SAN ANTONIO WATER SYSTEM

Brackish Groundwater Desalination Feasibility Assessment Report

VOLUME I — October 2008

San Antonio Water System

In Association with:
LBG-Guyton Associates
Mickley & Associates

R·W·BECK

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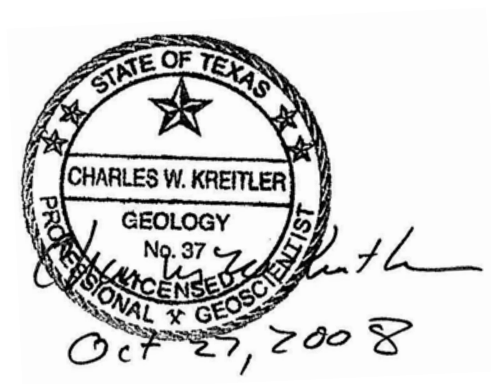

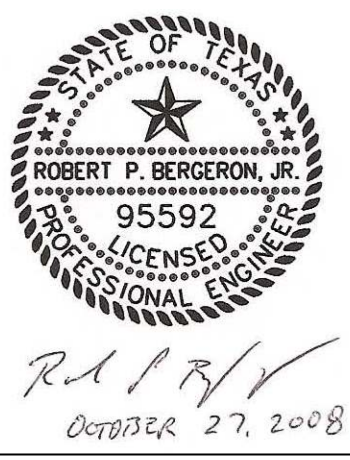

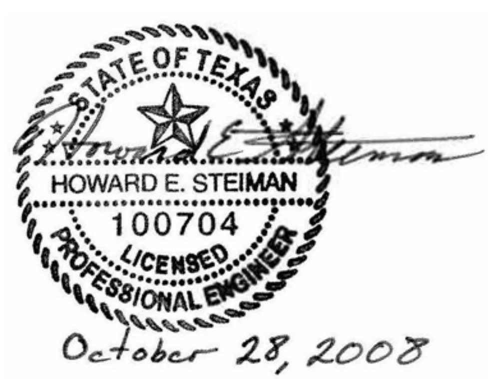

The seal affixed by Tara L. Hickey, P.E. 88518, applies to Section 1 of the report. The seal affixed by Charles W. Kreitler, P.G No. 37 applies to Section 2 of the report. The seal affixed by Howard E. Steiman, P.E. 100704, applies to Section 3 (except Sections 3.5 and 3.6) and Section 4 of the report. The seal affixed by Robert P. Bergeron Jr., P.E. 95592, applies to the Sections 3.5 and 3.6 of the report.

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The Brackish Groundwater Desalination Project (the "Project") will provide San Antonio Water System ("SAWS") with 20 to 25 million gallons per day ("MGD") of Finished Water for a planning period through 2060. The source water for the Project includes brackish groundwater, with a total dissolved solids ("TDS") concentration range of approximately 1,200 milligrams per liter ("mg/l") to 1,700 mg/l, from three proposed well field sites. The first is located in southern Bexar County, at the existing SAWS Aquifer Storage Recovery ("ASR") site. The second is located at SAWS Jasik site in Bexar County. The third is in Atascosa County. The Wilcox Aquifer will be the groundwater source for each site.

Hydrogeological Assessment

In association with R. W. Beck, Inc. ("R. W. Beck"), LBG-Guyton Associates ("LBG-Guyton") evaluated the feasibility of producing sufficient quantities of brackish groundwater from the Wilcox and Edwards Aquifers, located in the vicinity of San Antonio, Texas to serve as Raw Water for the Project.

LBG-Guyton evaluated the areal extent, depth and thickness of the brackish Wilcox sands in southern Bexar, western Wilson and northern Atascosa counties on a screening level basis, recommended four locations for additional consideration. In addition to the basic hydrogeologic evaluation, LBG-Guyton's screening criteria included: 1) competition for the water resource with other possible current users; 2) potential regulatory issues associated with existing groundwater districts and authorities; 3) access issues for testing and production well construction; and 4) presence of current or planned infrastructure. From this evaluation, LBG-Guyton recommended further testing at three well field sites, the SAWS' ASR and, Jasik sites, and a site in Atascosa County. At Location 4, there may only have up to 500 feet of brackish sands may be available for production and therefore was not considered for further evaluation.

In addition to the screening performed on the Lower Wilcox Aquifer, screening was performed for two possible sites in the Edwards Aquifer. Screening was performed by LBG-Guyton by selecting two sites for consideration: one in northern Atascosa County and one in western Guadalupe County near the creek in Cibolo. The Atascosa site was the recommended over the Cibolo site, as the potential for long-term production appears more feasible at Atascosa site. This area is currently regulated by the Evergreen Underground Water Conservation District and has a higher likelihood of permitting production, as compared to the Cibolo site, which is regulated by the Edwards Aquifer Authority. The Atascosa site is located farther from Comal and San Marcos Springs and therefore, would also have less possibility of impacting springflow as compared to the Cibolo site.

During the initial drilling in the Edwards Aquifer, elevated levels of hydrogen sulfide were discovered. Therefore, further consideration of the Edwards Aquifer as a source of brackish groundwater was not continued. However, for completeness, a summary of the Edwards Aquifer drilling was submitted to SAWS for information.

Based on the results of the site selection discussed above, a total of three test wells and two monitor wells were constructed in the Wilcox Aquifer with a monitor well constructed into the shallower Carrizo Aquifer at Site 3 in Atascosa County.

Monitor and test wells were installed and tested for water quality and production capability. In addition, modeling was conducted to predict the long-term effects of well field operation on aquifer drawdown and water quality.

Through the research, well construction, and hydrogeological assessment, the following conclusions can be made:

- SAWS production will be from Lower Wilcox; drilling confirmed resource availability.
- Large volumes of brackish groundwater available in Lower Wilcox are sufficient to supply 25 MGD.
- No other entities or landowners are currently producing from the Lower Wilcox Aquifer.
- Upper Wilcox aquitard is approximately 200 – 300 feet thick which provides a low vertical permeability and will further limit water level declines in the Carrizo.
- Modeling indicates production from the brackish zone of the Lower Wilcox will result in insignificant (4 feet at 20 MGD for 25 years) water level decline in freshwater Carrizo Aquifer over 50 years; natural seasonal variations in the Carrizo Aquifer range from 20 to 40 feet per year.
- Moderate transmissivities at 9,000 gallons per day per foot (“gpd/ft”) (1,200 ft^2/d).
- Water quality: TDS range 1,200-1,700 mg/l.
- Based on a Raw Water production rate of 25 MGD, 250-350 feet of water level decline in the Lower Wilcox Aquifer by 2060 (50 years).
- Regional water chemistry of the brackish Wilcox Aquifer is relatively consistent across the study area in southern Bexar and northern Atascosa counties and is not expected to vary during long-term production.

Table ES-1 summarizes LBG-Guyton’s recommended production well characteristics and withdrawal rates for all three well field sites, as determined from their hydrogeological study.

Table ES-1
Recommended Well Site Production and Well Spacing

Site	No. of Wells	Yield per Well (gpm)	Total Production (gpm)	Total Production (MGD)	Spacing (ft)
ASR	8	800	6,400	9.2	4,000
Jasik	7	800	5,600	8.1	4,000
Atascosa	10-15	1,000	10,000-15,000	14.4-21.6	4,000
Total	25-30		22,000-27,000	31.7-38.9	

Water Quality and Treatment Options

Raw Water will be obtained from the three proposed well fields located on the ASR, Jasik, and Atascosa properties. Four Raw Water quality scenarios were defined to provide maximum TDS; minimum TDS; average/normal operation TDS conditions; and high TDS normal operation conditions, for this assessment. As described in detail in the Water Quality Assessment Technical Memorandum, these Raw Water wells are feasible sources for the proposed reverse osmosis ("RO") Facility in terms of both sustainable production rate and quality.

To condition the Raw Water so it is suitable for an RO process, various pretreatment steps such as chemical addition to control deposition from sparingly soluble salts (e.g. calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate, and calcium fluoride), and silica appear necessary. In addition, a filtration step may be needed to reduce silt and iron levels to concentrations in the feedwater for the RO process that are compatible with membrane manufacturer's operational guidelines. SAWS began pilot testing RO membranes to be utilized in the treatment process in the third quarter of 2008. The test program includes an assessment of pretreatment process requirements.

The Project will produce up to 20 MGD of Finished Water with 25 production wells. The Finished Water will be a blend of desalination process effluent and Raw Water that is controlled such that the Finished Water meets United States Environmental Protection Agency ("USEPA") Primary and Secondary Drinking Water Standards, SAWS 400 mg/l TDS standard and the SAWS standards for the ASR Facility. In the configuration currently envisioned for the treatment process, the Raw Water by-pass will be treated to remove suspended solids in the pressure filter and combined with RO permeate (desalinated product stream). Then, the blended stream of Raw Water and RO permeate will be re-mineralized and disinfected to produce Finished Water.

RO permeate is a soft, low alkalinity water that can be corrosive. Therefore, several post treatment steps will be needed so that the Finished Water meets Texas Commission on Environmental Quality ("TCEQ") and SAWS Standards. The post treatment process steps that appear necessary consist of gas stripping for hydrogen sulfide removal; lime and carbon dioxide addition for pH adjustment, stabilization, and corrosion control; and sodium hypochlorite addition for disinfection (free chlorine residual level of 3.5 mg/l). While only limited laboratory data is available for the Atascosa wells, gas stripping also appears necessary.

Treatment Plant Siting and Distribution System Integration

The primary issues related to the siting of Project facilities are: 1) the availability of an electrical power supply; 2) the integration of the Finished Water into the SAWS distribution at a location where there are sufficient demands; 3) the distance to a suitable concentrate disposal site; and 4) if pretreatment media filtration is needed, the distance to a suitable surface water discharge location for filter backwash disposal.

SAWS has selected preliminary locations for the treatment plant and Finished Water distribution system integration point. SAWS current plans call for situating the proposed RO Facility at SAWS existing ASR Facility and using the existing Anderson Pump Station as the integration point for the Project. The change from the Trumbo/Englehart site to the ASR property for the RO Facility was finalized in May 2008, after the alignment study, cost estimate for the Project, the concentrate disposal evaluation, and the economic model were completed. The ASR Facility was chosen because it appears to have sufficiently robust electric utility infrastructure nearby and is located relatively near the ASR and Jasik Raw Water well fields. The Anderson Pump station has sufficient demand to accommodate the Project’s full Finished Water production capacity. However, the changes relocating the RO Facility to the ASR property and the point of integration to the Anderson Pump Station increased the length of the Finished Water transmission line, will necessitate several stream and river crossings, and will require a booster pump station.

Alignment studies for the concentrate disposal and pre-treatment media filter backwash disposal pipelines have not been conducted as disposal sites for these two streams have not been selected. Alignment studies for these two pipelines will be conducted during the next phase of the Project.

Residuals Management

With the use of RO as the treatment method for the brackish groundwater, it is anticipated that 3 to 4 MGD of concentrated TDS will be produced and about 4 MGD of pre-treatment filter backwash could be created if pre-treatment filtration proves necessary. These residuals may be comprised of RO concentrate, clean-in-place (“CIP”) waste, gas stripper wastes, pretreatment filter backwash, and pretreatment filter backwash sludge after dewatering for volume reduction. Pilot testing will confirm the need for specific pretreatment requirements and assist in quantifying the amount of pretreatment filter backwash, if any, requiring disposal. Backwash disposal will not be required if piloting shows the pretreatment filtration process can be eliminated. The primary residuals management options investigated for the purpose of developing conservative project costs are deep well injection for the concentrate stream and surface water discharge for pretreatment filter backwash. These options are summarized in Table ES-2.

Table ES-2
Residuals Disposal Options

Residual Stream	Disposal Method
Concentrate (RO concentrate, CIP waste and gas stripper cleaning waste Disposal)	Disposal by Class I well injection
Concentrate (RO concentrate, CIP waste and gas stripper waste disposal)	Surface water discharge to the San Antonio River
Single stage pressure backwash	Surface water discharge to the San Antonio River

The feasibility of the deep well injection option is dependent on identifying a suitable injection location. Preliminary research has revealed that the Saspamco Field in Wilson County could provide a favorable geology for deep well injection. Additionally, this research identified the existence of an abandoned oil production well which SAWS could use to conduct an evaluation of the suitability of the local geology as a deep well injection site.

The Medina River was also considered as a potential discharge location for concentrate disposal when the Trumbo/Englehart property was considered as a potential site for the RO Facility. However, the Medina River option was eliminated as a viable option after a TCEQ screening evaluation of the Medina River scenario indicated that the sulfates would exceed TCEQ's screening criteria.

We performed a second screening assessment of discharging concentrate to the San Antonio River using TCEQ's criteria after SAWS decision to re-locate the proposed RO Facility to the ASR property. At this stage of the screening evaluation there were no fatal flaws identified that prohibit further consideration of discharge to segment 1911 of the San Antonio River. Therefore, the results of this screening assessment show that it may be theoretically feasible to use a surface water discharge to the San Antonio River for concentrate either with or without co-mingling filter backwash with the concentrate discharge. Thus, if the concentrate disposal option via surface discharge to the San Antonio River proves to be practical, this alternative would eliminate the costs associated with the concentrate disposal pipeline and injection wells. However, further study related to the practicality of implementing the option should be conducted before its selection. Areas for further consideration include the need for aeration to increase the dissolved oxygen level of the groundwater-based concentrate, the permit limits for fluoride that may be applied, the exemption possible for discharges from drinking water facilities for naturally occurring radionuclides (“NORMs”), and levels of various toxic pollutants from an extensive list routinely considered by TCEQ at the permit application stage. The study should also encompass rights of way issues; coordination with organizations such as TCEQ, the San Antonio River Authority, and the South Central Texas Regional Water Planning Group (Region L); discussions with downstream water users; and public outreach efforts in addition to further assessment of the potential for environmental impacts.

In addition to the deep well and surface water disposal methods for concentrate, a third option is being evaluated. This disposal option is a high recovery process using the New Logic Research, Inc. Vibratory Shear Enhanced Process® (“VSEP®”). VSEP® will be piloted during the third quarter of 2008 to determine its feasibility. The process uses vibratory shear forces to allow a sheet-type RO membrane to operate beyond the solubility point of sparingly soluble salts to enhance process recoveries. According to New Logic Research, the process may be capable of recovering more than 50 percent of the concentrate stream which would likely be reused as feedwater for the conventional RO process. Thus, if feasible, VSEP® would reduce the volume of the concentrate residuals stream by more than 50 percent.

The pilot testing conducted by SAWS will investigate VSEP reliability and effluent and residuals quality and quantity to facilitate a decision about incorporating VSEP into the design. SAWS will be piloting the VSEP system during the third quarter of 2008 to determine its feasibility. If feasible, VSEP® will significantly reduce the concentrate volume. However, it will also increase the concentrate salinity substantially. The increase in concentrate salinity will need to be taken into consideration when locating a suitable site for deep injection wells.

Permitting

SAWS, with input from R. W. Beck as a reviewer, developed the Permitting Plan (the “Plan”) for the Project. The Plan was developed from a 2004 Texas Water Development Board (“TWDB”) guidance document for permitting desalination projects in Texas, is included as Appendix D. The Plan provides a breakdown of permitting responsibilities for SAWS and the DB Vendor and is based on the assumption that SAWS will install the Raw Water production wells for the Project and the DB Vendor will design and install the balance of the Project facilities. Based on this division of responsibilities for permitting, SAWS has effectively transferred much of the permitting risk to the DB Vendor while retaining control over critical permits such as those for the injection wells.

A significant portion of the overall permitting effort will involve acquisition of groundwater district permits for those wells located in Atascosa and Wilson counties. The Evergreen Underground Water Conservation District (“Evergreen”) will have regulatory authority over Raw Water produced from these Counties. It is anticipated that drilling permits, production, and transport permits for Raw Water will be obtained for the wells that are placed within the boundaries of the district. These aspects are reflected in the Permitting Plan for the Project, included in Appendix D, herein. Potable water treatment utilizing RO membrane technology falls under the

"Innovative Treatment Technologies" portion of the TCEQ permitting structure and pilot testing of the membranes is essential to initiate permitting of the proposed RO Facility. The majority of the other major permits will be obtained from TCEQ.

Procurement and Financial Analysis

The Texas Legislature passed House Bill ("HB 1886") which now permits Design-Build ("DB") as an additional method of project delivery for public entities like SAWS. Four procurement options, traditional design-bid-build ("DBB"), design-build-finance-own-operate ("DBFOO"), design-build-operate ("DBO"), and DB were analyzed with respect to key contractual relationships, roles and responsibilities, benefits and drawbacks to determine optimal project delivery method for the Project. Additionally, financial analyses of each option were conducted, which focused on two primary comparisons: 1) one compares the cost per 1,000 gallons in the first year of operation; 2) the other measures the total life-cycle cost over 30 years of operation.

The financial analysis also included operating the proposed RO Facility as a peaking facility. In general, the cost per 1,000 gallons of product water is projected to increase approximately 25 percent due to the reduced operating level for a peaking facility.

The results of the financial analyses include the following:

- The benefits of reduced capital and operating costs in the DBO option result in the analysis indicating that DBO would have the lowest overall cost of all options evaluated. The life-cycle cost of DBO is projected to be approximately 6 percent less than the cost of the DBB option. SAWS may not utilize DBO directly based on current legislation, but may attempt to deliver the project through a non-profit conduit.
- DB is also expected to cost less than DBB, but more than DBO, in terms of both capital and operating costs. SAWS is assumed to be the operator under the DB option in the analysis.
- The DBFOO option, which has some non-financial advantages over other delivery options, is more expensive due tax obligations under Texas statues. A combination of sales tax on construction and select operating costs, ad valorem taxes on the project assets and federal income taxes for the private entity cause the DBFOO option to be comparatively more expensive than the other options evaluated.
- All of the alternative delivery options (DBFOO, DBO and DB) are expected to be completed approximately six months faster than the DBB option due to overlapping design and construction schedules.

Faster Project delivery is a significant advantage in terms of cost and schedule if time is of the essence, the need for additional water on a date certain is critical, the cost of delay in water delivery is high, and if construction costs are escalating rapidly. For example, according to Engineering News Record (ENR) cost indices, the cost of materials in Texas has escalated by about 1.5 percent per month from January 2008 through August 2008 and general construction costs have escalated by about 3 percent over the same time frame (Dallas ENR Index)[1].

The financial analysis of the four delivery options does not fully reflect the potential value of early delivery of treated water. Therefore, it is important for SAWS to recognize this difference when evaluating these options. Further, Project costs are significantly impacted by the size of the well fields and the length of the transmission, Raw Water collection, concentrate disposal, and pretreatment filter backwash disposal pipelines associated with the Project, all of which were have not been finalized at this time.

Based on the above discussion, SAWS has opted to use a combination of DBB and DB project delivery methods. The DBB method will be utilized for the Raw Water wells at the ASR, Jasik and Atascosa well fields and the DB approach will be used for the remaining Project features.

[1] Engineering News Record (ENR). January 21, 2008 and August 18, 2008.

Section 1
INTRODUCTION

1.1 Introduction

In October 2005, SAWS requested proposals for a Feasibility Assessment related to the development of the Project to provide San Antonio with 20 to 25 MGD of Finished Water for a planning period through 2060. The Project is included as a recommended water management strategy in the summary of South Central Texas Region (L) Region section of the 2007 State Water Plan. Based on information from the TWDB, the South Texas region has substantial brackish groundwater resources that SAWS believes this project is well suited to develop. The brackish groundwater developed in this area would provide SAWS with the potential to utilize a new source of water that would help offset peak demands during the summer months. Once developed, the project is expected to provide SAWS up to 22,000 acre-feet per year. The more detailed goals of the Project were identified as follows:

- Assess the feasibility and constraints of brackish desalination prior to locating a well field or well fields in the Wilcox Aquifer or saline portion of the Edwards Aquifer for a plant output of up to 20 MGD.
- Identify, through the use of the best available technology, the optimal locations for situating monitoring wells and production test wells to evaluate the potential for the production of brackish groundwater (1,000–3,000 mg/l of TDS concentration).
- Perform a hydrogeologic evaluation of the brackish portion of the Wilcox formation or the saline portion of the Edwards Aquifer to establish target areas for monitoring and further hydrogeologic evaluation.
- Evaluate the Aquifers for up to four sites by drilling monitor and test wells and select the best alternative two sites for placement of well fields.
- Construct, modify, and calibrate a groundwater flow model that will determine the following:
  - Long-term availability, sustainability and productivity of brackish groundwater in terms of both production quantity and quality in the vicinity of each of the sites under consideration.
  - Determine the effects on surrounding well owners with respect to drawdown for life of the Project.
  - Appropriate spacing between individual production wells within a well field.

- Develop water quality models to assess:
  - Water quality parameters in preparation for selection of desalination treatment methods, including recommendations for pre-treatment and post-treatment methods.
  - Constituents of water quality that would adversely impact desalination process.
  - Potential water quality changes over time.
  - Determine the effects on surrounding well owners with respect to drawdown for life of the Project.
  - Impacts of blending available groundwater with other water sources quality and treatment processes.
- Evaluate potential options for the management of desalination concentrate byproduct.
- Advise SAWS staff on the necessary local, federal, and state permits required to complete the drilling of wells, construction, and operation of desalination facilities and concentrate disposal.
- Propose alternative procurement structures and the associated organizational relationship between SAWS and a private entity that could develop, finance, build, own, operate (and possibly transfer) the Brackish Desalination Facility. This proposal must recognize, identify, and evaluate current limitations imposed by Texas law upon such alternative methods.
- Develop a financial model of the anticipated costs to SAWS with respect to the conventional design-bid-build procurement method and one of the alternative procurement arrangements. Consideration of the costs to SAWS should reflect anticipated capital costs, operating and maintenance expenses, and analysis of financing methods for a term of 30 years.

The R. W. Beck team (the "Team") for the Project consisted of LBG-Guyton, Mickley and Associates ("Mickley"), and R. W. Beck. LBG-Guyton served as the hydrogeologic expert for the Team, Mickley focused on concentrate disposal issues, and R. W. Beck performed the water quality, treatment options, pipeline alignment, and assessments; compiled the cost estimate for the Project; and developed the financial model used for the Project.

The Finished Water quality characteristics were selected by SAWS so that the Finished Water would closely resemble the Edwards Aquifer water that SAWS currently distributes to its customers.

With these goals, the Team performed the above tasks, as summarized in the following:

- Section 2: Hydrogeological Assessment
- Section 3: Water Quality, Treatment and Facilities Assessment
- Section 4: Residuals Management

- Section 5: Permitting Plan
- Section 6: Procurement and Financial Analysis
- Section 7: References

Various Reports and Technical Memoranda were prepared throughout the Project. Each of these Reports and Technical Memoranda are included in an associated Appendix. Included in Appendix A are the following Technical Memoranda and reports submitted by LBG-Guyton during the course of the Feasibility Assessment:

- LBG-Guyton Associates. “Site Selection for San Antonio Water System’s Brackish Groundwater Resources in the Wilcox and Edwards Aquifers in the Vicinity of San Antonio, Texas.” March 29, 2006.
- LBG-Guyton Associates. “Data from Test Wells for SAWS Brackish Wilcox Groundwater Investigation Southern Bexar and Northern Atascosa Counties, Texas.” May 2008.
- Southwest Groundwater Consulting, LLC. “Modeled results of Mixing Ground Water from Three Test Wells, San Antonio Brackish Water Project.” May 7, 2008.
- LBG-Guyton Associates. “Evaluation of Well Spacing (Well Field Geometry) and Pumping Rates to Estimate Long-Term Drawdown for the SAWS Brackish Groundwater Wilcox Project.” December 2007 (revised May 2008).
- LBG-Guyton Associates. “Evaluation of the Brackish Groundwater Resources of the Wilcox Aquifer Southern Bexar, Atascosa and Wilson Counties.” August, 2008.
- LBG-Guyton Associates. “Suitability of Brackish Wilcox Groundwater for Use in Irrigation.” July 25, 2008.
- LBG-Guyton Associates. “Edwards Test Well for SAWS Brackish Groundwater Investigation Northern Atascosa County, Texas.” July 2008.
- LBG-Guyton Associates. “Consistency of Water Chemistry, Brackish Wilcox Aquifer: Southern Bexar and Northern Atascosa Counties.” August 2008.

Included in Appendix B are the following Technical Memoranda and reports submitted during the course of the Feasibility Assessment:

- R. W. Beck. “SAWS Brackish Groundwater Desalination Feasibility Assessment - Pipeline Alignment and Treatment Plant Siting Technical Memorandum.” March 24, 2008.
- R. W. Beck. “SAWS Brackish Groundwater Desalination Project Water Quality Assessment Technical Memorandum.” October 17, 2008.
- R. W. Beck. “SAWS Desalination Project Treatment Options Evaluation Technical Memorandum.” October 17, 2008.

Included in Appendix C are the following Technical Memoranda and reports submitted during the course of the Feasibility Assessment:

- Mickley & Associates. "Concentrate Management Screening Memorandum for SAWS Brackish Groundwater Desalination Feasibility Assessment Project." November 9, 2006.
- Mickley & Associates. "Enhanced Recovery Alternatives Review for SAWS Brackish Groundwater Desalination Feasibility Assessment Project." September 17, 2007.
- Geoffery A. Stone. "Brackish Groundwater Desalination Project Evaluation of Injection Location." February 11, 2008 (prepared directly for SAWS).

Included in Appendix D is the following report completed by SAWS during the course of the Feasibility Assessment:

- San Antonio Water System. "Permitting Plan." April 24, 2008.

Included in Appendix E are the following Technical Memoranda and reports submitted during the course of the Feasibility Assessment:

- R. W. Beck. "Draft Initial Procurement and Financial Memorandum." March 31, 2006.
- R. W. Beck. "Brackish Groundwater Desalination Feasibility Analysis of Procurement Options." January 2008.

As evidenced by the dates for the submittals, many of the Project components were accelerated. Land acquisition issues for the test well site for the Atascosa well field delayed the completion of the Raw Water quality and treatment options assessments. As a result, SAWS requested that the Team accelerate the schedule for preparing the cost estimate for the Study to complete it prior to finishing the Raw Water quality, treatment options, and pipeline alignment assessments. Further, the Project has evolved over the course of the Study such that it currently consists of 25 to 30 Raw Water production wells in three well fields, collection piping, a Raw Water booster pump station, Raw Water collection and supply piping, the proposed RO Facility, and a Finished Water transmission line terminating at SAWS Anderson Pump Station.

