DRAFT FEASIBILITY REPORT
FEASIBILITY ANALYSIS OF WATER SUPPLY FOR SMALL PUBLIC WATER SYSTEMS

KENDALL COUNTY WCID
PWS ID# 1300002, CCN# 10685

Prepared for:

THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Prepared by:

THE UNIVERSITY OF TEXAS BUREAU OF ECONOMIC GEOLOGY

AND

PARSONS

Preparation of this report was financed by the Texas Commission on Environmental Quality through the Drinking Water State Revolving Fund Small Systems Assistance Program

AUGUST 2006

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AUGUST 2006

EXECUTIVE SUMMARY

The University of Texas Bureau of Economic Geology (BEG) and its subcontractor, Parsons Infrastructure and Technology Group Inc. (Parsons), was contracted by the Texas Commission on Environmental Quality (TCEQ) to conduct a study to assist with identifying and analyzing alternatives for use by Public Water Systems (PWS) to meet and maintain Texas drinking water standards.

The overall goal of this project was to promote compliance using sound engineering and financial methods and data for PWSs that had recently recorded sample results exceeding maximum contaminant levels (MCL). The primary objectives of this project were to provide feasibility studies for PWSs and the TCEQ Water Supply Division that evaluate water supply compliance options, and to suggest a list of compliance alternatives that may be further investigated by the subject PWS for future implementation.

This feasibility report provides an evaluation of water supply alternatives for the Kendall County Water Control and Improvement District (WCID), which provides water and sewer service to the community of Comfort, Texas. Kendall County WCID PWS recorded radium concentrations from Well 10 that are greater than the radium MCL of 5 pCi/L. Well 10 is the only well that serves the northern part of the system and currently only includes a convenience store and a fast food restaurant, but is where future development will occur. Therefore, it was likely that Kendall County WCID PWS faces potential radium compliance issues in the Well 10 service area.

Basic system information for the Kendall County WCID PWS is shown in Table ES.1.

Table ES-1
Kendall County WCID PWS
Basic System Information

Population served	2,790 current for total system, 270 at full build out for the Well 10 service area
Connections	930 current for total system, 90 at full build out for the Well 10 service area
Average daily flow rate	0.258 million gallons per day (mgd) current for total system, 0.035 mgd at full build out for the Well 10 service area
Peak demand flow rate	0.14 mgd at full build out for the Well 10 service area
Water system peak capacity	1.117 mgd for total system
Typical radium range for Well 10	6.9 – 10.1 pCi/L
Typical total dissolved solids range	766 µg/L to 1,163 mg/L

STUDY METHODS

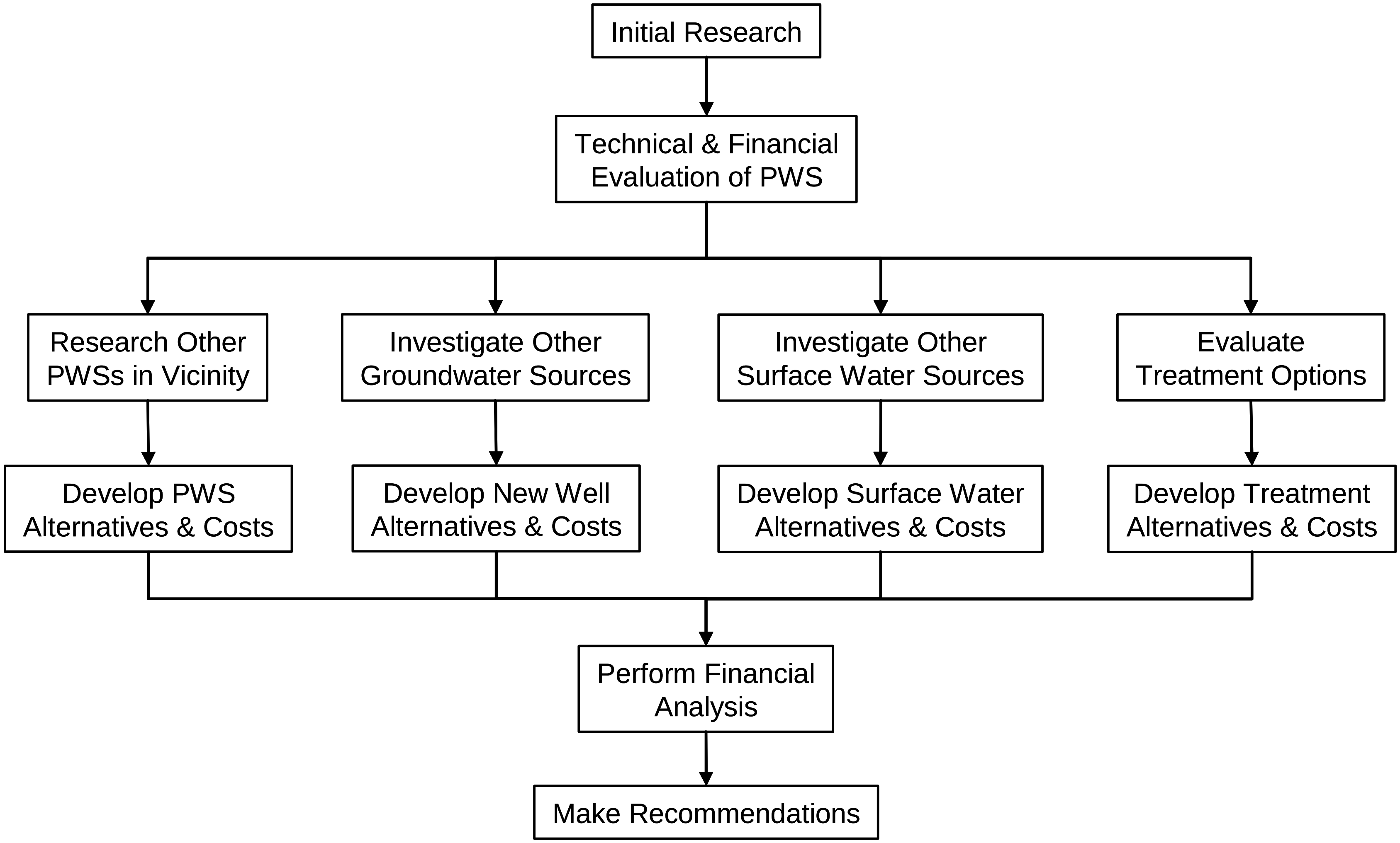
The methods used for this study were based on a pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. Methods for identifying and analyzing compliance options were developed in the pilot study (a decision tree approach).

The process for developing the feasibility study used the following general steps:

1. Gather data from the TCEQ and Texas Water Development Board databases, from TCEQ files, and from information maintained by the PWS;
2. Conduct financial, managerial, and technical (FMT) evaluations of the PWS;
3. Perform a geologic and hydrogeologic assessment of the study area;
4. Develop treatment and non-treatment compliance alternatives which, in general, consist of the following possible options:
5. Connecting to neighboring PWSs via new pipeline or by pumping water from a newly installed well or an available surface water supply within the jurisdiction of the neighboring PWS;
6. Installing new wells within the vicinity of the PWS into other aquifers with confirmed water quality standards meeting the MCLs;
7. Installing a new intake system within the vicinity of the PWS to obtain water from a surface water supply with confirmed water quality standards meeting the MCLs;
8. Treating the existing non-compliant water supply by various methods depending on the type of contaminant; and
9. Delivering potable water by way of a bottled water program or a treated water dispenser as an interim measure only.
10. Assess each of the potential alternatives with respect to economic and non-economic criteria;
11. Prepare a feasibility report and present the results to the PWS.

This basic approach is summarized in Figure ES-1.

Figure ES-1
Summary of Project Methods



HYDROGEOLOGICAL ANALYSIS

The Kendall County WCID PWS obtains groundwater from the lower and middle Trinity aquifer. Deeper wells screened in the lower formation of the Trinity aquifer tend to have higher concentrations of radium concentrations can vary significantly over relatively short distances; as a result, there could be good quality groundwater nearby. However, the variability of radium concentrations makes it difficult to determine where wells can be located to produce acceptable water. It may also be possible to do down-hole testing on non-compliant wells to determine the source of the contaminants. If the contaminants derive primarily from a single part of the formation, that part could be excluded by modifying the existing well, or avoided altogether by completing a new well.

COMPLIANCE ALTERNATIVES

The Kendall County WCID PWS was created in 1946 and is governed by a 5-member board of directors. It is financed through property taxes and service fees. Overall, the system had a very good level of FMT capacity. The system had many positive aspects, including knowledgeable and dedicated staff, good financial practices, attention to radium compliance problem, preventative maintenance program, and good emergency planning. Areas of concern for the system included lack of written long-term capital improvements plan.

Kendall County WCID PWS has six wells that have been compliant for radium. These wells or an additional new well could be used to supply the area north of I-10 in place of Well 10. Since Kendall County WCID PWS has a good water supply, obtaining water from another PWS is not considered as an alternative for addressing radium in the Well 10 water. There is a minimum of surface water available in the area, and developing a surface water source would require off-stream storage. A project like this might require significant time to develop. Obtaining surface water is not considered as an alternative to addressing radium in Well 10.

A number of centralized treatment alternatives for arsenic removal have been developed and were considered for this report, including ion exchange, WRT Z-88™ adsorption, and KMnO4-green sand filtration. Point-of-use (POU) and point-of-entry treatment alternatives were also considered.

Developing a new well near the Kendall County WCID PWS may be an attractive solution if compliant groundwater can be found. Having a new well near the Kendall County WCID PWS is likely to be one of the lower cost alternatives since the PWS already possesses the technical and managerial expertise needed to implement this option. The cost of new well alternatives quickly increases with pipeline length, making proximity of the alternate source a key concern. A new compliant well or obtaining water from a neighboring compliant PWS has the advantage of providing compliant water to all taps in the system.

Central treatment can be cost-competitive with the alternative of new nearby wells, but would require significant institutional changes to manage and operate. Like obtaining an alternate compliant water source, central treatment would provide compliant water to all water taps.

POU treatment can be cost competitive, but does not supply compliant water to all taps. Additionally, significant efforts would be required for maintenance and monitoring of the POU treatment units.

FINANCIAL ANALYSIS

Financial analysis of the Kendall County WCID PWS indicated that current water and sewer rates are funding operations, and a rate increase would not be necessary to meet operating expenses. The current average water bill of $786 represents approximately 2.8 percent of the median household income (MHI). Table ES.2 provides a summary of the financial impact of implementing selected compliance alternatives, including the rate increase necessary to meet current operating expenses. The alternatives were selected to highlight results for the best alternatives from each different type or category.

Some of the compliance alternatives offer potential for shared or regional solutions. A group of PWSs could work together to implement alternatives for developing a new groundwater source or expanding an existing source, obtaining compliant water from a large regional provider, or for central treatment. Sharing the cost for implementation of these alternatives could reduce the cost on a per user basis. Additionally, merging PWSs or management of several PWSs by a single entity offers the potential for reduction in administrative costs.

Table ES.2
Selected Financial Analysis Results

Alternative	Funding Option	Average Annual Water Bill	Percent of MHI
Current	NA	$786	2.8
New well at Kendal County WCID	100% Grant	$900	3.3
	Loan/Bond	$941	3.4
Central treatment - IX	100% Grant	$895	3.2
	Loan/Bond	$924	3.3
Point-of-use	100% Grant	$934	3.4
	Loan/Bond	$939	3.4

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ACRONYMS AND ABBREVIATIONS

μ/L	micrograms per liter
AFY	acre-feet per year
BAT	best available technology
BEG	Bureau of Economic Geology
BV	bed volume
CA	chemical analysis
CCN	Certificate of Convenience and Necessity
CFR	Code of Federal Regulations
CO	correspondence
ED	electrodialysis
EDR	electrodialysis reversal
EP	entry point
FMT	financial, managerial, and technical
ft^2	square foot
GAM	Groundwater Availability Model
gpm	gallons per minute
IX	Ion exchange
KC	Kendall County
$KMnO_4$	hydrous manganese oxide
MCL	Maximum contaminant level
mg/L	milligrams per Liter
mgd	million gallons per day
MHI	median household income
MnO_2	Manganese dioxide
MOR	monthly operating report
NMEFC	New Mexico Environmental Financial Center
NURE	National Uranium Resource Evaluation
O&M	operation and maintenance
Parsons	Parsons Infrastructure and Technology Group Inc.
pCi/L	picoCuries per liter
POE	Point-of-entry
POU	Point-of-use
PWS	public water system
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids

TSS	Total suspended solids
TWDB	Texas Water Development Board
USEPA	United States Environmental Protection Agency
WAM	Water Availability Model
WCID	Water Control and Improvement District
WRT	Water Remediation Technologies, Inc.

SECTION 1
INTRODUCTION

The University of Texas Bureau of Economic Geology (BEG) and its subcontractor, Parsons Infrastructure and Technology Group Inc. (Parsons), have been contracted by the Texas Commission on Environmental Quality (TCEQ) to assist with identifying and analyzing compliance alternatives for use by Public Water Systems (PWS) to meet and maintain Texas drinking water standards.

The overall goal of this project is to promote compliance using sound engineering and financial methods and data for PWSs that have recently had sample results that exceed maximum contaminant levels (MCL). The primary objectives of this project are to provide feasibility studies for PWSs and the TCEQ Water Supply Division that evaluate water supply compliance options, and to suggest a list of compliance alternatives that may be further investigated by the subject PWS with regard to future implementation. The feasibility studies identify a range of potential compliance alternatives, and present basic data that can be used for evaluating feasibility. The compliance alternatives addressed include a description of what would be required for implementation, conceptual cost estimates for implementation, and non-cost factors that could be used to differentiate between alternatives. The cost estimates are intended for comparing compliance alternatives, and to give a preliminary indication of potential impacts on water rates resulting from implementation.

It is anticipated the PWS will review the compliance alternatives in this report to determine if there are promising alternatives, and then select the most attractive alternative(s) for more detailed evaluation and possible subsequent implementation. This report contains a decision tree approach that guided the efforts for this study, and also contains steps to guide a PWS through the subsequent evaluation, selection, and implementation of a compliance alternative.

This feasibility report provides an evaluation of water supply compliance options for the Kendall County Water Control and Improvement District (WCID) PWS, ID# 1300002, Certificate of Convenience and Necessity (CCN) #10685, located in Comfort, Texas. Recent sample results from Kendall County WCID PWS Well 10 exceeded the MCL for radium of 5 picoCuries per liter (pCi/L) (USEPA 2006; TCEQ 2004a). The location of the Kendall County WCID PWS is shown on Figure 1.1. Various water supply and planning jurisdictions are shown on Figure 1.2. These water supply and planning jurisdictions are used in the evaluation of alternate water supplies that may be available in the area.

1.1 PUBLIC HEALTH AND COMPLIANCE WITH MCLS

The goal of this project is to promote compliance for PWSs that supply drinking water exceeding regulatory MCLs. This project only addresses those contaminants and does not address any other violations that may exist for a PWS. As mentioned above, the Kendall County WCID PWS had recent sample results exceeding the MCL for radium. In general, contaminant(s) in drinking water above the MCL(s) can have both short-term (acute) and long-term or lifetime (chronic) effects. Long-term ingestion of drinking water with radium-226 and/or radium-228 above the MCL may increase the risk of cancer (USEPA 2006).

1.2 METHOD

The method for this project follows that of the pilot study performed in 2004 and 2005 by TCEQ, BEG, and Parsons. The pilot study evaluated water supply alternatives for PWSs that supply drinking water with nitrate concentrations above U.S. Environmental Protection Agency (USEPA) and Texas drinking water standards. Three PWSs were evaluated in the pilot study to develop the method (*i.e.*, decision tree approach) for analyzing options for provision of compliant drinking water. This project is performed using the decision tree approach developed in the pilot study.

Other tasks of the feasibility study are as follows:

- Identifying available data sources;
- Gathering and compiling data;
- Conducting financial, managerial, and technical (FMT) evaluations of the selected PWSs;
- Performing a geologic and hydrogeologic assessment of the study area;
- Developing treatment and non-treatment compliance alternatives;
- Assessing potential alternatives with respect to economic and non-economic criteria;
- Preparing a feasibility report; and
- Suggesting refinements to the approach for future studies.

The remainder of Section 1 of this report addresses the regulatory background, and provides a summary of radium abatement options. Section 2 describes the method used to develop and assess compliance alternatives. The groundwater sources of radium are addressed in Section 3. Findings for the Kendall County WCID PWS, along with compliance alternatives development and evaluation, can be found in Section 4. Section 5 references the sources used in this report.

1.3 REGULATORY PERSPECTIVE

The Utilities & Districts and Public Drinking Water Sections of the TCEQ Water Supply Division are responsible for implementing requirements of the Federal Safe Drinking Water Act (SDWA) which include oversight of PWSs and water utilities. These responsibilities include:

- Monitoring public drinking water quality;
- Processing enforcement referrals for MCL violators;

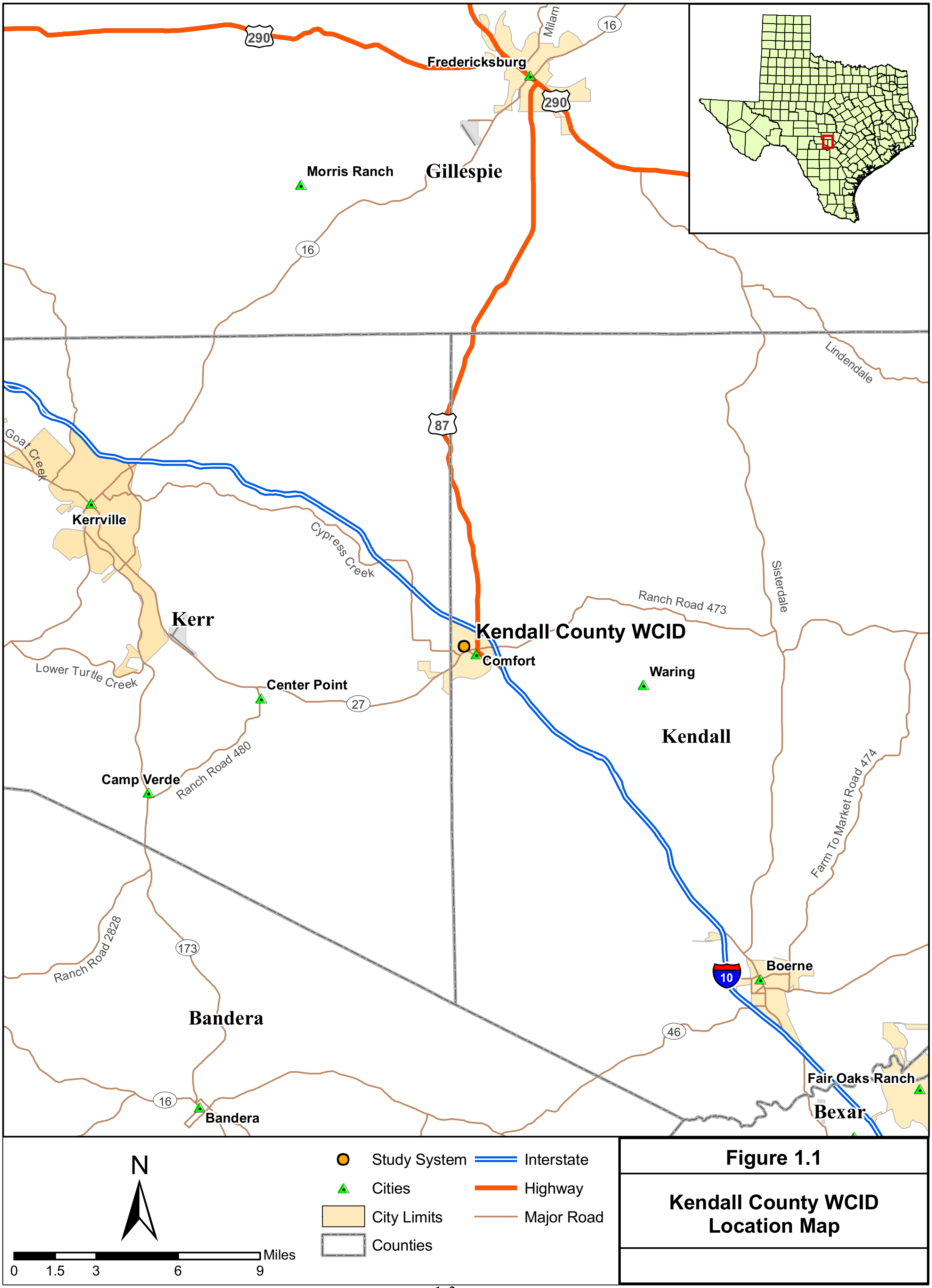

Figure 1.1

Kendall County WCID Location Map

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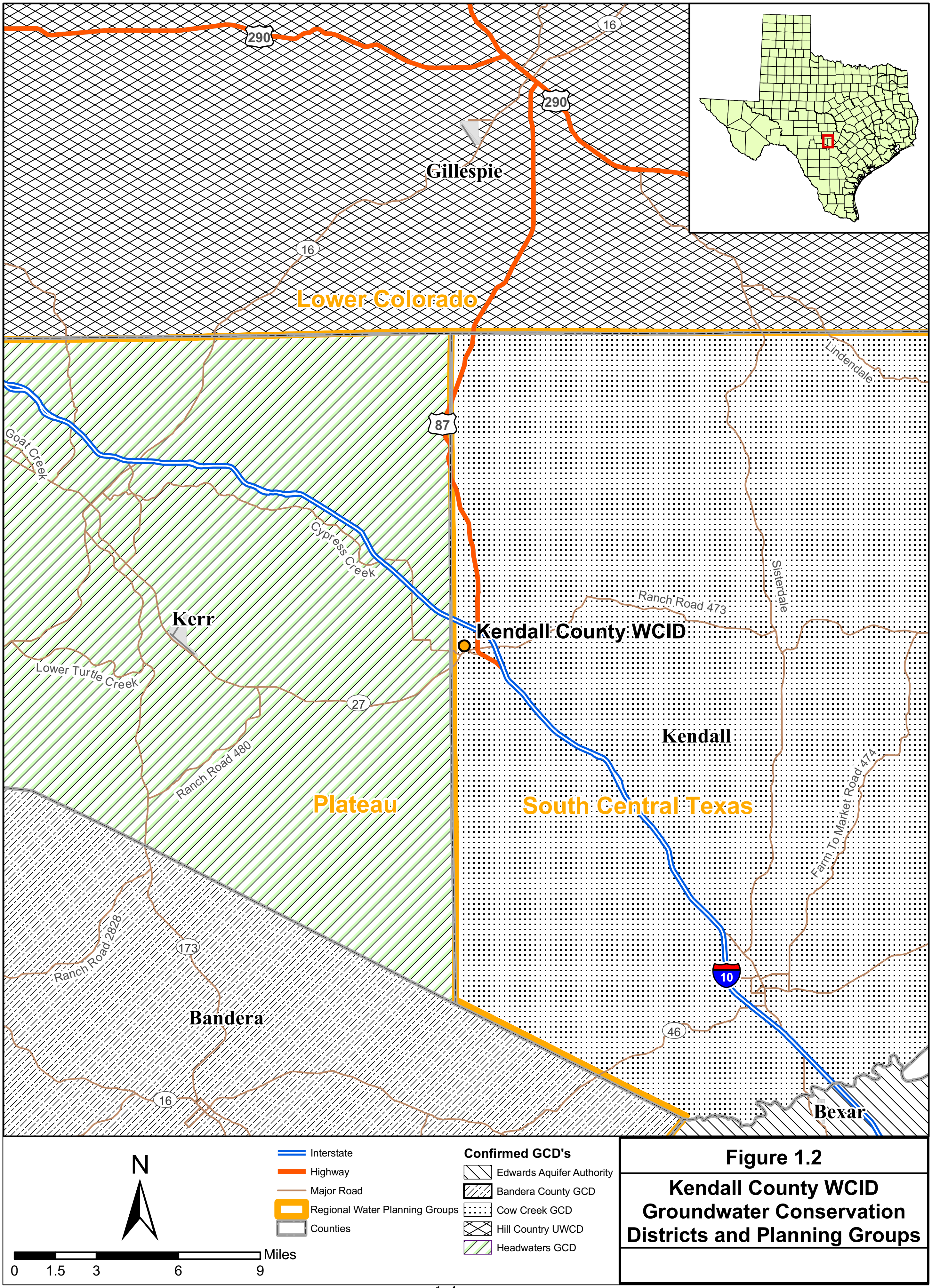

Figure 1.2

Kendall County WCID Groundwater Conservation Districts and Planning Groups

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- Tracking and analyzing compliance options for MCL violators;
- Providing FMT assessment and assistance to PWSs;
- Participating in the Drinking Water State Revolving Fund program to assist PWSs in achieving regulatory compliance; and
- Setting rates for privately-owned water utilities.

This project was conducted to assist in achieving these responsibilities.

1.4 ABATEMENT OPTIONS

When a PWS exceeds a regulatory MCL, the PWS must take action to correct the violation. The MCL exceedances at the Kendall County WCID PWS involve radium. The following subsections explore alternatives considered as potential options for obtain/providing compliant drinking water.

1.4.1 Existing Public Water Supply Systems

A common approach to achieving compliance is for the PWS to make arrangements with a neighboring PWS for water supply. For this arrangement to work, the PWS from which water is being purchased (supplier PWS) must have water in sufficient quantity and quality, the political will must exist, and it must be economically feasible.

1.4.1.1 Quantity

For the purposes of this report, quantity refers to water volume, flowrate, and pressure. Before approaching a potential supplier PWS, the non-compliant PWS should determine its water demand on the basis of average day and maximum day. Peak instantaneous demands can be met through proper sizing of storage facilities. Further, the potential for obtaining the appropriate quantity of water to blend to achieve compliance should be considered. The concept of blending involves combining water with low levels of contaminants with non-compliant water in sufficient quantity so the resulting blended water is compliant. The exact blend ratio would depend on the quality of the water a potential supplier PWS can provide, and would likely vary over time. If high quality water is purchased, produced or otherwise obtained, blending can reduce the amount of high quality water required. Implementation of blending will require a control system to ensure the blended water is compliant.

