Preliminary Engineering Assessment

Kenedy Brackish Desalination Plant
Karnes County, Texas

Prepared for
San Antonio River Authority

By
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In association with
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Contents

List of Tables

List of Figures

Introduction

The City of Kenedy, Texas is the largest community in Karnes County and lies about midway between San Antonio and Victoria. The City serves approximately 3,400 residents plus about 740 employees and 2,850 inmates of the John Connally Unit, a state maximum security prison located nearby.

Kenedy is located within the TWDB (Texas Water Development Board) Region L Planning Area (Figures 1 and 2). By 2060, the total population of Region L is expected to increase by 75 percent to 4.298 million and total water demands are projected to increase by 29 percent to 1.273 million acre-feet per year[1]. In the City of Kenedy, the total water demand, which is predominantly for municipal use, is projected to increase from 758 to 993 acre-feet per year (or by 31 percent) by 2060. These increasing demands require the City to replace or upgrade the existing water treatment equipment to consistently meet current water quality standards.

In May 2006, TWDB provided funding to the City of Kenedy and SARA (the San Antonio River Authority) to demonstrate the efficiencies gained by installing a new RO (reverse osmosis) system in an existing brackish groundwater desalination plant in the City of Kenedy, Texas. This preliminary engineering assessment represents the first of four tasks[2] associated with the project.

Objectives

Since the mid-1990s, the efficiency of desalination membrane technology and equipment has improved considerably. As improvements to the Kenedy RO system are evaluated, comparisons between existing and projected operating costs should provide a means to calculate the potential return on investment. The evaluation will also provide a valuable framework for other communities contemplating upgrades to their systems.

The primary objectives of this Preliminary Assessment include:

1. Evaluate existing RO treatment system equipment and operations.
2. Investigate the applicability of newer desalination technologies.
3. Recommend system improvements and estimate implementation costs.
4. Estimate performance parameters of an improved system and compare with historical operational processes and costs.
5. Develop a draft interactive internet-based presentation of anticipated efficiencies to be gained by improved technologies.

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1 Texas Water Development Board. 2007. Water for Texas. Document No. GP-8-1, Volume II. Texas Water Development Board, Austin, Texas. p. 79.

2 Remaining tasks include design of facility improvements, bidding and construction, and data collection and reporting.

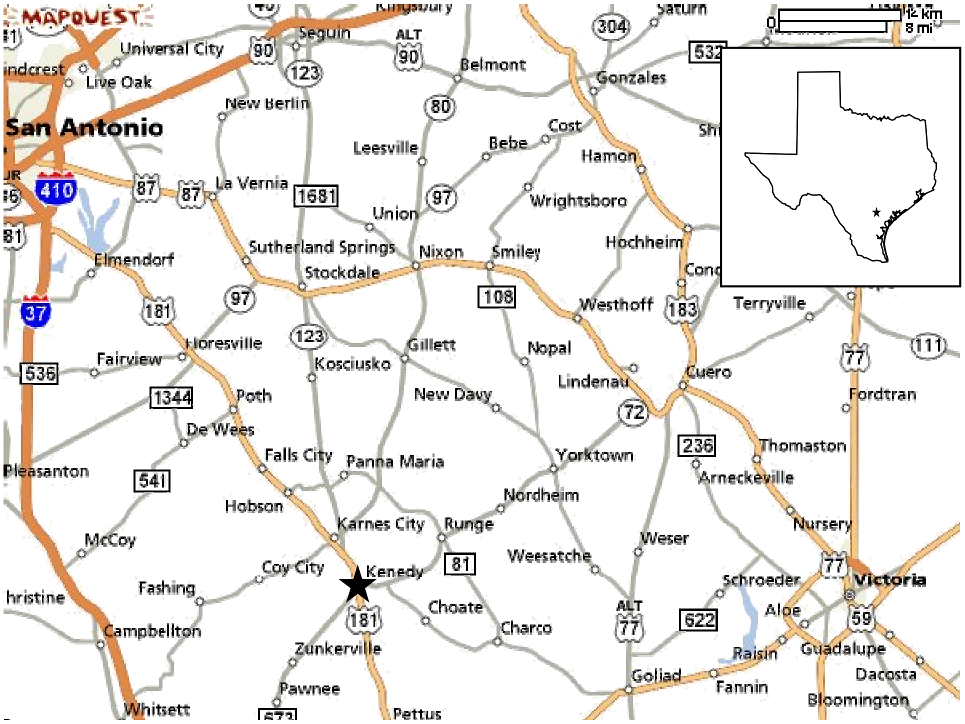

Figure 1: Project Location Map.

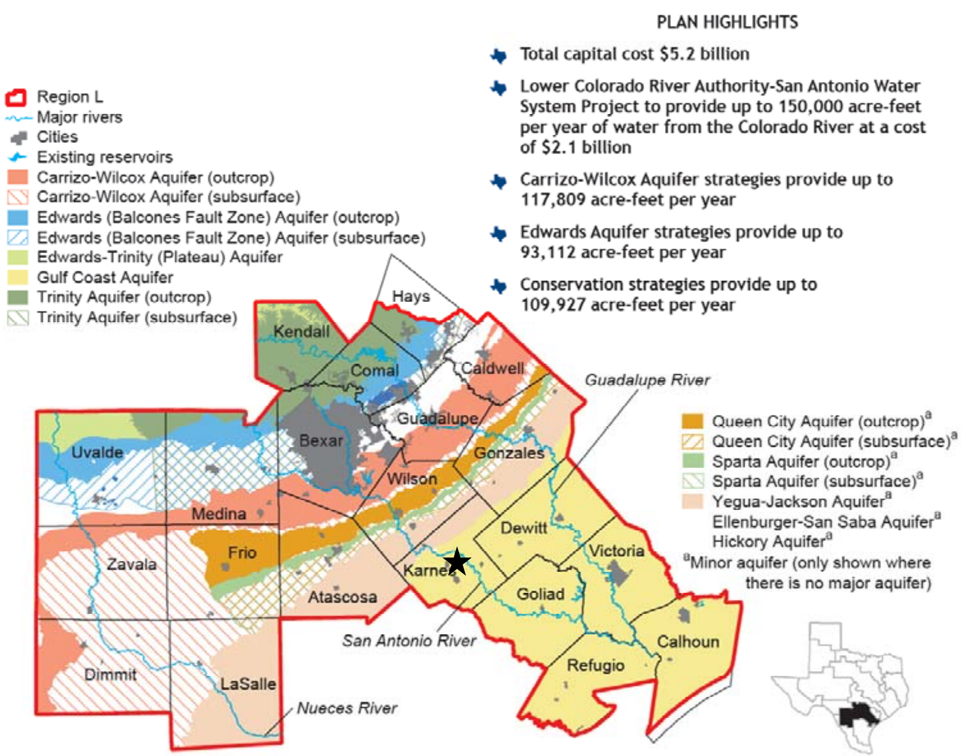

Figure 2: Summary of Region L Planning Area.
Graphic courtesy of TWDB.

Facility Overview

The City of Kenedy constructed a RO treatment system in 1995 at the Cottonwood Water Treatment Plant. The RO treatment capacity of the plant was subsequently expanded in 1996 and again in 2005. The RO system was primarily constructed to meet increasing demands for drinking quality water; specifically, to reduced the concentrations of TDS (total dissolved solids), chloride, and arsenic in the City groundwater wells. In 2007, an arsenic reduction system was also installed to help the facility meet drinking water regulations for this contaminant. Since 2002, Veolia Water has operated and maintained the desalination plant for the City under contract. A current map of the Kenedy water supply system is presented in Figure 3.

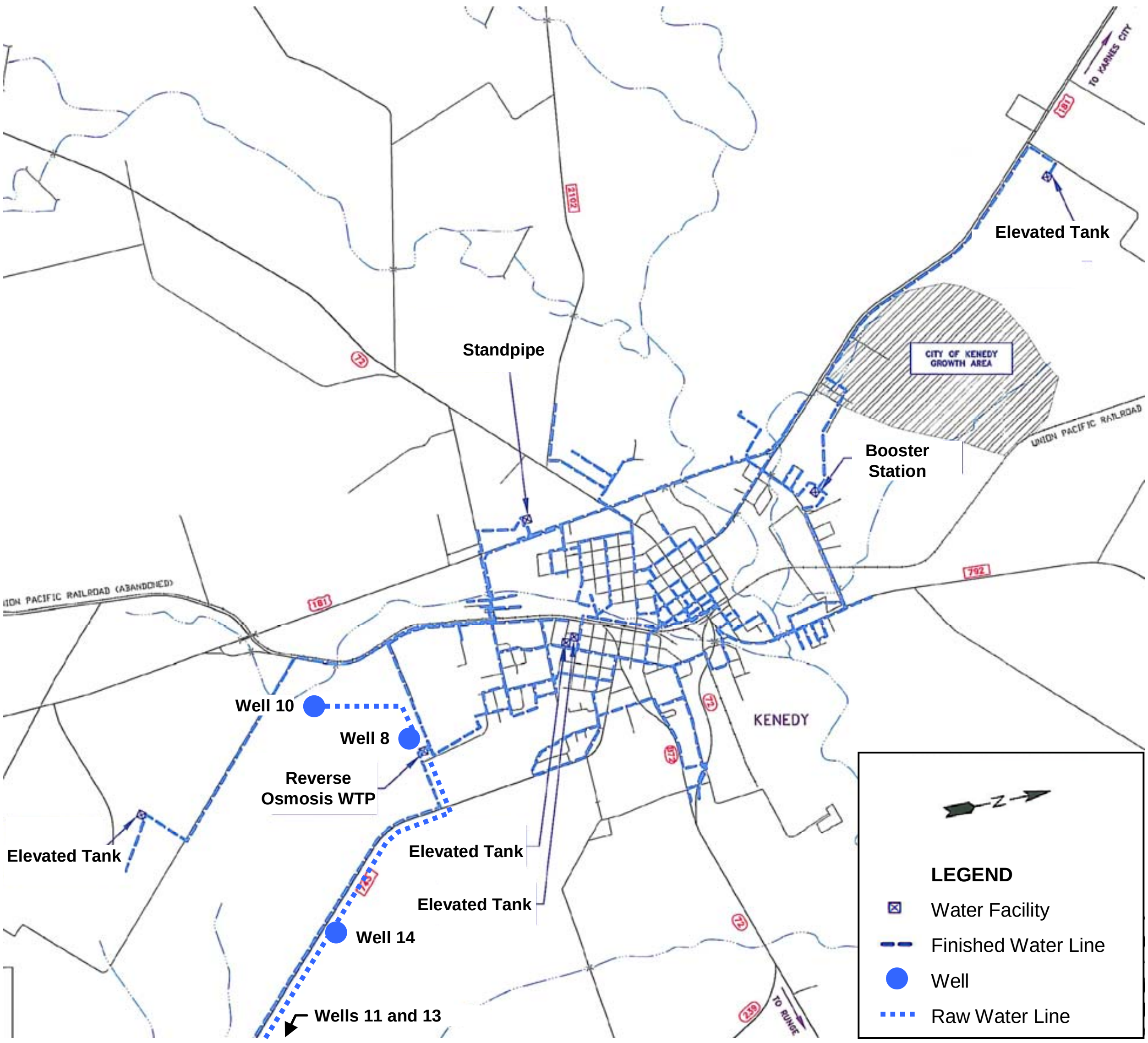

Figure 3: Map of the City of Kenedy Water Supply System.
Graphic courtesy of SARA.

