Dare County Regional Water System, County of Dare, North Carolina.

Water Treatment Plant Improvements

Northern Beaches Capacity Increase Study

Prepared by

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Tampa, Florida, 33646

In association with

WATEK Engineering Corporation
12122-B Heritage Park Circle
Silver Spring, MD, 20906

CERTIFICATION

I hereby certify that this Northern Beaches Expansion Study Report, prepared for the Dare County, North Carolina, Water Department, was prepared by me or under my direct supervision.

Signed, sealed and dated this 16th day of May, 2012

NORTH CAROLINA PROFESSIONAL SEAL 12532 ENGINEER IAN CHARLES WATSON

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Prepared for :

**Dare County Regional Water System,
Manteo, North Carolina**

May 14, 2012

Prepared by

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1. EXECUTIVE SUMMARY

1.0. Demand Forecast-2030

A demand forecast though the year 2030 was developed to assist in the location of the required water treatment plant expansion, and the capacity required. Expansion could take place either at the North RO plant (NRO) or at the Skyco plant on Roanoke Island. The forecast was made using data obtained from the planning agencies within Dare County, and historic records of pumpage from each facility provided by the Dare County Water Department.

As a summer resort destination, the northern beaches highest demand is during the four months of June through September, with peaks traditionally occurring over Memorial Day weekend, July 4th weekend, the month of August, and Labor Day weekend. For the NRO, Peak months have occurred with a demand of over 6.0 MGD since 2005. The economic slowdown in recent years has lowered the demand somewhat, but the starting in 2010, an upward trend has been occurring.

The Skyco demands have been relatively constant over this same time period, but the addition of North Roanoke Island and Wanchese to the County's system on the island is predicted to add as much as 1.0 MGD to the demand from the facility.

Table 1.1 below shows the population projection for 2030, together with the projected demand from each plant. An average daily demand for the summer months was established from County records, and applied to population projection to yield a projected daily demand.

Table 1-1. Estimated Dare County water demand in 2030

Water Demand	Skyco Service Area	NRO Service Area	Total Service Area
Peak population in 2010			121362
Water Demand per Capita in 2010 (gpcd)			73.5
Projected Population in 2030	77724	85840	163564
Estimated Water Demand in 2030 (MGD)	**5.7**	**6.3**	**12.0**

It can be seen from this table that 5.7 MGD will be required from Skyco, and 6.3 MGD from the NRO. As will be discussed later, the Skyco demand for the purposes of this study was set at 6.0 MGD, and the same for the NRO.

1.1. NRO Options

There are five options for expanding NRO that are covered in this report. Two of the options examined would expand the NRO by 2.0 MGD, and three options are for an expansion of 1.0 MGD. In addition to standard 8"diameter membranes, the possibility of using 16" diameter, or large format membranes has been included. Use of these membranes reduces the foot print of the skid, allowing for a 1.0 MGD skid to be located in the existing train 6 position, without the need to modify or replace the wooden office structure in the process room.

For the other three options, standard membranes were assumed, and two of the options would require that the wooden office structure be demolished and replaced. The third 1.0 MGD option, which does not require office structure work, is to replace the original three RO trains, with new trains of increased capacity. This option was offered since these three trains are reaching the end of their useful life, particularly in regards to the pressure vessels, which are now obsolete, and the train piping which has become a source of constant maintenance by the staff. These trains can be replaced, and the capacity increased to 1.33 MGD each without the need to replace the RO feed pumps.

Finally, an expansion of 2.0 MGD at NRO will require that the arsenic treatment system be expanded to its final capacity. By adding 1.0 MGD now, this significant capital expense can be deferred for several years.

1.2. Skyco Options

The Skyco plant treats well water with ion exchange to reduce the hardness, and to remove the organic precursors to trihalomethanes and halo-acetic acids, which are referred as a class as disinfection byproducts (DBPs) The design capacity of this treatment process is 5.0 MGD, but continuous operation at this capacity has some operational drawbacks, particularly as regards the consistency of the DBP precursor removal. An optional process is nanofiltration, a membrane process similar to RO, but one that operates at much lower pressure, and which performs a similar function to the existing treatment. This process has been used extensively in Florida for over 20 years for softening and DBP precursor removal.

There is also an option at Skyco to use brackish water RO, similar to NRO, using a deeper brackish aquifer. Some initial testing has been completed, and the potential exists for this to be a viable source of raw water. What still remains is for a full scale aquifer test to be conducted to determine the safe yield of the aquifer, and the long term impact of pumping on the water quality that wells using this source would produce. Brackish water options for Skyco are considered in this report, but with the codicil that no firm decision on capacity can be made without the aquifer testing described above being completed.

The preferred option for Skyco is therefore the construction of a new NF membrane facility designed to accommodate brackish water RO in the future, should this source prove to be viable. It is also a recommendation of this study that pilot testing be conducted ahead of engineering design, to examine the performance of NF membranes with this water source. Either 10 MGD or 2.) MGD can be built initially, with the ultimate goal of replacing the ion exchange treatment facility in its entirety. However, to supply 2.0 MGD while the ion exchange plant is still operational, and to provide for the expanded service from the Skyco plant, a new well will be required to provide the necessary volume of feed water to both plants.

2. FUTURE WATER DEMAND

2.1 Introduction

To fully evaluate the optimum solution as to where to locate the proposed expanded capacity for the Northern Beaches service area, it was first necessary to determine with as much accuracy as possible the expected future water demands to the year 2030. The North RO plant (NRO) at Kill Devil Hills serves the Towns of Kill Devil Hills, Kitty Hawk, Southern Shores and Duck, as well as the County's customers. Skyco provides water to the Towns of Manteo, Nags Head, and the southern part of Kill Devil Hills, as well as an expanded County customer base on Roanoke Island's north end and for the first time this year the village of Wanchese. Using historical water usage data, land use data, and population projections gathered from the County and Towns' planning departments, the water demand for the planning period was generated.

Water from Skyco reaches Nags Head and Kill Devil Hills through a 24" subaqueous pipeline crossing Albemarle Sound between Roanoke Island and the beaches. The capacity of this pipeline was evaluated as part of this study to assess the option of 2.0 MGD expansion located at Skyco, and to confirm the infrastructure could handle the additional demand without major modifications.

2.1 Water System Description

Dare County Water Department operates two Water Treatment Plants (WTPs) to provide public water supply to the Northern Beaches, the Skyco WTP and North RO WTP.

2.1.1 The Skyco WTP

The Skyco WTP with a capacity of 5.0 MGD was constructed in 1979 and it is located in central Roanoke Island. Three transmission mains from Skyco WTP serve the Town of Manteo and the County customers of unincorporated Dare County together with the Towns of Nags Head and the south part of Kill Devil Hills. Finished water from the Skyco WTP is stored in a new 2.0 MG concrete ground storage tank, with a typical operating range of elevations from 12 feet to24 feet and a high water elevation of 25.8 feet.

A pump station serves two functions, pulls water from the ground storage tank and is equipped with two sets of duplex pumping systems.

Pumps No. 1 and No 2 serve as the primary transmission pumps from the Skyco WTP to the northern beaches through the 24-inch subaqueous pipe under Albemarle Sound. This pipe supplies Nags Head at the Gull Street station, and also goes to the Kill Devil Hills station at 8th Street. Each pump is rated for 125 horsepower, with a two-speed 480 volt motor.

Pumps No. 5 and No. 6 serve as the primary distribution pumps from the Skyco WTP to customers located on Roanoke Island. Each pump is rated for 100 horsepower, with a 480-volt motor. These pumps deliver water to a tee just outside the Skyco WTP, where water can either fill both elevated storage tanks or pump directly to the distribution system. When the pumps are not running, finished water is supplied by gravity from elevated storage to the Roanoke Island/Manteo service area. Based on distributed water data approximately 17% of water production is supplied to Roanoke Island and 83% is supplied to North Beaches. A schematic of the tank configuration and service area of the Skyco WTP is shown on Figure 2-1

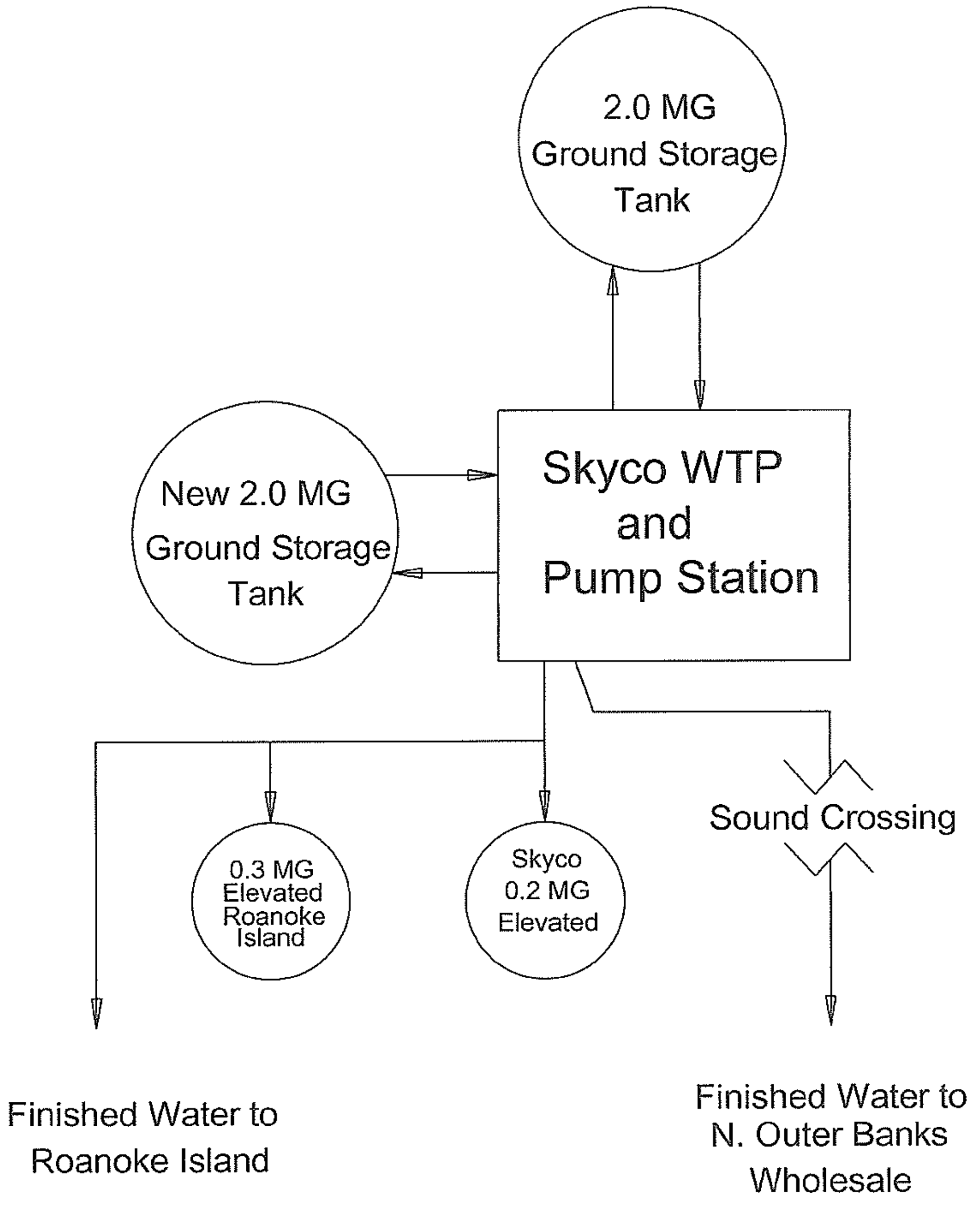


Figure 2-1 Skyco Distribution System

2.1.2 North RO WTP

The North Reverse Osmosis water treatment plant (NRO) was placed into operation in August 1989. NRO was designed for the ultimate installation of 8 brackish water RO units, for a combined capacity of 8.0 MGD. Finished water from the WTP is stored in two 5.0 MG ground storage tanks. A schematic of NRO water distribution is shown in Figure 2-2.

The Towns of Duck, Southern Shores and Kitty Hawk are retail customers of the Dare County water department. Dare County also "wholesales" water to the Towns of Nags Head, Kill Devil Hills and Manteo. Wholesale refers to the "rate" at which the wholesale customers pay for water vs. the rate that Dare County residential and commercial "retail" customers pay for the water they receive within the County's distribution systems. According to an existing Water Agreement between the County and the Towns of Nags Head and Kill Devil Hills, the Towns are entitled to receive 3.5 MGD and 3.0 MGD water respectively.

NRO does not have a high service pumping system. There are three transmission pumps that take water from ground storage, delivering to the Town of Kill Devil Hills ground storage, and to the County's ground storage tank in Kitty Hawk. The pumping station at the Kitty Hawk tank distributes water to the area north, serving County customers and the Towns of Kitty Hawk, Southern Shores, and Duck. A 1.0 MG elevated storage tank is located at Duck.

The NRO has the capability of taking water from the transmission main that originates at Skyco. However, this capability is rarely used, and the water leaving NRO mainly flows north. There is an interface between Skyco water and NRO water that occurs between 8th Street and NRO. The location of this pumping

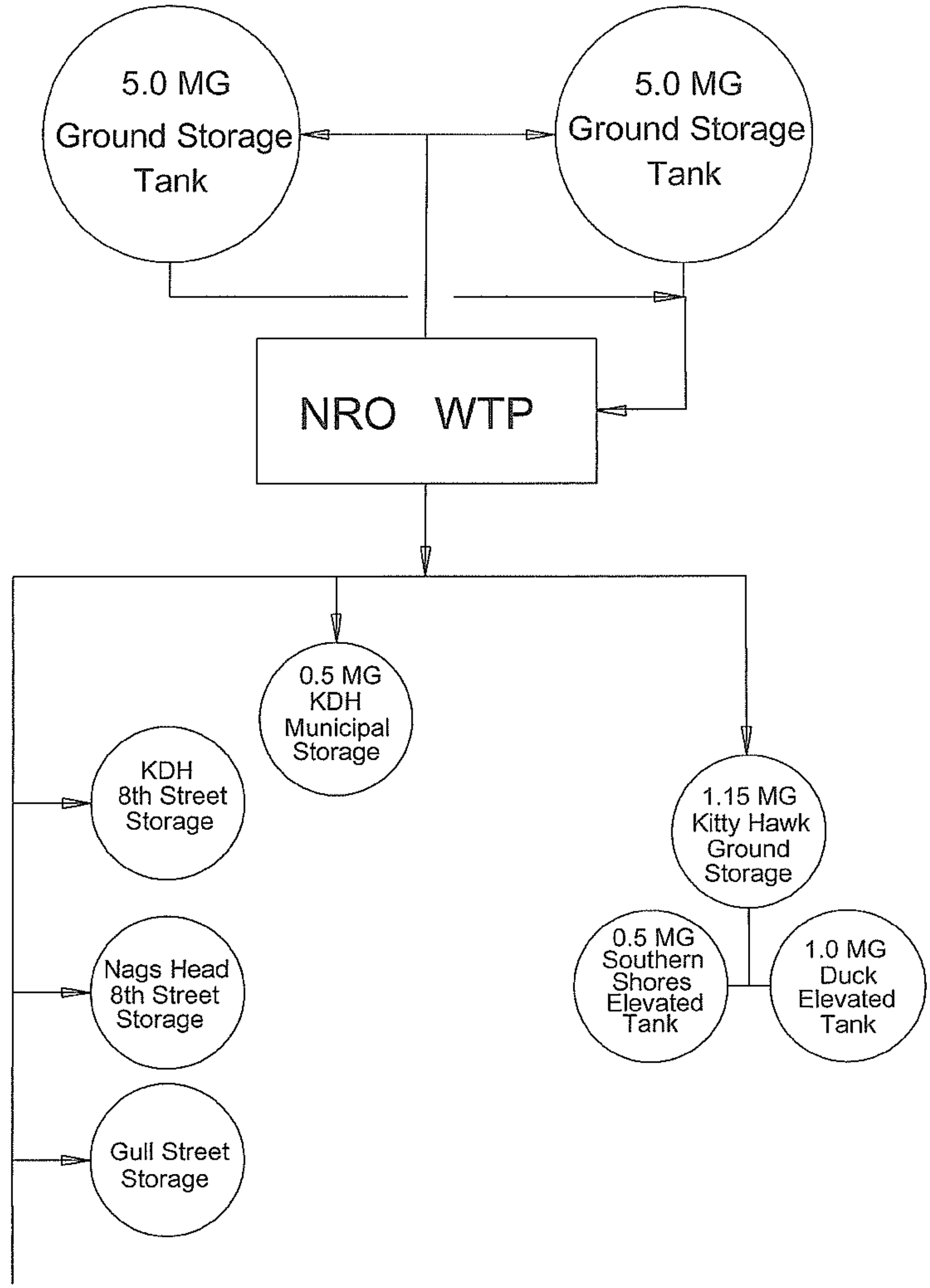


Figure 2-2 NRO Transmission System

interface varies depending on the relative rates from Skyco and NRO, and the volume of water taken by Nags Head and Kill Devil Hills at the 8th Street location

2.2 Future Water Demand Projection

To forecast water demand over twenty years for the Dare County Service area, population projection for the six towns has been estimated in Tables 2-1 and 2-2 for peak season and year-round population. Since there are no separate projection data for each town, populations have been estimated based on Dare County population projections. Peak season population projections information has been obtained from each town's planning department.

