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Changes in feed water salinity with pumping of the wellfield used to supply a brackish water RO facility at the City of Fort Myers, Florida

Erik J. Mead[a], Jesse Victory[b], Thomas M. Missimer[a,*]

[a]*Florida Gulf Coast University, Emergent Technologies Institute, U.A. Whitaker College of Engineering, 16301 Innovation Lane, Fort Myers, FL 33913, USA, email: tmissimer@fgcu.edu*
[b]*City of Fort Myers, RO Treatment Facility, 2751 Jacksonville Street, Fort Myers, FL 33916, USA*

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ABSTRACT

Many brackish-water reverse osmosis (BWRO) water treatment facilities that use groundwater typically display a linear increase in salinity over time based on upwards recharge of the production aquifer. The City of Fort Myers reverse osmosis facility pumps feed water from the upper part of the Floridan aquifer system which is a leaky aquifer. Aquifers containing saline water that is semi-confined or leaky tend to exhibit long-term changes in salinity. Aquifer characterization is an important component in the design and operation of a BWRO facility. The characteristics of the production aquifer feature an upper confining unit that is much thicker than the lower confining unit and when the aquifer is pumped, the recharge to the pumped aquifer is from the bottom upwards. Typically, salinity increases with depth so the pumped aquifer will take on the characteristics of the underlying aquifer over time. Data were collected and analyzed from production wells from May 2002 through August 2018 that includes pumping rates, total dissolved solids (TDS) concentrations, and dissolved chloride concentrations. The average wellfield TDS concentrations in May 2002 and August 2018 were 2,359 and 5,417 mg/L, respectively. A regression analysis was performed using the most recent five-year data and projected out 20 years. The average wellfield TDS concentrations are predicted to be 6,433 mg/L at 5 years and 7,683 mg/L estimated at 10 years. The 20-year projection shows an increase to 10,184 mg/L which is approximately 1.9 times greater than today. These are very large variations in the rate of salinity increase between production wells which may indicate that enhanced corridors of vertical permeability exist within the wellfield which could influence future facility operation.

Keywords: Brackish-water reverse osmosis; Floridan aquifer system; Water-quality changes

1. Introduction

The quality of feed water for brackish-water reverse osmosis (BWRO) facilities can vary greatly depending on geographic location with the process designed to meet localized conditions [1]. The characterization of the production aquifer is a very important component in the design and operation of a BWRO facility because unexpected changes in the quality of the feed water can reduce the efficiency of the process or cause it to fail. In order to assess a potential groundwater source for brackish-water desalination, it is important to understand the characteristics of the aquifer based on the initial plant capacity and with consideration for future expansion. Thus, aquifer characterization under pumping conditions is crucial for the development of brackish groundwater resources and the design of the facility [2].

Many coastal regions, such as Southwest Florida, are underlain by aquifers containing brackish water that is not suitable for direct potable use because of its high salinity but they are very good sources of feed water for BWRO

* Corresponding author.

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facilities [3]. Groundwater is typically used as the main source for the raw water supply of a BWRO plant and has approximately 4–10 times higher concentrations of dissolved salts compared to freshwater feed sources [4].

All of the aquifers within the Floridan aquifer system in Southern Florida are classified as leaky or semi-confined [5]. Leaky or semi-confined aquifers are recharged during pumping by water flowing through the confining beds above and below the pumped zone until equilibrium is achieved [6]. In Southern Florida, the uppermost confining bed is thick and has a very low leakance, so the systems tend to recharge from the bottom upwards (Fig. 1). Therefore, the production aquifer will eventually take on the water quality characteristics of the next lower aquifer [2]. In most cases the aquifer system is density-stratified, so the production aquifer water quality will become more saline in time [5].

The rate of salinity change in the production aquifer is dependent upon the wellfield design, the pumping rate, and the hydraulic characteristics of the aquifer which includes transmissivity, storativity, and leakance [2,7]. Typically, the most important hydraulic characteristic controlling the rate of salinity change is leakance [2]. The design of individual wells and the water quality in the bounding or surrounding aquifers can also have significant impacts on the salinity changes in the production aquifer [2,7].

In locations where there are large differences in aquifer water quality, the locations of old, deep, abandoned wells used for petroleum exploration in the past can cause high salinity anomalies and some faulting can allow upward movement of high salinity water, such as at the McGregor Isles area located about 12 km (7.5 miles) southwest of the facility [8]. Nearly 3,500 of these old wells have been found and plugged from bottom to top as part of an aquifer water quality maintenance program.

A critical issue in the design and the successful long-term operation for a BWRO plant is a full understanding of the stability of raw water quality being produced from the source aquifer over the design life of the reverse osmosis (RO) facility, usually 20 years. If rapid, unexpected increases in salinity occur, the process design of the facility, permeate quality and quantity, could be compromised or could require operational modifications. The operational modifications would involve increasing the operating pressure of the BWRO plant to treat the higher salinity water. It may also be necessary to decrease the recovery which began at 80% for the Fort Myers facility. When the plant recovery is reduced, additional raw water will be needed to maintain the rated capacity, and additional membrane areas may also be needed to reduce the average operating flux.

It is the purpose of this research to study the wellfield and the changes in water quality to assess if the Fort Myers, Florida facility will likely require design modifications in the future to meet current and future potable water supply-demand. This investigation will allow the development of a new conceptual model for the hydrogeology at this location that could be applied to other regions that share common hydrogeologic characteristics. The conceptual model for other BWRO facilities in the region shown in Fig. 1 may not apply to this site. Data presented in this investigation could also be used by BWRO facility designers to develop flexible designs that could accommodate operational adjustments needed for feedwater salinity changes, thus postponing any significant plant modification.

2. Background on hydrogeology and groundwater quality

2.1. Hydrogeology of wellfield

The City of Fort Myers pumps brackish water from 16 production wells located near the BWRO facility (Fig. 2). Raw water is pumped from the Lower Hawthorn aquifer [9] with some water coming from the upper Suwannee aquifer [10]. A north-south oriented geologic cross-section through wells P-1 to P-7 is shown in Fig. 3. The completed well depths range between 236 and 255 m. Wells P-1, P-2, P-3, and P-4 were back-plugged because of poorer water quality at greater depths [11]. Another geologic cross-section constructed through wells P-13 to P-17 is shown in Fig. 4 [12]. These wells range between 207 and 220 m in total depth. Well P-13 was back-plugged from 244 m back to 213 m [12].

Limited aquifer performance testing was conducted to determine aquifer hydraulic coefficients. In the western part of the wellfield (wells P-1 to P-7), the aquifer has measured transmissivity values from 8,000 to 21,000 ft^2/d with storativity values ranging from 2.0×10^{-4} to 5.0×10^{-4}. In the eastern part of the wellfield (wells P-13 to P-17) the measured transmissivity values were significantly lower, ranging from 2,017 to 7,230 ft^2/d. No determinations were made for storativity. No long-term testing was conducted to measure the aquifer leakance.

Groundwater modeling was conducted at the end of the initial hydrogeologic investigation using the data from wells P-1 to P-7 [11]. The modeling was only flow modeling and was used primarily to assess interference drawdowns between wells and regional impacts. The initial model was not revised based on the new data collected from the eastern part of the wellfield. No solute-transport modeling was conducted.

