coastal resources collaborative, ltd.

NAGS HEAD

North Carolina . Coastal Zone Management Program

CARRYING CAPACITY ANALYSIS

TOWN OF

NAGS HEAD, NORTH CAROLINA

512 Shady Lawn Road Chapel Hill, North Carolina 27514 919-942-8937

CARRYING CAPACITY ANALYSIS

TOWN OF NAGS HEAD

1984

Coastal Resources Collaborative, Inc.

David J. Brower

Lee D. Einsweiler

Luther Propst

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INTRODUCTION

The purpose of a carrying capacity analysis is to determine the amount of development a given geographic area can absorb without significantly damaging the environment or the public health, safety and welfare of the residents. Carrying capacity analysis is based on the assumption that the ability of the physical environment and the public infrastructure to absorb development is limited. Development which exceeds that ability will require the expenditure of public funds to avoid significant damage to the environment and/or harm to the public health, safety and welfare.

Carrying capacity analysis permits municipal officials to manage development to avoid exceeding carrying capacity thresholds or to budget for capaital improvements to make it possible to exceed these carrying capacity thresholds without endangering the public health, safety and welfare.

Several elements determine the ability of a municipality to absorb development (i.e. the carrying capacity of a municipality). The relevance of each in municipal decision-making varies according to existing development and infrastructure, the institutional framework of the jurisdiction, and the characteristics of the natural systems, for example soil conditions, flood prone areas, etc.

This report analyzes four primary factors that are important to the capacity of Nags Head to absorb development (i.e. four carrying capacity thresholds): the availability of land for development, wastewater treatment and disposal, water supply and distribution, and hurricane evacuation.

Land availability in Nags Head is determined by the amount of developable acreage which has not yet been developed and the permissible development densities within the Town. Densities are limited both by septic tank regulations and by the zoning ordinance.

Wastewater treatment and disposal is a pressing concern in Nags Head and throughout coastal North Carolina. It is a concern of both local and state government. This carrying capacity threshold plays the most important role in determining the capacity of Nags Head to absorb development.

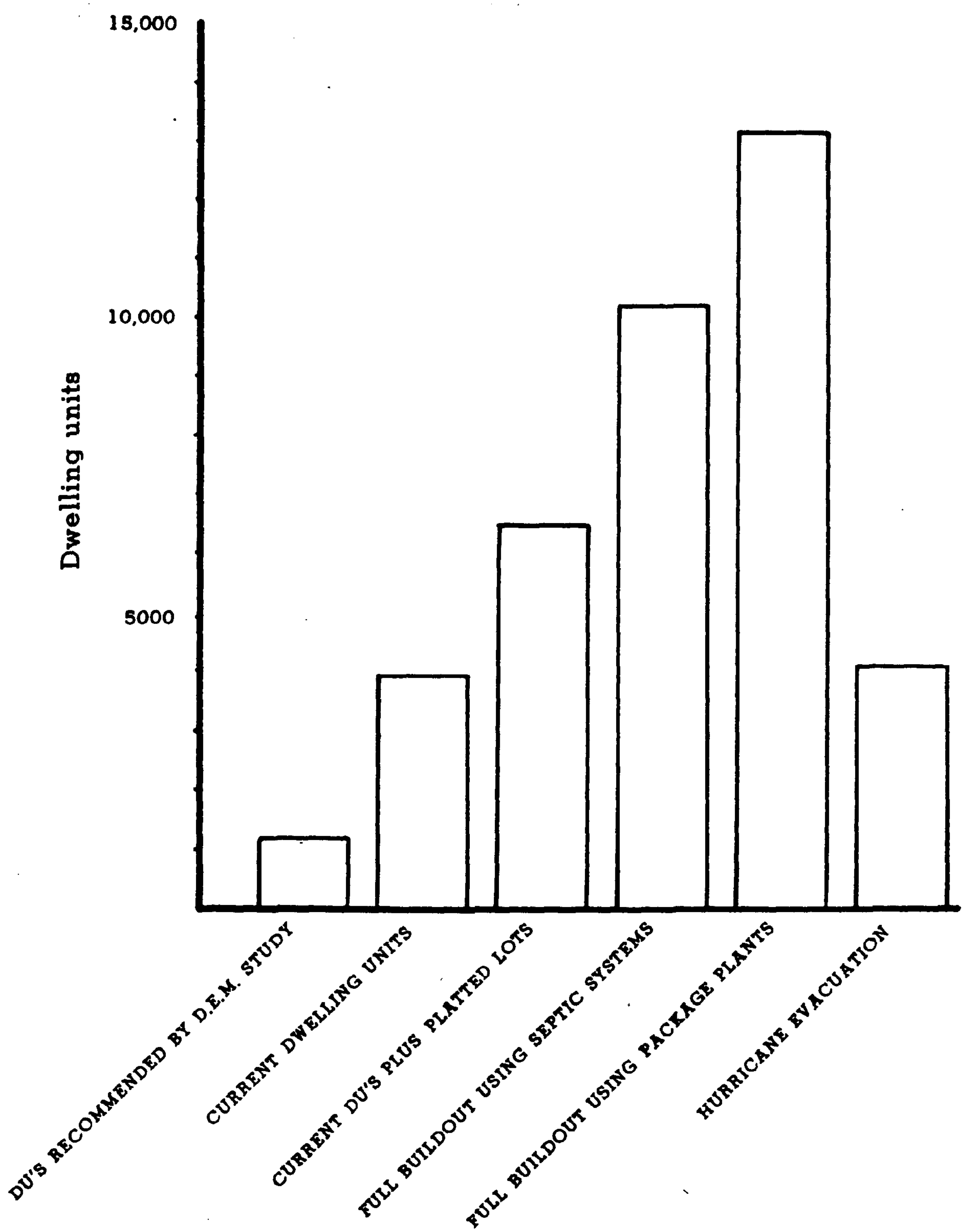
The Dare County Water System is the source of water for Nags Head and is beyond the direct control of the town. The developed aquifer on Roanoke Island has the capacity to meet the needs of the system for the near future. The aquifer however does have a capacity that growth in Dare County could exceed, requiring development of an expensive new source of raw water.

Hurricane evacuation is a regional concern. One cannot responsibly plan for evacuation by considering only local factors. It is important, however, for municipal officials to be aware of the parameters imposed by the need to evacuate a barrier island in the face of a hurricane.

