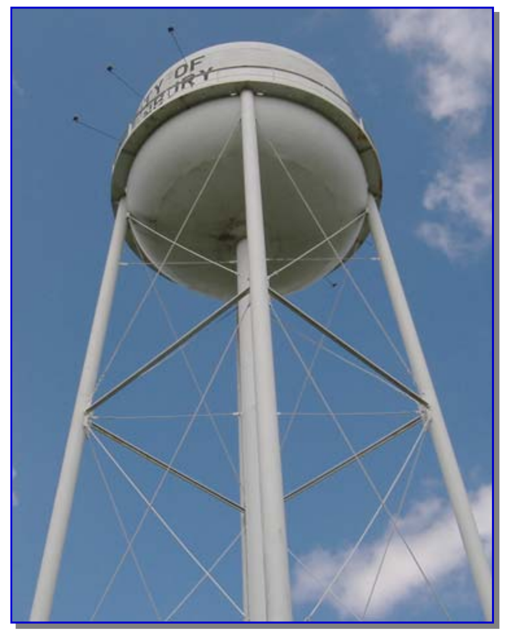
DRAFT FEASIBILITY REPORT
FEASIBILITY ANALYSIS OF WATER SUPPLY FOR SMALL PUBLIC WATER SYSTEMS

CITY OF DANBURY
PWS ID# 0200011, CCN# P0614

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

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EXECUTIVE SUMMARY

INTRODUCTION

The University of Texas Bureau of Economic Geology (BEG) and its subcontractor, Parsons Infrastructure and Technology Group Inc. (Parsons), were 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 City of Danbury PWS located in Brazoria County. Recent sample results from the City of Danbury water system exceeded the MCL for arsenic of 10 micrograms per liter (µg/L) which goes into effect January 23, 2006 (USEPA 2005a; TCEQ 2004a). A recent sample result for nitrate exceeded the MCL of 10 milligrams per liter (mg/L), and another recent result exceeded the secondary MCL (SMCL) for manganese of 50 µg/L, though these have not been typical problems for the City.

Basic system information for the City of Danbury PWS is shown in Table ES.1.

Table ES.1
City of Danbury PWS
Basic System Information

Population served	1,650
Connections	638
Average daily flow rate	0.213 million gallons per day (mgd)
Water system peak capacity	0.878 mgd
Typical nitrate range	0.01 to 0.02 mg/L
Typical arsenic range	2.4 to 14 µg/L
Typical manganese range	11 to 54 µg/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:

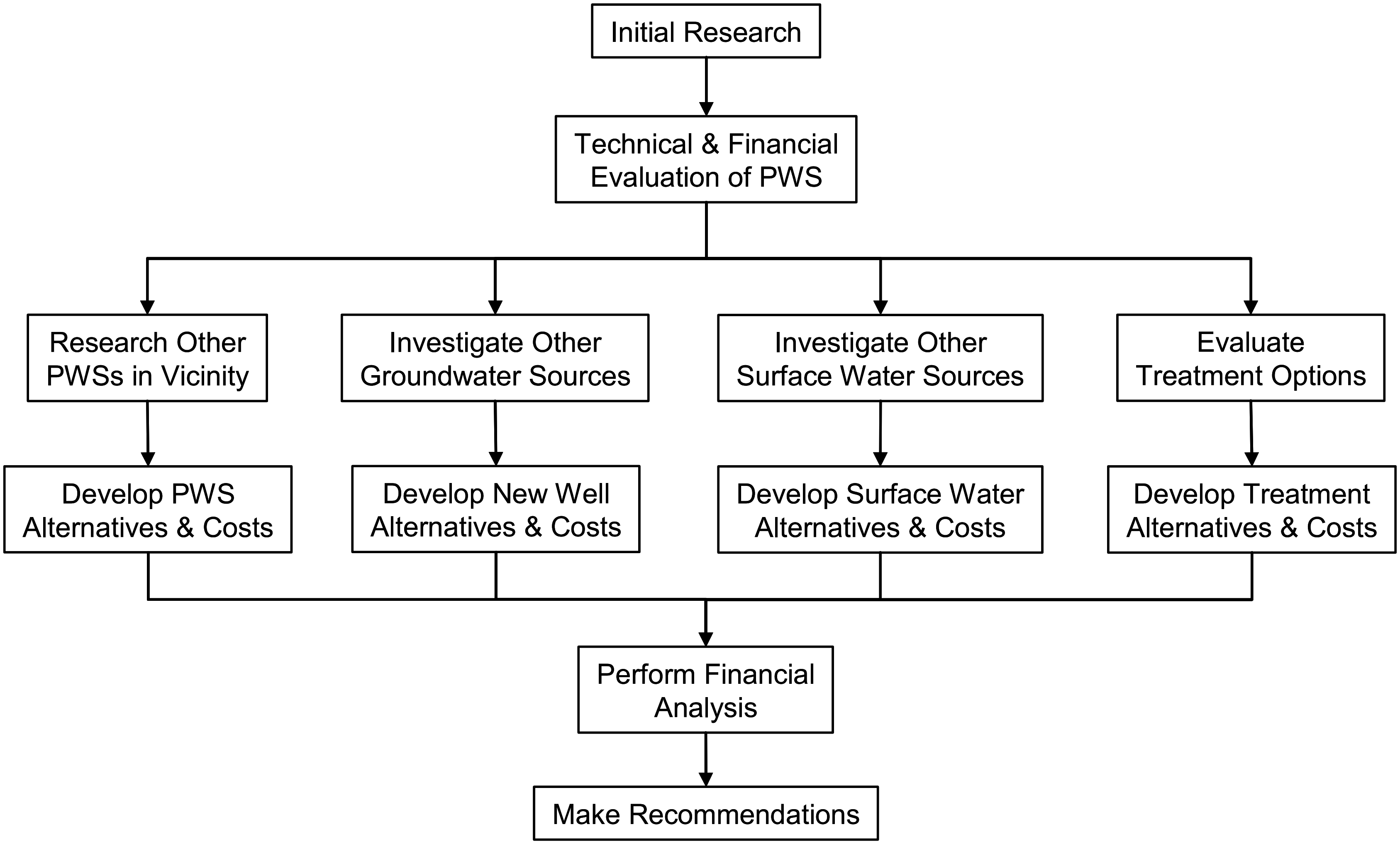
1. Gather data from the TCEQ and Texas Water Development Board databases, from TCEQ files, and from information maintained by the PWS;
2. Conduct financial, managerial, and technical (FMT) evaluations of the PWS;
3. Perform a geologic and hydrogeologic assessment of the study area;
4. Develop treatment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

This basic approach is summarized in Figure ES-1.

HYDROGEOLOGICAL ANALYSIS

The City of Danbury PWS obtains groundwater from the Chicot subunit of the Gulf Coast aquifer. Arsenic is commonly found in area wells at concentrations greater than the MCL. Volcanic ash incorporated into the aquifer material may be the source of arsenic. Arsenic concentrations can vary significantly over relatively short distances; as a result, there could be good quality groundwater nearby. However, the variability of arsenic concentrations makes it difficult to determine where wells can be located to produce acceptable water. Additionally, systems with more than one well should

Figure ES-1
Summary of Project Methods



characterize the water quality of each well. If one of the wells is found to produce compliant water, as much production as possible should be shifted to that well as a method of achieving compliance. 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 City of Danbury PWS is a municipal system managed by a chief officer. Overall, the system had an adequate level of FMT capacity. The system had some areas that needed improvement to be able to address future compliance issues; however, the system does have many positive aspects, including dedicated staff, good communication, good preventative maintenance program, and subsidy transparency. Areas of concern for the system included lack of separate budgets and rates for the water system, past construction problems, lack of water loss measurement and management, and lack of capital improvement planning.

There are numerous PWSs within 15 miles of the City of Danbury. Many of these nearby systems also have water quality issues, but there are several with good quality water. In general, feasibility alternatives were developed based on obtaining water from the nearest PWSs, either by directly purchasing water, or by expanding the existing well field. There is a minimum of surface water available in the area, and obtaining a new surface water source is considered through an alternative where treated surface water is obtained from the Brazosport Water Authority (BWA). In addition to the BWA, the City of Alvin is a potential large regional water supplier, and there are plans for the Gulf Coast Water Authority to build a surface water treatment plant in Fort Bend County that could potentially supply water to the City of Danbury.

A number of centralized treatment alternatives for arsenic removal have been developed and were considered for this report, for example, iron-based adsorption and coagulation/filtration. Point-of-use (POU) and point-of-entry treatment alternatives were also considered. Temporary solutions such as providing bottled water or providing a centralized dispenser for treated or trucked-in water, were also considered as alternatives.

Developing a new well close to the City of Danbury is likely to be the best solution if compliant groundwater can be found. Having a new well close to the City of Danbury 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.

Providing compliant water through a central dispenser is significantly less expensive than providing bottled water to 100 percent of the population, but a significant effort is required for clients to fill their containers at the central dispenser.

FINANCIAL ANALYSIS

Financial analysis of the City of Danbury PWS indicated that current water rates are under funding operations, and a rate increase of approximately 205 percent would be necessary to meet operating expenses. This increase would raise the average annual water bill from $258 to $530. The current average water bill represents approximately 0.65 percent of the 2000 median household income (MHI) for Texas, which is $39,927. Table ES.2 provides a summary of the financial impact of implementing selected compliance alternatives, including the rate increase necessary to meet future 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	$258	0.65
To meet current expenses	NA	$530	1.32
Nearby well within approximately 1 mile	100% Grant	$1,223	3.06
	Loan/Bond	$1,322	3.3
Central treatment	100% Grant	$1,326	3.3
	Loan/Bond	$1,508	3.8
Point-of-use	100% Grant	$1,2,353	5.9
	Loan/Bond	$1,2,451	6.1
Public dispenser	100% Grant	$1,343	3.4
	Loan/Bond	$1,354	3.4

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ACRONYMS AND ABBREVIATIONS

AA	Activated Alumina
BAT	Best available technology
BEG	Bureau of Economic Geology
BWA	Brazosport Water Authority
CA	Chemical analysis
CCN	Certificate of Convenience and Necessity
CO	Correspondence
EDR	Electrodialysis reversal
ETJ	Extra-territorial jurisdiction
FMT	Financial, managerial, and technical
GAM	Groundwater Availability Model
gpm	Gallons per minute
HGCSD	Harris-Galveston Coastal Subsidence District
ISD	Independent School District
IX	Ion exchange
MCL	Maximum contaminant level
μg/L	Microgram per liter
mg/L	Milligram per liter
mgd	Million gallons per day
MHI	Median household income
MOR	Monthly operating report
NMEFC	New Mexico Environmental Financial Center
O&M	Operation and Maintenance
POE	Point-of-entry
POU	Point-of-use
PVC	Polyvinyl chloride
PWS	Public water system
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
SSCT	Small System Compliance Technologies
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TSS	Total suspended solids
TWDB	Texas Water Development Board
USEPA	U.S. Environmental Protection Agency
WAM	Water Availability Model
WCID	Water Control and Improvement District

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 (PWSs) to meet and maintain Texas drinking water standards. A total of 15 PWSs were evaluated in this project and each is addressed in a separate report. The 15 systems evaluated for this project are listed below:

Public Water System	Texas County
o City of Danbury	o Brazoria
o Rosharon Road Estates Subdivision	o Brazoria
o Mark V Estates	o Brazoria
o Rosharon Township	o Brazoria
o Sandy Meadows Estates Subdivision	o Brazoria
o Grasslands	o Brazoria
o City of Eden	o Concho
o City of Mason	o Mason
o Falling Water Subdivision	o Kerr
o Greenwood Independent School District (ISD)	o Midland
o Country Village Mobile Home Estates	o Midland
o South Midland County Water Systems	o Midland
o Warren Road Subdivision Water Supply	o Midland
o Huber Garden Estates	o Ector
o Devilla Mobile Home Park	o Ector

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 that 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 City of Danbury Water System, PWS ID# 0200011, Certificate of Convenience and Necessity (CCN) #P0614, located in Brazoria County. Recent sample results from the City of Danbury Water System have exceeded the MCL for arsenic of 10 micrograms per liter (µg/L) that will go into effect January 23, 2006 (USEPA 2005a; TCEQ 2004a). A recent sample result also exceeded the MCL for nitrate of 10 milligrams per liter (mg/L) and another recent result exceeded the secondary MCL (SMCL) for manganese of 50 µg/L, although these have not been typical problems for the City.

The location of the City of Danbury Water System, also referred to as the "study area" in this report, 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 these contaminants and does not address any other violations that may exist for a PWS. As mentioned above, the City of Danbury Water System has had recent sample results that exceed the future MCL for arsenic. The health concerns related to drinking water above MCLs for this chemical are briefly described below.

In general, contaminant(s) in drinking water above the MCL(s) can have both short-term (acute) and long-term or lifetime (chronic) effects. Potential health effects from long-term ingestion of water with levels of arsenic above the MCL (10 µg/L) include non-carcinogenic effects, such as cardiovascular, pulmonary, immunological, neurological and endocrine effects, and carcinogenic effects including skin, bladder, lung, kidney, nasal passage, liver, and prostate cancer (USEPA 2005c).

1.2 METHODS

The methods used for this project follow those 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

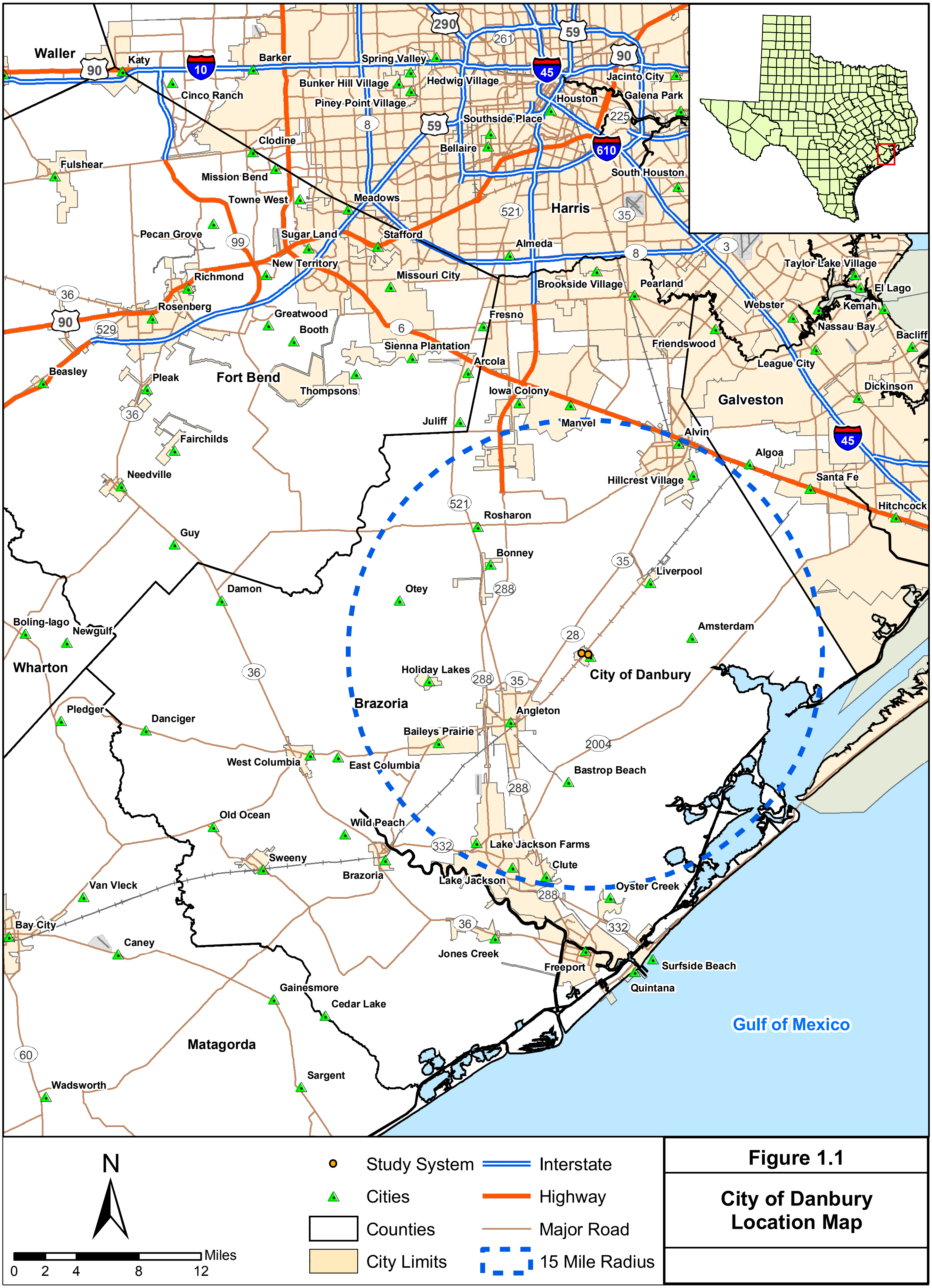

Figure 1.1

City of Danbury Location Map

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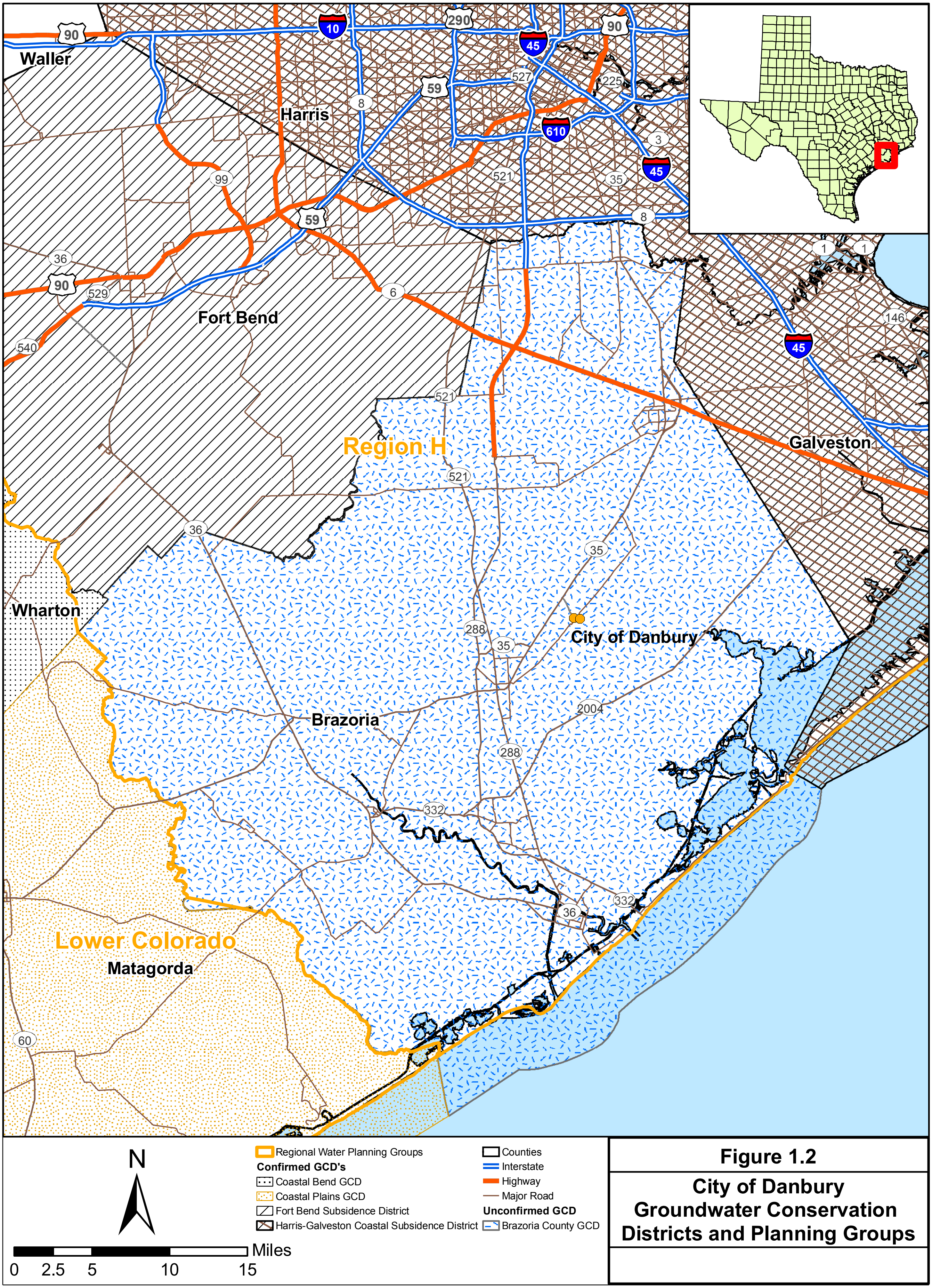

Figure 1.2

City of Danbury Groundwater Conservation Districts and Planning Groups

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PWSs were evaluated in the pilot study to develop the methodology (*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 arsenic abatement options. Section 2 describes the methods used to develop and assess compliance alternatives. The groundwater sources of arsenic are addressed in Section 3. Findings for the City of Danbury 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 the Federal Safe Drinking Water Act (SDWA) requirements that include oversight of PWSs and water utilities. These responsibilities include:

- Monitoring public drinking water quality;
- Processing enforcement referrals for MCL violators;
- 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 City of Danbury PWS involve arsenic. The following subsections explore alternatives considered as potential options for obtaining/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 purposes of this report, quantity refers to water volume, flow rate, and pressure. Before approaching a potential supplier PWS, the non-compliant PWS should determine the PWS's 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 that 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 at the supplier PWS where all the upstream pipes and appurtenances are of sufficient capacity to handle the new demand. The pipeline must tie in at a point at the non-compliant PWS 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 at 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. In the event 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 those 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 Brazoria County, the following standards could be used in a rough screening to identify compliant groundwater:
    - Arsenic concentrations less than 0.008 mg/L (below the MCL of 0.01 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 that have been used for industrial or irrigation purposes. Often the TWDB database will include well yields, which may indicate the likelihood of a particular well being 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 the willingness to work with the PWS. Once the owner agrees to participate with 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, flow rates, and other well characteristics.
- After collecting as much information as possible from cooperative owners, the PWS would then narrow down the selection and sample selected wells and analyze 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 that location would be suitable as a supply source.
- It is recommended that new wells be installed instead of using existing wells to ensure that 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 refer 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 will 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, where they are available, water rights 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, this 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 to 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 intake, treatment plant, and conveyance system.

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

Various treatment technologies for use as compliance alternatives for the treatment of arsenic to the regulatory level (*i.e.*, MCL) were investigated. Numerous options were identified by the USEPA as best available technologies (BAT) for non-compliant constituents. Identification and descriptions of the various BATs are provided in the following sections.

1.4.4.1 Treatment Technologies for Arsenic

In January 2001, the USEPA published a final rule in the Federal Register that established an MCL for arsenic of 0.01 mg/L (USEPA 2001). The regulation applies to all community water systems and non-transient, non-community water systems, regardless of size.

The new arsenic MCL of 0.01 mg/L is effective January 23, 2006, at which time the running average annual arsenic level must be at or below 0.01 mg/L at each entry point to the distribution system, although point-of-use (POU) treatment can be instituted in place of centralized treatment. All groundwater systems must complete initial monitoring or have a State-approved waiver by December 31, 2007.

The following BATs were identified in the final rule for achieving compliance with the arsenic MCL:

- Reverse osmosis (RO);
- Ion exchange (IX);
- Electrodialysis reversal (EDR);
- Activated alumina (AA);
- Oxidation/filtration;
- Enhanced coagulation/filtration; and
- Enhanced lime softening.

In addition, the following technologies are listed in the final rule as Small System Compliance Technologies (SSCT):

- RO (centralized and POU);
- IX;
- EDR;
- AA (centralized and POU);
- Oxidation/filtration;
- Coagulation/filtration, enhanced coagulation/filtration, and coagulation-assisted microfiltration; and
- Lime softening and enhanced lime softening.

1.4.5 Description of Treatment Technologies

According to a recent USEPA report for small water systems with <10,000 customers (EPA/600/R-05/001) a number of drinking water treatment technologies are available to reduce arsenic concentrations in source water to below the new MCL of 10 µg/L, including IX, membrane processes such as RO, adsorption, and coagulation/filtration-related processes. Many of the most effective arsenic removal processes available are iron-based treatment technologies such as chemical coagulation/filtration with iron salts, and adsorptive media with iron-based products. These processes are particularly effective at removing arsenic from aqueous systems because iron surfaces have a strong affinity for adsorbing arsenic. Other arsenic removal processes such as AA and enhanced lime softening are more applicable to larger water systems because of their operational complexity and cost. A description and discussion of arsenic removal technologies applicable to smaller systems follow.

1.4.5.1 Ion Exchange

<u>Process</u> – 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 water. The process relies on certain ions being 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 through the resin bed, the charged ions are released into the water, and are 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 bed, displacing the contaminant 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 resin 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. For arsenic removal, an anion exchange resin in the chloride form is used to remove arsenate [As(V)]. Because arsenite [As(III)] occurs in water below pH 9 with no ionic charge, As(III) is not consistently removed by the anionic exchange process.

