The Stage 1 D/DBP Rule proposes reduced TTHM and HAA5 MCLs. These lowered values are considered "placeholders" because their determination will be addressed in the Stage 2 Rule following further regulatory negotiations and review of results from the Information Collection Rule (ICR). The ICR required certain utilities to collect full-scale and/or bench- or pilot-scale data to evaluate DBP precursor removal. The implementation schedule for Stage 2 is shown in Table 6-2.

Table 6-2: Stage 2 D/DBP Rule Implementation Schedule

Begin Regulatory Negotiations	December 1998
Stakeholder Agreement	mid 2000
Re-Proposal	February 2001
Final (date of promulgation)	May 2002
Effective	Not before 2005

6.2.2 Stage 1 D/DBP Rule Requirements

Maximum Residual Disinfectant Levels (MRDLs):

Current TNRCC regulations require a minimum disinfectant residual in the distribution system of 0.2 mg/L for free chlorine or 0.5 mg/L for chloramine. Currently, there are no requirements for limiting the disinfectant concentrations in the distribution system. However, the Stage 1 D/DBP Rule establishes MRDLs for this purpose. Table 6-3 shows the MRDL for each disinfectant type.

Table 6-3: Maximum Residual Disinfectant Levels

Disinfectant	**Requirement**
Chlorine (as Cl_2)	4.0 mg/L
Chloramine (as Cl_2)	4.0 mg/L
Chlorine Dioxide (as ClO_2)	0.8 mg/L

Maximum Contaminant Levels (MCLs):

Currently, the TNRCC requires systems with service populations greater than 10,000 to maintain TTHM levels below 100 µg/L. Systems with service populations less than 10,000 are not regulated for DBPs.

Some of the identified DBPs, such as trihalomethanes (THMs), haloacetic acids (HAAs), bromate (BrO_3^-), and chlorite (ClO_2^-) are regulated for surface and ground water as a part of the Stage 1 D/DBP Rule as shown in Table 6-4. Microbial and chemical contaminant data collected under the ICR will be used in the development of the Stage 2 D/DBP Rule.

Table 6-4: MCLs for the Stage 1 D/DBP Rule

Parameter	**Requirement**
Total Trihalomethanes (TTHMs)	80 µg/L
Haloacetic Acids (HAA5)*	60 µg/L
Bromate	10 µg/L
Chlorite	1.0 mg/L

*sum of monochloro-, dichloro-, trichloro-, monobromo-, and dibromoacetic acid

Routine monitoring will be required to check the MRDLs and MCLs. Compliance is based on the running annual average of quarterly values. That is, the average of readings taken in a given month is averaged with the two other monthly averages in a given quarter. Then the average of the most recent 4-quarter averages is used to determine compliance.

As a minimum, chlorine and/or chloramine residuals must be measured at the same points in the distribution system and at the same time as total coliforms. Bromate, chlorine dioxide, and chlorite monitoring requirements are more stringent, requiring daily measurements at the entry to the distribution system.

Routine monitoring for TTHMs and HAA5 requires a minimum of four water samples each quarter for systems serving > 10,000. At least one sample, or 25% of the collected samples, if more than four, must be taken at the point of maximum residence time in the distribution system. The remaining 75% must be taken from representative locations in the distribution system.

Reduced monitoring is allowed for systems that meet certain established performance criteria and for systems serving smaller populations.

Proposed Stage 2 D/DBP Rule:

In addition to the MCLs discussed above, the Stage 1 D/DBP Rule proposes lowering the MCLs for TTHMs and HAA5 to 40 μg/L and 30 μg/L in a second stage of the Rule. As previously mentioned, these are "placeholder" values and will be finalized after further regulatory negotiations and completion of the ICR.

Recent regulatory discussions have indicated it is not likely the MCLs will be lowered to these values since health effects data will not be available in time for the Stage 2 Rule. Instead, possibilities for the final requirements of the Stage 2 D/DBP Rule include:

- establishing maximum, "not to be exceeded," values of 80 μg/L and 60 μg/L, or
- changing to quarterly compliance with the Stage 1 MCLs versus the running annual average of quarterly values.

It is highly likely the D/DBP Rule will proceed to a third stage upon evaluation of health effects data. This stage may propose MCLs for individual, or groups of, DBP species. In addition, either Stage 2 or a Stage 3 rule may lower the bromate MCL to 5 μg/L.

The EPA currently lists the Best Available Technology (BAT) for reducing DBPs as Granular Activated Carbon (GAC) filtration.

<u>TOC Removal:</u>

There are currently no TOC removal requirements for drinking water utilities. However, to reduce human exposure to unregulated and unknown DBPs, the Stage 1 D/DBP Rule includes a treatment technique requirement to remove TOC, a surrogate measure of NOM that serves as DBP precursor material. This treatment technique is termed "enhanced coagulation."

A public water system *must* implement "Enhanced coagulation" if...

the source water is surface water or ground water under the direct influence of surface water;

and

the system uses conventional treatment including coagulation, sedimentation, and filtration.

The primary intent of this treatment technique is to establish TOC removal requirements so that:

- significant TOC reductions can be achieved by systems treating surface water with coagulation and sedimentation processes by using elevated, but not unreasonable, amounts of coagulant.

To achieve this objective, a TOC-based performance standard was developed using a 2-step approach. Step 1 requires removal of a specific percent of influent TOC to demonstrate compliance, based on the TOC and alkalinity of the source water. Step 2 allows systems with "difficult-to-treat" waters, that cannot meet Step 1 criteria, to demonstrate to the State, through specific protocol, an alternative TOC removal percentage for defining compliance.

Step 1 TOC Removal Requirements:

Table 6-5 summarizes Step 1 percent TOC removal requirements. Systems must achieve the specified percent removal of TOC between the raw water source and the final TOC monitoring location (combined filter effluent).

Table 6-5: Step 1 TOC Removal Requirements

SOURCE WATER TOC (mg/L)	SOURCE WATER ALKALINITY (mg/L as CaCO3)		
	0 to 60	> 60 to 120	> 120
> 2.0 to 4.0	35%	25%	15%
> 4.0 to 8.0	45%	35%	25%
> 8.0	50%	40%	30%

The percent removal requirements specified in Table 6-5 were developed in recognition of the tendency for TOC removal to become more difficult (and more costly) as alkalinity increases and TOC decreases.

"If Step 1 TOC removal performance criteria or <u>alternative compliance criteria</u> cannot be met, systems must implement Step 2 requirements."

Alternative Compliance Criteria:

Certain waters are less amenable to effective removal of TOC by coagulation. For this reason, alternative compliance criteria have been developed to allow systems flexibility for establishing compliance. These criteria recognize the low potential of certain waters to produce DBPs, and also account for those waters amenable to TOC removal that may not meet the Step 1 TOC removal requirement.

A system can establish compliance with the treatment requirements if any one of the following six criteria are met:

1. Raw water TOC < 2.0 mg/L

2. Treated water TOC < 2.0 mg/L

3. Raw water Specific Ultra-violet Absorbance (SUVA) < 2.0 L/mg-m
   SUVA is UV254 absorbance divided by dissolved organic carbon (DOC) (m^{-1}/mg/L)

4. Treated Water SUVA < 2.0 L/mg-m

   The utility is in compliance if the quarterly, running annual average of one of the parameters in 1-4 meets the specified value. In addition, the system can establish compliance on a monthly basis.

5. Raw Water TOC < 4.0 mg/L; Raw Water Alkalinity > 60 mg/L (as $CaCO_3$); TTHM < 40 µg/L; HAA5 < 30 µg/L

   TOC, alkalinity, TTHM, and HAA5 parameters are based on running annual averages that are computed quarterly.

6. TTHM <40 µg/L and HAA5 <30 µg/L with only chlorine for disinfection

   The TTHM and HAA5 levels are based on a running annual average computed quarterly.

Utilities must collect at least one paired TOC sample (raw and treated water samples) per month to demonstrate compliance with the TOC removal requirements or to qualify for alternative compliance criterion.

Systems serving more than 3,300 people are required to submit a monitoring plan to the State no later than the first time data are submitted to the State to demonstrate compliance with any portion of the Stage 1 D/DBP Rule. The plan must indicate the sampling locations for compliance determination.

Step 2 TOC Removal Requirements:

Some systems required to implement enhanced coagulation will not qualify for alternative compliance criteria or achieve the removals in Table 6-6 because of unique water quality characteristics. These systems are required to conduct jar or bench-scale testing to establish an alternative TOC removal requirement to define compliance. Once an alternative TOC removal requirement is defined and approved by the State, the utility can achieve that removal in the full-scale plant with any combination of coagulant and pH control chemicals.

The alternative TOC removal requirement under Step 2 is established by determining the point of diminishing returns (PODR) for coagulant addition as follows:

- Bench or pilot tests are performed in which alum, or an equivalent dose of ferric coagulant is added in 10 mg/L increments until the pH is lowered to the appropriate target value as specified in Table 6-6.
- Once the bench or pilot tests are complete, TOC removal (mg/L) is plotted versus coagulant dose (mg/L).
- The alternative TOC removal percentage is established at the point on the plot where the slope changes from greater than 0.3/10 to less than 0.3/10 and remains less than 0.3/10.

Table 6-6: Maximum pH Under Step 2 Requirements

Alkalinity of Source Water (mg/L as CaCO3)	Maximum pH
0 to < 60	5.5
60 to < 120	6.3
120 to < 240	7.0
> 240	7.5

Systems that consistently fail to achieve the PODR at all coagulant dosages during the Step 2 jar test procedure are considered to have a water unamenable to enhanced coagulation, and may apply to the State for a waiver from enhanced coagulation requirements.

Determination of Compliance with Enhanced Coagulation Requirements:

Compliance with the TOC removal requirements is based on a running annual average, therefore systems need twelve months of TOC monitoring data to make a compliance determination. Since Step 2 bench or pilot-scale testing is only *required* when a system fails to achieve compliance, Step 2 testing does not have to be performed until the *second* year of TOC compliance sampling. Compliance shall be calculated quarterly by the following method:

1. Determine actual monthly TOC percent removal equal to: (1 - (treated water TOC/source water TOC)) x 100.

2. Determine the required monthly TOC percent removal based on either Step 1 or Step 2 requirements discussed above.

3. To determine the monthly removal ratio, divide the answer from #1 by the answer from #2 (for months that an alternate criterion is met, the facility shall use a value of 1.0 for the monthly ratio).

4. Sum the answers from #3 for the last three months and divide by 3. The result is the quarterly removal ratio.

5. Add the results of #4 for the last four quarters and divide by 4.

6. If the result from #5 >=1.0, the system is in compliance with the TOC percent removal requirements.

6.3 Interim Surface Water Treatment Rule

6.3.1 Background

The Enhanced Surface Water Treatment Rule (ESWTR) is proposed in two stages to correspond to the two stages of the D/DBP Rule. The first stage, the Interim Enhanced Surface Water Treatment Rule (IESWTR), applies to medium and large systems ($\geq$10,000 served) utilizing surface water or ground water under the influence of surface water. This Rule will become effective simultaneous with Stage 1 of the D/DBP Rule to ensure that disinfection is not compromised by utilities in their effort to minimize DBPs. The Long Term 1 ESWTR (LT1ESWTR) is the extension of the IESWTR to small systems (< 10,000 served). The second, or final stage which will apply to all systems, is the Long Term 2 ESWTR (LT2ESWTR).