If the supplier PWS does not have sufficient quantity, the non-compliant community could pay for the facilities necessary to increase the quantity to the extent necessary to supply the needs of the non-compliant PWS. Potential improvements might include, but are not limited to:

- Additional wells;
- Developing a new surface water supply,
- Additional or larger-diameter piping;

- Increasing water treatment plant capacity
- Additional storage tank volume;
- Reduction of system losses,
- Higher-pressure pumps; or
- Upsized, or additional, disinfection equipment.

In addition to the necessary improvements, a transmission pipeline would need to be constructed to tie the two PWSs together. The pipeline must tie-in at a point in the supplier PWS where all the upstream pipes and appurtenances are of sufficient capacity to handle the new demand. In the non-compliant PWS, the pipeline must tie in at a point where no down stream bottlenecks are present. If blending is the selected method of operation, the tie-in point must be at the proper point of the existing non-compliant PWS to ensure that all the water in the system is blended to achieve regulatory compliance.

1.4.1.2 Quality

If a potential supplier PWS obtains its water from the same aquifer (or same portion of the aquifer) as the non-compliant PWS, the quality of water may not be significantly better. However, water quality can vary significantly due to well location, even within the same aquifer. If localized areas with good water quality cannot be identified, the non-compliant PWS would need to find a potential supplier PWS that obtains its water from a different aquifer or from a surface water source. Additionally, a potential supplier PWS may treat non-compliant raw water to an acceptable level.

Surface water sources may offer a potential higher-quality source. Since there are significant treatment requirements, utilization of surface water for drinking water is typically most feasible for larger local or regional authorities or other entities that may provide water to several PWSs. Where PWSs that obtain surface water are neighbors, the non-compliant PWS may need to deal with those systems as well as with the water authorities that supply the surface water.

1.4.2 Potential for New Groundwater Sources

1.4.2.1 Existing Non-Public Supply Wells

Often there are wells not associated with PWSs that are located in the vicinity of the non-compliant PWS. The current use of these wells may be for irrigation, industrial purposes, domestic supply, stock watering, and other purposes. The process for investigating existing wells is as follows:

- Use existing data sources (see below) to identify wells in the areas that have satisfactory quality. For the Kendall County WCID PWS, the following standards could be used in a rough screening to identify compliant groundwater in surrounding systems:

  - Radium (total radium for radium-226 and radium-228) less than 4 pCi/L (below the MCL of 5 pCi/L);
  - Nitrate (measured as nitrogen) concentrations less than 8 mg/L (below the MCL of 10 milligrams per liter [mg/L]); and
  - Total dissolved solids (TDS) concentrations less than 1,000 mg/L.

- Review the recorded well information to eliminate those wells that appear to be unsuitable for the application. Often, the “Remarks” column in the Texas Water Development Board (TWDB) hard-copy database provides helpful information. Wells eliminated from consideration generally include domestic and stock wells, dug wells, test holes, observation wells, seeps and springs, destroyed wells, wells used by other communities, *etc*.
- Identify wells of sufficient size which have been used for industrial or irrigation purposes. Often the TWDB database will include well yields, which may indicate the likelihood that a particular well is a satisfactory source.
- At this point in the process, the local groundwater control district (if one exists) should be contacted to obtain information about pumping restrictions. Also, preliminary cost estimates should be made to establish the feasibility of pursuing further well development options.
- If particular wells appear to be acceptable, the owner(s) should be contacted to ascertain their willingness to work with the PWS. Once the owner agrees to participate in the program, questions should be asked about the wells. Many owners have more than one well, and would probably be the best source of information regarding the latest test dates, who tested the water, flowrates, and other well characteristics.
- After collecting as much information as possible from cooperative owners, the PWS would then narrow the selection of wells and sample and analyze them for quality. Wells with good quality would then be potential candidates for test pumping. In some cases, a particular well may need to be refurbished before test pumping. Information obtained from test pumping would then be used in combination with information about the general characteristics of the aquifer to determine whether a well at this location would be suitable as a supply source.
- It is recommended that new wells be installed instead of using existing wells to ensure the well characteristics are known and the well meets construction standards.
- Permit(s) would then be obtained from the groundwater control district or other regulatory authority, and an agreement with the owner (purchase or lease, access easements, *etc*.) would then be negotiated.

1.4.2.2 Develop New Wells

If no existing wells are available for development, the PWS or group of PWSs has an option of developing new wells. Records of existing wells, along with other hydrogeologic information and modern geophysical techniques, should be used to identify potential locations for new wells. In some areas, the TWDB's Groundwater Availability Model (GAM) may be applied to indicate potential sources. Once a general area has been identified, land owners and regulatory agencies should be contacted to determine an exact location for a new well or well field. Pump tests and water quality tests would be required to determine if a new well will produce an adequate quantity of good quality water. Permits from the local groundwater control district or other regulatory authority could also be required for a new well.

1.4.3 Potential for Surface Water Sources

Water rights law dominates the acquisition of water from surface water sources. For a PWS, 100 percent availability of water is required, except where a back-up source is available. For PWSs with an existing water source, although it may be non-compliant because of elevated concentrations of one or more parameters, water rights may not need to be 100 percent available.

1.4.3.1 Existing Surface Water Sources

"Existing surface water sources" of water refers to municipal water authorities and cities that obtain water from surface water sources. The process of obtaining water from such a source is generally less time consuming and less costly than the process of developing a new source; therefore, it should be a primary course of investigation. An existing source would be limited by its water rights, the safe yield of a reservoir or river, or by its water treatment or water conveyance capability. The source must be able to meet the current demand and honor contracts with communities it currently supplies. In many cases, the contract amounts reflect projected future water demand based on population or industrial growth.

A non-compliant PWS would look for a source with sufficient spare capacity. Where no such capacity exists, the non-compliant PWS could offer to fund the improvements necessary to obtain the capacity. This approach would work only where the safe yield could be increased (perhaps by enlarging a reservoir) or where treatment capacity could be increased. In some instances water rights, where they are available, could possibly be purchased.

In addition to securing the water supply from an existing source, the non-compliant PWS would need to arrange for transmission of the water to the PWS. In some cases, that could require negotiations with, contracts with, and payments to an intermediate PWS (an intermediate PWS is one where the infrastructure is used to transmit water from a "supplier" PWS to a "supplied" PWS, but does not provide any additional treatment to the supplied water). The non-compliant PWS could be faced with having to fund improvements to the intermediate PWS in addition to constructing its own necessary transmission facilities.

1.4.3.2 New Surface Water Sources

Communication with the TCEQ and relevant planning groups from the beginning is essential in the process of obtaining a new surface water source. Preliminary assessment of the potential for acquiring new rights may be based on surface water availability maps located on the TWDB website. Where water rights appear to be available, the following activities need to occur:

- Discussions with TCEQ to indicate the likelihood of obtaining those rights. The TCEQ may use the Water Availability Model (WAM) to assist in the determination.
- Discussions with land owners to indicate potential treatment plant locations.
- Coordination with U.S. Army Corps of Engineers and local river authorities.
- Preliminary engineering design to determine the feasibility, costs, and environmental issues of a new treatment plant.

Should these discussions indicate that a new surface water source is the best option, the community would proceed with more intensive planning (initially obtaining funding), permitting, land acquisition, and detailed designs.

1.4.4 Identification of Treatment Technologies for Radionuclides

Various treatment technologies were also investigated as compliance alternatives for treatment of radium to regulatory level (*i.e.*, MCL). The removal of radium would also remove gross alpha activity as the radium appears to be responsible for most of the gross alpha activity of the groundwater. Radium-226 and Radium-228 are cations (Ra^{2+}) dissolved in water and are not easily removed by particle filtration. A 2002 USEPA document (*Radionuclides in Drinking Water: A Small Entity Compliance Guide*, EPA 815-R-02-001) lists a number of small system compliance technologies that can remove radium (combined radium-226 and radium-228) from water. These technologies include ion exchange, reverse osmosis (RO), electrodialysis/electrodialysis reversal (ED/EDR), lime softening, greensand filtration, re-formed hydrous manganese oxide filtration ($KMnO_4$-filtration), and co-precipitation with barium sulfate. A relatively new process using the Water Remediation Technologies, Inc. (WRT) Z-88™ media specific for radium adsorption has been demonstrated to be an effective radium technology. Lime softening and co-precipitation with barium sulfate are technologies that are relatively complex and require chemistry skills that are not practical for small systems with limited resources and hence they are not evaluated further.

1.4.5 Description of Treatment Technologies

The application radium removal treatment technologies include ion exchange (IX), WRT Z88 media adsorption, RO, ED/EDR, and $KMnO_4$greensand filtration. A description of these technologies follows.

1.4.5.1 Ion Exchange

Process – In solution, salts separate into positively-charged cations and negatively-charged anions. IX is a reversible chemical process in which ions from an insoluble, permanent, solid resin bed are exchanged for ions in the water. The process relies on the fact that certain ions are preferentially adsorbed on the ion exchange resin. Operation begins with a fully charged cation or anion bed, having enough positively or negatively charged ions to carry out the cation or anion exchange. Usually a polymeric resin bed is composed of millions of spherical beads about the size of medium sand grains. As water passes the resin bed, the charged ions are released into the water, being substituted or replaced with the contaminants in the water (ion exchange). When the resin becomes exhausted of positively or negatively charged ions, the bed must be regenerated by passing a strong, sodium chloride, solution over the resin, displacing the contaminants ions with sodium ions for cation exchange and chloride ion for anion exchange. Many different types of resins can be used to reduce dissolved contaminant concentrations. The IX treatment train for groundwater typically includes cation or anion resins beds with a regeneration system, chlorine disinfection, and clear well storage. Treatment trains for surface water may also include raw water pumps, debris screens, and filters for pre-treatment. Additional treatment or management of the concentrate and the removed solids will be necessary prior to disposal, especially for radium removal resins which have elevated radioactivity.

For radium removal, a strong acid cation exchange resin in the sodium form can remove 99% of the radium. The strong acid resin has less capacity for radium on water with high hardness and it has the following adsorption preference: Ra^{2+} >Ba^{2+} >Ca^{2+} >Mg^{2+V} >Na^{+}. Because of the selectivity radium and barium are much more difficult to remove from the resin during regeneration than calcium and magnesium. Economical regeneration removes most of the hardness ions, but radium and barium buildup on the resin after repeated cycles to the point where equilibrium is reached and then radium and barium will begin to breakthrough shortly after hardness. Regeneration of the sodium form strong acid resin for water with 200 mg/L of hardness with application of 6.5 lb $NaCl/ft^3$ resin would produce 2.4 bed volumes (BV) of 16,400 mg/L TDS brine per 100 BV of product water (2.4%). The radium concentration in the regeneration waste would be approximately 40 times the influent radium concentration in groundwater.

Pretreatment – Pretreatment guidelines are available on accepted limits for pH, organics, turbidity, and other raw water characteristics. Pretreatment may be required to reduce excessive amounts of TSS, iron, and manganese, which could plug the resin bed, and typically includes media or carbon filtration.

Maintenance – The IX resin requires regular on-site regeneration, the frequency of which depends on raw water characteristics (especially hardness), the contaminant concentration, and the size and number of IX vessels. Many systems have undersized the IX vessels only to realize higher than necessary operating costs. Preparation of the sodium chloride solution is required. If used, filter replacement and backwashing will be required.

Waste Disposal – Approval from local authorities is usually required for disposal of concentrate from the regeneration cycle (highly concentrated salt solution with radioactivity); occasional solids wastes (in the form of broken resin beads) which are backwashed during regeneration; and if used, spent filters and backwash wastewater.

Advantages (IX)

- Well established process for radium removal.
- Fully automated and highly reliable process.
- Suitable for small and large installations.

Disadvantages (IX)

- Requires salt storage; regular regeneration.
- Concentrate disposal.
- Resins are sensitive to the presence of competing ions such as calcium and magnesium.

In considering application of IX for inorganic, it is important to understand what the effect of competing ions will be, and to what extent the brine can be recycled. Conventional IX cationic resin removes calcium and magnesium in addition to radium and thus the capacity for radium removal and frequency of regeneration depend on the hardness of the water to be treated. Spent regenerant is produced during IX bed regeneration, and it may have concentrations of the sorbed contaminants which will be expensive to treat and/or dispose because of hazardous waste regulations.

1.4.5.2 WRT Z-88 Media

Process – The WRT Z-88 radium treatment process is a proprietary process using a radium specific adsorption resin or zeolite supplied by WRT. The Z-88 process is similar to IX except that no regeneration of the resin is conducted and the resin is disposed of upon exhaustion. The Z-88 does not remove calcium and magnesium and thus it can last for a long time (2-4 years, according to WRT) before replacement is necessary. The process is operated in an upflow, fluidized mode with a surface loading rate of 10.5 gallons per minute (gpm)/ft^2. Pilot testing of this technology has been conducted successfully for radium removal in many locations including in the State of Texas. Seven full-scale systems with capacities of 750 to 1,200 gpm have been constructed in the Village of Oswego, Illinois since July 2005. The treatment equipment is owned by WRT and the ownership of spent media would be transferred to an approved disposal site. The customer pays WRT based on an agreed upon treated water unit cost (*e.g.*, $3.00/ thousand gallons for small systems).

Pretreatment – Pretreatment may be required to reduce excess amounts of total suspended solids (TSS), iron, and manganese, which could plug the resin bed, and typically includes media or carbon filtration. No chemical addition is required for radium removal.

Maintenance – Maintenance is relatively low for this technology as no regeneration or chemical handling is required. Periodical water quality monitoring and inspection of mechanical equipment are required.

Waste Disposal – The Z-88 media would be disposed of in an approved low level radioactive waste landfill by WRT once every 2-3 years. No liquid waste is generated for this process. However, if pretreatment filters are used then spent filters and backwash wastewater disposal is required.

Advantages (Z-88)

- Simple and fully automated process.
- No liquid waste disposal.
- No chemical handling, storage, or feed systems.
- No change in water quality except radium reduction.
- Low capital cost as WRT owns the equipment.

Disadvantages (Z-88)

- Relatively new technology.
- Proprietary technology without direct competition.
- Long term contract with WRT required.

From a small utilities point of view the Z-88 process is a desirable technology for radium removal because the operation and maintenance (O&M) effort is minimal and no regular liquid waste is generated. However, this technology is very new and without long-term full-scale operating experience. But since the equipment is owned by WRT and the performance is guaranteed by WRT the risk to the utilities is minimized.

1.4.5.3 Reverse Osmosis

Process – RO is a pressure-driven membrane separation process capable of removing dissolved solutes from water by means of particle size and electrical charge. The raw water is typically called feed; the product water is called permeate, and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate and polyamide thin film composite. Common RO membrane configurations include spiral wound and hollow fine fiber but most RO systems to date are of the spiral wound type. A typical RO installation includes a high pressure feed pump with chemical feed, parallel first and second stage membrane elements in pressure vessels, and valving and piping for feed, permeate, and concentrate streams. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, and regular monitoring and maintenance. RO is capable of achieving over 95% removal of radium. The treatment process is relatively insensitive to pH. Water recovery is 60-80%, depending on the raw water characteristics. The concentrate volume for disposal can be significant.

Pretreatment – RO requires careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling or other membrane degradation. Removal or sequestering of suspended and colloidal solids is necessary to prevent fouling, and removal of sparingly soluble constituents such as calcium, magnesium, silica, sulfate, barium, *etc*. may be required to prevent scaling. Pretreatment can include media filters, ion exchange softening, acid and antiscalant feed, activated carbon or bisulfite feed to dechlorinate, and cartridge filters to remove any remaining suspended solids to protect membranes from upsets.

Maintenance – Monitoring rejection percentage is required to ensure contaminant removal below MCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove foulants and scalants. Frequency of membrane replacement is dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal – Pretreatment waste streams, concentrate flows, spent filters and membrane elements all required approved disposal methods. The disposal of the significant volume of the concentrate stream is a problem for many utilities.

Advantages

- Can remove radium effectively.
- Can remove other undesirable dissolved constituents.

Disadvantages

- Relatively expensive to install and operate.
- Needs sophisticated monitoring systems.
- Needs to handle multiple chemicals.
- Reject requires discharge.
- Waste of water because of the significant concentrate flows.

RO is an expensive alternative to remove radium and is usually not economically competitive with other processes unless nitrate and/or TDS removal is also required. The biggest drawback for using RO to remove radium is the waste of water through concentrate disposal which is also difficult or expensive because of the volume involved.

1.4.5.4 Electrodialysis/Electrodialysis Reversal

Process – ED is an electrochemical separation process in which ions migrate through ion-selective semi-permeable membranes as a result of their attraction to two electrically charged electrodes. The driving force for ion transfer is direct electric current. ED is different from RO in that it removes only dissolved inorganics but not particulates, organics, and silica. EDR is an improved form of ED in which the polarity of the direct current is changed approximately every 15 minutes. The change of polarity helps to reduce the formation of scale and fouling films and thus a higher water recovery can be achieved. EDR has been the dominant form of ED system used for the past 25-30 years. A typical EDR system includes a membrane stack with a number of cell pairs, each consisting of a cation transfer membrane, a demineralized water flow spacer, an anion transfer membrane, and a concentrate flow spacer. Electrode compartments are at opposite ends of the stack. The influent feed water (chemically treated to prevent precipitation) and concentrate reject flow in parallel across the membranes and through the demineralized water and concentrate flow spacers, respectively. The electrodes are continually flushed to reduce fouling or scaling. Careful consideration of flush feed water is required. Typically, the membranes are cation or anion exchange resins cast in sheet form; the spacers are high density polyethylene; and the electrodes are inert metal. EDR stacks are tank-contained and often staged. Membrane selection is based on review of raw water characteristics. A single-stage EDR system usually removes 40-50 percent of the dissolved salts including radium, and multiple stages may be required to meet the MCL if radium concentration is high. The conventional EDR treatment train typically includes EDR membranes, chlorine disinfection, and clearwell storage.

<u>Pretreatment</u> – Guidelines are available on acceptable limits on pH, organics, turbidity, and other raw water characteristics. EDR typically requires acid and antiscalant feed to prevent scaling and a cartridge filter for prefiltration. Treatment of surface water may also require pretreatment steps such as raw water pumps, debris screens, rapid mix with addition of a coagulant, flocculation basin, sedimentation basin or clarifier, and gravity filters. MF could be used in place of flocculation, sedimentation, and filtration.

<u>Maintenance</u> – EDR membranes are durable, can tolerate pH from 1-10, and temperatures to 115^{o}F for cleaning. The can be removed from the unit and scrubbed. Solids can be washed off by turning the power off and letting water circulate through the stack. Electrode washes flush out byproducts of electrode reaction. The byproducts are hydrogen, formed in the cathode space, and oxygen and chlorine gas, formed in the anode spacer. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics, the membranes will require regular maintenance or replacement. If used, pretreatment filter replacement and backwashing will be required. The EDR stack must be disassembled, mechanically cleaned, and reassembled at regular intervals.

<u>Waste Disposal</u> – Highly concentrated reject flows, electrode cleaning flows, and spent membranes require approved disposal methods. Pretreatment process residuals and spent materials also require approved disposal methods.

Advantages

- EDR can operate with minimal fouling, scaling, or chemical addition.
- Low pressure requirements; typically quieter than RO.
- Long membrane life expectancy.

- More flexible than RO in tailoring treated water quality requirements.

Disadvantages

- Not suitable for high levels of iron, manganese, hydrogen sulfide, and hardness.
- Relatively expensive process and high energy consumption.
- Does not remove particulates, organics, or silica.

EDR can be quite expensive to run because of the energy it uses. If radium removal is the only purpose it is probably more expensive than other technologies. However, if nitrate and/or TDS removal is also required, then EDR is a competitive process.

1.4.5.5 Potassium Permanganate Greensand Filtration

Process – Manganese dioxide (MnO$_2$) is known to have capacity to adsorb radium from water. MnO$_2$ can be formed by oxidation of Mn^{2+} occurring in natural waters and/or reduction of KMnO$_4$ added to the water. The MnO$_2$ is in the form of colloidal MnO$_2$ which has a large surface area for adsorption. The MnO$_2$ does not adsorb calcium and magnesium so hardness is not a factor but iron and manganese and other heavy metal cations can compete strongly with radium adsorption. If these cations are present it would be necessary to install a good iron and manganese removal process before the MnO$_2$- filtration process or making sure that some MnO$_2$ is still available for radium sorption. The KMnO$_4$-greensand filtration process can accomplish this purpose as the greensand is coated with MnO2 which is regenerated by the continuous feeding of KMnO$_4$. Many operating treatment systems utilizing continuous feed KMnO$_4$, 30-minute contact time, and manganese greensand remove radium to concentrations below the MCL. The treatment system equipment includes a KMnO$_4$ feed system, a pressurized reaction tank, and a manganese greensand filter. Backwashing of the greensand filter is usually required but periodic regeneration is not required.

Pretreatment – The KMnO$_4$-greensand filtration process usually does not require pretreatment except if the turbidity is very high. The greensand filter usually has an anthracite layer to filter larger particles while the greensand adsorbs dissolved cations such as radium.

Maintenance – The greensand requires periodic backwashing to rid of suspended materials and metal oxides. KMnO$_4$ is usually supplied in the powder form and preparation of KMnO$_4$ solution is required. Occasional monitoring to ensure no overfeeding of KMNO$_4$ (pink water) is important to avoid problems in distribution system and household fixtures.

Waste Disposal – Approval from local authorities is usually required for the backwash wastewater. If local sewer is not available a backwash water storage and settling tank would be required to recycle settled water to the process and disposed of the settled solids periodically.

Advantages

- Well established process for radium removal.
- No regeneration waste generated.
- Low pressure operation and no re-pumping required.
- No additional process for iron and manganese removal.

Disadvantages

- Need to handle powdered $KMnO_4$, which is an oxidant.
- Need to monitor and backwash regularly.
- Need to dispose of settled solids.

The $KMnO_4$-greensand filtration is a well established iron and manganese removal process and is effective for radium removal. It is suitable for small and large systems and is cost competitive with other alternative technologies.

1.4.6 Point-of-Entry and Point-of-Use Treatment Systems

Point-of-entry (POE) and point-of-use (POU) treatment systems can be used to provide compliant drinking water. For radium removal, these systems typically use small adsorption or reverse osmosis treatment units that are installed "under the sink" in the case of point-of-use, and where water enters a house or building in the case of point-of-entry. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive. Point-of-entry and point-of-use treatment units would be purchased and owned by the PWS. These solutions are decentralized in nature, and require utility personnel entry into houses or at least onto private property for installation, maintenance, and testing. Due to the large number of treatment units that would be employed and would be primarily out of the control of the PWS, it is very difficult to ensure 100 percent compliance. Prior to selection of a point-of-entry or point-of-use program for implementation, consultation with TCEQ would be required to address measurement and determination of level of compliance.

The SDWA [§1412(b)(4)(E)(ii)] regulates the design, management and operation of POU and POE treatment units used to achieve compliance with an MCL. These restrictions, relevant to arsenic are:

- POU and POE treatment units must be owned, controlled, and maintained by the water system, although the utility may hire a contractor to ensure proper O&M and MCL compliance. The water system must retain unit ownership and oversight of unit installation, maintenance and sampling; the utility ultimately is the responsible party for regulatory compliance. The water system staff need not perform all installation, maintenance, or management functions, as these tasks may be contracted to a third party-but the final responsibility for the quality and quantity of the water supplied to the community resides with the water system, and the utility must monitor all contractors closely. Responsibility for O&M of POU or POE devices installed for SDWA compliance may not be delegated to homeowners.

- POU and POE units must have mechanical warning systems to automatically notify customers of operational problems. Each POU or POE treatment device must be equipped with a warning device (*e.g.*, alarm, light) that would alert users when their unit is no longer adequately treating their water. As an alternative, units may be equipped with an automatic shut-off mechanism to meet this requirement.
- If the American National Standards Institute has issued product standards for a specific type of POU or POE treatment unit, only those units that have been independently certified according to those standards may be used as part of a compliance strategy.

The following observations with regard to using POE and POU devices for SDWA compliance were made by Raucher, *et al.* (2004):

- If POU devices are used as an SDWA compliance strategy, certain consumer behavioral changes will be necessary (*e.g.*, encouraging people to drink water only from certain treated taps) to ensure comprehensive consumer health protection.
- Although not explicitly prohibited in the SDWA, USEPA indicates that POU treatment devices should not be used to treat for radon or for most volatile organic contaminants to achieve compliance, because POU devices do not provide 100 percent protection against inhalation or contact exposure to those contaminants at untreated taps (*e.g.*, shower heads).
- Liability – PWSs considering unconventional treatment options (POU, POE, or bottled water) must address liability issues. These could be meeting drinking water standards, property entry and ensuing liabilities, and damage arising from improper installation or improper function of the POU and POE devices.

1.4.7 Water Delivery or Central Drinking Water Dispensers

Current USEPA regulations (40 Code of Federal Regulations [CFR] 141.101) prohibit the use of bottled water to achieve compliance with an MCL, except on a temporary basis. State regulations do not directly address the use of bottled water. Use of bottled water at a non-compliant PWS would be on a temporary basis. Every 3 years, the PWSs that employ interim measures are required to present the TCEQ with estimates of costs for piping compliant water to their systems. As long as the projected costs remain prohibitively high, the bottled water interim measure is extended. Until USEPA amends the noted regulation, the TCEQ is unable to accept water delivery or central drinking water dispensers as compliance solutions.

Central provision of compliant drinking water would consist of having one or more dispensers of compliant water where customers could come to fill containers with drinking water. The centralized water source could be from small to medium-sized treatment units or could be compliant water delivered to the central point by truck.

Water delivery is an interim measure for providing compliant water. As an interim measure for a small impacted population, providing delivered drinking water may be cost effective. If the susceptible population is large, the cost of water delivery would increase significantly.

Water delivery programs require consumer participation to a varying degree. Ideally, consumers would have to do no more than they currently do for a piped-water delivery system. Least desirable are those systems that require maximum effort on the part of the customer (*e.g.*, customer has to travel to get the water, transport the water, and physically handle the bottles). Such a system may appear to be lowest-cost to the utility; however, should a consumer experience ill effects from contaminated water and take legal action, the ultimate cost could increase significantly.

