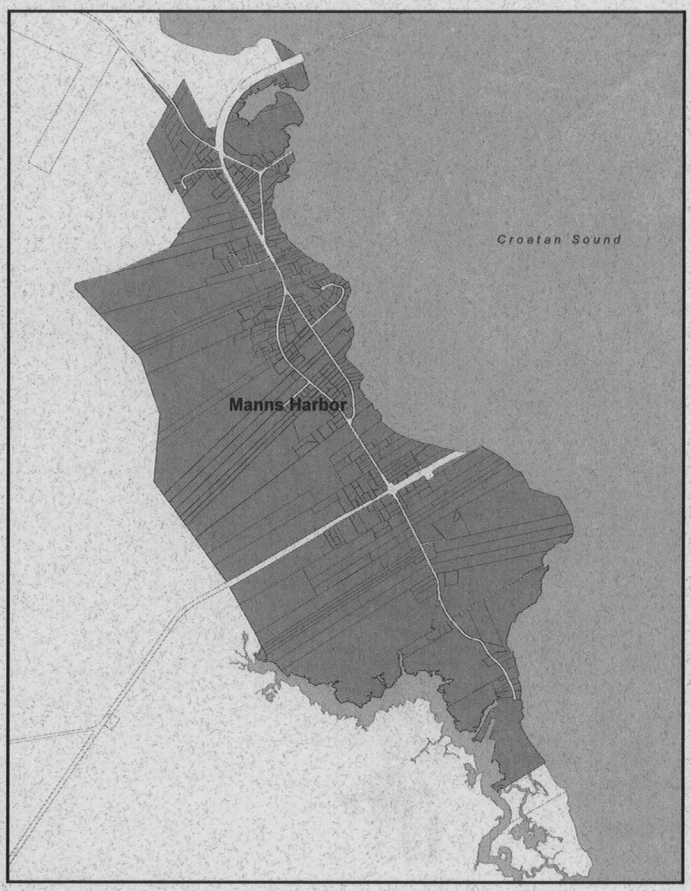
CDM

Dare County Water Department,
North Carolina

Manns Harbor
Water System Study

April 2006



Final Report

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North Carolina

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E.1 Introduction

Situated on the west side of Croatan Sound is Manns Harbor, the largest village of mainland Dare County. Manns Harbor is primarily rural and unzoned. Manns Harbor consists mostly of year-round residents that rely on private wells for potable water. The Manns Harbor Fire Department has expressed an interest to the County in providing public water supply to improve fire protection. It is a goal of the Dare County Water Department to work in a professional manner with engineers, private contractors, and State agencies to expand the distribution system and meet the water needs of areas within Dare County.

This study evaluates system improvements necessary to provide water service to Manns Harbor based on projected 2025 water demands. The evaluation was conducted using a computer model of the proposed water distribution system. The scope of work of the contractual agreement for this project also included a water system study for Dare County to extend public water service to unserved areas of Roanoke Island, Manteo, and Wanchese. The *Roanoke Island/Manteo/Wanchese Water System Study* is presented in a separate report.

E.2 Water Demands

Water demand projections for Manns Harbor were developed concurrent with the water demands for the Roanoke Island/Manteo/Wanchese service area. Water demand projections for the 2025 planning period were developed based on a review of water billing data, available population projections, parcel data, and land use data. A summary of the recommended water demand projections is presented in Table E-1.

Table E-1: Recommended Water Demand Projections

	2025 Average Day Demand (gpd)[1]	2025 Population Projection[2]	Per Capita Consumption (gpcd)[3]	2025 Maximum Day Demand (gpd)[4]
Manns Harbor	163,000	1,637	100	408,000

Notes:

1. Based on average of 350 gpd/acre and 466 developable land acres, rounded to nearest thousand.
2. Based on 2000 U.S. Census Bureau estimate for Manns Harbor zip code area less East Lake population estimate; assumes North Carolina State Data Center growth rate for Dare County.
3. 2025 Average Day Demand divided by 2025 population projection.
4. 2025 Average Day Demand x 2.5

E.3 Water Supply

Potential water supply sources for the Manns Harbor water system were identified for this study based on the *Dare County-Wide Hydrogeological Study and Groundwater Resource Evaluation Report,* dated May 1998, and the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* dated April 2006. These reports identified both the Principal aquifer (the shallow zone) and the Mid-Yorktown aquifer (the deep zone) as potential sources for a public water system. Test wells were drilled into each aquifer on a property owned by Dare County located behind the EMS station.

For the purposes of this evaluation, it is assumed that a water supply and treatment facility will be developed on the Dare County property behind the EMS station. The central location of this property in relation to the proposed Manns Harbor water system is beneficial to the design and operation of the distribution system. A water supply and treatment facility located on the north side of Manns Harbor was also considered in the event the facility is used to supplement the Skyco Water Treatment Plant (WTP).

E.4 Hydraulic Model Development

The hydraulic evaluation was performed using a computer model of the proposed water distribution system. The proposed water distribution system was modeled using WaterGEMS™, a software developed by Haestad Methods that directly interfaces with ArcGIS™. WaterGEMS™ was previously selected by Dare County for the hydraulic model of the northern beaches due to its direct integration with the GIS database of their water system.

For the Manns Harbor water system, it was assumed that the water mains required would be located along major roads within existing rights-of-way. Water mains were modeled using GIS road centerline data provided by the County. Nodes were provided at road intersections and at the end of the pipes. Each parcel was assigned to the closest model node. Water demands were distributed in the model based on the developable acreage of each parcel. Ground elevations were assigned to each node based on topographical data provided by the North Carolina Department of Transportation.

E.5 Evaluation Approach and Criteria

Hypothetical conditions were simulated on the computer model and their effects on the system observed. Hypothetical conditions included average day, maximum day, maximum day plus fire flow, and peak hour demand conditions. Computer simulations were also conducted to determine if the system is capable of filling the proposed storage facility during minimum nighttime demand conditions on the maximum day.

The evaluation was based on the following criteria:

- Maintaining the County's desirable minimum system pressure of 60 pounds per square inch (psi) during average day, maximum day, and peak hour demand conditions and 20 psi during maximum day plus fire flow demand conditions. A minimum system pressure of 30 psi is required by the North Carolina Department of Natural Resources (NCDENR) during peak demand conditions.

- Limiting velocity to 10 feet per second (fps), with velocities less than 5 fps as the desirable range

- Limiting headloss to 5 feet/1,000 feet.

- Providing a minimum fire flow of 500 gallons per minute (gpm) based on the Insurance Services Office (ISO) minimum residential fire flow requirement which is based on one- and two-family dwellings not exceeding two stories in height, spaced over 100 feet apart.

- Providing storage for equalization and fire protection. NCDENR requires the total volume of finished water storage to be one-half the average day demand. NCDENR also specifies a minimum capacity of 75,000 gallons for elevated storage tanks.

E.6 Evaluation Results

Water systems are designed to satisfy maximum day demand conditions from the WTP. A capacity of 408,000 gpd is required for the proposed Manns Harbor WTP to meet the projected 2025 maximum day demand of the service area. Specific requirements for the Manns Harbor WTP were evaluated by CDM under a separate study conducted concurrent with this project. Results of the water supply investigation are presented in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report*. Both the Principal aquifer and the Mid-Yorktown aquifer were identified as potential water supply sources. Ion exchange or membrane softening was identified as the treatment process for groundwater withdrawn from the Principal aquifer. Low pressure reverse osmosis or membrane softening was identified as the treatment process for groundwater withdrawn from the Mid-Yorktown aquifer.

To provide equalization during peak hour demands and fire protection, an elevated storage tank with a volume of at least 100,000 gallons at a high water level elevation of 160 feet is recommended. If additional volume is desired for emergency purposes, a larger tank may be implemented. Tank turnover must be monitored carefully to maintain water quality. It is recommended that the finished water pumps at the Manns Harbor WTP be controlled by the water level of the elevated storage tank to provide adequate turnover.

In general, fire protection governed the sizing of water distribution mains. To provide transmission to the south from a centrally located WTP, installation of a 12-inch diameter main on Old Manns Harbor Road to the Pecan Lane/Shipyard Road intersection and an 8-inch diameter main continuing south on Shipyard Road are recommended. To provide transmission to the north, installation of an 8-inch diameter main on Old Manns Harbor Road to Preston Twiford Road is recommended. Installation of 6-inch diameter mains is recommended for the other distribution mains in accordance with the County's minimum diameter requirement for fire protection. If the elevated storage tank is located on the north side of Manns Harbor instead of the WTP site, installation of a 12-inch diameter main from the central WTP to the elevated storage tank is recommended. If the WTP and elevated storage tank are located on the north side of Manns Harbor, installation of a 12-inch diameter main from the WTP site south to Old Manns Harbor Road is recommended.

E.7 Cost Estimates

Preliminary planning-level cost estimates were developed for the recommended system improvements. The intended use of this type of estimate is long-range planning. The final cost of any project will depend on the project complexity, actual labor and material costs, competitive market conditions, actual site conditions, final scope of work, implementation schedule, continuity of personnel, and engineering.

Preliminary planning level cost estimates for the Manns Harbor water system are presented in Table E-2. The preliminary cost estimates do not include costs for property acquisition.

Table E-2: Manns Harbor Water Distribution System Planning-Level Cost Estimates[3,4]

	Central WTP & Tank		North WTP & Tank		Central WTP & North Tank	
	Length (feet)	Cost Estimate ($)	Length (feet)	Cost Estimate ($)	Length (feet)	Cost Estimate ($)
WTP (O.4 mgd)[1]	---	2,000,000	---	2,000,000	---	2,000,000
100,000-gallon Elevated Storage Tank[2]	---	500,000	---	500,000	---	500,000
12" PVC Pipe	1,700	90,000	3,300	180,000	6,900	380,000
8" PVC Pipe	7,600	340,000	9,100	410,000	5,000	230,000
6" PVC Pipe	37,500	1,310,000	34,400	1,200,000	34,900	1,220,000
Subtotal	46,800	4,240,000	46,800	4,290,000	46,800	4,330,000
25% Construction Contingencies		1,060,000		1,070,000		1,080,000
15% Design, Legal, and Financial		640,000		640,000		650,000
Total		5,940,000		6,000,000		6,060,000
Annualized Cost[5]		500,000		500,000		510,000

Notes:
1. WTP assumes two wells, package-type membrane treatment, and disposal of concentrate to surface water.
2. Spheroid type tank with pile foundation.
3. Cost presented in 2006 dollars with an ENR construction cost index of 7695.10 (April 2006).
4. Costs do not include property acquisition.
5. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

Dare County can reduce water main installation costs by creating an in-house water main construction division and install all 6-inch diameter water mains and service connections. Installation of water mains greater than 6-inch diameter would be contracted.

E.8 Summary and Recommendations

This study identified system improvements necessary to extend water service to Manns Harbor. The analysis was based on projected 2025 water demands, which assumed build-out of developable acreage. It is recommended that the water demand projections be re-evaluated once a land use plan is developed for Manns Harbor. It is also recommended that property for the water treatment plant and well sites be acquired while land is still available.

