Dare County Water System Improvements

Preliminary Design Report

North Reverse Osmosis Water Treatment Plant
Capacity Expansion

County of Dare
Manteo, North Carolina

ROSTEK ASSOCIATES, INC.
P O Box 47567, Tampa, Florida, 33647
September, 2002

FINAL REPORT
September 23, 2002

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Prepared for

Dare County Water System,
Manteo, North Carolina

Prepared by

ROSTEK ASSOCIATES INC.
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CERTIFICATION

I hereby certify that this Preliminary Design Report for the North Reverse Osmosis Plant Capacity Expansion, a Dare County Water System Improvement project, was prepared by me or under my direct supervision.

Signed, sealed and dated this September 23, 2002

By:____________________________
IAN C. WATSON, P.E.
Reg. No. 12532

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Table of Contents

NORTH REVERSE OSMOSIS PLANT CAPACITY EXPANSION

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1.0 INTRODUCTION

1.1 Project Background

The North Reverse Osmosis water treatment plant (NRO) of the Dare County Water System was placed into commercial operation in August of 1989.

NRO was designed for the ultimate installation of eight (8) brackish water RO units, for a combined capacity of 8.0 mgd. The grass roots facility, designed by Black & Veatch and RosTek Services, Inc. (predecessor of RosTek Associates, Inc.) provides all the infrastructure required to support the RO operation, including bulk chemical storage; emergency diesel generator; disinfection facilities; ground storage; transmission pumping to both wholesale customers and to the Dare County System; and RO concentrate disposal to the Atlantic Ocean via a NCDOT highway drainage system. Initially, three (3) RO units were installed, each producing 0.85 mgd of permeate which was blended with 0.15 mgd of bypassed raw well water.

Because the well water does not contain hydrogen sulphide, degasification for removal of this contaminant is not required. The original water chemistry available from these wells was such that the only scaling potential was that of calcium carbonate. Although the design concentrate Langelier Saturation Index (LSI) was not high compared to the capabilities of modern scale inhibitors, some acidification of the feed water was required to maintain an LSI of about 1.5 in the exiting concentrate, and to generate carbon dioxide in the permeate. This carbon dioxide permeates the membrane and is available in the blended product water for reaction with caustic soda to form bicarbonate alkalinity.

The original three trains were installed with a total of thirty (30) six element pressure vessels in a 21:9 array. The vessels were loaded with Fluid Systems (now Koch Membranes) TFCL thin film composite low pressure membranes. These membranes had an active area of about 335 square feed, and operated at an average flux of 14 gfd. Design recovery was limited to 75% for reasons of both feed pressure and permeate quality. Space was provided on the RO skids for 4 additional pressure vessels in the first stage and one in the second, for a possible 25:10 array.

About two years after commissioning, the second stage vessels were reloaded with Hydranautics CPA-2 membrane elements. These elements had an active area of about 365 square feed, and a salt rejection of 99.2%, compared with 98.5% for the original membranes. This substitution was necessitated by a steady deterioration in feed water TDS from the startup value of about 2200 mg/l. This had been anticipated from the hydrogeologic investigations and solute transport modeling, but had not been expected to occur so soon. Additional vessels were installed in the mid-90's, filling all available spare spaces, and TFCL membranes from the second stage that had been pickled and stored were used for the additional first stage vessels, and new CPA-2 membranes were purchased for the tenth second stage vessel.

In 1999, after 10 year of service, the original TFCL membranes were replaced with Hydranautics CPA-3 membranes, a high performance product with 400 square feet of active area and a salt rejection of 99.5%. Two years later the second stage membranes were also replaced with CPA-3, and the average flux dropped to approximately 10 gfd.

The summer of 2001 brought high water demands for July 4th weekend, and a long drought and hot weather promoted very high water usage over the same weekend. To prepare for this, a series of tests were conducted in the January of 2002 to evaluate the potential for operation at higher flux, and increased permeate production. One train was successfully operated at a flux of 13.5 gfd, the limiting factor being the RO feed pump. The Dare County staff operated at an elevated flux during July of 2002, at a flux rate of 12 gfd producing approximately 0.47 mgd of additional permeate from the facility.

Also during the past two years, the County has replaced the process control system that was installed with the original plant. Other changes and upgrades have been made to the chemical feed systems, the concentrate control valves, and the RO feed pump speed controllers.

The Board of County Commissioners has authorized the engineering and construction of an expansion of a least one train, and possibly two trains, with the first train to be installed and operational by June 2003.

1.2 Project Description

Although this project is designed to be a capacity enhancement, Dare County faces a significant quality issue at NRO, which is compliance with the recently promulgated arsenic Maximum Contaminant Level (MCL) of 10 μg/l, to take effect in January of 2006. Although the need for additional water production from NRO is immediate, the process design must take into account that within two years an arsenic reduction strategy will be implemented and incorporated into the NRO plant. One of the possible strategies is a second-pass nanofiltration process, which would treat oxidized permeate from the brackish water RO system. This is only one of six strategies that will be pilot tested, but the new RO trains must be designed in anticipation of a second pass.

Although the feed water to NRO has experienced steady increase in TDS since 1989, the distribution of ions has not increased the scaling potential of the water. With modern high performance membranes, the salt passage is less than 1% and so a higher recovery without compromise of finished water quality could be achieved. This report will address this question.

The practice of boosting the pressure of the feed/concentrate stream between stages was not included in the original design, because suitable energy recovery devices were not available. However, the development of reliable energy recovery devices has made this practice possible without the use of an electric motor driven pump. Since modern membranes have high specific flux, increasing second stage production by boosting the interstage pressure is very advantageous to the plant operation and economies. it is recommended that this feature be included in this project. Retrofit of the existing trains will also be included.

1.3 Report Purpose and Scope

This report will establish design criteria for the following:

1 Expansion of treatment capacity by one or two trains.
2 Retrofit existing three trains with energy recovery devices.
3 Modifications to existing electric system to support this expansion.

Expansion of the plant treatment capacity will require additional raw water supply. New brackish water wells and raw water delivery system modifications are being designed under a separate contract by another consulting firm.

The level of design included in this document is assumed to be about 30%. RO system process design and equipment sizing has been accomplished and outline equipment and materials specifications prepared. Integration into the existing infrastructure has been examined.

Included in this report are the following:

1. Process flow diagram
2. Preliminary P&IDs
3. Preliminary equipment layouts
4. Preliminary equipment selection
5. Equipment and pipe sizing
6. Verification of infrastructure capacity
7. Opinion of probable cost

2.0 WATER QUALITY

2.1 Introduction

The water quality considerations at NRO fall into three main categories.

1. RO plant feedwater
2. Finished water
3. Concentrate quality

Since startup of the NRO in August of 1989, the RO plant feedwater TDS has increased gradually from about 2,200 mg/l to the current value of about 4,300 mg/l. When the original plant was designed in 1987, the equipment was selected so that an increase in feedwater TDS to 6,000 mg/l could be treated by the installed plant without major modifications. It was recognized that at the final design point, additional post treatment might be required to stabilize the finished water, since raw water blending at that point would be of little value.

The finished water today is in compliance with all Public Water Supply (PWS) standards for potable water, except for the recently adopted Arsenic Rule. Although in compliance until adoption of this rule in January, 2002, the RO permeate contains 14-20 µg/l of arsenic, depending on which combination of the ten existing wells is supplying feedwater to the plant. The County is currently pursuing a three-phase strategy to bring the arsenic into full compliance with the standard of 10 µg/l by January 2006, or before. The first phase has been completed (insert report reference). The second phase, long-term pilot testing of selected removal technologies, is in the planning stage, and will be initiated prior to the end of 2002. The third stage, implementation of selected strategy, will be initiated in late 2003. Solution of the arsenic issue does not have an impact on the expansion of the RO plant, except as discussed previously in Chapter 1.

The concentrate quality is important to Dare County for NPDES permitting reasons. While the expansion will not change the initial concentrate quality, continued degradation of the well water will result in increased concentrate TDS. The expansion will increase the concentrate discharge volume in proportion to the increase in production.

2.2 Well Field Facilities

The County currently operates 10 wells that provide feedwater to the RO plant. The original 8 wells that were constructed with the plant are all located on the original Baum Tract. Wells 9 and 10, constructed in 1994 are located to the west and south of Fresh Pond, in the Town of Nags Head. All 10 wells have approximately the same characteristics, and produce 450-550 gpm each when pumped individually. If all 10 wells are pumped together, the available system capacity considering all system head losses is 4,180 gpm. To run the three existing trains and the two new trains at 75% recovery with an 8% raw water bypass for blend, approximately 4,500 gpm is required. Therefore additional wells with a capacity similar to the existing 10 wells will be required.

As part of this expansion, the County will construct four new wells. However, this project is not part of the current work and will not be discussed in this PDR.

2.3 RO Feed Water Quality

2.3.1 Historic Quality

As mentioned earlier, the feed water quality when the plant started operations in August 1989, was about 2,200 mg/l TDS. The characteristics of this water relative to the RO process were fairly benign. The only scaling potential was for calcium carbonate and this was easily controlled by addition of (in those days) a polyacrylate scale inhibitor. Acid treatment was not required to control carbonate scaling, but the design incorporated an acid system, used to create carbon dioxide in the feed water for use in post treatment to form bicarbonate alkalinity upon the addition of caustic soda. About 40 mg/l of carbon dioxide were required for this purpose.

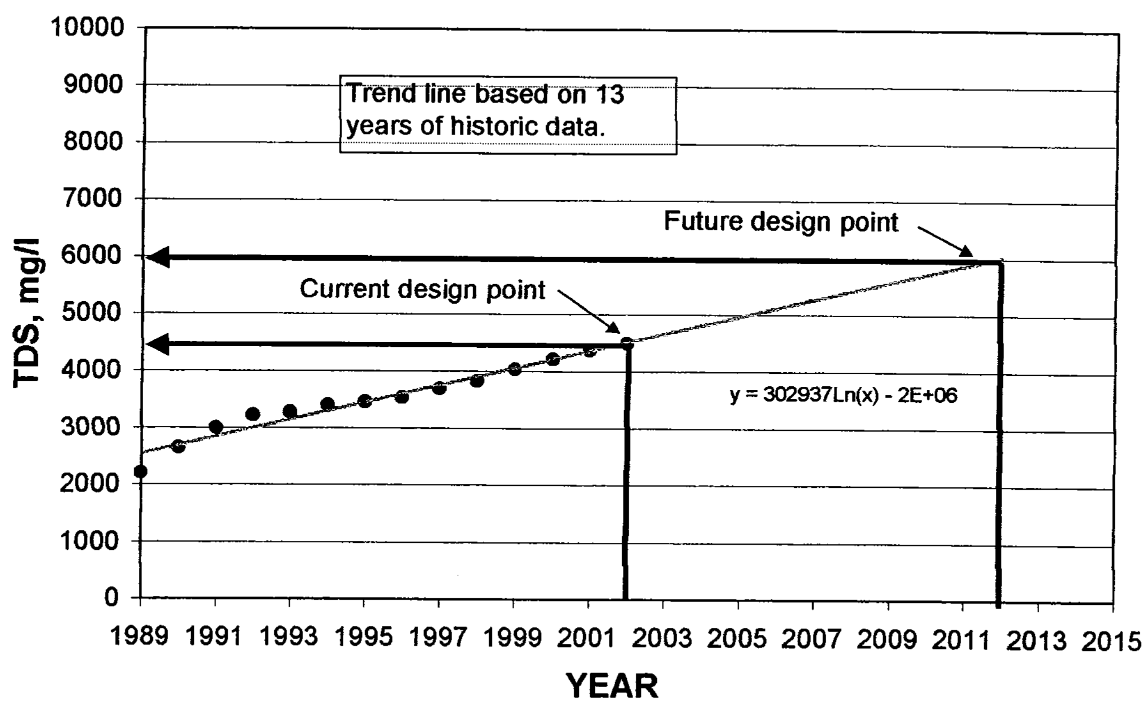
The only feed water issue that periodically requires membrane cleaning is the deposition of ferric iron on the membrane surface. The feed water has always contained about 0.5 mg/l of iron, and while the well water is anaerobic, with filtered turbidity of <0.5 NTU, and an SDI of <3.0, some iron fouling does occur. The membranes have traditionally been cleaned annually, specifically to remove this iron foulant.

2.3.2 Current and Predicted Quality

The current feed water TDS ranges from 4,200 mg/l to 4,500 mg/l, depending on the wells in service. As predicted in the early hydrogeologic studies, the water quality has declined over the intervening years. Figure 2-1 graphically illustrates the rate of TDS increase, and how closely the increase matches the trend line. The original prediction was that the TDS would reach 6,000 mg/l in 14 years after startup, or 2003. From Figure 2-1, it can be seen that 6,000 mg/l will, if the current trend continues, be reached about 2012.

Figure 2-2 shows the cumulative increase in TDS over the base line startup value. It can be seen from this curve that the rate of growth in TDS has increased more rapidly since 1999 than in the preceding 7 years. Although the earlier studies predicted TDS increase due to lateral intrusion from the Atlantic Ocean, a monitor well located at the beach access just north of the Best Western Ocean Reef in Kill Devil Hills has not registered the increase in chlorides that would be expected from such intrusion. Since the aquifer that is used by NRO is essentially unconfined, and early test well indicated high TDS in the basement of the formation, the current thinking is that the TDS increase experienced in the well field is caused by upconing, not lateral intrusion. Wells 9 and 10 exhibited water quality very similar to the original well field, but increased in TDS fairly rapidly, and are today only slightly lower in TDS than the average of the original eight wells. The construction of new wells, as mentioned earlier, is expected to once again slow the rate of increase in TDS, as happened previously with wells 9 and 10.

FIGURE 2-1 ANNUAL AVERAGE FEEDWATER TDS

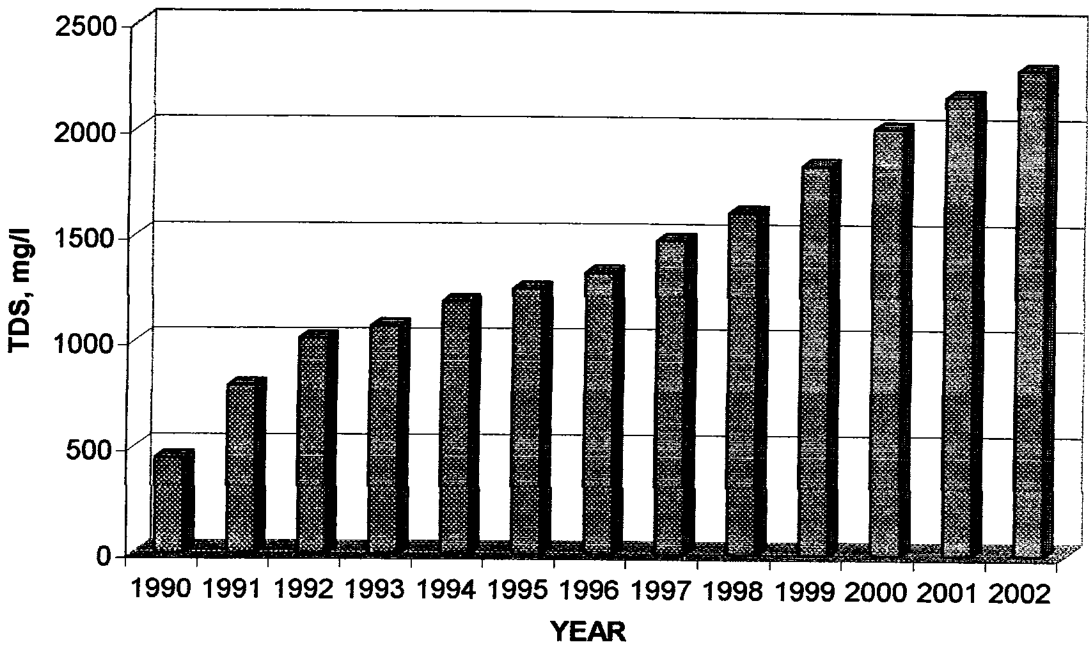


2.3.3 Design Feed Water Quality

Table 2-1 shows a comparison between the original feed water quality (1989), the expansion design feed water quality (2002), and the future design feed water quality (2012).

It will be noted that the future design feed water is based on the addition of only sodium chloride to reach the target TDS of 6,000 mg/l. While this is not strictly accurate, the basement water quality closely resembles seawater, whose sodium chloride content is about 85% of the total constituents. For the design of an RO system, sodium chloride represents the worse case condition in terms of salt rejection and osmotic pressure. Also, since there is an increase in ionic strength, the solubility product constants for potential scaling compounds increase proportionally. It is therefore reasonable to assume that no increase in scaling potential will occur, and the current pretreatment system will suffice for the future design conditions.

FIGURE 2-2 CUMULATIVE INCREASE IN TDS BY YEAR



2.4 Permeate Quality

Based on the scenario discussed above, Table 2-2 shows the permeate qualities related to the feed water quality in Table 2-1.

TABLE 2-1 NRO PLANT FEEDWATER QUALITIES

COMPONENT (in mg/l unless otherwise stated)	ORIGINAL (1988)	DESIGN (2002)	FUTURE (2012)
Calcium	19.00	72.00	72.00
Magnesium	24.00	97.60	97.600
Sodium	659.00	1355.00	2041.0
Potassium		18.00	18.00
Strontium	0.75	1.60	1.60
Barium		0.01	0.01
Iron	0.20	0.68	0.68
Bicarbonate	318.00	321.95	321.95
Sulphate	38.00	175.00	175.00
Chloride	953.00	2200.00	3257.30
Fluoride	1.60	0.30	0.30
TDS	2,117.00	4,256.12	6,000.00
pH units	8.00	7.86	7.86
Temperature, °C	20	20	20
Turbidity, NTU	0.6-0.8	<0.5	<0.5

TABLE 2-2 NRO PLANT PERMEATE QUALITY

COMPONENT (in mg/l unless otherwise stated)	DESIGN (1) (2002)	DESIGN (1) (2012)
Calcium	1.07	1.34
Magnesium	1.45	1.79
Sodium	37.42	70.11
Potassium	0.58	0.72
Bicarbonate	11.59	14.75
Sulphate	2.74	3.49
Chloride	55.60	105.22
Fluoride	0.01	0.01
TDS	110.86	197.94
pH (units)	5.98	6.09

(1) Based on Hydranautics CPA-3 membranes. Similar results will be obtained from other high rejection brackish water membranes.

2.5 Concentrate Quality

As the feed TDS increases, so will the concentrate TDS. Assuming that the current design recovery of 75% is maintained, each ion concentration in the concentrate will increase in proportion to the increase in feedwater concentration. Since the volume of concentrate produced per unit volume of feed water remains constant at constant recovery, the relationship between the ions in the current concentrate will be the same in the future concentrate.

Predicted concentrate TDS is shown below:

2002 Design	2012 Design
18,919 mg/l	23,428.9 mg/l

2.6 Finished Water Quality

The original NRO plant was designed for a blended train output of 1.0 mgd, 850,000 gpd of permeate and 150,000 gpd of bypassed raw water, a 15% blend. As the feed water TDS has increased, the ratio of permeate to bypassed raw water has increased. At the present time, only about 8% of raw water can be blended while meeting the finished water quality goals for TDS and chlorides. The permeate output of each train can be increased slightly, and during the summer peak months each train can be operated to produce close to the original design volume of 1 mgd.

If the raw water TDS continues to increase as expected, the amount of raw water that can be blended will continue to decrease. While the current status provides sufficient calcium hardness and bicarbonate alkalinity to stabilize the product water, together with a corrosion inhibitor, at some point in the future this will no longer be true. It is difficult to predict when this situation might occur, but when it does, a revised strategy for finished water stabilization will have to be implemented.

For the current expansion, however, sufficient blend water will be available to properly stabilize the water, particularly with the calcium increase as shown in Table 2-1.

3.0 Basis of Design - RO Process

3.1 RO Process

Because of the rapid improvement in the performance of brackish water RO membranes in recent years, the design of the proposed expansion can be modified somewhat to both conserve water and electric power.

The original plant was designed to utilize membranes that had a specific flux of about 0.11 gfd/psi net, and a salt rejection of 98.5% of sodium chloride. Today's high performance membranes have a specific flux approximately three times as much, and 99.5% rejection of sodium chloride.

The original plant design recovery was selected to maximize the blend ratio, and minimize RO feed pump energy consumption. The single element test on brackish water membranes is conducted at 25°C. The NRO feed water has consistently been 20°C since startup. Since flux is proportional to temperature, the feedwater temperature automatically imposes an approximate 15% penalty on net driving pressure. However, this penalty is consistent and therefore can easily be accommodated in the process design

As stated previously, the original plant recovery was established at 75%. Because of the performance of today's membranes, it is proposed that the two new trains be designed to operate at 78% recovery. This will result in less feed water per train, and a concomitant reduction in energy requirement for the feed pump. However, normal operation is expected to be 75% recovery.

Since the existing spare pump will be utilized for RO train #4, it is logical that a pump with the same characteristics be installed for train #5. The original pump curves were obtained from Afton Pump, Inc. The 4 pumps installed originally, including the spare pump, have the following characteristics:

Design flow	933 gpm
Design TDH	675 (292.0 psig)
Speed	3550 rpm
No. of stages	6 (space for 1 additional)
Motor hp	250
Electrical Supply	460 V/3 ph/60 Hz
Pump size	6x8x9

Membrane performance projections made with the modeling software of the major manufacturers (Hydranautics, Koch, Dow Filmtec, Osmonics, Toray and TriSep) indicate that at the current water quality, the pump characteristics described above are capable of delivering feed water to an RO train operating at 75% recovery, with a permeate output of 1 MGD (695 gpm). While the future design condition of 6,000 mg/l TDS requires the use of an interstage boost device, recovering concentrate energy, these devices will also improve current performance. The three types currently in common use, work exchanger, pressure exchanger, and Pelton Wheel, were examined for suitability and ease of integration.

The pressure exchanger cannot be used for interstage boost, since there is no increase in pressure through the device. A secondary electrically driven booster pump would be required. This is not practical for a retrofit of the existing three trains.

The Pelton Wheel is widely used in seawater applications and is capable of high conversion efficiency. It has one characteristic that would make it difficult to integrate into the existing NRO plant: it requires an atmospheric discharge. To integrate this device would require modifications to the foundation structure of the building and the concentrate discharge piping, or alternatively, installation of a system to collect the discharged concentrate, and re-pump it to the discharge point.

Dare County already utilizes the third type of energy recovery device at the Hatteras plant. Although there are other types of work exchangers, the Turbocharger® is most widely used in the US, with many examples of brackish water applications for interstage boost.

The manufacturer, Pump Engineering, Inc., has recently introduced a low-cost model specifically designed for brackish water interstage boosting. This device differs from the standard seawater models in the material of the casing, which is cast from 316 stainless steel rather than the expensive duplex alloy steel used for the Hatteras units.

It has been estimated that a minimum 40 psi boost can be obtained from this interstage device. This boost will reduce the first stage feed pressure sufficiently so that the future condition of feedwater TDS can be met without the addition of the seventh stage to the RO feed pumps. If, as expected, additional boost is available, the feed pressure will be reduced, and the permeate quality enhanced.

Table 3-1 shows the expected performance of the major membrane manufacturers products, together with current and future feed pressures. The projections include a 14 psig permeate backpressure, acidification to pH=7.4, and a 40 psig interstage pressure boost.

TriSep software has no mechanism for inserting interstage boost. The pressures shown in Table 3-1 are without the interstage boost pressure of 40 psi used for the other manufacturers projections. However, based on the results of the un-boosted model, the TriSep performance would appear to be competitive with the other 5 manufacturers

Pretreatment will remain as is currently configured. 93% sulphuric acid will continue to be used to lower the pH for carbon dioxide generation. This carbon dioxide passes through the membranes, and reacts with the caustic soda in post treatment to form bicarbonate alkalinity. A scale inhibitor, NSF approved, will be added to control carbonate scaling. Both chemicals are currently in use at NRO.

Two additional cartridge filter vessels will be installed at the locations existing for that purpose. Since there does not appear to be a reason to change the size and number of cartridge elements in each filter, the existing equipment will be duplicated.

There will be no change made to the post treatment processes, which involve the addition of chlorine, caustic soda (25%), hydro fluorosilicic acid, and a phosphate-based corrosion inhibitor.

PARAMETER	Hydranautics 8040-CPA3-400		Koch 8822-HR-400		Dow BW30-8040 400		Toray TM 720-400		Osmonics/Desal AG-8040F400		TriSep 8040-ACM2-UWA (1)	
	current	future	current	future	current	future	current	future	current	future	current	future
Feed pressure, psig	269	292	260.8	286	258	292	275	286	265	284	275	286
Ave. flux, gfd	13.5	11.6	13.5	11.6	13.45	11.58	13.5	11.6	13.5	11.6	13.5	11.6
# of vessels, total	31	36	31	36	31	36	31	36	31	36	31	36
Vessel array	21:10	24:12	21:10	24:12	21:10	24:12	21:10	24:12	21:10	24:12	21:10	24:12
Permeate TDS, mg/l	114.8	190.0	97	197.94	60.32	91.97	135	210	85	137	135	210
Blend flow, gpm	50	30	50	30	50	40	50	30	50	30	50	30
Permeate flow, gpm	695	695	695	695	695	695	695	695	695	695	695	695
Blend TDS mg/l	386	430	383	430	342	413	411	449	365	371	411	449
Recovery %	78	75	78	75	78	75	78	75	78	75	78	75
Conc. flow, gpm	196	232	196	232	196	232	196	232	196	232	196	232
Conc. TDS, mg/l	18,919	23,428	16,718	23,365	19,139	23,714	18,872	21,413	18,946	26,640	18,872	21,413

(1) Represents feed pressure with no interstage boost

TABLE 3-1 SUMMARY OF RO PERFORMANCE PROJECTIONS

4.0 Treatment Process Description

4.1 Introduction

As discussed in Chapters 1 and 2, this project is an expansion of an existing brackish water reverse osmosis water treatment plant located in the Town of Kill Devil Hills, Dare County, North Carolina.

