Long Beach Water Department Prototype Seawater Desalination Testing Facility

Test Plan
February 2006

LONG BEACH WATER

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A – Process Schematic

Glossary

CDHS	California Department of Health Services
DWPR	Desalination and Water Purification Research and Development Program
ERD	Energy Recovery Device
ERI	Energy Recovery Incorporated
ESWTR	Enhanced Surface Water Treatment Rule
GPD	gallons per day
IESWTR	Interim Enhanced Surface Water Treatment Rule
LADWP	Los Angeles Water and Power
LBWD	Long Beach Water Department
MF	microfiltration
O&M	operation and maintenance
NF/NF	two-pass nanofiltration process
NTU	nephelometric turbidity unit
QA/QC	quality assurance and quality control
Reclamation	Bureau of Reclamation, U.S. Department of Interior
RO	reverse osmosis
SWRO	sea water reverse osmosis
TDS	total dissolved solids
VFD	variable frequency drive

1.0 Process and Objectives

1.1 Process

The Long Beach Water Department (LBWD) has developed and patented a two-pass nanofiltration process, called NF/NF, to desalinate seawater to drinking water quality. Over the last several years, the LBWD has been testing the hybrid desalination process in the 9000 gallons per day (GPD) pilot scale unit at its Groundwater Treatment Plant. The hybrid desalination process consists of a two-pass multistage nanofiltration membrane process that can achieve treated water salinity better than or at least as good as a conventional single-pass seawater reverse osmosis (SWRO) desalination process utilizing cellulose acetate or thin-film composite membranes, at a lower operating pressure and energy cost. The key component is the 2nd pass concentrate recycle loop that dilutes the feed water and makes the use of nanofiltration membranes feasible. In its simplest form, the process is shown in **Figure 1.1** below.

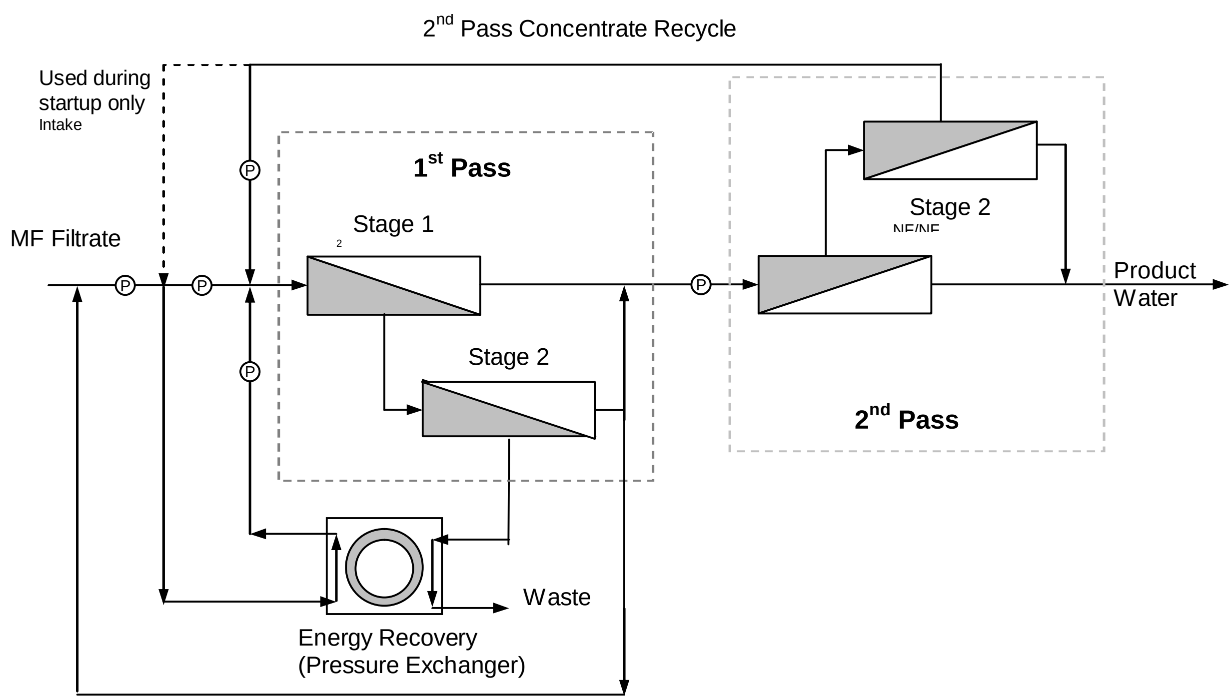


Figure 1.1: NF/NF Process Component Diagram

The next step in the development of the NF/NF process was to construct a 300,000 GPD prototype seawater desalination facility (prototype) to validate the performance results observed during initial pilot testing directly against SWRO and to test the long-term operating characteristics of the hybrid desalination process. This document will outline the test program to be employed at the prototype facility. It was compiled by personnel from LBWD, Bureau of Reclamation (Reclamation), and Los Angeles Department of Water and Power (LADWP).

1.2 Objectives

The Primary Objectives of this program are to:

A) Operate an efficient pretreatment system
B) Demonstrate that the NF/NF process is efficient and reliable.
    - **Efficiency is** defined as:
        - Maximized recovery
        - Minimized energy usage
        - Minimized chemical usage
        - Minimized cleaning cycles

    - **Reliability** is defined as:
        - Minimized down time
        - Product water quality meets primary and secondary drinking water standards

C) Measure consistency of the long term performance on the NF/NF process

D) Compare the capital and direct O&M cost of the NF/NF against SWRO under the same feed water quality conditions.

E) Provide for Regulatory Acceptability
    - Demonstrate the system meets Surface Water Treatment Rule requirements
    - Obtain California Department of Health Services (DHS) approval for the process for full-scale drinking water production

F) Develop Design Criteria (for technology transfer) relating input water quality and operating parameters to unit performance that will allow plants to be designed locally and at other locations, and to permit optimization of plant operation.

The secondary objectives for the NF/NF system include:

G) Determine the ability of the NF/NF and SWRO systems to remove emerging contaminants (e.g. boron)

2.0 Background

2.1 Site location and description

The prototype is located at the LADWP Haynes Generating Station (**Figure 2.1**). The location for the prototype facility, within the generating station site, is near the station's entrance (just north of Westminster Avenue), adjacent to and east of the station's cooling water channel.

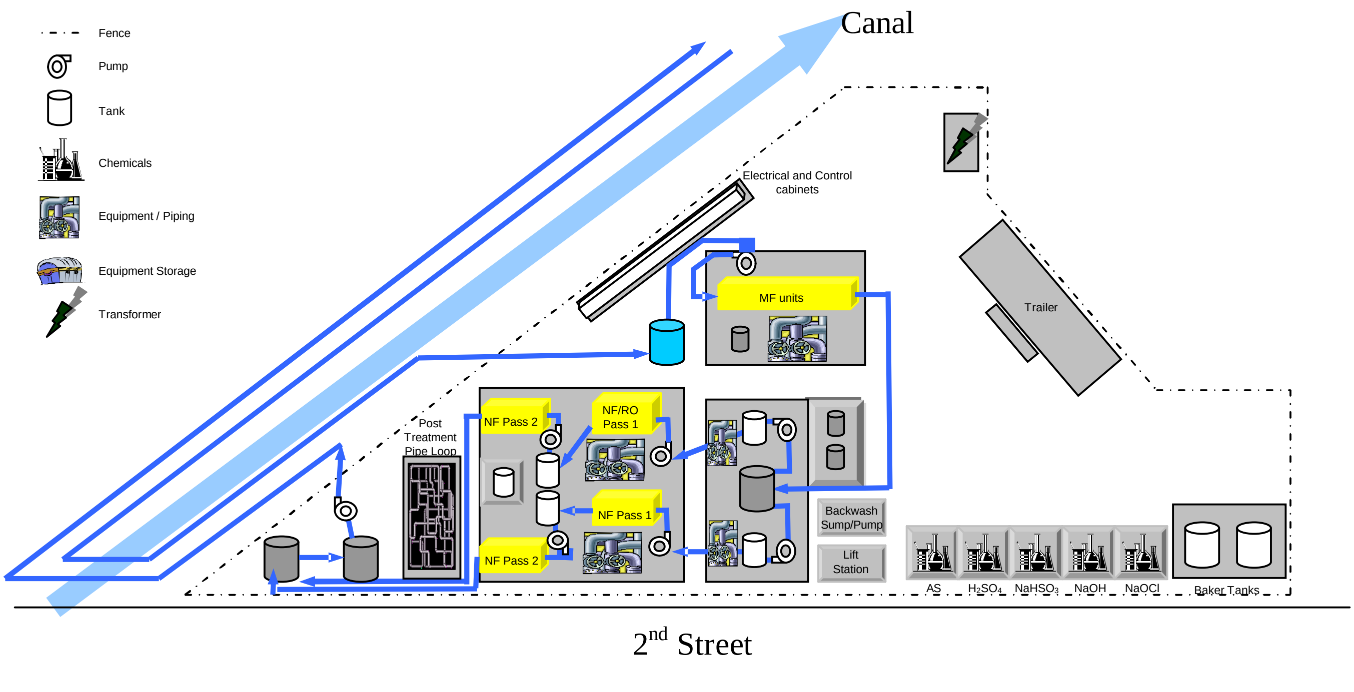


Figure 2.1: Site location and general layout

2.2 Water Composition

The source water for the prototype facility is seawater pumped from the Haynes Generating Station cooling water channel. The cooling water channel seawater intake is located within the Long Beach Marina, which is situated just west of the mouth of the San Gabriel River. The source water quality is characteristic of a coastal seawater off the coast of California. **Table 2.1** shows analyses of samples taken on two days in February 2003, one a dry day, one a rain day.

The dry day values are expected to be typical of values for that season. Rainy day samples may be unique, depending on the duration and intensity of the precipitation. It should be noted that salinity variations due to precipitation are strongly influenced by coastal currents and are site specific.

Seawater samples will be taken periodically during prototype testing to generate a database of compositions. This will allow prediction of the annual variation of seawater composition during dry weather and to estimate what kind of deviations in composition might be produced by precipitation.