Transmission and storage improvements directly affect water quality in distribution systems. Pipes sized to meet projected demands of the system may be oversized for the current demands of the system and, as a result, experience problems in maintaining a disinfectant residual. Prior to implementing the system improvements, potential water quality impacts should be evaluated, particularly with near-term demands (e.g., 2010). Alternative sources for fire protection in low density areas, such as the reliance on pumper trucks, should be evaluated if the demand in the area is insufficient to promote turnover in a pipe sized to provide fire protection. If fire protection is not required, a smaller diameter main could be installed in the near-term with a parallel main installed in the future when demands in the area increase.

Section 1
Introduction

Situated on the west side of Croatan Sound is Manns Harbor, the largest village of mainland Dare County. Manns Harbor is primarily rural and unzoned. Manns Harbor consists mostly of year-round residents that rely on private wells for potable water.

The Manns Harbor Fire Department has expressed an interest to the County in providing public water supply to improve fire protection. It is a goal of the Dare County Water Department to work in a professional manner with engineers, private contractors, and State agencies to expand the distribution system and meet the water needs of areas within Dare County.

The Dare County Water Department contracted Camp Dresser and McKee (CDM) to conduct a water system study to determine distribution system requirements to provide public water service to Manns Harbor. This report presents the results of the study which included the following tasks:

- Development of 2025 water demand projections
- Evaluation of potential water supply locations
- Development of a computer model of the proposed water distribution system using WaterGEMS™
- Hydraulic evaluation
- Development of planning-level cost estimates for the recommended water distribution system.

The scope of work of the contractual agreement for this project also included a water system study for Dare County to extend public water service to unserved areas of Roanoke Island, Manteo, and Wanchese. The *Roanoke Island/Manteo/Wanchese Water System Study* is presented in a separate report. CDM also completed the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* dated April 2006, which discusses potential water supply sources for Manns Harbor.

Section 2
Water Demands

2.1 General

Water demand projections for Manns Harbor were developed concurrent with the water demand projections for the Roanoke Island/Manteo/Wanchese service area. Water demands were developed based on a review of the following data:

- Population projections from the North Carolina State Data Center
- Population data from the U.S. Census Bureau
- *2003 Dare County Land Use Plan*
- North Carolina Department of Environment and Natural Resources (NCDENR) Rules Governing Public Water Systems
- Dare County and Town of Manteo historical water billing data.

A discussion of the methodology used to develop the demand projections follows.

2.2 Population

Historical population data for Dare County was obtained from the *2003 Dare County Land Use Plan*. The *2003 Dare County Land Use Plan* population data is based on the 2000 U.S. Census Bureau population data. The 2000 year-round population for Dare County was estimated to be 29,967 with a seasonal population of 200,000. U. S. Census Bureau population data for Dare County is shown on Figure 2-1.

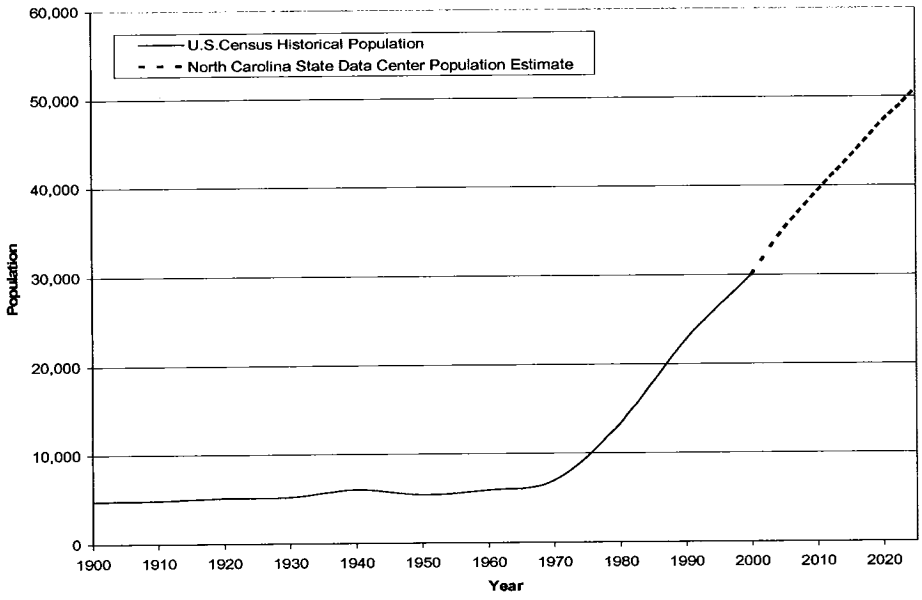

Figure 2-1: Dare County Population

Available population projections for the study area are limited to projections for Dare County provided by the North Carolina State Data Center. These projections are not geographically distributed within the County. Population estimates for Manns Harbor were based on the U.S. Census Bureau 2000 population estimates for the Manns Harbor zip code area, assuming the same growth rate as the County projections. The population projections for the Manns Harbor zip code area are presented in Table 2-1.

Table 2-1: Dare County Population Estimates

Year	Dare County[1,2]	Manns Harbor[1,3,4] (zip code 27953)	East Lake [5,6]	Manns Harbor[7] Study Area
2000	29,967	1,182	N/A	N/A
2005	35,145	1,386	187	1,199
2025	50,798	2,004	367	1,637

Notes:
N/A = Not Available
1. 2000 population estimates based on U.S. Census Bureau statistics (American FactFinder).
2. 2005 and 2025 Dare County population projections provided by North Carolina State Data Center.
3. Manns Harbor zip code area includes East Lake.
4. Manns Harbor 2005 and 2025 population estimate based on North Carolina State Data Center growth rate for Dare County.
5. 2005 East Lake population based on 76 developed residential properties for East Lake identified in Appendix C of the *2003 Dare County Land Use Plan* x 2.46 people per residence (U.S. Census Bureau average for Dare County and Manteo, Wanchese, and Manns Harbor zip code areas)
6. 2025 East Lake population based on (76 developed residential properties + 73 vacant private properties for East Lake in *2003 Dare County Land Use Plan*) x 2.46 people per residence
7. Manns Harbor Study Area population = Manns Harbor zip code area population – East Lake population

The Manns Harbor zip code area includes East Lake. The 2005 East Lake population was estimated based on the number of developed residential properties identified in Appendix C of the *2003 Dare County Land Use Plan*, assuming 2.46 people per household. To estimate the 2025 East Lake population, it was assumed that the vacant private properties identified in the *2003 Dare County Land Use Plan* were also developed for residential use. The estimated population of East Lake is presented in Table 2-1 and was subtracted from the Manns Harbor zip code area population to determine the Manns Harbor study area population. A summary of the Manns Harbor study area population estimates is presented in Table 2-1.

The estimated number of people per household of 2.46 used to determine the East Lake population was based on the average of the U.S. Census Bureau estimates for Dare County and the Manteo, Wanchese, and Manns Harbor zip code areas. The estimated number of people per household for each entity is presented in Table 2-2.

Table 2-2: Estimated Number of People per Household Based on 2000 U.S. Census Bureau Data

Entity	Estimated Number of People per Household
Dare County	2.34
Manteo (Zip Code 27954)	2.44
Wanchese (Zip Code 27981)	2.49
Manns Harbor (Zip Code 27953)	2.57
Average (Dare County + zip code areas)	2.46
Town of Manteo	2.03

Notes:
1. Source: U.S. Census Bureau (American FactFinder)
2. Manteo zip code area includes incorporated and unincorporated surrounding area.
3. Manns Harbor zip code area includes East Lake.

2.3 Unit Water Demand Estimates

Unit water demand estimates for the Manns Harbor water demand projections were developed as part of the water demand projections for the *Roanoke Island/Manteo/Wanchese Water System Study*. Preliminary unit water demand estimates were based on billing data for 2004/2005 provided by Dare County and the Town of Manteo. Unit water demand estimates established by NCDENR were also considered.

2.3.1 Historical Billing Data

Average day demand is defined as the total amount of water consumed in a given year divided by the number of days in the year. Residential average day demand per capita consumption rates ranged from 50 to 70 gallons per capita per day (gpcd) based on the Dare County and the Town of Manteo historical water billing data. Unit water demand per acre (rounded to the nearest hundred) ranged from 200 to 500 gallons per day (gpd)/acre (with the exception of 600 gpd/acre for the RS-8 zone code in outer Manteo). Summary tables of the unit water demand estimates are included in Appendix A.

2.3.2 NCDENR Criteria

NCDENR (NCAC T15A:18C.0409) indicates that units of local government which are operating under a local water supply plan (e.g., Dare County) shall not be limited in the number of service connections. For public water systems that do not have a water supply plan, NCDENR limits the number of service connections based on the following alternatives for calculating design flows:

- Design flow of 400 gpd per residential connection. Design flows for other types of connections (e.g., commercial establishments, schools, hospitals, etc.)

are also specified and are determined based on criteria such as the number of employees, students, etc.

- For public water systems serving different types of connections, design flow of a maximum day demand equivalent to 2.5 times the average day demand for communities serving 10,000 or less people or 2.0 times the average day demand for communities serving more than 10,000 people. Maximum day demand is defined as the largest demand to occur during a single day in a given year.

Although Dare County has a water supply plan, these NCDENR unit demands were considered for comparison purposes. The residential design flow of 400 gpd per connection results in an average day demand per capita consumption of 65 gpcd, based on the maximum day to average day factor of 2.5, assuming 2.46 people per household. Hence, the range of 50 to 70 gpcd based on the historical Dare County and Town of Manteo billing data is in range of the NCDENR criteria.

2.4 Water Demand Projections

Preliminary average day demand projections were developed using two methods:

- Population-based, assuming a per capita consumption rate of 70 gpcd, based on the upper range of the prior year's records for Dare County and the Town of Manteo and the NCDENR per capita estimate.

- Developable land area-based, assuming a unit demand per acre and that wetlands are considered undevelopable land. Wetland areas were identified based on information provided by the North Carolina Coastal Management. Wetland areas are shown on Figure 2-2. Wetland acreage was eliminated from the parcel acreage to estimate the developable acreage for the service area. Water demand projections were based on 200 to 500 gpd/acre based on the Dare County and Town of Manteo historical billing data. Build-out of developable acreage was assumed by 2025.

Preliminary projected average day demands developed based on these methods are presented in Table 2-3.

Appendix C of the *2003 Dare County Land Use Plan* lists the number of properties in Manns Harbor for various land use categories. A summary of the number of properties is presented in Table 2-4. Manns Harbor is currently unzoned. For comparison, it was assumed that build-out for Manns Harbor was based on development of the total number of properties listed. A single account was assumed per property. An average day unit water demand of 171 gpd per account was assumed based on the upper end of the range of values based on Dare County and the Town of Manteo historical data (refer to Appendix A). A summary of the water demand projections based on the number of properties is presented in Table 2-4.