The ideal system would:

- Completely identify the susceptible population. If bottled water is only provided to customers who are part of the susceptible population, the utility should have an active means of identifying the susceptible population. Problems with illiteracy, language fluency, fear of legal authority, desire for privacy, and apathy may be reasons that some members of the susceptible population do not become known to the utility, and do not take part in the water delivery program.
- Maintain customer privacy by eliminating the need for utility personnel to enter the home.
- Have buffer capacity (*e.g.*, two bottles in service, so when one is empty, the other is being used over a time period sufficient to allow the utility to change out the empty bottle).
- Provide for regularly scheduled delivery so the customer would not have to notify the utility when the supply is low.
- Use utility personnel and equipment to handle water containers, without requiring customers to lift or handle bottles with water in them.
- Be sanitary (*e.g.*, where an outside connection is made, contaminants from the environment must be eliminated).
- Be vandal-resistant.
- Avoid heating the water due to exterior temperatures and solar radiation.
- Avoid freezing the water.

SECTION 2
EVALUATION METHOD

2.1 DECISION TREE

The decision tree is a flow chart for conducting feasibility studies for a non-compliant PWS. The decision tree is shown in Figures 2.1 through 2.4. The tree guides the user through a series of phases in the design process. Figure 2.1 shows Tree 1, which outlines the process for defining the existing system parameters, followed by optimizing the existing treatment system operation. If optimizing the existing system does not correct the deficiency, the tree leads to six alternative preliminary branches for investigation. The groundwater branch leads through investigating existing wells to developing a new well field. The treatment alternatives address centralized and on-site treatment. The objective of this phase is to develop conceptual designs and cost estimates for the six types of alternatives. The work done for this report follows through Tree 1 and Tree 2, as well as a preliminary pass through Tree 4.

Tree 3, which begins at the conclusion of the work for this report, starts with a comparison of the conceptual designs, selecting the two or three alternatives that appear to be most promising, and eliminating those alternatives which are obviously infeasible. It is envisaged that a process similar to this would be used by the study PWS to refine the list of viable alternatives. The selected alternatives are then subjected to intensive investigation, and highlighted by an investigation into the socio-political aspects of implementation. Designs are further refined and compared, resulting in the selection of a preferred alternative. The steps for assessing the financial and economic aspects of the alternatives (one of the steps in Tree 3) are given in Tree 4 in Figure 2.4.

2.2 DATA SOURCES AND DATA COLLECTION

2.2.1 Data Search

2.2.1.1 Water Supply Systems

The TCEQ maintains a set of files on public water systems, utilities, and districts at its headquarters in Austin, Texas. The files are organized under two identifiers: a PWS identification number and a CCN number. The PWS identification number is used to retrieve four types of files:

- CO – Correspondence,
- CA – Chemical analysis,
- MOR – Monthly operating reports (quality/quantity), and
- FMT – Financial, managerial and technical issues.

Figure 2.1

TREE 1 – EXISTING FACILITY ANALYSIS

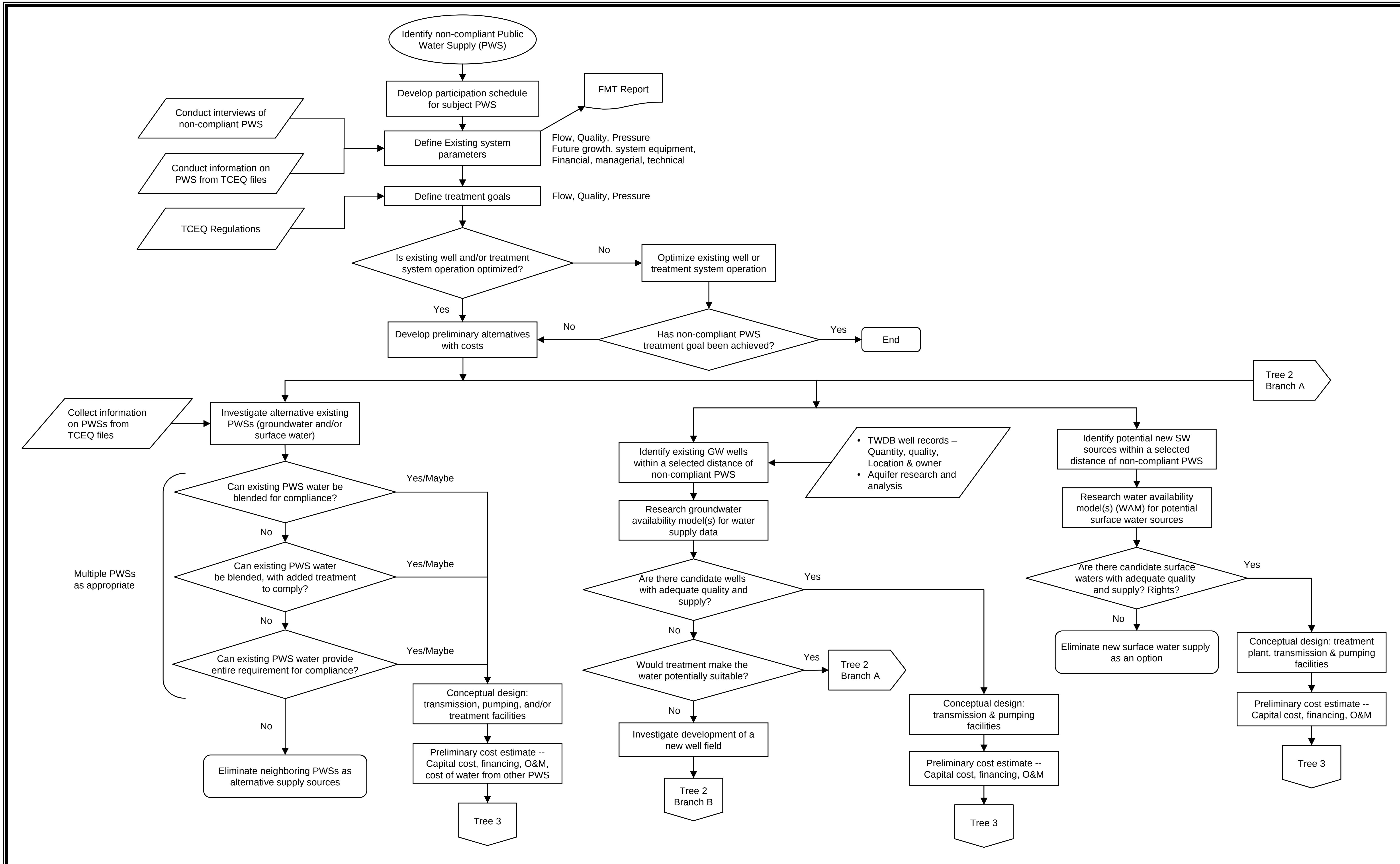


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATIVES

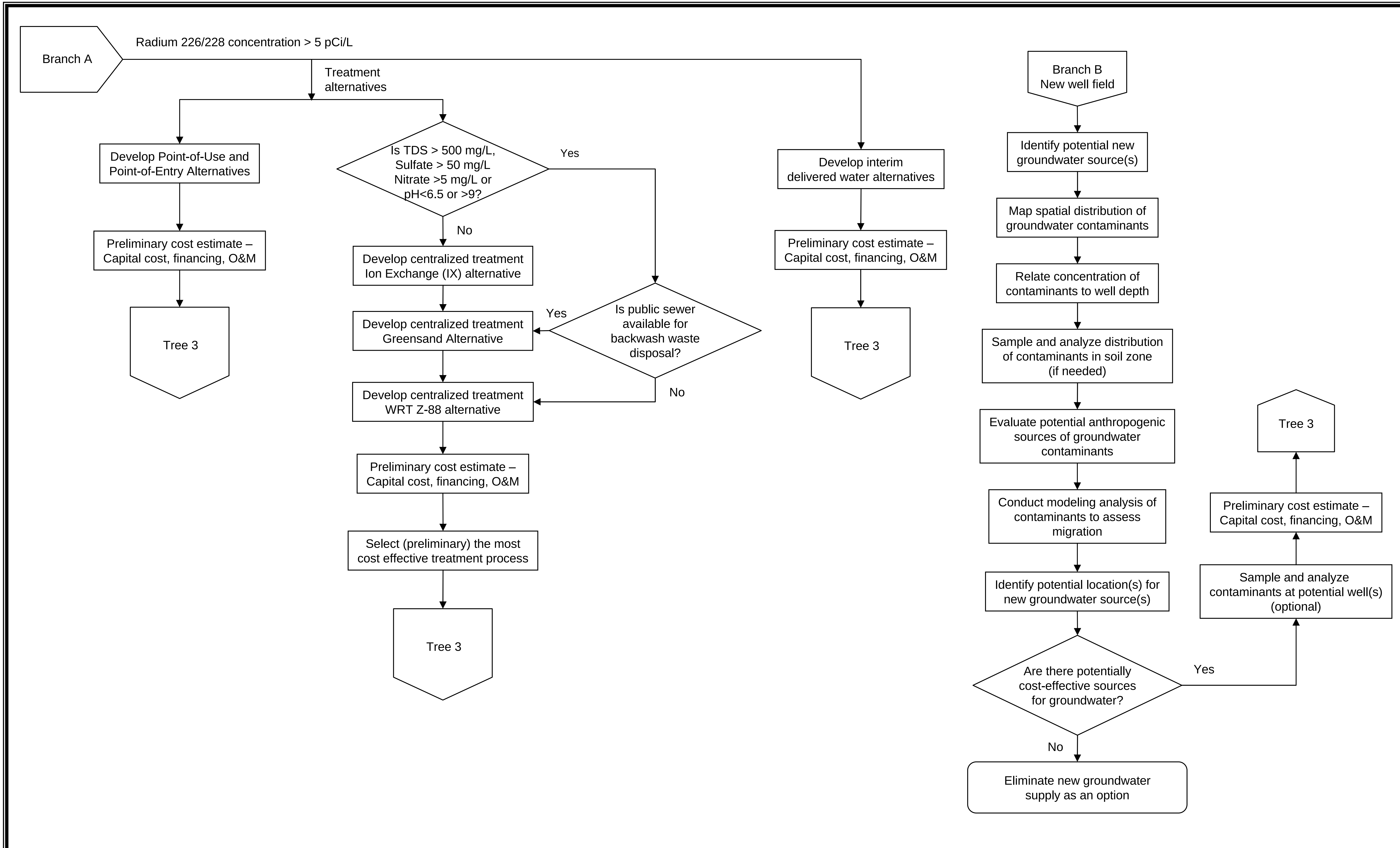


Figure 2.3
Tree 3 – PRELIMINARY ANALYSIS

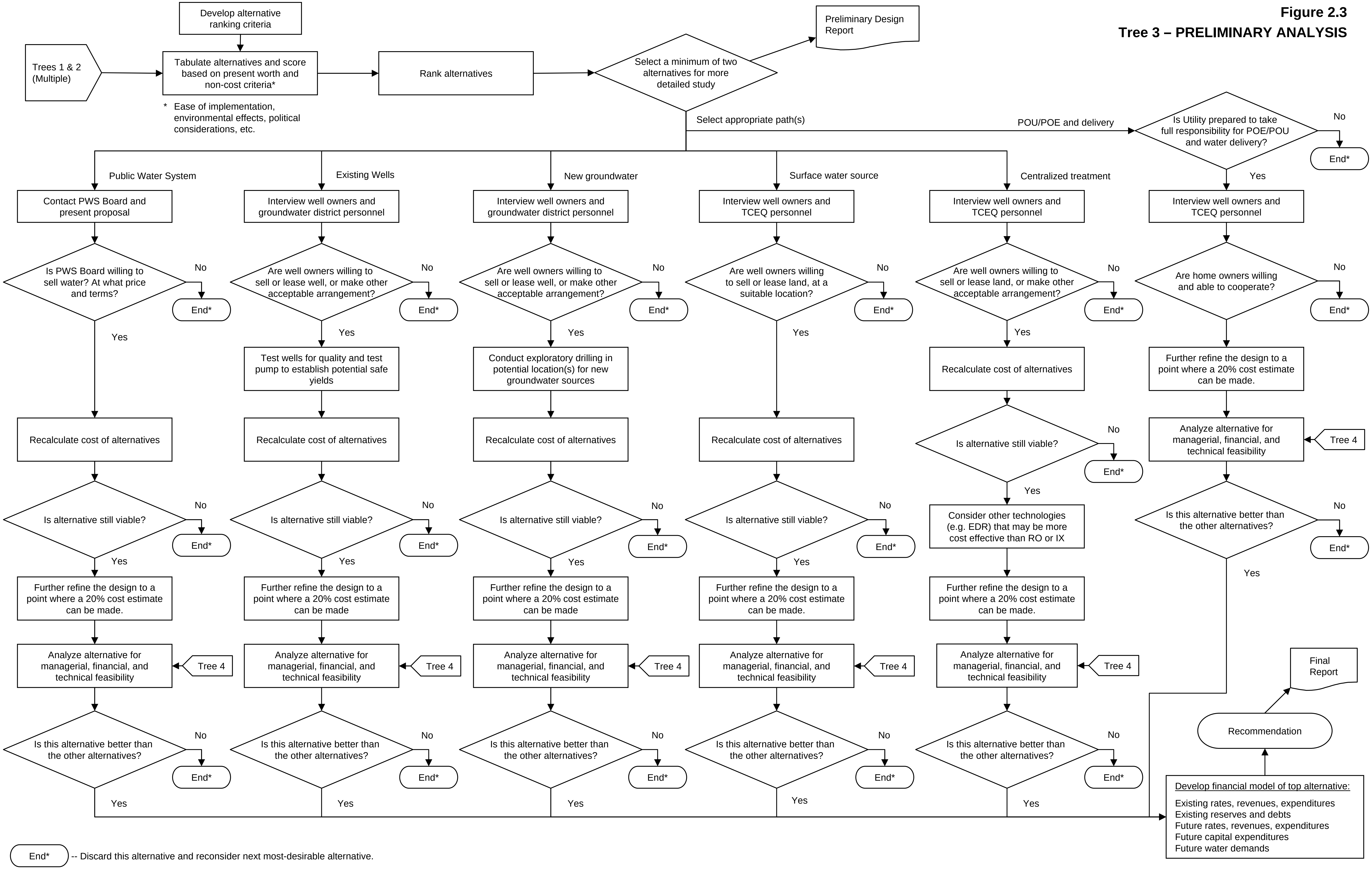
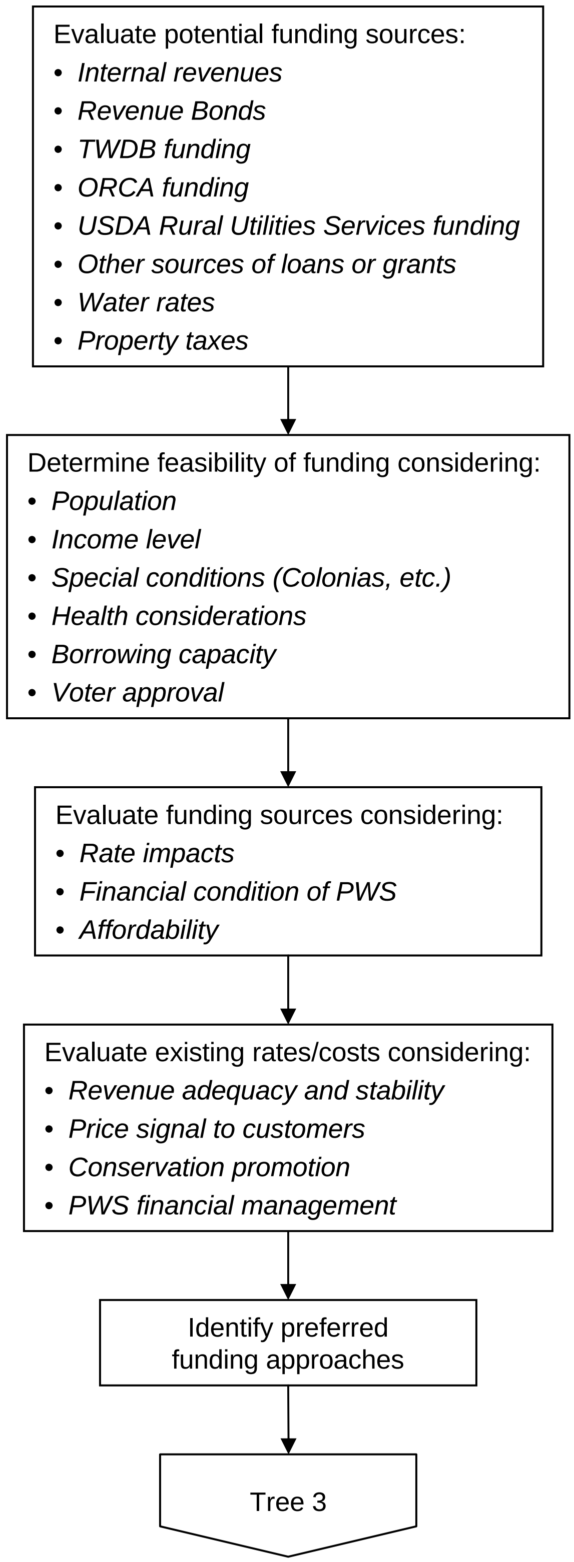


Figure 2.4
TREE 4 – FINANCIAL



The CCN files generally contain a copy of the system's Certificate of Convenience and Necessity, along with maps and other technical data.

These files were reviewed for the PWS and surrounding systems.

The following websites were consulted to identify the water supply systems in the study area:

- Texas Commission on Environmental Quality www.tnrcc.state.tx.us/iwud/pws/index.cfm. Under "Advanced Search", type in the name(s) of the county(ies) in the study area to get a listing of the public water supply systems.
- USEPA Safe Drinking Water Information System www.epa.gov/safewater/data/getdata.html

Groundwater Control Districts were identified on the TWDB web site, which has a series of maps covering various groundwater and surface water subjects. One of those maps shows groundwater control districts in the State of Texas.

2.2.1.2 Existing Wells

The TWDB maintains a groundwater database available at www.twdb.state.tx.us that has two tables with helpful information. The "Well Data Table" provides a physical description of the well, owner, location in terms of latitude and longitude, current use, and for some wells, items such as flowrate, and nature of the surrounding formation. The "Water Quality Table" provides information on the aquifer and the various chemical concentrations in the water.

2.2.1.3 Surface Water Sources

Regional planning documents were consulted for lists of surface water sources.

2.2.1.4 Groundwater Availability Model

GAMs, developed by the TWDB, are planning tools and should be consulted as part of a search for new or supplementary water sources. The GAM for the Edwards-Trinity Plateau aquifer was investigated as a potential tool for identifying available and suitable groundwater resources.

2.2.1.5 Water Availability Model

The WAM is a computer-based simulation predicting the amount of water that would be in a river or stream under a specified set of conditions. WAMs are used to determine whether water would be available for a newly requested water right or amendment. If water is available, these models estimate how often the applicant could count on water under various conditions (*e.g.*, whether water would be available only 1 month out of the year, half the year, or all year, and whether that water would be available in a repeat of the drought of record).

WAMs provide information that assist TCEQ staff in determining whether to recommend the granting or denial of an application.

2.2.1.6 Financial Data

Financial data were collected through a site visit. Data sought included:

- Annual Budget
- Audited Financial Statements
  - Balance Sheet
  - Income & Expense Statement
  - Cash Flow Statement
  - Debt Schedule
- Water Rate Structure
- Water Use Data
  - Production
  - Billing
  - Customer Counts

2.2.1.7 Demographic Data

Basic demographic data were collected from the 2000 Census to establish incomes and eligibility for potential low cost funding for capital improvements. Median household income (MHI) and number of families below poverty level were the primary data points of significance. If available, MHI for the customers of the PWS should be used. In addition, unemployment data were collected from current U.S. Bureau of Labor Statistics. These data were collected for the following levels: national, state, and county.

2.2.2 PWS Interviews

2.2.2.1 PWS Capacity Assessment Process

A capacity assessment is the industry standard term for an evaluation of a water system's financial, managerial, and technical capacity to effectively deliver safe drinking water to its customers now and in the future at a reasonable cost, and to achieve, maintain and plan for compliance with applicable regulations. The assessment process involves interviews with staff and management who have a responsibility in the operations and management of the system.

Financial, managerial, and technical capacity are individual yet highly interrelated components of a system's capacity. A system cannot sustain capacity without maintaining adequate capability in all three components.

Financial capacity is a water system's ability to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA regulations. Financial capacity refers to the financial resources of the water system, including but not limited to revenue sufficiency, credit worthiness, and fiscal controls.

Managerial capacity is the ability of a water system to conduct its affairs so the PWS is able to achieve and maintain compliance with SDWA requirements. Managerial capacity refers to the management structure of the water system, including but not limited to ownership accountability, staffing and organization, and effective relationships to customers and regulatory agencies.

Technical capacity is the physical and operational ability of a water system to achieve and maintain compliance with the SDWA regulations. It refers to the physical infrastructure of the water system, including the adequacy of the source water, treatment, storage and distribution infrastructure. It also refers to the ability of system personnel to effectively operate and maintain the system and to otherwise implement essential technical knowledge.

Many aspects of water system operations involve more than one component of capacity. Infrastructure replacement or improvement, for example, requires financial resources, management planning and oversight, and technical knowledge. A deficiency in any one area could disrupt the entire effort. A system that is able to meet both its immediate and long-term challenges demonstrates that it has sufficient financial, managerial, and technical capacity.

Assessment of the FMT capacity of the PWS was based on an approach developed by the New Mexico Environmental Finance Center (NMEFC), which is consistent with the TCEQ FMT assessment process. This method was developed from work the NMEFC did while assisting USEPA Region 6 in developing and piloting groundwater comprehensive performance evaluations. The NMEFC developed a standard list of questions that could be asked of water system personnel. The list was then tailored slightly to have two sets of questions – one for managerial and financial personnel, and one for operations personnel (the questions are included in Appendix A). Each person with a role in the FMT capacity of the system was asked the applicable standard set of questions individually. The interviewees were not given the questions in advance and were not told the answers others provided. Also, most of the questions are open ended type questions so they were not asked in a fashion to indicate what would be the "right" or "wrong" answer. The interviews lasted between 45 minutes to 75 minutes depending on the individual's role in the system and the length of the individual's answers.

In addition to the interview process, visual observations of the physical components of the system were made. A technical information form was created to capture this information. This form is also contained in Appendix A. This information was considered supplemental to the interviews because it served as a check on information provided in the interviews. For example, if an interviewee stated he or she had an excellent preventative maintenance schedule and the visit to the facility indicated a significant amount of deterioration (more than would be expected for the age of the facility) then the preventative maintenance program could be further investigated or the assessor could decide the preventative maintenance program was inadequate.

Following interviews and observations of the facility, answers that all personnel provided were compared and contrasted to provide a clearer picture of the true operations at the water system. The intent was to go beyond simply asking the question, "Do you have a budget?" to actually finding out if the budget was developed and being used appropriately. For example, if a water system manager was asked the question, "Do you have a budget?" he or she may say, "yes" and the capacity assessor would be left with the impression that the system is doing well in this area. However, if several different people are asked about the budget in more detail, the assessor may find that although a budget is present, operations personnel do not have input into the budget, the budget is not used by the financial personnel, the budget is not updated regularly, or the budget is not used in setting or evaluating rates. With this approach, the inadequacy of the budget would be discovered and the capacity deficiency in this area would be noted.

Following the comparison of answers, the next step was to determine which items noted as a potential deficiency truly had a negative effect on the system's operations. If a system had what appeared to be a deficiency, but this deficiency was not creating a problem in terms of the operations or management of the system, it was not considered critical and may not have needed to be addressed as a high priority. As an example, the assessment may have revealed an insufficient number of staff members to operate the facility. However, it may also have been revealed that the system was able to work around that problem by receiving assistance from a neighboring system, so no severe problems resulted from the number of staff members. Although staffing may not be ideal, the system does not need to focus on this particular issue. The system needs to focus on items that are truly affecting operations. As an example of this type of deficiency, a system may lack a reserve account which can then lead the system to delay much-needed maintenance or repair on its storage tank. In this case, the system needs to address the reserve account issue so that proper maintenance can be completed.

The intent was to develop a list of capacity deficiencies with the greatest impact on the system's overall capacity. Those were the most critical items to address through follow-up technical assistance or by the system itself.

2.2.2.2 Interview Process

PWS personnel were interviewed by the project team, and each was interviewed separately. Interview forms were completed during each interview.

2.3 ALTERNATIVE DEVELOPMENT AND ANALYSIS

The initial objective for developing alternatives to address compliance issues is to identify a comprehensive range of possible options that can be evaluated to determine which are the most promising for implementation. Once the possible alternatives are identified, they must be defined in sufficient detail so a conceptual cost estimate (capital and O&M costs) can be developed. These conceptual cost estimates are used to compare the affordability of compliance alternatives, and to give a preliminary indication of rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation. The basis for the unit costs used for the compliance alternative cost estimates is summarized in Appendix B. Other non-economic factors for the alternatives, such as reliability and ease of implementation, are also addressed.

2.3.1 Existing PWS

The neighboring PWSs were identified, and the extents of their systems were investigated. PWSs farther than 10 miles from the non-compliant PWSs were not considered because the length of the pipeline required would make the alternative cost prohibitive. The quality of water provided was also investigated. For neighboring PWSs with compliant water, options for water purchase and/or expansion of existing well fields were considered. The neighboring PWSs with non-compliant water were considered as possible partners in sharing the cost for obtaining compliant water either through treatment or developing an alternate source.

The neighboring PWSs were investigated to get an idea of the water sources in use and the quantity of water that might be available for sale. They were contacted to identify key locations in their systems where a connection might be made to obtain water, and to explore on a preliminary basis their willingness to partner or sell water. Then, the major system components that would be required to provide compliant water were identified. The major system components included treatment units, wells, storage tanks, pump stations, and pipelines.