<u>Table 2.1</u> Haynes cooling channel seawater composition

		Dry Day Samples February 12, 2003					**Rainy Day Samples February 2, 2003**		
Component	**Unit**	**High Tide**	**Mid Tide**	**Low Tide**	**Average**	**Max.**	**Low Tide**	**Mid Tide**	**High Tide**
Primary Regulated Ions									
Arsenic	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Barium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, total	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, VI	mg/L	ND	ND	*NA*	*NA*	*NA*	*NA*	ND	ND
Copper	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Fluoride	mg/L	0.68	0.68	0.67	0.68	0.68	0.61	0.58	0.59
Lead	mg/L	ND	ND	ND	ND	ND	ND	0.051	0.051
Mercury	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ug/L	ND	ND	ND	ND	ND	ND	ND	ND
Other Ions									
Aluminum	mg/L	0.068	0.052	0.040	0.053	0.068	0.149	0.148	0.202
Ammonia	mg/L	0.11	0.09	0.1	0.1	0.11	0.09	0.09	0.09
Bicarbonate	mg/L	113	113	113	113	113	112	112	113
Boron	mg/L	3.9	3.9	3.8	3.9	3.9	4.3	4.2	4.1
Bromide	mg/L	60.9	59.3	59.2	59.8	60.9	50.9	50.9	51.2
Calcium	mg/L	409	410	415	411	415	439	802	444
Carbonate	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Chloride	mg/L	18,566	18,236	18,476	18,426	18,566	18,948	18,828	18,903
Hardness, total	mg/L	6,150	6,176	6,241	6,189	6,241	6,214	7,087	6,205
Hydrogen sulfide	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Iron, total	mg/L	ND	ND	0.1	0.1	0.1	0.1	ND	0.1
Iron, dissolved	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	mg/L	1,246	1,251	1,246	1,254	1,264	1,243	1,235	1,238
Manganese	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Phosphate	mg/L	0.15	0.16	0.11	0.14	0.16	0.12	0.09	0.12
Potassium	mg/L	370	372	374	372	374	425	395	395
Silica (SiO2) total	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Silica (Reactive)	mg/L	0.85	0.7	0.87	0.81	0.87	0.86	0.64	0.38
Silica (Dissolved)	mg/L	0.43	0.41	0.4	0.41	0.43	*NA*	*NA*	*NA*
Silver	µg/L	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	mg/L	9,961	9,999	10,085	10,015	10,085	10,117	10,056	10,037
Strontium	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	6.6	6.5	6.6
Sulfate	mg/L	2,342	2,316	2,347	2,335	2,347	2,383	2,363	2,374
Sulfide	mg/L	ND	ND	ND	ND	0	ND	ND	ND
Vanadium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	mg/L	ND	ND	ND	ND	ND	ND	ND	ND

ND = Not Detected
NA = Not Available

Table 2.1 (con't) Haynes cooling channel seawater composition

Component	Unit	Dry Day Samples February 12, 2003					Rainy Day Samples February 2, 2003		
		High Tide	Mid Tide	Low Tide	Average	Max.	Low Tide	Mid Tide	High Tide
Algae Count	Natural Units/mL	3,160	4,440	1,440	3,013	4,440	2,160	972	2,230
Color, apparent	Pt-Co	29	19	20	22.7	29	40	38	48
Color, true	Pt-Co	5	6	7	6	7	15	12	16
Conductance	µS/cm	50,300	50,400	50,700	50,500	50,700	50,100	49,800	47,300
TDS/ conductance		0.68	0.676	0.662	0.671	0.662	0.69	0.694	0.73
Heterotrophic Plate Count	cfu/mL	300	200	95	198	300	110	170	218
MTBE	mg/L	ND	ND	ND	*NA*	*NA*	ND	ND	ND
DOC	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
Organic Carbon (Total)	mg/L	ND	ND	ND	ND	ND	ND	ND	ND
DO	mg/L	8.68	8.45	8.77/8.17	8.57	8.68	8.15	8.12	7.66
pH (sampling)	unit	7.98	8.03	7.84	7.95	8.03	8.07	8.01	7.99
Plankton Counts	Natural Units/	<1	<1	<1	*NA*	*NA*	<1	<1	<1
Temperature (sampling)	^oC	17.5	17	16	16.8	17.5	15.2	15.3	16.3
Total Dissolved Solids (TDS)	mg/L	34,115	33,950	33,630	33,898	34,115	34,580	34,565	34,460
Total Algal Count	Cells/ 100mL	78,000	64,000	52,000	64,667	78,000	20,000	*NA*	6,200
Total Suspended Solids (TSS)	mg/L	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Turbidity	ntu	2.1	2	2	2	2.1	3.3	2.5	4.1
UV_{254}	cm^{-1}	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
TDS (calculated)		33,141	32,814	33,179	33,044	33,179	33,879	34,052	33,769
%Difference		3%	3%	1%	3%	3%	2%	1%	2%

ND = Not Detected
NA = Not Available

3.0 Treatment Process and Equipment

A general process schematic diagram for the prototype desalination treatment system is presented in **Figure 3.1**. A detailed process schematic is shown in **Attachment A**.

The major treatment components of the test facility include pressurized microfiltration (MF) pretreatment, followed by two parallel desalination trains. The south desalination train (Train 1) is configured for NF/NF with optional energy recovery. A north desalination treatment train (Train 2) will be initially operated as conventional SWRO with optional energy recovery. In general the entire prototype system will be operated as one entity with the option of operating either Train 1 or Train 2 by itself. After completion of the initial phases of testing, Train 2 will be reconfigured as a second NF/NF train. The prototype facility includes a product water post-treatment testing station. Post-treatment testing will evaluate the effects of desalinated seawater before post-treatment and after post-treatment. This will include corrosion effects on common distribution system materials. Guidelines will be developed to minimize corrosion effects for desalination facilities.

3.1 Pretreatment

The source water for the prototype facility is seawater diverted from the Haynes Generating Station cooling water channel. Trash racks at the channel intake screen the flow to remove coarse materials. The influent raw seawater is passed through 300 µm self-backwashing strainers prior to reaching the pretreatment process. The prototype facility will use a Pall MF system as pretreatment for the desalination processes. The MF system will remove particulates greater than 0.1 µm in size from the raw seawater and provide a low fouling potential water to the downstream desalting processes.

The MF is expected to operate up to 10% recycle and a minimum and maximum filtrate flow of 556 gpm and 660 gpm, respectively. MF filtrate is directed to the 10,000 gal MF filtrate storage tank, which is adequate to continually supply MF filtrate to both trains, while the MF process undergoes backwash. A bypass pipe is provided to allow the off-spec feed water to be returned to the channel via the Combined Effluent Tank. Filtrate water entering the MF filtrate storage tank must have the following specifications:

- Turbidity ≤ 0.2 NTU
- Silt Density Index ≤ 5.0

Water exiting the MF filtrate tank after de-chlorination must have the following specification:

- Chlorine Residual ≤ 0.1 mg/L (membrane dependent)

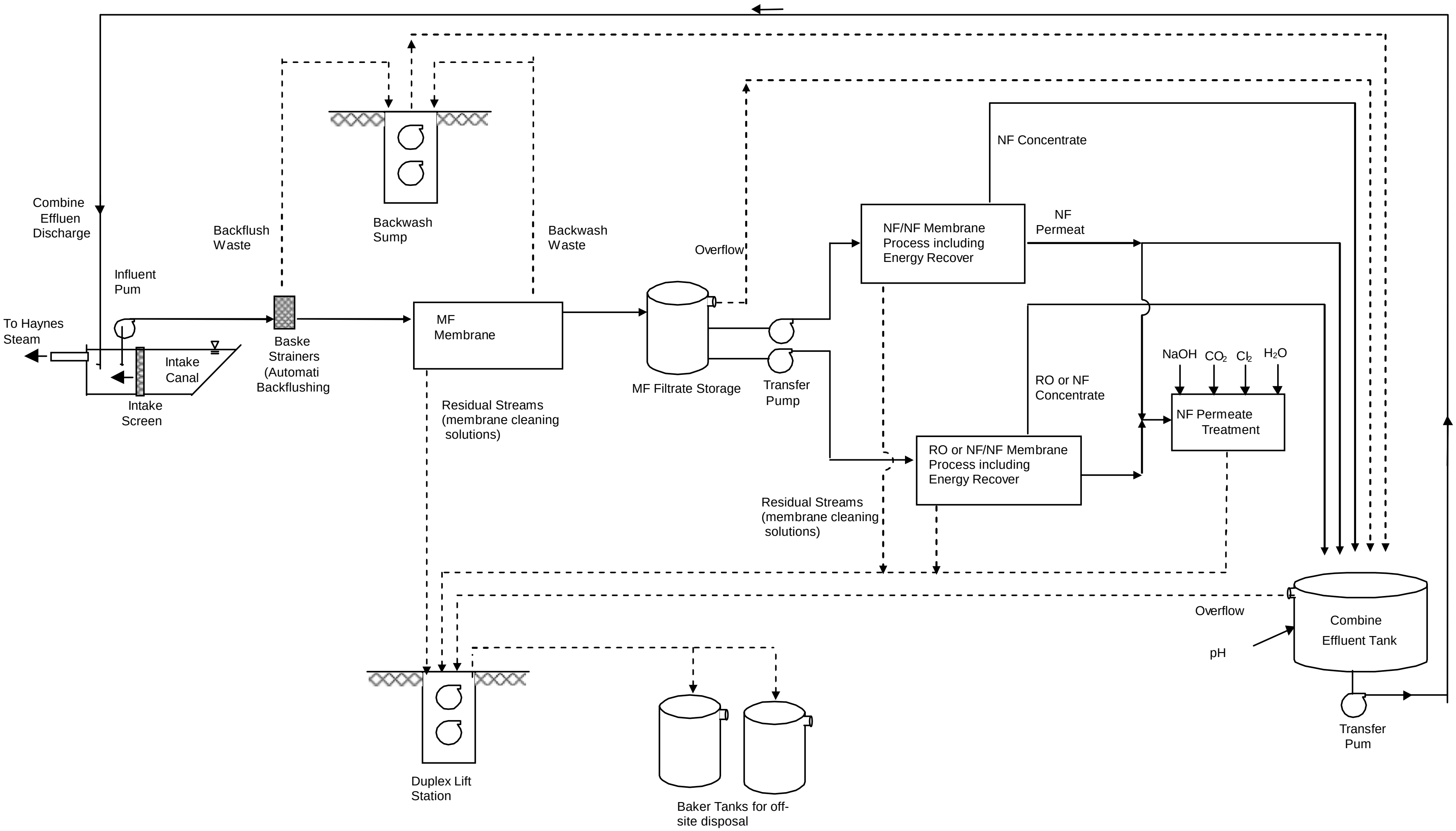
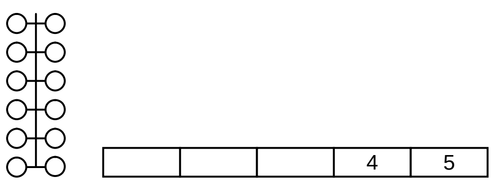


Figure 3.1 NF2 general process schematic

The MF system is backwashed at staggered intervals of approximately 15 to 60 minutes (currently 22 min.) and can be manually changed. Backwash frequency is based on how quickly head loss increases and the backwash cycle duration needed to restore the membrane. Source water quality changes and its effect on MF membrane performance will be considered. Chlorine will be used in the backwash water to assist in minimizing biogrowth on the membranes. Backwash water will be neutralized as required, and discharged to the Combined Effluent Tank. The MF system requires chemical cleaning with citric acid or sodium hydroxide/chlorine if fouling occurs. Fouling is recognized by a differential pressure exceeding 20 psi. Used cleaning chemical solutions are discharged to the on-site baker tanks after required neutralization.

