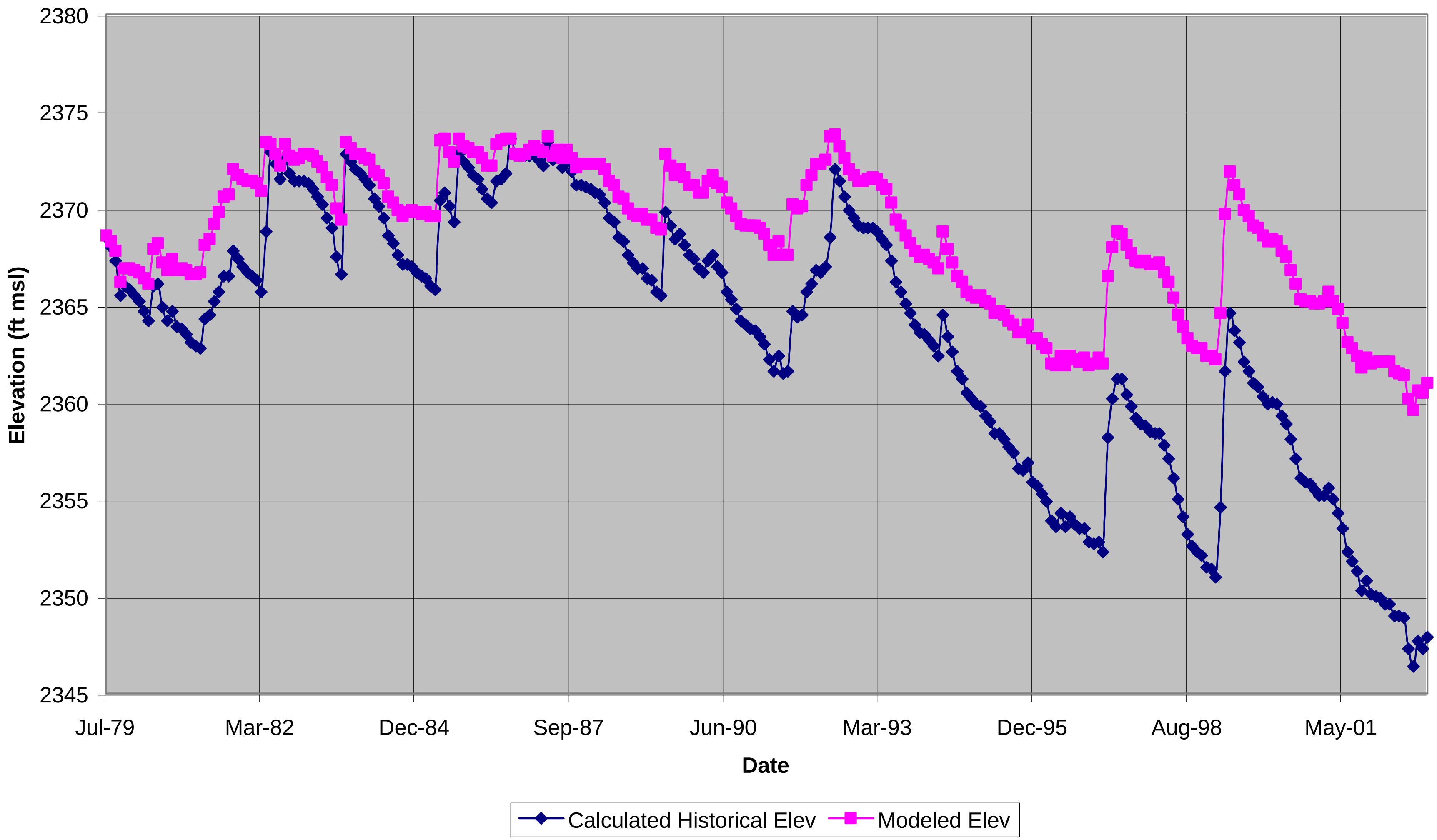


Figure 7-11: White River Reservoir
Calculated Total Dissolved Solids - 1-yr Running Average
Scenario 3a

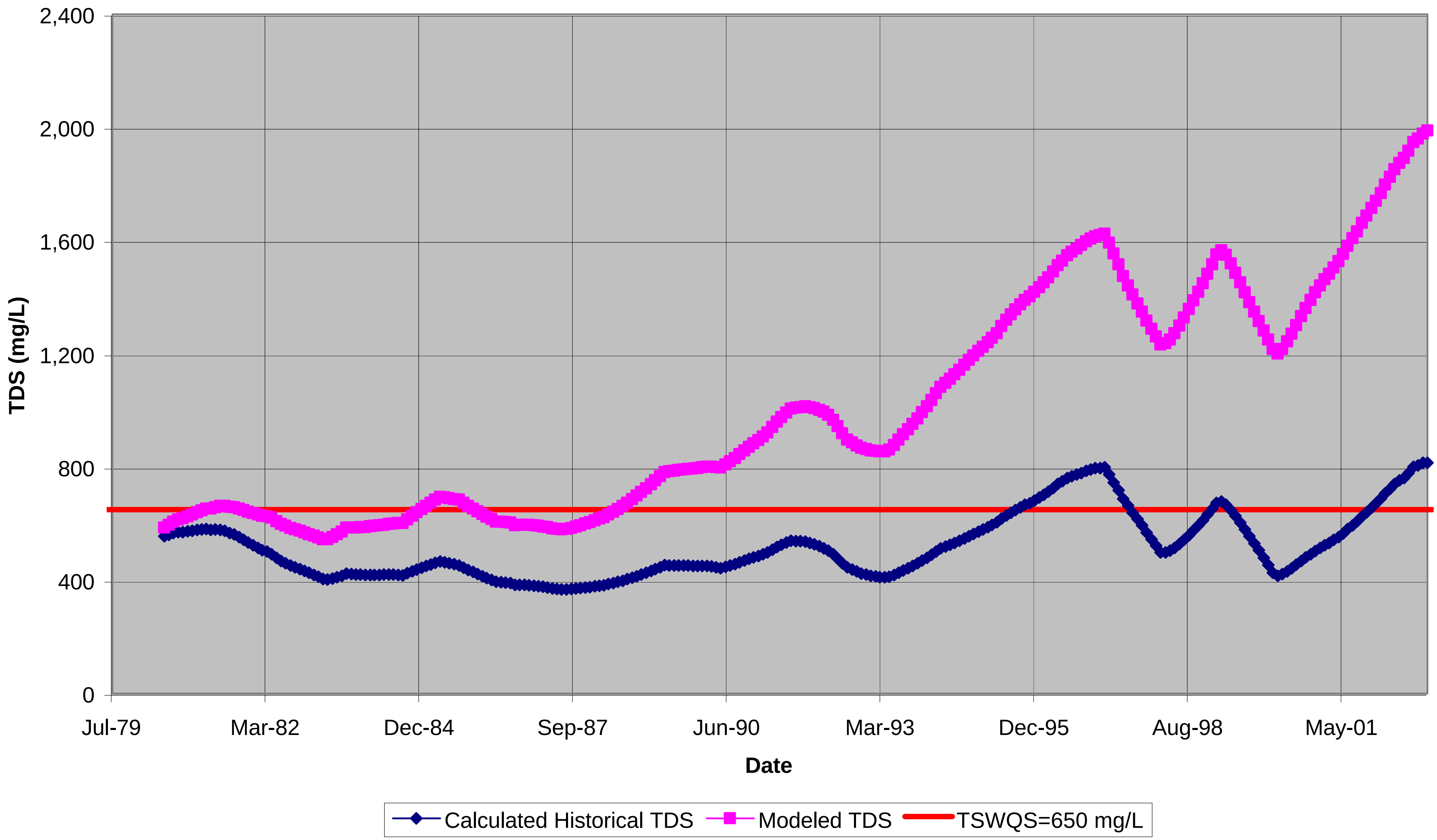
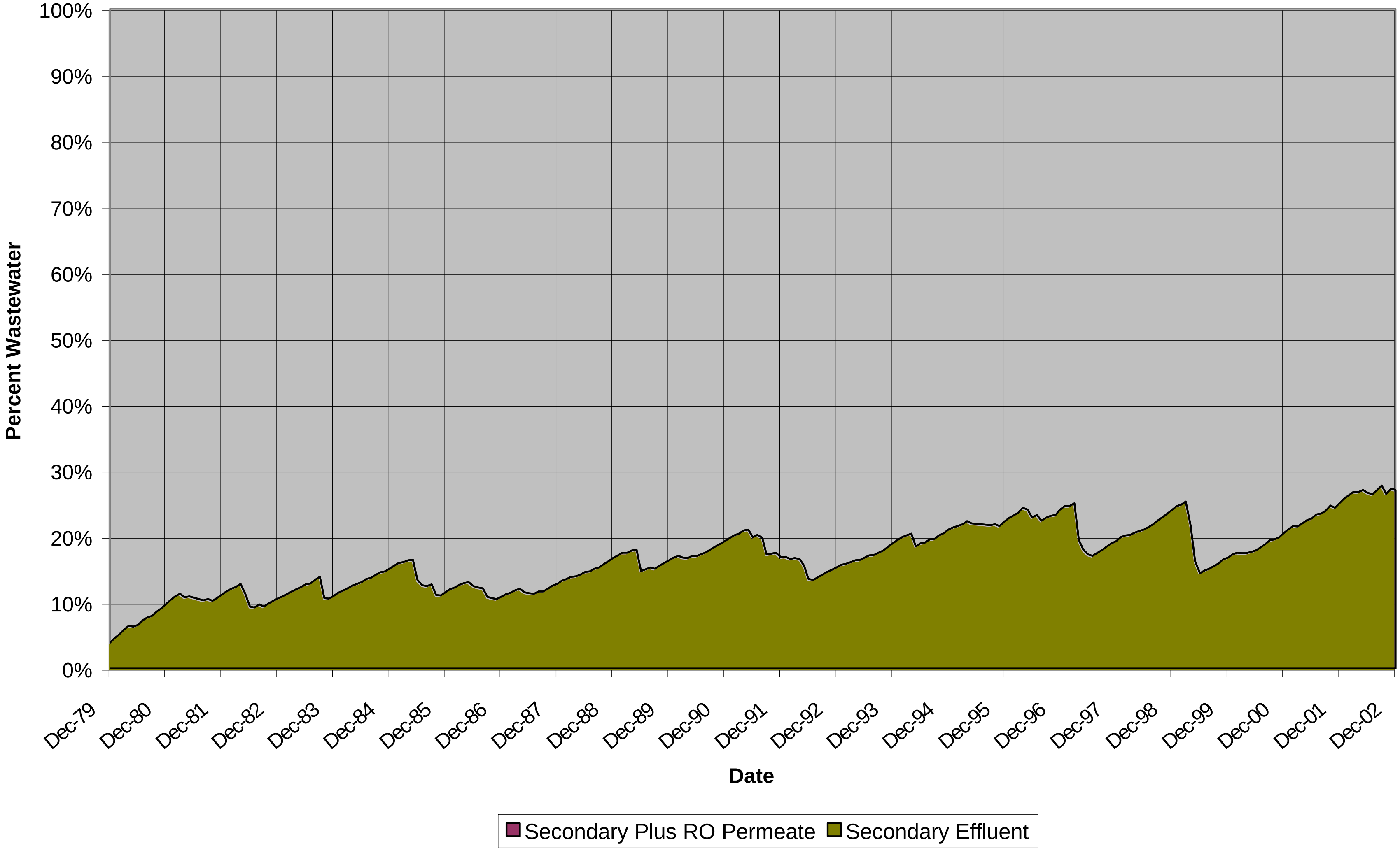