Pre-treatment – 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 total suspended solids (TSS), iron, and manganese, which could plug the resin bed, and typically includes media or carbon filtration. In addition, chlorination or oxidation may be required to convert As(III) to As(V) for effective removal.

Maintenance – The IX resin requires regular on-site regeneration, the frequency of which depends on raw water characteristics, the contaminant concentration, and the size and number of IX vessels. Operators of 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 would be required.

Waste Disposal – Approval from local authorities is usually required for disposal of concentrate from the regeneration cycle (highly concentrated salt solution); occasional solid 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 arsenic 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 sulfate.

In considering application of IX for inorganics removal, it is important to understand the effect of competing ions, and to what extent the brine can be recycled. Similar to AA, IX exhibits a selectivity sequence, which refers to an order in which ions are preferred. Sulfate competes with both nitrate and arsenic, but is more aggressive with arsenic in an anion exchange. Source waters with TDS levels above 500 mg/L or sulfate above 50 mg/L are not amenable to IX treatment for arsenic removal. Spent regenerant is produced during IX bed regeneration, and it may have high concentrations of the sorbed contaminants which are expensive to treat and/or dispose because of hazardous waste regulations. Research has been conducted to minimize this effect: recent research on arsenic removal shows that the brine can be reused as many as 25 times.

1.4.5.2 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 hollow fine fiber, but most RO systems to date are 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 97 percent removal of As(V) and 92 percent removal of As(III). The treatment process is relatively insensitive to pH. Water recovery is typically 60-80 percent, 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; removal of sparingly soluble constituents such as calcium, magnesium, silica, sulfate, barium, *etc*., may be required to prevent scaling. Pretreatment can include media filters, IX softening, acid and antiscalant feed, activated carbon of bisulfite feed to dechlorinate, and cartridge filters to removing any remaining suspended solids to protect membranes from upsets.

Maintenance – Monitoring rejection percentage is required to ensure contaminant removal below the 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 require approved disposal methods.

Advantages (RO)

- Can remove both As(III) and As(V) effectively.
- Can remove other undesirable dissolved constituents and excessive salts, if required.

Disadvantages (RO)

- Relatively expensive to install and operate.
- Need sophisticated monitoring systems.
- Need to handle multiple chemicals.
- Waste of water because of the significant concentrate flows.
- Concentrated disposal.

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

1.4.5.3 Adsorption

Process – The adsorptive media process is a fixed-bed process by which ions in solution, such as arsenic, are removed by available adsorptive sites on an adsorptive media. When the available adsorptive sites are filled, spent media may be regenerated or simply thrown away and replaced with new media. Granular AA was the first adsorptive media successfully applied for the removal of arsenic from water supplies. More recently, other adsorptive media (mostly iron-based) have been developed and marketed for arsenic removal. Recent USEPA studies demonstrate that iron-based adsorption media typically have higher arsenic removal capacities compared to alumina-based media. In the USEPA-sponsored Round 1, a full-scale demonstration of arsenic removal technologies for small water systems program, the selected arsenic treatment technologies included nine adsorptive media systems, one IX system, one coagulation/filtration system, and one process modification.

The selected adsorptive media systems used four different adsorptive media, including three iron-based media (*e.g.*, ADI's G2, Severn Trent and AdEdge's E33, and U.S. Filter's GFH), and one iron-modified AA media (*e.g.*, Kinetico's AAFS50, a product of Alcan). The G2 media is a dry powder of diatomaceous earth impregnated with a coating of ferric hydroxide, developed by ADI specifically for arsenic adsorption. ADI markets G2 for both As(V) and As(III) removal but it preferentially removes As(V). G2 media adsorb arsenic most effectively at pH values within the 5.5 to 7.5 range, and less effectively at a higher pH value.

The Bayoxide® E33 media was developed by Bayer AG for removal of arsenic from drinking water supplies. It is a dry granular iron oxide media designed to remove dissolved arsenic via adsorption onto its ferric oxide surface. Severn Trent markets the media in the U.S. for As(III) and As(V) removal as Sorb-33, and offers several arsenic package units (APU) with flow rates ranging from 150 to 300 gallons per minute (gpm). Another company, AdEdge, provides similar systems using the same media (marketed as AD-33) with flow rates ranging from 5 to 150 gpm. E33 adsorbs arsenic and other ions, such as antimony, cadmium, chromate, lead, molybdenum, selenium, and vanadium. The adsorption is effective at pH values ranging between 6.0 and 9.0. At greater than 8.0 to

8.5, pH adjustment is recommended to maintain its adsorption capacity. Two competing ions that can reduce the adsorption capacity are silica (at levels greater than 40 mg/L) and phosphate (at levels greater than 1 mg/L).

GFH is a moist granular ferric hydroxide media produced by GEH Wasserchemie GmbH of Germany and marketed by U.S. Filter under an exclusive marketing agreement. GFH is capable of adsorbing both As(V) and As(III). GFH media adsorb arsenic with a pH range of 5.5 to 9.0, but less effectively at the upper end of this range. Competing ions such as silica and phosphate in source water can adsorb onto GFH media, thus reducing the arsenic removal capacity.

The AAFS50 is a dry granular media of 83 percent alumina and a proprietary iron-based additive to enhance the arsenic adsorption performance. Standard AA was the first adsorptive media successfully applied for the removal of arsenic from water supplies. However, it often requires pH adjustment to 5.5 to achieve optimum arsenic removal. The AAFS50 product is modified with an iron-based additive to improve its performance and increase the pH range within which it can achieve effective removal. Optimum arsenic removal efficiency is achieved with a pH of the feed water less than 7.7. Competing ions such as fluoride, sulfate, silica, and phosphate can adsorb onto AAFS50 media, and potentially can reduce its arsenic removal capacity. The adsorption capacity of AAFS50 can be impacted by both high levels of silica (>40 mg/L) and phosphate (>1 mg/L). The vendor recommends the system be operated in a series configuration to minimize the chance for arsenic breakthrough to impact drinking water quality.

All iron-based or iron-modified adsorptive media are of the throwaway type after exhaustion. The operations of these adsorption systems are quite similar and simple. Some of the technologies such as the E33 and GFH media have been operated successfully on large scale plants in Europe for several years.

<u>Pretreatment</u> – The adsorptive media are primarily used to remove dissolved arsenic and not for suspended solids removal. Pretreatment to remove TSS may be required if raw water turbidity is >0.3 nephelometric turbidity units (NTU). However, most well waters are low in turbidity; hence, pre-filtration is usually not required. Pre-chlorination may be required to oxidize As(III) to As(V) if the proportion of As(III) is high. No pH adjustment is required unless pH is relatively high.

<u>Maintenance</u> – Maintenance for the adsorption media system is minimal if no pretreatment is required. Backwash is required infrequently (monthly) and replacement and disposal of the exhausted media occur between 1 to 3 years, depending on average water consumption, the concentrations of arsenic and competing ions in the raw water, and the media bed volume.

<u>Waste Disposal</u> – If no pretreatment is required, there is minimal waste disposal involved with the adsorptive media system. Disposal of backwash wastewater is required, especially during startup. Regular backwash is infrequent and disposal of the

exhausted media occurs once every 1 to 3 years, depending on operation conditions. The exhausted media are usually considered non-hazardous waste.

Advantages

- Some adsorbents can remove both As(III) and As(V).
- Very simple to operate.

Disadvantages

- Relatively new technology.
- Need replacement of adsorption media when exhausted.

The adsorption media process is the most simple and requires minimal operator attention compared to other arsenic removal processes. The process is most applicable to small wellhead systems with low or moderate arsenic concentrations with no treatment process in place (*e.g.*, iron and manganese removal; if treatment facilities for iron and/or manganese removal are already in place, incorporating ferric chloride coagulation into the existing system would be a more cost-effective alternative for arsenic removal). The choice of media would depend on raw water characteristics, life cycle cost, and vendor experience. Many adsorption media are at the field-trial stage, but others are already being used in full-scale applications throughout Europe and the U.S. Pilot testing may or may not be necessary prior to implementation depending on the vendor's experience with similar water characteristics.

1.4.5.4 Coagulation/Filtration and Iron Removal Technologies

<u>Process</u> – Iron removal processes can be used to remove arsenic from drinking water supplies. Iron removal processes involve the oxidation of soluble iron and As(III), adsorption and/or co-precipitation of As(V) onto iron hydroxides, and filtration. The filtration can be accomplished with granular media filter or microfilter. When the iron in raw water is inadequate to accomplish arsenic removal, an iron salt such as ferric chloride is added to form ferric hydroxide. The iron removal process is commonly called coagulation/filtration because iron in the form of ferric chloride is a common coagulant. The actual capacity to remove arsenic during iron removal depends on a number of factors, including the amount of arsenic present, arsenic speciation, pH, amount and form of iron present, and existence of competing ions, such as phosphate, silicate, and natural organic matter. The filters used in groundwater treatment are usually pressure filters fed directly by the well pumps. The filter media can be regular dual media filters or proprietary media such as the engineered ceramic filtration media, Macrolite®, developed by Kinetico. Macrolite is a low-density, spherical media designed to allow for filtration rates up to 10 gpm per square foot (gpm/ft^2), which is a higher loading rate than commonly used for conventional filtration media.

<u>Pretreatment</u> – Pre-chlorination to oxidize As(III) to As(V) is usually required for most groundwater sources. The adjustment of pH is required only for relatively high pH

value. Coagulation with the feed of ferric chloride is required for this process. Sometimes a 5-minute contact tank is required ahead of the filters if the pH is high.

Maintenance – Maintenance basically consists of handling the ferric chloride chemical and feed system, and regular backwash of the filters. No filter replacement is required for this process.

Waste Disposal – Waste from the coagulation/filtration process is mainly the iron hydroxide sludge with adsorbed arsenic in the backwash water. The backwash water can be discharged to a public sewer if available. If a sewer is not available, backwash water can be discharged to a storage and settling tank from which the supernatant is recycled in a controlled rate to the front of the treatment system and the settled sludge can be disposed periodically to a landfill. The iron hydroxide sludge is usually not classified as hazardous waste.

Advantages

- Well established technology for arsenic removal.
- Most economical process for arsenic removal.

Disadvantages

- Need to handle chemical.
- Need to dispose of regular backwash wastewater.
- Sludge disposal.

The coagulation/filtration process is usually the most economical arsenic removal alternative, especially if a public sewer is available for accepting the discharge of backwash water. However, because of the regular filter backwash requirements, more operation and maintenance (O&M) attention is required from the utilities. Because of potential interference by competing ions, bench-scale or pilot-scale testing may be required to ensure the arsenic MCL can be met with this process alternative.

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 arsenic removal, these systems typically use small RO or iron adsorption treatment units installed “under the sink” in the case of POU, and where water enters a house or building in the case of POE. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets in order to meet regulatory requirements, making purchase and installation more expensive. POE and POU 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 largely out of the control of the PWS, it is very difficult to ensure 100 percent compliance. Prior to selection of a POE or POU program for implementation, consultation with TCEQ would be required to address measurement and determine the 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 is ultimately the responsible party when it comes to 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 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 will 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 (ANSI) issued product standards for a specific type of POU or POE treatment unit, only those units independently certified according to those standards may be used as part of a compliance strategy.

The following observations regarding usage of 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 only drink water 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 compounds (VOC) 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 the 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 at locations where customers could fill containers with drinking water. The centralized water source could be from small to medium-sized treatment units or delivered to a 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, the consumer would have to do no more than he/she currently does for a piped-water delivery system. Least desirable are those systems that require maximum effort on the part of the customer (*e.g.*, customer required to travel to get water, transport it, 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 that 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 customers 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 METHODOLOGY

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 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 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

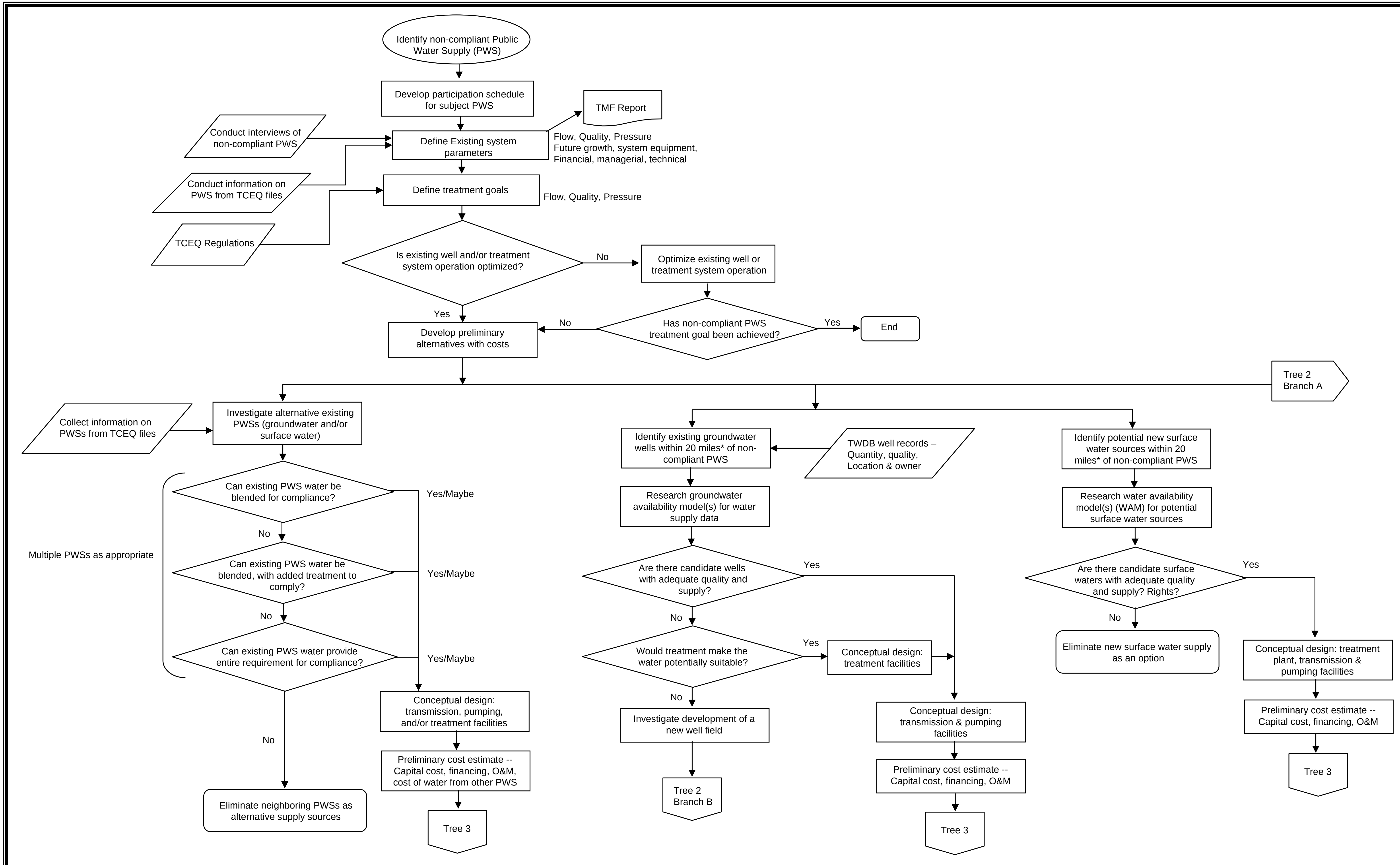


Figure 2.2
TREE 2 – DEVELOP TREATMENT ALTERNATAIVES

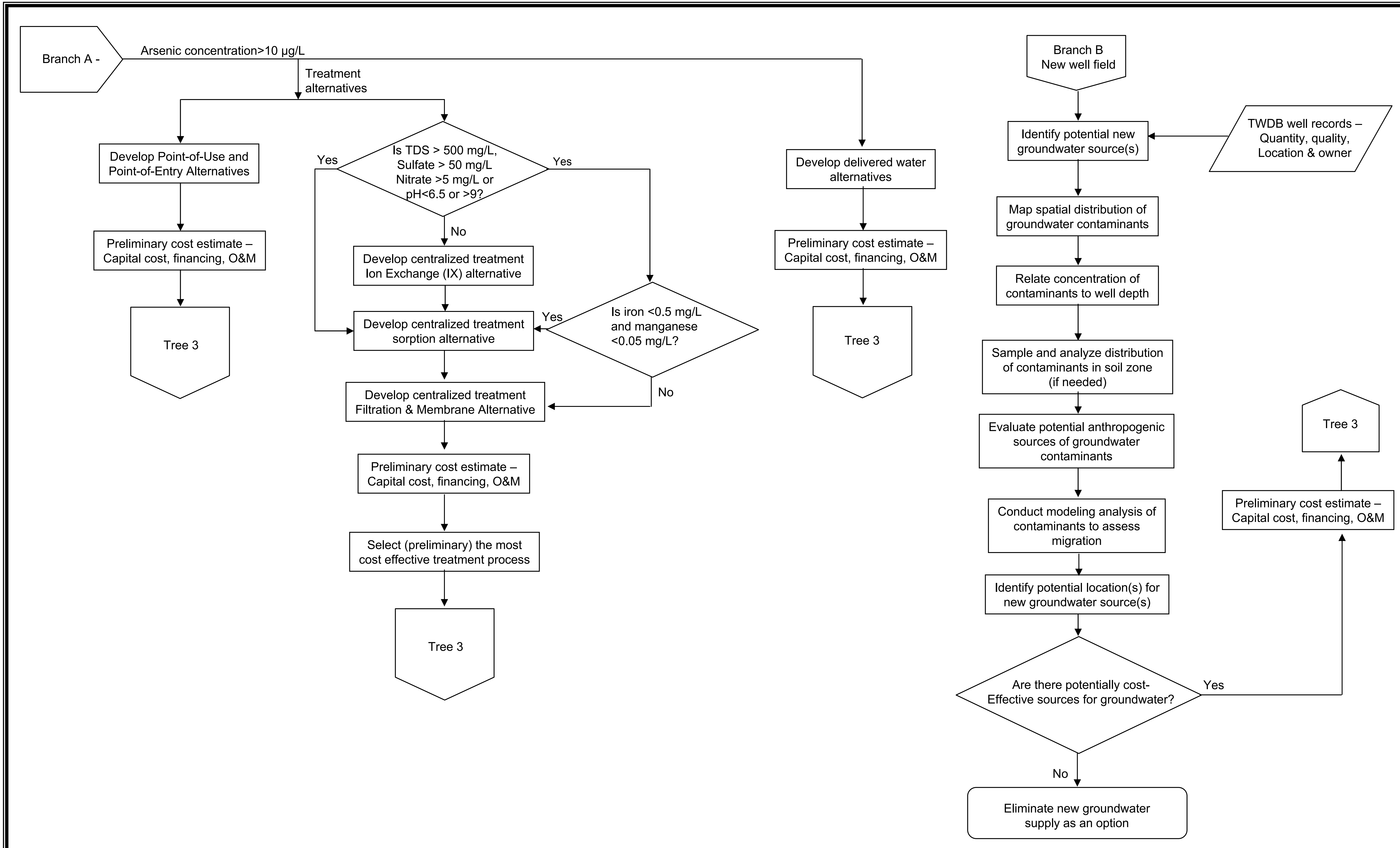


Figure 2.3
Tree 3 – PRELIMINARY ANALYSIS

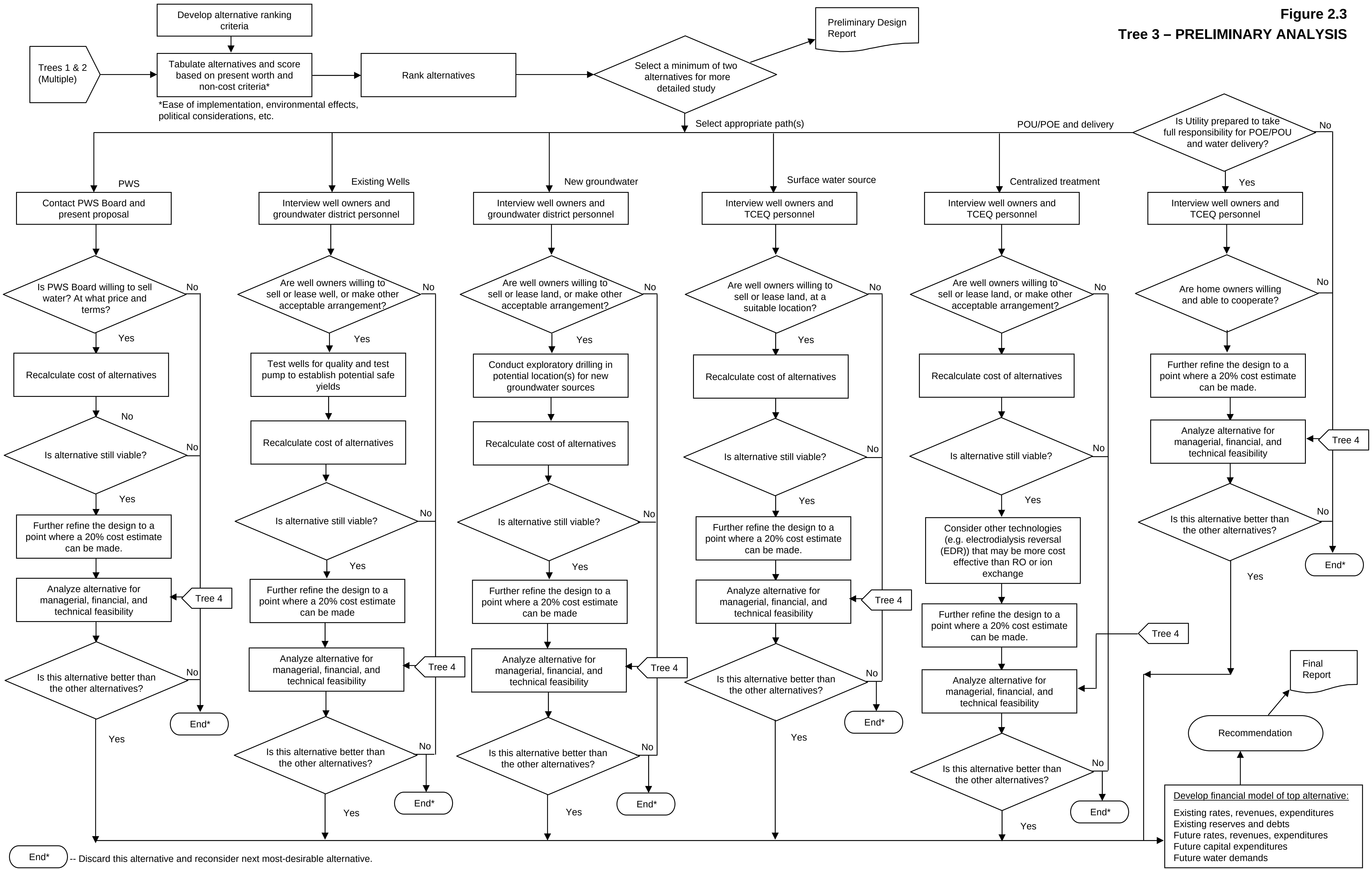
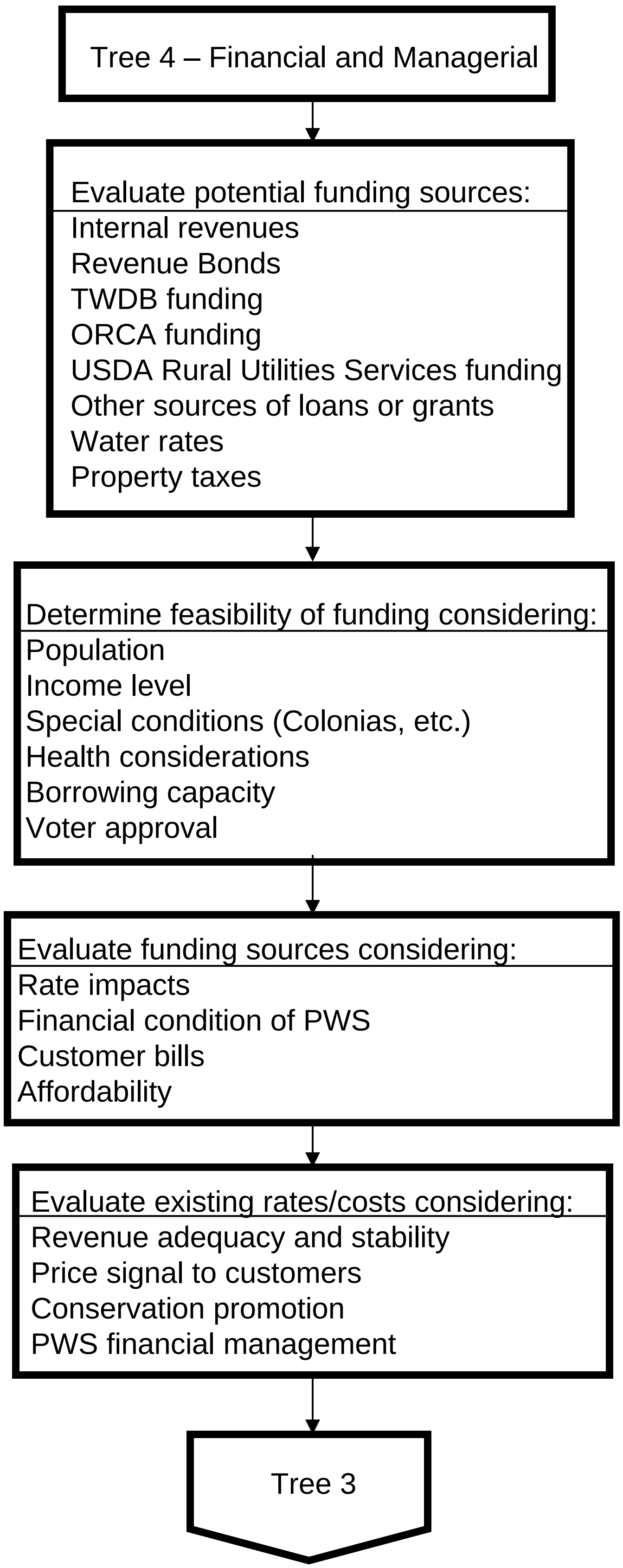


Figure 2.4
TREE 4 – FINANCIAL AND MANAGERIAL



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:

- TCEQ Water Utility Database: 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 (SDWIS): www.epa.gov/safewater/data/getdata.html.