Distinction is made between pretreatment equipment and desalination equipment at the NF/SWRO feed tank. One tank for each train has been provided to allow for limited short-term flow differences between the source water feed pumps and the low-pressure transfer pump. This permits a constant flow rate through the desalination process trains during microfiltration process backwashes. The MF filtrate water may be blended in the respective feed tanks with permeate from Pass 1 – Stage 2. As the tank fills, a high-level sensor signals that the NF/SWRO feed pumps for that respective train can be started. The NF/SWRO feed tank is provided with an overflow pipe leading to the Combined Effluent Tank.

3.2 Train 1: NF/NF Pass 1 – Stage 1



The NF/NF process is arranged in two passes, with the permeate from Pass 1 NF vessels being used as the feed water to the Pass 2 NF vessels. Under this treatment scheme, the total dissolved solids concentration of the MF pretreated water (approximately 34,000 mg/L) can be reduced to 340 mg/L or less when the TDS rejection in each NF pass is at least 90%.

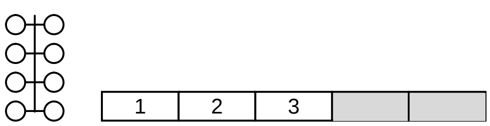
Pass 1 performs the preliminary desalination of the seawater. This membrane stage consists of 12 vessels. They are operated in parallel (6 vessels per side), each capable of holding five membrane elements.

The Pass 1 Feed Pump fills the Pass 1 membrane rack at a minimum inlet pressure of about 50 psi to the Pass 1 High Pressure Pump. Capability to feed acid and scale inhibitor chemicals is provided in the system to control the scaling potential of the pretreated water. The two chemicals can be injected into the Pass 1 Feed Pump discharge. After chemical addition, the pretreated water passes through a 10 µm cartridge filter that provides protection for the NF membranes and ensures that chemicals added are well mixed with the feed water.

The Pass 1 High Pressure Pump is controlled by a variable frequency drive (VFD) and provides flow and operating pressure up to 600 psi for Pass 1. While the Pass 1 High Pressure Pump provides the flow and high pressure, the pressure is further refined through a pressure control valve on the discharge side of the high pressure pump. The combination of the VFD driven high pressure pump and pressure control valve allows the testing of specific pressure and flow. The value of 530 psi, used in the bench test unit is a reasonable starting value. However, to optimize the unit performance, we need data covering a range of values.

When the energy recovery device (ERD), an Energy Recovery Incorporated (ERI) isobaric chamber pressure exchanger, is not being employed, the recovery of Train 1 Pass 1 is controlled by a flow control valve on the discharge of Train 1 Pass 1 concentrate line. By limiting the flow out of the Pass 1, more recovery can be achieved. However, it is important to note that increasing recovery will result in higher required pressure and subsequently poorer product quality. When the ERD is used, concentrate from Pass 1, Stage 2 is discharged through the device to recover the available energy. The ERD can potentially transfer up to 97% of the Pass 1 pressure remaining in the concentrate stream. The feed flow into the ERD must equal the concentrate flow. An energy recovery booster pump on the discharge side of the ERD will boost the flow to overcome the Pass 1 High Pressure Pump Pressure. Consequently, the energy recovery booster pump will control the recovery of Pass 1 when the ERD is employed.

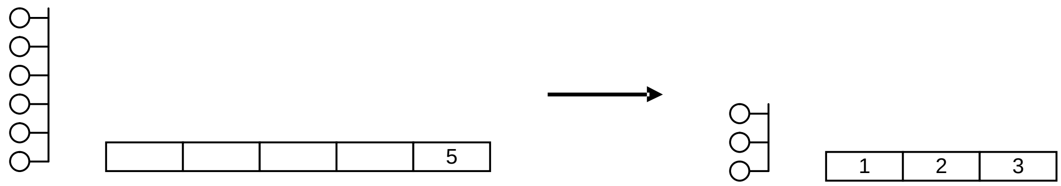
3.3 Train 1: NF/NF Pass 1 – Stage 2



The purpose of this portion of the system is to recover additional water from the still pressurized concentrate from Pass 1 – Stage 1 to increase the recovery of permeate of Pass 1. The Pass 1 – Stage 2 consists of eight vessels. They are operated in parallel (4 vessels per side), each capable of holding five membrane elements. Experience shows that after 3 membranes, the osmotic pressure is equal to the feed pressure and flow can not be obtained. The permeate from this section may be too high in salinity to be delivered to the Pass 2, but is less concentrated than the original feed (for full strength seawater), so it may be recycled to the Pass 1 Feedwater Tank. If the Stage 2 permeate TDS is not too high, it can be combined with the Stage 1 permeate.

Optimization of Pass 1, Stage 2, will be part of the model to be developed. The critical parameter is the dividing line between Stage 1 and Stage 2. This will be determined by calculation and confirmed by experiment. At this time, two membranes are in use (530 psi feed). This number may increase if TDS and corresponding feed pressures increase.

3.4 Train 1: NF/NF Pass 2 – Stage 1 & 2



Train 1: Pass 2 also consists of 2 stages; where Stage 1 consist of six vessels, each capable of holding five elements and Stage 2 consist of three vessels, each capable of holding three elements.

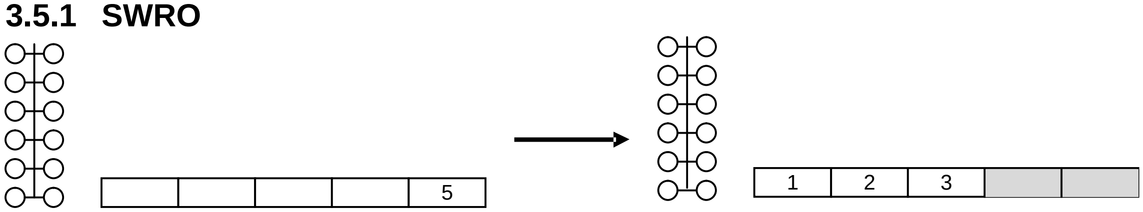
Permeate from the Pass 1 constitutes the feed for Pass 2. A VFD controls the Pass 2 High Pressure Pump. A control valve is located on the discharge side of the Pass 2 High Pressure Pump. Like Pass 1, the desired test flow and pressure is controlled with the combination of the two.

Based on pilot testing data, the final concentrate TDS from Pass 2 is still less than the raw seawater TDS, thus, it can be recycled to the Pass 1 feed. The final Pass 2 concentrate can be recycled to either the suction side of the Pass 1 High Pressure Pump or can be boosted through the Pass 2 booster pump to the discharge side of the Pass 1 High Pressure Pump. The latter will be the primary method of recycling the Pass 2 concentrate since this will allow the greatest energy recovery. Consequently, the recovery of Pass 2 is controlled by the amount of recycle to Pass 1.

The combined Pass 2 product TDS goal is 350 mg/L based on the LBWD existing distribution system TDS. It is a useful property of this process that the product salinity can be adjusted close to the desired value by configuration of the unit. To obtain a particular product salinity, the operating rejection of Stage 2 depends exclusively on the rejection of Pass 1 – Stage 1 and any contribution from Pass 1 – Stage 2. As the latter decreases, the former must increase. The operating pressure is determined by the membrane permeability and the desired water recovery.

3.5 Train 2: SWRO/NF – Stage 1 & 2

3.5.1 SWRO



Train 2 is initially configured as a conventional SWRO system. The SWRO system consists of two stages. The first stage and second stages have 12 vessels operated in parallel (6 vessels per side). Each vessel is capable of holding five membrane elements. Each second stage vessel is expected to hold from two to three elements. Using all eight second stage vessels, the second stage is an extension of the first stage that permits testing up to eight elements in series with sampling available after element 5.

Like Train 1, the Train 2 Feed Pump fills the SWRO membrane rack at a minimum inlet pressure of 50 psi to the SWRO High Pressure Pumps. Capability to feed acid and scale inhibitor chemicals is provided in the system to control the scaling potential of the pretreated water. The two chemicals can be injected into the SWRO Feed Pump discharge. After chemical addition, the pretreated water passes through a 10 µm cartridge filter that provides protection for the SWRO membranes and ensures that chemicals are well mixed with the feed water.

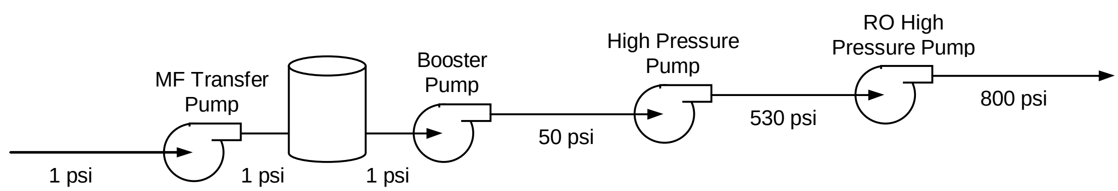


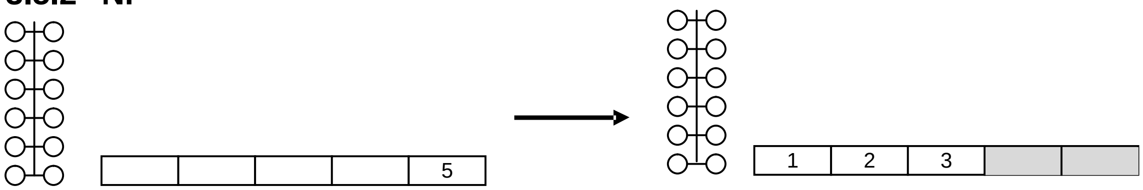
Figure 3.2: Membrane pumping system (energy recovery portion not shown)

There are two high pressure pumps for the SWRO train, staged in series. The SWRO High Pressure Pump 1 can increase the feed pressure to a maximum of 600 psi and the SWRO High Pressure Pump 2 can further increase the feed pressure up to a maximum of 1000 psi. Both SWRO High Pressure Pumps are controlled by a VFD and combined with a control valve on the discharge side of the SWRO High Pressure Pump 2 allows the testing of specific pressure and flow.