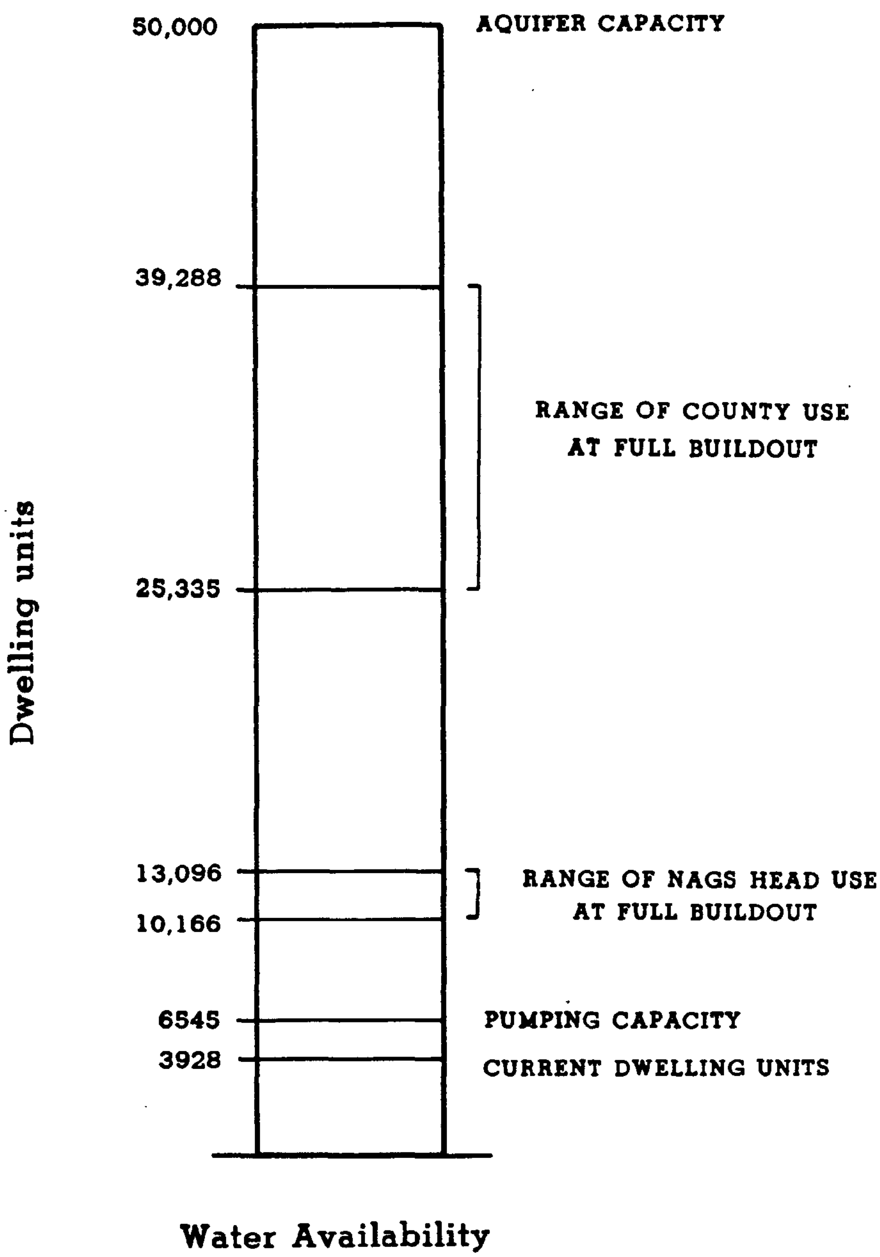
The report indicates the approximate number of dwelling units and other development that the Town can absorb before the reasonable capacity of these thresholds is exceeded.

The capacity of the municipality to absorb development is a function of capital expenditures. For example, a regional wastewater collection and treatment system, several new bridges to the mainland and increased road capacity for hurricane evacuation and traffic circulation, and development of new aquifers or desalinization technology could support virtually unlimited growth in Nags Head. Afterall, Hong Kong, Manhattan, and Singapore are each located on small islands.

Nags Head Carrying Capacity Analysis



Nags Head Carrying Capacity Analysis



(Gallons/day converted to dwelling units)

LAND AVAILABILITY AND WASTEWATER TREATMENT

It is known with a great degree of confidence that untreated or inadequately treated effluent can contaminate both groundwater supplies and surface waters, endangering public health and environmental quality. The primary factors that govern the overall acceptability of wastewater treatment and disposal with respect to protecting the public health and environmental quality include the following: 1) the method of wastewater treatment and disposal, 2) soil suitability for on-site wastewater disposal, 3) depth to the groundwater table, 4) proximity to surface waters, and 5) density of development.

It is possible to establish a relationship between development densities and practices in Nags Head and the ability of the soils to absorb and treat wastewater effluent using different wastewater treatment methods. It is, however, not possible to simplify the wastewater treatment and disposal problem enough to indicate precisely the density of development served by septic tanks or other wastewater treatment methods per given land area that will cause unacceptable contamination of the surficial or underlying aquifers and the adjacent surface waters.

The methods of treating wastewater that are considered feasible in Nags Head in the near future include the following: 1) on-site disposal using conventional septic systems, 2) on-site disposal using non-conventional septic systems, 3) package treatment plants with disposal by land application or by subsurface drainfields. A centralized sewage system is not considered economically feasible.

Before discussing development capacity limitations due to wastewater treatment constraints, four subjects require elaboration as background information: 1) a description of the three alternative methods of wastewater treatment and disposal that are feasible in Nags Head, 2) a description of the current wastewater treatment and disposal situation in Nags Head, 3) a discussion of the limitations to septic tank use based upon soil conditions, and 4) a discussion of the state regulations governing density limitations for development using septic tanks. Following these background sections, the report discusses actual carrying capacity thresholds.

1. Summary Description of Available Wastewater Treatment and Disposal Methods

A. On-Site Disposal Using Conventional Septic Systems

Currently the predominant method of wastewater disposal in Nags Head is by septic tank. A septic tank is basically a detention tank in which some of the solids settle out of the wastewater and undergo anaerobic digestion in the tank. The liquid effluent moves by gravity out of the tank to a system of subsurface trenches, the drainfield, where treatment by bacteria in the soil is followed by absorption of the wastewater by the soil. This is a form of on-site land application.

A properly functioning system relies upon the soil to absorb and adequately treat all wastewater generated from a site. All soils are not suitable for septic tanks as they may not allow wastewater to drain through the soil or they may allow wastewater to pass to the groundwater without adequate treatment.

The advantages of septic systems are the use of natural aeration and filtration to treat wastewater close to the source of the wastewater, and the cost-effectiveness of the alternative. The disadvantages of and the limitations to the use of septic systems are discussed later in this section. Overdependence on septic systems for wastewater disposal on the Dare Beaches has been associated with degradation of water quality in Roanoke Sound, the closing of shellfish beds in the Sound, contamination of the surface aquifer on the Dare Beaches, and the possible contamination of the underlying water supply aquifer for the region.

B. On-Site Disposal Using Non-Conventional Systems

There are several on-site alternatives to conventional septic systems, including mound systems, low-pressure pipe systems, evapotranspiration beds, duplex drain fields, aerobic systems, land application, holding tanks, and no-flush toilets. These alternative systems may permit on-site disposal in areas where state regulations do not permit conventional systems and may improve treatment of effluent in areas where septic tanks are permitted but soil conditions or proximity to surface waters insure that treatment by a conventional system will be inadequate. Development using alternative wastewater treatment systems is, however, likely to require larger minimum lot sizes than required for the use of a conventional system, due to the need to provide a large portion of the site to the wastewater disposal system.

For information on alternative wastewater treatment and disposal systems, contact EPA National Wastewater Flows Clearinghouse, West Virginia University, Morgantown, WV 26506, 800-624-8301. Two of the more promising technologies are low-pressure pipe systems and mound systems. Information on these systems is available in C. Cogger, B. Carlile, D. Osborne and E. Holland, May 1982, Design and Installation of Low-Pressure Pipe Waste Treatment Systems. UNC Sea Grant College Publication UNC-SG-82-03, and C. Cogger, B. Carlile, D. Osborne and E. Holland, August 1982, Design and Installation of Mound Systems for Waste Treatment. UNC Sea Grant College Publication UNC-SG-82-04. Alternative wastewater treatment systems are also discussed in the North Carolina Barrier Island Wastewater Management Environmental Impact Statement, June 1983.

