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Softening of Madison Water

Technical Memorandum Softening of Madison Water

City of Gillette, Wyoming

1.0 INTRODUCTION

This technical memorandum summarizes the water quality of the Madison Formation Wells and treatment alternatives for the softening that water. The City of Gillette utilizes ten (10) wells in the Madison Formation as sources of drinking water. Table 1 summarizes the current capacity of the Madison Formation Wells.

Table 1: Madison Formation Wells

Well Name	Year Installed	Casing Depth (ft)	Capacity (gpm)	Pump Setting (ft bgl)	Pump Manufacturer	Pump Size (hp)	Motor Manufacturer
M-1	1980	2,390	550	932	Crown	200	Franklin
M-2	1980	2,390	800	932	Crown	200	Franklin
M-3	1980	2,357	1,017	622	Crown	200	Franklin
M-4	1980	2,390	1,000	625	Crown	200	Franklin
M-5	1980	2,365	600	1,097	Crown	200	Franklin
M-6	1980	2,421	600	921	Crown	200	Franklin
M-7	1981	2,500	600	1,071	Crown	200	Franklin
M-8	1981	2,500	580	1,084	Crown	200	Franklin
M-9	1996	2,397	1,495	510	Johnson	250	US
M-10	1996	2,370	1,495	510	Johnson	250	I.E.M.
Total Capacity (gpm)			8,737				

1.1 Water Conveyance from the Madison Formation

This treatment strategy can be used as a stand alone unit on Madison groundwater, or after the surface water filtration/disinfection plant as tertiary treatment for softening. While these are

differing waste streams, they are substantially the same, and the analysis contained herein as well as the cost estimates are still valid for comparison purposes. Conveyance from the Madison can be via the existing and proposed new Madison pipelines for that alternative, the finished water pipeline from the surface water treatment alternative, or a combination of the existing Madison pipeline and the new finished water pipeline under the ASR concept.

1.2 Water Quality

Table 2 summarizes the water quality from the Madison Formation Wells.

Table 2: Water Quality Data for the Madison Formation Wells

Contaminant	Minimum	Maximum	Average
Hardness, mg/L as CaCO ₃	470	521	489
Total Dissolved Solids, mg/L	581	724	645
Sulfate, mg/L	257	326	283
Fluoride, mg/L	0.63	2.03	1.09
pH	7.0	8.05	7.58

1.3 Treatment Goals

The treatment alternatives should be able to meet all state and national water quality standards. The following standards set by the Environmental Protection Agency (EPA) and the State of Wyoming Department of Water Quality (WDEQ) should be considered.

Hardness

Hardness is generally defined as the sum of the polyvalent cations present in water, and is expressed in an equivalent quantity of CaCO₃. Although no distinctly defined levels exist for what constitutes a hard or soft water supply, water typically below 75 mg/L as CaCO₃ is generally considered soft, water between 75 mg/L and 150 mg/L is considered moderately hard, and water above 150 mg/L as CaCO₃ is considered hard. Currently there is no primary or secondary MCL related to hardness, since hard water is not currently known to adversely affect human health in any significant manner. Studies performed during the 1970s in the United

States, Canada, United Kingdom, and Japan have demonstrated an inverse correlation between the incidence of cardiovascular disease and the hardness level of drinking water. Yet conflicting studies have also been reported.¹ For this Technical Memorandum, it is assumed and recommended that the City of Gillette reduce the overall hardness concentration to 150 mg/L as CaCO₃ or less.

Total Dissolved Solids

Total dissolved solids (TDS) are a direct measure of the major ions present in the water. TDS is of interest as a secondary standard (500 mg/L) as well as its impact on water treatment with membranes. Since the TDS is directly related to the osmotic pressure of the water, the design and operation of the plant will be affected by fluctuations in dissolved solids.

Sulfate

Sulfate is of interest as a secondary drinking water standard (250 mg/L), and its potential impact on treatment of other contaminants. Specifically, it has been theorized that high sulfate concentrations can have an adverse impact on the removal of nitrates. Since nitrates are not a concern, sulfates impact to the water quality affects TDS and taste.

Fluoride

The most common source of fluoride in the environment is the natural mineral fluorapatite, which is a fluorinated calcium phosphate rock. Fluorapatite is mined as the primary source of phosphate fertilizer and also used in the manufacturing of glass and steel. Prolonged consumption of water with fluoride concentrations in excess of 4 mg/L causes skeletal fluorosis which is a serious bone crippling disorder resembling osteoporosis in addition to dental malformation, decalcification, mineralization of tendons, and digestive and nervous disorders. The current MCL is 4 mg/L and SMCL of 2 mg/L.

2.0 WATER TREATMENT ALTERNATIVES

The following treatment alternatives were evaluated to determine their effectiveness in reducing the sulfate, TDS and hardness levels in the drinking water. These are the main contaminants of concern in using the Madison Formation ground water as a potable water supply source.

2.1 Treatment Alternative 1 – Lime Softening

Lime softening (LS) is included in this technical memorandum because of its ability to reduce the concentrations of calcium and magnesium (hardness). Thus the process is called softening. The process uses a chemical addition (lime slurry) to the water to raise the pH and force the precipitation of calcium as calcium carbonate (removes calcium at a pH of 10) and magnesium as magnesium hydroxide (removes magnesium at a pH of 11) solids in a solids contact clarifier. The addition of

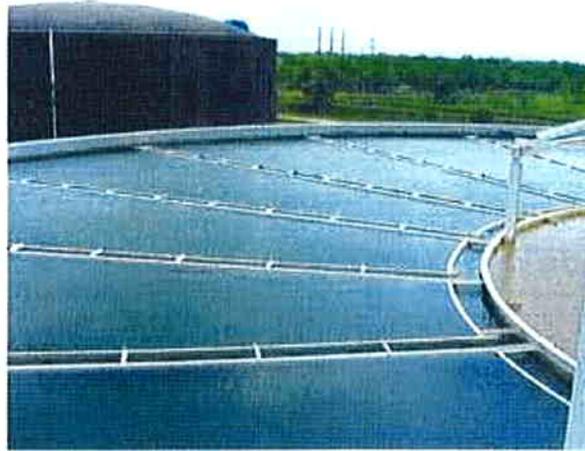


Figure 1: SCC

lime raises the system pH with the addition of hydroxide ions and converts the bicarbonate ions to the carbonate form allowing both the calcium and carbonate ion to exceed the solubility product of calcium carbonate. The solids contact clarifier (SCC) provides the mixing for coagulation, flocculation, and clarification of the treated water. Lime may be used in different forms of which the least expensive is using quick lime (CaO). Quick lime must be hydrated or slaked to $\text{Ca}(\text{OH})_2$ prior to application. The chemical precipitation involved in lime softening also results in reductions in raw water particulates, turbidity, TOC, and selected metals. Figure 1 of a SCC is courtesy of Westech.

Phase I – Lime Softening for Madison Formation Wells

Based on the water quality listed in Table 3, lime softening was evaluated to reduce hardness from the Madison Formation Wells. The Madison Formation Wells contains the following water quality:

Table 3:
Water Quality Expressed as CaCO₃ for the Madison Formation Wells

Chemical Species	Concentration mg/L	Equivalent Weight	Concentration meq/L	Concentration mg/L as CaCO ₃
Ca ²⁺	133	20	6.65	333
Mg ²⁺	43.4	12.2	3.56	178
Total Hardness				511
Na ⁺	5.7	23	0.25	12
HCO ₃ ⁻	254	61	4.16	208
Cl ⁻	6.76	35.5	0.19	10
SO ₄ ²⁻	283	48	5.90	295

Based on the water quality provided in Table 3, the Madison Formation Wells contains approximately 208 mg/L as CaCO₃ of calcium carbonate hardness. This would be the maximum calcium carbonate hardness reduced from lime softening if only lime was added to the SCC. The non-carbonate hardness is estimated at 302 mg/L which is composed of 124 mg/L as CaCO₃ from calcium and 178 mg/L as CaCO₃ from magnesium. Therefore, the softening process utilized requires excess lime and soda ash. Soda ash adds alkalinity into the water in order to precipitate the non-carbonate hardness.

Phase I – Excess Lime-Soda Softening Process

Two 60-foot diameter lime softening clarifiers with 18-ft side water depth (SWD) each rated at a capacity of 4.5 MGD (3,125 gpm) will be used for the softening process. The clarifiers each have a surface loading rate of 0.99 gpm/ft² and provide a solids recirculation rate of 25,000 gpm. A 20 minute detention time is provided in the flocculation well with an overall basin detention time of 155 minutes. The surface radial launder weir loading rate is 9.5 gpm/L.F.