The initial water quality in each well before production is shown in Table 1. Note that there is considerable variation in water quality with the dissolved chloride concentration ranging from 770 to 3,255 mg/L. The quality of water in well P-7 during construction using reverse air drilling showed dissolved chloride concentrations ranging from

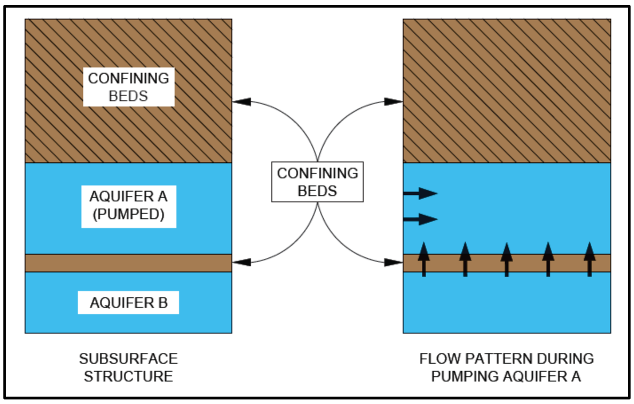

Fig. 1. Diagram showing upward recharge of an aquifer containing brackish-water during pumping (Missimer [2]).

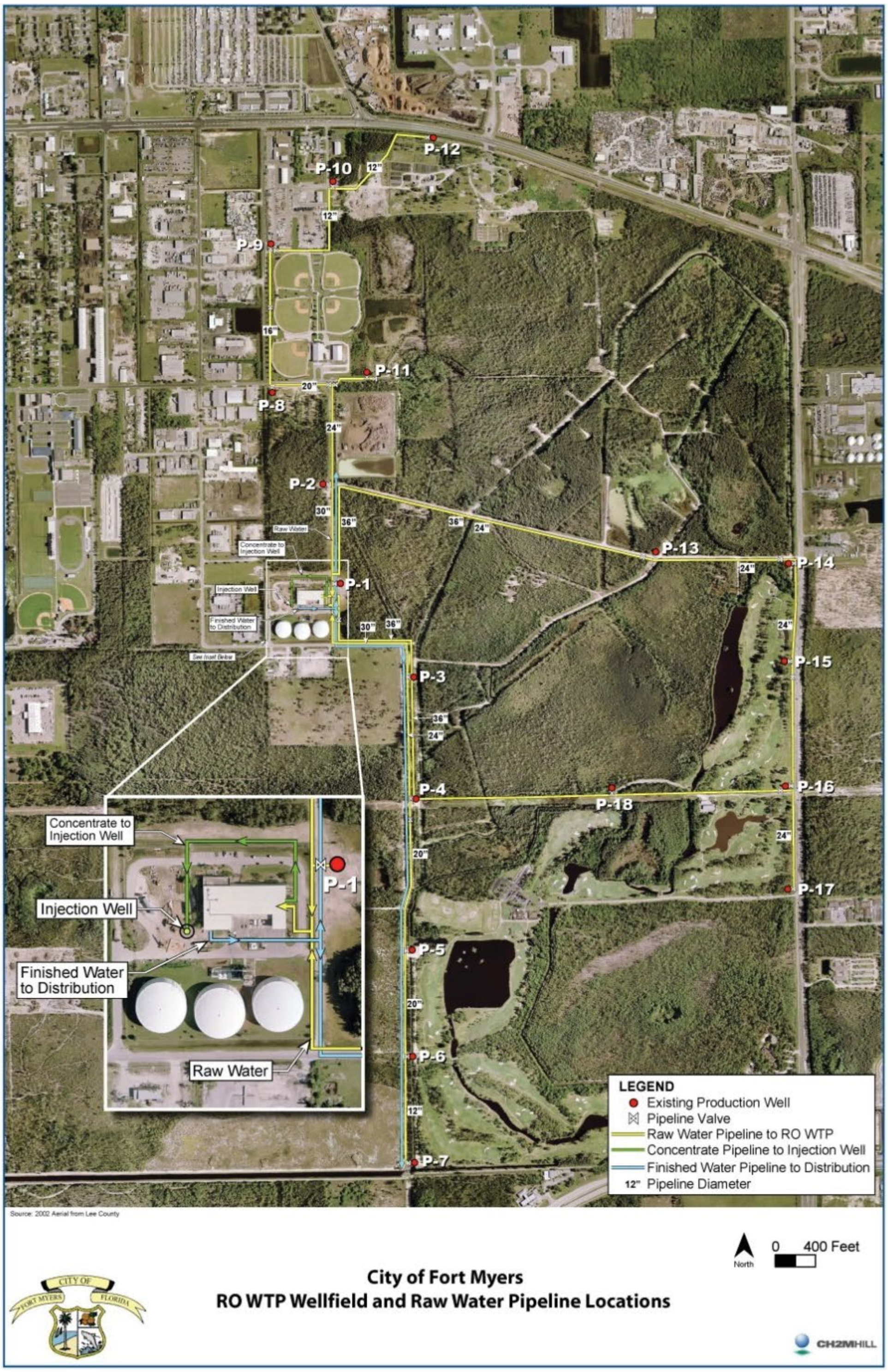

Fig. 2. Map of the City of Fort Myers RO water treatment facility and the production wells used to supply feed water.

930 to 1,050 mg/L which was higher than the initial value recorded during the startup of pumping. In well P-13, the water quality during construction showed density stratification with the chloride concentration at 1,400 mg/L at the top of the aquifer and increasing to 7,200 mg/L at a depth of 244 m. The well was back-plugged to 216 m to avoid the poorer quality water. No testing was conducted to ascertain the vertical connectivity within the aquifer. Overall, the dissolved chloride concentrations in the production wells varied greatly within a rather small geographic area.

Since the general recharge of this aquifer system is from the bottom upwards, it is quite important to assess the water