Once the major components were identified, a preliminary design was developed to identify sizing requirements and routings. A capital cost estimate was then developed based on the preliminary design of the required system components. An annual O&M cost was also estimated to reflect the change in O&M expenditures that would be needed if the alternative was implemented.

Non-economic factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.3.2 New Groundwater Source

It was not possible in the scope of this study to determine conclusively whether new wells could be installed to provide compliant drinking water. To evaluate potential new groundwater source alternatives, three test cases were developed based on distance from the PWS intake point. The test cases were based on distances of 10 miles, 5 miles, and 1 mile. It was assumed that a pipeline would be required for all three test cases, and a storage tank and pump station would be required for the 10-mile and 5-mile alternatives. It was also assumed that new wells would be installed, and that their depths would be similar to the depths of the existing wells, or other existing drinking water wells in the area.

A preliminary design was developed to identify sizing requirements for the required system components. A capital cost estimate was then developed based on the preliminary design of the required system components. An annual O&M cost was also estimated to reflect the change (*i.e.*, from current expenditures) in O&M expenditures that would be needed if the alternative was implemented.

Non-economic factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.3.3 New Surface Water Source

New surface water sources were investigated. Availability of adequate quality water was investigated for the main rivers in the study area, as well as the major reservoirs. TCEQ WAMs were inspected, and the WAM was run, where appropriate.

2.3.4 Treatment

Treatment technologies considered potentially applicable to radium removal are IX, WRT Z-88™ media, RO, EDR, and $KMnO_4$-greensand filtration. RO and EDR are membrane processes that produce a considerable amount of liquid waste: a reject stream from RO treatment and a concentrate stream from EDR treatment. As a result, the treated volume of water is less than the volume of raw water that enters the treatment system. The amount of raw water used increases to produce the same amount of treated water if RO or EDR treatment is implemented. Because the TDS is not very high (<1,000 mg/L) the use of RO or EDR would be considerably more expensive than the other potential technologies. And thus RO and EDR are not considered further. However, RO is considered for POU and POE alternatives. IX, WRT Z-88™ media, and $KMnO_4$-greensand filtration are considered as alternative central treatment technologies. The treatment units were sized based on flow rates, and capital and annual O&M cost estimates were made based on the size of the treatment equipment required. Neighboring non-compliant PWS's were identified to look for opportunities where the costs and benefits of central treatment could be shared between systems.

Non-economical factors were also identified. Ease of implementation was considered, as well as the reliability for providing adequate quantities of compliant water. Additional factors were whether implementation of an alternative would require significant increase in the management or technical capability of the PWS, and whether the alternative had the potential for regionalization.

2.4 COST OF SERVICE AND FUNDING ANALYSIS

The primary purpose of the cost of service and funding analysis is to determine the financial impact of implementing compliance alternatives, primarily by examining the required rate increases, and also the fraction of household income that water bills represent. The current financial situation is also reviewed to determine what rate increases are necessary for the PWS to achieve or maintain financial viability.

2.4.1 Financial Feasibility

A key financial metric is the comparison of average annual household water bill for a PWS customer to the MHI for the area. MHI data from the 2000 Census are used, at the most detailed level available for the community. Typically, county level data are used for small rural water utilities due to small population sizes. Annual water bills are determined for existing, base conditions, including consideration of additional rate increases needed under current conditions. Annual water bills are also calculated after adding incremental capital and operating costs for each of the alternatives to determine feasibility under several potential funding sources.

Additionally, the use of standard ratios provides insight into the financial condition of any business. Three ratios are particularly significant for water utilities:

- Current Ratio = current assets divided by current liabilities provides insight into the ability to meet short-term payments. For a healthy utility, the value should be greater than 1.0.
- Debt to Net Worth Ratio = total debt divided by net worth shows to what degree assets of the company have been funded through borrowing. A lower ratio indicates a healthier condition.
- Operating Ratio = total operating revenues divided by total operating expenses show the degree to which revenues cover ongoing expenses. The value is greater than 1.0 if the utility is covering its expenses.

2.4.2 Median Household Income

The 2000 U.S. Census is used as the basis for MHI. In addition to consideration of affordability, the annual MHI may also be an important factor for sources of funds for capital programs needed to resolve water quality issues. Many grant and loan programs are available to lower income rural areas, based on comparisons of local income to statewide incomes. In the 2000 Census, MHI for the State of Texas was $39,927, compared to the U.S. level of $41,994. For service areas with a sparse population base, county data may be the most reliable, and for many rural areas corresponds to census tract data. The census broke down MHIs geographically by block group and ZIP code. The MHIs can vary significantly for the same location, depending on the geographic subdivision chosen. The MHI for each PWS was estimated by selecting the most appropriate value based on block group or ZIP code based on results of the site interview and a comparison with the surrounding area.

2.4.3 Annual Average Water Bill

The annual average household water bill was calculated for existing conditions and for future conditions incorporating the alternative solutions. Average residential consumption is estimated and applied to the existing rate structure to estimate the annual water bill. The estimates are generated from a long-term financial planning model that details annual revenue, expenditure, and cash reserve requirements over a 30-year period.

2.4.4 Financial Plan Development

The financial planning model uses available data to establish base conditions under which the system operates. The model includes, as available:

- Accounts and consumption data
- Water tariff structure
- Beginning available cash balance
- Sources of receipts:
  - Customer billings
  - Membership fees
  - Capital Funding receipts from:
    - Grants
    - Proceeds from borrowing
- Operating expenditures:
  - Water purchases
  - Utilities
  - Administrative costs
  - Salaries
- Capital expenditures
- Debt service:
  - Existing principal and interest payments
  - Future principal and interest necessary to fund viable operations
- Net cash flow

- Restricted or desired cash balances:
  - Working capital reserve (based on 1-4 months of operating expenses)
  - Replacement reserves to provide funding for planned and unplanned repairs and replacements

From the model, changes in water rates are determined for existing conditions and for implementing the compliance alternatives.

2.4.5 Financial Plan Results

Results from the financial planning model are summarized in two areas: percentage of household income and total water rate increase necessary to implement the alternatives and maintain financial viability.

2.4.5.1 Funding Options

Results are summarized in a table that shows the following according to alternative and funding source:

- Percentage of the MHI the average annual residential water bill represents.
- The first year in which a water rate increase would be required.
- The total increase in water rates required, compared to current rates.

Water rates resulting from the incremental capital costs of the alternative solutions are examined under a number of funding options. The first alternative examined is always funding from existing reserves plus future rate increases. Several funding options were analyzed to frame a range of possible outcomes.

- Grant funds for 100 percent of required capital. In this case, the PWS is only responsible for the associated O&M costs.
- Grant funds for 75 percent of required capital, with the balance treated as if revenue bond funded.
- Grant funds for 50 percent of required capital, with the balance treated as if revenue bond funded.
- State revolving fund loan at the most favorable available rates and terms applicable to the communities.
- If local MHI >75 percent of state MHI, standard terms, currently at 3.8 percent interest for non-rated entities. Additionally:
  - If local MHI = 70-75 percent of state MHI, 1 percent interest rate on loan.
  - If local MHI = 60-70 percent of state MHI, 0 percent interest rate on loan.

- If local MHI = 50-60 percent of state MHI, 0 percent interest and 15 percent forgiveness of principal.
- If local MHI less than 50 percent of state MHI, 0 percent interest and 35 percent forgiveness of principal.

- Terms of revenue bonds assumed to be 25-year term at 6.0 percent interest rate.

2.4.5.2 General Assumptions Embodied in Financial Plan Results

The basis used to project future financial performance for the financial plan model includes:

- No account growth (either positive or negative).
- No change in estimate of uncollectible revenues over time.
- Average consumption per account unchanged over time.
- No change in unaccounted for water as percentage of total (more efficient water use would lower total water requirements and costs).
- No inflation included in the analyses (although the model has provisions to add escalation of O&M costs, doing so would mix water rate impacts from inflation with the impacts from the alternatives being examined).
- Minimum working capital fund established for each district, based on specified months of O&M expenditures.
- O&M for alternatives begins 1 year after capital implementation.
- Balance of capital expenditures not funded from primary grant program is funded through debt (bond equivalent).
- Cash balance drives rate increases, unless provision chosen to override where current net cash flow is positive.

2.4.5.3 Interpretation of Financial Plan Results

Results from the financial plan model for each alternative are presented in Table 4.5 in Section 4 of this report. The model used six funding alternatives: paying cash up front (all revenue); 100 percent grant; 75 percent grant; 50 percent grant, State Revolving Fund; and obtaining a Loan/Bond. Table 4.5 shows the projected average annual water bill, the maximum percent of household income, and the percentage rate increase over current rates.

2.4.5.4 Potential Funding Sources

A number of potential funding sources exist for rural utilities. Both state and federal agencies offer grant and loan programs to assist rural communities in meeting their infrastructure needs.

Within Texas, the following state agencies offer financial assistance if needed:

- Texas Water Development Board,
- Office of Rural Community Affairs, and
- Texas Department of Health (Texas Small Towns Environment Program).

Small rural communities can also get assistance from the federal government. The primary agencies providing aid are:

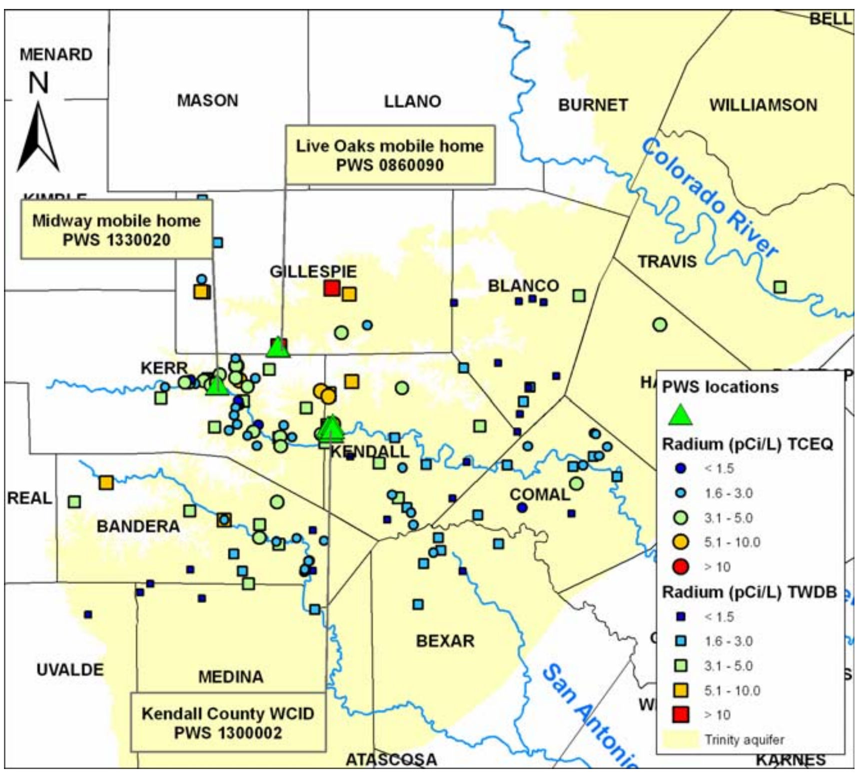
- United States Department of Agriculture, Rural Utilities Service, and
- United States Housing and Urban Development.

SECTION 3.
UNDERSTANDING SOURCES OF CONTAMINANTS

3.1 RADIUM, GROSS ALPHA, AND URANIUM IN THE SOUTHERN PART OF THE TRINITY AQUIFER

The Hill Country of Central Texas includes aquifers of Cretaceous age (mainly within the Trinity Group) but also of Paleozoic age (Hickory and Ellenburger - San Saba aquifers) as a result of the presence of the nearby Llano uplift whose southern confines crop out in northern Gillespie County (Bluntzer 1992). The PWS wells of concern are located in Gillespie, Kendall, and Kerr Counties and are completed in the southern part of the Trinity aquifer (south of the Colorado River). Most of the wells are designated as in the Trinity Group (aquifer code 218TRNT), and a few are designated specifically in the Hensell Sand and Cow Creek Limestone formations (218HNSL and 218HSCC) which are part of the middle Trinity aquifer. In general, radium concentrations in the southern part of the Trinity aquifer are low, and most samples are below the radium MCL of 5 pCi/L (Figure 3.1). Radium concentrations >5 pCi/L are found in the western part of the aquifer outcrop in Gillespie, Kendall, and Kerr Counties.

Figure 3.1 Radium Concentrations in Groundwater of Southern part of the Trinity Aquifer

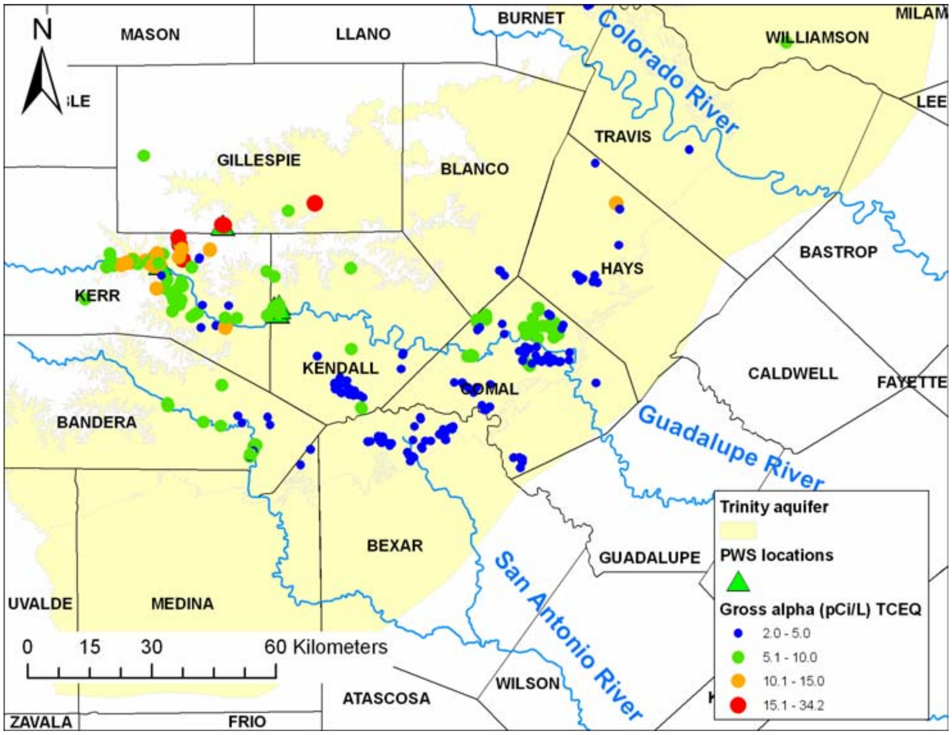


Data in Figure 3-1 are from the TWDB groundwater database (storet codes 09503 and 81366) and TCEQ public water supply database (contaminant ID 4020 and 4030). Figure 3.1 is based on the most recent values for wells from which both isotopes of radium were analyzed. The data include raw samples from wells and samples from entry points which are connected to a single well.

In this study the terms *radium* or *radium combined* are generally used to refer to radium-226 plus radium-228. Otherwise, radium-226 or radium-228 is specified. The values shown in Figure 3.1 generally represent the upper limit of the radium measurements because the detection limit was used for samples that are below the detection limit. Although TCEQ allows public water systems to subtract the reported error from the radium concentrations to assess compliance, the following analysis of general trends used the most recent radium concentration and did not subtract the reported error.

Gross alpha concentrations follow a trend similar to radium. Concentrations of gross alpha are generally <15 pCi/L throughout most of the aquifer. Concentrations >15 pCi/L are generally restricted to the western part of the aquifer in Gillespie and Kerr Counties (Figure 3.2). The MCL for uranium is 30 ppb, which is equivalent to 20 pCi/L (using a conservative factor of 0.67 pCi/micrograms (µg) for converting mass concentration to radiation concentration). Therefore a gross alpha level of 35 pCi/L in a well reflects a level from which the well fails to comply with either the MCL for gross alpha minus alpha radiation due to uranium, which is 15 pCi/L, or with the uranium MCL (neglecting the activity due to radon which is rarely measured in PWS wells). Gross alpha >5 pCi/L requires analysis of radium-226. Radium-228 testing must be done regardless of gross alpha results (TCEQ 2004b).

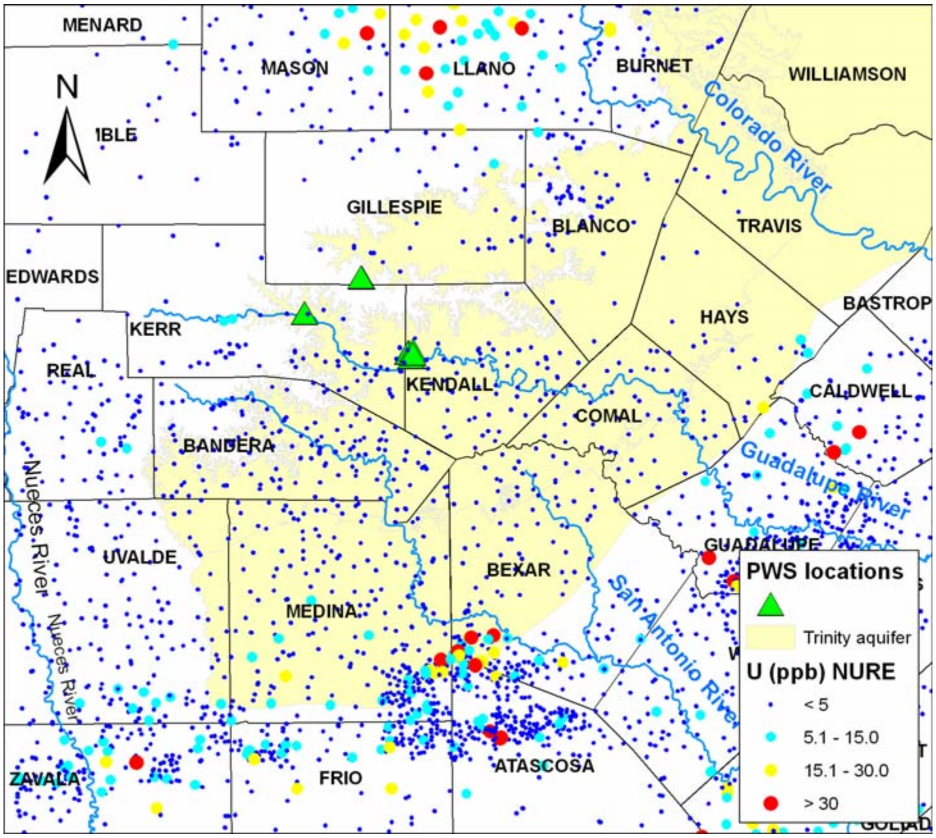
Figure 3.2 Gross Alpha in Groundwater in the Southern Part of the Trinity Aquifer



Data in Figure 3.2 are from the TCEQ public water supply database (contaminant id 4109). The most recent sample is shown for each well.

Data from the National Uranium Resource Evaluation (NURE) database were used to evaluate uranium concentrations in the study area (Figure 3.3). Uranium concentrations were below the MCL of 30 ppb and samples in the southern area of the Trinity aquifer were <5 ppb (the NURE database does not include aquifer information).

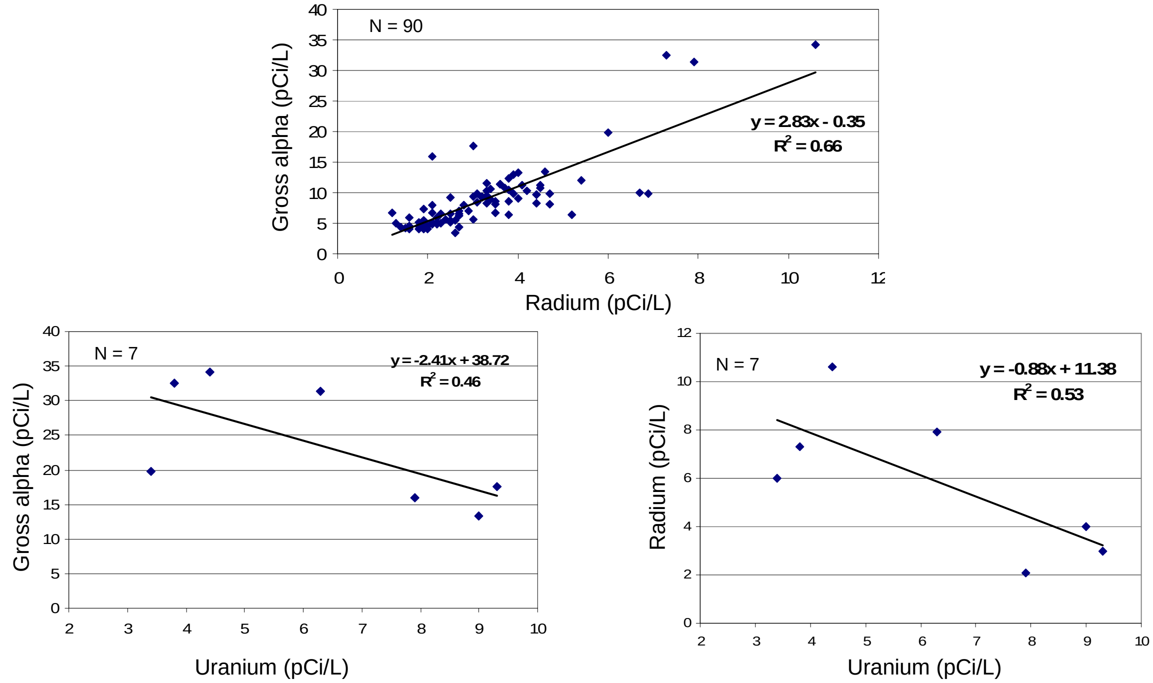
Figure 3.3 Uranium in Groundwater of the Southern Trinity Aquifer



A total of 11 wells in the Trinity aquifer (not shown in Figure 3.3) have uranium analyses and these show uranium concentrations <10 pCi/L (equivalent to 15 ppb).

The correlation between radium and gross alpha is strong (r^2=0.66) and positive, while correlations of gross alpha and radium with uranium are negative (Figure 3.4). Although the number of uranium analyses is small (only seven samples with radium and gross alpha), these trends suggest that gross alpha count is mostly from radium in the groundwater.

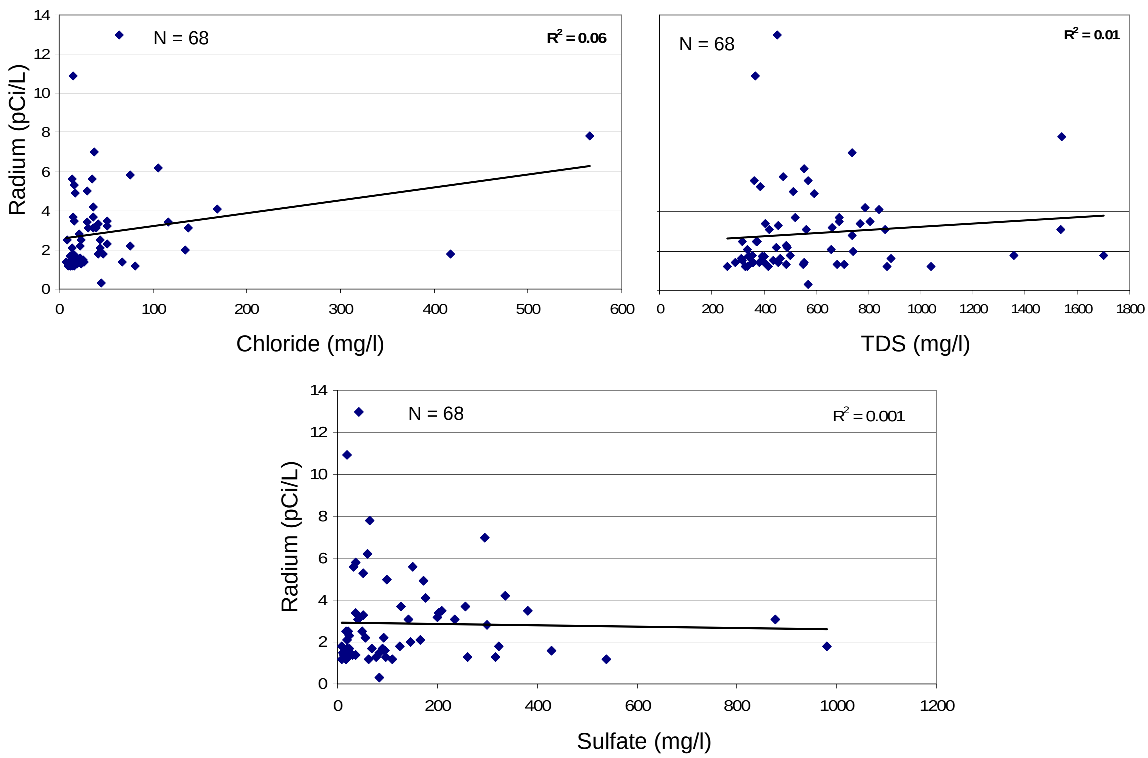
Figure 3.4 Relationships Between Radium, Gross Alpha, and Uranium in Groundwater in the Southern Part of the Trinity Aquifer



Data shown in Figure 3.4 are from the TCEQ public water supply database and include samples from entry points which are connected to a single well. For each well the most recent sample is used in the analysis (data include only samples where both parameters were analyzed on the same day). N represents the number of samples used in the analysis.

Correlations between gross alpha and radium concentrations and well depth in the southern part of the Trinity aquifer are weak (r^2 <0.1), and correlations with other general parameters such as chloride, TDS, and sulfate are also weak (Figure 3.5).

Figure 3.5 Relationships Between Radium Concentrations and Chloride, TDS, and Sulfate in the Southern Trinity Aquifer



Data in Figure 3.5 are from the TWDB groundwater database. Samples of radium, chloride, TDS, and sulfate were taken on the same day. N represents the number of samples in the analysis.