The following overview of the desalination plant facilities addresses four major components:

1. Well Field collection and conveyance;
2. Reverse Osmosis treatment;
3. Concentrate Disposal; and
4. Potable Water Delivery

A summary timeline showing major developments associated with each infrastructure component is presented in Figure 4.

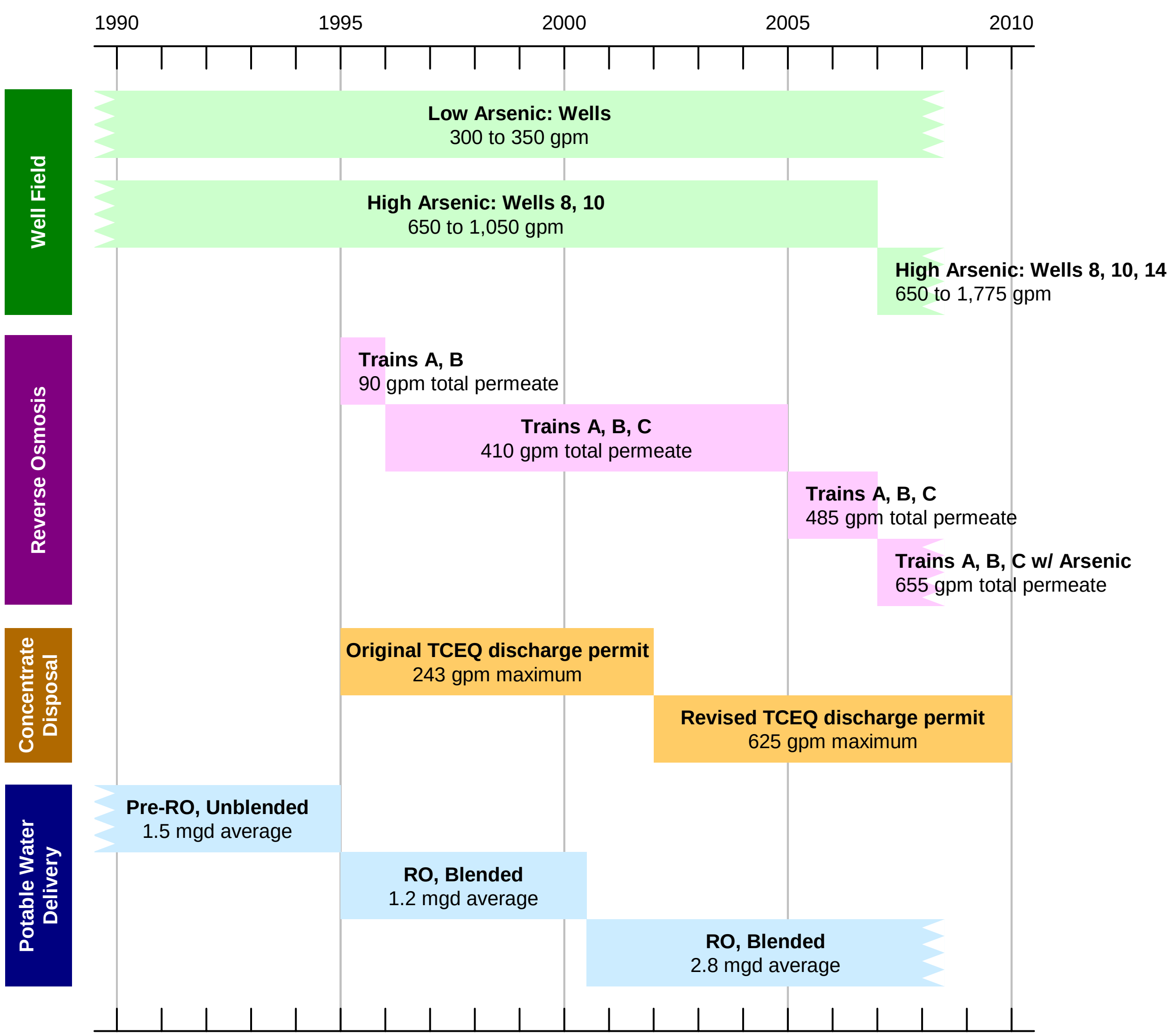

Figure 4: Infrastructure Timeline of the Kenedy Brackish Desalination Plant.

WELL FIELD COLLECTION AND CONVEYANCE

The City has traditionally relied on local wells for drinking water. Through 2006, these wells ranged in capacity from 50 gpm (gallons per minute) to greater than 700 gpm at discharge pressures of 35 to 50 psig (pounds per square inch, gauge pressure) at the wellhead. Figure 3 shows the location of each well in relation to the Cottonwood Treatment Plant, and a summary list of individual wells is presented in Table 1.

Table 1: Summary of Municipal Well Data, City of Kenedy, Texas

Well Number	Historical Capacity (gpm)	Notes[a]
8	400 to 600	Installed in 1969; motor replaced most recently in 2003 (100 hp); 650-ft depth.
10	250 to 450	Motor replaced most recently in 1993 (100 hp); 490-ft depth.
11	250 to 300	-
13	50	-
14	Up to 725	Installed in October 2007.

[a] Historical well installation data, including information about which wells were lowered in 2005 due to a drop in the water table, was unavailable.

Prior to the installation of the RO system in 1995, the City water supply system relied on four water wells: Wells 8, 10, 11 and 13. Water quality data for two of these wells (Wells 8 and 13) are unavailable. From the information available, it can be determined that all four wells contained elevated TDS and chlorides. In addition, at least one well (Well 10) had an elevated arsenic concentration. Table 2 reports available average water quality data of wells prior to 1995 and compares these values with the TCEQ (Texas Commission on Environmental Quality) MCL (Maximum Contaminant Level) for that period. Although the results are inconclusive without data for all active wells, a review of available data does indicate that there existed a need to improve the treatment process to produce potable water within the MCL for TDS and chloride, as well as arsenic (unless only Well 11 was used).

Table 2: Reported Well Water Quality Data, 1995 (Pre-RO)

Major Constituent	Units	Well 8 Average[a]	Well 10 Average	Well 11 Average	Well 13 Average[b]	Blended Feedwater to RO (Wells 10 and 11 only[a])	TCEQ MCL
pH	-	*NR*	*NR*	7.1	*NR*	*NR*	>7.0
TDS	mg/L	*NR*	1,275	1,166	*NR*	1,256	1,000
Alkalinity, total	mg/L	*NR*	344	260	*NR*	302	-
HCO3	mg/L	*NR*	400	314	*NR*	356	-
Hardness, as CaCO3	mg/L	*NR*	149	415	*NR*	235	-
Specific Conductance	mmhos/cm	*NR*	2,281	1,995	*NR*	2,322	-
Ca	mg/L	*NR*	45	134	*NR*	80	-
Cl	mg/L	*NR*	400	132	*NR*	408	300
Nitrate as N	mg/L	*NR*	2	1.6	*NR*	1.4	10 (as Nitrogen)
Nitrate + Nitrite	mg/L	*NR*	*NR*	0.87	*NR*	*NR*	-
SO4	mg/L	*NR*	189	73	*NR*	145	300
Na	mg/L	*NR*	424	257	*NR*	360	-
Mg	mg/L	*NR*	3	17.4	*NR*	11	-
Silica	mg/L	*NR*	77	45.8	*NR*	65	-
K	mg/L	*NR*	*NR*	10.4	*NR*	*NR*	-
Fe	mg/L	*NR*	0.07	0.0453	*NR*	0.05	0.3
As	µg/L (ppb)	*NR*	92.85	6.2	*NR*	58.74	50
As, total	µg/L (ppb)	*NR*	77.10	*NR*	*NR*	46.26	-
As III	µg/L (ppb)	*NR*	70.60	*NR*	*NR*	42.36	-
As V[b]	µg/L (ppb)	*NR*	5.02	0.09	*NR*	3.05	-
Ba	mg/L	*NR*	0.71	1.52	*NR*	1.03	2
Sr	mg/L	*NR*	*NR*	*NR*	*NR*	*NR*	-
Temperature	degrees F	*NR*	*NR*	*NR*	*NR*	*NR*	-

Note: NR = Not recorded.
[a] Sufficient data prior to 1995 was not available.
[b] The Primary Quantitative Limit for the technique used to measure this value is 10.0 mg/L.

Water quality data collected since the RO system expansion was completed in 1996 show some changes in the concentration of major ions, including arsenic, chloride, and silica. Table 3 presents the average feedwater quality from Wells 8, 10, 11, 13, and 14[3] for well water data collected up to 2007.

[3] Well 14 was brought online in 2007, but water quality data from this well is included in the Blended Feedwater averages for the period of 2005 to 2007 for because: there was such a small amount of data to work with; the RO equipment did not change during this period; and it gives a more accurate representation of current conditions.

Table 3: Reported Well Water Quality Data, 2005 to 2007

Major Constituent	Units	Well 8 Average	Well 10 Average	Well 11 Average	Well 13[a] Average (2 samples)	Well 14[b] (1 sample)	Blended Feedwater to RO (Wells 8, 10, and 14 only)	TCEQ MCL
pH	-	7.85	6.95	8.00	7.2	7.6	7.6	>7.0
TDS	mg/L	1,241	1,144	1,228	996	1,480	1,333	1,000
Alkalinity, total	mg/L	339	361	241	*NR*	329	341	-
HCO3	mg/L	447	445	290	305	329	386	-
Hardness, CaCO3	mg/L	159	150	363	382	172	163	-
Specific Conductance	mmhos/cm	1,580	1,991	2,384	1,800	*NR*	1,836	-
Ca	mg/L	57	54	133	124	58.3	57	-
Cl	mg/L	371	333	419	335	543	447	300
N	mg/L	3.75	1.47	1	1	1.1	2	10 (as Nitrogen)
SO4	mg/L	131	101	79	75	158	136	300
Na	mg/L	401	378	263	*NR*	325	355	-
Mg	mg/L	5.5	5.01	23	*NR*	6.33	6	-
Silica	mg/L	*NR*	*NR*	46	*NR*	*NR*	[b]	-
Fe	mg/L	0.092	0.125	0.03	0.09	0.195	0.15	0.3
As[c]	µg/L (ppb)	64.1	65	6.2	4	29	46.5	10 (50 before 01/23/06)
Temperature	degrees F/C	80.6/27	78.8/26	*NR*	75.0/24	*NR*	[d]	-

[a] Average values for Well 13 prior to 1995 were derived from one sampling date (November 9, 2004) and were not included in the calculated 'Blended Feedwater to RO' estimates in this table.
[b] Well 14 was brought on-line in October 2007 and limited data is available.
[c] Arsenic speciation not reported.
[d] Not enough data to support calculation of average condition.

Only Well 13 meets the MCL for TDS, and only Wells 11 and 13 have arsenic concentrations below the new MCL of 10 ppb (parts per billion). None of the wells meet the MCL for chloride.

Table 4: Summary of Key Finished Water Standards Compared to Reported Well Water Quality Data

Constituent	Units	TCEQ MCL	Feedwater Quality	
			1995 (Pre-RO)[a]	2005 to 2007[b]
TDS	mg/L	1,000	Up to 1,275	Up to 1,480
Chloride	mg/L	300	Up to 419	Up to 543
Arsenic	µg/L (ppb)	10	Potentially up to 93	Potentially up to 65

[a] Used for original RO design.
[b] Incorporates previous well water quality data and used for water quality comparisons.

