Texas Water Development Board
Report #0604830579

Final

Kenedy Brackish Desalination Plant Historical Data Review and Performance Evaluation

By:
Veolia Water

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Executive Summary

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. In the City of Kenedy, the total water demand, which is predominantly for municipal use, is projected to increase. 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.

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. The following overview of the desalination plant facilities addresses four major components. Task 1, the preliminary engineering assessment, included a detailed history of the operational changes and capital improvements made to the facility from its original construction in 1995 through 2007, which was completed by NRS Consulting Engineers (NRS, 2009). The recommendations from the preliminary assessment included the need for additional data collection and on-site pilot testing to develop operational protocols. These recommendations could not be effectively performed given that the Kenedy facility has been in constant operation to meet escalating water demands with limited well water supply. Instead, the managers decided to install an additional RO train with advanced design components. Tasks 2 and 3 included the facility improvements and bidding and construction of the installation of the fourth RO train in November 2011. The design considerations associated with the fourth RO train are defined in the request for quotation specification sent to the bidders and is attached in Appendix A for reference. This report summarizes the data collection and reporting activities. Task 4, aimed at reviewing trends in system performance and comparing key operating costs before and after recent system upgrades.

The primary goal of this study was to use operating data from the Kenedy facility to evaluate the impacts on overall performance and system operating costs due to improvements to the existing RO system. The intent was to provide information that would assist other similar communities in Texas make informed decisions regarding upgrades to older brackish groundwater desalination facilities. However, operation of the Kenedy facility has not followed typical protocols because the facility constantly has been challenged to meet growing water demands, as a result operational decisions have focused on meeting product water flow requirements. Over time, the constant drive to meet capacity with limited brackish well water supplies ultimately reduced treatment and subcomponent performance.

Despite the challenges, some of the trends may be site specific, but the following general conclusions can be drawn from the data evaluation:

- Replacement of aging membranes operating below startup baseline conditions with new membranes will improve overall system recovery and reduce feed pressure requirements.
    - Increased recovery results in higher permeate water rates and lower operating costs (chemical and electrical) per gallon of produced product water.
    - Reduction in feed pressure correlates to a direct savings in power consumption costs.
- Replacement of aging membranes with new higher yield membranes:
    - Improves permeate quality for a given raw water quality which, in turn, will increase the amount of product water that the plant is capable of producing. Improved permeate quality allows for the use of more bypass water while still maintaining product water quality.
    - Chemical and power costs per produced product water will also reduce as the percent of bypass water is increased.
- Replacement of aging membranes with new low energy membranes by definition directly reduces power costs.
- Use of an RO skid design that incorporates a VFD (variable frequency drive) on the high pressure feed pump also results in direct power cost savings as compared to older skid designs with constant speed pumps and throttling valves. The use of a VFD on Train D at the Kenedy facility reduced power consumption costs by roughly 15% over an eight month period.

The results of this study have been used to develop an internet-based educational tool for interactive use by the public. It allows for simple comparisons of performance and return on investment between older and newer RO membrane elements and skid design technologies. The site is sponsored by the San Antonio River Authority in their continued support as a resource to communities in the TWDB Region L Planning Area (www.sara-tx.org/public_services/water_planning/kenedy_brackish_water_reverse_osmosis_tool.php).

1 Introduction

The City of Kenedy, located in Karnes County, Texas, uses a brackish groundwater desalination plant to supply potable water to its residents as well as to the employees and inmates at the state maximum security prison, the John Connally Unit, located about two miles south of the city. The total population served by the facility is estimated at 6,750 people, with roughly a 50/50 split between city residents and prison staff and inmates. The desalination system was originally installed in 1995 and, since has undergone multiple modifications and expansions to meet the growing demand for water, with the latest facility expansion involving the addition of a fourth reverse osmosis (RO) train completed in November 2011. The design of the new RO train incorporates newer technology subcomponents and higher yield membranes. In December 2012, the membranes of the other three RO trains were also replaced with the same higher yield membranes.

In May 2006, the Texas Water Development Board funded a project entitled "City of Kenedy - Demonstration of Efficiencies Gained by Using Improved RO Technologies" with the objective to use the City of Kenedy water treatment system as a means to evaluate the benefits gained by upgrading older groundwater desalination systems. The project consisted of four main tasks:

Task 1 – Preliminary Engineering Assessment
Task 2 – Design Facility Improvements
Task 3 – Bidding and Construction
Task 4 – Data Collection and Reporting

Task 1, the preliminary engineering assessment, included a detailed history of the operational changes and capital improvements made to the facility from its original construction in 1995 through 2007, which was completed by NRS Consulting Engineers (NRS, 2009). The recommendations from the preliminary assessment included the need for additional data collection and on-site pilot testing to develop operational protocols. These recommendations could not be effectively performed given that the Kenedy facility has been in constant operation to meet escalating water demands with limited well water supply. Instead, the managers decided to install an additional RO train with advanced design components. Tasks 2 and 3 included the facility improvements and bidding and construction of the installation of the fourth RO train in November 2011. The design considerations associated with the fourth RO train are defined in the request for quotation specification sent to the bidders and is attached in Appendix A for reference. This report summarizes the data collection and reporting activities, Task 4, aimed at reviewing trends in system performance and comparing key operating costs before and after recent system upgrades.

2 Objective

The primary objective of this study was (1) to compile and review past and current operating data, (2) to provide insight into system operation and performance, and (3) to evaluate operating cost efficiencies gained through upgrading a RO system. The first three RO trains of similar design (Trains A, B, and C), were compared to the more recently installed fourth RO train (Train D). The study also compared the performance of Train A before and after membrane replacement, and the performance of the newer Train D before and after an on-site membrane cleaning. An internet-based educational tool was also developed to compare the system performance and return on investment between older and newer RO technologies. The tool can assist small communities contemplating to upgrade their brackish groundwater desalination system.

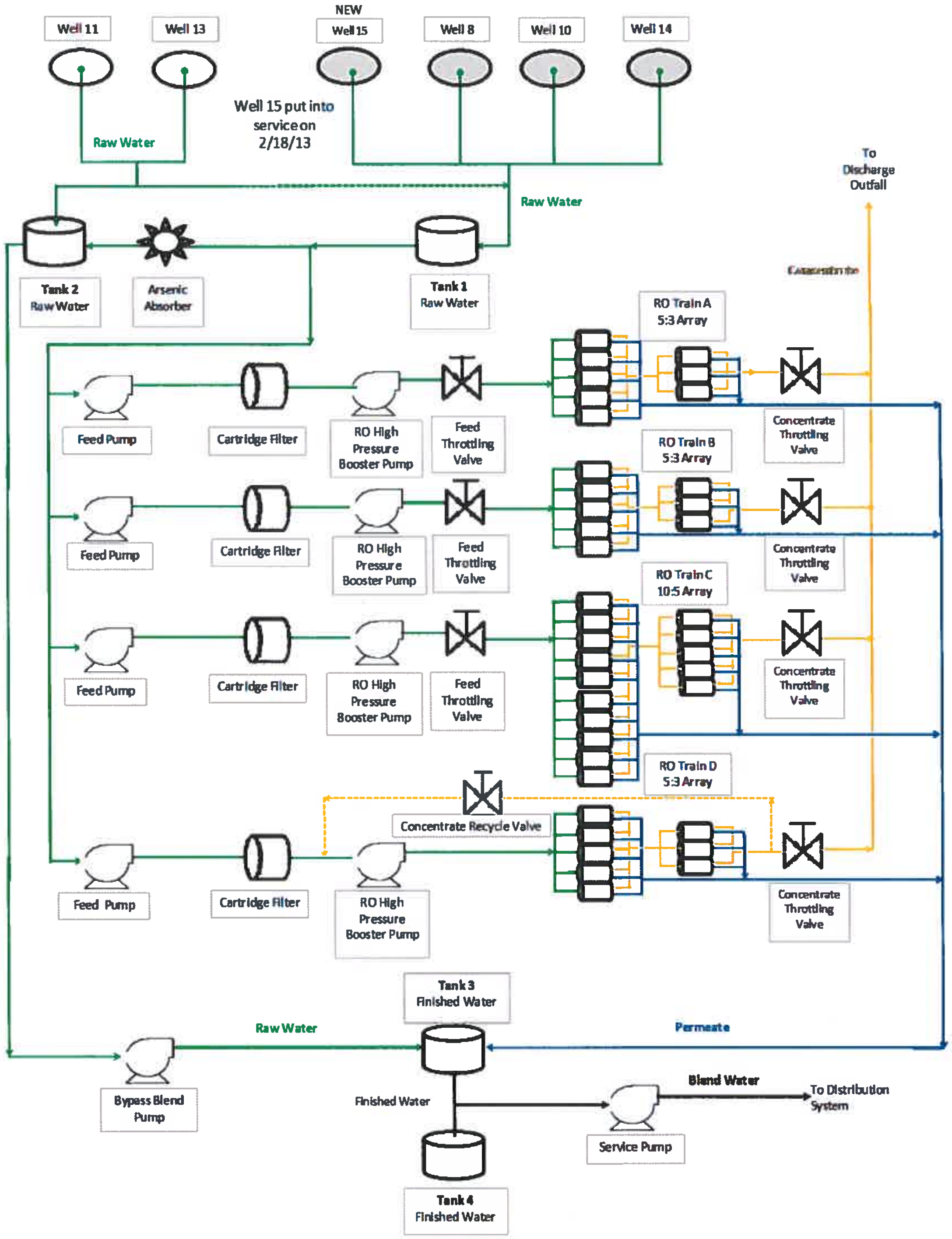
Metrics for the performance evaluation include recovery rate, permeate water quality, blending rate, flux rate, operating pressures and salt passage/rejection. Metrics for the operating cost evaluation include power consumption, chemical usage, and cartridge filter replacements.

3 Background

3.1 Facility Description

The City of Kenedy water treatment facility desalinates local brackish groundwater through an RO system to produce high quality permeate that is then blended with groundwater prior to distribution to the community. The groundwater used for blending is raw water that bypasses the RO treatment process. The RO concentrate is discharged to Escondido Creek in accordance with the requirements of the facility's TPDES permit (TDPES Permit No. WQ0003913000). A schematic of the treatment process is provided in Figure 3-1. The original plant capacity was 2.8 MGD and with the improvements is now 3.68 MGD.

Figure 3-1 Process Flow Diagram



Notes: Shaded wells represent those with elevated Arsenic levels.

During the length of the study, the raw water supply consisted of groundwater withdrawn from five wells (referred to as Wells 8, 10, 11, 13 and 14). The addition of a new sixth well (Well 15) began operation after the study was completed. Two of the wells (Wells 11 and 13) withdraw water from the Catahoula aquifer, and the other four wells (Wells 8, 10, and 14, and 15) withdraw water from the Oakville aquifer. The raw water has an average total dissolved solids (TDS) concentration of approximately 1750 mg/L and an average conductivity of roughly 2450 μS/cm.

Groundwater withdrawn for blending from the Oakville aquifer via Wells 8, 10, 14, and 15 can contain elevated levels of arsenic and is pre-treated through an arsenic adsorption system installed in 2007. Sodium hypochlorite is added prior to the arsenic adsorption system for iron and manganese oxidation, and carbon dioxide is used for pH adjustment at the arsenic adsorber. The dissolved arsenic is removed via adsorption onto granular ferric oxide adsorption media. Groundwater withdrawn from the Catahoula aquifer through Wells 11 and 13 do not require pre-treatment for arsenic removal.

The RO system consists of four RO trains in parallel, referred to as Trains A, B, C and D. Changes made to the configuration of each train since the system came online are summarized in Table 3-1. Installed in 1995, Trains A and B have a two-stage configuration with 3:2 pressure vessel array with six membrane elements in each pressure vessel. Train C has a two-stage configuration with 9:5 pressure vessel array with six membrane elements in each pressure vessel. All three trains were expanded in 2005 to include additional pressure vessels. Trains A and B were each expanded to a 5:3 array, and Train C was expanded to a 10:5 array. New RO membranes also were installed at that time of the expansion. The 2005 system upgrades were designed to operate all three trains at a 75% recovery with Trains A and B producing 170 gallons per minute (gpm) of permeate and Train C producing 315 gpm of permeate.

The preliminary engineering assessment report (NRS, 2009) indicates that the membranes installed in 2005 were Hydranautics ESPA1 membranes. However, the membranes removed from Trains A, B and C in December 2012 were DOW BW30-365 membranes. According to the facility operators, the membranes installed in 2005 were the BW30-365 membranes, because a membrane replacement had not taken place since the RO system commenced operation. In December 2012, the original membranes were removed from Trains A, B, and C and replaced with Hydranautics ESPA1 membranes. Train D, installed in November 2011, also contains ESPA1 membranes. The ESPA1 membrane element has an active area of 400 square feet, compared to the 365 square-feet active area of the BW30-365 membrane element. The membrane manufacturers' specifications indicate that the ESPA1 membrane has a slightly lower salt rejection of 99.3% than the BW30-365membrane of 99.5%, but a higher yield of permeate flow due to a larger membrane active area. Membrane projections from the Hydranautics RO design software indicate that a 5:3 array configuration (such as in Trains A, B and D) containing ESPA1 membranes operated at 75% recovery can produce an excess of 200 gpm of permeate flow. The software projection for Train C, indicates that with a 10:5 array configuration also operated at 75% recovery will generate 375 gpm of permeate flow. Copies of the membrane projections are included in Appendix B for reference.

Each RO train consists of a low pressure feed pump and cartridge filter, followed by a high pressure pump supplying water to a two-stage RO system. There are no interstage booster pumps. For Trains A, B, and C, the feed flow is adjusted via a manual throttling valve on the high pressure pump discharge. The high pressure pumps on the three older RO trains therefore run at constant speed. On Train D, the high pressure pump is equipped with a variable frequency drive (VFD) which automatically adjusts the pump motor speed to maintain a desired permeate flow. This is a more energy efficient design. The design of Train D also provides the option of recycling a portion of the concentrate to the front end of the train to improve recovery, but this feature is seldom utilized. Antiscalant is added to the RO feed water to minimize fouling potential. Two different antiscalant chemical products are used, one for Trains A, B, and C and another for Train D. The use of a different antiscalant for Train D is based on the recommendation of the equipment supplier. More details on the antiscalants used is found in Section 6.1 Chemicals – Antiscalant.

The permeate flows produced by each train are directed to a common Finished Water Tank where raw water is blended with the permeate to meet water demand. Gaseous chlorine is added to the final product water for disinfection and sodium hydroxide is added as needed for pH control prior to distribution. The concentrate flows generated from the RO trains are combined and discharged to Escondido Creek via a common four-inch diameter line. The discharge is monitored in accordance with the requirements of the facility's TPDES permit.

Table 3-1. Summary of RO Configuration from 1995 to present.

System Modification		Train A	Train B	Train C	Train D
1995 Original Installation					
	Array Configuration	3:2	3:2		
	Elements per Vessel	6	6		
	Manufacturer:	Hydranautics	Hydranautics		
	Type:	CPA2	CPA2		
	Membrane Area:	365 sf	365 sf		
	Year Installed:	1995	1995		
1996 Expansion					
	Array Configuration	3:2	3:2	9:5	
	Elements per Vessel	6	6	6	
	Manufacturer:	Hydranautics	Hydranautics	Hydranautics	
	Type:	ESPA1	ESPA1	ESPA1	
	Membrane Area:	400 sf	400 sf	400 sf	
	Year Installed:	1996	1996	1996	
2005 Expansion and Membrane Replacement					
	Array Configuration	5:3	5:3	10:5	
	Elements per Vessel	6	6	6	
	Manufacturer:	Dow	Dow	Dow	
	Type:	BW30-365	BW30-365	BW30-365	
	Membrane Area:	365 sf	365 sf	365 sf	
	Year Installed:	2005	2005	2005	
	Design Recovery	75%	75%	75%	
	Design Permeate Flow	170 gpm	170 gpm	315 gpm	
2011 Expansion					
	Array Configuration	5:3	5:3	10:5	5:3
	Elements per Vessel	6	6	6	6
	Manufacturer:	Dow	Dow	Dow	Hydranautics
	Type:	BW30-365	BW30-365	BW30-365	ESPA1
	Membrane Area:	365 sf	365 sf	365 sf	400 sf
	Year Installed:	2005	2005	2005	2011
	Design Recovery	75%	75%	75%	75% minimum
	Design Permeate Flow	170 gpm	170 gpm	315 gpm	215 gpm
2012 Membrane Replacement					
	Array Configuration	5:3	5:3	10:5	5:3
	Elements per Vessel	6	6	6	6
	Manufacturer:	Hydranautics	Hydranautics	Hydranautics	Hydranautics
	Type:	ESPA1	ESPA1	ESPA1	ESPA1
	Membrane Area:	400 sf	400 sf	400 sf	400 sf
	Year Installed	Dec 2012	Dec 2012	Dec 2012	2011
	Design Recovery	75%	75%	75%	75% minimum
	Design Permeate Flow	200 gpm	200 gpm	375 gpm	215 gpm

3.2 System Challenges

The Kenedy brackish water desalination facility has been faced with several challenges, the most significant of which has been the need to meet increasingly higher water demands with a limited well water supply. A growing demand for water in the service area is due to multiple factors including the influx of new businesses to the area, the construction of a new hotel and a new trailer park, and other development. Currently only three of the four trains are operated at any given time, which includes Train A, B, and D (Train C was taken off-line when Train D began consistent operation in February 2012). A train is offline due to the lack of well water supply. In addition, operating four trains produces a RO concentrate flow greater than the capacity of the existing discharge pipeline. The facility is taking steps to address the raw water supply issue. A new production well (Well 15) has been installed and placed into service in February 2013. The facility is operated based on product water demand. In this case, the water quality targets of the product water meet the TCEQ regulations and the discharge permit limits the quality and quantity of the discharge. Further discussion on these challenges is found in Section 5.6 Blending Ratios.

The increasing demand for water also has resulted in limited opportunities to remove trains from service to clean the RO membranes. In the past, routine membrane cleaning was performed off-site by a third party with minimal system downtime. However, that service was not available after 2005 due to budget reductions and, in order to meet the water demand, it was necessary to keep all three RO trains in continuous operation, essentially eliminating the opportunity for on-site membrane cleaning. More recently, after Train D was added, maintenance issues associated with the facility's Clean-In-Place (CIP) system surfaced, such as inoperable valves and flow meters, which limited the CIP's availability for use. The valves and flow meters were replaced and a CIP was performed on Train D in December 2012. According to the facility operator, a CIP of the membranes had not been conducted for Trains A, B, and C from the time they were installed in 2005 until the membranes were replaced in December 2012.

4 Evaluation Methods

The operating data used for this evaluation was obtained from the facility's electronic data management system which utilizes HACH's Water Information Management Solution (WIMS) software. The facility operator takes routine readings from existing meters, gauges, and analyzers and then enters the data into the WIMS system and records in the facility log books. Operating data was retrieved from the WIMS system from January 2005 through January 2013. Data available in the WIMS system prior to January 2009 was difficult to obtain and very limited.

Daily operating data retrieved from the system was reviewed and any obvious outliers in the data were eliminated. Gaps in the data due to field instruments and meters malfunctioning or out of service also were identified. The remaining data was then used to calculate monthly average values which were tabulated and graphed to illustrate historical trends and allow for an evaluation of system performance.

The operating parameters that were compiled for each RO train and used in the performance evaluation are summarized in Table 4-1. The compiled monthly average data are provided in Appendix C. Actual flow data was used instead of normalized data because the amount of normalized data available in the WIMS system was limited. The impact should not be significant given the consistent nature of the feed water salinity and temperature.