Several changes occurred after the cost estimate for the Project had been prepared. Some examples include decisions to change the point of integration for Finished Water from the Marbach Pump Station to the Anderson Pump Station, and to potentially increase the number of Raw Water production wells from 25 to up to 30, and consider relocating the site for the proposed RO Facility from a property in southern Bexar County bordered on the southeast by Trumbo Road and Englehart Road to a site on the ASR property.

Since there were several unknown factors at the time the Project cost estimate was prepared, a number of assumptions were necessary for the purpose of defining the Project sufficiently so that a cost estimate could be prepared. For example, specific locations for the concentrate disposal wells and for the surface water discharge had not been identified. Therefore, SAWS provided assumptions related to pipeline lengths for the concentrate disposal pipeline and for a surface water discharge pipeline that was required by the pretreatment system. Further, the Team did not have Raw Water quality data from the test well for the Atascosa well field.

Consequently, LBG-Guyton provided projections for major water quality parameters such as TDS, chlorides and sulfates, and R. W. Beck needed to make the assumption that the levels of other constituents would be similar to those reported in laboratory results for the ASR and Jasik test wells to develop a treatment process concept (the treatment process concept was verified after data for the Atascosa Test Well became available) and concentrate disposal alternative. Based on these uncertainties, the contingencies used for the cost estimate were conservatively selected. As a result, we recommend verifying the cost estimate once firm decisions about several Project aspects have been made. The Project's features needing confirmation include: 1) the number of Raw Water production wells; 2) the location of the proposed RO Facility; 3) concentrate disposal alternative and the location of the concentrate disposal wells (if deep well injection is selected as the disposal option); 4) whether a 400 mg/l or a 500mg/l Finished Water TDS Standard should be adopted; and 5) whether there is a need for a pretreatment filtration step with an attendant backwash disposal line and, if so, where the backwash discharge point will be located.

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Section 2
HYDROGEOLOGICAL ASSESSMENT

In association with R. W. Beck, LBG-Guyton Associates evaluated the feasibility of the long-term production of brackish groundwater from the Wilcox Aquifer in southern Bexar and northern Atascosa Counties. Following is a summary of the results and conclusions from the assessments performed from January 2006 through May 2008.

2.1 Site Selection

In association with R. W. Beck, LBG-Guyton evaluated the feasibility of producing approximately 20 to 25 MGD of brackish groundwater from the Wilcox and Edwards Aquifers, located in the vicinity of San Antonio, Texas. The brackish groundwater in the Wilcox Aquifer is found in southern Bexar, Wilson and Atascosa Counties, in south-central Texas (Figure 2-1). The brackish groundwater in the Edwards Aquifer is located in a northeast-southwest band across the approximate middle of Bexar County.

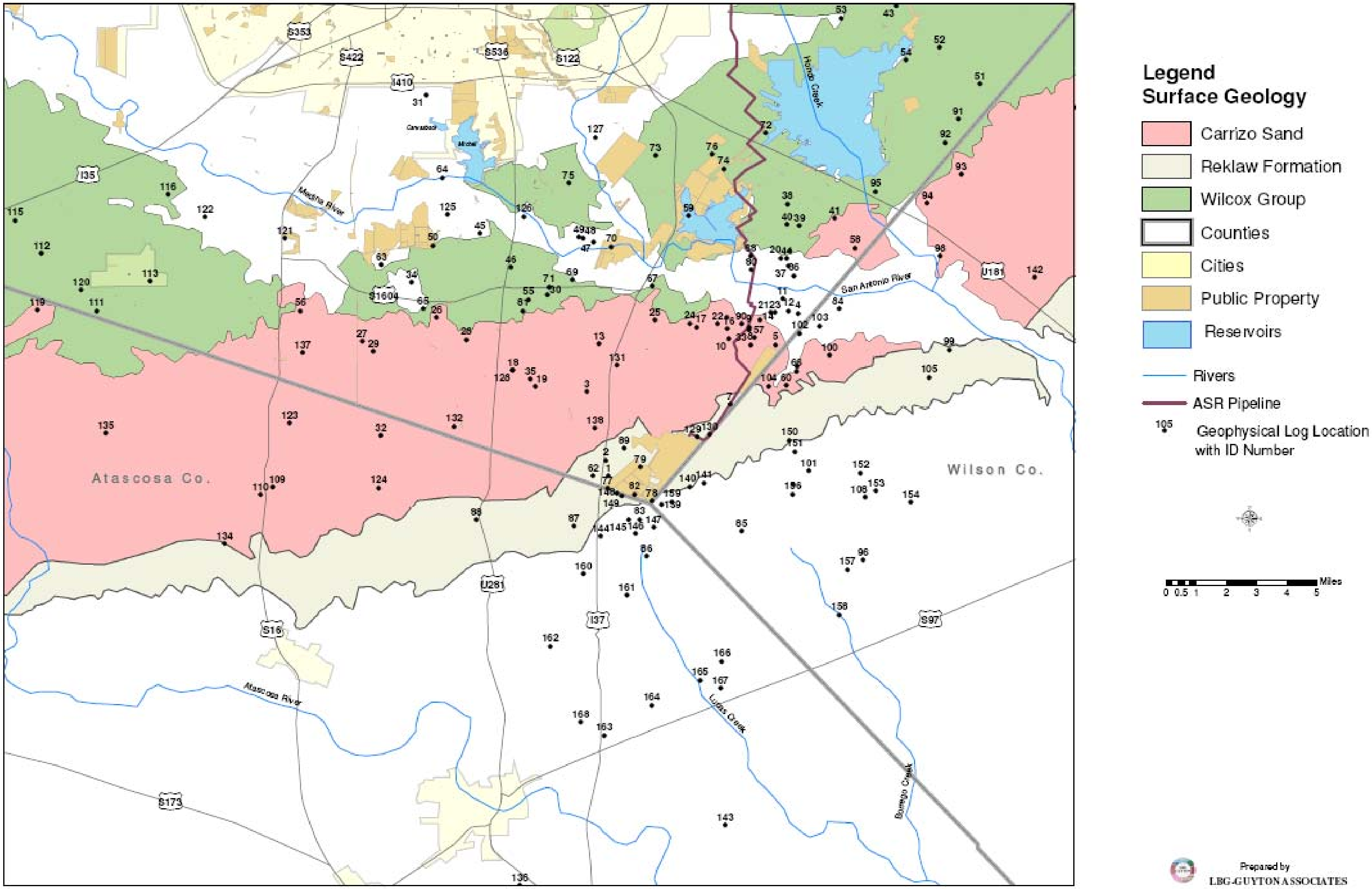

Figure 2-1 Location Map of Geologic Outcrops

The Wilcox Formation is a muddy sandstone, composed of fluvial/deltaic sediments. Its thickness ranges from a few hundred feet in the outcrop to approximately 2,000 feet, in the deep subsurface south and east of San Antonio. The Wilcox is overlain by the Carrizo Sandstone, a highly prolific aquifer in the area, and underlain by the Cretaceous Midway Formation, a thick shale. The Wilcox is divided into an Upper Wilcox and the Lower Wilcox (Reference 1). In southern Bexar County, the Upper Wilcox is predominantly composed of shale, which is interbedded with sands. The thickness of the Upper Wilcox ranges from 200 feet to 350 feet. The Lower Wilcox is a sandier part of the Wilcox, and may be as thick as 1,000 feet. Individual sands in the Lower Wilcox may be as much as 150 feet thick; cumulative sand thickness at any one location may exceed 500 feet. Therefore, the Lower Wilcox was the primary focus of LBG-Guyton’s investigation for the Wilcox Formation.

Fresh groundwater (with TDS less than 1,000 mg/l) occurs in the up-dip and outcrop locations of the Wilcox. Several domestic, municipal and irrigation wells produce groundwater from this section. These wells, however, are generally less than approximately 800 feet deep and have not tapped the total thickness, or the brackish section of the Wilcox. Farther down-dip, the Wilcox Aquifer thickens and the water quality becomes brackish. In some of the deepest sections of the Wilcox Aquifer in Wilson and Atascosa Counties, the water becomes saline (greater than 10,000 mg/l). The potential productivity of sands in the brackish part of the aquifer is considered to be similar to the sands in the produced fresh-water section. The geophysical log “signatures” (resistivity, gamma and SP logs) for the brackish sands appear similar to the sands in the fresh water section. The brackish groundwater is also within a thicker part of the aquifer and therefore may be more productive.

Data sets available from the Edwards Aquifer groundwater availability model (“GAM”) were utilized to construct contour maps of tops, bottoms and thickness of the aquifer. Figure 2-2 depicts a cross section of data for the Carrizo-Wilcox Aquifer which identifies the availability of brackish groundwater in the Carrizo and Wilcox Aquifers, where brackish groundwater is considered to have a TDS concentration between 1,000 mg/l and 10,000 mg/l.

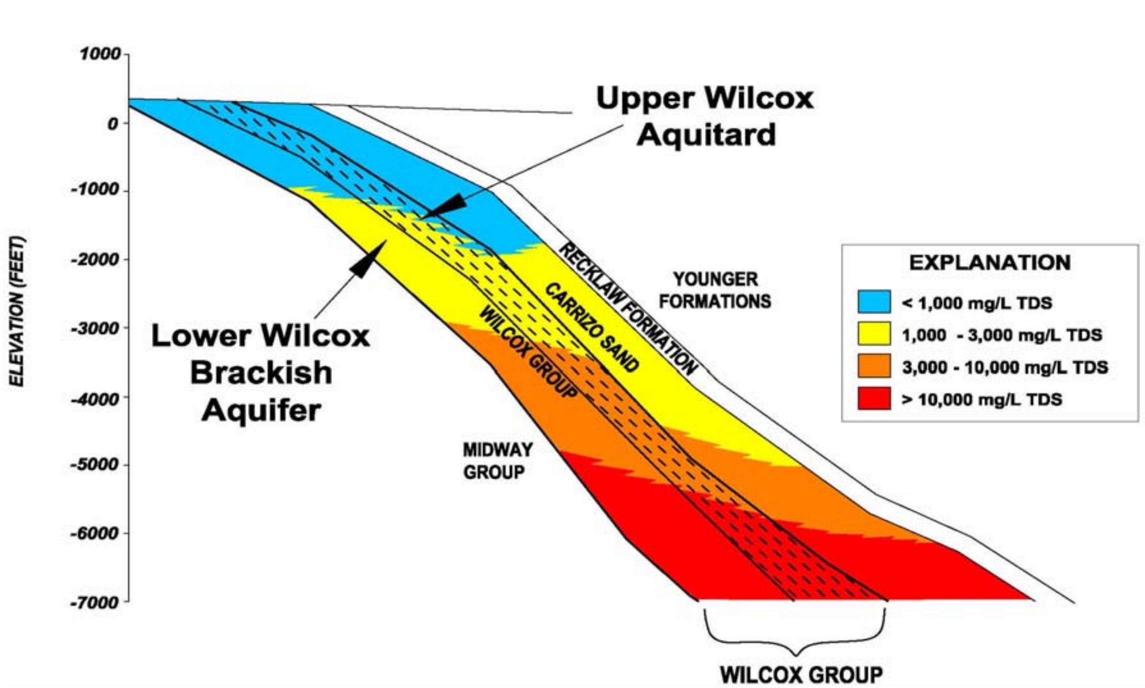

Figure 2-2 Schematic Cross-Section of Carrizo-Wilcox Aquifer

LBG-Guyton evaluated the areal extent, depth and thickness of the brackish Wilcox sands in southern Bexar, western Wilson and northern Atascosa counties, and recommended four locations for consideration at a screening level basis. Location 1 is in southern Bexar County. Location 2 is south of Braunig Lake. Location 3 is east of Pleasanton in Atascosa County. Location 4 is west of Floresville in Wilson County. Each location represents the thickest occurrence of brackish sand for that area. Figure 2-3 below identifies the Wilcox Aquifer recommended locations for a screening level review.

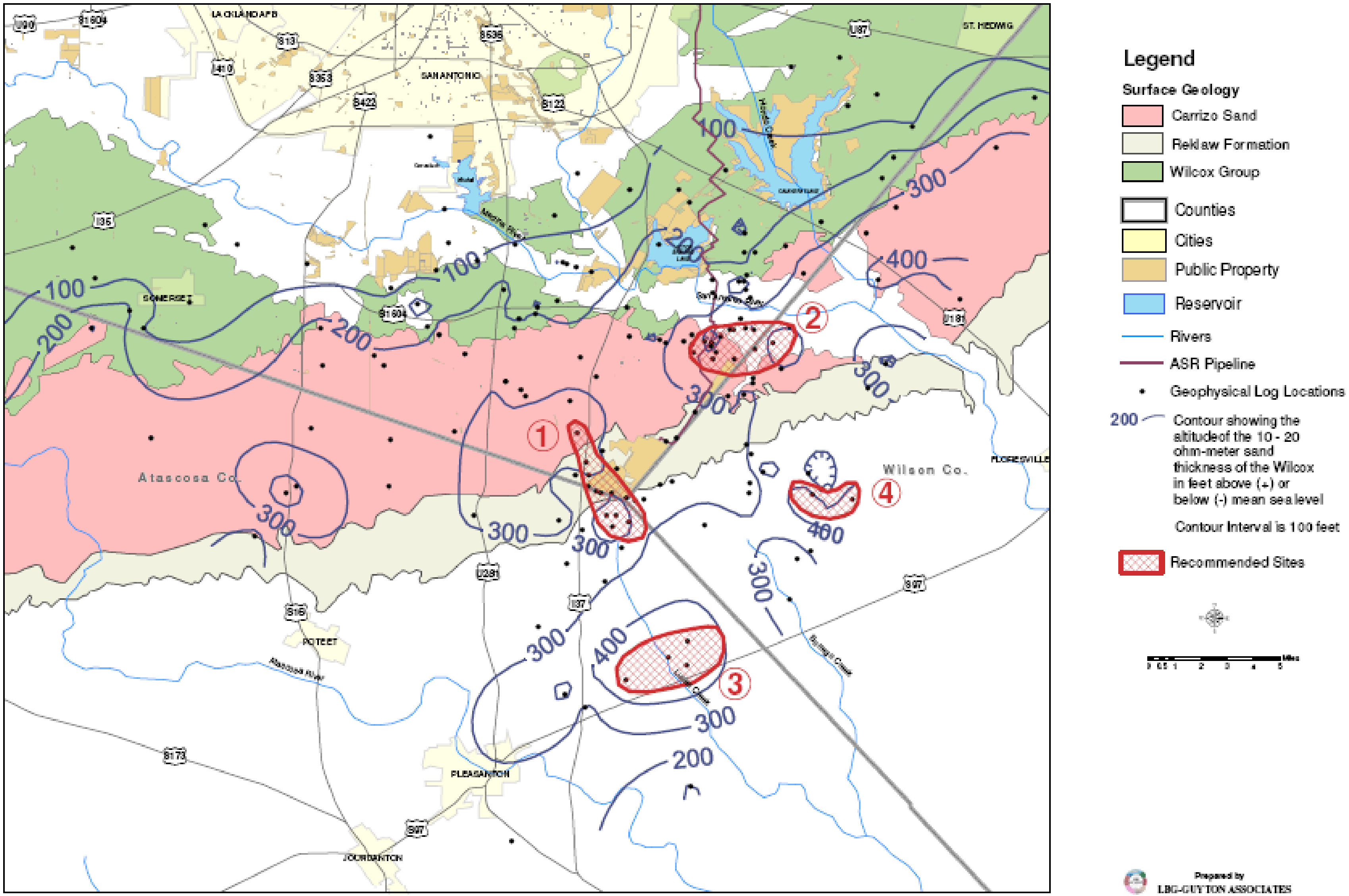

Figure 2-3 Locations in the Wilcox Aquifer Recommended for Screening Level Review During Site Selection Process

The hydrogeology of each location has been summarized below.

- Location 1 - At Location 1 there are several individual sands with thickness of 100 feet plus from depths of approximately 1,000 feet to approximately 1,900 feet. Cumulative sand thickness is up to 400 feet. Thick sands are also present in the wells in northern Atascosa County.
- Location 2 - At this location, there is a thick sand package from depths of approximately 650 feet to 900 feet. There is also a thick sand package at the base of the Wilcox from depths of approximately 1,000 feet to approximately 1,200 feet. These sand packages appear to be laterally continuous. Cumulative sand thickness approaches 400 feet.
- Location 3 - At this location, there are several sand packages of 100 feet plus at depths from 2,200 to 3,200 feet. There are at least three thick sand depositional packages that are laterally extensive for a distance of approximately five miles. Total sand thickness at this site approaches 500 feet.
- Location 4 - Location 4 is an area with a total sand thickness greater than 400 feet that extends from depths of 1,800 feet to 2,500 feet. Individual sand packages are greater than 100 feet thick. Other wells close to this sand thick, however, have a total sand thickness of approximately 200 feet. This thick sand area location appears to cover a smaller area than observed at Location 3.

In addition to the basic hydrogeologic evaluation, LBG-Guyton reviewed issues related to: 1) competition for the water resource with other possible current users; 2) potential regulatory issues associated with existing groundwater districts and authorities; 3) access issues for testing and production well construction; and 4) presence of current or planned infrastructure. These factors are summarized in Table 2-1.

Table 2-1
Decision Matrix for Screening Brackish Groundwater Well Field Locations in Wilcox Aquifer

Criteria	Location 1	Location 2	Location 3	Location 4
County	Bexar	Bexar	Atascosa	Wilson
Brackish Sand Thickness (ft)	300-405	225-415	450-490	438-465
Geologic Cross Sections (Presence of Thick Sands and Lateral Continuity)	Yes	Yes	Yes	Yes
Depth to Base of Wilcox (ft) (Maximum Depth of Well)	1,900	1,200	3,200	2,600
Depth to Top of Wilcox (ft) (Maximum Potential Drawdown)	1,400	400	2,000	1,400
Competition with other Users	No	Unknown at time of screening	No	No
Regulatory Issues(1)	Yes	No	Yes	Yes
Access to Well Locations	Yes	Yes	Unknown at time of screening	Unknown at time of screening
Access to Current SAWS Infrastructure, or Distance to SAWS ASR facilities	Yes	Yes	8 miles	8 miles

1. Regulatory items are associated with Evergreen Underground Water Conservation District

Based on the decision matrix and applicability of each of the four locations, LBG-Guyton recommended Locations 1, 2 and 3 for further testing. At Location 4, only up to 500 feet of brackish sands may be available for production. Other geophysical logs around the site do not show as many thick sands and may indicate a lack of lateral sand continuity in the area. Therefore, Location 4 was deemed the least attractive location and was not considered further during the Project.

In addition to the screening performed on the Lower Wilcox Aquifer, screening was performed for two possible sites in the Edwards Aquifer. Screening was performed by LBG-Guyton by selecting two sites for consideration: one in northern Atascosa County and one in western Guadalupe County near the creek in Cibolo. The Atascosa site was the recommended over the Cibolo site, as the potential for long-term production appears more feasible at Atascosa site. This area is currently regulated by the Evergreen Underground Water Conservation District and has a higher likelihood of permitting production, as compared to the Cibolo site, which is regulated by the Edwards Aquifer Authority. The Atascosa site is located farther from Comal and San Marcos Springs and therefore, would also have less possibility of impacting spring flow as compared to the Cibolo site.

During the initial drilling in the Edwards Aquifer, an elevated level of hydrogen sulfide was discovered. Therefore, further consideration of the Edwards Aquifer as a source of brackish groundwater was not continued. Due to the hydrogen sulfide, SAWS opted to plug and abandon the Brackish Edwards Test Well. In conformance with state of Texas requirements, the well was cemented from total depth to approximately within 6 feet of the surface and covered with soil.

2.2 Drilling and Well Construction

Based on the results of the site selection discussed above, in association with R. W. Beck, LBG-Guyton and their subconsultant, Alsay, Inc., drilled and constructed three test wells as listed in Table 2-2 and shown on Figure 2-4. This portion of the Project generally consisted of drilling and describing cuttings, geophysical logging, determining grain-size of selected intervals, constructing both test and monitor wells, performing pumping tests to determine aquifer parameters, and sampling water to ascertain water quality of the Lower Wilcox. A total of three test wells and two monitor wells were constructed in the Wilcox Aquifer with a monitor well constructed into the shallower Carrizo Aquifer at Site 3 in Atascosa County.

Table 2-2
Brackish Wilcox Test Sites

Site (#)	Type of Well	Actual Sand Thickness (ft)
ASR (TW-1)	Monitor	
	Test	364
Jasik (TW-2)	Monitor	
	Test	254
Atascosa (TW-3)	Test	431

Figure 2-4 provides the well locations. Table 2-3 further details the well construction of the Test Wells. Sites 1 and 2 included a test well and smaller diameter monitor well constructed in the sands of the Lower Wilcox. At Site 1, the Wilcox monitor well (MW-1) was located 403 feet east of the test well (TW-1). At Site 2, the Wilcox monitor well (MW-2) was located 438 feet northeast of the test well (TW-2). Site 3 has a test well (TW-3) completed in the Lower Wilcox and a monitor well (Carrizo MW) completed shallower in the Carrizo Aquifer located approximately 276 feet to the west of the test well.

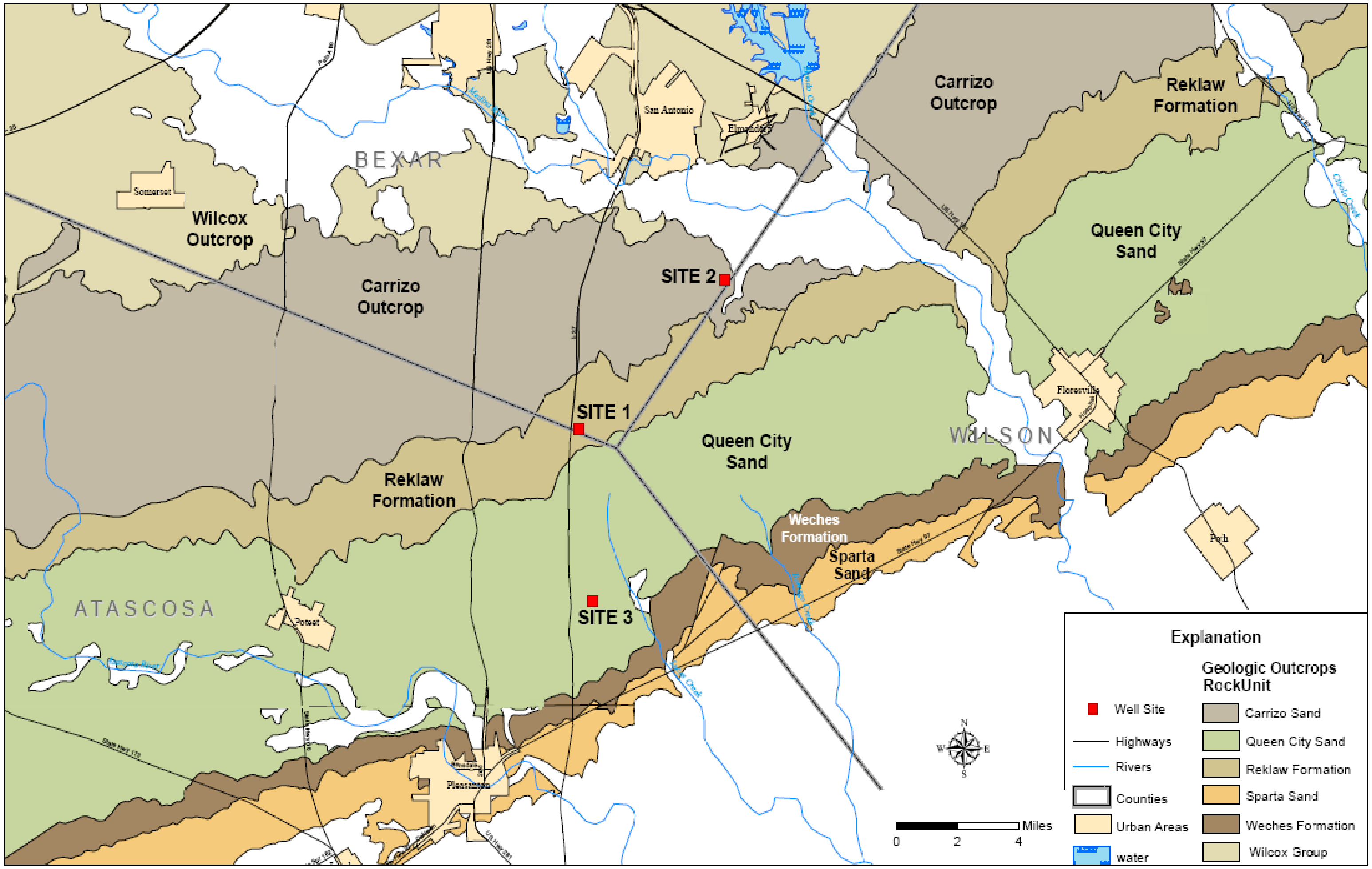

Figure 2-4 Brackish Wilcox Test Well Sites

Table 2-3
Test and Monitoring Well Construction

SAWS Well ID	TW-1	TW-2	TW-3
Construction Period	12/28/06 - 5/25/07	5/18/07 - 5/18/07	4/30/07 - 2/23/08
Well Depth	1,804	1,320	2,660
Screened Interval	1,226-1,784	752-1,230	1,965-2,640
Feet of Screen (ft)	364	254	431
Pumping Rate (gpm)	1,074	835	986
Annualized Rate (ac-ft)	1,559	1,212	1,278

Pumping tests were performed on each test and monitoring well installed during the investigation. The test wells had step tests that lasted two to three hours each at increasing rates, and then were tested at a constant rate for an extended period of two days or more. These tests were conducted to determine long-term discharge rates, water-level declines and to determine the aquifer parameters, such as transmissivity and storage coefficient that are utilized in groundwater flow modeling. Table 2-4 summarizes the aquifer parameters observed during the pump tests.

Table 2-4
Summary of Pumping Tests Performed on Wilcox Brackish Wells

Test Well	Average Pumping Rate	Total Minutes Pumped	Total Drawdown (ft)	2-hr Specific Capacity (gpm/ft)	Calculated Transmissivity (gpd/ft)	Calculated Transmissivity from Observ. Well (gpd/ft)	Storage Coefficient (unitless)
MW-1	176	194	82.6	2.4	6,460	--	--
TW-1	365	1,074	177.4	8.0	9,150	9,840	3.7×10^{-4}
TW-1	364	986	184.5	8.0	8,980	8,290	3.7×10^{-4}
MW-2	172	244	93.8	2.7	7,000	--	--
TW-2	254	853	203.2	5.2	9,200	9,050	2.5×10^{-4}
TW-3	431	986	143.4	9.7	9,970	--	--

Water-level hydrographs were measured in the Wilcox for both test (pumping) and monitor (observation) wells during these tests. A Wilcox monitor well was not constructed at Site 3. However, at the request of the Evergreen Underground Water Conservation District, a monitor well in the shallower Carrizo Aquifer was completed approximately 276 feet west of TW-3. This was done to observe any interaction between the Carrizo Aquifer and the deeper Wilcox Aquifer. No water-level decline occurred in the Carrizo MW while pumping the deeper Wilcox TW- 3. At the time of the pumping tests at Site 3, the Carrizo Aquifer static water level was approximately

50 feet deeper than the Wilcox Aquifer indicating a lower head and natural upward gradient from the Wilcox Aquifer compared to the Carrizo Aquifer.