REVERSE OSMOSIS TREATMENT

1995: Original Installation of RO Trains A and B

Prior to the installation of the reverse osmosis system, blended well water quality (and the potable water provided to customers) had elevated chlorides and TDS. In order to comply with TCEQ and EPA (Environmental Protection Agency) potable drinking water quality standards, the City initially procured and installed two reverse osmosis treatment systems in 1995. Trains A and B, each capable of independent operation, were designed to remove chlorides and TDS in the potable water (Figure 5). The design allowed for RO permeate to be blended with well water already containing low concentrations of chlorides and TDS.

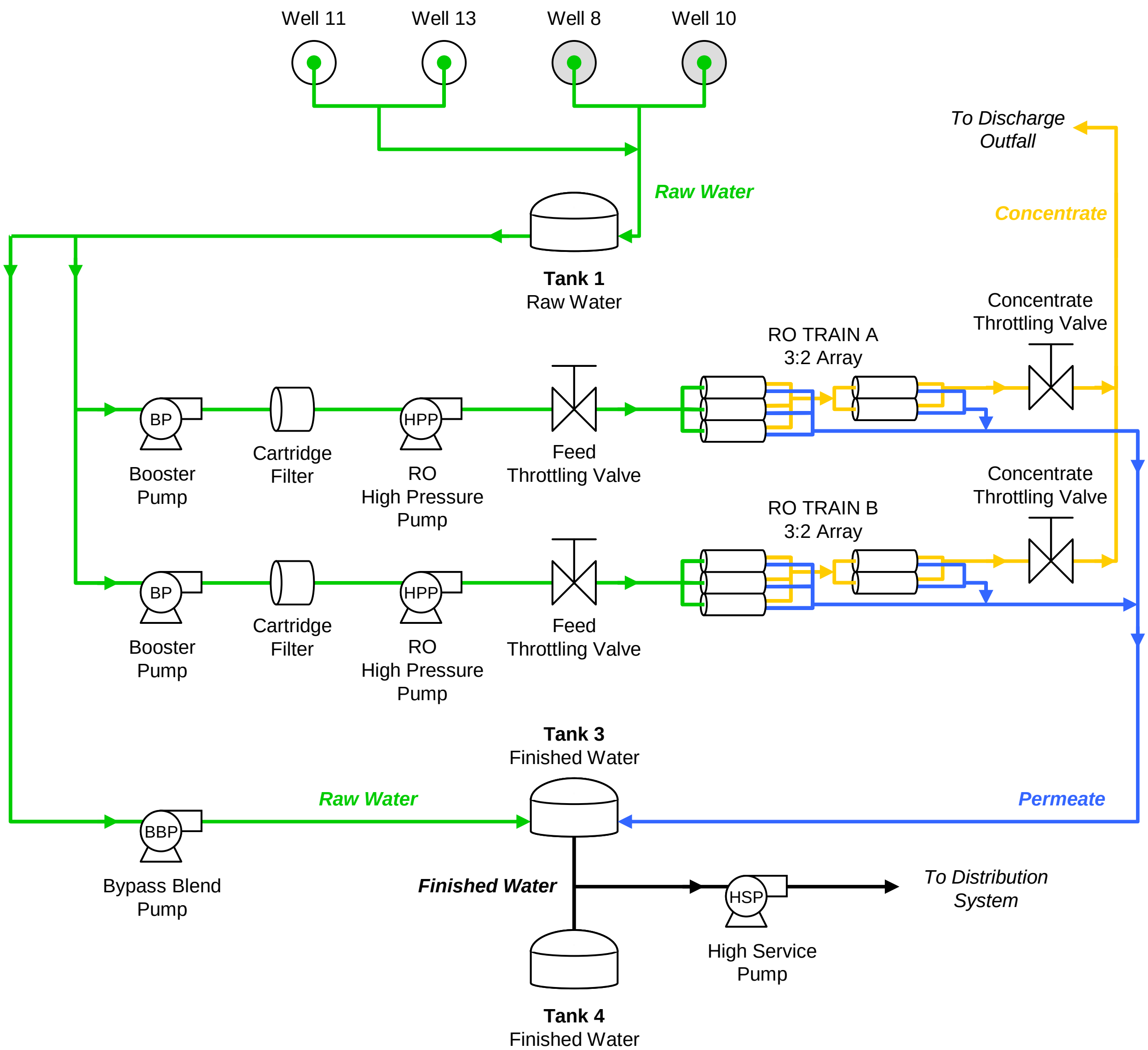

Figure 5: Facility Process Flow Diagram, 1995 (Trains A and B).
Shaded wells indicate those with elevated Arsenic.

1996: Train C Expansion

In 1996, the City significantly expanded the capacity of the water treatment plant by adding a third RO train, Train C (Figure 6).

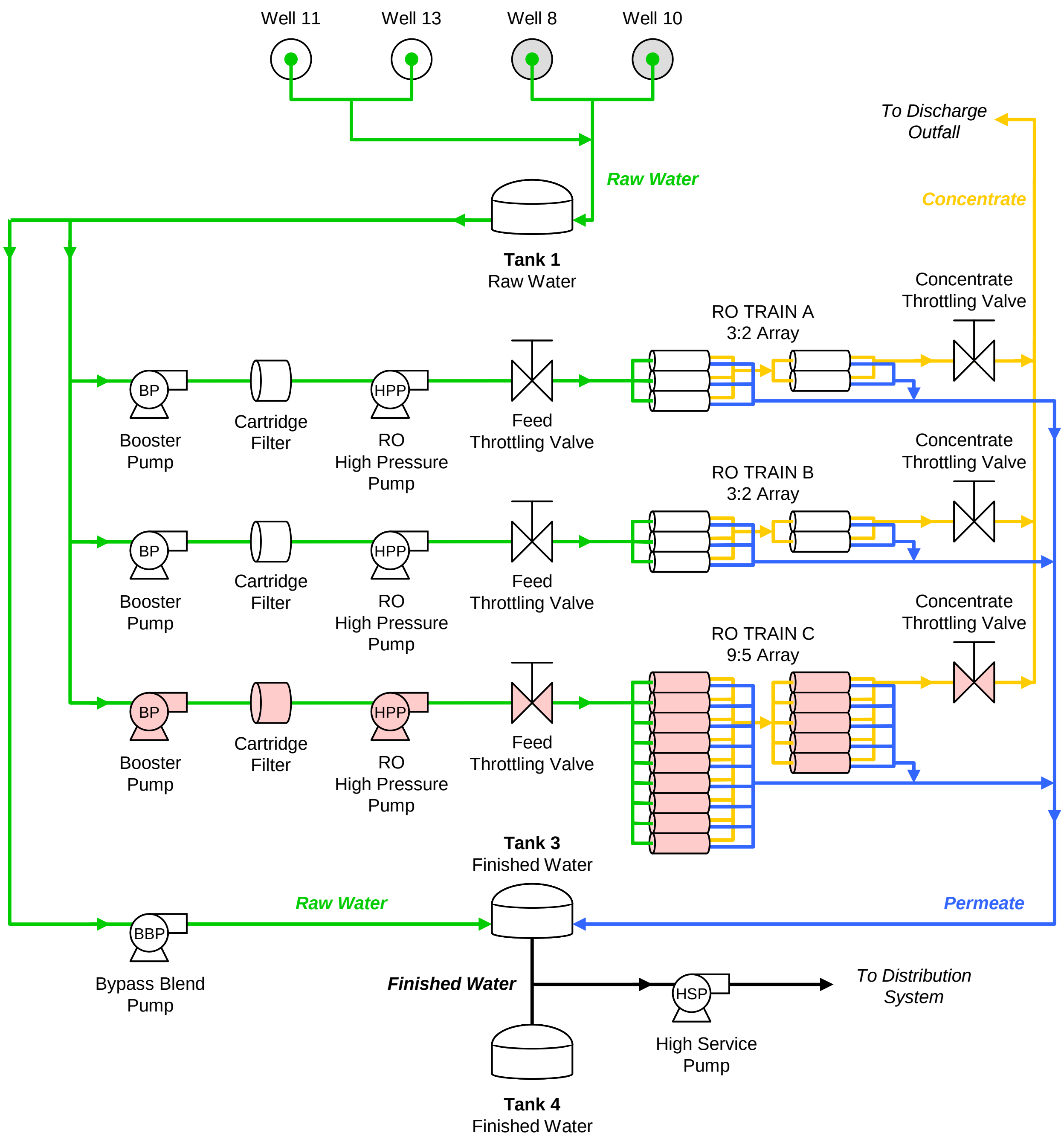

Figure 6: Facility Process Flow Diagram, 1996 (Addition of Train C).
New components shown in red. Shaded wells indicate those with elevated Arsenic.

Feedwater quality data utilized by the equipment manufacturer to design the RO system (Trains A and B) is not available. However, feedwater quality design criteria are available from the equipment manufacturer's documentation for Train C, which was installed the following year in late 1996 (Table 5).

Table 5: Train C Design Criteria Versus Water Quality by Analysis

Major Constituent	Units	1995/1996 Original Design Criteria for Train C[a]	Pre-1997 Blended Feedwater Analysis	2005 Blended Feedwater Analysis
pH	-	7.66	*NR*	7.6
TDS	mg/L	1,414	1,256	1,333
Alkalinity, total	mg/L	*NR*	302	341
HCO3	mg/L	568	356	386
Hardness, CaCO3	mg/L	*NR*	235	163
Specific Conductance	mmhos/cm	*NR*	2,322	1,836
Ca	mg/L	77	80	57
Cl	mg/L	311	408	447
Nitrate as N	mg/L	1.24	0.89	2
SO4	mg/L	92	145	136
Na	mg/L	356	360	355
Mg	mg/L	8	11	6
Silica	mg/L	69	65	46[b]
Fe	mg/L	*NR*	.05	0.15
As	µg/L (ppb)	*NR*	58.7	46.5
Temperature	degrees F	68	*NR*	*NR*

Note: NR = None reported.
[a] Specific feedwater design criteria is not available for RO Trains A and B, nor any future upgrades to the system, although some manufacturers' design drawings were available and referenced. In the absence of the representative feedwater quality for performance and system modeling purposes, the "Blended Feedwater" columns are indicative of the calculated quality of water remaining by blending raw water from the higher arsenic, chloride, and TDS wells to a split-stream feeding the RO system in 1995/1996 and later in 2005 (discussed later in this section).
[b] Based on reported Well 11 average only.

Since no wells were added or removed from service during that time period, for purposes of this analysis, the water quality feeding Trains A and B is not expected to differ much from that feeding Train C.

2005: Expansion and Upgrade

Due to increasing demand for potable water in the service area, the City revised the design of all three trains in 2005. Trains A and B were expanded in capacity by adding more pressure vessels and elements, and Train C design was revised presumably to offer a more hydraulically balanced array compared to the original design, although with a slight reduction in capacity of 5 gpm to 315 gpm (Figure 7).