Traditional SWRO membrane systems typically operate at much higher pressures than NF membranes (up to 1,000 psi). As compared with the NF/NF process, conventional SWRO is a one pass process, with recovery ranging from 40 to 50 percent. For SWRO membranes to achieve product water quality comparable to the NF/NF process, the overall salt rejection has to be greater than 99% in the single pass.

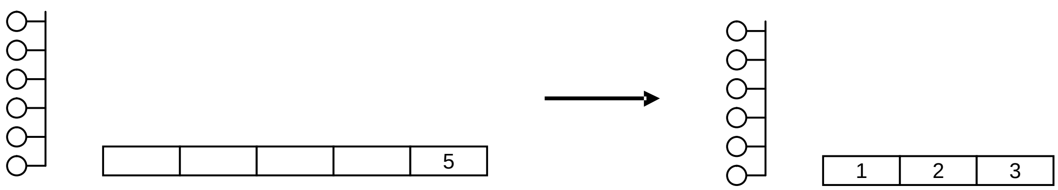
After the initial phase of testing comparing the performance of the NF/NF process with SWRO with respect to product water quality and overall system efficiency, the second treatment train will be reconfigured as a second NF/NF system for the remainder of testing. A bypass section of pipe is installed on the discharge of SWRO High Pressure Pump 1 to bypass SWRO High Pressure Pump 2 after the initial phase of testing. Regardless of whether Train 2 is operated as SWRO or as a second NF/NF train, recovery control is identical to that of Train 1.

3.5.2 NF



After the initial phase of testing comparing the performance of the NF/NF process with SWRO with respect to product water quality and overall system efficiency, the second treatment train will be reconfigured as a second NF/NF system for the remainder of testing. A bypass section of pipe is installed on the discharge of SWRO High Pressure Pump 1 to bypass SWRO High Pressure Pump 2 after the initial phase of testing. Regardless of whether Train 2 is operated as SWRO or as a second NF/NF train, recovery control is identical to that of Train 1. See section 3.2 to 3.4 for a description of NF/NF operation.

3.6 Train 2: NF/NF Pass 2 – Stages 1 & 2



Train 2: Pass 2 is nearly identical to Train 1: Pass 2 with the exception that Pass 2 – Stage 2 consists of six vessels, each capable of holding three elements. The basic operating capability of Train 2: Pass 2 is identical to that of Train 1.

3.7 Energy Recovery

The concentrate stream from Pass 1 – Stage 2 will consist of 45% to 55% of the feed volume of water at a pressure of several hundred psi. This represents energy that can be recovered and returned to the process.

Historically, the commonly used means of energy recovery was a Pelton wheel turbine. However, more recently developed units like the Pressure Exchanger (PX) operate more efficiently. Manufacturer performance projections for the PX indicate 20% greater energy recovery than can be achieved with a Pelton wheel turbine.

The Pressure Exchanger technology has been developed by Energy Recovery, Inc. The PX utilizes the principle of positive displacement to allow low-pressure pretreated seawater to be pressurized directly by the high-pressure concentrate stream from the desalination process. The device uses a cylindrical rotor with longitudinal ducts to transfer the pressure energy from the concentrate stream to the feed stream. The rotor spins inside a sleeve between two end covers with ported openings for low-pressure and high-pressure.

The low-pressure side of the rotor fills with seawater. The high-pressure side of the rotor fills with concentrate, which discharges the seawater at a higher pressure than the inlet pressure. The pressure exchanger pressurizes 45% to 55% of the Pass 1 Stage 1 feedwater to 95% of the pressure required. A booster pump provides the additional 5% of the pressure required. There is some inefficiency in the PX recognized by a small amount of salt transfer from the concentrate to the feed (1 to 2%) (**Figure 3.3**) and friction loss.

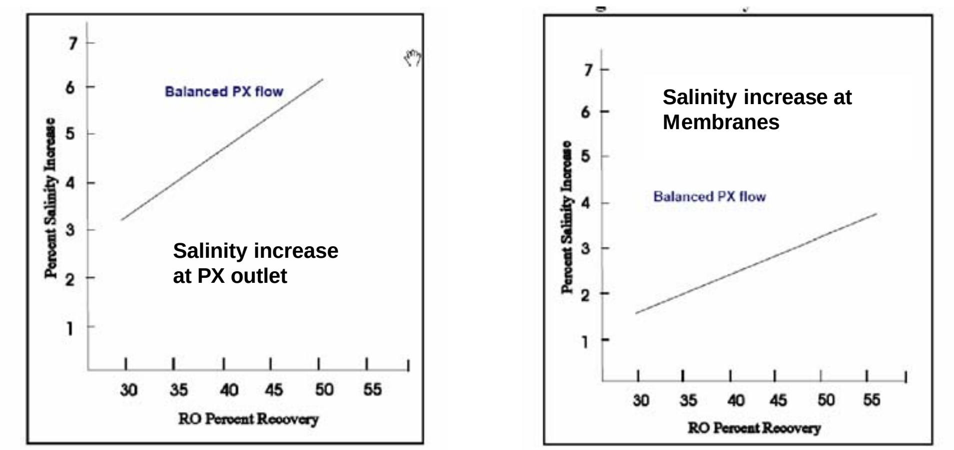


Figure 3.3: Salinity increase from the PX

3.8 Post Treatment

A portion of the product water stream from either Train 1 or Train 2 can be directed to the post-treatment system for evaluation of the effects of desalinated seawater on distribution system components. Post treatment equipment consists of chemical dosing systems for sodium hypochlorite (for disinfection), blend water (source of calcium), sodium hydroxide and carbon dioxide (both for pH adjustment). A chlorine contact loop with adjustable residence time (depending on the settings of multiple valves) follows addition of sodium hypochlorite. The corrosivity and pH of the product stream can then be adjusted through the addition of sodium hydroxide and carbon dioxide. Three evaluation stations will be used to evaluate the effects of the following water samples on common distribution system materials:

- Desalinated seawater before post-treatment
- Desalinated seawater after post-treatment
- Normal distribution system water

Post treatment results from the RO and NF systems will be compared. More detailed post treatment tests will be performed during later NF only testing.

The treatment system has 2 major goals, the reduction in viable pathogen content and the reduction in TDS. Pathogen reduction in this design is achieved through physical barriers (ultra filter (UF) membranes, cartridge filters, and reverse osmosis (RO) membranes) and oxidation (ultraviolet light (UV) and chloramines) (**Table 9.1**). TDS reduction is achieved through physical removal using RO membranes.

3.9 Pathogen Removal

Table 9.1: Log inactivation/removal credit provided from a regulatory standpoint

	Treatment Credit							Required Credit		
	200 μm Strainer	UF	Cartridge Filter	NF Pass 1	NF Pass 2	Chlorine	Total	SDWA [2]	Additional LT2 ESWTR [3]	Total
Giardia	-	4	0	0	0	3		3.0	N/A	
Total Credit	0	4	4	4	4	7	**7.0**	3.0	3.0	**3.0**
Viruses	-	2	0	0	0	4		3.0	N/A	
Total Credit	0	2	0	0	0	6	**6.0**	3.0	3.0	**3.0**
Cryptosporidium	-	4	0	0	0	0		3.0	2.5	
Total Credit	0	4	4	4	4	4	**4.0**	3.0	5.5	**5.5**

1 - RO is not given credit due to variability in the membrane surface and insufficient ability to integrity check. However, actual removal of all organisms is expected to be at least 3.0 log removal.
2 – SDWA = Safe Drinking Water Act
3 – LT2 ESWTR = Long Term 2 Enhance Surface Water Treatment Rule
4 – Additional credits may be needed due to diversion of wastewater before the chlorine contact basin

3.10 Chemical Addition

Chemical metering pumps are used to supply treatment chemicals to various system processes. The prototype facility will include chemical addition systems for the following:

- Sodium Hypochlorite prior to the MF for major cleaning only
- Sodium Hypochlorite to the MF backwash water to enhance backwash
- Sodium Hydroxide to the MF clean-in-place (CIP) process
- Sodium Bisulfite to the MF filtrate for dechlorination
- Sulfuric Acid to the Train 1 & 2 feed separately to reduce scaling
- Scale Inhibitor to the Train 1 & 2 feed separately to reduce scaling

- CIP Feed Solution of sodium hydroxide or Citric Acid to Trains 1 & 2 - Pass 1 & 2 separately for membrane cleaning
- Sodium Hydroxide to Train 1 & 2 Pass 2 feed separately for increased Boron removal
- Sodium Hypochlorite to Post Treatment system for distribution system disinfectant residual simulation
- Sodium Hydroxide to Post Treatment system for distribution system pH adjustment
- Carbon Dioxide to Post Treatment system for distribution system recarbonation
- Sodium Bisulfite to the combined effluent to remove any free chlorine before discharge
- Sodium Hydroxide to the combined effluent to ensure proper pH in the discharge water

3.11 Online Instrumentation

The following online instrumentation is included in the prototype facility:

- Alkalinity
- Conductivity
- Differential pressure
- Energy usage
- Flow
- Hardness
- Oxidation/Reduction potential
- pH
- Pressure
- Temperature
- Turbidity

4.0 Test Program

4.1 General Plan

A summary of the proposed project phases and their goals is shown in **Table 4.1**. The timeline for implementing the phases is shown in **Table 4.2**.

Table 4.1: Testing phases

Phase	Goal
1 System Startup	100% operational equipment with calibrated and verified instrumentation
2 Process Validation	Obtain data from the RO & NF/NF process for comparison purposes
3 NF/NF Optimization	Convert the RO system to an NF/NF system and optimize the process
4 Regulatory Approval	Provide the necessary data for the final approval of the NF/NF process for seawater desalination by CDHS
5 Report	Analyze remaining data and finish reporting, etc.

Table 4.2: Testing phase timeline

		2005	2006												2007		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
	Phase	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	System Startup	■	■	■													
2	Process Validation				■	■	■	■	■	■							
3	NF/NF Optimization										■	■	■	■			
4	Regulatory Approval														■	■	
5	Report																■

Table 4.3 combines the objectives with the plan on how to accomplish each objective. Specific goals are shown where relevant along with the phase in which each objective will be accomplished.

