

FLORIDA SURFACE WATER TO DRINKING WATER: AN INTEGRATED MEMBRANE SOLUTION

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Abstract

The RiverBend Motorcoach Resort Integrated Membrane Water Treatment Plant is one of the first dual membrane systems treating a surficial water for drinking water production in the State of Florida. The system incorporates ultrafiltration (UF) as pre-treatment prior to membrane softening. The plant includes a UF system designed to produce from 40,000 gpd to 80,000 gpd, and a 40,000 GPD R/O system divided into two 20,000 GPD trains. The R/O system is expandable to 80,000 GPD through the addition of two more, 20,000 GPD trains. This expansion will remain within the initial production capacity of the UF system.

The water of the Caloosahatchee River in western Hendry County is an excellent prospect for this innovative design. The river's variable turbidity requires a pre-treatment system that is reliable since suspended solids are detrimental to the performance and life of a spiral wound membrane. Cartridge filtration alone would be expensive as the raw water turbidity increases since filters will have a shortened operational life and would not provide the degree of protection required. Cartridge filtration may not block all the suspended solids from reaching the R/O unit. Ultrafiltration pretreatment will remove virtually all suspended solids prior to reaching the R/O unit. Additional treatment by membrane softening is required for color and organic removal. Due to time and budget constraints a pilot study was not conducted, therefore, the UF system design is conservative. As there are no other membrane plants operating on this source water, it was not known how much the turbidity, suspended solids, and organic content of the water may vary seasonally. From data obtained from operation of a conventional water treatment plant a few miles away the designers were aware that significant algae and suspended solids could be expected in the raw water periodically. Therefore the decision was made to design the UF for a relatively low flux initially to obtain reliable operating

data. Then based on successful operation of the UF, the operating flux could be increased as additional R/O capacity was required. The conservative design will also provide longer periods between backwashes and chemical cleanings, reducing operating costs. Another benefit of UF technology is that UF filtered water can be blended with the R/O permeate to increase capacity, providing the raw water color is not too high. The system has been on-line since April 2002.

Introduction

The RiverBend Motorcoach Resort is located on the north side of State Road 80 just east of the Lee County/Hendry County line in Southwest Florida. The property runs along the south side of the Caloosahatchee River. It is approximately 122 acres and is designed for upscale Class A motorcoaches. The site is a brand new development, laid out for 300 RV sites, with over 25 acres retained for nature preserves.

The Engineer, Johnson-Prewitt and Associates hired Ardaman and Associates to perform a groundwater study which determined there was very little groundwater available on-site, and what was found was of high salinity and low transmissivity. The Engineer approached the Florida Department of Environmental Protection (FDEP) about withdrawing from the Caloosahatchee River to treat water for the development. FDEP approved the concept and issued a permit to construct the water plant. Initially the Engineer had planned on a conventional surface water plant design incorporating softening, sedimentation, clarification and filtration. However, they knew from the experience of the Lee County water treatment plant a few miles away they should expect seasonal taste and odor problems, high chlorides occasionally, and visible color in the finished water. After some research into membrane treatment developments, the Engineer decided to investigate membrane treatment of the surface water in lieu of conventional treatment. It was well known that spiral-wound reverse osmosis or membrane softening post-treatment would take care of the color and chlorides, but there was virtually no information available on treating a Florida surface water with direct membrane treatment. The Engineer assembled a team of membrane specialists, including a consultant from the Netherlands, where ultrafiltration technology has been used extensively for surface water treatment.

The team decided a conservative approach for the ultrafiltration pre-treatment system would provide a stable and reliable water treatment process for the Resort. Several “quick-scan” tests were performed on the river water using miniature UF modules to determine roughly what flux to design for and what backwash frequencies to expect. Then the full-scale plant was designed.