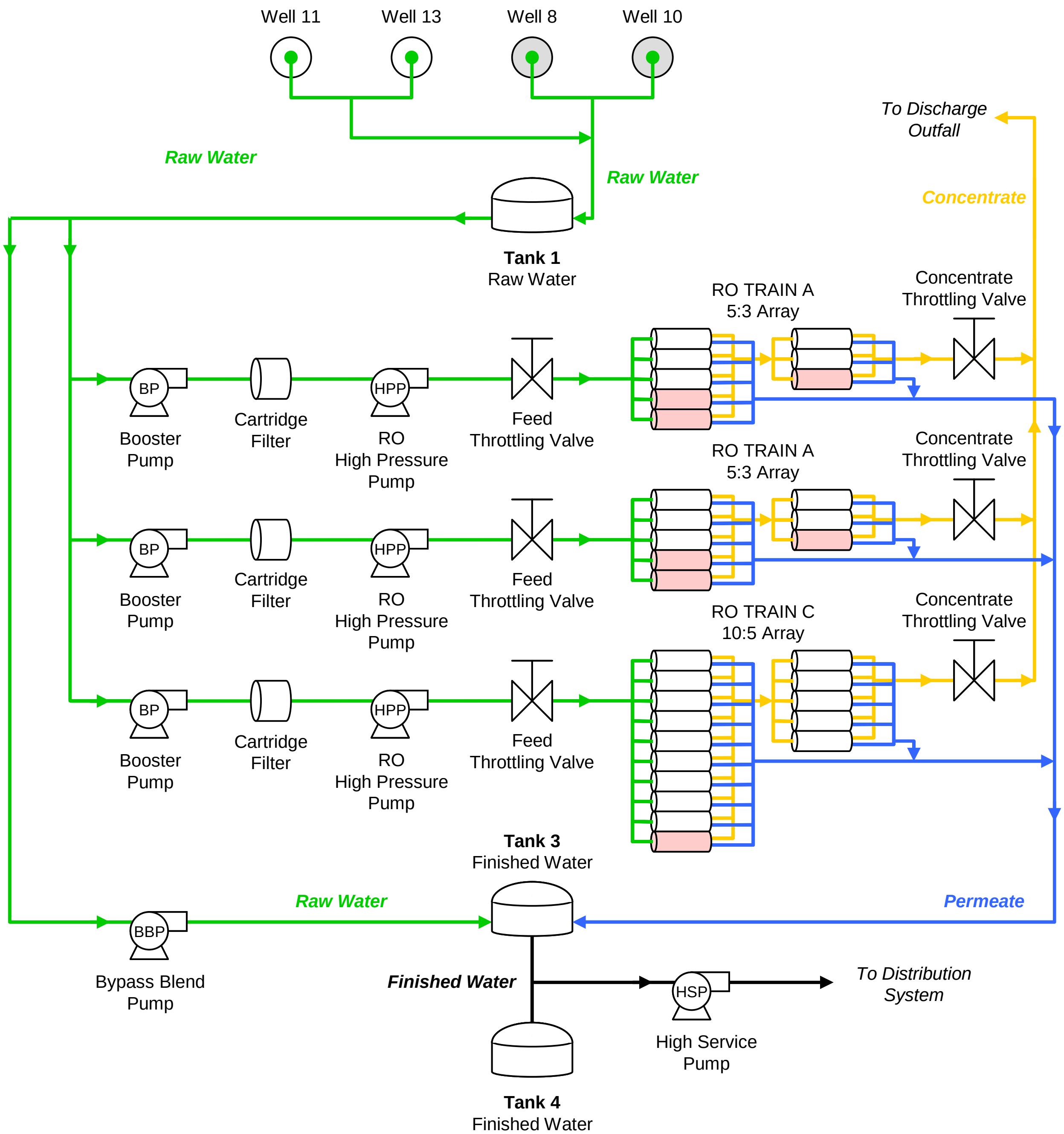

Figure 7: Facility Process Flow Diagram, 2005 (Upgrades to Trains A, B and C).
New components shown in red. Shaded wells indicate those with elevated Arsenic.

Another change that occurred commensurate with the installation of Train C was a complete replacement of the original Hydranautics CPA2 model elements in Trains A and B in 1996. Documentation that explains the reason why this occurred is unavailable. However, with the advancement of membrane element permeability and a specific flux twice as high as of the CPA2 membrane with slightly lower rejection characteristics, the replacement Hydranautics ESPA1 elements offered excellent performance and lower operating pressure compared to the CPA2 elements already installed. Specific water quality data utilized for that design of the Train C expansion is not available. However, changes in water quality by analytical report can be referenced in Tables 4 and 5. The reverse osmosis system design performance criterion established by the City, the City's Engineer, and the membrane system equipment manufacturer in 1995/1996 and 2005 is contained in Table 6.

Table 6: Design Performance Criteria for RO Trains A, B, and C.

Parameter	Unit	Trains A and B			Train C	
		1995	1996	2005	1996	2005
Inlet water pressure	psig	*NS*	– No change (element change out only) –	*NS*	*NS*	*NS*
Pre-booster pressure	psig	45		*NS*	30 minimum	*NS*
Feed pressure	psig	170		*NS*	121 max	*NS*
Feed flow	gpm/gpd	120/ 172,800		227/ 326,400	427/ 614,400	420/ 604,800
Permeate production	gpm/gpd	90/ 129,600		170/ 244,800	320/ 460,800	315/ 453,600
Design temperature	degrees F/C	*NS*		*NS*	68/20	*NS*
Concentrate pressure	psig	*NS*		*NS*	78 max	*NS*
Concentrate flow	gpm/gpd	30/ 43,200		57/ 82,080	106.5/ 153,360	*NS*
Array Configuration	-	3:2		5:3	9:5	10:5
Membrane Elements per Vessel	-	6		6	6	6
Design Feedwater/ Permeate TDS	mg/L	1,646/46		*NS*	1,470/45	*NS*
Array design recovery	percent	75		75	75	75
Membrane Element Manufacturer/Model	-	Hydranautics /CPA2	Hydranautics /ESPA1	Hydranautics /ESPA1	Hydranautics /ESPA1	Hydranautics /ESPA1
Average Flux Stage 1	gfd	13.8	14.1	16.1	16.6	15.6
Average Flux Stage 2	gfd	8.8	5.9	7.1	8.5	6.6
Average Flux, System	gfd	11.8	10.8	12.8	13.7	12.6

Note: NS = Not specified.

2007: Present Conditions

The need to install an arsenic treatment or reduction system was recognized by the City, which lead to the installation of the arsenic adsorber currently in service in 2007 (Figure 8). Arsenic from rocks and soils can be released into groundwater; and there are two different forms of arsenic: Arsenic III (arsenite) and Arsenic V (arsenate). Arsenic V is the most common form and is easier to remove from drinking water using adsorption media coagulation plus microfiltration, RO membranes, ion exchange, or electrodialysis reversal (all of which are EPA identified Best Available Technologies). Arsenic III can be more difficult to remove.

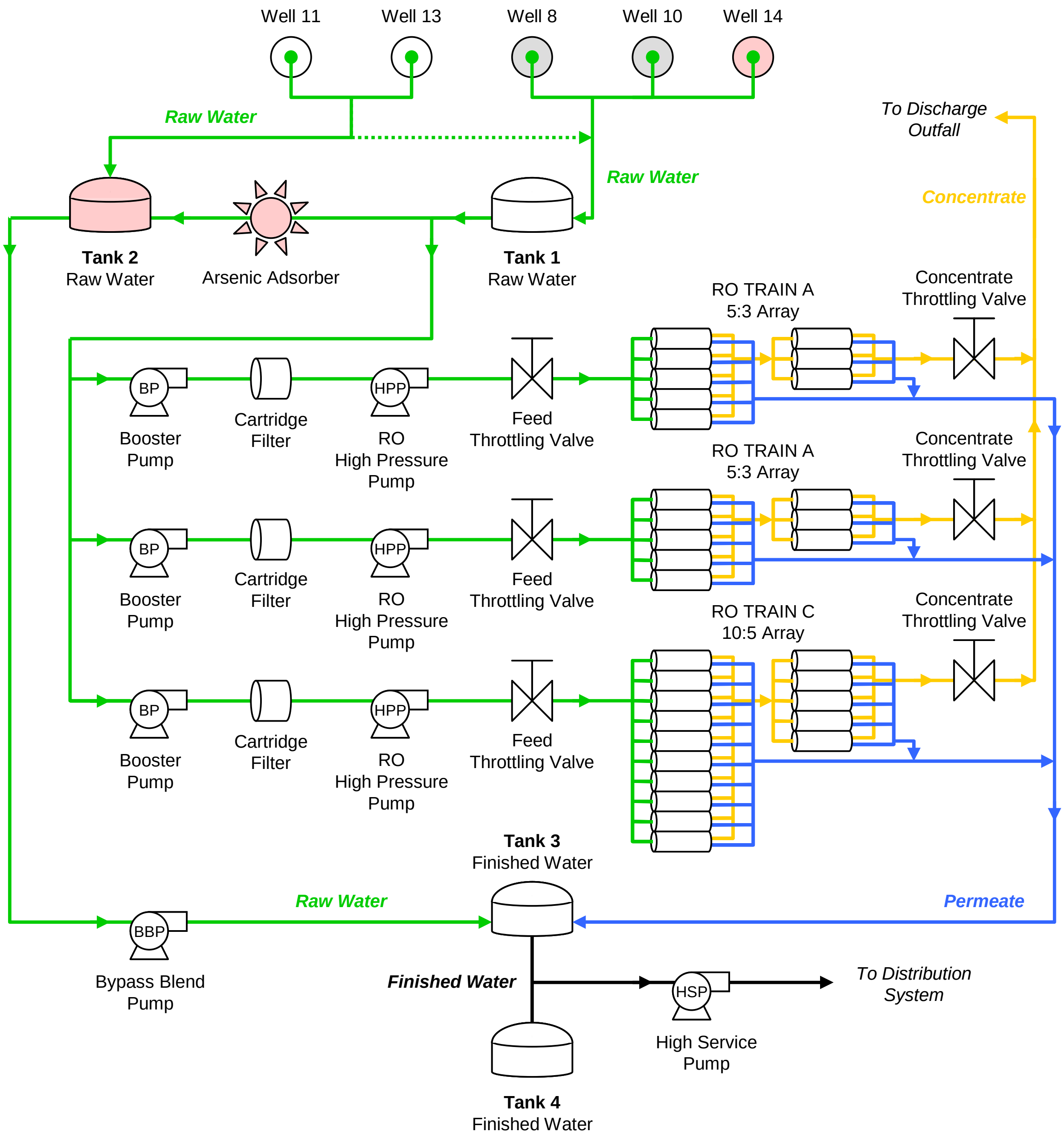

Figure 8: Facility Process Flow Diagram, 2007 (Addition of Well 14 and Arsenic Adsorber).
New components shown in red. Shaded wells indicate those with elevated Arsenic.

The arsenic adsorber installed onsite is capable of removing Arsenic III and Arsenic V. Pressurized water flows through a fixed-bed pressure vessel containing the granular ferric oxide adsorption media. As the water passes through the media, arsenic is adsorbed and removed. The City is informed by the manufacturer that the media is expected to last for at least one year between change-outs, with a low percent (less than 0.1) of the feedwater wasted as backwash. Used ferric oxide media containing the adsorbed arsenic is inert and can be disposed of as a non-hazardous solid waste to landfill after meeting a TCLP (Toxicity Characteristic Leaching Procedure) test used to characterize waste. Design performance criterion for the arsenic adsorber is contained in Table 7.