Representative water samples were collected from each Wilcox well after extensive well development and near the end of the long, continuous pumping test. Field parameters (e.g. temperature, specific conductance, and pH) were measured at the well prior to and after sample collection. In addition to the field parameters, basic inorganic analyses, organic, radiochemistry and other constituents of concern were also performed by external laboratories. As part of the quality assurance/quality control program, duplicate samples for each well were taken by LBG-Guyton and delivered to the Lower Colorado River Authority ("LCRA") Environmental Laboratory of Austin, Texas for analyses.

The TDS ranges from approximately 1,200 to 1,700 mg/l with maximum concentrations of chloride and sulfate at 615 and 545 mg/l, respectively. Stiff diagrams graphically show that the major cation and anion species present in the water from each brackish well. Figure 2-5 shows a diagram for the basic water chemistry of each well with the TDS posted above each. The trilinear Piper diagrams also graphically represent the chemistry of major dissolved salts for each sample taken for the five wells, as shown in Figure 2-6.

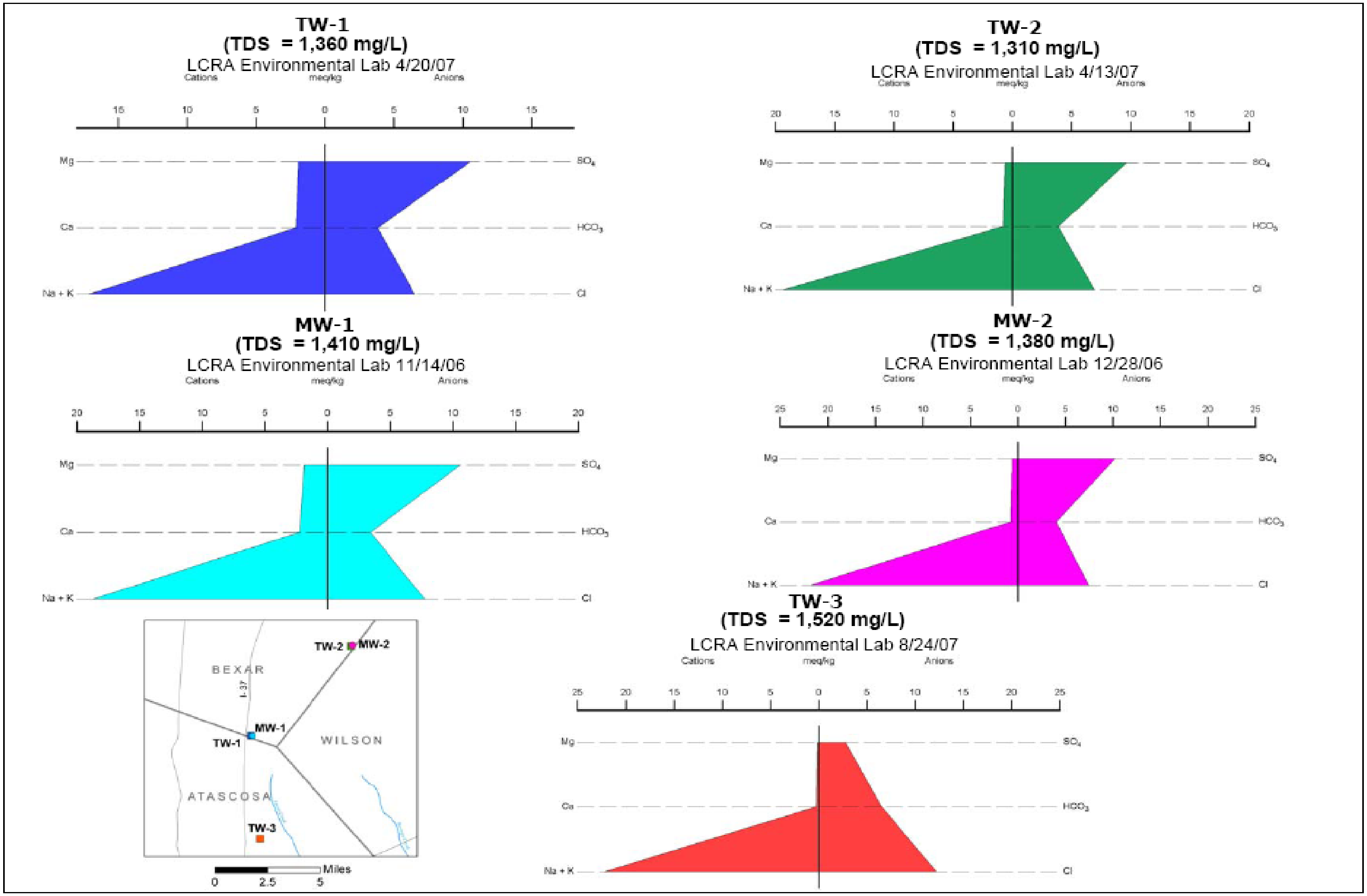

Figure 2-5 Stiff Diagrams for Test and Monitor Wells

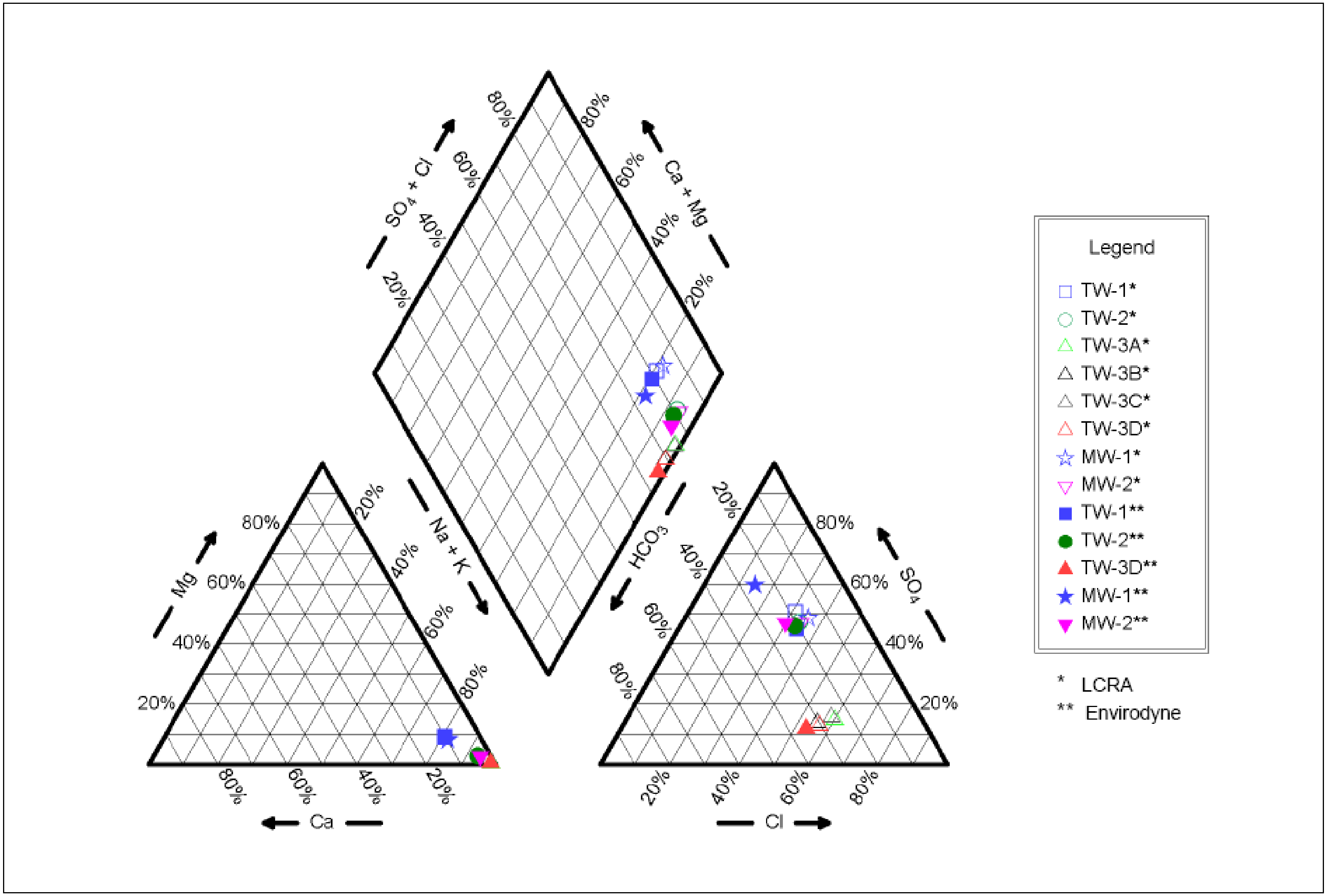

Figure 2-6 Piper Diagrams for Test and Monitor Wells

All samples analyzed illustrated that sodium (“Na”) is the predominant cation for the brackish Wilcox water. Samples from TW-3 in Atascosa County show high bicarbonate-chloride water, whereas the more geologically updip wells in Bexar County (TW-1, MW-1, TW-2 and MW- 2) are predominantly sulfate-chloride anion controlled water. The chemistry plots depicted as Piper diagrams and shown in Figure 2-6 exhibits the same general cation/anion species illustrated by the shapes of the Stiff diagrams in Figure 2-5.

In addition, an evaluation of the sodium absorption ration (SAR)[2], the ratio of Na to Ca and Mg was used in determining the suitability of groundwater for crop irrigation. The results are depicted in Table 2-5 for TW-1, TW-2 and TW-3. The higher the SAR, the more deleterious the use of the water is for irrigated crops. The presence of high SAR values indicates the potential hazard of Na replacing Ca and Mg in irrigated soils and soil structures.

Table 2-5
Sodium Adsorption Ratio (SAR) for TW-1, TW-2 and TW-3

Well	Ca (meq)	Mg (meq)	Na (meq)	SAR	Conductivity (umhos/cm)	Classification[(1)]
TW-1	2.14	1.92	16.90	11.86	1,970	C3-S3
TW-2	0.78	0.62	19.20	22.95	2,118	C3-S4
TW-3	0.26	0.14	27.50	61.49	2,472	N/A[(2)]

Notes:
1. Source: Driscoll, F.G., “Groundwater and Wells.” Johnson Division, 1986, Page 1089 and as depicted in Figure 2-7
2. N/A=Not applicable because the value is off of the scale

[2] SAR=Na/sqrt((Ca + Mg)/2)

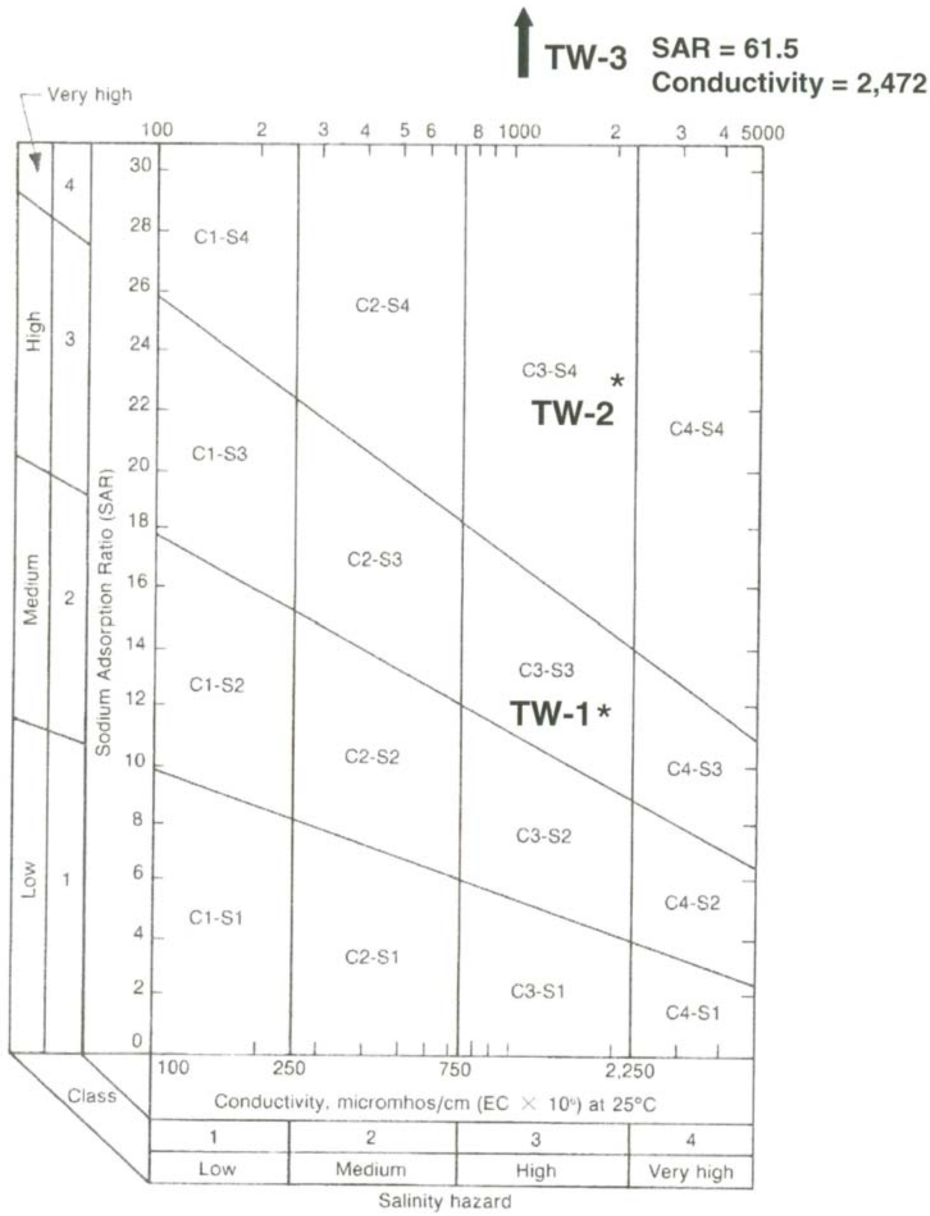

Figure 2-7 Groundwater Classification for Irrigation Use for TW-1, TW-2 and TW-3

During the sampling of some of the wells, entrained gas bubbles were noticed in the sampled water. The gases were analyzed and determined to be mostly nitrogen and oxygen, with small amounts of carbon dioxide ("CO_2") and trace quantities of methane. The water produced from the wells in some cases has come up from depths greater than 2,000 feet with substantial changes in pressure. Under these conditions, some degassing might be expected during pumping. The decreased water pressure permits the dissolved gasses to come out of solution.

Turbidity and silt density index ("SDI") are relative measures of suspended solids found in groundwater produced from the Wilcox Aquifer and are important to membrane selection and assessment of the need for pre-filtering of the well water prior to RO treatment. The suspended solids can clog membranes used in the proposed

RO Facility and shorten their lifespan. SDI is a calculation based on the time it takes a prescribed amount of water to pass through a 0.45-micron filter initially and at later time intervals. The suspended solids collect on the filter and accumulate through the testing duration making it progressively slower for water to pass through the filter paper.

One of the objectives of the long-term testing at TW-1 was to evaluate whether the SDI decreased with the duration of pumping. Carollo Engineer's ("Carollo"), who will be performing membrane pilot testing for TCEQ approval, performed sampling of TW-1, which indicated initially that TW-1 produced more turbid water with higher SDI values. As the pumping of TW-1 continued, the SDI measured in the field by Carollo declined to values less than 1.0 after the first day of pumping. The 0.45-micron filters used for these analyses had a rusty orange appearance. Dissolved iron was likely oxidizing and precipitating out of solution as iron oxide.

SDI testing performed by Carollo during the long-term pump test performed on the TW-1 showed that the SDI increased with time after sampling was conducted and samples were exposed to the atmosphere. Mineralogic analyses of some of the material left on the filter paper from the SDI testing were made using a Scanning Electron Microscope. The results indicated mostly clay (smectite and kaolinite) and quartz that are likely derived from the fine-grained sediment deposited in the Wilcox Formation. The higher SDI values measured during well development could potentially be attributed to a combination of either formation sediment accumulating in the well or the oxidation of ferrous iron in the groundwater to insoluble ferric oxide (rust) when the water was exposed to the atmosphere. Thus, the oxidation of the ferrous iron in the groundwater to insoluble ferric oxide may have contributed to the higher SDIs measured at the lab. Consequently, as discussed further in the Water Quality and Treatment Options presentations in Section 3, there is some uncertainty about the cause of the SDI issues. Carollo will perform additional SDI testing during the upcoming pilot testing to investigate SDI issues.

The regional water chemistry of the brackish Wilcox Aquifer is relatively consistent across the study area in southern Bexar and northern Atascosa counties and is not expected to vary during long-term production. This is based on three points of substantiation.

- The geophysical logs used in the construction of the regional cross section and brackish Wilcox sand thickness map indicate that the salinities calculated from the resistivity curves are consistently within a range of 1,000-3,000 mg/l of TDS across the area of investigation.
- The TDS between the three test wells is relatively consistent. There is a total TDS range of 500 mg/l. Na and Cl concentrations increase only slightly downdip. Sulfate ("SO_4") concentrations decrease slightly downdip and bicarbonate ("HCO_3") concentrations increase some. As groundwater flows downdip from the outcrop, dissolved sulfate may be reduced and organic material in the Wilcox sediments may be oxidized. This would explain the inverse relationship of concentrations between HCO_3 and SO_4.

Significant water chemistry changes were not observed during the sampling of individual test wells at different times. Water chemistry at TW-1 did not change from initial sampling in May 2007 to March 2008 (almost one year later). Nor were changes in water chemistry observed for water samples collected over time from the "14-day" pump test at TW-1. The sample collected on March 4, 2008, had a very similar chemical composition to the sample collected 14 days later on March 18, 2008 after continuously pumping a rate of approximately 1,000 gpm.

Thus, significant chemical changes in the brackish groundwater, are not anticipated during the long-term pumping of future well fields. Major water chemistry changes should not be expected for an individual well or well field over the life of the project (50 years). The electric logs reviewed indicated that salinity values are regionally consistent. There are no localized areas with significantly different resistivities. Conversely, the capture area for an individual pumping well is small in comparison to the regional extent of the brackish Wilcox Aquifer. The capture zone of the aquifer water from a pumping well is also different than the lateral extent of its cone of depression. Because of the very large volume of groundwater in a porous aquifer, such as the Wilcox, the radial distance from which a pumping well pulls water is very limited even though the cone of depression may extend much further away from the producing well. For example, after 50 years of hypothetically pumping of TW-3 at 1,000 gpm, the water has only moved from approximately 3,500 feet away. In other words, after 50 years of pumping, the source of water at TW-3 will only come from a "cylinder" in the Wilcox with a radius of approximately 3,500 feet. The cone of depression, however, may extend tens of miles from the pumping well. This capture zone calculation is based on the cylinder equation. It estimated a radius of influence, which was also needed for this study, that is, to define the source area for a long-term producing brackish well.

2.3 Hydrogeologic Modeling

In association with R. W. Beck, LBG-Guyton evaluated the impact of well spacing (well field geometries) and pumping rates for brackish Wilcox groundwater production on water level declines for periods up to the year 2060. Two computer modeling approaches, analytical and numerical, were used to assess potential drawdown for the proposed brackish groundwater production from the Wilcox. The results from this well field investigation also indicated:

- Increased spacing between wells does not significantly decrease well field drawdown.
- Increased pumping does cause increased head declines.

Water level declines in the Lower Wilcox calculated with QC-SPGAM (the numerical model) ranged from 154 to 307 feet. The analytical model indicated that the increase in well spacing from 3,000 feet to 7,500 feet decreased the amount of well field drawdown by approximately 100 feet, which LBG-Guyton considers insignificant. Increased well spacing, however, results in larger areas needed for a well field and increased length of pipeline needed to collect the water from the individual wells. For example, if the distance between wells is doubled from 3,000 feet to 6,000 feet, the well field area is approximately tripled from 1,470 acres to 4,500 acres. Increasing well spacing to reduce amounts of drawdown does not appear to be justified in the context of anticipated increased land and infrastructure costs. In addition, the numerical model indicated only minor amounts of head decline in the Carrizo from any of the pumping scenarios.

The amount of water-level decline within the well field area and regionally was evaluated for different pumping rates and different time periods (LBG-Guyton, revised May 2008). Water-level changes were simulated with the TWDB Queen City-Sparta ("QC-SP GAM", previously known as the CSW GAM). With the QC-SP GAM water-level declines in the Carrizo and Wilcox, future aquifer behavior can be simulated. Comparison of field data (e.g. transmissivity) from the three test wells to hydrologic parameters in the model shows the wells are similar; therefore, the official TWDB GAM model was used without modification. A well field was located in the general area of each of the three test sites and production was distributed between three well fields. The simulated production came primarily from the Lower Wilcox layer of the model. Total pumping rates were varied from 12.5 MGD to 20 MGD to 25 MGD to originally correlate with Finished Water production of 10 MGD, 16 MGD, and 20 MGD (or an 80 percent recovery rate). The 80 percent RO Facility recovery was developed prior to analysis and modeling. With the possible need for pretreatment filtration, the anticipated recovery is closer to 73 percent. The time periods for pumping were 5, 10, 25 and 53 years. The time period of 53 years (2060) was included since it represents the maximum water planning period being considered in the State of Texas regional water planning process. Water-level declines within the Lower Wilcox, middle Wilcox, upper Wilcox and Carrizo were evaluated.

With a production rate of 20 MGD for 25 years, water levels declined 250 feet in the Lower Wilcox in southeast Bexar County. Maximum simulated water-level decline in the overlying Carrizo for the same pumping rate and duration (20 MGD in the Lower Wilcox for 25 years) was approximately four feet. This is far less than is seasonally observed in the historic record of Carrizo water levels, which is 20 to 40 feet annually. Only minor simulated water-level declines are anticipated to occur in the Carrizo because the overlying upper Wilcox muddy aquitard provides a hydrologic seal between the Carrizo and the deep production zone in the Lower Wilcox (Reference 2). The model also predicts that most of the water-level declines will occur early, within the first five years of production; later (from five - 50 years), water-level declines will slow and stabilize. This permits an early evaluation of the expected drawdown in the well field and whether the model has accurately predicted future conditions in the brackish Wilcox and Carrizo Aquifers. The following Figures 2-8 through 2-16 depict various modeling results that describe the predicted future conditions. Figure 2-12 specifically displays the thickness of the Upper Wilcox aquitard; the aquitard thins the farther west it extends throughout Atascosa County.