Table 4-1. Operating Parameters Used for Performance Evaluation

Item	Operating Parameter	Units	Calculated or Measured Value
1	Permeate conductivity	µS/cm	Measured
2	Permeate flow rate	gpm	Measured
3	Concentrate flow rate	gpm	Measured
4	Feed flow rate	gpm	Calculated in WIMS
5	% Recovery	%	Calculated in WIMS
6	% Salt passage	%	Calculated in WIMS
7	% Salt rejection	%	Calculated in WIMS
8	Feed pressure	psig	Measured
9	Concentrate pressure	psig	Measured
10	Differential pressure	psig	Measured
11	Flux rate	gpd/sf	Calculated outside of WIMS
12	Total Potable Water to Distribution	gpm	Measured
13	% Blend water ratio (% of raw water that bypasses RO system and is blended with permeate)	%	Calculated outside of WIMS

In addition to compiling and evaluating performance data, average monthly operating costs were estimated based on available operating data and current unit costs. The average monthly operating costs are expressed in terms of dollars per thousand gallons of potable water sent to distribution, which includes the RO permeate plus the bypass flow. Due to the lack of available data in WIMS prior to 2009, operating cost data was compiled from January 2009 through January 2013. Operating costs that were evaluated included the "variable" costs listed in Table 4-2. These costs are directly related to the operation of the RO system. Antiscalant usage was the only chemical evaluated because the usage rates of the other chemicals typically are independent of the RO system operation. Fixed operating costs, i.e., costs not directly related to the RO system operation such as labor and administration also were not included in the evaluation. Estimates of the average monthly operating costs for each item listed in Table 4-2 are provided in Appendix D.

Table 4-2. Operating Cost Parameters

Item	Operating Cost Parameter	Unit Cost	Notes
1A	Antiscalant usage – Trains A, B & C	$1.80/lb	Consumption rates for the antiscalant used for Trains A, B, and C available in WIMS.
1B	Antiscalant usage – Train D	$2.53/lb	Usage rate for Train D antiscalant not available in WIMS. Assumed 2 gpd as average usage rate for Train D based on operator feedback.
2	Cartridge filter replacement	$15/filter	Cartridge filter replacement data available in WIMS. Compiled on an annual basis.
3	High Pressure RO Feed Pump Power Consumption	$0.085/kwh	Power consumption estimated based on feed flow and feed pressure

5 Performance Data Evaluation

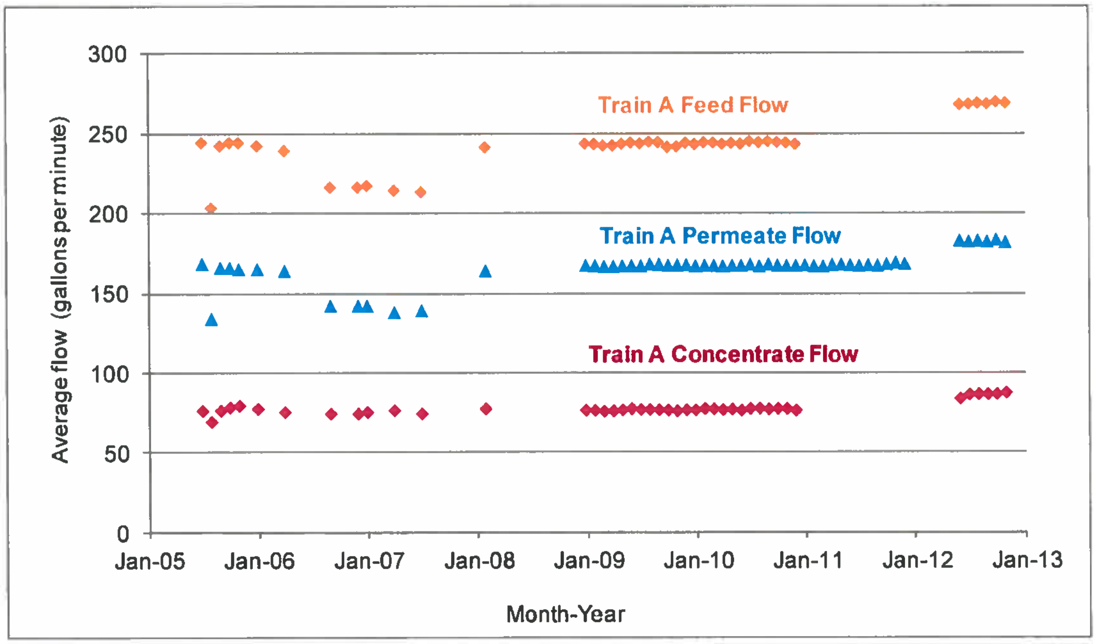
The performance evaluation was based on the historical trends for the various operating parameters identified in Table 4-2. Differences in the performances of the various trains are identified, with a focus on comparing the performance of the older RO trains (Trains A, B and C) prior to membrane replacement to the newer RO train (Train D). In addition, the impact on membrane performance due to the December 2012 membrane replacement of Train A, B and C and the on-site cleaning of Train D are assessed by comparing daily operating data for Train A versus Train D for the first six weeks following membrane cleaning/replacement. Insufficient post-membrane replacement operating data was available for Trains B and C.

5.1 Flow and Recovery

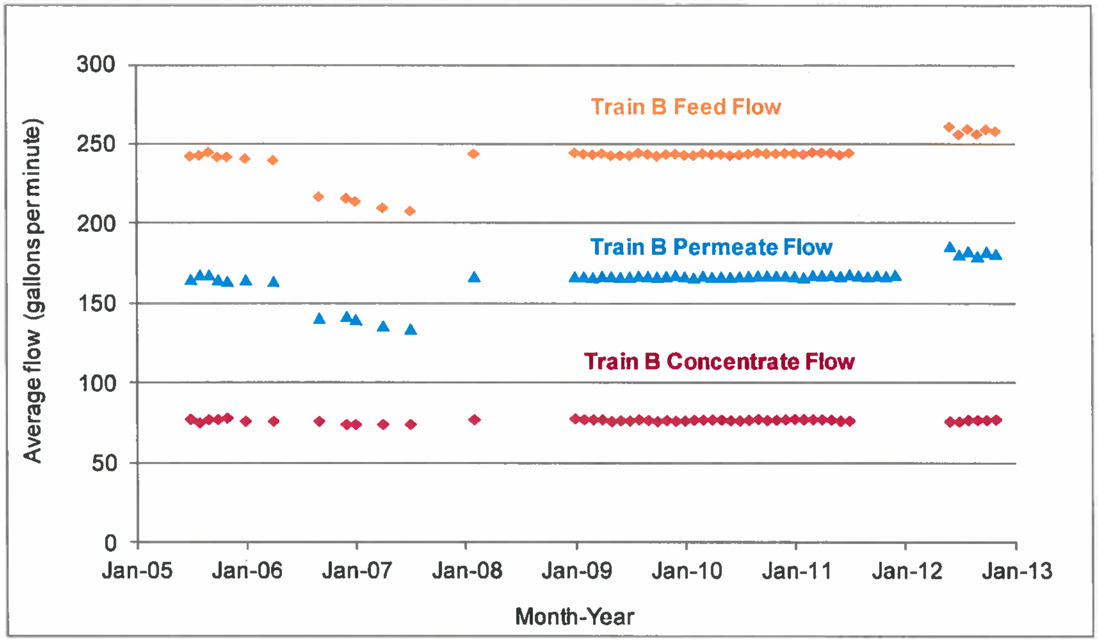
5.1.1 Older Trains vs Newer Train

The measured permeate and concentrate flows and the calculated feed flow for each of the four RO trains are illustrated in Figure 5-1(a)-(d).

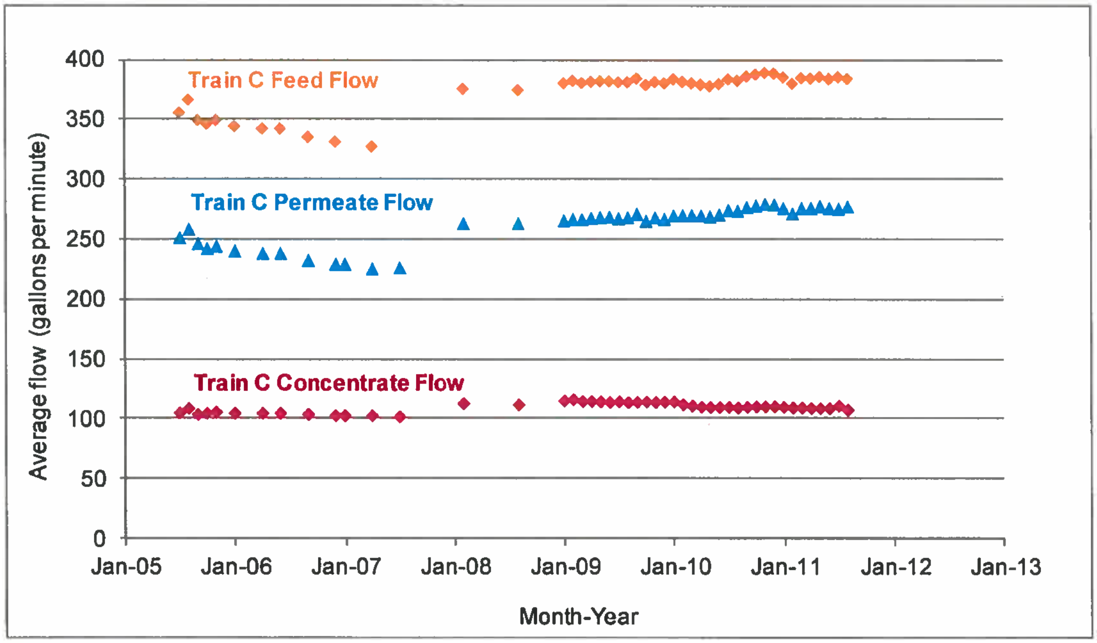
Figure 5-1 Flow Rates for Trains A, B, C, and D.



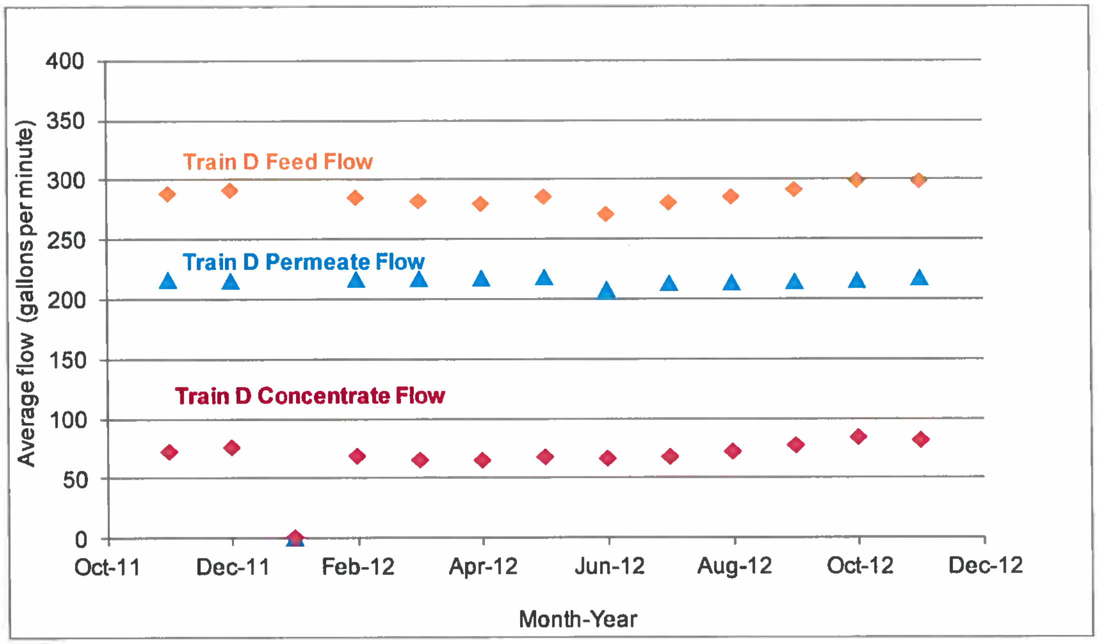
(a) Train A



(b) Train B



(c) Train C



(d) Train D

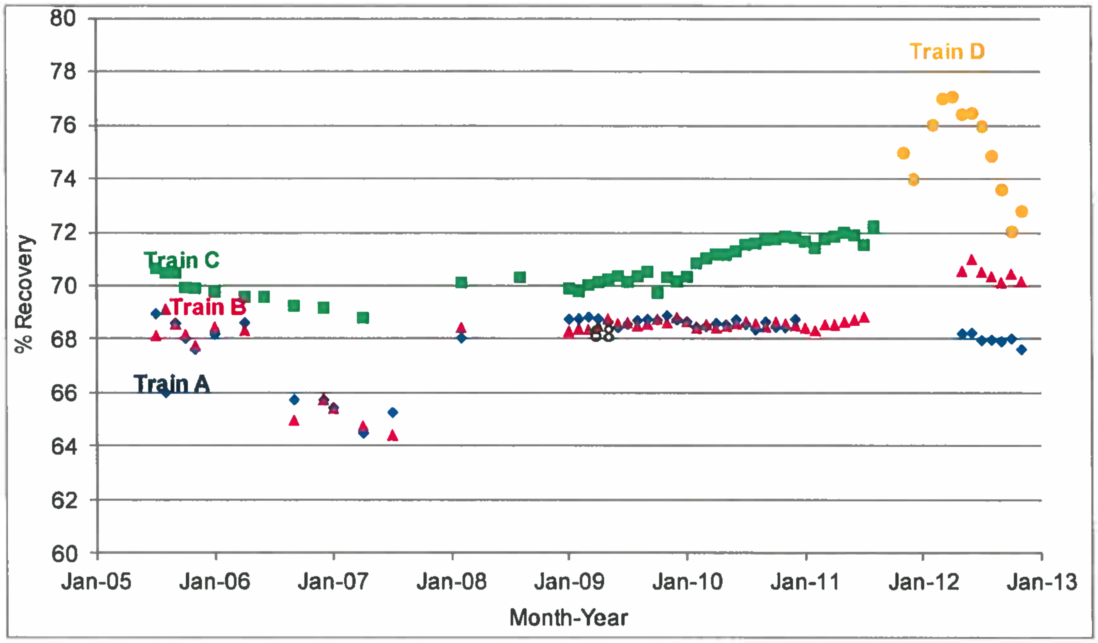
The feed, permeate, and concentrate flows of Trains A, B, and C (i.e., older trains) followed similar trends. For all three trains, the concentrate flow generally held steady over the entire time period examined. The amount of permeate flow produced by each train also remained fairly consistent since 2008, with the exceptions of a slight step increase in permeate production from Trains A and B in 2012 and a gradual increase of permeate flow in the Train C. The slight step increase of flows observed in Train A and B beginning in May 2012 is because the original turbine-type flow meters were removed and new magnetic flow meters were installed. The new magnetic flow meters, which tend to be more accurate than turbine meters, read higher flows. Train C experienced a gradual increase in permeate flows starting in June 2010. The reasons for the increase is unclear but suggest that the permeate flow meter was not functioning correctly.

Both Trains A and B produced close to their reported design permeate capacity of 170 gpm (NRS, 2009). Train C, which was taken out of service in February 2012 when Train D came online, never operated at its reported design capacity of 315 gpm permeate (NRS, 2009) due to the limited well water supply. From January 2008 until it was taken out of service, Train C produced an average permeate flow of approximately 262 gpm.

Similar to the performance of Trains A, B and C, the data for Train D indicates that during the first year of operation the train produced a fairly consistent permeate flow rate with an average close to its design capacity of 215 gpm (ITT, 2011). However, Figure 1(d) shows an upward trend in the feed flow and concentrate flow beginning in June 2012, roughly seven months after start-up of the train. The upward trend in concentrate flow is indicative of a reduced recovery due to membrane fouling. The cause of membrane fouling has not been defined, but may be related to antiscalant feed pump malfunctions that caused frequent interruptions in the dosing of antiscalant to the feed water of Train D during that time period.

The historical flow trends are best understood when expressed in terms of recovery, which is the percentage of the feed flow that passes through the membrane as permeate. The system recoveries for Trains A, B, C and D are shown in Figure 5-2.

Figure 5-2 System Recovery Achieved for Train A, B, C, and D.

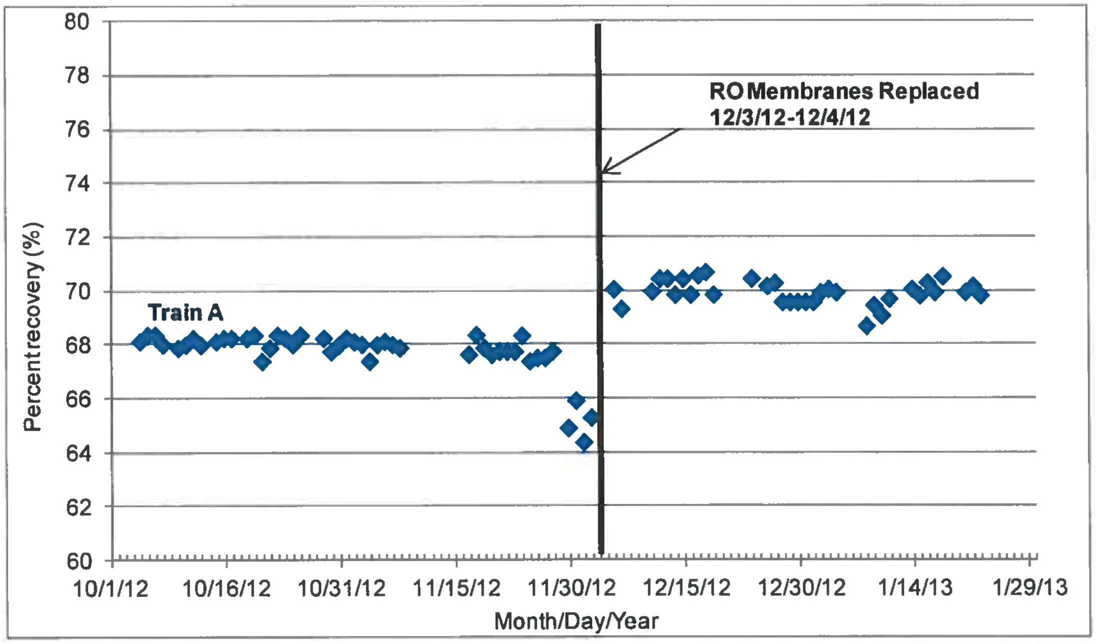


Over the time frame examined, Trains A and B operated at an average recovery of approximately 68% and Train C operated at an average recovery of 71%. The three trains failed to achieve their original design recovery of 75%. Train C produced a higher recovery rate from January 2010 through January 2011. This trend may have been a result of multiple factors including operation, aging membranes, or even changes in the feed water quality. The average recovery for Train D from the time it came online in November 2011 through June 2012 was 76% and then the recovery declined to 71% by October 2012 due to membrane fouling. Before the membranes began to foul, the recovery of Train D was higher than the three older trains and within the 75 to 85% recovery listed in the specifications provided by the equipment supplier (ITT, 2011).