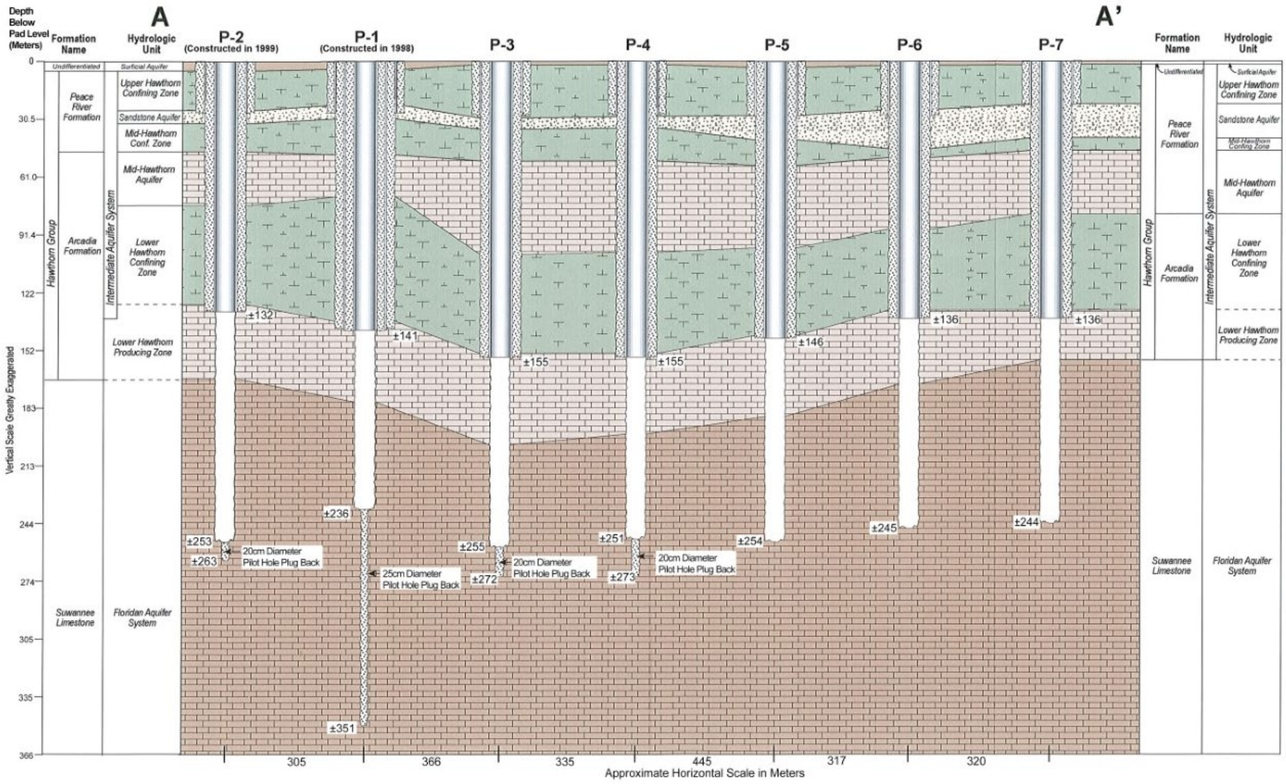

Fig. 3. North-south geological cross-section through wells P-1 to P-7 in the City of Fort Myers, Florida wellfield [11].

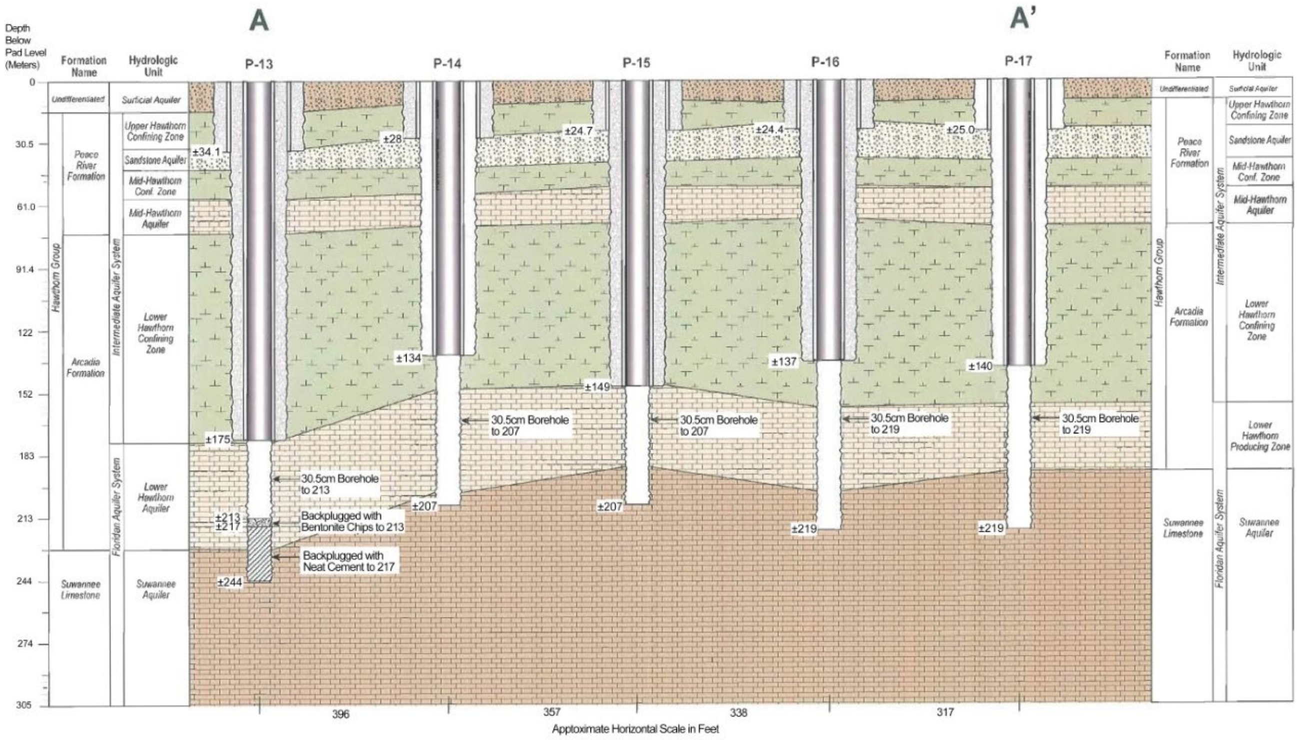

Fig. 4. North-south geological cross-section through wells P-13 to P-17 in the City of Fort Myers, Florida wellfield [12].

Table 1
Initial dissolved chloride concentration (mg/L) at production wells

Production well initial dissolved chloride (mg/L)																
P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-9	P-10	P-11	P-12	P-13	P-14	P-15	P-16	P-17	P-19
800	780	1,090	770	820	840	840	3,255	1,523	1,120	995	1,520	1,450	908	880	1,083	1,013

quality in the aquifer beneath a production aquifer [2,5]. Therefore, information from a deep injection well that was constructed on-site for concentrate disposal was used to investigate the deep geology and water quality. A geologic log of the deep injection well is shown in Fig. 5 along with the water quality in the aquifers beneath the production aquifer. The values show a progressive increase in salinity from that in the Lower Hawthorn aquifer to seawater in the "Boulder Zone" near the bottom of the well.

3. Materials and methods

3.1. Description of the BWRO facility

The City of Fort Myers BWRO Water Treatment Facility has a capacity of 45,455 m^3/d (12 million gallons/d) and currently has a daily demand of approximately 24,621 m^3/d (6.5 million gallons/d). The facility utilizes sixteen production wells located in the upper Floridan aquifer at operating depths ranging between 213 and 244 m (700 and 800 ft) below the land surface. The upper part of the Floridan aquifer system is the sole source of feed water for the facility. Fig. 2 in the previous section shows a map of the facility and the production wellfield.

Only 13 of the 19 wells constructed are currently in operation, providing raw feed water to the facility. The feed water is pretreated with sulfuric acid and a scale inhibitor prior to entering four cartridge filters. The membrane feed pumps convey the water to the first stage of RO membranes. The RO membranes consist of 2,688 low-pressure spiral-wound elements manufactured by TriSep Corporation (Lane Goleta, CA, USA), Dow Corporation (Midland, MI, USA), and Hydranautics (Owned by Nitto, US location in Oceanside, CA). Each element is 21.59 cm (8.5 inches) in diameter and 102 cm (40 inches) long. After the first membrane stage, the water then goes to the second membrane stage where the second stage permeate is blended with permeate from the first stage and raw water from the feed water bypass. Degasifiers are used to remove hydrogen sulfide from the product water. Immediately after degasification, the water is treated with carbon dioxide followed by caustic, fluoride, sodium hypochlorite and a corrosion inhibitor which are added to the water before it is sent to the finished water storage tanks. There are three storage tanks, each with a volume of 18,939 m^3 (five million gallons). From the storage tanks, the water is sent to the distribution system via high service pumps. Fig. 6 illustrates the process flow diagram for the facility.