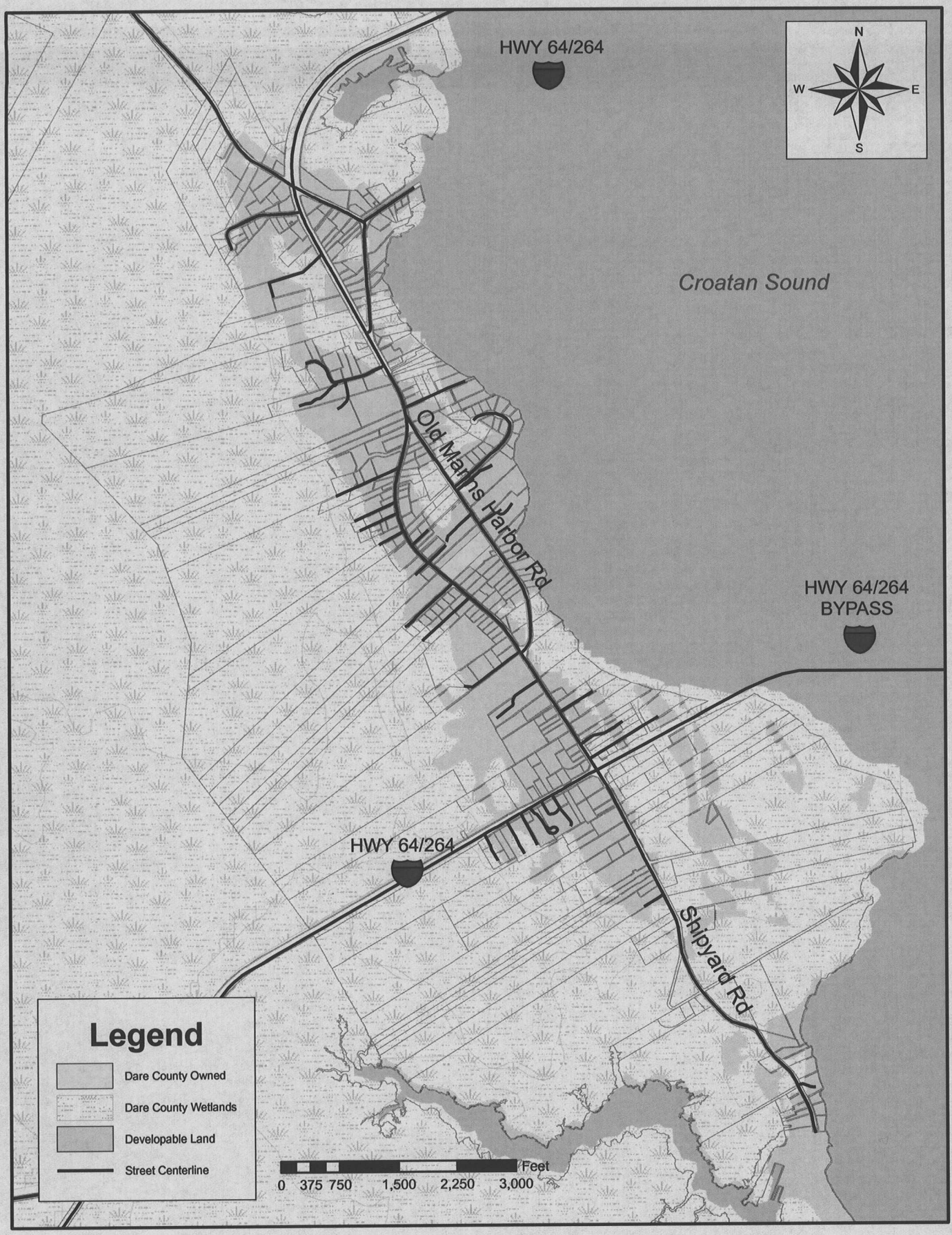

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Figure 2-2
MANNS HARBOR DEVELOPABLE LAND

Table 2-3: Preliminary Projected Average Day Demands

	2005		2025 Population-Based Projected Demand		2025 Developable Acreage-Based Projected Demand		
	2005 Population Estimate[1]	Estimated 2005 Water Demand (gpd)[2]	2025 Population Estimate[1]	2025 Projected Water Demand Based on Population (gpd)[2]	Developable Area (acres)[3]	200 gpd/acre Basis (gpd)	500 gpd/acre Basis (gpd)
Manns Harbor	1,199	84,000	1,637	115,000	466	93,000	233,000

Notes:
1. Refer to Table 2-1.
2. Based on 70 gpcd, rounded to nearest 1,000 gpd.
3. Excludes wetland areas; assumes build-out by 2025.

Table 2-4: Projected Build-Out Demand Based on Number of Properties in *2003 Dare County Land Use Plan*

	Manns Harbor
Vacant Land – Private Ownership	138
Vacant Land - Public Ownership	3
Developed Properties	
Residential Use	257
Commercial Use	19
Other Uses[1]	20
Government Uses[2]	6
Total Number of Properties	443
Average Day Demand (gpd) based on 171 gpd per account, rounded to nearest thousand	76,000

Notes:
1. Other Uses includes cemeteries, churches/religious buildings, secondary improvements.
2. Government Uses includes federal, state, and Dare County uses.

The projected 2025 average day demand for Manns Harbor based on the number of properties presented in Table 2-4 is approximately 18 percent less than the estimated average day demand based on 200 gpd/acre. However, it should be noted that the assumption of a single account per property does not taken into consideration potential subdivision of large acreage properties for multiple housing units. Hence, it is recommended that the Manns Harbor average day demand projections be based on an average of the unit demand acreage-based projections since it is more conservative than the population-based and property-based estimates.

Maximum day demand projections were based on NCDENR's maximum day to average day demand factor of 2.5 for systems serving 10,000 people or less. A summary of the recommended water demand projections is presented in Table 2-5.

Table 2-5: Recommended Water Demand Projections

	2025 Average Day Demand (gpd)[1]	2025 Population Projection[2]	Per Capita Consumption (gpcd)[3]	2025 Maximum Day Demand (gpd)[4]
Manns Harbor	163,000	1,637	100	408,000

Notes:
1. Based on average of 200 gpd/acre and 500 gpd/acre projections in Table 2-3.
2. Refer to Table 2-1.
3. 2025 Average Day Demand divided by 2025 population projection.
4. 2025 Average Day Demand x 2.5

As a "reasonableness" check, a per capita consumption rate was also estimated based on the acreage-based average day demand and population projections presented in Table 2-5. The estimated per capita consumption rate for Manns Harbor was 100 gpcd which is in range of typical values for residential communities. The per capita consumption rate of 100 gpcd is more conservative than the per capita consumption rate of 70 gpcd initially assumed in Table 2-3 based on historical billing data. The higher value assumed provides an allowance for commercial and/or industrial development, particularly since Manns Harbor is currently unzoned. It is recommended that the water demand projections be updated as zoning is established for undeveloped properties in Manns Harbor.

Section 3
Water Supply

Potential water supply sources for the Manns Harbor water system were identified for this study based on the *Dare County-Wide Hydrogeological Study and Groundwater Resource Evaluation Report* prepared by Missimer International, Inc., dated May 1998, and the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report* prepared by CDM, dated April 2006. The reports identified both the Principal aquifer (the shallow zone) and the Mid-Yorktown aquifer (the deep zone) as potential sources for a public water system. In 1998, test wells were drilled into each aquifer on a property owned by Dare County located behind the EMS station. The location of the property is shown on Figure 3-1.

The test wells drilled into the Principal aquifer and the Mid-Yorktown aquifer were identified as the "Mann-Shallow" well and the "Mann-Deep" well. A summary of the characteristics of each well and the 1998 water quality results is presented in Table 3-1.

Table 3-1: Manns Harbor 1998 Test Well Summary

Parameter	Mann-Shallow Well	Mann-Deep Well
Aquifer	Principal (Upper Yorktown)	Mid-Yorktown
Interval Tested (feet below surface)	135-195	250-350
Transmissivity	51,000 gpd/ft	73,000 gpd/ft
Dissolved Chloride Concentration	30 mg/l	240 mg/l
Total Dissolved Solids	300 mg/l	710 mg/l
Iron	0.036 mg/l	0.165 mg/l
Color	7 color units	14 color units
Minimum treatment requirement	Conventional or membrane softening	Membrane softening

Source: *Dare County-Wide Hydrogeological Study and Groundwater Resource Evaluation Report* prepared by Missimer International, Inc., dated May 1998

The 1998 water quality results indicate that the Principal aquifer is of better quality than the Mid-Yorktown aquifer. Private wells in Manns Harbor currently tap the water table and the Principal aquifer.

The results of drilling, testing, and data analyses conducted during the previous countywide hydrogeologic study indicate that development of a public water supply in Manns Harbor is feasible. The Principal (Upper Yorktown) aquifer is considered the most likely source for withdrawals. Ion exchange or membrane softening was