Table 7: Design Performance Criterion, Arsenic Adsorber

Parameter	Value
Flow	600 gpm
Feedwater pH	<7.2
Media	Bayoxide E 33 (shipped dry)
Feedwater arsenic	<88 µm/L (ppb)
Effluent arsenic	<8 µm/L (ppb)
Media type	90% α-FeOOH (Goethite)
Media life	4 to 6 months at 88 ppb in feedwater, 600 gpm
Mesh	10 x 35 (GAC is typically 8 x 30)
Minimum Bed Volumes	42,500
NSF 61 approved for human contact	Yes

Under certain elevated pH conditions, high levels of vanadium, phosphate and silica can reduce the adsorption of arsenic, requiring more frequent changing. Therefore, carbon dioxide is injected into the feed stream prior to the adsorber to lower the pH and enhance the run time of the media. A sodium hypochlorite system is available to pre-oxidize and particulate iron or manganese which could interfere with the removal capabilities of the adsorber. However, the consumption of sodium hypochlorite has been very limited and operating data is unavailable to demonstrate the effectiveness or utility of the additional chemical.

Naturally occurring iron can also interfere with the adsorptive capacity of the media since it, too has an affinity for arsenic. The arsenic system supplier's performance warranty stipulates maximum analyte concentrations of 333 mg/L alkalinity, 500 mg/L chloride, 27.2 mg/L silica, and less than 3 Fg/L of iron. These parameters have been exceeded in the high-arsenic wells (see Table 3).

The arsenic adsorber offers operating flexibility by allowing operations personnel to blend the filtrate from the arsenic adsorber with RO permeate from Trains A, B, or C prior to post-treatment and distribution. On January 16, 2006 TCEQ conditionally approved the City's arsenic removal system for construction. Based upon that conditional approval and other TCEQ documents regarding the system in a letter dated October 4, 2005, the adsorber flow rate was identified to be no greater than 600 gpm with pilot studies required if flow rates greater than this were required. Other requirements included monitoring the arsenic reduction capability of the system to determine replacement schedule and filing monthly blending operational reports. Such information was unavailable at the time this preliminary assessment was prepared.

Operating staff have stated that in 2007, and perhaps as early as 2005, Filmtec BW30-365 brackish RO elements were occasionally utilized since this element has similar salt rejection characteristics as the Hydranautics ESPA1 membrane.

However the nominal permeate flow rate for FilmtecBW30-365 is about 20 percent less. Table 8 contains the nominal performance comparison between the element models.

Table 8: Selected Design Performance Criteria, RO Trains A, B, and C

Membrane Element	Nominal Active Surface Area		Permeate Flow Rate		Stabilized Salt Percent Rejection	Minimum Salt Rejection
	ft²	m²	gpd	m³/d		
Filmtec BW30-365	365	34	9,500	36.0	99.5%	99.0%
Hydranautics CPA2	365	34	10,000	37.8	99.7%	99.5%
Hydranautics ESPA1	400	37	12,000	45.4	99.3%	99.0%

When the membrane trains were procured material specifications may have not been provided to the equipment manufacturer to establish the minimum criteria for the system materials of construction. The original piping for Trains A and B is predominantly 304 stainless steel for pressure service (including the cartridge filters) and PVC everywhere else. After Trains A and B were installed, plant operations personnel who were there at the time said that the piping developed pinhole leaks and the RO skid frames quickly began to deteriorate. It is reported that some of the piping was replaced by 316 stainless steel. Pump wetted parts were 316 stainless steel and valve wetted parts were a mixture of low-grade 304 stainless steel and 316 stainless steel. Very little else is known about the original materials employed in Train A and B. Representative materials of construction for Train C is contained in Table 9.

Table 9: Typical Train C Materials of Construction

Process Area	Component	Train C
Pre-treatment	Chemical Feed	316ss wetted parts for mixer; PVDF for pump w/TFE diaphragm
	Cartridge Filter	316 stainless steel
	Booster pump	Stainless steel for wetted parts; Grundfhos submersible type
	Metallic pipe	Schedule 40 carbon steel from wells to 5-micron cartridge filter; Schedule 10 304 stainless steel
Reverse Osmosis	Low pressure piping	Schedule 80 PVC
	High pressure piping	Schedule 10 304 stainless steel
	High pressure pump	316 SS wetted parts, Grundfhos 375S500-8DS
Clean in-Place (CIP) System	Piping	304L SS feed/return; S-80 PVC permeate; S-80 PVC waste disposal
	CIP pump	316 SS
Post-treatment	Chemical feed	Unspecified
Valves (general)	Pre-booster and cartridge filter	S-80 PVC permeate, concentrate (after throttling)

CONCENTRATE DISPOSAL

The City of Kenedy's concentrate discharge permit[4] was updated in 2002 because of the expected increase in RO design capacity (and commensurate volume of concentrate produced) scheduled for 2005. Under the terms of this permit, the City is authorized to discharge wastes, including RO concentrate, up to 625 gpm through a pipe to the abandoned arm of Escondido Creek[5] as long as those wastes meet the effluent limitations and monitoring requirements contained in Table 10. Note that the TPDES permitted discharge was 243 gpm in 1995 (prior to the 2002 update) and the operating parameters of the RO systems are within the requirements of the permit as originally stipulated in the (updated) permit.

Table 10: Current TPDES Permit Requirements for Selected Parameters, Kenedy Brackish Desalination Plant

Parameter	Sample Measure	Permit Requirement
Flow	Rate	625 gpm 0.9 mgd
TDS	Daily Average	46,154 lb/day 6,149 mg/L
	Daily Maximum	97,653 lb/day 13,010 mg/L
	Single Grab	13,010 mg/L
pH	Single Grab	>6.0 and <9.0

POTABLE WATER DELIVERY

The Kenedy facility delivers potable water to the City distribution infrastructure. Before the RO plant was constructed, the total delivery capacity of the plant and well field was about 1.5 mgd. After the completion of Trains A, B and C in 1996, the capacity of the plant was about 1.2 mgd, which included blending. After the system upgrades in 2005, the total potable water capacity of the plant was 2.8 mgd with blending.

4 TPDES Permit No. WQ0003913000, issued October 7, 2002 and expiring on March 1, 2010.

5 Escondido Creek leads to the lower San Antonio River (Segment No. 901 of the San Antonio River Basin).

Evaluation

Equipment

PRE-TREATMENT

Carbonate and sulfate salts will scale in the concentrate channel if they exceed their saturation limit. The original pretreatment system at Kenedy incorporated antiscalant addition in the feed stream to minimize or alleviate the potential for scale formation. The design basis was for addition of 4.3 mg/L antiscalant at a designed feedwater recovery of 75 percent for the membrane arrays.

Records are unavailable regarding the incidences of membrane cleaning and the cause for the cleanings. The operational strategy for the plant is to leave the facility on-line at all times to meet finished water demands This strategy precludes extended down times for cleaning purposes. Therefore, the plant operators send membrane elements off-site for cleaning purposes while rotating replacement/cleaned elements to maximize online time.

To gain a better understanding of the cause of the cleanings, the LSI (Langelier Saturation Index), which is a measure of the potential for scaling, was calculated. The result is that the LSI values at the RO plant are considered high without the addition of antiscalant or an acid to mitigate scaling potential. Most commercially available antiscalants are stipulated to be effective when the concentrate LSI is less than 1.5. At Kenedy, the concentrate LSI is 1.96. It is possible that, under the original facility design, antiscalant alone was determined to offer sufficient protection of the membrane elements. The operating history and outcome suggests otherwise. Table 11 contains the calculated LSI values of the feedwater and concentrate at 75 percent recovery.

Table 11: Calculated LSI values for Feedwater and Concentrate at 75 percent Recovery

	No Acid	Some Acid + Antiscalant	Only Acid
Recovery	75%	75%	75%
Raw Feed pH	7.5	7.5	7.5
Feed LSI	0.27	0.27	0.27
Antiscalant Dose (mg/L)	4.1	2	none
H2SO4 Acid Dose (mg/L)	none	39.7	216
Adjusted feed pH	7.5	7.0	6.0
Concentrate LSI	1.96	1.41	-0.01
Annual Cost at Full Membrane Capacity	Membrane scaling[a] (not acceptable)	$33,200 ($12,200 for acid + $21,000 for antiscalant)	$66,000

[a] Operating Conditions: 1,443 TDS and 75 degrees F.

Without the addition of an antiscalant, the LSI must be reduced to a negative value to control scaling. Similar control can be accomplished by the use of an antiscalant, but in the case of Kenedy, the cost of just using an antiscalant alone would likely be excessive (see Table 11).

The saturation limit for silica in the concentrate stream is 130 mg/L. Since the RO systems at Kenedy are operated at 75 percent recovery, silica concentration will increase to approximately four times the feedwater content in the concentrate. Special antiscalant products are required by chemical manufacturers to try and keep silica scale from forming in the concentrate stream. Silica is very difficult to remove from the membrane surface once deposited. Available silica data for the wells are contained in Table 12.

Table 12: Silica Content by Well

Major Constituent	Units	Well 8 12/15/2004	Well 10 09/03/1993	Well 10 12/15/2004	Well 10 12/13/1995	Well 11 12/15/2004	Well 11 07/25/1995
TDS	mg/L	1,372	1,594	1,156	1,114	1,264	1,286
Silica	mg/L	27.2	90.4	26.8	63.0	20.8	46.4
Fe	mg/L	0.03	0.034	0.03	0	0.03	0
pH	-	7.0	7.8	7.3	-	7.3	-

Well water quality data also reveal silica content of 26 to 90 mg/L, mostly contributed by Well 10 (average 46 mg/L in Table 5 by calculated mass balance). A review of the antiscalant use and consistent dose at Kenedy suggests that the operations protocols may not have addressed the silica content of the feedwater, or sensitivity to blend lower silica well water with higher silica content well water to within saturation limits in the concentrate. The City uses GE Betz Hypersperse MDC150 antiscalant. Although it appears that, at times, the feedwater silica in the concentrate could exceed saturation limits, this antiscalant is not specifically formulated for control of silica-related scaling. Silica can cause irreversible fouling and an increase in required feed pressure to produce the requisite quantity of water. Based on the operating data available, it cannot be determined if this has occurred at the Kenedy plant.

Pretreatment chemical manufacturers were contacted to assess the feasibility of operating at 75 percent recovery compared to non-acidified feedwater and in the presence of elevated silica.

REVERSE OSMOSIS

Recovery

The design feedwater recovery for all three reverse osmosis systems is 75 percent. This means there is an approximate four times increase in dissolved salt concentration from feed to concentrate stream. The facility has also operated at lower recoveries, but the extent and purpose are not documented. Operations personnel indicate they changed the percent recovery based on finished water demand, which seems atypical for this facility. This is because well water supply, at times, barely meets the demand, and operating at a lower recovery (unless required for design purposes) wastes more feedwater as rejected concentrate.

Train Performance

The performance of Trains A, B, and C were evaluated by comparing the actual collected data train operation against modeled performance based on membrane manufacturer's software at 75 percent feedwater recovery. Tables 13, 14 and 15 compare the operating parameters for Trains A, B and C, respectively, over time. Recovery did not change for the 2005 retrofit, or thereafter, by the City engineer's design basis.

The modeled performance is relative to an ideal scenario where the City's operations personnel replace elements of a like-kind. Complete documentation regarding these practices and to what extent elements from alternative manufacturers is employed is unavailable.

However, overall permeate water quality by TDS is comparable between the modeled runs and what is actually measured in the field. The two significant variances between modeled runs and actual data are feed pressure and recovery. The available feed pressure to the existing arrays is over 100 psig greater than needed to produce the requisite quantity of permeate from each array. Therefore, it is assumed that the RO high pressure pump is throttled to avoid producing too much permeate ("over-fluxing") the first stage of the arrays. The variation in pressure requirements is likely due to improvements in specific flux (lower pressure producing the same flow at similar permeate qualities).