Groundwater control districts were identified on the TWDB website, 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 flow rate, 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 northern part of the Gulf Coast 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 at the national, state, and county levels.

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 the 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 the Safe Drinking Water Act (SDWA) requirements. 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 that the system is able to achieve and maintain compliance with SDWA regulations. 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 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 who has a role in the FMT capacity of the system is asked the applicable standard set of questions individually. The interviewees are not given the questions in advance and are not told the answers others have provided. Also, most of the questions are open-ended so they do not pose a "right" or "wrong" answer. The interviews last between 45 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 are made. A technical information form was created to capture this information. This form is contained in Appendix A. This information was considered supplemental to the interviews because it could serve 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 that the preventative maintenance program was inadequate.

Following interviews and observations of the facility, answers provided by all personnel were compared and contrasted to provide a clearer picture of the true operations of 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 is asked the question, "Do you have a budget?" he or she may say, "yes" and the capacity assessor is 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 is to determine which items that were noted as a potential deficiency truly have a negative effect on the system's operations. If a system has what appears to be a deficiency, but this deficiency is not creating a problem in terms of the operations or management of the system, it is not critical and may not need to be addressed as a high priority. As an example, the assessment may reveal that there appear to be insufficient staff members to operate the facility. However, it may also be revealed that the system is able to work around this problem by receiving assistance from a neighboring system so no severe problems result 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 their storage tank. In this case, the system needs to address the reserve account issue so that proper maintenance can be completed.

The intent is to develop a list of capacity deficiencies with the greatest impact on the system's overall capacity. These are 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 development of compliance alternatives 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 have been 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 PWSs

The neighboring PWSs within approximately 15 miles of the City of Danbury were identified, and the extents of their systems were investigated. Fifteen miles was selected as the radius for the evaluation owing to the large number of PWSs in proximity to the City of Danbury. 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 development of an alternative source.

The neighboring PWSs were investigated to determine the water sources they use and the quantity of water they might have available for sale. Personnel at the PWSs were contacted to identify key locations in the 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 of the 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 for central treatment considered potentially applicable are IX, RO, adsorption, and coagulation/filtration (with an iron salt). Activated alumina and enhanced lime softening are more applicable to larger water systems because of their operational complexity and cost. For arsenic removal in small water systems, iron-based adsorption and coagulation/filtration are two of the most desirable technologies. Ion exchange and RO are more expensive, generate more wastes for disposal, and increase the amount of raw water used to produce the same amount of treated water. Hence, only the adsorption and coagulation/filtration alternatives are evaluated further.

Non-economic factors were also identified. Ease of implementation was considered, as well as 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 was to determine the financial impact of implementing compliance alternatives, primarily by examining the required rate increases, and analyzing the fraction of household income that water bills consume. The current financial situation was also reviewed to determine what rate increases were necessary for the PWS to achieve or maintain financial viability.

2.4.1 Financial Feasibility

A key financial metric is the comparison of the average annual household water bill for a PWS customer to the MHI for the area. MHI data from the 2000 census were 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 were determined for existing base conditions and included consideration of additional rate increases needed under current conditions. Annual water bills were 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 provided insight into the financial condition of any business. Three ratios are particularly significant for water utilities:

- Current Ratio = current assets divided by current liabilities provide 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 the 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 census was used as the basis for MHI. In addition to consideration of affordability, 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, correspond to census tract data.

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 was estimated and applied to the existing rate structure to estimate the annual water bill. The estimates were generated from a long-term financial planning model that detailed annual revenue, expenditure and cash reserve requirements over a 30-year period.

2.4.4 Financial Plan Development

The financial planning model used available data to establish base conditions under which the system operates. The model included, 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 a d replacements

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

2.4.5 Financial Plan Results

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

2.4.5.1 Funding Options

Results, summarized in Table 4.4, show the following according to alternative and funding source:

- Percentage that the average annual residential water bill represents of median annual household income.
- The first year in which a water rate increase will 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 were examined under a number of funding options. The first alternative examined was always funded 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 was 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 included:

- 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, as presented in Table 4.4, show the percentage of MHI represented by the annual water bill that resulted from any rate increases necessary to maintain financial viability over time. In some cases, this financial viability may require rate increases even without implementing a compliance alternative (the no action alternative). The table also shows any increases such as those separately. The results table shows the total increase in rates necessary, including both the no action alternative increase and any increase required for the alternative. For example, if the no action alternative required a 10 percent increase in rates and the results table shows a rate increase of 25 percent, then the impact from the alternative was an increase in water rates of 15 percent. Likewise, the percentage of household income in the table reflects the total impact from all rate increases.

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:

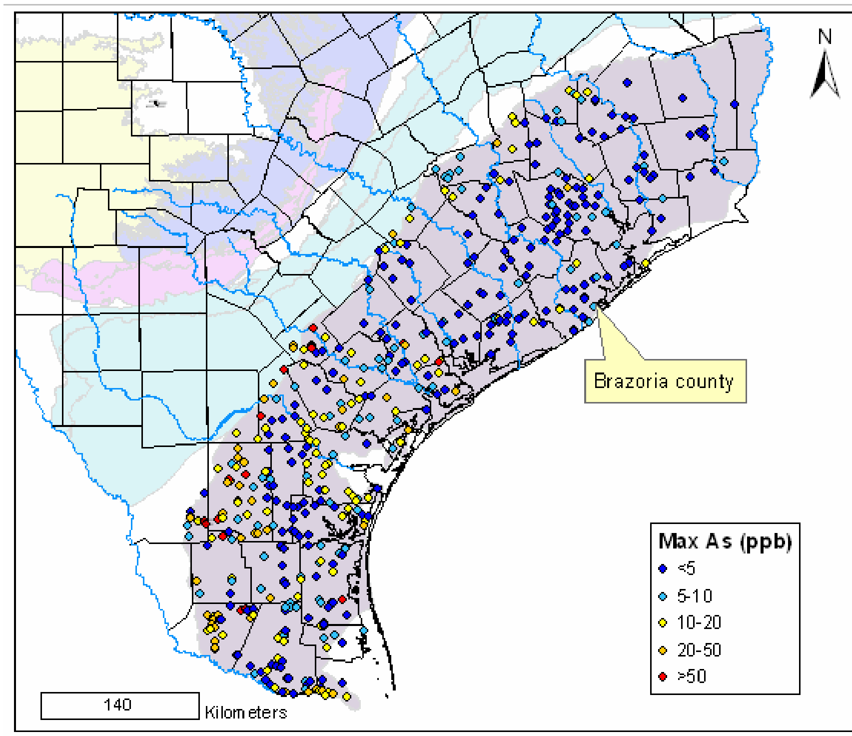
- United States Department of Agriculture, Rural Utilities Service, and
- United States Housing and Urban Development.

SECTION 3
UNDERSTANDING SOURCES OF CONTAMINANTS

3.1 ARSENIC IN THE GULF COAST AQUIFER

The Gulf Coast aquifer parallels the Texas Gulf Coast and extends from the Texas-Louisiana border to the Rio Grande. Subunits of the Gulf Coast aquifer are, from oldest to youngest, the Jasper, Evangeline, and Chicot aquifers. The aquifer is a leaky artesian system composed of middle to upper Tertiary and younger interbedded and hydrologically connected layers of clay, silt, sand, and gravel (Ashworth and Hopkins 1992). The PWS wells of concern in Brazoria County are completed in the Chicot aquifer. Figure 3.1 shows detectable arsenic concentrations in the Gulf Coast aquifer from the TWDB database, and Figure 3.2 shows arsenic concentrations from the National Geochemical Database, also known as the National Uranium Resource Evaluation (NURE) database (http://pubs.usgs.gov/of/1997/ofr-97-0492/index.html).

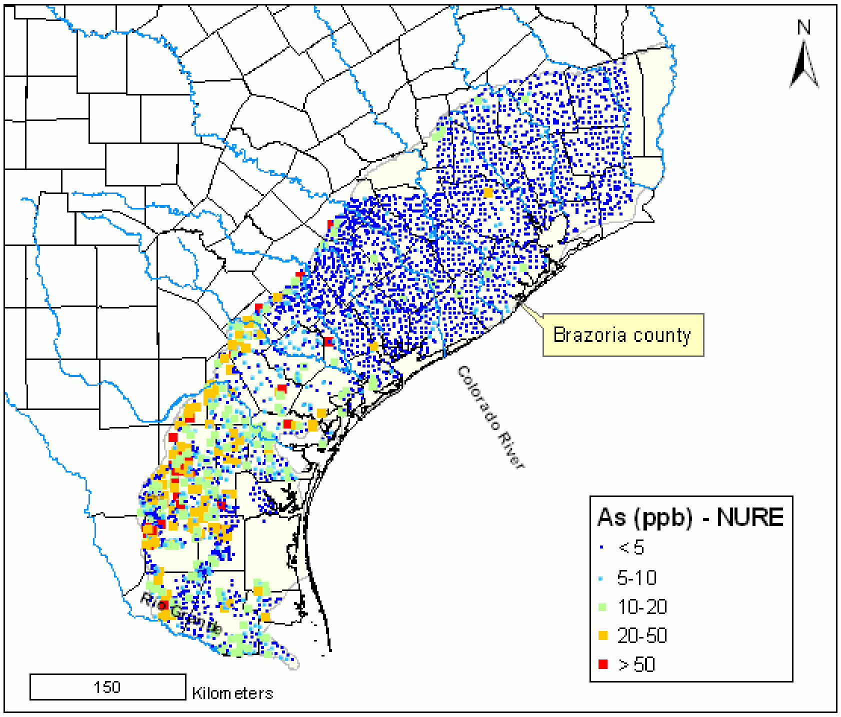
Figure 3.1 Detectable Arsenic Concentrations in Groundwater



Source: (TWDB database, analyses from 1987 through 2004)

The most recent value is shown for each well (number of samples shown is 503).

Figure 3.2 Detectable Arsenic Concentrations in Groundwater



Source: NURE database, analyses from 1976 through 1980

In the NURE database there is one sample per well (number of samples shown is 3,920).

3.2 GEOLOGY OF BRAZORIA COUNTY

Geologic units included in the Chicot aquifer are the Pleistocene formations, Willis, Lissie, and Beaumont (Doering 1935; Baker 1979). Since Pleistocene time, packages of fluvial sediments representing successively younger progradational cycles have been deposited along the Texas Gulf Coast (Blum 1992). The fluvial sediments, ranging in texture from gravel to clay, contain very little intergranular cement. The older parts of this depositional sequence are more coarse grained and dip 10 to 25 feet per mile (ft/mi) (Willis Formation), whereas the younger units are more fine grained and dip only approximately 1 ft/mi (Beaumont Formation) (Doering 1935).

The Willis Formation was first described as a formal stratigraphic unit by Doering (1935). It is red sand with minor amounts of coarse sand and gravel that unconformably overlie Pliocene-age clay layers of the Fleming Formation in the vicinity of Brazoria County. In this area, the Willis Formation has a 30- to 40-foot thick gravel layer at the base that can provide an ample supply of usable quality water. The Lissie Formation is finer grained than the underlying Willis Formation; it contains interbedded layers of light-colored, fine-grained sand, clayey sand, and sandy clay (Doering 1935). Although the Beaumont Formation as a whole is much more fine grained than directly underlying formations, it contains localized distributary channel deposits. The inclusive list of lithologies contained in the Beaumont Formation is clay, limey clay, sandy clay, clayey sand, and fine-grained sand (Doering 1935). Water wells completed in the Beaumont Formation section of the Chicot aquifer are usually no deeper than 75 to 100 feet and probably do not provide large quantities of water.

The lithology of geologic units within the Chicot aquifer is similar to that of the underlying Evangeline aquifer, which makes it difficult for drillers to determine in which aquifer they are completing water wells along the Texas Gulf Coast. The combined thickness of geologic units in the Chicot aquifer in the vicinity of Brazoria County varies among different researchers between 400 and 1,200 feet. According to Baker (1979), the maximum thickness of the entire Gulf Coast aquifer along the northern Gulf Coast is approximately 1,300 feet.

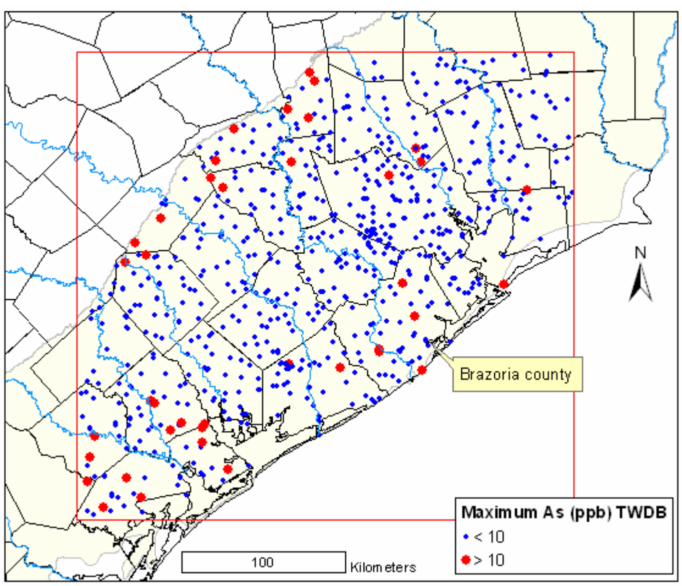
The 11 PWS wells of concern in Brazoria County are identified as being in the Chicot aquifer; completion depths are grouped around 300, 400, and 600 feet. It is possible the deeper wells are completed in the Evangeline aquifer or that screened intervals in these wells span both Chicot and Evangeline aquifers. A recognized geologic source of arsenic in groundwater is volcanic ash. Arsenic is often associated with other chemical elements such as fluoride, vanadium, molybdenum, selenium, and uranium. The association is generally seen at the subregional level, although not necessarily at the well level because of different geochemical behavior of individual elements. There are no reports of volcanic material in the geologic units that compose the Chicot aquifer. However, layers of bentonite (altered volcanic ash beds) and devitrified ash, have been recognized in some parts of the Evangeline aquifer especially in South Texas. The major geologic unit of the Evangeline aquifer in South Texas is the Goliad Formation, but it is not present in outcrops north of the Colorado River (Hoel 1982). General hydrologic patterns with upward cross-formational flow along the coast support this hypothesis. However, other sources of arsenic are also possible. Arsenic hot spots exist in older formations (Catahoula and Goliad); some of those have eroded and are now part of the Chicot aquifer sediment. Additional potential sources include upwelling of highly mineralized water from salt domes. However, the spatial mismatch between salt dome distribution and areas with high arsenic concentration, as well as the lack of correlation between chloride and arsenic concentrations, precludes such an association, as discussed later.

Using uranium and radioactivity as proxies for arsenic sources, geophysical logs in Brazoria County near the PWS wells were analyzed to assess potential linkages between geologic units and elevated arsenic concentrations. Given the common association between uranium deposits and occurrences of arsenic, it was reasonable to inspect local oilfield geophysical logs for evidence of radioactive fluids in sandstone strata at depths sufficiently shallow to potentially contact fresh groundwater. A total of 40 hydrocarbon wells were identified with geophysical well logs that had (1) recorded geophysical responses within the upper 500 feet of the subsurface; and (2) latitude/longitude coordinates. Of these wells, 17 were selected on the basis of proximity to the aforementioned PWS wells. Among these 17 hydrocarbon wells, only one provided the gamma ray and resistivity logs necessary for analysis. Wells range in depth between 295 and 625 feet and are completed in the Chicot aquifer. Only one well log for the area recorded sufficiently shallow data and also showed gamma ray and resistivity responses necessary to detect radioactively elevated pore fluids in the geologic section. The well is the Kilmarovo Jamison located at west longitude 95.3483° and north latitude 29.2586°. The nearest PWS wells are operated by the City of Danbury a few miles to the south of the logged well. Elevated gamma ray values greater than 150 American Petroleum Institute (API) units occurred in sandstone beds with resistivities greater than 10 ohms at 1,520- to 1,550 foot depths in the Jamison well. An additional bed containing fluids with elevated radioactivity occurred at the depth of approximately 177 feet. Both of these stratigraphic intervals dip toward the south and are, therefore, at greater depths in more southerly locations. The City of Danbury PWS wells are completed at depths of 295 to 304 feet. Unless groundwater flow is upward between excessively radioactive strata contacted by the Jamison well and the Danbury PWS wells, it appears unlikely that radioactive fluids and associated ionic constituents, including possible arsenic, would contact the Chicot aquifer in the Danbury area.

3.3 GENERAL TRENDS IN ARSENIC CONCENTRATIONS

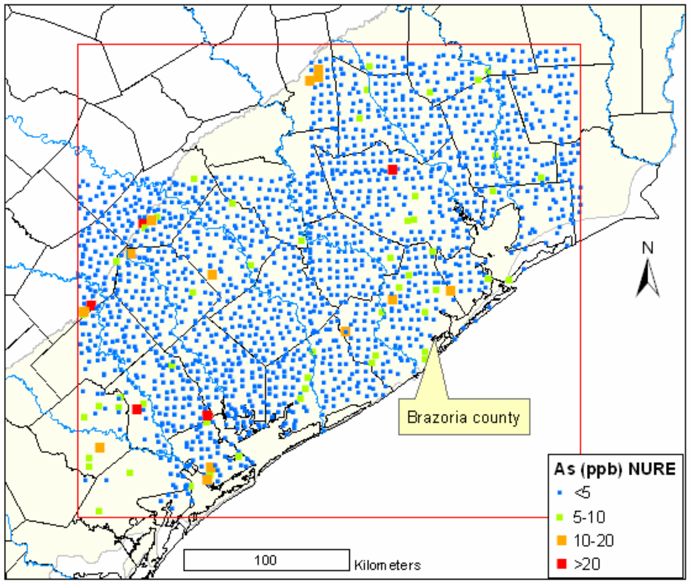
The geochemistry of arsenic is described in Appendix E. A general analysis of arsenic trends in the vicinity of Brazoria County was conducted to assess spatial trends, as well as correlations with other water quality parameters. Arsenic measurements from the TWDB database, the TCEQ database, and from a subset of the National Geochemical Database, also known as NURE (National Uranium Resource Evaluation) database, were used to assess arsenic trends. Figures 3.3 and 3.4 show spatial distribution of arsenic concentrations from TWDB (Figure 3.3) and NURE (Figure 3.4) databases.

Figure 3.3 Spatial Distribution of Arsenic Concentrations



Source: TWDB database

Figure 3.4 Spatial Distribution of Arsenic Concentrations

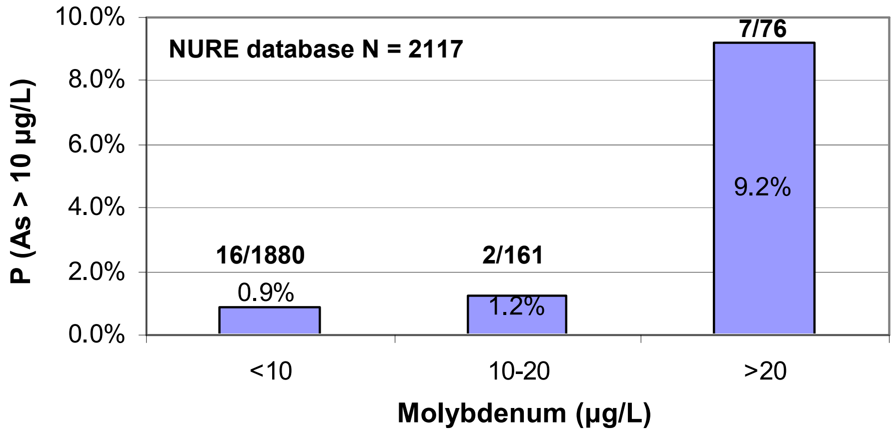


Source: NURE database

The databases were queried in an area delineated by the following coordinates: bottom left, -97.45, 28.18; top right, -94.30, 30.64. Seven hundred thirty measurements were extracted from the TWDB database. Measurements representing the most recent arsenic measurement taken at a specific well, and wells not in the Gulf Coast aquifer were excluded. The NURE database contained 2,118 groundwater (sample type 03) arsenic measurements within the defined boundary. Because the wells have no aquifer identifier, no measurements were excluded.

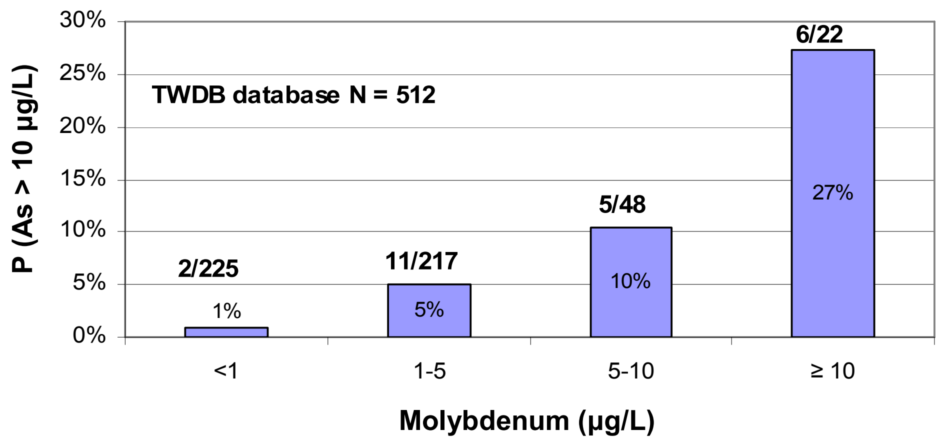
Relationships between arsenic and well depth, pH, SO_4, fluoride, chloride, TDS, dissolved oxygen, phosphorus, iron, selenium, boron, vanadium, uranium, and molybdenum, were evaluated using data separately from the NURE and TWDB databases. Correlations between arsenic concentrations and most parameters were weak (r square values < 0.1); the highest correlation was found between arsenic and molybdenum. The relationship between the probability of arsenic > 10 µg/L and molybdenum concentration levels is shown for the NURE (Figure 3.5) and TWDB (Figure 3.6) databases.

Figure 3.5 Relationship Between Arsenic and Molybdenum



Source: NURE database

Figure 3.6 Relationship Between Arsenic and Molybdenum

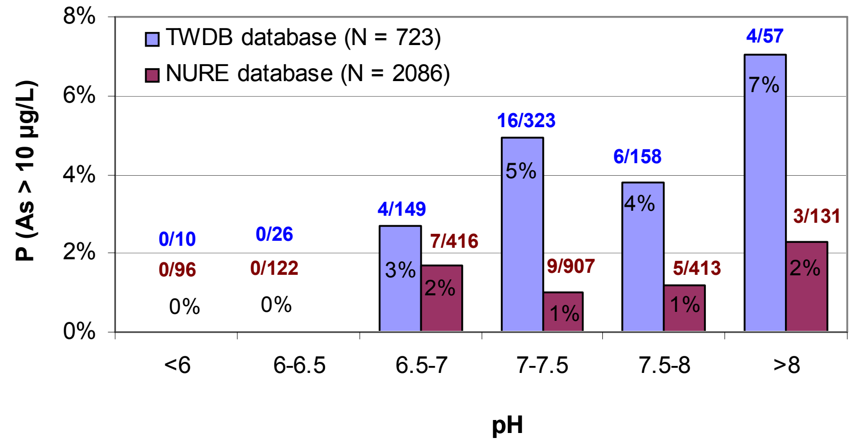


Source: TWDB database

N represents the number of measurements used from each database. Numbers on top of the graph columns show the number of arsenic measurements exceeding 10 µg/L and total number of measurements in each bin. For example, "7/76" in the bin of molybdenum > 20 means that seven of 76 arsenic measurements were greater than 10 µg/L.

Elevated arsenic concentrations and pH are also related (Figure 3.7). The absence of high arsenic concentrations (>10 µg/L) at pH less than 6.5 is notable.