Figure 7-12: White River Reservoir
Modeled Percent Wastewater
Scenario 3a



7.2.7 BENEFITS OF PROPOSED CONSTRUCTED WETLANDS

As discussed in Chapter 2, constructed wetlands are traditionally utilized for removal of nutrients and suspended solids. Efficient removal of these constituents has been demonstrated in numerous other projects and is well documented in the literature. With proper maintenance of vegetation and flows, efficient removal has been shown to occur during the winter months, even as far north as Michigan and Wisconsin. Removal of nutrients within the wetlands system will insure that nutrient levels are maintained within a range to control algae growth and eutrophication in the reservoir. The wetlands system also provides an additional treatment barrier to other potential constituents present in the wastewater. Although this benefit cannot be quantified, results of ongoing research in this area are very promising and suggest that the wetlands system may provide significant removals of a wide range of constituents.

The wetlands system can be constructed either on-channel or off-channel. For an off-channel wetlands system, the natural stream channel can be used to divert storm flows in excess of those that can be accepted by the wetlands system. For an on-channel system, a separate by-pass channel must be constructed for diversion of storm flows.

In addition to their treatment benefits, constructed wetlands can provide significant recreational and educational benefits to the surrounding community. Wetlands provide an ideal habitat for many species of birds, and provide an excellent setting for educating the public about aquatic life and the natural benefits of these systems.

7.2.8 SUMMARY OF WATER QUALITY EVALUATION RESULTS

The water quality evaluation of each of the reclaimed water augmentation alternatives can be summarized with the following points:

- In order to maintain percent blends and detention times within the range recommended as guidance criteria in Chapter 4 (average percent blend less than 30%, average detention time greater than 1 year), the maximum amount of wastewater that can be diverted to the proposed wetlands/reservoir system is approximately 4 MGD.

- In order to maintain TDS levels within the range of historically observed values in White River Reservoir, RO treatment must be provided for the wastewater effluent (Alternative #1) or for the North Fork Double Mountain Fork water (Alternative #2) prior to discharge to the proposed constructed wetlands. During drought periods, 100% of the discharge must be treated with RO in order to control TDS levels. This RO treatment not only removes TDS, but also provides an additional treatment barrier to other potentially harmful constituents that may be present in the wastewater.

- Due to the lack of RO treatment prior to discharge to the wetlands/reservoir system, Alternative #3 is considered to be the least preferable alternative from a water quality perspective. In addition to not providing the RO treatment barrier prior to discharge, it is unlikely that the TCEQ would modify the surface water quality standard to the extent necessary to support this alternative.

- The proposed constructed wetlands will provide for removal of nutrients and suspended solids. As such, the wetlands will serve to control algae levels and eutrophication in the reservoir. Furthermore, the wetlands system acts as an additional treatment barrier to other constituents that may be present in the wastewater.

7.3 Legal and Permitting Considerations

All three alternatives reviewed in this study involve water supply, water quality and other permitting considerations. Before pursuing any of the three alternatives reviewed, the District will need to obtain all necessary permits and authorizations from the Texas Commission on Environmental Quality (TCEQ) and the United States Army Corps of Engineers (USACE). Additionally, the District will need to enter into a contractual arrangement with the City of Lubbock (City) to guarantee the discharge and assignment of return flows from the City's wastewater treatment facility, either directly to White River Lake (Lake) or indirectly from the North Fork of the Double Mountain Fork of the Brazos River (North Fork).

7.3.1 WATER RIGHTS PERMITTING

Each of the three alternatives reviewed in this study will require some authorization pursuant to Chapter 11 of the Water Code to convey and divert flows through the Lake. Pursuant to Certificate of Adjudication No. 12-3693, the District is authorized to impound not to exceed 44,897 acre-feet per annum of water, and to divert up to 6,000 acre-feet per annum of said water (2,000 acre-feet per annum for mining purposes and 4,000 acre-feet per annum for municipal purposes) at a maximum rate of 4,100 gallons per minute. Although the District may not need to increase the authorized diversion rate to deliver water from any of the three alternatives presented in this study, it will need to obtain authorization pursuant to Water Code Section 11.042 to convey water through the Lake, and Water Code Section 11.122 to increase the annual amount diverted pursuant to Certificate of Adjudication No. 12-3693. Additionally, for Alternatives #1 and #3, the District will need to obtain authorization pursuant to Water Code Section 11.046 to recognize the indirect reuse of groundwater and developed water-based effluent discharged to the headwaters of the reservoir. Each of these authorizations can be pursued through an amendment to Certificate of Adjudication No. 12-3693. The District does not have to pursue a separate water right under either Alternative # 1 or #3.

If the District pursues Alternative #2, it will need to obtain an additional water right, separate from the required amendment to Certificate of Adjudication No. 12-3693, in order to divert from the North Fork. In Alternative #2, the District would need to request authorization to reuse the City's groundwater and/or developed water-based effluent pursuant to Water Code Section 11.046, and to convey said effluent through the North Fork pursuant to Water Code Section 11.042. Additionally, the District would need to obtain authorization to divert from the North Fork unless it intends to use the existing diversion point authorized in the Post Reservoir permit, which would first require construction of the Post Reservoir.

7.3.2 WATER QUALITY PERMITTING

Each of the three alternatives reviewed in this study will require some authorization from the TCEQ pursuant to the Clean Water Act and Chapter 26 of the Water Code. Alternatives #1 and #3 contemplate a new outfall from the City's wastewater treatment facility into the headwaters of the Lake. As such, TPDES Permit No. 10353-002, granted to the City, would need to be amended to authorize this discharge. Alternative #2 would utilize the City's existing permitted outfall authorized pursuant to TPDES Permit No. 10353-002, and any discharge of water from the North Fork to the headwaters of the Lake would be unrelated to the City's wastewater treatment facilities. However, based on a recent U.S. Supreme Court ruling,[17] even the transfer of water between the North Fork and the Lake, those being two "distinct sources" of water, would require a discharge permit pursuant to Chapter 26 of the Water Code.