3.2 REGIONAL GEOLOGY

Subsurface deposits of Cretaceous age in Gillespie, Kendall, and Kerr Counties overlie a Paleozoic basement. The Precambrian Llano uplift with its ring of Paleozoic formations crops out in northern Gillespie County (Bluntzer 1992). Although Kerr and Kendall Counties have access to Paleozoic aquifers, this supply is tapped mostly by Gillespie County operators. Water resources in this three-county area are relatively well known (Anaya and Jones 2004; Mace, *et al.* 2000; Preston, *et al.* 1996; Bluntzer 1992; Ashworth 1983; Walker 1979; Reeves 1969; and Reeves 1967).

Cretaceous sediments were deposited on a mostly flat stable platform and transitions between different depositional facies and rock type (sand, shale, carbonate) are generally laterally smooth. Sandy units suggest proximity to the continent when the sediments were deposited while shaley units reflect a greater distance from the continent. The development of important carbonate accumulations imply periodic limited clastic input. The Cretaceous sediments consist of a basal conglomerate grading into sandy material (Hosston Sand) overlain by mostly calcareous rock (Sligo Member). This marks the beginning of a more shaley and calcareous series of sediments until the deposition of another continuous sand unit (Hensell Sand). The formation between the Hosston Sand and Hensell Sand is known as the Pearsall formation and is composed of a shaley member overlain by the Cow Creek Limestone Member. The previously described formations have been traditionally called the Travis Peak formation in Central Texas. The Travis Peak is overlain by the thick accumulation of the Glen Rose formation. Formations from the Hosston Sand to the Glen Rose Limestone make up the Trinity Group. The Paluxy Sand, prevalent farther north, do not exist in the three-county study area. The mostly calcareous accumulations of the Fredericksburg and Washita Groups (including the Comanche Peak, Edwards, and Buda Limestone) that top the Lower Cretaceous close the local stratigraphic column. Pertinent Paleozoic formations are the Hickory Member (mainly sand), first formation of Cambrian age covering the Precambrian basement, and the Ellenburger Group (mostly carbonate) of Ordovician age. The dip of Cretaceous layers is generally toward the south and less than 0.3 percent (15 feet per mile) but can be higher and over 1 percent, especially near the Balcones Fault zone, just south of Kendall County. Paleozoic layers, which dip away from the Llano Uplift located just north of Gillespie County, display a higher dip of 7 to 17 percent (400 to 900 feet per mile; Bluntzer 1992). Paleozoic layers are also compartmentalized by faults that became inactive before the deposition of Cretaceous sediments. Because the Llano Uplift has been a structural high since at least the beginning of the Cretaceous, some layers thin or pinch out when approaching the uplift (*e.g*., Hosston Sand; Bluntzer 1992, Figure 5).

Major water-bearing formations are the Hosston Sand (Lower Trinity aquifer), the Hensell Sand forming the Middle Trinity aquifer to which is added the Cow Creek Limestone. Some Glen Rose beds can also locally produce some poor quality water; they are then collectively called the Upper Trinity aquifer. The uppermost water-bearing formation is the Edwards limestone under water-table conditions, unlike the other aquifers which are mostly confined. The State of Texas recognizes the Trinity aquifer as a major aquifer while the Hickory and Ellenburger / San Saba aquifers (mainly in Gillespie County) are considered minor aquifers (Ashworth and Hopkins 1995). Hydraulic connection between Cretaceous and Paleozoic aquifers is common (Bluntzer 1992). For example, in Gillespie County, the Hensell Sand was directly deposited on top of the Hickory Member.

Thickness of the entire Hickory Member is up to ~500 feet (McBride, *et al.* 2002). Black (1988) states that lower portions of the Hickory aquifer are nearly stagnant and have minimal interaction with outcrop portions of the aquifer. In Gillespie County, depth to the top of Hickory aquifer is variable from shallow water-table conditions to more than 2,500 feet (Preston, *et al*. 1996, Figure 5). The Ellenburger / San Saba aquifer, composed of over 2,000 feet of sediments, is located ~700 - 1,000 feet above the Hickory aquifer and follows its structural vagaries. Depth to the Hensell Sand and the Hosston Sand is generally less than 600 feet and 1,000 feet, respectively (Mace, *et al.*. 2000, Figure 9). The average thickness of the Hosston Sand can reach more than 250 feet but it pinches out in Gillespie County. The thickness of the Hensell Sand ranges from 150 to 300 feet. The Cow Creek Limestone is no more than 100-feet thick and pinches out along with the Hosston Sand.

The Paleozoic aquifers yield small to large quantities of fresh (mostly in Gillespie County) to slightly saline water (Ashworth 1983; LBG-Guyton Associates 2003). The Trinity Group aquifers can produce mostly fresh water often with high hardness (Anaya and Jones 2004) at highly variable yields.

3.3 DETAILED ASSESSMENT FOR KENDALL COUNTY WCID PWS

There are eight wells in the Kendall County WCID PWS G1300002A to G1300002H. The wells are designated as within the lower and middle Trinity aquifer and have depths from 310 to 640 feet (Table 3.1). The wells of the PWS are connected with four entry points (EP): Wells A and B are connected with EP1, wells C and H are connected with EP2, wells D, E, and F are connected with EP3, and Well G is connected to EP4.

Radium levels in the Kendall PWS exceed the MCL of 5 pCi/L at EP3 and EP4 (Table 3.2). Samples taken at EP1 and EP2 are <5 pCi/L suggesting that wells connected to these entry points yield groundwater with lower radium. Similar results are seen for gross alpha sampled at the entry points: gross alpha sampled at EP3 and EP4 ranges from 10 to 17 pCi/L, while gross alpha values from EP1 and EP2 are between 5.4 to 6.6 pCi/L (Table 3.3). Uranium levels are below the MCL and are <1.33 pCi/L (Table 3.4).

Table 3.1 Well Depth and Screen Interval Depths for Wells in the Kendall County WCID PWS

Water source	Entry point	Depth (ft)	Screen depth (ft)	Aquifer
G1300002A	EP1	310	Annular cement to 173	Middle Trinity
G1300002B	EP1	640	Annular cement to 550	Unknown
G1300002C	EP2	415	220-415	Middle Trinity (Hensell sand and cow creek limestone)
G1300002D	EP3	350	Annular cement to 158	Middle Trinity
G1300002E	EP3	490	391-490	Lower Trinity
G1300002F	EP3	508	440-527	Lower Trinity
G1300002G	EP4	412	-	Middle Trinity
G1300002H	EP2	400	-	Middle Trinity

Table 3.2 Radium Concentrations in Kendall County WCID PWS

Date	Source	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Radium total (pCi/L)
1/24/2000	D	3.9	2.2	6.1
6/11/2002	EP1	1.1	3.1	4.2
6/11/2002	EP2	1.4	2	3.4
6/11/2002	EP3	3.8	2	5.8
6/11/2002	EP4	2.2	7.9	10.1
11/5/2003	EP4	2	6.9	8.9
2/23/2004	EP3	3.8	1.5	5.3
11/30/2004	EP4	1.4	5.5	6.9
1/5/2005	EP1	1.2	2.8	4

Table 3.3 Gross Alpha Concentrations in Kendall County WCID PWS

Date	Source	Gross alpha (pCi/L)
2/19/1997	D	2.1
1/24/2000	D	14.2
6/11/2002	EP3	17.6
6/11/2002	EP1	5.9
6/11/2002	EP2	5.4
6/11/2002	EP4	13.9
11/5/2003	EP4	11.8
2/23/2004	EP3	16.3
11/30/2004	EP4	9.9
1/5/2005	EP1	6.6

Table 3.4 Uranium Concentrations in Kendall County WCID PWS

Date	Source	Total Uranium (pCi/L)
2/23/2004	EP 3	<1.3
6/11/2002	EP 3	<1.3

The TCEQ and TWDB databases have a number of wells with radium <5 pCi/L in the vicinity of the Kendall County WCID PWS (Figure 3.6). South and west of the Kendall County WCID PWS there are a number of wells with radium < 5 pCi/L, while north of the PWS radium is >5 pCi/L. The wells with radium <5 pCi/L have depths from 225 to 450 feet (six out of nine wells have depths <360 feet) and they are categorized as being in the Hensell Sand, Glen Rose, and middle Trinity. The wells to the north with radium >5 pCi/L are somewhat deeper (375 to 490 feet, four out of five wells have depth >400 feet) and they are categorized as in the middle Trinity, Glen Rose, and Hosston formations (Table 3.5). These data suggest that the deeper wells screened in the lower formations of the Trinity aquifer have higher levels of radium.

Figure 3.6 Radium in the 5- and 10-km Buffers of the Kendall County WCID PWS Wells

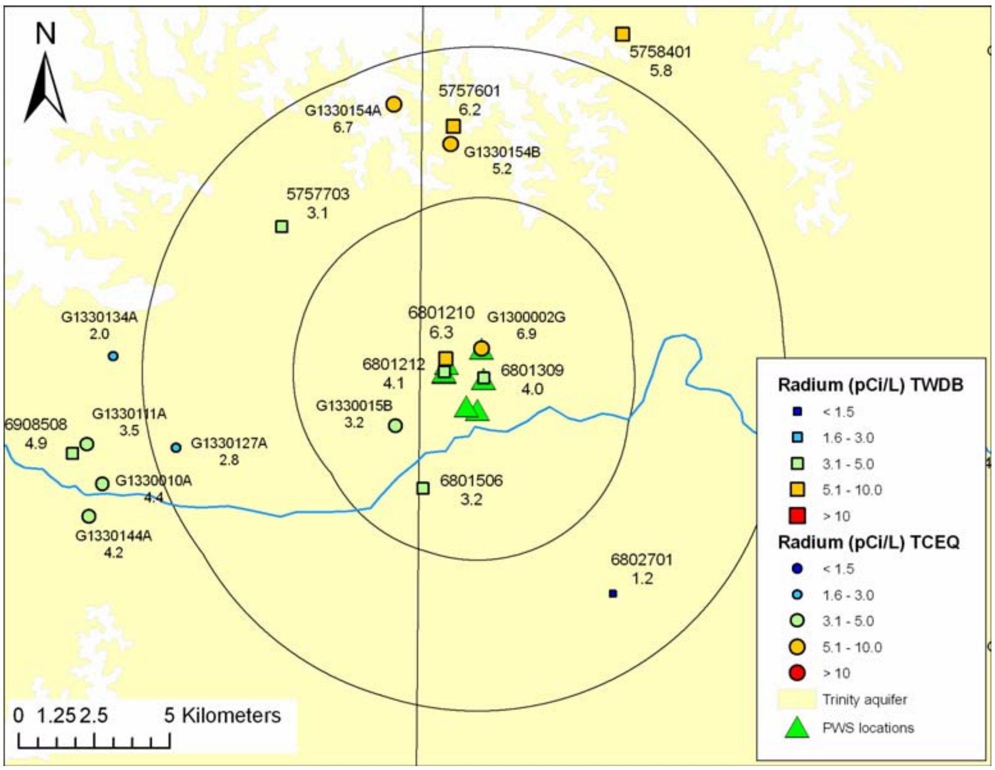


Table 3.5 Radium Concentration, Well Depth, and Designated Aquifer for Wells in the Vicinity of the Kendall County WCID PWS

Well	Depth (ft)	Aquifer	Radium (pCi/L)
6801212	350	Glen Rose (218GLRS)	4.1
6801309	415	Hensell sand and Cow Creek Limestone (218HSCC)	4.0
G1330015B	300	Middle Trinity (218TRNT)	3.2
6801506	320	Hensell Sand (218HNSL)	3.2
6802701	225	Upper Glen Rose (218GLRSU)	1.2
G1330127A	450	Middle Trinity (218TRNT)	2.8
5757703	360	Hensell Sand (218HNSL)	3.1

Well	Depth (ft)	Aquifer	Radium (pCi/L)
G1330010A	320	Hensell Sand (218HNSL)	4.4
G1330134A	415	Middle Trinity (218TRNT)	2.0
6801210	490	Hosston (217HSTN)	6.3
G1300002G	412	Middle Trinity (218TRNT)	6.9
G1330154B	400	Middle Trinity (218TRNT)	5.2
5757601	375	Glen Rose and Hensell Member (218GLRH)	6.2
G1330154A	460	Middle Trinity (218TRNT)	6.7

Potential Sources of Contamination are identified as part of TCEQ's Source Water Assessment Program. There are three waste sites (type 14 subtype 8) identified in the vicinity of the Kendall County WCID PWS. The nearest site is about 800 meters north of well G1300002. Given the distance of the sites from the wells of the PWS and the depths of the PWS wells, the identified sites are not expected to influence radium concentrations at the Kendall PWS.

3.3.1 Summary of Alternative Groundwater Sources for the Kendall County WCID PWS

Radium levels differ between the four entry points of the PWS: radium levels at EP1 and EP2 are <5 pCi/L while radium at EP3 and EP4 are >5 pCi/L. One alternative is to increase production from wells connected to entry points 1 and 2 and use the water to replace or dilute water from EP3 and EP4. The individual wells of the PWS should be sampled to determine whether specific wells have low radium.

There are a number of possible alternative groundwater sources that can be used to replace or dilute water from existing wells at the Kendall County WCID PWS (Figure 3.6 Table 3.5). Alternative sources are more likely to be found south of the PWS, where a number of wells have radium <5 pCi/L. These wells are generally shallower wells open to the upper formations of the Trinity aquifer, thus new sources will likely be shallower wells with depths <400 feet. Another alternative is to close the deeper sections of the Midway PWS wells and screen the existing wells at depths <400 feet, in the upper formations of the Trinity aquifer.

SECTION 4
ANALYSIS OF THE KENDALL COUNTY WCID PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1. Existing System

The Kendall County WCID PWS location is shown in Figure 4.1. Kendall County WCID PWS was created in 1946 and is governed by a 5-member board of directors. It is financed through property taxes and service fees. Kendall County WCID PWS provides water and sewer service to the community of Comfort, Texas. Most of the Kendall County WCID PWS wells are compliant for radium. Well 10, located on the north side I-10, across from the other wells and most of the existing distribution, has had radium concentrations greater than the MCL of 5 pCi/L. Kendall County WCID PWS currently has 930 connections, and at full build-out, 90 connections would be added to the area served by Well 10. The northern service area, which is served by Well 10, currently cannot be served by the other service area, which is supplied by radium compliant wells. The Well 10 service area currently only includes a convenience store and a fast food restaurant, but future development could expand the area to 90 connections.

The water sources for this PWS are seven wells, which are completed in the lower and middle Trinity aquifer. The wells range in depth from 310 to 640 feet in depth. The total tested production of the seven wells is 1.11 million gallons per day (mgd). Disinfection with gaseous chlorine is performed for each well or group of wells before water is pumped into ground storage tanks before prior to entering the distribution system. There is an elevated ground storage tank in the system that has a capacity of 0.15 million gallons.

Total radium has been detected in Well 10 between 6.9 pCi/L to 10.1 pCi/L, which exceeds the MCL of 5 pCi/L. Kendall County WCID PWS has not encountered any other water quality issues.

The treatment employed for disinfection is not appropriate or effective for removal of radium, so optimization is not expected to be effective for increasing removal of this contaminant. However, there is a potential opportunity for system optimization to reduce radium concentration. It may be possible to identify radium-producing strata through comparison of well logs or through sampling of water produced by various strata intercepted by the well screen.

Basic system information is as follows:

- Population served: current 2790, 270 at full build out for the Well 10 service area
- Connections: current 930, 90 at full build out for the Well 10 service area
- Average daily flow: 0.258 mgd current, 0.035 mgd at full build out for the Well 10 service area

- Total production capacity: 1.117 mgd current, and 0.054 mgd at full build out for the Well 10 service area

Raw water characteristics for the overall system:

- Typical total radium range for Well 10 only: 6.9 pCi/L to 10.1 pCi/L
- Typical total dissolved solids range: 766 to 1,163 mg/L
- Typical pH range: 7.1 to 8.1 s.u.
- Typical calcium range: 85.2 to 128 mg/L
- Typical magnesium range: 45.0 to 56.5 mg/L
- Typical sodium range: 91 to 216 mg/L
- Typical chloride range: 160 to 391 mg/L
- Typical bicarbonate (HCO_3) range: 337 to 392 mg/L
- Typical fluoride range: 1.4 to 2.3 mg/L
- Typical iron range: 0.05 to 0.47 mg/L
- Typical manganese range: 0.0018 to 0.0068 mg/L

Kendall County WCID PWS has investigated options for maintaining compliance. For example, they have researched the cost of boring under the river and connecting to a water system that is about 15 miles away. They are also exploring the possibility of using a nearby surface water source to supplement their wells. A preliminary engineering report for this project has been completed. This option would solve the radium issue, as well as provide flood control and improved water quality. However, this project will take a considerable amount of time to implement.

4.1.2 Capacity Assessment for the Kendall County WCID PWS

The project team conducted a capacity assessment of the Kendall County WCID PWS. The results of this evaluation are separated into four categories: general assessment of capacity, positive aspects of capacity, capacity deficiencies, and capacity concerns. The general assessment of capacity describes the overall impression of technical, managerial, and financial capability of the water system. The positive aspects of capacity describe those factors the system is doing well. These factors should provide opportunities for the system to build upon to improve capacity deficiencies. The capacity deficiencies noted are those aspects that are creating a particular problem for the system related to long-term sustainability. Primarily, these problems are related to the system's ability to meet current or future compliance, ensure proper revenue to pay the expenses of running the system, and to ensure the proper operation of the system. The last category is titled capacity concerns. These are items that in general are not causing significant problems for the system at this time. However, the system may want to address them before these issues have the opportunity to cause problems.

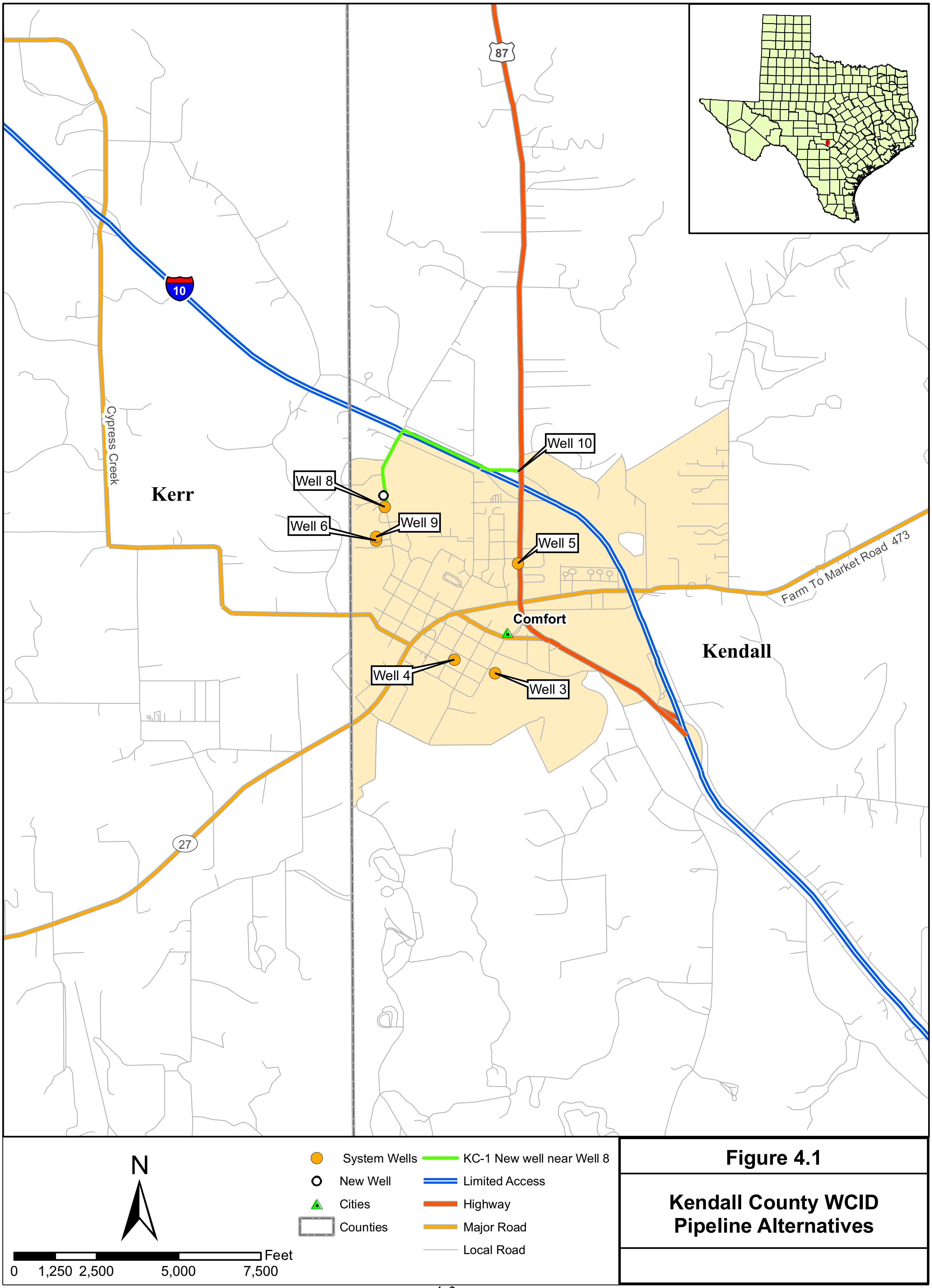


Figure 4.1

Kendall County WCID Pipeline Alternatives

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The following individuals were interviewed:

- Keith Marquart – General Manager
- Danny Morales – Operations Manager

4.1.2.1 General Structure

Kendall County WCID PWS was created in 1946 and provides water and sewer service. It is governed by a 5-member board of directors and is financed through property taxes and service fees. Capital projects are generally financed through revenue bonds. The water system has 840 connections and serves approximately 2,400 people. The system has seven wells. The operations staff consists of a general manager, operations manager, and 2 additional certified operators. Beginning in July 2006 the Kendall County WCID will operate a certified water and wastewater laboratory.

Only one of the 7 wells has high radium, and is the only well located on the north side of Interstate 10 (I-10). It currently serves a convenience store/gas station and a fast-food restaurant. However, if the pressure drops below a set-level in the other part of the distribution system, this well can also provide water to the areas on the south side of I-10. Future development is likely in the area that is served by this well, which makes it critical to address the radium issue.

4.1.2.2 General Assessment of Capacity

Based on the team's assessment, this system has a very good level of capacity. There are several positive managerial, financial and technical aspects of the water system.

4.1.2.3 Positive Aspects of Capacity

In assessing a system's overall capacity, it is important to look at all aspects – positive and negative. It is important for systems to understand those characteristics that are working well, so that those activities can be continued or strengthened. In addition, these positive aspects can assist the system in addressing the capacity deficiencies or concerns. The factors that were particularly important for Kendall County WCID PWS are listed below.

- **Knowledgeable and dedicated staff** - While the general manager is relatively new, to the PWS and is not currently certified, he has over 15 years experience in the water industry. The operations manager has been with the system for 23 years and is certified in both water and wastewater. The two operators have 10 and 8 years experience in water systems. The operations staff meets weekly to discuss all work activities. The water operators rotate being on-call, so the system is covered 24-hours per day. In addition, customers have access to the administrative office during business hours, or key staff via cell phones when the office is closed.

- **Financial Practices –** ***Budgets.*** The system maintains an annual budget for water and wastewater that is reviewed every fiscal year. The water system revenue and operating expenses are tracked separately, with the exception of payroll expenses. Payroll expenses are allocated to tax revenue.

- *Reserves***.** The Kendall County WCID PWS maintains a reserve account equal to 50 percent of the yearly operating expenses.
- ***Revenues.*** The Kendall County WCID PWS has also funded out of its revenues the addition of a water and wastewater laboratory that will increase revenues in the near future. In addition, it has a meter replacement program that will improve the accuracy of water meters and increase revenues.
- **Attention to Radium Compliance Problem –** The PWS has been aware of the radium issue for about the past 4 years and has issued public notices as required by TCEQ. Although they occasionally have an average that exceeds the standards of the radium regulation (based on quarterly sampling), they have actively investigated options for maintaining compliance. For example, they have researched the cost of boring under the river and connecting to a water system that is about 15 miles away. They are also exploring the possibility of using a nearby surface water source to supplement their wells. The Preliminary Engineering report for this project has been completed. This option would solve the radium issue, as well as provide flood control and improved water quality. However, this project will take a considerable amount of time to implement.
- **Preventative Maintenance Program –** The PWS has a preventative maintenance program that includes: daily well checks, flushing the lines, maintaining the chlorinators and pump motors, and inspecting/cleaning the storage tanks. There are also plans to loop some of the lines to reduce problems with rust. They also maintain an inventory of spare parts, and have a written O&M manual with operating procedures, which are referred to as needed.
- **Emergency Planning –** The system has an emergency plan and participates in county-wide drills. Flooding is a frequent problem in this area. In addition, the operations manager is also the fire chief.

4.1.2.4 Capacity Deficiencies

The following capacity deficiency was noted in conducting the assessment and could impact the ability of the water system to meet compliance with current and future regulations and to ensure long-term sustainability.

- **Lack of Written Long-Term Capital Improvements Plan –** While there appears to be some process in place to plan for future improvements, there is no formal written plan. The lack of a long-term written plan could negatively impact the system’s ability to develop a budget and associated rate structure that will provide for the system’s long term needs.

4.1.2.5 Potential Capacity Concerns

The following items were concerns regarding capacity but no specific operational, managerial, or financial problems can be attributed to these items at this time. The system should address the items listed below to further improve technical, managerial, and financial capabilities and to improve the system's long-term sustainability.

- **Lack of Written Job Descriptions –** While the current operators are very familiar with the system, the lack of written job descriptions could be a problem in hiring additional or replacement operators.
- **Emergency Equipment -** Although they have a good emergency planning program, they do not have emergency equipment such as generators. They indicated they would rely on storage facilities to provide water during a power outage.
- **Frequency of Rate Evaluation –** Kendall County WCID PWS has an approved rate structure and a high collection rate. Rates are approved and have been increased every 3 to 4-years. However, it does not appear they are evaluated on a regular basis to ensure that revenues are sufficient to cover the cost of service and future projects.