The existing plant, called the North RO plant (NRO) treats brackish groundwater from 10 wells constructed in the Mid Yorktowne Aquifer. The wells are cased to a depth of about 325 feet, with about 100 feet of screen and gravel pack. The maximum current total well field capacity is about 4,200 gpm. The wells are equipped with stainless steel submersible pumps and motors, and stainless steel discharge columns.

4.2 Pretreatment

Water enters the NRO process building at about 40-45 psig, and is treated with acid and scale inhibitor, followed by filtration through 5μ cartridge filters. The filters require changing about 6 times per year. The filter vessels are fabricated from 316 stainless steel, Parker Model 6S52-4-6FK1. Each vessel, of which there are four, contains 52 cartridges, 40 inches long, or 832 10" equivalents. For RO pretreatment, it is generally recommended that the flow/10" length not exceed 5 gpm. The existing filters therefore have a design capacity of 4,160 gpm, or approximately the capacity of the well field.

It is proposed that 2 additional filter vessels be installed as part of this work, raising the maximum filtration capacity to 6,240 gpm. The new vessels will duplicate the existing installation, and will be equipped with inlet and outlet valves, and pressure indicators.

4.3 RO Feed Water Pumps

Water from the cartridge filters is discharged into the RO feed pump suction header, at about 35 psig. The RO feed pumps are can-type vertical turbines, fabricated from the cast equivalent of 316 stainless steel. The existing cans are fabricated from FRP. It is recommended that the one new can required be fabricated from 316 L stainless steel, which has been pickled and passivated.

The existing RO feed pumps are sized to deliver 933 gpm of at a TDH of 675 feet, at the full speed of 3550 rpm. The original plant was installed with one complete spare pump and can. This pump has the characteristics to feed the new RO trains, and the one new pump required will have the same specification. It is recommended that a spare motor be provided with this contract. The motors will be 460 V, 5ph, 60 Hz, constructed for inverter duty. Each motor will be equipped with a thermistor to monitor winding temperature, and a heater to keep the windings dry when the motor is not in operation.

RO feed pump speed will be controlled by VFDs. The pump speed will be controlled by the train permeate flow set point, which will be 695 gpm at the design point.

With the pump characteristics and the pressure requirement of the new RO trains, it is recommended that energy recovery devices be incorporated as interstage boost pumps. If funding permits, the original three trains should be retrofitted to incorporate this energy saving device. Based on preliminary projections, it is recommended that the LPT-250, manufactured by Pump Engineering, Inc. of Monroe, Michigan, be specified for this application.

The inclusion of energy recovery devices as interstage boost pumps will impact the process in two ways. Because the feed pressure to the second stage is increased over what it would be without boost, the second stage flux increases, and there is a consequential improvement in permeate quality. Since the second stage is now producing more water, the first stage flux is reduced, thus reducing the first stage feed pressure requirement. The net result is a potential reduction in motor horsepower from 250 hp to 200 hp. However, given the possible future addition of the extra stage which has been planned for in the pump can depth, and because three new VFDs have recently been installed as replacements for the original units, it is recommended that the motor nameplate horsepower rating not be changed.

4.4 Reverse Osmosis Units

Two new Reverse Osmosis trains will be installed as part of this expansion. Since the original plant design was developed to accommodate 8.0 MGD, sufficient space is available for this expansion, which will bring the total design plant capacity to 5.0 MGD, plus blend. The additional feed water blend initially will be about 8% of permeate flow for the new trains for a maximum total output of finished water of 5.4 MGD.

The new RO trains will be capable of operating at 78% (75% normal operation) recovery initially, and 75% at the future design point of 6,000 mg/l TDS. The slight increase in recovery will provide some groundwater conservation, reduce concentrate flow, and provide for a slight improvement in energy efficiency.

Membrane performance has improved dramatically since the original plant was placed into service. The original membranes have been replaced with high rejection brackish water membranes, with test specification of 11,000 gpd and 99.5% sodium chloride rejection. Each membrane contains 400 square feet of membrane area. Similar membranes will be used for the expansion trains. The design feed water quality has been discussed previously in this document. The process design of the new trains is based on the use of interstage pressure boost using energy recovery devices. The initial array for current quality will be 21:10, using 6 element vessels, for a total of 186 elements. The average flux is 13.44 gfd for 400 square feet membranes. For the future condition, the array becomes 24:12, for a total of 216 elements, and an average flux of 11.57 gfd.

The proposed vessel arrangement for the new trains is 6 wide by 6 high. Since there is an existing cleaning system, it will not be possible to design the train with "flow through" multi-port vessels, as was done at the Hatteras plant. At the feed end, there will be two vertical manifolds, with 6 vessels arranged vertically on each side. This will accommodate 24 vessels at the future condition. The second stage will have a single vertical manifold, again with 6 vessels on each side.

At the interstage end the first stage concentrate manifolds will be connected to the energy recovery device, as will the second stage feed manifold. The second stage concentrate will be piped to the energy recovery device, from which it will discharge to the existing concentrate header in the pipe trench.

The permeate piping will be arranged to provide both first stage and total permeate flow meters with the requisite straight pipe runs, and will discharge to the existing permeate header in the pipe trench.

A sample panel and sink will be provided, as is the case with the existing trains.

4.5 Chemical Feed Systems

The existing chemical feed systems will be retained in their current locations and configurations. Review of the metering pump capacities and dosing rate by both RosTek Associates and the Dare County staff has been conducted and the following status determined for 5 MGD permeate production:

	Rate	Existing Pump
Scale Inhibitor	19.5 gpd	24 gpd
Sulphuric Acid	70.5 gpd	240 gpd
Corrosion Inhibitor	158 gpd	192 gpd
Fluoride	26 gpd	132 gpd

25% Caustic Soda	295-340 gpd	480 gpd

A spare pump backs up each system pump. Both are controlled by the PLC-based control, and can be selected manually at the operator console in the control room.

4.6 Membrane Cleaning System

The original membrane cleaning system will be used to clean the new trains. This system consists of a 1000 gallon cleaning solution tank, cleaning pump, cartridge filter, and associated piping, valves and controls.

The cleaning pump delivers 420 gpm at a TDH of 174 feet. For current high performance membranes, this capacity is marginal. It is generally recommended by the membrane manufacturers that a minimum flow of 40 gpm per vessel is needed for effective cleaning. For the proposed vessel arrangement on the new trains, this would mean a pump capacity of 480 gpm, or 14% more capacity than is currently available.

If there were a pattern of frequent and complex cleaning at NRO, it would be prudent to replace the existing cleaning pump with one of a least the recommended minimum capacity. However, since historically the primary foulant appears to be iron, and cleaning frequency is once or twice per year, it is not recommended that the capacity of the cleaning pump be increased at this time.

4.7 Instrumentation and Control

In discussions with the responsible staff at the NRO, it appears that insufficient space is available in the existing control cabinet to expand the discrete and analog 1/O racks to accommodate the two new trains.

Since the County has recently upgraded the supervisory control system, it is clearly not appropriate to reconfigure or replace the existing control cabinet, or try to add a supplemental cabinet.

It is therefore proposed that remote base units be installed on each of the two new trains. All of the monitoring and control data for the trains will be collected/distributed through these units and transmitted to the control-room by an Ethernet or similar network connection. Feed pump control can also be distributed to the electrical room for connection to the appropriate VFD.

All field instruments will be specified to match the scope of the existing plant. As the County has developed some preferences based on 13 years of operating experience, the specification will reflect these preferences. Two examples would be pressure switches, and flow meters. Other instruments and devices will be specified to reflect the current state-of-the-art for electronic instrumentation.

5.0 Preliminary Major Equipment Selection

5.1 Cartridge Filters

Number of Vessels	2
Orientation	Vertical
Maximum Capacity	1040 gpm
Material	316 SS
Manufacturer	Parker Filtration, 6S52-4-6FK1

5.2 RO Feed Pumps

Number of pumps	1
Number of motors	2
Type	Can-type Vertical Turbine
Material	316 LSS and CF8M
Bearings	Babbitted Carbon
Speed	3550 rpm
Power	480V 3ph 60 Hz
Motor	3,550 rpm, solid shaft, premium efficiency, 1.15 SF, 250 HP, WP1
Seal	Mechanical, John Crane Type
Capacity	926 gpm
Head	650 ft of water
Lubrication	Pumped fluid
Manufacturer	Afton Pump, or equal

5.3 Pressure Vessels

Number for current design/train	31 (21:10)
Number for future design/train	36 (24:12)
Type	Side Entry

Material	FRP
Dimension	8" dia. x 6 elements long
Pressure rating	450 psi
Manufacturer	Protec, or equal

5.4 RO Membrane Elements

Number of elements/train	186
Type	Spiral wound Thin Film Composite
Size	8" dia. x 40" long

Test Conditions

1500 mg/L NaCl solution,

P_F = 225 psi, Recovery = 15%

Temperature = 77°F (25°C)

30 minutes of operation prior to data

Performance	Rejection: 99.5% minimum Production: 11,000 gpd minimum
Manufacturers	Dow, Koch, Hydranautics, Toray, Desal, TriSep, or equal

5.5 Energy Recovery Device

Number for new trains	2
Number for existing trains	3
Type	Work transfer turbine
Material	316 stainless steel
Ancillaries	Auxiliary nozzle and valve for pressure balancing
Capacity	372 gpm - 232 gpm - concentrate
Estimated minimum boost	40 psig
Manufacturer	Pump Engineering

6.0 Contracting, Costs and Schedule

6.1 Introduction

This section of the report provides a discussion of the contracting approach recommended for the project, as well as preliminary opinion of the capital cost for the two train expansion, and an examination of scheduling issues.

6.2 Contracting Approach

North Carolina G.S. 87-10 (b) appears to require that the entity engaged to perform the NRO plant expansion be a licensed contractor in North Carolina. Certainly, given the extent of the electrical work involved in the expansion, a licensed electrical contractor will be needed for that part of the work, either as a sub-contractor, or as a separate prime.

The language of G.S. 87-10 can be interpreted in two ways. Either the license must be that of a public utilities contractor, specializing in water and wastewater treatment facilities, and appurtenances thereof; or as a specialty contractor performing construction work requiring special skill, but not including any operations.

However, since this project involves only the installation of equipment in a facility already constructed, and it is highly specialized work, it is recommended that the County Attorney review this situation to determine the need for a NC licensed contractor for the RO equipment installation, as opposed to a construction project.

If a NC license is required, the project should be advertised locally and in the major newspapers in the region. The specifications should clearly identify those RO system suppliers that the County considers pre-qualified, and require that the bidder name specifically the RO system supplier that will supply and install the equipment. Since this will consist of 95% of the work involved, excluding the electrical work, it is unlikely that any GC will want to bid this since there will be no work for him to perform, except contract administration, but he will have to commit bonding and insurance capacity. It may therefore be possible for the ROEM to "piggy-back" on a license held by a third party for a single project.

The potential ROEMs should be notified of this situation soon, so that they can begin their own investigations into the requirements under state law, since the specifications will require that each bidder be responsible for holding the appropriate active NC license. Regardless of the strategy, the County cannot award a contract to an unlicensed entity.

6.3 Cost Basis

6.3.1 Capital Costs

Costs are based on experience from current project estimates and proposals, vendor quotations, price catalogs and other current information. Cost premiums associated with construction on the Outer Banks area (remote location, seasonal cost variations) have also been considered.

All costs were estimated for the fourth quarter 2002 for equipment supply and construction in North Carolina. Costs include the following:

- Membranes and vessels with racks (2 lots).
- Instrumentation and controls.
- Electric motors (2), VFDs (2), Modifications to 480V entry switchboard.
- RO feed pump (1).
- Energy recovery devices (5).
- Piping and valves.
- Wire and cable.
- Installation labor cost

6.3.2 Indirect Capital Costs

Indirect costs are based on a percentage of the direct costs and include the following:

- Freight and insurance
- Overhead and profit
- Contingencies

Each of these are discussed below:

Freight and Insurance - Two percent of the total direct costs.

Construction Overhead and Profit - This cost is determined by adjusting the total direct costs by fifteen percent.

Contingency - This is taken as fifteen percent of the total direct costs, plus the other indirect costs.

6.4 Project Costs

The capital costs are based on the design recommendations in Section 4. The direct capital costs are given in Table 6-1, indirect costs in Table 6-2, and total cost in Table 6-3.

6.5 Project Schedule

It is the intent of this project to have the first expansion train operational before Memorial Day weekend, 2003. The second expansion train, if awarded under this contract, must be in full operation prior to July 4th weekend, 2003.

For the first train, since the RO feed pump is already in place, the longest lead item will be the RO feed pump VFD, at about 12 weeks. If both trains are constructed under this program, all of the required electrical equipment should be on site, and installed within about 4 months after Notice to Proceed.

TABLE 6-1 RO CAPITAL COSTS – 2 TRAINS

ITEM	NUMBER	UNIT COST ($)	TOTAL COST ($)
Cartridge Filters	2	33,000	66,000
RO Pump and motor	1	55,000	55,000
RO Pump motors	1 spare	12,000	12,000
Energy Recovery Device	5	18,500	92,500
Pressure Vessels	62	1,500	93,000
Membrane assemblies	2	75,000	150,000
Membranes	372	650	241,800
Piping & Valves	1 lot	55,000	55,000
Repair Transmission Pumps	2	25,000	50,000
New Transmission Pump	1	30,000	30,000
Instrument devices	1 lot	55,000	55,000
Control system, including software upgrade	1 lot	115,000	115,000
VFDs for RO pumps	2	40,000	80,000
VFDs for Transmission pumps	3	30,000	90,000
480V Disconnects	2	10,000	20,000
Active line filter	1	45,000	45,000
Wire and cable	1 lot	20,000	20,000
Installation labor	1 lot	180,000	180,000
Modify existing FW valves	3	3,000	9,000
Upgrade Well controls	10	3,500	35,000
Misc. Materials	1 lot	18,000	18,000
Mobilization	1 lot	10,000	10,000
Demobilization	1 lot	20,000	20,000

Sub-Total Direct Capital Cost	**$1,542,300**

TABLE 6-2 INDIRECT CAPITAL COSTS

INDIRECT COST ITEM	TOTAL COST ($)
Contractor's Overhead & Profit @ 15% of Direct Capital Cost	231,350
Freight and handling @ 2% of Direct Capital Cost	30,840
Contingency @ 15% of Direct Capital Cost	231,350
Sub-Total Indirect Cost	**$493,540**

TABLE 6-3 TOTAL PROJECT COSTS

COST ITEM	TOTAL COST ($)
Direct Capital Cost	$1,542,300
Indirect Cost	$493,540
Opinion of Total Project Cost	**$2,035,840**

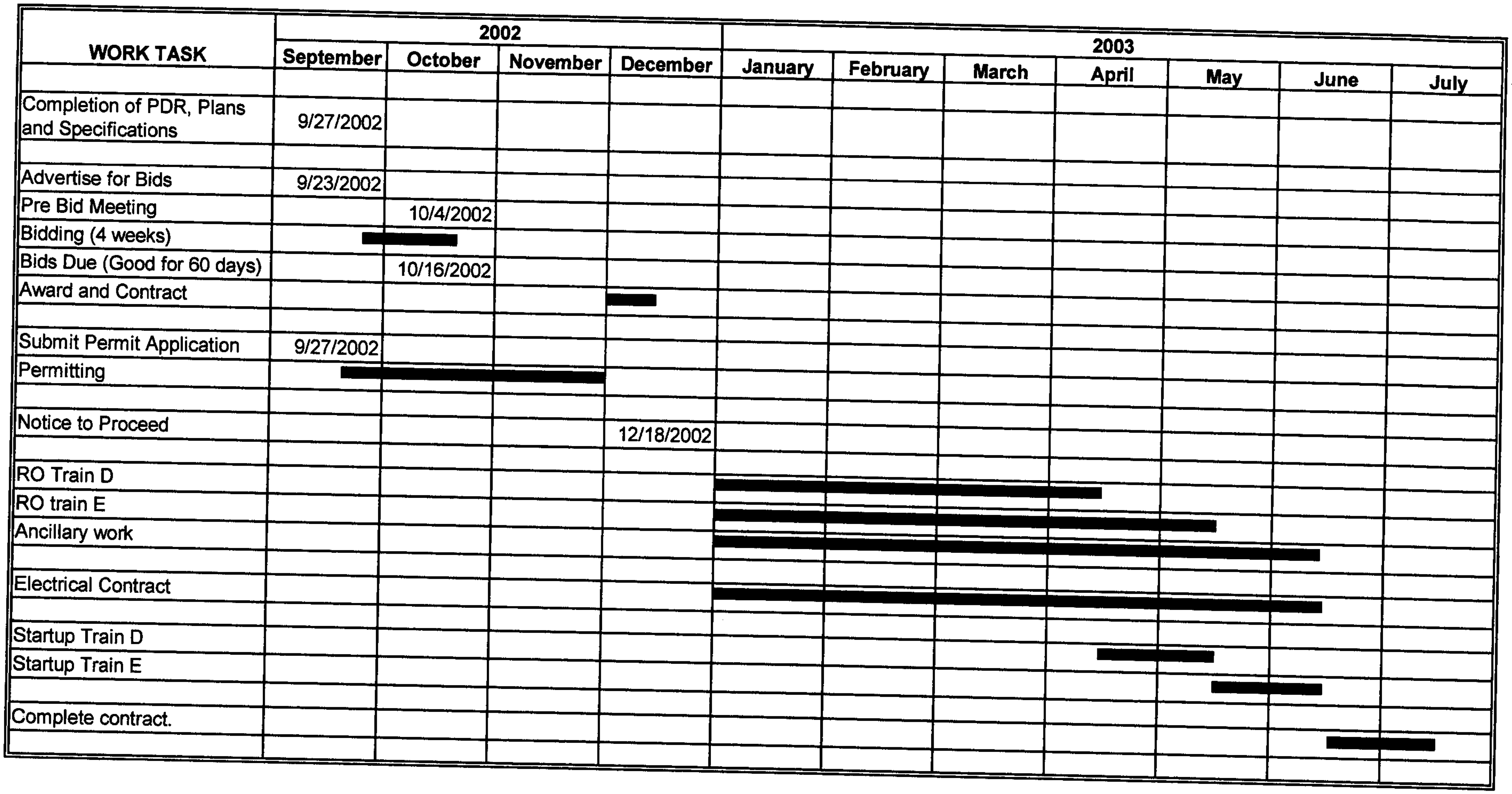
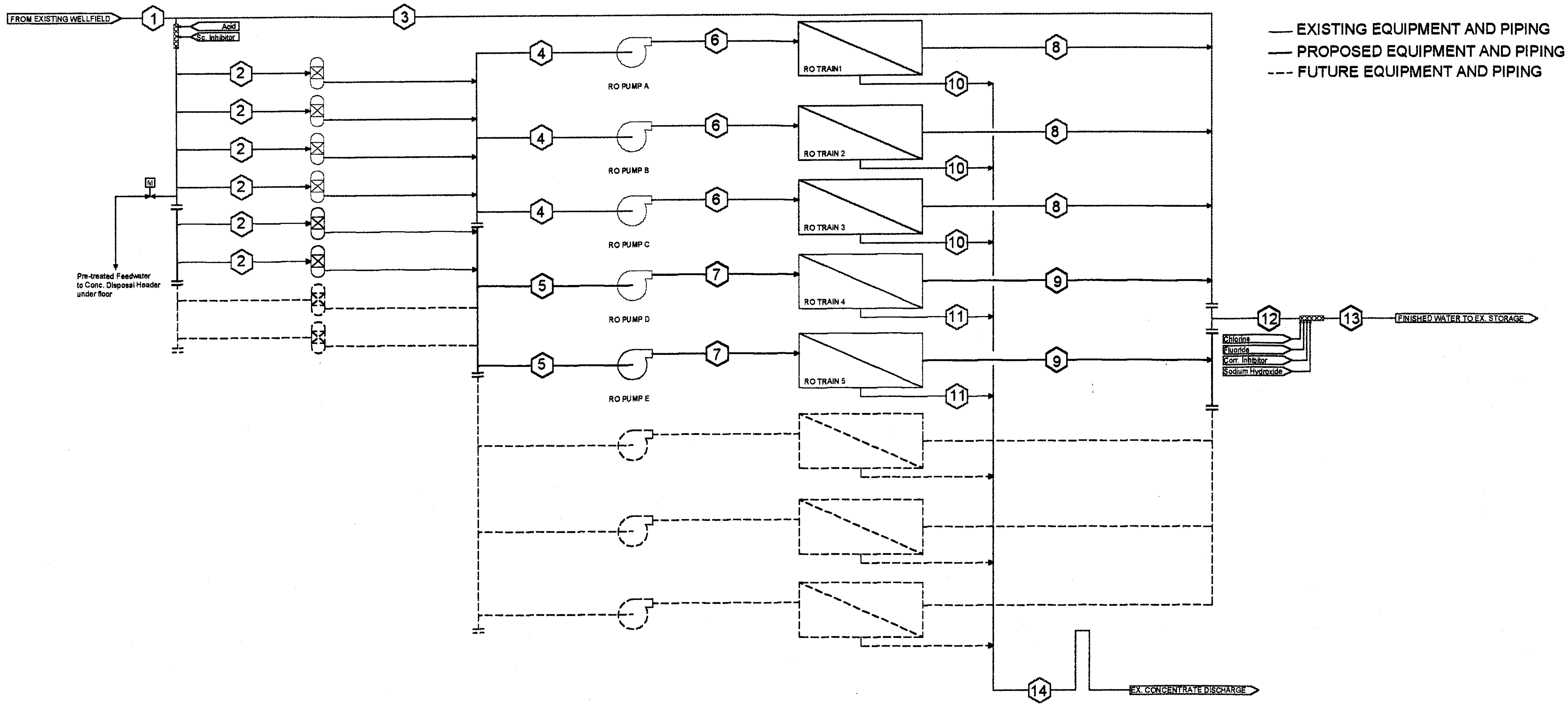


FIGURE 6-1 PRELIMINARY PROJECT SCHEDULE

APPENDIX A EXHIBITS



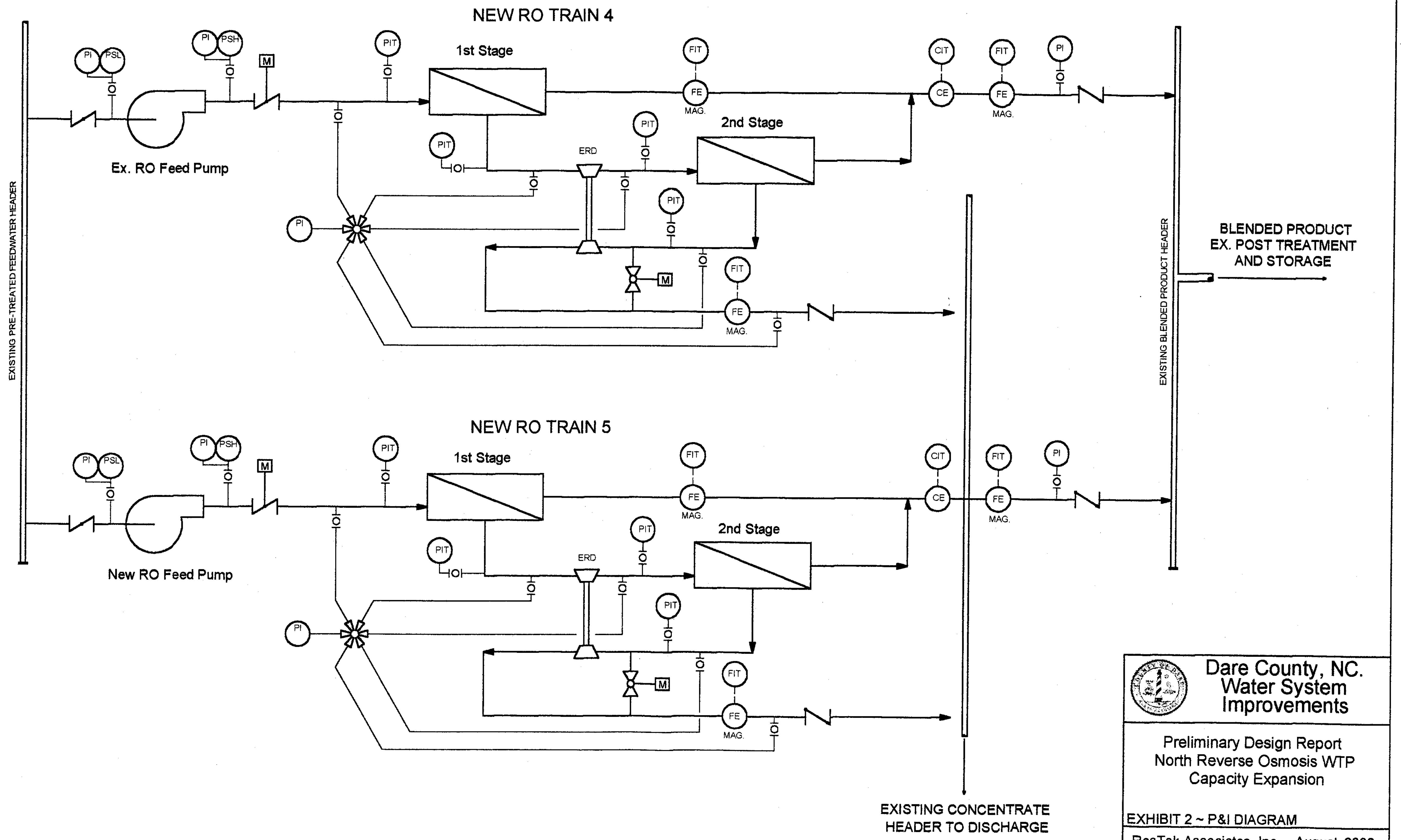
PARAMETER \ STREAM	1 Raw Well Water	2 Pretreated Water	3 Bypassed for blend	4 Filtered Feed (ex.)	5 Filtered Feed (new)	6 RO Feed (ex.)	7 RO Feed (new)	8 Permeate (ex.)	9 Permeate (new)	10 Concentrate (ex.)	11 Concentrate (new)	12 Blended Water	13 Finished Water	14 Concentrate to Disposal
FLOW, gpm	4695	691	348	855	891	855	891	642	695	197	196	3664	3664	983
PRESSURE, psig	45	40	45	35	35	280	260	14	14	10	10	14	14	10
TDS, mg/l	4250	4250	4250	4250	4250	4250	4250	140	110	16,600	18,900	420	445	17,520
PIPE DIA, ins	20	6	6	8	8	8	6	8	6	4	4	20	20	12
PIPE SCHEDULE	125#	Sch 80	Sch 80	Sch 80	Sch 80	S10	S10	Sch 80	Sch 80	150#	Sch 80	125#	125#	Sch 80
MATERIAL	FRP	PVC	PVC	PVC	PVC	316L SS	316L SS	PVC	PVC	FRP	PVC	FRP	FRP	PVC