5.1.2 Impact of Membrane Replacement/Cleaning

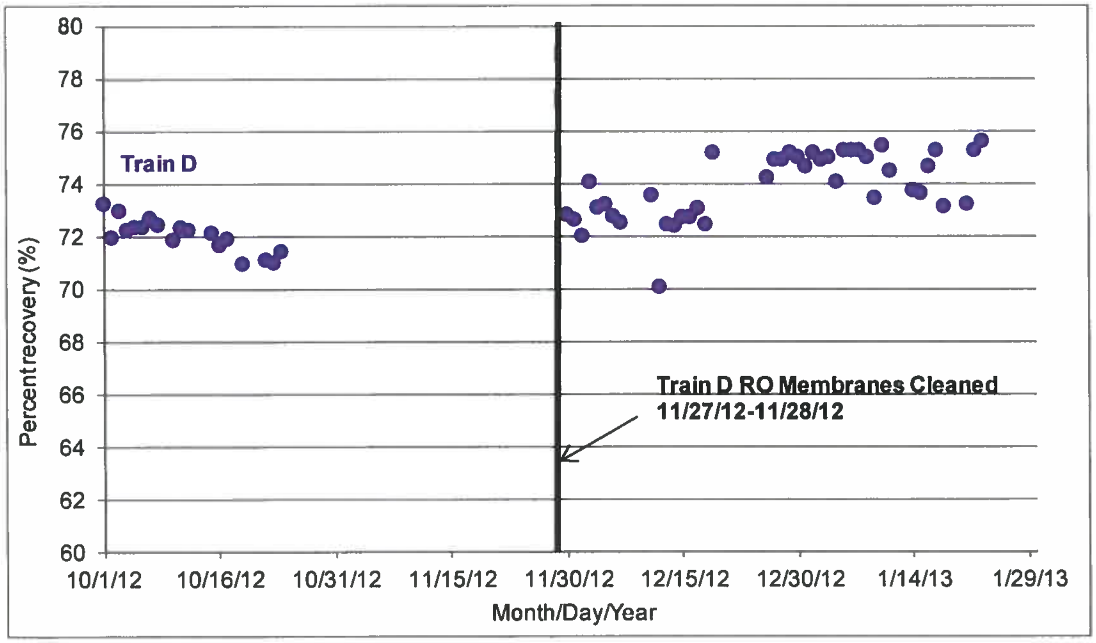
The impact of membrane replacement on the recovery achieved by Train A is illustrated in Figure 5-3. During the first six weeks following membrane replacement, Train A operated at a slightly higher recovery of approximately 70% as compared to 68% prior to membrane replacement. Based on theoretical software projections for the new ESPA1 membranes (Appendix B), it appears that Train A is being operated conservatively and that it should be capable of operating closer to a 75% recovery.

Figure 5-3 Impact of Membrane Replacement on Train A Recovery



The impact of membrane cleaning on the Train D recovery is shown in Figure 5-4. Cleaning of the membrane for Train D improved the percent recovery from a low of 71% just prior to cleaning to an average of approximately 75% once the system stabilized after cleaning. While the post-cleaning recovery did not return to the maximum of 76% recovery achieved when the membranes were new, it is within the original design range.

Figure 5-4 Impact of Membrane Cleaning on Train D Recovery



5.2 Flux Rates

Flux rate is a measure of the permeate flow produced per unit area of membrane surface. Since the total membrane area for a given system is fixed based on the membrane type and number of membranes installed, the flux rate varies directly with the permeate flow. At the Kenedy facility, the permeate produced for each train, with the exception of Train C, tended to remain fairly consistent over time. Changes in flux rate thus were related to physical changes to the system. The average flux rates for each train, before and after membrane replacement and cleaning, are summarized in Table 5-1.

Table 5-1. Average Flux Rates for Trains A, B, C, and D

Condition	Membrane Element Area (sf)	Train A Avg Flux (gfd)	Train B Avg Flux (gfd)	Train C Avg Flux (gfd)	Train D Avg Flux (gfd)
Prior to Membrane Replacement					
Old Flow Meters (1/09-5/12)	365	13.8	13.8	11.9	---
New Flow Meters (6/12-11/12)	365	15.0	15.0	No data	---
After Membrane Replacement	400	13.2	No data	No data	16.1
After Membrane CIP	400	---	---	---	16.1
Design Flux Rate	400	15.0	15.0	15.0	15.0

During the period of January 2009 through May 2012, when the system was operating with 365-square foot membranes and the permeate flows were measured by the original turbine type flow meters, both Trains A and B had an average flux of 13.8 gfd while Train C operated at a lower average flux of 11.9 gfd. The lower flux rate for Train C is because Train C was operated below its design feed flow capacity due to the limited raw water supply and the restricted amount of concentrate flow that can pass through the effluent discharge line. Operating at a low flux rate is not ideal because it increases the potential for membrane fouling. The average flux rate calculated for Trains A and B exhibited a step increase to 15 gfd in June 2012 due to the replacement of the turbine flow meters with new, more accurate meters which measured an average permeate flow of 183 gpm as compared to an average permeate flow of 168 gpm measured with the older meters.

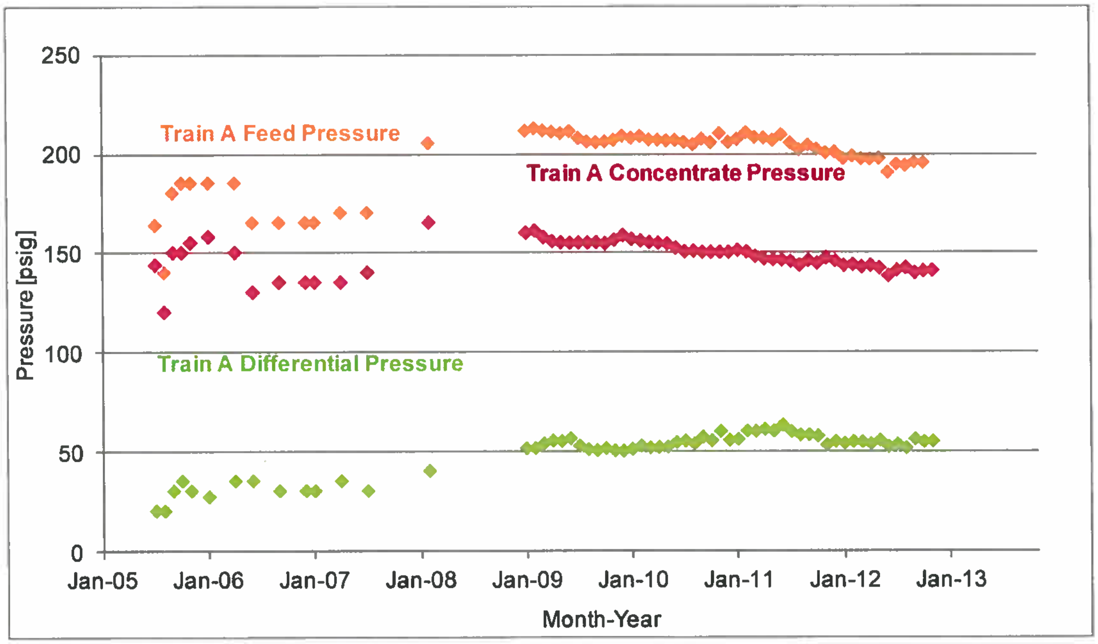
After the 365-square feet membranes were replaced with 400-square feet membranes in December 2012, Train A operated for the first six weeks with an average permeate production rate of 175 gpm corresponding to an average flux rate of 13.2 gfd. The flux rate is below the design flux of 15 gfd per the software projections included in Appendix B, further indication that Train A is not being pushed to its full potential. Train D, containing the same array configuration as Train A, has consistently operated above the design flux rate, with an average flux rate of 16.1 gfd both before and after membrane cleaning.

5.3 System Pressures

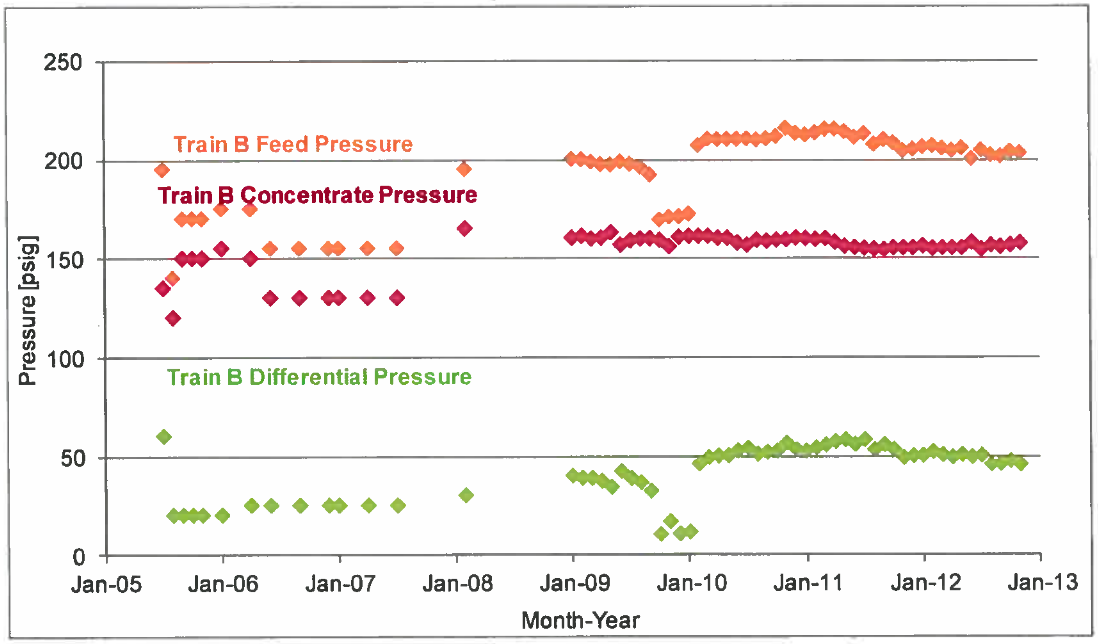
5.3.1 Prior to Membrane Replacement/Cleaning

System pressures, including feed pressure, final concentrate pressure and differential pressure, measured for each train prior to membrane replacement are illustrated in Figure 5-5 (a)-(d). Differential pressure is the calculated difference between the feed pressure and the final concentrate pressure. The feed and concentrate pressures for Trains A, B and C increased from July 2005 to January 2009 and then stabilized for the remaining timeframe. Train D pressures were steady for the first six or seven months of operation and then exhibited a significant increase, which is attributed to fouling of the membranes.

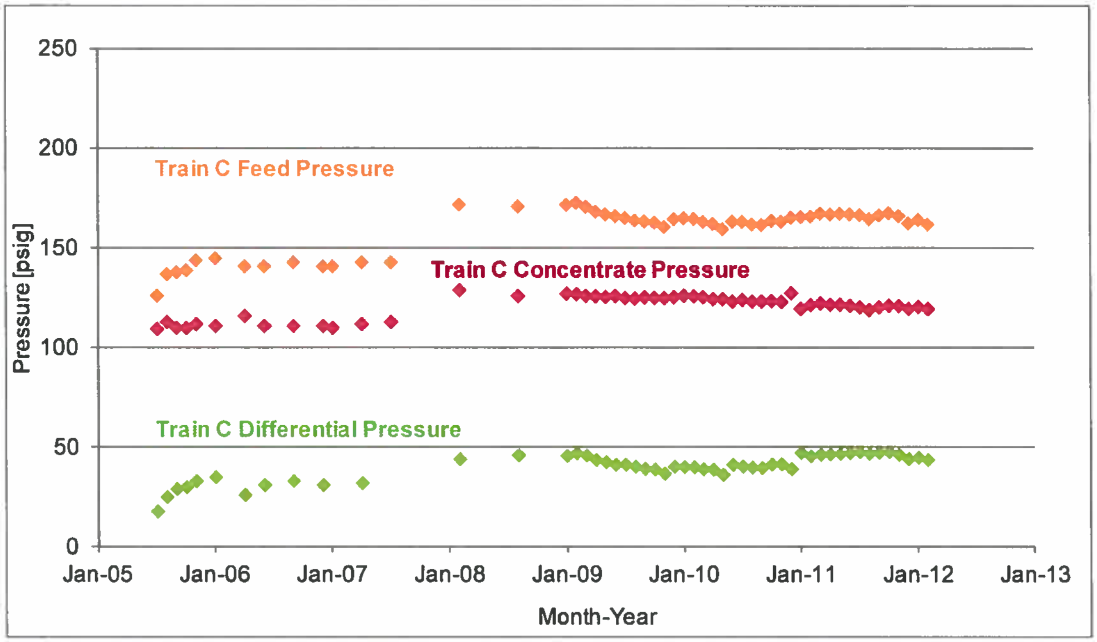
Figure 5-5 System Pressures for Train A, B, C, and D



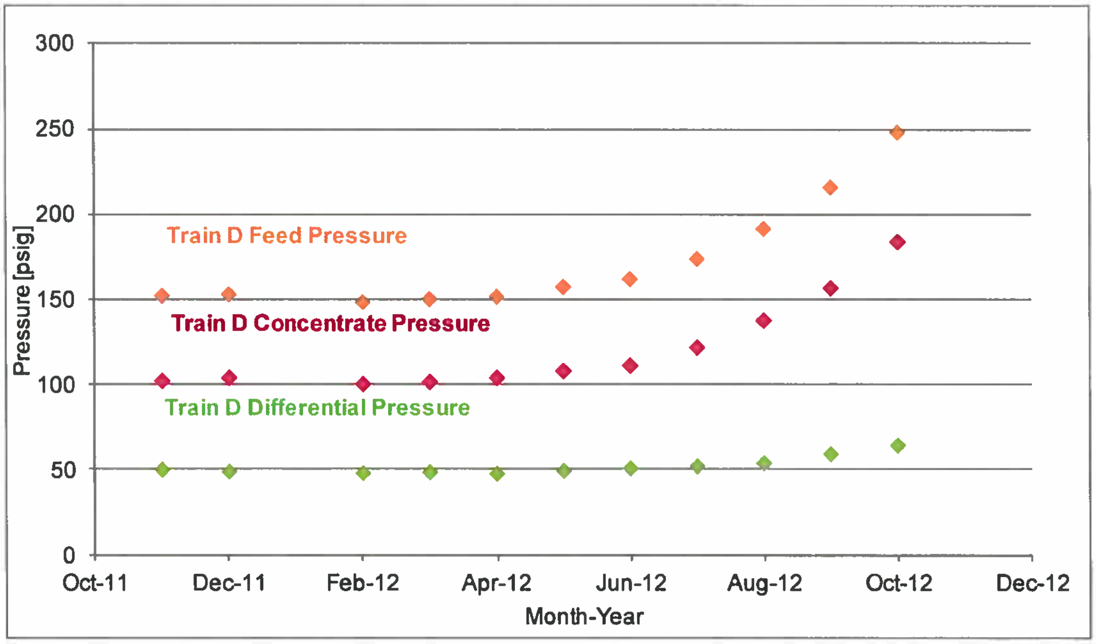
(a) Train A



(b) Train B



(c) Train C

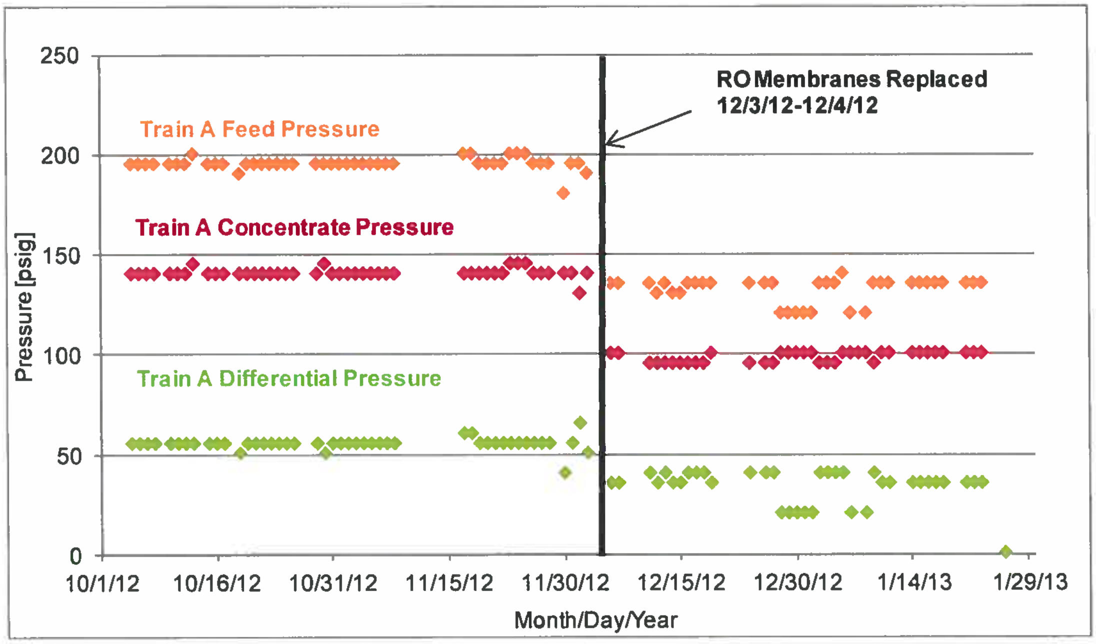


(d) Train D

5.3.2 Following Membrane Replacement/Cleaning

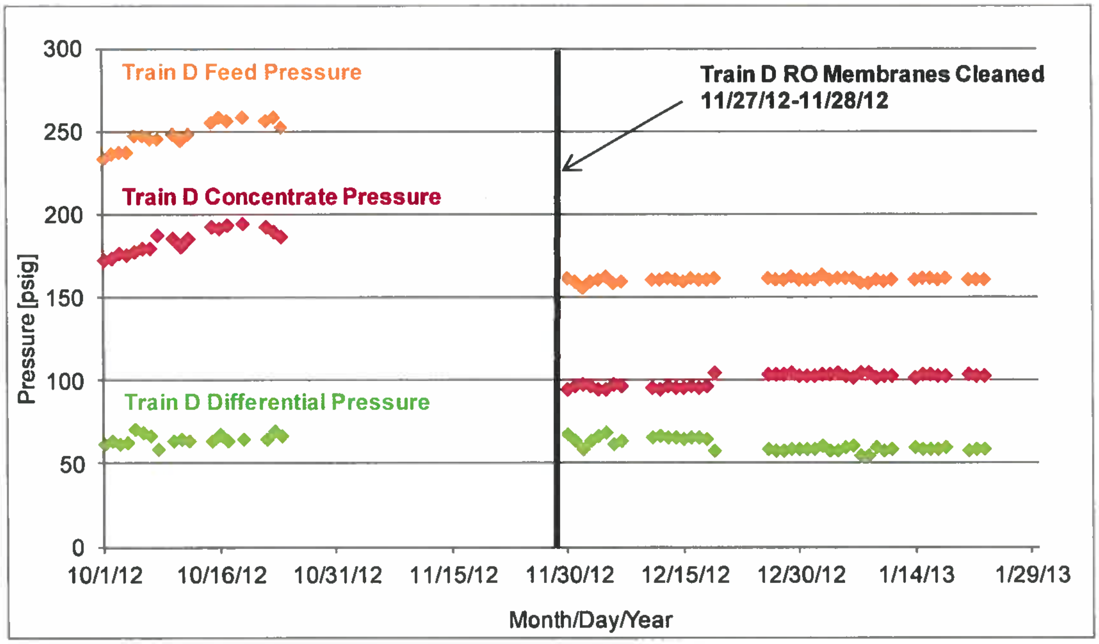
Replacement of the seven-year old BW30-365 membranes in Train A, which had never been cleaned, with new ESPA1 membranes resulted in a significant decrease in operating pressures as shown in Figure 5-6. The average feed pressure decreased from approximately 195 psi just prior to the membrane change out to roughly 130 psi during the first seven weeks of operation with the new membranes, a 33% reduction. The concentrate pressure and differential pressure across the membrane decreased accordingly.

Figure 5-6 Impact of Membrane Replacement on Train A Operating Pressures



Similarly for Train D, cleaning of the membranes also resulted in a notable decrease in operating pressures as shown in Figure 5-7. The feed pressure of Train D, which reached a maximum of greater than 250 psi due to membrane fouling, was reduced to an average of approximately 160 psi following on-site cleaning, a 36% reduction. The post-cleaning feed pressure is close to the original feed pressures measured when the membranes were first installed in November 2011, indicating that the cleaning process was effective in removing the majority of the fouling from the surface of the membranes.