Sequence of Operation

The Caloosahatchee River flows from Lake Okeechobee west to the Gulf of Mexico. It is brackish to a point approximately five miles west of RiverBend, where there are locks and a bubble curtain installed to minimize salinity migrating further upstream. The river water is very colored, with high levels of humic substances, tannins, and organics. The turbidity is normally low, however, there are occasional algae blooms, and the turbidity typically rises during the summer rainy season. The river water is

drawn through a coarse screen on a 16-inch intake pipe that extends approximately 30' from the bank into the river. The river water flows by gravity through the intake pipe into a concrete wetwell. Two submersible pumps are installed in the wetwell to transfer water to the WTP, about one mile away.

Submersible pumps in the wetwell are designed such that each pump has capacity to supply the entire WTP. The secondary pump is used if the primary pump fails. Both pumps are manifolded to one 4-inch pipe that transports water to the WTP. The river pump control system enclosure, located near the wet well, alternates operation of the two pumps upon each start/stop cycle. The river pumps start and stop based on demand of the UF feed storage tank in the WTP. Float switches inside the feed storage tank are connected to control relays that transmit start and stop signals to the river pump control enclosure.

An automatic strainer is installed above ground near the river intake wet well. The strainer removes large particulate matter before the water is transported to the WTP. The strainer automatically backwashes based on a timer or a pressure loss switch. Manual valves may be positioned to allow water flow through a manual strainer and bypass pipe that diverts water around the automatic strainer if necessary. The strainer has 75-micron baskets installed.

The strained river water reaches the WTP and flows into a conical bottom, 200-gallon ultra-filtration (UF) feed storage tank. UF feed piping connects the UF feed storage tank to the UF process skid. The UF process skid includes two 25-micron basket strainers mounted in parallel on the feed piping of the UF skid. Each strainer may be isolated with manual hand valves so it can be taken off-line and cleaned without interrupting the process.

The UF modules remove suspended solids and bacteria from the raw water. The modules are hollow fiber, 0.8 micron, inside-out operation. They filter out particles down to 40 angstroms to 0.1 micron. The unit is designed to supply 40,000 to 80,000 gallons per day. The UF process is designed to operate in a "dead-end" operation, that is during filtration mode all water fed to the unit comes out as treated filtrate, similar to a conventional sand filter.

Periodically, the UF membranes must be backwashed. The backwash solution is diverted to waste, also similar to a conventional filter. The backwash cycle is followed by a brief forward feed flush to drain. After a prescribed number of regular backwash cycles an enhanced backwash cycle occurs. During the enhanced backwash cycle, chemicals are injected and allowed to soak for 7 to 10 minutes. Then the UF unit is flushed to drain. The two chemicals are typically sodium hypochlorite followed by hydrochloric acid. The injection rates and durations are carefully established to ensure the UF modules are soaked in 100 mg/l of sodium hypochlorite and pH 2 solution during hydrochloric acid treatment. The rinse durations and flow are particularly critical as it is necessary to remove all trace of chemicals prior to initiating filtration again.

The UF unit operates through process cycles automatically based on precise control of pneumatically actuated diaphragm valves, feed pump, backwash pump, and two chemical feed pumps. The operator has the ability to modify parameters such as cycle duration and process flow to customize the UF operation.

The primary function of the UF system is to produce filtered water (filtrate). Filtrate is produced during filtration mode. The filtrate flows into a 2000-gallon, black,

flat-bottom filtrate storage tank. The filtrate water is used by the UF process for backwashing and as feed water for the R/O process. The UF process requires filtrate water for backwashes and during backwash mode the UF backwash pump draws from the filtrate tank. The R/O process requires filtrate for feed water and the R/O feed transfer pump also draws water from the filtrate tank.

The majority of the filtrate is pumped to the reverse osmosis or membrane softening units. There are two R/O units, each designed for 20,000 gallons per day. The R/O units remove dissolved solids, hardness, chlorides, sodium, bacteria, viruses, organics and color from the water. The R/O process is a “cross-flow” operation because a continuous waste stream is always produced. The waste stream is called concentrate and the product stream is called permeate. The ratio of permeate to concentrate is called recovery. The recovery at RiverBend is designed to be 80%. The membranes installed are nanofiltration – membrane softening elements. The concentrated is discharged to the on-site wastewater treatment system.