Dare County, NC.
Water System
Improvements

Preliminary Design Report
North Reverse Osmosis WTP
Capacity Expansion

EXHIBIT 1 ~ PROCESS FLOW DIAGRAM

RosTek Associates, Inc. August, 2002

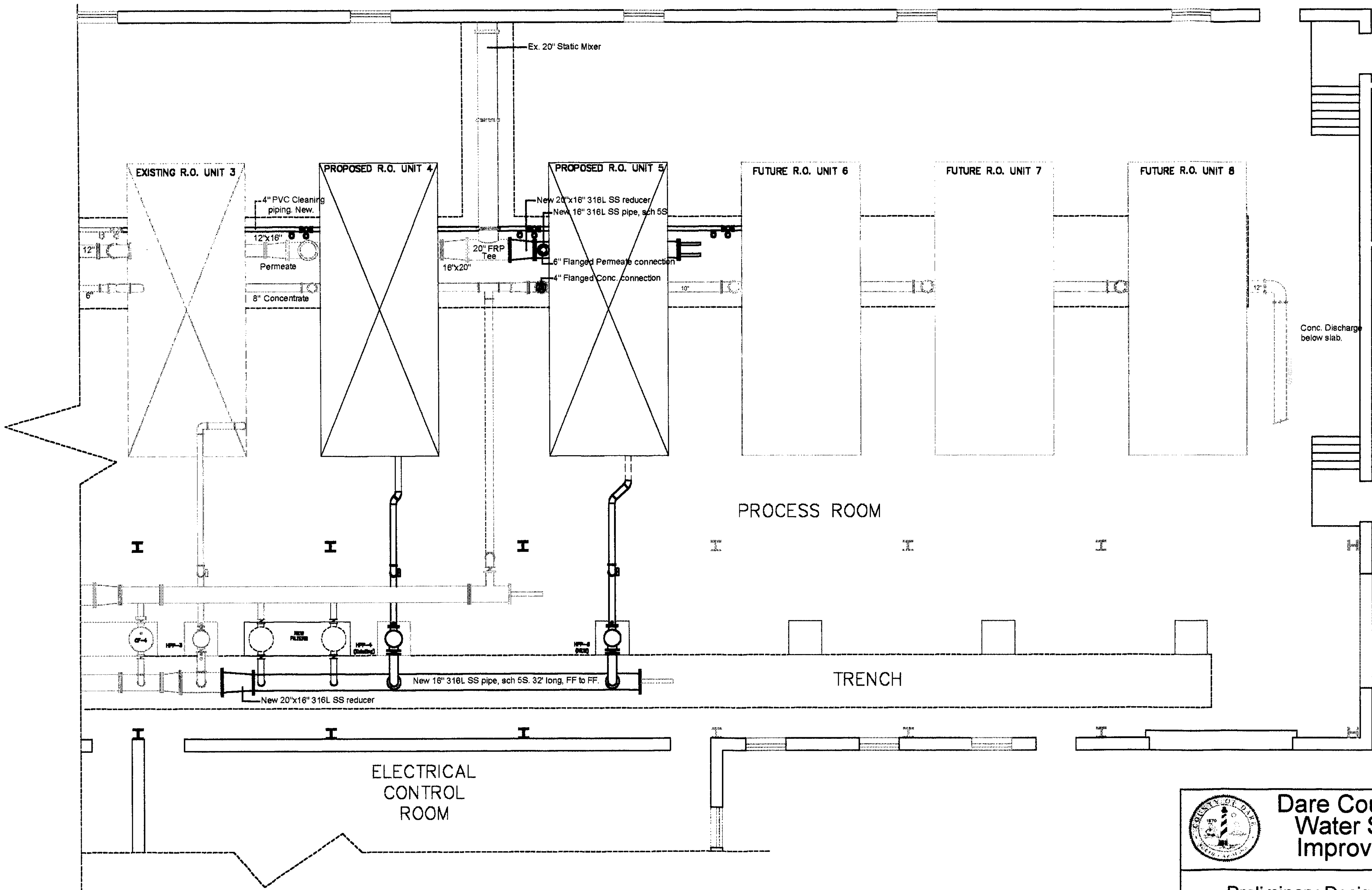


Dare County, NC.
Water System
Improvements

Preliminary Design Report
North Reverse Osmosis WTP
Capacity Expansion

EXHIBIT 2 ~ P&I DIAGRAM

RosTek Associates, Inc. August, 2002

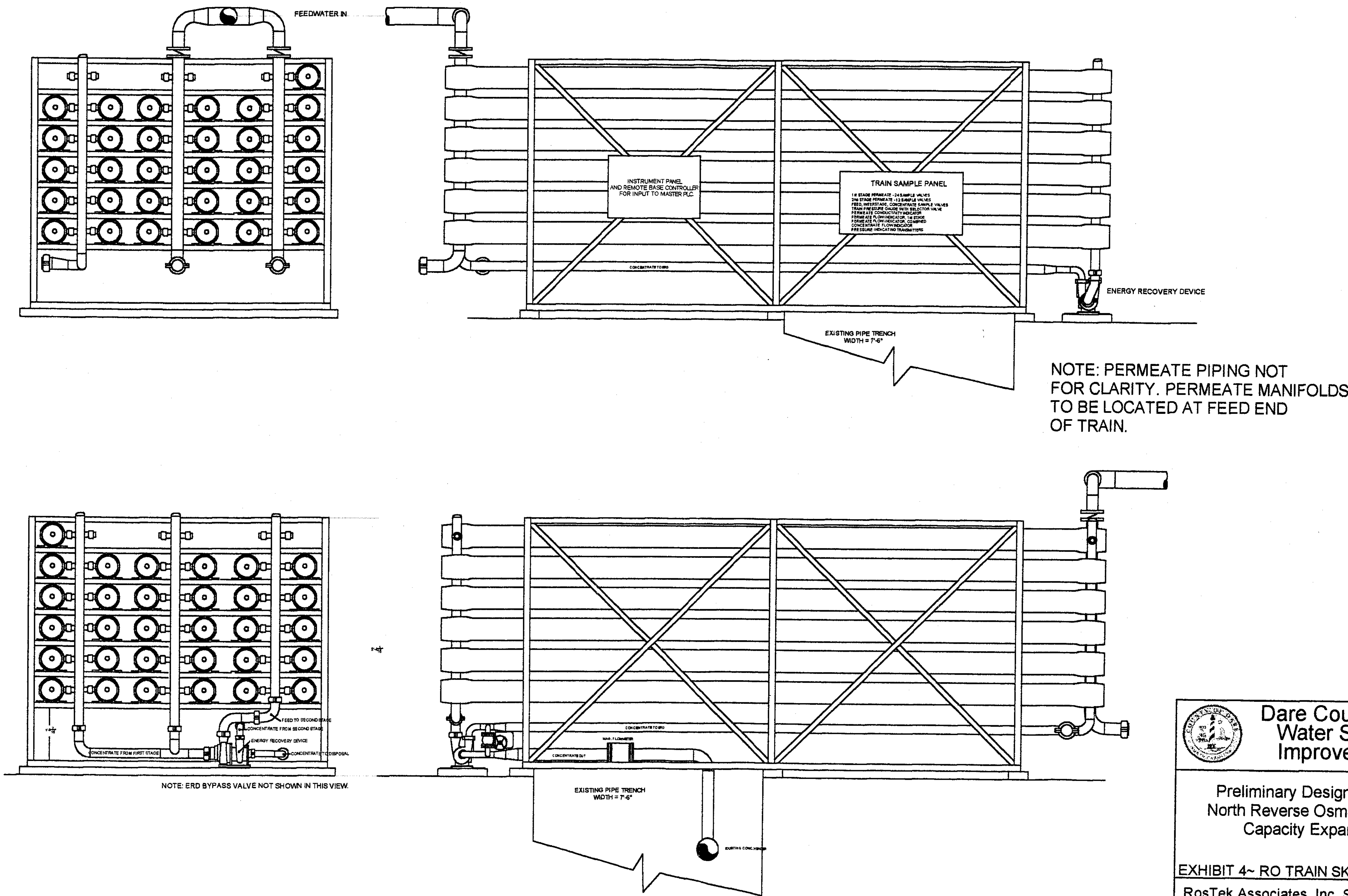


Dare County, NC.
Water System
Improvements

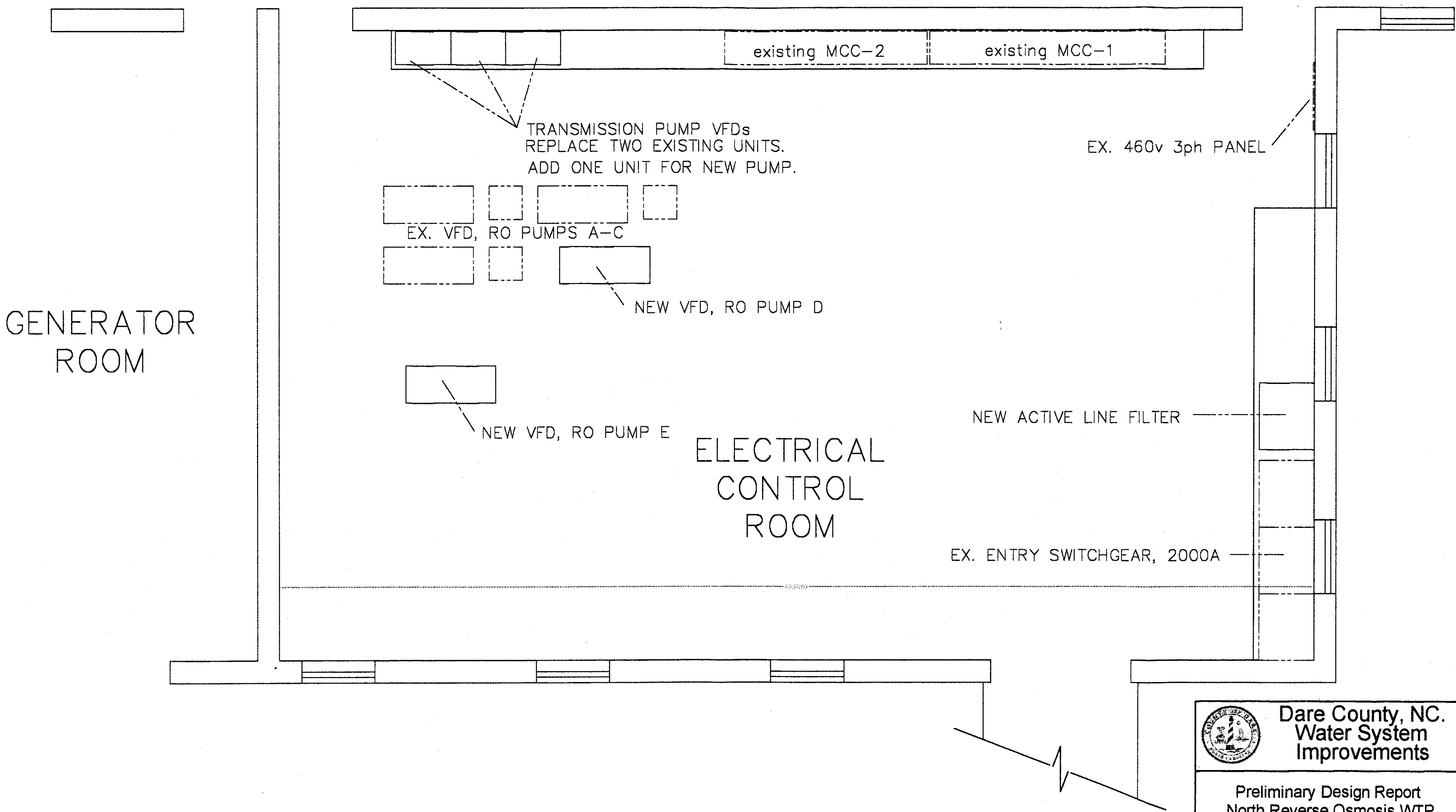
Preliminary Design Report
North Reverse Osmosis WTP
Capacity Expansion

EXHIBIT 3 ~ PROCESS ARRANGEMENT

RosTek Associates, Inc. August, 2002



Dare County, NC. Water System Improvements	
Preliminary Design Report North Reverse Osmosis WTP Capacity Expansion	
EXHIBIT 4~ RO TRAIN SKETCHES	
RosTek Associates, Inc. September, 2002	



Dare County, NC.
Water System
Improvements

Preliminary Design Report
North Reverse Osmosis WTP
Capacity Expansion

EXHIBIT 5 ~ ELECTRICAL ROOM

RosTek Associates, Inc.September 2002

APPENDIX B RO PROJECTIONS

PERMEATE BLENDING AND BOOSTER PUMP

RO program licensed to:
Calculation created by: Ian C. Watson
Project name: KDH Expansion

Add 14 psi for permeate press

HP Pump flow:	891.0 gpm	Permeate flow:	695.0 gpm
Recommended pump press.:	275.6 psi	Raw water flow:	941.0 gpm
Feed pressure:	255.5 psi	Blended flow:	745.0 gpm
Feedwater Temperature:	20.0 C(68F)	Permeate recovery ratio:	78.0 %
		Blending ratio:	6.7%
		Booster pump pressure:	40.0 psi
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	17.6 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	21.4	Salt passage increase, %/yr:	10.0
Average flux rate:	13.5 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc. Pressures psi	Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	541.8	42.4	16.6	15.5	1.17	237.6	0.0	CPA3	126	21x6
1-2	153.2	34.9	19.6	9.2	1.07	258.9	0.0	CPA3	60	10x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	72.0	179.6	72.0	179.6	5.1	12.8	325.6	812.1
Mg	97.6	401.6	97.6	401.6	7.0	28.7	441.4	1816.5
Na	1354.2	2943.9	1354.2	2943.9	127.1	276.3	6009.3	13063.7
K	18.0	23.1	18.0	23.1	1.8	2.3	79.4	101.8
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.010	0.0	0.010	0.0	0.001	0.0	0.045	0.0
Sr	1.600	1.8	1.600	1.8	0.114	0.1	7.236	8.3
CO3	1.0	1.7	0.3	0.5	0.1	0.1	1.4	2.3
HCO3	321.9	263.9	302.9	248.3	34.1	27.9	1327.3	1088.0
SO4	175.0	182.3	191.1	199.0	12.6	13.1	864.1	900.1
Cl	2200.0	3103.0	2200.0	3103.0	197.0	277.8	9798.8	13820.6
F	0.3	0.8	0.3	0.8	0.0	0.1	1.3	3.4
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	14.1		14.1		1.2		63.1	
TDS	4255.7		4252.1		386.1		18919.0	
pH	7.9		7.4		6.5		8.2	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	1%	1%	9%
SrSO4 / Ksp * 100:	2%	2%	13%
BaSO4 / Ksp * 100:	16%	18%	112%
SiO2 saturation:	11%	11%	49%
Langelier Saturation Index	0.47	-0.02	1.98
Stiff & Davis Saturation Index	0.30	-0.19	1.29
Ionic strength	0.08	0.08	0.35
Osmotic pressure	44.8 psi	44.7 psi	198.6 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

Hydranautics (USA) Ph:(760)901-2500 Fax:(760)901-2578 info@hydranautics.com
Hydranautics (Europe) Ph: 31 5465 88355 Fax: 31 5465 73288

PERMEATE BLENDING AND BOOSTER PUMP

RO program licensed to:			
Calculation created by:	Ian C. Watson		
Project name:	KDH Expansion	Permeate flow:	695.0 gpm
HP Pump flow:	891.0 gpm	Raw water flow:	941.0 gpm
Recommended pump press.:	275.6 psi	Blended flow:	745.0 gpm
Feed pressure:	255.5 psi	Permeate recovery ratio:	78.0 %
Feedwater Temperature:	20.0 C(68F)	Blending ratio:	6.7%
		Booster pump pressure:	40.0 psi
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	17.6 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	21.4	Salt passage increase, %/yr:	10.0
Average flux rate:	13.5 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	541.8	42.4	16.6	15.5	1.17	237.6	0.0	CPA3	126	21x6
1-2	153.2	34.9	19.6	9.2	1.07	258.9	0.0	CPA3	60	10x6

Stg	Elem no.	Feed pres psi	Pres drop psi	Perm flow gpm	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Concentrate saturation level CaSO4	SrSO4	BaSO4	SiO2	Lang.
1-1	1	255.5	4.7	5.2	18.6	1.12	35.4	50.3	0	2	21	12	-0.6
1-1	2	250.8	3.9	4.9	17.6	1.14	40.4	57.8	0	3	25	14	-0.4
1-1	3	246.9	3.2	4.6	16.4	1.15	46.8	67.2	0	3	31	16	-0.2
1-1	4	243.8	2.5	4.2	15.1	1.16	53.5	78.9	1	4	37	19	0.0
1-1	5	241.2	2.0	3.8	13.6	1.17	61.5	93.7	1	5	46	23	0.2
1-1	6	239.2	1.6	3.3	11.8	1.18	71.2	111.9	1	6	57	28	0.4
1-2	1	274.6	3.6	3.6	13.1	1.10	75.9	124.8	1	7	66	31	0.6
1-2	2	271.0	3.1	3.2	11.5	1.10	81.5	138.9	1	8	75	34	0.7
1-2	3	267.9	2.7	2.8	9.9	1.10	88.2	153.9	1	10	85	38	0.8
1-2	4	265.3	2.3	2.3	8.4	1.09	96.0	169.1	2	11	95	42	1.0
1-2	5	262.9	2.0	1.9	6.9	1.08	104.9	184.1	2	12	106	45	1.1
1-2	6	260.9	1.8	1.5	5.5	1.07	114.8	198.0	2	13	116	49	1.2

PERMEATE BLENDING AND BOOSTER PUMP

RO program licensed to:
Calculation created by: Ian C. Watson

Project name: KDH Expansion		Permeate flow:	695.0 gpm
HP Pump flow:	891.0 gpm	Raw water flow:	941.0 gpm
R[illegible]mmended pump press.:	275.6 psi	Blended flow:	745.0 gpm
F[illegible] pressure:	255.5 psi	Permeate recovery ratio:	78.0 %
Feedwater Temperature:	20.0 C(68F)	Blending ratio:	6.7%
		Booster pump pressure:	40.0 psi
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	17.6 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	21.4	Salt passage increase, %/yr:	10.0
Average flux rate:	13.5 gfd	Feed type:	Well water

****
*** THE FOLLOWING PARAMETERS EXCEED HYDRANAUTICS DESIGN LIMITS: ***
****

Concentrate Langelier Saturation Index too high (1.98)

The following are recommended general guidelines for designing a reverse osmosis system using Hydranautics membrane elements. Please consult Hydranautics for specific recommendations for operation beyond the specified guidelines.

Feed and Concentrate flow rate limits

Element diameter	Maximum feed flow rate	Minimum concentrate rate
[illegible].5 inches	6 gpm (22.7 lpm)	1.5 gpm (5.7 lpm)
[illegible].0 inches	16 gpm (60.6 lpm)	3 gpm (11.3 lpm)
6.0 inches	30 gpm (113.5 lpm)	7 gpm (26.5 lpm)
8.0 inches	75 gpm (283.9 lpm)	12 gpm (45.4 lpm)
8.5 inches	85 gpm (321.7 lpm)	14 gpm (53.0 lpm)

Concentrate polarization factor (beta) should not exceed 1.2

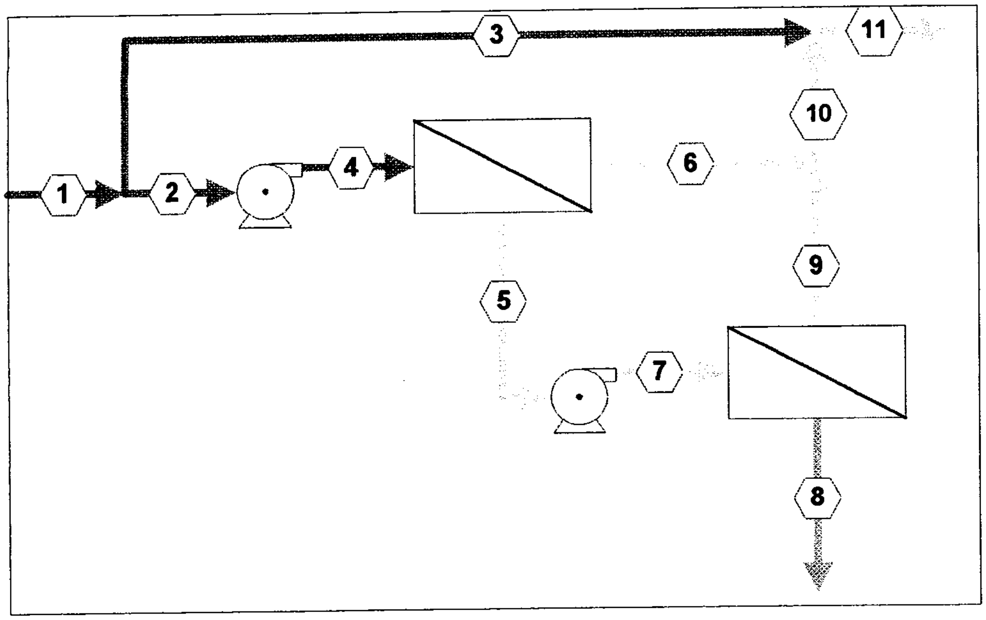
Saturation limits for sparingly soluble salts in concentrate

Soluble salt	Saturation
BaSO4	6000%
CaSO4	230%
SrSO4	800%
SiO2	100%

Langelier Saturation Index for concentrate should not exceed 1.8

The above saturation limits only apply when using effective scale inhibitor. Without scale inhibitor, concentrate saturation should not exceed 100%.