Figure 5-7 Impact of Membrane Cleaning on Train D Operating Pressures



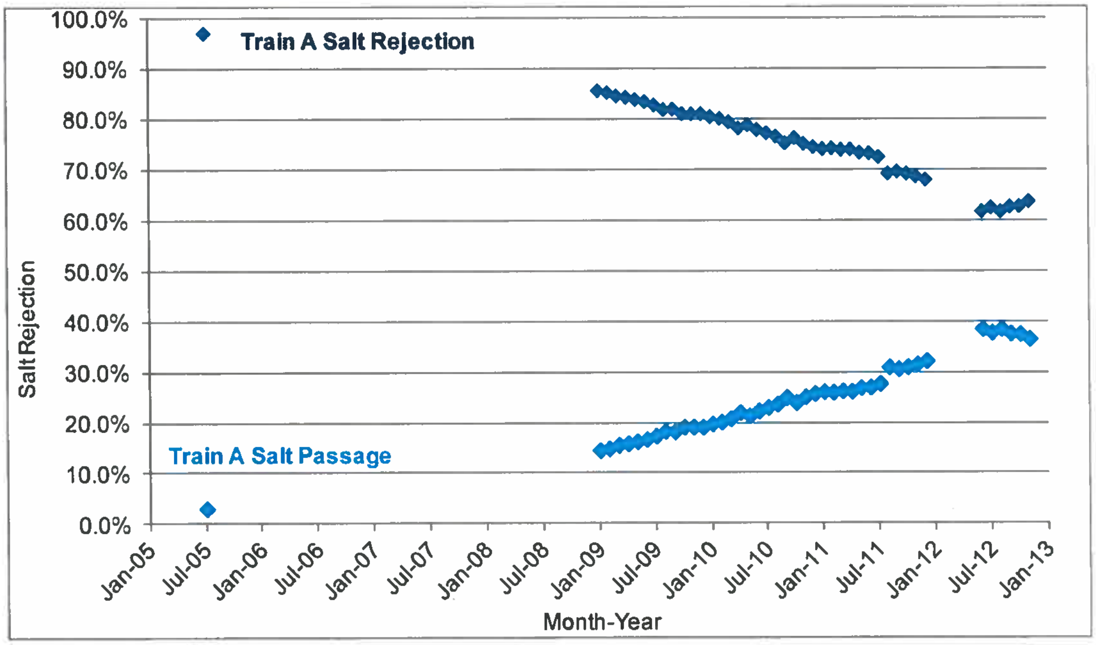
5.4 Membrane Performance – Salt Rejection and Passage

One means of evaluating the performance of RO membranes is to examine the percentage of the salt contained in the feed water that is rejected by the membranes and the corresponding percentage of salt that passes through the membranes. Most brackish water RO membranes are designed to achieve high salt rejection when they are new. As the membrane ages, the salt rejection capability decreases and the salt passage increases. The degree of increase in salt passage depends on the particular application and conditions under which the membranes are operated. Feed water temperature also affects salt passage, where higher temperatures result in higher salt passage. The calculation to determine the percentage of salt rejection and salt passage includes temperature correction factors.

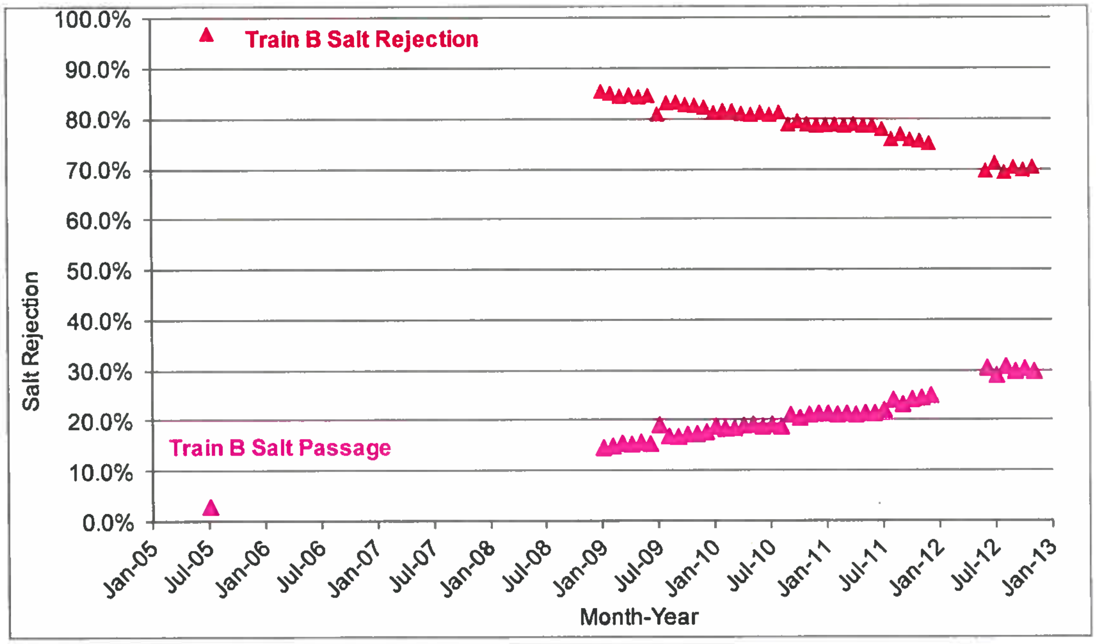
5.4.1 Prior to Membrane Replacement/Cleaning

Trends in salt rejection and salt passage for the four RO trains from January 2009 through November 2012 are illustrated in Figure 5-8(a)-(d). For Trains A, B, and C, the data shows a steady decrease in salt rejection and a corresponding steady increase in salt passage over time. In the initial stages of operation (July 2005), all three trains exhibited low salt passage in the range of 1 to 3%. Then, the salt passage increased at an average rate of 4 to 6% per year, which is a typical industry rate. The maximum salt passage for all three trains, which occurred just before the membrane replacement, was in the range of 30 to 37%. The data presented in Figure 5-8(d) for Train D represents the performance of a new membrane with a fairly consistent salt rejection average of 95% and a corresponding 5% salt passage.

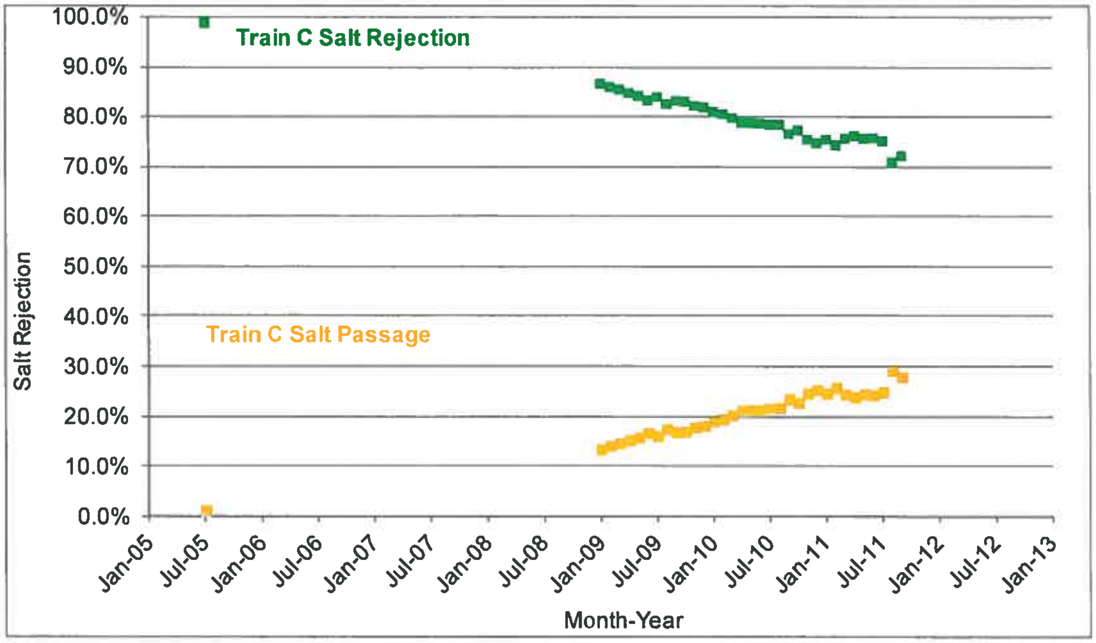
Figure 5-8 Salt Passage and Rejection for Train A, B, C, and D



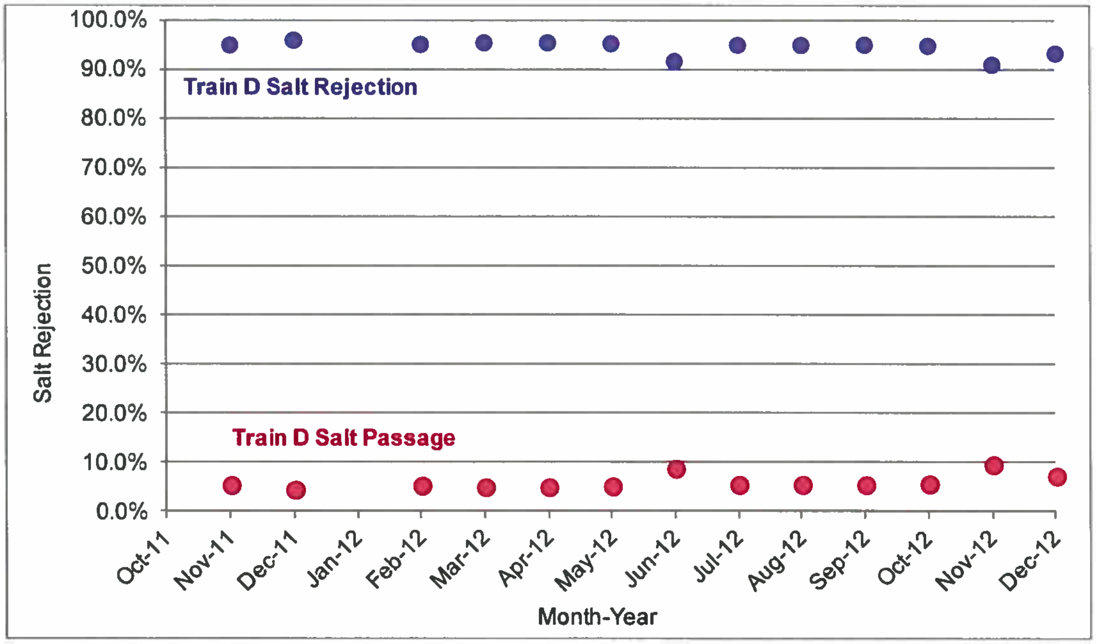
(a) Train A



(b) Train B



(c) Train C

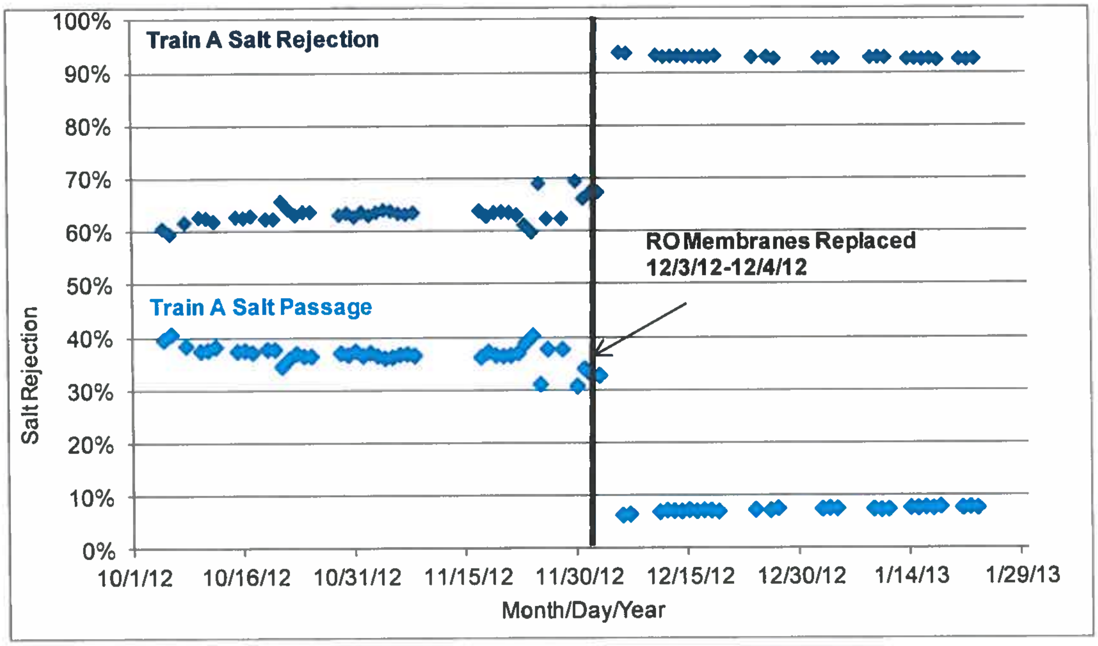


(d) Train D

5.4.2 Following Membrane Replacement/Cleaning

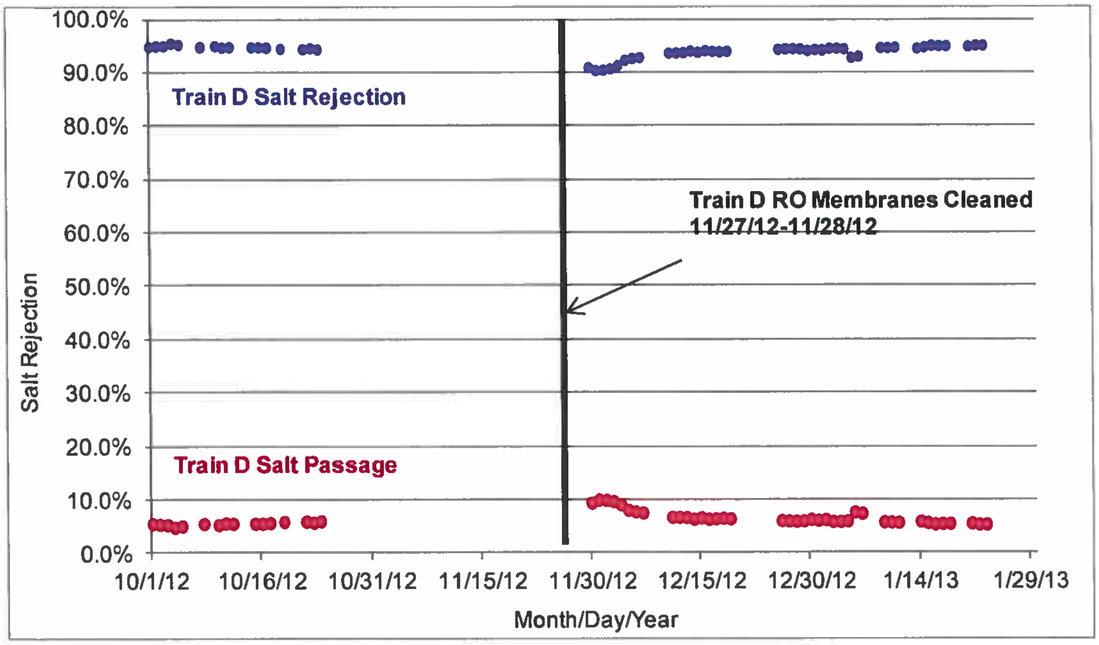
Membrane replacement significantly improved the salt rejection achieved by Train A. Figure 5-9 shows that the average salt rejection increased from roughly 63% with old membranes to 93% with the new membranes and the salt passage decreased correspondingly from an average of 37% to approximately 7%.

Figure 5-9 Impact of Membrane Replacement on Train A Salt Passage/Rejection



Conversely, membrane cleaning did not significantly affect the salt rejection achieved by Train D. Figure 5-10 shows that, once the system stabilized following the cleaning operation, the salt passage/rejection returned to approximately the same level achieved prior to cleaning, averaging approximately 96% salt rejection and 6% salt passage.

Figure 5-10 Impact of Membrane Cleaning on Train D Salt Passage/Rejection



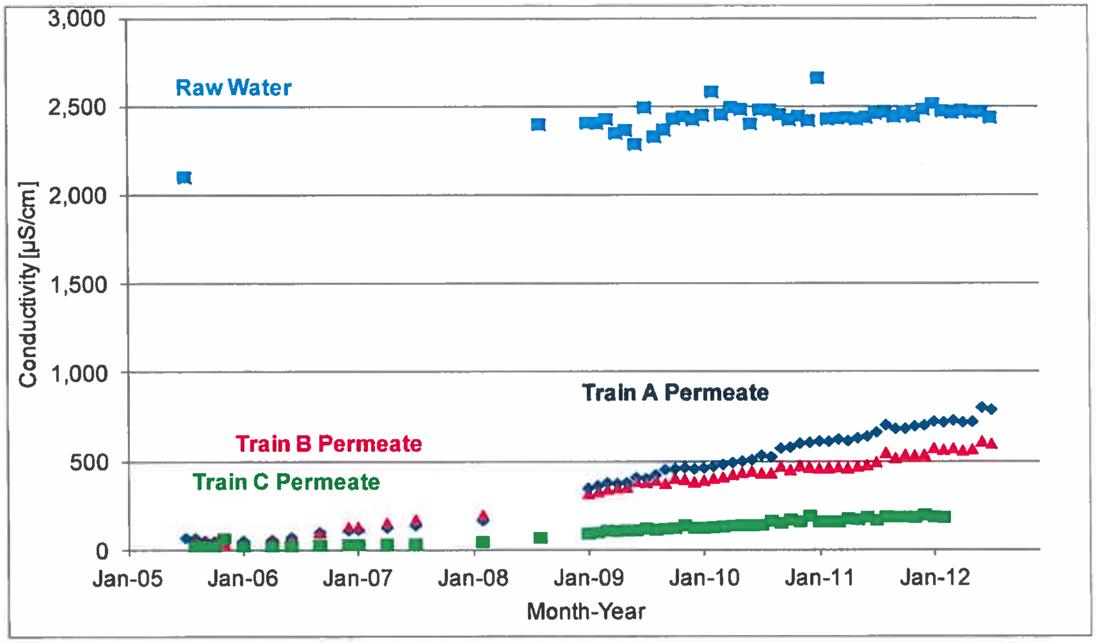
5.5 Permeate Quality – Conductivity

Another means of evaluating the performance of an RO system is to examine the permeate quality that it produces over time. The membranes are designed to reject the majority of the dissolved solids present in the feed water and to produce a permeate water with low TDS and conductivity.

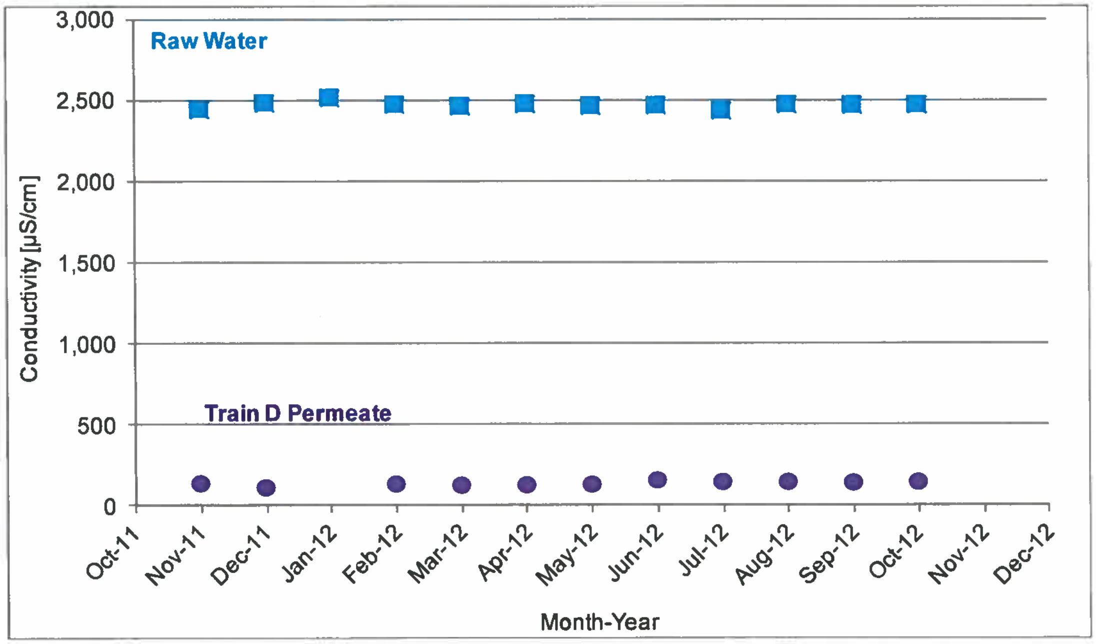
5.5.1 Prior to Membrane Replacement/Cleaning

The conductivity of the groundwater fed to the Kenedy water treatment system averages approximately 2,450 µS/cm. The feed water conductivity has remained fairly consistent over time as shown in Figure 5-11. Trends in the quality of the permeate produced by each of the RO trains, as measured by conductivity, are also illustrated in Figure 5-11.