3.2. Data collected on wellfield pumping of feed water

Data collected on the pumping rates and monthly production quantities were provided by the City of Fort Myers RO water treatment facility staff. Monthly operating reports

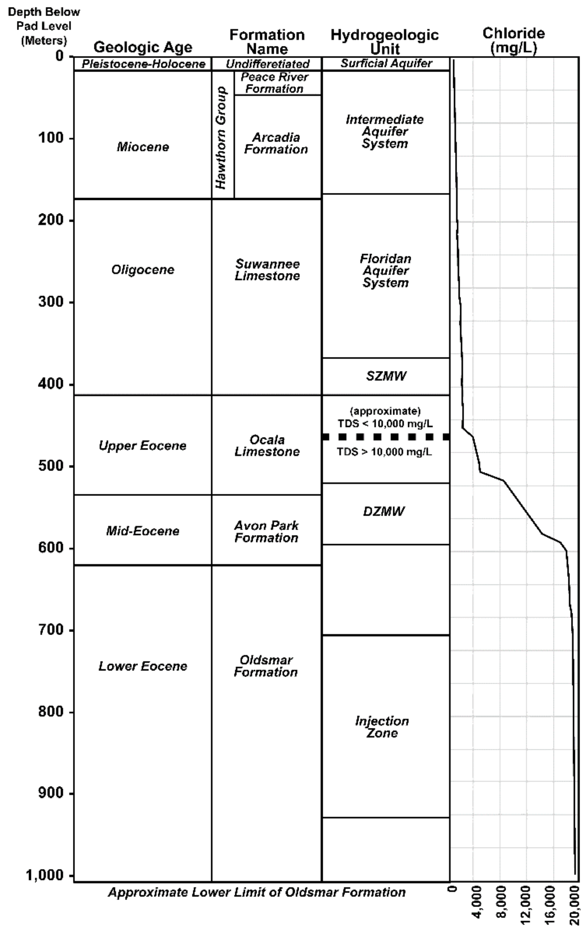

Fig. 5. The geological section of the injection well located at the City of Fort Myers wellfield with water quality in each aquifer penetrated (modified from CH2MHill [13]. Note that there is considerable inaccuracy in these data in that they conflict with the data from well P-1 which is located close to the injection well site.

(MOR) were provided for each month from May 2002 through August 2018. Dissolved chloride concentrations and pumping rates for each of the production wells were obtained from the data provided to the South Florida Water Management District (SFWMD). The data were compiled and the monthly average of chloride concentration for each production well was used for this study.

3.3. Analysis of feed water data

The dissolved chloride concentration data were plotted for each production well as well as the combined plant

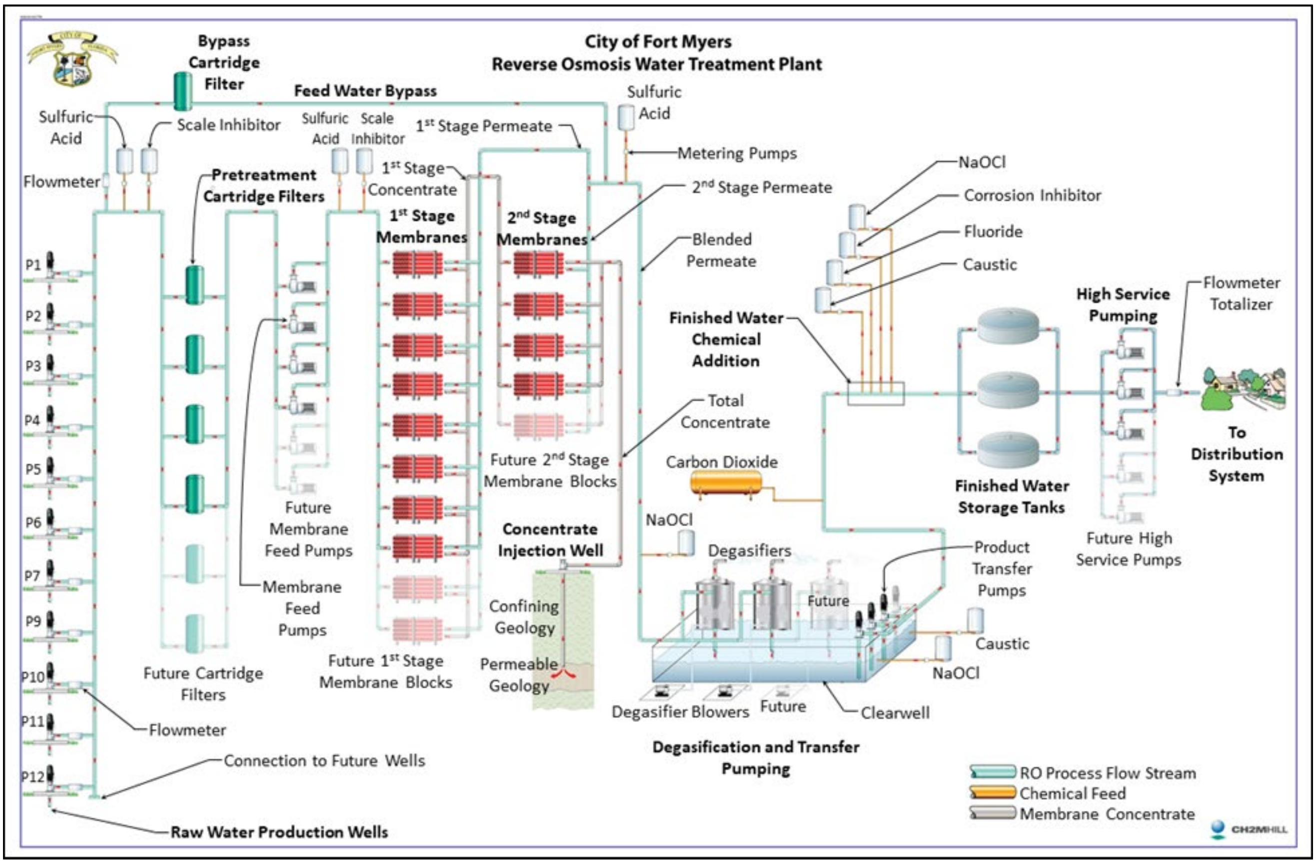

Fig. 6. Process flow diagram for the City of Fort Myers RO water treatment facility.

influent and effluent dissolved chloride concentrations. The dissolved chloride concentration vs. time was plotted and a trend line demonstrating a linear regression was developed. The plots included the dissolved chloride concentration change to the pumping rates for each well. This data set was analyzed, and a future projection of dissolved chloride concentration was established using the linear regression equation.

Total dissolved solids (TDS) were calculated using the electrical conductivity (EC) measurements provided in the MORs. TDS was estimated using the following equation based on EC values between 7,000 and 9,000 μS/cm with a groundwater temperature assumption of 20°C (Eq. (1)) taken from Goldberg et al. [14] and Thirumalini and Joseph [15]:

$$\text{TDS} = 0.67 \times \text{EC} \tag{1}$$

The dissolved chloride concentration was derived using the calculated TDS concentration and dividing by 0.559 as described by the standard ratio of dissolved chloride to TDS in typical seawater (global average) which is approximately 19,300 mg/L to ~ 34,500 mg/L [5,12].

4. Results

4.1. Feed water quality and pumping rates

The feed water for the City of Fort Myers RO facility is obtained from thirteen production wells drawing water from the upper part of the Floridan aquifer system (Lower Hawthorn aquifer). The aquifer is considered to be a leaky aquifer and when pumped, the recharge is primarily from the bottom upwards [5]. When recharge to the aquifer is from the bottom upwards and the upper confining unit is much thicker than the lower confining unit, there is a tendency for the dissolved chloride concentration of the pumped aquifer to increase since the aquifer system typically shows an increase of salinity with depth [5]. Fig. 7 shows the monthly water balance of total water withdrawn, finished water produced, and treatment losses.