C. Package Wastewater Treatment Facilities

Package wastewater treatment facilities are prefabricated units, which are smaller versions of conventional central wastewater treatment facilities. Package plants are commonly used to treat and dispose of wastewater from multi-unit condominium, motel, or townhouse projects. There are three primary methods of effluent disposal used with package plants: land application by spray irrigation, subsurface disposal by drain fields, and land application by rotary distributors. Discharge into surface waters is no longer permitted for new facilities under state regulations. Disposal by spray irrigation is not often used in coastal areas because the method requires large amounts of land. Subsurface disposal uses nitrification lines similar to septic systems for the distribution of effluent beneath the gound surface. This method of disposal requires a smaller land area for a drainfield than is required for spray irrigation. Land application by rotary distributors is particularly advantageous on barrier islands where high perculation rates are common. It uses rotary distributors similar to those employed on conventional trickling filters to disperse effluent into a prepared circular bermed pit of sandy soil. This method of effluent discharge requires less land than other methods and is more easily operated and maintained.

There are many advantages to the use of package plants: relatively small acreage required for the actual plant, ease of installation, capability of modular expansion to increase capacity to a certain maximum, and the potential for a private developer to lease or purchase capacity at a privately-owned facility. The disadvantages include: relatively high cost per unit especially for facilities with less than 10,000 gallons per day capacity (capacity for approximately 20 to 30 dwelling units), difficulty in assuring that the facility meets design specifications, sensitivity to seasonal fluctuations in wastewater flows, and the need for careful supervision of the facility.

2. Description of the Current Wastewater Treatment System in Nags Head

Two methods of wastewater treatment and disposal are commonly used in Nags Head: on-site disposal by septic systems and package treatment facilities. There are five package plants, all providing tertiary treatment, serving multi-family residential projects and a nursing home. The capacity, mode of effluent disposal, and the status of these treatment facilities are provided in Table 1. In addition to the 135 rooms at Elder Lodge Nursing Home, there are 295 dwelling units either completed or approved that are served by package wastewater treatment facilities.

All of the package plants except the facility at the Villas Condominiums utilize land application as the method of effluent disposal. Spray irrigation

Table 1

EXISTING (AND PROPOSED) PACKAGE WASTEWATER TREATMENT FACILITIES SERVING MULTI-UNIT HOUSING PROJECTS(1)

PROJECT/DEVELOPMENT	TOTAL # UNITS	LOCATION	SIZING OF TREATMENT FACILITY (GPD)(2)	DEGREE OF TREATMENT	MODE OF EFFLUENT DISPOSAL	PROJECT STATUS
Armada Inn	105	Old Lighthouse Road	31,700 GPD	Tertiary	Subsurface disposal	All units complete
Elder Lodge Nursing	135 rooms	Health Center Drive	20,000 GPD	Tertiary	Subsurface disposal	All rooms complete
Dune Lantern	16	Virginia Dare Trail	6,400 GPD	Tertiary	Tertiary subsurface disposal	All units complete
Nags Head Village	36	Ocean to Sound 14 mile post	Approved: 60,000 built 120,000 GPD	Tertiary	Rotary distributors	18 units complete
			Permit (b) to construct (pending) Permit (a) to discharge additional 60,000 approved			18 additional units local have rec. all permits
Villas Condominiums	120	Villa Dunes Drive	60,000 GPD	Tertiary	Discharges into Roanoke Sound	All units complete

(1) Source: Based on data on file with Washington Regional Office, N. C. Division of Environmental Management, Washington, N. C.
(2) Some facilities are to be built in stages and, therefore, are sized to accommodate only a portion of ultimate flow.

is not used, and is not likely to be used, because of the large amount of land required by the method. The two methods of disposal most commonly used on barrier islands are in use in Nags Head: subsurface application by drainfield and land application by rotary distributor.

The package plant at the Villas Condominiums discharges into Roanoke Sound. All future units will use some form of land application or alternative method of disposal because discharge into surface waters is no longer permitted by state regulations. The Villas package plant discharges into waters classified as SC waters, which could be classified as SA or SB if not for this wastewater discharge. The discharge existed prior to classification of the state's surface waters.

The remainder of the wastewater generated in Nags Head is disposed of by septic tanks. Currently (through May 1984) there are 3928 dwelling units completed or approved in Nags Head. 3633 of these are served by septic tanks.

3. Limitations to Septic Tank Use

There are three primary limitations to the on-site disposal of wastewater in a barrier island setting such as Nags Head: soil suitability and type, depth to the seasonal high water table, and proximity to surface waters. The first of these is soil suitability, or the ability of the soil to absorb and treat wastewater. The ability of the soil to absorb wastewater is largely a function of the texture of the soil material. The soil types found in Nags Head are described in Table 2. A cross-section of a typical portion of Nags Head is shown in Figure 1, which indicates the location of soil groupings and associated vegetation.

Table 2

Nags Head Septic Suitability of Soils

Soil Name	Soil Symbol	Suitability under State Regulations	Limitations to On-site Disposal, SCS criteria	Flooding	Depth to Seasonal High Water Table	Permeability (in/hr)
Beach Foredune Assn.	3	Suitable	Very Severe - flooding	frequent to rare	0.0' - 6.0'	Rapid, 6.3
Duneland	14	Suitable	Severe - blowing sand	none	6.0'	Very Rapid, 20.0
Fripp Fine Sand	15	Suitable	Slight	rare, storm tides	6.0'	Rapid, 6.3
Newhan Fine Sand	21	Suitable	Slight	none	6.0'	Very Rapid, 20.0
Newhan Complexes	22-24	Suitable	Depends on soil mix	-	-	-
Corolla Fine Sand	7	Marginal	Very Severe	rare to common	1.5' - 3.0'	Very Rapid, 20.0
Corolla Fine Sand, Forested	8	Marginal	Very Severe	rare, storm tides	1.5' - 3.0'	Very Rapid, 20.0
Corolla - Duckston Complex	9	Unsuitable	Depends on soil mix	-	-	-
Hobonny Soils	11	Unsuitable	Severe - flooding	surface ponding	0.0' - 0.5'	Very Rapid, 20.0
Duckston Fine Sands	12	Unsuitable	Severe - wet	rare to common	0.0' - 2.0'	Very Rapid, 20.0
Duckston Fine Sands, Forested	13	Unsuitable	Severe - wet	rare to common	0.0' - 2.0'	Rapid, 6.3
Carteret Soils, High	18	Unsuitable	Very Severe	monthly	1.0' - 3.0'	Rapid, 6.3
Carteret Soils	19	Unsuitable	Very Severe	monthly	0.0' - 3.0'	Rapid, 6.3
Conaby Soils	26	Unsuitable	Very Severe	surface ponding	0.0' - 1.0'	Rapid, 6.3
Dredge Spoils	10	Questionable		rare	3.0'	Rapid, 6.3
Madeland	17	Questionable	Severe	rare	3.0'	Rapid, 6.3