Figure 3.7 Relationship Between High Arsenic Concentrations and pH

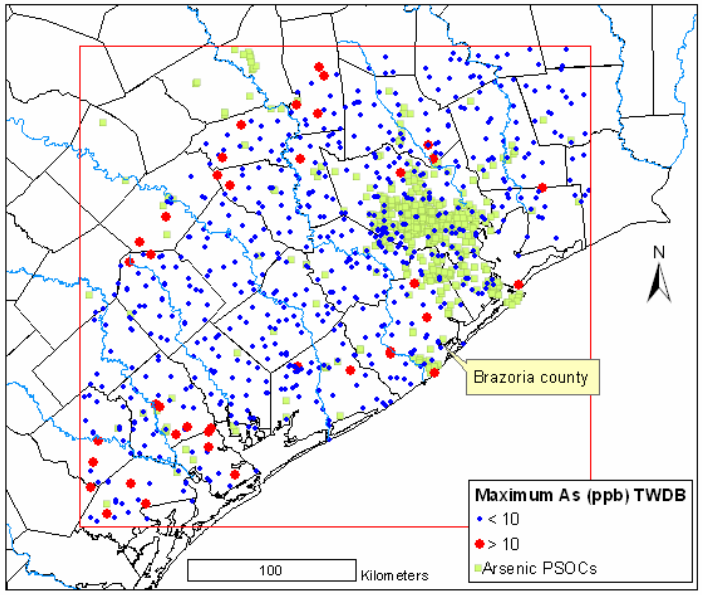


Correlations between arsenic, molybdenum, and pH suggest natural sources of elevated arsenic in Brazoria County; however, data are insufficient to make this conclusion definitively.

3.4 ARSENIC AND POINT SOURCES OF CONTAMINATION

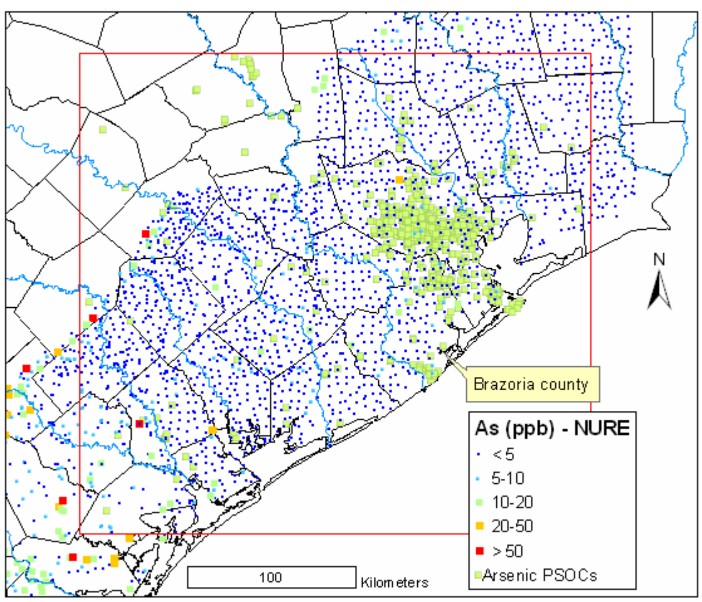
Information regarding the location of potential source of contamination (PSOC) is collected as part of the TCEQ Source Water Assessment Program (SWAP). Arsenic concentrations from TWDB (Figure 3.8) and NURE (Figure 3.9) databases were compared with PSOC coverage. A density map of PSOCs was generated (number of PSOCs per square kilometer), and PSOC density values were compared with arsenic concentrations from the NURE database.

Figure 3.8 Potential Sources of Arsenic Contamination and Arsenic Concentrations



Source: TWDB database

Figure 3.9 Potential Sources of Arsenic Contamination and Arsenic Concentrations



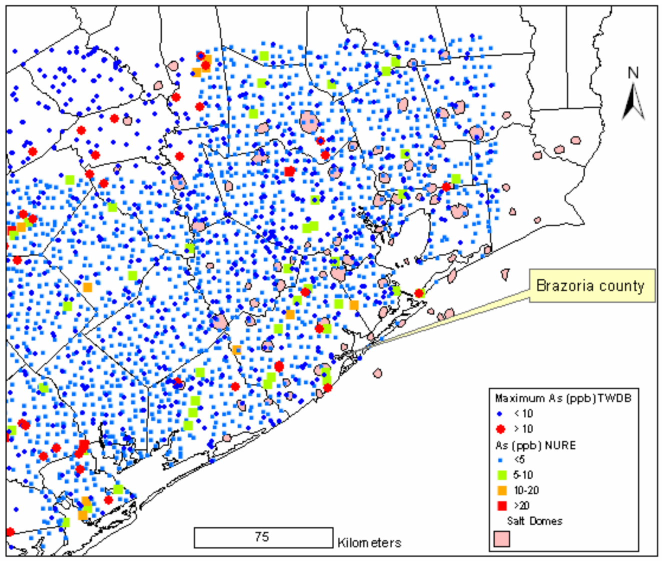
Source: NURE database

No correlation was found between high arsenic concentrations and density of potential sources of contamination, strengthening the conclusion that sources of arsenic in this area are natural.

3.5 SALT DOMES

Elevated arsenic concentrations were not correlated with salt dome locations (Figure 3.10).

Figure 3.10 Salt Dome Locations and Arsenic Concentrations

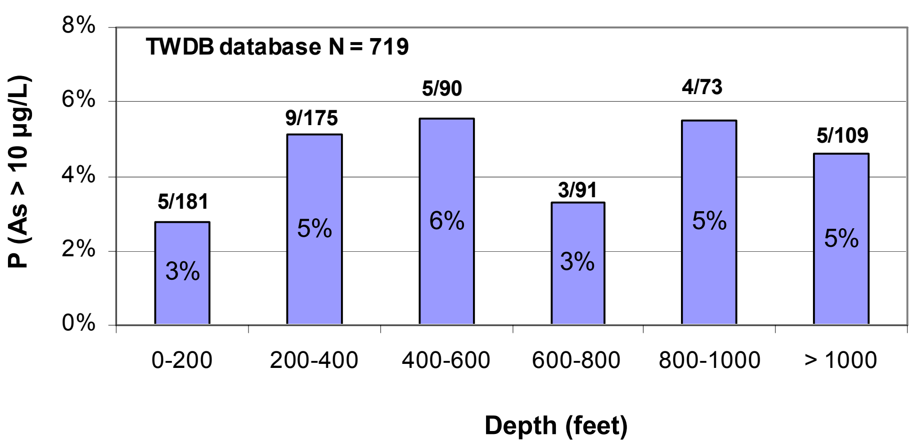


Source: TWDB and NURE databases

3.6 CORRELATION WITH DEPTH

Arsenic concentrations were compared with well depth in an attempt to assess relationships between elevated arsenic concentrations and specific stratigraphic units (Figure 3.11). Data do not show a definite correlation between arsenic levels and well depth. Lack of geologic descriptions and geophysical logs makes it difficult to further evaluate relationships between arsenic concentrations and depth distributions of geologic units.

Figure 3.11 Relationship Between Arsenic Concentrations and Well Depth



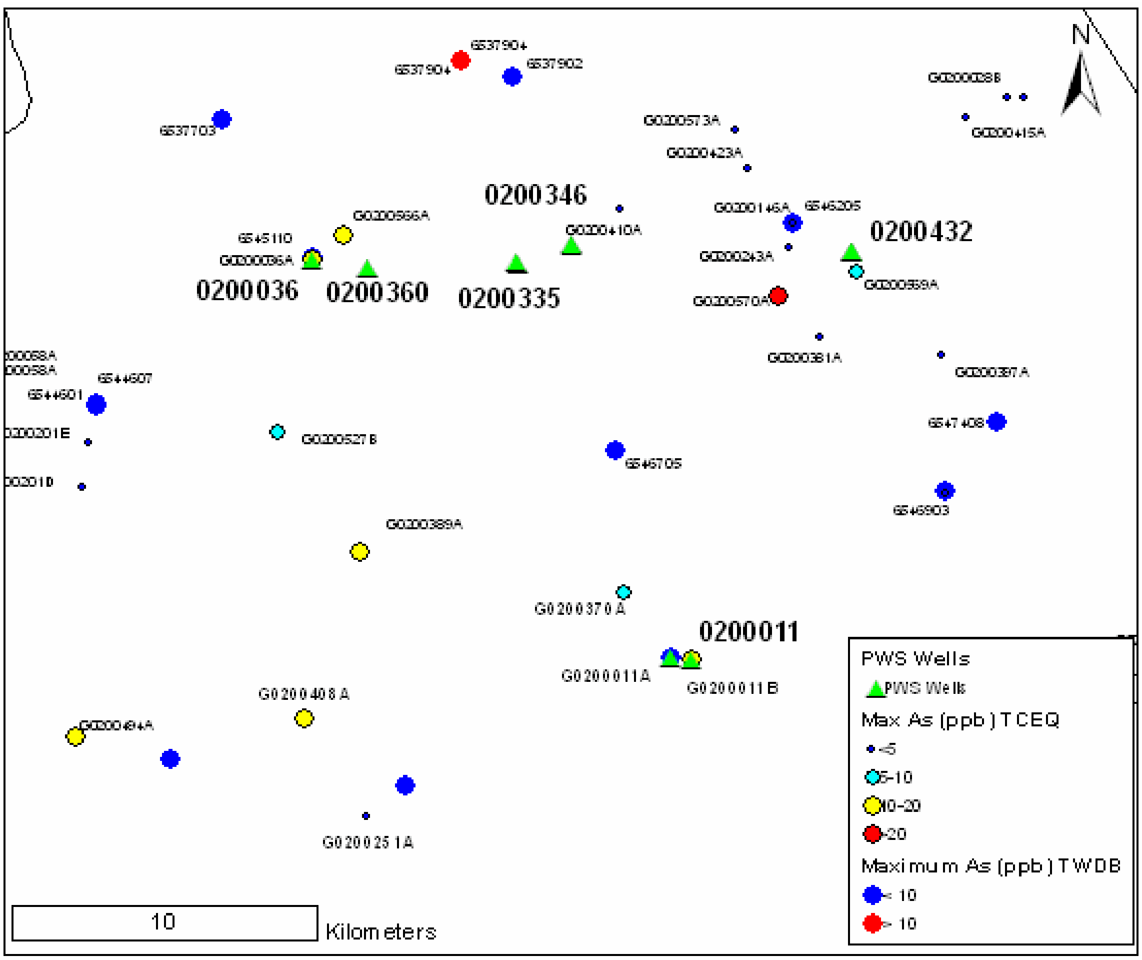
The most recent sample was used for each well. N represents total number of wells in the analysis (719), and numbers above each column represent number of arsenic measurements > 10 µg/L and total number of analyses in the bin. For example, 5/181 represents five samples > 10 µg/L out of 181 analyses at a well depth between 0 and 200 feet.

3.7 DETAILED ASSESSMENT

3.7.1 General Study Area

There are eight wells with arsenic samples > 10 µg/L near the assessed PWS wells, seven from the TCEQ database, and one from the TWDB database (Figure 3.12). Samples from the TCEQ PWS database include only those that could be related to a specific well.

Figure 3.12 Arsenic Concentrations in the Vicinity of PWS Wells



Arsenic samples are from TWDB and TCEQ databases. The maximum arsenic concentration is shown for each well. PWS wells from the TCEQ database include two types of samples: raw (related to a single well), and entry point (taken from a single entry point related to a single well). Table 3.1 details well and screen depths of PWS wells with high arsenic concentrations (> 10 μg/L).

Table 3.1 Maximum and Minimum Arsenic Concentrations

Water source	Max.-Min.-No. of As samples (□g/L)	Well depth (feet)	Screen depth (feet)	Geology	Source
G0200494A	16.7-14.2-2	419	399-419	NA	TCEQ
G0200011B	11.3 – 6.0 -2	235	160 - 230	NA	TCEQ
G0200036A	14.8 – 9.2 – 3	324	307-323	NA	TCEQ
G0200566A	10.3 - 9.4 – 4	310	NA	NA	TCEQ
G0200389A	11.7 – 8.3 – 2	374	NA	NA	TCEQ
G0200408A	10.6- 10.6 – 1	400	NA	NA	TCEQ
G0200570A	55.2-8-3	740	710-740	NA	TCEQ
6537904	16-16-1	400	NA	NA	TWDB

Well depths range from 235 to 740 feet, and wells are screened between 160 and 740 feet. These large ranges in depth make it difficult to make a definitive statement regarding local correlation of arsenic with well or screen depth. Lack of geologic descriptions of these wells also prohibits a more comprehensive evaluation of relationships between arsenic concentrations and geology.

3.7.2 The City of Danbury

Two wells are in this water supply system: G0200011A and G0200011B. Well G00200011A has a depth of 304 feet and is screened at between 267 and 298 feet. Well G0200011B is 235 feet deep and screened between 160 and 230 feet. Table 3.2 summarizes arsenic concentrations measured at the PWS.

Table 3.2 contains six arsenic measurements from the TCEQ database, between 1997 and 2005, and three from the TWDB database between 1992 and 2001. All high arsenic levels were detected in Well 11B or from point of collection (POC) 2, which is related to Well 11B. Samples taken only from Well 11A (two samples) had arsenic levels of 2.4 μg/L and 2.8 μg/L, suggesting that Well 11B is the source of high arsenic levels in the water supply. Figure 3.13 shows arsenic concentrations measured at wells in 5- and 10-km buffers of PWS wells.

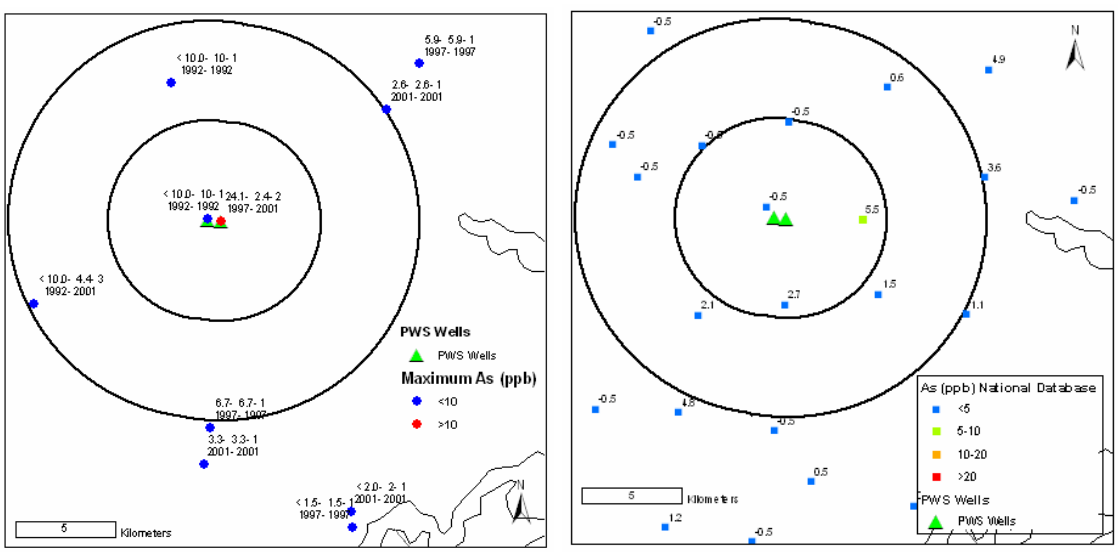
Based on these data, the possibility that one of the wells may produce compliant water is significant and should be verified through sampling. If one of the wells is found to produce compliant water, as much production as possible should be shifted to the compliant well. The wells should be compared in terms of depths and well logs to try and identify differences that could be responsible for the elevated concentration of arsenic. If blending of water from the existing wells cannot produce a sufficient quantity of compliant water, it may be possible to install a new well similar to the existing compliant well that also would provide compliant water.

Table 3.2 Arsenic Concentrations in the City of Danbury PWS

Date	POC 1 (Well G0200011A)	POC 2 (Well G0200011B)	As (µg/L)	Source
8/20/1997	1	2	10.5	TCEQ
11/6/2003	1		2.8	TCEQ
2/11/2003	1	2	14.0	TCEQ
2/29/2000	1		2.4	TCEQ
4/14/2005		2	6.0	TCEQ
11/6/2003		2	11.3	TCEQ
3/18/1992	G0200011A		< 10	TWDB
3/27/1997		G0200011B	24.1	TWDB
7/12/2001		G0200011B	2.36	TWDB

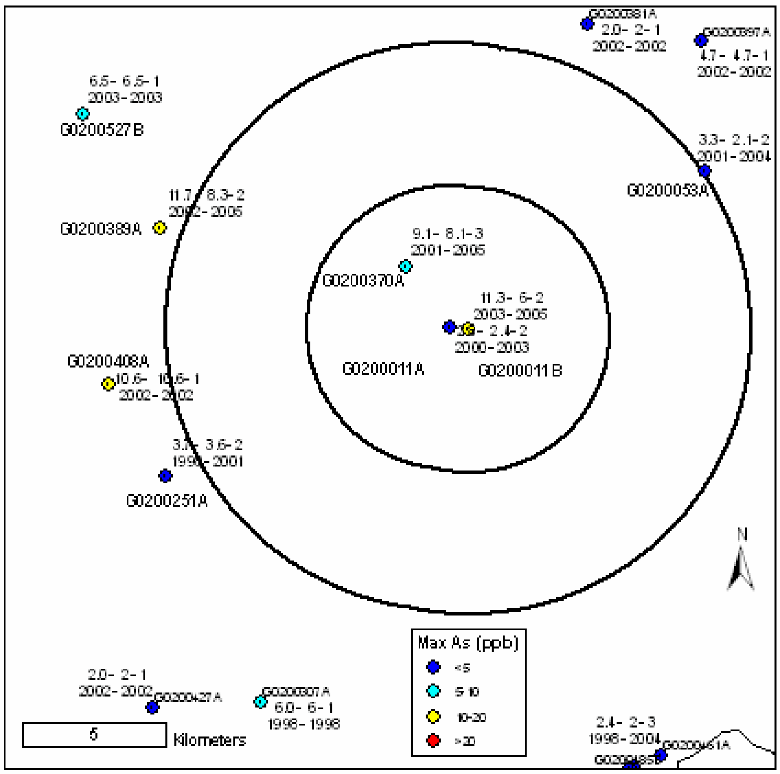
Source: TCEQ and TWDB databases

Figure 3.13 Arsenic Concentrations in 5- and 10-km Buffers of the City of Danbury PWS Wells (TWDB and NURE Databases)



The left figure shows arsenic concentrations from the TWDB database. Wells are symbolized by maximum concentrations, and labels show the maximum, minimum, and number of samples, as well as first and last sample year. Values from the NURE database were taken between 1976 and 1980. Negative values are less than the detection limit (0.5 µg/L). Except for the assessed well (G0200011B), arsenic measurements from the TWDB and NURE databases in the 5- and 10-km buffers around the wells do not show levels exceeding 10 μg/L, and only one measurement exceeds 5 μg/L. In addition to the TWDB and NURE databases, samples from the TCEQ PWS database were analyzed (Figure 3.14).

Figure 3.14 Arsenic Concentrations in the 5- and 10-km Buffers of the City of Danbury PWS Wells (TCEQ Database)



Source: TCEQ database

Samples from the TCEQ PWS database showed more wells with elevated arsenic concentrations. Two types of samples were used in the analysis: raw (related to a single well) and entry-point samples (taken from a single entry point related to a single well). Table 3.3 details arsenic concentrations, well depth, and screen depths of wells in 5- and 10-km buffers of PWS wells.

Table 3.3 Maximum and Minimum Arsenic Concentrations in the 5- and 10-km Buffers of the City of Danbury PWS

Water source	Max.-Min.-No. of As samples (μg/L)	Well depth (feet)	Screen depth (feet)
G0200011A	2.8 – 2.4 – 2	304	267 -298
G0200011B	11.3 – 6.0 -2	235	160 – 230
G0200053A	3.3 – 2.1 – 2	221	101 – 111
G0200370A	9.1 – 8.1 – 3	204	189 – 204
G0200389A	11.7 – 8.3 – 2	374	NA
G0200408A	10.6- 10.6 – 1	400	NA
G0200251A	3.7- 3.6 -2	150	NA

Source: TCEQ database
No information on geologic units is available for these wells

Wells in blue are assessed PWS wells, and wells in red are those with arsenic concentrations greater than 10 μg/L. Two wells with relatively high arsenic concentrations (G0200011B and G0200370A) are screened between 160 and 230 feet. Other wells with elevated arsenic concentrations (G0200389A and G0200408A) do not have screen depth information.

SECTION 4
ANALYSIS OF THE CITY OF DANBURY PWS

4.1 DESCRIPTION OF EXISTING SYSTEM

4.1.1 Existing System

The City of Danbury PWS is shown in Figure 4.1. The water sources for this community water system are two wells, completed in the Chicot aquifer (Code 112CHCTU), that are both approximately 300 feet deep and have a total production 0.878 mgd. Arsenic concentrations have been detected between 2.4 µg/L and 14 µg/L, with two results since 2003 exceeding the future MCL of 10 µg/L. While a recent result for nitrate of 20 mg/L was in excess of the 10 mg/L MCL, nitrate has not been a typical issue for the City of Danbury. The system has also experienced some issues with the presence of manganese, with one recent sample showing levels of 54 µg/L, which is slightly in excess of the SMCL of 50 µg/L. Typical TDS concentrations are in the range of 650 to 675 mg/L.

Well #1 is located at Avenue F and 6th Street, while Well #2 is located at Avenue D and 2nd Street. The water is chlorinated using chlorine gas and treated with polyphosphate before being transferred to a ground storage tank (0.10 million gallon capacity). Water is then pumped to an elevated storage tank (0.15 million gallon capacity) before entering the distribution system.

The treatment techniques employed are not appropriate or effective for the removal of arsenic, so optimization is not expected to be effective for increasing arsenic removal. However, there is a potential opportunity for system optimization to reduce arsenic concentrations. The system has two wells and the evaluation in Chapter 3 (Section 3.7.2) suggests that one of these wells might produce water with acceptable arsenic levels. This should be verified through further sampling and, if it is confirmed, as much production as possible should be shifted to the compliant well. It may also be possible to identify arsenic-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: 1,650
- Connections: 638
- Average daily flow: 0.213 mgd
- Total production capacity: 0.878 mgd
- Typical nitrate range: 0.01 to 0.02 mg/L (there was one recent result of 20.9 mg/L)
- Typical arsenic range: 2.4 µg/L to 14 µg/L
- Typical manganese range: 11 µg/L to 54 µg/L

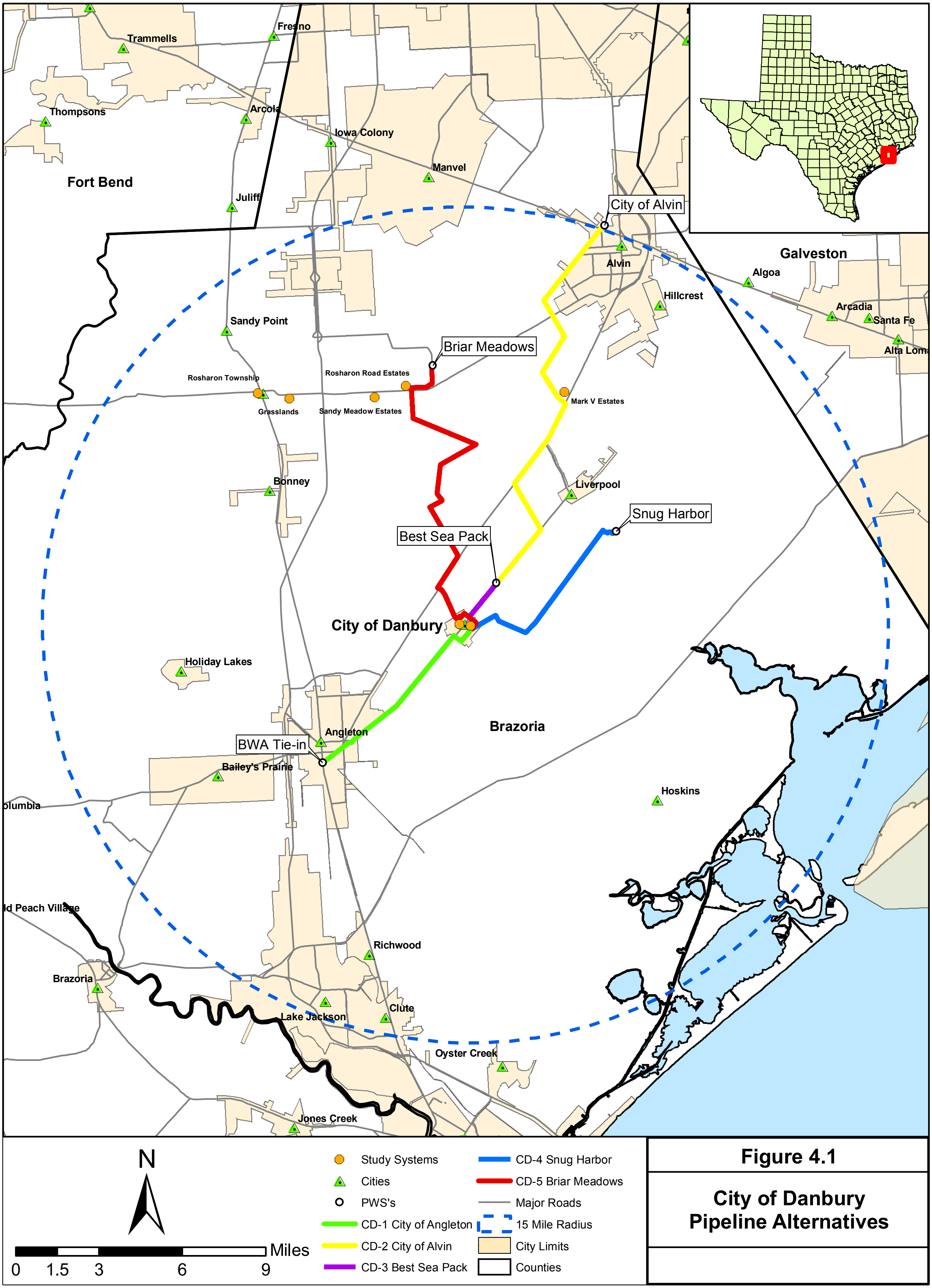


Figure 4.1

City of Danbury Pipeline Alternatives

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4.1.2 Capacity Assessment for the City of Danbury

The following personnel involved with the City of Danbury PWS were interviewed:

- Melinda Strong and Ken Walters, City Councilors.
- Jennie Broggs, City Secretary.
- Roger Thomas, Director of Public Utilities.
- Sherry Summers, Utilities and Court Clerk.

