EVALUATION OF SLOWSAND FILTRATION FOR REDUCING COSTS OF DESALINATION BY REVERSE OSMOSIS

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Summary

For desalination of surface waters, this study evaluates slowsand (SS) filtration as a low-cost pretreatment to reverse osmosis (RO). During 12 months of pilot tests at Reclamation's Water Quality Improvement Center (WQIC), SS filtration produced water with average values of 0.17 to 0.22 Nephelometric Turbidity Units (NTU) and 3.1 to 4.5 silt density index (SDI) for two surface water supplies: Colorado River water and Yuma Desalting Plant (YDP) brackish source water. With average values of 2.4 and 2.6 NTU for turbidity and 39 and 38 for SDI in the two raw water supplies, SS filtration reduced both turbidity and SDI by an average of 90 percent.

During 6 months of RO operation, SS filtration of 3,000-mg/L-TDS YDP brackish source water sufficiently removed particulates to avoid a decline in the water transport coefficient (A) of RO elements composed of polyamide membranes. Declining salt passage, however, may indicate fouling.

For both water supplies, rapid-sand "roughing filters" operating without coagulants reduced turbidity and SDI by 70 to 80 percent and extended SS filter run lengths by a factor of five or more.

The results indicate that with the existing rapid-sand filters at the YDP and a SS filtration rate of 5 million gallons per acre per day (mgad) (4.7 m/d, 0.08 gal/ft^2/min), the SS filters would require cleaning four times per year. At the same conditions with Colorado River water, the SS filters would require cleaning three times per year. Without roughing filters, the cleaning frequency increases to 25 per year with YDP source water and 15 per year with Colorado River water.

Planned future tests include evaluating filter sand dredged from the Colorado River and building and operating a 0.2-acre, 0.8-MGD SS filter as part of WQIC Pilot System 1.

Introduction

Desalination of seawater and inland brackish waters offers new drought-proof water supplies. In addition, desalination of moderate- (700- to 1,500-mg/L) salinity freshwater supplies offers benefits associated with improved water quality. For example, a municipal desalination plant that reduces the salinity (total dissolved solids (TDS)) of Colorado River water from 700 mg/L to 200 mg/L supplies water that meets the 500-mg/L value set by the USEPA as a secondary drinking water standard and by the World Health Organization as a recommended standard. The lower salinity water provides economic benefits of $6 to $14 per month per household (e.g., in reduced corrosion and use of detergents and elimination of water softeners), offers possible aesthetic and health benefits, and decreases the salinity of municipal wastewater by about 500 mg/L (1).

Because particulates in water supplies can rapidly coat and "foul" reverse osmosis (RO) membrane equipment, all surface-water RO plants operate pretreatment filtration equipment to remove particulates. Reclamation has experienced excellent results in pilot studies with microfiltration and ultrafiltration pretreatment equipment (2, 3, 4, 5).

To reduce the costs of desalination, Reclamation has begun evaluating the effectiveness of slowsand (SS) filtration, a "low-tech," "appropriate" water treatment technology. By gravity, with a water head up to about 4 feet, SS filtration filters water through 18 to 42 inches of sand with an effective

size of 0.15 to 0.4 mm at a filtration rate of 2 to 10 million gallons per acre per day (mgad) (1.9 to 9.4 m/d; 0.03 to 0.16 gal/ft^2/min; 1/100th to 1/20th that of 3-gal/ft^2/min "rapid-sand" filtration) (6, 7).

Slowsand filtration offers a valuable treatment technology in developing countries because of its effectiveness, low cost, low labor requirement, and no purchase or transport of chemicals.

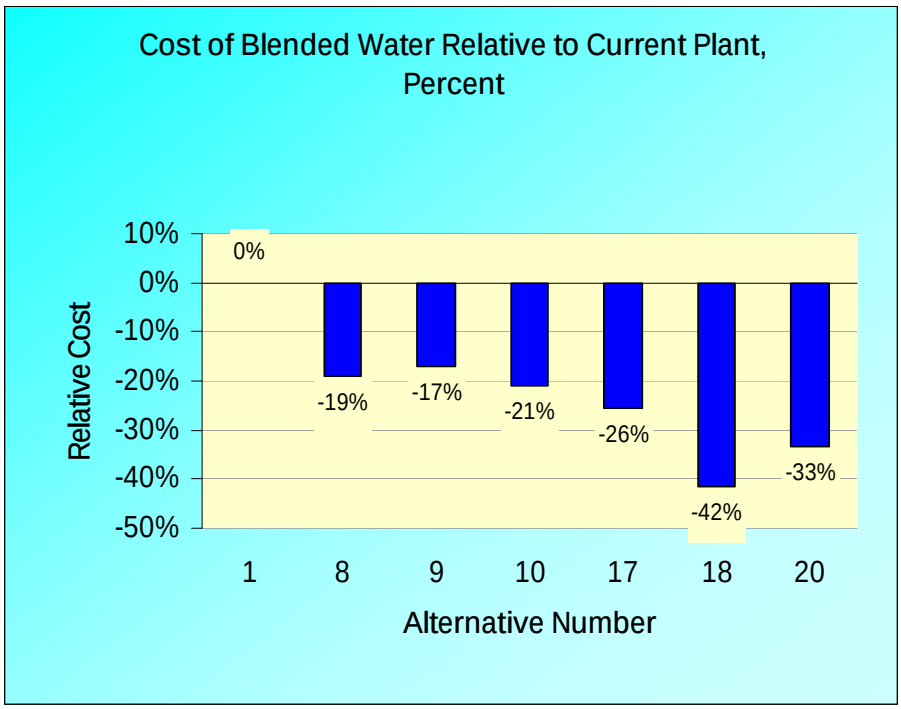
The City of Yuma, Arizona, previously used SS filtration to treat Colorado River water from about 1900 to 1954 (8, 9, 10). More recently, Brent Cluff reports good results using SS filtration as pretreatment to nanofiltration (11, 12).