Additionally, to the extent that each of the three alternatives examined involve the creation of wetlands and will result in a discharge of dredged or fill materials into waters of the United

[17] South Florida Water Management Dist. v. Miccosukee Tribe Of Indians, 2004 WL 555324, US. SCt (March 24, 2004).

States, it will be necessary to obtain authorization from the United States Army Corps of Engineers ("USACE") pursuant to section 404 of the Clean Water Act ("404 Permit"). An individual 404 Permit is usually required for any activity involving the discharge of dredged or fill material into waters of the U.S. However, Nationwide 404 Permits are available for a variety of activities that have been identified as causing only minimal adverse impacts. Nationwide permits allow certain minor-impact activities to take place without the burdensome process of obtaining an individual 404 Permit. All three alternatives proposed should fall within Nationwide Permit No. 27 ("NW27") for "stream and wetland restoration activities."[18] Additionally, all three alternatives will likely qualify for coverage pursuant to Nationwide Permit No. 12 ("NW12") for stream and river crossing of the proposed cross-country pipeline. Depending on the details of the final project selected, Alternative #2 may require an additional 404 Permit for construction of the proposed diversion works.

NW27 will be important to any project selected because it will authorize the construction of wetlands. NW27 covers activity associated with the creation of tidal and non-tidal wetlands and riparian areas. Thus, pursuant to NW27, wetlands can be created without an individual 404 Permit so long as a set of general conditions are met.[19] Pre-construction notification is required for activities authorized by NW27.[20] This notification requirement allows the USACE District Engineer to review proposed activities on a case-by-case basis to ensure that adverse effects of those activities on the aquatic environment are minimal. Within 45 days of receipt of a complete pre-construction notification, the District Engineer will notify the project proponent either that the proposed work is authorized by NW27 with any special conditions imposed, or that discretionary authority is asserted and the proposed work will require an individual permit. Based on the projects proposed in each of the three alternatives, it appears at this time that each will qualify for NW27.

As a side permit pursuant to the Clean Water Act, any project associated with one of the three alternatives studied will likely involve construction over an area that is greater than one acre. As such, pursuant to General Permit No. TXR150000, the District will need to file a notice of intent

[18] See 67 Fed. Reg. 2082 (Jan. 15, 2002).

[19] See 67 Fed. Reg. 2089-94 (Jan. 15, 2002).

[20] See 67 Fed. Reg. 2082 (Jan. 15, 2002). A pre-construction notification is reviewed in accordance with the procedures of General Condition 13. *See* 67 Fed. Reg. 2090 (Jan. 15, 2003).

to begin construction, prepare pollution prevention plans and materials, and notify TCEQ staff upon completion of construction.

7.3.3 SURFACE WATER QUALITY STANDARDS

As discussed in previous sections, TDS levels, in addition to chloride and sulfate, are currently in violation of the surface water quality standards in White River Reservoir. The elevated levels are primarily a result of the extended on-going drought condition in the region. In order to implement Alternative #3, the surface water quality standard for TDS in the lake would have to be increased significantly. Although it is unlikely that the TCEQ would consider such a major modification to the surface water quality standards, a more modest increase of the standard to reflect the historically observed water quality conditions in the lake may be possible. Consequently, it is recommended that the District pursue discussions with the TCEQ to adjust the standards so that they are consistent with these historical conditions.

7.3.4 MISCELLANEOUS AUTHORIZATIONS

As with the general stormwater permit for construction activities, there will be other miscellaneous approvals required from the TCEQ before pursuing construction of any facilities. For instance, the District will need to obtain approval for the design of any water or wastewater treatment facilities contemplated by these options. These design requirements are located in the TCEQ's rules in Title 30, Chapters 290 and 317. Additionally, there may be permits associated with obtaining rights-of-way for pipelines from the Texas Department of Transportation to convey effluent or raw water, depending on which option is selected. These and other authorizations will need to be fully addressed in the preliminary design report for the chosen project.

7.4 Preliminary Opinion of Probable Costs

A summary of the preliminary opinion of probable cost for each augmentation alternative is presented in Table 7-3. A detailed breakdown of costs is provided as an appendix to this report. All costs shown are in 2004 dollars and are based on a 30-year investment life at an annual interest rate of 6%. A 20% contingency was applied to all capital costs. An additional 20% was assumed for engineering, legal and bond acquisition costs. Costs for the use of 2 MGD of wastewater from the City of Lubbock WWTP are shown for Alternatives #1-#3. Based on results of the water balance model, this diversion amount would support demands of the District's existing customers. For Alternative #1, costs are also shown for the diversion of 4 MGD of wastewater, the recommended maximum diversion amount, as described in Section 7.2. Diversion of 4 MGD of Lubbock effluent would require that the District acquire additional customers in order to take advantage of the additional supply.

As can be seen from Table 7-3, the opinions of probable cost for Alternatives #2 and #3 are greater than those for Alternative #1 for the 2 MGD diversion cases. In terms of cost per acre-foot of water, Alternative #2 is the most expensive at $1,821/ac-ft, Alternative #3 is $1,478/ac-ft and Alternative #1 is $1,346/ac-ft. For a 4 MGD diversion, the opinion of probable cost for Alternative #1 is reduced to $1,045/ac-ft.

In order to compare the probable cost of the reclaimed water augmentation alternatives with probable costs of other potential sources of surface water supply for the District, two additional options are included in Table 7-4. These are construction and development of Post Reservoir as an additional surface water supply; and purchase of water from the existing Alan Henry Reservoir. For comparison purposes, the costs in Table 7-4 assume that 2 MGD of water is required and is used to maintain water levels in White River Reservoir, as with the reclaimed water augmentation alternatives. Based on TCEQ water quality monitoring data in Alan Henry Reservoir and data provided by the District for the North Fork Double Mountain Fork of the Brazos River (see Chapter 6), TDS levels in both the future Post Reservoir and Alan Henry Reservoir are assumed to be high enough to require that RO treatment of the water will be necessary prior to discharge into White River Reservoir. Alternatively, the water could be piped directly to the White River water treatment plant with RO provided prior to distribution to District customers. This approach would reduce losses to evaporation and, therefore, would likely require that a quantity less than 2 MGD be needed to serve existing customers. However, this approach would not provide for any direct maintenance of water levels in White River Reservoir.

The opinions of probable cost for the Post and Alan Henry Reservoir alternatives are not intended to provide detailed costs for each of these alternatives. Rather, they are intended to provide "ballpark" comparisons to demonstrate that the cost of obtaining additional surface water supply is likely to be in the general range shown in Table 7-4. Based on these estimates, the reclaimed water alternatives (and in particular, Alternative #1) are economically competitive with other surface water supply alternatives.

Table 7-3: Opinion of Probable Cost- Reclaimed Water Augmentation Alternatives

ALTERNATIVE #1@2MGD

	Capital Cost	Annual Cost	$/1000 gal	$/ac-ft
Raw Water (Wastewater Effluent)	$0	$0	$0.00	$0
MF/RO Water Treatment	$8,352,000	$606,764	$0.83	$271
Conveyance Pump Station and Pipeline	$22,821,785	$1,657,978	$2.27	$740
Wetland	$944,000	$68,581	$0.09	$31
O&M	--	$681,936	$0.93	$304
TOTAL	**$32,117,785**	**$3,015,258**	**$4.13**	**$1,346**

ALTERNATIVE #1@4MGD

	Capital Cost	Annual Cost	$/1000 gal	$/ac-ft
Raw Water (Wastewater Effluent)	$0	$0	$0.00	$0
MF/RO Water Treatment	$16,704,000	$1,213,527	$0.83	$271
Conveyance Pump Station and Pipeline	$30,808,152	$2,238,179	$1.53	$500
Wetland	$1,888,000	$137,161	$0.09	$31
O&M	--	$1,093,694	$0.75	$244
TOTAL	**$49,400,152**	**$4,682,561**	**$3.21**	**$1,045**

ALTERNATIVE #2@2MGD

	Capital Cost	Annual Cost	$/1000 gal	$/ac-ft
Raw Water (Wastewater Effluent)	$0	$0	$0.00	$0
MF/RO Water Treatment	$18,864,000	$1,370,449	$1.88	$612
Conveyance Pump Station and Pipeline	$22,813,278	$1,657,360	$2.27	$740
Wetland	$1,888,000	$137,161	$0.19	$61
O&M	--	$915,510	$1.25	$409
TOTAL	**$43,565,278**	**$4,080,480**	**$5.59**	**$1,821**