Table 6-7 shows the expected implementation schedule for these rules.

Table 6-7: ESWTR Implementation Schedule

IESWTR Final (date of promulgation)	December 16, 1998
IESWTR Effective for CRFWTP	December 16, 2001
LT1ESWTR Final (date of promulgation)	November 2000
LT1ESWTR Effective	November 2003
LT2ESWTR Final (date of promulgation)	May 2002
LT2ESWTR Effective	May 2007

The IESWTR includes requirements for turbidity removal and disinfection profiling and benchmarking. This Rule also addresses *Cryptosporidium* and refines the definition of "ground water under the influence of surface water."

6.3.2 IESWTR Requirements

Currently, the Surface Water Treatment Rule (SWTR) provides standards for turbidity removal and disinfection for inactivation of *Giardia Lamblia* and viruses. These standards are shown in Table 6-8.

Table 6-8: SWTR Requirements

Parameter	Requirement
Disinfection	
Giardia	0.5-log inactivation
Viruses	2-log inactivation
Turbidity Removal	
Combined Filter Effluent Turbidity (for systems that use conventional treatment or direct filtration)	0.5 NTU in at least 95% of measurements in a given month. At no time may the turbidity exceed 5.0 NTU.

The SWTR requires 3-log (99.9%) *Giardia* and 4-log (99.99%) virus removal/inactivation. Utilities using conventional treatment with filtration which meet required turbidity removals are credited with 2.5-log removal of *Giardia* and

2-log removal of viruses. Therefore, appropriate CT (disinfectant concentration in mg/L multiplied by contact time, t_{10}, in minutes) levels must be achieved to provide the 0.5-log inactivation for *Giardia* and 2-log inactivation for viruses.

The IESWTR includes more stringent requirements for turbidity removal and requires disinfection profiling and benchmarking for certain systems. Requirements for *Cryptosporidium* inactivation have not yet been established and will likely be addressed in the LT2ESWTR. The requirements of the IESWTR include:

<u>Turbidity:</u>

The IESWTR will require systems using conventional treatment or direct filtration to meet a turbidity standard in the combined filter effluent of 0.3 NTU in at least 95% of measurements in a given month. At no time may the turbidity exceed 1.0 NTU. Measurements should be taken at 4-hour intervals. In addition, individual filter effluent turbidity measurements must be taken. Turbidities in the individual filter effluent may not exceed 1.0 NTU.

Systems must report turbidity levels in excess of 1.0 NTU, based on two consecutive measurements 15 minutes apart, for any individual filter effluent measurement. Likewise, a turbidity in excess of 0.5 NTU for an individual filter in its first four hours of operation must be reported to the State.

<u>Disinfection Profiling and Benchmarking:</u>

Under the IESWTR, a microbial "backstop" is to be established for certain utilities to ensure water quality is not compromised from a microbial perspective as DBPs are reduced. A WTP that has a TTHM concentration greater than or equal to 64 µg/L or a HAA5 concentration greater than or equal to 48 µg/L or may need to make a significant change in disinfection strategy must establish a disinfection "benchmark." To develop the benchmark, the system must measure disinfection residual, contact time, water temperature, pH and perform the following:

- Determine CT values and daily inactivation of *Giardia* for 3 years of historical data or one year of new data must be collected if 3 years of historical data are not available

- Plot the ratio of disinfection achieved to disinfection required (CT/CTreq.) over time

- Determine the lowest inactivation levels for the critical month of each year

The benchmark is the CT value corresponding to the average of the lowest inactivation levels. This benchmark CT value must be maintained in the treatment process, or a notification must be made to the State.

Cryptosporidium:

In the future, increased disinfection levels and more powerful disinfectants will be needed to achieve CT values that could eventually be required for inactivation of *Cryptosporidium*. Inactivation requirements for *Cryptosporidium* have yet to be determined. Research shows that free chlorine, chloramines, and chlorine dioxide are not practically effective for *Cryptosporidium* inactivation. Currently, ozone is the USEPA's preferred disinfectant for *Cryptosporidium.*

The IESWTR will provide 2-log removal credit for *Cryptosporidium* (which meets SWTR requirements) for facilities using conventional or direct filtration that meet the new turbidity requirements. A Maximum Contaminant Level Goal (MCLG) of zero is currently proposed for *Cryptosporidium* until removal/inactivation requirements can be more fully defined.

In general, regulatory requirements for *Cryptosporidium* are moving away from looking only at disinfection and instead are focusing on overall "treatment" issues which may include requirements for monitoring source waters for pathogen content, requirements for inactivation using disinfectants, and physical removal requirements. In addition, the IESWTR will require all new finished water reservoirs be covered to prevent contamination and sanitary surveys will be necessary to evaluate source water, treatment, distribution, etc. These issues will be further addressed in the LT2ESWTR.

6.4 Long Term 2 Enhanced Surface Water Treatment Rule

6.4.1 Background

Currently there are no removal/inactivation requirements for *Cryptosporidium.* The LT2ESWTR, an extension of the IESWTR, may require *Cryptosporidium* removal/inactivation. The level of treatment will likely be related to the level of *Cryptosporidium* oocysts in the raw water. Requirements of the Rule could be based, in part, on evaluations of the source watershed and sanitary surveys. The Long Term Rules will also include requirements for the FBRR to regulate filter backwash recycle and filter-to-waste water quality.

6.4.2 LT2ESWTR Requirements

The LT2ESWTR will be proposed by EPA in November 2000. As part of this Rule, the EPA would maintain the MCLG of zero for *Cryptosporidium* as established in the IESWTR and further define pathogen control requirements.

The EPA is considering four options for defining pathogen densities in source waters (for surface water and ground water under the influence of surface water). These four options are:

- Arithmetic Mean of Data
- Geometric Mean of Data
- 90^{th} Percentile Value
- Maximum Measured Value

Water systems will be required to treat to an established level based on the resulting densities. The EPA is proposing five alternative treatment requirements for *Giardia*, viruses, and *Cryptosporidium*. These five alternatives are:

- Alternative A: Enhanced Treatment for *Giardia*
- Alternative B: Treatment for *Cryptosporidium*
- Alternative C: 2-log Removal of *Cryptosporidium*
- Alternative D: Specific Disinfection Treatment for Viruses
- Alternative E: No Change to Existing SWTR Requirements

The EPA may require any combination of these alternatives in the final rule. Alternative E would maintain current *Giardia* and virus requirements and call for one of the alternatives for *Cryptosporidium* or make a finding that *Cryptosporidium* is adequately controlled by filtration and disinfection requirements of the existing SWTR.

The LT2ESWTR will also add to the requirements of the IESWTR by:

- further defining requirements for sanitary surveys,
- proposing <u>*all*</u> finished water reservoirs be covered,
- requiring cross connection control programs,
- establishing watershed control requirements inclusive of *Cryptosporidium* for systems that wish to avoid filtration

The LT1ESWTR, and the LT2ESWTR, will include requirements for the Filter Backwash Recycling Rule (FBRR). This Rule will provide regulatory requirements for the recycle of filter backwash water within a WTP's treatment process. This rule will address the potential for concentrating pathogenic microorganisms in the treatment process and will apply to all systems. The expected date of promulgation for the FBRR is August 2000. The effective date of the rule will likely occur three years after promulgation.

The 1996 Amendments to the Safe Drinking Water Act (SDWA) included a provision for the USEPA to regulate recycling of spent filter backwash water in water treatment plants. Consequently, USEPA is developing a regulation that is expected to be proposed in the Fall of 1999. The stipulations of this rule have not yet been drafted.

Preliminary details from the EPA indicate several possible outcomes for this regulation, ranging from filter backwash water equalization to solids removal from the spent backwash water. The equalization alternative may require a maximum return flow based on percentage of total plant flow. The solids removal alternative may require removal of a certain percentage of solids from spent backwash water. A third alternative could enable a system to demonstrate that recycling of spent backwash water does not adversely impact finished water quality.

It appears likely that the Rule will require equalization of recycle flows. It is possible the Rule will require all recycle flows be returned to the head of the plant to ensure sufficient removal of *Cryptosporidium*, although systems meeting certain criteria may apply for State waivers to return recycled flows to a different location in the WTP.

6.5 Impacts of Current and Pending Regulations on Treatment Plant Design

This section provides potential impacts of current and pending regulations on the new WTP design. Available Canyon Lake raw water data and finished water data from an existing WTP (which treats Canyon Lake water) are used where appropriate to facilitate the discussion. These data are presented in Section 7.2.

6.5.1 Current Regulations

Current regulations impacting the design of the new WTP include:

- Surface Water Treatment Rule
  - Requires the WTP meet current removal/ inactivation requirements for *Giardia* (3-log) and viruses (4-log). This can be accomplished using conventional or membrane treatment with free chlorine or chloramines for primary disinfection if the appropriate CT is achieved. However, the LT2ESWTR may include more stringent requirements.

- Requires the WTP meet current turbidity standards (monthly 95th percentile rank of 0.5 NTU). However, the new turbidity standards of the IESWTR will likely be effective prior to start-up of the new facility.

➢ TNRCC, Texas Annotated Codes Chapter 290

- Requires the WTP design and construction to meet established state standards.

- Also included are finished water quality parameters such as MCLs for inorganic chemicals, synthetic organic chemicals (SOCs), and volatile organic chemicals (VOCs). Based on available raw water data, it appears these compounds are not present in the raw water at levels exceeding current MCLs.

➢ USEPA Primary and Secondary Drinking Water Standards

- Requires the WTP meet established MCLs and SMCLs for various compounds and water quality parameters. These include polychlorinated biphenyls (PCBs), poly aromatic hydrocarbons (PAHs), and aesthetic parameters as well. Extensive raw water data was not available to evaluate impacts on plant design. Current and future land use in the watershed includes minimal agricultural applications, therefore these compounds are not anticipated to be an issue.

- For arsenic, the current MCL is 0.05 mg/L. However, in May 2000, a new federal regulation for arsenic will likely propose an MCL of 5 μg/L with an effective date of January 1, 2004. In either case, raw water data indicate average arsenic concentrations of 0.001 mg/L.

6.5.2 D/DBP Rule

<u>TOC Removal:</u>

➢ If the WTP design incorporates conventional treatment (coagulation, sedimentation, filtration), the WTP will be required to meet TOC removal requirements and fulfill enhanced coagulation criteria.

  - Canyon Lake raw water alkalinity is typically greater than 120 mg/L as CaCO3 and TOC typically ranges from 2 to 3 mg/L. Therefore, Step 1 enhanced coagulation removal requirements would be 15% for this water.