Table 2-1. Year-Round Population Projection for Dare County Service Area

	1999	2000	2009	2010	2020	2030	% of County
Town of Nags Head	1838	2700	3058	3176	3718	4183	8.7
Town of Manteo	991	1052	1471	1479	1732	1949	4.0
Town of Southern Shores	1447	2201	2621	2602	3046	3428	7.1
Town of Kitty Hawk	1937	2991	3315	3435	4022	4525	9.4
Town of Kill Devil Hills	4238	5897	6826	7115	8329	9371	19.4
Town of Duck		448		550	644	722	1.5
Subtotal				18358	21491	**24179**	50
Dare County (total Population)	**22746**	**29967**	**34296**	**36681**	**42940**	**48315**	

Table 2-2 Population Projection over 20 years (2030)

	Seasonal population	Year-round population	Total
Manteo (Incorporated + Unincorporated)		1949	9435
Wanchese			2842
New Roanoke Island Customers			2000*
Nags Head	28294	4353	32647
Kill Devil Hills	56229	9371	65600
Southern Shores	12005	7120	19125
Duck	24116	749	24865
Kitty Hawk	4525	4525	9050
Skyco Service Area			**77724**
NRO Service Area			**85840**
Total Dare County Service Area			**163564**

*Rough Assumption

Distributed water data for the NRO and Skyco plants are shown in Figure 2-3. Water demand over the 20 year period is estimated based on peak distributed water from the Skyco and NRO plants in July and the peak population in service area. Peak distributed water in July 2010 was divided by the estimated peak population of the service area to get the water demand (per capita) for 2010 which has been estimated to be 73.5 gallon/day. The calculated water demand per capita in 2010 was then used to estimate the water demand in 2030 for the Dare County service area. A summary of results is shown in Table 2-3.

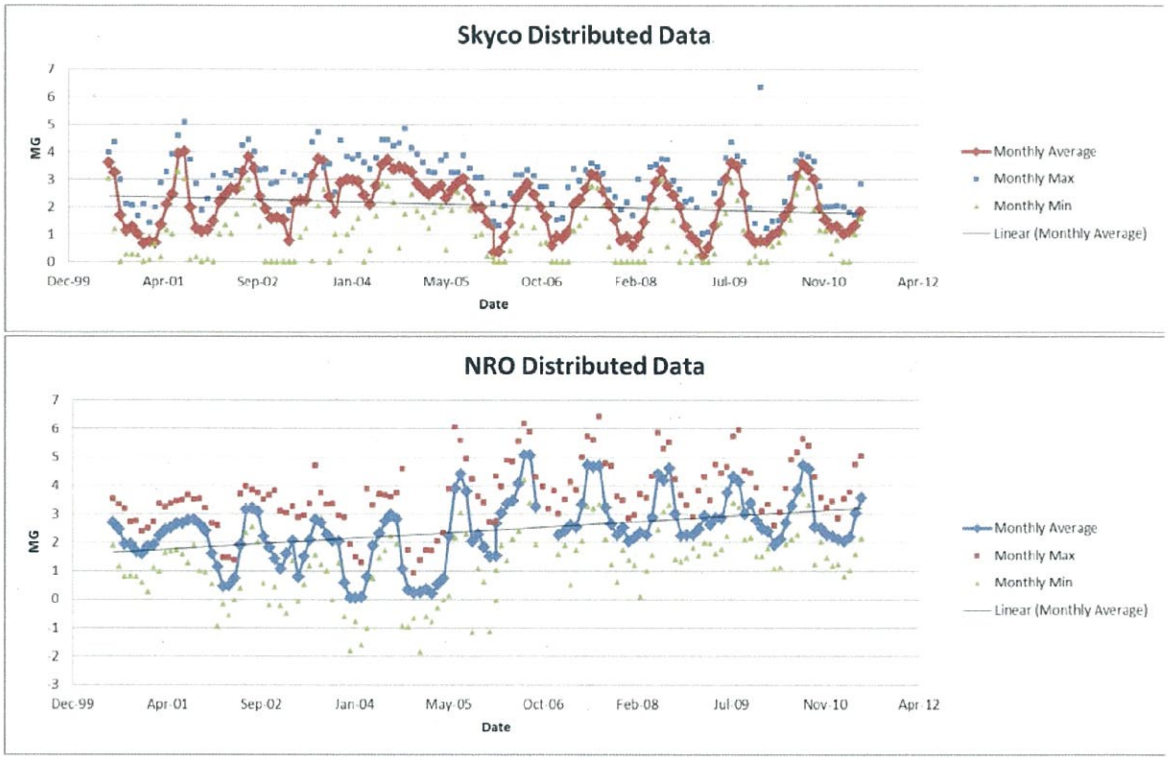


Figure 2-3. Distributed water data

It was assumed that the Skyco plant service area includes the Town of Manteo, the north unincorporated areas and Wanchese and the Towns of Nags Head and approximately half of Kill Devil Hills. The NRO plant serves the Towns of Duck, approximately half of Kill Devil Hills, Kitty Hawk and Southern Shores, and Dare County's customers north of the NRO plant, and Colington, which has its own pump station at the NRO Plant.

Table 2-3. Estimated Dare County water demand in 2030

Water Demand	Skyco Service Area	NRO Service Area	Total Service Area
Peak population in 2010			121362
Water Demand per Capita in 2010 (gpcd)			73.5
Projected Population in 2030	77724	85840	163564
Estimated Water Demand in 2030 (MGD)	**5.7**	**6.3**	**12.0**

2.3 Plant Capacity Evaluation

Based on population projection estimates, the estimated peak population of the Dare County service area will be 162,940 in 2030. The detail of this estimate is shown in Table 2-2. The estimated water demand based on the 73.5 gallons per capita per day will be 12 MGD of which more than 70% is indicated to be produced by the NRO plant. The current combined design capacity of Skyco and NRO is 10 MGD. To meet the estimated 2030 peak demand during the summer months, an additional 2.0 MGD must be added to the current treatment plant capacity.

2.4 24-Inch Pipeline Hydraulic Evaluation

Hydraulic analysis was performed for 24 inch ductile iron pipe sound crossing which connects the Skyco plant to the northern beaches. The length of pipe from Skyco water plant to Nags Head ground storage tank was estimated to be 26,340 ft based in aerial maps.

If a velocity of 5 feet per second is used, the theoretical capacity of this pipeline (if similar to new condition) would be approximately 10 MGD.

Based on recent pumping records, approximately 83% of produced water from the Skyco water plant goes to the northern beaches through the sound crossing. If the future demand is assumed to in the same proportion, the future water demand for Skyco water at Nags Head (Gull Street) and Kill Devil Hills (8th Street) will be 4.75 MGD which equals approximately 3300 gpm.

Utilizing a smooth pipe similar to new and a friction factor of (C=100) and a flow of 5.5 MGD, the total friction losses in this pipeline would be approximately 45 feet.
However if an aged pipe with a friction factor of (C=80) is used, and 15% reduction in pipe diameter is used due to tuberculation and scale buildup, the resulting friction factor would be 165 feet, or an additional 120 feet (52 psi) pressure to pump the same flow . This results in pumping electricity cost increase of approximately $100,000 per year, if 10 cents per KWH power cost is used.

Due to age of this pipeline and possible corrosion, tuberculation and scale buildup, it is recommended to further investigate rehabilitating this critical pipeline, such as slip lining to increase the reliability and add to its useful life.

Slip-lining is used to repair leaks and restore structural stability to an existing pipeline. This method involves installing a smaller, "carrier pipe" into a larger "host pipe", grouting the annular space between the two pipes, and sealing the ends. This technique has been used since the 1940s. The most common material used to slip-line an existing pipe is high density polyethylene (HDPE), but fiberglass reinforced pipe (FRP) and PVC are also common. Typically reduction of the internal pipe diameter is offset by smooth surface of new non-metallic pipe and resulting in approximately same hydraulic carrying capacity. The combination of new pipe, grout and the old host pipe has a superior structural integrity which significantly adds to the infrastructure reliability and expected life as compared to the old metallic pipe alone.

It is recommended that the County conduct a detailed engineering study, designed to establish the condition and remaining useful life of the sub-aqueous crossing A detailed investigation, survey and closed circuit TV inspection would be required to assess the pipeline condition and prepare realistic budget cost estimates for the slip-lining option. As part of this study, the County should also investigate the option of replacing the crossing, in the event that the study results indicate that it is necessary. Options for replacement include a bottom-resting pipeline similar to the existing, and a directionally bored option which would bury the pipe. Based on theoretical slip-lining cost formulas, with very limited data, the cost is estimated to be in the $4M to $5M range.

3. NORTH RO PLANT OPTIONS

3.1 Introduction

The North Reverse Osmosis (NRO) treatment plant is located in Kill Devil Hills. It was commissioned in 1989 with an installed capacity of 3.0 million gallons per day (MGD). Since that time the plant has been expanded with the installation of two additional treatment trains of 1.0 MGD each for a total production capability of 5.0 MGD of combined permeate and raw water bypass blend. The process building was designed to accommodate eight (8) RO trains of equal capacity for a total production of 8.0 MGD from this facility.

Subsequent to the completion of the first phase of the project, a two story interior structure was built in the northeast corner of the process room. Figure 3-1 shows the location and dimension of this structure relative to the locations reserved for RO Trains 6, 7 and 8. It can be seen that even Train 6 cannot be installed without modifying or removing the interior structure. Two additional trains can be accommodated by changing their orientation from North-South to East-West. While re-orienting the trains is possible, to do so would involve the relocation of embedded conduits that are located to provide 120 V power and 4-20 mA control wiring to and from the RO trains. A possible alternative would be to plug the existing conduits, and run new conduits overhead from the electrical room. Rotating the trains will also involve significant piping modifications, particularly for the permeate and concentrate connections.

The interior structure will eventually require the modification of the transmission pumping system. The system was designed originally for four (4) horizontal centrifugal pumps arranged in two pairs. The locations are shown in Figure 3-1, which also shows the pre-

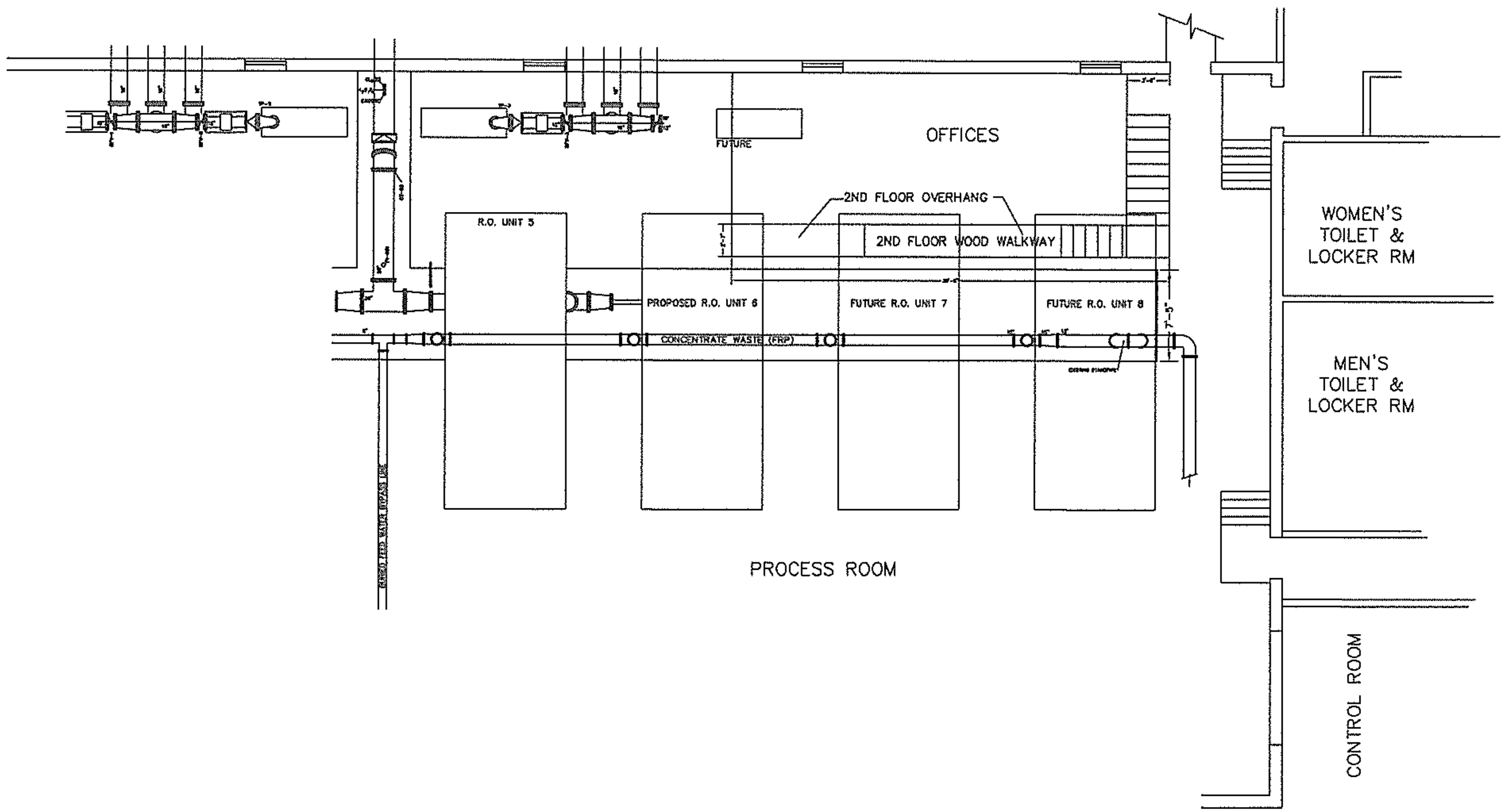


FIGURE 3-1 PROCESS ROOM PLAN EAST END

installed suction and discharge piping. It is clear that a fourth horizontal pump would be impossible to install with the current office structure. To install this pump without removing or significantly modifying the structure would require substantial piping changes, and the probable use of a vertical pump.

Removing the existing office and storage structure and replacing it with a similar structure built against the east wall of the process room (Figure 3-2) would open up the space currently occupied by the structure, including the location for the fourth transmission pump, and would continue to provide useful office and storage space for the County's use. Trains 6 and 7 could then be installed as planned, but there would be no space for Train 8, since the concentrate stand-pipe will need to be relocated to the west into the footprint of Train 8. However, given the future population forecasts in Section 1, it is clear that the need for Train 8 is beyond the practical planning horizon, and in fact Train 8 may never be required.

3.2 Expansion Options

Five options are considered for expansion at the NRO. These are based on increasing the production capacity by 1.0 MGD or 2.0 MGD, with either standard 8" membrane systems or large format (16") membrane systems.

- 2 MGD required

  Option 1. 2 trains of 1 MGD each (0.95 MGD plus blend, with 8" membranes

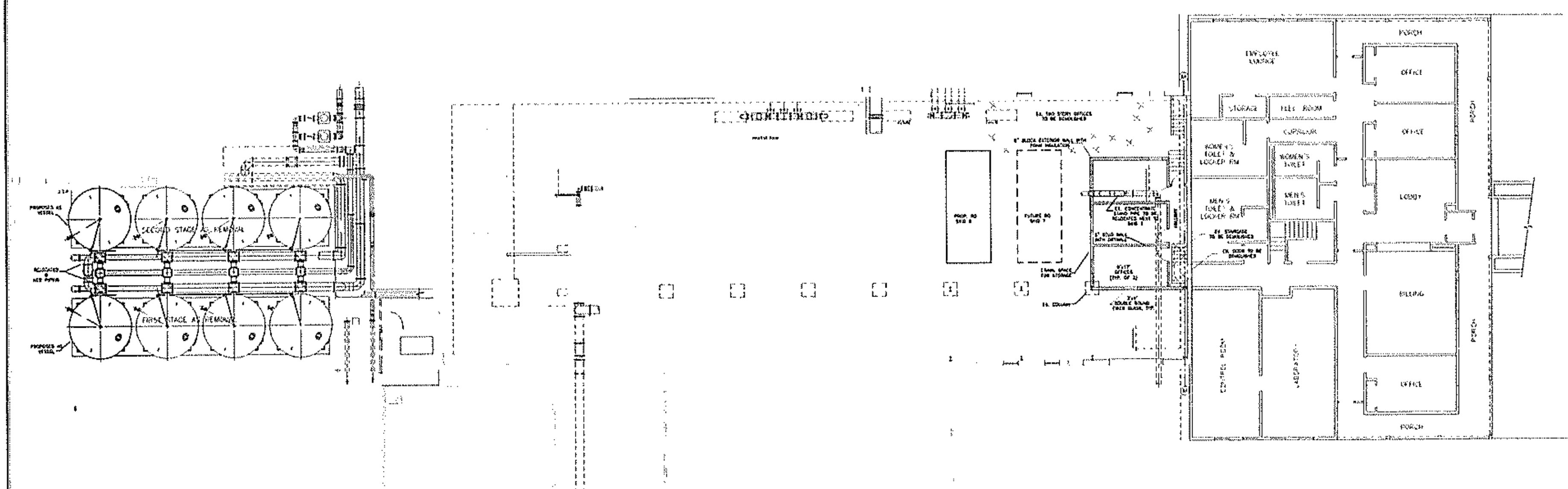
  Option 3. 2 trains of 1 MGD each (0.95 MGD plus blend, 16" membranes)

- 1 MGD required

  Option 2. 1 train of 1 MGD (0.95 MGD plus blend, with 8" membranes)

  Option 4. 1 train of 1 MGD (0.95 MGD plus blend, 16" membranes)

  Option 5. Increase capacity of Trains 1-3



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DETAILED	SSY
CHECKED	BRM
APPROVED	BRM
DATE	DEC. 2011

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NO.	DATE	REVISION	BY	CK

N RO PLANT UPGRADE
CONCEPTUAL LAYOUT

SCALE: 3/32" = 1'

XXXXX

SHEET X OF X

Large format membranes were considered only because the smaller footprint available with this configuration would allow two trains totaling 2 MGD to be installed in the footprint of a single 8" train. By making the arrangement back to back, (Figure 3-3) the 16" membrane option can provide 2 MGD of expansion capacity within the footprint of a single 1 MGD 8" skid, since the vessel length is the same for both membrane sizes. However, the County has no experience with the large format membranes, and installation of one or two trains using this approach may require a significant modification to the existing cleaning system, would require specialized equipment for loading and unloading, and would place the county in the position of replacing two different kinds of membrane.