The SCC utilizes a center drive mounted on a bridge that spans the

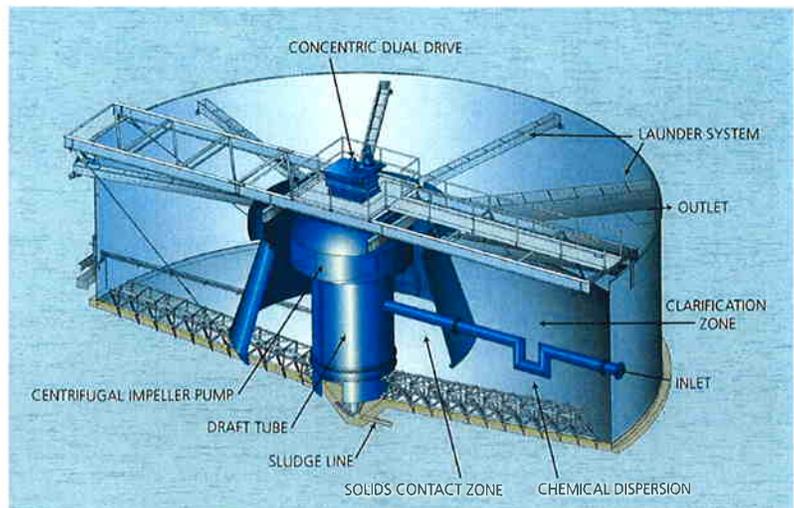


Figure 2: Section View of SCC

tank. Flow enters the center draft tube through a horizontal influent pipe. The tank provides for both recirculation of solids back into the center draft tube and solids wasting from the bottom of the tank. Flocculation and recirculation is provided by the use of a variable speed impeller that draws solids from the tank bottom up through the draft tube. The impeller combines the solids with the influent and chemical addition. Figure 2 was provided by WesTech.

It is estimated that the amount of lime required will be 342 mg/L which includes 60 mg/L of excess lime. The amount of soda ash required is estimated at 320 mg/L. These dose rates are preliminary and based on theoretical assumptions to reduce the total hardness of 511 mg/L as CaCO_3 . The actual dose rate should be verified using both jar testing and pilot evaluation prior to design and construction.

Typical excess lime-soda softening processes will result in an effluent concentration of 50 mg/L as CaCO_3 for calcium and 20 mg/L as CaCO_3 for magnesium since softening process will never remove all calcium and magnesium. The estimated hardness reduction is 440 mg/L as CaCO_3 but since soda ash is required to be added for the reduction of non-carbonate hardness, the sodium concentration is increased in the effluent water by approximately 302 mg/L as CaCO_3 . This results in an overall net TDS reduction of 138 mg/L as CaCO_3 .

At a capacity of 9 MGD, this results in a daily consumption of approximately 27,000 lbs/day of lime and 24,000 lbs/day of soda ash. For 15-day storage, using a bulk density of 35 lbs/ft³ for lime and 60 lbs/ft³ for soda ash, this will require approximately a 12,000 ft³ lime silo and 6,000 ft³ soda ash silo. Using a carbon steel storage silo with a capacity of 4,000 ft³, the dimensions will be 14'-0" diameter, 22'-0" storage height, and 51'-4" overall height to allow for full truck capacity deliveries. This would require three (3) storage silos to provide 15-days storage for lime and three (3) storage silos would provide 30-day storage for soda ash. The silo would also need to be equipped with a dust collector and ultrasonic level sensors. Both lime and soda ash would be metered using a weight batching assembly using a screw feeder with a variable frequency drive. The feeder would be mounted on a weight platform with a loss-in-weight controller to maintain desired concentration in the slurry tank prior to dosing in the SCC.

Phase II – Lime Softening for Madison Formation Wells

For phase II, two additional lime softening clarifiers each with a capacity of 4.5 MGD will be required resulting in a total of four (4) clarifiers operating at ultimate capacity. Both the lime and

soda ash silos per process train would be decreased in half thus providing only one-week storage for lime and 15 days storage for soda ash based on the preliminary calculations.

Based on the quantities and storage requirements for both lime and soda ash, it is determined that the excess lime-soda softening process is not feasible. It is also important to note that the effluent water from the SCC will still need to be further treated using multi-media sand filters or microfiltration/ultrafiltration (MF/UF) membrane processes followed by disinfection (See Chapter 8 for more information on the filtration and disinfection process). Both a clearwell and a high service pump station will be required.

2.2 Treatment Alternative 2 – Reverse Osmosis

Reverse osmosis (RO) processes are evaluated here because they are excellent at removing/reducing TDS, hardness, and fluoride from the raw water supply. RO is a pressure driven process utilizing membrane technology to separate dissolved ions and dissolved impurities from drinking water supplies. Higher driving pressures are required to achieve this separation since the membranes have a much smaller pore size. The RO systems require extensive pretreatment of the raw water to minimize potential fouling of the membranes since the membranes cannot be hydraulically backwashed to maintain flux for an extended duration. Depending on the blending options utilized, post-treatment of the RO permeate may be required. The extent of both pretreatment and post-treatment required is dependent on the constituents of concern in the raw water. Typical pretreatment processes for ground-water supplies include the addition of either acid, antiscalant, or both to the RO feed water. The addition of acid or antiscalant prevents inorganic scaling (the buildup of salts) during membrane filtration as the feed stream is concentrated. Prior to chemical treatment, a fine screen/cartridge filter is used ahead of the RO membranes to remove any larger sized particulates that may foul or damage the RO membranes. The surface of the RO membranes is coated with a thin layer of polymer with pores that range in size from 300 to 10,000 μm . The pressure driven process forces the water through the semi-permeable membrane while rejecting virtually all dissolved ions. Following membrane filtration, the water is post-treated using processes such as degasification, post-chemical treatment, and disinfection. In addition, RO membranes are also excellent barriers to microbial contaminants, viruses, and numerous organics.

Figure 3 shows the general flow process of feed solution as it enters a RO membrane element. The layers of the membrane are shown. As the feed solution moves through the feed channel

spacer, the membrane layer rejects the dissolved ions while allowing the water to pass through the membrane layer. The permeate or the filtered water moves through the permeate carrier to the perforated collection tube. The permeate from each vessel is collected in a common header and proceeds to the post-treatment step. The concentrate from each vessel is also collected in a common header and is disposed of accordingly. The disposal of the concentrate water is regulated by the EPA and will require further treatment (see the Technical Memorandum on Fox Hills for more information about residual handling alternatives).

Typical RO recovery rates are between 70% to 85% depending on the raw water quality and pretreatment.

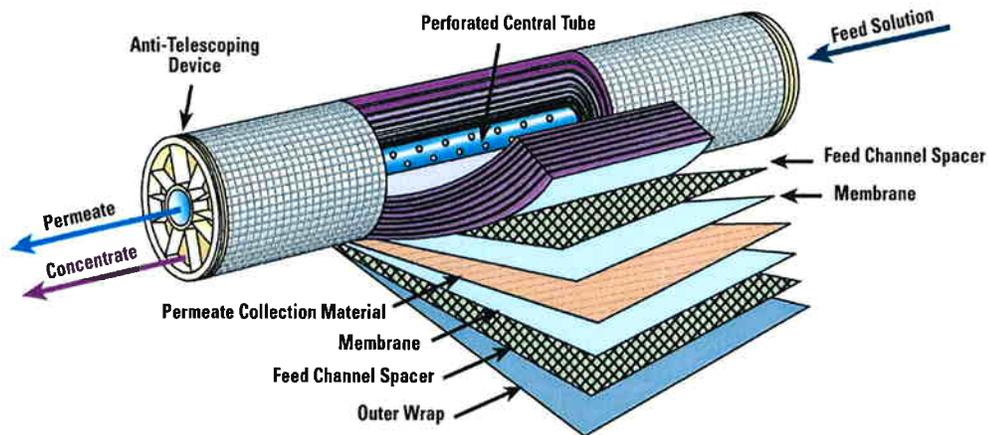


Figure 3: RO Membrane (Courtesy of GE Osmonics)

Phase I – RO System for Madison Formation Wells

The RO membrane system is proposed to reduce total dissolved solids (TDS), hardness and sulfate concentrations. In addition, RO membranes may also be used to reduce fluoride concentration. The initial phase (Phase I) of the proposed water treatment system for the Madison Formation Wells will require a maximum capacity of 9 MGD. Multiple options were evaluated using the RO System Analysis Model by Filmtec (Projections for each option are shown in Appendix 9-A). The following options and assumptions are summarized below for each RO Train:

Option 1 - Full Stream RO Treatment

- Option 2 - RO Treatment and 300 gpm Bypass
- Option 3 - RO Treatment and 577 gpm Bypass
- Option 4 - RO Treatment and 800 gpm Bypass

The simulation model was based on an overall minimum recovery of 75% and blending of raw water and RO permeate using average raw water concentrations as summarized in the following Table 4. The RO system was modeled using no chemical pretreatment and utilized the 8-inch diameter RO elements by Filmtec BW30-400. The model simulated a single train configured in a 2:1 array consisting of 36 pressure vessels in stage 1 and 18 pressure vessels in stage 2. Each vessel houses 6 RO elements for a total of 324 RO elements per train. Each train is capable of producing 1.25 MGD RO permeate at an average membrane flux of 9.61 gallons per square foot per day (gfd). This flux is very conservative since typical flux for RO membranes may range up to 16 gfd depending on the water quality. Pilot test prior to design and construction is required to assess the performance of the RO system.