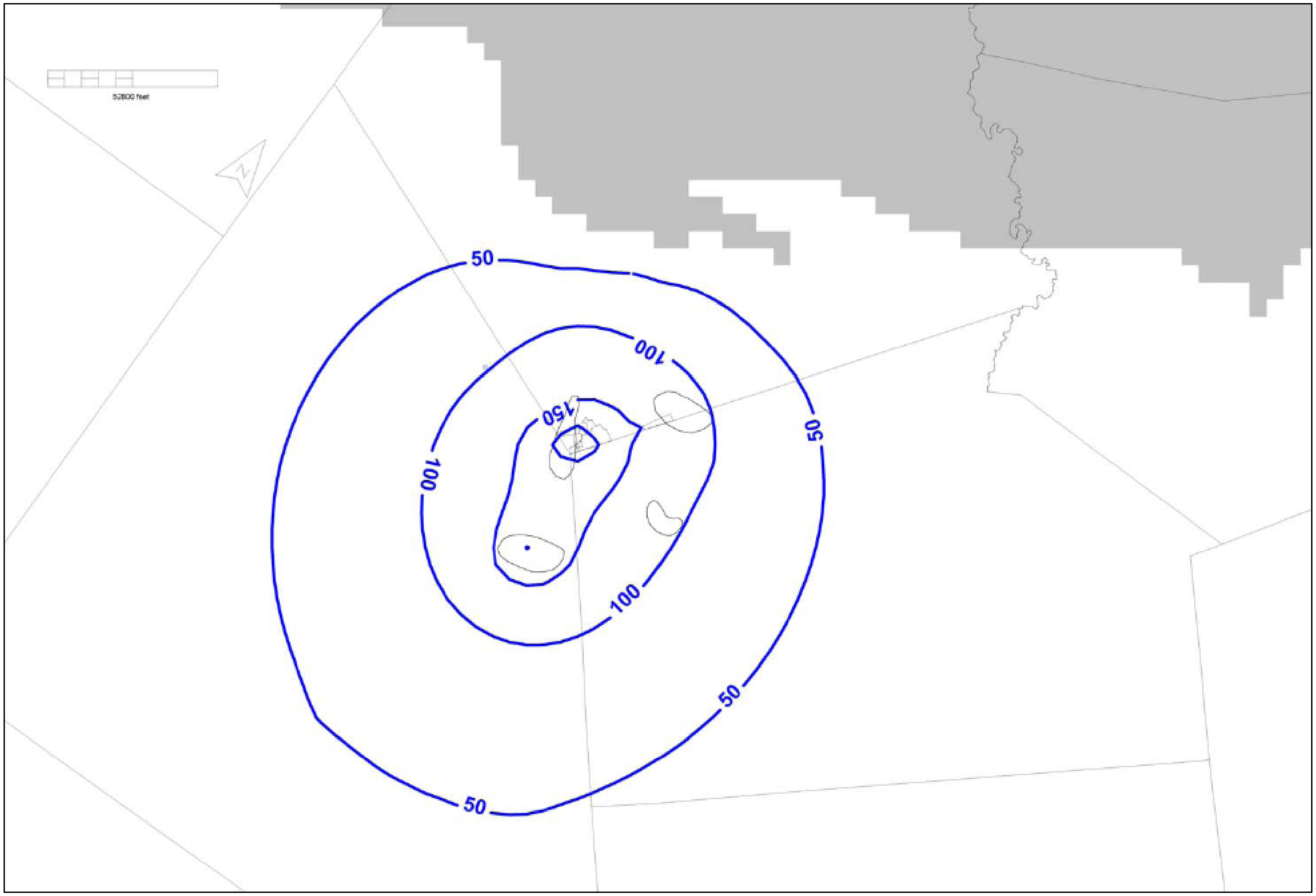

Figure 2-8 Projected Drawdown (ft) in Lower Wilcox after 25 Years Pumping (20 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

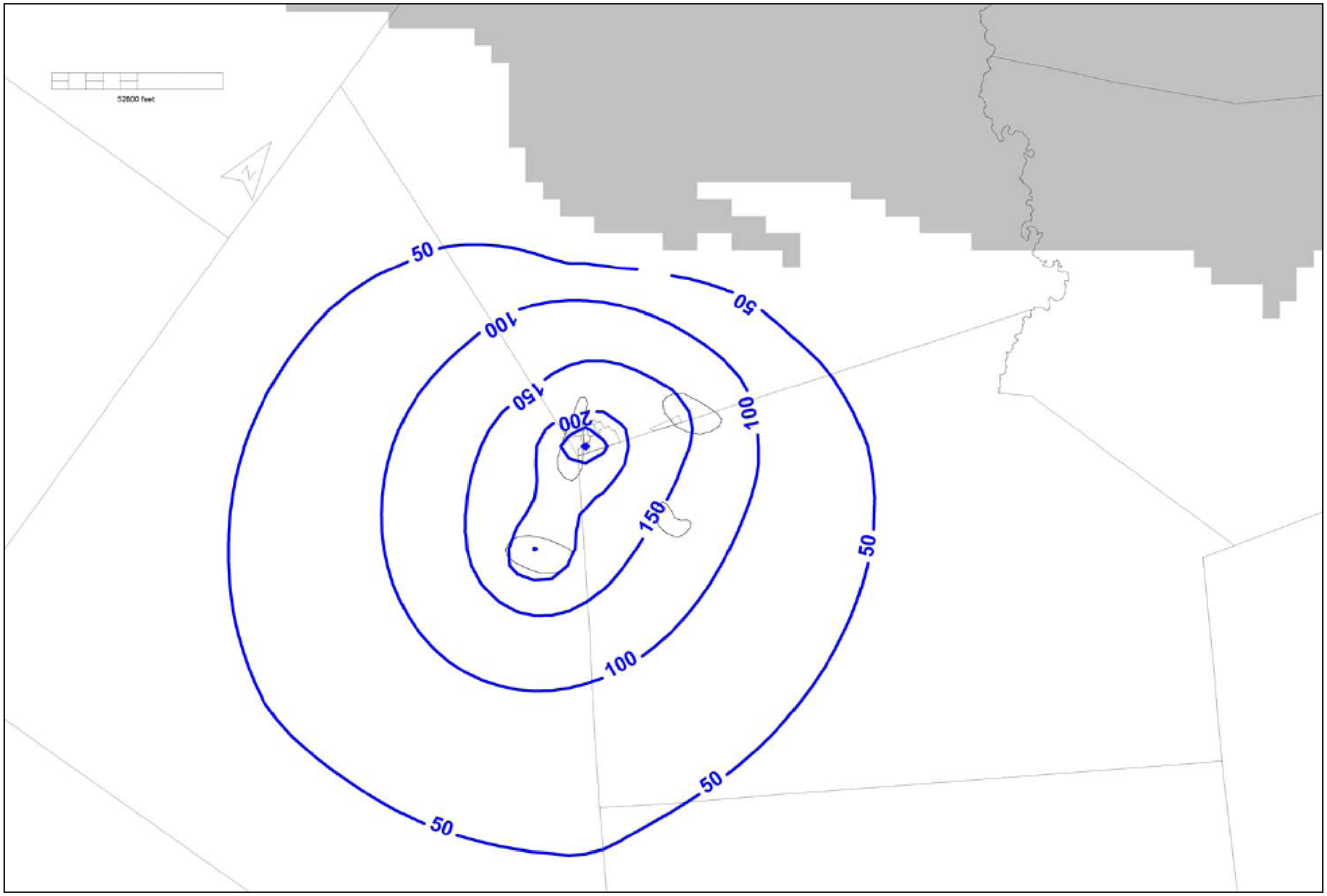

Figure 2-9 Projected Drawdown (ft) in Lower Wilcox at Year 2060 (20 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

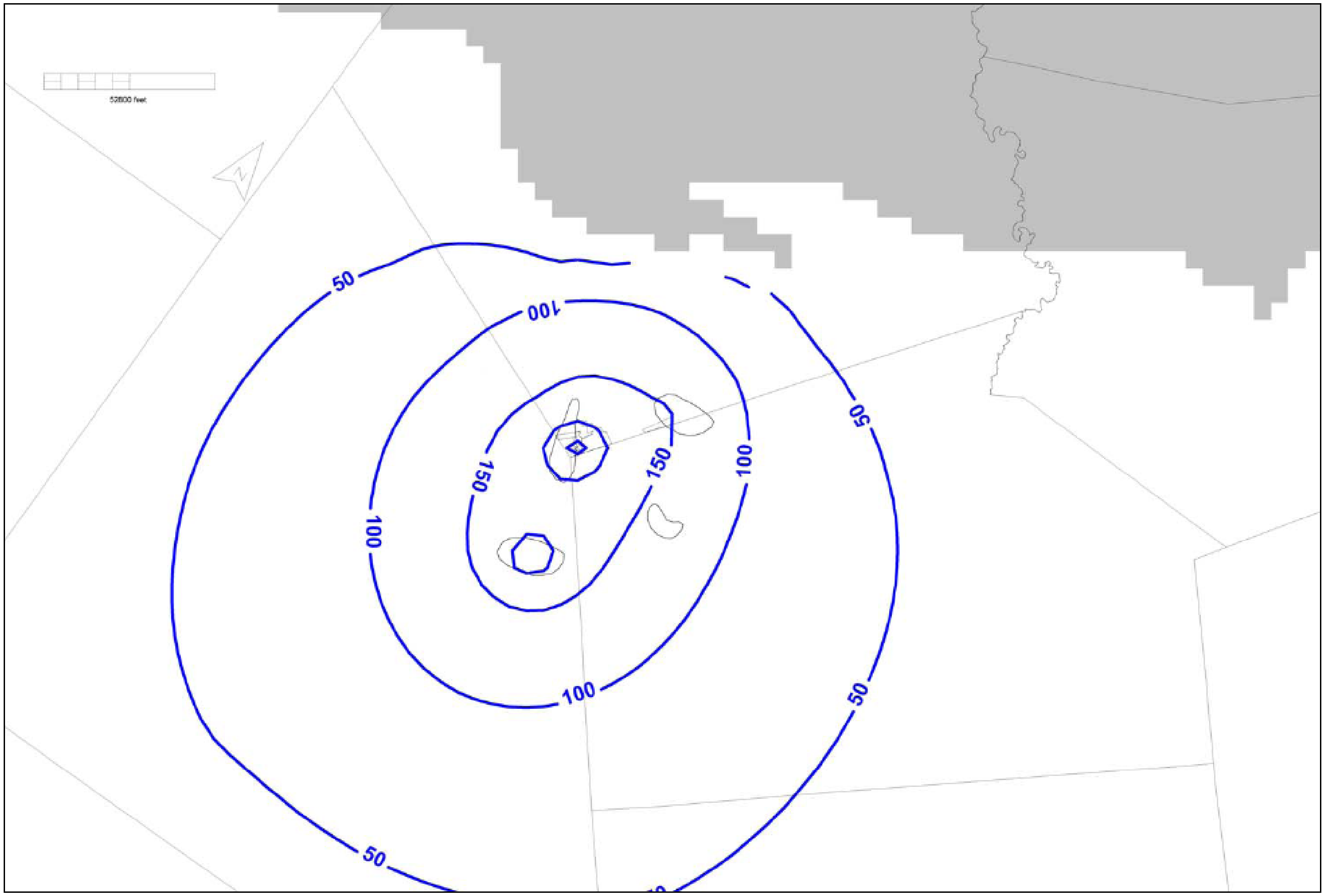

Figure 2-10 Projected Drawdown (ft) in Lower Wilcox after 25 Years Pumping (25 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

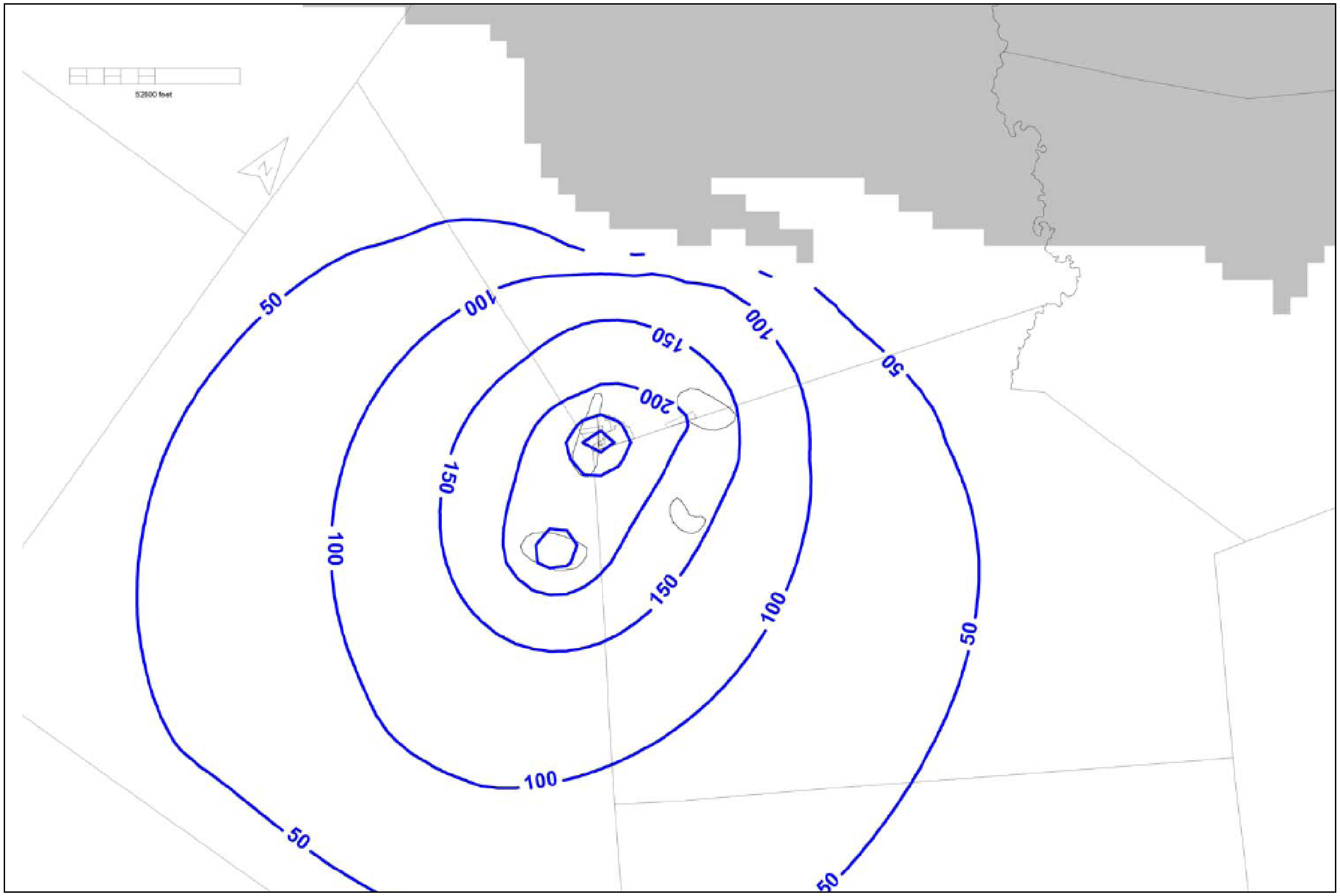

Figure 2-11 Projected Drawdown (ft) in Lower Wilcox at Year 2060 (25 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

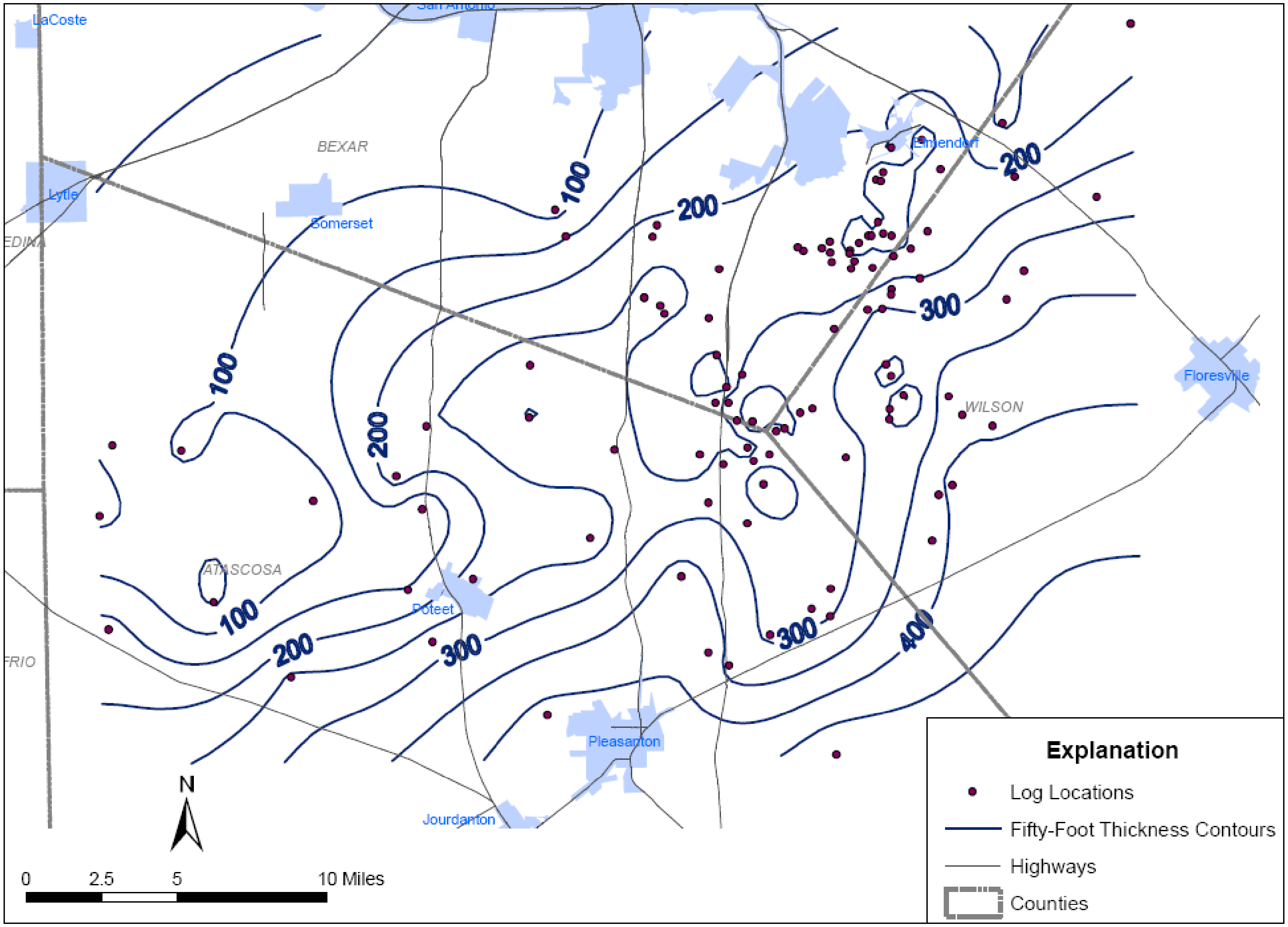

Figure 2-12 Upper Wilcox Aquitard Thickness Map for Bexar, Atascosa and Wilson Counties

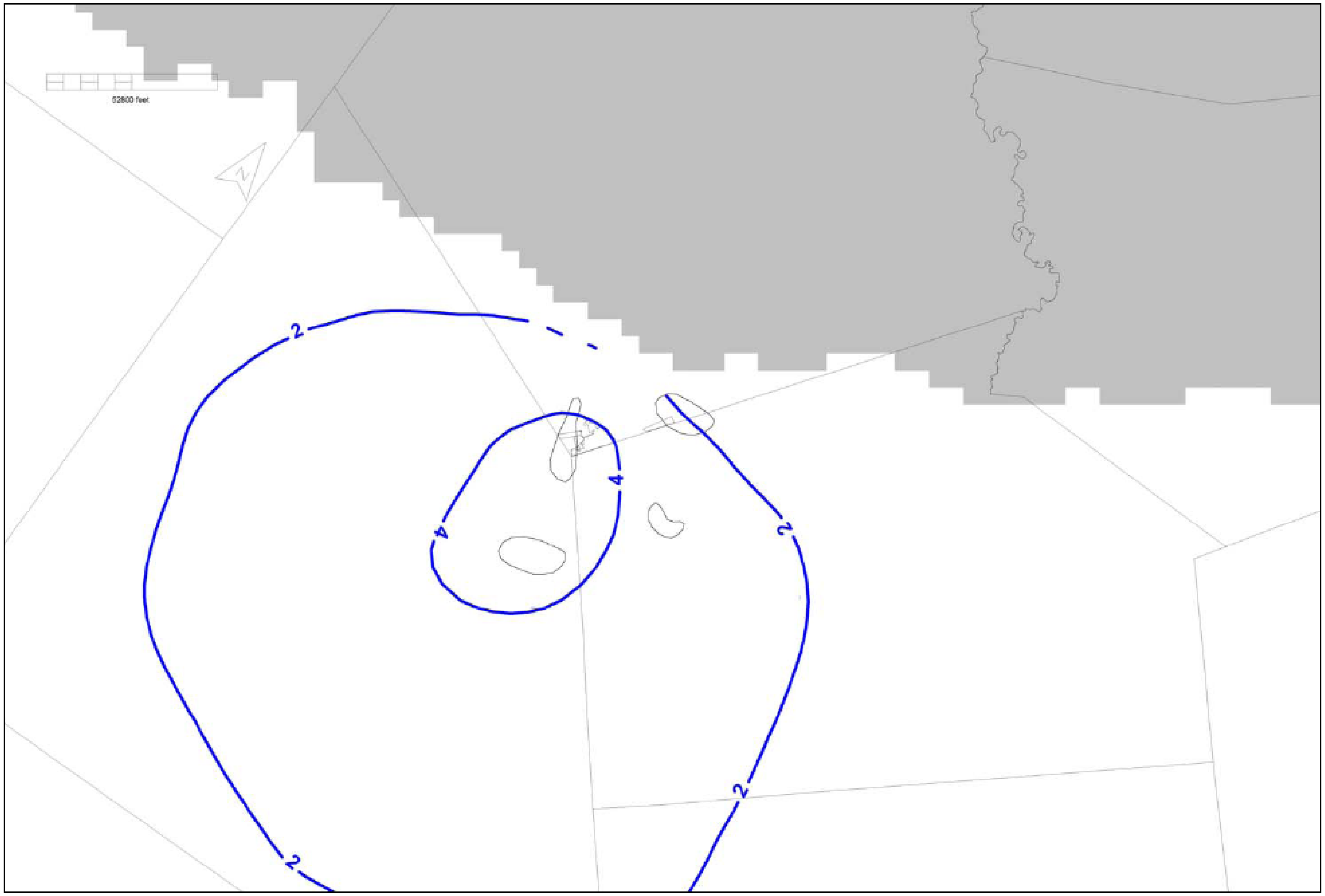

Figure 2-13 Projected Drawdown (ft) in Carrizo after 25 Years Pumping (20 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

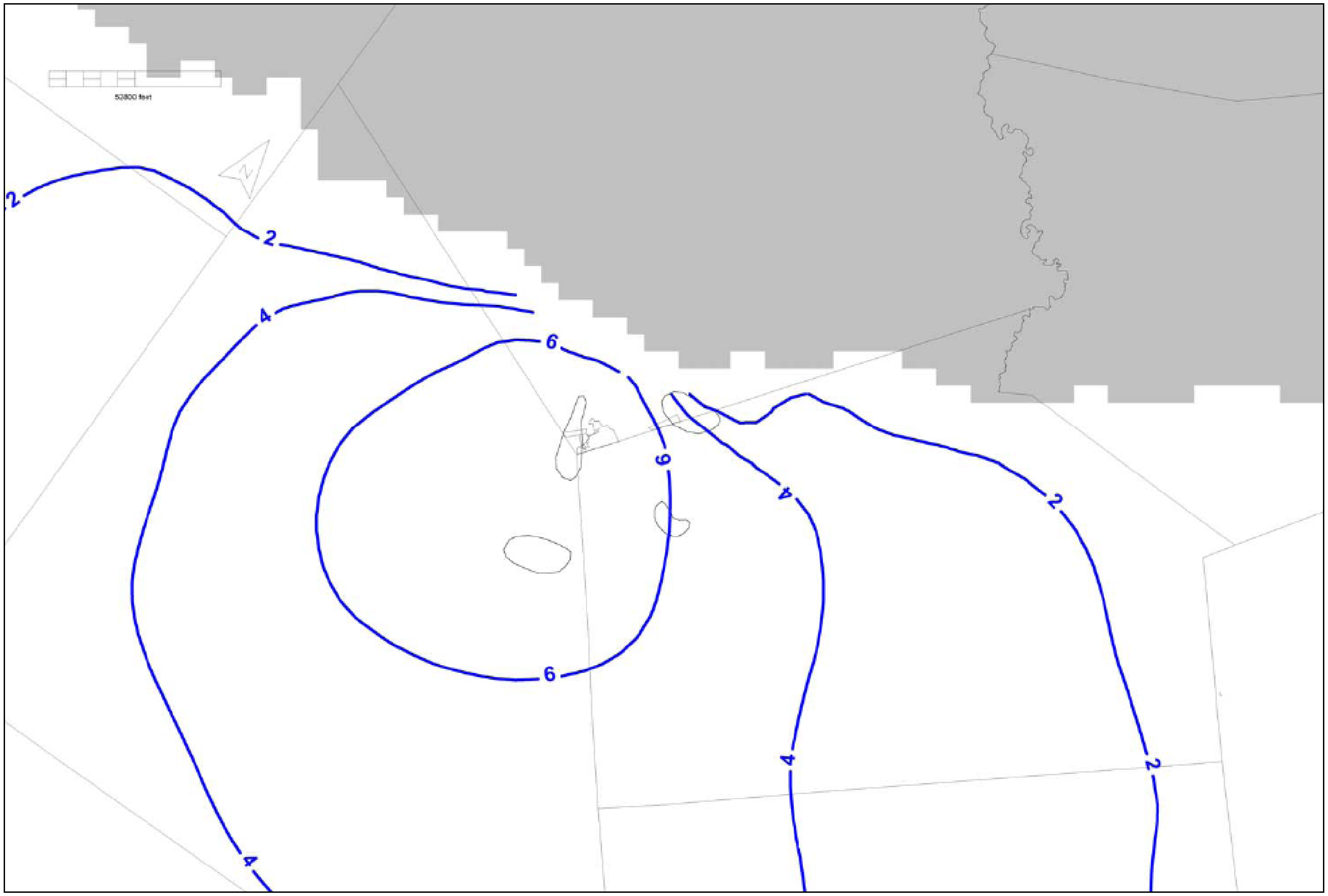

Figure 2-14 Projected Drawdown (ft) in Carrizo at 2060 (20 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

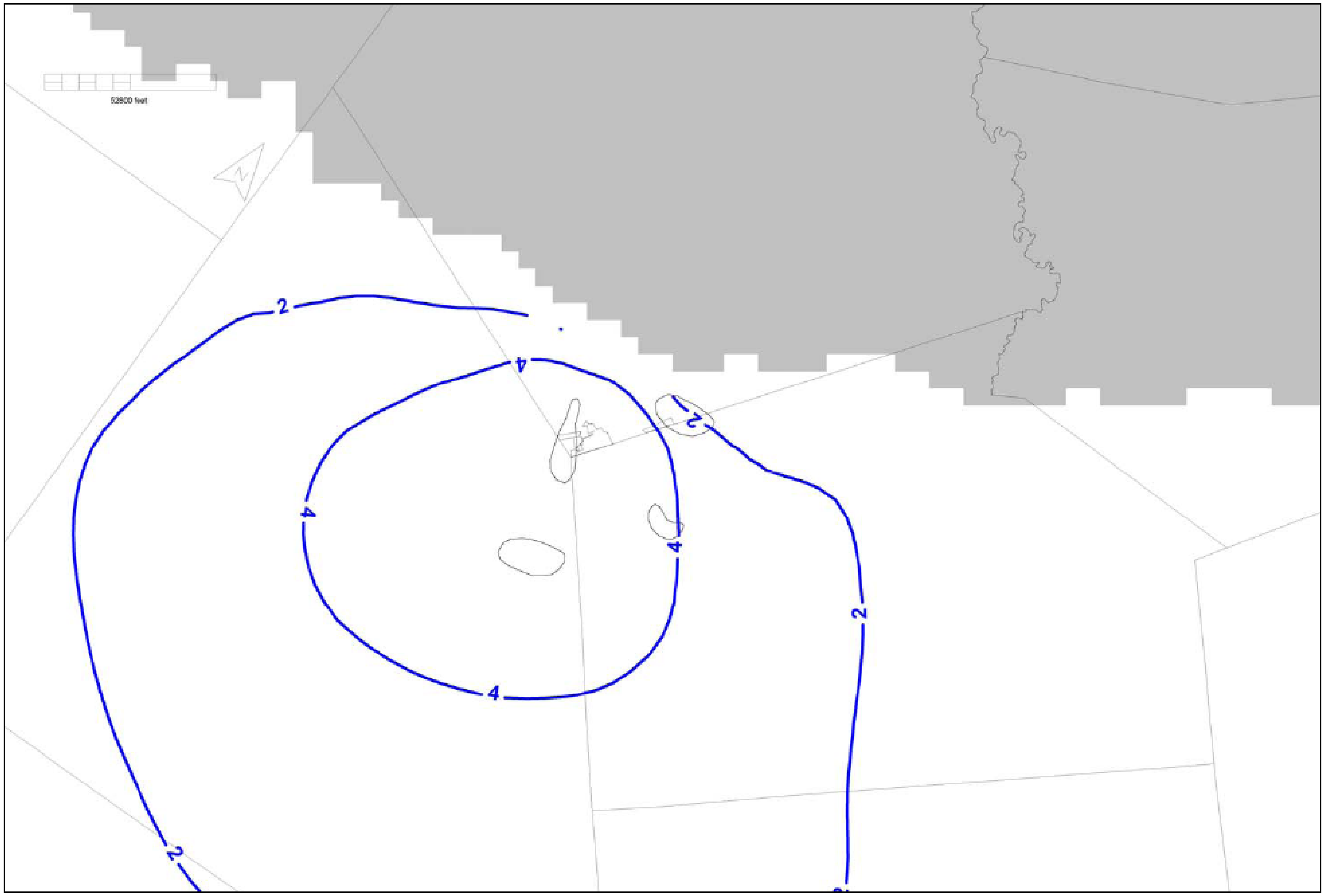

Figure 2-15 Projected Drawdown (ft) in Carrizo after 25 Years Pumping (25 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