- Jar testing conducted concurrent with the technology application indicated that 15% removal could be achieved through an enhanced coagulation process using moderate coagulant doses.

- It is possible that one or more of the six alternative compliance criteria could be met. However, additional jar tests and sampling may be warranted to fully evaluate seasonal temperature impacts (coagulation impacts and DBP formation potential) on a conventional WTP design.

- The existing conventional, package filtration WTP (CLWSC), provides an average treated water TOC less than 2 mg/L. Though this shows conventional treatment would likely allow compliance with TOC removal requirements, the level of TOC removal may not be significant enough to meet DBP MCLs.

➢ Conventional treatment combined with powdered activated carbon (PAC) or granular activated carbon (GAC) may provide enough TOC removal to meet Step 1 enhanced coagulation requirements. Ozone may also increase TOC removal.

➢ For a membrane plant, enhanced coagulation is not required and TOC removal is not stipulated. However, the plant would have to address DBP MCLs and would likely need to provide significant TOC removal considering the potentially high contact time for secondary disinfectants in distribution. A combination of microfiltration or ultrafiltration with PAC may achieve significant TOC removal as well as higher pressure membrane processes such as nanofiltration or a GAC filtration process.

6.5.3 IESWTR & LT2ESWTR

Turbidity:

➢ The new WTP will have to comply with the forthcoming 0.3 NTU standard. Since the plant will likely start operation after the effective date of this standard, the design should be based on IESWTR requirements (versus the SWTR).

- Raw water data indicate an average turbidity of 4 NTU. The existing WTP influent turbidity typically ranges from 0.5 to 2.5 NTU with finished water turbidity averaging 0.15 NTU. These data suggest that meeting the new turbidity standard can be achieved with conventional treatment.

- The lower raw water turbidities also suggest that filtration through a membrane unit may be possible without pretreatment. Additional data have shown occasional in-lake turbidity spikes up to 18 NTU, and upstream river turbidity spikes up to 80 NTU. In this case, since the turbidity spikes are infrequent, direct membrane filtration remains an option. The process would likely require higher backwash rates during spike periods.

Cryptosporidium:

- It is possible that the LT2ESWTR, an extension of the IESWTR, will require treatment for *Cryptosporidium*. The LT2ESWTR has not yet been drafted and promulgation is several years away. However, the WTP design will need to evaluate treatment strategies considering the potential requirements for *Cryptosporidium* and possible changes in requirements for *Giardia* and viruses as prescribed in previous sections.

  - Free chlorine and chloramines are not effective for *Cryptosporidium* inactivation. Chlorine dioxide's effectiveness is uncertain and the doses required may be precluded by its DBPs and MRDL.

  - Technologies such as membrane filtration, ozone, or UV disinfection may be required. If state or federal regulations require some measure of inactivation, and do not allow treatment to be achieved by a physical removal alone, a membrane plant may not be cost effective. Therefore, any new plant should have provisions in the site plan and hydraulic profile for ozone or UV disinfection.

  - The plant design will need to account for potential requirements outlined for water storage, cross-connections, watershed controls, etc.

6.5.4 Filter Backwash Recycle Rule

- If spent wash water at the new plant is to be recycled, it is likely that the Rule will require equalization based on the percentage of recycle filter backwash and filter-to-waste flow.

6.6 Impacts of Current and Pending Regulations on Distribution System

6.6.1 Current Regulations

Current regulations impacting the distribution system include:

- Total Coliform Rule
  - Requires analysis to verify the system does not test positive for fecal coliforms. The new WTP will be required to provide adequate disinfection to the individual delivery points to prevent introducing fecal coliforms in the distribution system. However, compliance with total coliform requirements is determined within customer distribution systems.
- Lead and Copper Rule
  - As with the Total Coliform Rule, the Lead and Copper Rule requires analysis to verify lead and copper levels in the customer distribution systems do not exceed established action levels (ALs). The current ALs are 0.015 mg/L for lead and 1.3 mg/L for copper. Limited historical data indicate lead and copper levels have not exceeded these ALs. The WTP is not expected to contribute to lead and copper levels.
- TNRCC, Texas Annotated Codes Chapter 290
  - Requires distribution system design and construction to meet established state standards.
  - Requires systems serving greater than 10,000 customers meet an MCL of 100 µg/L for TTHMs. Since waters are blended amongst providers that have varying service area sizes, all parties should be aware of DBP contributions to the delivered water especially upon implementation of the D/DBP Rule.
  - Also requires that a minimum disinfectant residual level be maintained in the distribution system (0.2 mg/L free chlorine and 0.5 mg/L chloramine). The new WTP design should provide minimum levels to reach each delivery point and should consider blending issues when selecting a secondary disinfection strategy. It is the responsibility of the customer entities to properly blend treated waters and maintain disinfectant levels for distribution.

6.6.2 D/DBP Rule

Maximum Residual Disinfectant Levels (MRDLs):

- Secondary disinfectant residuals (whether free chlorine or chloramines) must not exceed the MRDLs at any point between the WTP and customer delivery points. It is the responsibility of the customer entities to meet MRDLs upon distribution to consumers.

Disinfection By-Products Maximum Contaminant Levels (DBP MCLs):

- The new WTP must provide water that meets future DBP MCLs. The plant design should consider alternatives to meet Stage 1 and Stage 2 (potentially Stage 3) MCLs at the distribution delivery points. In addition, the design should select secondary disinfection practices that will facilitate blending with groundwater and other treated waters.

  - Though raw water TOC levels are moderate, the use of free chlorine as a primary and secondary disinfectant at the new WTP would likely promote significant DBP formation to levels possibly above drinking water MCLs. Short free chlorine contact with chloramines using conventional treatment could meet current disinfection requirements and potentially future DBP MCLs. However, these disinfectants would not be adequate for potential future pathogen inactivation.

  - Similarly, chlorine dioxide, would react with the TOC and likely exceed the chlorite MCL. In addition, it is unlikely that chlorine dioxide can meet potential future pathogen inactivation requirements, without creating DBP problems.

  - Ozone would likely provide necessary disinfection and limit TTHM and HAA formation when used with chloramines for secondary disinfection. However, raw water data indicate possible elevated bromide levels, which could lead to exceedance of the bromate MCL. Therefore, ozone may be technically and economically infeasible (pH adjustment may be necessary and potentially costly).

  - Membranes, PAC, GAC and UV could be used in various combinations to provide disinfection and reduce TOC to prevent DBP formation during secondary disinfection.

- In order to address DBP regulations, it is essential that use of free chlorine and chloramines be evaluated as secondary disinfectants, and that DBP formation potential be analyzed. Since the customer entities use free chlorine, using free chlorine at the plant is favored. However, due to the high residence time in the distribution system from the WTP, free chlorine could result in DBP formation above the MCLs.

6.6.3 GWDR

- The Groundwater Disinfection Rule (GWDR) will establish standards for operating and maintaining ground water systems. In developing the Rule's requirements, the D/DBP Rule, IESWTR, and LT2ESWTR regulations will be used as baselines. Therefore, it is likely ground water systems will have to comply similar water quality requirements as the WTP. The Rule is slated to become effective in late 2003.

6.7 Conclusions

The regulatory strategy for the new 10 mgd WTP design includes meeting the current and promulgated drinking water regulations such as Stage 1 D/DBP and IESWTR as well as future requirements such as Stage 2 D/DBP. The WTP design should include strategies to meet the foreseeable future requirements such as LT2ESWTR.

Regional Water Supply Project for Portions of Comal, Kendall, and Bexar Counties

Water Quality

Technical Memorandum

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7. Water Quality

7.1. Introduction

The purpose of the water quality evaluation is threefold: 1) to understand the raw water conditions in order to appropriately select an efficient and effective treatment technology for the new Western Comal water treatment plant (WTP), 2) to determine finished water quality goals that address GBRA and their customers' goals and applicable regulations, and 3) to confirm that the delivered water will be compatible with existing customer supplies and distribution system. To meet these objectives raw and finished water characterizations were completed, applicable regulations were reviewed, probable blending scenarios were defined, and delivered water quality goals were developed.

7.2. Raw Water Characterization

Raw water for the WTP will be provided from Canyon Lake in accordance with a water use permit from the TNRCC. Canyon Lake is an 8,240 surface acre reservoir located in Comal County on the Guadalupe River. The types of developments around and upstream of the lake within the watershed are important for raw water characterization. Municipal wastewater treatment plants in Kerrville, Center Point and Comfort discharge into the Guadalupe River at approximate distances of 70, 60 and 50 miles upstream of Canyon Lake. In addition, a small waterwater treatment plant for Canyon Park Estates on the north shore discharges approximately 55,000 gpd into the lake. Surface and groundwater throughout this area of Texas is rich in calcium due to lime deposits found in surrounding geological formations. The raw water characterization for Canyon Lake consisted of a review of the available historical water quality information and supplemental information obtained through additional sampling.

The water quality parameters that most influence a treatment technology selection in this project include total organic carbon (TOC), turbidity (and the nature of the particles), bromide, taste and odor, hardness, total dissolved solids (TDS), silica and arsenic. Table 7-1 describes the general impact of each of these parameters on treatment.

Table 7-1: Raw Water Quality Parameters Most Influencing Technology Selection

Quality Parameter	Treatment Impact
TOC	If removal is required, a coagulation, adsorption and/or oxidation process must be implemented. TOC levels affect the type of disinfection strategy applied, as TOC is a precurser to regulated and unregulated disinfection byproducts formed in chlorination.
Particles	Turbidity is a measure of particulate materials removed through coagulation and filtration. For membrane plants, high levels of turbidity requires pretreatment prior to filtration in order to optimize effective run times. In Texas, conventional plants are required to have pretreatment.
Bromide	Ozonation of bromide creates bromate, which will be a regulated compound in impending rules. High raw water bromide levels reduce the cost-effectiveness of ozonation as an alternative.
Taste & Odor	Removal of T&O is accomplished through coagulation (for inorganic T&O substances) and/or the use of adsorbants or oxidants (for organic T&O substances).
Hardness	High levels of hardness in the raw water may require softening. Hardness may cause scaling in pipes, water heaters, and interfere with the activity of soaps.
TDS	TDS levels in raw water indicate the need to incorporate softening into the treatment process.
Silica	Significant levels of silica can preclude the use of membrane treatment.
Arsenic	Removal of arsenic requires a coagulation process or use of higher pressure membranes.

7.2.1. Existing Water Quality Data

The basis for this raw water characterization was formulated primarily from existing historical information. Water quality data for Canyon Lake was obtained from the following sources:

- GBRA monthly sampling at a location (12598) on the north side of the lake (March 1987 – November 1999).
- GBRA monthly sampling in the Guadalupe River (13700), approximately 7.5 miles upstream of the lake (January 1998 – November 1999).