4.2 ALTERNATIVE WATER SOURCE DEVELOPMENT

4.2.1 Identification of Alternative Existing Public Water Supply Sources

Using data drawn from the TCEQ drinking water and TWDB groundwater well databases, the PWSs surrounding Kendall County WCID PWS were reviewed with regard to their reported drinking water quality and production capacity. PWSs that appeared to have water supplies with water quality issues were ruled out from evaluation as alternative sources, while those without identified water quality issues were investigated further Table 4.1 is a list of PWSs within approximately 10 miles of Kendall County WCID PWS.

Table 4.1 Public Water Systems within 10 Miles of Kendall County WCID PWS

System Name	Distance from Kendall County WCID PWS, miles	Comments/Other Issues
James Avery Craftsman Inc.	1	Small system. No radium data.
Hermann Sons Home	2	Small system. No radium data.
His Hill Ranch Camp	2	Small system. No radium data.
Nickerson Farm Water System	2	Small system. No WQ issues.
Pot O Gold Ranch Youth Camp	2	Small system. No radium data.
Westwood Park Subdivision	2	Small system. No WQ issues.

Table 4.1 Public Water Systems within 10 Miles of Kendall County WCID PWS

System Name	Distance from Kendall County WCID PWS, miles	Comments/Other Issues
Hermann Sons Youth Camp Hilltop	3	Small system. No radium data.
Mt Pisgah Water System	3	Small system. No radium data.
Heritage Park Water Service	5	Small system. No WQ issues.
Camp Capers	6	Small system. No radium data.
Park Place Subdivision Center Point	6	Small system. No WQ issues.
Camp Mira Sol	7	Small system. No radium data.
Oak Ridge Estates Water System	7	Small system. No WQ issues.
Center Point – Taylor System	8	Small system with WQ issues: nitrate and marginal for gross alpha.
Center Point ISD	8	Small system with WQ issues: nitrate.
Center Point North Water System	8	Small system. No WQ issues.
Center Point Wiedenfeld Water Works	8	Small system. No WQ issues.
Elmwood Mobile Home Park	8	Small system. No WQ issues.
Pecan Valley	8	Small system. No WQ issues.
Starlite Recovery Center	8	Small system. No radium data.
Verde Park Estates Wiedenfeld Water Works	8	Small system. No WQ issues.
Camp	8	Small system. No radium data.
Hill River Country Estates	9	Small system. No WQ issues.
TDH & PT Comfort Station I10	9	Small system. No radium data.
Ten West Ranches	9	Small system. No WQ issues.
Verde Hills WSC	9	Small system. No WQ issues.
Po Po Family Restaurant	10	Small system. No radium data.

Since Kendall County WCID PWS has six wells that are compliant for radium, no other PWSs are considered as possible alternate supplies.

4.2.1.1 Kendall County WCID PWS

The main Kendall County WCID PWS area is located south of I-10. The Kendall County WCID PWS also serves and area north of I-10, which currently includes only a convenience store and fast food restaurant. The north area is at a higher elevation than the south area, high enough so the south area cannot provide water to the north area. The north area is expected to see additional development to include 90 residential connections. There is currently one well, Well 10, that serves the north area.

The south area is served by six radium compliant wells that range in depth from 310 to 640 feet. These wells may not have sufficient capacity to serve the north area. There is potential for installing a new well in the south area that could serve the north area.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

Installation of a new well in the vicinity of the system intake point is likely to be an attractive option provided compliant water can be found, since the PWS is already familiar with operation of a water well.

In developing the cost estimates for new wells installed in areas where exiting wells are compliant, it is assumed the aquifer in these areas would produce the required amount of water with only one well. Site investigations and geological research, which are beyond the scope of this study, could indicate whether the aquifer at a particular site and depth would provide the amount of water needed or if more than one well would need to be drilled in separate areas.

4.2.2.2 Results of Groundwater Availability Modeling

The PWS is located in the southeast edge of the Edwards-Trinity Plateau aquifer that extends along central and west Texas. According to TCEQ records, the Kendall County WCID PWS groundwater supply is the Hensell Sand formation of the Edwards-Trinity Plateau aquifer. The 2002 Texas Water Plan indicates that the overall groundwater supply from this aquifer is likely to remain at nearly current levels over the next 50 years. The anticipated aquifer supply in the year 2050 is 220,374 acre-feet per year (AFY), representing a 3 percent decline relative to 2000 conditions.

In September 2004 the TWDB published results of the GAM for the Edwards-Trinity Plateau aquifer (Anaya and Jones 2004). The Kendall County WCID PWS is located within the Southeastern Edwards Plateau segment of the aquifer. Over this segment, groundwater pumping represents approximately 25 percent of the aquifer discharge. GAM data indicate that the rate of total withdrawal from the Edwards-Trinity Plateau aquifer in Kendall County would increase nearly 80 percent over the next decades, from an estimated 1,365 AFY in 2000, to 2,468 AFY by the year 2050. The Edwards-Trinity Plateau aquifer GAM was not run for the Kendall County WCID PWS. Potential groundwater usage by the system would be a small addition to the regional withdrawal, making potential changes in aquifer levels by the PWS beyond the spatial resolution of the regional GAM model.

The Kendall County WCID PWS overlays a second groundwater source, the outcrop of the Trinity aquifer present along the upper half of Kendall County; in some areas water-bearing rock formations are located below the Edwards-Trinity aquifer. The Trinity aquifer runs along central and north Texas, and its water supply is expected to moderately decrease over the next 50 years. The 2002 Texas Water Plan anticipates a supply of 150,317 acre-feet by the year 2050, a 4 percent decline in supply relative to value estimated for the year 2000. A GAM model for the Hill Country area of the Trinity aquifer was completed by the TWDB in September 2000. Long-term numerical simulation of future water levels for drought-of-record conditions indicated that water levels in the aquifer may decline up to 100 feet by 2050. The largest water level decline is anticipated in the Cibolo Creek area in northern Bexar, western Comal, and southern Kendall Counties. For west Kendall County, where Kendall County WCID PWS is located, the anticipated decline by the year 2050 is moderate, within the 10 to 25-foot range (Mace, *et al*. 2000).

An additional groundwater source, the downdip of the Hickory aquifer, extends through north and central Kendall County. Currently there is a minimum utilization of the Hickory aquifer by PWS in the Kendall County WCID PWS vicinity. The 2002 Texas Water Plan indicates that water supply from this aquifer, considered minor on the basis of potential water production, will steadily decline over several decades from 50,699 AFY in 2000 to 46,133 AFY in 2050.

4.2.3 Potential for New Surface Water Sources

There is a minimum potential for development of new surface water sources for the system as indicated by limited water availability over the entire river basin, and within the site vicinity.

Kendall County WCID PWS is located in the upper reach of the Guadalupe Basin. Current surface water availability in the Guadalupe Basin is expected to decrease moderately as a result of the increased water demand. The Texas Water Development Board’s 2002 Water Plan anticipates a 5 percent reduction in surface water availability in the Guadalupe Basin over the next 50 years, from 275,650 AFY in 2000 to 262,173 AFY in 2050.

The vicinity of Kendall County WCID PWS has a minimum availability of surface water for new uses as indicated by the TCEQ’s availability maps for the Colorado Basin. In the site vicinity, and over the entire Kendall County, unappropriated flows for new uses are available less than 50 percent of the time. This supply is inadequate as the TCEQ requires 100 percent supply availability for a PWS, unless an off-stream storage reservoir is employed.

4.2.4 Options for Detailed Consideration

The initial review of alternative sources of water results in the following options for more-detailed consideration:

1. Kendall County WCID PWS. A new groundwater well would be completed in the vicinity of existing Well 8. A pipeline would be constructed and the water would be piped to the storage tank at the Well 10 site (Alternative KC-1).

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of the Well 10 water is identified as a potential option. Ion exchange, WRT Z-88, and $KMnO_4$ treatment could all be potentially applicable. The central IX treatment alternative is KC-2, the central WRT Z-88 treatment alternative is KC-3, and the central $KMnO_4$ treatment alternative is KC-4.

4.3.2 Point-of-Use Systems

POU treatment using resin-based adsorption technology or RO is valid for total radium removal. The POU treatment alternative is KC-5.

4.3.3 Point-of-Entry Systems

POE treatment using resin based adsorption technology or RO is valid for radium removal. The POE treatment alternative is KC-6.

4.4 BOTTLED WATER

Since the area that would be supplied by Well 10 has not been developed, and provision compliant water would be necessary prior to development, an interim solution such as bottled water is not considered.

4.5 ALTERNATIVE DEVELOPMENT AND ANALYSIS

A number of potential alternatives for compliance with the MCL for total radium have been identified. Each of the potential alternatives is described in the following subsections. It should be noted that the cost information given is the capital cost and change in O&M costs associated with implementing the particular alternative. Appendix C contains cost estimates for the compliance alternatives. These compliance alternatives represent a range of possibilities, and a number of them are likely not feasible. However, all have been presented to provide a complete picture of the range of alternatives considered. It is anticipated that a PWS will be able to use the information contained herein to select the most attractive alternative(s) for more detailed evaluation and possible subsequent implementation.

4.5.1 Alternative KC-1: New Well Near Well 8

This alternative involves completing a new well in the vicinity of existing Well 8, and constructing a pump station and pipeline to transfer the pumped groundwater to the storage tank at the Well 10 site. Based on the water quality data for Well 8, it is expected that groundwater from this well would be compliant with drinking water MCLs.

This alternative would require completing a new 350-foot well and storage tank at the near Well 8, and constructing a pipeline from that well to the existing storage tank at Well 10. A pump station would also be required to overcome pipe friction and the elevation differences between Well 8 and Well 10. The required pipeline would be constructed of 4-inch pipe and would follow North Creek Road north and I-10 east to the Well 10 site. Using this route, the pipeline required would be approximately 1.2 miles in length.

The pump station would include two pumps, including one standby, and would be housed in a building. It is assumed the pumps and piping would be installed with capacity to meet all water demand for the northern service areas even if blending is planned, since the incremental cost would be relatively small, and it would provide operational flexibility.

This alternative does not have the potential to provide a regional solution.

The estimated capital cost for this alternative includes completing the new well, and constructing the pipeline and pump station. The estimated O&M cost for this alternative includes the maintenance cost for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $437,169, and the alternative's estimated annual O&M cost is $16,300. If the water was used for blending rather than for the full water supply, the annual O&M cost for this alternative could be reduced because of reduced pumping costs and reduced water purchase costs. However, additional costs would be incurred for equipment to ensure proper blending, and additional monitoring to ensure the finished water is compliant.

The reliability of adequate amounts of compliant water under this alternative should be good. From the perspective of the Kendall County WCID PWS, this alternative would be characterized as easy to operate and repair, since O&M and repair of pipelines and pump stations is well understood, and Kendall County WCID PWS personnel currently operate pipelines and a pump station. If the decision were made to perform blending, then the operational complexity would increase.

Implementation of this alternative would not be contingent on reaching agreement with outside water systems.

4.5.2 Alternative KC-2: Central IX Treatment

The system would continue to pump water from Well No. 10, and would treat the water through an IX system prior to distribution. For this option, the entire flow of the raw water will be treated to obtain compliant water as the radium concentration is relatively high. Water in excess of that currently produced would be required for backwashing and regeneration of the resin beds.

The IX treatment plant, located at the fenced Kendall County WCID PWS Well 10 site, features a 400 square foot (ft^2) building with a paved driveway; the pre-constructed IX equipment on a skid, a 24"x50" commercial brine drum with regeneration equipment, two transfer pumps, a 5,000-gallon tank for storing the treated water, a 2,000-gallon tank for storing spent backwash water, and a 2,000 gallon tank for storing regenerant waste. The spent backwash water would be discharged to the sewer at a controlled rate. The regenerant waste would be trucked off-site for disposal. The treated water would be chlorinated and stored in the existing storage tank prior to being pumped into the distribution system.

The estimated capital cost for this alternative is $303,920, and the estimated annual O&M cost is $25,417.

Reliability of supply of adequate amounts of compliant water under this alternative is good, since IX treatment is a common and well-understood treatment technology. IX treatment does not require high pressure, but can be affected by interfering constituents in the water. The O&M efforts required for the central IX treatment plant may be significant, and operating personnel would require training with ion exchange.

4.5.3 Alternative KC-3: Central WRT Z-88 Treatment

The system would continue to pump water from the existing Well 10, and would treat the water through the Z-88 adsorption system prior to distribution. The full flow of raw water would be treated by the Z-88 system as the media specifically adsorb radium and do not affect other constituents. There is no liquid waste generated in this process. The Z-88 media would be replaced and disposed of by WRT in an approved low-level radioactive waste landfill after 1-2 years of operation.

This alternative consists of constructing the Z-88™ treatment system at the existing, fenced Well 10 site. WRT owns the Z-88™ equipment and the District pays for the installation of the system and auxiliary facilities and an initial setup fee of $58,000 (to WRT). The plant comprises a 400 ft^2 building with a paved driveway; the pre-constructed Z-88 adsorption system (2- 32” diameter x 115” tall vessels) owned by WRT; and piping system. The treated water will be chlorinated prior to distribution. It is assumed the well pump has adequate pressure to pump the water through the Z-88 system and to the existing storage tank without requiring new pumps.

The estimated capital cost for this alternative is $286,230, and the estimated annual O&M cost is $22,292.

Based on many pilot testing results and some full-scale plant data this technology appears to be reliable. It is very simple to operate and the media replacement and disposal would be handled by WRT. Because WRT owns the equipment the capital cost is relatively low. The main operating cost is the treated water fee charged by WRT. One concern with this technology is the potential health effect of the level of radioactivity accumulated in the Z-88™ vessel on O&M personnel when the media have been operating for a long time.

4.5.4 Alternative KC-4: Central $KMnO_4$ Treatment

The system would continue to pump water from Well 10, and would treat the water through a greensand filter system prior to distribution. For this option, the entire flow of the raw water will be treated and the flow will be decreased when one of the two 50 percent filters is being backwashed by raw water. It is assumed the existing well pump has adequate pressure to pump the water through the greensand filters and into the existing storage tank.

The greensand plant, located at the Well 10 site, features a 400 ft^2 building with a paved driveway; the pre-constructed filters and a $KMnO_4$ solution tank on a skid; a 3,000 gallon spent backwash tank, and piping systems. The spent backwash water will be discharged to the sewer at a controlled rate.

The estimated capital cost for this alternative is $318,130, and the estimated annual O&M cost is $24,922.

Reliability of supply of adequate amounts of compliant water under this alternative is good, since $KMnO_4$-greensand is an established treatment technology for radium removal. The O&M efforts required is moderate and the operating personnel needs to ensure that $KMnO_4$ is not overfed. The spent backwash water contains MnO_2 particles with sorbed radium and the level of radioactivity in the backwash is relatively low.

4.5.5 Alternative KC-5: Point-of-Use Treatment

This alternative consists of the continued operation of the Well 10, plus treatment of water to be used for drinking or food preparation at the point of use to remove radium. The purchase, installation, and maintenance of POU treatment systems to be installed "under the sink" would be necessary for this alternative. Blending is not an option in this case.

This alternative would require installing the POU treatment units in residences and other buildings that provide drinking or cooking water. Kendall County WCID PWS staff would be responsible for purchase and maintenance of the treatment units, including media or membrane and filter replacement, periodic sampling, and necessary repairs. In houses, the most convenient point for installation of the treatment units is typically under the kitchen sink, with a separate tap installed for dispensing treated water. Installation of the treatment units in kitchens will require the entry of Kendall County WCID PWS or contract personnel into the houses of customers. As a result, cooperation of customers would be important for success implementing this alternative. The treatment units could be installed so they could be accessed without house entry, but that would complicate the installation and increase costs.

For the cost estimate, it is assumed the POU radium treatment would involve RO. RO treatment processes typically produce a reject water stream that requires disposal. The reject stream results in an increase in the overall volume of water used. POU systems have the advantage of using only a minimum volume of treated water for human consumption. This minimizes the size of the treatment units, the increase in water required, and the waste for disposal. For this alternative, it is assumed the increase in water consumption is insignificant in terms of supply cost, and that the reject waste stream could be discharged to the house septic or sewer system.

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes the cost to purchase and install the POU treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $59,400, and the estimated annual O&M cost for this alternative is $57,150. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the 90 connections that will be in the northern part of Kendall County WCID PWS at full-build-out. It should be noted that POU treatment units would need to be more complex than units typically found in commercial retail outlets to meet regulatory requirements, making purchase and installation more expensive.

The reliability of adequate amounts of compliant water under this alternative is fair, since it relies on the active cooperation of the customers for system installation, use, and maintenance, and only provides compliant water to single tap within a house. Additionally, the O&M efforts required for the POU systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Kendall County WCID PWS, this alternative would be characterized as more difficult to operate owing to the in-home requirements and the large number of individual units.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.6 Alternative KC-6: Point-of-Entry Treatment

This alternative consists of the continued operation of Well 10, plus treatment of water as it enters residences to remove radium. The purchase, installation, and maintenance of the treatment systems at the point of entry to a household would be necessary for this alternative. Blending is not an option in this case.

This alternative would require the installation of the POE treatment units at houses and other buildings that provide drinking or cooking water. Kendall County WCID PWS would be responsible for purchasing and maintaining the treatment units, including media or membrane and filter replacement, periodic sampling, and necessary repairs. It may also be desirable to modify piping so water for non-consumptive uses can be withdrawn upstream of the treatment unit. The POE treatment units would be installed outside the residences, so entry would not be necessary for O&M. Some cooperation from customers would be necessary for installation and maintenance of the treatment systems.

For the cost estimate, it is assumed the POE radium treatment would involve RO. RO treatment processes typically produce a reject water stream that requires disposal. The waste streams result in an increased overall volume of water used. POE systems treat a greater volume of water than POU systems. For this alternative, it is assumed the increase in water consumption is insignificant in terms of supply cost, and that the reject waste stream could be discharged to the house septic or sewer system.

This alternative does not present options for a shared solution.

The estimated capital cost for this alternative includes cost to purchase and install the POE treatment systems. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media or membranes, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $1,039,500, and the estimated annual O&M cost for this alternative is $126,900. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the 90 connections that will be in the northern part of Kendall County WCID PWS at full-build-out.

The reliability of adequate amounts of compliant water under this alternative are fair, but better than POU systems since it relies less on the active cooperation of the customers for system installation, use, and maintenance, and compliant water is supplied to all taps within a house. Additionally, the O&M efforts required for the POE systems will be significant, and the current personnel are inexperienced in this type of work. From the perspective of the Kendall County WCID PWS, this alternative would be characterized as more difficult to operate owing to the on-property requirements and the large number of individual units.

The feasibility of this alternative is not dependent on the cooperation, willingness, or capability of other water supply entities.

4.5.19 Summary of Alternatives

Table 4.2 provides a summary of the key features of each alternative for Kendall County WCID PWS.

1 **Table 4.2 Summary of Compliance Alternatives for Kendall County WCID PWS**

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost	Reliability	System Impact	Remarks
KC-1	New well near Well 8	- New well - Pump station - 1.2-mile pipeline	$ 437,169	$ 16,300	$ 54,414	Good	N	No opportunity to share costs with other PWSs.
KC-2	Continue operation of Well 10 with central IX treatment	- Central IX treatment plant	$ 303,920	$ 25,417	$ 51,914	Good	T	No opportunity to share costs with other PWSs.
KC-3	Continue operation of Well 10 with central WRT Z-88 treatment	- Central WRT Z-88 treatment plant	$ 286,230	$ 22,292	$ 47,247	Good	T	No opportunity to share costs with other PWSs.
KC-4	Continue operation of Well 10 with central $KMnO_4$ treatment	- Central $KMnO_4$ treatment plant	$ 318,130	$ 24,922	$ 52,658	Good	T	No opportunity to share costs with other PWSs.
KC-5	Continue operation of Well 10, and POU treatment	- POU treatment units.	$ 59,400	$ 57,150	$ 62,329	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
KC-6	Continue operation of Well 10, and POE treatment	- POE treatment units.	$ 1,039,500	$ 126,900	$ 217,528	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.

2
3 *Notes:* *N – No significant increase required in technical or management capability*
4 *T – Implementation of alternative will require increase in technical capability*
5 *M – Implementation of alternative will require increase in management capability*
6 *1 – See cost breakdown in Appendix C*
7 *2 – 20-year return period and 6 percent interest*

4.6 COST OF SERVICE AND FUNDING ANALYSIS

To evaluate the financial impact of implementing the compliance alternatives, a 30-year financial planning model was developed. This model can be found in Appendix D. The financial model is based on estimated cash flows, with and without implementation of the compliance alternatives. Data for such models are typically derived from established budgets, audited financial reports, published water tariffs, and consumption data. Information that was available to complete the financial analysis included consolidated 2005 revenues and expenses for the water and sewer districts and current water rates for the Kendall County Water Control & Improvement District (WCID). Kendall County WCID customers use on average 306 gallons per day (gpd) per connection.

This analysis will need to be performed in a more detailed fashion and applied to alternatives that are deemed attractive and worthy of more detailed evaluation. A more detailed analysis should include additional factors such as:

- Cost escalation,
- Price elasticity effects where increased rates may result in lower water consumption,
- Costs for other system upgrades and rehabilitation needed to maintain compliant operation.

4.6.1 Financial Plan Development

Total revenues reported by Kendall County WCID were $719,447. Water sales accounted for 30.4 percent of the total revenues generated, or $219,020. The water base rate is $8.00 per month for single family dwellings and $10.00 per month for all others.

The basic monthly water charge includes an allowance of 2,000 gallons of water. Kendall County WCID employs a tiered water usage rate structure of $1.95 per 1,000 gallons from 2001 to 10,000 gallons, $2.25 per 1,000 gallons from 10,001 up to 50,000 gallons, $2.85 per 1,000 gallons from 50,001 to 100,000 gallons, and $3.25 per 1,000 gallons thereafter. These values were entered into the financial model.

Total Expenses reported by Kendall County WCID were $711,550, and are detailed in Table 4.4. Actual Operating Expenses were $461,771; the difference between the two being $249,779 in principal and interest payments towards debt service.

Table 4.3 Summary of Kendall County Water Control & Improvement District 2005 Revenues and Expenses

Kendall County Water Control & Improvement District	
INCOME	$ 719,447
EXPENSES	
Water Service	$ 51,324
Sewer Service	$ 64,979
Salaries, Benefits, Taxes	$ 278,914
Professional Fees	$ 4,890
Contracted Services	$ 5,859
Administrative	$ 16,807
Other Operating	$ 13,061
Capital Outlay	$ 25,937
Debt Service	$ 249,779
Total Expenses	$ 711,550

4.6.2 Current Financial Condition

4.6.2.1 Cash Flow Needs

Using the base rate and water usage rates as noted above, the current average annual water bill for Kendall County WCID customers is estimated at $288, or about 1.0 percent of the Webb County MHI of $28,100, and 1.1 percent of the MHI ($25,893) of the ZIP code area for Kendall service area.

Kendall County WCID's 2005 Annual Financial Report reveals that the consolidated revenues are greater than the consolidated expenses. The long-term financial plan indicates that Kendall has a cash reserve of $401,272, which is sufficient to maintain operations for 6 months. However, Kendall County WCID will need to raise rates in the future to pay for any capital improvements for the various alternatives that may be implemented to address the compliance issue of radium in Well #10.

4.6.2.2 Ratio Analysis

Current Ratio= 3.58

The Current Ratio is a measure of liquidity. A Current Ratio of 3.58 indicates that the Kendall Water Control & Improvement District would be able to meet all of its current obligations, with total current assets of $556,430 exceeding total current liabilities of $155,158.

Debt to Net Worth Ratio=1.17

A Debt to Net Worth ratio is another measure of financial liquidity and stability. Kendall has a Net Worth of $2,094,363 and Total Debt amounting to $2,440,567 resulting in a Debt to Net Worth ratio of 1.17. Ratios less than 1.25 are indicative of financial stability, with lower ratios indicating greater financial stability and better credit risks for future borrowings. Based on the present ratio, Kendall may be approaching its long term borrowing limit.

Operating Ratio = 1.06

In 2005 Kendall RWSC had operating revenues of $719,447 and operating expenses of $711,550 resulting in an Operating Ratio equal to 1.01. Thus, for fiscal year 2005 the actual operating revenues were sufficient enough to cover the operating expenses resulting in a positive cash flow of just under $8,000. Kendall may be required to raise its rates some time in the future in order to meet its operating expenses.

4.6.3 Financial Plan Results

Each of the compliance alternatives for the Kendall County WCID was evaluated using the financial model to determine the overall increase in water rates that would be necessary to pay for the improvements. Each alternative was examined under the various funding options described in Subsection 2.4.

For State Revolving Fund (SRF) funding options, customer MHI compared to the state average determines the availability of subsidized loans. According to 2000 U.S. Census data, the Block group MHI for customers of Kendall County WCID was $27,621, which is 69 percent of the statewide income average of $39,927. Consequently, Kendall County WCID may qualify for a loan at an interest rate of 0 percent from the SRF.

The financial model results are summarized in Table 4.4. Since expenses for water and sewer services were aggregated in the financial report, Table 4.4 and Figure 4.2 are based on aggregate revenue and expenses for water and sewer service. Table 4.4 presents rate impacts assuming that any deficiencies in reserve accounts are funded immediately in the year following the occurrence of the deficiency, which would cause the first few years' water rates to be higher than they would be if the reserve account was built-up over a longer period of time. Figure 4.2 shows that the current estimated average annual water bill ($264) for Kendall County WCID customers is just sufficient to fully fund existing operations. The average customer water use is 9,180 gallons/month. Figure 4.2 provides a bar chart that shows the following:

- Current annual average bill,
- Projected annual average bill including rate increase, if needed, to match existing expenditures, and
- Projected annual bill including rate increases needed to fund implementation of a compliance alternative (this does not include funding for reserve accounts).