Because SS filtration uses no chemical coagulants or polymer coagulant aides, it avoids introducing these potential foulants into RO feedwater.

In 2000, Reclamation's Phoenix Area Office (1) estimated the costs of three water treatment filtration processes: SS filtration, "conventional treatment" (coagulation, flocculation, settling, and rapid-sand filtration), and low-pressure membrane filtration (microfiltration (MF) or ultrafiltration (UF)). The study estimated that for the subject locality, SS filtration costs 75-percent less than either conventional treatment or MF or UF water treatment. For pretreatment filtration to reverse osmosis (RO) desalination, the study estimated that, if effective, SS filtration could reduce total costs of desalination (including concentrate disposal by a low-volume pipeline from Tucson and Phoenix to Yuma) by 20 percent compared to conventional water treatment or to MF or UF.

In 2001 and 2002, Reclamation's Science and Technology Program co-sponsored a 5-month pilot test using SS filtration to treat Colorado River Water delivered by the Central Arizona Project (CAP) (13). In this test, RO polyamide membrane elements operated with moderate, but apparently removable fouling.

If effective on YDP source water, CH2M Hill engineers estimate that SS filtration may reduce YDP costs by an estimated 33 percent (see **Figure 1**) (14).



Pretreatment	RO
1. Lime softening, clarification, rapid-sand filtration with dual-media gravity filters (present design)	CA
8. Coagulation, flocculation, and rapid-sand filters	CA
9 & 10. Lime softening, clarification, and rapid-sand filters (71% RO recovery for 9 and 83% RO recovery for 10)	PA
17. Rapid-sand filters and MF or UF	PA
18. Coagulation, flocculation, and rapid-sand filters	PA
20 Rapid-sand filters and slowsand filters	PA

Figure 1.—Estimated annualized costs relative to present plant design of the Yuma Desalting Plant. RO membrane types include cellulose acetate (CA) and polyamide (PA).

To evaluate the effectiveness of SS filtration, 2006-2007 pilot tests at Reclamation's WQIC (http://www.usbr.gov/lc/yuma/facilities/wqic/yao_facilities_wqic.html) address the questions:

1. Does SS filtration effectively remove particulates from water so that polyamide RO membrane elements can operate with little or no fouling?
2. What effects do two surface water supplies: 800-mg/L-TDS Colorado River water and 3,000-mg/L-TDS YDP brackish source water, have on SS filter run length, turbidity, SDI, and RO fouling?
3. What effects do SS filtration rates have on SS filter run length, turbidity, and SDI?
4. To evaluate the benefit of using the existing rapid-sand filters at the YDP, what effects do rapid sand "roughing filters" operating without coagulants have on SS feed turbidity, SS feed SDI, and SS filter run length?
5. What effects does sand type have on SS filter run length, turbidity, SDI, and RO fouling?

This paper presents results of 2006 WQIC test results regarding questions 1, 2, and 4 above.

Procedure

2006 Tests at the WQIC evaluated the effects of the process variables listed in **Table 1** on the response variables listed in **Table 2**.

Table 1. Process variables

Process variable	Level	
	-1	**+1**
1. Water supply	SS1 and SS2 800-mg/L-TDS Colorado River water diverted at Imperial Dam	SS3 and SS4 3,000-mg/L-TDS brackish water supply to the YDP (delivered by MODE canal)
2. Roughing filter	SS2 and SS4 None	SS1 and SS3 Rapid-sand pressure filter without coagulant

Table 2. Response variables

Response variable	Unit	Measurement method
Filter run length	days	Duration between filter cleanings conducted at a filter pressure drop of 4 ft of water
Turbidity	NTU	Daily: Hach 2100P and Hach 2100N
Silt density index (SDI)	-	Weekly: Chemetek FPA 3300 Daily: Chemetek FPA 5000T
Changes in RO performance properties:		1,000 hours of operation or greater with 2.5-inch by 4-inch polyamide (PA) RO elements
Water transport coefficient (A)[1] normalized to 25 C	10^{-12} m/s/Pa (10^{-5} cm/s/bar)	
Salt passage	percent	

[1] The water transport coefficient (A) represents the proportionality coefficient between product water flux (q [m/s]) and hydrostatic and osmotic pressures difference (ΔP [Pa] - $\Delta\pi$ [Pa]) across the membrane in the equation: $q = A (\Delta P - \Delta\pi)$.