All interviews were conducted in person.

4.1.2.1 General Structure

The City of Danbury is a municipal water system. The City has a mayor and a City Council who provide managerial and financial oversight of the system. There is a chief operator who also acts as the Public Works Director, and who manages and operates the system on a daily basis. The chief operator has two assistants who assist in O&M of the system. There are two office staff members who handle billings and collections, answer phone calls, and type the budgets.

The water system has approximately 638 connections to serve the entire City population of 1,650 people. The system is fully metered and is supplied by groundwater.

4.1.2.2 General Assessment of Capacity

The capacity of the system appears to have significantly improved since 2004 with the hiring of new office and operational staff. While the system still needs some improvements, the City is moving in the right direction. Overall, the system had an adequate level of capacity.

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 those activities can be continued or strengthened. In addition, these positive aspects can assist the system in addressing the capacity deficiencies or concerns. As an example, this particular system has a very dedicated staff who are willing to learn new activities or approaches. This characteristic can be relied upon in addressing the deficiencies. The factors particularly important for the City of Danbury are listed below.

- **Dedicated Staff –** The office staff and chief operator are extremely dedicated to the system and are willing to work hard to address past problems. The system has made many improvements since new staff members were hired. The office staff is also interested in learning about the water system and routinely drive around the system looking for problems. In addition, staff members are working on cross-training so more than one person knows how to perform particular tasks.

- **Communication –** There is excellent communication among the staff. There is a safety meeting each morning and staff members meet regularly over breakfast and lunch to discuss issues.
- **Maintenance –** There is a good preventative maintenance program in place. The storage tanks are assessed daily and inspected once per year. In addition, there is a flushing program in place where lines are flushed once per week to keep problems to a minimum. Staff members advise customers not to wash clothes on the days the system is flushed in an attempt to minimize problems.
- **Subsidy Transparency –** The rates include a subsidy for seniors. The cost of this subsidy was openly discussed and presented to the mayor and City Council to ensure transparency in the rate process. When it was approved, the implications of the subsidy were well understood.

4.1.2.4 Capacity Deficiencies

The following capacity deficiencies were noted in conducting the assessment.

- **Budgets and Rates –** There is no separate budget for the PWS. There are two budgets for the City: one for general expenditures and one for utilities. In addition, debt service is lumped into a single fund along with all other City debt service. Tax payments and some revenue go toward debt service, but it is difficult to determine the balance between water debt service and water revenues. These practices make it difficult to determine if the utility is self-sufficient. Also, rates are set less on the basis of what the PWS truly needs to cover its costs and more on the basis of comparisons to other water system rates in the area. In addition, there is only one reserve account rather than separate accounts for capital improvements, emergencies, debt service, *etc*.
- **Long-term Planning –** The PWS does not practice long-term capital improvements planning and, consequently, the PWS is not determining future needs or including those needs in their rates. The lack of a reserve account for future capital expenditures is also a problem. If funds were collected, there would need to be a separate reserve account to hold those funds for future needs.
- **Past Construction Problems –** There were problems with recent construction projects. In one case, new water lines were placed in the street, but owing to conflicts between the City and the contractor, the old water lines were never taken out of service. Now there are two active sets of lines in the street and two sets of fire hydrants. This situation means that the old, leaking lines are still in service so overall system losses have not improved, nor can the system take advantage of the fact that it has put in new lines.
- **Water Losses –** The system does not have a program to measure or manage water system losses. They do not perform leak tests or water audits of any

type. This particular issue may be of even greater importance given the past construction issues noted above (*i.e.*, the double lines running in the street).

4.1.2.5 Potential Capacity Concerns

The following items were concerns regarding capacity though there are no particular operational, managerial, or financial problems that can be attributed as the cause of these items. The system should focus on the deficiencies noted above in the capacity deficiency section. Addressing the items listed below will help in further improving technical, managerial, and financial capabilities.

- **Source Water Protection –** The system has not implemented any type of source water protection program.
- **Administrative Training** - There is little to no administrative training provided for the office staff; training is all performed on the job. Additional training would help.
- **Staffing –** The system is running adequately with limited staff. However, the system could use additional staff members to relieve the burden of the front office staff and operational personnel. Currently the budget does not support additional staff members. However, if the budget and long-term planning issues discussed above are addressed, it may be possible to budget for additional staff in the future.
- **Written Procedures –** There are no written procedures for operational staff. At this time, staff members know what tasks need to be done and are able to operate the system without written procedures. However, if the personnel leave or if additional personnel are hired, the lack of written procedures may cause problems.

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 the City of Danbury 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 consideration as alternative sources, while those without identified water quality issues were investigated further. If it was determined that these PWSs had excess supply capacity and might be willing to sell the excess, or might be a suitable location for a new groundwater well, the system was taken forward for further consideration.

Table 4.1 lists the existing public water supply systems within approximately 15 miles of the City of Danbury. Fifteen miles was selected as the radius for the evaluation owing to the large number of PWSs in proximity to the City of Danbury.

Table 4.1
Existing Public Water Systems within 15 Miles of the City of Danbury

System Name	Dist. from Danbury	Comments/ Other Issues
Wolf Glen Water System	2 miles	WQ issues: Fe, Mn, TDS.
Best Sea Pack, Inc.	2 miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well. **Evaluate further**.
Brazoria Co. Detention Ctr. #2	3½ miles	WQ issues: As.
Angle Acres Water System	6 miles	WQ issues: Fe, Mn.
Beechwood Subdivision	6 miles	WQ issues: Fe, Mn.
City of Angleton/Brazosport Water Authority	6 miles	The City purchases supplemental treated water from BWA. BWA has excess capacity and is willing to sell. There is an 18-inch BWA main to north of city. **Evaluate further**.
City of Liverpool	6½ miles	WQ issues: As.
Snug Harbor Subdivision	6½ miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well. **Evaluate further**.
Anchor Rd Mobile Home Pk	7 miles	WQ issues: Fe, Mn.
Weybridge Subdivision WS	7½ miles	WQ issues: Mn.
Oak Manor MUD	7½ miles	WQ issues: As, Mn.
Wilco Water Co.	7½ miles	WQ issues: Fe, Mn.
Bayou Shadows WS	8 miles	WQ issues: As, Mn.
Anglecrest Subdivision	8½ miles	WQ issues: Mn.
Sandy Meadows Estates	9 miles	WQ issues: As, Mn.
Rosharon Road Estates	9 miles	WQ issues: As, Mn.
Mark V Estates	9 miles	WQ issues: As.
Oak Bend Estates	9½ miles	WQ issues: Mn.
Briar Meadows	9½ miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well. **Evaluate further**.
Town of Holiday Lakes	10 miles	WQ issues: Fe.
Grasslands	10½ miles	WQ issues: As.
Demi John Place WS	10½ miles	WQ issues: Fe, Mn.
Wood Oaks Water Works, Inc.	10½ miles	WQ issues: Mn.
3 Bridges RV Park	10½ miles	WQ issues: Fe, Mn.
Brazoria County Airport	10½ miles	WQ issues: Fe.
Oak Meadows Estates	11 miles	WQ issues: As.
Rosharon Township	11 miles	WQ issues: As.
Schlumberger Reservoir Comp	11½ miles	WQ issues: As, Mn.
Oak Ridge Mobile Home Pk.	11½ miles	WQ issues: Fe, Mn.
Shady Oaks MHP	11½ miles	WQ issues: Fe, Mn.
Brazoria Co. Parks, Resoft Pk.	12½ miles	WQ issues: As.
TDCJ ID Retrieve Unit	12½ miles	WQ issues: Fe.
Calico Farms Subdivision	12½ miles	WQ issues: Mn.
Ashley Oaks Mobile Home Pk.	12½ miles	WQ issues: Mn.
TDCJ ID Ramsey Area	13 miles	WQ issues: Fe.
City of Richwood	13 miles	WQ issues: Fe, Mn.
City of Hillcrest Village	13½ miles	Insufficient excess capacity though, based on WQ data, this PWS may provide a suitable location for a new well. However, there are two other closer locations that will be investigated for this alternative.
City of Lake Jackson	14 miles	Purchases supplemental treated water from BWA. See above for details on BWA.
Country Acres Estates	14 miles	WQ issues: Mn.
City of Clute	14½ miles	Purchases supplemental treated water from BWA. See above for details on BWA.
TDCJ ID Darrington Unit	14½ miles	No excess capacity.
Willow Wood Duplex	14½ miles	WQ issues: Mn.
City of Alvin	15 miles	Has excess capacity and is willing to sell. **Evaluate further**.

Based upon the initial screening summarized in Table 4.1 above, five alternatives were selected for further evaluation. These are summarized in Table 4.2.

Table 4.2
Public Water Systems within 15 miles of the City of Danbury
Selected for Further Evaluation

System Name	Pop	Conn	Total Production (mgd)	Ave Daily Usage (mgd)	Approx. Dist. from Danbury	Comments/ Other Issues
City of Danbury	**1,650**	**638**	**0.878**	**0.213**	**n/a**	**n/a**
Best Sea Pack, Inc.	30	1	0.345	Nd	2 miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well.
City of Angleton/Brazosport Water Authority	19,167	6,389	5.112	1.910	6 miles	The City purchases supplemental treated water from BWA. BWA has excess capacity and is willing to sell. There is an 18-inch BWA main to north of city.
Snug Harbor Subdivision	84	28	0.077	Nd	6½ miles	No excess capacity. However, based on WQ data, this PWS may provide a suitable location for a new well.
Briar Meadows	111	37	0.101	Nd	9½ miles	Not sufficient excess capacity for City of Danbury. However, based on WQ data, this PWS may provide a suitable location for a new well.
City of Alvin	17,916	5,972	8.739	1.307	15 miles	Has excess capacity and is willing to sell treated water.

nd – no data

4.2.1.1 Best Sea Pack, Inc.

Best Sea Pack, Inc. is located approximately 2 miles northeast of the City of Danbury and is a privately owned industrial facility that produces ice for shrimp packing. The system is supplied by a single well that draws water from the Chicot aquifer (Code 112CHCT), is 302 feet deep, and has a total production of 0.345 mgd. Well water is chlorinated before being discharged to a storage tank.

Best Sea Pack, Inc. does not have sufficient excess capacity to supplement the City of Danbury's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.2 City of Angleton/Brazosport Water Authority

The City of Angleton is located approximately 6 miles southwest of the City of Danbury. The PWS is supplied by six local groundwater wells, which are supplemented by treated surface water purchased from the Brazosport Water Authority (BWA). The BWA is a wholesale water provider that operates a water treatment plan (WTP) located in the City of Lake Jackson and supplies many communities in Brazoria County with treated water. Its primary water source is the Brazos River.

The City of Angleton's six wells draw water from the Chicot aquifer (Code 112CHCT), are between 650 and 960 feet deep, and have a total production of 5.112 mgd. Well water is aerated and treated with polyphosphate and chlorine before being discharged to two storage tanks. The City uses the purchased water from BWA to mix with water from the wells. The City of Angleton serves a population of 19,200 and has approximately 6,400 metered connections. It is currently not in a position to sell water to third parties.

The BWA has up to 5 mgd of excess treated water capacity it is willing to sell, assuming that suitable arrangements can be negotiated. The BWA has an 18-inch supply line that terminates on the north side of the City of Angleton, near the corner of Vasquez and Henderson. The BWA requires that all its customers provide for a minimum of 8 hours storage capacity to sustain supply in the event of BWA's maintenance activities. Based on recent experience with Dow Chemical, the negotiation and approval process could take up to 2 years; however, it is expected the process would be simpler for another PWS.

4.2.1.3 Snug Harbor Subdivision

Snug Harbor Subdivision is a mobile home park located approximately 6½ miles northeast of the City of Danbury. The PWS is supplied by a single groundwater well, completed in the Upper Chicot aquifer (Code 112CHCTU), which is 245 feet deep and has a total production of 0.077 mgd. Well water is treated with hypochlorite and polyphosphate before being discharged to a pressure tank. Snug Harbor serves a population of 84 and has 28 metered connections.

There is not sufficient excess capacity at Snug Harbor to supplement the City of Danbury's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.4 Briar Meadows

Briar Meadows is located on FM 1462, approximately 9½ miles north of the City of Danbury. The PWS is owned by Orbit Systems, Inc. and is supplied by a single groundwater well completed in the Chicot aquifer (Code 112CHCT), which is 210 feet deep. The well has a total production of 0.101 mgd, and water is hypochlorinated and treated with polyphosphate (for iron and manganese) before distribution. The system has 5,000 gallons of storage capacity. Briar Meadows serves a population of 111, has 37 metered connections, and has an approximate average daily usage of 0.014 mgd.

There is not sufficient excess capacity at Briar Meadows to supplement the City of Danbury's existing supply; however, based on the available water quality data, the location may be a suitable point for a new groundwater well.

4.2.1.5 City of Alvin

The City of Alvin is located approximately 15 miles north of the City of Danbury. The PWS is supplied by four local groundwater wells, three of which are completed in the Lower Chicot aquifer (Code 112CHCTL) and one of which is completed in the Evangeline aquifer (Code 121EVGL). The four wells are between 688 and 711 feet deep, and have a total production of 8.739 mgd. Well water is treated with polyphosphate and hypochlorite before being discharged to several ground and elevated storage tanks. The City serves a population of 17,916 and has 5,817 metered connections.

The City of Alvin currently provides finished water to several small PWSs within its extra-territorial jurisdiction (ETJ) and is building lines toward the City of Manvel, which is located west along Highway 6. The City eventually plans to build lines past Manvel. Alvin is planning to build a new water treatment plant and storage tank in that region sometime in the next couple of years. Currently, the City has up to 4 mgd of excess capacity, and is willing to negotiate to sell water to other PWSs outside its ETJ.

The Gulf Coast Water Authority plans to build a 150 mgd water treatment plant to treat Brazos River water. The new WTP may be built on 80 acres of land currently owned by the Fort Bend County Water Control & Improvement District (WCID) No. 2 (Fort Bend WCID, 2005). This would be a regional WTP that may serve west Harris County, the cities of Sugarland, Missouri City, Arcola, Pearland, Alvin, Manvel, Friendswood, and the area within the boundaries of Fort Bend County WCID No. 2, which includes the City of Stafford. The City of Danbury may be able to connect to this regional WTP's distribution system within the City of Alvin.

4.2.2 Potential for New Groundwater Sources

4.2.2.1 Installing New Compliant Wells

Developing new wells or well fields is recommended, provided good quality groundwater available in sufficient quantity can be identified. Since a number of water systems in the area also have problems with arsenic, it should be possible to share the cost and effort of identifying compliant groundwater and constructing well fields.

Since the PWS is already familiar with well operation, installation of a new well in the vicinity of the system intake point is likely to be an attractive option, provided compliant groundwater can be found. As a result, existing wells with good water quality should be investigated. Re-sampling and test pumping would be required to verify and determine the quality and quantity of water at those wells.

The use of existing wells should be limited to use as indicators of groundwater quality and availability. If a new groundwater source is to be developed, it is recommended that a new well or wells be installed instead of using existing wells. This will ensure the well characteristics are known and the well construction meets standards for drinking water wells.

4.2.2.2 Results of Groundwater Availability Modeling

Regional groundwater withdrawal in the vicinity of the City of Danbury is extensive and is likely to steadily increase over the next decades. In Brazoria County, the Chicot aquifer constitutes the primary groundwater source for public supplies. This aquifer is the upper unit of the Gulf Coast aquifer system that extends along the entire Texas coastal region. Throughout the northern part of the Gulf Coast aquifer system, large groundwater withdrawals since the 1900s have resulted in declines in the aquifer's potentiometric surface from tens to hundreds of feet. The largest declines have occurred in the Harris-Galveston Coastal Subsidence District (HGCSD), around the Houston metropolitan area, whose area of influence encompasses most of Brazoria County, including the City of Danbury PWS.

A GAM for northern part of the Gulf Coast aquifer was recently developed by the TWDB. Modeling was performed by the USGS to simulate historical conditions (Kasmerek and Robinson, 2004), and to develop long-term groundwater projections (Kasmerek, Reece and Houston, 2005). Two projections were evaluated, a TWDB scenario based on 50-year regional projections by regional user groups, and a HGCSD scenario that incorporates 30-year projections by the HGCSD for the Houston Metropolitan area. Modeling of both projections anticipates extensive groundwater use and drop in aquifer levels, with far more critical groundwater availability conditions anticipated under the 30-year HGCSD scenario.

Under the HGCSD scenario, withdrawals from the Chicot aquifer and underlying Evangeline aquifer would increase by 2030 to an estimated 1,520 million gallons per day, a 74 percent increase relative to 1995 conditions. Modeling of these projections indicate a significant increase in the aquifer's cone of depression by 2030, with depth increases of over 200 feet relative to current conditions (Kasmerek, Reece and Houston, 2005). The percent of withdrawals supplied by net aquifer recharges would also steadily decrease, from an estimated 72 percent in 1995 to 43 percent projected in 2030 (Kasmerek, Reece and Houston, 2005).

Under the TWDB scenario, long-term withdrawals from the Chicot aquifer and underlying Evangeline aquifer would moderately increase or remain level over the 50-year simulation period; the largest increase in withdrawal would occur between 2000 and 2010, with an 8 percent increase from 850 to 920 million gallons per day (Kasmerek, Reece and Houston, 2005). Modeling of the TWDB scenario showed relatively little change in elevation of the Chicot aquifer's potentiometric surface. In Matagorda County, however, a drop of elevation from 50 to 100 feet would occur under 2010 withdrawal conditions. The simulated net recharge of the aquifer, in contrast with the HGCSD scenario, would moderately increase under the TWDB scenario (Kasmerek, Reece and Houston, 2005).

The GAM of the northern part of the Gulf Coast aquifer was not run for the City of Danbury PWS as groundwater availability would reflect regional HGCSD conditions. Water use by the system would represent a minor addition to the regional HGCSD groundwater withdrawal, making potential changes in aquifer levels well beyond the spatial resolution of the regional GAM model.

4.2.3 Potential for New Surface Water Sources

There is a low potential for development of new surface water sources for the City of Danbury PWS as indicated by limited water availability within the site vicinity. The City of Danbury is located within the San Jacinto-Brazos Basin where current surface water availability is expected to remain at current levels over the next 50 years according to the Texas Water Development Board's 2002 Water Plan (approximately 47,692 acre-feet/year during drought conditions). Approximately 12 miles west of the site, the San Jacinto-Brazos Basin transitions into the Brazos River Basin where water availability is expected to decrease up to 17 percent over the next 50 years.

The vicinity of the City of Danbury PWS has a minimum availability of surface water for new uses. The TCEQ availability map for the San Jacinto-Brazos Basin and Brazos River Basin indicates that, over a 20-mile radius of the site, unappropriated flows for new uses are typically available less than 50 percent of the time. This supply is inadequate as the TCEQ requires 100 percent supply availability for a municipal water supply. Small areas with a greater potential for unappropriated flows – with potential availability from 50 to 100 percent of the time– are scattered south and southeast of the City of Danbury PWS. Development of a new surface water source, however, is not considered feasible for a small water system due to the permitting required, and the cost and complexity associated with construction and operation of intake works, treatment plant, and water conveyance. Development of a new surface water source is considered more appropriate as a regional solution to be undertaken by a group of small PWSs or by a regional water supply organization. For this study, surface water source development alternatives are limited to obtaining water from existing water providers that utilize surface water.

4.2.4 Options for Detailed Consideration

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

1. City of Angleton/BWA. Treated water would be purchased from BWA to supply the City of Danbury. A pipeline would be constructed to tie into the existing main north of the City of Angleton (Alternative CD-1).

2. City of Alvin. Treated water would be purchased from the City of Alvin to supply the City of Danbury. A pipeline would be constructed to tie into the existing City of Alvin system (Alternative CD-2).

3. Best Sea Pack, Inc. Two new wells would be completed in the vicinity of the well at Best Sea Pack, Inc. A pipeline would be constructed and the water would be piped to the City of Danbury (Alternative CD-3).

4. Snug Harbor Subdivision. Two new wells would be completed in the vicinity of the wells at Snug Harbor Subdivision. A pipeline would be constructed and the water would be piped to the City of Danbury (Alternative CD-4).

5. Briar Meadows. Two new wells would be completed in the vicinity of the existing well at Briar Meadows. A pipeline would be constructed and the water would be piped to the City of Danbury (Alternative CD-5).

In addition to the location-specific alternatives above, three hypothetical alternatives are considered in which new wells would be installed 10-, 5-, and 1-miles from the City of Danbury PWS. Under each of these alternatives, it is assumed that a source of compliant water can be located and then a new well would be completed and a pipeline would be constructed to transfer the compliant water to the City of Danbury. These alternatives are CD-10, CD-11, and CD-12.

4.3 TREATMENT OPTIONS

4.3.1 Centralized Treatment Systems

Centralized treatment of the well water is identified as an option for the City of Danbury. The two PWS wells have a combined capacity of 610 gpm (210 gpm and 400 gpm). It may be possible to treat groundwater from both wells at the Well No. 1 site, as water from Well No. 1 is pumped to fill a ground storage tank and a water tower near the Well No. 1 site. Both iron-based adsorption and coagulation/filtration are potentially applicable technologies for arsenic removal for the groundwater. The central iron-based adsorption treatment alternative is Alternative CD-6, and the central coagulation/filtration alternative is Alternative CD-7.

4.3.2 Point-of-Use Systems

POU treatment is assumed to be accomplished with iron-based adsorption technology for arsenic removal. The POU adsorption treatment alternative is CD-8.

4.3.3 Point-of-Entry Systems

POE treatment is assumed to be accomplished with iron-based adsorption technology for arsenic removal. The POE adsorption treatment alternative is CD-9.

4.4 BOTTLED WATER

Provision of bottled water is considered an interim measure to be used until a compliance alternative is implemented. Even though the community is small and people know each other; it would be reasonable to require a quarterly communication advising customers of the need to take advantage of the bottled water program. An alternative to providing delivered bottled water is to provide a central, publicly accessible dispenser for treated drinking water. Alternatives addressing bottled water are CD-13, CD-14, and CD-15.

4.5 ALTERNATIVE DEVELOPMENT AND ANALYSIS

A number of potential alternatives for compliance with the MCL for arsenic 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 CD-1: Purchase Treated Water from BWA

This alternative involves the purchase of treated surface water from the BWA, which will be used to supply the City of Danbury. BWA currently has sufficient excess capacity for this alternative to be feasible and BWA personnel indicated they would be amenable to negotiating an agreement to supply water to PWSs in the area.

This alternative would require the construction of a 5,000- gallon storage tank adjacent to the BWA 18-inch water main located on the north side of the City of Angleton, and a pipeline from the tank to the existing intake point for the City of Danbury system. A pump station would also be required to overcome pipe friction. The required pipeline would follow Route 171, be approximately 7½ miles long, and constructed of 8-inch polyvinyl chloride (PVC) pipe. The pipeline would terminate at the existing storage tanks owned by the City of Danbury.

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 City of Danbury, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes the construction of the pipeline and pump station. The estimated O&M cost for this alternative includes the purchase price for the treated water minus the cost the City of Danbury currently pays to operate its well field, plus maintenance cost for the pipeline, power, and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $2.63 million, and the estimated annual O&M cost for the alternative is $139,600. If the purchased 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.

Reliability of supply of adequate amounts of compliant water under this alternative should be good. BWA provides treated surface water on a large scale, facilitating adequate O&M resources. From the City of Danbury's perspective, 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 the City currently operates pipelines and a pump station. If the decision was made to perform blending then the operational complexity would increase.