The feed water dissolved chloride concentrations at the production wells are trending upward as suggested in Fig. 8. Production well 7 had a range of dissolved chloride concentrations between 773 and 1,217 mg/L from May 2002 through August 2018. Well 7 displayed the lowest concentrations of dissolved chlorides except for March 2012, when the measured chloride was 3,188 mg/L. Production well 10 had the highest dissolved chloride concentrations with a range between 980 and 8,810 mg/L from September 2004 through February 2015. It appears that well 10 was taken offline due to the extreme increase in dissolved chloride concentration. The data indicate that well 10 resumed production from November 2015 through February 2016, with chloride concentrations recorded at 5,706 to 7,480 mg/L respectively and was subsequently taken out of service again. The highest dissolved chloride concentration among production wells currently in operation was in production well 17 which

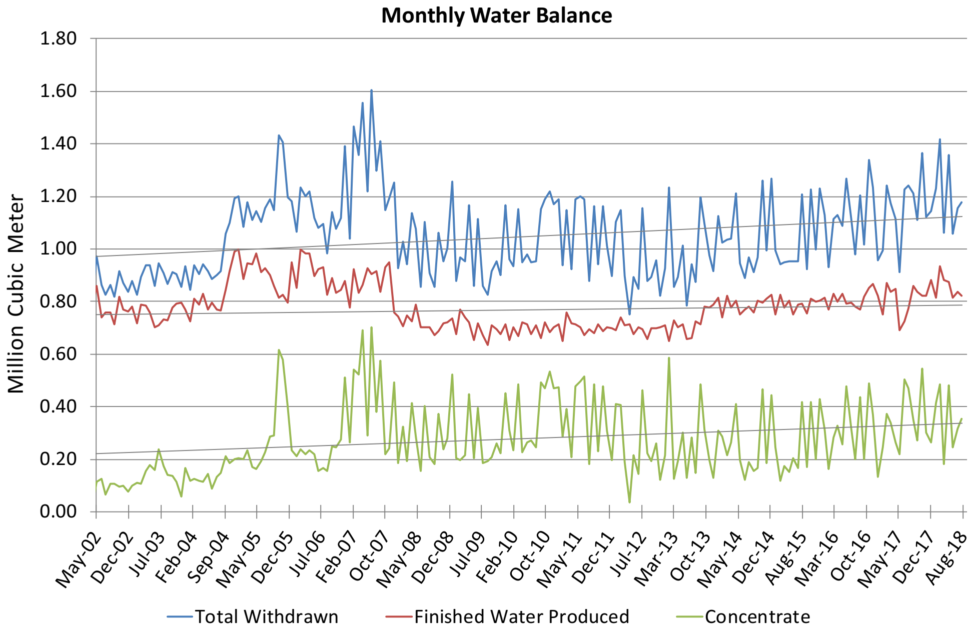

Fig. 7. Monthly water balance showing the total water withdrawn, finished water produced, and the treatment losses.

had a dissolved chloride concentration between 963 and 4,523 mg/L from April 2007 through August 2018. The water quality varies greatly within the aquifer in which the production wells are located. There is considerable variation in the response of individual production wells to pumping in BWRO systems. Localized variation in water quality, leakance, and horizontal hydraulic conductivity cause these variations.

Over the past seventeen years, the influent TDS and dissolved chloride concentrations have been trending upward while permeate TDS concentrations remain relatively steady as depicted in Fig. 9. The increases in TDS and dissolved chloride concentrations are typical of an aquifer that is recharged from the bottom upwards.

The operating pressure of the membrane system is critical not only in the operation of the process, but it also contributes to the overall energy consumption. Fig. 10 illustrates the correlation between monthly pumpage, influent and permeate TDS concentrations and the operating pressures of the membrane system. The operating pressures vary between 9.5 and 14.1 bar (138 and 205 psi) from May 2002 through August 2018. There has been an increasing trend in pressure as the TDS concentrations of the influent raw water have increased.

4.2. Water quality predictions using linear regression analysis

The relationship between the cumulative monthly pumpage and the concentration of dissolved chlorides is linear as shown previously in Fig. 8. The projections for groundwater concentrations of dissolved chlorides and TDS can be performed by linear regression analysis. The equations that were developed for each well are also shown in Fig. 8. The projections of groundwater salinity and TDS concentrations were estimated using the equations. Table 2 presents TDS and dissolved chloride concentrations from January 2013 through March 2018, with projections extending out forty years. The assumptions for future projections are based on current pumping rates and do not include any future development or impact on the performance of the production wells.

It should be noted that well 11 was exhibiting increases in dissolved chloride concentration in 2013 and 2014 but experienced a sharp decline during 2015 prior to the well being taken offline. The hypothetical projected numbers for well 11 show a negative value for dissolved chloride based on the linear regression analysis of the provided data. The wells showing high dissolved chloride values and negative slopes are not included in the analysis.

5. Discussion

5.1. Long-term increase in salinity and the impact on the operation of the facility

There are many causes for changes in the salinity of an aquifer. Some of these include aquifers with "high transmissivity flow zones and/or dual-porosity conditions that cause rapid movement of poor-quality water within the production aquifer towards production wells" [2,3]. Additionally, if there is a breakthrough in a confining layer or variation in thickness (variability in leakage), this will enable poor quality water to migrate into the production aquifer [2,3]. Unexpected, excessive vertical migration or "up-coning" of waters that are more saline has adversely impacted some RO systems because the salinity of the water delivered to the system exceeded the system design parameters [16]. In addition, water quality can vary within a production aquifer, particularly in locations where abandoned, deep wells have allowed higher salinity water to move upward through a subsurface borehole into an overlying aquifer under a lower pressure [17].