Filter Equipment

Tests operate with four pilot filters: SS1, SS2, SS3, and SS4. SS1 and SS2 operate in 14-ft-diameter HDPE tanks with an area of 150 ft^2. SS3 and SS4 operate in 10-ft-diameter HDPE tanks with an area of 75 ft^2. All SS tanks have a height of 10 ft. In 2006, all four SS filters contained filter media supplied by Oglebay Norton Industrial Sands, Inc. (www.oglebaynorton.com) with descriptions and quantities listed in **Table 3**. The underdrain consists of slotted 4-in PVC pipe with 1/16-in slot width. See **Figures 2, 3, and** 4 for the pilot process layout and top views of SS1 and SS2.

Table 3. Slowsand filter media sizes and depths

Layer	Media	Specification and gradation	Size (d_{10})	Uniformity coefficient (d_{60}/d_{10})	Depth (in)
Top: Filter sand	Silica sand	Specification	0.27 – 0.33 mm	1.7 max	42
		10/5-7/04 Oglebay Norton sieve	0.29 mm	1.42	
		5/05 sieve	0.31 mm	1.46	
Middle: Fine gravel	Silica gravel	Specification	No 10 (2.0 mm, 5/64 in) x No.4 (4.75 mm, 3/16 in)	-	4
		5/05 sieve	1.95 mm (d_{60} = 3.4 mm) (No.10 x No.6)	1.76	
Bottom: Gravel	Silica gravel	Specification	No.4 (4.75 mm, 3/16 in) x No. 1/2 (12.5 mm, 0.5 in)	-	8
		5/05 sieve	5.12 mm (d_{60} = 7.8 mm) (No. 4 x No. 5/16)	1.52	

Figure 2.—Slowsand pilot process area showing YDP grit basins serving as intake reservoirs in foreground, two pressure rapid-sand roughing filters, and four slowsand pilot filters

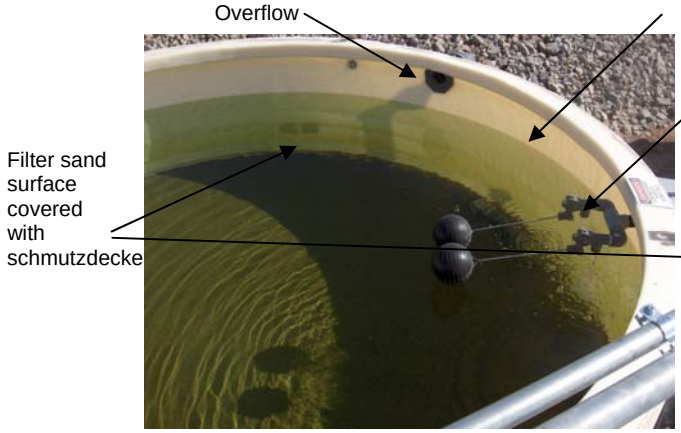


Figure 3.—SS1 using roughing filter RF1

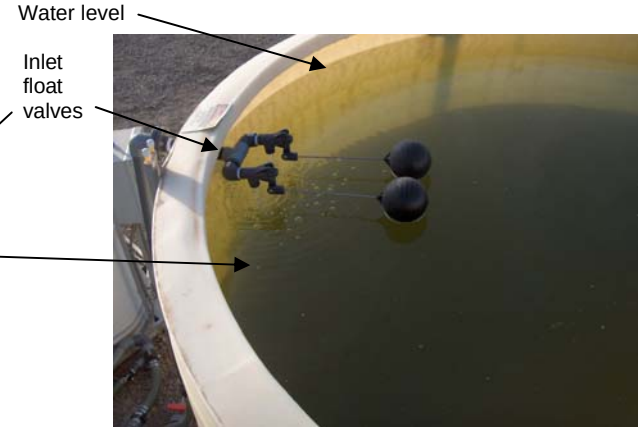


Figure 4.—SS2 (no roughing filter)

Pilot filters SS1 and SS3 each operate downstream of a 3-ft-diameter (7-ft^2) rapid-sand pressure "roughing filter" (RF1 and RF3). The two roughing filters contain filter media supplied by Wastewater Resources of Scottsdale, Arizona, with descriptions and quantities listed in **Table 4**.

Table 4. Roughing filter media sizes and depths

Layer	Material	Specification and gradation	Size (d_{10})	Uniformity coefficient (d_{60}/d_{10})	Depth (in)
1-top	Anthracite	Specification	1.0-1.1 mm	1.7 max	20
		8/9/04 sieve	1.02 mm	1.4	
2	Silica sand	Specification	0.45-0.55 mm	1.5 max	10
		8/9/04 sieve	0.49 mm	1.3	
3	Garnet sand (50 mesh)	Specification	0.25-.30 mm	1.6 max	4
		9/5/04 sieve	0.29 mm	1.3	
4	Garnet gravel (8/12 mesh)	Specification	1.40-1.55 mm	1.6 max	3
		8/8/04 sieve	1.67 mm	1.4	
5	Silica gravel	Specification	3/8 x 3/16 in	-	3
		8/17/04 sieve	3/8 x 3/16 in	1.4	
6	Silica gravel	Specification	3/4 x 3/8 in	-	3
		8/17/04 sieve	3/4 x 3/8 in	1.2	
7-bottom	Silica gravel	Specification	1.5 x 3/4 in	-	14
		8/17/04 sieve	1.5 x 3/4 in	1.4	