Figure 1

CHARACTERISTIC SOIL TYPES AND DOMINANT VEGETATION
NAGS HEAD WOODS & NORTH SECTION OF OUTER BANKS,
NORTH CAROLINA

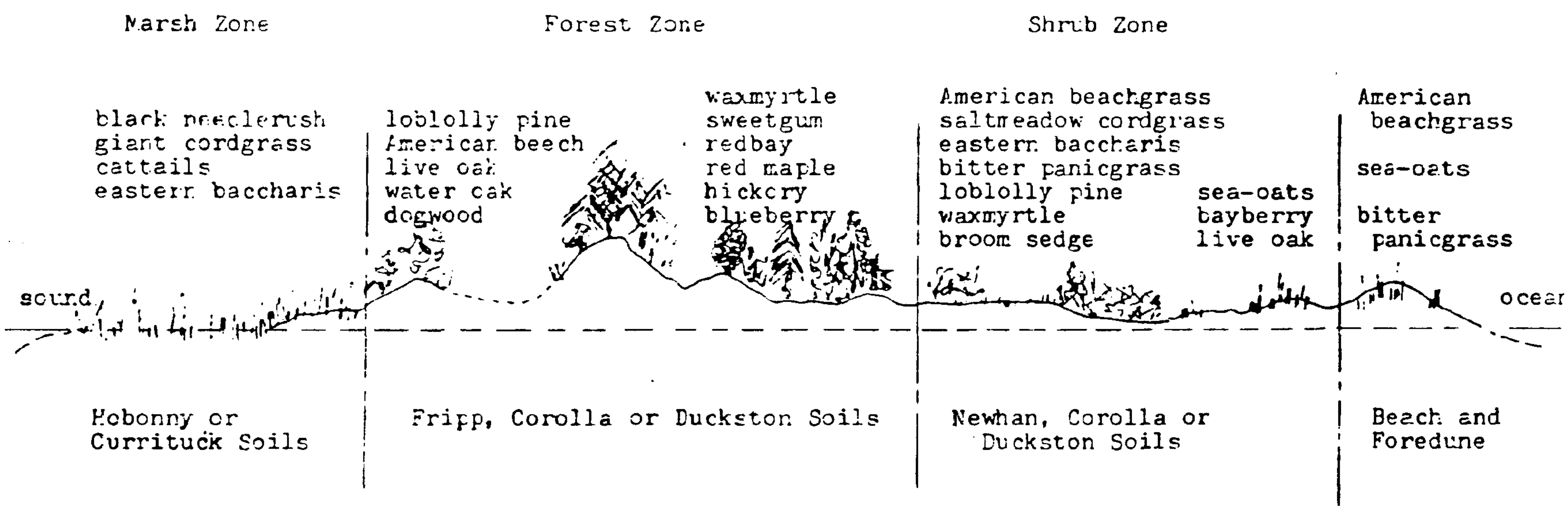


Table 2 lists the depth to the groundwater table of the soil types found in Nags Head. This is considered the most important factor affecting the suitability of a site for wastewater treatment and disposal. Unsaturated soil is necessary below the drainfield piping of an on-site wastewater disposal system in order to allow adequate treatment of the effluent before it reaches the groundwater. If the level of the groundwater table rises above the drainfield of the on-site disposal system, septic tank effluent can reach the surface of the gound, resulting in both public health concerns and aesthetic problems. The amount of unsaturated soil required for adequate treatment is between 1 foot and 4 feet, depending upon the permeability of the soil, in order to prevent contamination of the groundwater and nearby surface waters. The closer the system is to surface waters, the more likely is contamination of such waters.

State regulations require 12 inches of unsaturated soil for the issuance of a septic tank permit, without taking into account the permeability of the soil. The Soil Conservation Service ratings are based upon the assumption that when wastewater percolates rapidly through the soil, adequate time may not be allowed for proper biological treatment of the effluent. A 1980 study by the Water Resources Research Institute, Wastewater Management in Coastal North Carolina, states that in places where the water table rises to within four feet of the gound surface that there is inadequate filter depth for septic tank usage.

It should be noted that there is a large difference between the amount of land considered severely limited or very severely limited for on-site wastewater disposal systems according to the Soil Conservation Service criteria and the amount of land considered suitable for on-site wastewater disposal under existing state regulations. According to the SCS criteria, Newhan Fine Sand is the only soil type in Nags Head with slight limitations for septic tank use. The other soils are severely or very severely limited according to the SCS rating. Slight limitations indicate that soil properties are generally favorable or that minor limitations to the use of on-site septic systems can be easily overcome. The SCS criteria for rating soil suitability involves examination of properties that limit the absorption or treatment of effluent. Slope, susceptibility to flooding, depth to seasonal water table, and soil permeability are all considered.

The Soil Conservation Service criteria classifies the remainder of the soil types in Nags Head as having severe or very severe limitations for on-site wastewater treatment and disposal. A severe rating indicates that soil properties are unfavorable for septic system use and will require major and often expensive reclamation, usually including the addition of fill mateiral, for proper system performance. A very severe rating is reserved for soil types so unfavorable for wastewater disposal that extreme alteration will be required for septic tank use.

The discrepancy between the SCS criteria and the state regulations exists because the state regulations -- unlike the Soil Conservation Service criteria -- do not address soil permeability as a factor in soil suitability for septic system use. State regulations allow on-site wastewater disposal in extremely porous soil where depth to water table is greater than 12 inches.

The soils on the Outer Banks are generally unsuitable for septic systems, with the state regulations for septic tank use distinguishing between the varying degrees of unacceptability. An overlay of a map of the soil types in Nags Head and a map of current residential development indicates that the more suitable soils are currently developed and that future development is likely to take place on more severely limited soils.

4. State Regulations for the Use of Septic Tanks

State regulations govern the installation, location and use of septic tanks. (15 N.C.A.C. 2H, section .0300 *et seq*. and section .0400 *et seq*. and 10 N.C.A.C. 10A, section .1900 *et seq*.) The regulations which govern the density of development permitted with the use of septic tank systems are as follows: lots platted prior to July 1, 1977 may use on-site systems on parcels as small as 5000 square feet, which produces a density equivalent to approximately 8.7 units per acre; lots platted between July 1, 1977 and July 1, 1982 must be a minimum of 7500 square feet, a density equivalent of 5.8 units per acre; lots platted after July 1, 1982 must be a minimum of 15,000 square feet, or a density equivalent of 2.9 units per acre. These new regulations require a repair and replacement area of equal size to the septic system utilized, and a 50 percent increase in the absorption area requirements if beds instead of trenches are used. The new regulations also make it more difficult for property owners to obtain an exception to the minimum horizontal distance requirements for previously platted lots.

5. Nags Head Land Availability and Wastewater Treatment Carrying Capacity

This section of the report provides information on the capacity of Nags Head to absorb development and applies several scenarios concerning the density of future development in Nags Head. All of the build-out scenarios are based upon the assumption that future development will contain a mix of septic systems and package plants for wastewater treatment and disposal. The development scenarios are explained later.

First it is important to discuss the implications of widespread reliance on individual septic systems for wastewater disposal. Development in Nags Head will continue to use septic systems when permitted by state health regulations. The state regulations define extremely sandy soils as suitable for on-site wastewater treatment systems. The questionable effluent-filtering capabilities of these soils may lead to contamination of groundwater supplies and surface waters.