ALTERNATIVE #3@2MGD

	Capital Cost	Annual Cost	$/1000 gal	$/ac-ft
Raw Water (Wastewater Effluent)	$0	$0	$0.00	$0
MF/RO Water Treatment	$11,088,000	$805,531	$1.10	$360
Conveyance Pump Station and Pipeline	$22,821,785	$1,657,978	$2.27	$740
Wetland	$944,000	$68,581	$0.09	$31
O&M	--	$779,816	$1.07	$348
TOTAL	**$34,853,785**	**$3,311,905**	**$4.54**	**$1,478**

Table 7-4: Opinion of Probable Cost, Alternative Surface Water Sources

POST RESERVOIR (2 MGD)

	Capital Cost	Debt Service	$/1000 gal	$/ac-ft
Raw Water[a]	$54,849,387	$3,984,748	$0.66 - $1.29	$214-$419[b]
MF/RO Water Treatment	$8,352,000	$606,764	$0.83	$271
Conveyance Pump Station and Pipeline	$17,345,924	$1,260,162	$1.73	$563
Wetland	$0	$0	$0.00	$0
O&M	--	$1,515,760	$2.08	$677
TOTAL	**$80,547,311**	**$7,367,434**	**$5.29 - $5.92**	**$1724 - $1929**

ALAN HENRY RESERVOIR (2 MGD)

	Capital Cost	Debt Service	$/1000 gal	$/ac-ft
Raw Water	--	--	$0.44 - $1.84	$148 - $600[c]
MF/RO Water Treatment	$8,352,000	$606,764	$0.83	$271
Conveyance Pump Station and Pipeline	$22,196,545	$1,612,555	$2.21	$720
Wetland	$0	$0	$0.00	$0
O&M	--	$738,635	$1.01	$330
TOTAL	**$30,548,545**	**$2,957,954**	**$4.51 - $5.89**	**$1468 - $1920**

[a] Capital costs for Post Reservoir were taken from updated costs provided by Freese and Nichols, Inc. to the District in a document dated June 9, 2000. Costs were adjusted to 2004 dollars using the ENR construction index.
[b] Cost of raw water in Region O Water Plan for Post Reservoir is listed as $214/ac-ft. Cost of $419/ac-ft is based on updated capital costs (see note a above) and a yield of 9500 ac-ft/yr.
[c] Cost of raw water in Region O Water Plan for Alan Henry Reservoir is listed as $148/ac-ft. Raw water cost of $600/ac-ft is based on the best available information at the time this report was written, as provided by the Texas Water Development Board. This information is subject to change in the future.

CHAPTER 8: Summary and Recommendations

Based on results of the water quality evaluation, permitting issues, and opinions of probable cost presented in Chapter 7, implementation of Alternative #1 (Figure 8-1) is clearly the most feasible alternative for augmentation of water supply in White River Reservoir with City of Lubbock reclaimed water. This alternative provides the most economical means of conveying reclaimed water to the reservoir while maintaining an acceptable level of water quality within the reservoir. In addition, permitting issues for Alternative #1 are likely to be easier to address than for the other alternatives.

While feasible from a technical standpoint, ultimately the overall feasibility of this alternative will depend on the ability of the District to obtain adequate funding for the project, as well as additional long-term commitments for water supply from its member cities and customers. Without sources of outside funding, the additional cost incurred by the District's existing customers is likely to be prohibitive. This cost could be reduced somewhat if the District could serve additional customers and utilize the maximum recommended reclaimed water diversion quantity of 4 MGD. In addition, it is possible that RO treatment costs to the District could be reduced if the City of Lubbock has an interest in implementing RO treatment to additional quantities of wastewater for its own purposes.

There are a number of funding programs that could potentially be utilized to offset some of the costs of this project. Although a detailed review of funding sources is beyond the scope of this work, a listing of potential funding opportunities is provided as an appendix to this report.

As discussed in the previous chapter, although the opinion of probable cost of augmentation with reclaimed water is high, the development of any future surface water supply is likely to cost as much or more than the reclaimed water alternatives. Although the use of groundwater provides a much less costly alternative in the short-term, the long-term reliability of groundwater as a source in this region is much less certain. Conversely, reclaimed water is one of the most reliable sources of water available and, as such, would provide the District with a dependable long-term supply of water.

If adequate funding and support can be achieved, the following reclaimed water augmentation strategy is recommended for implementation by the District:

1. Per Alternative #1, construct a reverse osmosis (RO) treatment facility at the existing City of Lubbock wastewater treatment plant. This facility should be sized to accommodate the maximum amount of reclaimed water to be diverted to the reservoir (up to 4 MGD). However, the total capacity of the RO facility will only need to be utilized during periods of extended drought, in order to control TDS levels entering White River Reservoir. During non-drought periods, only a portion of the effluent will require RO treatment for control of TDS.

2. Build a constructed wetlands on a tributary upstream of White River Reservoir. The wetlands will serve to remove nutrients and suspended solids, as well as other constituents, prior to discharge to the reservoir.

3. Build a conveyance pump station and pipeline to transport the reclaimed water from the Lubbock WWTP to the constructed wetlands.

4. Develop a testing program to monitor the water quality of the Lubbock wastewater, the wetlands influent and effluent, and the reservoir. This characterization would specifically address those contaminants that have been identified as potential concerns with respect to indirect use of reclaimed water (e.g. pharmaceuticals, endocrine disruptors). Following an initial sampling program, periodic monitoring should continue to track the occurrence of known contaminants and to screen for the introduction of new ones.

It is likely that pilot testing of both the RO and wetlands facilities will be necessary prior to construction of the full-scale facilities. The pilot testing will assist in the selection of treatment trains that target the specific characteristics of the Lubbock effluent. As part of the pilot testing, characterization of the water quality should be carried out, as described in item 4 above.

Feasibility for the recommended augmentation plan will also require that the District reach an agreement with the City of Lubbock for use of the required amount of wastewater and for construction and operation of the RO facility and conveyance pump station. In addition, the required water rights, water quality, and other associated permits will need to be obtained from the state, as discussed in Chapter 7. Each of these aspects of the recommended augmentation plan will have to be achieved for the project to be considered completely feasible.

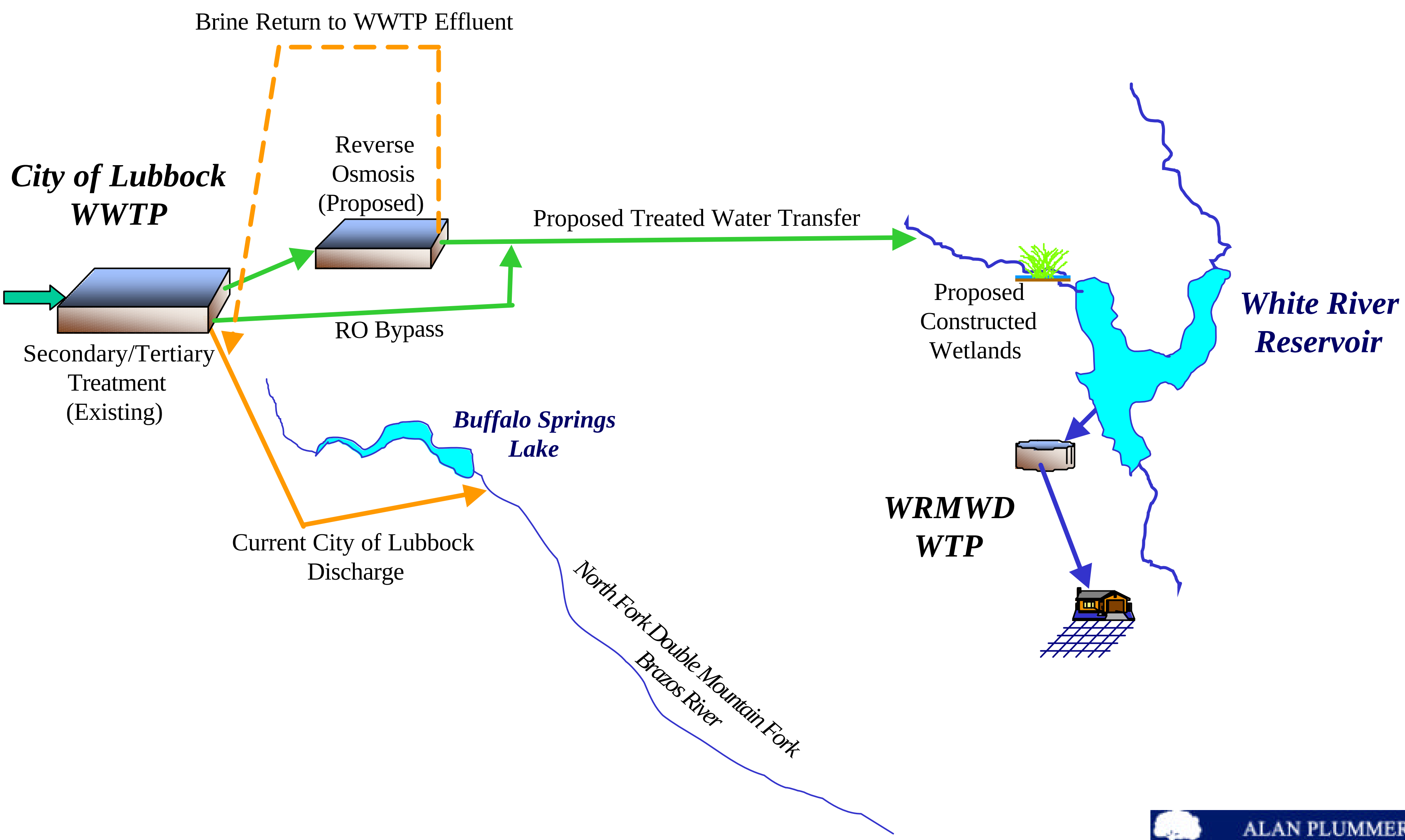
In order to take advantage of the total recommended diversion amount of 4 MGD, the District will need to bring more customers into its system. Potential candidates include the towns of Lorenzo and Idalou, located west of Ralls on Highway 82. Serving these towns could be cost-effective if the existing infrastructure to Ralls has enough capacity to accept the additional flows. The benefit of serving the towns along Highway 82 is that more growth is likely to occur in towns closer to Lubbock and, thus, these areas will likely experience increased water demands in the future. Other potential customers include the towns of Girard, Jayton and Aspermont, located southeast of Spur.