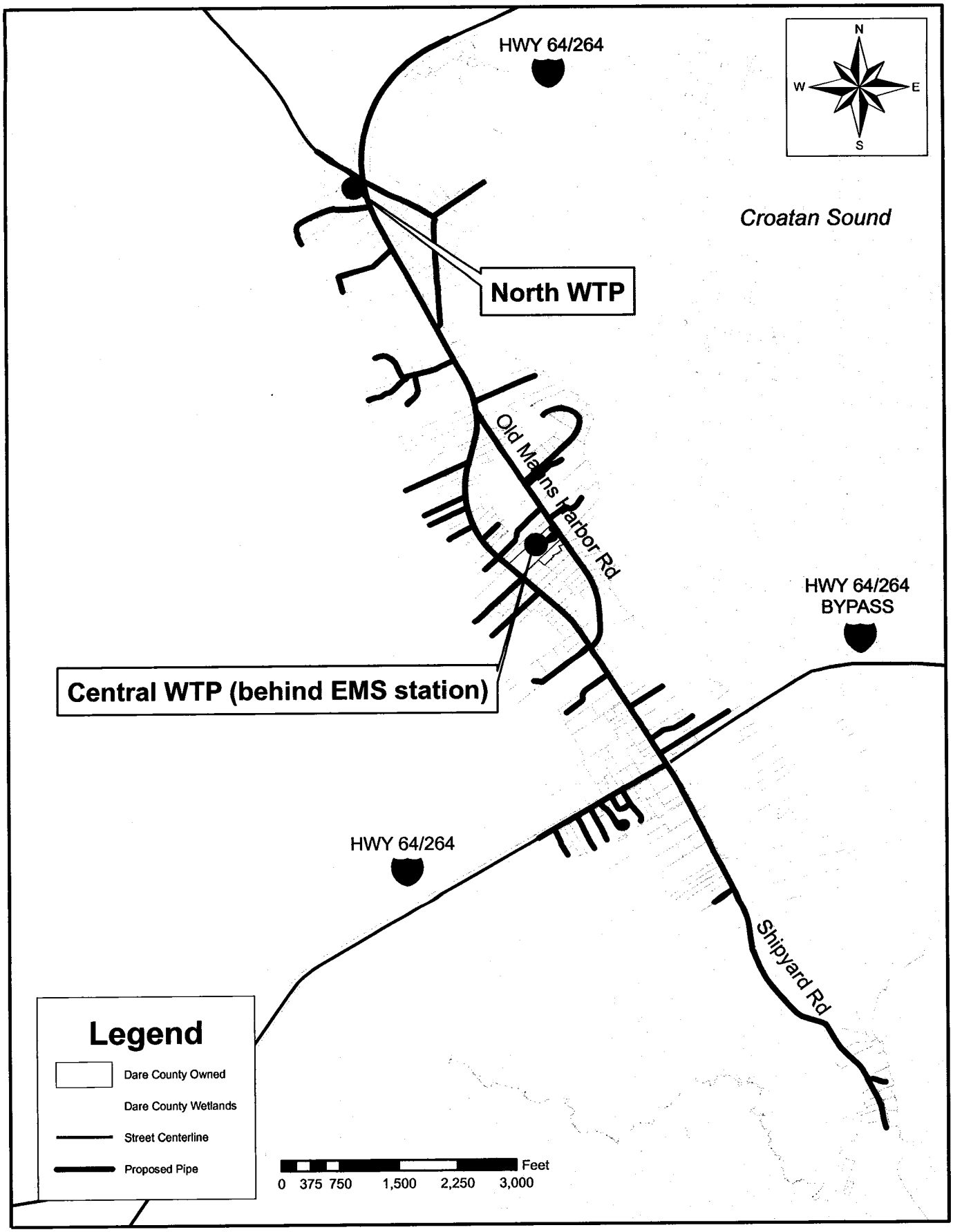

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Figure 3-1
MANNS HARBOR POTENTIAL WTP LOCATION

identified as the treatment process for groundwater withdrawn from the Principal aquifer. Low pressure reverse osmosis or membrane softening was identified as the treatment process for groundwater withdrawn from the Mid-Yorktown aquifer. Pumpage at a combined rate of 290,000 gpd from two wells was simulated during the previous investigation.

For the purposes of this water system study, it is assumed that a water supply source will be developed for Manns Harbor on the Dare County property behind the EMS station shown on Figure 3-1. This water supply location will be identified as the central Water Treatment Plant (WTP).

As discussed in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* large-scale pumpage from the Principal aquifer at Manns Harbor to supply Roanoke Island and the beaches may also be feasible. Hence, a WTP located on the north side of Manns Harbor was considered as an alternate location. The north WTP location is shown on Figure 3-1. Finished water would be transported through a pipe across Croatan Sound to the north end of Roanoke Island through bridge attachment or directional boring. The cost of constructing approximately 3 miles of pipeline to Roanoke Island would be very high. In addition, the County indicated that the North Carolina Department of Transportation (NCDOT) may remove the bridge in the future if maintenance is not cost-effective. Hence, although the concept of transporting water from mainland Dare County to the beaches is feasible, costs would likely make other options more economically viable.

Section 4
Model Development &Evaluation Criteria

4.1 Model Development

To evaluate water distribution system requirements, a computer model of the proposed Manns Harbor water system was developed using WaterGEMS™, a software developed by Haestad Methods that directly interfaces with ArcGIS™. WaterGEMS™ was previously selected by Dare County in 2004 for the hydraulic model of the northern beaches (Kitty Hawk, Southern Shores, Duck) due to its direct integration with the GIS database of their water system.

For the Manns Harbor water system, it was assumed that the water mains required would be located along major roads within existing rights-of-way. Water mains were modeled using GIS road centerline data provided by the County. The pipe network was overlayed on the developable portions of the parcels (i.e., the portion that is not located in wetland areas.) Pipes are characterized in the model by their diameter, length, and a Hazen-Williams roughness coefficient (C value). In accordance with the County's standards, it was assumed that all pipes 12 inches in diameter and smaller are constructed of polyvinyl chloride (PVC) and that the minimum pipe diameter is 6 inches.

Nodes were provided in the model at road intersections and at the end of pipes. Ground elevations were assigned to each node based on topographical data provided by the NCDOT. It is recommended that elevations in the model be updated as GIS elevation data becomes available. Water demands presented in Section 2.4 were distributed in the model based on the developable acreage of each parcel.

The proposed water supply was modeled with a reservoir and a pump. An elevated storage tank was also considered for equalization, fire protection, and emergency purposes. The proposed elevated storage tank is defined in the model by its operating range, elevation, and diameter.

4.2 Modeling Approach

To determine the adequacy of the proposed system to meet projected water demands, hypothetical conditions were simulated on the computer model and their effects on the system observed. Hypothetical conditions included average day, maximum day, maximum day plus fire flow, and peak hour demand conditions. Computer simulations were also conducted to determine if the proposed system is capable of filling the proposed storage facility during minimum nighttime demand conditions on the maximum day. A discussion of the criteria used to evaluate the model simulations follows.

4.3 Evaluation Criteria

4.3.1 System Pressures

The adequacy of a water system is evaluated based on its ability to provide the volume of water required to satisfy the demands of the customers at adequate system pressures. The American Water Works Association (AWWA) indicates that most municipal water systems operate with system pressures in the 30 to 90 pounds per square inch (psi) range, with desirable pressures in the 40 to 50 psi range during average day demand conditions. High pressures in excess of 100 psi are generally avoided due to the potential for higher water losses and water main breaks. In addition, the North Carolina Plumbing Code requires the installation of pressure reducing valves at service connections where pressures exceed 80 psi.

Water systems are designed to satisfy maximum day demand conditions from the WTP. Under maximum day demand conditions, system pressures greater than 30 psi are desirable and storage facilities should remain full, i.e., not draining or filling. Storage facilities are intended to provide equalization, fire protection, and emergency storage. Hence, under maximum day demand conditions, the adequacy of the transmission, distribution, and pumping systems are of significant importance.

Under peak hour and maximum day plus fire flow demand conditions, the adequacy of storage facilities is evaluated in addition to the transmission, distribution, and pumping systems. System pressures greater than 30 psi are required by NCDENR for peak hour demand conditions. Under maximum day plus fire flow demand conditions, a minimum system pressure of 20 psi is required. The residual pressure is necessary to overcome frictional losses through the hydrant and hoses, and maintain positive pressure on the suction side of the fire department pumper truck. NCDENR further states that the elevation of a storage facility must be sufficient to provide a designed minimum distribution system pressure of 20 psi during fire flow conditions and 30 psi during peak flow conditions (NCAC T15A:18c.0405b).

Dare County prefers to maintain system pressures in the 60 psi range to provide allowance for delivery of water to multi-story structures, particularly hotels and apartment buildings. Houses in waterfront areas also tend to have multiple stories to avoid potential flooding impacts to living spaces at ground level. The evaluation was based on the ability of the water system to provide the County's desirable minimum system pressure of 60 psi during maximum day demand conditions with the storage tank full. System pressures in the 40 to 60 psi range were considered for peak hour demand conditions when storage tank water levels fluctuate. Under maximum day demand plus fire flow demand conditions , a minimum system pressure of 20 psi must be maintained throughout the system to provide adequate fire flow.

4.3.2 Velocity and Headloss

For transmission mains, AWWA recommends a maximum design velocity of 10 feet per second (fps), with velocities less than 5 fps as the desirable range. AWWA

recommends limiting headloss in transmission mains to 10 feet/1,000 feet with headlosses limited to 3 feet/1,000 feet for pipe sizes greater than 16 inches in diameter. Cesario (1995) recommends limiting headloss to 2 to 5 feet/1,000 feet for pipe sizes less than 24 inches in diameter and 1 to 2 feet/1,000 feet for pipe sizes greater than 24 inches in diameter. These criteria were considered in the evaluation based on the role of the transmission main (e.g., major transmission mains from the WTP versus transmission mains for flow distribution) and its effectiveness in improving the hydraulics of the system. For this evaluation, velocity was limited to 10 fps, with velocities less than 5 fps as the desirable range. Headloss was generally limited to 5 feet/1,000 feet.

4.3.3 Fire Flow Requirements

The fire flow requirements used for the hydraulic evaluations were based on the Insurance Services Office (ISO) fire flow requirements. ISO is a rating service that is utilized by insurance companies for establishing fire flow requirements for communities. ISO determines required fire flows on the basis of a field survey and evaluation of data relative to the floor area of the structures, availability of sprinkler systems, type of construction, as well as other factors. Flows required for fire protection are based on maintaining a residual pressure of 20 psi. As discussed in the previous section, this residual pressure is necessary to overcome frictional losses through the hydrant and hoses, and maintain positive pressure on the suction side of the fire department pumper truck.

For residential areas, ISO estimates the following fire flow requirements for one- and two-family dwellings not exceeding two stories in height:

Distance Between Buildings (feet)	Needed Fire Flow (gpm)
Over 100	500
31-100	750
11-30	1,000
Less than 11	1,500

The County indicated that ISO's fire flow requirement of 500 gpm for residential buildings spaced over 100 feet apart is representative of the fire flow requirement for the predominantly rural development in Manns Harbor. Fire flow requirements for commercial/industrial areas are generally higher than residential areas. It is recommended that the County evaluate specific fire flow requirements for commercial/industrial developments as well as public facilities such as schools, hospitals, nursing homes, etc.

4.3.4 Storage Requirements

4.3.4.1 Storage Components

Storage in a water distribution system has three functions:

- Equalization Storage
- Fire Protection Storage
- Emergency Storage

A discussion of each function follows.

Equalization Storage

Equalization storage is needed to meet hourly fluctuations in demand that occur on a daily basis. The equalization storage needed to supply demand variations is determined from a diurnal water demand hydrograph. The diurnal water demand hydrograph is a graphical representation of hourly water demand variations over a 24-hour period.

For the purposes of this evaluation, the diurnal hydrograph developed as part of the northern Dare County water system evaluation (Duck, Southern Shores, Kitty Hawk) was used for this study. The model diurnal hydrogaph was based on the average of the hydrographs for July 4, 2004 through July 7, 2004. A copy of the diurnal hydrograph is included in Appendix B. The diurnal hydrograph was input into the hydraulic model to analyze the ability of the system to meet peak hour demands as well as the system's ability to refill the storage tanks during the low demand periods.

Fire Protection Storage

Fire protection storage must be sufficient to supply, at a minimum, the fire flow requirement for the service area for the expected duration of the fire. To supply 500 gpm (ISO's minimum residential fire flow requirement) for a duration of 2 hours, an estimated fire protection storage of 60,000 gallons is required. The fire protection storage must be delivered to the system at a minimum residual pressure of 20 psi to be considered adequate. From a system-wide perspective, it is assumed that only one fire is occurring in the system at a single time.