3.2.1 Option 1. 2.0 MGD Expansion with 8" Elements

Trains 6 and 7 cannot be installed in the planned design location without demolition of the interior office structure. Train 6 could be installed in the space allocated, but there would be no space for membrane loading and unloading at the north end of the train.

Without demolition of the office structure, the trains will have to be rotated 90°, so that they are oriented East-West. This will require some trench piping modifications.. The existing permeate piping would be modified to accommodate all trains on the east side of the tee, as would the concentrate piping. The concentrate standpipe would also require modification, since its current location would interfere with membrane loading or unloading for some of the vessels.

For rotated trains, the pre-installed train electrical conduits will need to be relocated, or abandoned and re-run from the electrical room overhead. Both Train 6 and 7 would require extended feed water piping from the pre-planned pump locations to the feed inlet manifolds.

In addition to the two additional trains, together with the pumps, piping, cartridge filters and electrical and controls required for complete installation, the post-treatment arsenic removal system would need to be completed with the addition of two vessels, and associated piping and walkway.

Table 3-1. Probable Cost for 8" Expansion of 2.0 MGD, including Arsenic Expansion

Item	Number	Description	Cost
RO Unit	2	RO unit, 950,000GPD permeate, 8" membrane vessels, 20:10 array, train mounted PLC, interstage energy recovery and pressure boost.	$ 1,010,000
Membranes	360	Assume $600/element	$ 216,000
RO feed pump	2	Vertical turbine, T head, 316L stainless steel, 316L statinless steel can, babbitted carbon bushings, 250hp 480V, 3Φ, 60Hz	$ 265,600
Cartridge filter	1	Same as installed	$ 22,474
CF steps	1 lot	Same as Installed	$ 5,000
Arsenic vessels	2	Same as installed with media and valves	$ 601,300
SS piping	1 lot	Extend vessel piping system to accommodate new vessels	$ 54,000
Walkway	1 lot	Extend existing grated walkway	$ 16,000
RO Off skid piping	1 lot	316L SS and Sch80 PVC	$ 25,000
VFD	2	Square D Altivar 61 250hp	$ 75,000
Wire and conduit	1 lot	MCC to VFD, VFD to RO puimp. Instrument and valve power 4-20mA cabling	$ 65,000
Control system modifications	1 lot	Add I/O, connections, reprogramming	$ 35,000
Misc concrete	1 lot	RO skid supports, pump base, cartridge filter base, etc.	$ 15,000
Installation Labor	1 lot	6 months at 6 men crew. @ $ $65.00/hour	$ 374,400
		ROEM personnel	$ 120,000
Interior Office		Remove and reconstruct existing office space	$ 150,000
		Subtotal	$ 3,049,774
Contractor O/H		assumed 20%	$ 609,955
Contractor profit		assumed 5%	$ 152,489
		Subtotal	$ 3,812,218
Contingency @ 15%			$ 571,833
		Total Estimated installed cost	**$ 4,384,050**

However, if the existing office space is relocated as discussed above, both trains 6 and 7 can be located as originally planned, which would reduce the cost of the installation, but would require an additional cost for demolition of the existing structure, and construction of the new structure.

3.2.2 Option 2. 1.0 MGD Expansion with 8" Elements.

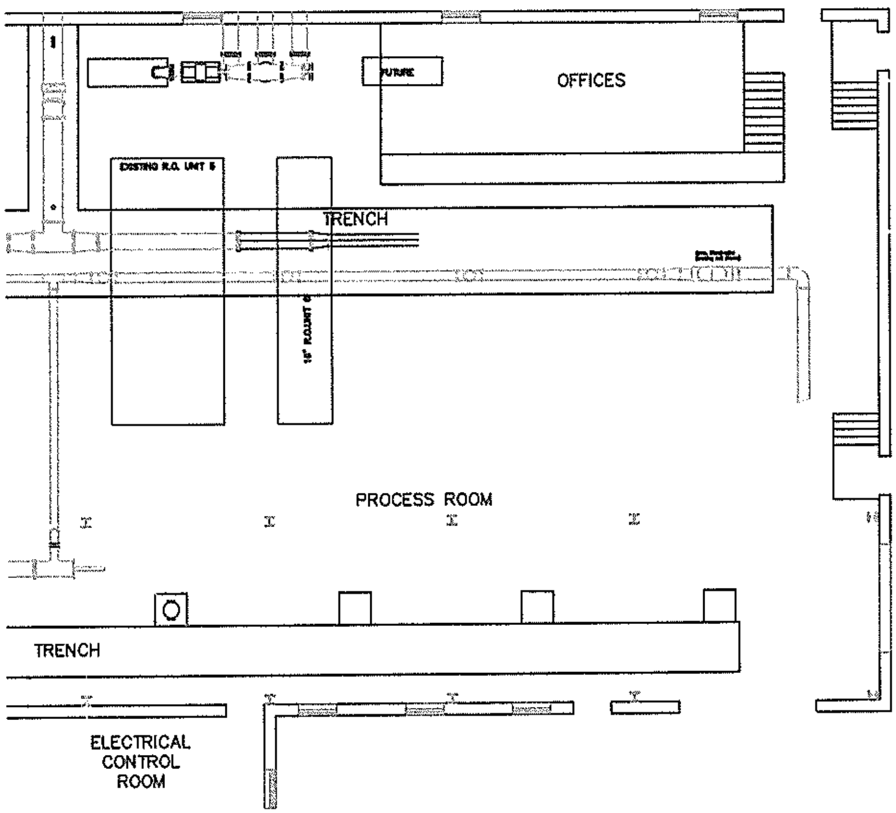
Expanding the NRO capacity by 1.0 MGD, with the remaining 1.0 MGD expansion at Skyco will not require the completion of the arsenic removal post-treatment system.. Installation of Train 6 in its pre-planned location will require the demolition or modification of the existing office structure.

Table 3-2. Probable Cost for 8" Expansion of 1.0 MGD.

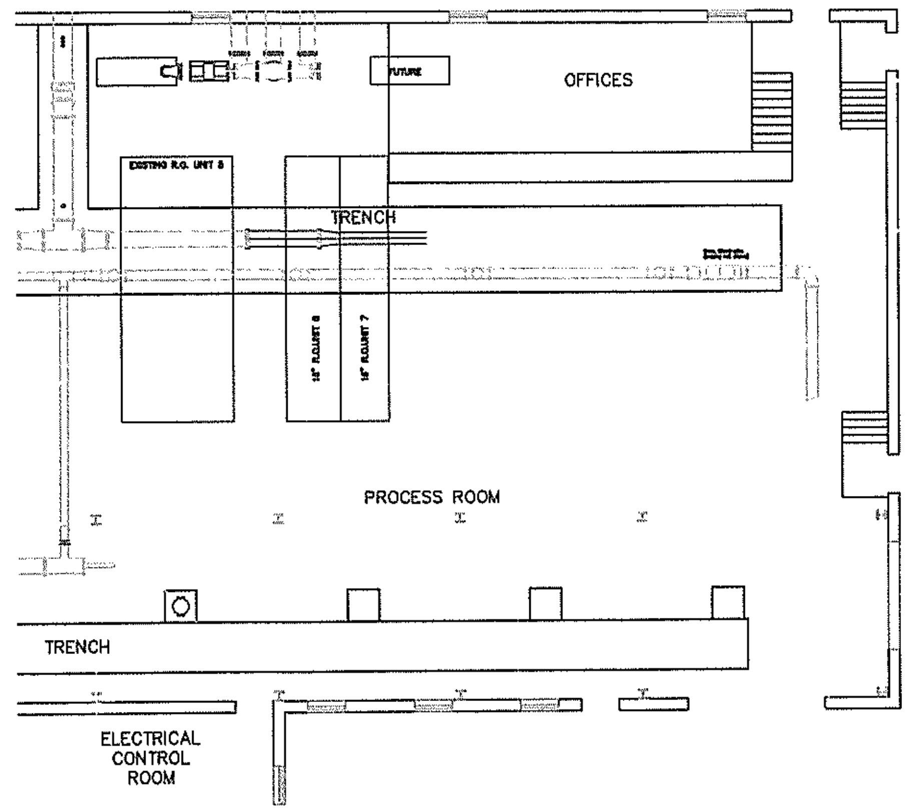
Item	Number	Description	Cost	Source
RO Unit	1	I RO unit, 950,000GPD permeate, 8" membrane vessels, 20:10 array, train mounted PLC, interstage energy recovery and pressure boost.	$ 525,000	Quote
Membranes	180	Assume $600/element	$ 108,000	Est.
RO feed pump	1	Vertical turbine, T head, 316L stainless steel, 316L statinless steel can, babbitted carbon bushings, 250hp 480V, 3Φ, 60Hz	$ 132,800	Quote
Cartridge filter	1	Same as installed	$ 22,474	Quote
Off skid piping	1 lot	316L SS and Sch80 PVC	$ 10,000	Est.
VFD	1	Square D Altivar 61 250hp	$ 37,500	Est.
Wire and conduit	1 lot	MCC to VFD, VFD to RO puimp. Instrument and valve power 4-20mA cabling	$ 35,000	Est.
Control system modifications	1 lot	Add I/O, connections, reprogramming	$ 20,000	Est.
Misc concrete	1 lot	RO skid supports, pump base, cartridge filter base, etc.	$ 15,000	Est.
Installation Labor	1 lot	4 months at 6 men crew. @ $ $65.00/hour	$ 249,600	Est.
		ROEM personnel	$ 80,000	
Interior Office		Remove and reconstruct existing office space	$ 150,000	
		Subtotal	$ 1,385,374	
Contractor O/H		assumed 25%	$ 346,344	
Contractor profit		assumed 5%	$ 69,269	
		Subtotal	$ 1,800,986	
Contingency @ 25%			$ 450,247	
		Opinion of Probable Installed cost	**$ 2,251,233**	

3.2.3. Option 3. 2.0 MGD Expansion with 16" Elements.

As shown in Figure 3-3, a single 16" structure containing two 1.0 MGD units will fit the footprint currently reserved for Train 6. However, the existing office structure must be demolished for the space to be available at the north end of the trains for membrane loading and unloading. Some modification of the trench piping



Showing 1 train of 1.0MGD with 16" elements.



Showing 2 trains of 1.0MGD each with 16" elements.

Figure 3–3

would be required to relocate the existing permeate and concentrate connections. For a 2.0 MGD expansion, all of the modifications and additions required for a standard 8" expansion will be required.

By selecting a 16" configuration, the space remaining, originally designated for Trains 7 and 8, can be utilized for a similar type of arrangement, turned east-west, allowing an increase in the buildings capacity to 9.0 MGD. This arrangement is shown in Figure 3-4.

Table 3-3. Probable Cost for 16" Expansion of 2.0 MGD with Arsenic Expansion

Item	Number	Description	Cost	Source
RO Unit	2	I RO unit, 950,000GPD permeate, 16" membrane vessels,5:3 array, train mounted PLC, interstage energy recovery and pressure boost.	$ 975,000	Quote
Membranes	96	Assume $2500/element	$ 240,000	Est.
RO feed pump	2	Vertical turbine, T head, 316L stainless steel, 316L statinless steel can, babbitted carbon bushings, 250hp 480V, 3Φ, 60Hz	$ 265,600	Quote
Cartridge filter	1	Same as installed	$ 22,474	Quote
CF steps	1 lot	Same as Installed	$ 5,000	Est.
Arsenic vessels	2	Same as installed with media and valves	$ 601,300	Quote
SS piping	1 lot	Extend vessel piping system to accommodate new vessels		
Walkway	1 lot	Extend existing grated walkway		
Waste piping	1 lot	Modify existing DIP waste piping		
RO Off skid piping	1 lot	316L SS and Sch80 PVC	$ 25,000	Est.
VFD	2	Square D Altivar 61 250hp	$ 100,000	Est.
Wire and conduit	1 lot	MCC to VFD, VFD to RO puimp. Instrument and valve power 4-20mA cabling	$ 65,000	Est.
Control system modifications	1 lot	Add I/O, connections, reprogramming	$ 35,000	Est.
Misc concrete	1 lot	RO skid supports, pump base, cartridge filter base, etc.	$ 30,000	Est.
Installation Labor	1 lot	6 months at 8 men crew. @ $ $65.00/hour	$ 539,760	Est.
		ROEM personnel	$ 120,000	Quote
Interior Office		Remove and reconstruct existing office space	$ 150,000	
		Subtotal	$ 3,174,134	
Contractor O/H		assumed 20%	$ 634,827	
Contractor profit		assumed 5%	$ 158,707	
		Subtotal	$ 3,967,668	
Contingency @ 15%			$ 595,150	
		Opinion of probable installed cost	**$ 4,562,818**	

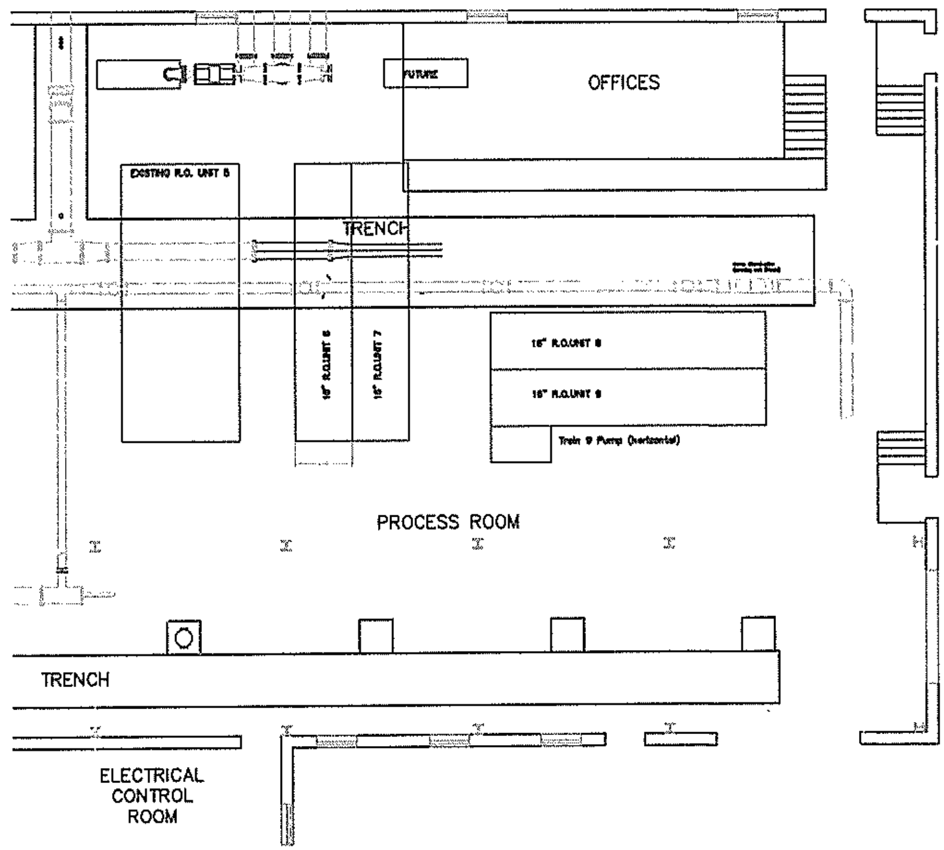

OFFICES
FUTURE
EXISTING R.O. UNIT 5
TRENCH
16" R.O.UNIT 6
16" R.O.UNIT 7
16" R.O.UNIT 8
16" R.O.UNIT 9
Train 9 Pump (horizontal)
PROCESS ROOM
TRENCH
ELECTRICAL
CONTROL
ROOM

Figure 3–4

3.2.4. Option 4. 1.0 MGD Expansion with 16" Elements

A 1.0 MGD expansion can be accomplished by using one half of the back to back 16" membrane arrangement described in 3.2.3 above. This installation will require one pump and VFD, cartridge filter, and associated piping, valves, electrical and controls modifications, and is the only "new train" option for NRO that does not require the removal and replacement of the existing office structure.

As with the 8" option for 1.0 MGD, the completion of the arsenic post treatment system and the transmission pumping system will not be required. As with the 2.0 MGD 16" expansion, the potential exists for increasing the plant capacity from its current 8.0 MGD limit to 9.0 MGD. e.

Table 3-4. Probable Cost for 16" 1.0 MGD Expansion.

Item	Number	Description	Cost	Source
RO Unit	1	RO unit, 950,000GPD permeate, 16" membrane elements, 5:3 array, train mounted PLC, interstage energy recovery and pressure boost.	$ 487,500	Quote
Membranes	48	assume $2500/element	$ 120,000	Est.
RO feed pump	1	Vertical turbine, T head, 316L stainless steel, 316L statinless steel can, babbitted carbon bushings, 250hp 480V, 3Φ, 60Hz	$ 132,800	
Cartridge filter	1	Same as installed	$ 22,474	Quote
Feed piping	1 lot		$ 10,000	Est.
VFD	1	Square D Altivar 61, 250hp	$ 37,500	Est.
Wire and conduit	1 lot	MCC to VFD, VFD to RO pump, Instrument and Valve power, 4-20mA cabling	$ 35,000	Est.
Control system modifications	1 lot	Add I/O, connections, reprogramming	$ 20,000	Est.
Misc concrete	1 lot	RO skid supports, pump base, cartridge filter base, etc.	$ 10,000	Est.
Installation Labor	1 lot	4 months, 6 man crew. @$65.00/hour	$ 249,600	Est.
		ROEM personnel	$ 80,000	
		Subtotal	$ 1,204,874	
Contractor O/H		assumed 20%	$ 240,975	
Contractor profit		assumed 5%	$ 60,244	
		Subtotal	$ 1,506,093	
Contingency @ 15%			$ 225,914	
		Opinion of Probable Installed Cost	**$ 1,732,006**	

3.2.5 Option 5. Increase Capacity of Trains 1-3.

The three original trains installed in the NRO plant went into operation in 1989. Originally equipped with Fluid Systems low pressure RO membranes in a 21:9 array, the increase in feed water TDS required a membrane change and the addition of 5 pressure vessels. These vessels are not the same design as the original 30 vessels, and both types are now obsolete. The painted steel frame, the vessels, and the train mounted instruments, many of which have been replaced over the 23 year life of the equipment, require constant attention and maintenance by the plant staff.