Filter operation

The SS filters operate with about 4.5 feet of water above the sand surface, generally with a slight overflow. When the pressure differential across the filter (as measured by the difference in the inlet and outlet water levels in two sight tubes) approaches 4 ft, the filter run ends. Operations personnel drain the water level to about 8 inches below the surface, enter the filter, and manually scrape off and remove 0.75-inch to 1-inch layer of sand. After backfilling with WQIC service water (RO product with pH adjusted to 8.5) to a 1-ft depth, filter operation resumes with discharge of supply water through the float valve into the tank.

In 2006, the roughing filters operated at average filtration rates of 3.5 gal/ft^2/min (25 gal/min) for RF1 and 2.0 gal/ft^2/min (14 gal/min) for RF3. Cleaning the roughing filters involved backwashing on Tuesdays and Friday of each week using air scour for 5 minutes at 3 cfm/ft^2 (20 cfm) for RF1 and 1.5 cfm/ft^2 (10 cfm) for RF3 followed by water wash for 6 minutes at approx. 13 gal/ft^2/min (90 gal/min).

RO equipment and operation

RO operation evaluates the pretreatment effectiveness of the SS filters in removing particulates from the water supplies and delivering foulant-free water to the pilot RO units. To evaluate RO operation at 80-percent recovery, a WQIC membrane unit (MU) operates twenty-one 2.5-inch by 40-inch RO elements in a two-stage array. The MU operates at 4.2 L/min reject flow and 16.8 L/min product flow, which for elements containing 25-ft^2 of membrane corresponds to a water flux of 12 gal/ft^2/day (gfd). Stage 1 can operate with product backpressure to maintain similar water fluxes in stages 1 and 2. Prior to delivery of the SS filter effluent to the MU, chemical feed pumps add bleach, ammonium sulfate, antiscalant (Ecolab Flocon 135), and sulfuric acid (to reduce pH to 6.8 to 7.0).

Results

Figures 5 and 6 summarize the performance during a 6-month test with 21 Hydranautics 2540 RO elements (14 LFC3 in stage 1 and 7 ESPA1 in stage 2) on SS3-filtered brackish MODE water. After initial operating adjustments, the water transport coefficients remained steady at 9 to 10 x 10^{-12} m/s/Pa (9 to 10 x 10^{-5} cm/s/bar, 0.13 to 0.15 gfd/psi). Salt passage decreased from 3.4 percent in July 2006 to 0.9 percent in February 2007. During the same period, water temperature decreased from 34 C to 17 C.

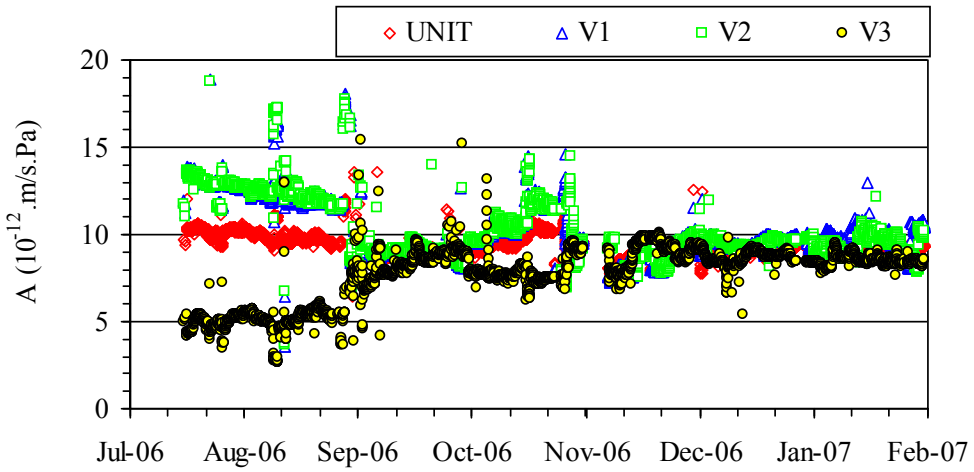


Figure 5.—Values of the membrane water transport coefficient (A) for Hydranautics ESPA1 2540 RO elements. To convert to gfd/psi, multiply y-scale by 0.0146.