Emergency Storage

Emergency storage is storage reserved for emergency situations such as power outages or water main breaks. An emergency storage capacity equal to one average day demand is desirable. However, some utilities consider emergency storage equal to one average day demand unrealistic for financial reasons. The County does not have specific emergency storage requirements for the system.

4.3.4.2 NCDENR Requirements

As required by NCDENR (NCAC T15A:18C.0805), "elevated storage for a municipality shall be sufficient to minimize the effect of fluctuating demand plus provide a reserve for fire protection, but not be less than 75,000 gallons in capacity. The combined elevated and ground storage of the finished water for community and non-transient, non-community water systems shall be a minimum of one-half day's supply of the average annual daily demand." NCDENR further states in that the elevation of the storage facility must be sufficient to provide a designed minimum distribution system pressure of 20 psi during fire flow conditions and 30 psi during peak flow conditions (NCAC T15A:18c.0405b).

4.3.4.3 Storage Evaluation Approach

The adequacy of storage facilities to meet the needs of a water system is dependent on several factors:

- volume
- geographic location with respect to demand distribution
- hydraulic effectiveness

The storage volume required is based on the volume required for equalization, fire protection, and emergency storage and NCDENR's requirements. The storage volume must be located in an appropriate location with respect to the demand distribution. The effectiveness and reliability of storage facilities are also highly affected by the hydraulics of the system. Storage requirements were evaluated based on these factors and are discussed in Section 5.

Section 5
Evaluation Results

5.1 Water Supply and Treatment Facility

Water systems are designed to satisfy maximum day demand conditions from the WTP. A capacity of 408,000 gpd is required for the proposed Manns Harbor WTP to meet the projected 2025 maximum day demand of the service area. Water treatment requirements for the facility are discussed in Section 3. Two WTP locations were evaluated:

- Central WTP located on County-owned property behind the EMS station (considered feasible if WTP only serves Manns Harbor's needs)

- North WTP located on the north side of Manns Harbor (considered feasible if the WTP is intended to supplement countywide water supply since its close proximity to the bridge make its location more suitable for a pipeline crossing to the northern end of Roanoke Island).

A discussion of storage, transmission, and distribution requirements for each WTP location follows.

5.2 Storage

Proposed water distribution systems for various WTP and storage tank locations are shown on Figures 5-1 through 5-3. The proposed water distribution systems shown on Figures 5-1 and 5-2 assume that distribution storage is provided on the WTP site. Alternatively, distribution storage for a centrally located WTP may be located on the north side of Manns Harbor as shown on Figure 5-3.

To meet NCDENR's minimum storage volume requirement of one-half the average day demand, a total finished water storage volume of approximately 82,000 gallons is required for the projected 2025 average day demand of 163,000 gpd (rounded to the nearest thousand). To provide equalization during peak hour demands and fire protection, it is recommended that at least 100,000 gallons of elevated storage with a high water level elevation of 160 feet be provided. Fire protection was based on a fire flow requirement of 500 gpm over a 2-hour duration. The capacity of the tank may be increased if additional storage is desired for emergency purposes and/or increased fire protection. Tank turnover must be monitored carefully to maintain water quality, particularly with a larger tank. It is recommended that the finished water pumps be controlled by the water level of the elevated storage tank to provide adequate turnover.

With the projected 2025 maximum day demand condition and the proposed storage tank full at the high water level elevation of 160 feet, the County's desirable minimum system pressure of 60 psi was observed throughout the service area. Hourly variations in the projected 2025 maximum day demand were simulated on the model