With the number of vessels that can be mounted on the frame, it is possible to increase the capacity of each train by 330,000 gpd. New vessels, and interconnecting piping would be required, and the existing vertical turbine feed pumps can be modified to deliver the required volume of feed water. This has been confirmed by correspondence with Afton Pump Co., the pumps manufacturer. New pump motors and cans will not be required.

By expanding these three trains, an additional 1.0 mgd can be developed in the building without the need to demolish and reconstruct the existing office space.

The interstage energy recovery turbine will be undersized for the revised larger flows. The current model is the ERI LPT-250. The next larger model, the LPTY-500 will be required for the increased capacity

Although it is possible to rebuild the existing trains, it is not recommended, due to the age of the equipment, and the requirement for all new train mounted piping. Instrumentation should also be upgraded to bring up to the standard of Trains 4 and 5. It is recommended that the existing trains be scrapped, and three new custom-designed units be installed. The County may wish to retain the three interstage energy recovery devices for use in future trains 6 and 7, should they ever be built.

To remove the existing trains and to bring in the new equipment, it will be necessary to breach the north wall of the building, and install a roll up door. The preferred location for this door would be directly opposite existing train 2.

Table 3.5 shows expected cost of completing the capacity increase with .new RO trains, and the necessary modifications to the existing RO feed pumps.

Table 3-5. Probable Cost to replace Trains 1-3.

Item	Number	Description	Cost	Source
RO Unit	3	1,330,000 GPD permeate, 8" membrane vessels, 25:12 array, train mounted PLC, interstage energy recovery and pressure boost.	$ 1,942,500	Quote
Membranes	666	Assume $600/element	$ 399,600	Est.
RO feed pump	1	Modifications to existing bowls, new impellers, seal, stuffing bearing, bowl and impeller wear rings, bowl and suction bell bearings, shaft, and shat sleeve.	$ 66,000	Quote
Off skid piping	1 lot	316L SS and Sch80 PVC	$ 10,000	Est.
Wire and conduit	1 lot	. Instrument and valve power 4-20mA cabling	$ 10,000	Est.
Control system modifications	1 lot	Add I/O, connections, reprogramming	$ 20,000	Est.
Misc concrete	1 lot	RO skid supports, etc.	$ 15,000	Est.
Labor	1 lot	Remove existing trains. I month 6 man crew @ $65/hr	$ 62,400	Est.
Labor	1 lot	Install 3 new trains. 7 months, 6 man crew @ $65/hr	$ 436,800	Est.
New O/H door	1 lot	Assume a 12' wide x 15' high	$ 20,000	Est.
		Subtotal	$ 2,982,300	
Contractor O/H		assumed 20%	$ 596,460	
Contractor profit		assumed 5%	$ 149,115	
		Subtotal	$ 3,727,875	
Contingency @ 25%			$ 559,181	
		Opinion of Probable Installed cost	**$ 4,287,056**	

3.3 Summary of NRO Option Costs

Option # and Capacity, MGD	Cost, $x1000	Office demolition	Arsenic Buildout
Option 1, 2.0 MGD, 8" elements.	4,384.1	Yes	Yes
Option 2, 1.0 MGD, 8"elements	2,251.2	Yes	No
Option 3, 2.0 MGD, 16" elements	4,562.8	Yes	Yes
Option 4, 1.0 MGD, 16" elements	1,732.0	No	No
Option 5. 1.0 MGD –Replace Trns 1-3	4,287.1	No	No

4 SKYCO OPTIONS

4.1 Introduction

The Skyco water treatment plant (WTP) is an ion exchange facility designed to reduce hardness and organic trihalomethane (THM) and haloacetic acid formation (HAA) potential (THMFP) from a shallow ground water system. THM and HAA are collectively known as disinfection byproducts (DBPs).

The water quality from this shallow aquifer is of the quality shown in Table 4-1 below..

Table 4-1. Expected Water Quality for nanofiltration Feed

Component	Concentration	Units
Calcium	63.0	mg/l
Magnesium	15.4	mg/l
Sodium	53.1	mg/l
Potassium	3.0	mg/l
Strontium	N/R	mg/l
Barium	N/R	mg/l
Iron	0.5	mg/l
Bicarbonate	292.7	mg/l
Chloride	70.0	mg/l
Sulphate	0	mg/l
Silica, as SiO2	24.4	mg/l
TDS	492.7	mg/l
Temperature	63	Deg. F
pH	7.5	
TOC	3.21	mg/l
Color	11.0	PCU

This WTP serves the Northern Beaches through a 24" subaqueous pipeline across Croatan Inlet to the Town of Nags Head. Nags Head receives this water at the Gull Street facility.

Water is also wholesaled to the Town of Manteo, and distributed to County Water System customers at the north end of Roanoke Island. In March 2012, the community of Wanchese at the South end of Roanoke Island will be connected to the County Water System, as will the expanded system for the northern part of Roanoke Island.

The options for increasing the capacity of the Skyco WTP include the development of a new brackish water treatment facility, the development of a nanofiltration facility, or a combination of the two.

Further expansion of the ion exchange treatment plant is not considered feasible, because to do so would require a significant change to the existing building, the back of which is very close to the original 2.0 MG storage tank. Expansion in this direction is not possible. Expansion to the south would be the only direction in which sufficient open space is currently available, and that area contains a significant amount of underground piping, which would require relocation. Expansion of the ion exchange treatment process would therefore be most easily accomplished with a completely new structure. In addition to the construction of a new building, much larger salt storage and brining equipment would be required. Since a new building would be also needed for the RO/NF membrane treatment option, it appears to make more sense for the County to take advantage of the opportunity to begin the conversion of the Skyco WTP from ion exchange to membrane based technology, which is used elsewhere in the County.

An additional driver is the higher capability of a membrane based system to reduce the disinfection byproduct (DBP) formation potential of the shallow groundwater. While the mixed bed ion exchange system has for the most part been successful in controlling the formation of DBP by reduction of the organic precursors, upsets have occurred from time to time, due to a variety of causes which are inherent in this type of system. Membrane based treatment systems produce much more consistent and controllable organic removal, and would produce a product with much lower DBP formation potential than the current treatment method.

An exploratory well to the Yorktown aquifer south of the Skyco site has demonstrated the availability of brackish water. The test well water quality data are shown in Table 4-2 below.

The initial exploratory work is described in the report.[1] Further testing is needed to verify the safe yield of this source, and solute transport modeling is required prior to piloting and the design of a brackish water RO facility to predict any changes in water quality over the twenty year life of the water treatment facility. However, based on the initial results, it would appear that at least a 1.0 MGD facility could be supported as an initial step.

Table 4-2. Preliminary Water Quality of the Yorktown Aquifer

Component	Concentration	Units
Calcium	11.8	mg/l
Magnesium	32.4	mg/l
Sodium	1106	mg/l
Potassium	N/R	mg/l
Strontium	0.56	mg/l
Barium	N/R	mg/l
Iron	0.17	mg/l
Bicarbonate	682.9	mg/l
Chloride	1512.0	mg/l
Sulphate	0	mg/l
Silica, as SiO2	17.9	mg/l
TDS	3428.6	mg/l
Temperature	68	Deg. F
pH	7.6	
TOC	N/r	mg/l
Color	45	PCU

Using this water quality as input to membrane projection software, a recovery of 80% is

[1] Test Well exploration of the Yorktown Aquifer beneath Roanoke Island, Dare County, North Carolina. Groundwater management Associates, Inc, Greenville, North Carolina, February 2009.

eminently feasible, with 85% being potentially achievable. The water quality is very similar in make-up to that present in the Rodanthe-Waves-Salvo plant, although the TDS is about twice as high. Permeate quality projected is about 100 mg/l TDS, consisting primarily of sodium, chloride, and alkalinity. In practice some calcium hardness would need to be added to the permeate to produce a stable, non-corrosive finished water. A typical projection is included in Appendix A.

The shallow well water can also be effectively treated by nanofiltration (NF). When the existing WTP was placed into service in the 1980, NF technology did not exist. Since the purpose of the plant was to soften the water, only lime softening of cation exchange were commercial processes available at the time. The County elected to proceed with cation exchange. In 2003, the plant was modified by the addition of a 5.0 MGD anion exchange (ANIX) system for THM and HAA precursor removal. Subsequently the County modified the ANIX system by converting to a mixed bed system, and taking the original softening system out of service. This system has operated well, but DBP formation can occasionally be problematic, and the cost of good quality salt for regeneration has increased dramatically over the past two years. These reasons, and the difficulty of effectively integrating an expansion into the current site plan as discussed previously, lead to the conclusion that with a planned expansion in mind, the first step should be to begin the replacement of the ion exchange system with nanofiltration.

Nanofiltration is a semi-permeable membrane processes that operates exactly like the RO systems that the County currently operates, but with the difference that the membranes are formulated to have rather low rejection of sodium chloride and other monovalent ions, but very high rejection for calcium, magnesium, and other divalent ions. Like RO membranes, NF membranes also are highly effective at rejecting the organic pre-cursors of DBPs. Because of the different chemistry involved in the rejection layer of the membrane, the specific flux tends to be significantly higher than RO membranes, which benefits the process by significant reduction in operating pressure, and thus energy cost.

Currently the shallow well field that provides feed water to the Skyco plant is capable of a peak output of about 6. MGD, but is more comfortably operated at 5.0 MGD. If a 1.0 MGD NF plant is built, at 85% recovery as indicated by membrane projection software, about 1.2 MGD will be required for the feed water flow. This will allow operation of the ion exchange plant at 4.0 MGD, for a total of 5.0 MGD, which is the current reliable safe capacity. Thus the addition of a 1.0 MGD NF unit to Skyco is not really an expansion of the current capacity. However, if a 1.0 MGD brackish water unit is built at the same time, the safe capacity of the Skyco plant would be 6.0 MGD.

There are some finished water quality advantages to using the this approach. Unlike brackish water RO (BWRO) membranes, which tend to be similar in terms of salt rejection, NF membranes are quite variable within one manufacturers' portfolio of products. A projection of performance of a relatively "loose" membrane is included in Appendix A

4.2 Expansion Options

Summarizing the discussion above, there are five options for the Skyco site all of which involve the construction of a new process building.

- Option 1. 1.0 MGD NF Single train. Not an expansion unless additional feed water is secured.
- Option 2. 2.0 MGD NF. Two trains of 1.0 MGD each. Will require additional feed water
- Option 3. 1.0 MGD BWRO. Will require a production well be constructed.
- Option 4. 2.0 MGD BWRO. Two trains of 1.0 MGD each. Will require a well field development to secure feed water
- Option 5. 1.0 MGD NF and 1.0 MGD BWRO

These options are discussed in more detail following.

4.2.1 Option 1. 1.0 MGD NF Single train.

This option may require additional feed water wells be constructed for it to be a true 1.0 MGD expansion of the existing Skyco capacity. While the existing ion exchange facility can process as much as 6.0 MGD if necessary, the reliable design rating is 5.0 MGD. Allowing for the water used in the process, such as for brining, backwashing and rinsing, the overall recovery is about 95%, which would require 5.26 MGD of feed water. The existing well field consists of ten wells with a total capacity of approximately 5,100 gallons per minute (gpm), or 7.34 MGD. The individual well capacities range from 420gpm to 620 gpm, with varying draw downs and specific capacities.

To operate a 1.0 MGD NF unit at 85% recovery in parallel with the ion exchange unit will require a well water flow rate of 1.18 MGD for the NF and 5.26 MGD for the ion exchange, for a total of 6.44 MGD. This could be accommodated by the existing well field with the largest capacity well, #8, out of service. Operationally it would be more prudent to have redundancy of two wells, which would then require the ion exchange plant to operate a flow rate below 5.0 MGD. However, a peak flow of 6.0 MGD would be required only for a few days during the summer, in which case well field expansion is not necessarily required immediately, but could be implemented at some later data when the requirement for peak flows extends for a longer period of time.

The use of NF to treat the shallow groundwater at the Skyco plant will result in a change in the quality of finished water distributed to the customers. NF membranes are quite variable in their rejection capabilities. For example, the NF-90 and NF-270 products offered by Dow Filmtec will produce water from the Skyco feed with a TDS of 55 mg/l and 380 mg/l respectively. (Full projections can be found in Appendix A) The latter quality is closer to that of the current finished water, and the plant would require somewhat less pressure than the tighter membrane, the NF-90, resulting in lesser energy cost to produce the treated water. Since the NF unit will run at a fixed rate, while the ion exchange plant's flow rate can be varied, using the NF-270 type of membrane will produce less variation in the TDS of the blend as the ratio of the two finished waters changes. Figure 4-1 shows the difference in blended hardness and alkalinity between the two types of NF membrane as the ion exchange contribution changes.

It can be seen in Figure 4-1 that the blended values for hardness and alkalinity are significantly different for the two types of membrane. Since the NF 90 produces water with less hardness and alkalinity than the ion exchange treatment, the blended value is always lower than the water currently supplied to the County's customers. In the case of the NF-270 membrane, the total hardness is higher than what is currently produced, and the alkalinity is lower, but not as much as the NF-90. This means that the hardness of the blended water with the NF-270 product will be three times higher than the IX product with no IX flow, but flatten out at about a 2 to 1 ratio, IX to NF, at a value of around 50 mg/l. Similarly, the alkalinity will flatten out at the same ratio to a value close to that currently produced. In the same way, the total hardness when considering the NF-90 membrane will level off at a value slightly below that produced today, while the alkalinity will start to flatten out at around two-thirds of the value today, or about 150 mg/l and then will rise slowly to the endpoint at 6.0 MGD of just less than 200 mg/l.

Generally, use of the NF-270, or similar "loose" membrane makes more sense in terms of the water quality sent to the customer. However, because of its characteristic higher salt passage, its ability to reject organic DBP precursors is somewhat less than the "tighter" NF-90, and similar products from other manufacturers. Therefore it is important to evaluate the organics rejection prior to making a decision on whether or not to use the looser membrane type, to take advantage of the energy savings potentially available.

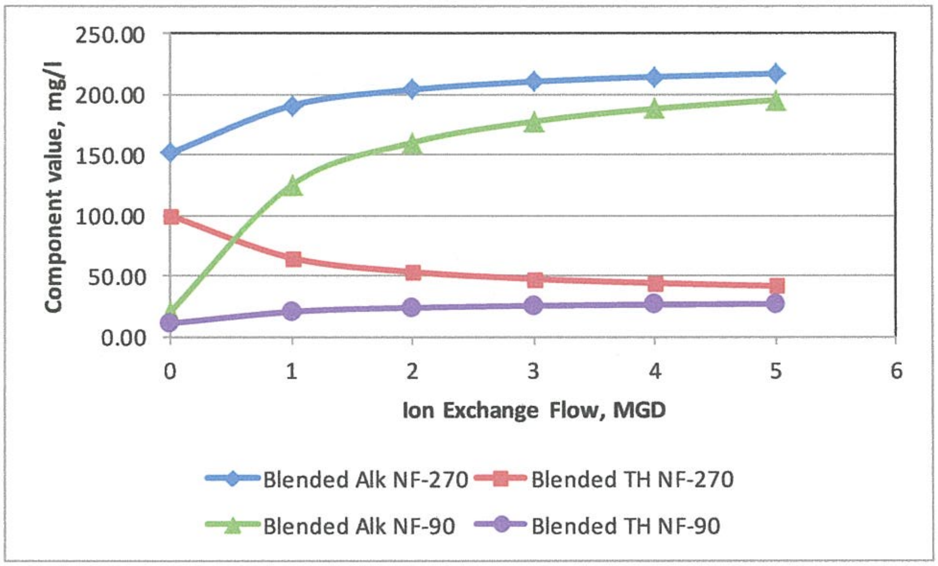


Figure 4-1 Comparison of Blended Product for NF-270 and NF-90-1.0 MGD

Table 4-3. Opinion of Capital Cost for 1.0MGD Nanofiltration.

Wells	2 each		
NF Train			$ 576,000
Feed pump			$ 120,000
Cartridge filter			$ 25,000
Cleaning system			$ 95,000
Chemical Feed system			$ 100,000
Piping in Bldg			$ 55,000
Electrical-Building			$ 40,000
Electrical Process			$ 130,000
Control system			$ 110,000
Bldg, 7000 sq ft			$1,680,000
Site work			$ 62,000
Yard piping			$ 150,000
Piping inside Ex. Bldg			$ 70,000
			$3,213,000
Contractor O/H	20%		$ 642,600
Contractor profit	5%		$ 160,650
			$4,016,250
Contingency	15%		$ 602,438
	TOTAL		$4,618,688

4.2.2 Option 2. 2.0 MGD NF.

This option will definitely require at least one additional well to make up for the difference lost in the lower recovery of the NF treatment method. The two NF trains will require 2.36 MGD of feed water, which leaves less than 5.0 MGD remaining for ion exchange feed, with all wells running.

Figure 4-2 shows the variation in hardness and alkalinity of the blended finished waters with 2.0 mgd of NF permeate as the basis. It will be seen that without the ion exchange contribution, the values are of course the same as the values in Option 1.

As the ion exchange contribution increases through 5.0 MGD, the rate of change in the concentration of the two components is fairly gradual for the NF-270, or "loose" membrane case, while the alkalinity for the Nf-90 case is very variable. Once again this points out the benefit of using the looser membrane type in terms of the mineral water quality. The same argument as Option 1 still holds for the difference in organic rejection.