UF Filtrate water is pumped from the filtrate tank to the R/O units with a low head transfer pump. The water is pretreated with a polymer scale inhibitor to prevent scaling of the membrane process. The R/O feed water flows through a 5-micron cartridge filter to protect the R/O membranes should particles get into the filtrate tank.

Because the R/O permeate is so pure, a small side stream of UF filtrate is blended with the R/O permeate to produce blended product. The blended product is then treated with sodium hypochlorite and discharged into the 50,000-gallon ground storage tank, as finished, potable water.

The water is pumped from the ground storage tank into the distribution system by the distribution pump station. The pump station has two pumps. One sized to meet flow requirements with the other on stand-by.

The system continuously supplies fresh water through the distribution system to the user. The process is initiated by demand and process control flows from finish to start on the process flow path. Usage is first detected by a loss of pressure in the distribution system. The distribution pump comes on when the distribution pressure falls to 40 psi. The distribution pump shuts off reaches 50 psi. The distribution pumps draw water from the ground storage tank. When the ground storage tank falls to a preset level, it calls for the R/O system(s) to start. The R/O units draw water from the 2000 gallon UF filtrate/ RO feed tank. As the R/O draws water from the UF filtrate/ RO feed tank it will lower the level. The UF unit will start as soon as the filtrate tank is not full. As the UF draws water from the 200 gallon UF feed tank it will lower the level. When the UF feed tank reaches a low level it turns on the river wetwell pumps. When the UF feed tank reaches a high level it shuts off the river wetwell pumps. When the UF filtrate tank reaches a high level it shuts the UF unit off. When the ground storage tank reached a high level it shuts the R/O units off.

Design Parameters

The design parameters for the UF and R/O systems are summarized in the tables below. When the system was started-up, the performance very closely matched the projected operating parameters. The current operating data is also summarized below.

Table 1. UF Design Parameters – Initial Operation

Parameters	SI Units		Metric Units	
Filtration flux	<i>17.64706</i>	g.f2.d	<i>30</i>	l/(h.m2)
Setpoint 1 feed pump filtration	<i>37.00441</i>	gpm	<i>8.4</i>	m3/h
Setpoint 2 feed pump forward flush	<i>110.1322</i>	gpm	<i>25</i>	m3/h
Backwash flux	<i>132.3529</i>	g.f2.d	<i>225</i>	l/(h.m2)
Setpoint backwash pump	<i>277.533</i>	gpm	<i>63</i>	m3/h
Filtration duration	<i>25</i>	min	<i>25</i>	min
Backwash duration	<i>15</i>	sec	<i>15</i>	sec
Forward flush duration	<i>30</i>	sec	<i>30</i>	sec
Loop counter for initiation Chemical Cleaning	<i>48</i>	n	<i>48</i>	n
Dosing time	<i>30</i>	sec	<i>30</i>	sec
Soaking time	<i>10</i>	min	<i>10</i>	min
Rinse time	<i>30</i>	sec	<i>30</i>	sec
Net production	<i>35.29832</i>	gpm	<i>8.012719</i>	m3/h