Table 4.3: Objectives, plan to accomplish objectives, goals, and relevant phases

Objective	Description	Detail	How to Accomplish Objective	Phase	Threshold	Goal	Estimated Optimum
A	Operate and efficient pretreatment system		SDI	2,3	5 (max)	<4	3
			Turbidity (NTU)	2,3	0.2 (max)	<0.2	0.05
			Flux (GFD)	2,3			30
B	Demonstrate that the NF/NF process is efficient and reliable	Efficiency	Maximize Recovery	2,3	30% (min.)	>35%	40%
			Minimize Energy Usage	2.3			
			Minimize Chemical Usage - Sulfuric Acid	2,3			
			Scale Inhibitor	2,3			
			Minimize MF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
			Minimize NF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
		Reliability	Minimize down time *	2	95% operational time	>95% operational time	
			Meet Primary Standards by obtaining data on all likely contaminants	2	100% of the time	100% of the time	
			Meet Secondary Standards by obtaining data on all likely contaminants	2	99% of the time	100% of the time	
C	Measure consistency of the long term performance on the NF/NF process		Demonstrate that changes in feed water do not substantially change the product water quality by recording feed and product water quality data	2			
			Demonstrate that initial performance levels are maintained (e.g. constant flux) and equipment (e.g. membranes) meet their projected lifespan	2			
D	Compare the Capital and O&M Cost of the NF/NF and RO system under the same usage conditions			2			
E	Regulatory Acceptability	SWTR	(see Objective **B**)	2,3,4			
		DHS	Work toward approval for treatment process	2,3,4			
F	Develop Design Criteria (for technology transfer) relating input water quality and operating parameters to unit performance		Develop a mathematical model to determine the most influential design parameters	2,3,4,5			
G	Determine the ability of each system to remove Boron	NF/NF	Measure boron and utilize the sodium hydroxide addition pt. between Pass 1 and Pass 2	2,3			
		RO		2			

* "down time" is not counted in the following situations:
-equipment failure where standard redundant equipment, not included here, would allow for maintenance. A design flaw with the NF/NF system could be an exception.
-shutdown for vacations and facility tours

During testing, the primary contact persons for the cooperating organizations are shown in **Table 4.4**.

Table 4.4: Contact Personnel

Organization	Primary Contact
LBWD	Tai Tseng or Robert Cheng
LADWP	Alvin Bautista
Reclamation	Frank Leitz

4.1.1 2005 AWWARF Study Recommendations

The 2005 AWWARF study entitled "A Novel Approach to Seawater Desalination Using Dual-Staged nanofiltration Process" makes a series or recommendations for further testing. These recommendations are re-phrased and detailed below:

1. Verify where the majority of desalting is taking place.
   The predictive model suggested that most of the desalting occurs within the first four elements in Stage 1 and the first three elements in Stage 2.
2. Determine the optimal distribution of membranes to obtain the best recovery/rejection relationship
   Generally, the conditions that result in low overall energy required included using tighter membrane in Stage 1 (94 percent rejection) and looser membrane in Stage 2 (84 percent rejection)
3. Determine the critical pressure point where salt rejection is optimized
   After a critical pressure was exceeded for some salts, rejection decreased in bench and pilot tests. Below this critical point, convection dominated and permeate water quality improved with increasing pressure. Once the critical point was reached, diffusion dominated and permeate water quality deteriorated with further increases in pressure.
4. Determine the fouling potential and most appropriate cleaning techniques
   Surface analysis of used membranes indicated organic fouling, diatoms (high in silica), and localized scale deposits (Si, Fe, Al, Ca)
5. Determine the most appropriate cross flow velocity
   Increasing the cross flow velocity improved flux and rejection by decreasing the thickness of the CP layer. However, the cross flow may not be able to overcome the negative fouling effects of the high flux rates.
6. Determine impact of maintaining a high pH for corrosion control and its negative effects on chloramination
7. Determine how to control the effects of bromide
   Bromide exerts a chlorine demand and deplete the disinfectant residual. Bromamines can react with NOM from blended water to form brominated DBPs. Oxidation of NOM from the blending stream by chlorine was identified as a possible solution if the chlorination process does not form too many DBPs.

8. Determine the treated water quality needed for proper corrosion control
   This includes blending and pH adjustment
9. Investigate the options for alternative viral surrogates to MS-2 phage
   Virus surrogates would need to be <30 nm and/or molecular weight <100,000 amu.

4.1.2 Post Treatment

Post treatment is a critical step for high-pressure membrane applications for drinking water treatment. ***The desalinated water quality needs to be adjusted and/or blended to ensure that it meets finished water quality goals and also to minimize corrosion potential in the distribution system. The impact of various blending and/or disinfection scenarios on finished water quality and DBP formation will be evaluated at a bench-scale at LBWD laboratory. The corrosion potential of the NF/NF process permeate with and without chemical addition will be evaluated using test coupons and current potable water as reference. Post treatment will be evaluated throughout the testing program and the generated data will be used to recommend effective post treatment strategies for the full-scale system.

4.1.3 Energy Recovery

Testing will take place with and without energy recovery. The data will be used to minimize the energy consumption by the NF/NF process and enhance process economics. Following stabilization the remaining first half (time wise) of every test is run without energy recovery. Energy recovery is then implemented for the second half (Figure 4.1)

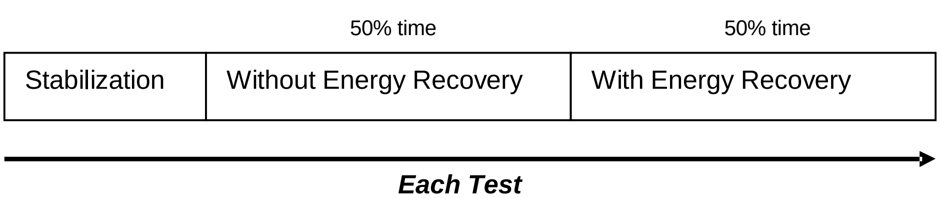


Figure 4.1: Energy recovery usage during each test

4.1.4 Membranes

The following membranes will be used during testing (Table 4.5):

Table 4.5: Membrane Selection

Type	Method	Model	Size	Surface Area	Salt Rejection	Max Feed Flow per Vessel	Max Pressure
MF	Pall		0.01 um	400 ft^2			
NF							
NF	Dow FIlmtec	NF90-400			85-95% NaCl >97% $MgSO_4$	70 gpm	600 psig
RO	Saehan	NE90					

4.1.5 Membrane Integrity Monitoring

A key factor to ensure the reliability of any membrane process is the monitoring of membrane integrity to ensure that adequate treatment is continuously being provided. The direct monitoring methods are typically applied directly to the membrane system and/or element to check its integrity. Indirect methods monitor a surrogate parameter in the membrane permeate and correlate it to membrane integrity. Several direct and indirect methods are available and some will be employed to monitor membrane integrity and overall treatment reliability and consistency (**Table 4.6 & Table 4.7**).

Method Type	Method	Employed	Frequency
Indirect	Online turbidity	Yes	Continuous
	Online particle-count	No	
Direct	Air Pressure Hold Test	Yes*	Once per month

<u>Table 4.6</u>: MF integrity monitoring methods

Method Type	Method	Employed	Frequency
Indirect	Online conductivity	Yes	Continuous
	Online sulfate	No	
	Online hardness	Yes	Continuous
Direct	Vacuum Hold Test	No	

<u>Table 4.7</u>: RO and NF integrity monitoring methods

4.1.6 Membrane Cleaning

Membrane cleaning should be minimized with thresholds, goals, and estimated optimum points shown below (**Table 4.8**).

<u>Table 4.8</u>: Membrane cleaning thresholds, goals, and estimated optimum points

Parameter	Phase	Threshold	Goal	Estimated Optimum
MF Backwash Cleaning Cycles *	2,3	1 per 15 min.	1 per 30 min.	1 per 30 min.
MF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year
NF Chemical Cleaning Cycles	2,3	1 per month	<1 per 3 months	1 per year

While minimized cleaning is the overall goal, it may not always be the goal of a specific test. Some tests may test the limits of the system where the limits is between scaling and not scaling, etc.

The treatment system is operated in a constant pressure / declining flux mode. Therefore, all indicators of required membrane cleaning are related to flux. Membrane cleaning indicators are established by the membrane manufacturers and are summarized below for both constant pressure and constant flux modes (**Table 4.9**).

Table 4.9: Membrane cleaning indicators and cleaning method details

Type	Membrane Manufacturer	Condition	Constant Pressure Mode Indicator for CIP	Constant Flux Mode Indicator for CIP	Cleaning Solution	Conc.	Duration
MF		Biological Fouling		TMP increase = 20%	NaOH		30 min.
			(if NaOH does not work)	(if NaOH does not work)	Add Sodium Hypochlorite		
		Scaling		NDP increase = 20%	Citric Acid		30 min.
		Scaling					
		Particle plugging		Feed – Retentate = 10 psi			
RO		Biological Fouling	Flux decline = *%	NDP increase = 20%	NaOH		
		Scaling	Flux decline = *%	NDP increase = 20%	Citric Acid		
		Particle plugging					
NF							

4.2 Phase 1: System Startup

The system startup involves the use of the separate "Testing and Start-up Plan". This phase includes initial startup and sufficient run time to ensure all equipment runs as specified. Plant operation staff will use this startup period to become familiar with proper operation of the system. If design modifications are needed, these will occur during this phase.

4.3 Phase 2: Process Validation

The process validation phase involves the operation of the NF/NF and RO systems for comparison purposes. This phase contains two distinct sub-phases (**Table 4.10**).

Table 4.10: "Process Validation" phase timeline

	Mar	Apr	May	Jun	Jul	Aug
Sub-phase	**4**	**5**	**6**	**7**	**8**	**9**
Optimization	■	■	■			
Validation				■	■	■

The optimization sub-phase is a 3 month period where the SWRO and NF/NF systems will be optimized as far as possible. The first week of this sub-phase will involve a fast optimization where the system will set at expected optimum settings with adjustments as needed. Subsequent testing will be more methodic to obtain quality data points. This is followed by a 3 month period of validation testing where control settings are held constant. This data will be crucial for Objective A (reliability), B, and C.

The SWRO system will be run at standard operating conditions for a seawater treatment system for the given water quality and optimized to fit local conditions where needed. The NF/NF system will be run according to parameters developed during previous pilot testing. The matrix of parameters is shown below (**Table 4.11**).

Initial operating parameters are summarized in **Attachment A**. The results of this phase must indicate that the NF/NF process is at least reasonably close in performance to the RO system in order to proceed to the NF/NF Optimization Phase.