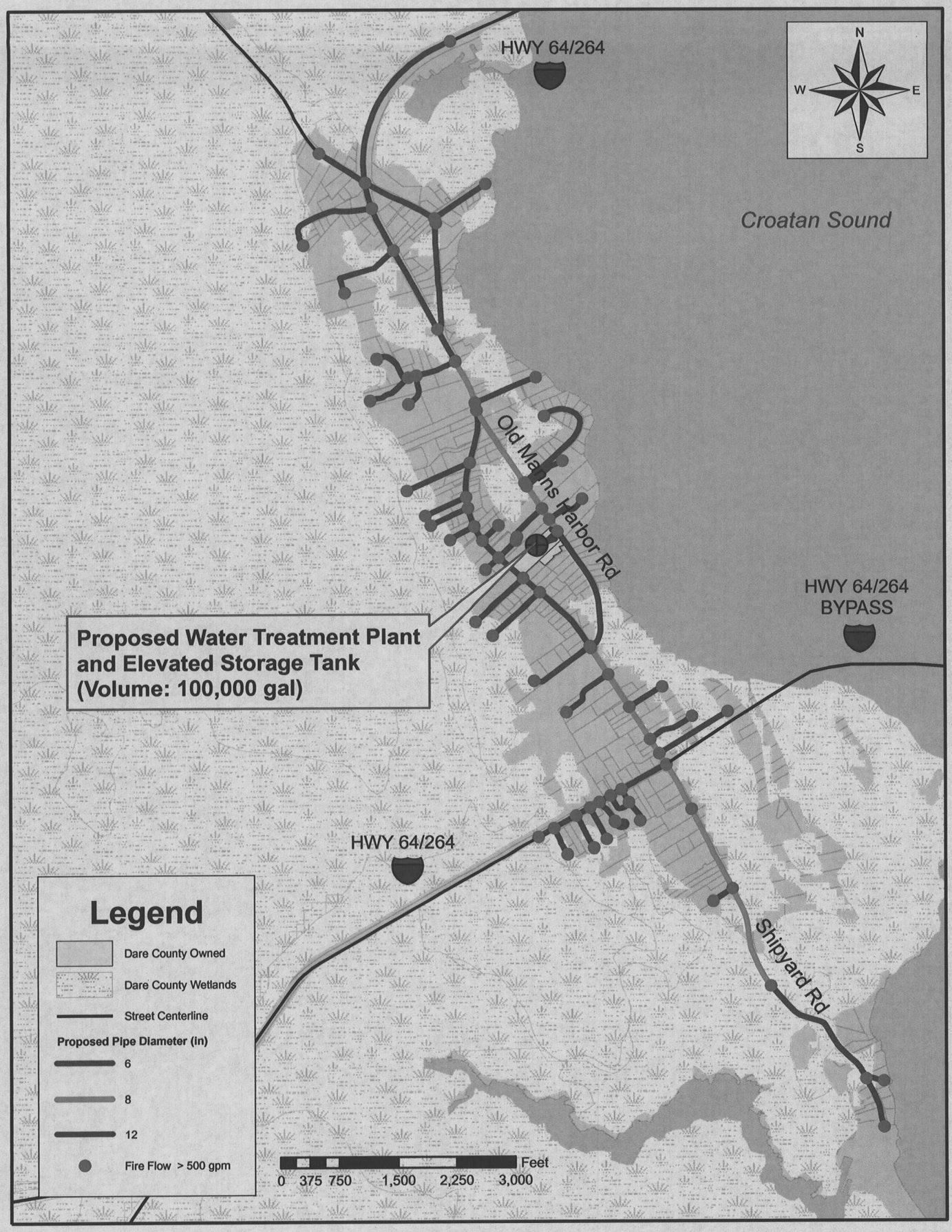


Figure 5-1
MANNS HARBOR - CENTRAL WTP & ELEVATED STORAGE TANK
PROPOSED WATER DISTRIBUTION SYSTEM

CDM

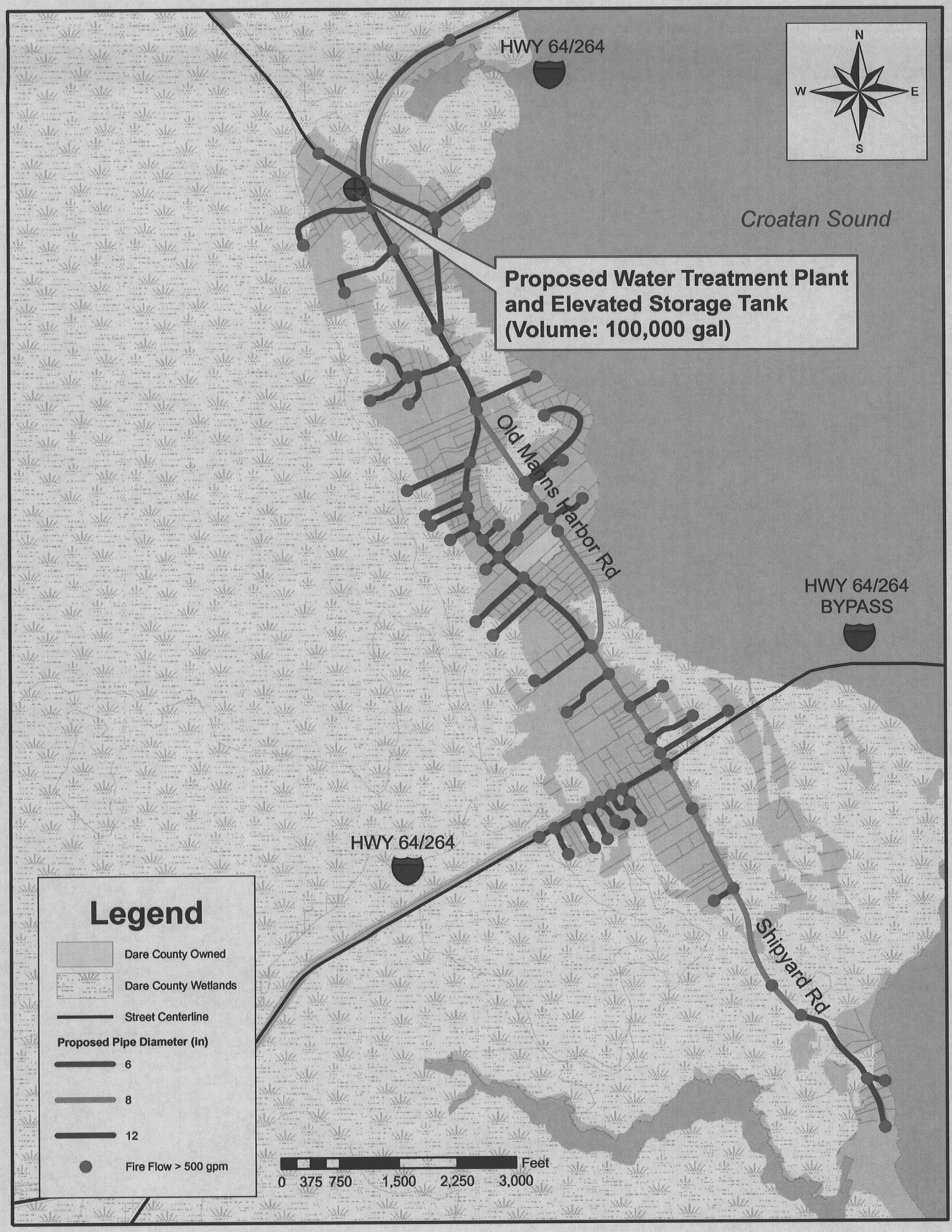


Figure 5-2
MANNS HARBOR - NORTH WTP & ELEVATED STORAGE TANK
PROPOSED WATER DISTRIBUTION SYSTEM

CDM

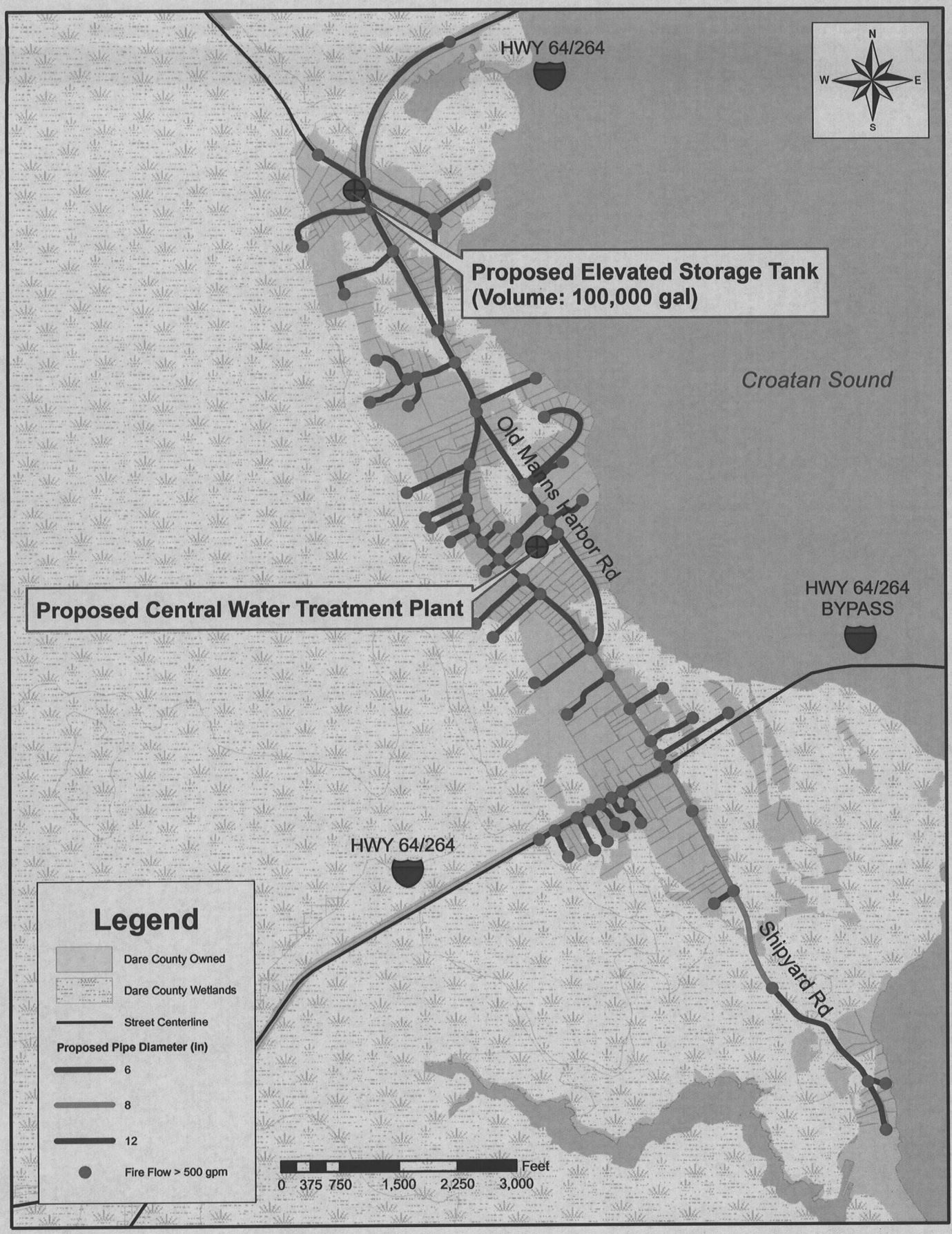


Figure 5-3
MANNS HARBOR - CENTRAL WTP & NORTH ELEVATED STORAGE TANK
PROPOSED WATER DISTRIBUTION SYSTEM

CDM

using a diurnal curve. Representative model simulation results of the elevated storage tank hourly water level elevations and capacity are shown on Figures 5-4 through 5-6. The elevated storage tank level generally fluctuates approximately 5 feet during the peak demand period. The peak demand period depleted approximately 20 percent of the elevated storage tank volume, with approximately 80,000 gallons remaining as available fire protection and emergency storage. Approximately 60,000 gallons is required for a fire flow of 500 gpm over a 2-hour duration.

The County indicated that the NCDOT Shipyard is equipped with a 200,000-gallon elevated storage tank. Approximately 75 percent of its capacity is dedicated to fire protection for the Shipyard. The hydraulic design of the tank is unknown. It is recommended that the feasibility of using the existing elevated storage tank be investigated if the NCDOT Shipyard becomes a water customer. However, since the volume of water available for public use would be limited to 50,000 gallons due to the fire protection storage requirement, the tank would only be considered as supplemental storage.

5.3 Transmission and Distribution

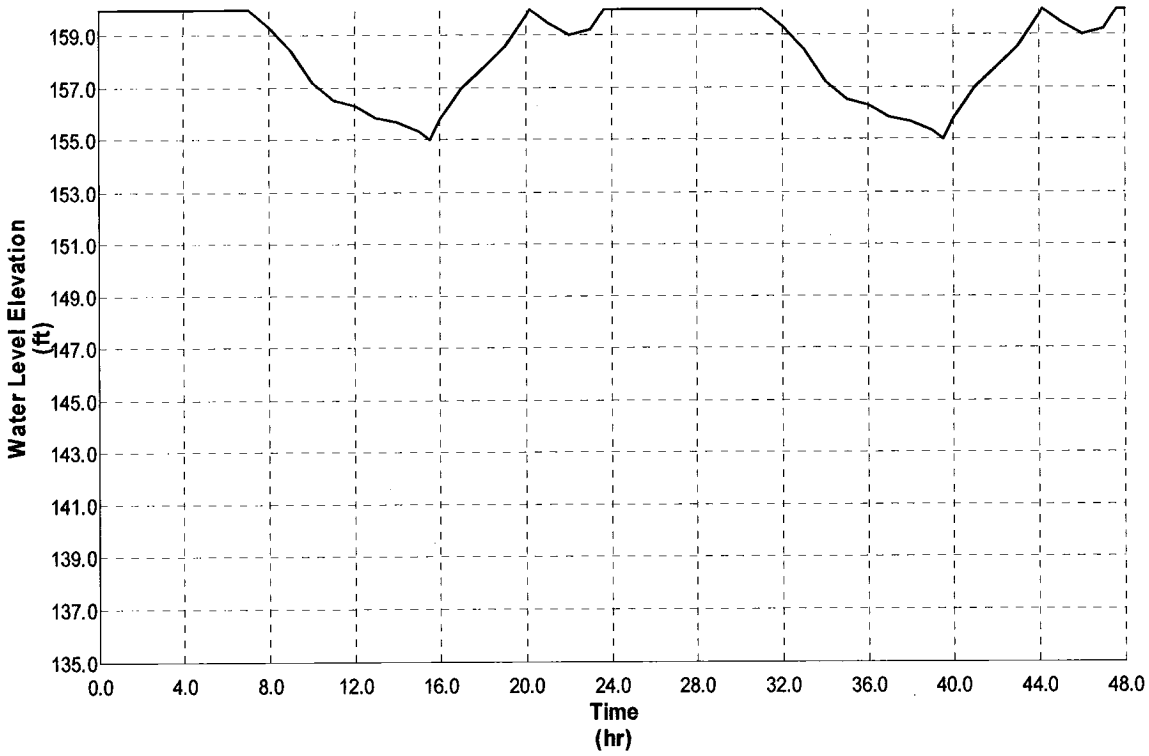
The size of the distribution mains for the WTP and elevated storage tank location options are identified on Figures 5-1 through 5-3. In general, fire protection and the location of the elevated storage tank governed the sizing of water distribution mains, particularly at system extremities. A discussion of the recommended transmission and distribution system for each WTP and storage location option follows.

5.3.1 Central WTP & Elevated Storage Tank

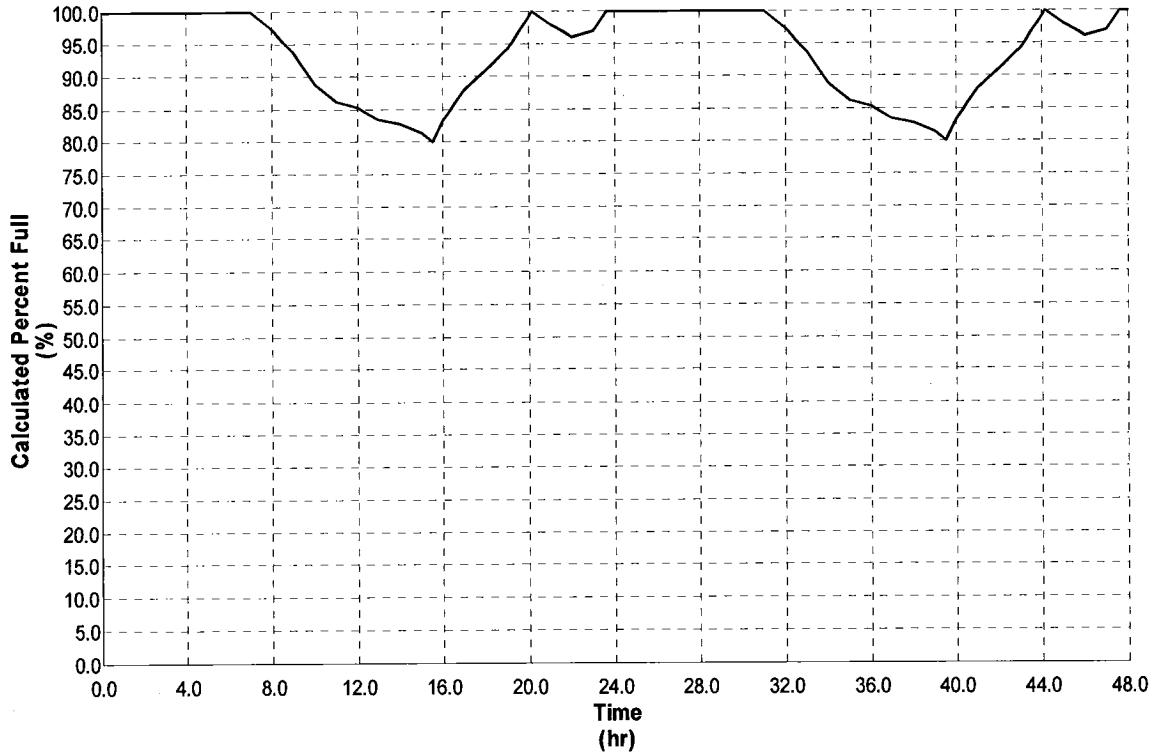
To provide transmission to the south from a central WTP and elevated storage tank, installation of a 12-inch diameter main on Old Manns Harbor Road to the Pecan Lane/Shipyard Road intersection followed by an 8-inch diameter main continuing south on Shipyard Road is recommended. To provide transmission to the north, installation of an 8-inch diameter main on Old Manns Harbor Road to Preston Twiford Road is recommended. Installation of 6-inch diameter mains is recommended for the other distribution mains in accordance with the County's minimum diameter requirement for fire protection.