- USGS sampling in the Guadalupe River (08167500), approximately 11 miles upstream of the lake (approximately 3 to 6 samples/year, November 1980 – September 1996).
- USGS sampling in the Guadalupe River (08167800), approximately 2 miles downstream of the lake (3 samples/year, February 1991 – August 1995).
- USGS quality vs. depth data (temp, DO, pH, conductance) and various parameters at the surface in the vicinity of the dam, taken from the engineering report for the CLWSC WTP (The Hogan Corporation, 1994). (3 samples/year, February 1990 – August 1993).

Figure 7-1 depicts a map of the sampling locations near Canyon Lake. Quality information from the available sources is summarized in Table 7-2. Complete water quality sampling data, cumulative percentile plots, and monthly average graphs for examination of seasonal changes are attached in Appendix A.

Table 7-2: Existing Canyon Lake Raw Water Quality Summary

Parameter	Texas WQ Standards (1)	Summary Range (2)
Turbidity		0.5 – 6 ntu Avg = 4 ntu (3)
Alkalinity (as $CaCO_3$)		150-200 mg/L
pH	6.5 - 9.0	8.0 - 8.4
Total Hardness (as $CaCO_3$)	153 mg/L	155-204 mg/L
TDS	400 mg/L	188 - 255 mg/L
TOC		2-3 mg/L
Iron (4)		3 - 6 µg/L
Sulfate	50 mg/L	14 - 21 mg/L
Barium	2 mg/L (d)	0.030 – 0.040 mg/L
Manganese		1 - 4 µg/L (5)
Temperature	32.2 °C	Low - 11 °C High - 29 °C
Fluoride	4 mg/L	0.1 - 0.3 mg/L
Arsenic	50 µg/L (d)	1 µg/L
Silica (4)		9 - 13 mg/L
Conductivity (uohms)		365 – 420
Chloride	50 mg/L	14 - 24 mg/L
Nitrate - N	10 mg/L	0.88 mg/L (winter) 0.14 mg/L (summer) (6)

Parameter	Texas WQ Standards (1)	Summary Range (2)
Ammonia - N		0.07 - 0.11 mg/L
TSS		2.8 – 5.5
Fecal Coliform	126/100mL	8 - 70/100mL
E. Coli		2 - 40/100mL
Transparency (M)		1.8 - 4.0
Dissolved Oxygen	6.0 mg/L (mean) 4.0 mg/L (min)	Winter - 8.8 mg/L @ 1 ft 8.8 mg/L @ 60 ft Summer - 6.8 mg/L @ 1 ft 1.5 mg/L @ 60 ft (7)

Notes:

(d) Value for dissolved portion in water.

(1) Source: 30 TAC 307.1(1) Appendix A – Site Specific Uses and Criteria for Classified Segments; 30 TAC 307.6(c)(1) Table 1 – Criteria in Water for Specific Toxic Materials – Aquatic Life Protection, Table 2 – Total Hardness and pH Values for Determining Select In-Stream Toxic Criteria, Table 3 - Criteria in Water for Specific Toxic Materials – Human Health Protection.

(2) Range created from in lake monthly average sample information, where available. Sample locations available include 2 USGS and 2 GBRA locations. Two sample locations are upstream of the lake, one sample is taken at depth of < 3 m below the water surface on the North shore of the lake, and one sample is taken downstream the lake's dam. Additional USGS samples taken (1990-1993) in the lake just upstream of the dam at a 1 foot depth were included from Canyon Lake Water Supply Corporation's WTP Preliminary Engineering Report (1994).

(3) In-lake samples show two peaks of 18 ntu within the past 13 years. Actual measured influent turbidity at the CLWSC Triple Peak plant (1/99-12/99) were 0.5 - 4.5 ntu.

(4) No sample information in the lake. The sample location was downstream from the dam. One sample point in June 1993 shows Iron at 80 ug/L.

(5) No sample information in the lake. The sample location downstream from the dam shows one sample point in the fall of each year which increases to between 60 and 75 ug/L.

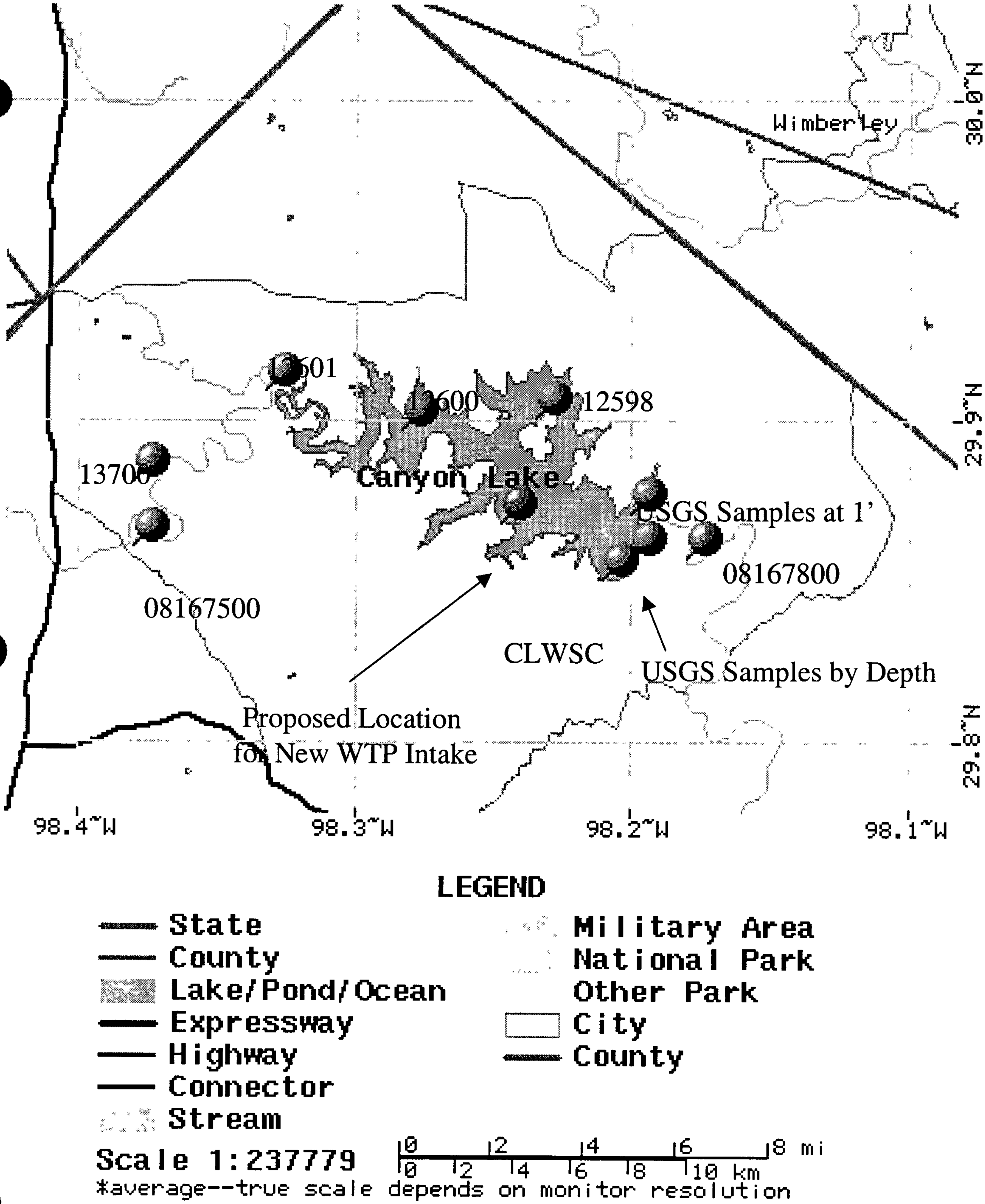
(6) USGS samples from CLWSC PER, Table A-1 show N- Organic = 0.2 - 0.4; N -Inorganic = <0.10 - 0.75.

(7) According to USGS quality/depth data within the CLWSC report, DO levels drop with depth in summer.

7.2.2. Additional Sampling and Testing

In order to characterize the water quality at the proposed intake location, additional samples were collected in January 2000 (Event 1) and February 2000 (Event 2). Samples during Event 1 were taken at two locations approximately 300 feet offshore from the western portion of Comal Park. Each location was sampled at two depths, anticipating the proposed intake will be located 15 - 20 feet below the water surface.

The raw water sample in Event 2 was also collected at the proposed intake location in conjunction with enhanced coagulation jar testing. Sampling results concur with the water quality summary in Table 7-2. They are included in Table 7-3.



Positions of all sampling locations are approximate.

Figure 7-1

Table 7-3: Canyon Lake Additional Sampling Results

	Event 1 (1/24/2000)				Event 2 (2/29/2000) (3)
Sample ID#	1	3	5	6	1
Depth (ft) (2)	20	5	20	5	15
pH	7.1	8.2	8.18	8.2	8.3
Alkalinity (mg/L)	144	144	144	140	162
Bromide (mg/L)	1.1	1.2	1.19	1.12	0.095 (4)
Calcium Hardness (mg/L)	102	101	100	101	NA
Total Hardness (mg/L)	163	170	168	167	187
Turbidity (NTU)	<0.01	<0.01	<0.01	<0.01	1.5
TOC (mg/L)	2	2	2	2	1.7
UV254 (cm-1)	0.0352	0.032	0.025	0.026	0.031
T. Arsenic (mg/L)	<0.01	<0.01	<0.01	<0.01	NA
TTHM (µg/L)	NA (1)	NA	NA	NA	<0.5

Notes:
(1) NA = Not Analyzed.
(2) All sample locations at proposed intake location (approximately 300 feet off shore from Comal Park).
(3) Sample Event 2 occurred in conjunction with Jar Test.
(4) Bromide (Event 2) was analyzed by Montgomery Watson Lab. This value is significantly lower than (Event 1) sample results on 1/24/2000 from San Antonio Testing Lab.

The measured concentrations for alkalinity, calcium and total hardness, turbidity, TOC, and arsenic are within the range of the existing water quality information listed in Table 7-2. Turbidity numbers appear low in Event 1 sampling, however sufficient historical sampling information from the lake is available to support appropriate influent turbidity assumptions used in the design. Historical information on UV_{254} and bromide levels was not available, however, the measured UV_{254} value of 0.025 – 0.035 cm^{-1} is reasonable, based on the low TOC levels. Bromide concentrations vary significantly between the two sampling events. Levels of 1.1 mg/L are very high and indicate that use of ozonation within the treatment plant is not feasible, while levels of 0.095 mg/L are within the acceptable rule of thumb range for treatment with ozonation. Confirmation of raw water bromide levels would be required prior to recommending ozone as a viable treatment process.

Results of the raw water characterization indicate the following:

- If free chlorine is desired for use as a secondary disinfectant, TOC must be removed to minimal levels to minimize DBP formation, as discussed in Chapter 8 - Treatment Technology. (DBP formation modeling results are included in the associated basis of design report for the distribution system).