PERMEATE BLENDING AND INTERSTAGE BOOSTER PUMP



		1	2	3	4	5	6	7	8	9	10	11
Flow	gpm	941.0	891.0	50.0	891.0	349.3	541.8	349.3	196.0	153.2	695.0	745.0
Pressure	psi	0.0	0.0	0.0	255.5	237.6	0.0	277.6	258.9	0.0	0.0	0.0
TDS (ppm)		4255.7	4255.7	4255.7	4252.1	10734.6	72.0	10734.6	18919.0	268.0	115.2	386.1

BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

6000 TDS

RO program licensed to:			
Calculation created by: Ian C. Watson			
Project name: KDH Expansion		Permeate flow:	695.0 gpm
HP Pump flow:	926.7 gpm	Raw water flow:	926.7 gpm
R[illegible]mmended pump press.:	312.8 psi	Booster pump pressure:	40.0 psi
[illegible] pressure:	292.0 psi	Permeate throttling(All st.)	14.0 psi
Feedwater Temperature:	20.0 C(68F)	Permeate recovery ratio:	75.0 %
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	8.2	Salt passage increase, %/yr:	10.0
Average flux rate:	11.6 gfd	Feed type:	Well water

Stage	Perm. Flow	Flow/Vessel Feed	Flow/Vessel Conc	Flux	Beta	Conc.&Throt. Pressures		Element Type	Elem. No.	Array
	gpm	gpm	gpm	gfd		psi	psi			
1-1	567.0	38.6	15.0	14.2	1.15	276.8	14.0	CPA3	144	24x6
1-2	128.0	30.0	19.3	6.4	1.04	300.3	14.0	CPA3	72	12x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	72.0	179.6	72.0	179.6	0.5	1.3	286.5	714.3
Mg	97.6	401.6	97.6	401.6	0.7	2.9	388.3	1597.9
Na	2041.0	4437.0	2041.0	4437.0	69.4	150.9	7955.8	17295.2
K	18.0	23.1	18.0	23.1	0.8	1.0	69.7	89.4
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.010	0.0	0.010	0.0	0.000	0.0	0.040	0.0
Sr	1.600	1.8	1.600	1.8	0.011	0.0	6.366	7.3
CO3	1.0	1.7	1.0	1.7	0.0	0.0	3.7	6.1
[illegible]3	321.9	263.9	321.9	263.9	17.5	14.4	1235.1	1012.4
[illegible]4	175.0	182.3	175.0	182.3	1.3	1.4	696.0	725.0
Cl	3257.3	4594.2	3257.3	4594.2	99.4	140.2	12731.0	17956.2
F	0.3	0.8	0.3	0.8	0.0	0.0	1.1	3.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	14.1		14.1		0.3		55.4	
TDS	5999.8		5999.8		190.0		23428.9	
pH	7.9		7.9		6.6		8.4	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	1%	1%	6%
SrSO4 / Ksp * 100:	1%	1%	8%
BaSO4 / Ksp * 100:	13%	13%	68%
SiO2 saturation:	11%	11%	43%
Langelier Saturation Index	0.45	0.45	2.09
Stiff & Davis Saturation Index	0.21	0.21	1.34
Ionic strength	0.11	0.11	0.43
Osmotic pressure	64.5 psi	64.5 psi	251.7 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

H[illegible]anautics (USA) Ph:(760)901-2500 Fax:(760)901-2578 info@hydranautics.com
[illegible]anautics (Europe) Ph: 31 5465 88355 Fax: 31 5465 73288 (63)

BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

RO program licensed to:
Calculation created by: Ian C. Watson

Project name: KDH Expansion		Permeate flow:	695.0 gpm
HP Pump flow:	926.7 gpm	Raw water flow:	926.7 gpm
Recommended pump press.:	312.8 psi	Booster pump pressure:	40.0 psi
Feed pressure:	292.0 psi	Permeate throttling(All st.)	14.0 psi
Feedwater Temperature:	20.0 C(68F)	Permeate recovery ratio:	75.0 %
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	8.2	Salt passage increase, %/yr:	10.0
Average flux rate:	11.6 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Element Type	Elem. No.	Array
1-1	567.0	38.6	15.0	14.2	1.15	276.8	14.0	CPA3	144	24x6
1-2	128.0	30.0	19.3	6.4	1.04	300.3	14.0	CPA3	72	12x6

Stg	Elem no.	Feed pres psi	Pres drop psi	Perm flow gpm	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Concentrate saturation level CaSO4	SrSO4	BaSO4	SiO2	Lang.
1-1	1	292.0	4.1	5.1	18.3	1.14	58.6	73.6	0	2	15	12	-0.1
1-1	2	287.9	3.3	4.7	17.0	1.15	65.5	85.6	0	2	18	15	0.1
1-1	3	284.6	2.7	4.3	15.4	1.16	74.1	100.4	0	3	22	17	0.3
1-1	4	281.9	2.1	3.8	13.6	1.16	84.9	118.4	0	3	28	20	0.5
1-1	5	279.8	1.6	3.2	11.6	1.17	98.4	139.7	1	4	34	24	0.7
1-1	6	278.2	1.3	2.6	9.3	1.16	115.2	163.4	1	5	41	28	0.9
1-2	1	313.9	2.9	2.8	10.2	1.09	123.9	180.2	1	5	46	31	1.1
1-2	2	310.9	2.6	2.4	8.5	1.09	134.0	197.1	1	6	52	34	1.2
1-2	3	308.4	2.3	1.9	6.9	1.07	145.7	213.2	1	7	57	36	1.3
1-2	4	306.1	2.0	1.5	5.4	1.06	159.0	227.9	1	7	62	39	1.3
1-2	5	304.0	1.9	1.2	4.2	1.05	173.5	240.6	1	8	66	41	1.4
1-2	6	302.2	1.7	0.9	3.2	1.04	189.5	251.1	1	8	70	43	1.5

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

Hydranautics (USA) Ph:(760)901-2500 Fax:(760)901-2578 info@hydranautics.com
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BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

RO program licensed to:			
Calculation created by: Ian C. Watson			
Project name: KDH Expansion		Permeate flow:	695.0 gpm
HP Pump flow:	926.7 gpm	Raw water flow:	926.7 gpm
Recommended pump press.:	312.8 psi	Booster pump pressure:	40.0 psi
Feed pressure:	292.0 psi	Permeate throttling(All st.)	14.0 psi
Feedwater Temperature:	20.0 C(68F)	Permeate recovery ratio:	75.0 %
Raw water pH:	7.86	Element age:	3.0 years
Acid dosage, ppm (93%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	8.2	Salt passage increase, %/yr:	10.0
Average flux rate:	11.6 gfd	Feed type:	Well water

****

*** THE FOLLOWING PARAMETERS EXCEED HYDRANAUTICS DESIGN LIMITS: ***

****

Concentrate Langelier Saturation Index too high (2.09)

The following are recommended general guidelines for designing a reverse osmosis system using Hydranautics membrane elements. Please consult Hydranautics for specific recommendations for operation beyond the specified guidelines.

Feed and Concentrate flow rate limits

Element diameter	Maximum feed flow rate	Minimum concentrate rate
2.5 inches	6 gpm (22.7 lpm)	1.5 gpm (5.7 lpm)
4.0 inches	16 gpm (60.6 lpm)	3 gpm (11.3 lpm)
6.0 inches	30 gpm (113.5 lpm)	7 gpm (26.5 lpm)
8.0 inches	75 gpm (283.9 lpm)	12 gpm (45.4 lpm)
8.5 inches	85 gpm (321.7 lpm)	14 gpm (53.0 lpm)

Concentrate polarization factor (beta) should not exceed 1.2

Saturation limits for sparingly soluble salts in concentrate

Soluble salt	Saturation
BaSO4	6000%
CaSO4	230%
SrSO4	800%
SiO2	100%

Langelier Saturation Index for concentrate should not exceed 1.8

The above saturation limits only apply when using effective scale inhibitor. Without scale inhibitor, concentrate saturation should not exceed 100%.

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes ROSA v5.00

Project: Dare County KDH expansion **Case:** 1

Ian C. Watson, PE, RosTek Associates, Inc 8/25/2002

System Summary

Feed Flow to Stage 1	891.03 gpm	**Permeate Flow**	694.99 gpm
Raw Water Flow to System	891.03 gpm	**Recovery**	78.00 %
Feed Pressure	258.18 psig	**Feed Temperature**	20.00 C
Fouling Factor	0.85	**Feed TDS**	4257.85 mg/l
Chem. Dose (100% H2SO4)	0.00 mg/l	**Number of Elements**	186
Total Active Area	74400.00 ft2	**Average System Flux**	13.45 gfd
Water Classification	RO Permeate SDI < 1		

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	21	6	891.03	253.18	0.00	352.75	235.12	538.27	15.38	14.00	0.00	39.95
2	BW30-400	10	6	352.75	270.12	0.00	196.03	254.27	156.72	9.40	14.00	40.00	130.29

(mg/l, except pH)	**Raw Water**	**Adj Feed**	**Permeate**	**Concentrate**
NH4	0.00	0.00	0.00	0.00
K	18.00	18.00	0.56	79.82
Na	1355.00	1355.00	19.27	6090.50
Mg	97.60	97.60	0.98	440.14
Ca	72.00	72.00	0.90	324.06
Sr	1.60	1.60	0.02	7.20
Ba	0.01	0.01	0.00	0.05
HCO3	321.95	321.95	7.34	1437.33
CO3	0.52	0.52	0.01	2.33
NO3	0.04	0.04	0.00	0.18
Cl	2200.00	2201.73	29.52	9902.75
F	0.30	0.30	0.00	1.35
SO4	175.00	175.00	1.21	791.12
SiO2	14.10	14.10	0.50	62.30
CO2	6.73	6.73	6.73	6.73
TDS	4256.12	4257.85	60.32	19139.12
pH	7.90	7.90	6.20	8.55

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes
Project: Dare County KDH expansion
Ian C. Watson, PE, RosTek Associates, Inc

ROSA v5.00
Case: 1
8/25/2002

Design Warnings

-None-

Solubility Warnings

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

Scaling Calculations

	Raw Water	**Adj Feed**	**Concentrate**
pH	7.90	7.90	8.55
Langelier Saturation Index	0.50	0.50	2.42
Stiff & Davis Stability Index	0.37	0.37	1.72
Ionic Strength (Molal)	0.08	0.08	0.36
TDS (mg/l)	4256.12	4256.12	19139.12
HCO3	321.95	321.95	1437.33
CO2	6.73	6.73	6.73
CO3	0.52	0.52	2.33
CaSO4 (% Saturation)	1.30	1.30	8.10
BaSO4	17.74	17.74	81.32
SrSO4	1.32	1.32	6.87
CaF2	0.37	0.37	17.88
SiO2	11.91	11.91	35.44

To balance: 1.73 mg/l Cl added to feed.

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes ROSA v5.00
Project: Dare County KDH expansion **Case:** 1
Ian C. Watson, PE, RosTek Associates, Inc 8/25/2002

Array Details

Stage 1 Element	**Recov.**	**Perm Flow (gpm)**	**Perm TDS (mg/l)**	**Feed Flow (gpm)**	**Feed TDS (mg/l)**	**Feed Press (psig)**
1	0.12	5.11	23.64	42.43	4257.85	253.18
2	0.13	4.82	28.21	37.32	4838.09	248.45
3	0.14	4.50	34.23	32.50	5550.94	244.53
4	0.15	4.15	42.41	28.00	6437.67	241.33
5	0.16	3.75	53.99	23.85	7550.98	238.75
6	0.16	3.30	71.12	20.09	8951.82	236.71
Stage 2 Element	**Recov.**	**Perm Flow (gpm)**	**Perm TDS (mg/l)**	**Feed Flow (gpm)**	**Feed TDS (mg/l)**	**Feed Press (psig)**
1	0.11	3.72	75.07	35.28	10693.97	270.12
2	0.10	3.28	92.65	31.56	11944.72	266.42
3	0.10	2.83	116.38	28.28	13318.39	263.25
4	0.09	2.38	148.88	25.45	14784.57	260.53
5	0.08	1.94	194.59	23.08	16292.96	258.18
6	0.07	1.53	260.13	21.13	17771.16	256.11

System Design Guidelines

ROSA 5 uses System Design Guidelines to assist the User in the design for reverse osmosis and nanofiltration systems. The specific values used in ROSA come from two Product Information bulletins: *Membrane System Design Guidelines for 8-inch FILMTEC™ Elements* and *Commercial Design Guidelines for Midsize FILMTEC ™ Elements*. These documents may be obtained from www.filmtec.com.

Table 1 provides general guidelines for the User on maximum and minimum flow rates for the elements.

Table 1: Maximum and Minimum Flow Rates Per Pressure Vessel

Element Diameter (in)	Max Feed Flow gpm	Max Feed Flow m³/h	Min Conc. Flow gpm	Min Conc. Flow m³/h
2.5	6	1.4	1	0.2
4.0	16	3.2	4	0.9
4.0 (full-fit)	18	4.1	6	1.4
8.0	85	19.0	16	16.0
8.0 (full-fit)	85	19.0	25	25.0

Note: The flow values shown in Table 1 may be changed depending on the Water Classification.

When the User selects Small Commercial System on the Project Information Tab, the guidelines in Table 2 should be used to determine the number of elements and design configuration.

Table 2: Small Commercial System Guidelines

Water Classification	Average Flux gfd	Average Flux L/m²-h	%Rec.
RO Permeate SDI < 1	30.0	51.0	30
Well Water SDI < 3	25.0	42.0	25
Surface or Softened Municipal SDI < 3	30.0	51.0	30
Surface or Softened Municipal SDI < 5	20.0	34.0	20

Table 3 has guidelines for systems when midsize elements are used for light industrial and small seawater applications.

Table 3: Light Industrial and Small Seawater Guidelines for Midsize Elements

Water Classification	Average Flux gfd	Average Flux L/m²-h	% Rec.
RO Permeate SDI < 1	25.0	42.0	30
Well Water SDI < 3	21.0	36.0	19
Surface Supply SDI < 3	18.0	31.0	17
Surface Supply SDI < 5	17.0	29.0	15
Tertiary Effluent (MF) SDI < 3	13.0	22.0	14
Tertiary Effluent (Conventional) SDI < 3	11.0	19.0	12
Seawater (Well or MF) SDI < 3	13.0	22.0	13
Seawater (Open Intake) SDI < 5	11.0	19.0	10

Table 4 provides guidelines for 8-inch system designs as shown below:

Water Classification	Average Flux gfd	L/m²-h	% Rec.
RO Permeate SDI < 1	23.0	39.0	30
Well Water SDI < 3	19.0	32.0	19
Surface Supply SDI < 3	16.0	27.0	17
Surface Supply SDI < 5	15.0	25.0	15
Tertiary Effluent (MF) SDI < 3	12.0	20.0	14
Tertiary Effluent (Conventional) SDI < 3	10.0	17.0	12
Seawater (Well or MF) SDI < 3	8.8	15.0	13
Seawater (Open Intake) SDI < 5	7.3	12.0	10

Table 4: Design Guidelines for 8-Inch Diameter Elements

Note: Tables 2 – 4 contain average flux rates that the User can use to determine the approximate number of elements needed for a system design. The number of elements and pressure vessels may change depending on the specific conditions for the application.

6000 TDS

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes ROSA v5.00

Project: Dare County KDH expansion **Case:** 2

Ian C. Watson, PE, RosTek Associates, Inc 8/25/2002

System Summary

Feed Flow to Stage 1	926.66 gpm	**Permeate Flow**	694.98 gpm
Raw Water Flow to System	926.66 gpm	**Recovery**	75.00 %
Feed Pressure	291.61 psig	**Feed Temperature**	20.00 C
Fouling Factor	0.75	**Feed TDS**	5997.66 mg/l
Chem. Dose (100% H2SO4)	15.18	**Number of Elements**	216
Total Active Area	86400.00 ft2	**Average System Flux**	11.58 gfd
Water Classification	Well Water SDI < 3		

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	24	6	926.66	286.61	0.00	371.61	270.91	555.05	13.88	14.00	0.00	60.14
2	BW30-400	12	6	371.61	305.91	0.00	231.67	291.90	139.93	7.00	14.00	40.00	218.19

(mg/l, except pH)	Raw Water	Adj Feed	Permeate	Concentrate
NH4	0.00	0.00	0.00	0.00
K	18.00	18.00	0.63	70.11
Na	2041.00	2041.00	31.39	8069.25
Mg	97.60	97.60	1.04	387.26
Ca	72.00	72.00	0.99	285.02
Sr	1.60	1.60	0.02	6.33
Ba	0.01	0.01	0.00	0.04
HCO3	321.95	303.37	7.65	1190.53
CO3	0.52	0.15	0.00	0.62
NO3	0.04	0.04	0.00	0.16
Cl	3253.00	3259.61	48.28	12893.61
F	0.30	0.30	0.00	1.19
SO4	175.00	189.87	1.40	755.28
SiO2	14.10	14.10	0.57	54.70
CO2	6.73	20.07	20.07	20.07
TDS	5995.12	5997.66	91.97	23714.10
pH	7.90	7.40	5.74	7.99

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes — ROSA v5.00

Project: Dare County KDH expansion — **Case:** 2

Ian C. Watson, PE, RosTek Associates, Inc — 8/25/2002

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: BW30-400, Limit: 16.00 gpm)

Solubility Warnings

Langelier Saturation Index > 0

Stiff & Davis Stability Index > 0

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

Scaling Calculations

	Raw Water	Adj Feed	Concentrate
pH	7.90	7.40	7.99
Langelier Saturation Index	0.49	-0.03	1.72
Stiff & Davis Stability Index	0.24	-0.28	0.94
Ionic Strength (Molal)	0.11	0.11	0.44
TDS (mg/l)	5995.12	5987.52	23714.10
HCO3	321.95	303.37	1190.53
CO2	6.73	20.07	20.07
CO3	0.52	0.15	0.62
CaSO4 (% Saturation)	1.04	1.04	5.76
BaSO4	12.79	12.76	56.86
SrSO4	0.99	0.99	4.87
CaF2	0.31	0.31	11.47
SiO2	11.91	12.26	43.65

To balance: 6.61 mg/l Cl added to feed.

Reverse Osmosis System Analysis for FILMTEC(TM) Membranes
Project: Dare County KDH expansion
Ian C. Watson, PE, RosTek Associates, Inc

ROSA v5.00
Case: 2
8/25/2002

Array Details

Stage 1 Element	**Recov.**	**Perm Flow (gpm)**	**Perm TDS (mg/l)**	**Feed Flow (gpm)**	**Feed TDS (mg/l)**	**Feed Press (psig)**
1	0.12	4.81	34.39	38.61	5997.66	286.61
2	0.13	4.48	41.55	33.80	6846.12	282.48
3	0.14	4.12	51.21	29.32	7886.80	279.07
4	0.15	3.72	64.70	25.19	9169.66	276.31
5	0.15	3.26	84.34	21.47	10746.56	274.08
6	0.15	2.73	114.41	18.22	12653.30	272.32
Stage 2 Element	**Recov.**	**Perm Flow (gpm)**	**Perm TDS (mg/l)**	**Feed Flow (gpm)**	**Feed TDS (mg/l)**	**Feed Press (psig)**
1	0.10	2.99	121.89	30.97	14866.35	305.91
2	0.09	2.54	153.78	27.98	16442.60	302.81
3	0.08	2.11	197.86	25.43	18072.51	300.11
4	0.07	1.69	259.93	23.33	19686.35	297.73
5	0.06	1.32	347.60	21.64	21204.25	295.61
6	0.05	1.01	469.14	20.32	22558.55	293.68

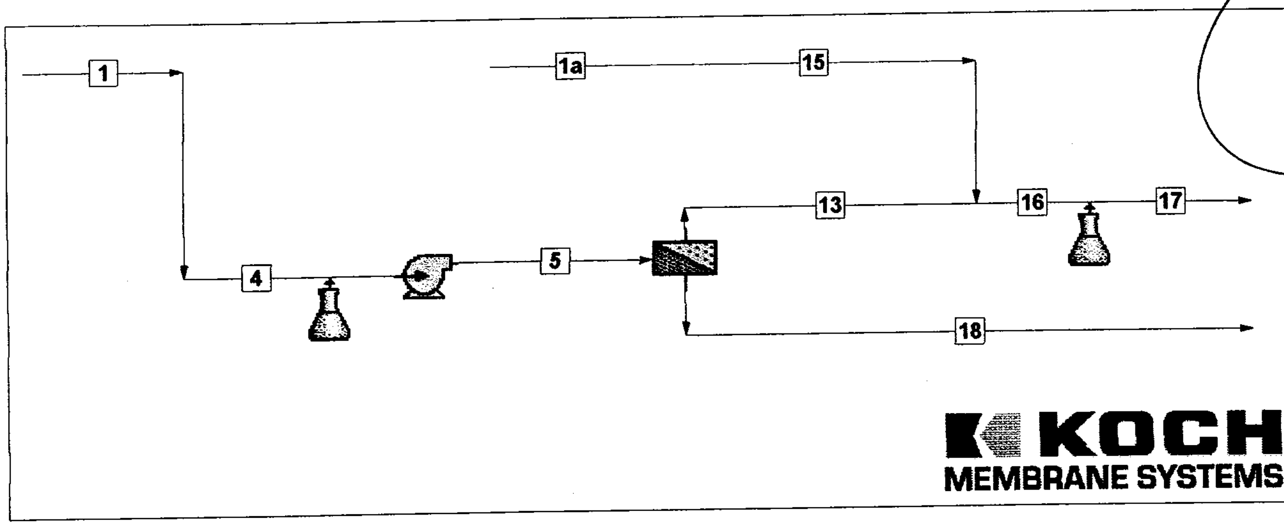
KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-27-2002

Project: KDH expansion
Prepared By: Ian C,.Watson, PE

Description: BWRO
Type: Single Pass Design

PROJECT SUMMARY

PROCESS FLOW DIAGRAM



75%
Current Quality

RO Recovery [13/4] = 75.0%
Design Temperature = 20.0 Deg C

Overall System Rec [17/(4+15)] = 76.3%

PASS 1
Array Recovery [13/4] = = 75.0%
Element Age = 3.00 Years
Fouling Allowance (FA) = 10.0%

Bank	Element Type	Tubes /Bank	Elems /Tube	Avg Flux (GFD)
1	TFC 8822HR-400	21	6	15.1
2	TFC 8822HR-400	10	6	9.9
System/Pass Total				13.5

Stream	Pressure with FA (Psig)	Flow Rate (USGPM)	TDS 180C (mg/L)	Hardness (CaCO3)	Chloride (mg/L)
1	0.0	926.7	4092.51	581.7	2200.0
4	0.0	926.7	4092.51	581.7	2200.0
5	238.3	926.7	4098.56	581.7	2200.0
13	0.0	695.0	92.16	7.5	48.8
15	0.0	50.0	4092.51	581.7	2200.0
16	0.0	745.0	360.64	46.1	193.2
17	0.0	745.0	384.03	46.1	193.2
18	246.0	231.7	16117.84	2304.3	8653.6

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-27-2002

Project: KDH expansion
Prepared By: Ian C,.Watson, PE

Description: BWRO
Type: Single Pass Design

ARRAY SUMMARY - PASS 1

Permeate Flow	695.0 USGPM	Temp (Design/Avg)	20.0/ 20.0 Deg C
Pass Recovery	75.0 %	Fouling Allowance (FA)	10.0 %

Inlet Pres w/FA 238.3 Psig

Bank	Element Type	Tubes /Bank (#)	Elems /Tube (#)	Elems /Bank (#)	Elem Age (Yr)	Boost Pressure (Psig)	Manifold Loss (Psig)	Perm Back Pressure (Psig)
1	TFC 8822HR-400	21	6	126	3.00	0.0	2.0	0.0
[illegible]	TFC 8822HR-400	10	6	60	3.00	40.0	2.0	0.0

Bank	Total Feed (GPM)	Tube Feed (GPM)	Total Conc. (GPM)	Tube Conc. (GPM)	Avg Flux (GFD)	Inlet Pres (Psig)	Avg NDP (Psig)	Bank DP (Psig)	Final Element Beta
1	926.7	44.1	396.5	18.9	15.1	220.5	139.0	14.3	1.104
2	396.5	39.7	231.2	23.1	9.9	244.2	98.4	14.0	1.048
System					13.5				

Stream Number Concentration	Net Feed 4 (mg/L)	RO Inlet 5 (mg/L)	Conc. 18 (mg/L)	Permeate 13 (mg/L)
Ca++	72.00	72.00	285.20	0.93
Mg++	97.60	97.60	386.60	1.27
Na+	1355.00	1355.00	5321.40	32.87
K+	18.00	18.00	70.47	0.51
NH4+	0.00	0.00	0.00	0.00
Sr++	1.60	1.60	6.34	0.02
Ba++	0.01	0.01	0.04	0.00
Fe++	0.68	0.68	2.69	0.01
Mn++	0.05	0.05	0.20	0.00
CO3--	0.00	0.63	2.49	0.01
HCO3-	321.95	302.92	1181.25	10.22
SO4--	175.00	189.77	751.88	2.39
Cl-	2200.00	2200.00	8653.57	48.81
NO3-	0.04	0.04	0.15	0.00
[illegible]	0.30	0.30	1.19	0.00
[illegible]2	14.10	14.10	55.43	0.32
CO2	7.75	21.03	21.02	20.97
Sum of Ions	4256.33	4252.69	16718.90	97.36
TDS (180 C)	4092.51	4098.56	16117.84	92.16
pH	7.86	7.40	7.99	5.93
Hardness (as CaCO3)	581.73	581.73	2304.28	7.54
Osm Pressure (Psig)	43.53	43.47	170.85	1.01
Langlier Index	0.57	0.09	1.87	-4.90
Stiff-Davis Index	0.38	-0.11	1.10	---

Membrane data file version: Jul-27-2001
Please review the Design Notes & Warnings page attached.
Concentrate exceeds solubility limit - see warnings sheet.

KOCH Membrane Systems, Inc.   ROPRO Ver. 7.0-CP   Date: Aug-27-2002

Project: KDH expansion
Prepared By: Ian C,.Watson, PE

Description: BWRO
Type: Single Pass Design

CHEMICAL ADDITION

[illegible].8 lb/day of 93.2% Sulfuric Acid (H_2SO_4) is required to achieve the target pH in stream [5].

CONCENTRATE SATURATION DATA - STREAM 18

Langlier Index	=	1.871	<== Warning: Scaling Potential
Stiff-Davis Index	=	1.102	<== Warning: Scaling Potential

DESIGN WARNINGS - PASS 1: None

APPROXIMATE PUMPING POWER REQUIREMENTS (kW)

Feed pumping power (w/FA) @65.0% efficiency	147.81
Interbank pumping power @65.0% efficiency	10.62

NOTE

This projection is the anticipated performance and is based on nominal properties of the elements, with manifold losses as included.