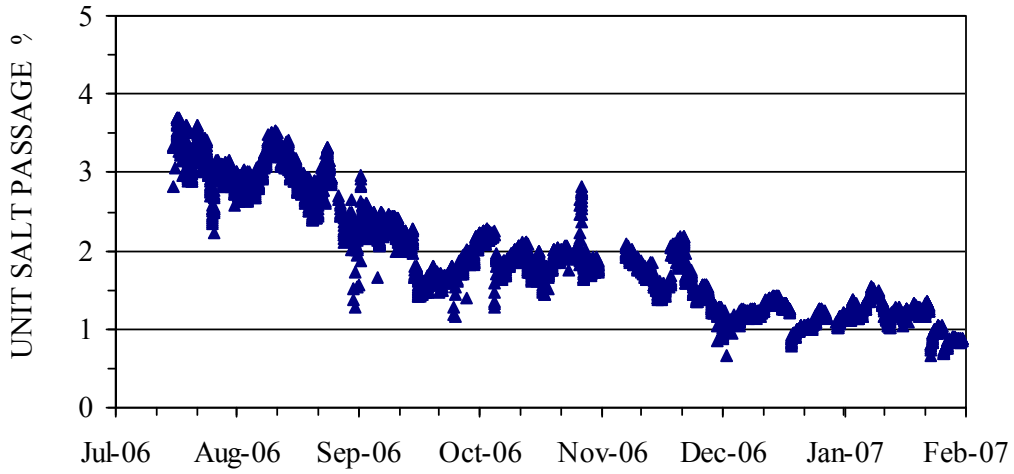


Figure 6.—Salt passage for WQIC MU4 operating with twenty-one Hydranautics 2540 RO elements (14 LFC3 in stage 1 and 7 ESPA1 in stage 2) at 12 gfd and 80-percent recovery.

Figures 7-10 show measurements of turbidity and SDI for the four SS pilot filters. By filter run number, **Tables 5-8** summarize filtration rates, filter run lengths, turbidity values, and SDI values.