As the science and technology develop with respect to potable use of reclaimed water, it is possible that greater amounts of wastewater effluent than those recommended in this report can be diverted to White River Reservoir for subsequent reuse. In future years it may even become feasible to use White River Reservoir as a receptor for reclaimed water that is then subsequently reused by the City of Lubbock itself. Development of additional customers along Highway 82 would provide an initial step towards this type of regional approach to water supply and is consistent with the overall goals of the TWDB regional planning process.

Figure 8-1

White River Municipal Water District Reuse Augmentation Study

System Schematic – Recommended Alternative (#1)



10/14/04

ALAN PLUMMER ASSOCIATES, INC.

APPENDIX A Detailed Cost Breakdowns

DIVERSION / WETLAND / RECYCLE PROJECT ECONOMIC MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Spur, Texas**
Alternative	**#1 @2MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields

	Qty	Units	Comments
Average System Capacity	2	MGD	
Design Factors			
Conveyance Operating Factor	100	%	Percent of year operable; maintenance, etc.
Capital Recovery Factor			
Investment Life	30	Years	
Annual Percentage Rate	6	%	
Calculated CRF	0.073		
Pumping Efficiency	80	%	
Motor Efficiency	95	%	
Power Cost	$ 0.07	$/kWHr	
Operating Labor Cost, Annual	0.50	%	of Capital Costs
Maintenance Costs, Annual			
Maintenance Labor	0.50	%	of Capital Costs
Maintenance Materials	0.75	%	of Capital Costs

Results

Project Costs			
Total Capital Costs	$31,053,542		New Facilities
Owner's Costs	$1,064,242		Land, Easements
Total Project Costs	**$32,117,785**		
Operating Costs, Annual			
Operating Labor	$155,268		
Maintenance Labor	$155,268		
Maintenance Materials	$232,902		
Power	$138,499		
Total Annual O&M Costs	**$681,936**		
Debt Service	$2,333,322		
Total Annual Costs	**$3,015,258**		
Total Water Recycled	730	MGal/yr	
Cost of Recycle Water	**$4.13**	**$/1000 Gal**	

DIVERSION / WETLAND / CONVEYANCE MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Spur, Texas**
Alternative	**#1 @2MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields (Yellow)

			Comments
Wetland Design			
Wetland Treatment Flow	MGD	**2.0**	Calc
Unit Size	Acre/MGD	20.00	Calc
Design Size	Acre	40	Calc
Force main			
Conveyance Operating Factor	%	100	From Economics Input
Conveyance Operating Days	Days	365	Calc
Design Flow	MGD	**2.0**	Calc
""	gpm	1389	Calc
""	ft^3/s	3	Calc
Inside Diameter	in	16	<=== Check
Flow Velocity	ft/sec	2.22	Typically 7 ft/s max
Length	Miles	40.6	From conceptual routing
	ft	214368	Calc
Fitting Factor	%	10	
Equivalent Length	ft	235805	Calc
H-W Friction Factor	C	130	
Friction Head	ft	273	Calc
	psi	118.1	Calc
Conveyance Pumping			
Flow	MGD	2.0	Calc
	gpm	1389	Calc
Suction Elevation	ft	3100	
Destination Elevation	ft	3100	
Static Head	ft	0	Calc
TDH	ft	273	Calc
HHP	HP	95.7	Calc
Pump Efficiency	%	80	From Economics Input
BHP	HP	119.6	Calc
Motor Efficiency	%	95	From Economics Input
Motor Power	KW	125.9	Calc

DIVERSON / WETLAND / CONVEYANCE MODEL

Client **White River Municipal Water District (WRMWD)**
Location **Spur, Texas**
Alternative **#1 @2MGD**
APAI Project No. **675-0501**
Project Title **Recycle Water Program**

Capital Costs							
Description		**Size**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**	**Subtotal**
					[$]	**[$]**	**[$]**
MF/RO Water Treatment							
	Pretreatment Facilities		2	MG	$1,000,000	$2,000,000	
	MF/RO Treatment Facilities		2	MG	$1,900,000	$3,800,000	
							$5,800,000
Conveyance Pump Station							
	Main Conveyance Pumps (1400 gpm)		2	EA	$200,000	$400,000	
	Civil		1	lot		$76,680	
	Structural		1	lot		$86,312	
	Piping		1	lot		$769,176	
	Electrical		1	lot		$323,256	
	Instrument		1	lot		$278,896	
	Paint		1	lot		$38,312	
	Insulation		1	lot		$96,048	
	Equipment Setting		1	lot		$29,200	
							$2,097,880
Force Main							
	Effluent Pipe Line	16	214368	LF	$60	$12,862,080	
	Air Valves/Blow Off Valves		41	EA	$5,000	$205,000	
							$13,067,080
Wetland							
	Constructed Wetland		40	Acre	$15,000	$600,000	
							$600,000
Subtotal Project Costs							**$21,564,960**
	Project Contingency		20	%			$4,312,992
Subtotal Project Costs							**$25,877,952**
Engineering, Legal, Bond Acquisition			20	%			$5,175,590
	Total Project Capital Costs						**$31,053,542**
Owner's Costs							
	Land - Wetland		40	Acre	$2,000	$80,000	
	Land - Pipeline Easement	100	492	Acre	$2,000	$984,242	
							$1,064,242
TOTAL PROJECT COSTS							**$32,117,785**

DIVERSION / WETLAND / CONVEYANCE MODEL

Client	**White River Municipal Water District (WRMWD)**
Location	**Spur, Texas**
Alternative	**#1 @2MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Operations and Maintenance Costs

Input from Definition and Capital Costs

Capital Costs	$31,053,542	
Operating	365	
Diverting Days	0	0%
Conveyance Days	365	100%
Energy Cost	$ 0.07	$/kWHr

Operating Costs

	Qty	Unit Rate	Unit	Total Cost [$/yr]
Operations				
Operations Labor		0.50	%	$155,268
Maintenance				
Maintenance Labor		0.50	%	$155,268
Maintenance Materials		0.75	%	$232,902
Power	**KW**	**Hrs**	**kWHr**	**[$/yr]**
Conveyance Pumping	126	8760	1102551	$77,179
Misc.	100	8760	876000	$61,320
Total Power Cost				$138,499

DIVERSION / WETLAND / CONVEYANCE MODEL

DIVERSION / WETLAND / RECYCLE PROJECT ECONOMIC MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#1 @ 4 MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields

Input Fields	Qty	Units	Comments
Average System Capacity	4	MGD	
Design Factors			
Conveyance Operating Factor	100	%	Percent of year operable; maintenance, etc.
Capital Recovery Factor			
Investment Life	30	Years	
Annual Percentage Rate	6	%	
Calculated CRF	0.073		
Pumping Efficiency	80	%	
Motor Efficiency	95	%	
Power Cost	$ 0.07	$/kWHr	
Operating Labor Cost, Annual	0.50	%	of Capital Costs
Maintenance Costs, Annual			
Maintenance Labor	0.50	%	of Capital Costs
Maintenance Materials	0.75	%	of Capital Costs