The fouling allowance option (if included) increases the required 'clean water' net driving pressure by the stated percentage. Program default values are estimates only, and may not be representative of the actual fouling potential of the water source.

This software is provided by Koch Membrane Systems, Inc as a service. The projections are based upon input by the User, and assume that sound engineering principles and practices have been followed.

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-27-2002

Project: KDH expansion
Prepared By: Ian C,.Watson, PE

Description: BWRO
Type: Single Pass Design

FEED STREAM SUMMARY

Stream	Name	Type	Percent of Total	Stream Flow Rate (USGPM)	Temperature Design (Deg C)	Temperature Average (Deg C)
1	Feed 1	Well Water	100.0	927	20.0	20.0
2	Feed 2	Other	0.0	0	25.0	25.0
3	Feed 3	Other	0.0	0	25.0	25.0
4	Net Feed	Other	100.0	927	20.0	20.0
5	Treated Feed	Other	100.0	927	20.0	20.0

CHEMICAL ADDITION

To achieve the target pH in stream [5], 179.8 lb/day of 93.2% Sulfuric Acid (H2SO4) is required.

FEED STREAM COMPOSITIONS

Stream Number Concentration	1 (mg/L)	2 (mg/L)	3 (mg/L)	4 (mg/L)	5 (mg/L)
Ca++	72.00	0.00	0.00	72.00	72.00
Mg++	97.60	0.00	0.00	97.60	97.60
Na+	1355.00	0.01	0.01	1355.00	1355.00
K+	18.00	0.00	0.00	18.00	18.00
NH4+	0.00	0.00	0.00	0.00	0.00
Sr++	1.60	0.00	0.00	1.60	1.60
Ba++	0.01	0.00	0.00	0.01	0.01
Fe++	0.68	0.00	0.00	0.68	0.68
Mn++	0.05	0.00	0.00	0.05	0.05
CO3--	0.00	0.00	0.00	0.00	0.63
HCO3-	321.95	0.01	0.01	321.95	302.92
SO4--	175.00	0.00	0.00	175.00	189.77
Cl-	2200.00	0.00	0.00	2200.00	2200.00
NO3-	0.04	0.00	0.00	0.04	0.04
F-	0.30	0.00	0.00	0.30	0.30
SiO2	14.10	0.00	0.00	14.10	14.10
CO2	7.75	0.00	0.00	7.75	21.03
Sum of Ions	4256.33	0.02	0.02	4256.33	4252.69
TDS (180 C)	4092.51	0.01	0.01	4092.51	4098.56
pH	7.86	7.00	7.00	7.86	7.40
Hardness (as CaCO3)	581.73	0.00	0.00	581.73	581.73
Osm Pressure (Psig)	43.53	0.00	0.00	43.53	43.47
Langlier Index	0.57	-7.00	-7.00	0.57	0.09
Stiff-Davis Index	0.38	---	---	0.38	-0.11

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-27-2002

Project: KDH expansion
Prepared By: Ian C,.Watson, PE

Description: BWRO
Type: Single Pass Design

PRODUCT STREAM SUMMARY

Stream	Name	Stream Flow Rate (USGPM)	Temperature Design (Deg C)	Temperature Average (Deg C)
13	Permeate	695	20.0	20.0
14	Stripped Permeat	695	20.0	20.0
15	Feed Bypass	50	20.0	20.0
16	Blended Product	745	20.0	20.0
17	Treated Product	745	20.0	20.0

CHEMICAL ADDITION

316.4 lb/day of 50% Sodium Hydroxide (NaOH) is required to achieve the target pH in stream [17].

PRODUCT STREAM COMPOSITIONS

Stream Number Concentration	13 (mg/L)	14 (mg/L)	15 (mg/L)	16 (mg/L)	17 (mg/L)
Ca++	0.93	0.93	72.00	5.70	5.70
Mg++	1.27	1.27	97.60	7.73	7.73
Na+	32.87	32.87	1355.00	121.60	131.77
K+	0.51	0.51	18.00	1.68	1.68
NH4+	0.00	0.00	0.00	0.00	0.00
Sr++	0.02	0.02	1.60	0.13	0.13
[illegible]++	0.00	0.00	0.01	0.00	0.00
[illegible]++	0.01	0.01	0.68	0.05	0.05
[illegible]++	0.00	0.00	0.05	0.00	0.00
CO3--	0.01	0.01	0.00	0.01	0.47
HCO3-	10.22	10.22	321.95	31.14	57.11
SO4--	2.39	2.39	175.00	13.98	13.98
Cl-	48.81	48.81	2200.00	193.19	193.19
NO3-	0.00	0.00	0.04	0.01	0.01
F-	0.00	0.00	0.30	0.02	0.02
SiO2	0.32	0.32	14.10	1.25	1.25
CO2	20.97	20.97	7.75	20.09	1.00
Sum of Ions	97.36	97.36	4256.33	376.49	413.09
TDS (180 C)	92.16	92.16	4092.51	360.64	384.03
pH	5.93	5.93	7.86	6.43	8.00
Hardness (as CaCO3)	7.54	7.54	581.73	46.08	46.08
Osm Pressure (Psig)	1.01	1.01	43.53	3.86	4.15
Langlier Index	-4.90	-4.90	0.57	-3.07	-1.23
Stiff-Davis Index	---	---	0.38	---	---

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-25-2002

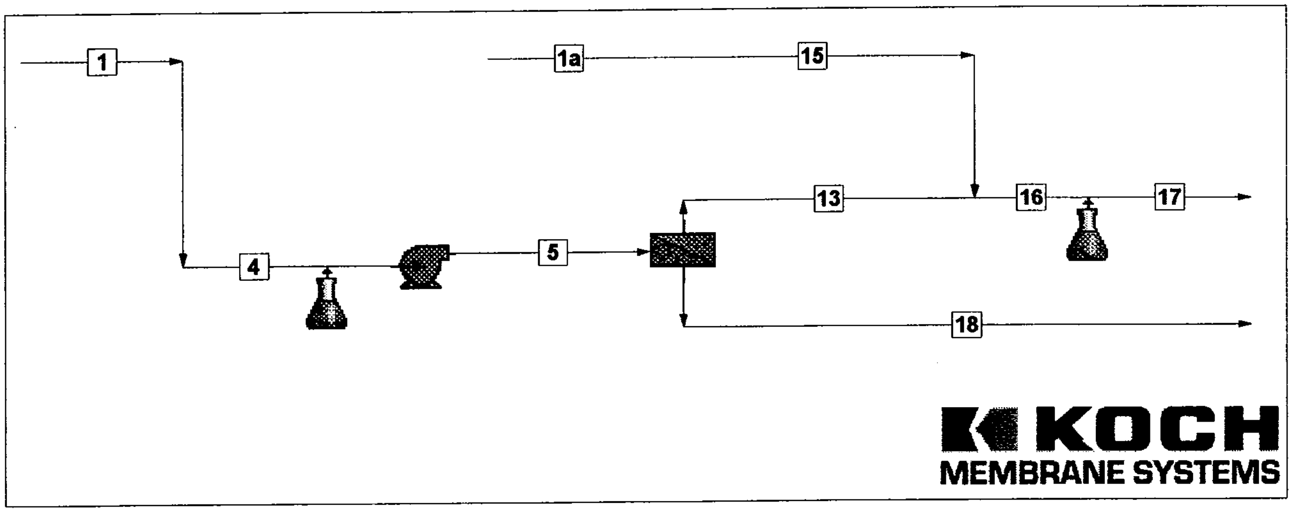
Project: Dare County NRO
Prepared By: Ian C. Watson, PE

Description: Existing Plant Expansion
Type: Single Pass Design

6000TDS

JECT SUMMARY

PROCESS FLOW DIAGRAM



RO Recovery [13/4] = 75.0%
Design Temperature = 20.0 Deg C

Overall System Rec [17/(4+15)] = 75.8%

PASS 1
Array Recovery [13/4] = = 75.0%
ment Age = 5.00 Years
ling Allowance (FA) = 10.0%

Bank	Element Type	Tubes /Bank	Elems /Tube	Avg Flux (GFD)
1	TFC 8822HR-400	24	6	14.1
2	TFC 8822HR-400	12	6	6.5
System/Pass Total				11.6

Stream	Pressure with FA (Psig)	Flow Rate (USGPM)	TDS 180C (mg/L)	Hardness (CaCO3)	Chloride (mg/L)
1	0.0	926.7	5829.91	575.1	3253.0
4	0.0	926.7	5829.91	575.1	3253.0
5	285.9	926.7	5836.21	575.1	3253.0
13	14.0	695.0	190.44	10.7	105.2
15	0.0	30.0	5829.91	575.1	3253.0
16	0.0	725.0	423.80	34.1	235.5
17	0.0	725.0	449.22	34.1	235.5
18	301.4	231.7	22773.62	2268.4	12696.4

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-25-2002

Project: Dare County NRO
Prepared By: Ian C. Watson, PE

Description: Existing Plant Expansion
Type: Single Pass Design

ARRAY SUMMARY - PASS 1

Permeate Flow	695.0 USGPM	Temp (Design/Avg)	20.0/ 20.0 Deg C
Pass Recovery	75.0 %	Fouling Allowance (FA)	10.0 %
Inlet Pres w/o FA	266.7 Psig	Conc. Pres w/o FA	282.2 Psig
Inlet Pres w/FA	285.9 Psig		

Bank	Element Type	Tubes /Bank (#)	Elems /Tube (#)	Elems /Bank (#)	Elem Age (Yr)	Boost Pressure (Psig)	Manifold Loss (Psig)	Perm Back Pressure (Psig)
1	TFC 8822HR-400	24	6	144	5.00	0.0	2.0	14.0
2	TFC 8822HR-400	12	6	72	5.00	40.0	2.0	14.0

Bank	Total Feed (GPM)	Tube Feed (GPM)	Total Conc. (GPM)	Tube Conc. (GPM)	Avg Flux (GFD)	Inlet Pres (Psig)	Avg NDP (Psig)	Bank DP (Psig)	Final Element Beta
1	926.7	38.6	361.9	15.1	14.1	266.7	130.9	10.8	1.099
2	361.9	30.2	231.2	19.3	6.5	293.9	71.9	9.7	1.032
System					11.6				

	Net Feed	RO Inlet	Conc.	Permeate
Stream Number	4	5	18	13
Concentration	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Ca++	72.00	72.00	283.97	1.34
Mg++	96.00	96.00	378.63	1.79
Na+	2041.00	2041.00	7953.67	70.11
[illegible]	18.00	18.00	69.85	0.72
[illegible]	0.00	0.00	0.00	0.00
Sr++	1.60	1.60	6.31	0.03
Ba++	0.01	0.01	0.04	0.00
Fe++	0.68	0.68	2.68	0.01
Mn++	0.05	0.05	0.20	0.00
CO3--	0.00	0.62	2.47	0.01
HCO3-	321.95	302.06	1164.13	14.75
SO4--	175.00	190.45	751.33	3.49
Cl-	3253.00	3253.00	12696.35	105.22
NO3-	0.04	0.04	0.15	0.00
F-	0.30	0.30	1.18	0.01
SiO2	14.10	14.10	55.01	0.46
CO2	7.07	20.97	20.97	20.93
Sum of Ions	5993.73	5989.91	23365.96	197.94
TDS (180 C)	5829.91	5836.21	22773.62	190.44
pH	7.90	7.40	7.99	6.09
Hardness (as CaCO3)	575.14	575.14	2268.37	10.73
Osm Pressure (Psig)	63.06	62.99	245.68	2.10
Langlier Index	0.62	0.09	1.85	-4.40
Stiff-Davis Index	0.29	-0.24	0.96	---

Membrane data file version: Jul-27-2001
Please review the Design Notes & Warnings page attached.
Concentrate exceeds solubility limit - see warnings sheet.

Project: Dare County NRO
Prepared By: Ian C. Watson, PE

Description: Existing Plant Expansion
Type: Single Pass Design

CHEMICAL ADDITION

188.1 lb/day of 93.2% Sulfuric Acid (H_2SO_4) is required to achieve the target pH in stream [5].

CONCENTRATE SATURATION DATA - STREAM 18

Langlier Index	=	1.852	<== Warning: Scaling Potential
Stiff-Davis Index	=	0.959	<== Warning: Scaling Potential

DESIGN WARNINGS - PASS 1: None

APPROXIMATE PUMPING POWER REQUIREMENTS (kW)

Feed pumping power (w/FA) @65.0% efficiency	177.32
Interbank pumping power @65.0% efficiency	9.69

NOTE

This projection is the anticipated performance and is based on nominal properties of the elements, with manifold losses as included.

The fouling allowance option (if included) increases the required 'clean water' net driving pressure by the stated percentage. Program default values are estimates only, and may not be representative of the actual fouling potential of the water source.

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This printout should not be considered a warranty or guarantee unless accompanied by a statement to that effect from Koch Membrane Systems, Inc.

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-25-2002

Project: Dare County NRO
Prepared By: Ian C. Watson, PE

Description: Existing Plant Expansion
Type: Single Pass Design

FEED STREAM SUMMARY

Stream	Name	Type	Percent of Total	Stream Flow Rate (USGPM)	Temperature Design (Deg C)	Temperature Average (Deg C)
1	Feed 1	Other	100.0	927	20.0	20.0
2	Feed 2	Other	0.0	0	25.0	25.0
3	Feed 3	Other	0.0	0	25.0	25.0
4	Net Feed	Other	100.0	927	20.0	20.0
5	Treated Feed	Other	100.0	927	20.0	20.0

CHEMICAL ADDITION

To achieve the target pH in stream [5], 188.1 lb/day of 93.2% Sulfuric Acid (H2SO4) is required.

FEED STREAM COMPOSITIONS

Stream Number Concentration	1 (mg/L)	2 (mg/L)	3 (mg/L)	4 (mg/L)	5 (mg/L)
Ca++	72.00	0.00	0.00	72.00	72.00
Mg++	96.00	0.00	0.00	96.00	96.00
Na+	2041.00	0.01	0.01	2041.00	2041.00
K+	18.00	0.00	0.00	18.00	18.00
NH4+	0.00	0.00	0.00	0.00	0.00
Sr++	1.60	0.00	0.00	1.60	1.60
[illegible]+	0.01	0.00	0.00	0.01	0.01
[illegible]+	0.68	0.00	0.00	0.68	0.68
Mn++	0.05	0.00	0.00	0.05	0.05
CO3--	0.00	0.00	0.00	0.00	0.62
HCO3-	321.95	0.01	0.01	321.95	302.06
SO4--	175.00	0.00	0.00	175.00	190.45
Cl-	3253.00	0.00	0.00	3253.00	3253.00
NO3-	0.04	0.00	0.00	0.04	0.04
F-	0.30	0.00	0.00	0.30	0.30
SiO2	14.10	0.00	0.00	14.10	14.10
CO2	7.07	0.00	0.00	7.07	20.97
Sum of Ions	5993.73	0.02	0.02	5993.73	5989.91
TDS (180 C)	5829.91	0.01	0.01	5829.91	5836.21
pH	7.90	7.00	7.00	7.90	7.40
Hardness (as CaCO3)	575.14	0.00	0.00	575.14	575.14
Osm Pressure (Psig)	63.06	0.00	0.00	63.06	62.99
Langlier Index	0.62	-7.00	-7.00	0.62	0.09
Stiff-Davis Index	0.29	---	---	0.29	-0.24

KOCH Membrane Systems, Inc. ROPRO Ver. 7.0-CP Date: Aug-25-2002

Project: Dare County NRO
Prepared By: Ian C. Watson, PE

Description: Existing Plant Expansion
Type: Single Pass Design

PRODUCT STREAM SUMMARY

Stream Name		Stream Flow Rate (USGPM)	Temperature Design (Deg C)	Temperature Average (Deg C)
13	Permeate	695	20.0	20.0
14	Stripped Permeat	695	20.0	20.0
15	Feed Bypass	30	20.0	20.0
16	Blended Product	725	20.0	20.0
17	Treated Product	725	20.0	20.0

CHEMICAL ADDITION

335.5 lb/day of 50% Sodium Hydroxide (NaOH) is required to achieve the target pH in stream [17].

PRODUCT STREAM COMPOSITIONS

Stream Number Concentration	13 (mg/L)	14 (mg/L)	15 (mg/L)	16 (mg/L)	17 (mg/L)
Ca++	1.34	1.34	72.00	4.27	4.27
Mg++	1.79	1.79	96.00	5.69	5.69
Na+	70.11	70.11	2041.00	151.66	162.74
K+	0.72	0.72	18.00	1.43	1.43
NH4+	0.00	0.00	0.00	0.00	0.00
Sr++	0.03	0.03	1.60	0.09	0.09
[illegible]+	0.00	0.00	0.01	0.00	0.00
[illegible]+	0.01	0.01	0.68	0.04	0.04
Mn++	0.00	0.00	0.05	0.00	0.00
CO3--	0.01	0.01	0.00	0.01	1.40
HCO3-	14.75	14.75	321.95	27.46	53.84
SO4--	3.49	3.49	175.00	10.58	10.58
Cl-	105.22	105.22	3253.00	235.47	235.47
NO3-	0.00	0.00	0.04	0.01	0.01
F-	0.01	0.01	0.30	0.02	0.02
SiO2	0.46	0.46	14.10	1.03	1.03
CO2	20.93	20.93	7.07	20.36	0.30
Sum of Ions	197.94	197.94	5993.73	437.77	476.61
TDS (180 C)	190.44	190.44	5829.91	423.80	449.22
pH	6.09	6.09	7.90	6.37	8.50
Hardness (as CaCO3)	10.73	10.73	575.14	34.08	34.08
Osm Pressure (Psig)	2.10	2.10	63.06	4.62	4.92
Langlier Index	-4.40	-4.40	0.62	-3.31	-0.87
Stiff-Davis Index	---	---	0.29	---	---

Winflows32 v 2.0.33 (VB6 **Input Data Summary** **01-Sep-2002 15:29**

Project:	NRO Capacity Expansion		
Project File	Dare NRO current.dsi.os	Engineer:	RosTek Associates, Inc
Analysis File:	Dare NRO current.dsi	Analysis Name:	User Defined
Element File Date:	Aug-24-2000		Page: 1

Project Information

Description:	NRO Capacity Expansion
Client Name:	Dare County Water System
Location:	Kill Devil Hills, NC
Engineer:	RosTek Associates, Inc
Comments:	Interstage boost, current conditions

Flowsheet Configuration

Flowsheet Type:	Two Stage Flowsheet
Feed Predosing?	Yes
Feed Afterdosing?	Yes
Interpass Dosing?	No
Product Dosing?	No
Feed CO2 Stripping?	No
Interpass CO2 Stripping?	No
Product CO2 Stripping?	No
Raw Feed Bypass?	Yes
First Pass Recycle?	No
Interpass Pumping?	Yes

Feed Information

Temperature, Deg C:	20.0	
Feed pH:	7.9	
Silt Density Index:	3.0	
Fouling Allowance:	0.85	
Feed Stream Composition (mg/l)		
Barium		0.01
Calcium		72.00
Iron		0.68
Potassium		18.00
Magnesium		97.60
Sodium		1,355.00
Strontium		1.60
Chloride		2,200.48
Fluoride		0.30
Bicarbonate		321.90
Sulfate		175.00
Phosphate		0.01
Silica		14.10
Carbonate		2.26
Carbon Dioxide		6.31

Flow Rate Specifications

Feed Flow:	931.0 Gal/min
Bypass Flow is:	40.0 Gal/min
First Stage Array Recovery:	58.0%
Second Stage Array Recovery:	47.6%

Winflows32 v 2.0.33 (VB6 **Input Data Summary** **01-Sep-2002 15:29**

Project: NRO Capacity Expansion
Project File Dare NRO current.dsi.os Engineer: RosTek Associates, Inc
Analysis File: Dare NRO current.dsi Analysis Name: User Defined
Element File Date: Aug-24-2000

First Stage Array Data

Interbank Pressure Loss: 0.00 Psi
Interbank Pressure Boost: 0.00 Psi
Bank 1 Permeate BackPressure = 14 Psi

Bank	Housings	Elements	Element Type	Element Age
1	21	6	AG8040F400	3.00 Years

Second Stage Array Data

Interbank Pressure Loss: 0.00 Psi
Interbank Pressure Boost: 40.00 Psi
Bank 1 Permeate BackPressure = 14 Psi

Bank	Housings	Elements	Element Type	Element Age
1	10	6	AG8040F400	3.00 Years

Chemical Dosing Specifications

First Feed Dosing to 0.0 pH using None
Second Feed Dosing to 0.0 pH using None

Pump Specifications

Feed Pump Selection:
Interstage Pump Selection:

Winflows32 v 2.0.33 (VB6 **Results Summary** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Engineer: RosTek Associates, Inc
Analysis File: Dare NRO current.dsi
Analysis Name: User Defined
Element File Date: Aug-24-2000

Flow Data	***Gal/min***	***Analytical Data***	***mg/L***
RO/NF Feed	891.0	RO/NF Feed TDS	4,258.9
Treated Permeate	694.9	Treated Permeate TDS	85.4
System Conc	196.1	System Conc TDS	18,946.3
System Feed	931.0	System Feed TDS	4,258.9
System Product	734.9	System Product TDS	312.5

System Data ***Two Stage Concentrator with Interstage Pump***

Temperature: 20.0 Deg C
Overall Recovery: 78.9%

Stage 1

Pass/Stage Recovery: 58.0% Concentrate TDS: 10,026 Conc. Flow: 374.2

Bank	Total Housings	Total Elem	Element Type	Feed Flow Gal/min	Perm Flow Gal/min	Feed Psi	Delta Psi	Perm TDS mg/L
1	21	126	AG8040F400	891.0	515.5	264.6	11.6	58.0
Total	**21**	**126**		**891.0**	**516.8**			**58.0**

Bank 1 Permeate BackPressure = 14 Psi

Stage 2

Pass/Stage Recovery: 47.6% Concentrate TDS: 18,946 Conc. Flow: 196.1

Bank	Total Housings	Total Elem	Element Type	Feed Flow Gal/min	Perm Flow Gal/min	Feed Psi	Delta Psi	Perm TDS mg/L
1	10	60	AG8040F400	374.2	177.7	300.3	10.4	164.9
Total	**10**	**60**		**374.2**	**178.1**			**164.9**

Bank 1 Permeate BackPressure = 14 Psi

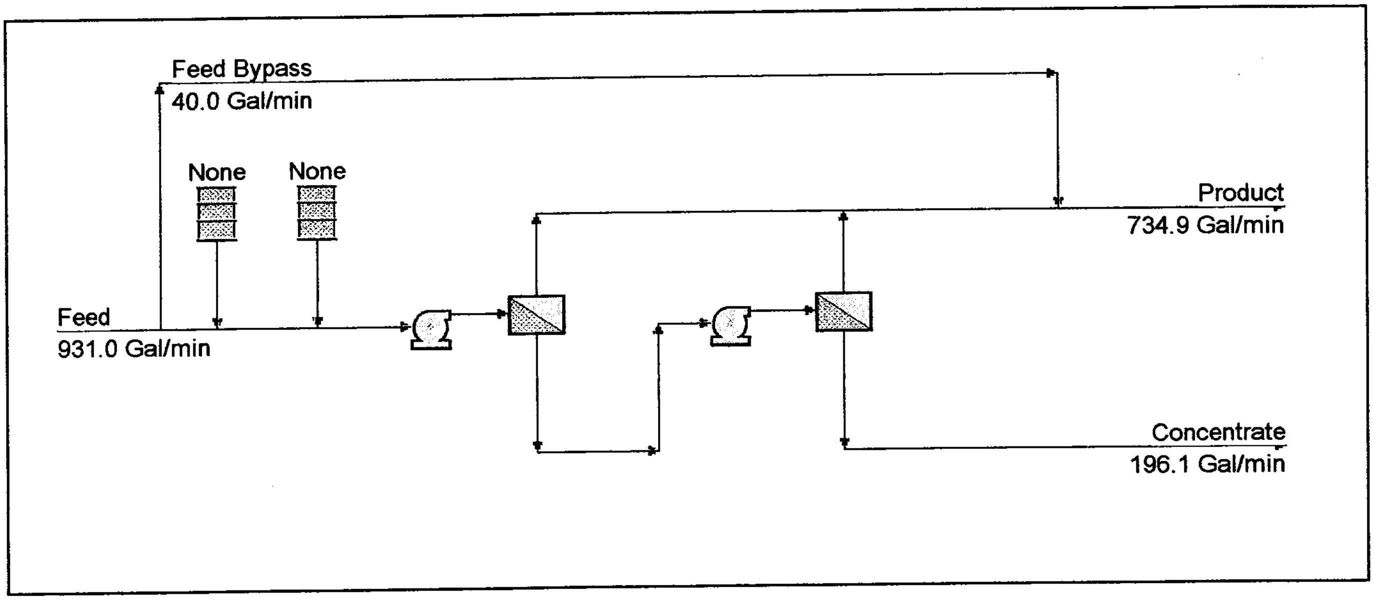
Analytical Data (mg/L)