**Table 4:
Raw Water Quality for Madison Formation Wells Used for RO Analysis**

Constituent	Constituent	Units/SMCL's	Average Concentration
USEPA SECONDARY CONTAMINANTS	Aluminum	0.05-0.2 mg/L	<0.1
	Chloride	250 mg/L	6.76
	Color	15 (color units)	NR
	Copper	1.0 mg/L	<0.01
	Corrosivity	Noncorrosive	NR
	Fluoride	2.0 mg/L	1.09
	Foaming Agents	0.5 mg/L	NR
	Iron	0.3 mg/L	0.34
	Manganese	0.05 mg/L	<0.02
	Odor	3 threshold odor no.	NR
	pH	6.5 – 8.5	7.58
	Silver	0.1 mg/L	<0.01
	Sulfate	250 mg/L	283
	Total Dissolved Solids	500 mg/L	645
Zinc	5 mg/L	<0.01	
Calcium	mg/L (no standard)	133	

	Magnesium	mg/L (no standard)	43.4
	Carbonate	mg/L (no standard)	ND
	Bicarbonate	mg/L (no standard)	254
	Total Alkalinity	mg/L as CaCO ₃	205
	Hardness	mg/L as CaCO ₃	489
	Sodium	250 mg/L	5.7

NR – Not Reported

ND – Not Detected

OPTION 1

Full stream RO treatment will require the installation of eight (8) trains providing the water treatment plant a total capacity of 10 MGD. Each RO train will require a feed pressure of approximately 152 psi necessitating the use of an RO feed pump. Chemicals such as antiscalant or acid may be used to pretreat the water prior to the RO to possibly increase overall recovery. The RO permeate will need to be chemically conditioned prior to service due to the aggressiveness of RO permeate. Soda ash is added to add alkalinity to stabilize the RO permeate. In addition, a base will need to be added to increase the pH of the RO permeate prior to distribution. The percentage of RO treated water is based on the raw water quality and finished water quality goals, and is operator adjustable as raw water quality changes.

Table 5 summarizes the RO permeate water quality for the constituents of concern as indicated by the City of Gillette.

**Table 5:
Full Stream RO Treatment Permeate Water Quality**

Contaminant	Permeate Water Quality
Hardness, mg/L as CaCO ₃	1.4
Total Dissolved Solids, mg/L	2.37
Sulfate, mg/L	0.60
Fluoride, mg/L	0.01
pH	5.40

OPTION 2

The second option evaluated blending 300 gpm for each train thus reducing the total number of RO Trains required from 8 trains to 6 trains for a total plant capacity of 10.1 MGD. This will provide an overall bypass stream of 1,800 gpm (2.6 MGD) while each train will produce 1.25 MGD. The treated water quality is summarized in Table 6.

**Table 6:
RO Treatment and 300 gpm Bypass per Train Water Quality**

Contaminant	Permeate Water Quality
Hardness, mg/L as CaCO ₃	132
Total Dissolved Solids, mg/L	190
Sulfate, mg/L	73.3
Fluoride, mg/L	0.3
pH	7.06

OPTION 3

The third option evaluated blending 577 gpm per train resulting in an overall production from each RO train of 1,442 gpm (2.1 MGD). This will result in an overall reduction from 6 RO trains to 5 RO trains for a total plant capacity of 10.5 MGD. Table 7 summarizes the treated water quality

**Table 7:
RO Treatment and 577 gpm Bypass per Train Water Quality**

Contaminant	Permeate Water Quality
Hardness, mg/L as CaCO ₃	205
Total Dissolved Solids, mg/L	294
Sulfate, mg/L	114
Fluoride, mg/L	0.44
pH	7.24

OPTION 4

The fourth option evaluated a bypass flow of 865 gpm per train resulting in an overall production capacity of 1,730 gpm per train. The overall bypass flow 3,460 gpm (5 MGD) and RO permeate