The design recovery for all of the arrays is 75 percent. The operations personnel indicated the actual recovery is reduced because of well supply volume limitations. However, reducing RO recover actually increases feedwater quantity if the permeate flow qualities remain consistent, which they have. Therefore, any reduction in recovery could be due to the other process issues not immediately apparent in the data provided.

Blending Ratio

When RO Trains A and B were installed in 1995, facility operations had the capability of mixing any or all of the well water in a blend tank prior to diverting a portion of the stream to the RO system for treatment (Figure 5). The bypass stream is re-blended with the RO permeate prior to sodium hydroxide addition, chlorination and distribution. When Train C was installed in 1996, the capability to treat a greater ratio of raw feedwater containing elevated arsenic, chlorides, and/or TDS was extended to the system because membrane treatment capacity was added. The permeate water quality produced from the original elements versus the new ones was not significant in terms of TDS.

When the facility was expanded again in 2005 and retrofit with additional membrane surface area to increase capacity in Trains A and B, additional raw water was directed to the trains to maximize the ability of the trains to reduce TDS, chlorides, and arsenic. Train C was retrofit presumably for a more optimal hydraulic balance and its' rated capacity was decreased from 320 gpm to 315 gpm (permeate). Another possible reason for Train C de-rating and hydraulic balancing could be due to excessive fouling in the first stage of the array which had produced a disproportionate quantity of permeate at an elevated flux.

Table 13: Train A Performance, Historic and Modeled

Parameter	Unit	5/16/1995		10/1/2005	8/1/2007	2007 By Projection
Temperature	degrees F	85		83	84	83
RO Feed	gpm	120		256	230	227
RO Concentrate	gpm	30		76	75	57
RO Permeate	gpm	90		166	140	170
Recovery	percent	75		65	61	75
Permeate Conductance	µS/cm	47		52	141	139 TDS
Concentrate Conductance	µS/cm	3.86	RETROFIT	6.6	6.1	5,355 TDS
RO Feed Booster Suction	psi	49		45	66	-
RO Feed Booster Discharge	psi	315		250	295	152
RO Feed Pressure	psi	165		175	170	123
Interstage Pressure	psi	145		160	150	104
Concentrate Pressure	psi	140		150	140	88
Permeate Pressure	psi	35		32	25	25

Table 14: Train B Performance, Performance, Historic and Modeled

Parameter	Unit	5/16/1995		10/1/2005	8/1/2007	2007 By Projection
Temperature	degrees F	85		83	82	83
RO Feed	gpm	122		251	215	227
RO Concentrate	gpm	30		77	74	57
RO Permeate	gpm	92		167	134	170
Recovery	percent	75		67	62	75
Permeate Conductance	µS/cm	69		47	158	139 TDS
Concentrate Conductance	µS/cm	7.1	RETROFIT	6.7	6.1	5,355 TDS
RO Feed Booster Suction	psi	44		54	62	-
RO Feed Booster Discharge	psi	310		260	310	152
RO Feed Pressure	psi	170		175	155	123
Interstage Pressure	psi	155		165	150	104
Concentrate Pressure	psi	155		150	130	88
Permeate Pressure	psi	35		29	29	25

Table 15: Train C Performance, Performance, Historic and Modeled

Parameter	Unit	5/16/1995		10/1/2005	8/1/2007	2007 By Projection
Temperature	degrees F	-		83	84.2	83
RO Feed	gpm	-		347	327	420
RO Concentrate	gpm	-		104	101	105
RO Permeate	gpm	-		243	226	315
Recovery	percent	-		70%	69%	75%
Permeate Conductance	µS/cm	-		23	35	156 TDS
Concentrate Conductance	µS/cm	-	RETROFIT	6.6	6.6	5,572 TDS
RO Feed Booster Suction	psi	-		0	0	-
RO Feed Booster Discharge	psi	-		240	259	147
RO Feed Pressure	psi	-		135	142	118
Interstage Pressure	psi	-		120	120	101
Concentrate Pressure	psi	-		110	112	84
Permeate Pressure	psi	-		21	21	21

Facility records and discussions with operations personnel do not reveal an explanation or operational directives whereby source well water quality, actual wells on-line, and quantity pumped are inter-related to the RO treatment-to-bypass ratio. Through 2007 it appears that the ratio changes, at times, on a daily basis and appears these changes are not driven by the need to change out membranes for cleaning or for system maintenance purposes.

In light of this information gap, a mass balance was developed for both 1996 and 2007 using existing well water quality data and a membrane arsenic rejection level of 70 percent (Figures 9 and 10). Over the years, analytical labs reported arsenic values as total, but sometimes as speciated. Speciated values are more helpful because they assist in the basic approach to process design and possible removal capabilities through a typical thin film composite membrane (and to compare to what is actually happening on site). Since the level of detailed speciation is not available in the Kenedy data record, the total values were utilized and an average, aggregate rejection of 70 percent was assumed for purposes of demonstration the potential capabilities of the RO system at Kenedy. Further analytical work would benefit this assessment.

Assuming the membrane arrays are operating at full capacity for maximum reduction of well water arsenic from the high arsenic wells (Wells 8 and 10) and water from the low arsenic wells (Wells 11 and 13) was used to blend and make up the difference, the calculated finished water arsenic level would be <10 Fg/L[6]. Figure 9 shows what the overall TDS would have been in 1996, after the well water bypass stream was blended with the RO permeate. Figure 10 demonstrates the possible treatment system blended finished water TDS and arsenic based on the blend ratios modeled and the assumption of removal rates throughout the treatment system.

An alternative operating scenario was considered whereby permeate production is limited and raw water quantity (from low arsenic wells) for permeate blending and finished water purposes is maximized. However, because the only wells that have low arsenic for bypass/blending purposes are Wells 11 (300 gpm maximum) and 13 (50 gpm maximum) and the arsenic adsorber is operating at maximum capacity of 600 gpm, there isn't enough available raw well water to reduce the RO capacity, increase bypass flow, and meet daily finished water quantity goals.

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[6] It is critical to note that this information is empirical. No data on permeate arsenic concentration were available for comparison with actual values.