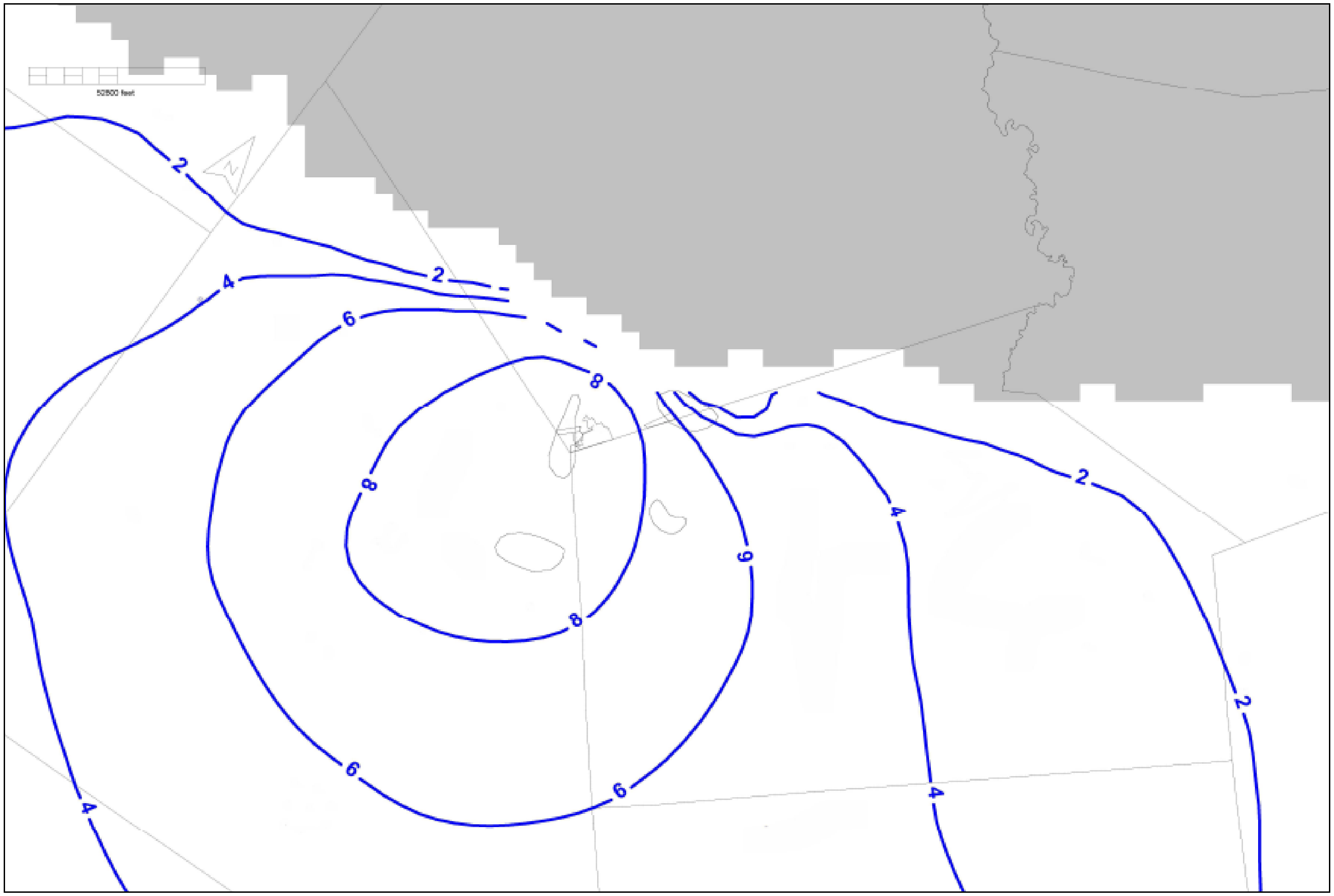

Figure 2-16 Projected Drawdown (ft) in Carrizo at 2060 (25 MGD - 3 Sites - 15 Wells - 4,000 ft. Spacing)

In summary, through the research, well construction, and hydrogeological assessment, the following conclusions can be made:

- SAWS production will be from Lower Wilcox; drilling confirmed resource availability.
- Large volumes of brackish groundwater in Lower Wilcox are sufficient to supply 25 MGD.
- No other entities or landowners are currently producing from the Lower Wilcox Aquifer.
- Upper Wilcox aquitard is approximately 200 – 300 feet thick which provides a low vertical permeability and will further limit water level declines in the Carrizo. The thickness of the aquitard decreases as it projects into western Atascosa County; therefore drilling for brackish groundwater is not recommended in western Atascosa County and, per discussion with SAWS, is not contemplated for the Project.
- Production from brackish zone in Lower Wilcox will result in minimal water level decline in freshwater Carrizo over 50 years.
- Production from brackish zone in Lower Wilcox will result in minor (four feet at 20 MGD for 25 years) water level decline in freshwater Carrizo Aquifer over 50 years; natural seasonal variations in the Carrizo Aquifer range from 20 to 40 feet per year. Further the quality of the Carrizo Aquifer is not anticipated to change from production in the Lower Wilcox brackish zone.
- Moderate transmissivities at 9,000 gpd/foot (1,200 square feet/day).
- Water quality: TDS range 1,200 - 1,700 mg/l.
- 250 to 350 feet of water level decline at a Raw Water production rate of 25 MGD by 2060 (50 years) in the Lower Wilcox Aquifer
- Significant water chemistry changes are not expected for an individual well or wellfield over the life of the Project.

Table 2-6 summarizes LBG-Guyton’s recommended production well characteristics for all three well field sites, as determined from the hydrogeological study.

Table 2-6
Recommended Well Site Production and Well Spacing

Site	No. of Wells	Yield per Well (gpm)	Total Production (gpm)	Total Production (MGD)	Spacing (ft)
ASR	8	800	6,400	9.2	4,000
Jasik	7	800	5,600	8.1	4,000
Atascosa	10	1,000	10,000	14.4	4,000

Section 3
WATER QUALITY, TREATMENT AND FACILITIES ASSESSMENT

3.1 Introduction

The following subsections describe the water quality, treatment, and pipeline evaluations performed during the Project feasibility assessment. More detailed descriptions of these evaluations are presented in the technical memoranda contained in Appendix B.

3.2 Water Quality Analysis

Raw Water will be obtained from the three proposed well fields located on the ASR, Jasik, and Atascosa properties. As described in detail in the Water Quality Assessment Technical Memorandum, these Raw Water wells are feasible sources for the proposed RO Facility in terms of both sustainable production rate and quality (Reference 3). Based on the Raw Water quality data collected to date, pretreatment activities, such as filtration, and chemical addition, should be used to condition the Raw Water from these sources so they are suitable for use as RO process feedwater.

A total of 25 to 30 production wells are anticipated with 8 wells (800 gpm per well) at the ASR site, 7 wells at 800 gpm per well on the Jasik property, and 10 to 15 wells at 1,000 gpm per well in the Atascosa County well field. These sources of supply are expected to provide 31.7 MGD, (25 wells) to 38.9 MGD (30 wells) (Reference 4). LBG-Guyton indicates the yields and water quality should remain relatively constant throughout the service life of the proposed RO Facility (Reference 5). Modeling performed by R. W. Beck indicates that the facility will require approximately 27.2 MGD of Raw Water to produce 20 MGD of Finished Water with the Raw Water assuming the pretreatment processes described in the Treatment Options Evaluation are employed[3]. Thus, the quantity of Raw Water available from the sites investigated should be sufficient for the proposed RO Facility for the duration of its service life to 2060.

Test and Monitoring Well Water qualities were obtained via a sampling and laboratory analysis program conducted for each well field to establish a basis for the Treatment Options Evaluation. The data from the sampling and laboratory analysis program indicates that the Raw Water sources do not meet TCEQ Standards for TDS, sulfate, and chloride levels. While these are TCEQ Secondary Standards, Title 30 Section 290.118 requires all public drinking water systems to comply with the TCEQ Secondary Standards. Therefore, a dissolved solids removal process such as RO is

[3] Appendix B, herein.

needed to treat the Raw Water from these wells so they can be used for drinking water supplies.

The laboratory data also revealed that the Raw Water does not comply with TCEQ Drinking Water Standards for: antimony (Atascosa), aluminum (ASR), beryllium (ASR, Jasik, and Atascosa), color (Jasik), fluoride (Jasik), hydrogen sulfide (Atascosa), iron (ASR, Jasik, and Atascosa), and odor (Atascosa). Based on the treatment process proposed for the Project, these constituents should not preclude use of the ASR, Jasik, and Atascosa Raw Water sources.

The aluminum, beryllium, fluoride, and iron should be removed by pretreatment steps for suspended solids removal and by the RO membranes in the desalination process. However, additional sampling and analysis is needed to confirm if antimony and beryllium levels are actually issues. Limited Raw Water data for these constituents are currently available. Two samples were analyzed for antimony, one ASR Test Well sample (the laboratory reported the level as non-detect) and one Atascosa Test Well sample (0.011 mg/l) a value close to the Practical Quantification Limit PQL[4] for this sample (Reference 6). The level of uncertainty about the beryllium question is similar. The beryllium concentrations sampled at ASR and Jasik were below the PQL. Therefore, as a conservative approach (Reference 7), the PQL was utilized as the measured value. Due to the limited information and the magnitudes of the analytical values for these constituents in relation to the PQL reported by the laboratory, it is unclear if these issues are the result of laboratory artifacts or if they are actually constituents requiring treatment. Therefore, we recommend additional sampling and analysis for antimony and beryllium at all three test wells to confirm whether Raw Water antimony and beryllium levels are concerns before the process design is finalized.

Due to the hydrogen sulfide and odor levels detected in the Atascosa samples, degasification[5] of all water processed as Finished Water appears necessary. This should address the hydrogen sulfide and odor issues as the odor issue is likely related to the hydrogen sulfide levels detected and would likely be resolved via degasification process employed to reduce the hydrogen sulfide levels. Assuming that the sampling point for odor will be upstream of the Finished Water sodium hypochlorite addition point, we do not anticipate that hydrogen sulfide and odor will be significant Finished

4 The Practical Quantification Limit ("PQL") stated by the laboratory for the results of each analysis defines the concentration which a particular analytic methodology can accurately detect and quantify an analyte.

5 Degasification appears necessary based on two sampling events from the Atascosa site. Since the Atascosa Test Well pumping and development activities were limited by issues related to well development water disposal, it is unclear if the water in the test well had achieved a steady state condition prior to sampling. Therefore, additional sampling data is needed to confirm if degasification is needed. SAWS has advised that they are considering the development of the Project with a phased approach that would rely on Raw Water from the ASR and Jasik Well Fields for the first phase and consider using Raw Water from the Atascosa Well Field in a second phase. Degasification may not be required for the first phase of development if this strategy is used because, Test Well sample results from the ASR and Jasik Well Fields have not exhibited hydrogen sulfide levels exceeding TCEQ Standards to date. Additional sampling should be performed to confirm the previous results for hydrogen sulfide before finalizing a decision about the need for degasification.

Water issues (our experience has shown sodium hypochlorite can contribute to odor levels).

Since there are Raw Water constituents that do not conform to TCEQ and SAWS Standards, their effect, if any, related to limitations on blending Raw Water with permeate to produce Finished Water (after post treatment) needs to be established. Modeling performed for the Treatment Options Evaluation indicates blending is controlled by SAWS TDS Standard of 400 mg/l. While the modeling did not indicate that the constituents that do not conform to TCEQ and SAWS Standards would result in additional limitations on blending Raw Water with permeate, the process efficacy for the removal of these constituents should be confirmed during pilot testing to verify the results of the modeling activities before the design for the treatment process is finalized.

Raw Water SDI values measured with ASTM Method D 4189 – 95 (Re-approved 2002) varied from approximately 0.6 (SDI_{15}) to nearly 19 (SD_5)[6]. This is significant because SDI is an indicator used to quantify the propensity of a feedwater for RO processes to cause membrane fouling. Higher SDI values indicate there is a higher potential for RO membrane fouling. Thus, membrane manufacturers commonly base their membrane performance and longevity guarantees on feedwater SDI_{15} levels that do not exceed 5.0, and are generally 4.0 or less. As a result, Raw Water with an SDI_{15} exceeding 4.0 should be treated to reduce the SDI_{15} below 4.0. As explained in the American Membrane Technology Associations' guidelines (Reference 8) an RO feedwater with an SDI less than 3.0 is good practice.

Field measurements of SDI values conducted by Carollo during an extended pump test of Test Well -1 (TW-1) show that SDI levels in Raw Water samples that had not been oxidized were approximately 1.0 after an extended period of pumping at 1,000 gpm. Laboratory results for the same time period yielded results in the 4.0 to 5.0 range. Based on this SDI data, it appeared that oxidation of dissolved species may potentially result in elevated SDI levels and should be avoided if feasible in the process design.

The results of additional field measurements of SDI conducted by Carollo after TW-1 was shutdown and restarted on March 25, 2008 appeared to show a similar effect. However, limited SDI testing was conducted after TW-1 was restarted due to concerns about well development water quantities. As a result, the observation could not be confirmed. Although promising, the SDI_{15} observed effect after the test well pump was restarted was somewhat inconclusive due to limited data. Therefore, additional testing should be conducted to confirm the observed effect before finalizing a decision about pretreatment steps. SAWS advised that they intend to investigate this issue further during the pilot testing SAWS will conduct during 2008.

SAWS is considering one change to their Finished Water Standards for the Project, increasing the Finished Water TDS from 400 mg/l to 500 mg/l. Based on the Finished

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6 A 15-minute SDI_{15} is an industry standard for assessing the propensity for a feedwater to cause RO membrane fouling. RO membrane manufacturers typically tie maximum process feedwater SDI_{15} levels to their membrane longevity warranties. A 5-minute or a ten-minute test, SDI_5 and SDI_{10}, is used when an SDI_{15} level can not be determined because the propensity for a feedwater to cause RO membrane fouling is too high for an SDI_{15} test.

Water TDS level SAWS selects, modeling shows an increase in Finished Water production from 20.0 MGD to 23.5 MGD may be feasible with 25 production wells. The production is specifically dependent on Finished Water TDS concentration. Modeling shows a higher Finished Water TDS allows more Raw Water to be blended with RO permeate. Conversely, with a higher Finished Water TDS concentration and more Raw Water blending, fewer concentrate disposal wells and a smaller RO capacity may be necessary to achieve the desired 20.0 MGD. Thus, there is a range of flexibility with the proposed sites available for SAWS as they move forward with the Project. The United States Environmental Protection Agency ("USEPA") and TCEQ Secondary Standards for TDS of 500 mg/l and 1,000 mg/l respectively provide benchmarks for this potential change.

SAWS also identified Finished Water temperature as a potential concern. Raw Water temperatures varying from a low of about 82^{o}F (Jasik) to a high of approximately 96^{o}F (Atascosa) were detected during field sampling activities for the test wells. Since the average temperature of the SAWS water from the Edwards Aquifer is reportedly approximately 75^{o}F, Finished Water temperature is a potential concern.

There are two basic scenarios related to the cooling issue, winter season and summer season conditions. Each generally has different ambient air wet bulb temperatures (a measure of absolute humidity which affects cooling tower performance) and water demands. Thus, a combination of strategies should be considered for cooling. During winter months, the demand for water is reduced and it is anticipated that the Finished Water would be used to displace water from the Edwards Aquifer. In this scenario, the ambient air wet bulb temperature should generally be appreciably lower than a desired Finished Water temperature in the vicinity of 70^{o}F to 75^{o}F. If so, cooling could be provided either from a cooling tower or by a gas stripper (if used)[7,8,9,10]. The other scenario occurs during the summer or warmer months when the ambient air is generally much closer to the desired Finished Water temperature. Depending on cooling tower design, they are generally capable of cooling to within 5^{o}F to 20^{o}F of

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7 Since a gas stripper provides the same type of intimate contact between water and air as a cooling tower, it would promote a similar cooling effect when the ambient air wet bulb temperature was lower than the water temperature.

8 The capital cost estimate for the Project did not include gas stripping because data from Atascosa test well was not available at the time when the cost was developed and the hydrogen sulfide levels detected in the ASR and Jasik test and monitoring wells were below the TCEQ Secondary Standard of 0.05 mg/l.

9 Based on budgetary estimates from Siemens and Duall, the cost for the gas stripper equipment with a chemical scrubber system for odor control for a 20 MGD Finished Water flow is approximately $1,700,000. Assuming 40 percent in additional cost for installation and using a 25 percent contingency, the installed cost is estimated as approximately $3,000,000. A chemical scrubbing system was included with the gas stripping equipment for odor control to conservatively estimate the cost for the gas stripping process.

10 Based on budgetary estimate from Delta Cooling Tower, Inc., the cost for the cooling tower equipment for a Finished Water flow of 20 MGD is approximately $1,150,000 (Quotation #TR091208-2A dated 9/19/08). Assuming approximately 55 percent in additional costs for items including earthwork, concrete in place, installation, piping, shipping, and contingency (25 percent), etc., the installed cost is estimated as approximately $1,800,000. Per the quotation, the tower is factory assembled.

the wet bulb temperature. Then, a cooling tower or a gas stripper, depending on the bulb temperature, may not reduce the Finished Water temperature to approximately 75°F. During the summer season, the demand for water is at a peak and both Finished Water and Edwards Aquifer water will be needed to meet demand. Then, assuming a sufficient quantity of Edwards Aquifer water was available; blending Finished Water with SAWS Water from the Edwards Aquifer could be an effective strategy for further attenuating the Finished Water temperature. Similarly, blending at the ASR site could also be used during periods of time when water stored in the aquifer at the ASR is being withdrawn.

Gas stripping to remove hydrogen sulfide will serve to lower the Finished Water temperature during periods of time when the ambient wet bulb air temperature is more than 5°F to 10°F below the water temperature. In a typical gas stripper process, the gas-laden water is pumped to the top of the gas stripper tower where it is evenly dispersed over a randomly packed, high surface area media. The water trickling down fully wets the media, creating a thin film of water with a large surface area. Air is injected at the bottom of the tower and flows upward through the media. This creates an intimate, turbulent contact between the air and water and induces stripping of relatively insoluble gases such as hydrogen sulfide into the air stream. After the hydrogen sulfide has been removed, the water is discharged from the bottom of the tower for the next steps in the post treatment process. Thus, a gas stripper operates in a manner similar to a cooling tower. In addition, some cooling in the transmission pipeline from the proposed RO Facility to the Anderson Pump Station is likely. However, mixing at the Anderson Pump Station between the Edwards Aquifer and Finished Water should be maximized to attenuate any Finished Water temperature impacts.

The Anderson Pump Station pumped approximately 5,475 MG in 2006 and 4,325 MG from January through August 2007. This corresponds to a range of 12 MGD to 15 MGD of average daily flow from the pump station. SAWS forecasts an average output from the existing wells at the Anderson Pump Station to be approximately 21.6 MGD to be combined with the 20 MGD from the proposed RO Facility to meet their system needs. With this level of supply at Anderson Pump Station, an approximate 1:1 ratio of Edwards Aquifer water and the proposed RO Facility's Finished Water will be distributed. Thus, the temperature of the water distributed to SAWS customers would be approximately equal to the numerical average of the Edwards Aquifer and Finished Water temperatures based on this1:1 ratio blend ratio.

3.3 Connection to Distribution System Evaluation

As part of the process for determining the feasibility of the Brackish Groundwater Desalination Project, an evaluation of the Finished Water delivery point to the distribution system was conducted by SAWS. Since 2000, the San Antonio metro area has seen a growth of 78 percent in residential home sales, much of which is in the north and west side of town. Therefore, SAWS staff opted to use this Project to boost the supply to the northwest side of the city via their Anderson Pump Station.

R. W. Beck reviewed the features of the Anderson Pump Station to evaluate the feasibility of using it as a Finished Water delivery point. The pump station appears suitable for service as the point of interconnection.

The Anderson Pump Station is currently equipped with: 1) one, 7.5 MG Ground Storage Tank; 2) one high service pump station serving two pressure zones (Service Level 7 with six, 10 MGD pumps, 50 MGD firm capacity); 3) one high service pump station (Service Level 8, activated in 2007, with three, 10 MGD and one, 2 MGD pumps, range of 22 to 30 MGD firm capacity); 4) five groundwater wells, where one well is not utilized because it is considered under the influence of surface water and only three of the four remaining wells are actively used; and 5) chlorination and electrical facilities. Space was originally planned for a second 7.5 MG Ground Storage Tank to the south of the existing 7.5 MG ground storage tank; the second tank will be constructed shortly. Upgrades to the Service Level 8 pump station are currently in the planning phase by Black & Veatch. The Anderson Pump Station property encompasses more than 90 acres. The production wells draw water from the Edwards Aquifer.

Four pump stations, Lackland 6/6A, Marbach, Micron, and Anderson, were considered as possible integration points for the Brackish Groundwater Desalination Project. SAWS staff reviewed daily operational data for the system from 2006 (a drought year) to 2007 (a wet year and therefore the worst case scenario for increasing supply), as historical data beyond 2006 was not applicable because of recent growth demands. Lackland and Marbach Pump Stations were eliminated from consideration due to their inability to maintain base demands. Micron and Anderson Pump Stations are interconnected by a 48 inch line, where Micron can be fed by gravity from the Anderson Pump Station.

The area served by Anderson Pump Station is heavily populated with industrial users, including Sea World and Microsoft. These industrial users are sensitive to fluctuations in water quality from their water source. Therefore, SAWS has defined a Finished Water quality for the Project that closely resembles the quality of their Edwards Aquifer water source. This strategy should minimize blending issues. As a result, delivery of the Project Finished Water could be performed through the connection, via addition of gate valves to direct or isolate flow to a specific ground storage tank. Since the high service pump stations will be directly connected to the inlets of the existing and future ground storage tanks, the Project Finished Water transmission lines will need to be “cut-in.” The valving and connections to the existing inlet piping should be configured to create the greatest amount of flexibility for SAWS operating scenarios.

3.4 Treatment Options Evaluation

The Treatment Options Evaluation presented in this section addresses:

- Raw Water quality parameters used as a basis for the evaluation.
- The RO Pretreatment System configuration anticipated for the Facility.

- The RO process configuration envisioned for the Project.
- Finished Water quantity, quality standards, post treatment steps, and the potential for blending Raw Water with RO permeate.

3.4.1 Raw Water Quality

Four Raw Water quality scenarios were defined to provide maximum TDS; minimum TDS; average/normal operation TDS conditions; and high TDS normal operation conditions, for this Treatment Options Assessment. The minimum and maximum scenarios represent bounding conditions for RO Facility operation. The average/normal and high TDS normal operation conditions provide likely operational scenarios for proposed RO Facility. The scenarios are summarized by the following Cases:

- Case 1 or "Maximum Raw Water TDS"- the maximum Raw Water TDS at a 20 MGD Finished Water production level. This scenario assumes two wells in the ASR Field are not available. As a result, the well field configuration includes six wells in the ASR well field, seven wells in the Jasik well field, and nine wells in the Atascosa well field. It represents the high TDS normal operation condition. Based on the modeling, a Raw Water TDS of approximately 1,560 mg/l is anticipated.
- Case 2 or "Average" - the typical Raw Water TDS normally anticipated for operation at a 20 MGD Finished Water production rate. It consists of eight wells in the ASR well field, seven wells in the Jasik well field, and seven wells in the Atascosa well field. The Raw Water well field configuration in Case 2 would normally be used since it will result in lower Raw Water TDS levels and hence, lower operating costs. Thus, Case 2 represents an average condition for 20 MGD production and is the average/normal operation TDS condition. Based on the modeling, a Raw Water TDS of approximately 1,440 mg/l is anticipated.
- Case 3 or "Worst Case Atascosa" - the maximum Raw Water quality values for the Atascosa water well field (without blending with the other Raw Water sources at ASR and Jasik) will be used as a conservative upper bound. This is anticipated to be a conservative upper bound for facility operation because the TDS levels measured in the other well fields are lower than those at Atascosa and the Atascosa well field does not have sufficient capacity to be used as the sole source of Raw Water for the plant. Based on the sampling results, a Raw Water TDS range of approximately 1,520 mg/l to 1,700 mg/l is anticipated.
- Case 4 or "Conservative Best Case ASR" - The minimum Raw Water quality values for the ASR well field should be a conservative best case since it represents a lower TDS boundary condition for facility operation. The TDS levels measured in the other well fields are higher than those at ASR and the ASR well field does not have sufficient capacity to be used as the sole source of Raw Water for the plant. Based on the sampling results, a Raw Water TDS range of approximately 1,240 mg/l to 1,460 mg/l is anticipated.

3.4.2 RO Pretreatment System Configuration

The purpose of pretreatment is to condition a source-water so that it is suitable for use as RO feedwater. Therefore, the pretreatment process was configured to address a number of potential constituents that can cause membrane fouling such as silt, insoluble iron, sparingly soluble salts, and biological activity. Table 3-1, below, summarizes RO membrane feedwater quality guidelines from several sources. As shown by the number of guidelines for feedwater constituents related to membrane fouling, membrane fouling is a paramount concern. Comparison with the Raw Water characteristics identified during the test well sampling program reveals that the Raw Water likely needs several pretreatment steps so that it can meet these guidelines. The data shows that the Raw Water constituents contain levels of silt, iron, calcium, fluoride, barium, and silica that could result in RO membrane fouling and scaling. Therefore, pretreatment steps such as filtration processes may be needed to reduce silt and iron levels to concentrations in the feedwater for the RO process that are acceptable to membrane manufacturers. Further, pretreatment steps such as acidification (for calcium carbonate control), anti-scalant addition for calcium fluoride, barium sulfate, and silica fouling and scaling also appear necessary.