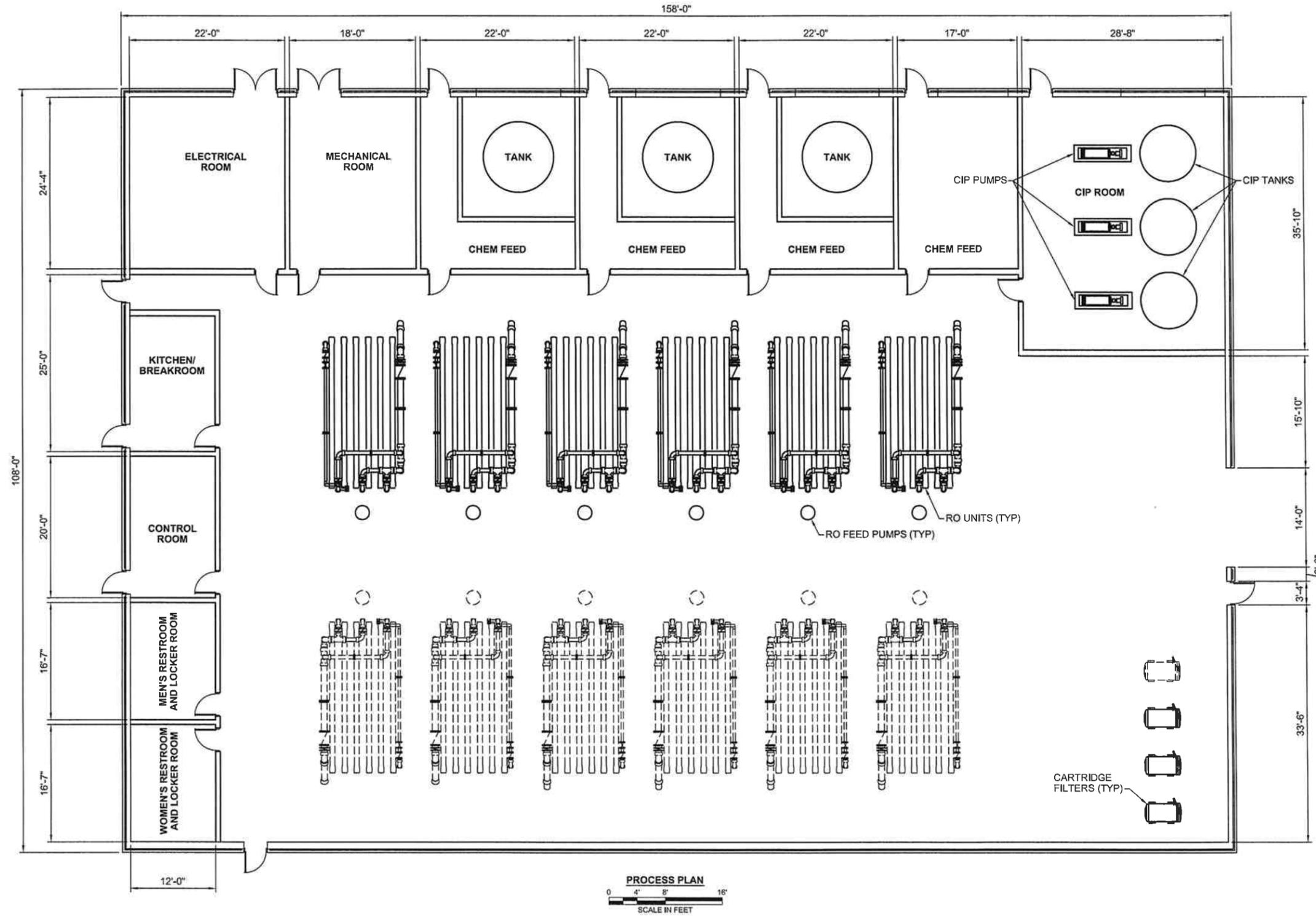
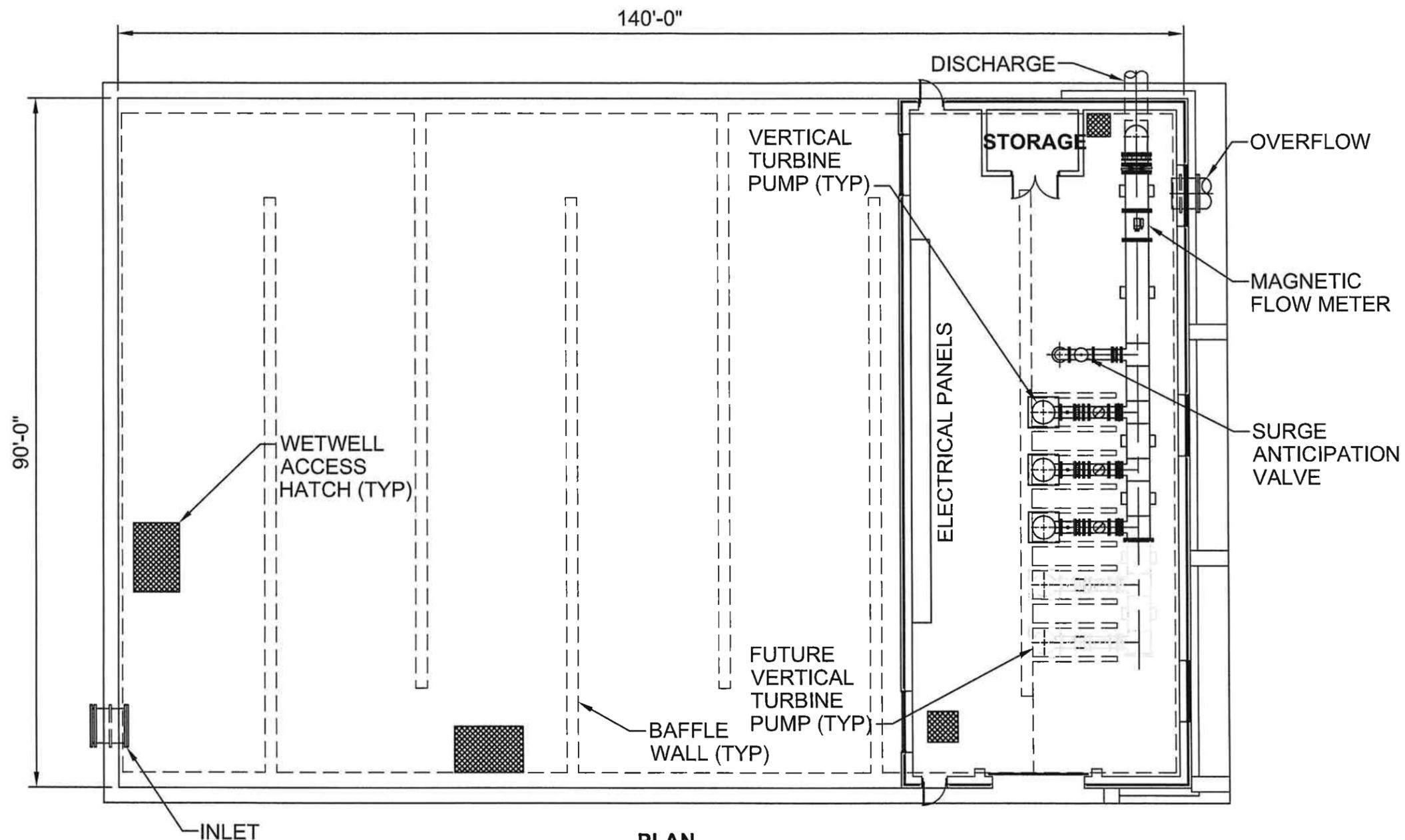
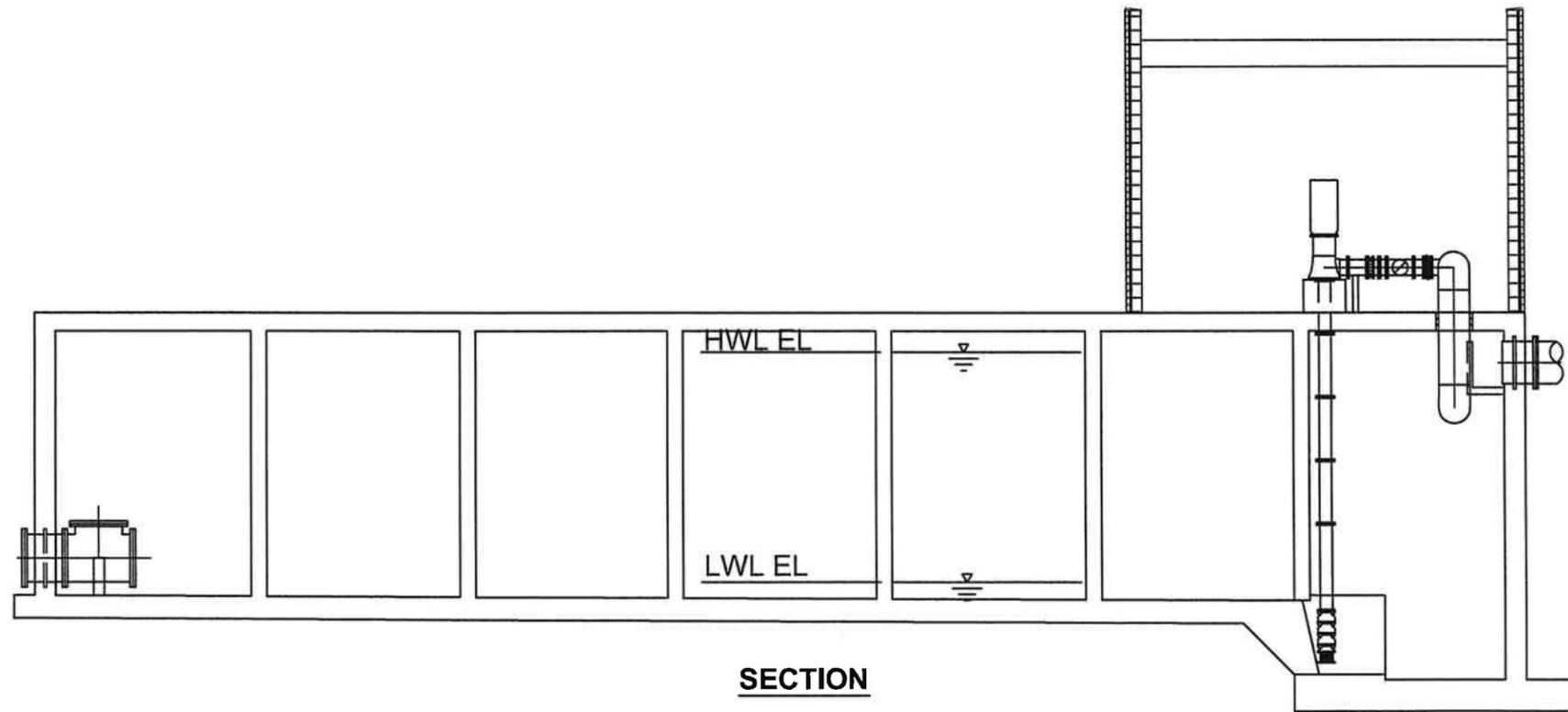


Figure 5
RO MEMBRANE
BUILDING



	<p>Figure 6 CLEARWELL AND HIGH SERVICE PUMP STATION PLAN</p>
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SECTION
0 8' 16' 32'
SCALE IN FEET



Figure 7
CLEARWELL AND HIGH
SERVICE PUMP
STATION SECTION

Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (75 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Project Information:RO Treatment for TDS and Sulfate Reduction at 75% Blend

System Details

Feed Flow to Stage 1	1153.00 gpm	Pass 1 Permeate Flow	864.63 gpm	Osmotic Pressure:	
Raw Water Flow to System	2018.00 gpm	Pass 1 Recovery	74.99 %	Feed	3.86 psig
Feed Pressure	152.14 psig	Feed Temperature	50.0 F	Concentrate	13.99 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.93 psig
Chem. Dose	None	Number of Elements	324	Average NDP	124.97 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	95.40 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	865.00 gpm	Specific Energy	0.92 kWh/kgal
System Recovery	85.71 %	Total Blended Product	1729.63 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400	36	6	1153.00	147.14	0.00	539.76	131.48	613.24	10.22	0.00	0.00	1.74
2	BW30-400	18	6	539.76	126.48	0.00	288.37	111.40	251.39	8.38	0.00	0.00	3.96