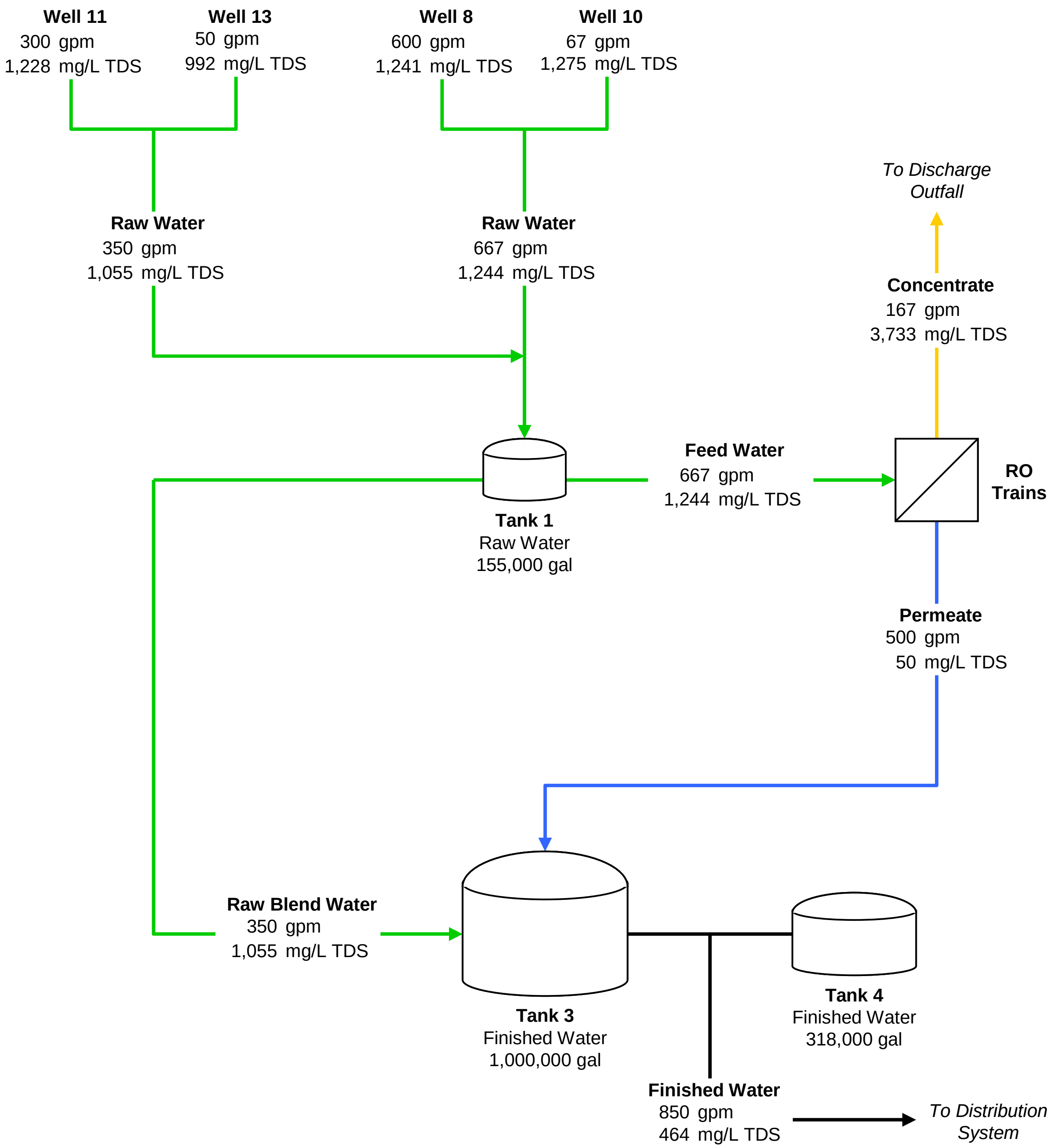

Figure 9: Representative Blending Ratio, 1996

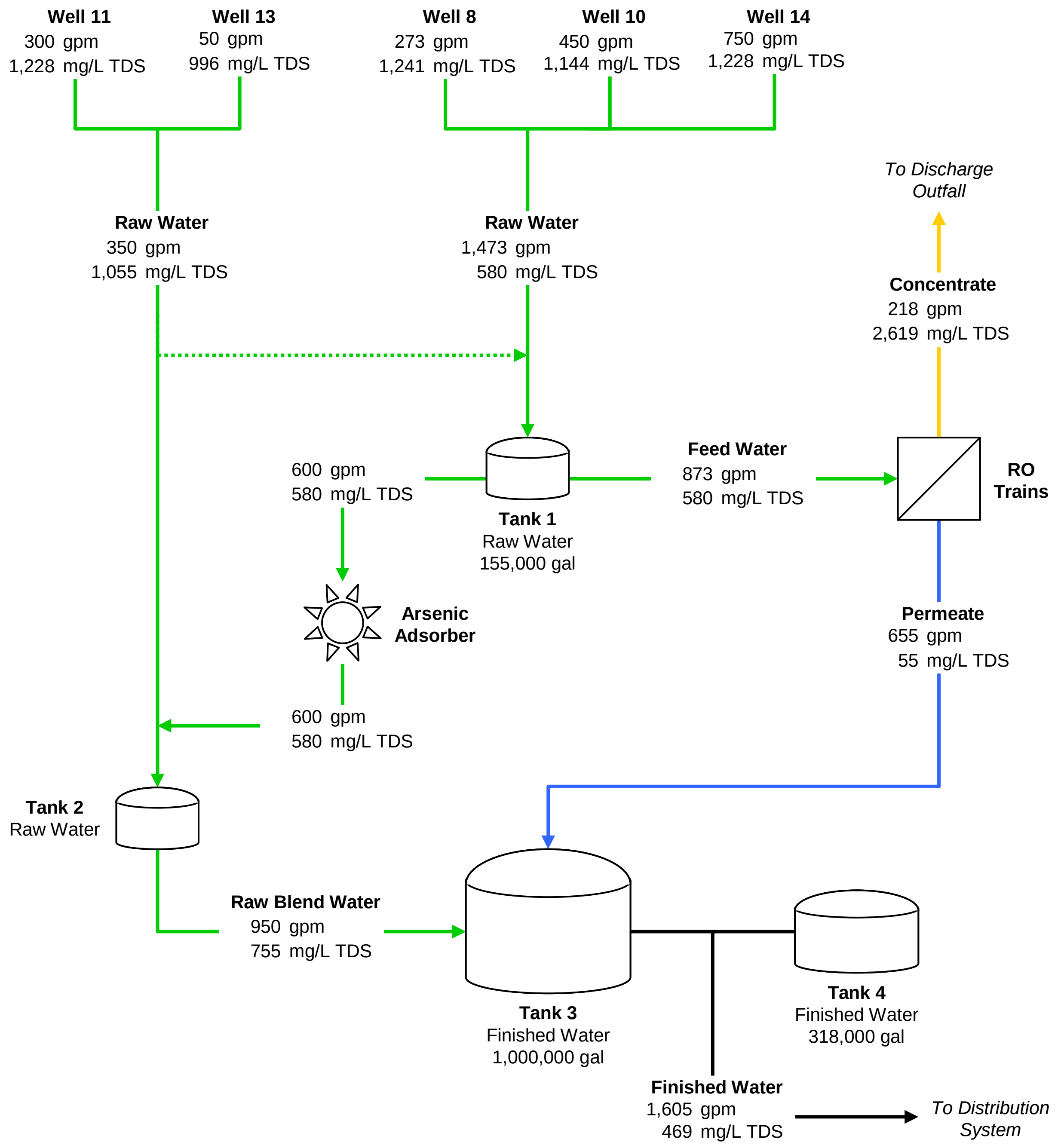

Figure 10: Representative Blending Ratio, 2007

Flux

Due to the change in membrane surface area accompanying the change in elements from Hydranautics CPA2 to Hydranautics ESPA1, the flux (permeate produced per equivalent area of membrane surface area) changed as well. Table 6 contains the average stage flux and overall average (Stage 1 + 2) flux rates for each train. Membrane manufacturers provide general flux rate guidance to engineers, based on a broad categorization of the type of source water to be treated. Well water is generally assumed to contain fewer quantities of suspended or dissolved material that could negatively impact the performance of the reverse osmosis membrane; therefore the manufacturer's suggest starting point for the design of a membrane array is based on higher flux rates compared to, say, a surface water with a comparatively greater silt or organic load. Typical design flux rates for a well water system as suggested by membrane manufacturers are compared to design flux rates at Kenedy in Table 16.

Table 16: Manufacturer's Suggested versus Actual Flux

Recommended Maximum Feedwater Parameters:		Brackish	Trains A + B	Train C
SDI @ 15 minutes	Maximum	4	*NR*	*NR*
Turbidity (NTU)	Typical	0.1	*NR*	*NR*
System Average Flux (gfd)	Conservative	10		
	Typical	12	12.8	12.6
	Aggressive	14		
Lead Element Flux (gfd)	Conservative	15		
	Typical	18	16.6	16.1
	Aggressive	24		

Note: NR = Not reported.

Feedwater Pump Pressure and Power Consumption

When the Hydranautics CPA2 elements were replaced with ESPA1 membrane elements, the feedwater pressure required to overcome the osmotic pressure of the concentrate was drastically reduced because permeability was much improved in the ESPA1 membrane. The original design incorporated a booster followed by high pressure pump to each array, of which the high pressure pumps' discharge had to be throttled to within acceptable feed pressure design limits for the lower-pressure ESPA1 membranes. This general arrangement is shown in Figure 11 and is the same for all RO trains.

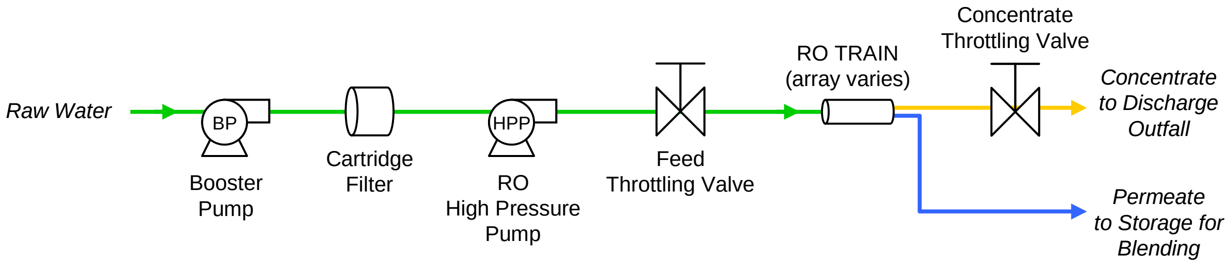

Figure 11: Existing RO Pump Configuration for Trains A, B, and C

Project documentation for the 1996 retrofit indicates the booster pumps for Trains A and B were not a part of the equipment manufacturer's package[7]. The choice of a booster pump and RO high pressure pump in series is usually applicable for situations where significant variability in pressure is necessary because of wide variations in feedwater temperature and/or TDS. It also allows the capability to use variable frequency drive motors on a smaller horsepower motor which could "trim" the pressure variations imposed by changes in feedwater. At Kenedy and other typical well water supplies, temperature and dissolved salt content do not vary significantly, making this configuration somewhat atypical.

A throttling valve was integrated into the design of each RO trains to account for the engineer's assessment of the requirement to eventually increase feed pressure to the membrane in order to produce the design quantity of permeate as membrane elements age or in case of feedwater temperature or TDS changes. A throttling valve essentially "blows off" unneeded feedwater pressure until a situation calls for where it might (if ever) be needed by the system.

The well water supplying the RO system is shown to be relatively constant in quality. In general, the pressure used is much greater than is needed to produce the required volume of permeate from the arrays, even after considering a 10 to 20 percent increase in feed pressure to account for element age and wear and tear. In some cases, this excess pressure has exceeded 100 psig.

Cleaning Frequency

The approach to cleaning at Kenedy is rooted in the need to maintain production volumes at all times. For several years, operations personnel have sent elements off for cleaning to a service facility in Houston. This practice is expensive and not commonly practiced at most municipal membrane treatment facilities. The Kenedy facility has a membrane clean in-place system, and early in the operation of the facility it was utilized. Data for the frequency of cleaning with the CIP system is unavailable, as are the performance conditions surrounding the decision to clean and the resulting effectiveness of the cleanings which took place.

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[7] Due to limited information, it is assumed in this preliminary assessment that the original equipment manufacturer decided to use a booster to artificially keep the pressure lower for the cartridge filter and piping to the RO pump.

Membrane elements utilized to replace the existing ones in-service are not always sourced from the same element manufacturer; which is atypical because membrane manufacturers are more likely to provide support service to systems containing all of their membranes; and pinpointing specific membrane performance deficiencies for warranty purposes and troubleshooting becomes more difficult otherwise. The Filmtec membrane nominal performance data indicate that the BW30-365 replacement membrane element is an equivalent performing alternative for TDS reduction and feed pressure; though surface area per equivalent 8-inch diameter element is less than the Hydranautics ESPA1 (see Table 8) raising the average flux per array and rate of fouling if that is a tendency of the Kenedy feedwater.

POST-TREATMENT

Post treatment consists of sodium hydroxide addition (for pH control, up) and gaseous chlorine. Sodium hydroxide has the effect of increasing pH in a low-pH permeate stream; however it is not an ideal choice to buffer permeate alone due to the relative absence of bicarbonate. Most likely, sodium hydroxide was chosen by the system supplier because permeate produced by the treatment arrays is blended with raw well water containing bicarbonate with buffering capacity.

The actual dose of sodium hydroxide maintained at the facility is unavailable, but can be estimated. Permeate pH is 6.8; blended with buffered well water containing alkalinity, a dose range of 5 to 10 to mg/L would result in a blended, finished water pH of 7.5.

Operation and Maintenance

Kenedy outsources the operation and maintenance of the membrane facility. Expenses specifically incurred and attributable to the membrane facility regarding power, maintenance, and consumables such as cartridge filter change out, membrane cleaning or replacement, is unavailable; general overall chemical consumption was provided and contained in Table 17.

Table 17: Reported Chemical Consumption, 2007

Chemicals	Feed Rate (ppm)	Flowstream (gpm)	Cost per Pound	Cost per Ton	Pounds per Year	Cost per Year	Cost per 1,000 gallons
Sodium Hypochlorite	*NR*	600	$ 0.18	$ 365	1,000	$ 183	$ 0.000
Gaseous Chlorine	*NR*	1,597	$ 0.18	$ 365	8,041	$ 1,467	$ 0.002
Scale Inhibitor, GE Hypersperse MDC 150	*NR*	873	$ 2.75	$ 5,500	1,452	$ 3,993	$ 0.005
Carbon Dioxide	*NR*	600	$ 0.09	$ 180	13,157	$ 1,184	$ 0.001
Sodium Hydroxide	*NR*	655	$ 0.18	$ 365	8,221	$ 1,500	$ 0.002
TOTAL[a]						$ 8,327	$ 0.010

Note: NR = Not reported.
[a] Does not include offsite cleaning services or membrane replacement costs.

However, chemical consumption and power costs for comparative purposes can be estimated and calculated based on known facility operating parameters. The results are contained in Tables 18 and 19 and based on the mass balance data of Figures 9 and 10. Note that the electrical power cost is $0.08680 per kWh[8].

Table 18: Calculated Chemical Consumption for Optimum Operation, 2007

Chemicals	Feed Rate (ppm)	Flowstream (gpm)	Cost per Pound	Cost per Ton	Pounds per Year	Cost per Year	Cost per 1,000 gallons
Sodium Hypochlorite	1	600	$ 0.18	$ 365	2,628	$ 480	$ 0.001
Gaseous Chlorine	4	1,597	$ 0.18	$ 365	27,979	$ 5,106	$ 0.006
Sulfuric Acid	40	873	$ 0.08	$ 170	152,950	$ 12,236	$ 0.015
Scale Inhibitor	2	873	$ 2.75	$ 5,500	16,442	$ 45,216	$ 0.054
Carbon Dioxide	20	600	$ 0.09	$ 180	52,560	$ 4,730	$ 0.006
Sodium Hydroxide	10	655	$ 0.18	$ 365	28,689	$ 5,236	$ 0.006
Detergent (4 per year)	0	-	$ 0.24	$ 480	1,000	$ 240	$ 0.000
Citric Acid (4 per year)	0	-	$ 0.13	$ 250	1,000	$ 125	$ 0.000
TOTAL[a]						**$ 49,948**	**$ 0.059**

[a] Does not include offsite cleaning services or membrane replacement costs.