Figure 5-11 Raw Water and Permeate Conductivity of Train A, B, C, and D



(a) Trains A, B and C



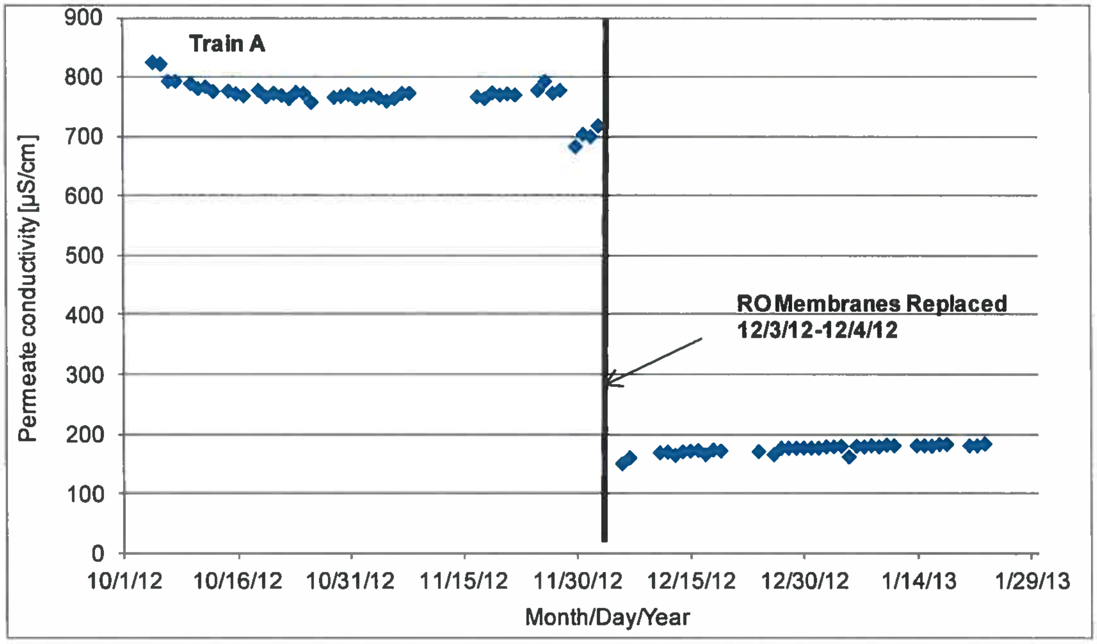
(b) Train D

As shown in Figure 5-11(a), the permeate conductivity for Trains A and B exhibited a steady and significant increase from mid-2006 through November 2012. The increase for Train A was the most significant, from a low of approximately 50 µS/cm to a high of 800 µS/cm. Train B followed a less steep rise, with a maximum permeate conductivity of roughly 600 µS/cm measured just prior to membrane replacement. Train C exhibited an even more gradual increase in permeate conductivity reaching a high of approximately 200µS/cm before the train was taken out of service. The increase in permeate conductivities exhibited in Figure 5-11(a) are indicative of aging membranes in the older RO trains. In the case of Train D which contains newer membranes, the conductivity of the permeate remained consistently within the range of approximately 100 to 150µS/cm during the first year of operation, as illustrated in Figure 5-11(b).

5.5.2 Following Membrane Replacement/Cleaning

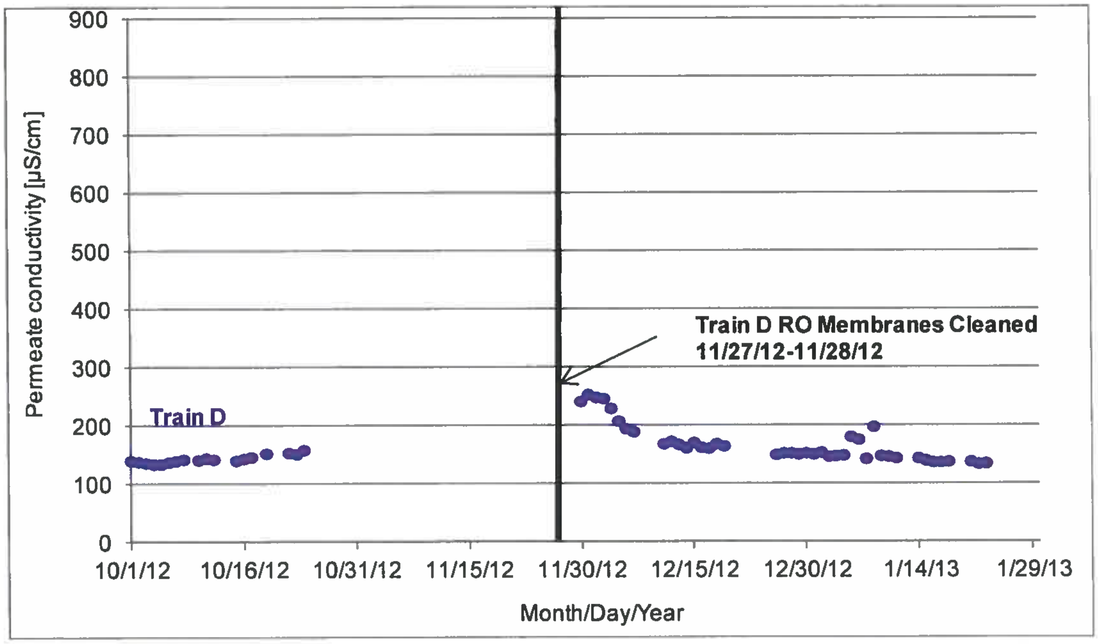
Replacement of the Train A membranes resulted in a marked improvement in the permeate quality. Figure 5-12 shows the permeate conductivity dropped by approximately 78% following membrane replacement, from 770 µS/cm to 170 µS/cm.

Figure 5-12 Impact of Membrane Replacement on Train A Permeate Conductivity



The effect of membrane cleaning on the quality of the permeate produced from Train D is illustrated in Figure 5-13. While the data show a slight increase in the conductivity immediately following the cleaning, the permeate quality returned to the pre-cleaning level of approximately 150 µS/cm once the system operation stabilized.

Figure 5-13 Impact of Membrane Cleaning on Train D Permeate Conductivity



A comparison of Figures 5-12 and 5-13 indicates that the conductivity of the permeate produced from the new membranes (Train A) is slightly higher than from one year old membranes (Train D), an unexpected result given that both trains contain the same type of membrane and the Train D membranes are a year older. However, the difference in permeate quality may be attributable to the fact that Train D is being operated at a slightly higher feed pressure and slightly higher flux rate than Train A.

5.6 Blend Ratio

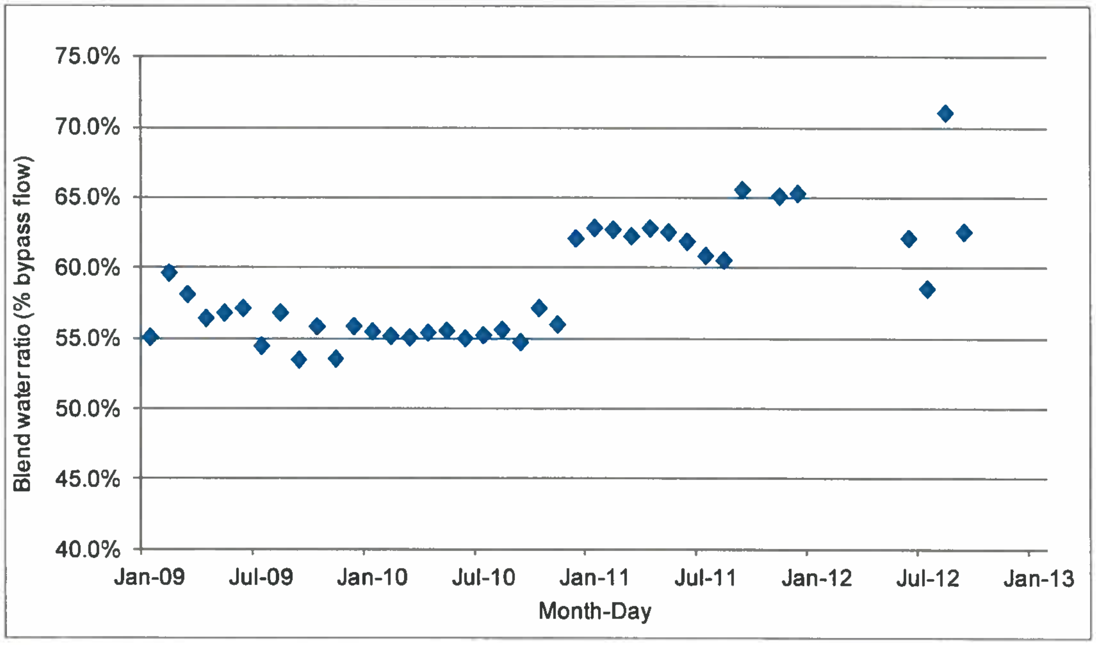
The final product water from the Kenedy treatment plant consists of RO permeate blended with raw water that bypasses the RO system. The raw water used for blending is referred to as bypass water. The blend ratio is the percentage of the total product water made up of bypass water. At the Kenedy facility, the flow of bypass water is manually adjusted to produce the volume of product water required to meet demand while maintaining compliance with applicable drinking water standards.

Theoretically, assuming no limitations on the volume of well water that can be supplied to the system, improvements in RO system result in an improved permeate quality and the more bypass water that can be used for blending (while maintaining the production quality) resulting in an increase in product water. Or, conversely, as a system ages and the quality of the permeate degrades due to the increase in salt passage through the membrane, the less bypass water typically can be used for blending resulting in a reduction in the volume of final product water. However, as shown below, the blend ratio data for the Kenedy facility does not follow this typical trend because the raw water is limited and the system is operated in a demand driven mode. At the Kenedy facility, the flow of bypass water is adjusted to meet the product water demand and the quality of the product water varies as a result within the standard TCEQ limits.

5.6.1 Prior to Membrane Replacement/Cleaning

For purposes of this evaluation, the average bypass water flow for a given month was estimated by subtracting the total permeate flow produced by the three operating RO trains from the average flow of final product water pumped to the potable water distribution system. The blend water ratio then was calculated by dividing the estimated bypass water flow by total the product water flow. The flow data used in the calculations were monthly averages of the instantaneous flow rates recorded daily in terms of gallons per minute. A plot of the estimated blend ratio trend from January 2009 through September 2012 is provided in Figure 5-14.

Figure 5-14 Blend Water Ratio for Water Treatment Plant



The estimated blend ratio averaged roughly 55% from 2009 to the start of 2011, and then exhibited an increase to 63% up to 65%. The upward trend is most likely related to the increase in water demand as previously noted.

5.6.2 Following Membrane Replacement/Cleaning

Estimates of the blend ratio for the period following the December 2012 membrane replacement/cleaning could not be determined because the flow meter on the final product water distribution pumps was malfunctioning. In a typical system that is not demand driven or operated with the constraints that exist at the Kenedy facility, improvements in permeate quality associated with the installation of new membranes should result in an increase in the blend ratio and the total volume of blend water produced. Membrane cleaning, on the other hand, is not expected to significantly affect blend ratio given the minimal affect that cleaning was shown to have on permeate quality (refer to Figure 5-13).

6 Operating Cost Data Evaluation

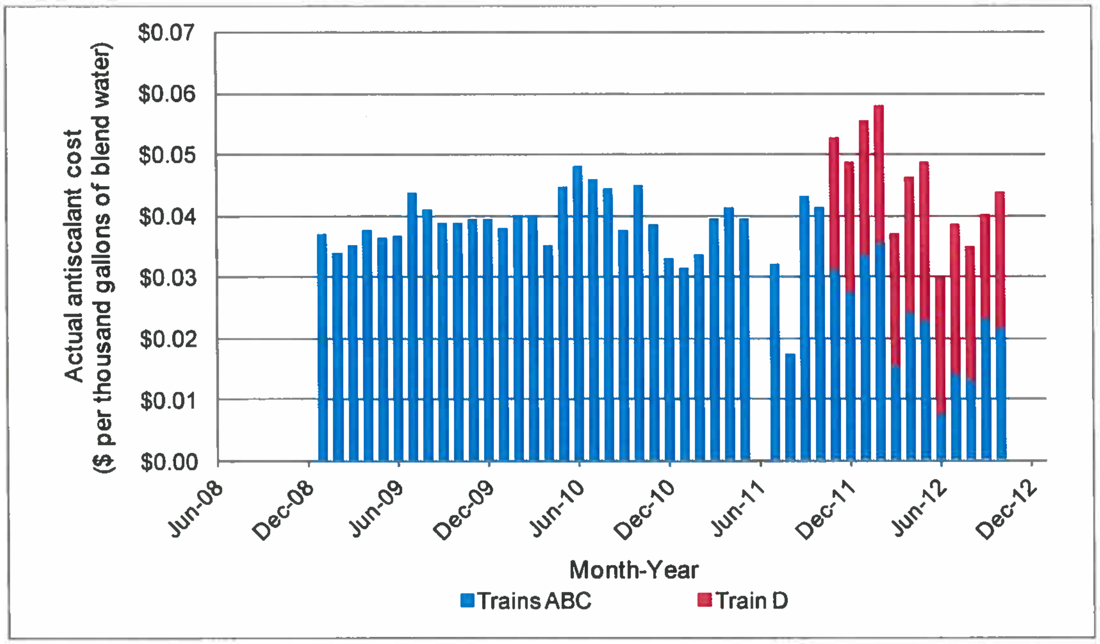
In addition to system performance, historical data relative to "variable" operating costs also was compiled and evaluated to determine the potential cost savings associated with improved RO system designs. For this evaluation, unit costs were assumed to not change and the same unit costs were applied across the timeframe of the project.

6.1 Chemicals – Antiscalant

The Kenedy water treatment system currently uses two different antiscalant products, GE Hypersperse^{TM} MDC 150 for Trains A, B, and C and ScaleFree 2800 for Train D. MDC 150 is added to the common feed at a single injection point upstream of the high pressure pumps on RO Skids A, B and C. ScaleFree 2800 is injected to the RO Skid D feed line upstream of the 5 micron cartridge filters. The Antiscalant dosage rate is specified by the vendor based on the raw water scaling characteristics. At Kenedy, the rate of Antiscalant feed is manually set. According to the plant operator, Train D is currently using ScaleFree 2800 as an antiscalant based on recommendations from the RO system equipment supplier. There are many antiscalants on the market for systems with varying scaling potentials and various scaling constituents. In the future, if Kenedy RO Trains A, B, C and D are supplied the same raw water quality and run at the same recovery rates, a single Antiscalant could be used for the entire system. The rate of the product used for Trains A, B, and C is tracked in the facility's WIMS system, but the usage rate for Train D is not. According to the operator, the antiscalant for Train D is used at an average rate of approximately 2 gallons per day (19.3 pounds per day), which is the value used in the evaluation.

Operating costs associated with average monthly antiscalant usage were estimated based on current unit costs of $1.80 per pound for the Train A, B and C product and $2.53 per pound for the Train D product. The variation in average monthly antiscalant costs expressed in terms of dollars per thousand gallons of blend water produced at the Kenedy facility for the time period of January 2009 through October 2012 is illustrated in Figure 6-1.

Figure 6-1 Actual Antiscalant Costs for Trains A, B, C



The facility's antiscalant cost data presented in Figure 6-1 does not show any distinct trend. This is due to a combination of the facility's atypical raw water blending practices, as previously described, and the manual nature of the antiscalant feed control. Typically, assuming a facility operates with a consistent antiscalant dosage rate and controls the blending ratio to produce a consistent blend water quality, the antiscalant cost per thousand gallons of blend water produced would tend to increase as the permeate quality degrades and more permeate has to be produced to meet demand. For example, Figure 6-2 illustrates the theoretical trend in Train A, B, C antiscalant costs that would be expected if Kenedy had operated Trains A, B, and C with a consistent usage rate of 46 pounds per day of antiscalant (based on the estimated average dosage of 4.4 mg/L to a combined RO feed of 876gpm) and if the blend ratio had been controlled to maintain 900 mg/L TDS in the blend water.

Figure 6-2 Expected Trend in Antiscalant Costs

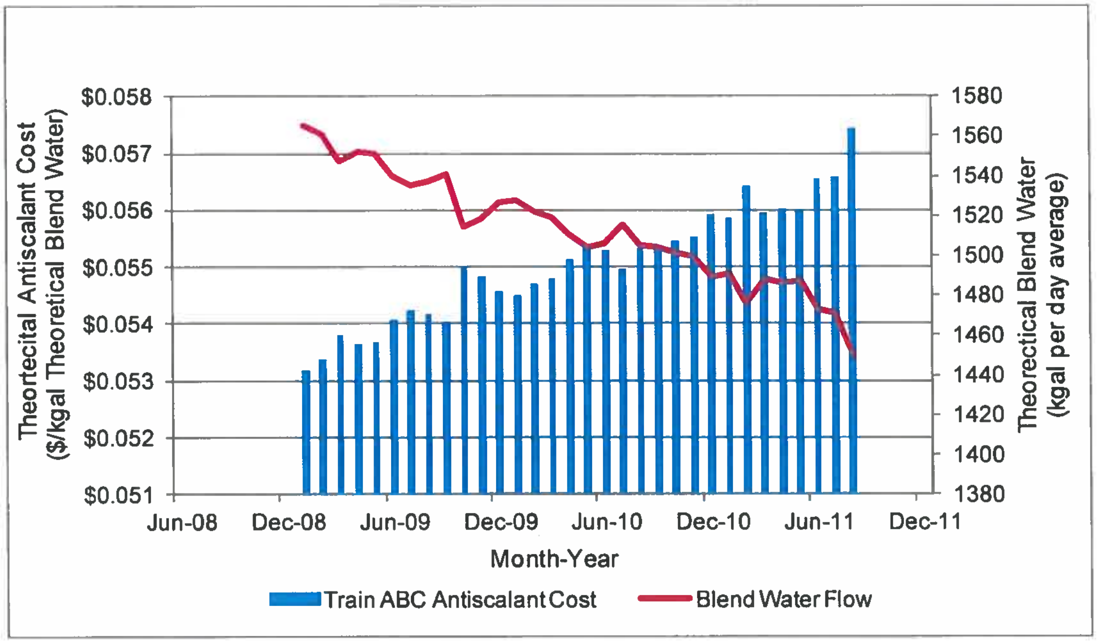


Figure 6-2 shows the expected increase in antiscalant cost per gallon of blend water that would be associated with a degradation in permeate quality over time. Conversely, antiscalant costs in terms of dollars per thousand gallons of blend water produced would be expected to decrease as a result of system modifications that improve permeate quality, such as replacement of older membranes.

6.2 Expendables – Cartridge Filter Replacement

Cartridge filter replacement, which represents another operating cost, is performed on a routine basis to provide consistent removal of particles from the water prior to entering the RO system and prevent membrane fouling. All of the cartridge filters used at the Kenedy water treatment plant are five micron nominal pore size filters. The criteria the operator uses to determine the need for filter replacement is different for Trains A, B and C compared to Train D. In the case of Trains A, B, and C, the filters are removed and replaced when the differential pressure across a given cartridge filter vessel reaches 10 psi, indicating a build-up of particulates on the filter media. In the case of Train D, the operator changes the filters based on visual inspection of the filter and not a specific differential pressure. According to the operator, the differential pressure across the Train D filters is typically below 10 psi and often below 5 psi when the filters are replaced. This practice is based on recommendations of the RO system supplier.