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	12.15	22.68	0.02	0.07	0.04	2.87
Mg	43.00	43.00	91.76	171.57	0.08	0.21	0.12	21.56
Ca	133.00	133.00	283.83	530.69	0.24	0.64	0.36	66.69
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	3.21	10.58	0.00	0.00	0.00	0.15
HCO3	254.00	254.00	538.20	996.61	0.96	1.90	1.22	127.88
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	21.36	39.92	0.02	0.06	0.03	5.02
F	1.10	1.10	2.34	4.38	0.01	0.01	0.01	0.55
SO4	283.00	283.00	604.06	1129.71	0.41	1.07	0.60	141.83
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.04	13.73	10.03	11.66	10.51	10.22
TDS	727.24	730.49	1556.93	2906.17	1.74	3.96	2.37	366.57
pH	7.60	7.60	7.84	7.96	5.32	5.54	5.40	7.33

Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume liability for results obtained or damages incurred from the application of this information. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of the customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (75 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	3.01	1.30	32.03	730.49	147.14
2	0.10	2.93	1.43	29.02	806.09	143.37
3	0.11	2.86	1.58	26.09	896.43	140.10
4	0.12	2.80	1.78	23.22	1006.54	137.32
5	0.13	2.74	2.05	20.43	1144.00	134.97
6	0.15	2.69	2.42	17.68	1320.80	133.03
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.54	2.74	29.99	1556.93	126.48
2	0.09	2.45	3.11	27.45	1700.26	123.02
3	0.09	2.37	3.56	25.00	1866.24	119.97
4	0.10	2.29	4.12	22.63	2060.60	117.32
5	0.11	2.20	4.85	20.35	2291.04	115.02
6	0.12	2.12	5.80	18.14	2568.05	113.05

Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume liability for results obtained or damages incurred from the application of this information. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

Scaling Calculations

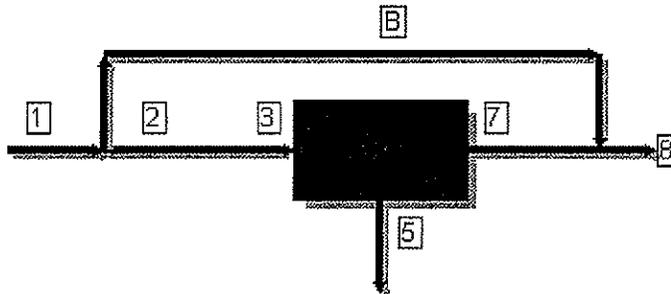
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.69
Stiff & Davis Stability Index	0.63	0.63	1.63
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2906.17
HCO3	254.00	254.00	996.61
CO2	10.01	10.01	13.72
CO3	0.67	0.67	10.58
CaSO4 (% Saturation)	8.12	8.12	64.74
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1350.55
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells RO (75 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	85.71 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
	1	2
Stage #	1	2
Element Type	BW30-400	BW30-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	10.22 gfd	8.38 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	0.92 kWh/kgal	

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Project: City of Gillette Madison Wells RO (75 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	2018.00	0.00	727.24
2	1153.00	0.00	730.49
3	1153.00	152.14	730.49
5	288.37	111.40	2906.17
7	864.63	-	2.37
B	865.00	0.00	730.49
8	1729.63	0.00	366.57
7/2	% Recovery	74.99	

Project Information:

RO Treatment for TDS and Sulfate Reduction at 75% Blend

Design Warnings:

-None-

Solubility Warnings:

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (No Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Project Information:RO Treatment for TDS and Sulfate Reduction (No Blend)

System Details

Feed Flow to Stage 1	1153.00 gpm	Pass 1 Permeate Flow	864.63 gpm	Osmotic Pressure:	
Raw Water Flow to System	1153.00 gpm	Pass 1 Recovery	74.99 %	Feed	3.86 psig
Feed Pressure	152.14 psig	Feed Temperature	50.0 F	Concentrate	13.99 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.93 psig
Chem. Dose	None	Number of Elements	324	Average NDP	124.97 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	95.40 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.84 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400	36	6	1153.00	147.14	0.00	539.76	131.48	613.24	10.22	0.00	0.00	1.74
2	BW30-400	18	6	539.76	126.48	0.00	288.37	111.40	251.39	8.38	0.00	0.00	3.96

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	12.15	22.68	0.02	0.07	0.04
Mg	43.00	43.00	91.76	171.57	0.08	0.21	0.12
Ca	133.00	133.00	283.83	530.69	0.24	0.64	0.36
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	3.21	10.58	0.00	0.00	0.00
HCO3	254.00	254.00	538.20	996.61	0.96	1.90	1.22
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	21.36	39.92	0.02	0.06	0.03
F	1.10	1.10	2.34	4.38	0.01	0.01	0.01
SO4	283.00	283.00	604.06	1129.71	0.41	1.07	0.60
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.04	13.73	10.03	11.66	10.51
TDS	727.24	730.49	1556.93	2906.17	1.74	3.96	2.37
pH	7.60	7.60	7.84	7.96	5.32	5.54	5.40

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (No Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	3.01	1.30	32.03	730.49	147.14
2	0.10	2.93	1.43	29.02	806.09	143.37
3	0.11	2.86	1.58	26.09	896.43	140.10
4	0.12	2.80	1.78	23.22	1006.54	137.32
5	0.13	2.74	2.05	20.43	1144.00	134.97
6	0.15	2.69	2.42	17.68	1320.80	133.03
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.54	2.74	29.99	1556.93	126.48
2	0.09	2.45	3.11	27.45	1700.26	123.02
3	0.09	2.37	3.56	25.00	1866.24	119.97
4	0.10	2.29	4.12	22.63	2060.60	117.32
5	0.11	2.20	4.85	20.35	2291.04	115.02
6	0.12	2.12	5.80	18.14	2568.05	113.05

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Scaling Calculations

	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.69
Stiff & Davis Stability Index	0.63	0.63	1.63
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2906.17
HCO3	254.00	254.00	996.61
CO2	10.01	10.01	13.72
CO3	0.67	0.67	10.58
CaSO4 (% Saturation)	8.12	8.12	64.74
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1350.55
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells RO (No Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (7/1)	74.99 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
	1	2
Stage #	1	2
Element Type	BW30-400	BW30-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	10.22 gfd	8.38 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	1.84 kWh/kgal	

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Project: City of Gillette Madison Wells RO (No Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1153.00	0.00	727.24
3	1153.00	152.14	730.49
5	288.37	111.40	2906.17
7	864.63	-	2.37
7/1	% Recovery	74.99	

Project Information:

RO Treatment for TDS and Sulfate Reduction (No Blend)

Design Warnings:

-None-

Solubility Warnings:

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF₂ (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (25 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Project Information:RO Treatment for TDS and Sulfate Reduction at 25% Blend

System Details

Feed Flow to Stage 1	1153.00 gpm	Pass 1 Permeate Flow	864.63 gpm	Osmotic Pressure:	
Raw Water Flow to System	1453.00 gpm	Pass 1 Recovery	74.99 %	Feed	3.86 psig
Feed Pressure	152.14 psig	Feed Temperature	50.0 F	Concentrate	13.99 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.93 psig
Chem. Dose	None	Number of Elements	324	Average NDP	124.97 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	95.40 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	300.00 gpm	Specific Energy	1.37 kWh/kgal
System Recovery	80.15 %	Total Blended Product	1164.63 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400	36	6	1153.00	147.14	0.00	539.76	131.48	613.24	10.22	0.00	0.00	1.74
2	BW30-400	18	6	539.76	126.48	0.00	288.37	111.40	251.39	8.38	0.00	0.00	3.96

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	12.15	22.68	0.02	0.07	0.04	1.50
Mg	43.00	43.00	91.76	171.57	0.08	0.21	0.12	11.16
Ca	133.00	133.00	283.83	530.69	0.24	0.64	0.36	34.53
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	3.21	10.58	0.00	0.00	0.00	0.04
HCO3	254.00	254.00	538.20	996.61	0.96	1.90	1.22	66.43
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	21.36	39.92	0.02	0.06	0.03	2.60
F	1.10	1.10	2.34	4.38	0.01	0.01	0.01	0.29
SO4	283.00	283.00	604.06	1129.71	0.41	1.07	0.60	73.34
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.04	13.73	10.03	11.66	10.51	10.41
TDS	727.24	730.49	1556.93	2906.17	1.74	3.96	2.37	189.89
pH	7.60	7.60	7.84	7.96	5.32	5.54	5.40	7.06