- Raw water turbidity levels are acceptable for direct membrane filtration (without pretreatment).
- Ozone treatment may not be feasible for this treatment plant, due to possible elevated bromide levels.
- Based on the raw water quality, surface water related taste and odor issues are not expected to be significant. However, due to the desire to reduce taste and odors to minimum levels, increasing the probability for successful blending, taste and odor control facilities should be included in the plant design.
- The lake water is considered hard at an average of 200 mg/L of total hardness. However, because the treatment goal for this water is compatibility with the customer's harder groundwater supplies (see Table 7–5), the raw water does not require softening.
- Silica levels are low and would not adversely affect membrane treatment.
- Arsenic levels are not problematic.

Based on this preliminary analysis, Canyon Lake water is a high quality source that is amenable to conventional or direct membrane filtration treatment. To minimize DBP formation in the pipeline and customer's systems, either TOC will need to be substantially reduced in the raw water in order to support free chlorine as a secondary disinfectant or, a disinfectant which does not form DBPs, such as chloramines, would need to be considered.

7.3. Existing Finished Water Characterization

7.3.1. Finished Water Description

Downstream of most customer delivery points, the treated Canyon Lake water will blend with existing customer water supplies. Each of the finished waters involved in this project was characterized to determine the compatibility between existing water supplies and the anticipated treated finished water from Canyon Lake. This characterization is used as a basis for the blending compatibility study, discussed further in the next section. A brief description of each water to be blended is included below.

<u>Canyon Lake (CLWSC Triple Peak Plant)</u>
The CLWSC Triple Peak Plant is the only existing plant currently treating Canyon Lake water. Supplemented by groundwater wells in the Trinity aquifer, CLWSC serves 1200 customers with a total delivery of 3.5 MGD. The current plant capacity of 1.5 MGD is pumped from a sunken intake structure approximately 34 feet deep and 300 feet offshore from the Triple Peak subdivision on the southeast shore of the lake. The water is treated in a conventional "Robert's filtration" type package plant with primary and secondary chlorine disinfection since start-up in January 1999. CLWSC is currently in design phase for an additional 2.0 MGD (6.0 MGD ultimate) Robert's filtration plant on the north side of the lake. For the purposes of the finished water analysis, this water is

considered representative of future conventionally-treated finished water from the Western Comal WTP.

Edwards Aquifer
An aquifer is a geologic formation which may contain sand, gravel, clays and/or limestone that collects and holds rainwater as it flows through the ground. The Edwards limestone is a rock formation about 500 feet thick which is fractured, honeycombed, and cavernous—found over a large area of Texas. However, water for the San Antonio area is obtained from a separate unit of the Edwards which lies in a strip of land 5 to 25 miles wide, extending through Uvalde, Hondo and San Marcos. The total length of the strip is about 175 miles.

A relatively high level of calcium carbonate (limestone) dissolved in the water is what makes water "hard." The average annual recharge to the Edwards is 450 million gallons per day and the total withdrawal for Bexar County is about 200 million gallons per day. The Edwards aquifer supplies water to out of district customers SAWS and BMWD.

Trinity Aquifer
The Trinity aquifer is also a limestone formation producing "hard" water. The aquifer is located north of the Edwards aquifer and extends from the northern portion of Bexar county into Kendall and Comal counties. It also extends south of the Edwards in Bexar county and Guadalupe county. The Trinity aquifer supplies water to Bexar Metropolitan Water District, Fair Oaks Ranch, and several other in-district customers.

Cibolo Creek WTP (Boerne)
Cibolo Creek provides raw water to the City of Boerne's 1.5 MGD (maximum capacity) conventional surface water treatment plant. Boerne currently combines effluent from this plant with chlorinated groundwater from the Trinity aquifer to serve its customers. The surface and ground waters are of similar quality and are compatible.

7.3.2. Finished Water Quality Comparison

Historical water quality information was obtained from select customers and summarized according to water source in Table 7-5. Additional quality information obtained from all other customers was compared with the listed values and confirmed as comparable to the respective water source. Effluent information from Canyon Lake Water Supply Corporation (CLWSC) Triple Peak Plant was included in the finished water table as a comparable indication of the future effluent quality from the Western Comal plant.

Based on a review of the available finished water information, the quality of the waters appears to be generally similar. As a result, compatibility issues due to precipitation or color are not anticipated. However, bench-scale blending studies will confirm this compatibility conclusion. Detailed water quality comparisons and blending analyses are described in the following section.

Table 7-4: Finished Water Quality Summary

Parameter	RAW Canyon Lake/ Guadalupe River	MCL / Secondary Constituent Levels	Treated Edwards Aquifer	Treated Edwards/ Trinity Aquifer	Treated Trinity Aquifer	Combined Treated Cibolo Crk & Trinity Aquifer	Canyon Lake Treated Surface Water
	USGS / GBRA (1)		SAWS (2)	BMWD (3)	Fair Oaks Ranch (4)	City of Boerne (5)	(CLWSC, CRWASWF) (10)
Turbidity	4 ntu (avg) (GBRA) (7)	0.5 ntu	0.32 ntu	* (9)	* (9)	0.28 (max) ntu	0.15 ntu
Alkalinity (as $CaCO_3$)	140-200 mg/L	NR	203-285 mg/L	257 - 299 mg/L	251 - 300 mg/L	131-195 mg/L	180 mg/L
pH (su)	7.1 - 8.4	6.5 - 8.5	7.1 – 7.4	7.1 - 8.1	7.1 - 7.7	7.3	7.8 – 8.05
Total Hardness (as CaCO3)	160-250 mg/L	NR	227 - 324 mg/L	280 - 445 mg/L	292 - 450 mg/L	159 mg/L	218 - 240 mg/L
TDS	188 - 255 mg/L	1000 mg/L	265 - 360 mg/L	303 - 562 mg/L	375 - 423 mg/L	194-290 mg/L	263- 330 mg/l
Arsenic	0-2 µg/L	50 µg/L	*	<2 µg/L	*	<2 µg/L	*
Fluoride	0.1 - 0.3 mg/L	2 mg/L	0.2 - 0.3 mg/L	0.2 - 1.5 mg/L	0.44 - 0.86 mg/L	0 - 2.4 mg/L	0.2 mg/l
Iron	<0.003 – 0.02 mg/L	0.3 mg/L	*	<0.006 - 0.34 mg/L	< 0.05 mg/L	<0.06 mg/L	*
Copper	*	1.0 mg/L	*	<0.006 - 0.016 mg/L	*	*	*
Lead	*	0.015 mg/L	*	<0.0010 - 0.006 mg/L	*	*	*
Conductivity (umhos)	400 - 520	NR	611 - 658	595 - 1113	665 - 682	*	504
TOC	2-3 mg/L	NR	< 0.5 mg/L	*	*	*	1.3 - 1.6 mg/L
UV254	0.025 - 0.035 cm^{-1}	*	0.006cm^{-1}	*	*	*	0.022 cm^{-1}
Temperature	Jan:11 - 12.5 C Jul/Aug: 29 C	*	22 C	*	*	*	15 C (Feb)
Silica	10 - 13 mg/L	NR	6.1 mg/L	*	*	*	4.7 mg/L
Total CL2	*	*	0.65 mg/L	Not tested	*	1.2 mg/L	1.5 mg/L
Free Cl2	*	> 0.2 mg/L	0.65 mg/L	0.5 - 1.5 mg/L	*	0.8 mg/L	1.5 mg/L
Manganese	<0.001- 0.004 mg/L (6)	0.05 mg/L	*	0.003 - 0.008 mg/L	< 0.05 mg/L	<0.008 mg/L	*
Calcium	*	NR	67 - 110 mg/L	39 - 110 mg/L	75 mg/L	47 - 66 mg/L	59 - 68 mg/l
Magnesium	*	NR	9 - 19 mg/L	7 - 78 mg/L	27 mg/L	12 – 18 mg/L	17 mg/l
Sulfate	13 - 24 mg/L	250 mg/L	11-37 mg/L	8 - 176 mg/L	38 - 48 mg/L	28 –43 mg/L	37 mg/l

Parameter	RAW Canyon Lake/ Guadalupe River	MCL / Secondary Constituent Levels	Treated Edwards Aquifer	Treated Edwards/ Trinity Aquifer	Treated Trinity Aquifer	Combined Treated Cibolo Crk & Trinity Aquifer	Canyon Lake Treated Surface Water
	USGS / GBRA (1)		SAWS (2)	BMWD (3)	Fair Oaks Ranch (4)	City of Boerne (5)	(CLWSC, CRWASWF) (10)
Chloride	14 - 24 mg/L	250 mg/L	14 - 24 mg/L	13 -30 mg/L	25 - 100 mg/L	20 mg/L	23 mg/l
Sodium	*	NR	9 - 20 mg/L	6 - 34 mg/L	10 - 16 mg/L	8 - 11 mg/L	15 mg/l
Nitrate as N	0.88 mg/L (win) 0.14 mg/L (sum) (8)	10 mg/L	1.2 - 2.4 mg/L	0.04 - 2.3 mg/L	0.9 - 1.3 mg/L	0 - 2.33 mg/L	0.72 mg/L
Nitrite as N	(8)	1 mg/L	<0.01 mg/L	<0.01 - 0.95 mg/L	*	*	*
Langlier S Index	*	*	0.86	*	*	*	0.13
Barium	0.03 – 0.04 mg/L	2mg/L	0.03 - 0.14 mg/L	0.013 - 0.041 mg/L	*	0 - 0.078 mg/L	*
Zinc	*	5 mg/L	0.007 - 0.086 mg/L	<0.02 - 0.624	< 0.05 mg/L	<0.02 mg/L	*
Mercury	*	2 μg/L	0.15 μg/L	0.16 - 0.2 μg/L	*	<0.29 – 0.43 ug/L	*
Total THMs	*	100 μg/L	32.2 μg/L	3.84 μg/L	*	<80 μg/L	*
Aluminum	*	0.05 – 0.2 mg/L	*	<0.02 - 0.19 mg/L	*	0.6 – 0.17 mg/L	*
Selenium	*	50 μg/L	*	0 - 4.5 μg/L	*	0 - 4.2 μg/L	*

NOTES:
(1) Information range developed from 3 sources: USGS/GBRA data; CLWSC PER Rpt.; and additional sampling info (1/2000).
(2) Information range developed from four sources: average of three points of entry (March, 96) from Hill Country System; 1998 MPI SAWS/Bexar Met Blending Study; SAWS 1999 WQ Report; and Information from the Wurzbach Pump Station.
(3) Concentration range developed from four source areas (including both Edwards and Trinity Water) within the BMWD system. (Bulverde Hills, Oakland Est, Timberwood Pk, Hill Country System).
(4) Average values 1994 – 1998.
(5) City of Boerne WQ is reported as combined Trinity GW & Cibolo Crk SW. The combined water is the finished water to be blended with the delivered Canyon Lake water. Source: 1998 WQ Report and City Engineer.
(6) The sample location downstream from the dam shows one sample point in the fall of each year which increases to between 60 and 75 ug/L One sample (3/92) for CLWSC was elevated to 20 ug/L.
(7) GBRA sampled on the north side of the lake (up to a depth of 10 ft) monthly between 87 - 94. CLWSC reports infl. Values of 0.5 to 2.5 ntu.
(8) N- Organic = 0.2 - 0.4; N - Inorganic = <0.10 - 0.75.
(9) * = unavailable data.
(10) Treated Canyon Lake water values were taken from Canyon Lake Water Service Corporation records and from Canyon Regional Waster Authority Surface Water Facility (sampled 2/98).