Table 3-1
RO Membrane Feedwater Quality Guidelines

Parameter	Unit	Dow FilmTec[1]	Hydranautics[2],[6]	Toray[3]	AMTA[4], [7]	Comments & Conditions
Turbidity	NTU		1[6]		0.5	Typical RO Membrane Manufacturer's Warranty Limit is up to 1.0.
SDI_{15}		5	2[2]	3[3]	3	Typical Membrane Manufacturer's Warranty Limit is up to 5.0 for some portion of operating time. Dow–FilmTec restricts the allowable membrane flux in relation to RO Feedwater SDI_{15}. Hydranautics correlates SDI_{15} and flux in their Design Limits.
Modified Fouling Index ($MFI_{0.45}$)		4	Not Provided	Not Provided	Not Provided	Dow–FilmTec Target: <1 According to Dow – FilmTec, an MFI value of <1 corresponds to a SDI value of about <3 and can be considered as sufficiently low to control colloidal and particulate fouling.

Table 3-1
RO Membrane Feedwater Quality Guidelines

Parameter	Unit	Dow FilmTec(1)	Hydranautics(2),(6)	Toray(3)	AMTA(4), (7)	Comments & Conditions
Temperature	°F/°C	113/45	113/45	113/45		Maximum Temperature from Manufacturer's Specification Sheets for Brackish Water RO Membrane Elements
Oil and Grease	mg/l	0.1			0.1	
Total Organic Carbon	mg/l	3	3(6)		2	
Assimilable Organic Carbon	µg/l Ac-C	10	Not Provided	Not Provided	Not Provided	Dow –FilmTec Target: <5
Biological Oxygen Demand	mg/l	Not Provided	5(6)	Not Provided	Not Provided	
Chemical Oxygen Demand	mg/l	10	8(6)	Not Provided	Not Provided	
Biofilm Formation Rate	pg/cm^2 ATP	5	Not Provided	Not Provided	Not Provided	Target: <1, where the accumulation of active biomass is measured as ATP (adenosinetriphosphate)
Free chlorine	mg/l	0.1	< 0.1	Not Detectable		
Ferrous iron	mg/l	4(5)	0.5(7)	Not Provided	1-2(8)	
Ferric iron	mg/l	0.05	0.05(7)	0.1(8)	0.1(8)	
Manganese	mg/l	0.05	Not Provided	Not Provided	0.05	
Aluminum	mg/l	0.05	Not Provided	Not Provided	Not Provided	

1. Maximum Level FILMTEC Membranes Water Chemistry and Pretreatment: Guidelines for Feedwater Quality - Table 2.10 Guidelines for feedwater quality
2. <2 for Well Water and <4 for Surface Water, Hydranautics Design Limits dated 1/23/01
3. <3 for Well Water and <4 for Surface Water, Toray Design Guidelines, http://www.torayro.com/sys.html
4. Table 2, AMTA News Letter February 2007
5. pH <6, oxygen <0.5 mg/l, FILMTEC Membranes Water Chemistry and Pretreatment: Guidelines for Feedwater Quality - Table 2.10 Guidelines for feedwater quality
6. Hydranautics RO Water Chemistry dated 1/23/01
7. pH <7, Hydranautics RO Water Chemistry dated 1/23/01
8. If no chance of air entry and pH<7, dissolved iron values as high as 1-2 mg/l may be acceptable, Table AMTA News Letter February 2007

The pretreatment filtration process contemplated for the Project consists of a single stage pressure filter sized for the full Raw Water flow required for the RO process plus the amount of Raw Water that will be blended with RO permeate to produce 20 MGD of Finished Water. Other filtration processes such as membrane-based microfiltration or ultrafiltration processes could also be used. However, these were not selected at this stage of conceptual design because they are generally more expensive than media filtration.

As discussed in the Water Quality Section above, field data collected by Carollo during an extended pumping test of the test well at ASR indicated that, if anaerobic (reducing) conditions can be maintained in the Raw Water collection and supply system, it may be possible to achieve: 1) an SDI_{15} of approximately one; and 2) maintain the iron in a soluble state (as ferrous iron) so that acceptable RO feedwater is achieved without media filtration. If so, considerable savings would be realized by eliminating the media filtration process and thereby eliminating the media filter backwash flow and disposal pipeline. Eliminating the media filter backwash flow would reduce the Raw Water required by the facility by about 4.1 MGD for the scenario with average Raw Water quality (Case 2) and 20 MGD of Finished Water with a dissolved solids content of 400 mg/l. Thus, approximately three fewer Raw Water wells would be needed for this scenario.

While promising, as shown in Table 3-1, the SDI_{15} observed effect after the test well pump was restarted was somewhat inconclusive due to limited data. Therefore, additional testing should be conducted to confirm the observed effect before finalizing a decision about pretreatment steps. In addition, piloting should be conducted to confirm if a pretreatment filtration step is needed and, if so, to optimize the selection of the type of process, pressure filtration, microfiltration or ultrafiltration, etc. that should be used. Our understanding is that SAWS will be investigating pretreatment issues during the pilot testing they will conduct during the latter half of 2008.

Approximately 5 to 15 percent of the influent Raw Water will be used for pressure filter backwashing resulting in a waste stream of approximately 4.1 MGD. The filter backwash will have dissolved salt levels (TDS, chloride, and sulfate, etc.) approximately equal to those in the Raw Water. Therefore, we anticipate that pretreatment filter backwash could be disposed via surface water discharge to the San Antonio River after treatment for suspended solids removal. The solids removal treatment would consist of polymer addition, a Lamella Clarifier for suspended solids removal, a sludge holding tank for solids from the clarifier, and a belt filter press for sludge dewatering. Sludge will be disposed of at an appropriately licensed landfill.

Provisions for pretreatment chemical addition will consist of sodium hypochlorite, sulfuric acid, coagulant (ferric chloride or ferric sulfate), anti-scalant, and sodium meta-bisulfite chemical feeds. Anti-scalant is needed due to the potential for sparingly soluble materials such as calcium, barium and fluorides in the Raw Water.

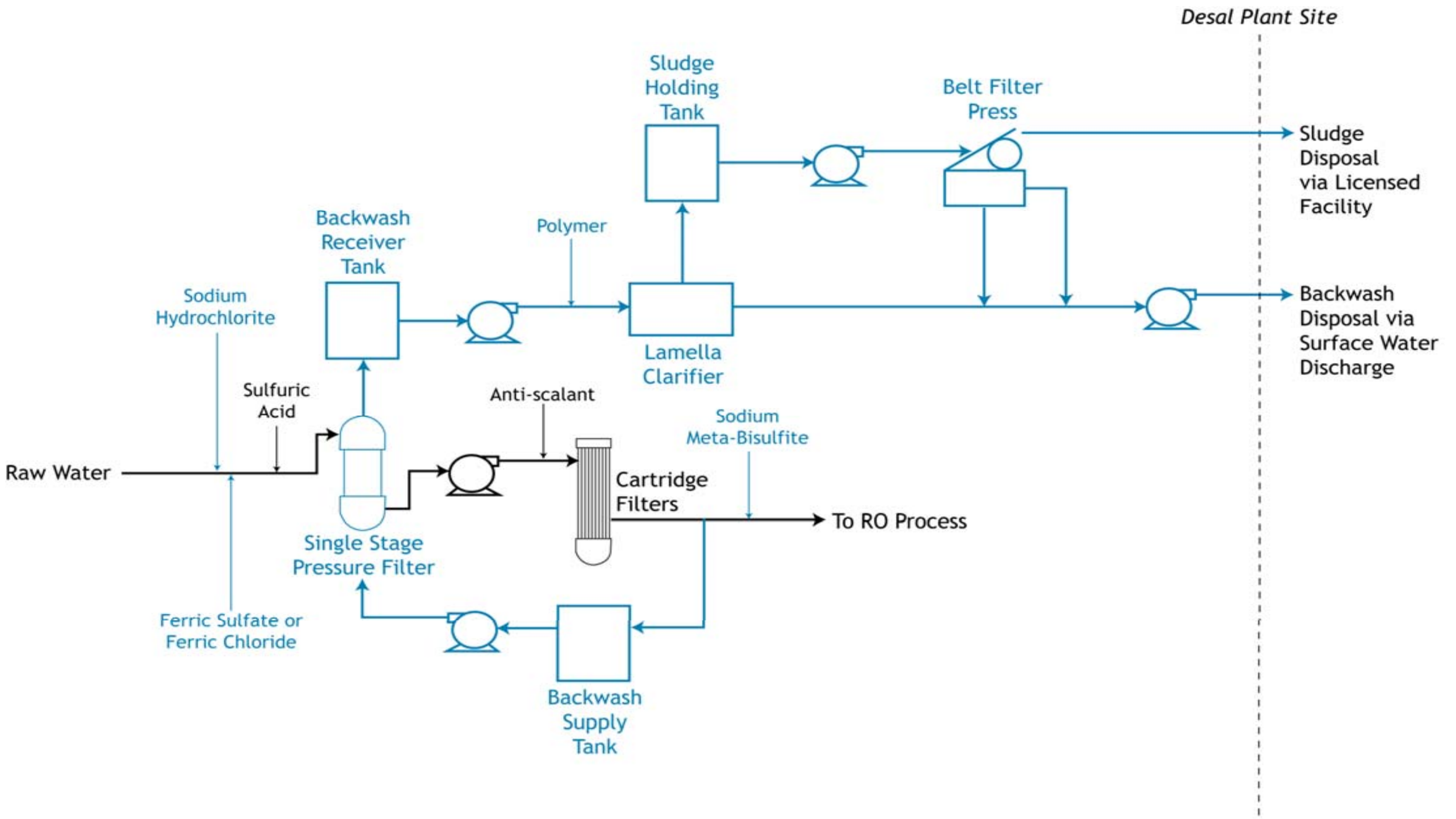
Sodium hypochlorite would not typically be required with these Raw Water sources if anaerobic conditions in the Raw Water supply pipelines could be maintained. However, the Project potentially has long Raw Water supply pipelines that will contain components such as air valves that can experience air in-leakage. Air in-leakage can result in significant biological activity and thus a need for an oxidant such as sodium hypochlorite as a biocide. Therefore, provisions for adding sodium hypochlorite have been included in the conceptual design as a precaution. Because RO membranes are not tolerant of oxidants such as chlorine, the capability to apply a controlled dose of sodium meta-bisulfite will also be provided in the event that the Raw Water is chlorinated prior to the RO process. Additional data related to the potential for biofouling should be obtained before a decision about the need for chlorination and de-chlorination is finalized. SAWS indicated that they also intend to investigate potential for biofouling during the pilot testing they conduct in 2008.

A 5-micron Cartridge Filter will be used as a protective device upstream of each RO Train as a final protective device for the membranes.

Figure 3-1 provides a flow diagram of the pretreatment process. As shown, the figure contains a number of components color-coded in blue. This blue color identifies the components that could be eliminated if further testing shows the media filtration and sodium hypochlorite, and sodium meta bisulfite addition steps are not needed. SAWS has indicated that they will also evaluate the feasibility of deleting filtration and sodium hypochlorite, and sodium meta bisulfite addition steps during their RO process piloting program during the latter half of 2008.

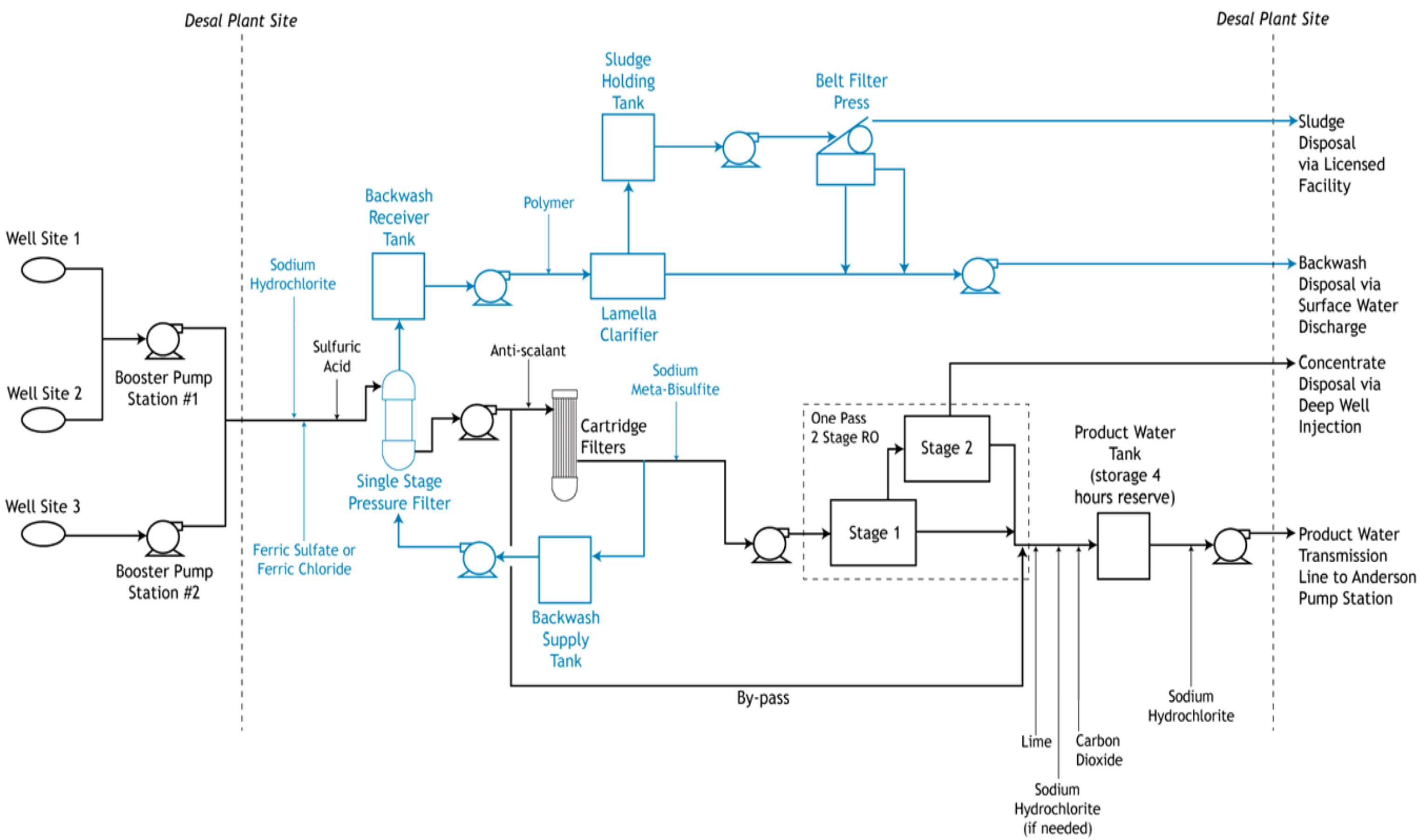
3.4.3 RO Process Configuration

Figure 3-2 shows the overall treatment process. To enhance process recovery and lower Finished Water production costs, the process includes a Raw Water by-pass around the RO system. The Raw Water by-pass is first treated to remove suspended solids in the pressure filter, combined with RO permeate (desalinated product stream), degassed for hydrogen sulfide removal, stabilized with lime and carbon dioxide, and disinfected with sodium hypochlorite to produce Finished Water.



Note: Items in blue may be eliminated if media filtration and sodium hypochlorite and sodium meta-bisulfite addition steps are not needed

Figure 3-1 Pretreatment System Configuration



Note: Items in blue may be eliminated if media filtration and sodium hypochlorite and sodium meta-bisulfite addition steps are not needed

Figure 3-2 Overall Treatment Process

The RO Process Recovery[11] was limited to 85 percent due to the presence of sparing soluble salts such as calcium carbonate, calcium sulfate, calcium fluoride, barium sulfate and silica that could cause membrane fouling issues. Membrane flux[12] levels were conservatively set since RO feedwater SDI_{15} levels and the attendant concerns about membrane fouling, are potential issues. Membrane manufacturers' typically recommend lowering the flux when RO feedwater SDI_{15} levels and membrane fouling are concerns.

The RO system will be configured as a two-stage process with a 2:1 array that includes one spare train. In this arrangement, the concentrate from the first stage is treated in the second stage to improve RO recovery. It is envisioned that each RO train will be capable of producing about 2.0 MGD of permeate. Since process modeling indicates approximately 2.5 MGD of Raw Water could be blended with RO permeate with a Finished Water TDS standard of 400 mg/l, nine RO trains are needed to produce 20 MGD of Finished Water. A spare RO train is included to enhance facility reliability at a 20 MGD Finished Water production level or if SAWS opts not to blend Raw Water with permeate. Consequently, there will be a total of 10 RO trains[13]. The design will be based on 8-inch diameter, brackish water type RO membranes because they are currently available from several manufacturers. To simplify operation, each train will be fed with a dedicated feed pump. Depending on feedwater TDS, modeling[14] indicates the required RO inlet feedwater pressure is approximately 200 to 225 pounds per square inch gauge ("psig").

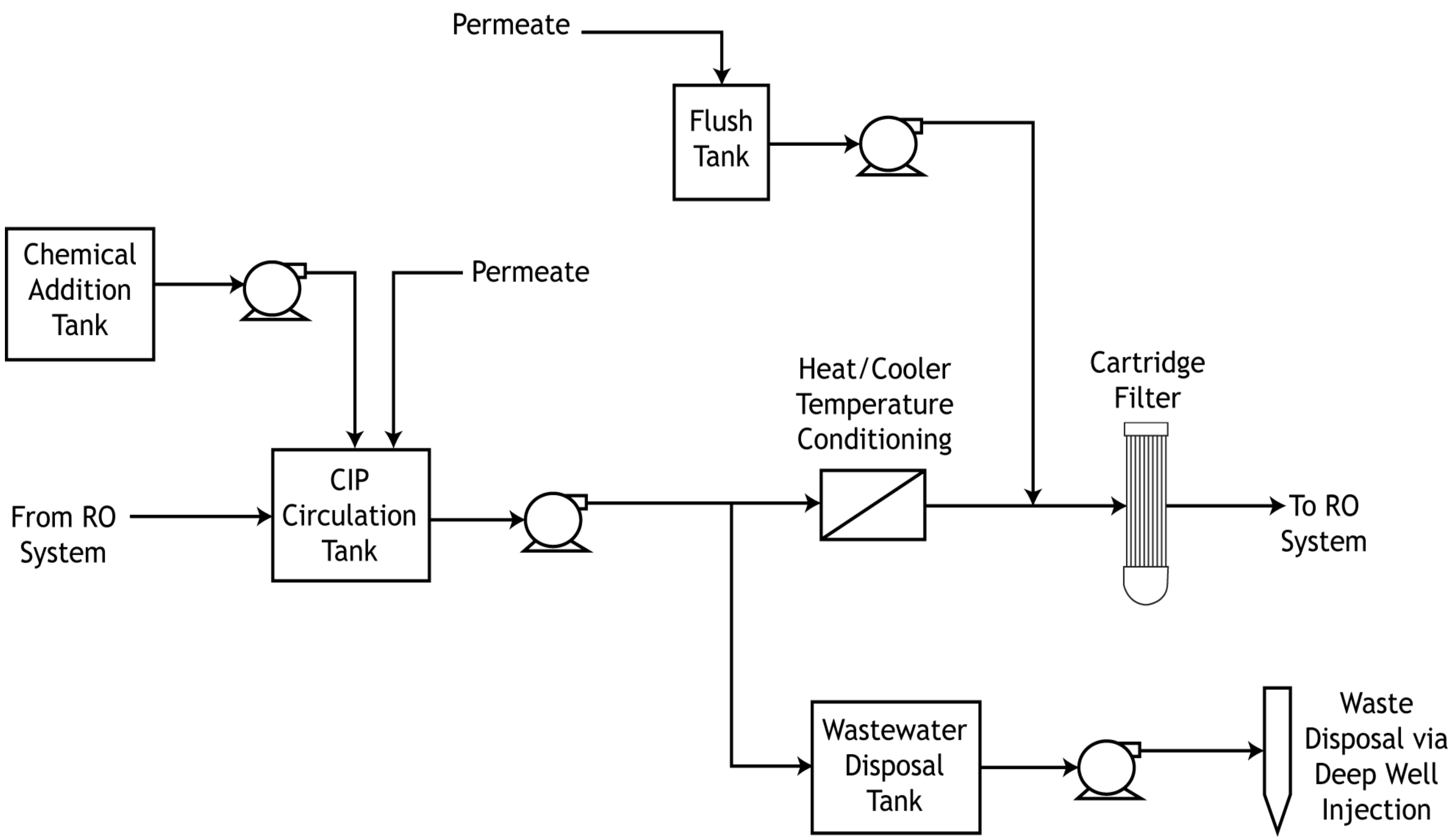
The RO process will also be equipped with a clean-in-place system ("CIP") for membrane cleaning. Various combinations of acids and caustics are used, depending on the foulant materials on the membranes. As shown, the CIP solution is circulated via the CIP Circulation Tank through the RO membranes to clean them and is flushed out of the membranes with permeate. CIP liquid wastes are collected in the Wastewater Tank for disposal. It is anticipated that these CIP wastes could be disposed via the deep injection wells used for concentrate disposal since it is common practice to dispose of CIP wastes in this manner. A typical CIP system process flow diagram is illustrated in Figure 3-3.

11 RO Process Recovery is defined as RO permeate flow multiplied by 100 and divided by RO feedwater flow.

12 Membrane flux is defined as the flow though the membrane divided by the membrane area.

13 Note that the capital cost estimate for the Project conservatively assumed 11 RO trains with no Raw Water bypass because insufficient Raw Water data was available to perform system modeling when the cost was developed. Data from the Atascosa test well was not available at that time.

14 RO system performance modeled with Dow-FilmTec ROSA v6.1.5 ConfigDB U238786_55 freeware.



Note: Heating and cooling are sometimes required for CIP operations. These have been combined as one unit operation to simplify the process diagram

Figure 3-3 Clean-In-Place (CIP) System Diagram

3.4.4 Finished Water

The Project will produce up to 20 MGD of Finished Water. The Finished Water will be a blend of desalination process effluent and Raw Water that is controlled such that the Finished Water meets USEPA Primary and Secondary Drinking Water Standards, SAWS 400 mg/l TDS standard (Reference 9) and the SAWS standards for the ASR Facility (Reference 10).

RO permeate is a soft, low alkalinity water that can be corrosive. Therefore, several post treatment steps will be needed so that the Finished Water meets TCEQ and SAWS Standards. The post treatment process steps will consist of gas stripping for hydrogen sulfide removal; lime and carbon dioxide addition for pH adjustment, stabilization, and corrosion control; and sodium hypochlorite addition (Reference 11) for disinfection (free chlorine residual level of 3.5 mg/l). SAWS has advised that the pH range for the Finished Water will be 7.8 to 8.2 and that others will be performing pipe loop corrosion testing for SAWS to confirm the Finished Water Standards or to further optimize them if necessary.

While only limited laboratory data is available for the Atascosa wells, gas stripping appears necessary because: 1) the hydrogen sulfide level in the Atascosa test well was measured at 1.0 mg/l during two separate sampling events; and 2) this level exceeds the TCEQ Secondary Standard of 0.05 mg/l[15].

Depending on the manufacturer, four to five gas stripper towers would be needed. The gas strippers will need periodic maintenance washes to remove scale, slime, or other material that may foul the packing and inhabit performance. Dilute concentrations of hydrochloric acid, sulfuric acid, sodium hypochlorite or sodium hydroxide are commonly used for this purpose. Similar to the CIP residuals for RO membrane cleaning, it is anticipated that these gas stripper cleaning wastes could be disposed via the deep injection wells used for concentrate disposal.

The system configuration also assumes a 4 MG on-site reservoir storage tank and three, 50 percent Finished Water transmission pumps will be used to deliver the Finished Water to an atmospheric tank located at the Anderson Pump Station.

3.4.5 Pipeline Alignment

R. W. Beck prepared the evaluations to identify the preferred transmission pipeline alignments for Raw Water produced from the ASR, Jasik, and Atascosa well fields to the proposed RO Facility and to deliver Finished Water to the Anderson Pump Station. The concentrate and pretreatment filter backwash disposal pipelines were not included because locations for the deep wells for concentrate disposal and for the surface water

15 Note that the capital cost estimate for the Project did not include gas stripping because data from Atascosa test well was not available at the time when the cost was developed and the hydrogen sulfide levels detected in the ASR and Jasik test and monitoring wells were below the TCEQ Secondary Standard of 0.05 mg/l.

discharge for the filter backwash were not available at the time the alignment study was prepared.

Several key assumptions were made regarding the location of project elements were required. These included:

- General pipeline alignment and easement requirements based on a previous study provided by SAWS
- Per SAWS instruction, the integration site for Finished Water is the Anderson Pump Station, the proposed RO Facility would be located at property in southern Bexar County bordered on the southeast by Trumbo Road and Englehart Road[16], and a Raw Water well spacing of 3,000 feet was used.
- General configuration and location of proposed treatment plant and booster pump stations in accordance with previous memorandum
- Well field configurations based on GIS information provided by client

The preferred routing presented herein borrows heavily from the Gonzales County Carrizo Aquifer Program and its associated studies (completed by SAWS in late 2004). Substantial residential and commercial development has occurred on the west side of the city since the alignment for the Gonzales County Carrizo Aquifer Program was completed. Therefore, we anticipate that portions of the current alignment could undergo significant reconfiguration as the project progresses from the feasibility study phase to detailed design. Expected changes include: 1) relocating the Finished Water pipeline origination from the Trumbo Road and Englehart Road site to the ASR property if, as discussed with SAWS, SAWS opts to implement a change to relocate the desalination facility on the ASR site; 2) incorporating the three production wells located on the west side of IH 37; 3) changing the Raw Water well spacing from 3,000 feet to 4,000 feet; and 4) readjustment due to land acquisition issues.

Potential individual well site locations were provided by SAWS for use in developing a conceptual well field collection system. SAWS also indicated the desired number of wells in each well field and anticipated production rates associated with each well field with the requirement of Raw Water delivery of approximately 28 MGD in total (to produce 20 MGD of Finished Water. Using the given potential well sites and taking into consideration such things as proximity to collector lines, well spacing, varying aquifer depths and potential conflicts, 25 well sites (including two spare wells in Atascosa County) were selected for inclusion in the system. Well collection lines within the well field properties were generally assumed as straight lines connecting individual wells to the water integration lines and pump stations unless obvious conflicts were identified. Well collection lines and the integration pipeline network outside of the well fields assume alignments along property lines to the extent practicable and where parcel data was readily available.

16 SAWS had not made a decision about relocating the proposed RO Facility to the ASR site at the time the alignment study was performed.

3.5 Pipeline Alignment and Booster Pump Station Characteristics

The results of the alignment studies for both the Raw and Finished Water transmission pipelines are summarized in Table 3-2, below. While the quantities shown would need to be revised if the proposed RO Facility is re-located to the ASR property, the data is illustrative of constructing long pipelines in the San Antonio metro area.