The annual cartridge filter replacement rates for the Kenedy facility are illustrated in Figure 6-3. The replacement rates in 2012 are significantly higher than previous years primarily due to the frequent filter replacements of Train D. The Train D filter replacement rate averaged more than thirteen filters per month. The replacement rates on Trains A and B also increased from an average of three to four filters per month to more than seven filters per month in 2012. It is unclear whether the increase in filter replacement was related to a change in the

RO feed water quality. The corresponding cartridge filter replacement costs in terms of dollars per thousand gallons of blend water produced, assuming the current unit cost of $15 per filter, are shown in Figure 6-4.

Figure 6-3 Cartridge Filter Replacement Quantities

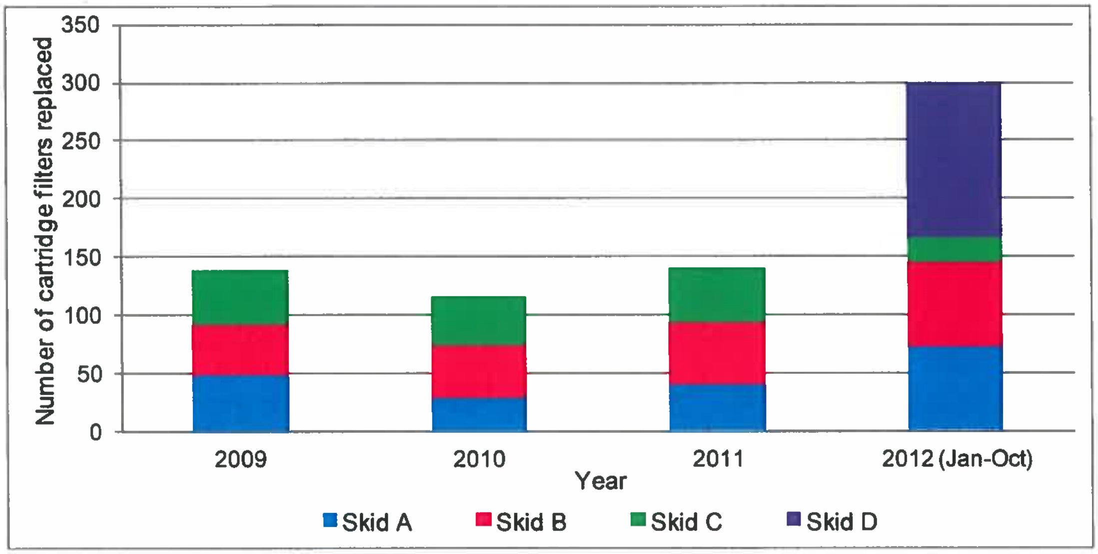
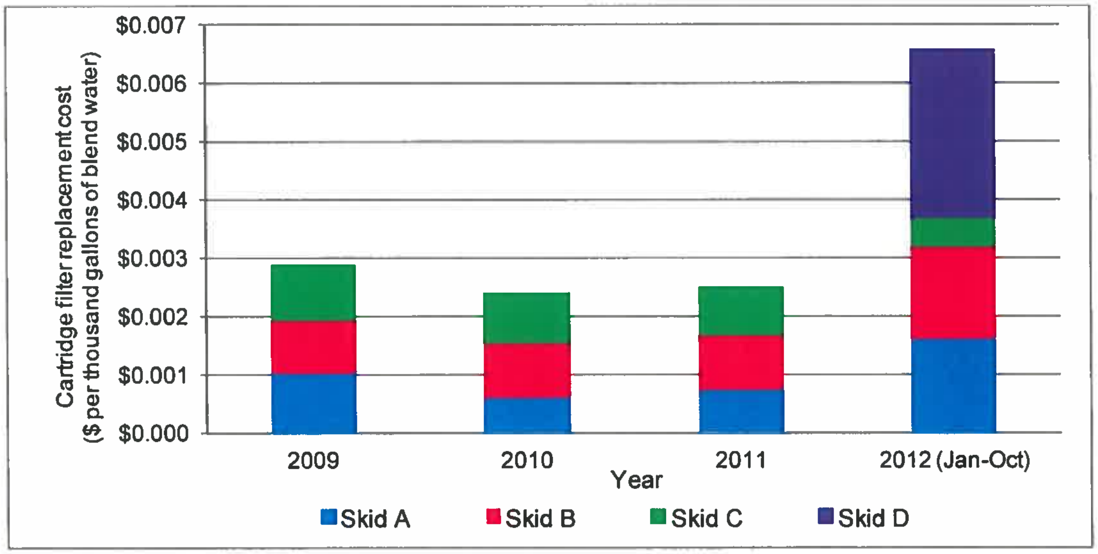


Figure 6-4 Cartridge Filter Replacement Costs



In a typical system, all cartridge filters are changed out based on the same criteria, often related to number of days in service, and the final blend water ratio is controlled to produce a consistent product water quality. Under these conditions, improvements in permeate quality and the associated increase in product water production should result in a decrease in the cartridge filter replacement costs per thousand gallons of product water.

6.3 Power Consumption – High Pressure RO Feed Pump

The largest energy user on an RO system is the high pressure feed pump. When designing an RO system, these pumps generally are oversized to account for the increase in pressure required to maintain a fixed permeate flow throughout feed water temperature and quality swings or as the membrane fouls or compacts as it ages. In older RO systems, the feed pressure is regulated by a throttling valve on the discharge of the high pressure pump. In the case of Trains A, B, and C at Kenedy, the throttling is done with a manual valve which is an inefficient approach that results in wasted energy. Newer systems, such as Train D, use variable frequency drives on the high pressure pump motors to allow for automatic adjustment of flow and feed pressure with minimal loss in efficiency.

Kenedy does not have a means of monitoring and comparing the power consumption of Train D to the other trains. Therefore, theoretical calculations were performed to estimate the power consumption for the high pressure pumps using the feed flows and pressures and assuming a 72% pump efficiency and 90% motor efficiency. Associated operating costs were estimated assuming a unit cost of $0.0.085 per kilowatt-hour.

First, a comparison was made of the estimated power consumption for Train A versus Train D from February 2012 through September 2012. During this time period, Train A was operating at 68% recovery, a feed flow of 269 gpm, and steady elevated feed pressure of approximately 195 psi. Train A contained old membranes and produced poor permeate quality with a conductivity of approximately 750 uS/cm. Train D, on the other hand, was experiencing a steady increase in feed pressure over this time period due to membrane fouling related to issues with the antiscalant feed pump. The feed pressure of Train D increased from 148 psi to 195 psi over the eight month period, with the final feed pressure equaling to the feed pressure of Train A. Train D, which is equipped with a feed pump VFD and was operating at approximately 75% recovery with a feed flow of 290 gpm, contained relatively new membranes and produced permeate with 135 uS/cm conductivity. A comparison of the estimated power consumption for each train is shown in Figure 6-5 and the accumulated power costs are shown in Figure 6-6. The results indicate that Train D, which was treating a slightly greater feed flow, operated with approximately 8% lower power costs as compared to Train A.

Figure 6-5 Estimated Power Consumption: Train A vs. Train D

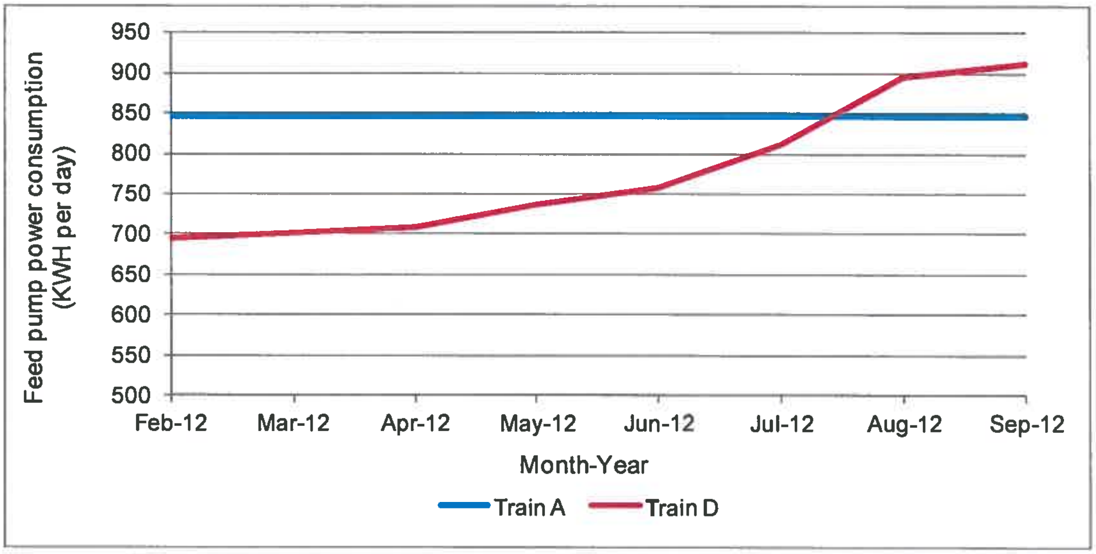
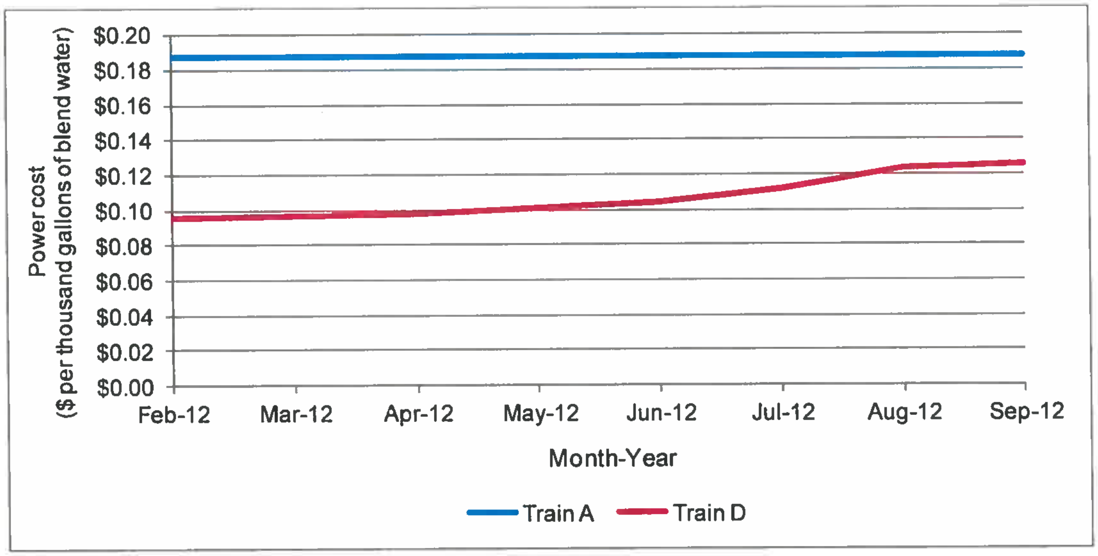


Figure 6-6 Accumulated Power Costs: Train A vs Train D

Figure 6-7 illustrates the difference in estimated power costs for Trains A and D in terms of the cost per thousand gallons of product water that could be produced from each train, assuming that the blend water ratio was controlled to produce a consistent product water quality of 900 mg/L TDS. This scenario assumes $0.085 per kilowatt-hour and 24 hours per day operation. The wide gap in costs reflects the lower power consumption associated with Train D due to the fact that its high pressure pump is driven by a VFD and it only puts out the required pressure whereas the Train A pump discharge is throttled. The gap in costs also reflects the higher product water production rate associated with Train D due to its improved permeate quality.

Figure 6-7 Power Costs per Thousand Gallons of Product Water: Train A vs Train D



As noted above, the comparison of power costs associated with Train A and D is affected by a multitude of factors. The potential savings associated strictly with the use of a VFD on a high pressure feed pump is illustrated in Figures 6-8 and 6-9 which compare the estimated power costs for Train D operating with and without a VFD. Without a VFD, it was assumed that the Train D feed pump would consistently operate at maximum pressure.

Figure 6-8 Effect of a Pump Variable Frequency Drive on Accumulated Power Costs

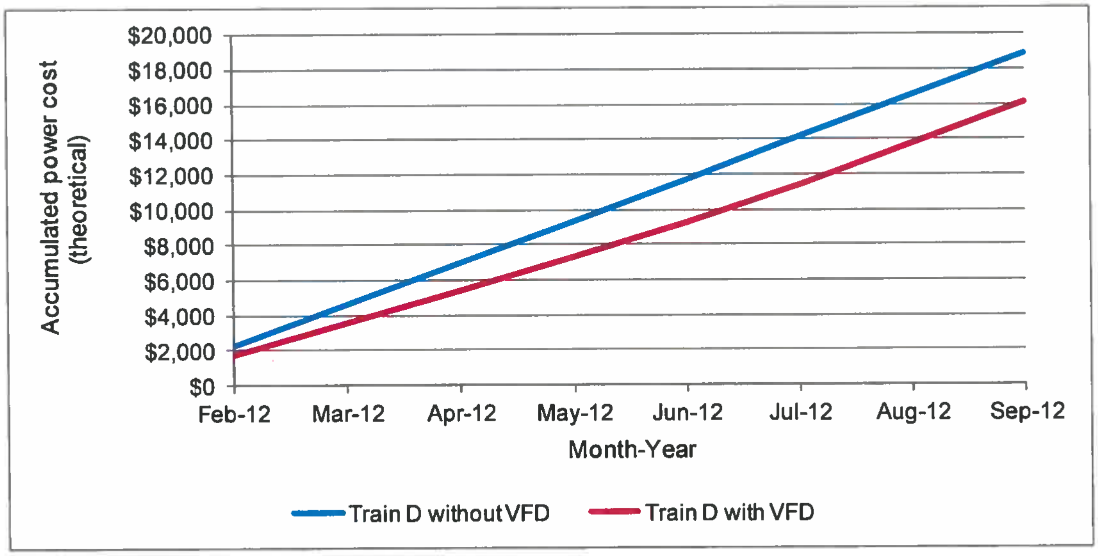
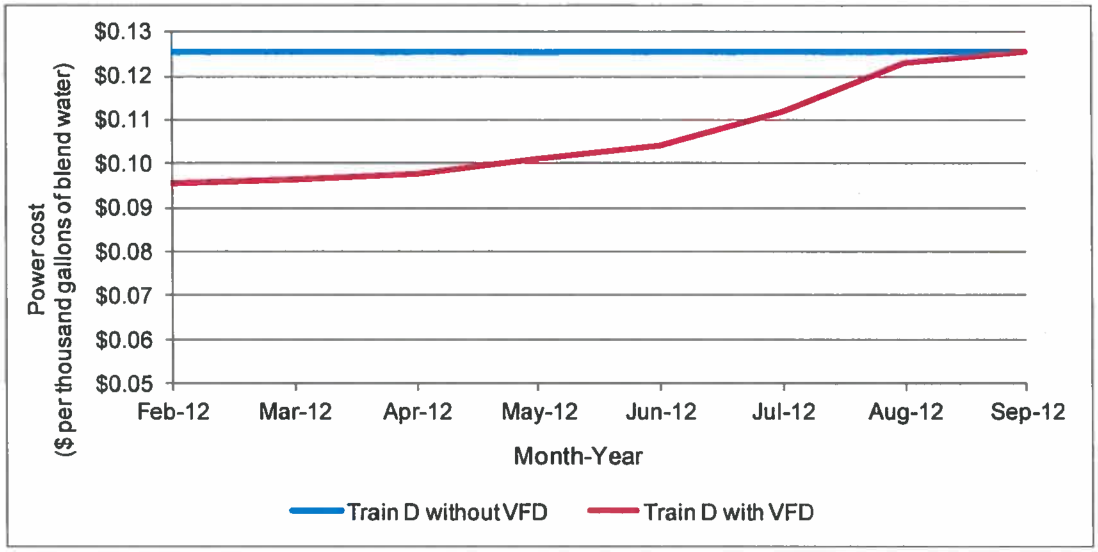


Figure 6-9 Effect of a Pump Variable Frequency Drive on Power Costs per Gallon of Blend Water



The results in Figure 6-8 show that the VFD on Train D theoretically provided for approximately a 15% reduction in the total accumulated power cost over the eight-month period evaluated. The cost savings per thousand gallons of blend water, as shown in Figure 6-9, is a function of the variation in system feed pressure. In the case of Train D, the feed pressure increased by more than 30% during the eight-month period. In typical RO systems, increases in feed pressure or differential pressure across the membranes are limited to a maximum of approximately 15%, at which point a CIP is performed.

7 Conclusions

The primary goal of this study was to use operating data from the Kenedy facility to evaluate the impacts on overall performance and system operating costs due to improvements to the existing RO system. The intent was to provide information that would assist other similar communities in Texas make informed decisions regarding upgrades to older brackish groundwater desalination facilities. However, operation of the Kenedy facility has not followed typical protocols because the facility constantly has been challenged to meet growing water demands, as a result operational decisions have focused on meeting product water flow requirements. Over time, the constant drive to meet capacity with limited brackish well water supplies ultimately reduced treatment and subcomponent performance.

Despite the challenges, some of the trends may be site specific, but the following general conclusions can be drawn from the data evaluation:

- Replacement of aging membranes operating below startup baseline conditions with new membranes will improve overall system recovery and reduce feed pressure requirements. .
    - Increased recovery results in higher permeate water rates and lower operating costs (chemical and electrical) per gallon of produced product water.
    - Reduction in feed pressure correlates to a direct savings in power consumption costs.
- Replacement of aging membranes with new higher yield membranes:
    - Improves permeate quality for a given raw water quality which, in turn, will increase the amount of product water that the plant is capable of producing. Improved permeate quality allows for the use of more bypass water while still maintaining product water quality.
    - Chemical and power costs per produced product water will also reduce as the percent of bypass water is increased.
- Replacement of aging membranes with new low energy membranes by definition directly reduces power costs.
- Use of an RO skid design that incorporates a VFD on the high pressure feed pump also results in direct power cost savings as compared to older skid designs with constant speed pumps and throttling valves. The use of a VFD on Train D at the Kenedy facility reduced power consumption costs by roughly 15% over an eight month period.

The results of this study have been used to develop an internet-based educational tool for interactive use by the public. It allows for simple comparisons of performance and return on investment between older and newer RO membrane elements and skid design technologies. The site is sponsored by the San Antonio River Authority in their continued support as a resource to communities in the TWDB Region L Planning Area (www.sara-tx.org/public_services/water_planning/kenedy_brackish_water_reverse_osmosis_tool.php).

8 References

ITT. (2011). *City of Kenedy RO Water Treatment System Installation, Operation and Maintenance.*

NRS. (2009). *Preliminary Engineering Assessment. Prepared for the San Antonio River Authority.*

Appendix A: Request for Quotations for RO Train D

SPECIFICATIONS:

Process Design Capacity

The design capacity for the proposed Reverse Osmosis process improvements is established at .309 MGD (215gpm). The pretreatment system design and membrane feed pump capacity will be based upon a 75% recovery rate and .309 MGD of permeate capacity because of the higher flows associated with lower recovery. The membrane process and post treatment will be based on 85% percent recovery with an option to run at 75% if the system shows premature fouling potentials.

Pretreatment Systems

This section presents a summary of the proposed membrane pretreatment system including raw water booster pump, static mixer, sulfuric acid addition, antiscalant addition, and cartridge filtration. The antiscalant feed system, static mixer, and main feed-water cartridge filtration system are sized for the maximum Reverse Osmosis feed-water requirement, assuming a 75 percent permeate recovery rate. Change-out frequencies for filter cartridges are in the range of once every 1 to 2 months. The Static mixer is installed as a precaution if acid feed is required at a future date.