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (25 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	3.01	1.30	32.03	730.49	147.14
2	0.10	2.93	1.43	29.02	806.09	143.37
3	0.11	2.86	1.58	26.09	896.43	140.10
4	0.12	2.80	1.78	23.22	1006.54	137.32
5	0.13	2.74	2.05	20.43	1144.00	134.97
6	0.15	2.69	2.42	17.68	1320.80	133.03
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.54	2.74	29.99	1556.93	126.48
2	0.09	2.45	3.11	27.45	1700.26	123.02
3	0.09	2.37	3.56	25.00	1866.24	119.97
4	0.10	2.29	4.12	22.63	2060.60	117.32
5	0.11	2.20	4.85	20.35	2291.04	115.02
6	0.12	2.12	5.80	18.14	2568.05	113.05

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Scaling Calculations

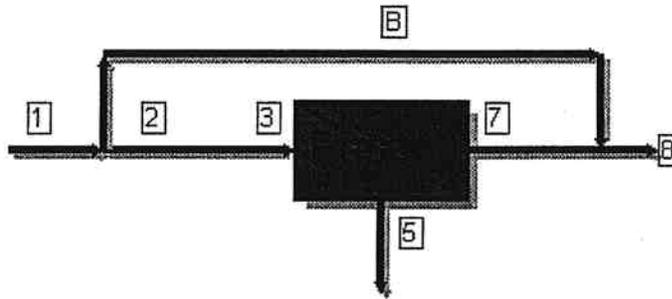
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.69
Stiff & Davis Stability Index	0.63	0.63	1.63
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2906.17
HCO3	254.00	254.00	996.61
CO2	10.01	10.01	13.72
CO3	0.67	0.67	10.58
CaSO4 (% Saturation)	8.12	8.12	64.74
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1350.55
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells RO (25 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	80.15 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
Stage #	1	2
Element Type	BW30-400	BW30-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	10.22 gfd	8.38 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	1.37 kWh/kgal	

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Project: City of Gillette Madison Wells RO (25 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1453.00	0.00	727.24
2	1153.00	0.00	730.49
3	1153.00	152.14	730.49
5	288.37	111.40	2906.17
7	864.63	-	2.37
B	300.00	0.00	730.49
8	1164.63	0.00	189.89
7/2	% Recovery	74.99	

Project Information:

RO Treatment for TDS and Sulfate Reduction at 25% Blend

Design Warnings:

-None-

Solubility Warnings:

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (50 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

Project Information: NF/RO Treatment for TDS and Sulfate Reduction 50% Blend

System Details

Feed Flow to Stage 1	1152.83 gpm	Pass 1 Permeate Flow	864.63 gpm	Osmotic Pressure:	
Raw Water Flow to System	1729.83 gpm	Pass 1 Recovery	75.00 %	Feed	3.86 psig
Feed Pressure	152.14 psig	Feed Temperature	50.0 F	Concentrate	14.00 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.93 psig
Chem. Dose (100% H2SO4)	0.00	Number of Elements	324	Average NDP	124.97 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	95.38 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	577.00 gpm	Specific Energy	1.10 kWh/kgal
System Recovery	83.34 %	Total Blended Product	1441.63 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400	36	6	1152.83	147.14	0.00	539.60	131.48	613.23	10.22	0.00	0.00	1.74
2	BW30-400	18	6	539.60	126.48	0.00	288.21	111.41	251.39	8.38	0.00	0.00	3.96

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	12.15	22.69	0.02	0.07	0.04	2.30
Mg	43.00	43.00	91.78	171.64	0.08	0.21	0.12	17.28
Ca	133.00	133.00	283.87	530.92	0.24	0.64	0.36	53.45
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	3.22	10.59	0.00	0.00	0.00	0.09
HCO3	254.00	254.00	538.28	997.03	0.96	1.90	1.22	102.60
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	21.36	39.94	0.02	0.06	0.03	4.03
F	1.10	1.10	2.34	4.38	0.01	0.01	0.01	0.44
SO4	283.00	283.00	604.15	1130.20	0.41	1.07	0.60	113.63
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.04	13.73	10.03	11.66	10.51	10.29
TDS	727.24	730.49	1557.17	2907.41	1.74	3.96	2.37	293.82
pH	7.60	7.60	7.84	7.96	5.32	5.54	5.40	7.24

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells RO (50 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	3.01	1.30	32.02	730.49	147.14
2	0.10	2.93	1.43	29.01	806.10	143.36
3	0.11	2.86	1.58	26.08	896.46	140.10
4	0.12	2.80	1.78	23.22	1006.59	137.32
5	0.13	2.74	2.05	20.42	1144.09	134.97
6	0.15	2.69	2.42	17.68	1320.95	133.04
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.54	2.74	29.98	1557.17	126.48
2	0.09	2.45	3.11	27.44	1700.57	123.02
3	0.09	2.37	3.56	24.99	1866.64	119.98
4	0.10	2.29	4.12	22.62	2061.12	117.32
5	0.11	2.20	4.85	20.34	2291.73	115.03
6	0.12	2.12	5.80	18.13	2568.97	113.06

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Scaling Calculations

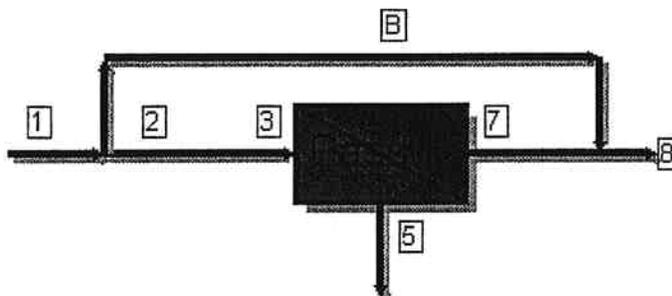
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.69
Stiff & Davis Stability Index	0.63	0.63	1.63
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2907.41
HCO3	254.00	254.00	997.03
CO2	10.01	10.01	13.73
CO3	0.67	0.67	10.59
CaSO4 (% Saturation)	8.12	8.12	64.77
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1352.29
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells RO (50 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	83.34 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
Stage #	1	2
Element Type	BW30-400	BW30-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	10.22 gfd	8.38 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	1.10 kWh/kgal	

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Project: City of Gillette Madison Wells RO (50 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1729.83	0.00	727.24
2	1152.83	0.00	730.49
3	1152.83	152.14	730.49
5	288.21	111.41	2907.41
7	864.63	-	2.37
B	577.00	0.00	730.49
8	1441.63	0.00	293.82
7/2	% Recovery	75.00	

Project Information:

NF/RO Treatment for TDS and Sulfate Reduction 50% Blend

Design Warnings:

-None-

Solubility Warnings:

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (No Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Project Information:NF Treatment for TDS and Sulfate Reduction (No Blend)

System Details

Feed Flow to Stage 1	1153.00 gpm	Pass 1 Permeate Flow	864.77 gpm	Osmotic Pressure:	
Raw Water Flow to System	1153.00 gpm	Pass 1 Recovery	75.00 %	Feed	3.86 psig
Feed Pressure	67.90 psig	Feed Temperature	50.0 F	Concentrate	13.74 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.80 psig
Chem. Dose	None	Number of Elements	324	Average NDP	41.48 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	42.58 kW
Water Classification: Well Water SDI < 3				Specific Energy	0.82 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	36	6	1153.00	62.90	0.00	467.35	48.52	685.65	11.43	0.00	0.00	12.25
2	NF90-400	18	6	467.35	43.52	0.00	288.23	30.64	179.12	5.97	0.00	0.00	41.64

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	13.55	21.24	0.35	1.18	0.52
Mg	43.00	43.00	105.12	169.05	0.66	2.24	0.99
Ca	133.00	133.00	325.19	523.03	2.00	6.85	3.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	4.16	10.16	0.00	0.00	0.00
HCO3	254.00	254.00	612.39	972.85	6.29	21.26	9.38
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	23.99	37.88	0.48	1.64	0.72
F	1.10	1.10	2.61	4.08	0.07	0.24	0.11
SO4	283.00	283.00	694.66	1121.26	2.40	8.22	3.61
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.43	13.57	10.25	11.97	10.61
TDS	727.24	730.49	1781.69	2859.56	12.25	41.64	18.33
pH	7.60	7.60	7.87	7.96	6.10	6.55	6.26

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (No Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Design Warnings

CAUTION: The concentrate flow rate is less than the recommended minimum flow. Please change your system design to increase concentrate flow rates. (Product: NF90-400, Limit: 13.00gpm)