Results

Project Costs			
Total Capital Costs	$48,255,909		New Facilities
Owner's Costs	$1,144,242		Land, Easements
Total Project Costs	**$49,400,152**		
Operating Costs, Annual			
Operating Labor	$241,280		
Maintenance Labor	$241,280		
Maintenance Materials	$361,919		
Power	$249,216		
Total Annual O&M Costs	**$1,093,694**		
Debt Service	$3,588,867		
Total Annual Costs	**$4,682,561**		
Total Water Recycled	1460	MGal/yr	
Cost of Recycle Water	**$3.21**	**$/1000 Gal**	

DIVERSION / WETLAND / CONVEYANCE MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#1 @ 4 MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields (Yellow)

			Comments
Wetland Design			
Wetland Treatment Flow	MGD	**4.0**	Calc
Unit Size	Acre/MGD	20.00	Calc
Design Size	Acre	80	Calc
Force main			Force main assumed needed fc
Conveyance Operating Factor	%	100	From Economics Input
Conveyance Operating Days	Days	365	Calc
Design Flow	MGD	**4.0**	Calc
""	gpm	2778	Calc
""	ft^3/s	6	Calc
Inside Diameter	in	20	<=== Check
Flow Velocity	ft/sec	2.84	Typically 7 ft/s max
Length	Miles	40.6	From conceptual routing
	ft	214368	Calc
Fitting Factor	%	10	
Equivalent Length	ft	235805	Calc
H-W Friction Factor	C	130	
Friction Head	ft	332	Calc
	psi	143.7	Calc
Conveyance Pumping			
Flow	MGD	4.0	Calc
	gpm	2778	Calc
Suction Elevation	ft	3100	
Destination Elevation	ft	3100	
Static Head	ft	0	Calc
TDH	ft	332	Calc
HHP	HP	232.9	Calc
Pump Efficiency	%	80	From Economics Input
BHP	HP	291.1	Calc
Motor Efficiency	%	95	From Economics Input
Motor Power	KW	306.4	Calc

DIVERSON / WETLAND / CONVEYANCE MODEL

Client **White River Municipal Water District (WRMWD)**
Location **Lubbock, TX**
Alternative **#1 @ 4 MGD**
APAI Project No. **675-0501**
Project Title **Recycle Water Program**

Capital Costs							
Description	**Size**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**	**Subtotal**
				[$]	**[$]**	**[$]**
MF/RO Water Treatment						
Pretreatment Facilities		4	MG	$1,000,000	$4,000,000	
MF/RO Treatment Facilities		4	MG	$1,900,000	$7,600,000	
						$11,600,000
Conveyance Pump Station						
Main Conveyance Pumps (2800 gpm)		2	EA	$320,000	$640,000	
Civil		1	lot		$122,688	
Structural		1	lot		$138,099	
Piping		1	lot		$1,230,682	
Electrical		1	lot		$517,210	
Instrument		1	lot		$446,234	
Paint		1	lot		$61,299	
Insulation		1	lot		$153,677	
Equipment Setting		1	lot		$46,720	
						$3,356,608
Force Main						
Effluent Pipe Line	20	214368	LF	$80	$17,149,440	
Air Valves/Blow Off Valves		41	EA	$5,000	$205,000	
						$17,354,440
Wetland						
Constructed Wetland		80	Acre	$15,000	$1,200,000	
						$1,200,000
Subtotal Project Costs						**$33,511,048**
Project Contingency		20	%			$6,702,210
Subtotal Project Costs						**$40,213,258**
Engineering, Legal, Bond Acquisition		20	%			$8,042,652
Total Project Capital Costs						**$48,255,909**
Owner's Costs						
Land - Wetland		80	Acre	$2,000	$160,000	
Land - Pipeline Easement	100	492	Acre	$2,000	$984,242	
						$1,144,242
TOTAL PROJECT COSTS						**$49,400,152**

DIVERSION / WETLAND / CONVEYANCE MODEL

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#1 @ 4 MGD**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Operations and Maintenance Costs

Input from Definition and Capital Costs

Capital Costs	$48,255,909	
Operating	365	
Diverting Days	0	0%
Conveyance Days	365	100%
Energy Cost	$ 0.07	$/kWHr

Operating Costs

	Qty	Unit Rate	Unit	Total Cost [$/yr]
Operations				
Operations Labor		0.50	%	$241,280
Maintenance				
Maintenance Labor		0.50	%	$241,280
Maintenance Materials		0.75	%	$361,919
Power	**KW**	**Hrs**	**kWHr**	**[$/yr]**
Conveyance Pumping	306	8760	2684222	$187,896
Misc.	100	8760	876000	$61,320
Total Power Cost				$249,216

DIVERSION / WETLAND / RECYCLE PROJECT ECONOMIC MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#2**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields

Input Fields	Qty	Units	Comments
Average System Capacity	2	MGD	
Design Factors			
"River Low" Factor	50	%	Percent of year stream has low flow; cannot divert
Conveyance Operating Factor	50	%	Percent of year operable; maintenance, etc.
Capital Recovery Factor			
Investment Life	30	Years	
Annual Percentage Rate	6	%	
Calculated CRF	0.073		
Pumping Efficiency	80	%	
Motor Efficiency	95	%	
Power Cost	$ 0.07	$/kWHr	
Operating Labor Cost, Annual	0.50	%	of Capital Costs
Maintenance Costs, Annual			
Maintenance Labor	0.50	%	of Capital Costs
Maintenance Materials	0.75	%	of Capital Costs

Results

Project Costs			
Total Capital Costs	$42,833,157		New Facilities
Owner's Costs	$732,121		Land, Easements
Total Project Costs	**$43,565,278**		
Operating Costs, Annual			
Operating Labor	$214,166		
Maintenance Labor	$214,166		
Maintenance Materials	$321,249		
Power	$115,930		
Brine Disposal	$50,000		
Total Annual O&M Costs	**$915,510**		
Debt Service	$3,164,970		
Total Annual Costs	**$4,080,480**		
Total Water Recycled	730	MGal/yr	
Cost of Recycle Water	**$5.59**	**$/1000 Gal**	

DIVERSION / WETLAND / CONVEYANCE MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#2**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields (Yellow)

			Comments
Wetland Design			
Wetland Treatment Flow	MGD	**4.0**	Calc
Unit Size	Acre/MGD	20.00	Calc
Design Size	Acre	80	Calc
Conveyance Pipeline			
Conveyance Operating Factor	%	50	From Economics Input
Conveyance Operating Days	Days	183	Calc
Design Flow	MGD	**4.0**	Calc
""	gpm	2778	Calc
""	ft^3/s	6	Calc
Inside Diameter	in	20	<=== Check
Flow Velocity	ft/sec	2.84	Typically 7 ft/s max
Length	Miles	23.6	From conceptual routing
	ft	124608	Calc
Fitting Factor	%	10	
Equivalent Length	ft	137069	Calc
H-W Friction Factor	C	130	
Friction Head	ft	193	Calc
	psi	83.5	Calc
Conveyance Pumping			
Flow	MGD	4.0	Calc
	gpm	2778	Calc
Suction Elevation	ft	2500	
Destination Elevation	ft	2500	
Static Head	ft	0	Calc
TDH	ft	193	Calc
HHP	HP	135.4	Calc
Pump Efficiency	%	80	From Economics Input
BHP	HP	169.2	Calc
Motor Efficiency	%	95	From Economics Input
Motor Power	KW	178.1	Calc

DIVERSON / WETLAND / CONVEYANCE MODEL

Client **White River Municipal Water District (WRMWD)**
Location **Lubbock, TX**
Alternative **#2**
APAI Project No. **675-0501**
Project Title **Recycle Water Program**

Capital Costs							
Description		**Size**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**	**Subtotal**
					[$]	**[$]**	**[$]**
MF/RO Water Treatment							
	Pretreatment Facilities		4	MG	$1,000,000	$4,000,000	
	MF/RO Treatment Facilities		4	MG	$1,900,000	$7,600,000	
	Evaporation Beds for Brine Disposal		1	EA	$1,500,000	$1,500,000	
							$13,100,000
Conveyance Pump Station							
	Main Conveyance Pumps (2800 gpm)		2	EA	$320,000	$640,000	
	Civil		1	lot		$122,688	
	Structural		1	lot		$138,099	
	Piping		1	lot		$1,230,682	
	Electrical		1	lot		$517,210	
	Instrument		1	lot		$446,234	
	Paint		1	lot		$61,299	
	Insulation		1	lot		$153,677	
	Equipment Setting		1	lot		$46,720	
							$3,356,608
Conveyance Pipeline							
	Effluent Pipe Line	20	124608	LF	$80	$9,968,640	
	Air Valves/Blow Off Valves		24	EA	$5,000	$120,000	
							$10,088,640
Diversion Structure			1	EA	$2,000,000	$2,000,000	
							$2,000,000
Wetland							
	Constructed Wetland		80	Acre	$15,000	$1,200,000	
							$1,200,000
Subtotal Project Costs							**$29,745,248**
	Project Contingency		20	%			$5,949,050
Subtotal Project Costs							**$35,694,298**
Engineering, Legal, Bond Acquisition			20	%			$7,138,860
	Total Project Capital Costs						**$42,833,157**
Owner's Costs							
	Land - Wetland		80	Acre	$2,000	$160,000	
	Land - Pipeline Easement	100	286	Acre	$2,000	$572,121	
							$732,121
TOTAL PROJECT COSTS							**$43,565,278**