The feasibility of this alternative is dependent on an agreement being reached with BWA to purchase treated drinking water.

4.5.2 Alternative CD-2: Purchase Treated Water from City of Alvin

This alternative involves the purchase of treated groundwater from the City of Alvin, which will be used to supply the City of Danbury. The City of Alvin currently has sufficient excess capacity for this alternative to be feasible and officials have indicated they would be amenable to negotiating an agreement to supply water to PWSs in the area.

This alternative would require construction of two 5,000-gallon storage tanks at a point adjacent to the City of Alvin water system, and a pipeline from the tank to the existing intake point for the City of Danbury PWS. Two pump stations would also be required to overcome pipe friction. The required pipeline would be constructed of 8-inch PVC pipe and would follow Routes 35 and 171. Using this route, the length of pipe required would be approximately 18 miles. The pipeline would terminate at the existing storage tanks owned by the City of Danbury.

Each 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 City of Danbury, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes the cost to construct the pipeline and pump stations. The estimated O&M cost for this alternative includes the purchase price for water minus the cost that the City of Danbury currently pays to operate their well field, plus maintenance cost for the pipeline, and power and O&M labor and materials for the pump stations. The estimated capital cost for this alternative is $6.37 million, and the alternative's estimated annual O&M cost is $167,400. If the purchased 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 for additional monitoring to ensure the finished water is compliant.

Reliability of supply of adequate amounts of compliant water under this alternative should be good. The City of Alvin already supplies groundwater on a fairly large scale, and has adequate O&M resources. From the City of Danbury's perspective, 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 the City currently operates pipelines and a pump station. If the decision was made to perform blending then the operational complexity would increase.

This alternative provides some opportunity for a shared solution, since the new pipeline would pass Mark V Estates and could be used to supply them as well. Additionally, several other systems that were evaluated in this study (Rosharon Road Estates, Sandy Meadows Estates Subdivision, Grasslands, and Rosharon Township) lie to the west of the suggested pipeline route and could also use water from the City of Alvin. In this event, while the pipeline would need to be larger to accommodate the increased flows, some of the construction costs could be shared.

The feasibility of this alternative is dependant on an agreement being reached with the City of Alvin to purchase treated drinking water.

4.5.3 Alternative CD-3: New Wells at Best Sea Pack, Inc.

This alternative involves the completion of two new wells at Best Sea Pack, Inc., a local commercial shrimp packing business, and a pump station, and a pipeline to transfer the pumped groundwater to the City of Danbury. Based on the water quality data in the TCEQ database, it is expected that groundwater from these wells will be compliant with drinking water MCLs. An agreement would need to be negotiated with Best Sea Pack, Inc. to expand their well field.

This alternative would require the completion of two new wells at Best Sea Pack, Inc., and the construction of a storage tank and a pipeline from the tank to the existing intake point for the City of Danbury PWS. A pump station would also be required to overcome pipe friction. The required pipeline would be constructed of 8-inch PVC pipe and would follow Route 171. Using this route, the pipeline required would be approximately 2 miles in length. The pipeline would terminate at the existing storage tanks owned by the City of Danbury.

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 City of Danbury, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes the cost to complete the new wells, and construct the pipeline and pump station. The estimated O&M cost for this alternative includes maintenance costs for the pipeline, and power and O&M labor and materials for the pump station. The estimated capital cost for this alternative is $0.89 million, and the alternative's estimated annual O&M cost is $16,400.

Reliability of supply of adequate amounts of compliant water under this alternative should be good. From the City of Danbury's perspective, 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 the City currently operates pipelines and a pump station.

The feasibility of this alternative is dependant on the City of Danbury being able to reach an agreement with Best Sea Pack, Inc. with regard to completing a new groundwater well.

4.5.4 Alternative CD-4: New Wells at Snug Harbor

This alternative involves the completion of two new wells in the vicinity of Snug Harbor, a mobile home park that is located approximately 6½ miles to the northeast, and the construction of a pump station and pipeline to transfer the pumped groundwater to the City of Danbury. Based on the water quality data in the TCEQ database, it is expected that groundwater from these wells will be compliant with drinking water MCLs. An agreement would need to be negotiated with Snug Harbor to expand their well field.

This alternative would require the completion of two new wells at Snug Harbor, and the construction of a storage tank and a pipeline from the tank to the existing intake point for the City of Danbury PWS. A pump station would also be required to overcome pipe friction between Snug Harbor and Danbury. The required pipeline would be constructed of 8-inch PVC pipe and would be approximately 7½ miles in length. The pipeline would terminate at the existing storage tanks owned by the City of Danbury.

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 City of Danbury, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes the cost to complete the new wells, and construct 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 $2.68 million, and the alternative's estimated annual O&M cost is $25,600.

Reliability of supply of adequate amounts of compliant water under this alternative should be good. From the City of Danbury's perspective, 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 the City currently operates pipelines and a pump station.

This alternative also presents some opportunity for a shared solution, since the expansion of the Snug Harbor well field could also be used to supply Mark V Estates, which is about 5½ miles away to the north. However, this would require the construction of a separate pipeline.

The feasibility of this alternative is dependant on the City of Danbury being able to reach an agreement with Snug Harbor with regard to completing a new groundwater well.

4.5.5 Alternative CD-5: New Wells at Briar Meadows

This alternative involves the completion of two new wells in the vicinity of Briar Meadows, a PWS approximately 9½ miles to the north that is owned by Orbit Systems, Inc., and the construction of a pump station and pipeline to transfer the pumped groundwater to the City of Danbury. Based on the water quality data in the TCEQ database, it is expected that groundwater from these wells will be compliant with drinking water MCLs. An agreement would need to be negotiated with Briar Meadows PWS to expand their well field.

This alternative would require the completion of two new wells at Briar Meadows, and the construction of a storage tank and pipeline from that tank to the existing intake point for the City of Danbury PWS. A pump station would also be required to overcome pipe friction. The required pipeline would be constructed of 8-inch PVC pipe and would be approximately 14½ miles in length. The pipeline would terminate at the existing storage tanks owned by the City of Danbury.

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 City of Danbury, since the incremental cost would be relatively small, and it would provide operational flexibility.

The estimated capital cost for this alternative includes the cost to complete the new wells, and construct 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 $4.80 million, and the alternative's estimated annual O&M cost is $34,800.

Reliability of supply of adequate amounts of compliant water under this alternative should be good. From the City of Danbury's perspective, 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 the City currently operates pipelines and a pump station.

This alternative also presents some opportunity for a shared solution, since the expansion of the Briar Meadows well field could also be used to supply Mark V Estates, Rosharon Road Estates, Sandy Meadows Estates Subdivision, Grasslands, and Rosharon Township to the north. However, this scheme would require the construction of separate pipelines.

The feasibility of this alternative is dependant on the City of Danbury being able to reach an agreement with Briar Meadows with regard to completing a new groundwater well.

4.5.6 Alternative CD-6: Central Iron-Based Adsorption Treatment

The City of Danbury would treat groundwater from both Wells No. 1 and No. 2 using an iron-based adsorption system prior to distribution. This alternative consists of constructing the adsorption treatment plant at or near the Well No. 1 site. The plant comprises an 800-square foot building with a paved driveway, the pre-constructed adsorption system on a skid (*e.g.*, two Model APU-300 package units from Severn Trent), and a 5,000-gallon backwash wastewater equalization tank. The entire facility would be fenced. The water will be pre-chlorinated to oxidize As(III) to As(V) and post-chlorinated for disinfection prior to flowing to the distribution system. Backwash would be required monthly with raw well water supplied directly by the well pump. The backwash wastewater would be equalized in the 5,000-gallon tank and discharged to the sewer at a controlled rate. The adsorption media are expected to last approximately 2 years before replacement and disposal. The media replacement cost would be approximately $54,000.

The estimated capital cost for this alternative is $781,000, and the estimated annual O&M cost is $57,100 which includes the annualized media replacement cost of $27,000. Reliability of supply of adequate amounts of compliant water under this alternative is good as the adsorption technology has been demonstrated effective in full-scale and pilot-scale facilities. The technology is simple and requires minimal O&M effort.

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

4.5.7 Alternative CD-7: Central Coagulation/Filtration Treatment

The City of Danbury would treat groundwater from both Wells No. 1 and No. 2 using a coagulation/filtration system prior to distribution. This alternative consists of constructing the coagulation/filtration plant at or near the Well No. 1 site. The plant comprises an 800-square foot building with a paved driveway, the pre-constructed coagulation/filtration system on a skid (*e.g.,* three Macrolite filters from Kinetico), a ferric chloride feed and storage system, and a 5,000-gallon backwash wastewater equalization tank. The entire facility would be fenced. The water will be pre-chlorinated to oxidize As(III) to As(V) and post-chlorinated for disinfection prior to flowing to the distribution system. Ferric chloride solution would be fed to the well water after pre-chlorination and before entering the filters. The filters would be backwashed once every 1 to 2 days by well water directly from the well pump. The backwash wastewater would be equalized in the 5,000-gallon tank and discharged to the sewer at a controlled rate. The Macrolite media do not need replacement.

The estimated capital cost for this alternative is $704,800, and the estimated annual O&M cost is $87,200. This alternative requires more O&M labor cost and sewer disposal charges than the adsorption alternative. Reliability of supply of adequate amounts of compliant water under this alternative is good as the coagulation/filtration is a well-established technology. The technology is simple but requires significant effort for chemical handling and backwash monitoring.

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

4.5.8 Alternative CD-8: Point-of-Use Treatment

This alternative consists of the continued operation of the City of Danbury well field, plus treatment of water to be used for drinking or food preparation at the point of use to remove arsenic. 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 the installation of the POU treatment units in houses and other buildings that provide drinking or cooking water. The City of Danbury would be responsible for purchase and maintenance of the treatment units, including media 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 City or contract personnel into the houses of customers. As a result, the cooperation of customers will be important for success in implementation of this alternative. The treatment units could be installed so that they could be accessed without house entry, but that would complicate the installation and increase costs.

POU arsenic treatment processes typically produce spent media that requires disposal and possibly a small backwash waste stream. The backwash waste stream results in a slight increase in the overall volume of water used. POU systems have the advantage that a minimum volume of water (only that for human consumption) is treated. This minimizes the size of the treatment units, the increase in water required, and the waste for disposal. For this alternative, it is assumed that the increase in water consumption is insignificant in terms of supply cost, and that the backwash waste stream can be discharged to the house septic or sewer system.

This alternative does not present options for a regional 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, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $421,100 and the estimated annual O&M cost is $398,800. For the cost estimate, it is assumed that one POU treatment unit will be required for each of the 638 existing connections to the City of Danbury system. It should be noted that the POU treatment units would need to be more complex than units typically found in commercial retail outlets in order to meet regulatory requirements, making purchase and installation more expensive.

Reliability of supply 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 a single tap within a house. Additionally, the O&M efforts required for the POU systems will be significant, and City personnel are inexperienced in this type of work. From the City of Danbury's perspective 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 dependant on the cooperation, willingness, or capability of other water supply entities.

4.5.9 Alternative CD-9: Point-of-Entry Treatment

This alternative consists of the continued operation of the City of Danbury well field, plus treatment of water as it enters residences to remove arsenic. 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. The City of Danbury would be responsible for purchase and maintenance of the treatment units, including media and filter replacement, periodic sampling, and necessary repairs. It may also be desirable to modify piping so that water for non-consumptive uses can be withdrawn upstream of the treatment unit. The POE treatment units will be installed outside of the houses, so that entry will not be necessary for O&M. Some cooperation from customers will be necessary for installation and maintenance of the treatment systems.

POE arsenic treatment processes typically produce spent adsorption media as a waste, as well as possibly backwash water that requires disposal. The backwash water stream results in a slight increased overall volume of water used. POE systems treat a greater volume of water than POU systems. For this alternative, it is assumed that the increase in water consumption is insignificant in terms of supply cost, and that the backwash waste stream can be discharged to the house septic or sewer system.

This alternative does not present options for a regional 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, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $7.37 million and the estimated annual O&M cost is $893,200. For the cost estimate, it is assumed that one POE treatment unit will be required for each of the 638 existing connections to the City of Danbury system.

Reliability of supply of adequate amounts of compliant water under this alternative is 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 City personnel are inexperienced in this type of work. From the City of Danbury's perspective this alternative would be characterized as difficult to operate owing to the in-home requirements and the large number of individual units.

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

4.5.10 Alternative CD-10: New Wells at 10 Miles

This alternative consists of the installation of two new wells within 10 miles of the City of Danbury that would produce compliant water in place of the water produced by the Danbury well field. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require the construction of two new 420-foot wells, a new pump station with storage tank near the new wells, and a pipeline from the new wells/tank to the existing intake point for the City of Danbury system. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be approximately 10 miles long, and would be an 8-inch PVC line that discharges to the existing storage tank at the City of Danbury. The pump station would include two pumps, including one standby, and would be housed in a building.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes cost to install the wells, and construct the pipeline and pump station. The estimated O&M cost for this alternative includes the cost for O&M for the pipeline and pump station, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing City of Danbury wells. The estimated capital cost for this alternative is $3.53 million, and the estimated annual O&M cost for this alternative is $29,200.

Reliability of supply of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the City of Danbury's perspective, this alternative would be similar to operate as the existing system. The City of Danbury has experience with O&M of wells, pipelines and pump stations.

The feasibility of this alternative is dependant on the ability to find adequate existing wells or success in installing new wells that produce an adequate supply of compliant water. It is likely that the alternate groundwater source will not be found on the City of Danbury's controlled land, so landowner cooperation will likely be required.

4.5.11 Alternative CD-11: New Wells at 5 Miles

This alternative consists of the installation of two new wells within 5 miles of the City of Danbury that would produce compliant water in place of the water produced by the Danbury well field. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require the construction of two new 420-foot wells, a new pump station with storage tank near the new wells, and a pipeline from the new wells/tank to the existing intake point for the City of Danbury system. The pump station and storage tank would be necessary to overcome pipe friction and changes in land elevation. For this alternative, the pipeline is assumed to be approximately 5 miles long, and would be an 8-inch PVC line that discharges to the existing storage tank at the City of Danbury. The pump station would include two pumps, including one standby, and would be housed in a building.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes cost to install the wells, and construct the pipeline and pump station. The estimated O&M cost for this alternative includes the cost for O&M for the pipeline and pump station, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing City of Danbury wells. The estimated capital cost for this alternative is $1.82 million, and the estimated annual O&M cost for this alternative is $22,000.

Reliability of supply of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the City of Danbury's perspective, this alternative would be similar to operate as the existing system. The City of Danbury has experience with O&M of wells, pipelines and pump stations.

The feasibility of this alternative is dependant on the ability to find adequate existing wells or success in installing new wells that produce an adequate supply of compliant water. It is likely that the alternate groundwater source will not be found on the City of Danbury's controlled land, so landowner cooperation will likely be required.

4.5.12 Alternative CD-12: New Wells at 1 Mile

This alternative consists of the installation of two new wells within 1 mile of the City of Danbury that would produce compliant water in place of the water produced by the Danbury well field. At this level of study, it is not possible to positively identify an existing well or the location where a new well could be installed.

This alternative would require the construction of two new 420-foot wells, and a pipeline from the new wells to the existing intake point for the City of Danbury system. For this alternative, the pipeline is assumed to be approximately 1 mile long, and would be an 8-inch PVC line that discharges to the existing storage tank at the City of Danbury.

Depending on well location and capacity, this alternative could present some options for a more regional solution. It may be possible to share water and costs with another nearby system.

The estimated capital cost for this alternative includes cost to install the wells and construct the pipeline. The estimated O&M cost for this alternative includes the cost for O&M for the pipeline, plus an amount for plugging and abandoning (in accordance with TCEQ requirements) the existing City of Danbury wells. The estimated capital cost for this alternative is $0.42 million, and the estimated annual O&M cost for this alternative is $200.

Reliability of supply of adequate amounts of compliant water under this alternative should be good, since water wells, pump stations and pipelines are commonly employed. From the City of Danbury's perspective, this alternative would be similar to operate as the existing system. The City of Danbury has experience with O&M of wells, pipelines and pump stations.

The feasibility of this alternative is dependant on the ability to find adequate existing wells or success in installing new wells that produce an adequate supply of compliant water. It is likely that the alternate groundwater source will not be found on the City of Danbury's controlled land, so landowner cooperation will likely be required.

4.5.13 Alternative CD-13: Public Dispenser for Treated Drinking Water

This alternative consists of the continued operation of the City of Danbury well field, plus dispensing treated water for drinking and cooking at a publicly accessible location. For this alternative, it is assumed that iron-based arsenic treatment is employed. Implementing this alternative would require the purchase and installation of four treatment units at a location where customers would be able to come and fill their own containers. This alternative also includes notifying the customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of water requires treatment, but customers are required to pick up and deliver their own water. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

The City of Danbury would be responsible for maintenance of the treatment unit, including media replacement, periodic sampling, and necessary repairs. The spent media will require disposal. This alternative relies on a great deal of cooperation and action from the customers in order to be effective.

This alternative does not present options for a regional solution.

The estimated capital cost for this alternative includes cost to purchase and install the treatment system to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes the purchase and replacement of filters and media, as well as periodic sampling and record keeping. The estimated capital cost for this alternative is $46,400, and the estimated annual O&M cost for this alternative is $66,600.

Reliability of supply of adequate amounts of compliant water under this alternative is fair, because of the large amount of effort required from the customers and the associated inconvenience. The City of Danbury has not provided this type of service in the past though, from the City's perspective, this alternative would be characterized as relatively easy to operate because these types of treatment units are highly automated, and there would only be a single unit.

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

4.5.14 Alternative CD-14: 100 Percent Bottled Water Delivery

This alternative consists of the continued operation of the City of Danbury well field, but compliant drinking water will be delivered to customers in containers. This alternative involves setting up and operating a bottled water delivery program to serve all of the customers in the system. It is expected that the City of Danbury will find it most convenient and economical to contract a bottled water service. The bottle delivery program will have to be flexible enough to allow the delivery of smaller containers should customers be incapable of lifting and manipulating 5-gallon bottles. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

This alternative does not involve capital cost for construction, but would require some initial costs for system setup, and then ongoing costs to have the bottled water furnished. It is assumed for this alternative that bottled water is provided to 100 percent of the City of Danbury's customers.

This alternative does not present options for a regional solution.

The estimated initial capital cost is for setting up the program. The estimated O&M cost for this alternative includes program administration and purchase of the bottled water. The estimated capital cost for this alternative is $23,900, and the estimated annual O&M cost for this alternative is $987,300. For the cost estimate, it is assumed that each person requires 1 gallon of bottled water per day.

Reliability of supply of adequate amounts of compliant water under this alternative is fair, since it relies on the active cooperation of customers to order and utilize the water. Management and administration of the bottled water delivery program will require attention from the City of Danbury.

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

4.5.15 Alternative CD-15: Public Dispenser for Trucked Drinking Water

This alternative consists of continued operation of the City of Danbury well field, plus dispensing compliant water for drinking and cooking at a publicly accessible location. The compliant water would be purchased from BWA, and delivered by truck to storage tanks at a central location where customers would be able to fill their own containers. This alternative also includes notifying customers of the importance of obtaining drinking water from the dispenser. In this way, only a relatively small volume of water needs to be purchased, but customers are required to pick up and deliver their own water. Blending is not an option in this case. It should be noted that this alternative would be considered an interim measure until a compliance alternative is implemented.

The City of Danbury would purchase a truck suitable for hauling potable water, and install four 5,000-gallon storage tanks. It is assumed the storage tanks would be filled once a week, and that the chlorine residual would be tested for each truckload. The truck would have to meet requirements for potable water, and each load would be treated with bleach. This alternative relies on a great deal of cooperation and action from the customers for it to be effective.

This alternative presents limited options for a regional solution if two or more systems share the purchase and operation of the water truck.

The estimated capital cost for this alternative includes the purchase of a water truck and construction of the storage tanks to be used for the drinking water dispenser. The estimated O&M cost for this alternative includes O&M for the truck, maintenance for the tanks, water quality testing, record keeping, and water purchase, The estimated capital cost for this alternative is $150,900, and the estimated annual O&M cost for this alternative is $62,400.

Reliability of supply of adequate amounts of compliant water under this alternative is fair because of the large amount of effort required from the customers and the associated inconvenience. The City of Danbury has not provided this type of service in the past. From the perspective of the City, this alternative would be characterized as relatively easy to operate, but the water hauling and storage would have to be done with care to ensure sanitary conditions.

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

4.5.16 Summary of Alternatives

Table 4.3 provides a summary of the key features of each alternative for the City of Danbury.

Table 4.3 Summary of Compliance Alternatives for the City of Danbury

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost[2]	Reliability	System Impact	Remarks
CD-1	Purchase treated water from BWA	- Pump station - 7½-mile pipeline	$2,629,900	$139,600	$368,900	Good	N	Agreement must be successfully negotiated with BWA. Blending may be possible.
CD-2	Purchase treated water from City of Alvin	- Pump stations - 18-mile pipeline	$6,372,300	$167,400	$723,000	Good	N	Agreement must be successfully negotiated with the City of Alvin. Blending may be possible.
CD-3	New well at Best Sea Pack, Inc.	- New GW wells - Pump station - 2-mile pipeline	$889,900	$16,400	$94,000	Good	N	Agreement must be successfully negotiated with Best Sea Pack, or land must be purchased. Blending may be possible.
CD-4	New well at Snug Harbor	- New GW wells - Pump station - 7½-mile pipeline	$2,675,000	$25,600	$258,800	Good	N	Agreement must be successfully negotiated with Snug Harbor, or land must be purchased. Blending may be possible.
CD-5	New well at Briar Meadows	- New GW wells - Pump station - 14½-mile pipeline	$4,804,000	$34,800	$453,700	Good	N	Agreement must be successfully negotiated with Briar Meadows, or land must be purchased. Blending may be possible.
CD-6	Continue operation of Danbury well field w/ central treatment (adsorption)	- Central adsorption treatment plant	$781,000	$57,100	$125,200	Good	T	No nearby system to possibly share treatment plant cost.
CD-7	Continue operation of Danbury well field w/ central treatment (coagulation)	- Central coagulation treatment plant	$704,800	$87,200	$148,600	Good	T	No nearby system to possibly share treatment plant cost.
CD-8	Continue operation of Gilliland well field and POU treatment	- POU treatment units	$421,100	$398,800	$435,500	Fair	T, M	Only one compliant tap in home. Cooperation of residents required for installation, maintenance, and testing.
CD-9	Continue operation of Gilliland well field and POE treatment	- POE treatment units	$7,368,900	$893,200	$1,535,700	Fair (*better than POU*)	T, M	All home taps compliant and less resident cooperation required.
CD-10	Install new compliant wells within 10 miles	- New GW wells - Storage tank - Pump station - 10-mile pipeline	$3,527,900	$29,200	$336,800	Good	N	May be difficult to find well with good water quality.
CD-11	Install new compliant wells within 5 miles	- New GW wells - Storage tank - Pump station - 5-mile pipeline	$1,815,100	$22,000	$180,200	Good	N	May be difficult to find well with good water quality.
CD-12	Install new compliant wells within 1 mile	- New GW wells - 1-mile pipeline	$422,900	$200	$37,100	Good	N	May be difficult to find well with good water quality.

Table 4.3 Summary of Compliance Alternatives for the City of Danbury

Alt No.	Alternative Description	Major Components	Capital Cost[1]	Annual O&M Cost	Total Annualized Cost[2]	Reliability	System Impact	Remarks
CD-13	Continue operation of Danbury well field, but furnish public dispenser for treated drinking water	- Water treatment and dispenser unit	$46,400	$66,600	$70,600	Fair/interim measure	T	INTERIM SOLUTION: Does not provide compliant water to all taps, and requires a lot of effort by customers.
CD-14	Continue operation of Danbury well field, but furnish bottled drinking water for all customers	- Set up bottled water system	$23,900	$987,300	$989,400	Fair/interim measure	M	INTERIM SOLUTION: Does not provide compliant water to all taps, and requires customers to order and use. Management of program may be significant.
CD-15	Continue operation of Danbury well field, but furnish public dispenser for trucked drinking water	- Construct storage tanks and dispenser - Purchase potable water truck	$150,900	$62,400	$75,600	Fair/interim measure	M	INTERIM SOLUTION: Does not provide compliant water to all taps, and requires a lot of effort by customers.

Notes: *N – No significant increase required in technical or management capability*
T – Implementation of alternative will require increase in technical capability
M – Implementation of alternative will require increase in management capability
1 – See cost breakdown in Appendix C
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 derived from established budgets, audited financial reports, and published water tariffs, and consumption data.

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 City of Danbury Financial Data

Copies of the annual budget and the audited financial reports were made available by the City of Danbury. The City operates its water utility as part of its Utility Fund, which includes water, sewer, and garbage. The Utility Fund does not separate financial data by type of service provided, but rather combines data for all of its utility services. The financial analysis for the City of Danbury assumes that the services other than water remain static and fixed. Data from the FY 2003 audited financial reports, the interim financial statements for the first seven months of 2004-05, and the 2004-05 budget have been utilized in developing the financial analysis. More current financial data was not available, primarily due to recent changes in City staffing that has held up development of more current data.