Table 3-2
Integration Pipeline System(1),(2)

Description	Quantity	
Length of Pipe		
36" diam. main transmission line	231,950 lf	43.93 mi
Well field to Plant	66,845 lf	12.66 mi
Plant to Anderson PS	165,106 lf	31.27 mi
30" diam. collector line	13,500 lf	2.57 mi
18" diam. collector line	30,518 lf	5.78 mi
ASR to Jasik property	17,000 lf	3.22 mi
ASR to Atascosa property	13,500 lf	2.56 mi
8" diam. water well line	42,000 lf	7.95 mi
Collection/Distribution System		
No. of well pumps (100 to 250 hp each)		25
No. of booster pump stations (700 and 3600 hp each)		2
Required Easements (2)		
No. of affected properties		190
Total area of easement	740 ac	1.16 sq mi
Potential Conflicts		
No. of roadway crossings	85	
No. of stream crossings	22	
No. of existing water main crossings(3)	22	
No. of proposed water main crossings(4)	7	
No. of sanitary sewer main crossings(5)	17	

1. Values are based on locating the RO Treatment Plant at the Trumbo/Englehart site; Does not include concentrate disposal or pretreatment filter backwash disposal pipeline
2. Does not include Jasik, ASR, Atascosa well field collection pipelines or concentrate disposal well field pipelines
3. Estimate based on available SAWS and Bexar Metropolitan Water District mapping of existing infrastructure
4. Estimate may include proposed improvements to existing lines in addition to new lines (i.e., actual number of conflicts indicated may be lower than shown)
5. Estimate based on available SAWS mapping

3.6 Treatment Plant Location

SAWS has advised that they had originally selected the Trumbo Road and Englehart Road property as a site for the proposed RO Facility to geographically diversify the locations of their drinking water treatment plants[17]. As SAWS evaluation of the site progressed, the analysis revealed that there were a number of potential disadvantages associated with the Trumbo Road and Englehart Road site. Consequently, SAWS has opted to consider relocating the proposed RO Facility to a site situated on the ASR property.

The primary criteria SAWS used for selecting a location for the proposed RO Facility were: 1) the availability of a power supply infrastructure with sufficient capacity to supply the Project without major upgrades; 2) the proximity to an integration point for Finished Water into the SAWS distribution system at a location with sufficient demand and pump station capacity so that blending issues are minimized; 3) the distance to a suitable concentrate disposal site; 4) the distance to a suitable surface water discharge location for filter backwash disposal if pretreatment media filtration is needed; 5) the cost of property acquisition and site development; and 6) the proximity to other SAWS facilities so that cost savings could be achieved by resource and staff sharing between facilities.

SAWS analysis showed that the Trumbo Road and Englehart Road site would need to be acquired by SAWS; is located in a relatively undeveloped, wooded area that would require extensive site development, new roadways and electric utility infrastructure upgrades; and is remote from other SAWS water treatment facilities, the potential concentrate disposal sites and the point of integration at the Anderson Pump Station. Therefore, SAWS has relocated the plant to the ASR site.

SAWS incorporated this change because SAWS already owns the ASR property, it appears to have sufficiently robust electric utility infrastructure nearby, and the site is located relatively near the ASR facility, the ASR and Jasik Raw Water well fields, and a potential concentrate disposal location in the Saspamco Well Field, if deep well injection is used. There is one disadvantage. Since the ASR site is further east than the Trumbo Road and Englehart Road site, relocating the proposed RO Facility to the ASR site would appreciably increase the length of the Finished Water Transmission Pipeline.

17 Site selection performed by SAWS; a site evaluation as part of the Team's scope of services.

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Section 4
RESIDUALS MANAGEMENT

4.1 Introduction

With the selection of a brackish groundwater treatment option, an important component of the treatment includes the management of the residuals produced. Based on the process configuration depicted in Figure 3-2, potential residuals may include**:**

- RO concentrate
- CIP waste
- Gas stripper wastes
- Pretreatment filter backwash
- Pretreatment filter backwash sludge after dewatering for volume reduction

Modeling shows RO concentrate is expected to have a flow of approximately 3-5 MGD and a TDS level of approximately 10,000 to 12,000 mg/l for production of 20 MGD of Finished Water. Filter backwash, the other major liquid residual, will have a flow of approximately 4.1 mgd with TDS levels approximately the same as the Raw Water (approximately 1,200 to 1,700 mg/l).

Based on the information available to when the residuals management assessment was conducted, deep well injection appeared to be the most viable option for RO concentrate, CIP waste, and if gas stripping is employed, for gas stripper waste disposal. RO concentrate was expected to be the major constituent of flow disposed via deep well injection with flow of 3-5 MGD and a TDS level of approximately 10,000 to 12,000 mg/l for production of 20 MGD of Finished Water.

A potential site for the deep well injection option has been identified. An investigation by Stone (Reference 12) revealed that the Saspamco Field in Wilson County could provide a favorable geology for a deep well injection for concentrate and CIP and gas stripping waste disposal and the existence of an abandoned oil production well that could be used for experimental testing the injection capability.

If SAWS elects to pursue deep well injection as a disposal alternative, we recommend that SAWS consider conducting an evaluation of this well to determine the suitability of the local geology as a deep well injection site if an agreement with the Texas Railroad Commission for the study can be reached. If the results indicate the formation at the site may be suitable, we further recommend that SAWS drill a separate well for injection testing to substantiate the conclusions from the above activities as a next step. This separate bore hole would begin as a test hole that would be logged and then reamed to a larger diameter for injection or pump testing to determine if the formation at this location meets the injection well criteria.

However, due to the cost of drilling a test well, we recommend that SAWS consider completing an assessment of the practicality of surface water discharge to the San Antonio River first. To minimize the potential for delaying the Project, this evaluation could be conducted in parallel with the geological evaluation of the abandoned oil production well in the Saspamco Field.

Two screening analyses for surface water discharge options were conducted using TCEQ's screening criteria as delineated by Texas Administrative Code Title 30 Chapter 307, Texas Surface Water Quality Standards. Both analyses used the incremental TDS, chloride, and sulfate loadings resulting from a concentrate discharge to estimate the potential for increasing concentrations of these constituents in the receiving water body and then compared the concentrations with TCEQ's water quality criteria for the affected segments of the rivers.

The first analysis was conducted early in the feasibility evaluation process for a discharge to the Medina River (river segment 1903)[18]. This showed that the Medina River alternative was not viable because the analysis showed the incremental salt loadings caused TDS levels to exceed TCEQ water quality screening levels.

The second analysis was recently performed after the Facility was relocated and after data from the Atascosa Test Well became available. This indicated that when TCEQ's screening criteria is applied; it is theoretically possible to use a surface water discharge to segment 1911 of the San Antonio River both with and without co-mingling filter backwash filter backwash with the concentrate. Because the results of the incremental TDS, chloride, and sulfate loading analysis predict that the levels of these constituents would be below TCEQ's water quality criteria for them in this river segment, a second step considering metals levels was also conducted in collaboration with TCEQ by Mickley using Excel® program that TCEQ uses in their permitting activities, as provided to Mickley by TCEQ (Reference 13).

While the results of the second screening analysis were promising, further study is required to address areas identified for further consideration and to determine whether this alternative is practical once more detailed and extensive concentrate water quality data are available from pilot tests. Areas for further consideration include the need for aeration to increase the dissolved oxygen level of the groundwater-based concentrate, the permit limits for fluoride that may be applied, the exemption possible for discharges from drinking water facilities for naturally occurring radionuclides ("NORMs"), and levels of various toxic pollutants from an extensive list routinely considered by TCEQ at the permit application stage. The assessment related to the practicality of implementing the option should also encompass rights of way issues; coordination with organizations such as TCEQ, the San Antonio River Authority and the South Central Texas Regional Water Planning Group (Region L); evaluation of potential effects on downstream water users, and public outreach efforts in addition to further assessment of the potential for environmental impacts. If the concentrate

[18] Since a feasible disposal option is a critical feature of a viable project, the first screening evaluation was conducted prior to the relocation of the treatment plant to the ASR site and before water quality data from the Atascosa Test Well was available. Once the Medina River discharge alternative was eliminated, a deep well injection option was investigated to assure that a viable alternative could be identified.

disposal option via surface discharge to the San Antonio River proves to be practical, it would eliminate the costs associated with the concentrate disposal pipeline and injection wells.

At this screening stage evaluation there were no fatal flaws identified that prohibit further consideration of discharge to segment 1911 of the San Antonio River. Study of the above items is required to address the evolving scrutiny that accompanies projects as they proceed to the implementation stage and as more extensive and representative water quality data for feed water and pilot-produced concentrate become available.

If a pretreatment filtration step is employed, the filters will require periodic backwashing. As discussed above, since the TDS of the backwash will be approximately the same as the TDS of the Raw Water, we also anticipate that: 1) the residuals from the backwashing operations would likely be disposed via a surface water discharge after treatment for suspended solids removal; and 2) as shown in Figures 3-1 and 3-2, the suspended solids removal processes would include chemical addition, clarification and sludge dewatering prior to discharge. The backwash suspended solids will be hauled off-site as sludge after dewatering with a belt filter press to approximately 25 to 30 percent solids for disposal at licensed landfill.

Table 4-1 below provides a summary of traditional disposal options that currently appear feasible for the residual streams:

Table 4-1
Residual Disposal Options

Residual Stream	Disposal Method
Concentrate (RO concentrate, CIP waste and gas stripper cleaning waste Disposal)	Disposal by Class I well injection
Concentrate (RO concentrate, CIP waste and gas stripper waste disposal)	Surface water discharge to the San Antonio River
Single stage pressure backwash	Surface water discharge to the San Antonio River

4.2 Concentrate Management Screening and Options Overview

An overview of the screening process used to identify the most viable disposal alternatives for the RO concentrate, CIP waste, and if gas stripping cleaning waste streams is presented below. For convenience, since all have elevated TDS levels, the term "concentrate" in this section will include RO concentrate, CIP waste and gas stripper cleaning waste.

The viability of a disposal option is dependent on: 1) characteristics (volume, salinity, and residual constituents) of the residual produced; 2) available locations for disposal; 3) potential environmental impacts; 4) cost; and 5) the risk of regulatory agency rejection of the option. Other important issues include the volume, salinity, and nature of constituents making up the concentrate and the distances between potential desalination and disposal sites.

As an initial step to identify a viable concentrate disposal option, Mickley developed an initial screening report (Reference 14) discussing commonly considered alternatives. As explained therein, various options have been utilized or considered in the United States ("US") for disposal of concentrate disposal, including:

- Traditional: Surface discharge; discharge to sewer (or waste water treatment plant ("WWTP"); deep well injection ("DWI"); evaporation pond; land application
- Beneficial Use: Oil well field injection (blend with produced water for injection into Class II wells); solar ponds; aquaculture wetlands; transport of mineral resources; subsurface storage; feedstock for hypochlorite generation; cooling water; dust control and deicing; scrubber water
- High Recovery Processing / Zero Liquid Discharge ("ZLD"): Evaporation pond; land fill (after solidification); selective salt recovery (for market)

The anticipated characteristics of the concentrate have been defined further through collection of additional water quality data and performance modeling. Future results will be available when Carollo has completed the Pilot Testing. As discussed previously, there is a possible location for concentrate DWI at the Saspamco Field. In addition to identification of a possible DWI site, the VSEP technology will be piloted during Carollo's testing to determine the viability of the technology. Also as discussed previously, discharge to segment 1911 of the San Antonio River remains a possible disposal option.

Various concentrate management approaches were evaluated and screened to eliminate those not considered to be feasible and to define candidate approaches for further study. Options eliminated included:

- Direct discharge of concentrate to Medina River – A preliminary TDS screening evaluation performed by TCEQ notes that potential impact to the river would likely rule out this scenario as viable option.

- Direct discharge of concentrate to Mitchell Lake - Discharge of concentrate to the lake results in rapid salt loading as there is no mechanism to remove the salt from the lake that is incoming with the concentrate. An evaluation of this option by TCEQ was conducted on the arbitrary basis of blending the concentrate with the total permitted discharge from the Leon Creek Water Recycling Center ("WRC") and then discharging the blend into Mitchell Lake. This blending scenario represented a more favorable scenario than direct discharge of concentrate into the lake. However, TCEQ noted that there would need to be a policy change on what could be discharged to the lake from the Leon Creek WRC and this scenario was ruled out as viable option.
- Discharge to the influent of Leon Creek or Dos Rios Water Reclamation Center ("WRCs") – Generally, discharge of desalination concentrate to wastewater treatment facilities is not feasible unless the salt load (salinity and volume) of the concentrate is relatively small compared to the influent to the facility. Screening evaluations for these two options were concurrently conducted by TCEQ and Mickley. Since there is only a low probability that TCEQ will approve either of these options this scenario was ruled out as viable option.
- Disposal by evaporation ponds – Consistent with historical use of evaporation ponds only with very small volumes of concentrate, use of evaporation ponds for a concentrate of the volume anticipated for this Project is not feasible. In addition to that, pond costs have recently ranged from an unusually low value of $70,000 per acre to a high of $600,000 per acre. It is estimated that 1 MGD of concentrate would require 347 acres for an evaporation pond. At a value of $200,000 per acre, 347 acres of pond is estimated to cost $69 million ruling out this scenario as viable option.
- Disposal by land application – As with evaporation ponds, disposal of concentrate by land application is generally feasible only for very small volumes of concentrate. Dilution water is typically needed to make the concentrate compatible with the vegetation being irrigated, resulting in large land needs – areas larger than required for evaporation ponds. As the land area to be irrigated increases, a more sophisticated distribution system for the applied water is needed. Due to these reasons, use of land application of concentrate is judged not to be feasible for this Project.
- Disposal by Class II well injection - Using Class II wells for disposal of industrial waste is currently not legal. Feedback from a meeting with TCEQ's Underground Injection Control ("UIC") Program suggested that the State does not want to deal with Class II well distinctions.

As mentioned in Section 4.1, traditional options screened for further consideration include surface discharge to the San Antonio River and Class I deep well injection.

The beneficial uses identified above are generally unproven, are only available opportunistically at specific sites, and may result in additional environmental impacts. Consequently, they were considered not feasible. For example, opportunities for Class II well injection for enhanced oil recovery are dependent on well proximity to oil and gas operations that are available for the service life of the desalination facility.

Then, if the concentrate is non-hazardous, it may be injected along with produced water to maintain reservoir pressures.

High recovery processes were also evaluated. These convert more concentrate to product water and thereby reduce the concentrate volume. A typical endpoint for these processes is to reduce the concentrate volume sufficiently such that either evaporation ponds become more feasible or the concentrate is reduced to a solid salt material for disposal. High recovery processes are considerably more expensive than the conventional (low recovery) treatment systems due to additional processing equipment and associated energy costs. Currently, no municipal membrane systems employ high recovery processing.

Mickley performed an evaluation of high recovery processes and identified three commercially available systems (Reference 15):

- Thermal brine concentrator (such as manufactured by GE-Ionics-RCC; AquaTech, and others)
- HERO (high efficiency reverse osmosis) system patented by AquaTech
- VSEP system by New Logic Research

The results of the screening evaluation that Mickley performed showed the VSEP system is the most viable of these three options for the Project. According to New Logic's research, the process may be capable of recovering more than 50 percent of the concentrate stream which would likely be reused as feedwater for the conventional RO process. Thus, if feasible, VSEP would reduce the volume of the concentrate residuals stream by more than 50 percent.

The VSEP system uses vibratory shear forces to allow a sheet-type RO membrane to operate beyond the solubility point of sparingly soluble salts to enhance process recoveries. Thus, issues related to the potential for formation plugging and well maintenance requirements will need to be evaluated if the concentrate from the VSEP process is ultimately disposed via deep well injection. SAWS will be piloting the VSEP system during the third quarter of 2008 to determine its feasibility.

Section 5
PERMITTING

5.1 Introduction

SAWS, with input from R. W. Beck as a reviewer, developed the Permitting Plan ("Plan") for the Project (Reference 16). The Plan, developed from a 2004 the Texas Water Development Board ("TWDB") guidance document (Reference 17) for permitting desalination projects in Texas, is included as Appendix D.

The Plan contains a brief description of the Project; a list of local, state and federal permits with estimated durations for obtaining each permit; a breakdown of responsibilities for permitting activities under the proposed design-build ("DB") project delivery structure that SAWS intends to use; the modeling SAWS utilized to identify which permits are needed; and a set of recommendations for the effective implementation of the plan. As shown, it uses the decision trees in the TWDB document to identify the permits needed for the Project. Figure 5-1, excerpted from the Plan illustrates the use of the decision trees. Items color-coded with green shading show Project features that are subject to regulatory oversight. Consequently, the sub-tier decision trees in the TWDB's guidance document were then used to identify the permitting requirements for each such feature.

A significant portion of the overall permitting effort will involve acquisition of groundwater district permits for those wells located in Atascosa and Wilson counties. Evergreen will have regulatory authority over Raw Water produced from these Counties. It is anticipated that drilling permits, production, and transport permits for Raw Water will be obtained for the wells that are placed within the boundaries of the district. The majority of the other major permits will be obtained from TCEQ.

It should also be noted that the current permitting plan assumes concentrate disposal will be accomplished via deep well injection. Therefore, the permitting plan will need to be updated if SAWS elects to pursue surface water discharge to the San Antonio River as a concentrate disposal option for the project.

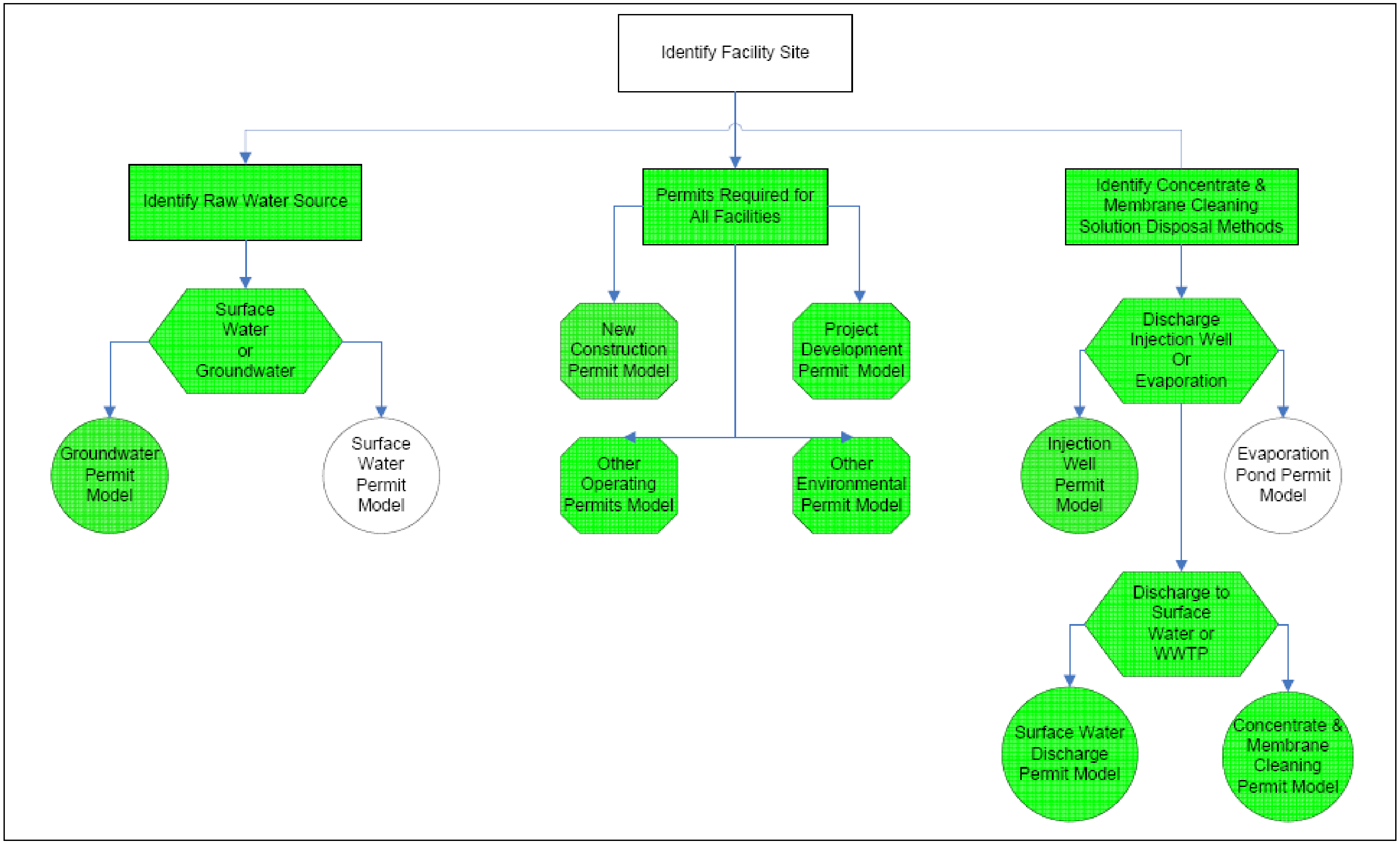

Figure 5-1 Permitting Model for Desalination Facilities Using RO Technology in Texas

Tables 5-1 through 5-6 below were excerpted from the Plan. The tables provide a breakdown of permitting responsibilities for SAWS and the DB Vendor and are based on the assumption that SAWS will install the Raw Water production wells for the Project and the DB Vendor will design and install the balance of the Project facilities. Per this project delivery concept, the DB vendor will be responsible for the Raw Water collection piping and transmission pipeline feeding the proposed RO Facility, any Raw Water booster pump stations, the proposed RO Facility, the Finished Water transmission pipeline from the proposed RO Facility to the Anderson pump Station, the concentrate disposal pipeline, and (if used) the pretreatment filter backwash disposal line. Thus, as explained in Table 5-1, below, SAWS is responsible for all permitting for the Raw Water production wells; the DB vendor has prime responsibility for construction-related permits such as building permits, road crossings, railroad crossings and drainage issues, etc.; and SAWS and the DB vendor share the responsibility for the other permits for the Project. Some examples of the permits with shared responsibility include those required for tree preservation, river crossings (Army Corps of Engineers 404 permit), rights of way and easements, and those related to facility operation if SAWS decides to be the operator for the Project.

Based on this division of responsibilities for permitting, SAWS has effectively transferred much of the permitting risk to the DB Vendor while retaining control over critical permits such as those for the injection wells. To provide a basis of comparison with traditional DBB, if DBB is employed for the entire project, SAWS would be responsible for the timely acquisition of all permits and would likely incur delay costs for permits that are late. Thus, the strategy adopted by SAWS using the DB approach should be effective in assuring that the Project realizes the benefits of SAWS relationships with the regulatory agencies that have oversight for the Project while effectively sharing the risk of permitting delays with the DB Vendor.