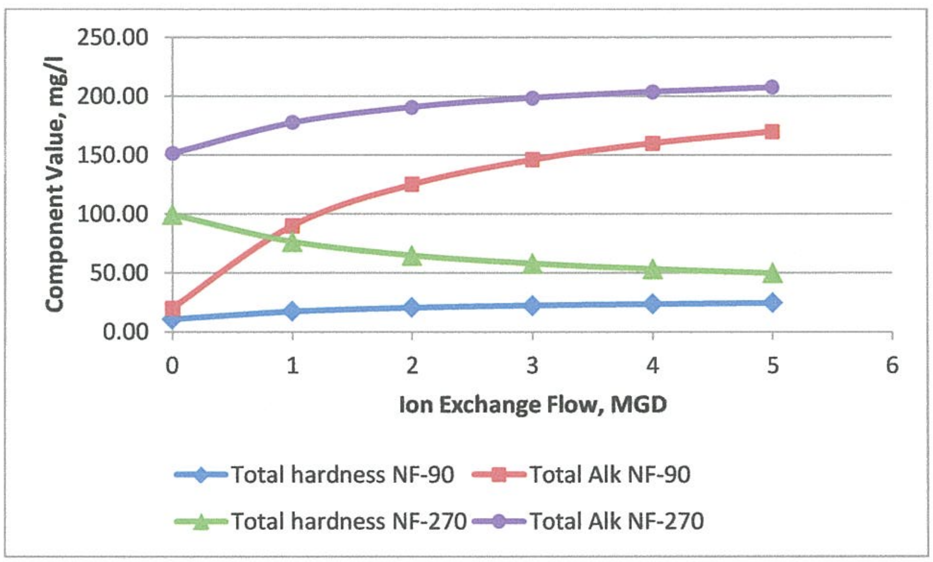


Figure 4-2 Comparison of Blended Product for NF-270 and NF-90-2.0 MGD

Table 4-4. **Opinion of Capital Cost for 2.0MGD Nanofiltration.**

Wells	3 each		
NF Train			$ 1,100,000
Feed pump			$ 240,000
Cartridge filter			$ 50,000
Cleaning system			$ 95,000
Chemical Feed system			$ 100,000
Piping in Bldg			$ 55,000
Electrical-Building			$ 40,000
Electrical Process			$ 195,000
Control system			$ 110,000
Bldg, 7000 sq ft			$ 1,680,000
Site work			$ 62,000
Yard piping			$ 150,000
Piping inside Ex. Bldg			$ 70,000
			$ 3,947,000
Contractor O/H	20%		$ 789,400
Contractor profit	5%		$ 197,350
			$ 4,933,750
Contingency	15%		$ 740,063
	TOTAL		$ 5,673,813

4.2.3 Option 3. 1.0 MGD BWRO.

The addition of a brackish water treatment process to the Skyco plant would not use the existing well system, but would require, depending on the safe yield capacity of the source, at least two new wells and well water collection piping system. In addition, it is recommended that additional hydro-geological data be obtained from a full size test well that would become the first production well. This additional work should include detailed solute transport modeling to predict the potential future water quality that could be expected over the lifetime of the plant.

Initial projections using the water quality included in tabular form in the introduction to this chapter indicate that a recovery of at least 80% is achievable.

This would require a feed pressure of between 190 psi and 225 psi depending upon the membrane used, and the actual raw water quality obtained from a production well. In the projections a conservative interstage boost pressure (based on the use of an energy recovery turbo) of 50 psi was assumed.

The permeate quality will be between 50 mg/l and 75 mg/l, again depending on the membrane used. As is typical for BWRO permeate, the major components will be sodium and chloride, with some alkalinity since the Yorktown alkalinity is quite high. A suitable post treatment for this water would be calcite beds, to add some calcium hardness and alkalinity before blending with the ion exchange product at those times when the ion exchange is operating at low flows.

Figure 4.3 shows the hardness and alkalinity, as with the NF options, with no permeate post-treatment.

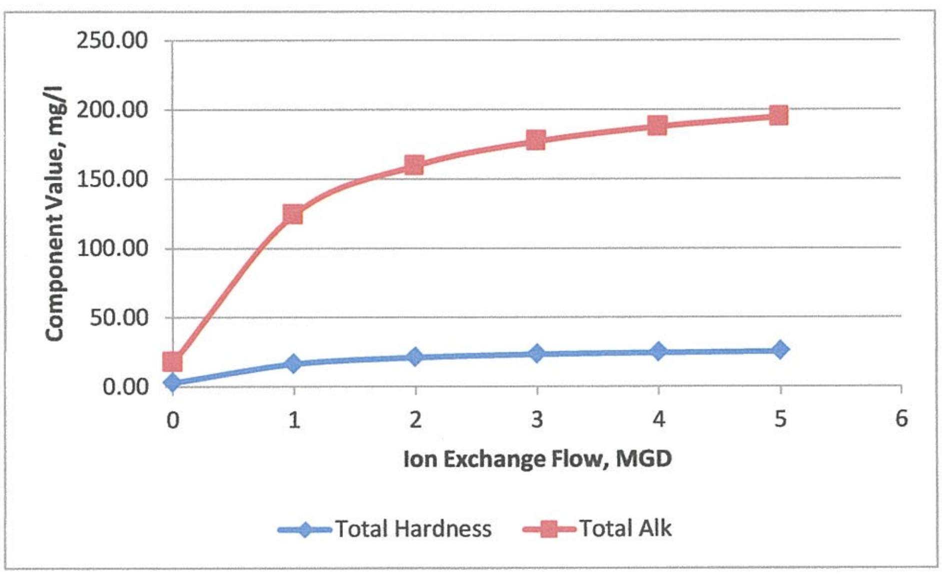


Figure 4-3 Comparison of Blended Product for 1.0 MGD BWRO Permeate

As can be seen from Figure 4-3, with only the BWRO running, post treatment in the form of calcium and bicarbonate alkalinity would be required to stabilize the permeate and create a non-corrosive water. Operationally, this expensive post treatment step could be avoided by starting the BWRO only when the flow through the ion exchange reaches about 1.5 MGD.

Table 4-5. Opinion of Capital Cost for 1.0MGD Brackish Water RO.

Wells	2 each		
BWRO Train			$ 525,000
Feed pump			$ 132,800
Cartridge filter			$ 25,000
Cleaning system			$ 95,000
Chemical Feed system			$ 100,000
Piping in Bldg			$ 55,000
Electrical-Building			$ 40,000
Electrical Process			$ 160,000
Control system			$ 110,000
Bldg, 7000 sq ft			$1,680,000
Site work			$ 62,000
Yard piping			$ 150,000
Piping inside Ex. Bldg			$ 70,000
			$3,204,800
Contractor O/H	20%		$ 640,960
Contractor profit	5%		$ 160,240
			$4,006,000
Contingency	15%		$ 600,900
	TOTAL		$4,606,900

4.2.4 Option 4. 2.0 MGD BWRO.

Additional wells would be required for this option, possibly as many as five, together with the raw water collection piping. It is very probable that acquiring well sites for this many wells would be problematic and certainly time consuming. As with the 1.0 MGD option, post treatment for the addition of calcium hardness and alkalinity will be required if the BWRO is operated as the only water treatment. Starting up a 1.0 MGD train when the ion exchange flow reaches 1.5 MGD and the second train when the ion exchange flow reaches about 3.5 MGD would appear to remove the need for post treatment until such time as the BWRO installed capacity reaches a point at which ion exchange flow will no longer adequately stabilize the combined flow.

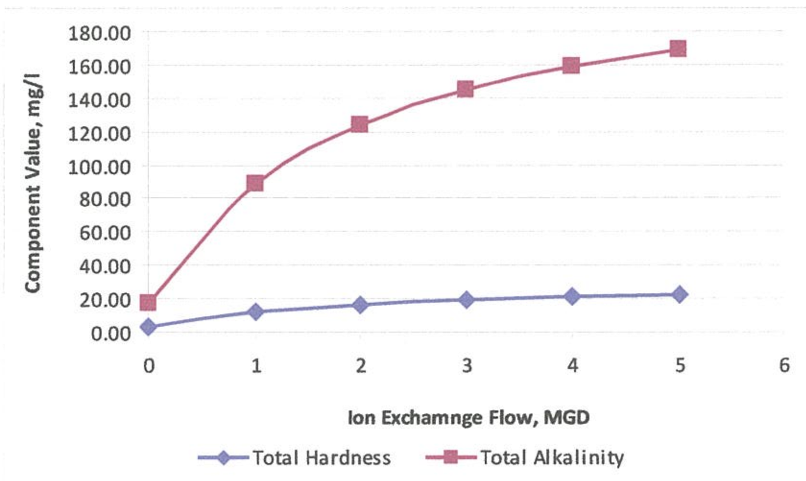


Figure 4-4 Comparison of Blended Product for 2.0 MGD BWRO Permeate

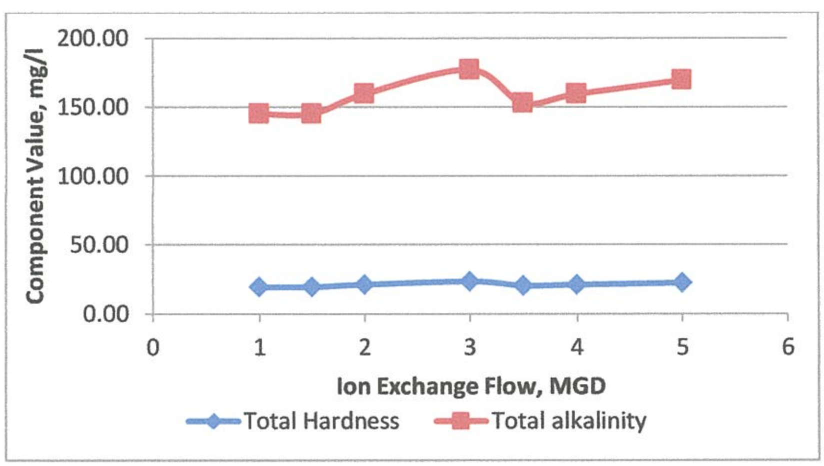


Figure 4-5 Values for TH and Alkalinity with phased BWRO Start-up

4.2.5 Option 5. 1.0 MGD BWRO with 1.0 MGD NF

This option provides both a low pressure and high pressure system with differing permeate characteristics. As with options 1 and 2, the NF permeate quality can be varied by the membrane type that is selected for the installation. Given the high rejection characteristics of the BWRO membrane, there could be some advantage in terms of post treatment in combining the low hardness low alkalinity permeate with the permeate from the looser NF membrane.

Table 4-6. Opinion of Capital Cost for 2.0MGD Brackish Water RO.

Wells	4 each		
BWRO Train			$ 1,050,000
Feed pump			$ 265,600
Cartridge filter			$ 50,000
Cleaning system			$ 95,000
Chemical Feed system			$ 100,000
Piping in Bldg			$ 55,000
Electrical-Building			$ 40,000
Electrical Process			$ 260,000
Control system			$ 110,000
Bldg, 7000 sq ft			$ 1,680,000
Site work			$ 62,000
Yard piping			$ 150,000
Piping inside Ex. Bldg			$ 70,000
			$ 3,987,600
Contractor O/H	20%		$ 797,520
Contractor profit	5%		$ 199,380
			$ 4,984,500
Contingency	15%		$ 747,675
	TOTAL		$ 5,732,175

As with the options discussed earlier, additional wells will be required. Since there is currently no brackish water well field, a complete system with wells, pumps and piping will need to be installed, and as with the earlier discussion on the BWRO options, additional hydro-geologic investigation is mandatory. In considering the blended quality of the two permeate streams, the combined total hardness and alkalinity will be 51 and 84 mg/l respectively, as $CaCO_3$. When this blended water is mixed with ion exchange product, the hardness and alkalinity will be as shown in Figure 4-6.

When operating the membrane trains only, there is sufficient hardness and alkalinity in the NF permeate to offset the lack of these components in the BWRO permeate, and to produce a stable water with minimal pH adjustment only. Of course this only applies if a loose NF membrane is used. If a tighter membrane is installed, then some ion exchange flow will be required to increase the alkalinity, again with the possibility of some pH adjustment, or alternatively a post treatment stabilization process will be required to add calcium and alkalinity to the blended product.

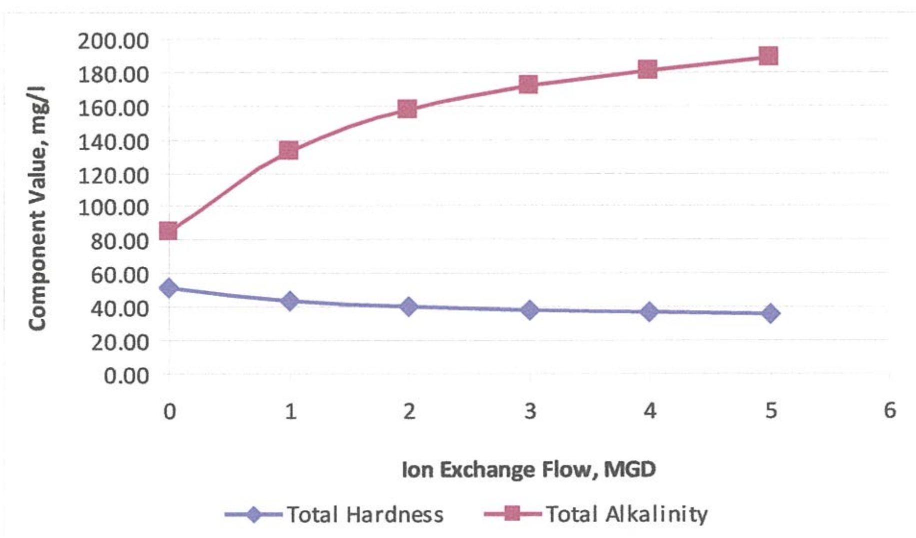


Figure 4-6 Values for TH and Alkalinity with 2.0 MGD RO/NF Permeate

Table 4-7. Opinion of Capital Cost for 2.0MGD BWRO/NF.

Wells	3 each		
NF Train			$ 576,000
BWRO Train			$ 525,000
Feed pump			$ 252,600
Cartridge filter			$ 50,000
Cleaning system			$ 95,000
Chemical Feed system			$ 100,000
Piping in Bldg			$ 55,000
Electrical-Building			$ 40,000
Electrical Process			$ 250,000
Control system			$ 110,000
Bldg, 7000 sq ft			$ 1,680,000
Site work			$ 62,000
Yard piping			$ 150,000
Piping inside Ex. Bldg			$ 70,000
			$ 3,439,600
Contractor O/H	20%		$ 687,920
Contractor profit	5%		$ 171,980
			$ 4,299,500
Contingency	15%		$ 644,925
	TOTAL		$ 4,944,425

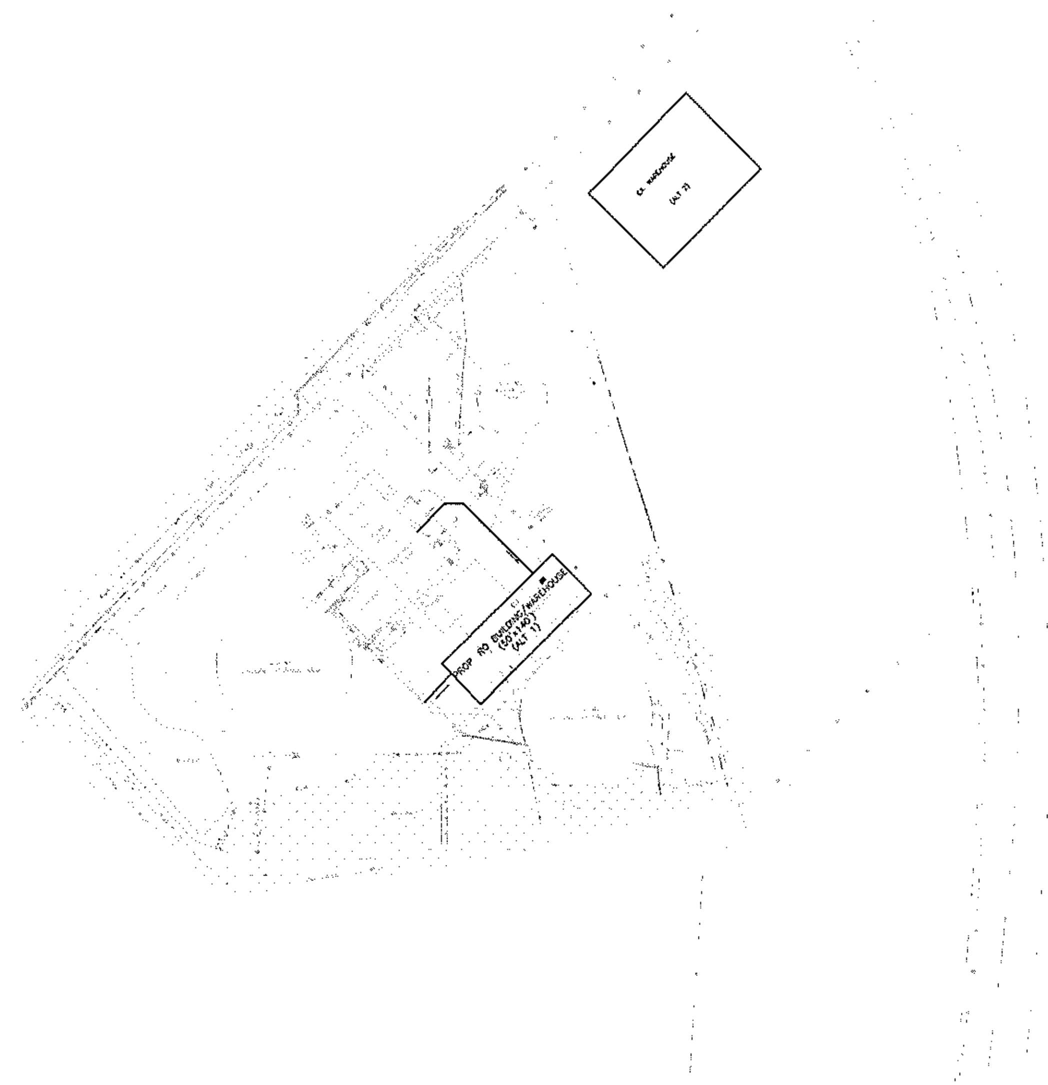
4.3 Summary of Skyco Options Costs

The following table summarizes the costs for the five expansion options for Skyco.