	Perm	**Feed**	**Conc**		**Perm**	**Feed**	**Conc**
Ca	4.4	72.0	323.8	HCO3	27.2	321.9	1,364.1
Mg	5.9	97.6	438.8	CO3	0.1	2.3	64.6
Na	102.0	1,355.0	6,018.5	Cl	159.5	2,200.5	9,796.5
K	1.4	18.0	79.8	SO4	10.9	175.0	785.7
Ba	0.0	0.0	0.0	F	0.0	0.3	1.3
Sr	0.1	1.6	7.2	NO3	0.0	0.0	0.0
NH4	0.0	0.0	0.0	PO4	0.0	0.0	0.0
Fe	0.0	0.7	3.1	SiO2	1.0	14.1	62.8
Mn	0.0	0.0	0.0	CO2	6.3	6.3	6.1
TDS	312.5	4,258.9	18,946.3	pH	6.5	7.9	8.4
Saturation Data							
CaSO4	0.0%	1.4%	8.5%	BaSO4	0.3%	16.8%	90.7
CaF2	0.0%	0.0%	1.1%	SiO2	1.0%	11.5%	37.6
LSI	-2.9	0.4	2.1	SrSO4	0.0%	1.6%	6.2

Winflows32 v 2.0.33 (VB6 **Process Data Sheet** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Analysis File: Dare NRO current.dsi
Element File Date: Aug-24-2000

Engineer: RosTek Associates, Inc
Analysis Name: User Defined



Flow Data	*Gal/min*	*Analytical Data*	*mg/L*
RO/NF Feed	891.0	RO/NF Feed TDS	4,258.9
Treated Permeate	694.9	Treated Permeate TDS	85.4
System Conc	196.1	System Conc TDS	18,946.3
System Feed	931.0	System Feed TDS	4,258.9
System Product	734.9	System Product TDS	312.5

System Data — *Two Stage Concentrator with Interstage Pump*

	Stage 1	Stage 2	
Temperature	20.0	Deg C	
Fouling Allowance	85.0	85.0	Percent
Feed Pressure	264.6	300.3	Psi
Interbank Boost	0.00	40.00	Psi
Interbank Loss	0.00	0.00	Psi
Element Age	3.00	3.00	Years

Pumping Summary	*Gal/min*	*DP, Psi*	*kW @ 65.0% Efficiency*
Stage 1 Feed	891.0	264.62	157.8
Stage 1 Interbank Boost	------	0.00	0.0
Stage 2 Feed	374.2	300.28	75.2
Stage 2 Interbank Boost	------	40.00	0.0

Chemical Usage	*Chemical*	*Lb/Day*	*Kg/Day*	*pH or ppm TH*
Feed Predosing	None	0.0	0.0	5.0
Feed Afterdosing	None	0.0	0.0	5.0

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Engineer: RosTek Associates, Inc
Analysis File: Dare NRO current.dsi
Analysis Name: User Defined
Element File Date: Aug-24-2000

mg/L	System Feed	Feed Bypass	RO/NF Feed	Predosed Feed	Treated Feed
Barium	0.01	0.01	0.01	0.01	0.01
Calcium	72.00	72.00	72.00	72.00	72.00
Iron	0.68	0.68	0.68	0.68	0.68
Potassium	18.00	18.00	18.00	18.00	18.00
Magnesium	97.60	97.60	97.60	97.60	97.60
Manganese	0.00	0.00	0.00	0.00	0.00
Sodium	1,355.00	1,355.00	1,355.00	1,355.00	1,355.00
Ammonium	0.00	0.00	0.00	0.00	0.00
Strontium	1.60	1.60	1.60	1.60	1.60
Chloride	2,200.48	2,200.48	2,200.48	2,200.48	2,200.48
Fluoride	0.30	0.30	0.30	0.30	0.30
Bicarbonate	321.90	321.90	321.90	321.90	321.90
Nitrate	0.00	0.00	0.00	0.00	0.00
Sulfate	175.00	175.00	175.00	175.00	175.00
Phosphate	0.01	0.01	0.01	0.01	0.01
Silica	14.10	14.10	14.10	14.10	14.10
Carbonate	2.26	2.26	2.26	2.26	2.26
Carbon Dioxide	6.31	6.31	6.31	6.31	6.31
TDS, mg/L	4,258.94	4,258.94	4,258.94	4,258.94	4,258.94
Flow, Gal/min	931.00	40.00	891.00	891.00	891.00
Temp, Deg C	20.00	20.00	20.00	20.00	20.00
Pressure, Psi	0.00	0.00	0.00	0.00	0.00
Osm Pres, Psi	45.68	45.68	45.68	45.68	45.68
pH	7.86	7.86	7.86	7.86	7.86
LSI	0.43	0.43	0.43	0.43	0.43
Stiff-Davis	0.40	0.40	0.40	0.40	0.40
BaSO4 Sat, %	16.79	16.79	16.79	16.79	16.79
CaSO4 Sat, %	1.36	1.36	1.36	1.36	1.36
CaF2 Sat, %	0.01	0.01	0.01	0.01	0.01
SrSO4 Sat, %	1.62	1.62	1.62	1.62	1.62
SiO2 Sat, %	11.46	11.46	11.46	11.46	11.46

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Analysis File: Dare NRO current.dsi
Element File Date: Aug-24-2000

Engineer: RosTek Associates, Inc
Analysis Name: User Defined

mg/L	1st Stage Permeate	2nd Stage Feed	2nd Stage Permeate	Total Permeate	System Product
Barium	0.00	0.02	0.00	0.00	0.00
Calcium	0.31	170.41	0.89	0.46	4.36
Iron	0.00	1.61	0.01	0.00	0.04
Potassium	0.29	42.31	0.84	0.43	1.39
Magnesium	0.44	230.99	1.23	0.64	5.92
Manganese	0.00	0.00	0.00	0.00	0.00
Sodium	20.23	3,187.40	57.69	29.83	101.96
Ammonium	0.00	0.00	0.00	0.00	0.00
Strontium	0.01	3.79	0.02	0.01	0.10
Chloride	28.45	5,182.29	81.50	42.05	159.53
Fluoride	0.00	0.71	0.01	0.00	0.02
Bicarbonate	7.04	744.03	19.37	10.20	27.17
Nitrate	0.00	0.00	0.00	0.00	0.00
Sulfate	1.00	413.87	2.83	1.47	10.92
Phosphate	0.00	0.02	0.00	0.00	0.00
Silica	0.18	33.21	0.52	0.27	1.02
Carbonate	0.00	15.47	0.00	0.00	0.12
Carbon Dioxide	6.29	6.22	6.19	6.26	6.26
TDS, mg/L	57.97	10,026.12	164.91	85.38	312.54
Flow, Gal/min	516.78	374.22	178.13	694.91	734.91
Temp, Deg C	20.00	20.00	20.00	20.00	20.00
Pressure, Psi	0.00	252.99	0.00	0.00	0.00
Osm Pres, Psi	0.65	105.89	1.84	0.96	3.45
pH	6.29	8.20	6.72	6.40	6.48
LSI	-4.76	1.38	-3.48	-4.33	-2.93
Stiff-Davis	-4.87	1.15	-3.55	-4.43	-2.97
BaSO4 Sat, %	0.00	44.57	0.02	0.00	0.27
CaSO4 Sat, %	0.00	3.99	0.00	0.00	0.02
CaF2 Sat, %	0.00	0.13	0.00	0.00	0.00
SrSO4 Sat, %	0.00	4.37	0.00	0.00	0.03
SiO2 Sat, %	0.18	22.20	0.55	0.27	1.03

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Analysis File: Dare NRO current.dsi
Element File Date: Aug-24-2000

Engineer: RosTek Associates, Inc
Analysis Name: User Defined

mg/L	System Conc
Barium	0.04
Calcium	323.76
Iron	3.06
Potassium	79.82
Magnesium	438.83
Manganese	0.00
Sodium	6,018.54
Ammonium	0.00
Strontium	7.19
Chloride	9,796.47
Fluoride	1.34
Bicarbonate	1,364.13
Nitrate	0.00
Sulfate	785.69
Phosphate	0.04
Silica	62.77
Carbonate	64.57
Carbon Dioxide	6.07
TDS, mg/L	18,946.27
Flow, Gal/min	196.09
Temp, Deg C	20.00
Pressure, Psi	289.86
Osm Pres, Psi	197.44
pH	8.44
LSI	2.12
Stiff-Davis	1.66
BaSO4 Sat, %	90.66
CaSO4 Sat, %	8.54
CaF2 Sat, %	1.07
SrSO4 Sat, %	6.21
SiO2 Sat, %	37.56

Winflows32 v 2.0.33 (VB6 **Errors and Warnings** **01-Sep-2002 15:26**

Project: NRO Capacity Expansion
Project File
Engineer: RosTek Associates, Inc
Analysis File: Dare NRO current.dsi
Analysis Name: User Defined
Element File Date: Aug-24-2000

WARNING!! High LSI. LSI > 0.0. Concentrate CaCO3> saturation.

WARNING!! High Stiff Davis Index. SDSI > 0.0. Concentrate CaCO3 > saturation.

Warning! - The feed water analysis was balanced with added Na or Cl.

Winflows32 v 2.0.33 (VB6 **Input Data Summary** **01-Sep-2002 15:35**

Project:	NRO Capacity Expansion		
Project File	Dare NRO future dsi.osm	Engineer:	RosTek Associates, Inc
Analysis File:	Dare NRO future dsi.osm	Analysis Name:	User Defined
Element File Date:	Aug-24-2000		Page: 1

Project Information

Description:	NRO Capacity Expansion
Client Name:	Dare County Water System
Location:	Kill Devil Hills, NC
Engineer:	RosTek Associates, Inc
Comments:	Interstage boost,future conditions

Flowsheet Configuration

Flowsheet Type:	Two Stage Flowsheet
Feed Predosing?	Yes
Feed Afterdosing?	Yes
Interpass Dosing?	No
Product Dosing?	No
Feed CO2 Stripping?	No
Interpass CO2 Stripping?	No
Product CO2 Stripping?	No
Raw Feed Bypass?	Yes
First Pass Recycle?	No
Interpass Pumping?	Yes

Feed Information

Temperature, Deg C:	20.0
Feed pH:	7.9
Silt Density Index:	3.0
Fouling Allowance:	0.85

Feed Stream Composition (mg/l)

Barium	0.01
Calcium	72.00
Iron	0.68
Potassium	18.00
Magnesium	97.60
Sodium	2,041.00
Strontium	1.60
Chloride	3,257.00
Fluoride	0.30
Bicarbonate	321.90
Sulfate	175.00
Phosphate	0.01
Silica	14.10
Carbonate	2.53
Carbon Dioxide	6.13

Flow Rate Specifications

Feed Flow:	957.0 Gal/min
Bypass Flow is:	30.0 Gal/min
First Stage Array Recovery:	58.0%
Second Stage Array Recovery:	47.6%

Winflows32 v 2.0.33 (VB6 **Input Data Summary** **01-Sep-2002 15:35**

Project: NRO Capacity Expansion
Project File Dare NRO future dsi.osm Engineer: RosTek Associates, Inc
Analysis File: Dare NRO future dsi.osm Analysis Name: User Defined
Element File Date: Aug-24-2000

First Stage Array Data

Interbank Pressure Loss: 0.00 Psi
Interbank Pressure Boost: 0.00 Psi
Bank 1 Permeate BackPressure = 14 Psi

Bank	Housings	Elements	Element Type	Element Age
1	24	6	AG8040F400	3.00 Years

Second Stage Array Data

Interbank Pressure Loss: 0.00 Psi
Interbank Pressure Boost: 40.00 Psi
Bank 1 Permeate BackPressure = 14 Psi

Bank	Housings	Elements	Element Type	Element Age
1	12	6	AG8040F400	3.00 Years

Chemical Dosing Specifications

First Feed Dosing to 0.0 pH using None
Second Feed Dosing to 0.0 pH using None

Pump Specifications

Feed Pump Selection:
Interstage Pump Selection:

Winflows32 v 2.0.33 (VB6 **Results Summary** **01-Sep-2002 15:35**

Project: NRO Capacity Expansion
Project File Dare NRO future dsi.osm Engineer: RosTek Associates, Inc
Analysis File: Dare NRO future dsi.osm Analysis Name: User Defined
Element File Date: Aug-24-2000 Page: 1

Flow Data	***Gal/min***	***Analytical Data***	***mg/L***
RO/NF Feed	927.0	RO/NF Feed TDS	6,001.7
Treated Permeate	723.0	Treated Permeate TDS	137.3
System Conc	204.0	System Conc TDS	26,640.1
System Feed	957.0	System Feed TDS	6,001.7
System Product	753.0	System Product TDS	371.0

System Data ***Two Stage Concentrator with Interstage Pump***

Temperature: 20.0 Deg C
Overall Recovery: 78.7%

Stage 1

Pass/Stage Recovery: 58.0% Concentrate TDS: 14,118 Conc. Flow: 389.3

Bank	Total Housings	Total Elem	Element Type	Feed Flow Gal/min	Perm Flow Gal/min	Feed Psi	Delta Psi	Perm TDS mg/L
1	24	144	AG8040F400	927.0	536.4	283.9	9.9	90.8
Total	**24**	**144**		**927.0**	**537.7**			**90.8**

Bank 1 Permeate BackPressure = 14 Psi

Stage 2

Pass/Stage Recovery: 47.6% Concentrate TDS: 26,640 Conc. Flow: 204.0

Bank	Total Housings	Total Elem	Element Type	Feed Flow Gal/min	Perm Flow Gal/min	Feed Psi	Delta Psi	Perm TDS mg/L
1	12	72	AG8040F400	389.3	184.9	356.2	8.2	272.3
Total	**12**	**72**		**389.3**	**185.3**			**272.3**

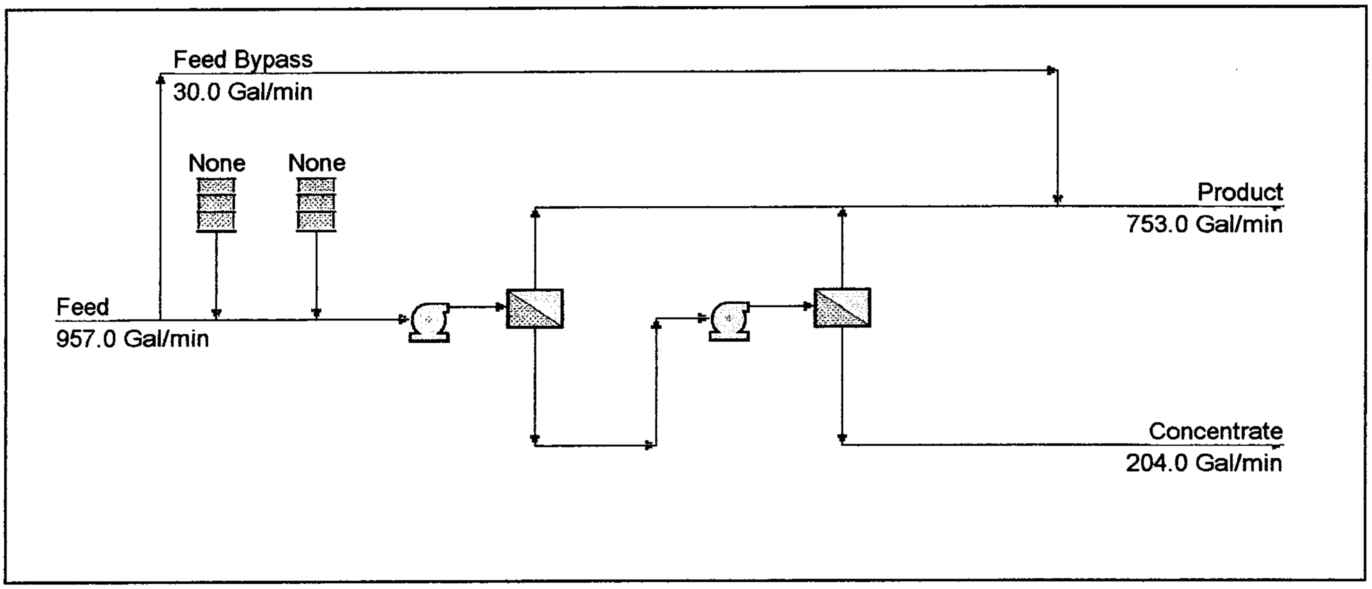
Bank 1 Permeate BackPressure = 14 Psi

Analytical Data (mg/L)

	Perm	**Feed**	**Conc**		**Perm**	**Feed**	**Conc**
Ca	3.4	72.0	323.6	HCO3	24.1	321.9	1,352.2
Mg	4.6	97.6	438.6	CO3	0.1	2.5	72.3
Na	129.1	2,041.0	9,048.7	Cl	199.0	3,257.0	14,465.8
K	1.2	18.0	79.7	SO4	8.6	175.0	784.9
Ba	0.0	0.0	0.0	F	0.0	0.3	1.3
Sr	0.1	1.6	7.2	NO3	0.0	0.0	0.0
NH4	0.0	0.0	0.0	PO4	0.0	0.0	0.0
Fe	0.0	0.7	3.1	SiO2	0.9	14.1	62.6
Mn	0.0	0.0	0.0	CO2	6.1	6.1	5.9
TDS	371.0	6,001.7	26,640.1	pH	6.5	7.9	8.4
Saturation Data							
CaSO4	0.0%	1.1%	6.6%	BaSO4	0.2%	12.8%	68.7
CaF2	0.0%	0.0%	1.2%	SiO2	0.9%	11.5%	37.5
LSI	-3.1	0.4	2.1	SrSO4	0.0%	1.2%	4.7

Winflows32 v 2.0.33 (VB6 **Process Data Sheet** **01-Sep-2002 15:35**

Project:	NRO Capacity Expansion		
Project File	Dare NRO future dsi.osm	Engineer:	RosTek Associates, Inc
Analysis File:	Dare NRO future dsi.osm	Analysis Name:	User Defined
Element File Date:	Aug-24-2000		Page: 1



Flow Data	*Gal/min*	*Analytical Data*	*mg/L*
RO/NF Feed	927.0	RO/NF Feed TDS	6,001.7
Treated Permeate	723.0	Treated Permeate TDS	137.3
System Conc	204.0	System Conc TDS	26,640.1
System Feed	957.0	System Feed TDS	6,001.7
System Product	753.0	System Product TDS	371.0

System Data	*Two Stage Concentrator with Interstage Pump*		
Temperature	20.0	Deg C	
	Stage 1	Stage 2	
Fouling Allowance	85.0	85.0	Percent
Feed Pressure	283.9	356.2	Psi
Interbank Boost	0.00	40.00	Psi
Interbank Loss	0.00	0.00	Psi
Element Age	3.00	3.00	Years

Pumping Summary	*Gal/min*	*DP, Psi*	*kW @ 65.0% Efficiency*
Stage 1 Feed	927.0	283.93	176.2
Stage 1 Interbank Boost	------	0.00	0.0
Stage 2 Feed	389.3	356.18	92.8
Stage 2 Interbank Boost	------	40.00	0.0

Chemical Usage	*Chemical*	*Lb/Day*	*Kg/Day*	*pH or ppm TH*
Feed Predosing	None	0.0	0.0	5.0
Feed Afterdosing	None	0.0	0.0	5.0

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:35**

Project: NRO Capacity Expansion
Project File Dare NRO future dsi.osm Engineer: RosTek Associates, Inc
Analysis File: Dare NRO future dsi.osm Analysis Name: User Defined
Element File Date: Aug-24-2000

mg/L	System Feed	Feed Bypass	RO/NF Feed	Predosed Feed	Treated Feed
Barium	0.01	0.01	0.01	0.01	0.01
Calcium	72.00	72.00	72.00	72.00	72.00
Iron	0.68	0.68	0.68	0.68	0.68
Potassium	18.00	18.00	18.00	18.00	18.00
Magnesium	97.60	97.60	97.60	97.60	97.60
Manganese	0.00	0.00	0.00	0.00	0.00
Sodium	2,041.00	2,041.00	2,041.00	2,041.00	2,041.00
Ammonium	0.00	0.00	0.00	0.00	0.00
Strontium	1.60	1.60	1.60	1.60	1.60
Chloride	3,257.00	3,257.00	3,257.00	3,257.00	3,257.00
Fluoride	0.30	0.30	0.30	0.30	0.30
Bicarbonate	321.90	321.90	321.90	321.90	321.90
Nitrate	0.00	0.00	0.00	0.00	0.00
Sulfate	175.00	175.00	175.00	175.00	175.00
Phosphate	0.01	0.01	0.01	0.01	0.01
Silica	14.10	14.10	14.10	14.10	14.10
Carbonate	2.53	2.53	2.53	2.53	2.53
Carbon Dioxide	6.13	6.13	6.13	6.13	6.13
TDS, mg/L	6,001.73	6,001.73	6,001.73	6,001.73	6,001.73
Flow, Gal/min	957.00	30.00	927.00	927.00	927.00
Temp, Deg C	20.00	20.00	20.00	20.00	20.00
Pressure, Psi	0.00	0.00	0.00	0.00	0.00
Osm Pres, Psi	65.68	65.68	65.68	65.68	65.68
pH	7.86	7.86	7.86	7.86	7.86
LSI	0.38	0.38	0.38	0.38	0.38
Stiff-Davis	0.29	0.29	0.29	0.29	0.29
BaSO4 Sat, %	12.80	12.80	12.80	12.80	12.80
CaSO4 Sat, %	1.08	1.08	1.08	1.08	1.08
CaF2 Sat, %	0.01	0.01	0.01	0.01	0.01
SrSO4 Sat, %	1.24	1.24	1.24	1.24	1.24
SiO2 Sat, %	11.46	11.46	11.46	11.46	11.46

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:35**

Project: NRO Capacity Expansion
Project File Dare NRO future dsi.osm Engineer: RosTek Associates, Inc
Analysis File: Dare NRO future dsi.osm Analysis Name: User Defined
Element File Date: Aug-24-2000

mg/L	1st Stage Permeate	2nd Stage Feed	2nd Stage Permeate	Total Permeate	System Product
Barium	0.00	0.02	0.00	0.00	0.00
Calcium	0.34	170.39	1.01	0.51	3.36
Iron	0.00	1.61	0.01	0.01	0.03
Potassium	0.32	42.28	0.96	0.48	1.18
Magnesium	0.47	230.96	1.39	0.71	4.57
Manganese	0.00	0.00	0.00	0.00	0.00
Sodium	32.88	4,798.18	98.81	49.78	129.11
Ammonium	0.00	0.00	0.00	0.00	0.00
Strontium	0.01	3.79	0.02	0.01	0.07
Chloride	47.52	7,663.67	143.32	72.08	198.97
Fluoride	0.00	0.71	0.01	0.00	0.02
Bicarbonate	7.91	741.61	22.80	11.72	24.08
Nitrate	0.00	0.00	0.00	0.00	0.00
Sulfate	1.13	413.73	3.35	1.70	8.60
Phosphate	0.00	0.02	0.00	0.00	0.00
Silica	0.21	33.18	0.62	0.31	0.86
Carbonate	0.00	17.39	0.01	0.00	0.10
Carbon Dioxide	6.11	6.04	6.00	6.09	6.09
TDS, mg/L	90.78	14,117.54	272.33	137.32	370.96
Flow, Gal/min	537.66	389.34	185.33	722.99	752.99
Temp, Deg C	20.00	20.00	20.00	20.00	20.00
Pressure, Psi	0.00	274.03	0.00	0.00	0.00
Osm Pres, Psi	1.04	152.09	3.10	1.57	4.20
pH	6.35	8.19	6.80	6.46	6.52
LSI	-4.63	1.34	-3.30	-4.19	-3.07
Stiff-Davis	-4.73	1.00	-3.35	-4.26	-3.10
BaSO4 Sat, %	0.00	33.41	0.02	0.01	0.16
CaSO4 Sat, %	0.00	3.07	0.00	0.00	0.01
CaF2 Sat, %	0.00	0.14	0.00	0.00	0.00
SrSO4 Sat, %	0.00	2.88	0.00	0.00	0.02
SiO2 Sat, %	0.20	22.20	0.65	0.31	0.87

Winflows32 v 2.0.33 (VB6 **Analytical Data Sheet** **01-Sep-2002 15:35**

Project: NRO Capacity Expansion
Project File Dare NRO future dsi.osm Engineer: RosTek Associates, Inc
Analysis File: Dare NRO future dsi.osm Analysis Name: User Defined
Element File Date: Aug-24-2000

mg/L	System Conc
Barium	0.04
Calcium	323.60
Iron	3.06
Potassium	79.65
Magnesium	438.60
Manganese	0.00
Sodium	9,048.73
Ammonium	0.00
Strontium	7.19
Chloride	14,465.77
Fluoride	1.34
Bicarbonate	1,352.23
Nitrate	0.00
Sulfate	784.91
Phosphate	0.04
Silica	62.62
Carbonate	72.28
Carbon Dioxide	5.87
TDS, mg/L	26,640.06
Flow, Gal/min	204.01
Temp, Deg C	20.00
Pressure, Psi	348.03
Osm Pres, Psi	283.17
pH	8.44
LSI	2.12
Stiff-Davis	1.54
BaSO4 Sat, %	68.72
CaSO4 Sat, %	6.59
CaF2 Sat, %	1.18
SrSO4 Sat, %	4.72
SiO2 Sat, %	37.53

ROMEMBRA
TORAY REVERSE OSMOSIS ELEMENTS

Project:
Comments:

Prepared For:
Location:
Prepared By:
Date Prepared:

current.