Solubility Warnings

Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	3.74	7.17	32.03	730.49	62.90
2	0.12	3.48	8.69	28.28	826.16	59.19
3	0.13	3.25	10.60	24.80	940.79	56.10
4	0.14	3.05	13.05	21.55	1080.95	53.55
5	0.15	2.85	16.32	18.50	1256.39	51.47
6	0.17	2.67	20.81	15.65	1481.99	49.81
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.18	26.54	25.96	1781.69	43.52
2	0.08	1.95	31.90	23.78	1942.37	40.70
3	0.08	1.74	38.41	21.83	2112.75	38.20
4	0.08	1.54	46.31	20.09	2291.73	35.98
5	0.07	1.36	55.97	18.55	2477.61	34.01
6	0.07	1.18	67.84	17.20	2667.93	32.24

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Scaling Calculations

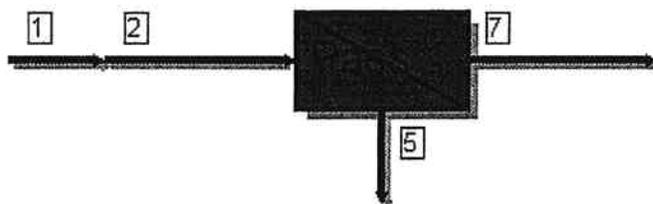
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.67
Stiff & Davis Stability Index	0.63	0.63	1.61
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2859.56
HCO3	254.00	254.00	972.85
CO2	10.01	10.01	13.56
CO3	0.67	0.67	10.16
CaSO4 (% Saturation)	8.12	8.12	63.92
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1154.72
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells NF (No Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (7/1)	75.00 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
Stage #	1	2
Element Type	NF90-400	NF90-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	11.43 gfd	5.97 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	0.82 kWh/kgal	

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Project: City of Gillette Madison Wells NF (No Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 1
 5/24/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1153.00	0.00	727.24
3	1153.00	67.90	730.49
5	288.23	30.64	2859.56
7	864.77	-	18.33
7/1	% Recovery	75.00	

Project Information:

NF Treatment for TDS and Sulfate Reduction (No Blend)

Design Warnings:

CAUTION: The concentrate flow rate is less than the recommended minimum flow. Please change your system design to increase concentrate flow rates. (Product: NF90-400, Limit: 13.00gpm)

Solubility Warnings:

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (25 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

Project Information:NF Treatment for TDS and Sulfate Reduction (25% Blend)

System Details

Feed Flow to Stage 1	1153.03 gpm	Pass 1 Permeate Flow	864.77 gpm	Osmotic Pressure:	
Raw Water Flow to System	1453.03 gpm	Pass 1 Recovery	75.00 %	Feed	3.86 psig
Feed Pressure	67.90 psig	Feed Temperature	50.0 F	Concentrate	13.74 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.80 psig
Chem. Dose (100% H2SO4)	0.00	Number of Elements	324	Average NDP	41.48 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	42.58 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	300.00 gpm	Specific Energy	0.61 kWh/kgal
System Recovery	80.16 %	Total Blended Product	1164.77 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	36	6	1153.03	62.90	0.00	467.38	48.52	685.65	11.43	0.00	0.00	12.25
2	NF90-400	18	6	467.38	43.52	0.00	288.26	30.64	179.12	5.97	0.00	0.00	41.64

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	13.55	21.24	0.35	1.18	0.52	1.86
Mg	43.00	43.00	105.11	169.03	0.66	2.24	0.99	11.81
Ca	133.00	133.00	325.18	522.99	2.00	6.85	3.00	36.49
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	4.16	10.16	0.00	0.00	0.00	0.04
HCO3	254.00	254.00	612.37	972.79	6.29	21.26	9.38	72.62
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	23.99	37.88	0.48	1.64	0.72	3.11
F	1.10	1.10	2.61	4.08	0.07	0.24	0.11	0.36
SO4	283.00	283.00	694.64	1121.18	2.40	8.22	3.61	75.57
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.43	13.57	10.25	11.97	10.61	10.38
TDS	727.24	730.49	1781.63	2859.36	12.25	41.64	18.33	201.86
pH	7.60	7.60	7.87	7.96	6.10	6.55	6.26	7.10

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (25 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55

Case: 2
 5/25/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	3.74	7.17	32.03	730.49	62.90
2	0.12	3.48	8.69	28.28	826.15	59.19
3	0.13	3.25	10.60	24.80	940.79	56.10
4	0.14	3.05	13.05	21.55	1080.94	53.55
5	0.15	2.85	16.32	18.50	1256.37	51.47
6	0.17	2.67	20.81	15.65	1481.96	49.81
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.18	26.53	25.97	1781.63	43.52
2	0.08	1.95	31.90	23.78	1942.30	40.70
3	0.08	1.74	38.40	21.83	2112.67	38.20
4	0.08	1.54	46.31	20.09	2291.62	35.98
5	0.07	1.36	55.97	18.55	2477.48	34.01
6	0.07	1.18	67.83	17.20	2667.77	32.24

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Scaling Calculations

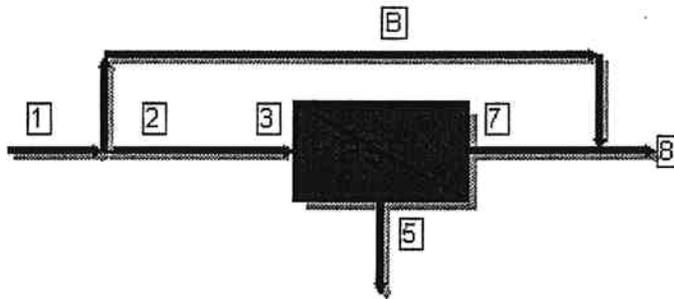
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.67
Stiff & Davis Stability Index	0.63	0.63	1.61
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2859.36
HCO3	254.00	254.00	972.79
CO2	10.01	10.01	13.56
CO3	0.67	0.67	10.16
CaSO4 (% Saturation)	8.12	8.12	63.92
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1154.48
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells NF (25 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	80.16 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
Stage #	1	2
Element Type	NF90-400	NF90-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	11.43 gfd	5.97 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	0.61 kWh/kgal	

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Project: City of Gillette Madison Wells NF (25 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 2
 5/25/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1453.03	0.00	727.24
2	1153.03	0.00	730.49
3	1153.03	67.90	730.49
5	288.26	30.64	2859.36
7	864.77	-	18.33
B	300.00	0.00	730.49
8	1164.77	0.00	201.86
7/2	% Recovery	75.00	

Project Information:
 NF Treatment for TDS and Sulfate Reduction (25% Blend)

Design Warnings:
 -None-

Solubility Warnings:
 Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (50 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 3
 5/25/2007

Project Information:NF Treatment for TDS and Sulfate Reduction (50% Blend)

System Details

Feed Flow to Stage 1	1153.03 gpm	Pass 1 Permeate Flow	864.77 gpm	Osmotic Pressure:	
Raw Water Flow to System	1730.03 gpm	Pass 1 Recovery	75.00 %	Feed	3.86 psig
Feed Pressure	67.90 psig	Feed Temperature	50.0 F	Concentrate	13.74 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.80 psig
Chem. Dose (100% H2SO4)	0.00	Number of Elements	324	Average NDP	41.48 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	42.58 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	577.00 gpm	Specific Energy	0.49 kWh/kgal
System Recovery	83.34 %	Total Blended Product	1441.77 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	36	6	1153.03	62.90	0.00	467.38	48.52	685.65	11.43	0.00	0.00	12.25
2	NF90-400	18	6	467.38	43.52	0.00	288.26	30.64	179.12	5.97	0.00	0.00	41.64

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	13.55	21.24	0.35	1.18	0.52	2.59
Mg	43.00	43.00	105.11	169.03	0.66	2.24	0.99	17.80
Ca	133.00	133.00	325.18	522.99	2.00	6.85	3.00	55.03
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	4.16	10.16	0.00	0.00	0.00	0.10
HCO3	254.00	254.00	612.37	972.79	6.29	21.26	9.38	107.59
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	23.99	37.88	0.48	1.64	0.72	4.44
F	1.10	1.10	2.61	4.08	0.07	0.24	0.11	0.51
SO4	283.00	283.00	694.64	1121.18	2.40	8.22	3.61	115.42
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.43	13.57	10.25	11.97	10.61	10.27
TDS	727.24	730.49	1781.63	2859.36	12.25	41.64	18.33	303.48
pH	7.60	7.60	7.87	7.96	6.10	6.55	6.26	7.26

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (50 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 3
 5/25/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

