Operation of 4 Water Treatment Processes to Meet Blended Product Quality Goals at the Jupiter Water Treatment Plant

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With the proliferation of reverse osmosis (RO), nanofiltration (NF), and other membrane water treatment processes in Florida, the coexistence of multiple treatment processes at a treatment plant site or in a utility system has become relatively common. The town of Jupiter operates a water treatment plant that blends product waters from lime softening (LS), brackish water RO and anion exchange (IX) processes. A proposed NF plant will be constructed to augment capacity and replace a portion of LS production.

When the NF plant becomes operational, the plant capacity will include the following maximum production rates for each treatment process:

Reverse Osmosis	13.7 mgd
Anion Exchange	1.8 mgd
Lime Softening	9.0 mgd (standby capacity)
Nanofiltration	14.5 mgd (17.0 mgd potential)

This article describes how the contributions of each process will be balanced to meet the town's finished-water quality goals and a demand of up to 30 mgd.

Existing Finished Water Quality

The blended product currently being supplied to the distribution system is a soft to moderately hard water of relatively consistent composition in spite of the large differences in quality among the three individual product streams. Table 1 summarizes significant existing blended finished water parameters.

Finished-water stability is maintained at a slightly supersaturated condition with respect to calcium carbonate. This is controlled by the blend ratios of the three process streams and the addition of sodium hydroxide to adjust pH and alkalinity. The alkalinity adjustment is approximately a 30 mg/L increase in the RO product or a 10 mg/L increase in the total finished water.

Table 1
Existing Finished Water Quality

Parameter	Range
Calcium Hardness, mg/L as $CaCO_3$	40-65
Total Hardness, mg/L as $CaCO_3$	50-75
Total Alkalinity, mg/L as $CaCO_3$	30-60
Iron, mg/L	0.02-0.06
Color, Units	6-15
pH	8.5-8.8

Figure 1 illustrates the range of the Langelier Saturation Index (LSI) for the most recent one-year period, which shows that the finished water is generally supersaturated with respect to calcium carbonate.

A more quantitative index of super saturation is the Calcium Carbonate Precipitation Potential (CCPP). Figure 2 shows that the CCPP is typically 2 mg/L as $CaCO_3$ or higher.

The finished-water pH is also a signifi-

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Figure 1: Langelier Saturation Index (LSI)

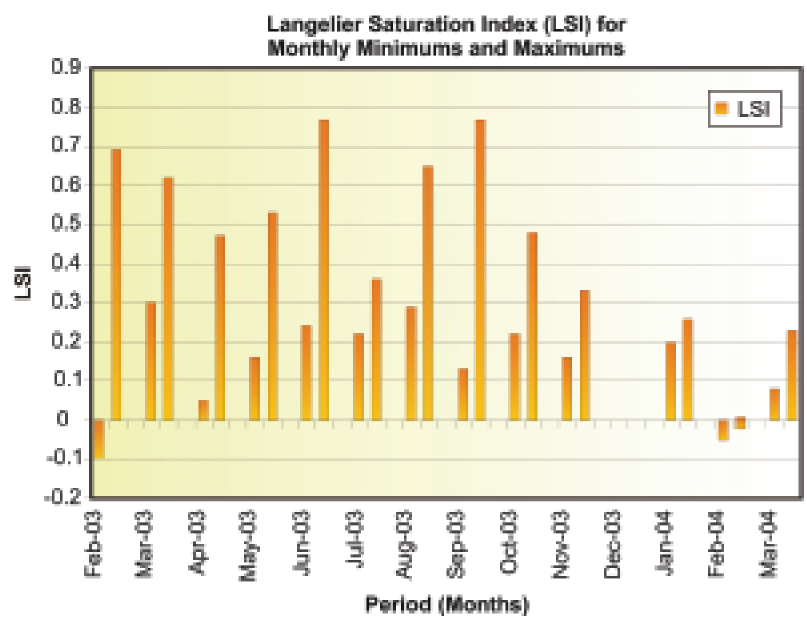

Figure 2: Calcium Carbonate Precipitation Potential (CCPP)