Boost Pump	
Number	2
Design Flow per Pump (gpm)	253 - 287
Pump Type Vertical Multi-Stage	316L
Minimum Suction Pressure (psi)	5
Maximum Discharge Pressure (psi)	60
Calculated HP	13.4
Motor Size (HP)	20
Assumed Efficiency (%) pmp +mtr	71%
Driver type	TEFC
VFD	yes

Antiscalant System	
Design Flow Basis (mgd) (75% recovery is worst case)	.413
Maximum Antiscalant Dosage (mg/L)	4
Average Antiscalant Dosage (mg/L)	3
Minimum Antiscalant Usage (gph)	TBD
Maximum Antiscalant Usage (gph)	TBD
Average Day Antiscalant Usage (gpd)	TBD
Number of Metering Pumps	2 x 100%
Day Tank Storage Capacity	21 days
Pump Type	motor driven diaphragm
Metering Pump Capacity Range (gph)	<0.1 to >.4
Antiscalant	30 days supply with equipment

** The antiscalant chemical supplier must provide a minimum of 2 year membrane warranty based on the feed rate and dosage requirements.

Cartridge Filtration	
Cartridge Filter Housing Orientation	Vertical
Filter Housing Material	316L Stainless Steel
Number of Filter Housings	1
Design Flow per Vessel (mgd)	.413
Design Flow per Vessel (gpm)	287
Number of Equivalent 10-inch Cartridge Filters per Vessel	77
Loading Rate - All-in-service (gpm per 10-inches filter length)	3.75

Length of Each Cartridge Filter (in)	40
Pressure Drop, Clean (psi)	4
Pressure Drop, Dirty (psi)	10
Model (or equall)	Shelco
Inlet and outlet nozzle size (in)	4
Drain size (in)	3/4
Nominal Pore Size (micron)	5

Feed Static Mixer

Type Motionless	with 1 injection point
Material of Construction	PVC
Flow (gpm)	287
Size (in)	4
Head Loss (psi)	3
Model (or equal)	Ko-Flo

Membrane System

The membrane feed pumps will be located downstream of the cartridge filtration system. A total of two vertical centrifugal membrane feed pumps will be provided (one on-line one stand-by, they will alternate based on usage or pump failure). The pumps will be dedicated to this specific unit only. The membrane feed pumps will have a pumping capacity ranging from .364 or 253gpm to .413mgd or 287gpm to meet the 75 to 85 percent recovery rate design criteria. The design head condition for the pump is based upon the projected membrane feed pressure minus the available booster pressure under the various operating scenarios. The various operating scenarios considered include "clean" and "dirty" pretreatment process component conditions affecting the suction pressure, as well as first-stage permeate backpressure throttling, and a membrane fouling allowance, which affect the design membrane feed pressure.

The calculation of necessary pump motor horsepower assuming 70 percent overall pump and motor efficiency result is greater than 40 horsepower (hp) at the worst condition. As such, a 50 horsepower pump motor will be selected. Due to the fact that the membrane feed pumps will be equipped with VFDs, the pump impeller trim will be specified to take full advantage of the available motor horsepower. This will maximize the membrane "fouling allowance" safety factor, and provide the City with the greatest flexibility with respect to future operating pressures. It should be noted that under new membrane, clean (no fouling) conditions, the required discharge pressure will be significantly lower. However, it is necessary to design the pump and associated motor for the "fouled" design conditions previously discussed.

Each pump will be supplied with a variable frequency drive to maintain water production under different water quality and fouling conditions. To maintain the proper flux in stage 3 of the unit, interstage boost pumps with VFDs may be installed to boost the pressure of the Stage 2 concentrate to the desired Stage 3 feed pressure if required.

Membrane Feed Pumps

Number	2
Design Flow per Pump (gpm) (at 75% recovery)	287
Firm Capacity (gpm) (at 105%)	301
Pump Type	Vertical Multistage
Maximum Suction Pressure (psi)	50
Minimum Suction Pressure (psi)	20

Maximum Discharge Pressure (psi)	TBD by BWRO MFG
Calculated HP	TBD by BWRO MFG
Motor Size (HP)	TBD by BWRO MFG
MInimum Efficiency (%)	70%
VFD	yes

Membrane Treatment Skids	75% recovery (base case)
Total Permeate Capacity (mgd)	.309
Number of Skids	1
Number of Stages	TBD by BWRO MFG
Array Configuration (stg 1/stg 2 /stg 3)	TBD by BWRO MFG
Elements per Pressure Vessel	TBD by BWRO MFG
Average Permeate Flux (gfd)	15
First Stage Permeate Backpressure (psi)	TBD by BWRO MFG

Control System

The control system shall be a programmable Logic controller with Human Machine Interface (HMI). The HMI provides operator interface to the control system. The HMI will provide control screens, alarm functions, and trend functions necessary to monitor and control the BWRO membrane system. The operational controller shall be an Allen Bradley model (comparable to existing units) with enough inputs and outputs for system operation and 3% spares for additional data points if required. The controller shall have the ability to add an Ethernet card at a later date. The HMI shall be a 10" screen and display flows, pressures, and water quality in real time.

Pressure and flow transmitters will be supplied by the system manufacturer to send data back to the PLC to be used for monitoring and or trending. (no trending software is operational at this time, but will be added at a future date)

All submittals should be based on the highest sustained, repeatable performance under worst case conditions, and in accordance with ASTM and NSF standards for each BWRO product quoted.

Main power to the BWRO skid shall be 460/3/60. An internal step-down transformer will be used for control power of 120v/1/60.

All motors will be the high-efficiency TEFC type. Unless stricter requirements are required by the power utility, reduced voltage auto-transformer starters or solid state soft start starters will be provided for all constant speed motors 40 hp and larger.
Motors used in conjunction with VFDs will be rated for inverter duty and be in strict accordance with NEMA MG-1, 2003 Part 31. Pumps and equipment controlled by variable frequency drives will be started from zero and will then be ramped up to reduce the starting inrush current. Electrical subcomponents may be as manufactured by:

☐ General Electric (Switchboards, Panelboards and MCCs)
☐ Square D (Switchboards, Panelboards and MCCs)
☐ Cutler Hammer (Switchboards, Panelboards and MCCs)
☐ Robicon (VFDs)
☐ Square D (VFDs)
☐ Allen Bradley (VFDs)

All wire and cables for this project will be run in Schedule 80 PVC or rigid aluminum conduit. Seal-tight weather proof conduit may be used for final connection, not to exceed 6 foot in overall length.

Unless otherwise specified electrical enclosures shall have the following ratings:

☐ NEMA 1 for dry, non-process indoor above grade locations.
☐ NEMA 12 as indicated on the construction drawings.
☐ NEMA 4 for outdoor locations, rooms below grade (including buried vaults).
☐ NEMA 4X for corrosive, wet or damp locations for process areas indoor or outside and BWRO skids

The controls for the membrane plant will be designed to provide automatic and semiautomatic control. Under either control condition, the startup, normal shutdown and emergency shutdown will be done through the PLC at the BWRO skid. A manual start-up and shut-down procedure will also be provided through the processors.

In the automatic mode, the operator will initiate the automatic control and the PLC will make the appropriate checks of required equipment and process conditions and send the appropriate commands to start after adjustable predetermined time delays, before moving to the next step. If the sequence reaches a step for which the proper equipment or process status is not evident, it will hold for operator intervention for a preset period of time, after which it will abort the startup and inform the operator through the HMI.

In the semi-automatic mode, the startup and shutdown sequences will be designed to operate in a step-wise mode. At the end of each step, there will be a hold point which will require the operator to approve the next step.

Local controls and indicators will be provided for all of the equipment for manual local control of the system in the event of catastrophic central control system failure.

An alternating sequencing logic will be provided that will allow the operator to select between Automatic or Manual sequence of the membrane high pressure and booster pumps. In the manual sequence mode the operator will assign the pump sequence manually while in the automatic mode the sequence will be based on runtime. The lead pump or the next pump in sequence will be determined by the pump with the least amount of hours of operation. The pumping system sequence will follow the Last In First Out logic (LIFO).

All equipment run, fail and remote switch status will be monitored at the BWRO HMI. In the event of the selected equipment failure an alarm will be generated to alert the operator and, if operating in the automatic mode, the next pump in sequence will be called to start.

All parameters that are monitored shall be stored in a system database that is accessed by the HMI.

Startup

1. The PLC checks the status of the plant equipment and all permissive conditions.
2. The pre-selected Booster will be called to start.

3. The antiscalant feed pump will be called to start.
4. Pressure at the feed water manifold will be monitored and will determine available feed pressure to the BWRO (shown on HMI)
5. Pre-flush - check permissive and preset prior to pre-flush:
a. Open concentrate by-pass valve.
b. Open feed valve, start booster pump at minimum speed.
c. Pre-flush timer running.
d. Start antiscalant feed pump.
e. Pre-flush timer times out after preset flush.
6. Operate unit:
a. Close Concentrate by-pass valve.
b. Ramp up membrane feed pump to pre-selected flow set point.
7. Checks during operation/action:
a. Stage 1 and 2 differential pressure.
b. Permeate flow rate.
c. Calculate recovery rate. 74% /alarm 70% /shut down unit
d. Conductivity out-of-range alarm and initiate a dump to concentrate line, initiate normal shutdown.
e. Feed-water low-pressure/below 30 psi alarm, below 20 psi and initiate
f. Normal shutdown.

Normal Shut Down

The steps during a normal unit shutdown are described below:
1. Stop unit command from computer or any predetermined alarm condition.
2. Booster pump ramps down.
3. Feed valve remains open.
4. Concentrate by-pass valve opens.
5. Feed flush for 5 minutes.
6. Booster pump ramps down and turns-off
7. Permeate feed valve opens
8. Permeate flush for 6 minutes
7. Permeate valve closes.
8. Unit valves closed.
9. Concentrate by-pass valve closed.

Emergency Shut Down (Loss of Power)
1. Unit stop.
2. Booster Pumps stop, even if the well is powered.
3. Unit concentrate valve opens.
4. Membrane feed valve remains closed.
5. Plant automation will determine plant restart or an operator-initiated reset.

GENERAL:

All raw water piping through the pretreatment systems to the membrane feed pump to the membrane units will be PVC, Schedule 80. All concentrate, permeate, raw water blend, cleaning supply, and cleaning return lines within the Membrane Building, primarily installed in trenches or above grade will be PVC Schedule 80. All high pressure pipe downstream of the membrane feed pump, concentrate lines up stream of the control valve, and interconnecting manifolds will be 316L,Sch10 stainless steel

MATERIALS

A. Provide model and make of all pumps & motors. (accepted Models)
   1. Grundfos
   2. ITT (Goulds)
   3. TNT
   4. EBARA

B. Provide model and make of all valves and valve operators (accepted Models)
   1. Limitorque
   2. Apollo
   3. Hayward
   4. EMI
   5. Rotork

C. Provide model and make of Cartridge Filter Housings (accepted Models)
   1. Shelco
   2. Harmsco
   3. Parker
   4. Cuno
   5. Aerex

D. Provide model and make of Pressure Vessels (accepted Models)
   1. Protec
   2. Codeline
   3. Bel
   4. Harbin ROPV

E. Provide model and make of Chemical Feed pumps (accepted Models)
   1. Liquid Metronics (LMI)
   2. Pulsafeeder
   3. Prominent

GUARANTEE:

For one year following completion of the Project, the equipment manufacturer shall assist the City of Kenedy, without additional compensation, in securing correction of defects, and shall in the sixth and eleventh months make inspections of the project with the City and report observed discrepancies to the manufacturer for correction.

All equipment supplied under these Specifications shall be warranted by the equipment manufacturers for a period of one (1) year. Warranty period shall commence on the date of OWNER acceptance. Preference will be given to Contractors submitting greater warranty length.

Appendix B: RO Membrane Projection Results (ESPA1 membranes)

Permeate THROTTLING(1ST STAGE)

RO program licensed to:	*Gil Turner				
Calculation created by:	*Gil Tumer				
Project name:	Kenedy, City of, Train A		Permeate flow:	200.00	gpm
HP Pump flow:	266.7	gpm	Raw water flow:	266.7	gpm
			Permeate throttling(1st st.)	30.0	psi
Feed pressure:	152.7	psi	Permeate recovery:	75.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	7.1		Element age:	3.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	7.0	
			Fouling factor:	0.80	
			Salt passage increase, %/yr:	10.0	
Average flux rate:	15.0	gfd	Feed type:	Well Water	

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	135.1	53.3	26.3	16.2	1.12	125.3	30.0	ESPA1	30	5x6
1-2	64.9	43.9	22.2	13.0	1.10	101.6	0.0	ESPA1	18	3x6

	Raw water		Feed water		Permeate		Concentrate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	72.9	181.8	72.9	181.8	1.122	2.8	288.2	718.8
Mg	8.3	34.2	8.3	34.2	0.128	0.5	32.8	135.0
Na	428.0	930.4	428.0	930.4	31.144	67.7	1618.6	3518.6
K	27.4	35.1	27.4	35.1	2.443	3.1	102.3	131.1
NH4	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
Ba	0.037	0.0	0.037	0.0	0.001	0.0	0.146	0.1
Sr	0.750	0.9	0.750	0.9	0.012	0.0	2.965	3.4
CO3	0.3	0.5	0.3	0.5	0.000	0.0	1.3	2.1
HCO3	302.0	247.5	302.0	247.5	52.044	42.7	1051.9	862.2
SO4	120.0	125.0	120.0	125.0	1.821	1.9	474.5	494.3
Cl	495.0	698.2	495.0	698.2	21.176	29.9	1916.5	2703.1
F	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
NO3	1.7	1.4	1.7	1.4	0.839	0.7	4.3	3.5
B	0.00		0.00		0.000		0.00	
SiO2	27.4		27.4		3.08		100.4	
CO2	35.74		35.74		35.74		35.74	
TDS	1483.8		1483.8		113.8		5593.8	
pH	7.1		7.1		6.4		7.6	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	2%	2%	11%
SrSO4 / Ksp * 100:	1%	1%	7%
BaSO4 / Ksp * 100:	86%	86%	467%
SiO2 saturation:	20%	20%	72%
Langelier Saturation Index	-0.17	-0.17	1.42
Stiff & Davis Saturation Index	-0.16	-0.16	1.21
Ionic strength	0.03	0.03	0.10
Osmotic pressure	14.5 psi	14.5 psi	54.7 psi

Permeate THROTTLING(1ST STAGE)

RO program licensed to:	*Gil Tumer				
Calculation created by:	*Gil Tumer				
Project name:	Kenedy, City of, Train A		Permeate flow:	200.00	gpm
HP Pump flow:	266.7	gpm	Raw water flow:	266.7	gpm
			Permeate throttling(1st st.)	30.0	psi
Feed pressure:	152.7	psi	Permeate recovery:	75.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	7.1		Element age:	3.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	7.0	
			Fouling factor:	0.80	
			Salt passage increase, %/yr:	10.0	
Average flux rate:	15.0	gfd	Feed type:	Well Water	

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	135.1	53.3	26.3	16.2	1.12	125.3	30.0	ESPA1	30	5x6
1-2	64.9	43.9	22.2	13.0	1.10	101.6	0.0	ESPA1	18	3x6

Stg	Elem no.	Feed pres psi	Pres drop psi	Perm flow gpm	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	CaSO4	SrSO4	BaSO4	SiO2	Lang.
									Concentrate saturation levels				
1-1	1	152.7	6.6	5.4	19.5	1.10	34.1	16.1	2	1	98	22	0.0
1-1	2	146.2	5.6	5.0	18.0	1.10	38.0	17.9	3	2	112	24	0.1
1-1	3	140.6	4.8	4.6	16.7	1.10	42.7	20.1	3	2	129	27	0.2
1-1	4	135.8	4.1	4.3	15.5	1.11	48.3	22.5	3	2	149	30	0.4
1-1	5	131.7	3.5	4.0	14.3	1.12	54.7	25.4	4	3	173	34	0.5
1-1	6	128.2	2.9	3.6	13.1	1.12	62.7	28.7	5	3	203	38	0.7
1-2	1	122.3	5.0	4.6	16.7	1.11	66.9	32.7	5	4	231	43	0.8
1-2	2	117.3	4.2	4.2	15.0	1.10	73.0	36.4	6	4	265	47	1.0
1-2	3	113.1	3.6	3.8	13.5	1.10	80.8	39.6	7	5	305	53	1.0
1-2	4	109.5	3.1	3.4	12.3	1.10	89.8	44.2	8	5	351	58	1.2
1-2	5	106.4	2.6	3.0	10.8	1.10	100.8	49.1	10	6	404	65	1.3
1-2	6	103.7	2.3	2.6	9.4	1.11	114.2	54.3	11	7	462	71	1.4

Stage	NDP psi
1-1	88.5
1-2	73.8

Permeate THROTTLING(1ST STAGE)

RO program licensed to:	*Gil Tumer		
Calculation created by:	*Gil Tumer		
Project name:	Kenedy, City of, Train C	Permeate flow:	375.00 gpm
HP Pump flow:	500.0 gpm	Raw water flow:	500.0 gpm
		Permeate throttling(1st st.)	20.0 psi
Feed pressure:	144.6 psi	Permeate recovery:	75.0 %
Feedwater Temperature:	25.0 C(77F)		
Feed water pH:	7.1	Element age:	3.0 years
Chem dose, ppm (100%):	0.0 H2SO4	Flux decline % per year:	7.0
		Fouling factor:	0.80
		Salt passage increase, %/yr:	10.0
Average flux rate:	15.0 gfd	Feed type:	Well Water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	278.2	50.0	22.2	16.7	1.15	120.7	20.0	ESPA1	60	10x6
1-2	96.8	44.4	25.0	11.6	1.08	95.4	0.0	ESPA1	30	5x6

	Raw water		Feed water		Permeate		Concentrate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	72.9	181.8	72.9	181.8	1.160	2.9	288.1	718.5
Mg	8.3	34.2	8.3	34.2	0.132	0.5	32.8	135.0
Na	428.0	930.4	428.0	930.4	32.182	70.0	1615.5	3511.9
K	27.4	35.1	27.4	35.1	2.524	3.2	102.0	130.8
NH4	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
Ba	0.037	0.0	0.037	0.0	0.001	0.0	0.146	0.1
Sr	0.750	0.9	0.750	0.9	0.012	0.0	2.964	3.4
CO3	0.3	0.5	0.3	0.5	0.000	0.0	1.3	2.1
HCO3	302.0	247.5	302.0	247.5	53.691	44.0	1046.9	858.1
SO4	120.0	125.0	120.0	125.0	1.881	2.0	474.4	494.1
Cl	495.0	698.2	495.0	698.2	21.870	30.8	1914.4	2700.1
F	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
NO3	1.7	1.4	1.7	1.4	0.863	0.7	4.2	3.4
B	0.00		0.00		0.000		0.00	
SiO2	27.4		27.4		3.18		100.1	
CO2	35.74		35.74		35.74		35.74	
TDS	1483.8		1483.8		117.5		5582.7	
pH	7.1		7.1		6.4		7.6	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	2%	2%	11%
SrSO4 / Ksp * 100:	1%	1%	7%
BaSO4 / Ksp * 100:	86%	86%	467%
SiO2 saturation:	20%	20%	71%
Langelier Saturation Index	-0.17	-0.17	1.41
Stiff & Davis Saturation Index	-0.16	-0.16	1.20
Ionic strength	0.03	0.03	0.10
Osmotic pressure	14.5 psi	14.5 psi	54.6 psi

Permeate THROTTLING(1ST STAGE)

RO program licensed to:	*Gil Tumer				
Calculation created by:	*Gil Tumer				
Project name:	Kenedy, City of, Train C		Permeate flow:	375.00	gpm
HP Pump flow:	500.0	gpm	Raw water flow:	500.0	gpm
			Permeate throttling(1st st.)	20.0	psi
Feed pressure:	144.6	psi	Permeate recovery:	75.0	%
Feedwater Temperature:	25.0	C(77F)			
Feed water pH:	7.1		Element age:	3.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	7.0	
			Fouling factor:	0.80	
			Salt passage increase, %/yr:	10.0	
Average flux rate:	15.0	gfd	Feed type:	Well Water	

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	278.2	50.0	22.2	16.7	1.15	120.7	20.0	ESPA1	60	10x6
1-2	96.8	44.4	25.0	11.6	1.08	95.4	0.0	ESPA1	30	5x6