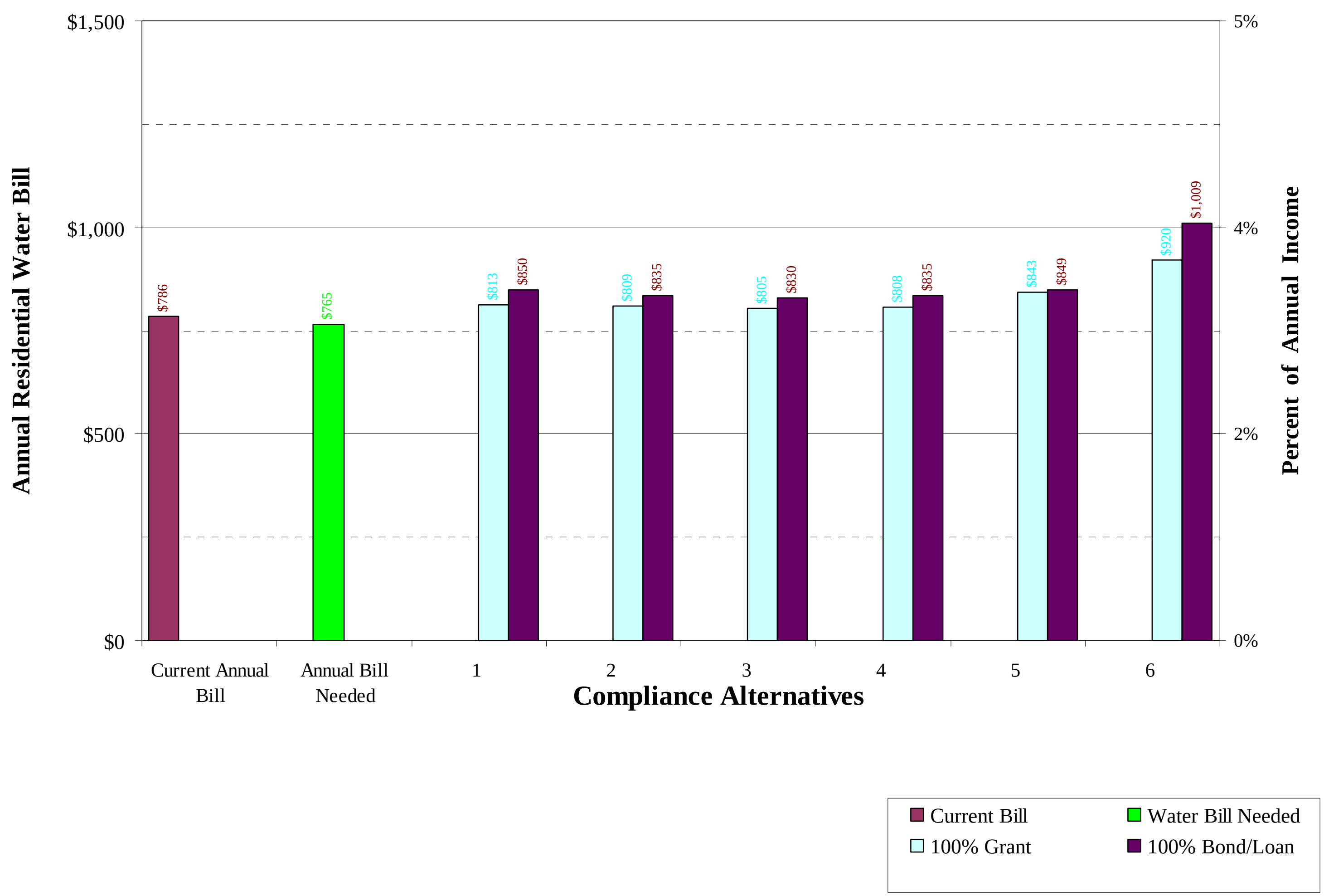
The two bars shown for each compliance alternative represent the rate changes necessary for revenues to match total expenditures assuming 100 percent grant funding and 100 percent loan/bond funding. Most funding options will fall between 100 percent grant and 100 percent loan/bond funding, with the exception of 100 percent revenue financing. Establishing or increasing reserve accounts would require an increase in rates. If existing reserves are insufficient to fund a compliance alternative, rates would need to be raised before implementing the compliance alternative. This would allow for accumulation of sufficient reserves to avoid larger but temporary rate increases during the years the compliance alternative was being implemented.

Table 4.4 Financial Impact on Households

Alternative	Description		All Revenue	100% Grant	75% Grant	50% Grant	SRF	Bond
1	New well near Well 8	Max % of HH Income	10%	8%	8%	8%	8%	8%
		Max % Rate Increase Compared to Current	241%	180%	182%	185%	186%	190%
		Average Water Bill Required by Alternative	$ 2,537	$ 2,088	$ 2,105	$ 2,122	$ 2,132	$ 2,157
2	Central Treatment - IX	Max % of HH Income	9%	8%	8%	8%	8%	8%
		Max % Rate Increase Compared to Current	219%	176%	178%	179%	180%	183%
		Average Water Bill Required by Alternative	$ 2,372	$ 2,060	$ 2,072	$ 2,084	$ 2,090	$ 2,108
3	Central Treatment - WRT Z-88	Max % of HH Income	9%	8%	8%	8%	8%	8%
		Max % Rate Increase Compared to Current	216%	176%	177%	179%	180%	182%
		Average Water Bill Required by Alternative	$ 2,350	$ 2,056	$ 2,067	$ 2,079	$ 2,085	$ 2,101
4	Central Treatment - KMnO4	Max % of HH Income	9%	8%	8%	8%	8%	8%
		Max % Rate Increase Compared to Current	220%	176%	178%	180%	180%	183%
		Average Water Bill Required by Alternative	$ 2,386	$ 2,059	$ 2,072	$ 2,084	$ 2,091	$ 2,109
5	Point-of-Use Treatment	Max % of HH Income	8%	8%	8%	8%	8%	8%
		Max % Rate Increase Compared to Current	190%	181%	182%	182%	182%	183%
		Average Water Bill Required by Alternative	$ 2,157	$ 2,096	$ 2,099	$ 2,101	$ 2,102	$ 2,106
6	Point-of-Entry Treatment	Max % of HH Income	12%	8%	9%	9%	9%	9%
		Max % Rate Increase Compared to Current	338%	193%	199%	205%	208%	216%
		Average Water Bill Required by Alternative	$ 3,244	$ 2,182	$ 2,223	$ 2,264	$ 2,287	$ 2,346

1

Figure 4-2 Alternative Cost Summary



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APPENDIX A
PWS INTERVIEW FORM

CAPACITY DEVELOPMENT ASSESSMENT FORM

*Prepared By*___________________________________ *Date*____________________________

Section 1. Public Water System Information

1. PWS ID # [ ] 2. Water System Name [ ]

3. County [ ]

4. Owner [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

5. Admin [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

6. Operator [ ] Address [ ]
   Tele. [ ] E-mail [ ]
   Fax [ ] Message [ ]

7. Population Served [ ] 8. No. of Service Connections [ ]

9. Ownership Type [ ] 10. Metered (Yes or No) [ ]

11. Source Type [ ]

12. Total PWS Annual Water Used [ ]

13. Number of Water Quality Violations (Prior 36 months)

    Total Coliform [ ] Chemical/Radiological [ ]
    Monitoring (CCR, Public Notification, etc.) [ ] Treatment Technique, D/DBP [ ]

A. Basic Information

1. Name of Water System:

2. Name of Person Interviewed:

3. Position:

4. Number of years at job:

5. Number of years experience with drinking water systems:

6. Percent of time (day or week) on drinking water system activities, with current position (how much time is dedicated exclusively to the water system, not wastewater, solid waste or other activities):

7. Certified Water Operator (Yes or No):

    If Yes,
    7a. Certification Level (water):

    7b. How long have you been certified?

8. Describe your water system related duties on a typical day.

B. Organization and Structure

1. Describe the organizational structure of the Utility. Please provide an organizational chart. (Looking to find out the governance structure (who reports to whom), whether or not there is a utility board, if the water system answers to public works or city council, etc.)

2. If not already covered in Question 1, to whom do you report?

3. Do all of the positions have a written job description?

    3a. If yes, is it available to employees?

    3b. May we see a copy?

C. Personnel

1. What is the current staffing level (include all personnel who spend more than 10% of their time working on the water system)?

2. Are there any vacant positions? How long have the positions been vacant?

3. In your opinion, is the current staffing level adequate? If not adequate, what are the issues or staffing needs (how many and what positions)?

4. What is the rate of employee turnover for management and operators? What are the major issues involved in the turnover (e.g., operator pay, working conditions, hours)?

5. Is the system staffed 24 hours a day? How is this handled (on-site or on-call)? Is there an alarm system to call an operator if an emergency occurs after hours?

D. Communication

1. Does the utility have a mission statement? If yes, what is it?

2. Does the utility have water quality goals? What are they?

3. How are your work priorities set?

4. How are work tasks delegated to staff?

5. Does the utility have regular staff meetings? How often? Who attends?

6. Are there separate management meetings? If so, describe.

7. Do management personnel ever visit the treatment facility? If yes, how often?

8. Is there effective communication between utility management and state regulators (e.g., NMED)?

9. Describe communication between utility and customers.

E. Planning and Funding

1. Describe the rate structure for the utility.

2. Is there a written rate structure, such as a rate ordinance? May we see it?

    2a. What is the average rate for 6,000 gallons of water?

3. How often are the rates reviewed?

4. What process is used to set or revise the rates?

5. In general, how often are the new rates set?

6. Is there an operating budget for the water utility? Is it separate from other activities, such as wastewater, other utilities, or general city funds?

7. Who develops the budget, how is it developed and how often is a new budget created or the old budget updated?

8. How is the budget approved or adopted?

9. In the last 5 years, how many budget shortfalls have there been (i.e., didn't collect enough money to cover expenses)? What caused the shortfall (e.g., unpaid bills, an emergency repair, weather conditions)?

    9a. How are budget shortfalls handled?

10. In the last 5 years how many years have there been budget surpluses (i.e., collected revenues exceeded expenses?

    10a. How are budget surpluses handled (i.e., what is done with the money)?

11. Does the utility have a line-item in the budget for emergencies or some kind of emergency reserve account?

12. How do you plan and pay for short-term system needs?

13. How do you plan and pay for long- term system needs?

14. How are major water system capital improvements funded? Does the utility have a written capital improvements plan?

15. How is the facility planning for future growth (either new hook-ups or expansion into new areas)?

16. Does the utility have and maintain an annual financial report? Is it presented to policy makers?

17. Has an independent financial audit been conducted of the utility finances? If so, how often? When was the last one?

18. Will the system consider any type of regionalization with any other PWS, such as system interconnection, purchasing water, sharing operator, emergency water connection, sharing bookkeeper/billing or other?

F. Policies, Procedures, and Programs

1. Are there written operational procedures? Do the employees use them?

2. Who in the utility department has spending authorization? What is the process for obtaining needed equipment or supplies, including who approves expenditures?

3. Does the utility have a source water protection program? What are the major components of the program?

4. Are managers and operators familiar with current SDWA regulations?

5. How do the managers and operators hear about new or proposed regulations, such as arsenic, DBP, Groundwater Rule? Are there any new regulations that will be of particular concern to the utility?

6. What are the typical customer complaints that the utility receives?

7. Approximately how many complaints are there per month?

8. How are customer complaints handled? Are they recorded?

9. (If not specifically addressed in Question 7) If the complaint is of a water quality nature, how are these types of complaints handled?

10. Does the utility maintain an updated list of critical customers?

11. Is there a cross-connection control plan for the utility? Is it written? Who enforces the plan's requirements?

12. Does the utility have a written water conservation plan?

13. Has there been a water audit of the system? If yes, what were the results?

14. (If not specifically answered in 11 above) What is the estimated percentage for loss to leakage for the system?

15. Are you, or is the utility itself, a member of any trade organizations, such as AWWA or Rural Water Association? Are you an active member (i.e., attend regular meetings or participate in a leadership role)? Do you find this membership helpful? If yes, in what ways does it help you?

G. Operations and Maintenance

1. How is decision-making authority split between operations and management for the following items:

   a. Process Control

   b. Purchases of supplies or small equipment

   c. Compliance sampling/reporting

   d. Staff scheduling

2. Describe your utility's preventative maintenance program.

3. Do the operators have the ability to make changes or modify the preventative maintenance program?

4. How does management prioritize the repair or replacement of utility assets? Do the operators play a role in this prioritization process?

5. Does the utility keep an inventory of spare parts?

6. Where does staff have to go to buy supplies/minor equipment? How often?

   6a. How do you handle supplies that are critical, but not in close proximity (for example if chlorine is not available in the immediate area or if the components for a critical pump are not in the area)

7. Describe the system's disinfection process. Have you had any problems in the last few years with the disinfection system?

7a. Who has the ability to adjust the disinfection process?

8. How often is the disinfectant residual checked and where is it checked?

8a. Is there an official policy on checking residuals or is it up to the operators?

9. Does the utility have an O & M manual? Does the staff use it?

10. Are the operators trained on safety issues? How are they trained and how often?

11. Describe how on-going training is handled for operators and other staff. How do you hear about appropriate trainings? Who suggests the trainings – the managers or the operators? How often do operators, managers, or other staff go to training? Who are the typical trainers used and where are the trainings usually held?

12. In your opinion is the level of your on-going training adequate?

13. In your opinion is the level of on-going training for other staff members, particularly the operators, adequate?

14. Does the facility have mapping of the water utility components? Is it used on any routine basis by the operators or management? If so, how is it used? If not, what is the process used for locating utility components?

15. In the last sanitary survey, were any deficiencies noted? If yes, were they corrected?

16. How often are storage tanks inspected? Who does the inspection?

    16a. Have you experienced any problems with the storage tanks?

H. SDWA Compliance

1. Has the system had any violations (monitoring or MCL) in the past 3 years? If so, describe.

2. How were the violations handled?

3. Does the system properly publish public notifications when notified of a violation?

4. Is the system currently in violation of any SDWA or state regulatory requirements, including failure to pay fees, fines, or other administrative type requirements?

5. Does the utility prepare and distribute a Consumer Confidence Report (CCR)? Is it done every year? What type of response does the utility get to the CCR from customers?

I. Emergency Planning

1. Does the system have a written emergency plan to handle emergencies such as water outages, weather issues, loss of power, loss of major equipment, etc?

2. When was the last time the plan was updated?

3. Do all employees know where the plan is? Do they follow it?

4. Describe the last emergency the facility faced and how it was handled.

Attachment A

A. Technical Capacity Assessment Questions

1. Based on available information of water rights on record and water pumped has the system exceeded its water rights in the past year? YES ☐ NO ☐

   In any of the past 5 years? YES ☐ NO ☐ How many times? _____

2. Does the system have the proper level of certified operator? *(Use questions a – c to answer.)*
   YES ☐ NO ☐

   a. What is the Classification Level of the system by NMED? _____

   b. Does the system have one or more certified operator(s)? [20 NMAC 7.4.20]

   YES ☐ NO ☐

   c. If YES, provide the number of operators at each New Mexico Certification Level. [20 NMAC 7.4.12]

   _____NM Small System _____Class 2

   _____NM Small System Advanced _____Class 3

   _____Class 1 _____Class 4

3. Did the system correct any sanitary deficiency noted on the most recent sanitary survey within 6 months of receiving that information? [20 NMAC 7.20.504]

   YES ☐ NO ☐ No Deficiencies ☐

   What was the type of deficiency? *(Check all that are applicable.)*

   Source ☐ Storage ☐

   Treatment ☐ Distribution ☐

   Other _____

   From the system's perspective, were there any other deficiencies that were not noted on the sanitary survey? Please describe.

4. Will the system's current treatment process meet known future regulations?

   Radionuclides YES ☐ NO ☐ Doesn't Apply ☐

   Arsenic YES ☐ NO ☐ Doesn't Apply ☐

   Stage 1 Disinfectants and Disinfection By-Product (DBP)

   YES ☐ NO ☐ Doesn't Apply ☐

   Surface Water Treatment Rule YES ☐ NO ☐ Doesn't Apply ☐

5. Does the system have a current site plan/map? [20 NMAC 7.10.302 A.1.]

   YES ☐ NO ☐

6. Has the system had a water supply outage in the prior 24 months?

YES ☐ NO ☐

What were the causes of the outage(s)? *(Include number of outages for each cause.)*

Drought _____ Limited Supply _____

System Failure _____ Other _____

7. Has the system ever had a water audit or a leak evaluation?

YES ☐ NO ☐ Don't Know ☐

If YES, please complete the following table.

Type of Investigation	Date Done	Water Loss (%)	What approach or technology was used to complete the investigation?	Was any follow-up done? If so, describe

8. Have all drinking water projects received NMED review and approval? [20 NMAC 7.10.201]

YES ☐ NO ☐

If NO, what types of projects have not received NMED review and approval.

Source ☐ Storage ☐

Treatment ☐ Distribution ☐

Other ☐ _____

9. What are the typical customer complaints that the utility receives?

10. Approximately how many complaints are there per month? _____

11. How are customer complaints handled? Are they recorded?

12. What is the age and composition of the distribution system? ***(Collect this information from the Sanitary Survey)***

Pipe Material	Approximate Age	Percentage of the system	Comments
			Sanitary Survey Distribution System Records Attached

13. Are there any dead end lines in the system?
YES ☐ NO ☐

14. Does the system have a flushing program?
YES ☐ NO ☐
If YES, please describe.

15. Are there any pressure problems within the system?
YES ☐ NO ☐
If YES, please describe.

16. Does the system disinfect the finished water?
YES ☐ NO ☐
If yes, which disinfectant product is used? ______

Interviewer Comments on Technical Capacity:

B. Managerial Capacity Assessment Questions

17. Has the system completed a 5-year Infrastructure Capital Improvement Plan (ICIP) plan?
YES ☐ NO ☐
If YES, has the plan been submitted to Local Government Division?
YES ☐ NO ☐

18. Does the system have written operating procedures?
YES ☐ NO ☐

19. Does the system have written job descriptions for all staff?
YES ☐ NO ☐

20. Does the system have:

A preventative maintenance plan?
YES ☐ NO ☐
A source water protection plan?
YES ☐ NO ☐ N/A ☐
An emergency plan?
YES ☐ NO ☐
A cross-connection control program?
YES ☐ NO ☐
An emergency source?
YES ☐ NO ☐
System security measures?
YES ☐ NO ☐

21. Does the system report and maintain records in accordance with the drinking water regulations concerning:

Water quality violations
YES ☐ NO ☐

Public notification
YES ☐ NO ☐

Sampling exemptions
YES ☐ NO ☐

22. Please describe how the above records are maintained:

23. Describe the management structure for the water system, including board and operations staff. Please include examples of duties, if possible.

24. Please describe type and quantity of training or continuing education for staff identified above.

25. Describe last major project undertaken by the water system, including the following: project in detail, positive aspects, negative aspects, the way in which the project was funded, any necessary rate increases, the public response to the project, whether the project is complete or not, and any other pertinent information.

26. Does the system have any debt? YES ☐ NO ☐

If yes, is the system current with all debt payments?
YES ☐ NO ☐

If no, describe the applicable funding agency and the default.

27. Is the system currently contemplating or actively seeking funding for any project?
YES ☐ NO ☐

If yes, from which agency and how much?

Describe the project?

Is the system receiving assistance from any agency or organization in its efforts?

28. Will the system consider any type of regionalization with other PWS? *(Check YES if the system has already regionalized.)*

YES ☐ NO ☐

If YES, what type of regionalization has been implemented/considered/discussed? *(Check all that apply.)*

System interconnection ☐
Sharing operator ☐
Sharing bookkeeper ☐
Purchasing water ☐
Emergency water connection ☐
Other: _____

29. Does the system have any of the following? *(Check all that apply.)*

Water Conservation Policy/Ordinance ☐ Current Drought Plan ☐
Water Use Restrictions ☐ Water Supply Emergency Plan ☐

Interviewer Comments on Managerial Capacity:

C. Financial Capacity Assessment

30. Does the system have a budget?

YES ☐ NO ☐

If YES, what type of budget?

Operating Budget ☐

Capital Budget ☐

31. Have the system revenues covered expenses and debt service for the past 5 years?

YES ☐ NO ☐

If NO, how many years has the system had a shortfall? _____

32. Does the system have a written/adopted rate structure?

YES ☐ NO ☐

33. What was the date of the last rate increase? _____

34. Are rates reviewed annually?

YES ☐ NO ☐

IF YES, what was the date of the last review? _____

35. Did the rate review show that the rates covered the following expenses? *(Check all that apply.)*

Operation & Maintenance ☐

Infrastructure Repair & replacement ☐

Staffing ☐

Emergency/Reserve fund ☐

Debt payment ☐

36. Is the rate collection above 90% of the customers?

YES ☐ NO ☐

37. Is there a cut-off policy for customers who are in arrears with their bill or for illegal connections?

YES ☐ NO ☐

If yes, is this policy implemented?

38. What is the residential water rate for 6,000 gallons of usage in one month. _____

39. In the past 12 months, how many customers have had accounts frozen or dropped for non-payment? _____

[Convert to % of active connections

Less than 1% ☐ 1% - 3% ☐ 4% - 5% ☐ 6% - 10% ☐

11% - 20% ☐ 21% - 50% ☐ Greater than 50% ☐]

40. The following questions refer to the process of obtaining needed equipment and supplies.

a. Can the water system operator buy or obtain supplies or equipment when they are needed?

YES ☐ NO ☐

b. Is the process simple or burdensome to the employees?

c. Can supplies or equipment be obtained quickly during an emergency?

YES ☐ NO ☐

d. Has the water system operator ever experienced a situation in which he/she couldn't purchase the needed supplies?

YES ☐ NO ☐

e. Does the system maintain some type of spare parts inventory?

YES ☐ NO ☐

If yes, please describe.

41. Has the system ever had a financial audit?

YES ☐ NO ☐

If YES, what is the date of the most recent audit? ______

42. Has the system ever had its electricity or phone turned off due to non-payment? Please describe.

Interviewer Comments on Financial Assessment:

43. What do you think the system capabilities are now and what are the issues you feel your system will be facing in the future? In addition, are there any specific needs, such as types of training that you would like to see addressed by NMED or its contractors?

APPENDIX B
COST BASIS

This section presents the basis for unit costs used to develop the conceptual cost estimates for the compliance alternatives. Cost estimates are conceptual in nature (+50%/-30%), and are intended to make comparisons between compliance options and to provide a preliminary indication of possible rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation. Capital cost includes an allowance for engineering and construction management. It is assumed that adequate electrical power is available near the site. The cost estimates specifically do not include costs for the following:

- Obtaining land or easements.
- Surveying.
- Mobilization/demobilization for construction.
- Insurance and bonds

In general, unit costs are based on recent construction bids for similar work in the area; when possible, consultations with vendors or other suppliers; published construction and O&M cost data; and USEPA cost guidance. Unit costs used for the cost estimates are summarized in Table B.1.

Unit costs for pipeline components are based on 2006 RS Means Building Construction Cost Data. The number of borings and encasements and open cuts and encasements is estimated by counting the road, highway, railroad, stream, and river crossings for a conceptual routing of the pipeline. The number of air release valves is estimated by examining the land surface profile along the conceptual pipeline route. It is assumed gate valves and flush valves would be installed, on average, every 5,000 feet along the pipeline. Pipeline cost estimates are based on use of C-900 PVC pipe. Other pipe materials could be considered for more detailed development of attractive alternatives.

Pump station unit costs are based on experience with similar installations. The cost estimate for the pump stations include two pumps, station piping and valves, station electrical and instrumentation, minor site improvement, installation of a concrete pad, fence and building, and tools. Construction cost of a storage tank is based on 2006 RS Means Building Construction Cost Data.

Labor costs are estimated based on RS Means Building Construction Data specific to each region.

Electrical power cost is estimated to be $0.136 per kWH. The annual cost for power to a pump station is calculated based on the pumping head and volume, and includes 11,800 kWH for pump building heating, cooling, and lighting, as recommended in USEPA publication, *Standardized Costs for Water Supply Distribution Systems* (1992).

In addition to the cost of electricity, pump stations have other maintenance costs. These costs cover: materials for minor repairs to keep the pumps operating; purchase of a maintenance vehicle, fuel costs, and vehicle maintenance costs; utilities; office supplies, small tools and equipment; and miscellaneous materials such as safety, clothing, chemicals, and paint. The non-power O&M costs are estimated based on the USEPA publication, *Standardized Costs for Water Supply Distribution Systems* (1992), which provides cost curves for O&M components. Costs from the 1992 report are adjusted to 2006 dollars based on the ENR construction cost index.

Pipeline maintenance costs include routine cleaning and flushing, as well as minor repairs to lines. The unit rate for pipeline maintenance is calculated based on the USEPA technical report, *Innovative and Alternate Technology Assessment Manual MCD 53* (1978). Costs from the 1978 report are adjusted to 2006 dollars based on the ENR construction cost index.

Storage tank maintenance costs include cleaning and renewal of interior lining and exterior coating. Unit costs for storage tank O&M are based on USEPA publication *Standardized Costs for Water Supply Distribution Systems* (1992). Costs from the 1992 report are adjusted to 2006 dollars based on the ENR construction cost index.

The purchase price for POU water treatment units is based on vendor price lists for treatment units, plus installation. O&M costs for POU treatment units are also based on vendor price lists. It is assumed that a yearly water sample would be analyzed for the contaminant of concern.

The purchase price for POE water treatment units is based on vendor price lists for treatment units, plus an allowance for installation, including a concrete pad and shed, piping modifications, and electrical connection. O&M costs for POE treatment units are also based on vendor price lists. It is assumed that a yearly water sample would be analyzed for the contaminant of concern.

Central treatment plant costs, for both adsorption and coagulation/filtration, include pricing for buildings, utilities, and site work. Costs are based on pricing given in the various R.S. Means Construction Cost Data References, as well as prices obtained from similar work on other projects. Pricing for treatment equipment was obtained from vendors.

Well installation costs are based on quotations from drillers for installation of similar depth wells in the area. Well installation costs include drilling, a well pump, electrical and instrumentation installation, well finishing, piping, and water quality testing. O&M costs for water wells include power, materials, and labor. It is assumed that new wells located more than 1 mile from the intake point of an existing system would require at least one storage tank and pump station.

Purchase price for the treatment unit dispenser is based on vendor price lists, plus an allowance for installation at a centralized public location. The O&M costs are also based on vendor price lists. It is assumed that weekly water samples would be analyzed for the contaminant of concern.