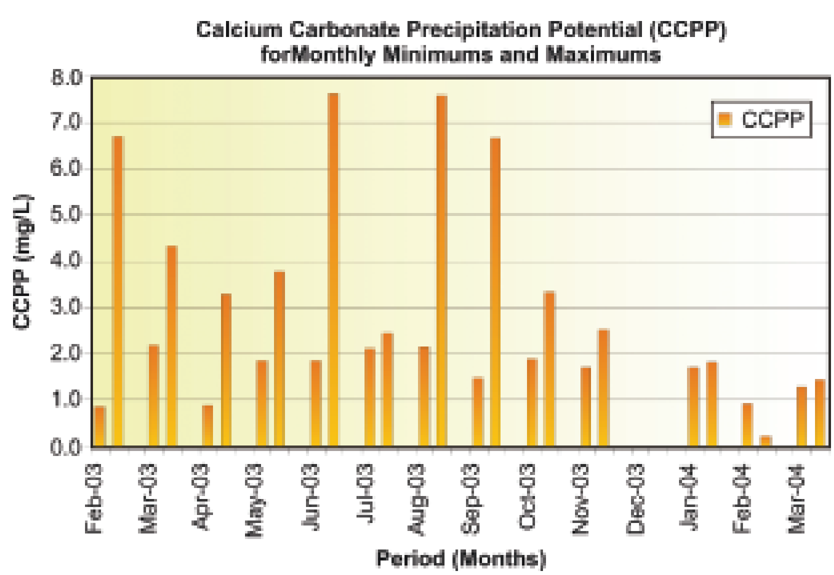

Table 2
Treatment Stream Composition for Blending Projections

Treatment Stream	Calcium Hardness (mg/L as $CaCO_3$)	Total Alkalinity (mg/L as aCO_3)	Color (Units)
IX	300	285	5
LS	65	45	15
NF	158	107	2
RO	5	13	1

Table 3
Finished-Water Quality Goals for the Blended Product

Parameter	Range
Calcium Hardness, mg/L as $CaCO_3$	60 to 90
Total Alkalinity, mg/L as $CaCO_3$	55 to 80
CCPP, mg/L as $CaCO_3$	3 to 6
Color, units	10
pH	8.6 to 8.8

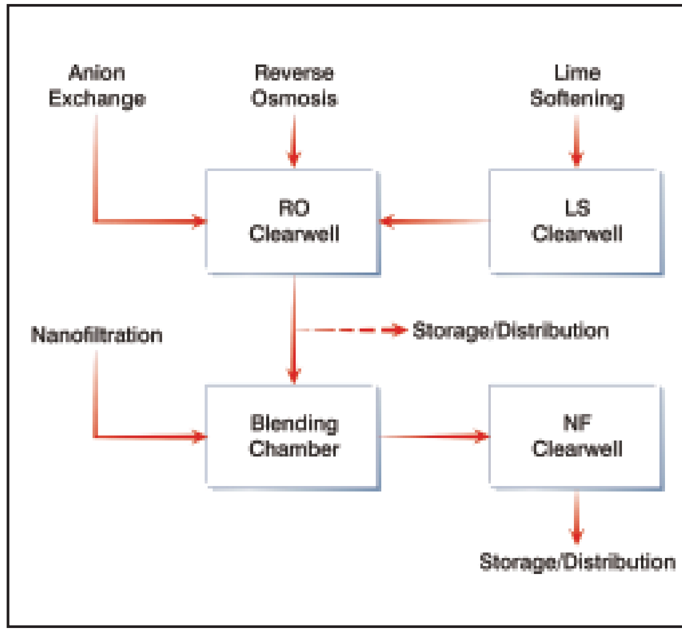

Figure 3: Product Streams Blending Configuration

cant parameter for the maintenance and effectiveness of a disinfectant residual in the distribution system. The current pH range of 8.5-8.8 is favorable for disinfection by a monochloramine residual maintained in the town's system. Once the NF plant is on line, the feasibility of switching to a free chlorine residual will be evaluated.

Color is a critical determinant of the required blend ratios. It is maintained at approximately 15 color units by blending low-color RO and IX product with higher-color LS product. Color is also indicative of the organic substances in the water and therefore is an indirect indicator of the disinfection byproduct formation tendency in the distribution system.

Future Water Quality Goals

The addition of the NF process will modify the protocol used to blend all four treatment streams and alter finished-water quality goals. Critical parameters have been projected for future finished-water blends to evaluate blend ratios and quality goals.

Blending projections are based on the characteristics of the four treatment streams given in Table 2. The parameters for RO, LS, and IX are typical of the existing treatment processes. The NF process is configured for a relatively high salt passage, producing permeate with high hardness and alkalinity values. This approach is based on a number of considerations and constraints.