Several studies of wastewater management on the Outer Banks have indicated the inadequacies of wastewater disposal by septic tanks. According to the 1980 Land Use Plan Update for Nags Head, the major cause of pollution in the Sound west of Nags Head is septic tank failure. In January 1979, 45 of 459 private sewage disposal systems examined were in need of repair. This failure rate corresponds with similar rates documented in other surveys. (See 1980 Land Use Plan, p.65.).

In addition, a 1980 report by the Water Resources Research Institute, Wastewater Management in Coastal North Carolina, concluded that "septic tanks cannot be assumed to be an adequate solution for wastewater disposal throughout the [Dare Beaches]." (p.2-10) The report concludes that "wastewater treatment and disposal facilities are inadequate in the Dare County area. The high water table and poor soils limit the effectiveness of septic tanks and overdevelopment of the area is beginning to show its effects on water quality. Direct contamination of the water supply aquifers is likely as the unconfined aquifer receives the effluents of the septic tank systems. . .. Stringent protection of the water resources is needed." The unconfined aquifer in Nags Head is connected to Freshwater Pond, which has been identified as a potential supplementary or reserve water supply source. The unconfined aquifer is also connected to the surface waters of the Roanoke Sound.

Both the Water Resources Research Institute study (1980) and the Dare Beaches Complex 201 Facility Plan (1977, von Oesen and Associates) recommend a community wastewater treatment and disposal system. They conclude that a community system with ocean disposal is the most environmentally sound method of wastewater management, as ocean disposal would end discharges to the fragile inland coastal waters and would offer the prospect of reclaiming and preserving shellfish growing areas.

Finally, a study done in New Hanover County by the North Carolina Department of Environmental Management has shown that septic tank systems can pollute the groundwater and adjacent estuarine waters. (The Impact of Septic Tanks on Shellfish Waters) This study indicates that as more septic tanks are installed in coastal areas with a high amount of soil with severe limitations for septic tank use, greater levels of fecal and total coliform bacteria are recorded in nearby estuarine areas. Higher bacteria counts are recorded in both wet and dry periods, indicating that the contamination is due to septic tank systems rather than surface runoff. In the study, a watershed with an estimated density of one septic tank drainfield per every seven acres had acceptable water quality. Two watersheds with estimated densities greater than one drainfield per every four acres were contaminated to the point of having to be closed to shellfishing. The conclusion of the study is that contamination of estuarine waters is to be expected when dense development with conventional septic tank systems occurs on unacceptable soils.

These studies are referred to as a preface to the discussion of the Nags Head wastewater carrying capacity to point out that development in Nags

Head served by on-site septic tank systems already exceeds the capacity of the soils in the area to treat and absorb wastewater effluent. The data concerning the maximum permissible densities of development served by septic systems should not therefore be considered as the carrying capacity of the Town of Nags Head for septic tank disposal of wastewater without significant environmental deterioration and risk to public health.

There are approximately 3928 dwelling units in Nags Head, of which approximately 3633 are served by septic systems. The study done by the Department of Environmental Management, The Impact of Septic Tanks on Shellfish Waters, indicates that the maximum density for septic tank use without contamination of surface waters may be one septic tank for between every four to seven acres. Septic tank densities of one tank every four acres, in soils commonly found in coastal North Carolina, were found to lead to contamination of nearby surface waters.

Nags Head contains approximately 4600 acres. There are currently about 3600 septic systems in the Town. The average septic system density over the acreage of the entire Town is therefore 1.1 systems per acre.

Approximately 850 acres in Nags Head are currently developed. There are approximately 3600 septic systems on these 850 acres. This produces an average density on developed acreage in Nags Head of 4.2 systems per acre.

According to the data derived by the Department of Environmental Management in the septic tank study done in New Hanover county, the maximum density of septic tanks that does not result in water quality degradation is one tank for every four to seven acres. Based upon this data, the maximum number of septic tanks that Nags Head can sustain within the entire Town is between 661 and 1157 septic systems. The total number of systems that can be sustained in Nags Head on the 850 developed acres within the Town without the likelihood of water quality degradation is between 122 and 213 units. Instead the Town currently has 3600 units on the 850 acres.

The information concerning the possible densities of septic tanks without water quality degradation around Nags Head is not definitive, so these numbers should be treated as conditional. These figures do provide an accurate representation of the wastewater management problem facing future development in Nags Head with the continued reliance on septic tanks.

In summary, this report discusses buildout scenarios that include development served by septic systems. The use of septic systems at the density of development already existing in Nags Head on the type of soils found in Nags Head and the depth of water table commonly-found on the Outer Banks, with the proximity of the Roanoke Sound and freshwater lakes in Nags Head, leads to the contamination of the groundwater and the adjacent surface waters.

Given this caveat on the continued use of septic systems for wastewater disposal, this report analyzes the wastewater treatment carrying capacity of the Town of Nags Head. This entails a projection of buildout at maximum permissible density for the currently undeveloped land. This projection assumes that no redevelopment of currently developed acreage at higher densities than currently exist will take place. In other words, existing development is left at existing densities and all growth is assumed to take place on currently undeveloped acreage. Maximum development and wastewater flows will be higher if tracts in Nags Head undergo redevelopment at higher than existing densities.

The report also compares development densities under market trends derived from building activity over the past four years to determine differences in densities under current development patterns and maximum permissible densities.

Development projections assume undeveloped platted lots in existing subdivisions to represent the potential for one dwelling unit with a conventional septic system, in areas where conventional septic systems and residential development are allowed. Platted lots that cannot support residential development or a septic tank under state regulations are also computed. This figure includes lots that are entirely within a CAMA Area of Environmental Concern, that are entirely situated on unsuitable soils, and that are within the purview of federal or state wetlands regulations.

Unplatted parcels are computed at maximum regulatory density according to the zoning ordinance, and alternatively at maximum density that may be served by septic tanks for newly platted parcels, i.e. at 15,000 square foot lots.

The maximum density of development served by septic tanks is determined by density limitations imposed by state regulations governing the use of septic tanks. The maximum density of development served by a community wastewater treatment system -- either a developer provided package facility or a regional wastewater collection and treatment system -- is not determined by limitations due to wastewater disposal. The density of such development is determined instead by local regulatory density limits and the amount of land available for development or redevelopment.

Finally, this section of the report accounts for development that is possible on platted lots with unsuitable soils for the use of conventional septic systems, that may be developed at lower densities with the use of alternative on-site waste treatment and disposal systems.

There are 2621 unimproved platted lots in the Town of Nags Head. Of these, 1883 are acceptable for development and connection to a conventional on-site septic system. The remaining 709 unimproved platted lots cannot be developed with a conventional system due to location in a CAMA ocean erodible AEC, in a regulated wetland, or in an area with unsuitable soils. 127 of these lots are completely unbuildable due to CAMA and the federal wetlands protection program. The remaining 582 lots are unbuildable with conventional septic systems due to unsuitable soils. These 582 lots may be built upon using alternative methods of wastewater treatment and disposal.

The total number of improved and unimproved platted lots in Nags Head is 6520. Of these, the total potential buildout on lots not subject to state or federal wetland or ocean erodible constraints of dwelling units with septic systems is 5811 dwelling units. An additional 582 dwelling units can be built, but are located on soils considered unsuitable for the use of conventional septic systems. See Table 3.