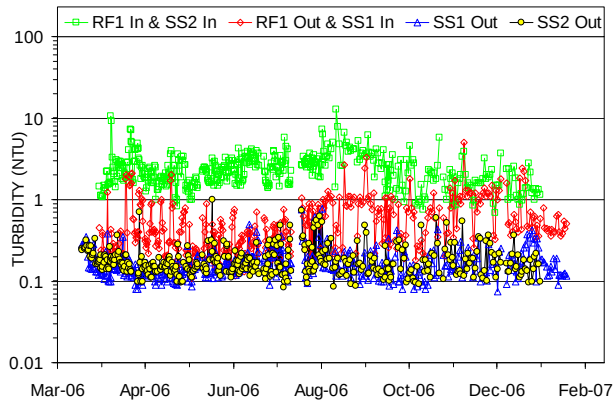


Figure 7.—Turbidity measurements: SS1 and SS2 on Colorado River water

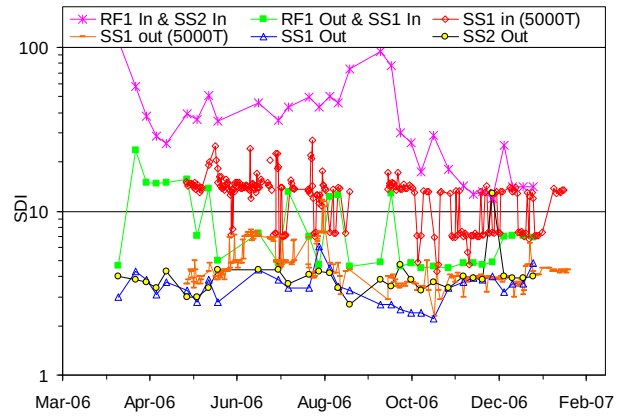


Figure 8.—SDI measurements: SS1 and SS2 on Colorado River water

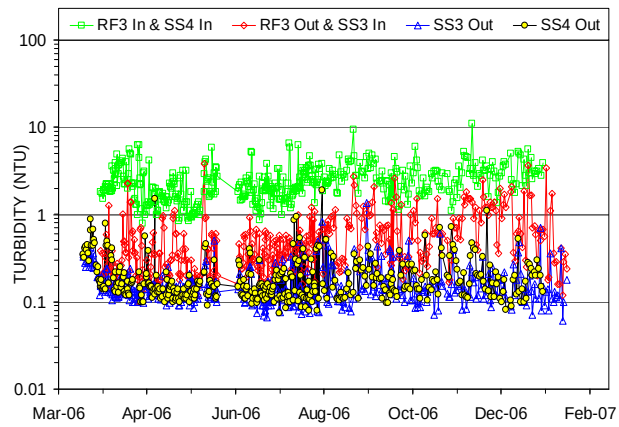


Figure 9.—Turbidity measurements: SS3 and SS4 on MODE water

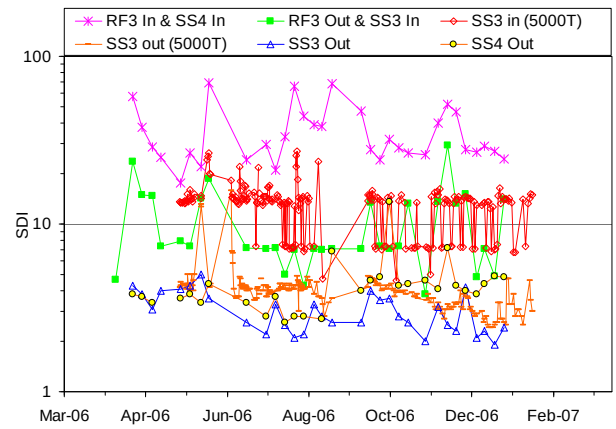


Figure 10.—SDI measurements: SS3 and SS4 on MODE water

Table 5. SS1 performance with roughing filter 1 (RF1) on Colorado River water

No.	End date	Flow gal/min	SS filtration rate mgad	m/d	gal/ft²/min	dP_{end} ft	Length days	Temp C	pH	Turbidity (d) NTU RF In	SS In	SS Out	SDI (w) RF In	SS In	SS Out	SDI (d) SS In	SS Out	Removal, percent Turbidity RF	RF+SS	SDI (w) RF	SS	RF+SS	SDI (d) SS
Start	2/28/2006							SS Out															
1	5/26/2006	14	6.1	5.7	0.10	1.9	102	22.8	8.0	2.5	0.53	0.15	50	14.7	3.5	14.7	3.7	79	94	70	76	93	75
2	7/14/2006	23	9.5	8.9	0.15	4.4	45	28.7	7.9	2.3	0.30	0.16	42	8.3	3.5	14.6	5.3	87	93	80	58	92	64
3	11/17/2006	22	9.3	8.7	0.15	5.0	106	27.1	7.8	2.9	0.61	0.19	47	7.3	3.3	12.8	4.9	79	93	85	55	93	62
4	1/12/2007	20	8.5	7.9	0.14	4.3	47	13.3	8.1	1.7	0.99	0.17	15	5.6	3.7	9.3	3.8	43	90	64	35	76	59
	Average	20	8.3	7.8	0.13	3.9	75	23.0	7.9	2.4	0.61	0.17	39	9.0	3.5	12.8	4.4	72	93	75	56	89	65

dP = Pressure drop across filter, ft of water Filter run length corresponds to dP = 4 ft

(d) and (w) refer to averages of approximately daily and weekly measurements

SDI (d) lists averages of daily measurements recorded with a Chemetek FPA 5000T tape unit.

SDI (w) lists averages of weekly measurements recorded with a Chemetek FPA 3300.

SDI values of 0 to 5 divide the plugging factor by the 15-minute time period

SDI values of 5 to 110 divide the ending plugging factor of ca. 75% by the time period (between 40 s and 15 min)

Table 6. SS3 performance with roughing filter 3 (RF3) on 3,000-mg/L-TDS MODE water

No.	End date	Flow gal/min	SS filtration rate mgad	m/d	gal/ft²/min	dP_{end} ft	Length days	Temp C	pH	Turbidity (d) NTU RF In	SS In	SS Out	SDI (w) RF In	SS In	SS Out	SDI (d) SS In	SS Out	Removal, percent Turbidity RF	RF+SS	SDI (w) RF	SS	RF+SS	SDI (d) SS
Start	2/17/2006							SS Out															
1	4/13/2006	7.7	6.4	6.0	0.10	4.0	55	21.0	7.9	2.6	0.29	0.20	-	4.7	-	-	-	89	92	-	-	-	-
2	5/18/2006	8.7	7.3	6.8	0.12	2.0	108	24.2	7.8	2.1	0.38	0.13	37	15.2	3.8	-	-	82	94	59	75	90	-
3	8/2/2006	9.0	7.6	7.1	0.12	4.5	58	29.3	7.7	2.0	0.39	0.14	32	10.4	3.6	15.1	4.6	80	93	67	65	88	69
4	8/25/2006	8.7	7.3	6.8	0.12	3.4	22	30.4	7.6	2.7	0.46	0.17	41	5.9	2.5	12.4	4.2	83	94	86	57	94	66
5	10/5/2006	10.9	9.1	8.5	0.15	3.3	41	28.2	7.7	3.2	0.81	0.23	49	7.1	2.9	12.2	3.9	75	93	85	59	94	68
6	1/19/2007	9.4	7.8	7.3	0.12	5.8	100	18.0	7.8	2.9	0.88	0.17	32	10.8	2.8	11.7	3.5	70	94	67	74	91	70
	Average	9.1	7.6	7.1	0.12	3.8	64	25.2	7.7	2.6	0.53	0.18	38	9.0	3.1	12.8	4.1	80	93	73	66	92	68