System Results

Flow Rates	Gal/min	Concentrations	mg/l
RO Feed	891	RO Feed TDS	4258
Permeate	695	Permeate TDS	135
Concentrate	196	Concentrate TDS	18872
Total Feed	941	Total Feed TDS	4260
Total Product	745	Total Product TDS	4260

System Details — **Single Stage Design with Bypass**

Temperature: 20 Deg C — Water Type: Well Water Softened Supply
System Recovery: 79.2 %

Pass 1 **Units: Pressure - Psi** **Flow - Gal/min** **TDS - mg/l**

Array 1 Recovery: 78.0% Concentrate TDS: 18872 Concentrate Flow: 196

Bank	Total Vessels	Total Elements	Element Model	Feed Flow	Perm Flow	Feed Press	Delta Press	Perm TDS
1	21	126	TM720-400	941	551	275	8.29	74.3
2	10	60	TM720-400	390	183	304	7.58	320
Total	**31**	**186**		**941**	**734**			**135**

Concentration, Saturation and pH Data mg/l

Ion	Permeate	Treated Feed	Feed	Concentrate
Ca	0.71	72.0	72.0	325
Mg	0.96	97.6	97.6	440
Na	47.6	1355	1355	5991
K	0.71	18.0	18.0	79.3
Ba	9.84E-05	0.01	0.01	0.0451
Sr	0.0157	1.6	1.6	7.22
NH4	0.0	0.0	0.0	0.0
Fe	0.0067	0.68	0.68	3.07
HCO3	15.0	308	322	1329
Cl	67.6	2200	2200	9760
SO4	2.39	188	175	847
NO3	0.0035	0.04	0.04	0.17
F	0.0063	0.3	0.3	1.34
B	0.0	0.0	0.0	0.0

Ion	Permeate	Treated Feed	Feed	Concentrate
SiO2	0.35	14.1	14.1	62.8
PO4	0.0066	0.77	0.77	3.48
CO3	0.001	0.75	2.26	21.6
CO2	17.4	17.4	6.31	17.2
TDS	135	4258	4260	18872
pH	6.17	7.4	7.86	7.98
Saturation Data (%)				
CaSO4	0.0006	1.46	1.36	9.26
CaPO4	0.0	4306	10000	10000
CaF2	6.89E-09	0.0072	0.0072	1.08
BaSO4	0.0114	18.0	16.8	98.4
SiO2	0.34	12.3	11.5	47.1
SrSO4	0.0015	1.74	1.62	6.74
LSI	-4.23	-0.0549	0.43	1.64

System Summary

System Configuration

System Type:	
Feed Predosing?:	Yes
Feed Afterdosing?:	No
Interpass Dosing?:	No
Product Dosing?:	No
Feed CO2 Stripping?:	No
Interpass CO2 Stripping?:	No
Product CO2 Stripping?:	No
Raw Feed Bypass?:	Yes
First Pass Recycle?:	No
Interpass Pumping?:	No

Feed Information

Water Type:	Well Water Softened Supply
Temperature, Deg C:	20.0
Feed pH:	7.86
Silt Density Index:	2.5

Feed Ion Concentration (mg/l)

Ca	72.0
Mg	97.6
Na	1355
K	18.0
Ba	0.01
Sr	1.6
NH4	0.0
Fe	0.68
HCO3	322
Cl	2200
SO4	175
NO3	0.04
F	0.3
B	0.0
SiO2	14.1
PO4	0.77
CO3	2.26
CO2	6.31

System Flux, Flows and Recoveries

Average System Flux:	13.4 Gal/ft2/day
Feed Flow:	941.00 Gal/min
Bypass Flow:	50.0 Gal/min
Product Flow:	744.98 Gal/min
Concentrate Flow:	196.02 Gal/min
First Pass Recovery:	78.0 %
System Recovery:	79.2 %

First Pass Array

Interbank Pressure Drop: 2.0 Psi

Interbank Pressure Boost
Bank 1-2: 40.0 Psi

Bank 1 Back Pressure: 14.0 Psi
Bank 2 Back Pressure: 14.0 Psi

Number of Banks: 2

Total Elements: 186

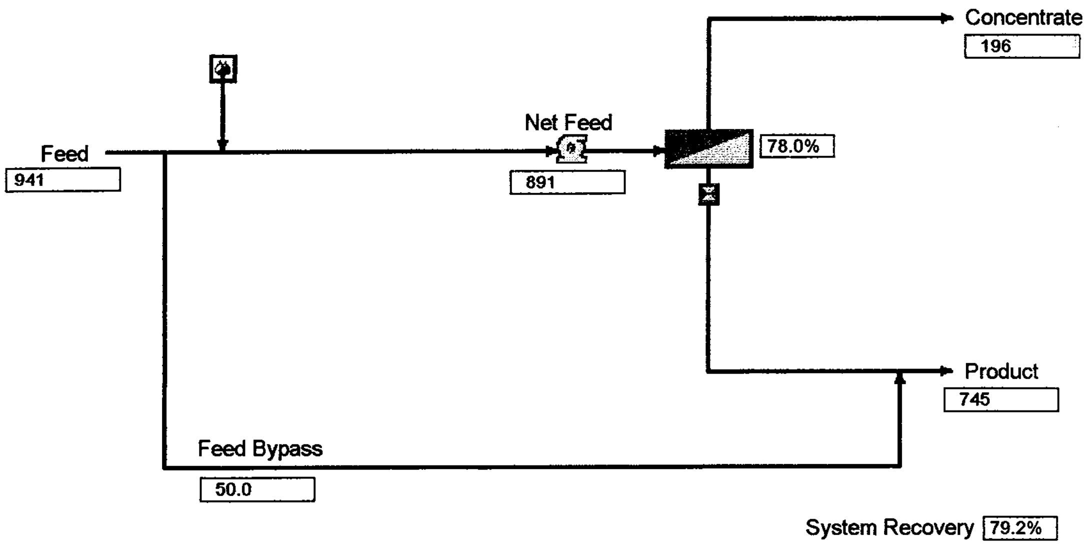
Bank	# Vessels	# Elements/Vessel	Element Type	Element Age
1	21	6	TM720-400	3
2	10	6	TM720-400	3

Chemical Treatment

Station	Chemical	Target pH
Feed Pre-Treat	Sulfuric Acid	7.4

Process Data

Flow Units: Gal/min
Pressure Units: psi



Flow Rates	Gal/min	Concentrations	mg/l
RO Feed	891	RO Feed TDS	4258
Permeate	695	Permeate TDS	135
Concentrate	196	Concentrate TDS	18872
Total Feed	941	Total Feed TDS	4260
Total Product	745	Total Product TDS	4260

System Data		Single Stage Design with Bypass
Temperature:	20.0 Deg C	

	Stage 1
Fouling Allowance	85.0 %
Feed Pressure	275 Psi
Interbank Loss	2.0 Psi
Element Age	3.0 Years

Interbank Boost Pressure	Stage 1
Banks 1-2	40.0 Psi

Chemical Usage	Chemical	lb/day	kg/day	Target pH
Feed Pre-Treat	Sulfuric Acid	154	69.9	7.4

Stream Data

Units: Pressure - psi Flow - Gal/min TDS - mg/l Saturation - %

Stream --->	System Feed	Feed Bypass	RO Feed	Predosed Feed	1st Pass Feed
Ca	72.0	72.0	72.0	72.0	72.0
Mg	97.6	97.6	97.6	97.6	97.6
Na	1355	1355	1355	1355	1355
K	18.0	18.0	18.0	18.0	18.0
Ba	0.01	0.01	0.01	0.01	0.01
Sr	1.6	1.6	1.6	1.6	1.6
NH4	0.0	0.0	0.0	0.0	0.0
Fe	0.68	0.68	0.68	0.68	0.68
HCO3	322	322	322	308	308
Cl	2200	2200	2200	2200	2200
SO4	175	175	175	188	188
NO3	0.04	0.04	0.04	0.04	0.04
F	0.3	0.3	0.3	0.3	0.3
B	0.0	0.0	0.0	0.0	0.0
SiO2	14.1	14.1	14.1	14.1	14.1
PO4	0.77	0.77	0.77	0.77	0.77
CO3	2.26	2.26	2.26	0.75	0.75
CO2	6.31	6.31	6.31	17.4	17.4
TDS	4260	4260	4260	4258	4258
pH	7.86	7.86	7.86	7.4	7.4
LSI	0.43	0.43	0.43	-0.0549	-0.0549
Stiff-Davis	0.4	0.4	0.4	-0.0832	-0.0832
BaSO4 Sat	16.8	16.8	16.8	18.0	18.0
CaSO4 Sat	1.36	1.36	1.36	1.46	1.46
CaPO4 Sat	10000	10000	10000	4306	4306
CaF2 Sat	0.0072	0.0072	0.0072	0.0072	0.0072
SrSO4 Sat	1.62	1.62	1.62	1.74	1.74
SiO2 Sat	11.5	11.5	11.5	12.3	12.3
Flow	941	0.0	941	941	941
Temp, Deg C	20.0	20.0	20.0	20.0	20.0
Pressure	275	0.0	275	275	275
Osm Pressure	45.7	45.7	45.7	45.6	45.6

Units: Pressure - psi Flow - Gal/min TDS - mg/l Saturation - %

Stream —>	Total Permeate	System Product	System Concentrate
Ca	0.71	72.0	325
Mg	0.96	97.6	440
Na	47.6	1355	5991
K	0.71	18.0	79.3
Ba	9.84E-05	0.01	0.0451
Sr	0.0157	1.6	7.22
NH4	0.0	0.0	0.0
Fe	0.0067	0.68	3.07
HCO3	15.0	322	1329
Cl	67.6	2200	9760
SO4	2.39	175	847
NO3	0.0035	0.04	0.17
F	0.0063	0.3	1.34
B	0.0	0.0	0.0
SiO2	0.35	14.1	62.8
PO4	0.0066	0.77	3.48
CO3	0.001	2.26	21.6
CO2	17.4	6.31	17.2
TDS	135	4260	18872
pH	6.17	7.86	7.98
LSI	-4.23	0.43	1.64
Stiff-Davis	-4.31	0.4	1.17
BaSO4 Sat	0.0114	16.8	98.4
CaSO4 Sat	0.0006	1.36	9.26
CaPO4 Sat	0.0	10000	10000
CaF2 Sat	6.89E-09	0.0072	1.08
SrSO4 Sat	0.0015	1.62	6.74
SiO2 Sat	0.34	11.5	47.1
Flow	695	50.0	196
Temp, Deg C	20.0	20.0	20.0
Pressure	0.0	0.0	297
Osm Pressure	1.52	45.7	197

TORAY

Toray Industries, Inc. Membrane Products Dept.
8-1, Mihama 1-chome, Urayasu, Chiba 279-8555, Japan
TEL: (+81) 47-350-6030
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ROMEMBRA
TORAY REVERSE OSMOSIS ELEMENTS

Project:
Comments:

Prepared For:
Location:
Prepared By:
Date Prepared:

6000 TDS

System Results

Flow Rates	Gal/min
RO Feed	987
Permeate	718
Concentrate	239
Total Feed	1017
Total Product	748

Concentrations	mg/l
RO Feed TDS	6001
Permeate TDS	210
Concentrate TDS	21413
Total Feed TDS	6003
Total Product TDS	6003

System Details — **Single Stage Design with Bypass**

Temperature: 20 Deg C
System Recovery: 73.5243491004948 %
Water Type: Well Water Softened Supply

Pass 1 **Units: Pressure - Psi** **Flow - Gal/min** **TDS - mg/l**

Array 1 Recovery: 72.7% Concentrate TDS: 21413 Concentrate Flow: 239

Bank	Total Vessels	Total Elements	Element Model	Feed Flow	Perm Flow	Feed Press	Delta Press	Perm TDS
1	24	144	TM720-400	1017	559	286	7.9	126
2	12	72	TM720-400	457	180	316	7.88	472
Total	**36**	**216**		**1017**	**739**			**210**

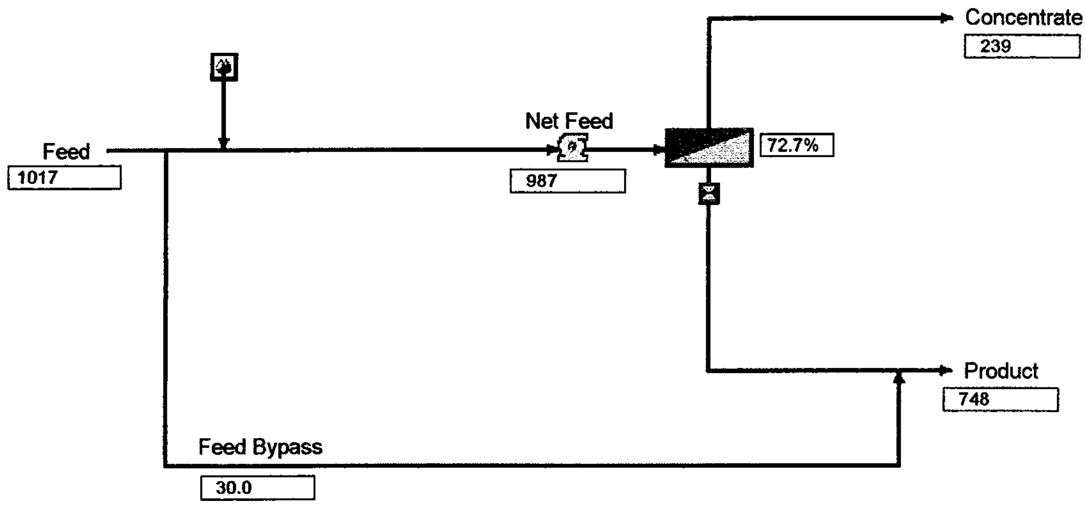
Concentration, Saturation and pH Data mg/l

Ion	Permeate	Treated Feed	Feed	Concentrate
Ca	0.76	72.0	72.0	262
Mg	1.03	97.6	97.6	355
Na	76.6	2041	2041	7270
K	0.76	18.0	18.0	63.9
Ba	0.0001	0.01	0.01	0.0363
Sr	0.0169	1.6	1.6	5.81
NH4	0.0	0.0	0.0	0.0
Fe	0.0072	0.68	0.68	2.47
HCO3	16.7	309	322	1074
Cl	111	3257	3257	11630
SO4	2.66	188	175	682
NO3	0.0038	0.04	0.04	0.14
F	0.007	0.3	0.3	1.08
B	0.0	0.0	0.0	0.0

Ion	Permeate	Treated Feed	Feed	Concentrate
SiO2	0.37	14.1	14.1	50.6
PO4	0.0074	0.77	0.77	2.8
CO3	0.0014	0.84	2.53	14.9
CO2	16.9	17.0	6.13	16.8
TDS	210	6001	6003	21413
pH	6.22	7.4	7.86	7.89
Saturation Data (%)				
CaSO4	0.0007	1.16	1.08	5.52
CaPO4	0.0	4306	10000	10000
CaF2	1.12E-08	0.0081	0.0081	0.58
BaSO4	0.0127	13.7	12.8	58.3
SiO2	0.36	12.3	11.5	40.2
SrSO4	0.0016	1.33	1.24	3.98
LSI	-4.13	-0.1	0.38	1.36

Process Data

Flow Units: Gal/min
Pressure Units: psi



System Recovery 73.5%

Flow Rates	Gal/min	Concentrations	mg/l
RO Feed	987	RO Feed TDS	6001
Permeate	718	Permeate TDS	210
Concentrate	239	Concentrate TDS	21413
Total Feed	1017	Total Feed TDS	6003
Total Product	748	Total Product TDS	6003

System Data	Single Stage Design with Bypass
Temperature:	20.0 Deg C

	Stage 1	
Fouling Allowance	85.0	%
Feed Pressure	286	Psi
Interbank Loss	2.0	Psi
Element Age	3.0	Years

Interbank Boost Pressure	Stage 1	
Banks 1-2	40.0	Psi

Chemical Usage	Chemical	lb/day	kg/day	Target pH
Feed Pre-Treat	Sulfuric Acid	164	74.6	7.4

TriSep R.O. Implementation (TROI) Design
Version 1.3.3

Project Name: KDH Expansion
Projection By: Ian C. Watson
Date: 9/2/200 10:11:23AM

Permeate Flow:	695.0	GPM			
System Recovery:	78.0	%	Acid Dosage, H2SO4	14.3	ppm
Feedwater Temp:	20.0	C	Feed CO2:	19.7	ppm
Element Age:	3.0	years	Flux Decline Coef.:	-0.025	%
Raw Water pH:	7.9		3-yr S.P.I.F:	1.3	
Feed Pressure:	284.4	psi	Concentrate Pressure:	245.2	psi
Recirc. Flow:	0.0	GPM	Blend Flow:	50.0	GPM
			Blended Perm. Flow:	745.0	GPM

	Raw Water		Feed Water		Concentrate		Permeate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	72.00	180.00	72.00	180.00	322.78	806.96	5.17	12.94
Mg	97.60	406.67	97.60	406.67	437.55	1,823.12	7.01	29.23
Na	1,354.60	2,944.78	1,354.60	2,944.78	5,976.91	12,993.28	122.83	267.03
K	18.00	23.08	18.00	23.08	78.95	101.22	1.76	2.25
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.01	0.01	0.01	0.04	0.03	0.00	0.00
Sr	1.60	1.82	1.60	1.82	7.19	8.17	0.11	0.13
CO3	1.08	1.79	0.35	0.59	1.59	2.65	0.02	0.04
HCO3	321.95	263.89	305.23	250.19	1,349.12	1,105.83	27.05	22.18
SO4	175.00	182.29	189.35	197.24	850.70	886.14	13.12	13.67
Cl	2,200.00	3,098.59	2,200.00	3,098.59	9,723.97	13,695.73	195.00	274.65
F	0.30	0.79	0.30	0.79	1.34	3.52	0.02	0.06
NO3	0.04	0.03	0.04	0.03	0.17	0.14	0.00	0.00
SiO2	14.10	11.75	14.10	11.75	62.32	51.93	1.25	1.04
TDS	4,256.28	7,115.49	4,253.18	7,115.53	18,812.63	31,478.73	373.37	623.21
pH	7.86		7.40		8.05		5.77	

** Calculations are accurate within +/- 10%

PASS	Array	No of Elements	Element	Feed Flow (GPM)	Conc. Flow (GPM)	Conc. Press (psi)	Perm Press (psi)	Beta	Avg. Flux (gfd)
1	21x6	126	8040-ACM2-UWA	891.0	307.2	264.7	14.00	1.21	16.7
2	10x6	60	8040-ACM2-UWA	307.2	196.0	245.2	14.00	1.04	6.7

*** This projection is not to be used for warranty purposes ***

TriSep R.O. Implementation (TROI) Design

Version 1.3.3

Project Name: KDH Exp future
Projection By: Ian C. Watson
Date: 9/2/200 10:08:42AM

Permeate Flow:	695.0 GPM				
System Recovery:	75.0 %	Acid Dosage, H2SO4	14.3 ppm		
Feedwater Temp:	20.0 C	Feed CO2:	19.7 ppm		
Element Age:	3.0 years	Flux Decline Coef.:	-0.025 %		
Raw Water pH:	7.9	3-yr S.P.I.F:	1.3		
Feed Pressure:	310.6 psi	Concentrate Pressure:	277.1 psi		
Recirc. Flow:	0.0 GPM	Blend Flow:	30.0 GPM		
		Blended Perm. Flow:	725.0 GPM		

	Raw Water		Feed Water		Concentrate		Permeate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	72.00	180.00	72.00	180.00	283.75	709.36	3.39	8.47
Mg	97.60	406.67	97.60	406.67	384.63	1,602.64	4.59	19.14
Na	2,041.00	4,436.96	2,041.00	4,436.96	7,901.48	17,177.14	141.88	308.43
K	18.00	23.08	18.00	23.08	69.22	88.75	1.40	1.80
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.01	0.01	0.01	0.04	0.03	0.00	0.00
Sr	1.60	1.82	1.60	1.82	6.32	7.18	0.07	0.08
CO3	1.08	1.79	0.35	0.59	1.40	2.33	0.02	0.03
HCO3	321.95	263.89	305.23	250.19	1,183.23	969.86	20.71	16.98
SO4	175.00	182.29	189.35	197.24	747.96	779.12	8.34	8.69
Cl	3,253.00	4,581.69	3,253.00	4,581.69	12,610.25	17,760.91	220.75	310.92
F	0.30	0.79	0.30	0.79	1.18	3.09	0.02	0.04
NO3	0.04	0.03	0.04	0.03	0.15	0.12	0.00	0.00
SiO2	14.10	11.75	14.10	11.75	54.66	45.55	0.96	0.80
TDS	5,995.68	0,090.77	5,992.58	0,090.80	23,244.26	39,146.09	402.13	675.37
pH	7.86		7.40		7.99		5.85	

** Calculations are accurate within +/- 10%

PASS	Array	No of Elements	Element	Feed Flow (GPM)	Conc. Flow (GPM)	Conc. Press (psi)	Perm Press (psi)	Beta	Avg. Flux (gfd)
1	24x6	144	8040-ACM2-UWA	926.7	303.5	294.2	14.00	1.18	15.6
2	12x6	72	8040-ACM2-UWA	303.5	231.7	277.1	14.00	1.02	3.6

*** This projection is not to be used for warranty purposes ***

Project Name: KDH Exp future
Projection By: Ian C. Watson
Date: 9/2/200 10:08:42AM

Water Saturation Indexes

	Raw Water	Feed Water	Concentrate
Langelier Saturation Index	0.46	-0.03	1.70
S and DSI Index	0.21	-0.28	0.94
CaSO4/Ksp*100%	0.99	1.07	5.94
SrSO4/Ksp*100%	1.40	1.51	8.29
BaSO4/Ksp*100%	12.62	13.64	71.86
SiO2 Saturation	12.26	12.26	47.53
Fe (ppm)	0.00	0.00	0.00
Al (ppm)	0.00	0.00	0.00
Osmotic Pressure, psi	64.10	64.06	252.72

Recommended Chemical Dosages

For optimum system performance, treatment should include Tripol 9000 series antiscalant at a dosage rate of 4.7 ppm. Inject 16.5 ml/min into the RO feedstream. Antiscalant should be injected at a point where there is a turbulent flow prior to or just after the pre-RO cartridge filters. The most common injection point is just prior to or just after the pre-RO cartridge filters.

Operating 24 hours per day, the maximum daily antiscalant usage will be 6.3 gallons. Operating 24 hours per day for 30 days each month, the maximum monthly antiscalant usage will be 187.9 gallons.

*** This projection is not to be used for warranty purposes ***

DARE COUNTY WATER SYSTEM IMPROVEMENTS

For the Supply and Installation of Two Reverse Osmosis Trains and Associated Work for Capacity Expansion.
North RO Plant, Kill Devil Hills, North Carolina

Addendum #1 to the Specifications

Issued Friday, October 04, 2002

Prepared for

Dare County Water System,
Manteo, North Carolina

Prepared by
ROSTEK ASSOCIATES INC.
P O BOX 47567, Tampa, Florida 33647

Supply and Installation of Two Reverse Osmosis Trains and Associated Work for Capacity Expansion.
North RO Plant, Kill Devil Hills, North Carolina

ADDENDUM #1

NOTICE TO ALL BIDDERS:

This addendum corrects a discrepancy in the bid bond amount; corrects the number of days from notice to proceed to final completion; replaces two specification sections; adds two new specification sections; adds on sketch to Supplemental information.

Bidders must acknowledge receipt of this addendum with their bid.

1. Bid Form, page 4 of 7. Change 10% to 5%.

2. Contract, page 2 of 4. In "Completion" change as follows:

    a. Substantial Completion, Train 4. Delete "207 Calendar days". Insert "148 calendar days"
    b. Substantial Completion, Train 5. Delete "238 Calendar days". Insert "179 calendar days"
    c. Final Completion, all work. Delete "268 Calendar days". Insert "209 calendar days"

3. Question: Can the Bid Form be detached from the specification book, or additional copies made?

    Answer. Yes, the Bid Form may be detached from the specification book. Additional copies are available from RosTek Associates, Inc.

4. Specification Section 16157. Replace complete section with revised section dated October 2, 2002, attached.

5. Specification Section 16900. Replace complete section with revised section dated October 2, 2002, attached.

6. Add new Specification Section 15067, Disinfection and Pressure Testing, dated October 2, 2002.

7. Add new Specification Section 15068, Flanged Ductile Iron Piping, dated October 2, 2002.

October 4, 2002

8. Add Existing RO Train Elevation sketch to Supplemental Information.

9. Instructions to Bidders, page 1 of 2. To list of qualified ROEMs, add the following:

   Hydropro, Inc., Lake Park, Florida. 561-848-6788

This Addendum #1 was prepared on October 2, 2002 by RosTek Associates, Inc. Contact Ian C. Watson, PE at 813-987-9473 for any further clarification.

SECTION 15067 - DISINFECTION AND LEAK TESTING

PART 1 - GENERAL

A. Description

This section describes the requirements for disinfection for new sections of piping, previously unused section of existing piping, new pumping equipment and new RO trains, and leak testing of the completed syatem.

B. Submittals

1. Submit written description of procedure, materials to be used, and safety precautions for handling liquid chlorine.
2. Submit plan for disposal of chlorinated water.
3. Submit procedure for leak testing piping assemblies and the RO trains.

C. Measurement and Payment

Payment for the work in this section shall be included as part of the lump-sum bid amount stated in the Proposal.

PART 2 - MATERIALS

A. General

1. Use sodium hypochlorite solution, commercial strength, or solid calcium hypochlorite dissolved in water. Do not place solid hypochlorite in pipe or equipment.
2. Use existing connections on piping. Do not create new openings.