The buildout potential of unplatted parcels is measured under two scenarios: assuming the use of septic systems at a density of 15,000 square feet per dwelling unit; and assuming package wastewater treatment at maximum density permitted by the Town zoning ordinance.

As shown in Table 4, there are 1526 acres in the Town of Nags Head that are unplatted, unimproved, privately-owned and subject to development. This acreage does not include Jockey's Ridge State Park or property in Nags Head Woods owned by the Town or by The Nature Conservancy. Approximately 106 acres of this total consist of parcels which are entirely unsuitable for development with the use of on-site septic systems. This results in 1115 acres which are suitable for development with conventional septic systems, at a density of 15,000 square foot lots. In addition, 411 acres in the Epstein tract will be developed without septic tanks. The capacity of the 1486 acres at a density of 2.9 units per acre (15,000 square foot lots) is 1848 dwelling units served by septic systems on unimproved and unplatted parcels. An additional 1798 dwelling units and 900 motel rooms have been approved for development on the Epstein tract.

If development on the unplatted and unimproved parcels is served by package wastewater treatment facilities, the density of this development is determined by the Nags Head zoning ordinance. 1526 acres, including the Epstein tract, are available for development with the use of package facilities. At the permitted levels of density in the various zoning districts, 6576 dwelling units could be built, plus 900 motel rooms approved on the Epstein tract.

There are 582 unimproved platted lots in Nags Head which cannot be developed with the use of a septic system due to unsuitable soils. These lots may however be developed with the use of alternative on-site wastewater treatment technology. The two most widely-used methods of on-site wastewater treatment on unsuitable soils are low-pressure pipe systems and mound systems. These systems require approximately one acre per dwelling unit for use.

In summary, the total amount of buildout in Nags Head on currently platted lots, assuming no redevelopment at higher than existing densities, is 6520 dwelling units, not including development on the approved Master Plan for the Epstein tract. 3928 of these already exist and 2592 are unimproved lots. Approximately 709 of these lots face severe constraints to development, leaving a likely buildout between 5811 dwelling units and 6520 dwelling units.

Total buildout of the Epstein tract is 1798 dwelling units and 900 motel rooms. The total buildout on unimproved and unplatted parcels other than the Epstein tract is between 1848 and 4778 dwelling units. The total amount of buildout, including the Epstein tract, on unimproved and unplatted parcels is between a low figure of 3646 dwelling units and a high figure of 6576 dwelling units, plus 900 motel rooms.

The total buildout in Nags Head is therefore between 10,166 dwelling units and 13,096 dwelling units, plus the 900 motel rooms in the Epstein tract.

6. Building Activity Trends

The density of actual construction that has occurred in Nags Head since April 1980 has been higher than the density permitted by the zoning ordinance. This is due to development on lots which were platted earlier when the zoning regulations permitted smaller lots than currently permitted.

The actual "market" buildout trend over the past five years indicates that buildout is occurring at maximum permissible densities or greater. In none of the zoning districts in Nags Head is development proceeding at a density appreciably less than the density permitted by the zoning ordinance. See Table 5. The only significant differences between maximum permissible buildout under the zoning ordinance and market trends over the past five years are due to the development of grandfathered lots in previously platted parcels.

During the period between 1975 and 1979, there were 479 building starts in Nags Head according to the Land Use Plan Update. From April 1980 through May 1984, there were approximately 530 building starts according to data from the county Tax Office. The development over the past five years has consumed approximately 50 acres per year. See Table 5. With approximately 1500 acres of undeveloped privately-owned land subject to development, and assuming a continuation of recent development rates (50 acres per year), Nags Head will reach full buildout in approximately 30 years.

Table 3
Buildout Factors for Unimproved Platted Lots

District	Total Pl. Lots	'Acceptable' Pl. Lots *
R1	27	23
R2	1229	909
R3	70	63
CR	108	73
C2	959	625
SPD-20	199	190
Total	2592	1883

* Acceptable based on marginal or suitable soils and location not in CAMA AEC.

Existing Dwelling Units (from 1980 Land Use Plan + bldg. permits to 1984)		3928 DU's
Unimproved Platted Lots		2592
Total potential buildout on pl. lots (on septic systems)		6520 DU's
Unacceptable platted lots		-709
wetland AEC lots	80	
ocean erodible AEC lots	47	
unsuitable soil lots	582	
Estimated Carrying Capacity (using septic systems on lots permitted by state regulations.)		5811 DU's

Table 4
Buildout Factors for Unimproved Unplatted Parcels

District	Total Unimproved Acreage	'Unsuitable' Acreage *
R1	95.3	31.5
R2	237.6	25.6
R3	25.2	
CR	7.0	
C2	90.8	17.1
SPD-40	658.7	31.5
SPD-C	411.2	–
Total Acres	1525.8	105.7

Note: This total does not include publicly owned land.
* Unsuitable soil on entire parcel.

Densities Permitted by
Nags Head Zoning Ordinance

District	Acreage	Density Permitted
R1	95.3	2.9 DU's/acre
R2	237.6	3.9 DU's/acre
R3	25.2	(8.0 DU's on first acre,
CR	7.0	12.0 DU's on all
C2	90.8	subsequent acres)
SPD-40	658.7	4.0 DU/acre
SPD-C	411.2	* as in master plan
Total	1525.8 Acres	

Table continued on next page

Table 4 (cont.)

Buildout at Maximum Permissible Densities
(as found in the Zoning Ordinance)

District	Acreage	Buildout
R1	95.3	249 DU's
R2	237.6	834 DU's
R3	25.2	272 DU's
CR	7.0	72 DU's
C2	90.8	980 DU's
SPD-40	658.7	2371 DU's
SPD-C	411.2	1798 DU's
SPD-C	-	900 Motel Rooms
Total	1525.8	6576 DU's 900 Motel Rooms

Note: Acreage here not constrained by septic regulations.

Buildout at Densities from State Health Regulations
(based on 15,000 sq. ft. lots for septic use)

District	Acreage	Buildout
R1	95.3	249 DU's
R2	237.6	620 DU's
R3	25.2	66 DU's
CR	7.0	18 DU's
C2	90.8	237 DU's
SPD-40	658.7	658 DU's
SPD-C	411.2	1798 DU's
SPD-C	-	900 Motel Rooms
Total	1525.8	3646 DU's 900 Motel Rooms

Table 5
Nags Head Building Activity Trends

(April 1,1980 - May 23, 1984)

Zone	4/1/80 to 12/31/80	Calendar 81-82-83	1/1/84 to 5/23/84	Period Total	Acres Used	Implied Density
R1	-	8 SF	3 SF	11 SF	3.8 *	2.9 DU's/acre
R2	58 SF	200 SF	44 SF	302 SF	104.1 *	2.9 DU's/acre
	2 Duplex	17 Duplex	2 Duplex	21 Duplex	10.8 *	3.9 DU's/acre
R3	5 SF	8 SF	-	13 SF	4.5 *	2.9 DU's/acre
CR	-	6 SF	2 SF	8 SF	4.0	2.0 DU's/acre
	1 Duplex	13 Duplex	1 Duplex	15 Duplex	11.1	2.7 DU's/acre
	-	41 MF	45 MF	86 MF	6.5	13.2 DU's/acre
	-	69 Motel	17 Motel	86 Motel	5.1	16.9 Rooms/acre
C2	25 SF	61 SF	9 SF	95 SF	16.3	5.8 DU's/acre
	1 Duplex	1 Duplex	-	2 Duplex	0.7	5.7 DU's/acre
	Other: Motel, retail, etc.				61.7	-
SPD 20&40	1 SF	13 SF	10 SF	24 SF	11.4	2.1 DU's/acre
	1 Church	1 Nursing home			17.0	

* Acres used according to zoning density

Table continued on next page

Table 5 (cont.)