CaF2 (% Saturation) > 100%

Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	3.74	7.17	32.03	730.49	62.90
2	0.12	3.48	8.69	28.28	826.15	59.19
3	0.13	3.25	10.60	24.80	940.79	56.10
4	0.14	3.05	13.05	21.55	1080.94	53.55
5	0.15	2.85	16.32	18.50	1256.37	51.47
6	0.17	2.67	20.81	15.65	1481.96	49.81
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.18	26.53	25.97	1781.63	43.52
2	0.08	1.95	31.90	23.78	1942.30	40.70
3	0.08	1.74	38.40	21.83	2112.67	38.20
4	0.08	1.54	46.31	20.09	2291.62	35.98
5	0.07	1.36	55.97	18.55	2477.48	34.01
6	0.07	1.18	67.83	17.20	2667.77	32.24

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Scaling Calculations

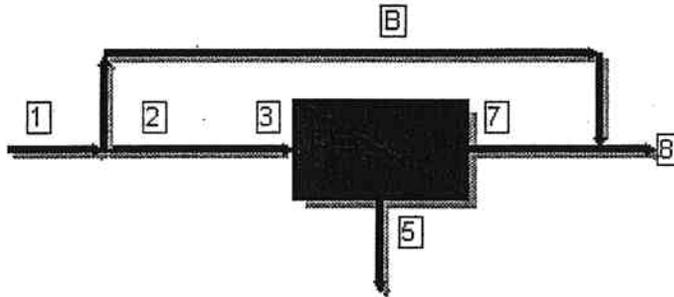
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.67
Stiff & Davis Stability Index	0.63	0.63	1.61
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2859.36
HCO3	254.00	254.00	972.79
CO2	10.01	10.01	13.56
CO3	0.67	0.67	10.16
CaSO4 (% Saturation)	8.12	8.12	63.92
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1154.48
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells NF (50 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 3
 5/25/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	83.34 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
	1	2
Stage #		
Element Type	NF90-400	NF90-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	11.43 gfd	5.97 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	0.49 kWh/kgal	

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Project: City of Gillette Madison Wells NF (50 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 3
 5/25/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	1730.03	0.00	727.24
2	1153.03	0.00	730.49
3	1153.03	67.90	730.49
5	288.26	30.64	2859.36
7	864.77	-	18.33
B	577.00	0.00	730.49
8	1441.77	0.00	303.48
7/2	% Recovery	75.00	

Project Information:
 NF Treatment for TDS and Sulfate Reduction (50% Blend)

Design Warnings:
 -None-

Solubility Warnings:
 Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (75 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 4
 5/25/2007

Project Information:NF Treatment for TDS and Sulfate Reduction (75% Blend)

System Details

Feed Flow to Stage 1	1153.03 gpm	Pass 1 Permeate Flow	864.77 gpm	Osmotic Pressure:	
Raw Water Flow to System	2018.03 gpm	Pass 1 Recovery	75.00 %	Feed	3.86 psig
Feed Pressure	67.90 psig	Feed Temperature	50.0 F	Concentrate	13.74 psig
Fouling Factor	1.00	Feed TDS	730.49 mg/l	Average	8.80 psig
Chem. Dose (100% H2SO4)	0.00	Number of Elements	324	Average NDP	41.48 psig
Total Active Area	129600.00 ft²	Average Pass 1 Flux	9.61 gfd	Power	42.58 kW
Water Classification: Well Water SDI < 3		Bypass Blending Flow	865.00 gpm	Specific Energy	0.41 kWh/kgal
System Recovery	85.72 %	Total Blended Product	1729.77 gpm		

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	36	6	1153.03	62.90	0.00	467.38	48.52	685.65	11.43	0.00	0.00	12.25
2	NF90-400	18	6	467.38	43.52	0.00	288.26	30.64	179.12	5.97	0.00	0.00	41.64

Pass Streams (mg/l as Ion)								
Name	Feed	Adjusted Feed	Concentrate		Permeate			
			Stage 1	Stage 2	Stage 1	Stage 2	Total	Blended Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	5.70	5.70	13.55	21.24	0.35	1.18	0.52	3.11
Mg	43.00	43.00	105.11	169.03	0.66	2.24	0.99	22.00
Ca	133.00	133.00	325.18	522.99	2.00	6.85	3.00	68.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.67	0.67	4.16	10.16	0.00	0.00	0.00	0.16
HCO3	254.00	254.00	612.37	972.79	6.29	21.26	9.38	132.04
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	6.76	10.01	23.99	37.88	0.48	1.64	0.72	5.37
F	1.10	1.10	2.61	4.08	0.07	0.24	0.11	0.60
SO4	283.00	283.00	694.64	1121.18	2.40	8.22	3.61	143.32
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	10.01	10.00	11.43	13.57	10.25	11.97	10.61	10.20
TDS	727.24	730.49	1781.63	2859.36	12.25	41.64	18.33	374.61
pH	7.60	7.60	7.87	7.96	6.10	6.55	6.26	7.34

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Reverse Osmosis System Analysis for FILMTEC™ Membranes
 Project: City of Gillette Madison Wells NF (75 Blend)
 Bayard Yang, Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 4
 5/25/2007

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	3.74	7.17	32.03	730.49	62.90
2	0.12	3.48	8.69	28.28	826.15	59.19
3	0.13	3.25	10.60	24.80	940.79	56.10
4	0.14	3.05	13.05	21.55	1080.94	53.55
5	0.15	2.85	16.32	18.50	1256.37	51.47
6	0.17	2.67	20.81	15.65	1481.96	49.81
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	2.18	26.53	25.97	1781.63	43.52
2	0.08	1.95	31.90	23.78	1942.30	40.70
3	0.08	1.74	38.40	21.83	2112.67	38.20
4	0.08	1.54	46.31	20.09	2291.62	35.98
5	0.07	1.36	55.97	18.55	2477.48	34.01
6	0.07	1.18	67.83	17.20	2667.77	32.24

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Scaling Calculations

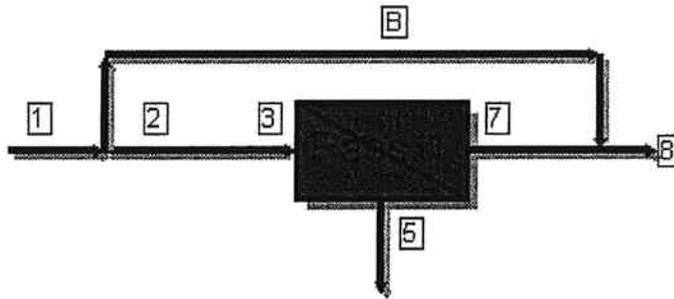
	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.96
Langelier Saturation Index	0.19	0.19	1.67
Stiff & Davis Stability Index	0.63	0.63	1.61
Ionic Strength (Molal)	0.02	0.02	0.07
TDS (mg/l)	727.24	730.49	2859.36
HCO3	254.00	254.00	972.79
CO2	10.01	10.01	13.56
CO3	0.67	0.67	10.16
CaSO4 (% Saturation)	8.12	8.12	63.92
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	21.39	21.39	1154.48
SiO2 (% Saturation)	0.00	0.00	0.00
Mg(OH)2 (% Saturation)	0.00	0.00	0.05

To balance: 3.25 mg/l Cl added to feed.

Project: City of Gillette Madison Wells NF (75 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 4
 5/25/2007

System Design Overview



Raw Water TDS	727.24 mg/l	% System Recovery (8/1)	85.72 %
Water Classification	Well Water SDI < 3	Fouling Factor (Pass 1)	1.00
Feed Temperature	50.0 F		

Pass #	Pass 1	
Stage #	1	2
Element Type	NF90-400	NF90-400
Pressure Vessels per Stage	36	18
Elements per Pressure Vessel	6	6
Total Number of Elements	216	108
Pass Average Flux	9.61 gfd	
Stage Average Flux	11.43 gfd	5.97 gfd
Permeate Back Pressure	0.00 psig	0.00 psig
Booster Pressure	0.00 psig	0.00 psig
Chemical Dose	-	
Energy Consumption	0.41 kWh/kgal	

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Project: City of Gillette Madison Wells NF (75 Blend)
 Prepared By: Bayard Yang
 Burns & McDonnell

ROSA v6.1.4 ConfigDB U238786_55
 Case: 4
 5/25/2007

Pass 1			
Stream #	Flow (gpm)	Pressure (psig)	TDS (mg/l)
1	2018.03	0.00	727.24
2	1153.03	0.00	730.49
3	1153.03	67.90	730.49
5	288.26	30.64	2859.36
7	864.77	-	18.33
B	865.00	0.00	730.49
8	1729.77	0.00	374.61
7/2	% Recovery	75.00	

Project Information:
 NF Treatment for TDS and Sulfate Reduction (75% Blend)

Design Warnings:
 -None-

Solubility Warnings:
 Langelier Saturation Index > 0
 Stiff & Davis Stability Index > 0
 CaF2 (% Saturation) > 100%
 Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

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