DIVERSION / WETLAND / CONVEYANCE MODEL

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#2**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Operations and Maintenance Costs

Input from Definition and Capital Costs

Capital Costs	$42,833,157	
Operating	365	
Diverting Days	0	0%
Conveyance Days	182.5	50%
Energy Cost	$ 0.07	$/kWHr

Operating Costs

	Qty	Unit Rate	Unit	Total Cost [$/yr]
Operations				
Operations Labor		0.50	%	$214,166
Maintenance				
Maintenance Labor		0.50	%	$214,166
Maintenance Materials		0.75	%	$321,249
Power	**KW**	**Hrs**	**kWHr**	**[$/yr]**
Conveyance Pumping	178	4380	780143.4	$54,610
Misc.	100	8760	876000	$61,320
Total Power Cost				$115,930
Brine Disposal				$50,000

DIVERSION / WETLAND / CONVEYANCE MODEL

DIVERSION / WETLAND / RECYCLE PROJECT ECONOMIC MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#3**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields	**Qty**	**Units**	**Comments**
Average System Capacity	2	MGD	
Design Factors			
Evaporation	0	%	Percent of Average System Capacity
"Lake Full" Factor	0	%	Percent of year lake full; cannot recycle
"River Low" Factor	0	%	Percent of year stream has low flow; cannot divert
Conveyance Operating Factor	100	%	Percent of year operable; maintenance, etc.
Capital Recovery Factor			
Investment Life	30	Years	
Annual Percentage Rate	6	%	
Calculated CRF	0.073		
Pumping Efficiency	80	%	
Motor Efficiency	95	%	
Power Cost	$ 0.07	$/kWHr	
Operating Labor Cost, Annual	0.50	%	of Capital Costs
Maintenance Costs, Annual			
Maintenance Labor	0.50	%	of Capital Costs
Maintenance Materials	0.75	%	of Capital Costs

Results

Project Costs			
Total Capital Costs	$33,789,542		New Facilities
Owner's Costs	$1,064,242		Land, Easements
Total Project Costs	**$34,853,785**		
Operating Costs, Annual			
Operating Labor	$168,948		
Maintenance Labor	$168,948		
Maintenance Materials	$253,422		
Power	$138,499		
Brine Disposal	$50,000		
Total Annual O&M Costs	**$779,816**		
Debt Service	$2,532,090		
Total Annual Costs	**$3,311,905**		
Total Water Recycled	730	MGal/yr	
Cost of Recycle Water	**$4.54**	**$/1000 Gal**	

DIVERSION / WETLAND / CONVEYANCE MODEL

Project Identification

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#3**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Input Fields (Yellow)

			Comments
Wetland Design			
Wetland Treatment Flow	MGD	**2.0**	Calc
Unit Size	Acre/MGD	20.00	Calc
Design Size	Acre	40	Calc
Conveyance Pipeline			
Conveyance Operating Factor	%	100	From Economics Input
Conveyance Operating Days	Days	365	Calc
Design Flow	MGD	**2.0**	Calc
""	gpm	1389	Calc
""	ft^3/s	3	Calc
Inside Diameter	in	16	<=== Check
Flow Velocity	ft/sec	2.22	Typically 7 ft/s max
Length	Miles	40.6	From conceptual routing
	ft	214368	Calc
Fitting Factor	%	10	
Equivalent Length	ft	235805	Calc
H-W Friction Factor	C	130	
Friction Head	ft	273	Calc
	psi	118.1	Calc
Conveyance Pumping			
Flow	MGD	2.0	Calc
	gpm	1389	Calc
Suction Elevation	ft	3125	
Destination Elevation	ft	3125	
Static Head	ft	0	Calc
TDH	ft	273	Calc
HHP	HP	95.7	Calc
Pump Efficiency	%	80	From Economics Input
BHP	HP	119.6	Calc
Motor Efficiency	%	95	From Economics Input
Motor Power	KW	125.9	Calc

DIVERSON / WETLAND / CONVEYANCE MODEL

Client **White River Municipal Water District (WRMWD)**
Location **Lubbock, TX**
Alternative **#3**
APAI Project No. **675-0501**
Project Title **Recycle Water Program**

Capital Costs							
Description		**Size**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**	**Subtotal**
					[$]	**[$]**	**[$]**
MF/RO Water Treatment							
	MF/RO Treatment Facilities		3	MG	$1,900,000	$5,700,000	
	Evaporation Beds for Brine Disposal		1	EA	$2,000,000	$2,000,000	
							$7,700,000
Conveyance Pump Station							
	Main Conveyance Pumps (1400 gpm)		2	EA	$200,000	$400,000	
	Civil		1	lot		$76,680	
	Structural		1	lot		$86,312	
	Piping		1	lot		$769,176	
	Electrical		1	lot		$323,256	
	Instrument		1	lot		$278,896	
	Paint		1	lot		$38,312	
	Insulation		1	lot		$96,048	
	Equipment Setting		1	lot		$29,200	
							$2,097,880
Conveyance Pipeline							
	Effluent Pipe Line	16	214368	LF	$60	$12,862,080	
	Air Valves/Blow Off Valves		41	EA	$5,000	$205,000	
							$13,067,080
Wetland							
	Constructed Wetland		40	Acre	$15,000	$600,000	
							$600,000
Subtotal Project Costs							**$23,464,960**
	Project Contingency		20	%			$4,692,992
SubTotal Project Costs							**$28,157,952**
Engineering, Legal, Bond Acquisition			20	%			$5,631,590
	Total Project Capital Costs						**$33,789,542**
Owner's Costs							
	Land - Wetland		40	Acre	$2,000	$80,000	
	Land - Pipeline Easement	100	492	Acre	$2,000	$984,242	
							$1,064,242
TOTAL PROJECT COSTS							**$34,853,785**

DIVERSION / WETLAND / CONVEYANCE MODEL

Client	**White River Municipal Water District (WRMWD)**
Location	**Lubbock, TX**
Alternative	**#3**
APAI Project No.	**675-0501**
Project Title	**Recycle Water Program**

Operations and Maintenance Costs

Input from Definition and Capital Costs

Capital Costs	$33,789,542	
Operating	365	
Diverting Days	0	0%
Conveyance Days	365	100%
Energy Cost	$ 0.07	$/kWHr

Operating Costs

	Qty	Unit Rate	Unit	Total Cost [$/yr]
Operations				
Operations Labor		0.50	%	$168,948
Maintenance				
Maintenance Labor		0.50	%	$168,948
Maintenance Materials		0.75	%	$253,422
Power	**KW**	**Hrs**	**kWHr**	**[$/yr]**
Conveyance Pumping	126	8760	1102551	$77,179
Misc.	100	8760	876000	$61,320
Total Power Cost				$138,499
Brine Disposal				$50,000

APPENDIX B Listing of Potential Funding Opportunities

B.1 Clean Water State Revolving Fund Loan Program

The Clean Water State Revolving Fund Program (CWSRF) provides loans at interest rates lower than what can be obtained through commercial markets. The CWSRF also includes Federal (Tier III) funds and Disadvantaged Community funds that provide even lower interest rates for applicants meeting the respective criteria.

Any political subdivision with the authority to own and operate a sewerage system can apply for the funding. Nonprofit water supply corporations are **not** eligible to receive assistance from the CWSRF wastewater loan program. The program is financed with a combination of federal capitalization grants and state funds. A water quality based priority system is used to rank potential applicants and fund projects with the greatest environmental benefits.

Loans can be used for planning, design, and construction of wastewater treatment facilities, wastewater recycling and reuse facilities, collection systems, storm water pollution control projects. They can also be used for implementation of non-point source pollution control projects.

Type: Loan

Uses: Planning, acquisition and construction, wastewater treatment, stormwater and non-point source pollution control, and reclamation/reuse projects.

Applicants: Political Subdivisions. Individuals are eligible to apply for non-point source pollution control projects.