Stg	Elem no.	Feed pres psi	Pres drop psi	Perm flow gpm	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Concentrate saturation levels CaSO4	SrSO4	BaSO4	SiO2	Lang.
1-1	1	144.6	6.0	5.5	19.8	1.11	33.7	16.3	2	1	99	22	0.0
1-1	2	138.6	5.0	5.1	18.5	1.10	37.7	18.3	3	2	115	25	0.1
1-1	3	133.6	4.2	4.8	17.2	1.10	42.6	20.8	3	2	135	28	0.3
1-1	4	129.4	3.5	4.4	16.0	1.13	48.6	23.8	4	2	159	32	0.4
1-1	5	125.9	2.9	4.1	14.8	1.14	55.9	27.4	4	3	190	37	0.6
1-1	6	123.0	2.3	3.8	13.5	1.15	65.2	31.8	5	4	230	42	0.8
1-2	1	117.7	5.1	4.2	15.2	1.09	70.3	35.9	6	4	259	47	0.9
1-2	2	112.6	4.4	3.8	13.5	1.10	77.2	39.4	7	4	291	51	1.1
1-2	3	108.2	3.9	3.3	12.1	1.09	85.5	42.0	8	5	330	56	1.1
1-2	4	104.3	3.4	3.0	10.9	1.10	94.7	46.0	9	6	370	61	1.2
1-2	5	100.9	3.0	2.7	9.5	1.09	105.5	50.0	10	6	415	66	1.3
1-2	6	97.9	2.6	2.3	8.3	1.08	118.1	54.1	11	7	462	71	1.4

Stage	NDP psi
1-1	90.6
1-2	67.0

Appendix C: Performance Evaluation Data Summaries

Train D

Average Monthly Operating Data PRIOR TO Membrane Cleaning

Membrane Area (sf) = 400

		RO Train D Permeate Flow Rate	RO Train D Concentrate Flow Rate	RO Train D Calculated Feed Rate	RO Train D %Recovery	RO Train D Stage 1 Feed Pressure	RO Train D Concentrate Pressure	RO Train D Differential Press	RO Train D Permeate Conductivity	RO Train D Percent Salt Passage	RO Train D Percent Salt Rejection	Avg Flux Rate
Year	Month	GPM	GPM	GPM	%	PSIG	PSIG	psi	uS/cm	%	%	GFD
2011	November	216	72	288	75	152	102	50	134	5	95	16.2
	December	215	76	291	74	153	104	49	110	4	96	16.1
2012	January	-	-	-	-	-	-	-	-	-	-	
	February	216	68	284	76	148	100	48	131	5	95	16.2
	March	217	65	281	77	150	101	49	123	5	95	16.3
	April	217	64	282	77	152	104	48	124	5	95	16.3
	May	218	67	285	76	157	108	49	128	5	95	16.3
	June	207	66	270	76	162	111	51	153	9	91	15.6
	July	213	67	280	76	174	122	52	142	5	95	16.0
	August	213	72	285	75	191	137	54	142	5	95	16.0
	September	214	77	291	74	216	156	59	139	5	95	16.1
	October	215	83	299	72	248	184	64	143	5	95	16.1
	November	-	-	-	-	-	-	-	-	-	-	-

Train A

Daily Operating Data
AFTER Membrane Replacement

Membrane replacement performed 12/3-/12/4/12

New Membrane Area (sf) = 400

	RO Train A Permeate Flowrate	RO Train A Concentrate Flowrate	RO Train A Calculated Feed Rate	RO Train A %Recovery	RO Train A Stage 1 Feed Pressure	RO Train A Concentrate Pressure	RO Train A Differential Press	Raw Water Conductivity	RO Train A Permeate Conductivity	RO Train A Percent Salt Passage	RO Train A Percent Salt Rejection	Flux Rate (calc)
	GPM	GPM	GPM	%	PSIG	PSIG	psi	uS/cm	uS/cm	%	%	GFD
12/6/12	177	76	253	70	135	100	35	2,474	148	6	94	13.3
12/7/12	171	76	247	69	135	100	35	2,463	158	6	94	12.8
12/8/12												
12/9/12												
12/10/12												
12/11/12	174	75	249	70	135	95	40	2,470	166	7	93	13.1
12/12/12	178	75	253	70	130	95	35	2,501	167	7	93	13.4
12/13/12	178	75	253	70	135	95	40	2,495	162	7	93	13.4
12/14/12	173	75	248	70	130	95	35	2,472	168	7	93	13.0
12/15/12	178	75	253	70	130	95	35	2,415	169	7	93	13.4
12/16/12	173	75	248	70	135	95	40	2,478	170	7	93	13.0
12/17/12	179	75	254	70	135	95	40	2,457	163	7	93	13.4
12/18/12	180	75	255	71	135	95	40	2,485	171	7	93	13.5
12/19/12	173	75	248	70	135	100	35	2,475	169	7	93	13.0
12/20/12												
12/21/12												
12/22/12												
12/23/12												
12/24/12	178	75	253	70	135	95	40	2,475	168	7	93	13.4
12/25/12												
12/26/12	178	76	254	70	135	95	40	2,431	163	7	93	13.4
12/27/12	179	76	255	70	135	95	40	2,494	174	8	92	13.4
12/28/12	173	76	249	69	120	100	20	2,466	174			13.0
12/29/12	173	76	249	69	120	100	20	2,520	174			13.0
12/30/12	173	76	249	69	120	100	20	2,470	174			13.0
12/31/12	173	76	249	69	120	100	20	2,571	174			13.0
1/1/13	173	76	249	69	120	100	20	2,420	174			13.0
1/2/13	176	76	252	70	135	95	40	2,465	176	7.5	92.5	13.2
1/3/13	177	76	253	70	135	95	40	2,485	176	7.6	92.4	13.3

Train A

Daily Operating Data
AFTER Membrane Replacement

Membrane replacement performed 12/3-/12/4/12

New Membrane Area (sf) = 400

	RO Train A Permeate Flowrate	RO Train A Concentrate Flowrate	RO Train A Calculated Feed Rate	RO Train A %Recovery	RO Train A Stage 1 Feed Pressure	RO Train A Concentrate Pressure	RO Train A Differential Press	Raw Water Conductivity	RO Train A Permeate Conductivity	RO Train A Percent Salt Passage	RO Train A Percent Salt Rejection	Flux Rate (calc)
1/4/13	176	76	252	70	135	95	40	2,488	177	7.5	92.5	13.2
1/5/13		76			140	100	40	2,462	159			
1/6/13		76			120	100	20	2,462	177			
1/7/13		76				100		2,485	176			
1/8/13	166	76	242	69	120	100	20	0	178			
1/9/13	172	76	248	69	135	95	40	2,481	176	7.4	92.6	12.9
1/10/13	169	76	245	69	135	100	35	2,501	179	7.3	92.7	12.7
1/11/13	174	76	250	70	135	100	35	2,471	178	7.4	92.6	13.1
1/12/13												
1/13/13												
1/14/13	177	76	253	70	135	100	35	2,497	178	7.6	92.4	13.3
1/15/13	175	76	251	70	135	100	35	2,473	178	7.6	92.4	13.1
1/16/2013	179	76	255	70	135	100	35	2,470	177	7.7	92.3	13.4
1/17/2013	176	76	252	70	135	100	35	2,470	180	7.6	92.4	13.2
1/18/2013	181	76	257	70	135	100	35	2,473	180	7.9	92.1	13.6
1/19/2013												
1/20/2013												
1/21/2013	176	76	252	70	135	100	35	2,480	178	7.7	92.3	13.2
1/22/2013	178	76	254	70	135	100	35	2,474	178	7.8	92.2	13.4
1/23/2013	175	76	251	70	135	100	35	2,479	181	7.6	92.4	13.1

BLEND WATER RATIO

Average Monthly Operating Data
PRIOR TO Membrane Replacement

		Potable Water to Distribution	Total Permeate Flow (calculated)	Bypass Flow (calculated)	Blend Water Ratio
Year	Month	GPM	GPM	GPM	%
2009	January	1,332	600	732	55.0%
	February	1,483	600	883	59.5%
	March	1,426	599	827	58.0%
	April	1,375	601	774	56.3%
	May	1,390	602	788	56.7%
	June	1,401	602	799	57.0%
	July	1,315	600	715	54.3%
	August	1,393	603	790	56.7%
	September	1,298	606	693	53.4%
	October	1,352	599	753	55.7%
	November	1,293	602	691	53.4%
	December	1,360	602	758	55.7%
2010	January	1,351	603	748	55.4%
	February	1,342	603	739	55.1%
	March	1,340	604	737	54.9%
	April	1,348	603	746	55.3%
	May	1,351	602	749	55.4%
	June	1,338	604	734	54.9%
	July	1,356	609	748	55.1%
	August	1,364	607	757	55.5%
	September	1,348	612	736	54.6%
	October	1,425	612	813	57.0%
	November	1,390	613	777	55.9%
	December	1,612	613	999	62.0%

BLEND WATER RATIO

Average Monthly Operating Data
PRIOR TO Membrane Replacement

		Potable Water to Distribution	Total Permeate Flow (calculated)	Bypass Flow (calculated)	Blend Water Ratio
Year	Month	GPM	GPM	GPM	%
2011	January	1,638	610	1028	62.7%
	February	1,616	604	1012	62.6%
	March	1,612	610	1001	62.1%
	April	1,638	611	1027	62.7%
	May	1,631	613	1018	62.4%
	June	1,595	610	985	61.8%
	July	1,555	610	945	60.8%
	August	1,546	612	935	60.4%
	September	1,588	549	1039	65.4%
	October	1,557			
	November	1,577	552	1025	65.0%
	December	1,584	551	1032	65.2%
2012	January	1542			
	February	1516			
	March	1565			
	April	1542			
	May	1307			
	June	1,516	576	940	62.0%
	July	1,384	575	808	58.4%
	August	1990	579	1412	70.9%
	September	1534	576	958	62.5%
	October				
	November				
	December				

Appendix D: Operating Cost Data Summaries

Average Monthly Operating Cost Data

Year	Month	Antiscalant Trains ABC Cost $/day	Antiscalant Train D Cost $/day	Total Antiscalant Cost $/day	Cartridge Filters Train A Qty	Cartridge Filters Train B Qty	Cartridge Filters Train C Qty	Cartridge Filters Train D Qty
2009	January	$71.13		$71.13				
	February	$72.51		$72.51				
	March	$72.35		$72.35				
	April	$74.40		$74.40	17	12	17	
	May	$72.79		$72.79				
	June	$74.19		$74.19				
	July	$83.06		$83.06	8	8	8	
	August	$82.45		$82.45			22	
	September	$72.46		$72.46				
	October	$75.68		$75.68				
	November	$73.50		$73.50	12	12		
	December	$77.28		$77.28	11	11		
2010	January	$73.66		$73.66				
	February	$77.72		$77.72				
	March	$77.12		$77.12				
	April	$68.10		$68.10		12		
	May	$86.96		$86.96	12			
	June	$92.67		$92.67			22	
	July	$89.45		$89.45				
	August	$87.42		$87.42		12		
	September	$72.77		$72.77	12			
	October	$92.50		$92.50		17	17	
	November	$77.28		$77.28				
	December	$76.61		$76.61	4	4	4	

Average Monthly Operating Cost Data

Year	Month	Antiscalant Trains ABC Cost $/day	Antiscalant Train D Cost $/day	Total Antiscalant Cost $/day	Cartridge Filters Train A Qty	Cartridge Filters Train B Qty	Cartridge Filters Train C Qty	Cartridge Filters Train D Qty
2011	January	$73.89		$73.89				
	February	$78.44		$78.44		12		
	March	$91.88		$91.88			22	
	April	$97.19		$97.19	4	4	4	
	May	$92.71		$92.71				
	June							
	July	$72.00		$72.00		12		
	August	$38.84		$38.84	12			
	September	$98.55		$98.55		12	22	
	October	$92.34		$92.34	12			
	November	$70.80	$49.00	$119.80		12		
	December	$62.33	$49.00	$111.33	12			
2012	January	$74.38	$49.00	$123.38	12	12		
	February	$77.40	$49.00	$126.40	12	12	22	
	March	$34.65	$49.00	$83.65				
	April	$53.34	$49.00	$102.34	12	12		22
	May	$42.85	$49.00	$91.85				
	June	$16.20	$49.00	$65.20				22
	July	$27.90	$49.00	$76.90	12	12		22
	August	$29.77	$49.00	$78.77				22
	September	$66.09	$49.00	$115.09	12	12		22
	October	$47.45	$49.00	$96.45	12	12		22
	November	$55.80	$49.00	$104.80	12	12		
	December	$27.00	$49.00	$76.00	12			22

Appendix E: Comments/Responses

Report Comments/Responses

This is a well written report. Here are my review comments on the report.

1. Page 6, first paragraph – Please provide RO treatment unit's capacity as well as the raw water blending capacity of the plant. - Completed
2. Page 8, third paragraph, lines 4 to 6 – Please mention how many membranes (6 or 7) were arranged in each pressure vessel. Completed
3. Page 8, third paragraph, line 13 – Please define the term "6M." Completed
4. Page 9, first paragraph – Please provide the name of the antiscalant(s). - Provided in section 6.1
5. In this section (section 3.1), please include a Table that summarizes data (from 2009 to 2012) for raw water quality, RO permeate quality, finished water quality (after blending RO permeate with raw water), and TCEQ standards of key parameters (TDS, arsenic, hardness, iron silica) in the facility. – Too much information to include in one table; all info can be found in Appendix C.
6. Table 4-2:
    a. If chemical cost and labor cost are not included as operational cost, then the estimate is much lower than the actual operation cost. These costs should remain the same as the current estimates used for O&M.
    b. Please explain why membrane replacement cost was not included in the Table.- Costs included in appendix D.
7. Section 5.1.1 – Figure 5-2 shows that recovery in Train C started increasing in January 2010. Please explain the reason. The reasons for the increase is unclear but suggest that the permeate flow meter was not functioning correctly. Explained in first paragraph on page 18.
8. Section 5.1.1 – Figure 5-2 shows that recovery in Train D was unstable the entire year of 2012. Please explain reasons for continued instability of recovery in Train D after start-up. May have been due to the membrane fouling. Discussed in second paragraph on page 18.
9. Page 8, first paragraph – Please provide reasons why Train A membranes are not operating as projected in the model. Please mention if the plant operators discussed the issue with membrane manufacturer / vendor. – The slight step increase of flows observed in Train A and B beginning in May 2012 is because the original turbine-type flow meters were removed and new magnetic flow meters were installed. The new magnetic flow meters, which tend to be more accurate than turbine meters, read higher flows. Veolia did not respond if this was discussed with vendor.
10. • Please include review comments and team's responses for the draft final report and Saquib's comments. For the comments on the final report where only the word document was submitted back to SARA please summarize comments that are asking for clarification or change in graphs. The comments and responses will be included at the end of the report. - Completed

11. ⍰ In the team's response, please indicate if the TWDB comment was addressed and if not provide a short explanation. - Completed
12. ⍰ Please add an executive summary. - Completed
13. ⍰ Please adjust figure captions to be below the figure. – SARA does not have access to Veolia's figures, tables, nor graphs and cannot make updates to them. No updates received from Veolia.
14. ⍰ For Figure 6-7 and 6-8, please add labels to the graph and remove legend. If a reader prints black and white, the reader will not be able to differentiate between colors - SARA does not have access to Veolia's figures, tables, nor graphs and cannot make updates to them. No updates received from Veolia.
15. ⍰ For Figure 6-3, please change "skid" to "train". Please also add labels or use hatching and remove legend. - SARA does not have access to Veolia's figures, tables, nor graphs and cannot make updates to them. No updates received from Veolia.
16. ⍰ Please include a link to the web tool in various key locations in the report (i.e., executive summary and conclusions). - Completed
17. ⍰ Please make all changes to graphs requested in the past final report comments. For example, some graphs have two decimal places. Please show no decimal places and add % sign to the numbers in the y-axis. - SARA does not have access to Veolia's figures, tables, nor graphs and cannot make updates to them. No updates received from Veolia.

Web Tool Comments

Consider renaming User Input or Existing WTP	Done
Considering renaming to User Input or Existing WTP	Done
Considering replacing title with: Kenedy BWRO - 1995 or Kenedy BWRO - Train A 1995	Changed to Kenedy BWRO—Skid A
Should this be permeate?	NO
Please replace with ft^2	Done
Please consider moving the membrane are a row under element properties.	Done
Considering replacing title with: Kenedy BWRO - 2012 or Kenedy BWRO - Train A 2012	Considered, We felt the original title is more descriptive.
Please replace with ft^2	Done
Please considering moving the membrane area row under element properties.	Done
Please considering adding a clear or reset button for the user.	Done
Please clarify energy savings entry. How does the user determine how much reduction in pressure it should enter. Would changing this row to a Feed Pressure entry be more appropriate. Energy savings in pressure reduction seems like an outco\ me that would be presented in the output report.	Agreed, however, energy savings calculations are based on Consultant data and cannot be reconsidered. The manufactures will quote pressure reductions and these can be used for this level of planning
Place the manufacturer name: Hydranautics	Done
Please fill in the model: ESPA1	Done
Please consider renaming "Existing System"	Done
Please considering removing column.	The comparison shows the expected change from upgrading the Skid A membranes as desired
Please consider renaming Kenedy BWRO System - 1995 or Kenedy BWRO System - Train A 1995, depending what the group decided to compare	Considered, We felt the original title is more descriptive.
Add a unit column	Done
Please consider naming "Feed water Flow"	Done
Please replace "quality" with "Conductivity". Please consider placing what is in the parenthesis as note at the end of that particular table and add asterisk after "Permeate Quality"	Done
Please consider renaming Byplass Flow as in report.	Done
Please considering name Permeate Flow to be consistent with report.	Done
Please place "Permeate to Product" in parenthesis. And change "Total Water" to "Product" to be consistent. Please note this blend ratio is different from the report.	Done
Add spaces between tables applies to whole output report	This is a function of the CSS not loading for the reviewer
Please consider removing decimal places.	Done
Please consider changing "blend" to "bypass" flow to be consistent with report	Done
Please consider removing column since the information is the same as above in Process flow table, if not the same keep column.	Kept
Please considering renaming to Kenedy BWRO 2012 or Kenedy BWRO Train A 2012	Considered, We felt the original title is more descriptive.
Please considering renaming to Kenedy BWRO 2012 or Kenedy BWRO Train A 2012	Considered, We felt the original title is more descriptive.
Please consider renaming "Existing BWRO Process" or "Existing WTP Process"	Done
Please replace with "N/A" to be consistent with table. Applies to row below.	Done
Please replace "blend" with "Product" to be consistent.	Done
Please consider replacing "original" to "existing". Applies to third row as well.	Done
Please consider replacing "new" to "proposed". Applies to fourth row as well.	N/A
Graph Missing??	CSS/load issue
If no graph center numbers and titles.	
General Comment:	
1. Please consider formatting output report by adding spaces between\ tables,etc..	CSS/load issue
2. Please consider providing the user an option to print a pdf.	Beyond Scope

Web Tool Comments

3. Please consider adding at the end of the outpu\ t report the name of tool, version, year, and a disclosure.	Disclosure included
4. The user only inputs the permeate flow. Please clarify how the other flow such as bypass and product flow are calculated. State \ any assumptions. Should the user be asked for those flows?	Based on permeate flow, recovery percentage, TDS, and WQ Target other flows are calculated. Language describing the limitations has been added.
5. Please consider comparing the Kenedy WTP \(as whole\) from 1995 to 2012. Or compare only Train A in 1995 to 2012. Othewise the cu\ rrent title descriptions are unclear.	We are comparing just train A. Adjusted naming to Kenedy WTP Train A Comparison
6. Please consider adding a water quality table for the Kenedy example to be consistent. The report has consistent shown the Kenedy information.	Considered, WQ table was outside of scope. WQ data for Kenedy not readily available to SARA
Think this should be Chloride.	Changed