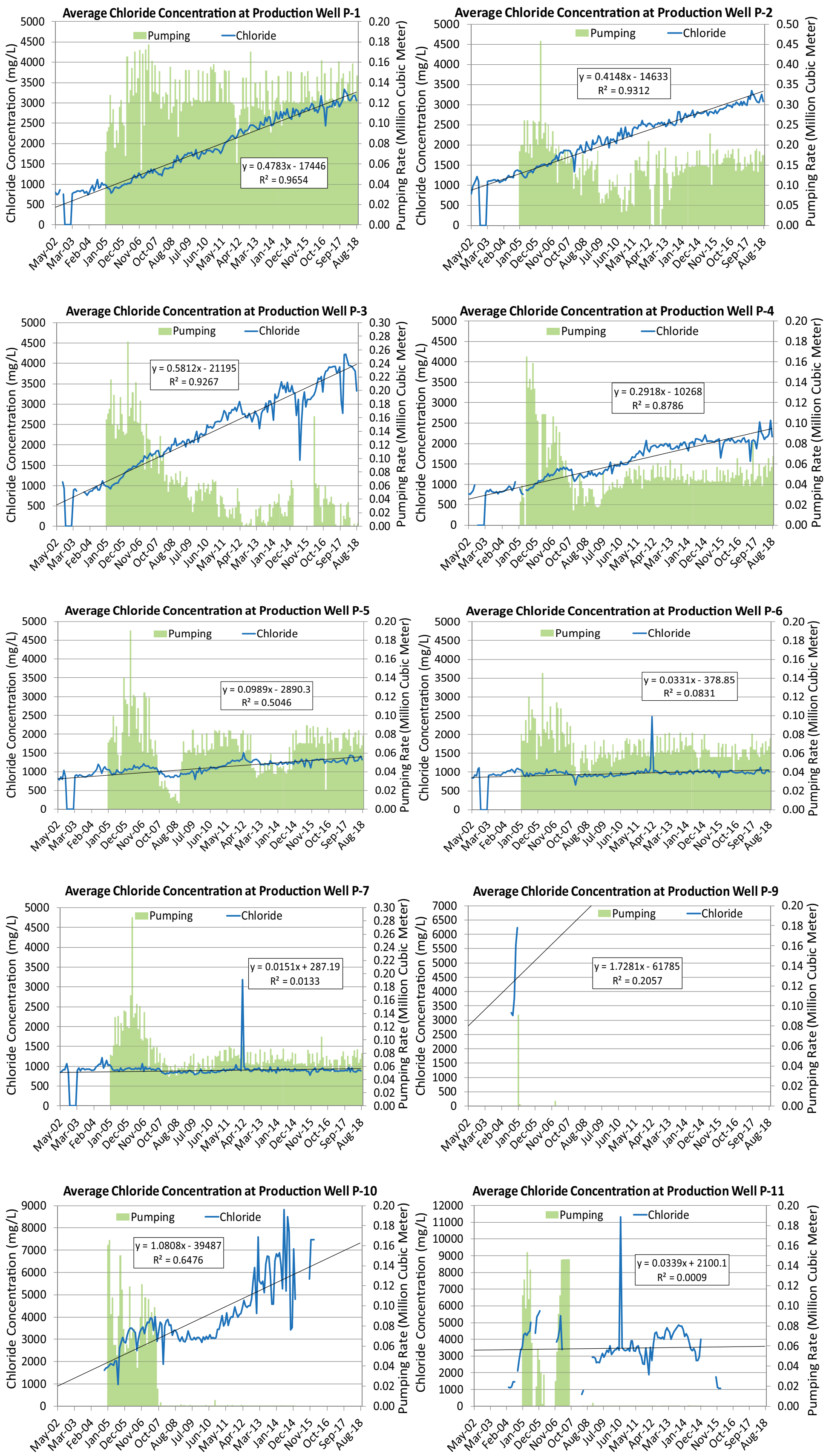

Fig. 8. *Continued*

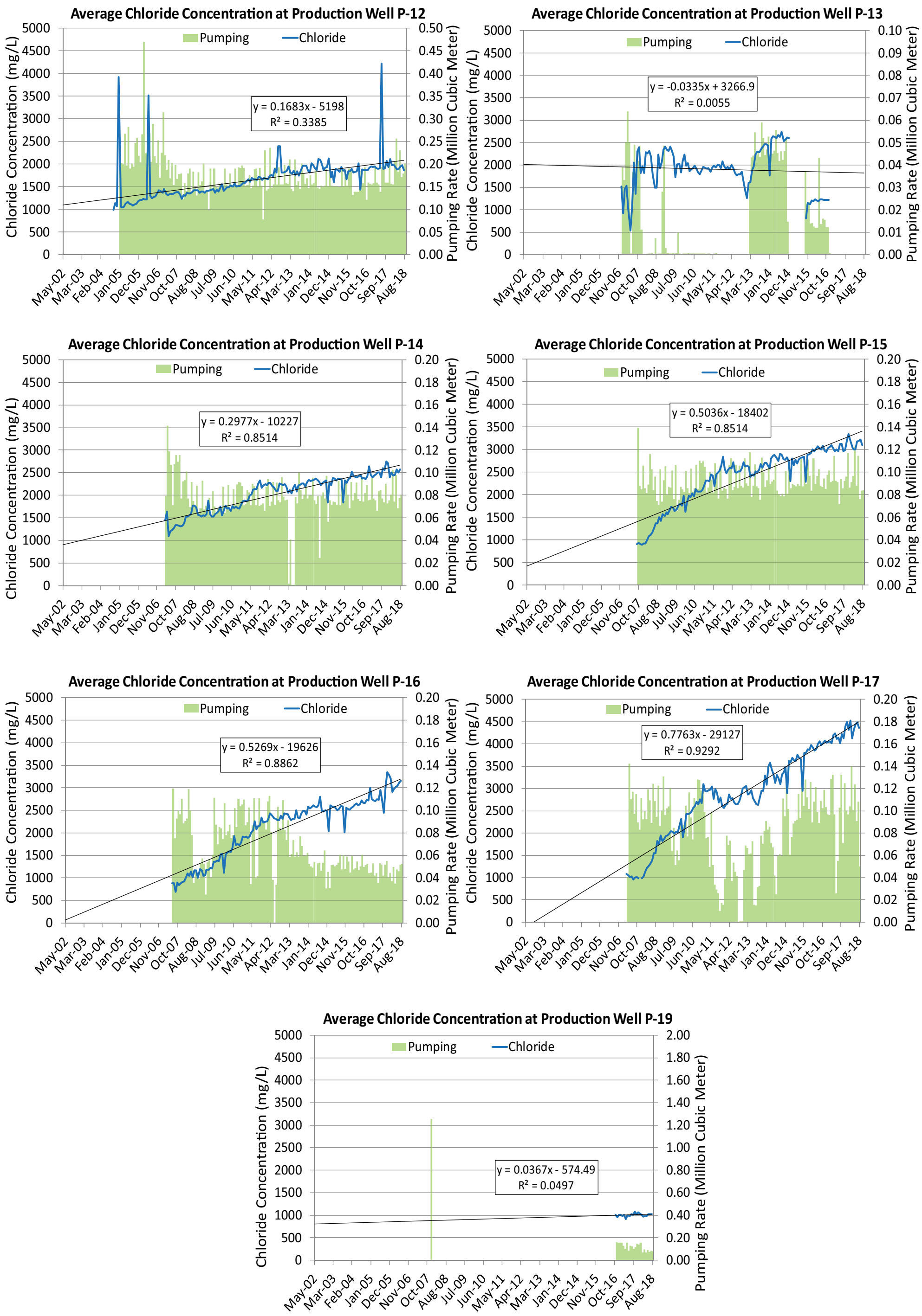

Fig. 8. Graphs depicting the pumping and dissolved chloride concentration for each production well from May 2002 through August 2018. Note that the green bars represent the monthly pumping volumes and the blue values are the measured dissolved chloride concentrations. The line equations and R^2 values are also shown. Note that 16 of the 19 wells were initially placed into produced and that number was later reduced to 13 wells.

There is a linear increase in TDS and dissolved chloride concentration over time. The increasing trendline for chloride concentration has a relatively low slope overall, apart from three production wells, as depicted previously in Fig. 8. Two of the three production wells appear to be offline or not in service and as of August 2018, well 17 had an approximate dissolved chloride and TDS concentrations of 4,358 and 7,788 mg/L respectively. The changes in water quality based on the current overall pumping rate can aid in predicting future feed water characteristics and future pumping rates.