Table 7. SS2 performance on Colorado River water

No.	End date	Flow gal/min	SS filtration rate mgad	m/d	gal/ft²/min	dP_{end} ft	Length days	Temp C	pH	Turbidity (d) NTU		SDI (w)		Removal, percent Turbidity	SDI (w)
Start	2/28/2006							SS Out		SS In	SS Out	SS In	SS Out	SS	SS
1	4/10/2006	8	3.5	3.3	0.06	5.0	36	20.8	8.1	2.4	0.20	110	4.0	91	96
2	5/8/2006	16	6.8	6.4	0.11	4.7	25	22.5	8.1	2.7	0.17	42	3.6	94	91
3	5/26/2006	23	9.4	8.8	0.15	2.9	20	26.2	8.1	2.1	0.15	33	3.7	93	89
4	6/13/2006	23	9.6	9.0	0.15	4.0	16	27.4	7.9	1.8	0.16	44	3.2	91	93
5	6/23/2006	24	10.0	9.3	0.16	4.2	9	28.2	8.0	2.2	0.25	36	4.4	89	88
6	6/29/2006	21	8.6	8.0	0.14	4.9	5	28.3	8.0	2.5	0.17	-	-	93	-
7	7/6/2006	22	9.0	8.4	0.14	5.2	5	29.1	7.8	2.3	0.17	-	-	93	-
8	7/12/2006	24	9.9	9.2	0.16	5.1	4	29.8	7.8	3.3	0.16	-	-	95	-
9	7/26/2006	18	7.5	7.0	0.12	5.0	10	32.1	7.8	2.5	0.17	46	4.4	93	90
10	8/7/2006	18	7.3	6.8	0.12	4.9	9	29.4	7.8	2.8	0.22	39	4.0	92	90
11	9/19/2006	17	6.9	6.5	0.11	5.1	33	30.0	7.9	3.7	0.23	53	3.7	94	93
12	10/2/2006	15	6.3	5.9	0.10	4.2	13	26.0	7.9	3.9	0.21	-	-	95	-
13	10/17/2006	16	6.6	6.2	0.11	4.8	11	24.7	8.0	2.5	0.14	86	3.7	94	96
14	11/3/2006	15	6.2	5.8	0.10	4.9	13	20.5	8.0	2.0	0.17	25	3.9	91	84
15	11/22/2006	17	7.2	6.7	0.11	4.4	14	19.4	8.1	1.9	0.25	24	3.6	87	85
16	12/21/2006	17	7.2	6.8	0.12	4.0	28	13.4	8.1	1.8	0.21	13	6.2	89	53
17	1/24/2007	18	7.5	7.0	0.12	5.0	29	11.5	8.1	1.5	0.16	17	4.0	89	77
	Average	18	7.6	7.1	0.12	4.6	16	24.7	8.0	2.5	0.19	43	4.0	92	86

Table 8. SS4 performance on 3,000-mg/L-TDS MODE water

No.	End date	Flow gal/min	SS filtration rate mgad	m/d	gal/ft²/min	dP_{end} ft	Length days	Temp C	pH	Turbidity (d) NTU		SDI (w)		Removal, percent Turbidity	SDI (w)
Start	2/17/2006							SS Out		SS In	SS Out	SS In	SS Out	SS	SS
1	3/21/2006	7.3	6.1	5.7	0.10	6.1	28	20.1	7.9	-	0.38	-	-	-	-
2	4/5/2006	7.5	6.2	5.8	0.10	6.1	10	22.4	7.9	2.0	0.35	-	-	82	-
3	4/13/2006	7.3	6.1	5.7	0.10	4.5	6	21.6	7.8	3.2	0.21	-	-	94	-
4	4/18/2006	7.5	6.3	5.9	0.10	5.6	4	22.9	7.9	3.1	0.15	-	-	95	-
5	5/1/2006	6.3	5.2	4.9	0.08	6.0	11	22.5	7.8	2.4	0.19	48	3.8	92	92
6	5/11/2006	6.1	5.1	4.8	0.08	2.3	10	25.3	7.8	1.7	0.21	29	3.4	87	88
7	5/22/2006	6.5	5.4	5.1	0.09	6.2	9	27.5	7.8	1.8	0.13	25	-	92	-
8	6/13/2006	7.0	5.9	5.5	0.09	4.0	17	27.3	7.8	1.9	0.16	22	3.6	92	84
9	6/23/2006	8.8	7.3	6.9	0.12	4.6	3	27.3	7.8	2.6	0.16	70	4.4	94	94
10	7/11/2006	8.8	7.3	6.9	0.12	6.1	16	29.4	7.7	2.2	0.18	-	-	92	-
11	8/2/2006	8.8	7.4	6.9	0.12	3.6	22	31.1	7.6	1.9	0.15	27	3.1	92	88
12	8/25/2006	6.7	5.6	5.2	0.09	4.0	21	30.2	7.6	2.7	0.22	41	3.0	92	93
13	9/13/2006	9.0	7.5	7.0	0.12	5.7	15	29.6	7.7	2.7	0.29	39	2.7	89	93
14	9/27/2006	4.9	4.1	3.8	0.07	5.3	11	25.4	7.7	3.9	0.23	69	6.9	94	90
15	10/17/2006	4.7	3.9	3.7	0.06	6.0	15	25.9	7.7	2.8	0.17	37	4.3	94	89
16	10/26/2006	6.2	5.2	4.8	0.08	5.8	7	20.6	7.8	2.1	0.21	24	4.8	90	80
17	11/3/2006	7.7	6.4	6.0	0.10	4.0	8	20.8	7.8	3.0	0.18	30	9.0	94	70
18	11/14/2006	5.8	4.9	4.6	0.08	6.0	7	20.9	7.8	2.5	0.20	26	4.4	92	83
19	11/22/2006	6.7	5.6	5.3	0.09	6.0	5	19.3	7.8	2.3	0.36	26	4.6	84	82
20	12/4/2006	6.7	5.6	5.2	0.09	6.1	8	16.8	7.8	3.0	0.26	40	4.1	92	90
21	12/21/2006	8.5	7.1	6.6	0.11	6.0	16	14.3	7.8	3.5	0.29	49	5.8	92	88
22	1/12/2007	8.3	6.9	6.5	0.11	6.0	18	14.4	7.8	3.2	0.16	28	4.3	95	85
23	1/23/2007	9.9	8.3	7.7	0.13	6.1	7	13.9	7.7	3.3	0.20	-	-	94	-
	Average	7.3	6.1	5.7	0.10	5.3	12	23.0	7.8	2.6	0.22	37	4.5	92	87

Discussion of Results

During 12 months of pilot tests on two surface water supplies: 800-mg/L-TDS Colorado River water and 3,000-mg/L-TDS YDP brackish MODE source water with average values of turbidity of 2.4 and 2.6 NTU and 39 and 38 SDI, the SS filters produced water with average values of 0.17 to 0.22 NTU turbidity and 3.1 to 4.5 SDI. These values meet the levels required for RO feedwater.