Table 4.11: "Process Validation" phase testing matrix

		Independent Variables		Dependent Variables	
	Parameter	**Estimated Optimum**	**Values to be tested**	**Estimated Optimum**	**Estimated Values**
UF	Membranes				
	Feed Pressure (psi)				
	Feed Flow (gpm)				
	Flux (gfd)				
NF Pass 1	Membranes				
	Feed Pressure (psi)	530	520 540 560 580		
	Feed Flow (gpm)		*** (+10%) *** (-10%)		
	Flux (gfd)				
	Recovery				
NF Pass 2	Membranes				
	Feed Pressure (psi)			***	*** *** *** ***
	Feed Flow (gpm)				*** (+10%) *** (-10%)
	Flux (gfd)				
	Recovery				
RO	Membranes				
	Feed Pressure (psi)	***	*** *** *** ***		
	Feed Flow (gpm)		*** (+10%) *** (-10%)		
	Flux (gfd)				
	Recovery				

4.3.1 Model Design

Reclamation will design an empirical model to analyze the data and determine which parameters are most influential. Data from this phase will be entered into the model as a starting point. This model will be essential for Phase 3.

4.4 Phase 3: NF/NF Optimization

Upon the completion of the validation phase, the Train 2 will be converted to an NF/NF system to initiate the NF/NF optimization phase. There does not currently exist a suitable experience and models for NF membrane performance under the conditions employed in the NF/NF process, thus the optimization phase of this testing program will focus on this process. The optimization of the NF/NF will focus on several factors that should improve the process. These factors include:

- Membrane brands and suppliers
- Number of membrane elements per stage
- Feed pressure
- Feed flow
- Chemical dosage

This phase will provide critical design and operating parameters that are required for costing of the NF/NF process.

Model Development

The model designed in Phase 2 will use the independent and dependent variable data obtained in this phase to generate curves. These curves will indicate potential optimal operation points that should be tested in this iterative process. Parameters may be evaluated one at a time while keeping the parallel system as a reference. In some cases, multiple parameters may be changed at once to move in on the optimization point faster.

4.5 Phase 4: Regulatory Approval

Representative staff from the following regulatory agencies will be invited to key project meetings during the Validation, NF/NF Optimization, Regulatory Approval phases:

- California Department of Health Services (CDHS)
- Regional Water Quality Control Board

These regulatory authorities will also be frequently updated with data on the overall process performance and their comments on the system operation will be addressed (if possible) during the optimization phase. Towards the end of the NF/NF Optimization phase, specific regulatory testing requirements to approve the NF/NF process by the regulatory authorities will be identified and addressed in the subsequent testing phase.

The current CDHS accepted protocol for approving membrane filtration systems as “alternative filtration technology” under the Enhanced Surface Water Treatment Rule (ESWTR) requires the following:

- ***Giardia* Removal**: Demonstrate a minimum of 2-log removal of Giardia sized particles (e.g., 5 – 15 um).
- ***Cryptosporidium* Removal**: Demonstrate producing a time-weighted maximum turbidity in the permeate water of no more than 0.1 ntu.
- **Virus Removal**: Demonstrate a minimum of 1-log virus removal.

- **Operational Reliability**: Develop data for demonstrating the reliability of the membrane system, including membrane performance, permeate water quality, chemical cleaning residual die-away, membrane integrity monitoring, etc.
- **Quality Control**: Document a procedure for quality assurance and quality control sufficient to ensure the integrity of the data collection of the above requirements.

Preliminary discussions with CDHS staff indicated that the overall treatment train should meet the ESWTR requirements. Hence, the above requirements may need to be evaluated and addressed during the regulatory approval evaluation phase. The expected removal credit is shown below:

Table 4.12: Log inactivation/removal credit expected by the NF2 system

	Treatment Credit							Required Credit		
	300 μm Strainer	UF	Cartridge Filter	NF (Pass 1)	NF (Pass 2)	Chlorine	Total	SDWA [2]	Additional LT2 ESWTR	Total
Giardia	-	4	0	1	1	3		3.0	N/A	
Total Credit	0	4	4	5	6	9	**9.0**	3.0	3.0	**3.0**
Viruses	-	2	0	1	1	4		3.0	N/A	
Total Credit	0	2	2	3	4	8	**8.0**	3.0	3.0	**3.0**
Cryptosporidium	-	4	0	1	1	0		3.0	2.5	
Total Credit	0	4	4	5	6	4	**6.0**	3.0	5.5	**5.5**

1 – SDWA = Safe Drinking Water Act
2 – LT2 ESWTR = Long Term 2 Enhance Surface Water Treatment Rule

In addition, CDHS identified the following specific concerns regarding seawater desalination that will also need to be evaluated during this testing phase

- Boron
- Marine Biotoxins (Domoic Acid is the general surrogate for now)

The regulatory approval phase should provide the necessary data for the final approval of the NF/NF process for seawater desalination by CDHS.

4.5.1 Pathogen Challenge Testing

Pathogen challenge testing using microbial contaminants will not be included on this system due to the high cost associated with such testing at these flow rates. If pathogen challenge testing is needed, the pilot unit will be used.

4.6 Phase 5: Report

This phase will include analyzing remaining data and writing reports. The main project report will conform to Reclamation "Desalination and Water Purification Research and Development Program" (DWPR) report guidelines.

5.0 Quality Assurance / Quality Control

To ensure the data generated during the test period are representative and accurate, the following quality assurance and quality control (QA/QC) procedures will be implemented. Spreadsheet data collection forms are used to document the performance of the QA/QC procedures (LBWD) (**Attachment ***). Instruments will be calibrated on a periodic basis according to **Table 5.1**.

Table 5.1: Equipment calibration information

		Specification			Calibration Frequency	Test Parameter	Maximum Deviation from Test Parameter
	Equipment	**1**	**2**	**Brand/ Model**			
1	Pressure gauge	Manual			Yearly	20% of max.	5%
2	Pressure gauge	Electronic	Magnetic		Yearly		0.25
3	Flow meter	Manual			Never	-	-
4	Flow meter	Electronic			Yearly		5%
5	Temperature	Electronic			2 Years or B/E		5%
6	pH probe				Weekly	pH 4, 7, 10	-
7	Conductivity probe				Weekly		
8	ORP probe				Monthly		
9	Hardness	Online		Hach	Monthly		
10	Alkalinity	Online			Monthly		
11	Chlorine	Online					
12	Turbidity	Online			Yearly (Turbidty) Weekly (Flow)		
13	Turbidity	Manual			Weekly		
14	Power Meter				2 Years or B/E		
15	Chemical Pumps				Weekly		5%
16	Analog Signal				B/E & after 2 Mo.		

Calibration information in table 5.1 is also shown on the Calibration Schedule in **Attachment *.**

5.1 SCADA

Operating data acquired by the SCADA will be verified against online instrument readouts near the low end of expected operating values (pressures, flows, temperatures) and near the high end of expected operating values. All analog signals will be verified and adjusted if needed to ensure they are within 5% of the field calibrated value. Digital signals should not need calibration due to nature of the signal. SCADA system operating data will be compared against online instrument readouts at the beginning of testing, after 2 months, and near the end of testing.

6.0 Sampling and Analysis

6.1 Constituents to be Sampled

Table 6.1 shows the samples to be taken during the course of testing. Exact locations are detailed in **Attachment A**.

Table 6.1: Constituents to be sampled

Parameter		NF/NF and SWRO
Unregulated Constituents	General	Alkalinity Boron DOC Hardness * ORP pH * Silica (total) TDS * TSS
	Gases	-
	Cations (dissolved)	Ammonium (NH_4^+) Aluminum (Al^{+3}) Calcium (Ca^{+2}) Iron (Fe^{+2}) Magnesium (Mg^{+2}) Manganese (Mn^{+2}) Nickel (Ni) Phosphorous (total) (P) Potassium (K^+) Silver (Ag) Sodium (Na^+) Strontium (Sr^{+2}) Zinc (Zn^{+2})
	Anions (dissolved)	Bromide (Br^-) Chloride (Cl^-) Orthophosphate (PO_4^{-3}) Sulfate (SO_4^{-2}) * Sulfide

	Biological & fouling potential	Marine Biotoxins via Domoic Acid MS2 bacteriophage SDI
Regulated Primary Contaminants	Cations	Antimony (Sb) Arsenic (As) Asbestos Barium (Ba) Beryillium (Be) Cadmium (Cd) Chromium (total) (Cr) Copper (Cu) Lead (Pb) Mercury (inorganic) (Hg) Selenium (Se) Thallium (Tl)
	Anions	Fluoride (F^-) Nitrate (NO_3^-) (as N) Nitrite (NO_2^-) (as N)
	Radionuclide	-
	Disinfectants	Chlorine (free)
	DBP	HAA5 THM
	Biological & fouling potential	Turbidity Heterotrophic Plate Count Giardia Cryptosporidium

* = secondary limit

The following process data will be measure continuously:

- Flow
- Pressure
- Temperature
- Conductivity
- pH
- Hardness

6.2 Sample Timing

The short term tests are typically run from one Tuesday to the following Tuesday. Online equipment is measured continuously, but polled every 2 minutes.

For sampling, the beginning, middle and end of tests are defined as follows:

“Beginning” may mean one of two different times, depending on the type of test and should be taken at two different times. Those which will be compared to values at the end of the test should be taken early. Those which will be compared to other measurements and whose value would change if membrane properties change should be taken a day after the test starts.

“Middle” means Thursday or Friday.
“End” means the following Tuesday, before conditions are changed.

6.2.1 Storm Events

Because of the possibility that precipitation may affect the composition and quality of water in the intake to the demonstration unit and because the timewise relationship between precipitation and its effect on the feedwater is unknown, special procedures must be used to obtain samples during storm events. The proposed procedure, which may be refined with experience, is as follows. The only continuously monitored parameter that should be affected by precipitation is raw water conductivity (Sample port 5). When precipitation occurs, samples will be taken at the critical points:

- Feed Water to MF unit, SP-9
- Feed water to first pass NF, SP-55
- Permeate from first pass, SP-90
- Product from second pass, SP-116

Samples will be taken every half hour. The maximum effect of precipitation on the feed water will be considered to occur when the conductivity reaches a minimum. Sample #’s correspond to the sample port.

Sample 5 taken at the time closest to the time of the minimum will be analyzed. There is some lag time for this water to reach points further into the system because of the residence time in various feedwater tanks. Residence time in the piping and the pressure vessels will be ignored. When the active volume of these tanks is determined, the residence time for these tanks can be calculated.

Sample 9 taken nearest the time of minimum conductivity plus the residence time of the MF Feedwater Tank will be analyzed.

Sample 55 taken nearest the time of minimum conductivity plus the residence time of MF and Pass 1 Feedwater Tanks will be analyzed.

Sample 90 taken nearest the time of minimum conductivity plus the residence time of MF and Pass 1 Feedwater Tanks will be analyzed.