4.6.2 Current Financial Condition

4.6.2.1 Cash Flow Needs

Based on the 2003 audited financial statements and the seven month unaudited financial statements, it appears that the Utility Fund has consistently operated in a negative position. Retained earnings at April 30, 2005 were a negative $99,068, compared to a negative $29,705 at September 30, 2003. For the first seven months of FY 2005, total revenues were $41,591 greater than expenditures. However, depreciation of $49.067 yielded a net income of minus $7,476 for the period. The shortfalls in the Utility fund have been offset by interfund loans from the general fund, special projects fund, and the debt service fund.

Current Danbury water rates for both residential and businesses consist of a base rate of $17.50 per month, which includes up to 1,500 gallons each month. Consumption between

1,500 gallons and 5,000 gallons are billed at $1.12 per 1000 gallons. Consumption between 5,000 gallons and 10,000 gallons are billed at $1.14 per 1000 gallons. Any consumption over 10,000 gallons in a month is billed at $1.16 per 1000 gallons.

Based on the budgeted revenues, the current average annual water bill for City of Danbury customers is estimated to be $258, or about 0.5 percent of annual household income of $52,540.

4.6.2.2 Ratio Analysis

Current Ratio = 2.15

The Current Ratio of 2.15 indicates that the Utility Fund would be able to meet all of its current obligations, with readily available short-term assets of $81,712 (exclusive of $25,919 of funds held for meter deposits) exceeding short-term obligations of $37,920 (excluding $173,420 due to other City funds for which immediate payment would be unlikely).

Debt to Net Worth Ratio = 0.13

A Debt to Net Worth Ratio of 0.13 indicates that the Utility Fund is in good shape overall, having generated enough funds to pay for its assets from internal earnings without reliance on borrowing to get the assets that it needs to run the business. However, the ratio may be somewhat misleading as the City maintains a separate Debt Service Fund, which holds the long-term debt for all City departments, including the Utility department. The debt is funded through property taxes. The water system has $72,000 in identified outstanding bond debt. An unknown portion of the City's 2003 $2,500,000 Certificates of Obligation issue was also for the utility fund.

Operating Ratio = 1.27

The Utility Fund budgeted operating revenues of $378,067 exceeds its operating budget of $298,000, exclusive of budgeted contributions of $80,000 for payment to the Debt Service Fund and depreciation.

4.6.3 Financial Plan Results

Each of the compliance alternatives for the City of Danbury was evaluated, with emphasis on the impact on affordability (expressed as a percentage of household income), and 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 Section 2.4.

For SRF funding options, customer MHI compared to the state average determines the availability of subsidized loans. Since the MHI for the City of Danbury was estimated to be $52,540 for 2003, compared to $40,063 for the State of Texas, the City would not qualify for reduced financing rates or low income grants.

Results of the financial impact analysis are provided in Table 4.4 and Figure 4.2. Figure 4.2 provides a bar chart that in terms of the yearly billing to an average customer (12,000 gallons/month consumption) shows the following:

- Current yearly billing, and
- Projected yearly billing including rate increases to maintain financial viability and also for implementing the various compliance alternatives.

The two bars shown for each compliance alternative represent the maximum rate increases necessary 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. If existing reserves are insufficient to fund a compliance alternative, rates would need to be raised ahead of implementation of the compliance alternative to allow the accumulation of sufficient reserves, in order to avoid larger but temporary rate increases during the years the compliance alternative is implemented.

Table 4.4 Financial Impact on Households for the City of Danbury

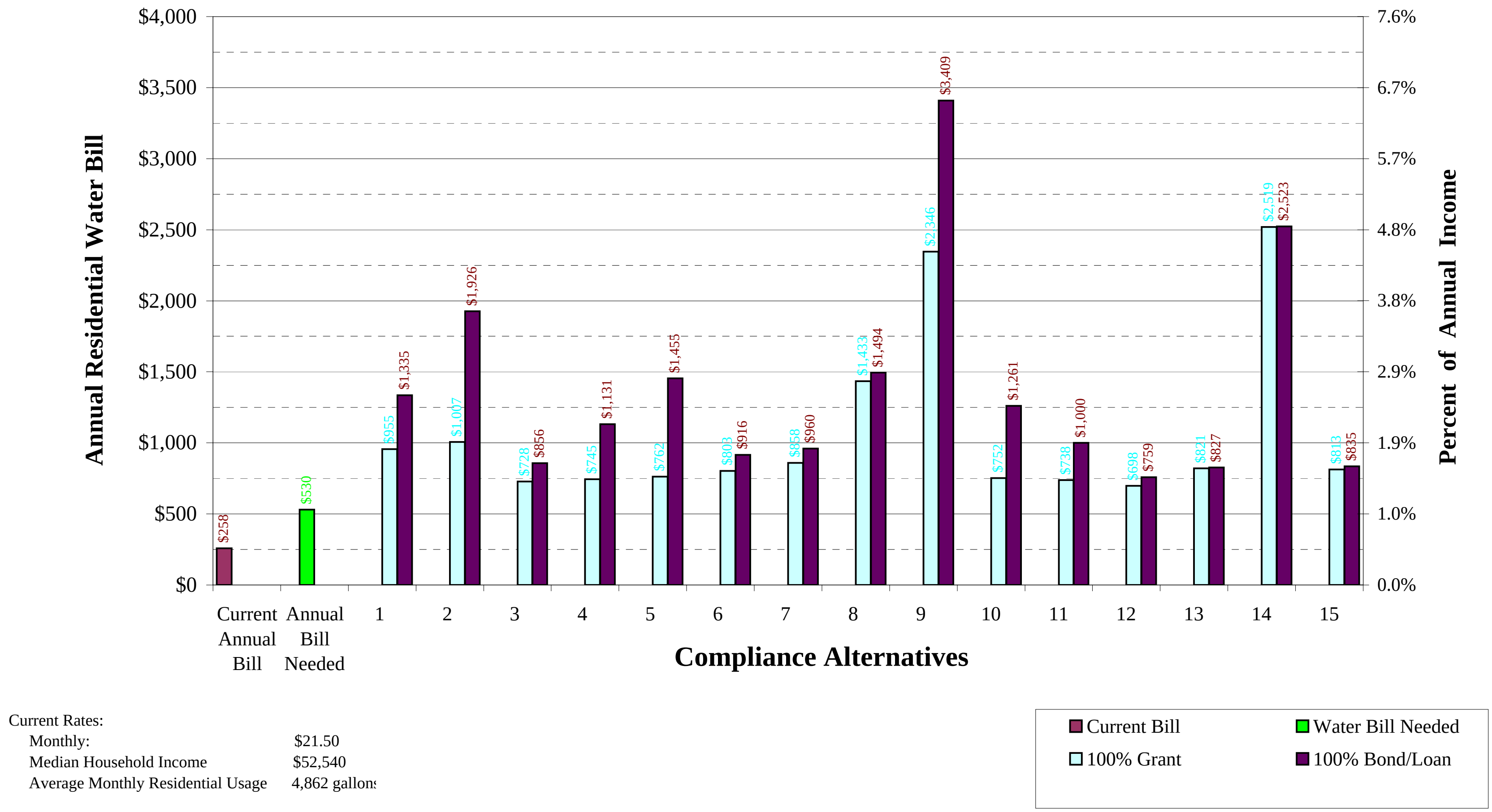
No-Action Results (Alternative 0)		**0.49%**	**Current Year % of Income**				
Funding Source 0 = Revenue Funding		**29.0%**	**Rate Increase % Needed to Maintain Current Status**				
		0.63%	**% of Income with Rate Increases Needed for Current Status**				
		Difference between No-Action Result and Table Result is Impact from Alternative					
	Funding Source #	**0**	**1**	**2**	**3**	**4**	**5**
ALTERNATIVES		**All Revenue**	**100% Grant**	**75% Grant**	**50% Grant**	**SRF**	**Loan/Bond**
CD-1 BWA	Average Annual Water Bill	$ 6,052.44	$ 1,512.84	$ 1,687.34	$ 1,861.84	$ 2,126.53	$ 2,210.83
	Maximum % of HH Income	12%	3%	3%	4%	4%	5%
	Percentage Rate Increase Compared to Current	2406%	528%	601%	675%	786%	821%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-2 Alvin	Average Annual Water Bill	$ 12,524.67	$ 1,532.42	$ 1,955.24	$ 2,378.05	$ 3,019.42	$ 3,223.69
	Maximum % of HH Income	25%	3%	4%	5%	6%	7%
	Percentage Rate Increase Compared to Current	5083%	536%	714%	892%	1162%	1248%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-3 Best Sea Pack, Inc.	Average Annual Water Bill	$ 2,788.35	$ 1,252.30	$ 1,311.34	$ 1,370.39	$ 1,459.95	$ 1,488.48
	Maximum % of HH Income	6%	3%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	1052%	416%	441%	466%	504%	516%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-4 Snug Harbor	Average Annual Water Bill	$ 5,886.21	$ 1,268.97	$ 1,446.45	$ 1,623.93	$ 1,893.15	$ 1,978.89
	Maximum % of HH Income	12%	3%	3%	3%	4%	4%
	Percentage Rate Increase Compared to Current	2333%	423%	498%	573%	686%	722%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006

No-Action Results (Alternative 0)		0.49%	Current Year % of Income				
Funding Source 0 = Revenue Funding		**29.0%**	**Rate Increase % Needed to Maintain Current Status**				
		0.63%	**% of Income with Rate Increases Needed for Current Status**				
		Difference between No-Action Result and Table Result is Impact from Alternative					
	Funding Source #	**0**	**1**	**2**	**3**	**4**	**5**
ALTERNATIVES		**All Revenue**	**100% Grant**	**75% Grant**	**50% Grant**	**SRF**	**Loan/Bond**
CD-5 Briar Meadows	Average Annual Water Bill	$ 9,578.10	$ 1,285.56	$ 1,604.32	$ 1,923.08	$ 2,406.60	$ 2,560.59
	Maximum % of HH Income	19%	3%	3%	4%	5%	5%
	Percentage Rate Increase Compared to Current	3861%	431%	565%	699%	902%	967%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-6 Central Adsorption	Average Annual Water Bill	$ 2,673.86	$ 1,325.77	$ 1,377.59	$ 1,429.41	$ 1,508.01	$ 1,533.05
	Maximum % of HH Income	5%	3%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	1005%	448%	470%	491%	525%	535%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-7 Central Coagulation	Average Annual Water Bill	$ 2,596.73	$ 1,380.04	$ 1,426.81	$ 1,473.58	$ 1,544.52	$ 1,567.12
	Maximum % of HH Income	5%	3%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	974%	471%	491%	510%	540%	550%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-8 POU-Adsorption	Average Annual Water Bill	$ 2,669.49	$ 2,352.78	$ 2,380.72	$ 2,408.66	$ 2,451.04	$ 2,464.54
	Maximum % of HH Income	5%	5%	5%	5%	5%	5%
	Percentage Rate Increase Compared to Current	1013%	894%	906%	918%	936%	941%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-9 POE-Adsorption	Average Annual Water Bill	$ 15,555.40	$ 4,106.39	$ 4,595.34	$ 5,084.28	$ 5,825.96	$ 6,062.17
	Maximum % of HH Income	32%	9%	10%	11%	12%	13%
	Percentage Rate Increase Compared to Current	6356%	1659%	1865%	2071%	2383%	2483%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006

No-Action Results (Alternative 0)		0.49%	Current Year % of Income			
Funding Source 0 = Revenue Funding		**29.0%**	**Rate Increase % Needed to Maintain Current Status**			
		0.63%	**% of Income with Rate Increases Needed for Current Status**			
		Difference between No-Action Result and Table Result is Impact from Alternative				
	Funding Source #	**0**	**1**	**2**	**3**	**4**	**5**
ALTERNATIVES		**All Revenue**	**100% Grant**	**75% Grant**	**50% Grant**	**SRF**	**Loan/Bond**
CD-10 New well 10 mi	Average Annual Water Bill	$ 7,365.29	$ 1,275.47	$ 1,509.56	$ 1,743.65	$ 2,098.73	$ 2,211.82
	Maximum % of HH Income	15%	3%	3%	4%	4%	5%
	Percentage Rate Increase Compared to Current	2945%	426%	525%	623%	773%	820%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-11 New well 5 mi	Average Annual Water Bill	$ 4,395.57	$ 1,262.39	$ 1,382.83	$ 1,503.27	$ 1,685.96	$ 1,744.14
	Maximum % of HH Income	9%	3%	3%	3%	3%	4%
	Percentage Rate Increase Compared to Current	1717%	421%	471%	522%	599%	623%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-12 New well 1 mi	Average Annual Water Bill	$ 1,953.03	$ 1,223.03	$ 1,251.09	$ 1,279.16	$ 1,321.72	$ 1,335.28
	Maximum % of HH Income	4%	2%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	706%	404%	416%	427%	445%	451%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-13 Dispenser	Average Annual Water Bill	$ 1,423.02	$ 1,342.92	$ 1,346.00	$ 1,349.08	$ 1,353.75	$ 1,355.24
	Maximum % of HH Income	3%	3%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	488%	455%	456%	458%	460%	460%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006
CD-14 100% Bottled	Average Annual Water Bill	$ 4,442.88	$ 4,440.03	$ 4,441.62	$ 4,443.21	$ 4,445.62	$ 4,446.38
	Maximum % of HH Income	9%	9%	9%	9%	9%	9%
	Percentage Rate Increase Compared to Current	1805%	1805%	1806%	1806%	1807%	1808%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006

No-Action Results (Alternative 0)		0.49%	Current Year % of Income				
Funding Source 0 = Revenue Funding		**29.0%**	**Rate Increase % Needed to Maintain Current Status**				
		0.63%	**% of Income with Rate Increases Needed for Current Status**				
		Difference between No-Action Result and Table Result is Impact from Alternative					
	Funding Source #	**0**	**1**	**2**	**3**	**4**	**5**
ALTERNATIVES		**All Revenue**	**100% Grant**	**75% Grant**	**50% Grant**	**SRF**	**Loan/Bond**
CD-15 Central Trucked	Average Annual Water Bill	$ 1,595.98	$ 1,335.42	$ 1,345.43	$ 1,355.45	$ 1,370.64	$ 1,375.48
	Maximum % of HH Income	3%	3%	3%	3%	3%	3%
	Percentage Rate Increase Compared to Current	560%	452%	456%	460%	467%	469%
	Year First Rate Increase Needed	2006	2006	2006	2006	2006	2006

Figure 4-2 Alternative Cost Summary



SECTION 5
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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 recent bids on Texas Department of Highways projects. The amounts of boring and encasement and open cut and encasement were 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 and building, and tools. Construction cost of a storage tank is based on similar recent installations.

Electrical power cost is estimated to be $0.136 per kWH, as supplied by Reliant Energy, Houston, Texas. 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 2005 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 2005 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 2005 dollars based on the ENR construction cost index.

The purchase price for point-of-use (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 point-of-entry (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 is from a USEPA arsenic removal demonstration project (USEPA 2004).

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 a 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 each week, and that chlorine residual would be determined for each truck load.

Table B.1
Summary of General Data
City of Danbury
PWS #0200011
General PWS Information

Service Population	1,650	**Number of Connections**	638
Total PWS Daily Water Usage	0.213 (mgd)	**Source**	2005 Report

Unit Cost Data
East Texas

General Items	**Unit**	**Unit Cost**
Treated water purchase cost	*See alternative*	
Water purchase cost (trucked)	$/1,000 gals	$ 1.80
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, 08"	LF	$ 37
Bore and encasement, 12"	LF	$ 70
Open cut and encasement, 12"	LF	$ 40
Gate valve and box, 08"	EA	$ 670
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, 08"	EA	$ 4,000
Gate valve, 08"	EA	$ 960
Check valve, 08"	EA	$ 1,400
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 - 5,000 gals	EA	$ 7,025
Electrical Power	$/kWH	$ 0.136
Building Power	kWH	11,800
Labor	$/hr	$ 30
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	$ 30

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	$ 40
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 Tr	**Unit**	**Unit Cost**
Site prepar	acre	$ 4,000
Slab	CY	$ 1,000
Building	SF	$ 60
Building ele	SF	$ 8.00
Building plu	SF	$ 8.00
Heating an	SF	$ 7.00
Fence	LF	$ 15
Paving	SF	$ 2.00
Electrical, A	JOB	$ 50,000
Electrical, C	JOB	$ 45,000
Piping, Ads	JOB	$ 20,000
Piping, Coa	JOB	$ 15,000
Adsorption	UNIT	$ 330,000
Coagulatio	UNIT	$ 286,000
Transfer pu	EA	$ 5,000
Sewer conn	EA	$ 15,000
Chlorinatio	EA	$ 2,000
Coagulant	GAL	$ 3.00
Backwash	GAL	$ 2.00
Excavation	CYD	$ 3.00
Compacted	CYD	$ 7.00
Lining	SF	$ 0.50
Vegetation	SY	$ 1.00
Access roa	LF	$ 30
Building Po	kwh/yr	$ 0.136
Equipment	kwh/yr	$ 0.136
Labor	hr	$ 40
Adsorption	year	$ 27,000
Coagulatio	year	$ 2,000
Backwash	MG/year	$ 5,000
Chemicals,	year	$ 2,000
Analyses	test	$ 200
Spent med	CY	$ 20

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.15. 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 *City of Danbury*
Alternative Name *Purchase Water from BWA*
Alternative Number *CD-1*

Distance from Alternative to PWS (along pipe)	7.5	miles
Total PWS annual water usage	77.745	MG
Treated water purchase cost	$ 1.60	per 1,000 gals
Number of Pump Stations Needed	1	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	19	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 08"	39,447	LF	$ 37.00	$ 1,459,539
Bore and encasement, 12"	3,800	LF	$ 70.00	$ 266,000
Open cut and encasement, 12"	150	LF	$ 40.00	$ 6,000
Gate valve and box, 08"	8	EA	$ 670.00	$ 5,286
Air valve	7	EA	$ 1,000.00	$ 7,000
Flush valve	8	EA	$ 750.00	$ 5,917
Metal detectable tape	39,447	LF	$ 0.15	$ 5,917
Subtotal				**$ 1,755,659**
Pump Station(s) Installation				
Pump	1	EA	$ 7,500	$ 7,500
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 58,035**
Subtotal of Component Costs				**$ 1,813,694**
Contingency	20%			$ 362,739
Design & Constr Management	25%			$ 453,423
TOTAL CAPITAL COSTS				**$ 2,629,856**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	7.5	mile	$ 200	$ 1,494
Subtotal				**$ 1,494**
Water Purchase Cost				
From Source	77,745	1,000 g	$ 1.60	$ 124,392
Subtotal				**$ 124,392**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	101,250	kWH	$ 0.136	$ 13,770
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 28,525**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 139,609**

Table C.2

PWS Name *City of Danbury*
Alternative Name *Purchase Water from City of Alvin*
Alternative Number *CD-2*

Distance from Alternative to PWS (along pipe)	18.0	miles
Total PWS annual water usage	77.745	MG
Treated water purchase cost	$ 1.65	per 1,000 gals
Number of Pump Stations Needed	2	

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	49	n/a	n/a	n/a
Number of Crossings, open cut	9	n/a	n/a	n/a
PVC water line, Class 200, 08"	95,010	LF	$ 37.00	$ 3,515,370
Bore and encasement, 12"	9,800	LF	$ 70.00	$ 686,000
Open cut and encasement, 12"	450	LF	$ 40.00	$ 18,000
Gate valve and box, 08"	19	EA	$ 670.00	$ 12,731
Air valve	18	EA	$ 1,000.00	$ 18,000
Flush valve	19	EA	$ 750.00	$ 14,252
Metal detectable tape	95,010	LF	$ 0.15	$ 14,252
Subtotal				**$ 4,278,604**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	2	EA	$ 4,000	$ 8,000
Gate valve, 08"	8	EA	$ 960	$ 7,680
Check valve, 08"	4	EA	$ 1,400	$ 5,600
Electrical/Instrumentation	2	EA	$ 10,000	$ 20,000
Site work	2	EA	$ 2,000	$ 4,000
Building pad	2	EA	$ 4,000	$ 8,000
Pump Building	2	EA	$ 10,000	$ 20,000
Fence	2	EA	$ 5,870	$ 11,740
Tools	2	EA	$ 1,000	$ 2,000
Storage Tank - 5,000 gals	2	EA	$ 7,025	$ 14,050
Subtotal				**$ 116,070**
Subtotal of Component Costs				**$ 4,394,674**
Contingency	20%			$ 878,935
Design & Constr Management	25%			$ 1,098,669
TOTAL CAPITAL COSTS				**$ 6,372,278**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	18.0	mile	$ 200	$ 3,599
Subtotal				**$ 3,599**
Water Purchase Cost				
From Source	77,745	1,000 gal	$ 1.65	$ 128,279
Subtotal				**$ 128,279**
Pump Station(s) O&M				
Building Power	23,600	kWH	$ 0.136	$ 3,210
Pump Power	153,350	kWH	$ 0.136	$ 20,856
Materials	2	EA	$ 1,200	$ 2,400
Labor	730	Hrs	$ 30	$ 21,900
Tank O&M	2	EA	$ 1,000	$ 2,000
Subtotal				**$ 50,365**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 167,442**

Table C.3

PWS Name	***City of Danbury***
Alternative Name	***New Well at Best Sea Pack***
Alternative Number	***CD-3***

Distance from PWS to new well location	2.02	miles
Estimated well depth	620	feet
Number of wells required	2	
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	5	n/a	n/a	n/a
Number of Crossings, open cut	2	n/a	n/a	n/a
PVC water line, Class 200, 08"	10,663	LF	$ 37	$ 394,531
Bore and encasement, 12"	1,000	LF	$ 70	$ 70,000
Open cut and encasement, 12"	100	LF	$ 40	$ 4,000
Gate valve and box, 08"	2	EA	$ 670	$ 1,429
Air valve	2	EA	$ 1,000	$ 2,000
Flush valve	2	EA	$ 750	$ 1,599
Metal detectable tape	10,663	LF	$ 0.15	$ 1,599
Subtotal				**$ 475,159**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 65,535**
Well Installation				
Well installation	1,240	LF	$ 25	$ 31,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 73,000**
Subtotal of Component Costs				**$ 613,694**
Contingency	20%			$ 122,739
Design & Constr Management	25%			$ 153,423
TOTAL CAPITAL COSTS				**$ 889,856**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	2.0	mile	$ 200	$ 404
Subtotal				**$ 404**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	3,600	kWH	$ 0.136	$ 490
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 15,244**
Well O&M				
Pump power	17,369	kWH	$ 0.136	$ 2,362
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 15,562**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 16,409**

Table C.4

PWS Name *City of Danbury*
Alternative Name *New Well at Snug Harbor*
Alternative Number *CD-4*

Distance from PWS to new well location	7.48	miles
Estimated well depth	430	feet
Number of wells required	2	
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	16	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 08"	39,501	LF	$ 37	$ 1,461,537
Bore and encasement, 12"	3,200	LF	$ 70	$ 224,000
Open cut and encasement, 12"	150	LF	$ 40	$ 6,000
Gate valve and box, 08"	8	EA	$ 670	$ 5,293
Air valve	7	EA	$ 1,000	$ 7,000
Flush valve	8	EA	$ 750	$ 5,925
Metal detectable tape	39,501	LF	$ 0.15	$ 5,925
Subtotal				**$ 1,715,680**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 65,535**
Well Installation				
Well installation	860	LF	$ 25	$ 21,500
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 63,500**
Subtotal of Component Costs				**$ 1,844,715**
Contingency	20%			$ 368,943
Design & Constr Management	25%			$ 461,179
TOTAL CAPITAL COSTS				**$ 2,674,837**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	7.5	mile	$ 200	$ 1,496
Subtotal				**$ 1,496**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	68,750	kWH	$ 0.136	$ 9,350
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 24,105**
Well O&M				
Pump power	12,055	kWH	$ 0.136	$ 1,639
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 14,839**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 25,639**

Table C.5

PWS Name *City of Danbury*
Alternative Name *New Well at Briar Meadows*
Alternative Number *CD-5*

Distance from PWS to new well location	14.38	miles
Estimated well depth	430	feet
Number of wells required	2	
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	22	n/a	n/a	n/a
Number of Crossings, open cut	10	n/a	n/a	n/a
PVC water line, Class 200, 08"	75,922	LF	$ 37	$ 2,809,114
Bore and encasement, 12"	4,400	LF	$ 70	$ 308,000
Open cut and encasement, 12"	500	LF	$ 40	$ 20,000
Gate valve and box, 08"	15	EA	$ 670	$ 10,174
Air valve	14	EA	$ 1,000	$ 14,000
Flush valve	15	EA	$ 750	$ 11,388
Metal detectable tape	75,922	LF	$ 0.15	$ 11,388
Subtotal				**$ 3,184,064**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 65,535**
Well Installation				
Well installation	860	LF	$ 25	$ 21,500
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 63,500**
Subtotal of Component Costs				**$ 3,313,099**
Contingency	20%			$ 662,620
Design & Constr Management	25%			$ 828,275
TOTAL CAPITAL COSTS				**$ 4,803,994**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	14.4	mile	$ 200	$ 2,876
Subtotal				**$ 2,876**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	126,200	kWH	$ 0.136	$ 17,163
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 31,918**
Well O&M				
Pump power	12,055	kWH	$ 0.136	$ 1,639
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 14,839**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 34,832**