The RO pilot unit performed well on SS3-filtered MODE water for 6 months with non-declining values of water transport coefficient (A) of 9 to 10 x 10^{-12} m/s/Pa (9 to 10 x 10^{-5} cm/s/bar, 0.13 to 0.15 gfd/psi). Although partially a result of declining water temperature, the declining salt passage from 3.4 percent to 0.9 percent may indicate fouling.

For Colorado River water, on average, the rapid-sand RF reduced turbidity by 72 percent (from 2.4 to 0.61 NTU) and SDI by 75 percent (from 39 to 9.0). For MODE water, the RF reduced turbidity by 80 percent (from 2.6 to 0.53 NTU) and SDI by 73 percent (from 38 to 9.0).

For Colorado River water, the combination of roughing filter and SS filter reduced turbidity by 93 percent (from 2.4 to 0.17 NTU) and SDI by 89 percent (from 39 to 3.6). For MODE water, the combination of roughing filter and SS filter reduced turbidity by 93 percent (from 2.6 to 0.18 NTU) and SDI by 92 percent (from 38 to 3.1).

For Colorado River water (with no roughing filter), the SS filter reduced turbidity by 92 percent (from 2.5 to 0.19 NTU) and SDI by 86 percent (from 43 to 4.0). For MODE water, the SS filter reduced turbidity by 92 percent (from 2.6 to 0.22 NTU) and SDI by 87 percent (from 37 to 4.5).

The roughing filters greatly increased the SS filter run length, by approximately a factor of five. For Colorado River water, the SS filter had an average filter run length of 75 days (at an average filtration rate of 8.3 mgad (7.8 m/d. 0.13 gal/ft^2/min)) with a roughing filter and 16 days (at an average filtration rate of 7.6 mgad (7.1 m/d, 0.12 gal/ft^2/min)) without a roughing filter.

For MODE water, the SS filter had an average filter run length of 64 days (at 7.6 mgad (7.1 m/d, 0.12 gal/ft^2/min)) with a roughing filter and 12 days (at 6.1 mgad (5.7 m/d, 0.10 gal/ft^2/min)) without a roughing filter.

At a lower filtration rate of 5 mgad (4.7 m/d, 0.08 gal/ft^2/min) and assuming a similar filter run volume, on Colorado River water, the SS filters would require cleaning every 125 days with RF and 25 days without RF (for comparison, previous tests without RF on Colorado River water near Marana, Arizona, observed a filter run length of 22 days at a filtration rate of 6.9 mgad (6.5 m/d, 0.11 gal/ft^2/min) (13) corresponding to a filter run length of 30 days at 5 mgad).

On MODE water, at a filtration rate of 5 mgad (4.7 m/d, 0.08 gal/ft^2/min), the SS filters would require cleaning approximately every 97 days with RF and 15 days without RF.

Future Tests

Planned future tests include evaluating local sand and building and operating a 0.2-acre SS filter as part of WQIC Pilot System 1 (PS1).

Because sand and gravel represent major capital costs for SS filters, 2007 WQIC pilot tests compare the effectiveness of commercial filter sand (0.3-mm effective size (50 mesh) and 1.4 uniformity coefficient) with Reclamation sand (0.1-mm effective size (140 mesh) and 2.2 uniformity coefficient) accumulated by the necessary dredging of the adjacent Colorado River. SS1 and SS3 continue to operate with commercial filter sand. SS2 and SS4 operate with local sand. SS1 and SS2 operate on RF1-filtered Colorado River water. SS3 and SS4 operate on RF3-filtered MODE water. All four SS filters initially operate at 7.5 mgad (7.0 m/d, 0.12 gal/ft^2/min).

The proposed WQIC PS1 SS pilot filter consists of two 0.09-acre cells, each 50 ft by 80 ft, designed to treat 0.83 MGD (570 gal/min, 36 L/s) of water. With both cells in operation, PS1 SS operates at 4.5 mgad (4.2 m/d, 0.072 gal/ft^2/min). With one cell in operation, PS1 SS operates at 9.0 mgad (8.4 m/d, 0.143 gal/ft^2/min). The PS1 SS filter operates on the filter effluent from existing dual-media gravity filters operating at 3 gal/ft^2/min without chemical coagulants.

To evaluate RO performance, a Metropolitan Water District of Southern California RO unit with fifteen 18-inch-diameter by 60-inch long Koch Mega Magnum polyamide RO elements operates on the PS1 SS-filtered water.

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