Costs for bottled water delivery alternatives are based on consultation with vendors that deliver residential bottled water. The cost estimate includes an initial allowance for set-up of the program, and a yearly allowance for program administration.

The cost estimate for a public dispenser for trucked water includes the purchase price for a water truck and construction of a storage tank. Annual costs include labor for purchasing the water, picking up and delivering the water, truck maintenance, and water sampling and testing. It is assumed the water truck would be required to make one trip per dispenser each week, and that chlorine residual would be determined for each truck load.

Appendix references

USEPA 1978. Technical Report, *Innovative and Alternate Technology Assessment Manual* MCD 53.

USEPA. 1992. Standardized Costs for Water Supply Distribution Systems. EPA/600/R-92/009.

Table B.1
Summary of General Data
Kendall County WCID
PWS # 1300002
General PWS Information

Service Population	270	**Number of Connections**	90
Total PWS Daily Water Usage	0.035 (mgd)	**Source**	Calculated using assumed 130 gpcd

Unit Cost Data
Central Texas

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	NA
Contingency	20%	n/a
Engineering & Constr. Management	25%	n/a
Procurement/admin (POU/POE)	20%	n/a

Pipeline Unit Costs	**Unit**	**Unit Cost**
PVC water line, Class 200, 04"	LF	$ 27
Bore and encasement, 10"	LF	$ 60
Open cut and encasement, 10"	LF	$ 35
Gate valve and box, 04"	EA	$ 395
Air valve	EA	$ 1,000
Flush valve	EA	$ 750
Metal detectable tape	LF	$ 0.15
Bore and encasement, length	Feet	200
Open cut and encasement, length	Feet	50

Pump Station Unit Costs	**Unit**	**Unit Cost**
Pump	EA	$ 7,500
Pump Station Piping, 04"	EA	$ 4,000
Gate valve, 04"	EA	$ 460
Check valve, 04"	EA	$ 540
Electrical/Instrumentation	EA	$ 10,000
Site work	EA	$ 2,000
Building pad	EA	$ 4,000
Pump Building	EA	$ 10,000
Fence	EA	$ 5,870
Tools	EA	$ 1,000

Well Installation Unit Costs	**Unit**	**Unit Cost**
Well installation	*See alternative*	
Water quality testing	EA	$ 1,500
Well pump	EA	$ 7,500
Well electrical/instrumentation	EA	$ 5,000
Well cover and base	EA	$ 3,000
Piping	EA	$ 2,500
Storage Tank - 20,000 gals	EA	$ 27,000
Electrical Power	$/kWH	$ 0.136
Building Power	kWH	11,800
Labor	$/hr	$ 31
Materials	EA	$ 1,200
Transmission main O&M	$/mile	$ 200
Tank O&M	EA	$ 1,000

POU/POE Unit Costs		
POU treatment unit purchase	EA	$ 250
POU treatment unit installation	EA	$ 150
POE treatment unit purchase	EA	$ 3,000
POE - pad and shed, per unit	EA	$ 2,000
POE - piping connection, per unit	EA	$ 1,000
POE - electrical hook-up, per unit	EA	$ 1,000
POU treatment O&M, per unit	$/year	$ 225
POE treatment O&M, per unit	$/year	$ 1,000
Contaminant analysis	$/year	$ 100
POU/POE labor support	$/hr	$ 31

Dispenser/Bottled Water Unit Costs		
Treatment unit purchase	EA	$ 3,000
Treatment unit installation	EA	$ 5,000
Treatment unit O&M	EA	$ 500
Administrative labor	hr	$ 41
Bottled water cost (inc. delivery)	gallon	$ 1.60
Water use, per capita per day	gpcd	1.0
Bottled water program materials	EA	$ 5,000
Storage Tank - 5,000 gals	EA	$ 7,025
Site improvements	EA	$ 4,000
Potable water truck	EA	$ 60,000
Water analysis, per sample	EA	$ 100
Potable water truck O&M costs	$/mile	$ 1.00

Central Treatment Unit Costs	**Unit**	**Unit Cost**
General		
Site preparation	acre	$ 4,000
Slab	CY	$ 1,000
Building	SF	$ 60
Building electrical	SF	$ 8.00
Building plumbing	SF	$ 8.00
Heating and ventilation	SF	$ 7.00
Fence	LF	$ 15
Paving	SF	$ 2.00
Chlorination point	EA	$ 2,000
Building power	kwh/yr	$ 0.136
Equipment power	kwh/yr	$ 0.136
Labor, O&M	hr	$ 31
Analyses	test	$ 200
Ion exchange		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
Ion exchange package plant	UNIT	$ 30,000
Transfer pumps (10 hp)	EA	$ 5,000
Clean water tank	gal	$ 1.00
Regenerant tank	gal	$ 1.50
Backwash tank	gal	$ 2.00
Sewer connection fee	EA	$ 15,000
Ion exchange materials	year	$ 1,000
Ion exchange chemicals	year	$ 1,000
Backwash discharge to sewer	kgal/year	$ 5.00
Waste haulage truck rental	days	$ 700
Mileage charge	mile	$ 1.00
Waste disposal fee	kgal/yr	$ 200
WRT Z-88 package		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
WRT Z-88 package plant	UNIT	$ 58,000
(Initial setup *cost for WRT Z-88 package*)		
WRT treated water charge	1,000 gal/yr	$ 2.70
KMnO4-greensand package		
Electrical	JOB	$ 50,000
Piping	JOB	$ 20,000
KMnO4-greensand package plant	UNIT	$ 60,000
Backwash tank	gal	$ 2.00
Sewer connection fee	EA	$ 15,000
KMnO4-greensand materials	year	$ 1,000
KMnO4-greensand chemicals	year	$ 1,000
Backwash discharge to sewer	1,000 gal/yr	$ 5.00
Sludge truck rental	days	$ 700
Sludge truck mileage fee	miles	$ 1.00
Sludge disposal fee	1,000 gal/yr	$ 2,200.00

APPENDIX C
COMPLIANCE ALTERNATIVE CONCEPTUAL COST ESTIMATES

This appendix presents the conceptual cost estimates developed for the compliance alternatives. The conceptual cost estimates are given in Tables C.1 through C.6. The cost estimates are conceptual in nature (+50%/-30%), and are intended for making comparisons between compliance options and to provide a preliminary indication of possible water rate impacts. Consequently, these costs are pre-planning level and should not be viewed as final estimated costs for alternative implementation.

Table C.1

PWS Name *Kendall County WCID*
Alternative Name *New well near Well 8*
Alternative Number *KC-1*

Distance from PWS to new well location	1.20	miles
Estimated well depth	490	feet
Number of wells required	1	
Well installation cost (location specific)	$25	per foot
Number of pump stations needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	1	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 04"	6,323	LF	$ 27	$ 167,560
Bore and encasement, 10"	200	LF	$ 60	$ 12,000
Open cut and encasement, 10"	100	LF	$ 35	$ 3,500
Gate valve and box, 04"	1	EA	$ 395	$ 500
Air valve	1	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 948
Metal detectable tape	6,323	LF	$ 0.15	$ 948
Subtotal				**$ 186,456**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 04"	1	EA	$ 4,000	$ 4,000
Gate valve, 04"	4	EA	$ 460	$ 1,840
Check valve, 04"	2	EA	$ 540	$ 1,080
Electrical/Instrumentation	1	EA	$ 10,000	$ 10,000
Site work	1	EA	$ 2,000	$ 2,000
Building pad	1	EA	$ 4,000	$ 4,000
Pump Building	1	EA	$ 10,000	$ 10,000
Fence	1	EA	$ 5,870	$ 5,870
Tools	1	EA	$ 1,000	$ 1,000
Storage Tank - 20,000 gals	1	EA	$ 27,000	$ 27,000
Subtotal				**$ 81,790**
Well Installation				
Well installation	490	LF	$ 25	$ 12,250
Water quality testing	2	EA	$ 1,500	$ 3,000
Well pump	1	EA	$ 7,500	$ 7,500
Well electrical/instrumentation	1	EA	$ 5,000	$ 5,000
Well cover and base	1	EA	$ 3,000	$ 3,000
Piping	1	EA	$ 2,500	$ 2,500
Subtotal				**$ 33,250**
Subtotal of Component Costs				**$ 301,496**
Contingency	20%			$ 60,299
Design & Constr Management	25%			$ 75,374
TOTAL CAPITAL COSTS				**$ 437,169**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.2	mile	$ 200	$ 240
Subtotal				**$ 240**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	6,566	kWH	$ 0.136	$ 893
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 31	$ 11,315
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 16,013**
Well O&M				
Pump power	2,195	kWH	$ 0.136	$ 299
Well O&M matl	1	EA	$ 1,200	$ 1,200
Well O&M labor	180	Hrs	$ 31	$ 5,580
Subtotal				**$ 7,079**
O&M Credit for Existing Well Closure				
Pump power	1,845	kWH	$ 0.136	$ (251)
Well O&M matl	1	EA	$ 1,200	$ (1,200)
Well O&M labor	180	Hrs	$ 31	$ (5,580)
Subtotal				**$ (7,031)**
TOTAL ANNUAL O&M COSTS				**$ 16,300**

Table C.2

PWS Name *Kendall County WCID*
Alternative Name *Central Treatment - IX*
Alternative Number *KC-2*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	3,200	SF	$ 2	$ 6,400
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Ion exchange package including:				
Regeneration system				
Brine tank				
IX resins & FRP vessels	1	UNIT	$ 30,000	$ 30,000
Transfer pumps (10 hp)	2	EA	$ 5,000	$ 10,000
Clean water tank	5,000	gal	$ 1.00	$ 5,000
Regenerant tank	2,000	gal	$ 1.50	$ 3,000
Backwash Tank	2,000	gal	$ 2.00	$ 4,000
Sewer Connection Fee	1	EA	$ 15,000	$ 15,000
Subtotal of Component Costs				**$ 209,600**
Contingency	20%			$ 41,920
Design & Constr Management	25%			$ 52,400
TOTAL CAPITAL COSTS				**$ 303,920**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Ion Exchange Unit O&M				
Building Power	12,000	kwh/yr	$ 0.136	$ 1,632
Equipment power	10,000	kwh/yr	$ 0.136	$ 1,360
Labor	400	hrs/yr	$ 31	$ 12,400
Materials	1	year	$ 1,000	$ 1,000
Chemicals	1	year	$ 1,000	$ 1,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharge to sewer	5	kgal/yr	$ 5.00	$ 25
Subtotal				**$ 22,217**
Haul Regenerant Waste and Brine				
Waste haulage truck rental	3	days	$ 700	$ 2,100
Mileage charge	300	miles	$ 1.00	$ 300
Waste disposal	4	kgal/yr	$ 200.00	$ 800
Subtotal				**$ 3,200**
TOTAL ANNUAL O&M COSTS				**$ 25,417**

Table C.3

PWS Name *Kendall County WCID*
Alternative Name *Central Treatment - WRT Z-88*
Alternative Number *KC-3*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	1,600	SF	$ 2	$ 3,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
WRT Z-88 package including:				
Z-88 vessels				
Adsorption media	1	UNIT	$ 58,000	$ 58,000
(Initial Setup Cost for WRT Z-88 package plant)				
Subtotal of Component Costs				**$ 197,400**
Contingency	20%			$ 39,480
Design & Constr Management	25%			$ 49,350
TOTAL CAPITAL COSTS				**$ 286,230**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	6,000	kwh/yr	$ 0.136	$ 816
Equipment power	5,000	kwh/yr	$ 0.136	$ 680
Labor	400	hrs/yr	$ 31	$ 12,400
Analyses	24	test	$ 200	$ 4,800
WRT treated water charge	1,332	kgal/yr	$ 2.70	$ 3,596
Subtotal				**$ 22,292**
TOTAL ANNUAL O&M COSTS				**$ 22,292**

Table C.4

PWS Name *Kendall County WCID*
Alternative Name *Central Treatment - KMnO4*
Alternative Number *KC-4*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit Purchase/Installation				
Site preparation	0.50	acre	$ 4,000	$ 2,000
Slab	30	CY	$ 1,000	$ 30,000
Building	400	SF	$ 60	$ 24,000
Building electrical	400	SF	$ 8	$ 3,200
Building plumbing	400	SF	$ 8	$ 3,200
Heating and ventilation	400	SF	$ 7	$ 2,800
Fence	-	LF	$ 15	$ -
Paving	1,600	SF	$ 2	$ 3,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
KMnO4-Greensand package including:				
Greensand filters				
Solution tank	1	UNIT	$ 60,000	$ 60,000
Backwash tank	3,000	gal	$ 2.00	$ 6,000
Sewer connection fee	1	EA	$ 15,000	$ 15,000
Subtotal of Component Costs				**$ 219,400**
Contingency	20%			$ 43,880
Design & Constr Management	25%			$ 54,850
TOTAL CAPITAL COSTS				**$ 318,130**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Coagulation/Filtration Unit O&M				
Building Power	6,000	kwh/yr	$ 0.136	$ 816
Equipment power	6,000	kwh/yr	$ 0.136	$ 816
Labor	400	hrs/yr	$ 31	$ 12,400
Materials	1	year	$ 1,000	$ 1,000
Chemicals	1	year	$ 1,000	$ 1,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharge to sewer	50	kgal/yr	$ 5.00	$ 250
Subtotal				**$ 21,082**
Sludge Disposal				
Truck rental	4.0	days	$ 700	$ 2,800
Mileage	240	miles	$ 1.00	$ 240
Disposal fee	4	kgal/yr	$ 200.00	$ 800
Subtotal				**$ 3,840**
TOTAL ANNUAL O&M COSTS				**$ 24,922**

Table C.5

PWS Name *Kendall County WCID*
Alternative Name *Point-of-Use Treatment*
Alternative Number *KC-5*

Number of Connections for POU Unit Installation 90

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	90	EA	$ 250	$ 22,500
POU treatment unit installation	90	EA	$ 150	$ 13,500
Subtotal				**$ 36,000**
Subtotal of Component Costs				**$ 36,000**
Contingency	20%			$ 7,200
Design & Constr Management	25%			$ 9,000
Procurement & Administration	20%			$ 7,200
TOTAL CAPITAL COSTS				**$ 59,400**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	90	EA	$ 225	$ 20,250
Contaminant analysis, 1/yr per unit	90	EA	$ 100	$ 9,000
Program labor, 10 hrs/unit	900	hrs	$ 31	$ 27,900
Subtotal				**$ 57,150**
TOTAL ANNUAL O&M COSTS				**$ 57,150**

Table C.6

PWS Name *Kendall County WCID*
Alternative Name *Point-of-Entry Treatment*
Alternative Number *KC-6*

Number of Connections for POE Unit Installation 90

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	90	EA	$ 3,000	$ 270,000
Pad and shed, per unit	90	EA	$ 2,000	$ 180,000
Piping connection, per unit	90	EA	$ 1,000	$ 90,000
Electrical hook-up, per unit	90	EA	$ 1,000	$ 90,000
Subtotal				**$ 630,000**
Subtotal of Component Costs				**$ 630,000**
Contingency	20%			$ 126,000
Design & Constr Management	25%			$ 157,500
Procurement & Administration	20%			$ 126,000
TOTAL CAPITAL COSTS				**$ 1,039,500**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	90	EA	$ 1,000	$ 90,000
Contaminant analysis, 1/yr per unit	90	EA	$ 100	$ 9,000
Program labor, 10 hrs/unit	900	hrs	$ 31	$ 27,900
Subtotal				**$ 126,900**
TOTAL ANNUAL O&M COSTS				**$ 126,900**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Table D.1 Example Financial Model

Water System	Kendall County
Funding Alternative	Bond
Alternative Description	Central Treatment - IX

Sum of Amount		Year										
Group	Type	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ -	$ -	$ 303,920	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	$ 303,920	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds				$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775
	State Revolving Funds				$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum					$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775
Operating Expenditures	Administrative Expenses			$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807
	Contract Labor			$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859
	Other Operating Expenditures 1			$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979
	Other Operating Expenditures 2			$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061
	Professional and Directors Fees			$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890
	Salaries & Benefits			$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914
	Supplies			$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937
	O&M Associated with Alternative					$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417
	Other Operating Expenditures 3			$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324
	Other Operating Expenditures 4			$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779
Operating Expenditures Sum				$ 711,550	$ 711,550	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967
Residential Operating Revenues	Residential Base Monthly Rate			$ 579,650	$ 579,650	$ 1,155,172	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982
	Residential Tier 1 Monthly Rate			$ 136,385	$ 136,385	$ 271,798	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632
	Residential Tier2 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier3 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier4 Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Unmetered Monthly Rate			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residential Operating Revenues Sum				$ 716,035	$ 716,035	$ 1,426,970	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614

Group	Type	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Grants	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Capital Expenditures-Funded from SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Capital Expenditures Sum		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service	Revenue Bonds	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775
	State Revolving Funds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt Service Sum		$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775	$ 23,775
Operating Expenditures	Administrative Expenses	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807	$ 16,807
	Contract Labor	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859	$ 5,859
	Other Operating Expenditures 1	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979	$ 64,979
	Other Operating Expenditures 2	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061	$ 13,061
	Professional and Directors Fees	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890	$ 4,890
	Salaries & Benefits	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914	$ 278,914
	Supplies	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937	$ 25,937
	O&M Associated with Alternative	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417	$ 25,417
	Other Operating Expenditures 3	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324	$ 51,324
	Other Operating Expenditures 4	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779	$ 249,779
Operating Expenditures Sum		$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967	$ 736,967
Residential Operating Revenues	Residential Base Monthly Rate	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982	$ 1,638,982
	Residential Tier 1 Monthly Rate	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632	$ 385,632
	Residential Tier2 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier3 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Tier4 Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Residential Unmetered Monthly Rate	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Residential Operating Revenues Sum		$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614

Location_Name	Kendall County
Alt_Desc	Central Treatment - IX

		Current_Year										
Funding_Alt	Data	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bond	Sum of Beginning_Cash_Bal	$ 401,273	$ (142,944)	$ (710,935)	$ (597,644)	$ 113,290	$ 824,225	$ 1,535,160	$ 2,246,095	$ 2,957,030	$ 3,667,965	$ 4,378,900
	Sum of Total_Expenditures	$ 711,550	$ 1,039,245	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742
	Sum of Total_Receipts	$ 716,035	$ 1,019,955	$ 1,426,970	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614
	Sum of Net_Cash_Flow	$ 4,485	$ (19,290)	$ 666,228	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873
	Sum of Ending_Cash_Bal	$ 405,758	$ (162,233)	$ (44,707)	$ 666,228	$ 1,377,163	$ 2,088,098	$ 2,799,033	$ 3,509,968	$ 4,220,903	$ 4,931,838	$ 5,642,773
	Sum of Working_Cap	$ 118,592	$ 118,592	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828
	Sum of Repl_Resv	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110
	Sum of Total_Reqd_Resv	$ 548,702	$ 548,702	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938
	Sum of Net_Avail_Bal	$ (142,944)	$ (710,935)	$ (597,644)	$ 113,290	$ 824,225	$ 1,535,160	$ 2,246,095	$ 2,957,030	$ 3,667,965	$ 4,378,900	$ 5,089,835
	Sum of Add_Resv_Needed	$ (142,944)	$ (710,935)	$ (597,644)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	99%	42%	0%	0%	0%	0%	0%	0%	0%	0%
	Sum of Percent_Rate_Increase	0%	0%	99%	183%	183%	183%	183%	183%	183%	183%	183%

Funding_Alt	Data	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Bond	Sum of Beginning_Cash_Bal	$ 5,089,835	$ 5,800,770	$ 6,511,705	$ 7,222,640	$ 7,933,575	$ 8,644,510	$ 9,355,445	$ 10,066,379	$ 10,777,314	$ 11,488,249	$ 12,199,184
	Sum of Total_Expenditures	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742	$ 760,742
	Sum of Total_Receipts	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614	$ 2,024,614
	Sum of Net_Cash_Flow	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873	$ 1,263,873
	Sum of Ending_Cash_Bal	$ 6,353,708	$ 7,064,643	$ 7,775,578	$ 8,486,513	$ 9,197,447	$ 9,908,382	$ 10,619,317	$ 11,330,252	$ 12,041,187	$ 12,752,122	$ 13,463,057
	Sum of Working_Cap	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828	$ 122,828
	Sum of Repl_Resv	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110	$ 430,110
	Sum of Total_Reqd_Resv	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938	$ 552,938
	Sum of Net_Avail_Bal	$ 5,800,770	$ 6,511,705	$ 7,222,640	$ 7,933,575	$ 8,644,510	$ 9,355,445	$ 10,066,379	$ 10,777,314	$ 11,488,249	$ 12,199,184	$ 12,910,119
	Sum of Add_Resv_Needed	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Sum of Rate_Inc_Needed	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0
	Sum of Percent_Rate_Increase	183%	183%	183%	183%	183%	183%	183%	183%	183%	183%	183%

APPENDIX E
RADIONUCLIDE GEOCHEMISTRY

Radionuclide impact on water quality is measured according to two scales: intrinsic measurement of radioactivity and impact on human beings. Activity or number of disintegrations per unit time is typically measured in picoCuries (pCi) while impact on living organisms is measured in mRem. Radioactive decay can generate alpha or beta particles as well as gamma rays. Two radioactive elements with the same activity may have vastly different impacts on life depending on the energy released during decay. Each radionuclide has a conversion factor from pCi to mRem as a function of the exposure pathway. Activity is related to contaminant concentration and half-life. A higher concentration and a shorter half-life lead to an increase in activity. Radium is approximately one million times more radioactive than uranium based on the ratio of their half lives (Table E.1). Concentrations of gross alpha and beta emitters take into account the whole decay series and not just uranium and radium as well as other elements such as K40.

Uranium and thorium (atomic number 92 and 90, respectively), both radium sources, are common trace elements and have a crustal abundance of 2.6 and 10 mg/kg, respectively. They are abundant in acidic rock. Intrusive rock such as granite partially sequesters uranium and thorium in erosion-resistant accessory minerals (*e.g.*, monazite, thorite) while uranium in volcanic rocks is much more labile and can be leached by surface water and groundwater. Lattice substitution in minerals (*e.g.*, Ca^{+2} and U^{+4}) have almost the same ionic radius) as well as micrograins of uranium and thorium minerals are other possibilities. In sedimentary rock, uranium and thorium aqueous concentrations are controlled primarily by the sorbing potential of the rock (metal oxide, clay, and organic matter).

The geochemistry of uranium is complicated but can be summarized by the following. Uranium(VI) in oxidizing conditions exists as the soluble positively charged uranyl ion UO_2^{+2}. Solubility is higher at low pH (acid), decreases at neutral pHs, and increases at high pH (alkaline). The uranyl ion can easily form aqueous complexes, such as with hydroxyl, fluoride, carbonate, and phosphate ligands. Hence in the presence of carbonates, uranium solubility is considerably enhanced in the form of uranyl-carbonate (UO_2CO_3) and other higher order carbonate complexes: uranyl-di-carbonate ($UO_2(CO_3)_2^{-2}$ and uranyl-tri-carbonates $UO_2(CO_3)_3^{-4}$). Adsorption of uranium is inversely related to its solubility and is highest at neutral pHs (De Soto, 1978, p.11). Uranium sorbs strongly to metal oxides and clays.

Uranium (IV) is the other common redox state. In that state, however, uranium is not very soluble and precipitates as uraninite, UO_2, coffinite, $USiO_4.nH_2O$ (if SiO_2 >60 mg/L, Henry, *et al*. 1982, p.18), or related minerals. In most aquifers, there is no mineral controlling uranium solubility in oxidizing conditions. However, uranite and coffinite are the controlling minerals if the Eh drops below 0-100 mV.

Thorium exists naturally only in one redox state, Th(IV). Th^{+4} forms complexes with most common aqueous anions. However, thorium solubility remains low except maybe at higher pH when complexed by carbonate ions (EPA, 1999). Similarly to uranium, thorium sorbs strongly to metal oxides.

Radium has an atomic number of 88. Radium originates from the radioactive decay of uranium and thorium. Radium-226 is an intermediate product of U238 (the most common uranium isotope >99%, Table 1) decay while radium-228 belongs to the Th232 (~100% of natural thorium) decay series. Both radium isotopes further decay to radon and ultimately to lead. Radon is a gas and tends to volatilize from shallower units. Ra223 and Ra224 isotopes are also naturally present but in minute quantities. Radium-224 belongs to the thorium decay series while radium-223 is derived from the much rarer U235 (~0.7%). Radium is an alkaline earth element and belongs to the same group (2A in periodic table) as magnesium, calcium, strontium, and barium. It most resembles barium chemically as evidenced by removal technologies such as ion exchange with Na and lime softening. Sorption on iron and manganese oxides is also a common trait of alkaline earth elements. Radium exists only under one oxidation state, the divalent cation Ra^{+2}, similar to other alkaline earth elements (Ca^{+2}, Mg^{+2}, Sr^{+2}, and Ba^{+2}). $RaSO_4$ is extremely insoluble (more so than barium sulfate) with a log K solubility product of -10.5 compared to that of barium sulfate at ~-10. Radium solubility is mostly controlled by sulfate activity.

Table E.1 Uranium, Thorium, and Radium Abundance and Half-Lives

Decay Series	Uranium/Thorium	Radium	Radon
U238	U238 – ~99.3% (4.47×10^9 yrs)	Ra226 - (1,599 yrs)	Rn222 - (3.8 days)
	U234 – 0.0055% (0.246×10^9 yrs)	Intermediate product of U238 decay	
U235	U235 - ~0.7% (0.72×10^9 yrs)	Ra223 – (11.4 days)	Rn219 - (4 seconds)
Th232	Th232 – ~100% (14.0×10^9 yrs)	Ra228 - (5.76 yrs) Ra224 - (3.7 days)	Rn220 - (~1 min)

NOTE: half-life from Parrington, et al. 1996

USEPA Maximum Contaminant Levels

- Uranium: 30 ppb
- Gross alpha: 15 pCi/L
- Beta particles and photon emitters: 4 mrem/yr
- Radium-226 and radium-228: 5 pCi/L

Appendix references

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