7.4. Finished Water Blending

The objective of this blending section is to confirm the chemical compatibility conclusions established from the finished water quality evaluation. This section describes anticipated blending scenarios, finished water quality comparisons and a description of bench scale blending tests. Based on previously executed compatibility evaluations and tests described in this section, the possibility of chemical precipitation and color issues between waters using the same disinfectant appears to be minimal. The experiences of other utilities suggest that when waters with different secondary disinfectants (such as chlorine and chloramines) are mixed, issues with taste and odor and disinfectant residuals frequently occur.

7.4.1. Anticipated Blending Scenarios

Establishing appropriate blending scenarios within each customer's system is complex and depends on the following variables:

- water demand peaking factors
- initial and ultimate delivery request quantities
- blending location within the existing system
- proximity of the user to the surface water delivery storage tank and groundwater wells

The significance of each variable will fluctuate depending on a customer's system operational strategy. Two anticipated customer operating scenarios are described below.

In order to estimate how this new source of water will blend with existing sources, it is important to understand the basic mode of operation of the customer system. Treatment plants and groundwater pump stations typically operate on a variable flow basis to meet the daily and seasonal water demands of the customers. The base-flow of a water system is generally considered to be the average daily flow delivered to customers. Peak flows in a water system occur daily and seasonally during periods of higher customer use. The ratio of the peak daily flow to the average daily flow of a system is called the peaking factor.

<u>Scenario 1: Constant Delivered Water Flow Meets Base Demands</u>

The agreement for purchasing water from Western Comal WTP is non-typical because it requires customers to accept a constant flow rate from the treatment plant. This flow rate has a major influence on the operational strategy of the systems. Most customers plan to use the delivered water to meet system base demands and supplement their systems with pumped groundwater (GW) to satisfy peak demands. Since maximum day peaking factors can vary between large systems (2.3-2.5) and small systems (up to 4), corresponding blends will vary. For example, during peak flows, systems with higher peaking factors will observe the lowest % ratio of surface water (SW) in the system. Table 7-5 shows sample blending ratios for small and large systems.

Table 7-5: Blending Percentages for Systems Using Delivered Water to Meet Average Day/Base Demands

Extreme Blending Ranges	
Peak Factor = 4 (Max day, Small Systems)	
Winter	100% SW, 0% GW
Summer	25% SW, 75% GW
Peak Factor = 2.5 (Max day, Large Systems)	
Winter	100% SW, 0% GW
Summer	40% SW, 60% GW

(1) City of Boerne will blend treated Canyon Lake water (SW) with treated Cibalo Creek water and will use Trinity groundwater to meet peak demand requirements.

Within this overall customer system operational strategy, the actual blend received by individual users will also vary, depending on the location of the customer within the system. In the case where existing groundwater supplies and delivered surface water supplies are consistently blended in a storage tank, prior to distribution, the blends across the system should be similar. However, in the case where surface water enters the distribution system from a storage tank and groundwater enters from the well location, blends will vary. Users closer to the surface water storage tank will receive higher percentages of surface water, while users closer to the functioning wells will receive higher percentages of groundwater.

Scenario 2: Variable Delivered Water Flows

SAWS and BMWD are the only systems in this scenario. They will receive a constant base flow during periods of peak demand (when other customers are accepting their full requests). During periods of low demand (when other customers cannot accept requested amounts), SAWS and BMWD will receive the excess flows. As the other customers expand capacity and accept their ultimate flow requests, less excess flow will be delivered to SAWS and BMWD.

SAWS plans to deliver the anticipated base constant flow of treated Canyon Lake water to a specific service area within their system. Depending on delivered flow quantities and system demands, the delivered water may require delivery to an additional service level. In this case, blending ranges are not dependent on peaking factors. Blending could range from 0% surface water (in the case of the second service level) to 100% surface water (during periods of minimum demand in primary service level). Since blending would occur within the distribution system, variations based on proximity to the water supply would pertain.

BMWD plans to deliver treated Canyon Lake water to three or four isolated systems where it will supplement Edwards or be supplemented by Trinity aquifer water during peak demand. Additional delivered flow capacity will be absorbed by the largest system, reducing Edwards aquifer pumping requirements. Blending will vary from approximately 40% to 100% (SW to GW) when blending with Trinity water and from approximately 0% to 60%+ (SW to GW) when blending with Edwards water.

Table 7-6: Blending Percentages for Systems With Variable Delivered Water Flows

Extreme Annual Blending Ranges	
SAWS	
Primary service level	65% SW to 100% SW
Secondary service level	0% SW to 35% SW
BMWD	
Bulverde Hills, Oakland Est., Timberwood Pk.	40% SW to 100% SW
Hill Country System (1)	0% to 50% SW

(1) Hill Country System is to be operated as two sections: one section will use Canyon Lake water to meet base demands and Trinity water to meet peak demands in summer, and the other section will use Edwards water to meet base demands and will use Canyon Lake water to meet peak demands in summer.

7.4.2. Desk-top Evaluation

Prior to conducting bench-scale blending tests, a 'desk-top' evaluation of the blending compatibility for each of the historical water qualities was completed. This evaluation included a compatibility review of the finished waters in Table 7-4 and a review of previous studies on these waters.

The success of blending between two waters is most influenced by specific parameters. These parameters are listed, along with potential blending impacts, in Table 7-7.

Table 7-7: Finished Water Quality Parameters Most Influencing Blending/Disinfection Approach

Quality Parameter	Blending Impact
pH	Lower pH blended water can cause corrosion of the pipe or pipe lining which may result in undesirable taste or color. Blended waters will likely exhibit higher pHs.
TDS	An increase in the TDS levels as a result of blending could lead to undesireable aesthetic changes in water. Blended water will likely result in lower TDS levels.
Temperature	Blending waters with different temperatures may instigate taste and odor problems, degrading the aesthetic quality of the water.
Hardness	Blended waters with significantly different levels of hardness may result in noticeable aesthetic changes at the tap. Hardness can affect the water's clarity, feel, ability to lather with soap, and inclination to form scale.
TOC	TOC levels in waters to be blended will affect the type of disinfection that may be applied. In free chlorine applications, TOC levels that increase as a result of the blend will lead to increased disinfection by-product (DBP) formation.

Water Quality Comparison

Table 7-4 compares the water qualities between each of the existing water supplies that will be blended with treated Canyon Lake water. Based on a detailed review, no parameters exist at concentrations considered problematic for blending. A brief comparison of several water quality parameters is summarized below.

Calcium Carbonate (hardness):

- The Edwards aquifer contains up to 35-40% more total hardness (as $CaCO3$) than treated Canyon Lake water.
- The Trinity aquifer contains up to 90% more total hardness than the treated Canyon Lake water.
- Treated Cibolo Creek water contains approximately 25% lower total hardness, however the blended Boerne water is similar to the treated Canyon Lake water.
- While raw Canyon Lake water is softer than the Trinity and the Edwards aquifer water, it is still classified as hard (defined as between 150 – 200 mg/L as $CaCO_3$). No problems from hardness are anticipated as a result of blending, however individual customers with water softeners should be notified of the anticipated change in hardness in the delivered water.

Alkalinity:

- The Edwards aquifer GW contains approximately up to 58% higher alkalinity than the treated Canyon Lake water.

- The Trinity aquifer contains approximately 40 - 65% higher alkalinity than the treated Canyon Lake water.
- Treated Cibolo Creek water contains approximately 25% lower alkalinity, however the Boerne surface water/ground water blend is similar to the treated Canyon Lake water.

pH

- The Edwards and Trinity aquifers have a slightly lower pH than the treated Canyon Lake water, though they remain compatible.
- Treated Cibolo Creek water has a lower pH (6) than treated Canyon Lake water (7.8), though the Boerne surface water/ground water blend is only slightly lower (7.3).

TDS

- The Edwards aquifer GW contains similar TDS levels to the treated Canyon Lake water.
- The Trinity aquifer contains up to 40% higher alkalinity than the treated Canyon Lake water.
- Treated Cibolo Creek water contains approximately 30% lower alkalinity, however the Boerne surface water/ground water blend is only slightly lower than treated Canyon Lake water.

Temperature

- Groundwater temperatures are consistently near 22°C, while the surface water temperatures vary from 11°C to 30°C. During the summer seasons when temperatures are higher, incidents of taste and odor may increase in frequency due to algal conditions in the raw water. However, process additions to remove TOC will lower the probability for taste and odor issues by removing precursors. Also, significant residence times in the influent and effluent pipelines and in the plant may help to reduce the higher water temperatures.

TOC

- Little information is available for the finished groundwaters in this project, however TOC in groundwater is typically at minimal or non-detect levels. Treated surface water from the CLWSC has levels in the 1.3 to 1.6 mg/L range. Blended waters with effluent TOC concentrations of greater than 1.5 mg/L may require alternative disinfectants or alternative treatment to free chlorine in order to avoid DBP formation.

Additional Blending Information

In 1998, Malcolm Pirnie was retained by SAWS to evaluate the compatibility of Edwards aquifer groundwater and treated Canyon Lake Water (from the Canyon Regional Water Authority Surface Water Facility). Chemical compatibility was evaluated based on both historical data (similarities between waters) and bench-scale data (obtained from jar tests from five blends of groundwater and surface water). The historical quality comparison showed that the groundwater had approximately 50% higher levels of hardness (as CaCO3) and alkalinity, 30% higher TDS values, a slightly lower pH, and 25 to 50% lower sulfate levels than the surface water. Overall, the waters are similar. Blending tests on the waters confirmed compatibility and did not result in precipitation. To ensure that the blended water would be compatible with the existing distribution system, the test report recommended further testing of the waters with distribution pipe samples. The report also indicated that seasonal changes in taste and odor and temperature may cause complaints from customers habituated to groundwater.

Another indication of the probability for successful blending is in the experiences of local water agencies. CLWSC blends Canyon lake and Trinity aquifer water most of the year (up to a blending ratio of 40% groundwater to 60% surface water), typically using surface water as a base flow and groundwater to meet the peaking factors. Discussions with the General Manager indicate that this system does not experience blending problems and he anticipates that Edwards aquifer water, which has lower TDS values, should blend even better. CLWSC does retain a 2 ppm free chlorine residual in the treated surface water effluent and a 1 ppm free chlorine residual is kept in the groundwater. The City of Boerne also blends groundwater with surface water in their distribution systems. Blend ratios are currently about 50% Trinity groundwater with treated Cibolo Creek surface water. The City does not experience any problems associated with blending. Recently, BMWD has begun to blend treated surface water from Medina Lake with Edwards groundwater prior to distribution.