Table 4-6 Summary of Probable Cost for Skyco Options

Option	Cost, $x1,000
Option 1. 1.0 MGD NF	4,101.2
Option 2. 2.0 MGD NF	5,156.3
Option 3. 1.0 MGD BWRO	4,089.4
Option 4. 2.0 MGD BWRO	5,214.7
Option 5. 1.0 MGD NF+ 1.0 MGD BWRO	4,426.9

Figure 4-7 shows a conceptual layout of the proposed new membrane plant building. Due to existing utilities, yard piping, and limited available site, the recommendation is to



DESIGNED	BBM
DETAILED	SSY
CHECKED	BBM
APPROVED	BBM
DATE	APRIL 2012

WATEK ENGINEERING CORPORATION
12122B HERITAGE PARK CIRCLE
SILVER SPRING, MARYLAND 20906
(301) 933-9590
www.watek.com

RosTek Associates, Inc.
P O Box 47567, Tampa, Florida, 33647

NO.	DATE	REVISION	BY	CK

SKYCO PLANT
UPGRADE CONCEPTUAL LAYOUT

SCALE 1" = 50'

FIG. 4-7

SHEET 1 of 1

demolish the existing wooden building which houses parts and supplies and is currently used as a warehouse. The new building will need to be elevated above the 100-year flood plain. A ramp should be provided to the upper level for chemical delivery and for access. The lower portion could be used for storage of materials that would not be damaged by flooding such as pipe, hydrants valves, etc.

The new building will be approximately 7,000 square feet, of 2,000 square feet is allocated for storage/warehouse The opinion of probable cost includes an insulated split face block building structure with metal roofing, glass block for natural light, and overhead doors. Other building types and materials could be evaluated during design.

As an alternative to constructing a new building to house the proposed membrane based WTP, the county may wish to consider an alternative.

The metal warehouse building that sits on the entrance road to the Skyco WTP would with some retrofitting, provide sufficient space for a 6.0 MGD membrane WTP, together with its supporting civil, structural, mechanical and electrical infrastructure. This building, which is elevated above the surrounding land, and the adjoining undeveloped property is believed to be available for sale by the owner. In addition to reducing the cost of any of the alternatives by replacing the new building construction with existing building retrofit, the adjoining property provides a potential site for one or more wells, together with space for additional ground storage.

The metal building is large enough to contain the proposed WTP, with space still available to support other space requirements the County may have. Unfortunately, dimension data for the building was not available, and an opinion of retrofit cost could not be provided. However, based on observations made of the interior of this building, it is believed that a savings of at least $500,000 can be realized compared to the cost of constructing a new building. This does not include constructing offices or other types of spaces within the metal building.

5. Discussion of Preferred Options

5.1 Forecasted Demand

In Chapter 2, the demand for water on the northern beaches was estimated using information provided by the Towns of Nags Head and Kill Devil Hills, and the County Planning Department. The planning horizon was set as the year 2030. Based on the use of recorded demand data through 2010, and using the estimated peak populations for that year to develop average per capita daily consumption, a total demand forecast of 12.0 MGD average day was developed.

Examination of the potential growth in demand for the supply traditionally provided from the Skyco WTP, which serves the Town of Manteo, the County customers on Roanoke Island, the Town of Nags Head through the Gull Street take-off, and the Towns of Nags Head and Kill Devil Hills through the 8th Street take-off, shows that the Roanoke Island demand in 2030 indicates that the 2030 demand for the Skyco system will be 5.5 MGD by 2030. The balance of the demand to be supplied by the NRO WTP would therefore be 6.5 MGD.

5.2. NRO Expansion

Although the results of the demand forecast indicate that an expansion of 1.5 MGD should be installed at NRO, and 0.5 MGD at Skyco for a total system capacity of 12.0 MGD, expansion of the NRO plant should take place in 1.0 MGD increments, to maintain the consistency of the original design philosophy. To depart from this criterion at this point, although possible, is not considered to be in the best long term interests of the County.

Having reached that decision, the question remains whether 1.0 mgd or 2.0 mgd should be installed at NRO. For three out of the five options, demolition and reconstruction of the interior office space is required. The two options that do not require this step for an expansion to be implemented are Options 4, which is a 1.0 MGD expansion using large format membranes, and Option 5, increasing the capacity of Trains 1-3. For a 2.0 MGD expansion, completion of the arsenic removal post-treatment is required, at an estimated cost of approximately $1,000,000.

Although the use of 16" diameter membranes for a 1.0 MGD expansion would not require any action to demolish and rebuild the existing office structure, large format membranes is a departure from the traditional design of the NRO treatment equipment. Special loading and unloading equipment will be required, since a 16" element is too heavy to be manually loaded and unloaded. Each manufacturer has its own approach to membrane handling, and as yet there is no standardization for this equipment. It is expected that as large format membranes become more commonplace, such standardization in handling techniques will naturally follow.

The option that can be accomplished without changing the existing office space is to upsize the capacity of trains 1-3, adding 1.0MGD to the NRO capacity. As discussed previously, this can be accomplished with the same feed pumps, although larger energy recovery devices will be required. No changes to the cleaning system will be needed, and the replacement trains will fit in the existing footprint available. However it is recommended that the existing units be replaced, since they are approaching the end of their useful life, and maintenance of the obsolete pressure vessels, and the associated piping require significant staff time.

5.3 Skyco Expansion

While the Skyco ion exchange plant can, and has on occasion, operated at around 6.0 MGD, its design capacity is 5.0 mgd. To meet the future demand, it will be necessary to expand the Skyco plant by 1.0 MGD. The options for doing this have been discussed in Chapter 4.

The existing ion exchange plant was originally commissioned in 1980. At the time it was considered to have a large capacity for a municipal ion exchange plant used for softening water. A 1984 study by Moore, Gardner and Associates discusses various operating difficulties that had been experienced with the plant. In 2003, a plant modification, consisting of the addition of a 5.0 MGD anion exchange system for the removal of the organic precursors to DBPs, was commissioned. The water from the initial softening step was directed to the new anion system, where the pre-softened water was treated for organics removal. As with the softening step, the regenerant used is a sodium chloride solution.

In 2010, a further modification took place. The anion exchange vessels were converted to a "mixed bed" configuration, in which both anion and cation exchange resin is loaded into the same vessel. Upon the successful completion of this conversion, the original plant equipment was decommissioned. Although the modified system has shown significant improvement over the previous arrangement in terms of its operability, and consistency of product quality, the ability to bypass part of the raw water flow around the original softening system, then combining the flows prior to the organics removal step has resulted in a much lower hardness content than before. Fortunately the alkalinity remains high, so that overall the process produces a stable but quite soft water.

While the existing treatment scheme produces good quality water, it is sometimes difficult for the operators to control under certain conditions, and does not provide for consistent removal of the organic precursors. Also the regenerant used, sodium chloride, or common salt, has more than doubled in cost. When these factors are considered in combination with the significant improvements in membrane technology, it would appear that constructing the first phase of what will eventually become a 6.0 MGD membrane plant is a viable solution to the expansion of the Skyco plant. The result will be a public water supply for Roanoke Island and the southern beaches that is of a consistent high quality in terms of the regulated and un-regulated components alike.

Having made the decision to start the conversion of Skyco from ion exchange treatment to membrane based treatment, the County must decide whether to start with NF, or with BWRO. The discussion in Chapter 4 points out the difference in alkalinity and hardness in blended product for NF vs. BWRO, and for a combination of both membrane types. Traditionally, NF is used for exactly the treatment goals as is the current system. Many examples exist, particularly in Florida, where the largest municipal NF membrane plant in the USA at 40.0 MGD is located in Boca Raton. The newest, a 17.0 MGD plant commissioned in August of 2010, incorporates a unique split feed vessel design, which lowers the energy cost over the traditional design by about 30%. Operation of NF plants is simple, reliable, and modern membranes have a life expectancy of seven to ten years. Energy costs are low for NF, since the osmotic pressure of the feed water is very low, and the specific fluxes quite high. A very preliminary opinion of operating cost, for power, chemicals, and cartridge filters is ~$0.20/kgal of water produced. This assumes no post-treatment chemicals, since it is likely that blending with IX water will provide the necessary stabilization, and the other post-treatment chemicals, such as chlorine and fluoride are already in use at Skyco.

6. CONCLUSIONS AND RECOMMENDATIONS.

In considering the future water needs of the Northern Beaches, it is clear that expansion will be required at both locations over the next 4-6 years. As discussed above, it is proposed that the expansion take place by the addition of 1.0 MGD at each location. In addition it is important that the County verify (or otherwise) the integrity of the 24" sub-aqueous Sound crossing, since this is the only way that water can be transferred from Skyco to Nags Head and Kill Devil Hills without creating shortages elsewhere in the Northern Beaches system,

Considering all the possible options and costs, the following conclusions can be drawn;

- Expanding the North RO plant in Kill Devil Hills by 1.0 MGD will not require the expansion of the arsenic treatment system.
- The addition of Train 6 in its planned location will require the demolition or significant modification of the existing interior office structure.
- The original three trains, 1, 2 and 3, are nearing the end of their useful life, particularly in regards to the pressure vessels.
- Replacement of Trains 1-3 will not require any action in regards to the office structure, but will require an overhead roll-up door to be installed in the north wall of the process room.
- Replacement of Trains 1-3 will result in a capacity increase of 1.0 MGD located in the existing footprint
- The existing pumps can be modified to provide the head and additional capacity required, without increasing the motor horsepower.
- Starting the conversion of the Skyco water treatment technology from Ion Exchange to a membrane based system will provide for greater consistency in the finished water quality, particularly as regards DBPs, and will better position the

County to deal with expected future tightening of the DBP standards. This conversion would start out as nanofiltration, with the possible addition of brackish water RO in the future, should the Yorkton Aquifer under Roanoke Island prove to be sustainable over a twenty year plant life.

Therefore the following recommendations are offered for consideration by the County:

1. Begin a long term pilot test of NF technology at the Skyco WTP. This will include the following actions:
    a. Acquisition of a suitable surplus pilot plant.
    b. The preparation of a test plan and protocol.
    c. Monitoring and data acquisition.
    d. Data evaluation and pilot plant report.
2. Prepare documentation for the acquisition of a testing and inspection service for the 24" sub-aqueous sound crossing
3. Start design and bid document preparation for the replacement and upgrading of NRO Trains 1-3.
4. Start design and bid document preparation for the construction of the first phase of a new membrane based WTP and building at the Skyco site.

7. PROPOSED CAPITAL IMPROVEMENTS

The capital improvement projects identified earlier in this report should be scheduled and funded in a logical sequence. A proposed priority listing, together with opinions of probable cost, is shown below.

1. Nanofiltration pilot.

   To be located at the Skyco WTP. This task includes:

   a. the acquisition of the pilot plant equipment,
   b. preparation of pilot test plan, and protocol
   c. monitoring and data logging
   d. data analysis, and pilot test report.
   e.

   The opinion of probable cost for this task, including hardware procurement of surplus equipment, $150,000.

2. Sub-aqueous Sound crossing

   Engineering study to determine the need for replacement of rehabilitation of the 24" diameter sub-aqueous pipeline crossing the Sound.

   The opinion of probable cost to acquire the specialized services and complete the engineering report $250.000.

3. Modification of trains 1-3 at NRO

   This task includes a preliminary design report, plans and specifications for civil works required to install a new roll-up door, and plans and specifications for the removal and replacement of trains 1-3, modifications required for the existing RO feed pumps, and necessary modifications to the trains' control logic.

The opinion of probable cost to accomplish this task:

Preliminary design report	$30,000
Civil works engineering	$15,000
Construction	$50,000
Plans and specifications for train replacement	$75,000
Shop drawing review, on-site services	$75,000
Purchase and install new trains	$4,300,000

4. 1^{st} phase of new membrane WTP at Skyco

This task includes the preparation of a preliminary design report, surveying services, soil boring and geotechnical report, plans and specifications, bidding, permitting, and services during construction.

The opinion of probable cost to complete this task:

Preliminary design report	$50,000
Survey and soils testing	$60,000
Plans and specifications for new facility	$420,000
Permitting, bidding, shop drawing review	$75,000
Facility construction	$4,200,000
On-site services during construction	$85,000

APPENDICES

APPENDIX 1

NRO TRAINS 1-3
UPSIZING PROJECTION

Based on future water quality for NRO

Reverse Osmosis System Analysis for FILMTEC™ Membranes — ROSA 7.0.1 ConfigDB U238786_93
Project: Dare County NRO 2011 — Case: 3
Ian C Watson, PE, RosTek Associates, Inc — 5/3/2012

Project Information: NRO

Case-specific: Expanded trains 1-31.33mgd@78% Y

System Details

Feed Flow to Stage 1	1183.33 gpm	Pass 1 Permeate Flow	922.82 gpm	Osmotic Pressure:	
Raw Water Flow to System	1183.33 gpm	Pass 1 Recovery	77.98 %	Feed	54.35 psig
Feed Pressure	239.95 psig	Feed Temperature	68.0 F	Concentrate	236.67 psig
Fouling Factor	0.85	Feed TDS	5341.85 mg/l	Average	145.51 psig
Chem. Dose	None	Number of Elements	222	Average NDP	115.76 psig
Total Active Area	97680.00 ft²	Average Pass 1 Flux	13.60 gfd	Power	173.05 kW
Water Classification: Well Water SDI < 3				Specific Energy	3.13 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	LE-440i	25	6	1183.33	234.95	0.00	438.27	217.43	745.07	16.26	12.00	0.00	82.06
2	LE-440i	12	6	438.27	282.43	0.00	260.51	267.25	177.75	8.08	12.00	70.00	318.65

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	142.00	142.00	379.31	631.56	2.41	9.62	3.80
Na	1625.00	1625.01	4341.84	7232.91	26.90	104.75	41.89
Mg	64.20	64.20	172.42	288.67	0.54	2.04	0.83
Ca	176.40	176.40	473.81	793.33	1.45	5.53	2.24
Sr	1.76	1.76	4.73	7.92	0.01	0.06	0.02
Ba	0.01	0.01	0.03	0.04	0.00	0.00	0.00
CO3	2.94	2.94	17.24	40.15	0.00	0.00	0.00
HCO3	304.90	304.90	794.62	1299.61	5.78	21.35	8.78
NO3	0.06	0.06	0.15	0.23	0.01	0.03	0.01
Cl	2782.73	2782.73	7439.51	12399.78	43.50	169.84	67.84
F	0.34	0.34	0.91	1.51	0.01	0.03	0.01
SO4	232.00	232.00	624.10	1046.48	1.36	5.08	2.07
SiO2	9.50	9.50	25.51	42.70	0.08	0.32	0.13
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	5.59	5.59	10.47	17.30	6.68	12.39	7.78
TDS	5341.85	5341.85	14274.17	23784.89	82.06	318.65	127.63
pH	7.73	7.73	7.77	7.69	6.14	6.40	6.25

Design Warnings

WARNING: Maximum recommended element permeate flow rate has been exceeded. Please change your system design to reduce the element permeate flows. (Product: LE-440i, Limit: 6.94gpm)

Solubility Warnings

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

Stage Details

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.15	7.10	38.42	47.33	5341.85	234.95
2	0.16	6.31	50.43	40.23	6277.43	230.05
3	0.16	5.45	68.06	33.92	7434.65	226.19
4	0.16	4.55	94.76	28.47	8845.10	223.16
5	0.15	3.63	136.33	23.92	10508.16	220.79
6	0.14	2.76	202.14	20.29	12362.45	218.92
Stage 2 Element	**Recovery**	**Perm Flow (gpm)**	**Perm TDS (mg/l)**	**Feed Flow (gpm)**	**Feed TDS (mg/l)**	**Feed Press (psig)**
1	0.12	4.34	151.73	36.52	14274.17	282.43
2	0.11	3.42	210.83	32.18	16179.18	278.94
3	0.09	2.61	297.42	28.76	18077.94	275.99
4	0.07	1.94	423.23	26.14	19852.43	273.44
5	0.06	1.46	588.15	24.20	21410.37	271.19
6	0.05	1.03	855.13	22.74	22747.10	269.15

Scaling Calculations

	Raw Water	Adjusted Feed	Concentrate
pH	7.73	7.73	7.69
Langelier Saturation Index	0.69	0.69	1.90
Stiff & Davis Stability Index	0.48	0.48	1.11
Ionic Strength (Molal)	0.10	0.10	0.45
TDS (mg/l)	5341.85	5341.85	23784.89
HCO3	304.90	304.90	1299.61
CO2	5.59	5.59	17.30
CO3	2.94	2.94	40.15
CaSO4 (% Saturation)	3.63	3.63	21.89
BaSO4 (% Saturation)	18.81	18.81	88.13
SrSO4 (% Saturation)	1.64	1.64	8.39
CaF2 (% Saturation)	2.71	2.71	239.61
SiO2 (% Saturation)	8.26	8.26	37.13
Mg(OH)2 (% Saturation)	0.01	0.01	0.02

To balance: 0.01 mg/l Na added to feed.