An NF product water recovery of 85 percent is required to utilize the water supply from the town's surficial wellfields efficiently and to limit the volume of concentrate produced. At the same time, the total dissolved solids (TDS) concentration in the concentrate stream is limited to 2,200 mg/L to allow beneficial use of the concentrate for turf irrigation when blended with reclaimed water or canal water.

The existing raw-water supply has an average total iron concentration of 0.3 mg/L which limits permeate iron concentration to less than 0.1 mg/L, even with high NF salt passage. The NF stream alkalinity in Table 2 is an adjusted value based on acidifying the NF permeate to a pH of 6.4 prior to degasification to enhance hydrogen sulfide removal and limit alkalinity in the blended product.

Figure 3 illustrates how the four produce streams will be combined. The RO, LS, and IX streams are blended in the existing RO clearwell. After the NF plant goes into operation, the blend from the RO clearwell will be transferred to the NF clearwell, where final disinfectant addition and pH adjustment will be made. The blend from the RO clearwell will have a free chlorine residual sufficient to achieve a 2-log virus inactivation prior to blending with NF product and establishment of a chloramine residual.

Table 3 presents the finished-water quality goals for the blended product. The minimum CCPP level is increased to 3 mg/L to improve corrosion control in the distribution system. The values for calcium hardness,

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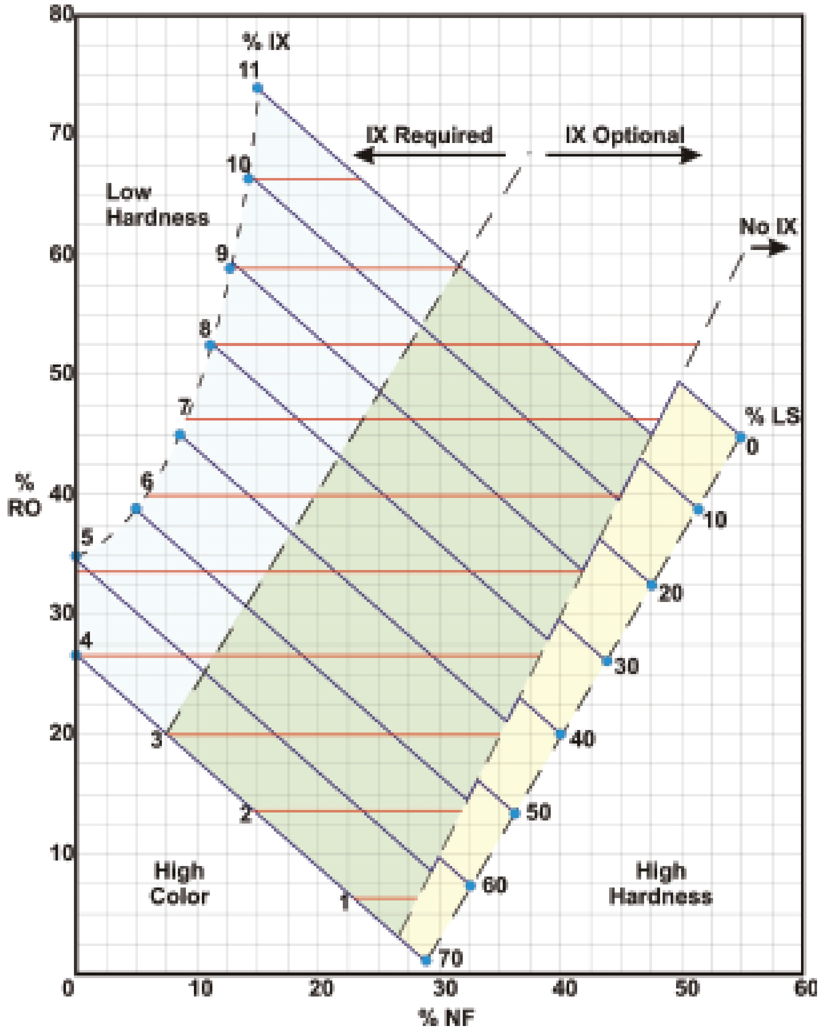