7.4.3. Bench-Scale Tests

This section describes the objectives and facets of the bench-scale tests on blended water. In order to obtain meaningful results, it is necessary to use a water that is very similar to anticipated treated effluent from the plant. Thus, testing will be completed in conjunction with treatment process pilot studies.

Bench scale tests will address important aesthetic water quality parameters to which drinking water customers are especially sensitive (such as turbidity, color, taste and odor, temperature, and disinfectant residual). While color, taste and odor are directly measurable parameters which may indicate customer acceptability of a water, turbidity is an indirect measurement which indicates the level of suspended particulate matter in a water.

These aesthetic data are important for predicting customer response to a new water scenario. Delivered water that is within acceptable limits may still generate complaints from customers that are accustomed to a given water quality. Therefore, the goals of the blending tests are as follows:

(1) to evaluate the impacts of various blends of finished water in terms of precipitation, turbidity, conductivity, particle counts, and color, and

(2) to evaluate the potential for undesirable reactions between the blended water and the pipe interior that may lead to deteriorated aesthetic quality.

In light of the variable nature of the blending scenarios discussed in Section 7.4.1, bench scale blending test are based on 25% through 100% water blends between treated Canyon Lake water and three different finished water sources. These waters are:

- Edwards water (SAWS or portions of BMWD)
- Trinity water (Fair Oaks or portions of BMWD)
- Cibolo Creek water (Boerne)

The blending test protocol (attached in Appendix B) includes test details such as number of samples, blending percentages, water quality parameters being tested, and laboratory requirements.

7.4.4. Blending Conclusions

Based on the variable nature of the operational strategies for customer's systems, blending ratios between a customer's existing water and delivered water will vary substantially. Review of the finished water quality and the previous blending study indicates that the water quality parameters are generally congruent and that blending these waters with treated Canyon Lake water in any ratio should not produce precipitates or other undesirable effects.

Although similar blending strategies have shown success in other systems, customer expectations that are based on a specific water source may lead to increased complaints for slight differences in compatible high-quality waters. For this reason, it is essential to carefully evaluate aesthetic similarity in addition to chemical compatibility. Additional confirmation on blended water quality and distribution system compatibility will be obtained during blending tests. However, because the recommended treatment process of MF/UF combined with granular activated carbon (GAC) would produce a water of higher quality than the representative waters used in this evaluation, it is recommended that the bench-scale tests be conducted in conjunction with the pilot study of the treatment process.

7.5. Delivered Water Quality Goals

The objective of this section is to describe a set of water quality objectives for the project that are related to regulatory compliance goals, aesthetic issues, water treatment initiatives (Partnership for Safe Water; Texas Optimization Program; etc). Customers were interviewed to determine their specific delivery requirements and water quality expectations, in order to develop overall water quality objectives. Applicable current and pending drinking water regulations were also evaluated. Current and recently enacted rules and anticipated requirements of future rules are summarized in a separate section and reviewed for their impact on the water treatment technology selection.

Water quality goals and treatment objectives for GBRA are primarily driven by the need for safe and aesthetically-pleasing drinking water. To satisfy these goals, GBRA's objectives are:

1) to produce water that complies with all applicable regulations while minimizing or eliminating objections related to aesthetic water quality

2) to provide water that will blend with treated groundwater in varying amounts while providing no undesireable difference in water quality to the customers, and

3) To continue the ability to use free chlorine as the secondary disinfectant in the distribution systems while complying with the regulations.

It is also important to plan for flexible processes for meeting pending and anticipated regulations. To meet the regulations and specific treated water quality goals, GBRA will need to construct a new WTP that incorporates, or has provisions for, advanced water treatment technologies such as membrane filtration, GAC, or UV. Table 7-9 below summarizes the delivered water quality goals and acceptable ranges for the new WTP.

Table 7-8: Delivered Water Quality Goals[1]

<table>
<tr><th>Item</th><th>GBRA Goal</th><th>Acceptable Upper Bound</th></tr>
<tr><td rowspan="2">DBPs</td><td>Achieve the following target values (80% of Stage 1 D/DBP Rule MCLs):

64 μg/L TTHMs
48 μg/L HAA_5
8 μg/L bromate</td><td>Achieve the following maximum "not to exceed" values (Stage 1 D/DBP Rule MCLs):

80 μg/L TTHMs
60 μg/L HAA_5
10 μg/L bromate</td></tr>
<tr><td colspan="2">Achieve compliance with the Stage 2 (and potentially Stage 3) D/DBP Rule MCLs when finalized (through modification of an existing treatment process):
40 μg/L TTHMs
30 μg/L HAA_5 (current placeholder MCLs)
5 μg/L bromate
Individual DBP MCLs (potential Stage 3 MCLs)</td></tr>
<tr><td>Other DBPs</td><td>Finished water TOC < 0.8 mg/L
(to blend with current customer water quality and limit DBP formation)</td><td>Finished water TOC < 1.3 mg/L</td></tr>
<tr><td>Combined filter turbidity</td><td>Less than 0.1 NTU</td><td>Less than 0.2 NTU</td></tr>
<tr><td>Disinfection</td><td>Meet all disinfection standards and eliminate transmission of waterborne disease</td><td>Meet all disinfection standards Minimize/eliminate transmission of waterborne disease</td></tr>
<tr><td>Taste and odor</td><td>No complaints</td><td>Less than 50 complaints per month</td></tr>
<tr><td>Hardness</td><td>150 to 250 mg/L as CaCO3 (to blend with current customer water quality)</td><td>150 to 250 mg/L as CaCO3 (to blend with current customer water quality)</td></tr>
<tr><td>pH</td><td>Maintain pH between 7 and 8 (to blend with current customer water quality)</td><td>Maintain pH between 7 and 8 (to blend with current customer water quality)</td></tr>
<tr><td>Treatment</td><td>Treatment using technologies that facilitate blending with no noticeable change in water quality</td><td>Treatment using technologies that facilitate blending with no noticeable change in water quality</td></tr>
</table>

[1] The goals shown are in addition to meeting current and pending standards for other regulated compounds or water quality parameters.

7.6. Conclusions

Conclusions from the water quality analysis are listed as follows:

- The Canyon Lake water is high quality, and is amenable to either conventional or membrane treatment.

- The treatment process selection should focus on TOC reduction to enable the continued use of free chlorine disinfection in the customers systems.

- Based on anticipated delivered water quality, no precipitation or color issues are expected as a result of blending the treated surface water and groundwater supplies. Chemical reactions between blended waters and pipes should not produce undesirable precipitation or particle formation. Bench scale tests will be used to confirm this.

Regional Water Supply Project for Portions of Comal, Kendall, and Bexar Counties

Treatment Technology Selection

Technical Memorandum

Table of Contents

8. Treatment Technology Evaluations

8.1 Introduction

This section discusses the selection of the recommended surface water treatment process for the new Canyon Lake Regional Water System that meets the GBRA and their customers' objectives as follows:

- A treated surface water that is chemically compatible with existing customer supplies and results in customer satisfaction.
- A treated surface water that enables the customers to continue using free chlorine disinfection within their distribution systems.
- A treated surface water that complies with the current and pending regulations, including aesthetics such as taste and odor and is flexible to respond to future regulations.
- A treatment process that is economically feasible to construct and operate.

The major focus of the discussion of alternatives in the following sections is devoted to the liquids-process components that specifically address particle removal, organic precursor (compounds that form disinfection byproducts when reacted with a disinfectant – DBPs) removal/reduction and primary and secondary disinfection. A strategy for mitigating taste and odor and corrosion is addressed at the end of this section.

8.2 Abbreviations

The abbreviations used in this section are as follows:

Cl_2	Chlorine	NH_3	Ammonia
ClO_2	Chlorine Dioxide	O_3	Ozone
DBP	Disinfection By Product	O&M	Operations and maintenance
GAC	Granular Activated Carbon	PAC	Powdered activated carbon
Gfd	Gallons per square foot per day	RO	Reverse osmosis
		SWTR	Surface water treatment rule
HAA	Halo-acetic acids	T&O	Taste and odor
$KMnO_4$	Potassium Permanganate	TOC	Total organic carbon
MCL	Maximum contaminant level	TTHM	Total trihalomethanes
MF	Micro-filtration	UF	Ultra-filtration
NF	Nano-filtration	UV	Ultraviolet irradiation

8.3 Technology Alternatives

Assuming that several processes can produce treated water meeting or exceeding regulatory requirements, the parameter most influencing process selection for the GBRA plant is TTHM resulting from the use of chlorine as the primary and secondary disinfectant. Two commonly employed approaches to reduce TTHM formation is 1) to remove or reduce the naturally occurring organic precursors that form TTHMs when reacted with chlorine, or 2) to utilize an alternative disinfectant which minimizes the formation of TTHMs, such as chloramines or chlorine dioxide. Chlorine dioxide, while it does not form TTHMs, does form regulated DBPs such as chlorite that can produce an acute health effect. Due to the rapid decay of chlorine dioxide and the formation of chlorite, this chemical may not be suitable as a secondary disinfectant since the amount needed to maintain a residual would produce chlorite in excess of its current MCL of 1.0 mg/L. As a result, it is typically not recommended for use as a secondary disinfectant.

Chlorine is the stated preference for secondary disinfectant since all of the initial customers currently use chlorine within their system and they would prefer not to change. However, to evaluate the impacts of the ultimate secondary disinfectant choice, the alternatives for process selection were divided into two categories:

- Conventional or advanced treatment with emphasis on organics removal to enable the continued use of chlorine as a secondary disinfectant.
- Conventional or advanced treatment processes with chloramines as a secondary disinfectant.

8.3.1 Screening Evaluation

A screening review was first conducted on several candidate liquids-process alternatives to narrow the selection to four to five alternatives for further detailed evaluation. Each alternative was subjectively evaluated against the following basic screening parameters:

- Efficiency of particle reduction
- Microbial reduction through physical removal and further inactivation with disinfection
- DBP formation
- Flexibility to respond to regulatory changes (i.e. *Cryptosporidium* removal/inactivation, lower DBPs, etc.)
- Relative costs

The alternatives ranged from conventional coagulation/filtration processes to advanced treatment with membranes. Membrane treatment, referred to as MF/UF in this report, represents the use of microfilters (MF) or ultrafilters (UF). Both MF and UF processes separate substances from feed water through a sieving action, though they differ in membrane pore sizes and typical operating pressures. Either may be used in this treatment plant. Primary disinfection ranged from the use of chlorine, chlorine dioxide, ozone, and ultraviolet irradiation. A summary description and results of the screening are shown in Table 8-1. The terms and rating factors used in the table are defined as follows:

Particle Reduction (PR)
- Ineffective – partially achieves required reduction for particles and turbidity, may violate standards.
- Effective – particles and turbidity are removed to comply with standards.
- Highly Effective – particles and turbidity are removed to well below standards.

Microbial Reduction/Inactivation (MRI)
- Ineffective – partially achieves reduction/inactivation of microbials.
- Effective – achieves typical reduction/inactivation of microbials.
- Highly Effective – achieves substantial reduction/inactivation of microbials.