Sample 116 taken nearest the time of minimum conductivity plus the residence times of MF, Pass 1 and Pass 2 Feedwater Tanks will be analyzed.

7.0 Data Management

A database system developed by LBWD allows easy access to test data, including operations data, water quality data and chemical dosing data. The database allows for sorting and downloading of subsets of the data. Database management software such as Microsoft Access®, or other relational database software, including database software utilized by the SCADA, will be used for this purpose. Data recorded by hand on data sheets will be stored and recorded in spreadsheet format.

7.1 SCADA System

The prototype facility utilizes supervisory control and data acquisition (SCADA) using Industrial Sequel software. The SCADA system has the following functions:

- Data collection and storage
- Process monitoring and control
- Remote monitoring and control (limited to 128 tag points)
- Data trending
- Paging for alarms
- Automatic shutdown for alarms

7.2 Data Recording

7.2.1 Operational Data

Process operating data is recorded on data collection forms once each weekday as a quality control check on the data collected by the SCADA system. Data collection forms are located in **Attachment ***. Data from Industrial Sequel can be readily exported to spreadsheets for analysis.

7.2.2 Chemical Dosage Data

A spreadsheet based chemical dosing sheet created by LBWD assures accurate chemical doses are delivered to the system process flows (**Attachment ***). The dosing spreadsheet will allow chemical dilution factors in the appropriate flow range for each metering pump to be easily determined. Chemical metering pump flow rates will be verified on a weekly basis, or more frequently as required, to assure their reliable operation. Data collection forms will include date and time, feed tank concentration, target flow and dosage, and measured flow and dosage.

7.2.3 Chemical Cleaning Data

Spreadsheet data collection forms created by LBWD are available for recording the specifics related to chemical cleanings performed on each membrane test system (**Attachment ***). These forms will document the date of cleaning, cleaning chemical doses, chemical solution contact times, temperatures, pressures and flows. Process flow, temperature and pressure data will be collected before and after cleaning to determine cleaning efficiency

7.2.4 Membrane Element Position

A spreadsheet based membrane element form developed by LBWD details the membrane element location (Attachment *). The data form includes:

- process name
- date of configuration change
- pressure vessel
- element position within the pressure vessel
- manufacturer
- model
- serial number
- hours of operation of each membrane element.

The form will be updated each time a change is made to the membrane element configuration.

7.2.5 Project Log Book

A permanently bound project log book will be maintained onsite in the staff trailer. The log book will be used for recording information, calculations, etc. not collected on prepared data collection forms. Each entry in the project log book will be dated and initialed by the operator making the entry.

7.3 Data Backup

All electronic data collected by the project SCADA will be backed up to an appropriate storage device at least once weekly during the operation of the test facility processes. Backup records will be maintained. Data maintained electronically on computers, will be backed up at least once weekly. Completed data collection forms should be copied once weekly and maintained at a separate location.

7.4 Data Distribution

The plots developed will be distributed to project team members on a weekly basis. Web-based project collaboration software developed by LBWD will be utilized to distribute updated project information, including plots to project team members.

7.5 Data Backup

All electronic data collected by the project SCADA will be backed up to an appropriate storage device at least once weekly during the operation of the test facility processes. Backup records will be maintained. Data maintained electronically on computers, will be backed up at least once weekly. Completed data collection forms should be copied once weekly and maintained at a separate location.

7.6 Data Analysis

Some of the data, particularly those relating to meeting challenge tests are of a pass/fail sort and require little analysis. These need to be put into a proper format and the conditions under which the prototype passes need to be sorted from the conditions under which is does not. More complex analysis is required to establish the economic comparison of NF/NF with RO and development of a model for the NF/NF process itself.

The economic comparison of the two processes will take good technical judgment. An appropriate comparison of the two processes will be on the basis of life cycle costs. This will require assignment of cost of equipment, cost of power and cost of money.

The most difficult analysis is development of a functional model of the NF/NF process itself. If each vessel were to contain the same number of elements, we could do this analysis on a vessel-by-vessel basis. However, this would not necessarily lead to a unit with optimal performance.

The element is the basic unit for analysis. We begin with the assumption that all elements of a particular manufacturer and type are identical in performance. This is an incorrect assumption since the variability of nanofiltration membranes is well known. However, in the absence of individual element tests, it is the only practical assumption that we can use.

The independent variables that determine the performance of an element are temperature (T, °C), inlet pressure (P, psi), volumetric flow rate (Q, gallons per minute), and concentration of various species (Cx, mg/L). Since the rejection of various species varies widely, we will track each species separately. We will relate the output variables, product low, and product concentrations to these input variables by empirical relations to be developed.

Temperature is an independent variable over which we have no control. Over the course of the year the temperature of the raw water may vary over a 15° C range. Within the process, the biggest change in temperature, estimated to be about 1° C, is caused by inefficiencies of the high pressure pumps. Other than that, we can assume that the process is isothermal. For NF Pass 1 and SWRO, the values from instruments (**53**) for Train 1 and (**142**) for Train 2 will be used. For Pass 2, the values from instruments (**85**) for Train 1 and (**175**) for Train 2 will be used.

The major effect that change in temperature has is on the volumetric flux through the membranes. Flux will be normalized to 25° C using the equation:

$$Q_{25} = Q_T e^{-0.0239(T-25)} \qquad 7.1$$

A manufacturer suggested the flux correction factor (0.0235). This will be used until we have enough data to extract our own flux correction factor.

Runs will be made at four values of inlet pressure and four different values of feed water flow to each pass. These should be within the manufacturer's recommended limits and ideally they will encompass the optimum range of operation for the process. The purpose of having four values is to allow us to make a reasonably accurate determination of the relationship of dependant variables, flux and permeate concentration on the independent variables.

Each run will last for one week. This is to allow the operation of the prototype unit to come to steady state. The chemical analyses at the end of the run and the operating data over some period of time on the last day of the run will be used for the analysis. Only data from weeks without rain days will be used.

A certain amount of redundancy of flow and TDS measurements has been built into the unit. This redundancy is to provide a check on the validity of the data. This validity check will be performed ahead of any other analysis.

Since measurements are made only on performance of vessels, and we want to know performance of elements, some approximations have to be made. The pressure difference between the inlet and outlet of an element will be taken to be 1/n th of the pressure difference of the vessel containing n elements. While we know that the pressure difference of the 1st element should be greater than that of any downstream element because the flow is greater, we don't know how much greater. Since the inlet pressure is large compared to the pressure difference, the error introduces by this simplification is trivial.

Initially, we will assume that the permeate flux from each element and the rejection for each element is the same in a vessel. When some data are available, we may attempt to improve on this approximation.

8.0 Safety and Communications

8.1 Safety

Safety is the number one consideration at the project test site. All project staff working at the test site will be familiar with and follow the guidance of the Job Hazard Analysis (separate document developed by LBWD.

Table 8.1 Emergency Phone Numbers

Emergency	**Phone**
Fire, Police, Ambulance, Paramedics	911
Poison Control	800-332-6633

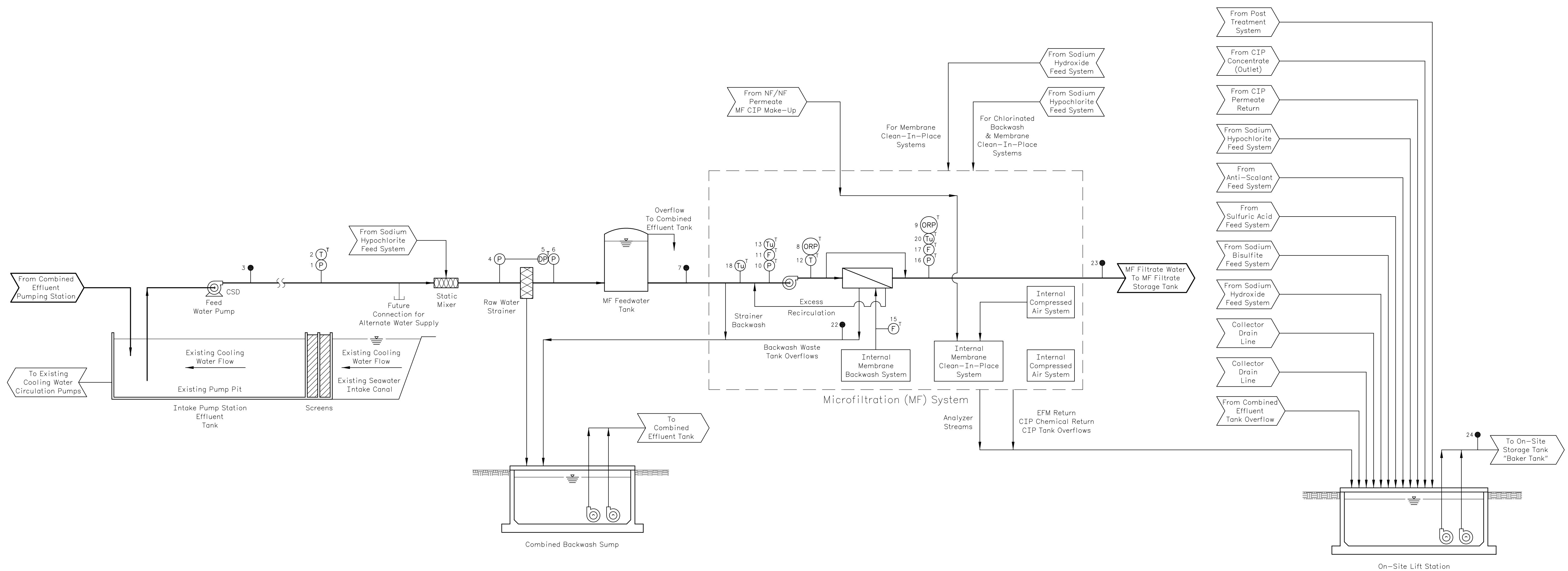
8.2 Project Staff

This project is a cooperative effort between LBWD, USBR, and LADWP. A steering Committee composed of representatives of these three organizations will provide overall management of the project.