Table 19: Calculated Power Consumption, 2007

		Flow Rate (gpm)	Feet TDH	Pressure (psig)	Pump Efficiency	Motor Efficiency	BHP	kW (factor)	Daily kW Use
	Well Pumps	950	57.8	25	75%	92%	18	13.775	330.594
Bypass Blend	Pump 1	-	50.8	22	75%	92%	0	-	-
	Pump 2	-	50.8	22	75%	92%	0	-	-
Train A	Pre-Booster Pump 1	226	104.0	45	72%	92%	8	6.144	147.462
	RO Feed Booster Pump 1	226	559.0	242	72%	92%	44	33.042	793.019
Train B	Pre-Booster Pump 2	226	104.0	45	72%	92%	8	6.144	147.462
	RO Feed Booster Pump 2	226	559.0	242	72%	92%	44	33.042	793.019
Train C	Pre-Booster Pump	420	104.0	45	72%	92%	15	11.419	274.045
	RO Feed Booster Pump	420	559.0	242	72%	92%	82	61.406	1,473.752
	High Service Pumps	1,605	277.2	120	82%	92%	137	102.170	2,452.080
	Miscellaneous (hp equivalent for CIP, building, etc.)	-	-	-	-	-	15	11.185	268.452
	Total								**6,679.885**

Based on the information above, the total energy usage for the entire facility is about 2.89 kWh per 1,000 gallons, which results in a total energy cost of $0.25 per 1,000 gallons. Per year, the total energy cost is approximately $211,632.

The City's annual budget incorporates costs related to the membrane facility operation. The budget does not segregate expenses into chemical consumption, other consumables, and power costs attributed to the membrane facility, or the

8 Commercial Electricity Service Agreement No. T04061655472900 between CPL Retail Energy, L.P. and the City of Kenedy.

portion of the operations contract is allocated to these costs. Unscheduled costs such as membrane replacement is allocated in the 2008 FY.

Conclusions and Recommendations

NRS Consulting Engineers was contracted to make an assessment of the Kenedy Reverse Osmosis Facility and ultimately prepare plans and specifications to facilitate improvements to the facility based on the recommendations found in the assessment. The assumption was made when the project was approached that there was a 10-year record of operational data to allow a comparison of new technology with that of the existing Kenedy plant and development of design parameters for upgrading the facility. Those parameters would then provide guidance to other reverse osmosis groundwater facilities in Texas seeking similar improvements in efficiency.

Upon completion of this preliminary assessment, it is concluded that the data required to satisfy the original objectives is unavailable. There have also been multiple changes within the RO system over the years, including membrane change out and operational conditions, which are not apparently consistent with the equipment manufacturer’s design or the process design basis. This limits the effectiveness of using reliable assumptions in lieu of unavailable data. This data and information is critical for the ultimate design of the upgraded facility, especially with regard to projecting potential cost savings from such upgrades. Therefore, the original scope of the preliminary assessment cannot be completed.

Outstanding Information Needs

There are three main areas of concern. These include 1) source water quality and quantity data by well; 2) power consumption data; and 3) pilot protocols. Each of these information requirements are explained below.

TASK 1.0: ESTABLISH SOURCE WATER QUANTITY AND QUALITY

There is not enough well data to determine the variation of constituents found in the source water. It is expected that the plant will treat whatever is presented to the system. Without adequate source water data, a system modification or recommendations for improvements would have to be over-designed to accommodate the unavailable information, leading to increased upgrade costs. It is also difficult to determine the well performance and reliability of the aquifer, which also should significantly influence the system design considerations.

It is recommended[9] that the following scope of work be accomplished to provide source water quantity and quality data prior to design of upgrades to the Kenedy Brackish Desalination Plant:

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[9] These recommendations recognize that very limited data are available on the construction and production potential (and resulting drawdown) from the existing wells.

1.1 Data Compilation

Prior to any well testing, a records search should be conducted to locate information on the well completion (i.e., casing depth, screened intervals, pump setting) and testing data from one or more of the following sources: TCEQ, TWDB, the City, and/or drilling contractors. Success in locating reliable well completion and aquifer testing data may greatly reduce the costs for this evaluation. Additionally, an experienced field hydrologist should visit each well site to evaluate the well head completion in preparation for well testing.

1.2 Well Testing

Assuming that a) well completion information is available, b) reliable aquifer testing data are not available, and c) the wells are equipped to obtain reliable drawdown and pumping rate data, a 24-hour test should be conducted on each of the five existing wells to determine the capability of the existing pumping equipment and the drawdown characteristics of the aquifer. At the end of each aquifer test, water level recovery measurements should also be made. Following water level recovery, a few short step tests should be made at various pumping rates to estimate the pressure versus flow characteristics of the existing pumping equipment and to evaluate changes to well efficiency at various pumping rates. If well completion data are not available or the wells are insufficiently equipped to obtain reliable drawdown data, then it will be necessary to perform the following subtasks to obtain that information:

1.2.1 Video Surveys

In order to properly evaluate the production potential from the existing wells, accurate well construction information is needed. This optional task would include removing the existing pumping equipment and conducting a downhole video of the wells to determine the casing setting and screened intervals of the wells. Additionally, the video surveys would provide information on the condition of the casing and screen so that future replacement needs can be estimated.

Another circumstance that will require this task to be performed is the absence of a suitable way to measure the drawdown in the wells. Typically, municipal wells are equipped with an airline and pressure gauge to measure water levels. With older wells, this equipment is often missing or not functional. When the pumping equipment is re-installed, it is recommend that the airline be replaced and, if possible, strap a small diameter pipe to the pump column so that water level measurements can be made with a downhole electronic water level measuring device, which will provide a substantially more reliable aquifer test and serve as a back-up to the airline.

1.3 Data Evaluation

Upon completion of the aquifer testing, the data should be evaluated and estimates made of the production potential of each well. Analytical modeling should be performed to estimate interference drawdown between wells and long-term drawdown. Although the interference drawdown cannot be predicted from existing users or potential future pumping, an estimate of the long-term production potential of the existing well field should be possible to provide a reasonable safety factor to account for unknown future pumping. Upon completion of the data evaluation, a report should be prepared that summarizes the findings and provides recommendations.

TASK 2.0: ESTABLISH POWER CONSUMPTION AND CAPACITY

Power consumption accounts for a major portion of operation costs of an RO plant. Part of the intended analysis of this facility is to determine the potential cost savings of upgrades, such as newer, lower pressure membranes. However, there is inadequate data to develop a sound basis to recommend specific components of the overall design.

It is recommended that the following scope of work be accomplished to provide power consumption data prior to design of upgrades to the Kenedy Brackish Desalination Plant:

2.1 Power Evaluation at Each Well Location

In coordination with the serving power provider, the available fault currents at each service location should be determined. Other specific requirements include a) examining over-current devices for interrupting rating, time-current coordination, and arc flash requirements; b) evaluating motor starters with respect to NEMA size rating as it applies to the associated motor horsepower rating for the existing and any future upgrade of Well Field; c) evaluating if existing distribution system needs to be up-graded to accommodate potential well motor change-out to larger size based on Well Field Evaluation, d) exploring adequacy of existing SCADA (telemetry) system; and e) exploring the possibility of using variable frequency drives to match required flows and to save power costs.

2.2 Power Evaluation at the Water Treatment Plant Location

The possibility of deleting the existing transfer pumps between the ground storage tank and the input to the cartridge filters and using variable frequency drives on the high pressure pumps to match required flows and to save power costs should be explored. This would also require the following: a) evaluating the potential change of the RO control system to automatically select and control the various well pump motors to pump directly into the suction of the high pressure pumps (via the cartridge filters); b) evaluating the implementation of an automatic valve system on the incoming raw water supply piping to accommodate the deletion of the transfer pumps; c) evaluating in more detail the existing instrumentation and SCADA systems, and d) evaluating the re-design and modification to the electrical power, control, SCADA, and instrumentation systems to comply with the latest edition of NFPA 70 (National Electrical Code) as a minimum.

TASK 3.0: PERFORM OPERATIONAL PROTOCOL PILOT

Without an overall facility operational protocol and proof testing of the new arsenic adsorption unit, it is difficult to identify components for upgrade. A rationale should be developed to ascertain the most economical split/bypass/arsenic treatment on the raw feedwater. This work can be better assessed with more accurate feedwater quality and well system data. A piloting program conducted at the existing facility would allow these issues to be addressed. Such a program should run for a minimum of three months.

It is recommended that the following scope of work be accomplished to provide pilot operational protocol data prior to design of upgrades to the Kenedy Brackish Desalination Plant:

3.1 Pretreatment

Additional well water data should be integrated into the analysis of current and projected design in the areas of sparingly soluble salts (Ba, Sr, Ca, Mg), silica, and arsenic; and temperature. Some particulate fouling may be occurring without the operator's apparent knowledge because some wells contain iron, which when oxidized can be a cause of particulate fouling. This would influence the pretreatment approach. Data collected by the operator is insufficient to ascertain normalized system production or salt passage because of the lack of startup data (to normalize-to) each time elements are cleaned or switched-out. Consideration should be given to adding a preoxidant in the feed stream.

Capability of the well pumps needs to be better understood, including pump and well capacity, pressures, flow capabilities, and pipe pressure class. Well water quality may change dynamically based on pumped capacity and this effect should be considered in the pilot protocol.

3.2 RO Treatment

Well quality data (Recommended Task 1) should be utilized to perform bench scale modeling for rejection, salt passage, recovery, and power calculations. The results of the modeling should be used to pilot the RO system using Train A. The elements should be cleaned and baseline of operations begun. New elements would be optional. The existing RO system would need to be tested with a supply from each well independently and then the blended feedwater. During this process, the normalized performance and permeate water quality would be measured, including As for reduction assessment.

3.3 Arsenic Adsorber

Current performance of the adsorber, including the existing capacity, remaining capacity, and removal rates, is not known. The recommended pilot should establish these values initially as-operating and then at various doses of preoxidant, on separate well water streams. Vanadium or iron in the raw well water may influence the removal capability of the adsorber, so the potential influence of these types of ions should be carefully evaluated. Feedwater quality should be sampled and incorporated into the routine analyses.

Remaining Tasks in Original Scope

TASK A: DETERMINE TREATMENT SYSTEM PERFORMANCE

The pre-treatment system, including the arsenic removal system, does not test for arsenic removal. Without this data, it cannot be known within any reasonable degree of accuracy what will be required with the plant upgrade or for improvements. The key constituents for system performance include arsenic and silica. Secondary to these considerations is iron, a potential source of particulate which can foul a reverse osmosis membrane, and other metals which could influence the performance of either the arsenic adsorber or the membranes. These data are key design consideration and directly influence plant efficiency, costs and upgrade recommendations.

This task is within the original scope of work for this preliminary assessment and would be completed once the other tasks recommended in this section have been accomplished.

TASK B: DEVELOP INTERNET-BASED PRESENTATION

All of the information and graphics developed for this preliminary assessment have been prepared so as to allow their inclusion in an interactive internet-based presentation of the project, as envisioned in the original scope of work. This presentation, in draft form for the preliminary assessment, was to serve as a tool for comparison showing the anticipated efficiencies that would be gained by utilizing improved RO technologies and the calculated return on investments. Given the general lack of available operational information, this internet-based presentation was not developed. This task is within the original scope of work for this preliminary assessment and would be completed once the other tasks recommended in this section have been accomplished.

Recommendations

1. Conclude the Preliminary Assessment phase of the project.

2. Move to the Design phase by including each outstanding work task as part of 'pre-design' work item. Cost estimates for each task would be developed upon request. The remaining tasks in the original preliminary assessment scope of work would be included in and completed as part of this pre-design item.