Table 5-1
Anticipated Well Field Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Evergreen Underground Water Conservation District ("EUWCD")			
Test Wells	Monitor and report water quality/quantity well data	X	
Monitor Wells	Monitor, record and report water quality/quantity and production well data	X	
Production Wells	Provide monthly reports containing water	X	
Transfer Permit	Comply with groundwater district inspections and monthly water production reports	X	
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirement and includes passing inspections	X	
Right of Way (ROW)/ Easements	Secure all ROW/Easements needed to install project infrastructure by coordination with the appropriate state, county, and local governments. Follow legal guidance for "good faith negotiations in cases where condemnation is required	X	
Registrations/Approvals			
TCEQ Design Approval (All wells)	Compliance with approved plans and specifications	X	
Texas Department of Licensing and Regulation (TDLR) Well Registration (Submitted by Driller)	No specific permit required; comply with historical commission and environmental review	X	
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review	X	
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing other utilities	X	

Table 5-2
Anticipated Collection System Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Permits			
TxDOT	DB vendor should obtain the TxDOT permit and comply with engineering requirements and specifications for crossing major highways		X
Tree Preservation (Bexar County)	No ordinance for Wilson and Atascosa counties. Compliance with City of San Antonio Tree Mitigation and/or Tree Preservation Plan. SAWS will initiate permitting activities and then transfer to the DB vendor	X	X
County Road Crossing	Comply with County-approved engineering construction standards and specifications		X
Railroad Crossing	Comply with railroad approved engineering construction standards and specifications. (In Bexar County)		X
Scour Analysis	Comply with City of San Antonio scour analysis requirements		X
U. S. Army Corps of Engineer 404 Permit	Comply with requirements of approved specifications for floodplain crossing and dredging of navigable waterways. SAWS will initiate the permitting activities and then transfer to the DB Vendor	X	X
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirement and includes passing inspections		X
Right of Way (ROW)/ Easements	Secure all ROW/Easements needed to install project infrastructure by coordination with the appropriate state, county, and local governments. Follow legal guidance for “good faith” negotiations in cases where condemnation is required	X	X
Registrations/Approvals			
TCEQ Design Approval	Compliance with approved plans and specifications		X
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review. SAWS will initiate the permitting and then turn over to the Vendor	X	X

Table 5-2
Anticipated Collection System Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing another utilities infrastructure. SAWS will initiate contact with the utility and then turn over to the DB Vendor	X	X

Table 5-3
Anticipated Treatment Plant Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Tree Preservation	No ordinance for Wilson and Atascosa counties. Compliance with City of San Antonio Tree Mitigation and/or Tree Preservation Plan. SAWS will initiate the process and then turn over to DB Vendor	X	X
City of San Antonio Building Permit	Comply with City of San Antonio Building Codes and Specifications		X
Floodplain	Comply with Bexar County Floodplain requirements		X
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirements, Notice of Intent (NOI) and includes passing inspections		X
Drainage	Comply with City of San Antonio drainage requirements		X
Petroleum Storage	Comply with applicable state and local petroleum storage requirements		X
On-site Sewer Facility Permit	Comply with state and local sewer facility regulations and specifications		X
Federal Aviation Administration (FAA)	Comply with FAA regulations for antenna height and placement		X
ROW/ Easements	Secure all ROW/ Easements needed to install project infrastructure by coordinating with the appropriate state, county, and local governments. Follow legal guidance for “good faith” negotiations in cases where condemnation is required	X	X
Commercial Hazard Waste	Comply with commercial hazard waste regulations and standards to include maintaining records of waste quality, quantity, location and transportation	X[1]	X
Notification of Hazardous or Industrial Waste	Comply with requirements and standards associated with the submittal of a Notification of Hazardous or Industrial Waste Management	X[1]	X
Public Water System	Comply with existing Public Water System permit regulations		X

Table 5-3
Anticipated Treatment Plant Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
TPDES	Comply with permit regulations and limits	X[(1)]	X
Registrations/Approvals			
TCEQ Design Approval	Compliance with approved plans and specifications	X[(1)]	X
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review. SAWS will initiate and then turn over to Vendor	X	X
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing another utilities infrastructure. SAWS will initiate coordination with the utilities and then turn over to DB Vendor	X	X

1. If SAWS opts to operate

Table 5-4
Anticipated Distribution System Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Permits			
TxDOT	Comply with engineering requirements and specifications for crossing major highways		X
Tree Preservation	No ordinance for Wilson and Atascosa counties. Compliance with City of San Antonio Tree Mitigation and/or Tree Preservation Plan	X	X
County Road Crossing	Comply with county approved engineering construction standards and specifications		X
Railroad Crossing	Comply with railroad approved engineering construction standards and specifications. (In Bexar County)		X
Scour Analysis	Comply with requirements of approved City of San Antonio Scour Analysis		X
Army Corps of Engineering 404 Permit	Comply with requirements of approved specifications for floodplain crossing and dredging of navigable waterways	X	X
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirements, Notice of Intent (NOI) and includes passing inspections		X
ROW/ Easements	Secure all ROW/ Easements needed to install project infrastructure by coordinating with the appropriate state, county, and local governments. Follow legal guidance for "good faith" negotiations in cases where condemnation is required	X	X
Electrical	Comply with City of San Antonio Electrical Codes and Regulations		X
Registrations/Approvals			
TCEQ Design Approval	Compliance with approved plans and specifications		X
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review. SAWS will initiate and then turn over to DB Vendor	X	X

Table 5-4
Anticipated Distribution System Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing another utilities infrastructure	X	X
TCEQ Notification of New Water Source in System	Written notification of the startup of new facility	X	X

Table 5-5
Anticipated Concentrate Transport Pipelines Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Permits			
TxDOT	Comply with engineering requirements and specifications for crossing major highways		X
Tree Preservation	No ordinance for Wilson and Atascosa counties. Compliance with City of San Antonio Tree Mitigation and/or Tree Preservation Plan. SAWS will initiate the process and then turn over to the DB Vendor	X	X
County Road Crossing	Comply with county approved engineering construction standards and specifications		X
Railroad Crossing	Comply with railroad approved engineering construction standards and specifications (In Bexar County)		X
Scour Analysis	Comply with requirements of approved City of San Antonio Scour Analysis		X
Army Corps of Engineers 404 Permit	Comply with requirements of approved specifications for floodplain crossing and dredging of navigable waterways	X	
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirements, Notice of Intent (NOI) and includes passing inspections		X
ROW/ Easements	Secure all ROW/ Easements needed to install project infrastructure by coordinating with the appropriate state, county, and local governments. Follow legal guidance for “good faith” negotiations in cases where condemnation is required	X	X
Electrical	Comply with City of San Antonio Electrical Codes and Specifications		X
Registrations/Approvals			
TCEQ Design Approval	Compliance with approved plans and specifications		X
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review	X	X

Table 5-5
Anticipated Concentrate Transport Pipelines Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Store or Process Industrial Non-hazardous Waste	Comply with regulations and standards associated with the storing or processing of Industrial non hazardous waste to include security, inspection, maintenance, monitoring and record keeping, equipment and personnel tracking requirements		X
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing another utilities infrastructure	X	X

Table 5-6
Anticipated Concentrate Injection Site Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Permits			
Pre-Injection Registration	Compliance of Class I non-hazardous, noncommercial waste disposal well application for the authorization of Pre-Injection registration		X
Injection Well	Comply with regulations and standards for injection wells to include financial assurances, fees, renewals, monitoring and reporting, testing, inspection and component maintenance and instrument integrity to be conducted on an annual basis or as indicated in permit	X	X
Tree Preservation	No ordinance for Wilson and Atascosa counties. Compliance with City of San Antonio Tree Mitigation and/or Tree Preservation Plan. SAWS will initiate process and then turn over to DB Vendor	X	X
Hazardous Waste Permit	If greater concentrate disposal stream is greater than 10,000 TDS, hazardous waste permit for the transporting of such waste will be required. Comply with hazard waste regulations and standards to include maintaining records of waste quality, quantity, location and transportation	X	X
Electrical	Comply with City of San Antonio Electrical Codes and Regulations		X
Construction Storm Water Pollution Prevention Plan (SWPPP)	Compliance with local SWPPP requirements, Notice of Intent (NOI) and includes passing inspections		X
ROW/ Easements	Secure all ROW/ Easements needed to install project infrastructure by coordinating with the appropriate state, county, and local governments. Follow legal guidance for “good faith” negotiations in cases where condemnation is required	X	X

Table 5-6
Anticipated Concentrate Injection Site Permitting Obligations

Permit Type	Obligations	Permitting Responsibility	
		SAWS	Vendor
Registrations/Approvals			
TCEQ Design Approval	Compliance with approved plans and specifications		X
Historical/Archaeological/ Environmental Clearances	No specific permit required; comply with historical commission and environmental review	X	X
Utility Coordination	No specific permit required; comply with utility specifications and engineering requirements when crossing another utilities infrastructure	X	X

Permitting for the Project will require significant coordination efforts, partnerships and resources. Therefore, Section 4 of the Plan contains a number of recommendations for effectively implementing the plan. These are shown below:

- Determine whether SAWS will be operating the desalination plant or if operation of the plant will be contracted. This will impact permit obligations for specific operator permits.
- Shift the responsibility for permitting to the DB vendor to the extent practical. This will minimize the potential for contractor delay claims due to delays in the permitting process.
- Clearly communicate the permitting risks SAWS is willing to retain to the Owner's Representative so that the Owner's Representative can appropriately define the permitting responsibilities in the DB vendor procurement documents. SAWS should request that the Owner's Representative include the requirement for the DB vendor to conduct periodic permit progress meetings and summary status reports to SAWS.
- Screen all DB Vendors during the procurement process to assure they have sufficient, if not extensive, permitting experience with local, state and federal permits.
- Determine the ultimate project capacity. This will allow SAWS to incorporate provisions for future expansions including pipelines, outfalls, and other non-modular project components into the initial design and permits of the project. This in turn will save time and costs associated with future expansions of the plant.
- Conduct initial and periodic project update meetings with appropriate members of the regulatory community so they are familiar with the project before they review specific permit applications.

- Designate a specific SAWS representative who in coordination with the Owner's Representative will be responsible for managing SAWS permitting activities and monitoring DB vendor permitting efforts. A tracking tool such as a master project schedule should also be developed to assist with monitoring the status of permit reviews and approvals. Changes in permit status can immediately be reflected in the overall project schedule.
- Conduct permitting status review meetings throughout the project development phase with both SAWS internal permitting team and the DB vendor to confirm permitting activities are on schedule.
- For permitting activities to be pursued by SAWS or which are critical paths activities where SAWS will take the lead (i.e. injection site permit), SAWS should include in the Owner's Representative responsibilities assistance with these permitting activities. Such shall include any modeling or other expertise associated with these permitting needs in which SAWS can not provide internally.
- Conduct coordination/progress meeting with the electrical companies providing service to the plant and other project components to assure the infrastructure is in place on a timely manner for the DB vendor.
- Determine to the extent possible, the alignments for pipeline project components and require the Owner's Representative to include these as prescriptive alignments in the DB vendor procurement package. This will minimize cost and delays with the known alignments and will allow SAWS to proactively address permitting activities and required approvals (such as tree preservation, archaeological/environmental studies, and right of ways), eliminating potential delays if alignments are changed during construction.

R. W. Beck participated in the development of these recommendations and concurs with them.

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Section 6
PROCUREMENT AND FINANCIAL EVALUATION

6.1 Introduction

As a part of the Project, R. W. Beck performed a comprehensive evaluation of the possible procurement options available for delivery. This process began with a vast number of delivery options and narrowed to four likely options. These were evaluated during a detailed financial analysis (the "Analysis"). The purpose of the Analysis was to examine cost of each alternative delivery option as compared with traditional DBB.

6.2 Procurement Options Evaluation

The Edwards Aquifer Authority ("EAA") has mandated that SAWS reduce its dependence on fresh water supplies from the Edwards Aquifer in a timely manner. In order to meet the scheduled reduction requirements, and potentially benefit from the efficiencies of the private sector, SAWS requested the evaluation of alternative delivery options, in addition to traditional DBB, for the brackish groundwater desalination facilities. Numerous procurement options were considered by R. W. Beck, some of which were not available under existing Texas statutes. The delivery options selected for closer examination are summarized below.

- DBB with SAWS Operations: The conventional procurement process with sequential design, construction and operation. The owner has separate contracts with the designer and constructor with low bid selection of the construction contractor. SAWS staff would operate the facilities.
- DBB with Contract Operations: The conventional procurement process with sequential design, construction and operation. The owner has separate contracts with the designer and constructor with low bid selection of the construction contractor. Operation is provided via a private operating contract procured through a separate, competitive process.
- DB with SAWS Operations: This would entail the competitive selection of a single design-build contractor to design and construct the facilities. SAWS staff would operate the facilities.

Commodity Purchase/Design Build-Own-Operate-Transfer ("DBOOT"): This would entail the competitive selection of a single private entity to finance, design, construct, own and operate the facilities for a contract period, with the potential for a transfer of the facilities to SAWS at the conclusion of the contract period.

- DB-Operate ("DBO"): This would entail the competitive selection of a single entity to design, construct and operate the facilities for a defined contract period.

The key contractual relationships, benefits and drawbacks of each of these procurement options was described in a memorandum from R. W. Beck to SAWS labeled as “Draft Initial Procurement and Financial Memorandum” dated March 31, 2006 (Appendix E).

6.3 Procurement Options for the Analysis

Based on extensive discussions between R. W. Beck and SAWS regarding the suitability of various delivery options, and the expectation that a legislative change would allow DB delivery SAWS selected four procurement options to be evaluated in the Analysis.

6.3.1 Traditional Design-Bid-Build

The DBB method of project delivery is commonly used for public projects in the US. Under this option, SAWS would first contract with a design engineer to develop the project design (to the 100 percent design level) under a qualifications-based selection process. Then, SAWS would contract for the construction of the project with the lowest responsive bidder. Operation of the facilities would be the responsibility of SAWS. Although SAWS could contract with a private entity for operation services, the Analysis assumes that SAWS will operate the facilities. Further, SAWS would own and finance the project under this option.

6.3.2 Design-Build-Finance-Own-Operate

The Design-Build-Finance-Own-Operate (“DBFOO”) method of project delivery is similar to a DBOOT project method of project delivery. Under DBFOO, SAWS would contract with a private sector entity for water treatment services, rather than for the construction of a public water project. In the Analysis, the private entity would own, finance and operate the project facilities and sell Finished Water to SAWS as a commodity.

6.3.3 Design-Build-Operate

The DBO method of project delivery would require SAWS to utilize a non-profit government corporation as a conduit in the project. It is similar to the DBFOO alternative in that the non-profit would own and finance the project and a private entity would operate the facilities. However, it differs in that Project ownership and the responsibility for operation would by a non-profit government corporation rather than a private sector entity. This option is delivered under a single contract, through a competitive proposal process, and provides a single point of responsibility for project performance.

6.3.4 Design-Build

The DB method of project delivery would allow SAWS to deliver the project under a single contract, through a competitive proposal process, without utilizing a non-profit conduit. This option provides a single point of responsibility for project performance up to, and including, the successful completion of an acceptance test. SAWS would own, finance and operate the facilities under this option.

6.4 Roles and Responsibilities

Although it may be possible for the roles and responsibilities of each party to change within each procurement option, what follows is a description of the assumed roles and responsibilities for the purposes of the Analysis. Table 6-1 provides a brief summary of roles under each procurement option evaluated.

Table 6-1
Summary of Roles by Procurement Option

	DBB	DBFOO	DBO(1)	DB
Owner	SAWS	Private	Non-Profit	SAWS
Financier	SAWS	Private	Non-Profit	SAWS
Operator	SAWS	Private	Private	SAWS

1. Non-Profit would substitute for SAWS under this option based on the description provided by Hawkins Delafield (February 23, 2007 memo)

6.4.1 Financial Analysis Assumptions

R. W. Beck has provided SAWS with three technical memorandums related to the technical aspects of the brackish groundwater desalination project and the associated assumptions utilized in the Analysis.

- "SAWS Conceptual Cost Estimate Methodology Narrative" revised January 15, 2008 (Appendix E)
- "SAWS Desalination Project – Concept Level Estimate of O&M Costs for Chemicals and Electricity" dated July 20, 2007 (Appendix E)
- "SAWS Desalination Project – Modeled Estimate of Capital and O&M Costs for Design-Build-Finance-Own-Operate, Design-Build-Operate and Design-Build Cases" dated July 24, 2007 (Appendix E)

These memoranda convey the assumptions and rationale underlying the capital construction costs and the operating costs for each procurement option evaluated in the Analysis. A summary of the capital construction costs, by procurement option, are provided in Table 6-2.

Table 6-2
Summary of Estimated Capital Construction Costs[1]

(In $ Millions)	DBB	DBFOO	DBO	DB
Raw Water Wells	$ 54.6	$ 54.6	$ 54.6	$ 54.6
Raw Water Conveyance	22.9	20.6	20.6	20.6
RO Treatment Plant	33.6	28.6	28.6	28.6
Injection Wells	11.7	11.5	11.5	11.5
Concentrate Pipeline	12.7	11.5	11.5	11.5
Surface Water Pipeline	10.9	9.8	9.8	9.8
Product Water Pipeline (to Marbach)	34.5	31.0	31.0	31.0
Subtotal	$ 180.9	$ 167.6	$ 167.6	$ 167.6
Sales Tax	-	8.2	-	-
Estimated Contingency	56.1	52.0	52.0	52.0
Total Construction Cost	$ 237.0	$ 227.8	$ 219.6	$ 219.6

1. In 2007 US Dollars

It should be noted that there were several outstanding issues at the time the conceptual construction cost estimate was developed, which could have a significant bearing on total Project costs. For example, as discussed in Section 3, the pretreatment needs for the Project require additional study and could exceed $15,000,000 capital costs for pretreatment filtration and residuals disposal-related equipment and facilities. Further, the costs are significantly impacted by the size of the well fields and the length of the transmission, Raw Water collection, concentrate disposal, and pretreatment filter backwash disposal pipelines associated with the Project.

The overall Project construction cost contingency of approximately 31 percent is appropriate since there were several unknown factors at the time the Project cost estimate was prepared. Therefore, a number of assumptions were necessary for the purpose of defining the Project sufficiently so that a cost estimate could be prepared. For example, specific locations for the concentrate disposal wells and for the surface water discharge had not been identified. Therefore, SAWS provided assumptions related to pipeline lengths for the concentrate disposal pipeline and for a surface water discharge pipeline that was required by the pretreatment system. Further, the Team did not have Raw Water quality data from the test well for the Atascosa well field. Consequently, LBG-Guyton provided projections for major water quality parameters such as TDS, chlorides and sulfates and R. W. Beck needed to make the assumption that the levels of other constituents would be similar to those reported in laboratory results for the ASR and Jasik test wells to develop a treatment process concept (the treatment process concept was verified after data for the Atascosa Test Well became available). Based on these uncertainties, the contingencies used for the cost estimate were conservatively selected. This Project features include: 1) the number of Raw Water production wells; 2) the location of the proposed RO Facility;

3) the location of the concentrate disposal wells; 4) whether a 400 mg/l or a 500 mg/l Finished Water TDS Standard should be adopted; and 5) whether there is a need for a pretreatment filtration step with an attendant backwash disposal line and, if so, where the backwash discharge point will be located.

Finally, with the changes to the Project after the cost estimate was prepared, it is possible that the cost of the Project may have changed. For example, SAWS recently conducted an independent evaluation of the estimated Project cost with these changes and estimated the cost at approximately $300,000,000. As a result, based on the changes and uncertainties discussed above, we recommend verifying the cost estimate once firm decisions about several Project aspects have been made.

SAWS is currently in the process of applying for TWDB grant funding for the Project. According to the TWDB, additional grant funding will not be available until the Texas Legislature reconvenes in January 2009. At that time, the Texas Legislature could appropriate additional funds for the financial assistance of water projects. These funds would become available in June 2009, at the earliest. SAWS should continue to pursue TWDB funding as it is made available.

Additional assumptions critical to the Analysis were provided in the memorandum "Brackish Groundwater Desalination Feasibility – Analysis of Procurement Options" dated January 21, 2008 (Appendix E). These assumptions were identified and developed with the assistance of SAWS staff. A few assumptions of significance include:

- Financing costs as listed in Table 6-3;

Table 6-3
Summary of Financing Assumptions

	SAWS	Private Entity
Equity Investment	N/A(1)	20.00%
Return on Equity	N/A(1)	12.00%
Interest During Construction	3.75%	8.00%
Long-Term Debt Rate(2)	5.50%	8.00%(3)
Long-Term Debt Term (Years)	30	30
Bond Issuance (% of Principal)	1.50%	3.00%
Debt Service Coverage Ratio	1.25	N/A(1)
Reserve (Months)	6	6
Interest Earned on Reserve	3.75%	3.75%

1. Not Applicable
2. Level, semi-annual payments
3. SAWS and R. W. Beck mutually agreed to utilize an 8.00% interest rate for the private entity based on commercially achievable interest rates for private, non-recourse financed projects contemporary with the time period. The interest rate is not indexed to a particular bond rating, but is for projects that are generally rated above "junk" status

- Annual construction cost escalation of 3.2 percent (Reference: Handy Whitman, W-4, January 1992 to January 2007 average, water utility construction and equipment for source, pumping and treatment);
- Annual operating cost escalation of 2.7 percent (Reference: March 2007 issue, *Blue Chip Economic Indicators*, top 10 average projection for CPI for 2007 to 2018);
- RO plant operating at 20 MGD and an operating capacity of 98 percent (allowing some down time for maintenance);
- Discount rate of 6.0 percent (utilized in the life-cycle cost evaluation); and
- Purchase of the Trumbo/Englehart property for the proposed RO Facility site for an estimated $1.74 million.

It should be noted that R. W. Beck provided to SAWS the comprehensive financial model developed to compare the four procurement options. Therefore, SAWS may evaluate the impact of changing any number of these (or other) assumptions as desired.

6.5 Financial Analysis Results

R. W. Beck evaluated the procurement options based on the two financial analysis summaries included in the financial model provided to SAWS. One compares the cost per 1,000 gallons in the first year of operation and the other measures the total life-cycle cost over 30 years of operation. Each of these summaries illustrates part of the overall picture; and changing assumptions can be readily evaluated based on these results. For example, reducing the proposed RO Facility operating level from 20 MGD to 15 MGD will show a reduced total life-cycle cost due to reduced variable expenses incurred. However, the cost per 1,000 gallons will be correspondingly higher since the fixed expenses, such as debt service, are being spread across fewer gallons of product water. Considered together, the two summaries provide a complete assessment of costs based on the four options evaluated.

6.5.1 Capital Costs

The capital assumptions for each option are reflected in the resulting debt and fixed capital costs per 1,000 gallons. DB is less capital intensive than DBB, and DBO requires a lower capital investment than DB. Although construction costs under DBFOO are equal to the construction costs for the other alternative delivery options (DB and DBO), the sales tax on construction adds more than $8.2 million to the total construction cost under DBFOO. Further, other private entity costs, such as more expensive financing, cause the overall capital costs under DBFOO to be the highest of all options evaluated.

6.5.2 Operating Costs

The relative ranking of procurement options from an operating perspective mirrors that of the capital requirements – the DB option is slightly less expensive than DBB, and DBO is less costly than DB. Although most of the operating costs under the DBFOO option are similar to the other alternative delivery options, ad valorem taxes significantly impact the operating cost for DBFOO. Property taxes on the improvements alone are projected to be greater than $5.8 million in the first year of operation. Federal income taxes and the return on equity for the private entity also add to the cost of operation under the DBFOO option.

6.5.3 Cost per Unit of Volume

Table 6-4 lists the cost per 1,000 gallons of treated water and the cost per acre-foot in the first year of operation for each procurement option.

Table 6-4
Summary of Cost in First Year of Operation[1]

	Cost Per 1,000 Gallons Treated	Cost Per Acre-Foot[2]	Percent of DBB Cost
DBB			
SAWS Debt	$ 3.99	$ 1,299	
SAWS O&M	2.55	831	
Total	$ 6.54	$ 2,130	100%
DBFOO			
SAWS Debt	$ 0.40	$ 132	
SAWS O&M	-	-	
Private Fixed	6.45	2,101	
Private Variable	1.48	483	
Total	$ 8.33	$ 2,716	127%
DBO			
SAWS Debt	$ 0.69	$ 226	
SAWS O&M	-	-	
Private Fixed Capital	2.95	961	
Private O&M	2.41	785	
Total	$ 6.05	$ 1,972	93%
DB			
SAWS Debt	$ 3.71	$ 1,209	
SAWS O&M	2.53	825	
Total	$ 6.24	$ 2,034	95%

1. In 2011 US Dollars assuming 20 MGD operation
2. Comparison with other water supply projects on a cost per acre-foot basis may not be equivalent due to the 98% operating capacity assumed in the Analysis (in lieu of 100%)

6.5.4 Life-Cycle Analysis

Table 6-5 shows, for each procurement option, the estimated life-cycle cost of operating the project facilities for 30 years.

Table 6-5
Summary of Life-Cycle Cost

(In $ Millions)	Total Life-Cycle Cost(1)	Percent of DBB Cost
DBB		
SAWS Debt	$ 401.6	
SAWS O&M	350.1	
Total	$ 751.7	100%
DBFOO		
SAWS Debt	$ 41.4	
SAWS O&M	-	
Private Fixed	768.3	
Private Variable	206.0	
Total	$ 1,015.7	135%
DBO		
SAWS Debt	$ 71.2	
SAWS O&M	-	
Private Fixed Capital	302.7	
Private O&M	333.9	
Total	$ 707.8	94%
DB		
SAWS Debt	$ 380.7	
SAWS O&M	350.7	
Total	$ 731.4	97%

1. In 2011 US Dollars assuming normalized cost of producing 212,856,000,000 gallons of treated water from 20 MGD operation for 30 years

Comparing Table 6-4 and Table 6-5, shows the cost for each option as a percent of the DBB option is similar, with the exception of the DBFOO option. The cost of DBFOO, as a percent of DBB, is slightly higher in the life-cycle analysis than the costs in the first year of operation would indicate. This is due to the federal income tax implications of a private owner.

6.5.5 Peaking Facility

SAWS has indicated they may consider the use of the proposed RO Facility as a peaking facility – implying the production would vary with seasonal demand. For example, under this approach, the proposed RO Facility might be operated at 10 MGD in the winter, 14 MGD in the spring, 20 MGD in the summer and 16 MGD in the autumn. In this example, the proposed RO Facility would produce an annual average of 15 MGD. A comparison of the projected cost of operating the proposed RO Facility at 15 MGD and 20 MGD is shown in Table 6-6[19]. In general, the cost per 1,000 gallons of product water is projected to increase approximately 25 percent due to the reduced operating level. However, the total annual cost declines with the reduced operating level, due to lower total variable cost. SAWS may choose to reduce production at the proposed RO Facility during periods of lower (off-peak) demand due to the proposed RO Facility's higher variable cost per unit of water produced as compared to other water sources, such as ground water.

Table 6-6
Impact of Operating Level on Cost(1)

	15 MGD(2)		20 MGD	
	Per 1,000 Gallons	Annual Total(3) (In $ Millions)	Per 1,000 Gallons	Annual Total(4) (In $ Millions)
DBB	$ 8.21	$ 44.1	$ 6.54	$ 46.8
DBFOO	10.59	56.8	8.33	59.6
DBO	7.55	40.5	6.05	43.3
DB	7.82	42.0	6.24	44.6

1. In 2011 US Dollars; steady state operation throughout the year; cost per 1,000 gallons is based on the first year of operation
2. The 15 mgd case represents a 20 MGD RO Facility operated at an average of 15 MGD for the year. As a result, while the O&M costs vary with the production level, the capital costs do not vary and remain based on a 20 MGD RO Facility
3. Assumes 5,365,500,000 gallons of product water are produced
4. Assumes 7,154,000,000 gallons of product water are produced

The results shown in Table 6-6 assume the proposed RO Facility is operated at the same operating level at steady state throughout the year. In reality, using the proposed RO Facility as a peaking facility would not mirror the operationally efficient steady state, but the analysis is sufficient to illustrate the impact of operating level on cost.

It is important to note that operating the proposed RO Facility as a peaking facility may prove to be operationally inconvenient. The logistics of adjusting the operating level can involve additional labor and expenses. To take a membrane filter out of service on a long term basis, it must be filled with preservatives and, thereafter, checked weekly for acceptable pH levels. If this procedure is not performed properly

[19] The costs for the 15 MGD scenario were developed by varying the average plant production parameter in the model.

the membrane can foul, reducing efficiency or shortening membrane life. The membrane must be thoroughly flushed of preservatives to be placed back into service.

6.6 Financial Analysis Conclusions

The benefits of reduced capital and operating costs in the DBO option result in the Analysis indicating that DBO would have the lowest overall cost of all options evaluated. The life-cycle cost of DBO is projected to be approximately six percent less than the cost of the DBB option. As mentioned earlier, it is our understanding that SAWS may not utilize DBO directly, but may attempt to deliver the project through a non-profit conduit as described by Hawkins Delafield.

DB is also expected to cost less than DBB, but more than DBO. SAWS is assumed to be the operator under the DB option in the Analysis. However, if SAWS were to contract with a private operator, through procurement separate from the design and construction, the overall cost may be reduced to approach that of the DBO. In discussions with SAWS staff this method has been referred to as DB+O or DB plus distinct O.

The DBFOO option, which has some non-financial advantages over other delivery options, is more expensive due to tax obligations under Texas statues. A combination of sales tax on construction and select operating costs, ad valorem taxes on the project assets and federal income taxes for the private entity cause the DBFOO option to be comparatively more expensive than the other options evaluated.

R. W. Beck would reiterate that all of the alternative delivery options (DBFOO, DBO, and DB) are expected to be completed approximately six months faster than the DBB option due to overlapping design and construction schedules. This is a significant advantage when time is of the essence, the need for additional water is critical and the cost of delay in water delivery is high. The financial analysis of the four delivery options does not fully reflect the potential value of early delivery of treated water. Therefore, it is important for SAWS to recognize this difference when evaluating these options.

Finally, some assumptions regarding the Project have changed since the Analysis. For example, the planned site for the proposed RO Facility has been changed to the existing ASR site. This, and many other modifications, may be entered into the financial model provided to SAWS in order to evaluate the impact on the cost of the Project. However, in the case of the Trumbo/Englehart property not being purchased for the proposed RO Facility site, the savings of an estimated $1.74 million impacts all four options evaluated equally. Therefore, there would be no change in the conclusions stated in this report.

Section 7
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