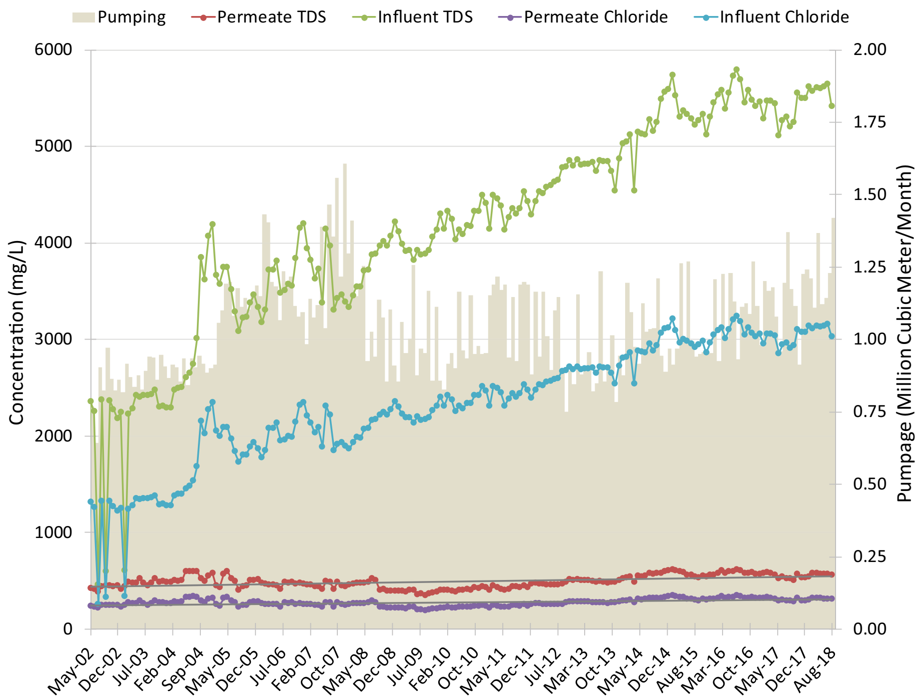

Fig. 9. Diagram showing monthly pumpage, influent and permeate concentrations of TDS and dissolved chlorides. The BWRO process in the plant has been adjusted to produce permeate that consistently meets drinking water standards.

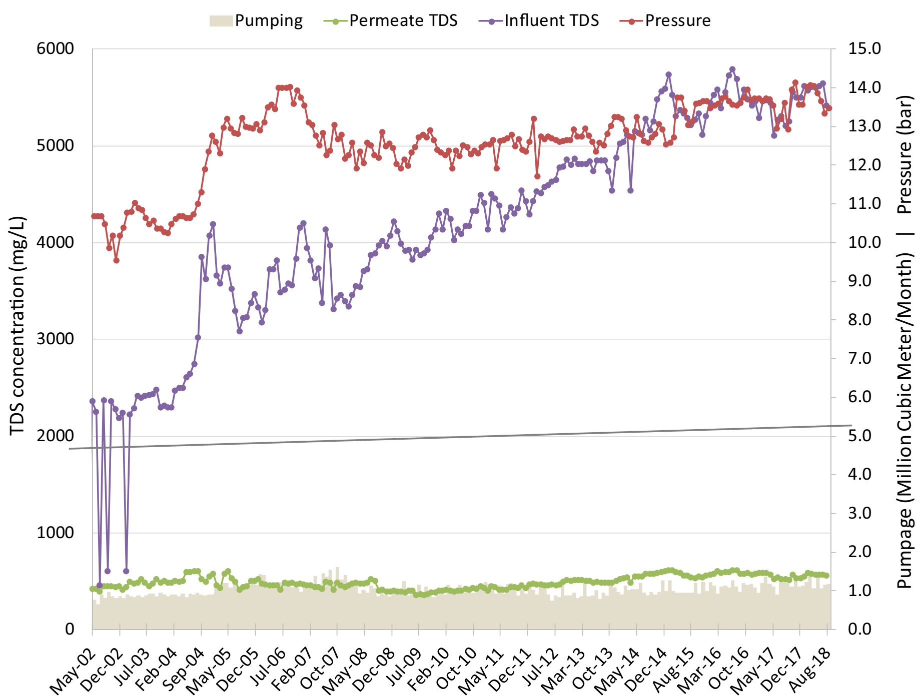

Fig. 10. Diagram showing monthly pumpage, influent and permeate TDS concentrations, and membrane operating pressure.

BWRO membrane systems are designed to treat water within a specified salinity range [2,3]. The chart referenced in Fig. 11 shows feed pressures up to approximately 16.2 bar (235 psi) as ultra low-pressure BWRO membranes that can process TDS concentrations up to about 4,000 mg/L. The next available BWRO membrane is a low-pressure membrane which can treat TDS concentrations of approximately 6,000 mg/L with a pressure up to about 24.1 bar (350 psi).

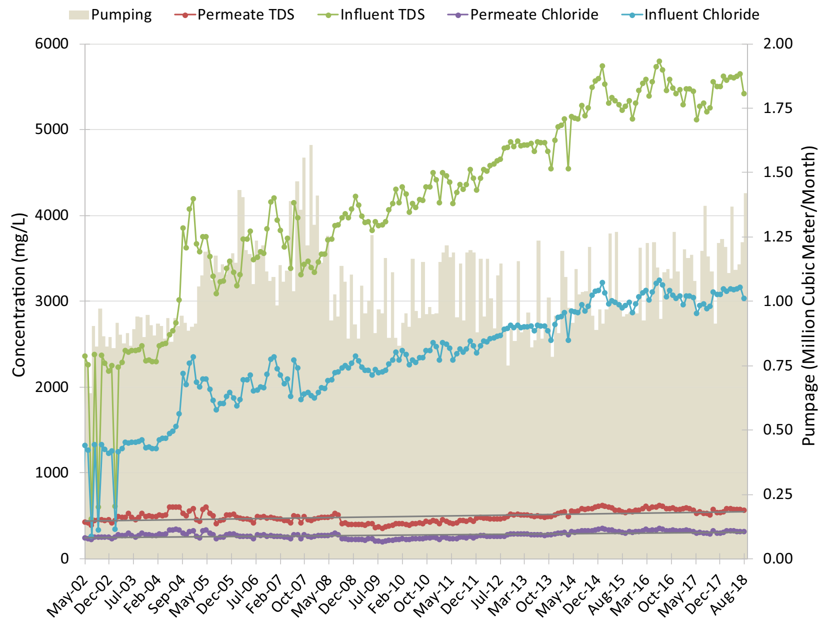

Fig. 9. Diagram showing monthly pumpage, influent and permeate concentrations of TDS and dissolved chlorides. The BWRO process in the plant has been adjusted to produce permeate that consistently meets drinking water standards.

Table 2
Production well water concentrations of dissolved chlorides and TDS from January 2013 through March 2018, and projections out 40 years

Well no.	January 2013, Cl^- (mg/L)	January 2013, TDS (mg/L)	March 2018, Cl^- (mg/L)	March 2018, TDS (mg/L)	5 year, Cl^- (mg/L)	5 year, TDS (mg/L)	10 year, Cl^- (mg/L)	10 year, TDS (mg/L)	20 year, Cl^- (mg/L)	20 year, TDS (mg/L)	40 year Cl^- (mg/L)	40 year, TDS (mg/L)
1	2,455	4,388	3,085	5,515	3,759	6,719	4,406	7,877	5,701	101,92	8,291	148,21
2	2,490	4,451	3,115	5,568	3,781	6,759	4,405	7,874	5,652	101,03	8,145	145,60
3	2,688	4,804	3,953	7,065	4,935	8,821	6,023	107,66	8,199	146,57	125,52	224,38
4	1,925	3,441	2,105	3,763	2,291	4,096	2,462	4,401	2,804	5,012	3,487	6,233
5	1,308	2,337	1,285	2,297	1,443	2,580	1,561	2,791	1,797	3,213	2,269	4,056
6	980	1,751	980	1,752	1,032	1,844	1,057	1,889	1,107	1,978	1,207	2,157
7	945	1,689	875	1,564	884	1,580	873	1,561	852	1,523	810	1,448
10[a]	4,170	7,454	0	0	9,290	16,607	110,67	197,84	146,22	261,37	193,00	345,00
12	1,850	3,307	1,940	3,468	2,245	4,012	2,453	4,385	2,870	5,130	3,704	6,621
13[a]	1,263	2,257	0	0	7,100	12,692	9,711	173,58	149,32	266,91	193,00	345,00
14	2,248	4,018	2,503	4,474	2,919	5,218	3,304	5,906	4,073	7,282	5,612	100,32
15	2,633	4,706	3,010	5,381	3,742	6,689	4,339	7,756	5,533	9,890	7,920	141,58
16	2,418	4,321	2,905	5,193	3,430	6,131	3,977	7,109	5,072	9,067	7,262	129,81
17	3,035	5,425	4,523	8,085	5,972	10,676	7,540	134,78	106,75	190,82	169,45	302,91
19	0	0	973	1,739	1,160	2,073	1,296	2,316	1,568	2,803	2,112	3,775
Avg.	2,172	3,623	2,404	4,297	3,599	6,433	4,298	7,683	5,697	101,84	7,928	141,71