Table 8.2 Contact Information

Name	Agency	Phone	Cell Phone	Fax	Email
Bautista, Alvin	LADWP	213-367-0800		213-367-1131	alvin.bautista@water.ladwp.com
Cheng, Robert	LBWD	562-570-2487		562-426-9625	robert_c_cheng@lbwater.org
Dundorf, Steve	Reclamation, Denver	303-445-2263	(303)349-7691	303-445-6354	sdundorf@do.usbr.gov
Jurenka, Robert	Reclamation, Denver	303-445-2254		303-445-6354	bjurenka@do.usbr.gov
Karimi, Ali	LADWP				ali.karimi@water.ladwp.com
Leitz, Frank	Reclamation, Denver	303-445-2255		303-445-6329	fleitz@do.usbr.gov
Leung, Eric	LBWD	562-570-2347		562-492-9631	eric_leung@lbwater.org
Tseng, Tai	LBWD	562-570-2472		562-426-9625	tai_tseng@lbwater.org
Vuong, Diem	LBWD		(562)508-0614	949-366-9174	diemvuong@hotmail.com
Wolfe, Dennis	Reclamation, Temecula	909-695-5310		909-695-5319	dwolfe@lc.usbr.gov
Wu	Theresa	562-570-2341			theresa_wu@lbwater.org

DRAWING 1



NOTES

1. This drawing was developed from the Montgomery Watson Harza August 2003 final submittal drawings.
2. Some process lines, valves, etc are not shown for clarity.
3. Potable water hardness and alkalinity must meet Pall's requirements to prevent $CaCO_3$/MgOH scaling during high pH cleaning.
4. High pressure and/or low flow sensors for pump overload protection are not shown, but are to be included.
5. Level sensors with transmitters for all tanks are not shown, but are to be included.
6. Hardness meters are not furnished by owner within furnished by owner box.

LEGEND

P – Pressure
C – Conductivity
F – Flow Rate
Cl – Chlorine
pH
T – Temperature
Tu – Turbidity
H – Hardness
Al – Alkalinity
DP – Difference Pressure
ORP – Oxidation/Reduction Potential
G – Generator
LC – Load Cell
VSD – Variable Speed Drive
CSD – Constant Speed Drive

Typical Main Process Flow
Process Flow
Future Use
Owner Furnished
Sensor
Transmitter
Sampling Port

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LONG BEACH WATER DEPARTMENT
NF/NF DEMONSTRATION UNIT
PROCESS FLOW SCHEMATIC

DESIGNED S. DUNDORF CHECKED F. LEITZ
DRAWN R.D. RODRIGUEZ TECH. APPR.
APPROVED
PEER REVIEWER

CADD SYSTEM AutoCAD Rel. 16.0s	CADD FILENAME MEMBRANE PROCESS_NEW	DATE AND TIME PLOTTED JANUARY 27, 2006 13:20
DENVER, COLORADO	JANUARY 22, 2004	DRAWING 1

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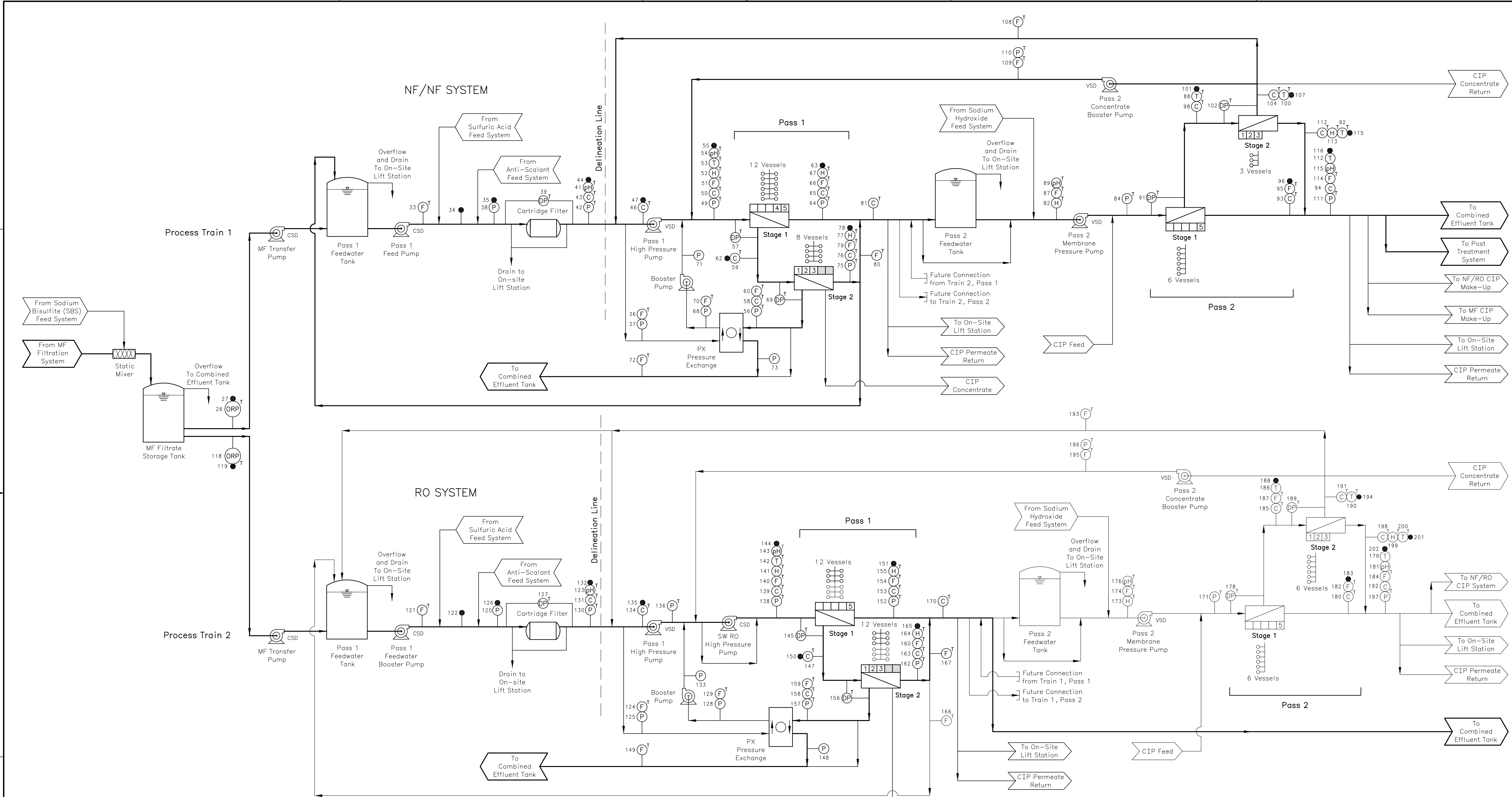
DRAWING 2



ELEMENT AND VESSEL CONFIGURATION KEY

- 8 Vessels — Indicates layout of pressure vessels (end view)
- Indicates tests will be performed on 3 or 4 elements
- Spacer (no element)

LEGEND

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Typical Main Process Flow
Process Flow
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DENVER, COLORADO | JANUARY 22, 2004 | DRAWING 2

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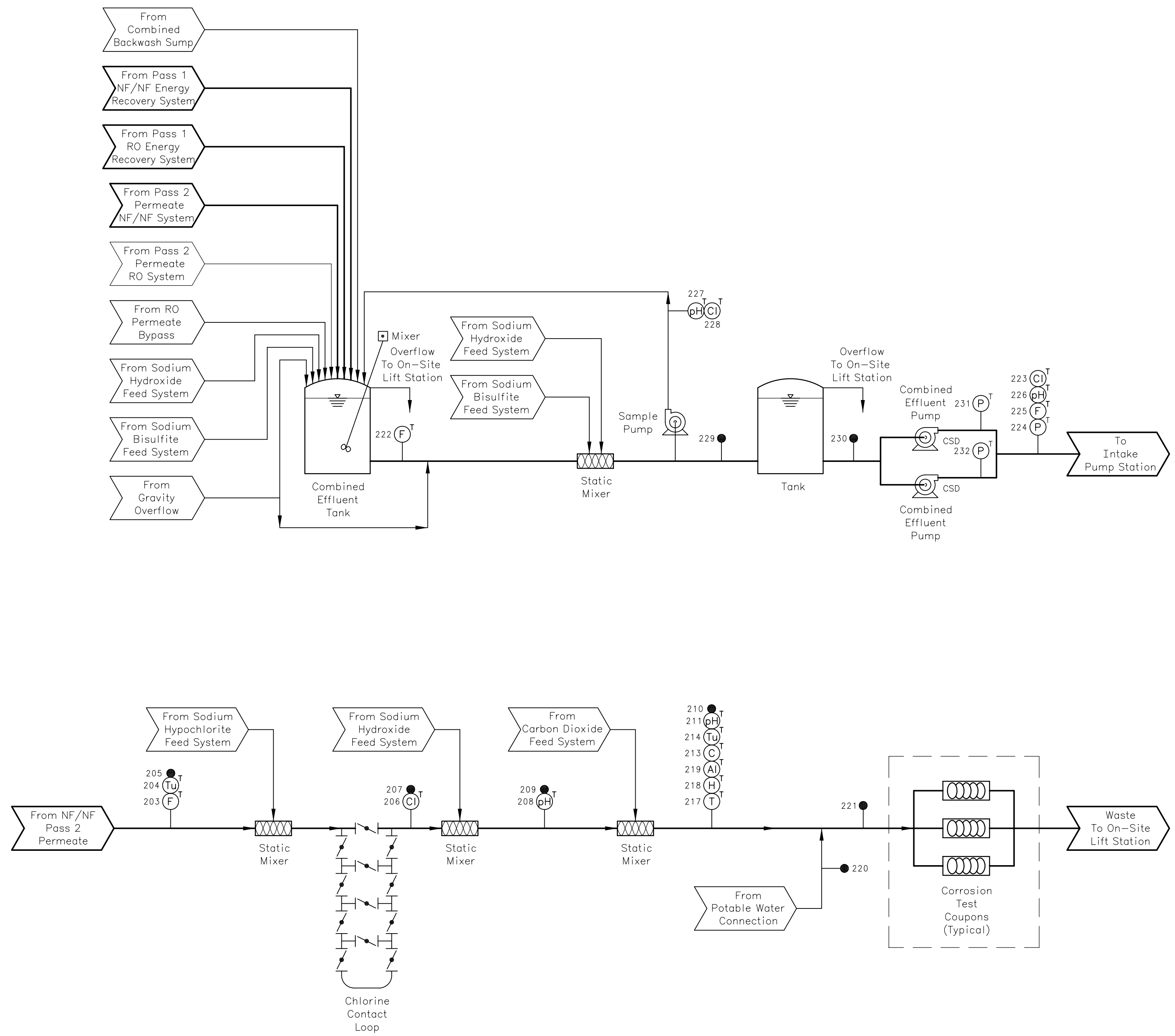

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Typical Main Process Flow
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LONG BEACH WATER DEPARTMENT
NF/NF DEMONSTRATION UNIT
PROCESS FLOW SCHEMATIC

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CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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