DBP Formation (DBP)
- Ineffective – DBPs may violate Stage 1 and anticipated placeholder values for DBPs in the Stage 2 D/DBP standards.
- Effective – DBPs are formed yet comply with Stage 1 D/DBP regulatory requirements but not necessarily anticipated Stage 2 standards.
- Highly Effective – DBPs are formed at low levels that are expected to comply with Stage 1 D/DBP and anticipated Stage 2 regulatory standards.

Flexibility (FLEX)
- Low – process changes and additional components will be required for the initial plant to meet anticipated regulatory requirements (i.e. *Cryptosporidium* removal/inactivation, lower DBP formation, etc.).
- Moderate – additional process components will be required to meet new regulatory requirements (i.e. *Cryptosporidium* removal/inactivation, lower DBP formation, etc.).
- High – minimal changes are required to comply with anticipated requirements of future regulations.

Costs ($$)
- Moderate – capital and operating costs are comparable to a typical conventional plant.
- High – capital and operating costs are high compared to a typical conventional plant.
- Very High – capital and operating costs are very high compared to a typical conventional plant.

Table 8-1: Screening Summary of Candidate Water Treatment Plant Alternatives

No.	Alternative	PR	MRI	DBP	FLEX	$$	Comments
Process Alternatives Using Chlorine as Residual Disinfectant							
1	Rapid Mix + Flocculation + Sedimentation (RM/F/S) + Filtration + primary Cl_2 or ClO_2	Effective	Effective	Ineffective[1]	Low[2]	Moderate	1. Excessive DBPs may form with residual chlorine. 2. May need additional DBP and *Cryptosporidium* control.
2	RM/F/S + O_3 + Filtration	Effective	Highly Effective	Ineffective[1]	Low[2]	High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
3	RM/F/S + Filtration +UV	Effective	Highly Effective	Ineffective[1]	Moderate[2]	Moderate	1. Excessive DBPs may form with residual chlorine. 2. Would need organic reduction features to reduce DBPs to acceptable levels.
4	Enhanced Coagulation + RM/F/S + O_3+ Filtration	Highly Effective	Highly Effective	Ineffective[1]	Low[2]	High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
5	Enhanced Coagulation + RM/F/S + Filtration + UV	Effective	Highly Effective	Ineffective[1]	High	Moderate	1. Plant would reduce TOC but likely not adequately to prevent excessive DBP formation in customers systems.
6	PAC + RM/F/S + O_3 + Filtration	Highly Effective	Highly Effective	Ineffective[1]	Low[2]	High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
7	PAC + RM/F/S + Filtration + UV	Effective	Highly Effective	Ineffective[1]	High	Moderate	1. Coagulation plus PAC may reduce TOC but likely not to the levels needed to prevent excessive DBP formation in the customer's systems.
8	RM/F/S + O_3 + Filtration + GAC	Highly Effective	Highly Effective	Ineffective[1]	Low[2]	Very High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
9	RM/F/S + O_3 + Filtration + NF	Highly Effective	Highly Effective	Ineffective[1]	Low[2]	Very High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.

No.	Alternative	PR	MRI	DBP	FLEX	$$	Comments
10	RM/F/S + Filtration + GAC + UV	Highly Effective	Highly Effective	Highly Effective	High	Very High	Plant would likely produce a water low in DBPs, good tasting, and regulatory compliant.
11	RM/F/S + Filtration + NF + UV	Highly Effective	Highly Effective	Highly Effective	High	Very High	Plant would likely produce a water low in DBPs and regulatory compliant. Some softening could occur.
12	MF/UF (membrane) +PAC + UV	Highly Effective	Highly Effective	Ineffective$_1$	Moderate$_2$	High	1. Excessive DBPs may form with residual chlorine. 2. May need organic reduction features to reduce DBPs to acceptable levels.
13	MF/UF + GAC/NF + primary Cl_2 or ClO_2	Highly Effective	Highly Effective	Highly Effective	High	Very High w/NF High w/GAC	Plant would likely produce a water low in DBPs, good tasting, and regulatory compliant. Some softening could occur with NF.
14	Extra Coagulation for TOC removal + MF/UF + PAC + primary Cl_2 or ClO_2	Highly Effective	Highly Effective	Effective	High	High	Extra coagulation should reduce TOC hence DBPs.
15	MF/UF +O_3 + biofilter	Highly Effective	Highly Effective	Ineffective$_1$	Low$_2$	High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
16	MF/UF +O_3 + GAC	Highly Effective	Highly Effective	Ineffective$_1$	Low$_2$	Very High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.
17	MF/UF + NF/UV	Highly Effective	Highly Effective	Highly Effective	High	Very High w/NF	Plant would likely produce a water low in DBPs and regulatory compliant. Some softening could occur.
Process Alternatives Using Chloramines as Residual Disinfectant							
18	RM/F/S + Filtration + primary Cl_2 or ClO_2	Effective	Effective	Effective$_1$	Moderate$_2$	Moderate	1. Chloramines controls DBP formation. 2. Need *Cryptosporidium* control (i.e. UV).
19	PAC/$KMnO_4$+ RM/F/S +O_3 +filtration	Highly Effective	Highly Effective	Ineffective$_1$	Low$_2$	High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.

No.	Alternative	PR	MRI	DBP	FLEX	$$	Comments
20	PAC/$KMnO_4$ + RM/F/S +filtration + UV	Effective	Highly Effective	Effective[1]	High	Moderate	1. Coagulation plus PAC will likely reduce TOC hence DBP formation. Also, chloramines further controls DBP formation.
21	MF/UF + PAC + primary Cl_2 or ClO_2	Highly Effective	Highly Effective	Effective[1]	Moderate[2]	Moderate	1. Chloramines controls DBP formation. 2. Need *Cryptosporidium* control (i.e. UV).
22	$KMnO_4$+ MF/UF + PAC + primary Cl_2 or ClO_2	Highly Effective	Highly Effective	Effective[1]	High	Moderate	1. PAC slightly reduces TOC hence DBP formation. Also, chloramines further controls DBP formation.
23	$KMnO_4$+ MF/UF + PAC + UV	Highly Effective	Highly Effective	Effective[1]	High	High	1. PAC slightly reduces TOC hence DBP formation. Also, chloramines further controls DBP formation.
24	MF/UF + O_3 + biofilter	Highly Effective	Highly Effective	Ineffective[1]	Low[2]	Very High	1. Excessive bromate may be formed with ozone. 2. May need bromate control.

8.3.2 Discussion of Screening Results

Based on the results of the screening evaluation, below are the general conclusions:

Conventional Treatment

- Conventional coagulation treatment alone or conventional treatment with enhanced coagulation and PAC could potentially reduce the precursor materials low enough to use free chlorine as the secondary disinfectant and meet the Stage 1 DBP levels at the point of delivery, however, DBPs in the customer's distribution system may increase above the MCLs with the continuance of chlorine. Like the membrane options, it is doubtful that the Stage 2 DBP placeholder levels could be met even at the delivery points without supplemental precursor removal.
- Conventional treatment in combination with GAC would substantially remove the organics, resulting in a low potential to form DBPs.
- If chloramines are used as the residual disinfectant, conventional treatment could be used without the need for supplemental removal of organic precursor materials. However, if the customers convert the chloramine residual to chlorine at the point of entry, it is likely that additional DBPs could form.

Membranes

- Due to the low to moderate turbidity levels in the source water, MF/UF filtration does not require pre-treatment to meet particle/turbidity reduction requirements.
- Like the conventional plant, membranes in combination with PAC or pre-treatment with coagulation could reduce TOC levels such that free chlorine potentially could be used as a residual disinfectant without exceeding Stage 1 DBP levels at the point of delivery. It is doubtful the standards would be met within each customer's system due to the additional detention time. Secondly, it is doubtful that the Stage 2 DBP placeholder levels could be met even at the delivery points without supplemental precursor removal.
- If chloramines are used as the residual disinfectant, membrane treatment can be used without the need to remove additional organic precursor materials. However, if the customers convert the chloramine residual to chlorine at the point of entry, additional DBPs could form.
- MF/UF membranes in combination with either NF or GAC would substantially remove the organics, resulting in a low potential to form DBPs.
- MF/UF followed by NF/RO would be costly when compared to direct membrane filtration or conventional treatment.

Disinfection

- Ozonation of the water at high bromide levels (recently measured at levels > 1 mg/L) would exceed the 10 g/L maximum contaminant level for bromate. Therefore, ozone is not considered a cost-effective option and is not recommended for further consideration.
- Conventional treatment is flexible for meeting future disinfection requirements provided UV is installed and is accepted by regulatory agencies for inactivation for

Cryptosporidium. Testing is being conducted by other researchers on the effectiveness of UV and thus far results have been promising. Based on preliminary costs, UV would be about 1/3rd the cost of an equivalent ozone facility. Based on the current understanding of the EPA workgroups, membrane technology will likely meet anticipated removal requirements for *Cryptosporidium*.

- The use of chloramines as a secondary disinfectant would likely satisfy both Stage 1 and 2 D/DBP requirements for DBP formation when used with either conventional or membrane processes. However, the customer would be required to convert the chloramines to chlorine at the point of entry if chlorine is still used in the distribution system, which as discussed later presents other operational issues.

8.3.3 Liquid Process Alternatives

From the screening evaluation, the following alternatives were formulated for further detailed evaluation. Alternatives A and C are standard treatment approaches utilizing chloramines as the residual disinfectant. Alternatives B, D, E and F include advanced treatment for removal of precursor materials so that free chlorine can be used as the residual disinfectant in the transmission pipeline.

<u>Conventional</u>

- ***Alternative A*** – Conventional plant; chlorine or chlorine dioxide for primary disinfection with provisions for addition of UV in future; chloramines for secondary disinfectant through the transmission line. (Screening alternatives 18 and 20)
- ***Alternative B*** – Conventional plant; GAC for organics reduction; chlorine or chlorine dioxide for primary disinfection with provisions for addition of UV in future; chlorine for secondary disinfectant in the transmission line. (Screening alternative 10)

<u>Membrane</u>

- ***Alternative C*** – MF/UF membranes; chlorine or chlorine dioxide for satisfying inactivation requirements beyond the removal achieved by MF/UF; chloramines for secondary disinfectant through the transmission line. (Screening alternatives 21, 22 and 23)
- ***Alternative D*** – MF/UF membranes; NF for organics reduction; chlorine or chlorine dioxide for satisfying inactivation requirements beyond the removal achieved by MF/UF; chlorine for secondary disinfectant through the transmission line. (Screening alternatives 13 and 17)
- ***Alternative E*** – MF/UF membranes; GAC for organics reduction; chlorine or chlorine dioxide for satisfying inactivation requirements beyond the removal achieved by MF/UF; chlorine for secondary disinfectant through the transmission line. (Screening alternatives 13)

A detailed tabular evaluation and rating for each alternative is presented at the end of this section.