Figure 4 Blending Matrix

Number of RO Skids (RO Capacity in MGD)		Number of Nanofiltration Skids (NF Capacity in MGD): 1 (2.9)		2 (5.8)		3 (8.7)		4 (11.6)		5 (14.5)	
1 (1.5)	LS (MGD)	8.3 - 9.0	CaH	CaH > 90		CaH > 90		CaH > 90		CaH > 90	
	IX (MGD)	0.225	83 - 82								
2 (3.0)	LS (MGD)	3.0 - 9.0	CaH	9.0	CaH	CaH > 90		CaH > 90		CaH > 90	
	IX (MGD)	0.450	88 - 78	0.450	90						
3 (4.5)	LS (MGD)	0 - 9.0	CaH	6.0 - 9.0	CaH	9.0	CaH	CaH > 90		CaH > 90	
	IX (MGD)	0.675	85 - 74	0.675	90 - 86	0	90				
4 (6.0)	LS (MGD)	0 - 9.0	CaH	3.0 - 9.0	CaH	3.0 - 9.0	CaH	CaH > 90		CaH > 90	
	IX (MGD)	0.900	77 - 71	0.900	90 - 83	0	90 - 84				
5 (7.5)	LS (MGD)	0 - 9.0	CaH	0 - 9.0	CaH	7.5 - 9.0	CaH	6.0 - 9.0	CaH	CaH > 90	
	IX (MGD)	1.125	72 - 69	1.125	89 - 80	1.125	90 - 89	0	90 - 87		
6 (9.0)	LS (MGD)	0 - 9.0	CaH	0 - 9.0	CaH	4.5 - 9.0	CaH	3.0 - 9.0	CaH	CaH > 90	
	IX (MGD)	1.350	69 - 67	1.350	85 - 78	1.350	90 - 86	0	88 - 83		
7 (10.5)	LS (MGD)	0 - 9.0	CaH	0 - 9.0	CaH	3.0 - 9.0	CaH	0 - 8.0	CaH	4.0 - 5.0	CaH
	IX (MGD)	1.575	65 - 65	1.575	80 - 75	1.575	88 - 83	0	85 - 80	0	90 - 89
8 (12.0)	LS (MGD)	0 - 9.0	CaH	0 - 9.0	CaH	0 - 7.5	CaH	0 - 6.5	CaH	0 - 3.5	CaH
	IX (MGD)	1.800	63 - 64	1.800	77 - 73	1.800	88 - 82	0	80 - 77	0	89 - 86
9 (13.7)	LS (MGD)	7.5 - 9	CaH	0 - 9.0	CaH	0 - 6.0	CaH	0 - 3.0	CaH	0	CaH
	IX (MGD)	1.800	60 - 60	1.800	72 - 70	1.800	82 - 79	1.800	90 - 80	0	84

Note: Shaded combinations allow 30 MGD total plant output.

Figure 5: Operating Combinations for Each Unit Process

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alkalinity, and pH shown in the table are consistent with this CCPP goal. A maximum color goal of 10 is feasible with the addition of NF treatment to the plant.

Treatment Process Operation Matrix

The contribution of each of the four treatment processes to the total blended product flow must be adjusted to meet the finished-water quality goals in Table 3. Calcium hardness and total alkalinity are the most significant factors affecting the blend ratios. One limiting condition is the requirement that calcium hardness and alkalinity must be high enough to provide a CCPP of at least 3 in the blend. At the other extreme, calcium hardness and total alkalinity should be limited to no more than 90 mg/L and 80 mg/L, respectively.

The upper calcium and alkalinity limits are necessary to avoid excessive scaling tendencies. Alkalinity should also be limited to control the dissolved inorganic carbonate concentration which tends to increase corrosivity toward lead.

An overall blending matrix is presented graphically in Figure 4 which shows the relative contributions of each process that meet the blended quality goals of Table 3. In Figure 4, the IX contribution is 15 percent of the RO production, which reflects the operating strategy of the existing plant. At relatively high NF percentages, the IX must be curtailed to avoid excessive hardness. Blended product alkalinity includes 10 mg/L added for pH adjustment.

Figure 5 shows the blending matrix in terms of the flows from each process. This figure incorporates the following additional constraints:

- Flows are limited to available capacities.
- RO and NF flows are in discrete blocks reflecting skid capacities.
- LS cannot be operated at less than 3 mgd.

The maximum plant production of 30.0 mgd is available for those combinations that are shaded in Figure 5. All other combinations are capacity limited by one of the four processes.

Conclusions

The implementation of NF treatment at the town of Jupiter's water treatment plant will result in the following operational and finished-water quality benefits:

- Increase capacity and retire obsolete facilities.
- Reduce quantity of lime sludge.
- Reduce finished-water color.
- Increase distribution system corrosion protection.
- Meet near-term disinfection requirements using a chloramine residual with the possibility of changing to a free chlorine residual in the future.