Availability: An annual priority rating process applies to projects.

B.2 Drinking Water State Revolving Fund Loan Program

The Drinking Water State Revolving Fund (DWSRF) provides loans at interest rates lower than the market offer to finance projects for public drinking water systems that facilitate compliance with primary drinking water regulations or otherwise significantly further the health protection objectives of the federal Safe Drinking Water Act (SDWA). Applicants may be a political subdivision of the state, a nonprofit water supply corporation, privately owned water system and state agencies.

Loans can be used for the planning, design, and construction of projects to upgrade or replace water supply infrastructure, to correct exceedances of SDWA health standards, to consolidate water supplies and to purchase capacity in water systems. DWSRF loan proceeds can also be used to purchase land integral to the project.

Under the Source Water Protection Program, an applicant may apply for a loan to purchase land or conservation easements, if the purpose of the purchase is to protect the source water of a public system from contamination and to ensure compliance with national primary drinking water regulations.

Type: Loans and additional subsidies (subsidies are for disadvantaged communities only)

Uses: Planning, acquisition and construction of water related infrastructure, including water supply and Source Water protection.

Applicants: Community water system owners and Nonprofit Non-Community water system owners are eligible to apply for the funding. This includes political subdivisions of the state and private individuals.

Availability: An annual priority rating process applies to projects.

B.3 Rural Water Assistance Fund Program

The Texas Water Development Board (TWDB) administers the Rural Water Assistance Fund (RWAF), created in 2001 by the 77th Texas Legislature. The RWAF program is designed to assist small rural water utilities to obtain low cost financing for water or water-related projects. The TWDB offers attractive interest rate loans with short and long-term finance options at tax-exempt rates. Funding through this program gives an added benefit to Nonprofit Water Supply Corporations by making construction purchases qualify for a sales tax exemption.

Eligible Applicants are defined as Rural Political Subdivisions which include nonprofit water supply or sewer service corporations, water districts, or municipalities serving a population of up to 10,000, or that otherwise qualify for federal financing, or counties in which no urban area has a population exceeding 50,000. Generally, the program targets Non-profit Water Supply Corporations with eligible water supply projects.

The RWAF loans may be used to fund water-supply construction projects including, but not limited to, line extensions, overhead storage, the purchase of well fields, the purchase or lease of rights to produce groundwater, and interim financing of construction projects. Costs of planning, design, and construction are all eligible for funding. The fund may also be used to enable a rural water utility to obtain water supplied by a larger utility or to finance the consolidation or regionalization of a neighboring utility.

Type: Loan

Uses: Planning, acquisition and construction of water supply related infrastructure, including water treatment, water distribution pipelines, reservoir construction, and storage acquisition.

Applicants: Political Subdivisions and Nonprofit Water Supply Corporations.

Availability: Not restricted.

B.4 Water and Wastewater Loan Program

(State Loan Program - Development Fund II)

The Development Fund II refers to the source of funding from State loans are made. This is essentially a pure state loan program that does not receive Federal subsidies. The program includes loans for water supply, water quality enhancement, flood control and municipal solid waste. This Development Fund II serves the purposes previously served by Development Fund (Development Fund I), but separates the Loan Programs from the State Participation Program component. Also, the Economically Distressed Areas component of the Program is separate. While not changing what may be funded, Development Fund II enables the Board to fund multiple eligible components in one loan to borrowers, e.g., if an applicant applies for funding of a water and wastewater component, this is done with one loan.

Generally, funding is available for all Political Subdivisions of the State (at tax exempt rates) and Water Supply Corporations (at taxable rates) with eligible water, wastewater, flood and municipal solid waste projects.

Financial assistance for Water Supply may include acquisitions, improvements or construction of wells, retail distribution and wholesale transmission lines, pumping facilities, storage reservoirs and tanks, and water treatment plants. It also provides financing for the purchase of water rights. Non-point Source pollution abatement is also eligible

Financial assistance for Wastewater (Water Quality Enhancement Purposes) may include acquisitions and improvements or construction of wastewater facilities such as sewer treatment plants and collection systems.

Financial assistance for Flood Control may include structural and nonstructural flood protection improvements such as construction of storm water retention basins, enlargement of stream channels, modification or reconstruction of bridges, acquisition of floodplain land for use in public open space, acquisition and removal of buildings located in a floodplain, relocation of residents of buildings removed from a floodplain, public beach re-nourishment, flood warning systems, control of coastal erosion, and the development of flood management plans.

Type: Loan

Uses: Planning, acquisition and construction of water related infrastructure, including water supply, wastewater treatment, storm water and non-point source pollution control, flood control, reservoir construction, storage acquisition, and agricultural water conservation projects, and municipal solid waste facilities.

Applicants: Political Subdivisions and Nonprofit Water Supply Corporations.

Availability: Not restricted

APPENDIX C Texas Water Development Board Review Comments

ATTACHMENT 1

TEXAS WATER DEVELOPMENT BOARD
Review Comments of the Draft Final Report: Contract No. 2003-483-487
"Augmentation of Water Supply Using Reclaimed Water"

Page 7-14 Table 7-2. There appears to be an extraneous footnote indicator (**) unless there is an omitted methodology assumption about maximum percent blend for Alternative #3.

Page 7-11 Section 7.2.6. In the last paragraph, please specify the source of the average annual demand (1.95 MGD). According to the Llano Estacado Regional Water Plan (RWP), Year 2000 demands for the four-member cities total 1,919 acre-foot/yr (1.71 MGD). A smaller demand would increase the cost per acre-foot of water.

Page 7-16 Figure 7-16. It appears that the same graph was inserted for Figures 7-7 and 7-11. In Section 7.2.6, it is stated that RO treatment is used to maintain the range of historical TDS concentrations, but Figure 7-7 shows an increasing trend. Please insert the correct graph. If this is the correct graph, please clarify whether Alternatives #1 and #2 can maintain TDS concentrations in White River Reservoir. (According to Table 7-1, it appears that this figure is not correct).

Page 7-19 Section 7.2.6. The second paragraph states that the "maximum amount of water that could be diverted is approximately 45 MGD." This figure should probably be "5 MGD." Please correct.

Page 7-30 Table 7-4. The $600/ac-ft figure provided by the TWDB was a best available estimate at the time and may not be a valid figure based upon the latest information available. APAI may wish to indicate this in the footnote.

Page 8-3 At the end of the summary and recommendations section, it would be helpful to I include the schematic of the recommended option (Figure 7-1)

Appendix A Page 3 of 4. TWDB staff working on desalination projects are interested in how you arrived at the cost estimate for the "MF/RO Water Treatment". Is it possible to provide a more detailed description of this item?

APPENDIX D Response to Texas Water Development Board Review Comments

Responses prepared by Alan Plummer Associates, Inc. on behalf of White River Municipal Water District.

Comment 1 (page 7-14): Extraneous footnote indicator was deleted.

Comment 2 (page 7-11): A footnote was added to the text to document the source of the average annual demand. As stated in this footnote, the source is pumped treated water flow data provided by the District.

Comment 3 (page 7-16): Figures have been corrected in the final report. Reviewer was correct that Figure 7-7 was incorrect in the draft report. The corrected Figure 7-7 does not show the same increasing TDS trend.

Comment 4 (page 7-19): The text should have read "maximum amount of water that could be diverted is approximately 4 – 5 MGD". This was a pdf conversion problem and has been corrected in the final version.

Comment 5 (page 7-30): Footnote c for Table 7-4 has been modified to state that the $600/ac-ft figure was the best available estimate at the time and is subject to change in the future.

Comment 6 (page 8-3): Figure 7-1 has been added to the end of the summary and recommendations section (as Figure 8-1).

Comment 7 (Appendix A): A brief description of how the cost estimate for MF/RO was derived is provided below:

Treated secondary effluent from Lubbock's WWTP, after chlorine disinfection but before dechlorination, will be taken to the RO plant. It was assumed that the facilities would consist of chemical feed facilities for coagulation, either granular or fabric filters, pumping through the MF membranes, cartridge filters and chemical conditioning of the water, pumping through the RO membranes, backwash and in-place chemical cleaning, brine disposal pumping and piping (back to the plant effluent stream), finished water storage, final disinfection, and pumping.

It is estimated that the MF/RO equipment alone (without basins, buildings, installation, electrical/instrumentation, filters, pumps, storage, chemical feed facilities, or site work) will cost over $1/gallon. We estimated a total of $2.90/gallon finished construction cost, which includes a 25% built-in contingency. This cost is consistent with costs on other MF/RO plants designed by APAI and current opinions of cost being developed for other clients. However, it should be noted that membrane equipment costs have been decreasing as their use becomes more prevalent. It is anticipated that this trend will continue for some time in the future.