[a]No data collected on P13 since 2/1/2015, hypothetical projected values are displayed.
No data collected on P10 since 2/1/2016, hypothetical projected values are displayed.

The standard pressure BWRO membrane can treat up to 10,000 mg/L with a pressure up to approximately 31–34.5 bar (450–500 psi). At the aforementioned pressures and concentrations, the BWRO membranes can achieve approximately 80% recovery, which is reasonable for BWRO facilities [5].

In August 2018, the average monthly TDS concentration of the influent water was 5,417 mg/L and the feed pressure was 13.5 bar (196 psi) on average. The City of Fort Myers RO facility currently utilizes a two-stage low-pressure membrane system. The average TDS concentration of the influent water

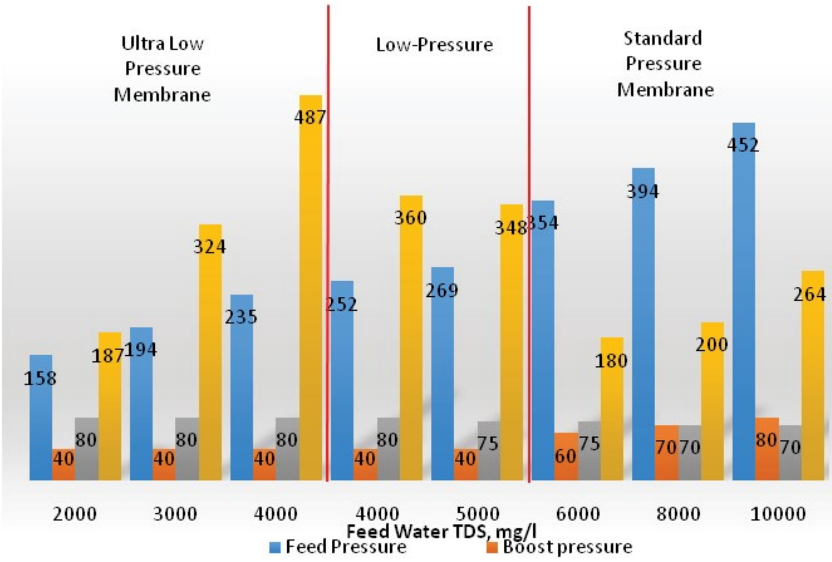

Fig. 11. Brackish water membrane options based on increasing feed water TDS and the impact on permeate quality, membrane feed pressure, and recovery (Missimer et al. [5]).

is within the operating range for low-pressure membranes as shown in Fig. 11. The five-year prediction of TDS and dissolved chloride concentrations are 6,433 and 3,599 mg/L respectively. A prediction out ten years gives a TDS concentration of 7,683 mg/L and a twenty-year prediction has TDS concentrations of about 10,184 mg/L. It is not until 40 years out that TDS concentrations increase to over 15,000 mg/L. The 40-year prediction is well beyond the useful life of the BWRO facility; therefore, consideration of predicted values will have to be revisited during the design of a new facility.

5.2. Cause(s) of the extreme variation in the salinity of the Lower Hawthorn aquifer under pumping conditions

The variation in water quality within the Lower Hawthorn aquifer appears to follow the standard assumption of upward leakage being the prime cause of salinity increases caused by pumping with time. This contention is supported by the generally linear nature of the increases within production wells as found by Missimer [2] and Drendel et al. [7]. However, the very high initial salinity concentrations in some wells and extreme variation in the rate of increase in other wells may indicate the occurrence of unusual salinity variation within the Lower Hawthorn aquifer. Some of the most rapid increases in salinity appear to occur in a south to north trend through wells P-4, P-3, P-1, P-2, P-11, P-9, and P-10 (Fig. 2). This could be indicative of leakage along a vertical fault or a linear zone of higher leakance. Vertical movement of saline water along subsurface faults has been documented in Lee County, Florida by Sproul et al. [8]. Other wells with a high rate of salinity increase are rather isolated. Enhanced upward movement of higher salinity water via old, unplugged wells is another potential cause of the “spotty” salinity pattern [17]. Future research on this issue will be required to ascertain if there are upward corridors of enhanced permeability or old well conduits which could be verified using some isotopic analyses.

6. Conclusions

BWRO is a very well established technology and the limits of implementing brackish-water desalination are related to raw water supply and concentrate disposal vs. the actual desalination technology available [3]. The preferred source of brackish water RO systems is groundwater since groundwater sources are typically more reliable and stable over long periods when compared to surface-water sources and usually require significantly less pretreatment [1,2].

The upper part of the Floridan aquifer system that supplies the feed water to the City of Fort Myers RO Facility is considered to be a semi-confined or leaky aquifer. This type of aquifer will have long-term water quality changes with regards to salinity (TDS). Salinity increases with depth, reaching seawater values of approximately 35,000 mg/L, therefore, groundwater pumping will cause increases in salinity in the pumped aquifer as it recharges upwards.

Considering the future predictions based on linear regression, the City of Fort Myers BWRO Facility can operate for approximately fifteen to twenty years based on the predicted wellfield TDS concentrations of 7,683 mg/L at year ten and 10,184 mg/L at year twenty. However, this will require the rotation of the pumping wells to control the feedwater salinity. The current two-stage configuration of membrane skids typically provides higher recovery compared to a single-stage RO configuration.

Since the City of Fort Myers RO water treatment facility uses two-stage membrane treatment, it is reasonable to expect the facility to be able to treat the predicted TDS concentrations out twenty years at which time the facility will likely need to be rebuilt as it will be at the end of its useful life. If the current membrane configuration shows signs of excessive fouling or if membrane feed pump pressures increase beyond the system capabilities, a re-evaluation of the membranes should be considered. The re-evaluation may consider reduced recovery of the existing membrane system, which started at approximately 80% and may require additional membrane skids to be added to the current configuration as well as supplementary raw water production wells to maintain the rated capacity of the facility. Additionally, increasing the operating pressure of the membrane system to treat higher salinity water may result in sustained recovery without supplemental raw water, but may decrease the useful life of the current membrane system. Furthermore, other equipment such as pumps may need to be replaced to achieve an increase in operating pressure. As influent TDS concentrations increase, there will be decreased permeate production as well as increased permeate TDS concentrations diminishing the water quality produced by the facility.

Over the past few years, three of the production wells have been taken out of service due to the increases in salinity or poor performance. Additional wells may have to be taken out of service and new wells added to maintain the feedwater salinity at acceptable concentrations to allow the plant to operate through its full lifecycle.

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