Total New Construction, 4/1/80 through 5/23/84

453 Single Family DU's on	144.1 acres, or	3.1 DU's/acre
76 Duplex DU's on	22.6 acres, or	3.4 DU's/acre
86 Multi-family DU's on	6.5 acres, or	13.2 DU's/acre
Other	83.8 acres	
Total	257.0 acres	

Total Residential Acreage	173.2 acres
Overall Residential Density	3.6 DU's/acre

Note: All MF development occurred in CR zoning district

Building Starts, Single Family, 1975 - 1979 (1980 LUP)	479
Building Starts, Single Family, 4/80 - 5/84	529

WATER SUPPLY AND DISTRIBUTION SYSTEM CAPACITY

The central issue with respect to water supply carrying capacity is at what level of development are capital improvements in the water supply, transmission, and distribution system required. Each component in the water supply system represents a fixed and limited capacity which must be increased when demand exceeds that supply capacity. Increased capacity is a matter of increased capital expenditure.

1. Aquifer Capacity

The most important supply threshold is the capacity of the Roanoke Island aquifer. A recent Engineering Report by Moore, Gardner and Associates for the County of Dare concluded that "it is evident that sufficient water supplies are available from the Roanoke Island Aquifer System to supply 15 mgd to the county water system." (p.5-14). The report concludes that once the capacity of the Roanoke Island aquifer is exceeded, the most feasible source of supply is development of the aquifer on the mainland. Development of this water supply source would be costly, requiring the construction of a transmission main across Croatan Sound. The 15 mgd capacity of the Roanoke Island aquifer seems to represent the most important water supply threshold. This threshold applies to water demand for the entire county population served by the regional water system. This includes Nags Head, Kill Devil Hills, Kitty Hawk, Manteo and unincorporated portions of the county.

The Moore Gardner Water System Improvement Study also projects water demand for the Dare County Water Authority Service Area. They project the water demand for Nags Head in 2005 to be 6.1 mgd, and the water demand for the county system to be 15.49 mgd. (Moore Gardner, Table 4.2-1)

In 1983 Nags Head accounted for a demand of 1.5 mgd out of a total demand for 4.5 mgd for the entire system. This constitutes 33 percent of the total demand. In 2005 Nags Head is projected to account for a demand of 6.1 mgd out of a total demand for 15.49 mgd for the entire system. This will constitute approximately 40 percent of the total system demand.

These projections in the Moore Gardner Study are based upon continuation of the population and water demand trends that occurred between 1980 and 1984. Average annual growth between 1980 and 1984 was approximately 15 percent. (Moore Gardner, p.4-1)

Based upon projected water demand at full buildout in Nags Head, the ultimate water demand created within the Town of Nags Head will be substantially less than the 6.1 mgd projected by Moore Gardner. Total water demand in Nags Head at full buildout -- under the conditions as explained in the land availability and wastewater section of this report -- will be between 4.39 mgd and 4.68 mgd. See Table 6.

Under existing development patterns, therefore, the portion of the total county water system demand created by Nags Head will allow the Roanoke Island aquifer to provide adequate quantities of water for the county without the need for development of a new aquifer on the mainland. If the share of the entire county supply devoted to Nags Head remains at 33 to 40 percent of the total county demand, then the total county demand will be between 10.9 mgd and 14.0 mgd. This level of demand is within the sustainable capacity of the Roanoke Island aquifer.

Table 6 indicates the computations performed to derive these projections. Total potential buildout on platted lots in Nags Head is 6520 dwelling units. Total potential buildout on unimproved parcels with the use of package wastewater treatment facilities is 6576 dwelling units plus 900 motel rooms. The total potential buildout in Nags Head is therefore 13,096 dwelling units and 900 motel rooms. These figures are explained in earlier sections of the report.

In order to establish the relationship between the number of total dwelling units and the total potential water demand in Nags Head, the demand for water generated by each additional dwelling unit must be determined. The 1980 Nags Head Land Use Plan Update and the 1984 Moore Gardner Water System Improvement Study provide data that establish the relationship between the total number of dwelling units and the demand for water. According to the Land Use Plan Update, average daily water use for residential users is 303.8 gallons per unit during the peak season, with that of motel rooms at 75 gallons per day. (p.31)

Average non-housing water sales to restaurants, retail businesses, and so forth in 1980 was approximately 10 percent of the total water sales for the Town. In 1980, 94,900 gallons out of total sales of 949,000 gallons in a representative month were to non-housing commercial users.

The Land Use Plan Update provides a second method of projecting water demand. According to the Update, dwelling units along the beach area consume 110 gallons per day per bedroom. Dwelling units along the Bypass and toward the Sound consume 85 gallons per day per bedroom. 100 gallons per day per bedroom seems a reasonable estimate of the total per day per bedroom water consumption. The Land Use Plan Update also contains data that indicates that the average number of bedrooms per dwelling unit in Nags Head is 3.2. (p.27) As shown in Table 6, Projection 1 -- which assumes water demand of 300 gallons per day for dwelling units and 75 gallons per day for motel rooms -- indicates that projected water demand at full build-out is 4.39 mgd.

Projection 2, which assumes 100 gallons water demand per day per bedroom and assumes a continuation of the average number of bedrooms per dwelling unit as 3.2, indicates that projected water demand at full build-out is 4.68 mgd.

Both of these projections assume that water demand by commercial users remains at 10 percent of total demand. These projections also assume that the Nags Head zoning districts C-2 and C-R will continue the recent trend of developing with multi-family housing rather than hotel/motel development. Therefore the assumed densities within these zoning districts is approximately 12 units per acre, rather than approximately 50 units per acre which would be permitted with the construction of hotel or motel units.

If total potential water demand in Nags Head is limited to between 4.39 mgd and 4.68 mgd and the other areas within the Dare County Water Service Area limit their water demand to similar ratios of the total county water demand, the total demand on the Roanoke Island aquifer will peak at between 10.9 mgd and 14.0 mgd. This is based upon the demand created in Nags Head remaining between 33 percent and 40 percent of the total county demand.

2. Water Distribution System

There are three factors affecting the capacity of the Town of Nags Head to transport and distribute water to its residents following delivery to the Town by the Dare County Water System. These portions of the water delivery under the town's control include the following: local pumping capacity, storage tank capacity, and capacity of the local water mains used for distribution.

The current capacity of the pumps which provide water for Nags Head is 2500 gallons per minute. During peak periods in the summer months, Nags Head consumes 1500 gallons per minute of this capacity. This results in 1000 gallons per minute excess capacity for use by future development. At current average use per dwelling unit, an additional 2600 dwelling units can be added to the system before additional pumping capacity is necessary. See Table 7. The units approved for the Epstein tract alone will consume this excess capacity.