Table C.6

PWS Name *City of Danbury*
Alternative Name *Central Treatment - Adsorption*
Alternative Number *CD-6*

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Adsorption				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	800	SF	$ 60	$ 48,000
Building electrical	800	SF	$ 8.00	$ 6,400
Building plumbing	800	SF	$ 8.00	$ 6,400
Heating and ventilation	800	SF	$ 7.00	$ 5,600
Fence	600	LF	$ 15	$ 9,000
Paving	1,600	SF	$ 2.00	$ 3,200
Electrical	1	JOB	$ 50,000	$ 50,000
Piping	1	JOB	$ 20,000	$ 20,000
Adsorption package including: 4 Adsorption vessels E33 Iron oxide media Controls & instruments	1	UNIT	$ 330,000	$ 330,000
Backwash Tank	5,000	GAL	$ 2.00	$ 10,000
Sewer Connection Fee	1	EA	$ 15,000	$ 15,000
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal				**$ 538,600**
				107,720
				134,650
Total				**$ 780,970**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	1000	kwh/yr	$ 0.136	$ 136
Labor	500	hrs/yr	$ 40	$ 20,000
Materials	1	year	$ 27,000	$ 27,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharge to sewer	0.74	MG/yr	$ 5,000	$ 3,700
Spent Media Disposal	12	CY	$ 20	$ 240
Subtotal				**$ 57,100**
Total				**$ 57,100**

Table C.7

PWS Name ***City of Danbury***
Alternative Name ***Central Treatment - Coag-Filt***
Alternative Number ***CD-7***

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Central-Coagulation/Filtration				
Site preparation	0.75	acre	$ 4,000	$ 3,000
Slab	30	CY	$ 1,000	$ 30,000
Building	800	SF	$ 60	$ 48,000
Building electrical	800	SF	$ 8.00	$ 6,400
Building plumbing	800	SF	$ 8.00	$ 6,400
Heating and ventilation	800	SF	$ 7.00	$ 5,600
Fence	600	LF	$ 15	$ 9,000
Paving	1,600	SF	$ 2.00	$ 3,200
Electrical	1	JOB	$ 45,000	$ 45,000
Piping	1	JOB	$ 15,000	$ 15,000
Coagulant/Filter package including:				
Chemical feed system				
Pressure ceramic filters				
Controls & Instruments	1	UNIT	$ 286,000	$ 286,000
Backwash Tank	5,000	GAL	$ 2.00	$ 10,000
Sewer Connection Fee	1	EA	$ 15,000	$ 15,000
Coagulant Tank	500	GAL	$ 3.00	$ 1,500
Chlorination Point	1	EA	$ 2,000	$ 2,000
Subtotal				**$ 486,100**
				97,220
				121,525
Total				**$ 704,845**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
Building Power	9,000	kwh/yr	$ 0.136	$ 1,224
Equipment power	1000	kwh/yr	$ 0.136	$ 136
Labor	1,000	hrs/yr	$ 40	$ 40,000
Materials	1	year	$ 2,000	$ 2,000
Chemicals	1	year	$ 2,000	$ 2,000
Analyses	24	test	$ 200	$ 4,800
Backwash discharg	7.4	MG/yr	$ 5,000	$ 37,000
Subtotal				**$ 87,160**
Total				**$ 87,160**

Table C.8

PWS Name *City of Danbury*
Alternative Name *Point-of-Use Treatment*
Alternative Number *CD-8*

Number of Connections for POU Unit Installation 638

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POU-Treatment - Purchase/Installation				
POU treatment unit purchase	638	EA	$ 250	$ 159,500
POU treatment unit installation	638	EA	$ 150	$ 95,700
Subtotal				**$ 255,200**
Subtotal of Component Costs				**$ 255,200**
Contingency	20%			$ 51,040
Design & Constr Management	25%			$ 63,800
Procurement & Administration	20%			$ 51,040
TOTAL CAPITAL COSTS				**$ 421,080**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POU materials, per unit	638	EA	$ 225	$ 143,550
Contaminant analysis, 1/yr per unit	638	EA	$ 100	$ 63,800
Program labor, 10 hrs/unit	6,380	hrs	$ 30	$ 191,400
Subtotal				**$ 398,750**
TOTAL ANNUAL O&M COSTS				**$ 398,750**

Table C.9

PWS Name *City of Danbury*
Alternative Name *Point-of-Entry Treatment*
Alternative Number *CD-9*

Number of Connections for POE Unit Installation 638

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
POE-Treatment - Purchase/Installation				
POE treatment unit purchase	638	EA	$ 3,000	$ 1,914,000
Pad and shed, per unit	638	EA	$ 2,000	$ 1,276,000
Piping connection, per unit	638	EA	$ 1,000	$ 638,000
Electrical hook-up, per unit	638	EA	$ 1,000	$ 638,000
Subtotal				**$ 4,466,000**
Subtotal of Component Costs				**$ 4,466,000**
Contingency	20%			$ 893,200
Design & Constr Management	25%			$ 1,116,500
Procurement & Administration	20%			$ 893,200
TOTAL CAPITAL COSTS				**$ 7,368,900**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
POE materials, per unit	638	EA	$ 1,000	$ 638,000
Contaminant analysis, 1/yr per unit	638	EA	$ 100	$ 63,800
Program labor, 10 hrs/unit	6,380	hrs	$ 30	$ 191,400
Subtotal				**$ 893,200**
TOTAL ANNUAL O&M COSTS				**$ 893,200**

Table C.10

PWS Name *City of Danbury*
Alternative Name *New Well at 10 Miles*
Alternative Number *CD-10*

Distance from PWS to new well location	10.0	miles
Estimated well depth	420	feet
Number of wells required	2	
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	22	n/a	n/a	n/a
Number of Crossings, open cut	5	n/a	n/a	n/a
PVC water line, Class 200, 08"	52,800	LF	$ 37	$ 1,953,600
Bore and encasement, 12"	4,400	LF	$ 70	$ 308,000
Open cut and encasement, 12"	250	LF	$ 40	$ 10,000
Gate valve and box, 08"	11	EA	$ 670	$ 7,075
Air valve	10	EA	$ 1,000	$ 10,000
Flush valve	11	EA	$ 750	$ 7,920
Metal detectable tape	52,800	LF	$ 0.15	$ 7,920
Subtotal				**$ 2,304,515**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 65,535**
Well Installation				
Well installation	840	LF	$ 25	$ 21,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 63,000**
Subtotal of Component Costs				**$ 2,433,050**
Contingency	20%			$ 486,610
Design & Constr Management	25%			$ 608,263
TOTAL CAPITAL COSTS				**$ 3,527,923**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	10.0	mile	$ 200	$ 2,000
Subtotal				**$ 2,000**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	91,833	kWH	$ 0.136	$ 12,489
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 27,244**
Well O&M				
Pump power	11,776	kWH	$ 0.136	$ 1,602
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 14,802**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 29,244**

Table C.11

PWS Name	***City of Danbury***
Alternative Name	***New Well at 5 Miles***
Alternative Number	***CD-11***

Distance from PWS to new well location	5.0	miles
Estimated well depth	420	feet
Number of wells required	2	
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	11	n/a	n/a	n/a
Number of Crossings, open cut	3	n/a	n/a	n/a
PVC water line, Class 200, 08"	26,400	LF	$ 37	$ 976,800
Bore and encasement, 12"	1,800	LF	$ 70	$ 126,000
Open cut and encasement, 12"	100	LF	$ 40	$ 4,000
Gate valve and box, 08"	5	EA	$ 670	$ 3,538
Air valve	5	EA	$ 1,000	$ 5,000
Flush valve	5	EA	$ 750	$ 3,960
Metal detectable tape	26,400	LF	$ 0.15	$ 3,960
Subtotal				**$ 1,123,258**
Pump Station(s) Installation				
Pump	2	EA	$ 7,500	$ 15,000
Pump Station Piping, 08"	1	EA	$ 4,000	$ 4,000
Gate valve, 08"	4	EA	$ 960	$ 3,840
Check valve, 08"	2	EA	$ 1,400	$ 2,800
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 - 5,000 gals	1	EA	$ 7,025	$ 7,025
Subtotal				**$ 65,535**
Well Installation				
Well installation	840	LF	$ 25	$ 21,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 63,000**
Subtotal of Component Costs				**$ 1,251,793**
Contingency	20%			$ 250,359
Design & Constr Management	25%			$ 312,948
TOTAL CAPITAL COSTS				**$ 1,815,099**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	5.0	mile	$ 200	$ 1,000
Subtotal				**$ 1,000**
Pump Station(s) O&M				
Building Power	11,800	kWH	$ 0.136	$ 1,605
Pump Power	45,916	kWH	$ 0.136	$ 6,245
Materials	1	EA	$ 1,200	$ 1,200
Labor	365	Hrs	$ 30	$ 10,950
Tank O&M	1	EA	$ 1,000	$ 1,000
Subtotal				**$ 20,999**
Well O&M				
Pump power	11,776	kWH	$ 0.136	$ 1,602
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 14,802**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 21,999**

Table C.12

PWS Name *City of Danbury*
Alternative Name *New Well at 1 Mile*
Alternative Number *CD-12*

Distance from PWS to new well location	1.0 miles
Estimated well depth	420 feet
Number of wells required	2
Well installation cost (location specific)	$25 per foot
Number of pump stations needed	0

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline Construction				
Number of Crossings, bore	2	n/a	n/a	n/a
Number of Crossings, open cut	1	n/a	n/a	n/a
PVC water line, Class 200, 08"	5,280	LF	$ 37	$ 195,360
Bore and encasement, 12"	400	LF	$ 70	$ 28,000
Open cut and encasement, 12"	50	LF	$ 40	$ 2,000
Gate valve and box, 08"	1	EA	$ 670	$ 708
Air valve	1.00	EA	$ 1,000	$ 1,000
Flush valve	1	EA	$ 750	$ 792
Metal detectable tape	5,280	LF	$ 0.15	$ 792
Subtotal				**$ 228,652**
Pump Station(s) Installation				
Pump	-	EA	$ 7,500	$ -
Pump Station Piping, 08"	-	EA	$ 4,000	$ -
Gate valve, 08"	-	EA	$ 960	$ -
Check valve, 08"	-	EA	$ 1,400	$ -
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	$ -
Storage Tank - 5,000 gals	-	EA	$ 7,025	$ -
Subtotal				**$ -**
Well Installation				
Well installation	840	LF	$ 25	$ 21,000
Water quality testing	4	EA	$ 1,500	$ 6,000
Well pump	2	EA	$ 7,500	$ 15,000
Well electrical/instrumentation	2	EA	$ 5,000	$ 10,000
Well cover and base	2	EA	$ 3,000	$ 6,000
Piping	2	EA	$ 2,500	$ 5,000
Subtotal				**$ 63,000**
Subtotal of Component Costs				**$ 291,652**
Contingency	20%			$ 58,330
Design & Constr Management	25%			$ 72,913
TOTAL CAPITAL COSTS				**$ 422,895**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Pipeline O&M				
Pipeline O&M	1.0	mile	$ 200	$ 200
Subtotal				**$ 200**
Pump Station(s) O&M				
Building Power	-	kWH	$ 0.136	$ -
Pump Power	-	kWH	$ 0.136	$ -
Materials	-	EA	$ 1,200	$ -
Labor	-	Hrs	$ 30	$ -
Tank O&M	-	EA	$ 1,000	$ -
Subtotal				**$ -**
Well O&M				
Pump power	11,776	kWH	$ 0.136	$ 1,602
Well O&M matl	2	EA	$ 1,200	$ 2,400
Well O&M labor	360	Hrs	$ 30	$ 10,800
Subtotal				**$ 14,802**
O&M Credit for Existing Well Closure				
Pump power	11,776	kWH	$ 0.136	$ (1,602)
Well O&M matl	2	EA	$ 1,200	$ (2,400)
Well O&M labor	360	Hrs	$ 30	$ (10,800)
Subtotal				**$ (14,802)**
TOTAL ANNUAL O&M COSTS				**$ 200**

Table C.13

PWS Name *City of Danbury*
Alternative Name *Public Dispenser for Treated Drinking Water*
Alternative Number *CD-13*

Number of Treatment Units Recommended 4

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Public Dispenser Unit Installation				
POE-Treatment unit(s)	4	EA	$ 3,000	$ 12,000
Unit installation costs	4	EA	$ 5,000	$ 20,000
Subtotal				**$ 32,000**
Subtotal of Component Costs				**$ 32,000**
Contingency	20%			$ 6,400
Design & Constr Management	25%			$ 8,000
TOTAL CAPITAL COSTS				**46,400**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Treatment unit O&M, 1 per unit	4	EA	$ 500	$ 2,000
Contaminant analysis, 1/wk per unit	208	EA	$ 100	$ 20,800
Sampling/reporting, 1 hr/day	1,460	HRS	$ 30	$ 43,800
Subtotal				**$ 66,600**
TOTAL ANNUAL O&M COSTS				**$ 66,600**

Table C.14

PWS Name *City of Danbury*
Alternative Name *Supply Bottled Water to Population*
Alternative Number *CD-14*

Service Population	1,650	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	602,250	gallons

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Implementation				
Initial program set-up	500	hours	$ 40	$ 19,950
Subtotal				**$ 19,950**
Subtotal of Component Costs				**$ 19,950**
Contingency	20%			$ 3,990
TOTAL CAPITAL COSTS				**$ 23,940**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water purchase costs	602,250	gals	$ 1.60	$ 963,600
Program admin, 9 hrs/wk	468	hours	$ 40	$ 18,673
Program materials	1	EA	$ 5,000	$ 5,000
Subtotal				**$ 987,273**
TOTAL ANNUAL O&M COSTS				**$ 987,273**

Table C.15

PWS Name ***City of Danbury***
Alternative Name ***Central Trucked Drinking Water***
Alternative Number ***CD-15***

Service Population	1,650	
Percentage of population requiring supply	100%	
Water consumption per person	1.00	gpcd
Calculated annual potable water needs	602,250	gallons
Travel distance to compliant water source (roundtrip)	15	miles

Capital Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Storage Tank Installation				
Storage Tank - 5,000 gals	4	EA	$ 7,025	$ 28,100
Site improvements	4	EA	$ 4,000	$ 16,000
Potable water truck	1	EA	$ 60,000	$ 60,000
Subtotal				**$ 104,100**
Subtotal of Component Costs				**$ 104,100**
Contingency	20%			$ 20,820
Design & Constr Management	25%			$ 26,025
TOTAL CAPITAL COSTS				**$ 150,945**

Annual Operations and Maintenance Costs

Cost Item	Quantity	Unit	Unit Cost	Total Cost
Program Operation				
Water delivery labor, 4 hrs/wk	832	hrs	$ 30	$ 24,960
Truck operation, 1 round trip/wk	3,120	miles	$ 1.00	$ 3,120
Water purchase	602	1,000 gals	$ 1.80	$ 1,084
Water testing, 1 test/wk	208	EA	$ 100	$ 20,800
Sampling/reporting, 2 hrs/wk	416	hrs	$ 30	$ 12,480
Subtotal				**$ 62,444**
TOTAL ANNUAL O&M COSTS				**$ 62,444**

APPENDIX D
EXAMPLE FINANCIAL MODEL

Table D.1 Example Financial Model

Step 1

Water System: Danbury

Step 2

Click Here to Update Verification and Raw

Water System	Danbury
Alternative Description	New Well at 1 Mile

Sum of Amount		Year	Funding Alt
		2007	
Group	Type	100% Grant	Bond
Capital Expenditures	Capital Expenditures-Funded from Bonds	$ -	$ 422,895
	Capital Expenditures-Funded from Grants	$ 422,895	$ -
	Capital Expenditures-Funded from Revenue/Reserves	$ 5,000	$ 5,000
	Capital Expenditures-Funded from SRF Loans	$ -	$ -
Capital Expenditures Sum		$ 427,895	$ 427,895
Debt Service	Existing Debt Service	$ 80,000	$ 80,000
	Revenue Bonds	$ -	$ 33,082
	State Revolving Funds	$ -	$ -
Debt Service Sum		$ 80,000	$ 113,082
Operating Expenditures	Administrative Expenses	$ 13,900	$ 13,900
	Chemicals, Treatment	$ 46,600	$ 46,600
	Contract Labor	$ 500	$ 500
	Insurance	$ 12,000	$ 12,000
	Other Operating Expenditures 1	$ 53,000	$ 53,000
	Other Operating Expenditures 2	$ 1,000	$ 1,000
	Professional and Directors Fees	$ 500	$ 500
	Repairs	$ 5,667	$ 5,667
	Salaries & Benefits	$ 101,100	$ 101,100
	Supplies	$ 5,667	$ 5,667
	Utilities	$ 43,300	$ 43,300
	Maintenance	$ 5,667	$ 5,667
	Auto and Travel	$ 4,167	$ 4,167
Operating Expenditures Sum		$ 293,067	$ 293,067
Residential Operating Revenues	Residential Tier2 Annual Rate	$ -	$ -
	Residential Tier3 Annual Rate	$ -	$ -
	Residential Tier4 Annual Rate	$ -	$ -
	Residential Unmetered Annual Rate	$ -	$ -
	Residential Tier 1 Annual Rate	$ 26,240	$ 26,240
	Residential Base Annual Rate	$ 113,807	$ 113,807
Residential Operating Revenues Sum		$ 140,047	$ 140,047
NonOpIncome	Non-Operating Income	$ 238,067	$ 238,067
NonOpIncome Sum		$ 238,067	$ 238,067

Location_Name	Danbury
Alt_Desc	New Well at 1 Mile

	Current_Year	Funding_Alt
	2007	
Data	100% Grant	Bond
Sum of Beginning_Cash_Bal	$ (181,777)	$ (181,777)
Sum of Total_Expenditures	$ 800,962	$ 834,044
Sum of Total_Receipts	$ 562,942	$ 562,942
Sum of Net_Cash_Flow	$ (238,020)	$ (271,101)
Sum of Ending_Cash_Bal	$ (419,796)	$ (452,878)
Sum of Working_Cap	$ 24,422	$ 24,422
Sum of Repl_Resv	$ 16,823	$ 16,823
Sum of Total_Reqd_Resv	$ 41,245	$ 41,245
Sum of Net_Avail_Bal	$ (461,042)	$ (494,123)
Sum of Add_Resv_Needed	$ (461,042)	$ (494,123)
Sum of Rate_Inc_Needed	329%	353%
Sum of Percent_Rate_Increase	0%	0%

APPENDIX E
GENERAL ARSENIC GEOCHEMISTRY

Geochemistry of arsenic is complex because of (1) the possible coexistence of two or even three redox states, (2) the complex chemistry of organo-arsenicals, and (3) the strong interaction of most arsenic compounds with soil particles, particularly iron oxides (and to a lesser degree, aluminum and manganese oxides). Fully deprotonated arsenate AsO_4^{-3} is the expected form of arsenic in most soil under aerobic conditions only at high pH (Figure E.1). At more neutral and acid pH's, $HAsO_4^{-2}$ and $H_2AsO_4^{-1}$ forms, respectively, are dominant. General understanding of arsenic mobility in soil and aquifers is that it increases with increasing pH and phosphate concentration and with decreasing clay and iron oxide content. As pH increases, the negative charge of the arsenate ion increases, making it less likely to sorb on negatively charged soil particles. Phosphates have a chemical structure similar to that of arsenates and sorb to soil preferentially in some conditions. Nitrogen also belongs to the same group in the periodic table but does not show the same competing behavior as phosphate. Other structurally similar oxyanions, sulfate and selenate, are also weak sorbers. Under less oxidizing conditions, arsenite ion H_3AsO_3 is most stable. Lack of charge renders the ion more mobile and less likely to sorb to soil particles. Its pH stability spread ranges from acid to alkaline. The first deprotonated form, $H_2AsO_3^{-1}$, exists at significant concentrations only above a pH of approximately 9. Redox processes seem to be mediated by microorganisms (Welch, *et al.* 2000) and to take place next to mineral surfaces.

Under even more reducing conditions, arsenide is the stable ionic form of arsenic. Arsenic has a complex geochemistry with sulfur, both in solution where several thioarsenic ions can form and in associated minerals. Arsenic metal –As(0)- rarely occurs. Methylated arsenic compounds are generally present at low aqueous concentrations (<1ppb), if at all, except perhaps when there is an abundance of organic matter (Welch, *et al*., 2000).

As(V) and As(III) minerals are fairly soluble and do not control arsenic solubility in oxidizing or mildly reducing conditions, except, perhaps, if barium is present (Henry, *et al.* 1982). This situation is in contrast to that of other companion oxyanions which are not as mobile under reducing conditions, except vanadium. In reducing conditions, arsenic precipitates as arsenopyrite (FeAsS), although more commonly in solid solution with pyrite. Realgar (AsS) and orpiment (As_2S_3) require high sulfur activity and are unlikely in the southern Gulf Coast.

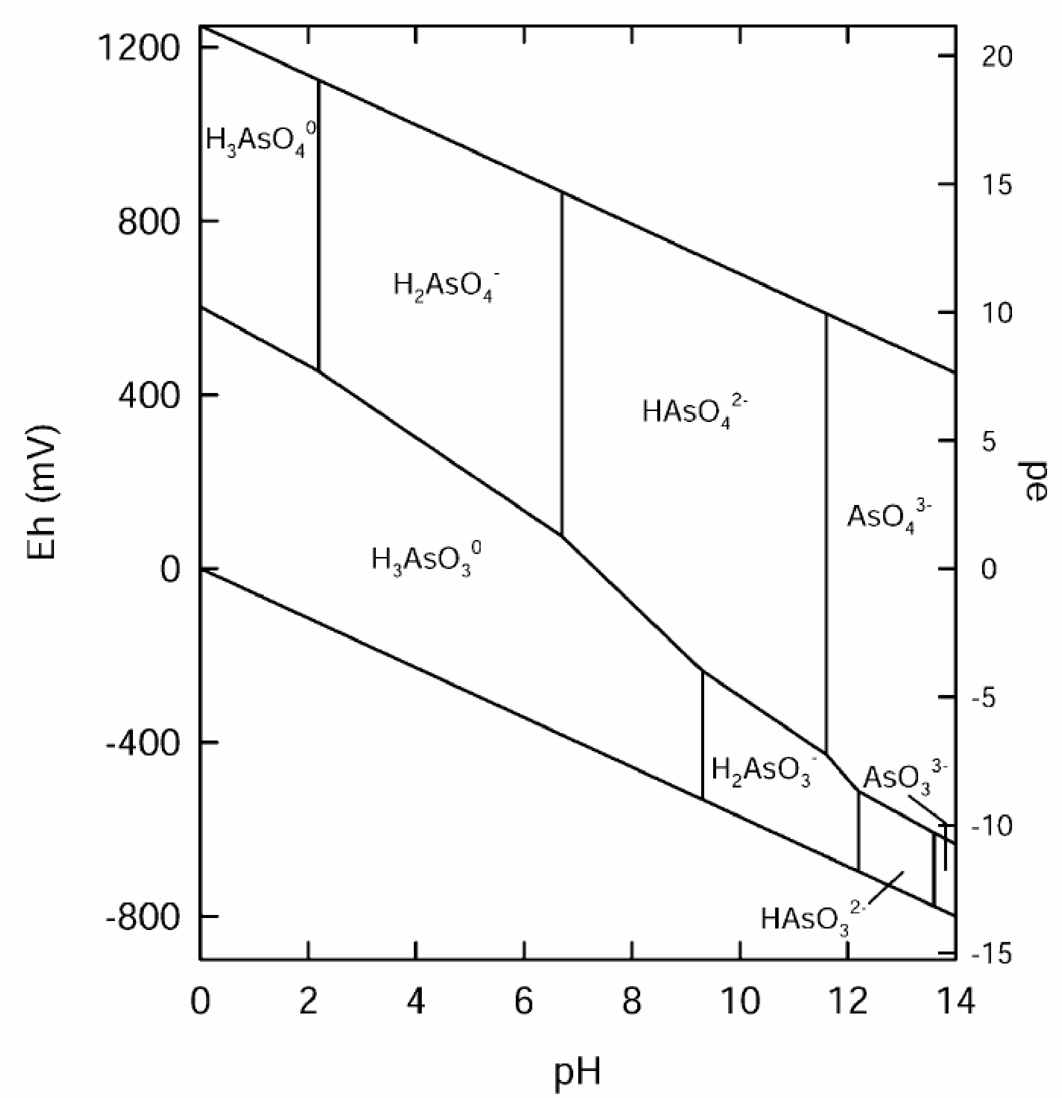

Figure E.1
Eh-pH Diagram for Arsenic Aqueous Species in the As-O_2-H_2O System at 25°C and 1 bar (Smedley and Kinniburgh 2002)