APPENDIX 2
SKYCO
BWRO PROJECTION

Project Information: Using WQ data from Spruill hydrogeology report

Case-specific: 1 MGD 80% Y

System Details

Feed Flow to Stage 1	871.25 gpm	Pass 1 Permeate Flow	696.95 gpm	Osmotic Pressure:	
Raw Water Flow to System	871.25 gpm	Pass 1 Recovery	79.99 %	Feed	35.30 psig
Feed Pressure	188.37 psig	Feed Temperature	68.0 F	Concentrate	167.46 psig
Fouling Factor	0.85	Feed TDS	3429.04 mg/l	Average	101.38 psig
Chem. Dose	None	Number of Elements	210	Average NDP	96.72 psig
Total Active Area	84000.00 ft²	Average Pass 1 Flux	11.95 gfd	Power	97.79 kW
Water Classification: Well Water SDI < 3				Specific Energy	2.34 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	LE-400	20	7	871.25	183.37	0.00	314.03	163.22	557.22	14.33	12.00	0.00	62.72
2	LE-400	10	7	314.03	208.22	0.00	174.30	193.24	139.73	7.19	12.00	50.00	255.99

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	1166.53	1166.53	3197.97	5690.31	21.67	88.91	35.15
Mg	32.40	32.40	89.26	159.68	0.36	1.41	0.57
Ca	11.80	11.80	32.51	58.17	0.13	0.51	0.20
Sr	0.56	0.56	1.54	2.76	0.01	0.02	0.01
Ba	0.01	0.01	0.03	0.05	0.00	0.00	0.00
CO3	3.61	3.61	26.34	72.17	0.00	0.01	0.00
HCO3	683.26	683.26	1838.61	3219.67	13.50	53.20	21.45
NO3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	1512.00	1512.47	4148.50	7384.99	26.88	111.17	43.78
F	0.50	0.50	1.37	2.43	0.01	0.04	0.02
SO4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SiO2	17.90	17.90	49.36	88.34	0.17	0.72	0.28
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	18.87	18.87	27.41	42.09	20.75	31.68	22.94
TDS	3428.57	3429.04	9385.50	16678.58	62.72	255.99	101.46
pH	7.60	7.60	7.77	7.76	6.03	6.40	6.17

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 recovery.

Stage Details

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.13	5.50	29.32	43.56	3429.04	183.37
2	0.13	5.02	36.81	38.06	3919.81	178.47
3	0.14	4.52	46.82	33.04	4508.47	174.45
4	0.14	4.01	60.51	28.52	5214.58	171.16
5	0.14	3.48	79.74	24.51	6056.14	168.50
6	0.14	2.94	107.41	21.03	7042.49	166.36
7	0.13	2.40	148.02	18.10	8164.75	164.63
Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.11	3.60	114.86	31.40	9385.50	208.22
2	0.11	2.96	153.29	27.80	10584.44	205.10
3	0.09	2.36	207.84	24.84	11822.74	202.46
4	0.08	1.83	285.47	22.48	13037.06	200.19
5	0.07	1.39	394.90	20.66	14162.58	198.19
6	0.05	1.04	545.84	19.27	15151.26	196.40
7	0.04	0.80	729.13	18.23	15981.80	194.77

Scaling Calculations

	Raw Water	Adjusted Feed	Concentrate
pH	7.60	7.60	7.76
Langelier Saturation Index	-0.25	-0.25	1.24
Stiff & Davis Stability Index	-0.25	-0.25	0.64
Ionic Strength (Molal)	0.06	0.06	0.28
TDS (mg/l)	3428.57	3429.04	16678.58
HCO3	683.26	683.26	3219.67
CO2	18.87	18.87	42.08
CO3	3.61	3.61	72.17
CaSO4 (% Saturation)	0.00	0.00	0.00
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	0.39	0.39	45.79
SiO2 (% Saturation)	15.57	15.57	76.82
Mg(OH)2 (% Saturation)	0.00	0.00	0.02

To balance: 0.47 mg/l Cl added to feed.

APPENDIX 3

SKYCO
NF PROJECTION
NF-270

Project Information: New NF application. Colored Groundwater. No H2S. Some iron.

Case-specific: Same array, NF-270

System Details

Feed Flow to Stage 1	820.00 gpm	Pass 1 Permeate Flow	696.94 gpm	Osmotic Pressure:	
Raw Water Flow to System	820.00 gpm	Pass 1 Recovery	84.99 %	Feed	4.00 psig
Feed Pressure	59.66 psig	Feed Temperature	63.0 F	Concentrate	9.96 psig
Fouling Factor	0.85	Feed TDS	545.23 mg/l	Average	6.98 psig
Chem. Dose	None	Number of Elements	224	Average NDP	43.16 psig
Total Active Area	89600.00 ft²	Average Pass 1 Flux	11.20 gfd	Power	26.60 kW
Water Classification: Well Water SDI < 3				Specific Energy	0.64 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF270-400	23	7	820.00	58.66	0.00	250.69	43.05	569.31	12.73	12.00	0.00	321.45
2	NF270-400	9	7	250.69	42.05	0.00	123.06	28.99	127.63	7.29	12.00	0.00	657.65

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	30.30	30.30	48.67	60.01	22.21	37.74	25.05
Na	59.74	59.74	95.44	117.75	44.03	73.93	49.50
Mg	3.65	3.65	9.46	15.80	1.09	3.35	1.50
Ca	63.00	63.00	139.99	207.31	29.10	75.08	37.52
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.60	0.60	2.85	5.88	0.14	0.86	0.23
HCO3	293.00	293.00	621.90	900.96	147.11	350.91	184.52
NO3	0.10	0.10	0.04	0.02	0.13	0.05	0.11
Cl	70.00	70.18	99.81	114.25	57.13	85.89	62.40
F	0.25	0.25	0.34	0.36	0.21	0.31	0.23
SO4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SiO2	24.40	24.40	33.71	38.06	20.30	29.51	21.99
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	13.69	13.69	14.66	15.95	13.65	14.10	13.70
TDS	545.05	545.23	1052.21	1460.41	321.45	657.65	383.06
pH	7.50	7.50	7.76	7.87	7.22	7.56	7.31

Design Warnings

WARNING: Maximum element recovery has been exceeded. Please change your system design to reduce the element recoveries. (Product: NF270-400, Limit: 19.00%)

CAUTION: The concentrate flow rate is less than the recommended minimum flow. Please change your system design to increase concentrate flow rates. (Product: NF270-400, Limit: 13.00gpm)

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 recovery.

Stage Details

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	4.38	223.81	35.65	545.23	58.66
2	0.13	4.00	252.93	31.27	590.22	54.82
3	0.14	3.68	284.99	27.27	639.61	51.64
4	0.15	3.43	320.82	23.59	694.92	49.03
5	0.16	3.23	361.49	20.16	758.50	46.93
6	0.18	3.07	409.56	16.93	834.11	45.27
7	0.21	2.96	469.58	13.86	928.10	43.99
Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.10	2.72	511.83	27.85	1052.21	42.05
2	0.10	2.44	564.88	25.13	1110.67	39.29
3	0.10	2.19	620.20	22.69	1169.25	36.90
4	0.10	1.97	677.68	20.50	1227.85	34.84
5	0.10	1.78	737.14	18.52	1286.38	33.05
6	0.10	1.61	798.45	16.74	1344.72	31.50
7	0.10	1.46	861.40	15.13	1402.76	30.16

Scaling Calculations

	Raw Water	Adjusted Feed	Concentrate
pH	7.50	7.50	7.87
Langelier Saturation Index	0.01	0.01	1.34
Stiff & Davis Stability Index	0.72	0.72	1.67
Ionic Strength (Molal)	0.01	0.01	0.02
TDS (mg/l)	545.05	545.23	1460.41
HCO3	293.00	293.00	900.96
CO2	13.69	13.69	15.94
CO3	0.60	0.60	5.88
CaSO4 (% Saturation)	0.00	0.00	0.00
BaSO4 (% Saturation)	0.00	0.00	0.00
SrSO4 (% Saturation)	0.00	0.00	0.00
CaF2 (% Saturation)	0.52	0.52	3.60
SiO2 (% Saturation)	22.29	22.29	34.41
Mg(OH)2 (% Saturation)	0.00	0.00	0.00

To balance: 0.18 mg/l Cl added to feed.

APPENDIX 4

SKYCO

NF PROJECTION

NF-90

Project Information: New NF application. Colored Groundwater. No H2S. Some iron.

Case-specific: Standard 8" 7M vessel, NF-90

System Details

Feed Flow to Stage 1	820.00 gpm	Pass 1 Permeate Flow	697.09 gpm	Osmotic Pressure:	
Raw Water Flow to System	820.00 gpm	Pass 1 Recovery	85.01 %	Feed	4.00 psig
Feed Pressure	75.10 psig	Feed Temperature	63.0 F	Concentrate	22.98 psig
Fouling Factor	0.85	Feed TDS	545.23 mg/l	Average	13.49 psig
Chem. Dose	None	Number of Elements	224	Average NDP	54.67 psig
Total Active Area	89600.00 ft²	Average Pass 1 Flux	11.20 gfd	Power	34.95 kW
Water Classification: Well Water SDI < 3				Specific Energy	0.84 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	23	7	820.00	74.10	0.00	269.02	58.16	550.98	12.32	12.00	0.00	35.94
2	NF90-400	9	7	269.02	67.16	0.00	122.91	53.38	146.11	8.35	12.00	10.00	123.46

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	30.30	30.30	86.05	175.84	3.08	10.52	4.64
Na	59.74	59.74	170.60	350.68	5.62	19.11	8.45
Mg	3.65	3.65	10.81	23.03	0.15	0.53	0.23
Ca	63.00	63.00	186.79	398.21	2.56	8.94	3.89
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO3	0.60	0.60	5.42	21.23	0.00	0.02	0.00
HCO3	293.00	293.00	852.66	1780.69	16.22	55.96	24.54
NO3	0.10	0.10	0.20	0.31	0.05	0.11	0.06
Cl	70.00	70.18	199.69	409.00	6.95	23.61	10.44
F	0.25	0.25	0.70	1.42	0.03	0.10	0.04
SO4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SiO2	24.40	24.40	71.73	151.56	1.29	4.58	1.98
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	13.69	13.69	15.61	20.94	14.01	16.90	14.62
TDS	545.05	545.23	1584.66	3312.00	35.94	123.46	54.28
pH	7.50	7.50	7.85	8.00	6.31	6.74	6.46

APPENDIX 5

MISCELLANEOUS GRAPHICS

NORTHERN SERVICE AREA
STORAGE AND PUMPING SCREEN
SOUND CROSSING

DARE COUNTY WATER
GIS
TIM BUTCH
MAY 17, 2011

NORTH DISTRIBUTION SERVICE AREA
DARE COUNTY, NC

0 1,750 3,500 7,000 10,500 14,000 Feet

1 inch = 3,500 feet

North Distribution Service Area
Currituck County
Dare County towns not serviced

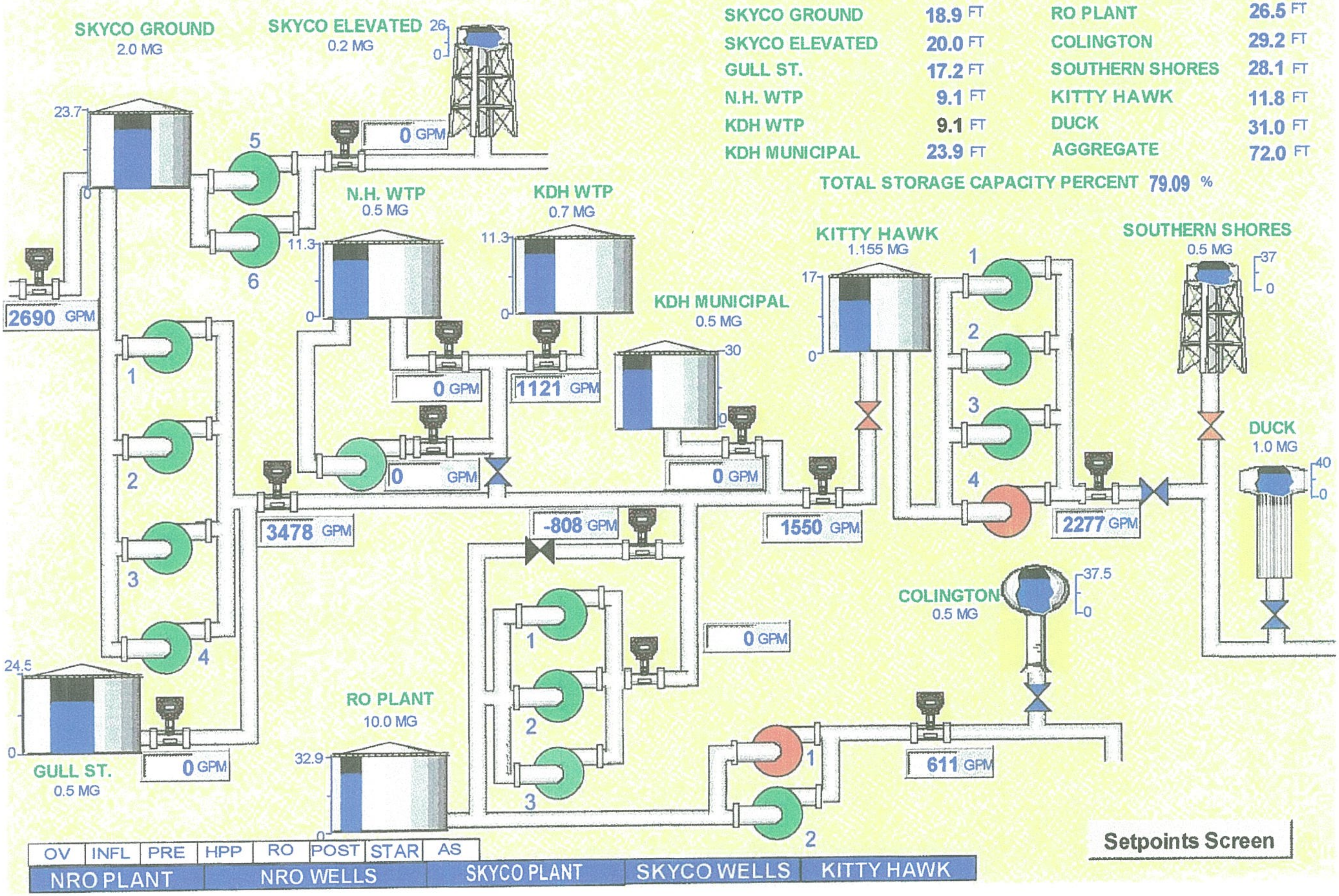
N
W E
S

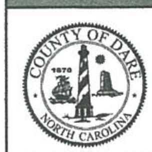
DISTRIBUTION SYSTEM

5/17/2011 9:00:08

SKYCO GROUND	18.9 FT	RO PLANT	26.5 FT
SKYCO ELEVATED	20.0 FT	COLINGTON	29.2 FT
GULL ST.	17.2 FT	SOUTHERN SHORES	28.1 FT
N.H. WTP	9.1 FT	KITTY HAWK	11.8 FT
KDH WTP	9.1 FT	DUCK	31.0 FT
KDH MUNICIPAL	23.9 FT	AGGREGATE	72.0 FT

TOTAL STORAGE CAPACITY PERCENT 79.09 %





DARE COUNTY WATER
GIS
TIM BUTCH
MARCH 22, 2012

TRANSMISSION MAIN
DARE COUNTY, NC

0 250 500 1,000 1,500 Feet
1 inch = 500 feet

Channel 7 centerline
Transmission Line buoy

Transmission Main Valves
Air Release
Main

Transmission Main
24"

N E S W

APPENDIX 6

ALTERNATIVE DISINFECTION STUDY North RO Plant-2007

B. NORTH RO PLANT

Sodium hypochlorite is a disinfectant already in use by the county at the South Hatteras plant at Frisco, at Skyco, and at Stumpy Point. Therefore the County has gained hands-on experience with the operation of these systems. Several changes have been made to the Skyco system, and this experience will be incorporated in to the proposed system design for NRO, and used in developing the cost opinion.

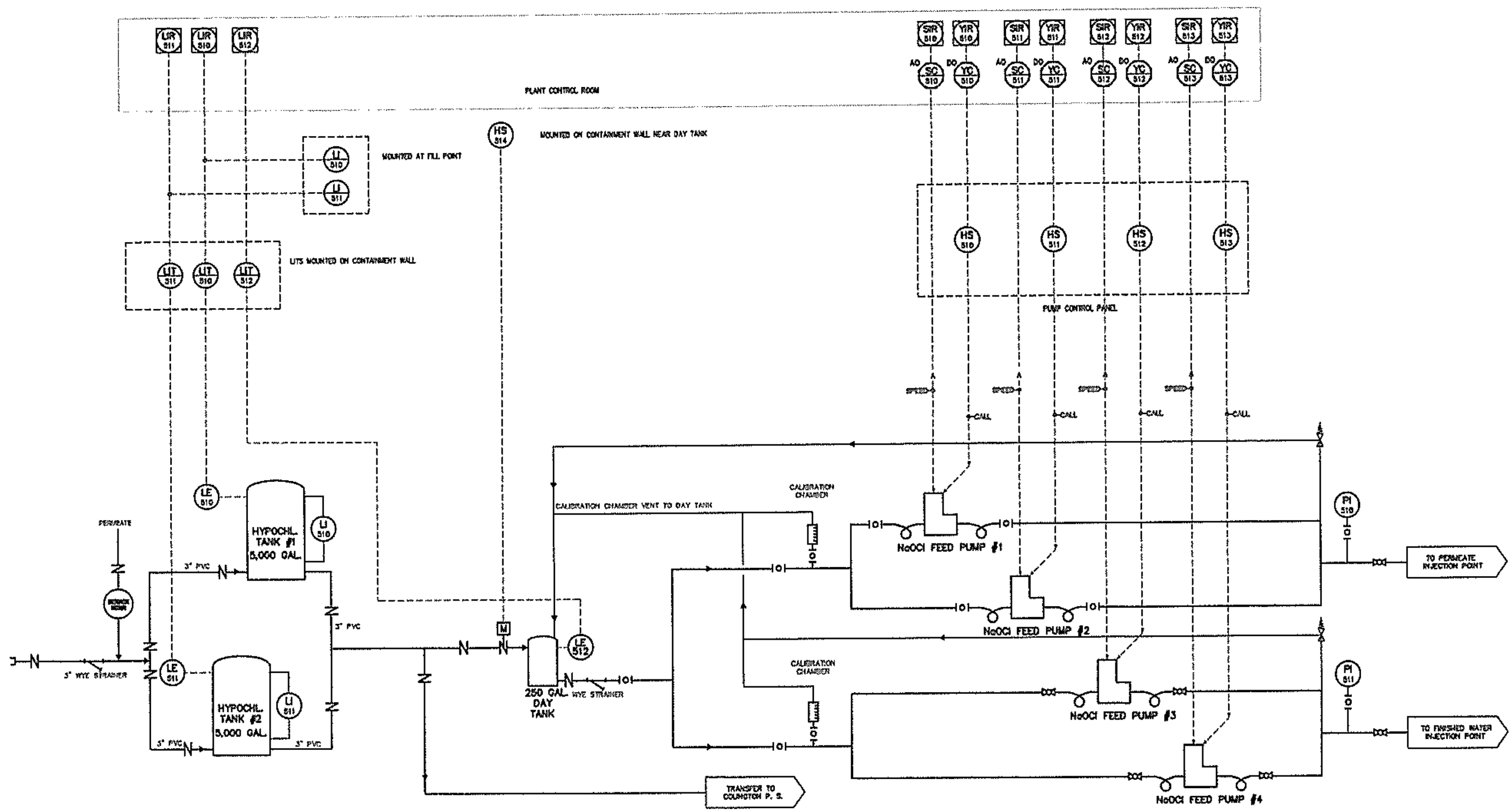
The installation at South Hatteras uses commercial strength hypochlorite, 12.5%, but dilutes it upon delivery because of concerns about deterioration due to heat and sunlight at the bulk storage tanks. The Skyco tanks are installed inside and dilution is not used. At Stumpy Point, the delivered solution is also stored inside the plant building, which is temperature-controlled.