5.3.2 North WTP & Elevated Storage Tank

If the WTP and elevated storage tank are located on the north side of Manns Harbor, installation of a 12-inch diameter main from the WTP south to Old Manns Harbor Road is recommended. On Old Manns Harbor Road, the 12-inch diameter main reduces to an 8-inch diameter main to the Pecan Lane/Shipyard Road intersection. The sizes of the other distribution mains with the north WTP and elevated storage tank option are generally the same size as the mains of the central WTP and elevated storage tank option, with a slightly longer extension of the 8-inch diameter main on Shipyard Road to provide fire protection to the southern end of the system.



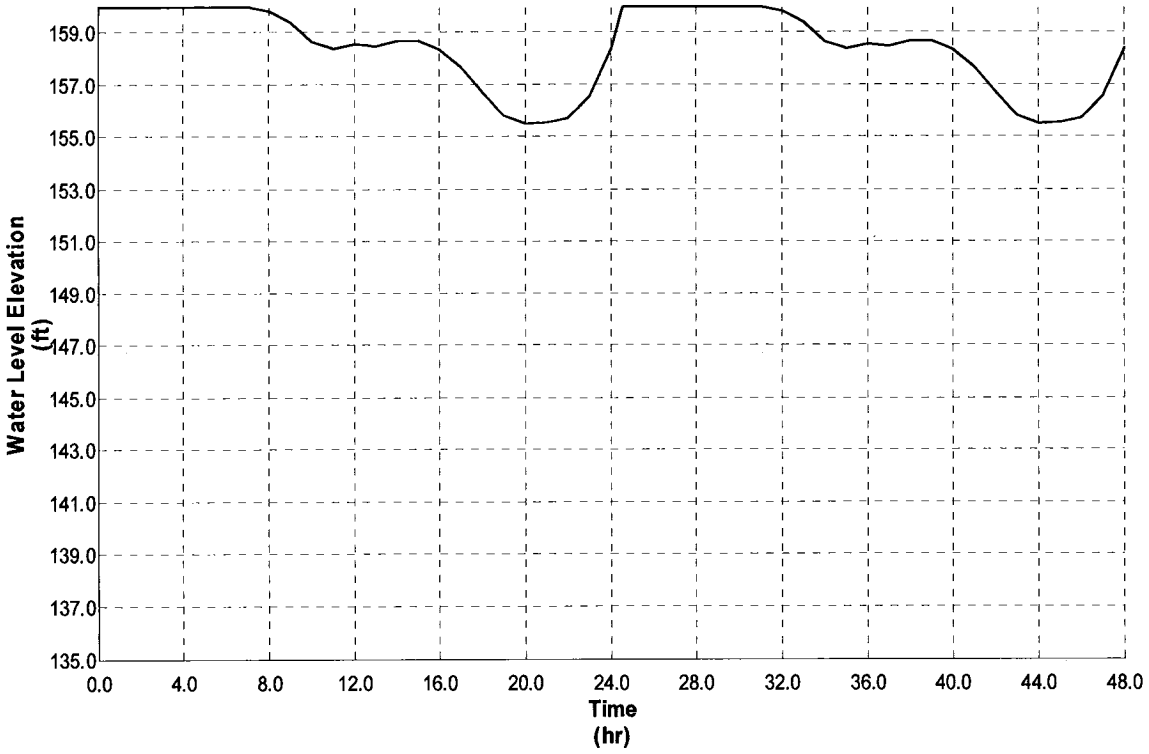
Elevated Storage Tank Water Level Elevation vs Time



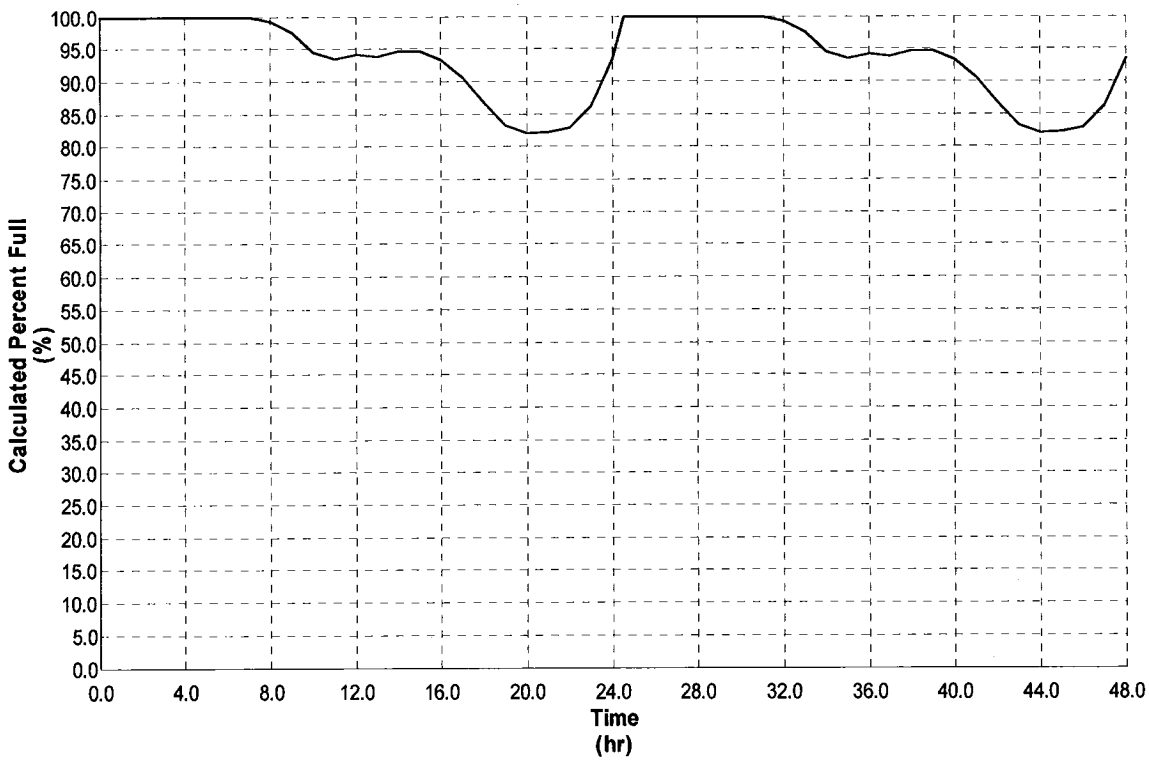
Elevated Storage Tank Calculated Percent Full vs Time

Figure 5-4
2025 MAXIMUM DAY DEMAND
CENTRAL WTP & ELEVATED STORAGE TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

CDM



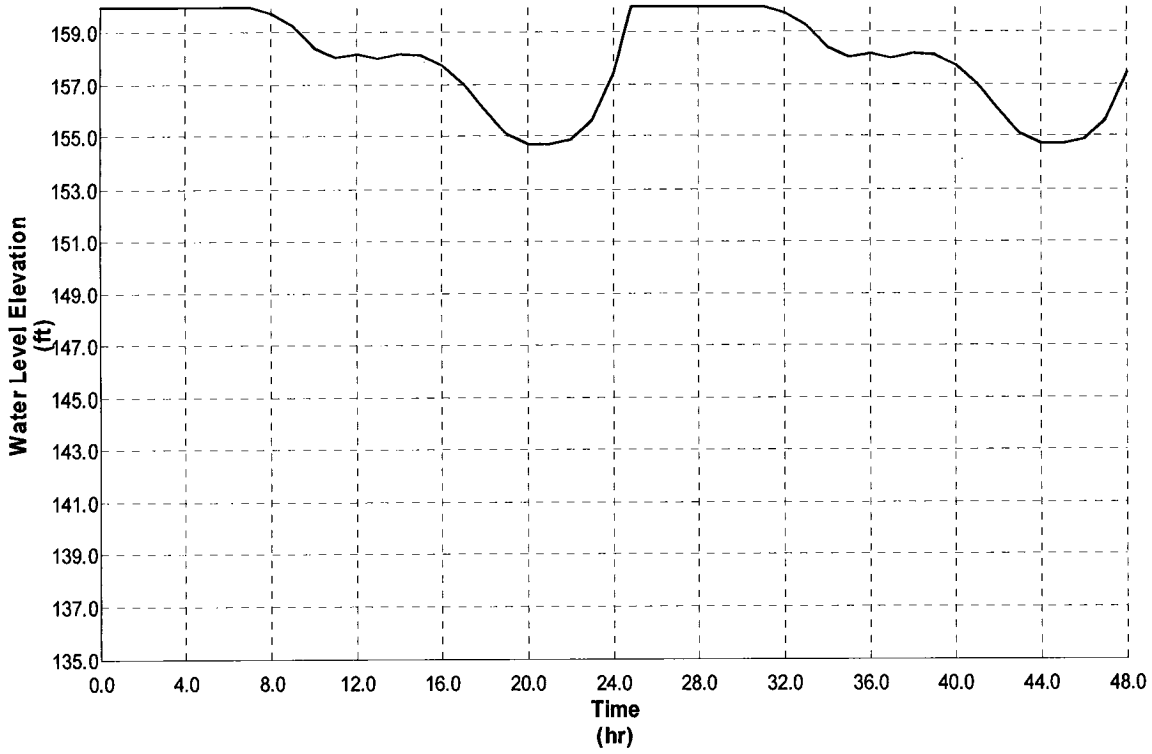
Elevated Storage Tank Water Level Elevation vs Time