Table 2. UF Design Parameters – Future Operation

Overview parameters	SI Units		Metric Units	
Filtration flux	<i>35.29412</i>	g.f2.d	<i>60</i>	l/(h.m2)
Setpoint 1 feed pump filtration	<i>74.00881</i>	gpm	<i>16.8</i>	m3/h
Setpoint 2 feed pump forward flush	<i>110.1322</i>	gpm	<i>25</i>	m3/h
Backwash flux	<i>264.7059</i>	g.f2.d	<i>450</i>	l/(h.m2)
Setpoint backwash pump	<i>555.0661</i>	gpm	<i>126</i>	m3/h
Filtration duration	<i>12.5</i>	min	<i>12.5</i>	min
Backwash duration	<i>15</i>	sec	<i>15</i>	sec
Forward flush duration	<i>30</i>	sec	<i>30</i>	sec
Loop counter for initiation Chemical Cleaning	<i>48</i>	n	<i>48</i>	n
Dosing time	<i>30</i>	sec	<i>30</i>	sec
Soaking time	<i>10</i>	min	<i>10</i>	min
Rinse time	<i>30</i>	sec	<i>30</i>	sec
Net production	<i>67.48524</i>	gpm	<i>15.31915</i>	m3/h

Table 3. R/O System Design Parameters

Parameter	SI Units		Metric Units	
Permeate Flow	<i>13.9</i>	gpm	<i>61.2</i>	m ³ /h
Design Flux	<i>13.7</i>	gfd	<i>23.3</i>	lmh
Feed Pressure	<i>90</i>	psi	<i>6.1</i>	bar
Recovery	<i>80</i>	%	<i>80</i>	%
Permeate Quality	<i>100</i>	mg/l	<i>100</i>	mg/l

Current Operation

The RiverBend Integrated Membrane Treatment System has been operating successfully since April 2002. It has experienced several river intake disturbances involving high turbidity events with no upset. The filtrate produced is consistently under 1.0 silt density index level. The UF modules have been integrity tested once to date and only had two broken fibers. The UF filtration demonstrates a small degree of color removal, of course the R/O (nanofiltration) system removes all remaining color. There has been discussion about experimenting with adding a polymer or coagulant upstream of the UF to improve color removal through the UF, as the color is the limiting factor for blending UF filtrate with the R/O permeate. The plant is operating about 12 hours a day and the enhanced backwash frequency cycle has been changed to every 24 regular backwash cycles to ensure it goes through an enhanced backwash once per day. The tables below summarize the current operating data.

Table 4. UF Current Operation – Sample Data from March 28, 2002

Parameter	12:19 PM filtration	1:30 PM backwash	4:49 PM filtration	5:15 PM backwash
UF Feed Pump Hour Meter	107.2	117.6	149.2	153.2
UF Bckws Pump Hour Meter	30.5	30.9	31.3	--
Feed Water Temperature, °C	20.7	20.4	20.7	--
Feed Pressure, psi	2.9	17	2.9	16.6
Conc. Pressure, psi	0.9	16.5	0.8	16
Filtrate Pressure, psi	-0.9	27.8	-1.3	27.4
Transmembrane Pressure, psi	2.8	11.2	3.2	11.2
Filtrate Flow, gpm	35	0	37	0
Backwash Flow, gpm	0	277	0	277
Feed Conductivity, umhos	930	660	628	--

**Table 5. R/O Current Operation – Sample Data from March 19, 2002
(from one train)**

Parameter		
Permeate Flow	13.9	gpm
Concentrate Flow	3.5	gpm
Feed Pressure	92	psi
Feed Conductivity	652	<i>umhos/cm</i>
Permeate Conductivity	56	<i>umhos/cm</i>
Rejection	91.4	%
Blended, Finished Water Conductivity	146	<i>umhos/cm</i>

The owner, operator, engineer, FDEP and the customers are very satisfied with the reliability of the system and the quality of the product. It is anticipated that a great deal of data can be obtained from this system that will be useful for the design of new surface water integrated membrane treatment plants and possibly for retrofitting existing surface water treatment plants.

The RiverBend WTP was designed and procured as a non-proprietary UF/RO system, that is, any UF module of similar design and dimension can be installed in the system, similar to the ability to install any spiral wound membrane in the R/O system. This provides the owner with the maximum flexibility to adapt to new advances in the technology or changing conditions at the site. Hopefully more UF module manufacturers will recognize this trend and see the benefit in developing more variety in interchangeable UF modules, as the R/O industry has done over the past decade.