Safety is the primary reason for considering a change from gas chlorination to hypochlorite disinfection at the NRO, since the hypochlorous ions the mechanism for disinfection in both cases. Although not yet required in North Carolina, many states are requiring gas chlorination installations to be retrofitted with closed ventilation systems and air scrubbers. It is reasonable to expect that this requirement will be eventually adopted by all states, and when this rule takes effect in North Carolina, and if still using gas chlorination, Dare County would be required to undertake this capital improvement.

Hypochlorite can also be generated onsite, by the electrolysis of sodium chloride solution. Typical commercial systems yield a very dilute solution, about 0.8% chlorine by weight. This means that a large volume of water must be used in the process, and because of the chemistry involved, must be essentially free from calcium hardness. Consequently commercial units incorporate ion exchange softening of the process water supply to the generating system. This feature would not be required in Dare County, since permeate could be used at both RWSRO and NRO. However, this equipment is very costly to install for small capacity systems, and is not considered economically competitive with either liquid or pellet hypochlorite systems.

1. Process Design

It is proposed that the sodium hypochlorite system for NRO be installed in the existing chlorine storage area. The proposed P & ID is shown in **Figure 1.** The installation will consist of two bulk storage tanks, of 5,000 gallons each, a 250 gallon day tank and associated piping, valves, and instruments located in the existing chlorine room. It is proposed that the two chemical metering pump systems required be located in the existing chlorinator room. Also included in the equipment is a transfer pump to transfer diluted solution to the Colington Pump Station. This subsystem will be described later, but it is proposed that this



DARE COUNTY WATER SYSTEM
DISINFECTION ALTERNATIVES STUDY
Figure 1. NRO P&ID

pump be located at the pumping station, and not in the NRO building. A piping connection will be made from the outlet of the bulk tanks. This connection will be buried, and will be installed in a containment pipe from the bulk storage containment area to the proposed Colington system.

Because of the inherent instability of commercial strength sodium hypochlorite, it is recommended that the delivered material, which is about 12.5% by weight, be diluted to about 8% strength as it is transferred from the delivery vehicle to the storage tanks. It is proposed that this be done by the use of a setback meter, which upon initiation allows a preset volume of water to be mixed with the incoming hypochlorite during transfer. The volume of water required per unit volume of delivered hypochlorite may be calculated from the following formula:

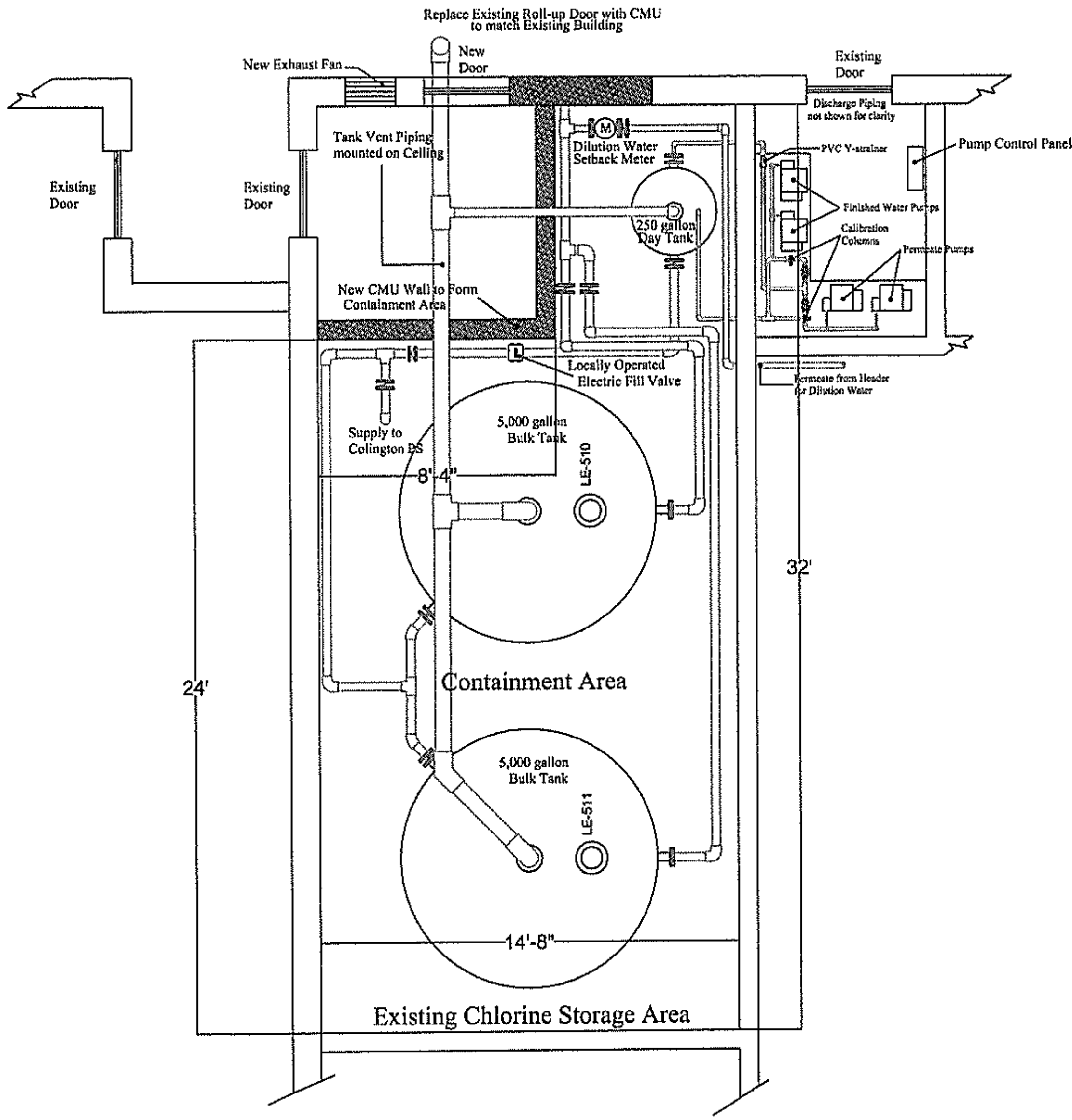
$$V = X * H * ((A-B)/B)$$

where: A = weight percent of delivered hypochlorite
B = weight percent of final hypochlorite
X = gallons of delivered hypochlorite = 1
H = specific gravity of delivered hypochlorite = 1.17 *(should be measured for each delivery. This value will vary depending upon the residual NaOH in the delivered hypochlorite solution).*
V = volume of water required for dilution of one gallon of delivered hypochlorite.

Although the diluted hypochlorite will be much more stable than the delivered strength solution, precautions in handling, storage and pumping similar to those required for delivered strength solution should be taken. These include the absence of metal in contact with the solution, control of the storage temperature of the solution, and the use of peristaltic pumps for metering the solution into the two injection points. It is also proposed that permeate from the existing NRO plant be used as the dilution water, to guard against the possibility of precipitants forming in the diluted hypochlorite.

Hypochlorite from the bulk storage tanks will be transferred to the day tank by gravity. To maximize the use of stored solution, the day tank selected will be selected to provide the lowest possible liquid level when full. Filling of the day tank will be controlled by a locally-operated electrically actuated valve. The valve control, and a locally-mounted level indicator will be provided.

Hypochlorite solution from the day tank will be delivered to the two existing injection points by peristaltic pumps. These will be located in the existing chlorinator room, arranged in two sets, each set having a service unit and standby. Calibration columns will be provided in the piping for operator use. A wye strainer will be installed in the common suction piping, to



DARE COUNTY WATER SYSTEM
DISINFECTION ALTERNATIVES STUDY
Figure 2. NRO Hypochlorite System Layout

guard against the possibility of suspended material entering the pumps. The pumps will discharge into the existing chlorine solution piping in the chlorinator room.

Both bulk tanks and the day tank will be vented outside the building as shown in **Figure 2**. This venting system will be fabricated from thin wall PVC duct piping, and will be suspended from the chlorine room ceiling.

The new system will be instrumented as shown in **Figure 1**. When a delivery is made the operator will set the dilution water meter for the volume that is needed to dilute the delivery volume. As the solution is transferred to the bulk tanks, the operator can monitor the tank level displayed on indicators located at the fill point. It is proposed that in normal operation, one bulk tank will be in service while the second tank awaits refilling. Valves are provided on both inlet and outlet piping for the operator to select the tank online, and the tank to be filled.

As described above, transfer to the day tank will be by gravity, and is proposed as a manual operation, requiring operator presence. Normal operation of the two metering pumps will be automatic, based on plant operation, and controlled by chlorine residual set points in the NRO plant logic. Both locally mounted switches and software switches will permit the operator to turn pumps on and off manually, both locally and in the control room at the HMI.

2. ***Building Modifications***

Option (a)

The preliminary proposed layout for the NRO system is shown in **Figure 2**.

It is proposed that the existing roll up door be removed, the existing chlorine storage and handling equipment dismantled and removed, and the resulting opening filled with CMU to match the existing walls of the RO building. A new positive wall ventilation system will be required, and it is proposed that an air-conditioning duct be connected to the arsenic room air handler system to provide a small flow of tempered air in the hypochlorite storage area during the summer months.

To provide ease of access to the operators, a personnel door is shown located in the new masonry wall section. The second, existing door will be retro-fitted with new panic hardware.

Option (b)

The alternative approach is to leave the roll-up door in place, and not replace it with CMU. However, some work will still be required to prepare the space for the hypochlorite system. The existing chlorine cylinder rails will need to be removed, and it is recommended that the cylinder handling structure also be removed.

Regardless of the approach taken to prepare the space, it will be necessary to create a containment area by erecting a CMU wall as shown in Figure 2. This containment area must be capable of holding the full contents of both bulk storage tanks, and the day tank. The volume to be contained is 10,500 gallons. Using the footprint shown in Figure 2, the containment wall height will be 4 feet. The inside will be coated with a chemical resistant sealer to prevent seepage through the block structure.

3. Colington Pump Station Subsystem.

A secondary disinfection system has been proposed for the Colington Pump Station, located on the NRO property. A P&ID and proposed layout is shown in **Figure 3**.

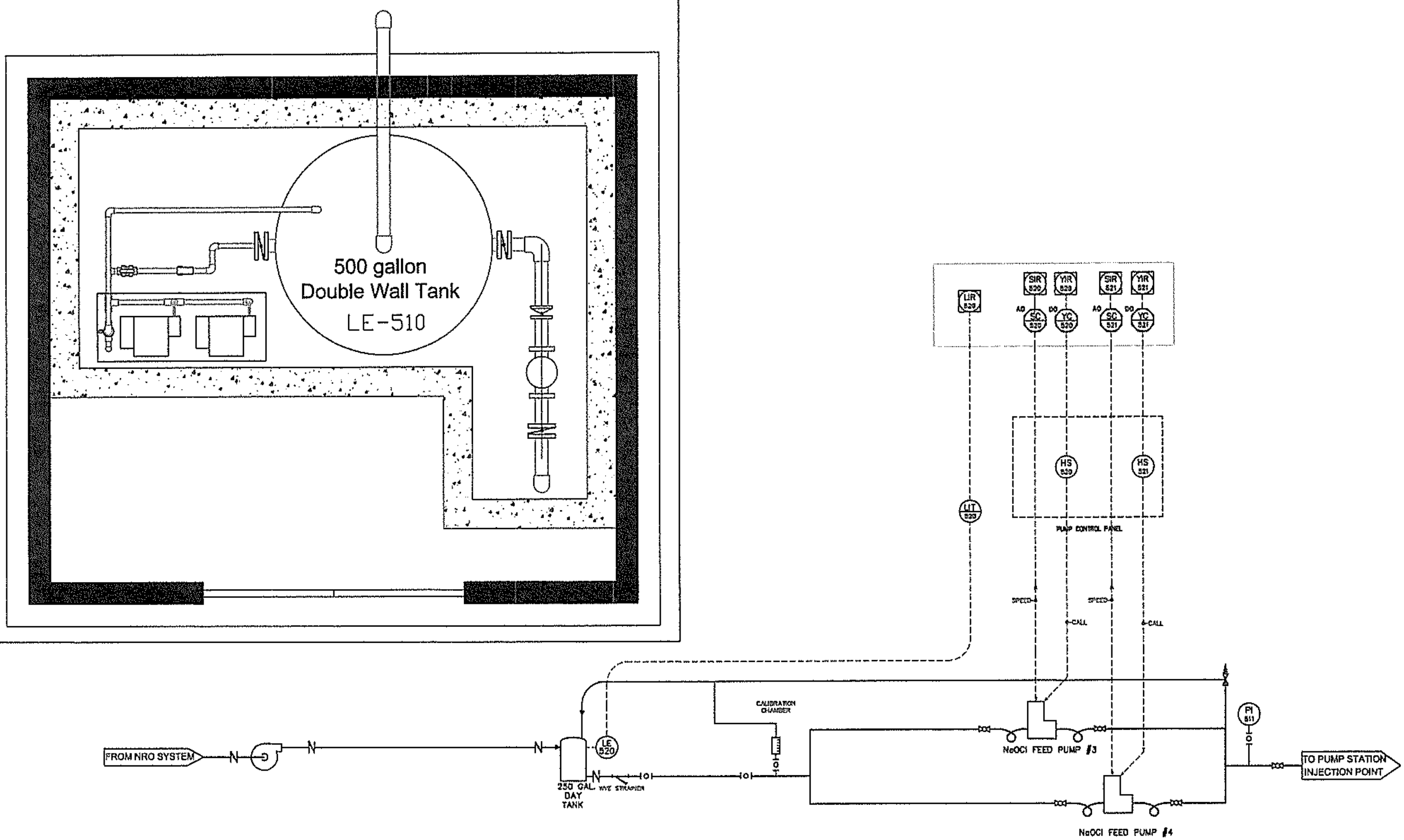
It is proposed that the supply to the pump station be by buried, double walled pipeline from the new hypochlorite system in the NRO building, In the event that the level in the bulk storage is low, not providing sufficient head for reasonable gravity flow rates, a small booster pump will be provided in the system. A double-walled day tank of 500 gallons capacity will be provided, and a two pump peristaltic metering pump system, one service and one standby, will discharge to an injection point located in the adjacent pump station discharge piping. It is proposed that tank filling and metering pump flow adjustment be controlled locally by an operator. The delivery system will be interlocked with the pump station pump starter logic.

A small prefabricated wooden building will be provided on a concrete slab adjacent to the pump station. The building will be insulated, and provided with a small HV&AC system.

4. Opinion of Probable Project Cost

Assuming that Option (a) for NRO building modifications is selected, the following opinion of probable project cost has been prepared, for Colington and NRO projects.

Wherever possible actual price list costs have been used for the equipment and piping. Labor rates and task man-hours have been taken from RS Means Building Construction Cost Data, 2006 edition. The costs taken from this source have been adjusted to reflect inflation through the beginning of 2007, using the Engineering News Record index.



DARE COUNTY WATER SYSTEM
DISINFECTION ALTERNATIVES STUDY
Figure 3. Colington Pump Station System

Table 1 Colington Pump Station Project

	Materials	Labor	Total
Civil Work	$ 25,000.00	$ 8,000.00	$ 35,960.00
Equipment	$ 14,000.00	$ 1,000.00	$ 15,250.00
I&C	$ 3,300.00	$ 300.00	$ 3,660.00
Electrical	$ 4,200.00	$ 2,800.00	$ 7,000.00
Piping and Valves	$ 2,500.00	$ 1,500.00	$ 4,225.00
	$ 49,000.00	$13,600.00	$ 66,095.00
Contingency @ 20%			$ 13,250.00
Contractor O/H & Profit			$ 19,850.00
Probable Constructed Cost			$ 99,195.00
Engineering, Construction Services			$ 15,000.00
			$ 114,195.00

Table 2 North RO WTP Hypochlorite Project

	Materials	Labor	Total
Demolition	$ 7,500.00	$10,300.00	$ 17,800.00
Civil Work	$ 13,500.00	$15,800.00	$ 29,300.00
Equipment	$ 52,500.00	$ 8,500.00	$ 61,000.00
I&C	$ 13,600.00	$15,600.00	$ 29,200.00
Electrical	$ 35,000.00	$20,600.00	$ 55,600.00
Piping and Valves	$ 11,300.00	$ 4,900.00	$ 16,200.00
	$133,400.00	$75,700.00	$ 209,100.00
Contingency @ 20%			$ 41,820.00
Contractor O/H & Profit, 25%			$ 62,730.00
Probable Constructed Cost			$ 313,650.00
Engineering, Const. Services			$ 50,184.00
			$ 363,834.00