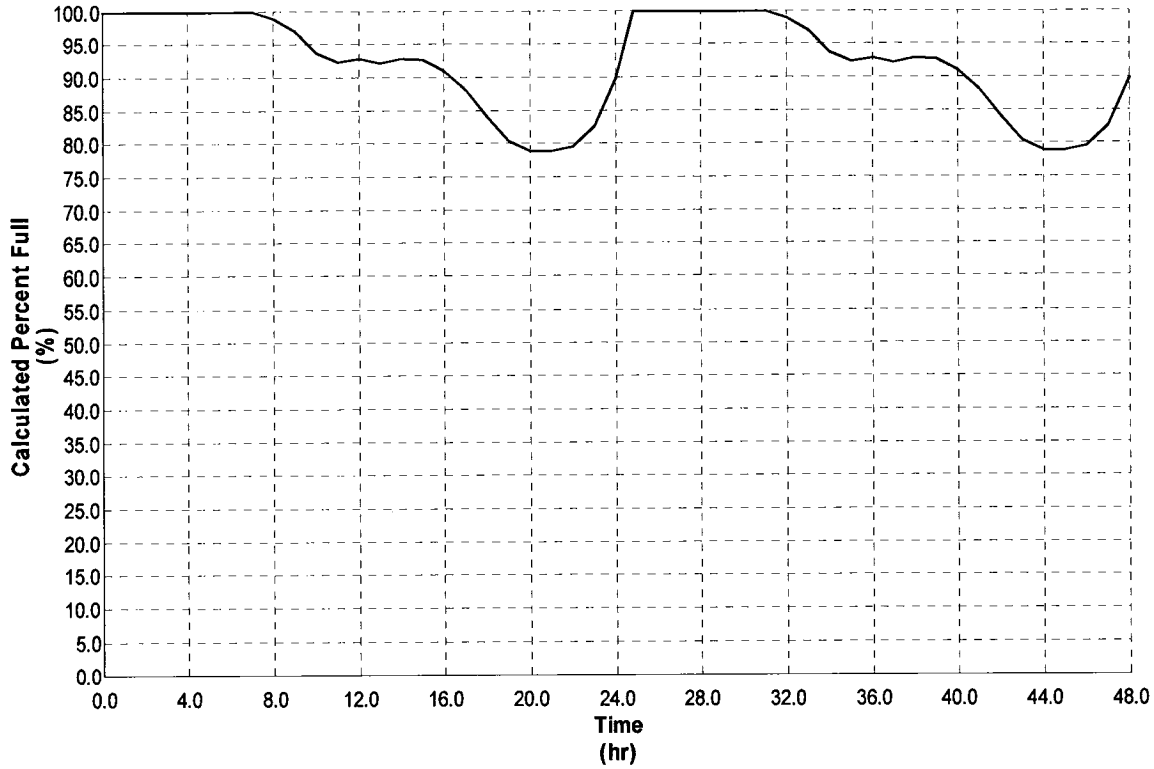
Elevated Storage Tank Calculated Percent Full vs Time

Figure 5-5
2025 MAXIMUM DAY DEMAND
NORTH WTP & ELEVATED STORAGE TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

CDM



Elevated Storage Tank Water Level Elevation vs Time



Elevated Storage Tank Calculated Percent Full vs Time

Figure 5-6
2025 MAXIMUM DAY DEMAND
CENTRAL WTP & NORTH ELEVATED STORAGE TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

CDM

5.3.3 Central WTP & North Elevated Storage Tank

If the elevated storage tank is located on the north side of Manns Harbor in conjunction with a central WTP, installation of a 12-inch diameter main from the WTP north to the elevated storage tank is recommended. The sizes of the other distribution mains are the same size as the mains of the central WTP and elevated storage tank option.

5.4 Summary

In summary, a central WTP is more desirable than a north WTP if the WTP is intended to serve only Manns Harbor's needs due to its strategic location. In conjunction with a central WTP, a north elevated storage tank increases system reliability on the north side of Manns Harbor. However, implementation of a north elevated storage tank requires installation of larger diameter main from the central WTP to the tank in comparison to the central elevated storage tank option. Water quality considerations are of significant importance due to the low demands of the area. With the larger transmission mains and remote tank location, water residence time in north Manns Harbor will be longer than the residence time with a centrally located elevated storage tank. As water residence time increases, disinfectant residuals tend to decrease, thus increasing the potential for bacterial regrowth. A water quality evaluation is not included in the scope of work of this project.

A north WTP is recommended if the WTP is intended to supplement Countywide water supply. Its close proximity to the bridge makes its location more suitable for a pipeline crossing to the northern end of Roanoke Island.

Section 6
Cost Estimates and Recommendations

6.1 Planning-Level Cost Estimates

The American Association of Cost Engineers (AACE) defines three levels of cost estimates, each of which is applicable at a different stage of project completion. The three levels of estimates are: (1) order-of-magnitude, (2) budgetary, and (3) definitive. The comparative construction cost estimates presented in this report are intended to represent "order-of-magnitude" estimates as defined by AACE. An order-of-magnitude estimate is made without detailed engineering data, and relies on the use of previous estimates and historical data from comparable work, estimating guides, handbooks, and costing curves.

The intended use of this type of estimate is long-range planning and for comparing alternatives, not for project control. The final cost of any project described in this report will depend on the project complexity, actual labor and material costs, competitive market conditions, actual site conditions, final scope of work, implementation schedule, continuity of personnel, and engineering. In order to estimate total capital costs, the estimated construction costs have been increased using the following percentages:

- Construction contingency: 25 percent
- Design engineering, construction administration, legal, and financial: 15 percent

The following criteria were used to develop planning-level cost estimates for the recommended system improvements:

- Preliminary estimated construction costs were based on bid tabulations provided by the County, budget costs provided by equipment suppliers, and recent bid tabulations from similar projects.
- It is assumed that piping will be installed within existing easements and right-of-ways to the extent feasible.
- New water pipes will be PVC.
- Elevated storage tanks will be spheroid-type with pile foundation.
- Costs do not include property acquisition.

Unit costs for pipeline construction based on these assumptions are presented in Table 6-1.

Table 6-1: Unit Costs for Water Mains

PVC Pipe Diameter (inches)	Unit Cost ($/Linear Foot)
6	35
8	45
12	55

Planning-level cost estimates for the Manns Harbor water distribution system are presented in Table 6-2. Costs presented in Table 6-2 are in 2006 dollars with an Engineer News Record (ENR) Construction Cost Index of 7695.10 (April 2006).

Table 6-2: Manns Harbor Water Distribution System Planning-Level Cost Estimates[3,4]

	Central WTP & Tank		North WTP & Tank		Central WTP & North Tank	
	Length (feet)	Cost Estimate ($)	Length (feet)	Cost Estimate ($)	Length (feet)	Cost Estimate ($)
WTP (O.4 mgd)[1]	---	2,000,000	---	2,000,000	---	2,000,000
100,000-gallon Elevated Storage Tank[2]	---	500,000	---	500,000	---	500,000
12" PVC Pipe	1,700	90,000	3,300	180,000	6,900	380,000
8" PVC Pipe	7,600	340,000	9,100	410,000	5,000	230,000
6" PVC Pipe	37,500	1,310,000	34,400	1,200,000	34,900	1,220,000
Subtotal	46,800	4,240,000	46,800	4,290,000	46,800	4,330,000
25% Construction Contingencies		1,060,000		1,070,000		1,080,000
15% Design, Legal, and Financial		640,000		640,000		650,000
Total		5,940,000		6,000,000		6,060,000
Annualized Cost[5]		500,000		500,000		510,000

Notes:
1. WTP assumes two wells, package-type membrane treatment, and disposal of concentrate to surface water.
2. Spheroid type tank with pile foundation.
3. Cost presented in 2006 dollars with an ENR construction cost index of 7695.10.
4. Costs do not include property acquisition.
5. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

The planning-level cost estimate for the Manns Harbor WTP was based on a unit cost per gallon developed from a recent CDM project of similar capacity. Costs for the WTP assume two wells, package-type membrane treatment, and disposal of concentrate to surface water (i.e., the Sound). The cost is based on a simple block building designed to house two membrane treatment units, pumps, chemical facilities, small office, and one bathroom. For the design capacity of the Manns Harbor WTP, a 3-acre site with a building of approximately 3,000 to 3,500 square feet is a potential conceptual plan. The WTP site would have a degasifier mounted on top of a clearwell. A prestressed ground storage tank with a capacity of 0.5 million gallons would be provided for the finished water. The facility could be designed to fit on a smaller site, if necessary.

Dare County can reduce water main installation costs by creating an in-house water main construction division and install all 6-inch diameter water mains and service connections. Installation of water mains greater than 6-inch diameter would be contracted.

6.2 Summary and Recommendations

This study identified water distribution system requirements necessary to extend water service to Manns Harbor. The analysis was based on projected 2025 water demands, which assumed build-out of developable acreage. It is recommended that the water demand projections be re-evaluated once zoning is established for Manns Harbor. It is also recommended that property for the WTP and well sites be acquired while land is still available.

Transmission and storage improvements directly affect water quality in distribution systems. Pipes sized to meet projected demands of the system may be oversized for the current demands of the system and, as a result, experience problems in maintaining a disinfectant residual. Prior to implementing the system recommendations, potential water quality impacts should be evaluated, particularly with near-term demands (e.g., 2010). Alternative sources for fire protection in low density areas, such as the reliance on pumper trucks, should be evaluated if the demand in the area is insufficient to promote turnover in a pipe sized to provide fire protection. If fire protection is not required, a smaller diameter main could be installed in the near-term with a parallel main installed in the future when demands in the area increase.

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North Carolina Department of Environment and Natural Resources. *Rules Governing Public Water Systems, North Carolina Administrative Code, Title 15A, Subchapter 18C – Water Supplies – Sections .0100 through .2100, Division of Environmental Health, Public Water Supply Section,* September 2004.

North Carolina Office of State Planning. North Carolina State Data Center 2004 through 2029 Dare County Population Projections.

U. S. Bureau of Census (American FactFinder). 2000 census data for Dare County, Manteo zip code area, Wanchese zip code area, and Manns Harbor zip code area.

Appendix A
Unit Water Demand Estimates

Source:
CDM Report, *Roanoke Island-Manteo-Wanchese Water System Study*, February 2006.

Dare County Unit Water Demand Estimates

Service Area	Zone Code[1]	Number of Accounts Basis[2]	Average Acreage per Account[4]	gpd/acre[3,4]	gpd/account[2,3]	gpcd[5]
Dare County	All	1,994	0.34	443	150	61
Outer Manteo	R-1	10	0.48	356	171	70
	R-2	123	0.36	465	171	70
	RS-8	46	0.27	611	162	66

Notes:
1. Includes only zone codes with sufficient amount of data for calculation.
2. Includes accounts geocoded to parcels.
3. Based on Dare County billing data from December 1, 2004 through September 1, 2005
4. Based on parcel acreage for accounts; gpd = gallons per day
5. gpcd = gallons per capita per day; gpcd; assumes 2.46 people per household (U.S. Census Bureau average for study area)

Town of Manteo Unit Water Demand Estimates

Customer Category	Number of Accounts[1,2]	gpd/account[1]	gpcd[3]	gpd/acre[4]
Residential	1,128	102	50	187
Commercial	123	162	80	162

Notes:
1. Based on available Town of Manteo, July 15, 2004 through June 30, 2005, billing data.
2. Excludes 45 accounts related to public facilities, e.g. government buildings, hospitals, etc.
3. Based on U.S. Census Bureau estimate for Manteo of 2.03 people per household (account) for 2000.
4. Based on acreage from geocoded parcel data.

Appendix B
Dare County Northern Service Area Diurnal Hydrograph

DARE COUNTY - KITTY HAWK, SOUTHERN SHORES & DUCK SERVICE AREA