PART 3 - EXECUTION

A. Disinfection

1. RO Trains and Associated Piping and Equipment.

   Clean interior of 16" stainless steel pipe thoroughly. Swab inside of pipe with 50 mg/l sodium or calcium hypochlorite solution, immediately before connecting sections to existing headers. After installation of the RO train the system will be flushed from the feed header, through the cartridge filters, pump suction header and RO feed pumps and the RO trains.

The permeate outlet should be blocked to prevent untreated water from entering the treated water side. Flush through the RO train until no chlorine residual is detected. At this point start bacteriological sampling under the direction of Dare County staff. If the bacteriological test fails, fill the system from cartridge filter inlet to concentrate outlet and re-disinfect.

This procedure occurs without the membranes being installed in the pressure vessels. Extreme care must be taken not to expose the existing membranes to any chlorine.

Upon receipt of successful test results, the train will be flushed with permeate using the existing cleaning system prior to loading the membranes.

2. EXISTING TRANSMISSION PIPING

(a) The replacement pumps shall be partially filled with hypochlorite solution prior to piping connection. The pumps shall be connected to the piping and filled with water so that the hypochlorite concentration is about 50mg/l, let stand for 4 hours, then isolated with the valves and drained through the casing drain plug. The pumps shall be allowed to refill with treated water from storage for bacteriological sampling.
(b) The existing piping to which the new transmission pump will be connected must be thoroughly flushed with treated chlorinated water. The existing transfer pumps may be used for flushing. Hypochlorite solution will then be pumped into the piping and allowed to stand for 24 hours. This solution must then be flushed out, and bacteriological samples taken.

(Note: This piping has been in place and unused since 1989. Dare County staff will inspect that part of the interior of the pipe that can be seen for evidence of lining failure.)

3. LEAK TESTING

Since this is an operating facility, leak testing will be ongoing through out the flushing and startup procedures. If leaks are observed, the Contractor will make such adjustments or repairs that may be required.

The work will not be accepted with active leakage.

4. ALTERNATE PROPOSALS

The Contractor is free to offer and use alternate procedures as he sees fit, provided he has the concurrence of the Owner. Such concurrence will not relieve the

Contractor of the responsibility of obtaining bacteriological clearances at each step of the retrofit procedure.

END OF SECTION

SECTION 15068 FLANGED DUCTILE IRON PIPE

PART 1 GENERAL

A. Description

This section includes materials and installation of flanged ductile iron pipe and fittings 18 inches in diameter and smaller conforming to AWWA C115/ANSI A21.15.

B. Submittals

1. Submit shop drawings in accordance with the General Conditions.

2. Show material of construction, with ASTM reference and grade. Submit manufacturer's certificates of compliance with referenced pipe standards.

3. Submit piping layout drawings showing location and dimensions of pipe and fittings. Include layout lengths of valves, couplings, and other equipment determining piping dimensions. Label or number each fitting or piece of pipe.

4. Submit manufacturer's catalog data for the flange gaskets.

C. Measurement and Payment

Payment for the work in this section shall be included as part of the lump-sum bid amount stated in the Proposal.

PART 2 MATERIALS

A. Pipe

1. Pipe shall conform to AWWA C115/ANSI A21.15, Class 53 as indicated in the drawings.

2. Ductile iron pipe, unless otherwise specified, shall be cement lined in accordance with AWWA C104/ANSI A21.14, and shall be furnished with shop prime coating ready for finish coating in the field.

B. Fittings

1. Fittings for pipe shall be ductile iron flanged fittings conforming to AWWA C110/ANSI A21.10. Elbows shall be long radius.

2. Fittings shall be shop primed ready for field finish painting.

3. Fittings shall be mortar lined to match the companion piping.

C. Joints

1. Where indicated on the drawings, restrained couplings shall be installed. Coupling detail is shown in Supplemental Information at the end of the specifications.

2. All other joints shall be flanged.

D. Flanges

Flanges shall be Class 150, conforming to AWWA C115/ANSI A21.15.

E. Bolts and Nuts for Flanges

1. Bolts and washers for flanges shall be Type 316L stainless steel conforming to ASTM A 193, Grade B8M. Nuts shall be silicon bronze.

2. Lubricant shall be TRX-Synlube by Ramco, Anti-Seize by Ramco, Husk-It Husky Lube O'Seal, or equal.

F. Gaskets for Flanges

1. 150# Flanges: Full face, 1/8" thick, fabricated from red rubber or neoprene, with hardness #80.

PART 3 - EXECUTION

A. Installation

.1. Pipe and fittings shall be installed in accordance with AWWA C600

END OF SECTION

SECTION 16157

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.01 DESCRIPTION

A. This section provides specification requirements for adjustable frequency drives, variable speed drives or herein identified as VFDs for use with NEMA.

1.02 SUBMITTALS

A. Submit shop drawings in accordance with the specification Section 16900.

B. Submit catalog sheets showing voltage, horsepower, maximum current ratings, and recommended replacement parts with part numbers.

PART 2 MATERIALS

2.01 MANUFACTURERS

A. The VFDs for the 250HP pressure pumps shall be provided by Square D Company, Class 8839, Type: ATV 66.

B. The VFDs for the 60HP transmission pumps shall be provided by square D company, Model 6, Type: ATV 58.

2.02 GENERAL

A. The VFDs shall convert the input AC main power to an adjustable frequency and voltage as defined in the following sections.

B. The input power section shall utilize a full wave bridge design incorporating diode rectifiers. The diode rectifiers shall convert fixed voltage and frequency, AC line power to fixed DC voltage. This power section shall be insensitive to phase rotation of the AC line.

C. The DC bus shall have external connections for standby battery back-up or for linking multiple, VFD DC buses for management of regeneration power.

D. The output power section shall change fixed DC voltage to adjustable frequency AC voltage. This section shall utilize insulated gate bipolar transistors (IGBTs) or intelligent power modules (IPMs) as required by the current rating of the motor.

2.03 ENCLOSURE

A. The VFDs shall be mounted in a Type 1 enclosure with an external operated disconnect device.

B. A mechanical interlock shall prevent an operator from opening the VFD door when the disconnect is in the "on" position. Another mechanical interlock shall prevent an operator from placing the disconnect in the "on" position while the VFD door is open. It shall be possible for authorized personnel to defeat these interlocks.

C. Provisions shall be provided for locking all disconnects in the "off" position with up to three padlocks.

D. Current limiting fuses shall be installed and wired to the VFD input.

E. Provisions shall be made for accepting a padlock to lock the enclosure door.

2.04 MOTOR DATA

A. The VFDs shall be sized to operate the following AC motor:

Motor Horsepower: 250
Motor Full Load Ampere: 278
Motor RPM: 3600
Motor Voltage: 460
Motor Service Factor: 1.15

2.05 ENVIRONMENTAL RATINGS

A. The VFDs shall be designed to operate in an ambient temperature from 0 to +40 degrees C (+32 to 104 degrees F).

B. The maximum relative humidity shall be 95% at 40 degrees C, non-condensing.

C. The VFDs shall be rated to operate at altitudes less than or equal to 3,300 feet (1000 meters). For altitudes above 3,300 feet, de-rate the VFD by 1.2% for every 300 feet (100 meters).

2.06 RATINGS

A. The VFDs shall be designed to operate from an input voltage of 400 ±15% Vac and 460 ±15% Vac.

B. The VFDs shall operate from an input voltage frequency range from 47.5 to 63 Hertz.

C. The displacement power factor shall not be less than .95 lagging under any speed or load condition.

D. The efficiency of the VFDs at 100% speed and load shall not be less than 96%.

E. The variable torque rated VFDs overcurrent capacity shall be 110% for 1 minute.

F. The output carrier frequency of the VFDs shall be randomly modulated and selectable at 2, 4, or 10 kHz depending on Drive rating for low noise operation. No VFD with an operable carrier frequency above 10kHz shall be allowed.

G. The output frequency shall be from .1 to 400 Hertz for Drives up to 75 hp. At horsepower's above 75 hp, the maximum output frequency will be 200 Hertz.

H. The VFDs will be able to develop rated motor torque at .5 Hertz (60 Hz base) in a Sensorless Flux Vector mode using a standard induction motor without an encoder feedback signal.

2.07 VARIABLE FREQUENCY CONTROLLERS

A. Controller shall consist of a power conversion bridge and inverter.

B. Controller shall be pulse width modulated (PWM) design.

C. Controller shall be variable voltage/variable frequency (constant volts per hertz).

D. The controller shall include the following features:

1. 460-volt a-c, 3-phase, 3 wire, 60-Hz input power.
2. 460 volt a-c, 3-phase, 3-wire, ungrounded output power.
3. Input fusing, fast acting.
4. Input power surge protector, for transient protection up to 10 kV and 250 Joules. (Refer to Section 16670.)
5. 0 to 650 Hz continuous operating range with 0.01 Hz frequency resolution.
6. Output current limit, 0% to 250% adjustable, minimum. Limits motor inrush current during startup.
7. Regulation +/-3% of base speed.
8. Adjustable acceleration and deceleration rates.
9. Maximum and minimum speed adjustments.
10. Frequency skip adjustment (3 minimum).
11. 115-volt a-c control power for run/stop circuits.
12. Blower cooled with thermal switch cutout and filters for all intake and exhaust openings.

E. The controller shall include protective circuitry that initiates an orderly shutdown of the inverter without component failure. The controller shall shut down and require manual reset for the following fault conditions.

1. Overload.
2. Instantaneous overcurrent.
3. Inverter fault.
4. Overfrequency.
5. D-C link overvoltage.
6. Cabinet overtemperature.
7. Motor overtemperature, sensed by motor thermal switch.

F. The controller shall shut down for the following fault conditions. The controller shall automatically restart upon a cleared fault condition.

1. Incorrect phase sequence.
2. Loss of an input phase.
3. Input undervoltage.

G. Provide a common failure contact for remote indication of fault conditions previously listed.

2.08 CONTROLS

A. The following data shall be accessible via a digital display mounted on the control cabinet door, and interfaced to the variable frequency drive.

1. Control power on.
2. Drive run.
3. Drive fault.
4. Drive speed indication, 0% to 100% rpm and 0-60 Hz.
5. Elapsed time meter, six digits, reading in hours and tenths.
6. Drive output current and voltage.
7. System mode, local/remote.
8. Manual speed adjustment, 0% to 100% rpm and 0-60 Hz.
9. Drive, start/stop (local mode).
10. As indicated on the drawings.

2.09 FACTORY TESTING

A. Subject the variable frequency drives to a rated motor load operational test prior to shipment. Provide written certification of completed and approved factory test.

2.10 SPARE PARTS

A. Provide one complete drive, including enclosures of each type and ampere rating installed.

2.11 SOFTWARE

A. Provide all configuration software and cables for connection of each type of drive to a laptop computer for setting the drive parameters.

2.12 MODBUS PLUS COMMUNICATIONS

A. Provide and install all required cable, conduits, and devices to implement Modbus Plus communications from the PLC in existing control room to each of the two Variable Frequency Drives (VFD). Each VFD shall include a Modbus Plus Interface Board (Part Number VW3A66305U) to provide direct communications from VFD to the PLC. All drive setup, configuration, status, alarm, and control parameters shall be accessible to the PLC via the Modbus Plus Communication Link.

B. Provide all equipment, such as terminal blocks, power supplies, connections, wiring, and other equipment, in the VFDs as required for this interface.

C. Provide all programming and configuration of the PLC system and VFDs for the operation of the VFDs using Modbus Plus Communications.

PART 3 EXECUTION

3.01 INSTALLATION

A. Drives shall be installed in enclosures at locations as shown on the drawings. Mount drive with the recommended clearances per the manufacturer and local codes.

B. Secure drive enclosure to floor or wall with stainless steel hardware. Provide access of digital display on front on drive.

3.02 PRELIMINARY INSPECTION/TEST

A. Test the operation of each interlock to verify that the interlock performs its function.

B. The variable speed drive system shall be tested to check correct operation of each drive in the manual variable speed mode and automatic variable speed mode.

C. Test the total demand distortion and odd harmonic distortion of the system at the point of common coupling. The Contractor shall provide all equipment required to test the system. A certified test report shall be submitted by the Contractor for review and approval by the Owner. If the maximum harmonic limits, as required by IEEE 519-1992, for this application, are not satisfied the Contractor shall include additional equipment to meet these requirements at no additional cost to the Owner.

3.03 FINAL INSPECTION/TEST

Repeat Preliminary Inspection/Test.

END OF SECTION

SECTION 16900

GENERAL CONTROL REQUIREMENTS

PART 1 GENERAL

1.01 DESCRIPTION

A. This section includes requirements for materials, testing, and installation of the programmable controller components and control systems as specified herein and indicated on the drawings.

B. Equipment, materials, and workmanship shall comply with the latest revisions of the following codes and standards:

1. Wiring: National Electrical Code (NEC), ISA S5.3 and S5.4.

2. Control Panels and Equipment: NEMA, UL, and ANSI.

3. Control Logic: Joint Industrial Council (JIC).

C. The system supplier (Subcontractor) shall provide the specified equipment under the following sections:

1. Variable Frequency Drive: 16920

2. Low Voltage Motor Control: 16965

1.02 SUBMITTALS

A. Submittal Drawings and Data: Submittals shall be in accordance with this section. These drawings and data shall be submitted as a complete package at one time.

1. Submittals shall be in three-ring hard-cover binders and arranged for convenient use including tab sheets, all indexed, and cross referenced

2. Data sheets for each component, together with a technical product brochure or bulletin. The data sheets shall show:

a. Component name.
b. Manufacturer's model number.
c. Project location.
d. Input and output characteristics.
e. Requirements for electric supply.

B. The data sheets shall be grouped together in the submittal by systems or loops. If within a single system, a single component is employed more than once, one data sheet with one brochure or bulletin may cover all identical uses of that component in that system.

C. Submit component interconnect drawings showing the interconnecting wiring between each component including equipment supplied under other sections requiring interfacing with the control system.

D. Submit software in 3 ½" diskette media and printout. Software control points and rungs shall be documents with complete description.

E. Submit arrangement and construction drawings for special enclosed assemblies for field installation. These drawings shall include dimensions, identification of all components, preparation and finish data, nameplates, and the like. These drawings also shall include enough other details to define the style and overall appearance of the assembly including a finish color sample.

F. Submit installation, mounting and anchoring details for all new and relocated components or entry details.

G. Complete detailed bills of material.

H. Operation, maintenance, and repair manuals.

1. The organization of the initial submittal shall be compatible to eventual inclusion one volume of the operation, maintenance and repair manuals.

2. Operation manuals shall be prepared and submitted to the Customer.

3. The complete operation and maintenance manual shall contain all the information included in the submittal drawings and data, and the additional information required herein, all bound in hard cover binders and arranged for convenient use including tab sheets, all indexed and cross referenced, and all final as-built drawings.

4. The operation manual shall contain:

a. Programming operating instructions written for the benefit of plant operating personnel for normal operational conditions.

b. Calibration and maintenance instructions.

c. Trouble-shooting instructions.

d. Instructions for ordering replacement parts.

1.03 QUALIFICATIONS AND RESPONSIBILITY OF SUBCONTRACTOR

A. The Contractor shall furnish and install all proposed hardware and software as specified herein. All systems shall be the unit responsibility of a system subcontractor. The system installation and wiring connections to peripheral equipment shall be the responsibility of this subcontractor using qualified personnel possessing the necessary equipment and having experience in making similar installations. Evidence of such qualification, as well as notification of the supplier assuming unit responsibility, shall be furnished to the Customer in writing prior to commencement of the work. The qualification evidence shall include the following:

1. The Subcontractor shall have had a minimum of five years' experience with the installation of systems similar to those to be installed in this project.

2. The Subcontractor's main place of business shall be located within a 50 radius of the jobsite.

3. A list of completed similar installations including name and address of customer, name of project, and date of completion.

4. The name and qualifications of supervisory personnel to be directly responsible for the installation of the control system.

B. The single Subcontractor shall be responsible for coordinating and interfacing with equipment supplied under other divisions of the contract documents which are an integral part of the system. This interfacing shall be incorporated in the detailed systems drawings and data sections.

C. The proposed field equipment shall be new. Manufacturers and model or type numbers are provided as part of the equipment narrative descriptions. The proposed manufacturers are those on which the equipment design has been based.

D. The Contractor shall be responsible for coordinating and interfacing with equipment supplied under these contract documents which are integral parts of the system. Incorporate interfacing in the detailed systems drawings and data section of the contract documents.

1.04 WARRANTY

The Contractor shall repair or replace defective components, rectify malfunctions, and correct faulty workmanship, at no additional cost to the Customer during the one-year warranty period. To fulfill this obligation, he shall utilize technical service personnel designated by the equipment supplier who was originally assigned project responsibility. Services shall be performed within five calendar days after notification by the Customer.

PART 2 MATERIALS

2.01 DESIGNATED COMPONENTS

In these specifications and on the plans, all systems, and other elements are represented schematically and are designated by numbers, as derived from criteria in Instrument Society of America Standards. The nomenclature and numbers designated herein and on the plans shall be employed exclusively throughout shop drawings, data sheets, and the like. Any other symbols, designations, and nomenclature unique to a manufacturer's standard methods shall not replace those prescribed above, as used herein, and on the plans.

2.02 EQUIPMENT TAGGING

Attach a stainless-steel tag to the equipment at the factory. Permanently mark the stainless-steel tag with the equipment tag number. The manufacturer's standard metal nameplate as a minimum shall denote model number, serial number, operating electrical voltage and amperage (when applicable), and date of manufacture.

2.03 MODBUS PLUS COMMUNICATIONS MODULE

The contractor shall provide and install a Prosoft Technology-Modbus Plus Communications Module, Model number 3300-MBP, for communications between existing PLC system and new Variable Frequency Drives along with associated equipment for a complete system.

2.04 MATCHING STYLE, APPEARANCE, AND TYPE

All display equipment of each type shall represent the same outward appearance, having the same physical size and shape and the same size and style of numbers and points.

2.05 TWO WAY RADIO I/O MODULE

A. The two-way radio I/O module shall provide remote monitoring and control by radio or twisted-pair wire, over short or long distances. The module shall come complete with all the components necessary for operation including power supply, microprocessor controller, input/output (I/O) circuits, radio receiver and/or serial transceiver (RS485/232) as well as a wireless radio link for digital (switch contact), pulse and analogue signals.

B. The two-way radio shall include a switch-mode power supply, which will accept a variety of voltage sources and will automatically alarm on losses of mains supply, loss of solar charging or low battery charge. The module shall provide reliable operation even in noisy environments.

C. The two-way radio I/O module shall be single channel, synthesized, and shall use direct frequency modulation. The module shall be EMC Compliant 89/336/EEC, EN55022, EN50082-1, and AS3548.

D. The two-way radio I/O module shall have the following requirements:

1) Input Voltage: 12-24 VAC or 15-30 VDC or 110-250 VAC
2) Inputs/Outputs: analogue or digital inputs
   analogue or digital outputs
   Pulse input & output
   RS-232/485 port
3) Temperature Range: -20 to 60 degC
4) Transmission Rates: Radio 4800; Serial 9600

E. Provide and install module for each well and at the Water Treatment Plant to provide transmission of monitoring and control parameters.

F. The two-way radio I/O module shall be manufactured by Elpro Technologies.

PART 3 EXECUTION

3.01 UNIFORMITY OF COMPONENTS

A. Components which perform the same or similar functions shall, to the greatest degree possible, be of the same or similar type, the same manufacture, the same grade of construction, the same size, and have the same appearance.

3.02 INSTALLATION OF THE MODBUS PLUS COMMUNICATIONS MODULE

A. Install new communications module in existing PLC rack located in existing control room. Prior to installation contractor shall verify the availability of open slots on the existing PLC rack.

B. Test the completed system after installation to assure that all components are operating properly.

3.03 FACTORY TESTING

A. Operational tests shall be performed prior to shipping the control system to the jobsite to demonstrate that the hardware and software will perform each operation required for all specified conditions. The customer shall witness the tests. After the testing is completed, provide a certification and log of all tests to the Customer for review and comment. The panel wiring shall be checked against the submittal drawings.

B. The factory witness test shall take as long as necessary to demonstrate to the Customer and the Engineer that the hardware performs each operation as required per the specifications.

C. Prior to factory system testing, submit a written detailed test procedure for review by the Customer. Notify the Customer in writing four weeks in advance of the scheduled testing.

3.04 PRELIMINARY INSPECTION/TESTING:

A. All hardware and software shall be exercised through point to point tests, including the factory test procedure, in the presence of the Customer in order to demonstrate achievement of the specified performance.

B. Schedule tests among all parties involved so that the tests may proceed without delays or disruptions by uncompleted work. Coordinate operational tests dependent upon completion of work specified elsewhere.

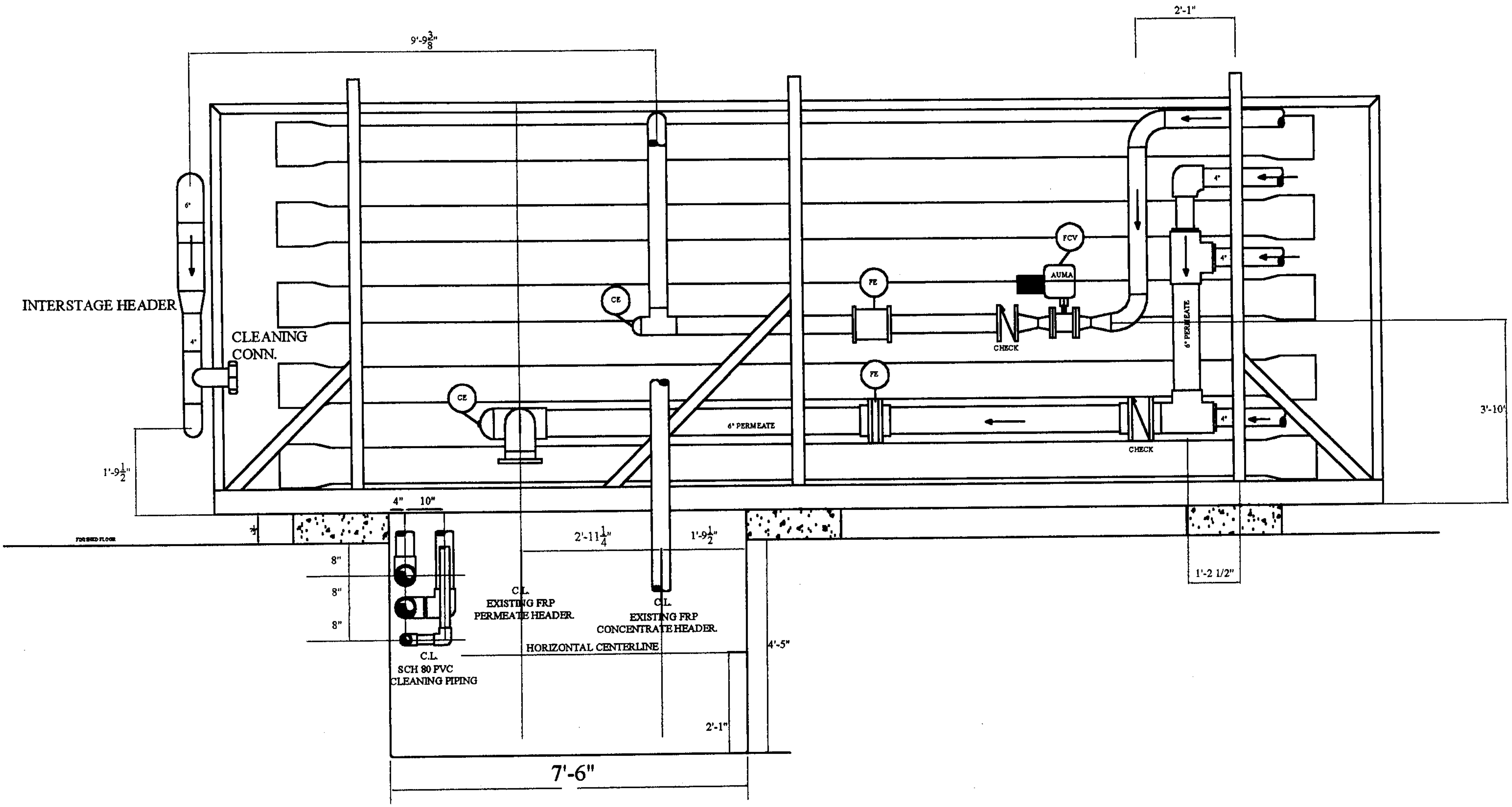
3.05 CONDITIONAL ACCEPTANCE INSPECTION/TEST

A. When systems are assessed to have been successfully carried through a preliminary test and the Customer concurs in this assessment, a date for system start-up involving the Customer's operating personnel will be agreed upon.

B. The complete control system shall be rechecked by the contractor as required in the preliminary inspection test at this time to verify proper operation, and final adjustments shall be made.

C. The system start-up testing shall consist of 14 consecutive days of system testing. The operational tests shall have a success factor of 95% system uptime. If the equipment and control system should fall below the 95% factor, the system problems shall be corrected by the Contractor and the system start-up shall start over again from day one. This will continue until the system functions for 27 consecutive days with a 95% uptime success factor. The contractor is responsible for all hardware operation of the system.

END OF SECTION



PARTIAL ELEVATION AT RO TRAIN 1, SHOWING CONC. PIPING AND INTERSTAGE HEADER.