An additional concern with pumping capacity is the speed with which storage tanks serving the town can be refilled. As the town approaches its pumping capacity, less excess capacity is available to refill these tanks and the rate of refill therefore is slower.

Storage tank capacity in Nags Head is currently 300,000 gallons. An additional 500,000 gallon tank is expected to be completed this summer. This 800,000 gallon storage capacity could serve Nags Head water consumption from storage alone for approximately 9 hours at peak consumption. If the tanks were empty, over 13 hours would be required to refill them while serving regular demand, using the excess 1000 gallons per minute of pumping capacity currently available. As more water users are added to the system, this excess capacity diminishes, and the refill period becomes longer.

The capacity of the water distribution mains which serve individual neighborhoods in Nags Head is a critical threshold to the growth in these neighborhoods. When the size of a water main is inadequate for the volume of water demanded by its users, pressure loss results. This leads to user dissatisfaction and potential safety concerns. Relating the size of such mains in newly developed areas to the potential total demand on the main is crucial to the future capacity of the main to provide water to all potential users.

Currently, 12 inch trunk lines carry water to the town along the beach road and the bypass. These 12 inch lines feed a distirbution network of 10 inch, 8 inch and 6 inch water lines, with much of the town served by the 6 inch line. The number of dwelling units which can be connected to the 6 inch line is limited. As more units tap onto this system, velocity of the water in the mains must increase to provide the same level of service. This in turn increases the head loss, or loss of pressure due to friction in the pipes.

The Nags Head system currently operates at 58 to 62 p.s.i.. The losses of pressure due to friction over distance can be severe. If pressure falls low enough, the ability to fight fires using hydrants along the water line becomes inadequate.

Table 6
Nags Head Water System

Total Potential Buildout on Platted Lots (DU's)	6520
Total Potential Buildout on Unimproved Parcels	6576
Additional Motel Rooms	900
Total Potential Dwelling Units at Full Buildout	13096
Additional Motel Rooms	900

Projection 1

- Assume 300 gal/DU/day
- Assume 10% of water used by commercial sector
- Assume 75 gal/unit/day in motels

Expected Residential Water Use	3928800 gal/day
Expected Motel Water Use	67500 gal/day
Expected Commercial Water Use	392880 gal/day
Total Water Use at Full Buildout	4389180 gal/day or 4.39 MGD

Projection 2

- Assume 100 gal/bedroom/day
- Assume 3.2 bedrooms/DU
- Assume 10% of water used by commercial sector
- Assume 75 gal/unit/day in motels

Expected Residential Water Use	4190720 gal/day
Expected Motel Water Use	67500
Expected Commercial Water Use	419072 gal/day
Total Water Use at Full Buildout	4677292 gal/day or 4.68 MGD

Table 7
Nags Head Water Distribution

Pumping Capacity

Current Pumping Capacity of Dare County System (supply available to Nags Head)	2500 gal/min
Current Nags Head Peak Use	1500 gal/min
Excess Capacity for Future Use	1000 gal/min

Current Dwelling Units	3928 DU's
Current Peak Use	1500 gal/min
Current Avg. Use	0.382 gal/DU/min

Total Capacity Currently Available	2500 gal/min
Current Average Use per Dwelling Unit	0.382 gal/DU/min
Total Dwelling Units Served at Capacity (capacity divided by average use)	6545 DU's

-- Note that this is pumping capacity only...

Total Additional Units Possible (without adding pumping capacity)	2617 DU's

Storage Tank Capacity

Current Capacity of Tanks	800000 gallons
Current Consumption per Hour	90000 gallons
Hours Available on Tank Service Alone	8.9 hours
Hours Required to Fill Tanks from Empty (while still serving at peak use)	13.3 hours

HURRICANE EVACUATION CAPACITY

Hurricanes are a major threat in any coastal community. They are even more dangerous on a barrier island because of the unstable nature of the island's natural systems, the limited elevation of the island, and the limited number of transportation links to the mainland. In addition, there are usually not enough adequate shelters in beach communities to safely allow people to remain, therefore the majority of residents and visitors must evacuate.

The capacity of the bridges and causeways which connect the islands to the mainland present a threshold beyond which development results in safety concerns, since evacuation beyond this capacity cannot be assured. It is difficult to create an effective model of hurricane evacuation for Nags Head because the community is only one of many which rely on the same evacuation routes. Nags Head is one portion of a far larger area -- covering from the Currituck Banks to Ocracoke -- which responsible evacuation planning must treat as a single system.

The methodology used here is adapted from John R. Stone's manuscript, Hurricane Emergency Planning: Estimating Evacuation Times for Non-Metropolitan Coastal Communities (UNC Sea Grant Publication, 1982). His process isolates the bottleneck in the evacuation system, and then calculates the time necessary to get all the evacuating vehicles through this bottleneck. For Nags Head, this bottleneck is the bridge and causeway to Roanoke Island.

Four elements must be considered to determine the total evacuation time: bridge capacity, evacuation demand, travel time, and evacuation capacity.

Each of these elements is described below, with the calculations which lead to total evacuation time.

1. Bridge Capacity

Capacity of the bridge and causeway system is based upon the maximum normal flow of traffic over the bridge. Five factors are then subtracted from this normal maximum to allow for the specific conditions during hurricane evacuation. These factors assume that the capacity will be reduced by blocked lanes, inclement weather, shoulder width and sight distance, oversize vehicles, and emergency vehicles. Each factor is discussed below:

Normal Flow - The Highway Capacity Manual describes normal flow for this type of road (the bridge and causeway) as 2000 vehicles per hour total in both lanes.

Blockage Factor - Fifteen percent of normal flow is lost due to stalled cars, fallen road signs, loose electric or phone lines, and so forth.

Weather Reduction Factor - Another 35 percent of the normal capacity is lost due to slippery roads, gale force winds, and heavy rains.

Lane/Clearance Factor - A further 23 percent reduction in capacity is due to limitations of the road itself such as lack of shoulder and limited sight distances.

Oversize Vehicle Factor - One lane is closed for emergency vehicle use ten percent of the time.

After these five factors are subtracted from the normal flow capacity, the remaining total bridge capacity for hurricane evacuation is found to be 768 vehicles per hour.

2. Evacuation Demand

The number of vehicles which will be used to evacuate prior to a hurricane is calculated by using the number of dwelling units in Nags Head. Other vehicles which can be expected to arrive from Hatteras Island are also included. This does not include day tourists who are not staying either in Nags Head or on Hatteras Island.

Evacuation demand is computed as follows:

Permanent and Tourist Residential Units - Data determining the number of dwelling units was taken from the 1980 Nags Head Land Use Plan and updated to the present using building permit information. There are 2238 tourist residential dwelling units (cottage courts and motels) and 1690 permanent residential dwelling units.

Vehicles Per Dwelling Unit - Estimates from current trends are: 1.6 vehicles per permanent dwelling unit, and 1.1 vehicles per tourist dwelling unit.

Early Evacuators - Fifteen percent of the population leaves before the order to evacuate is given.

Other Vehicles - Approximately 5000 vehicles can be expected to arrive from Hatteras Island according to the Hatteras Island Carrying Capacity Analysis (May 1984).

Total evacuation Demand at peak occupancy is 9391 vehicles.

3. Travel Time

Travel time is the amount of time it would ordinarily take to drive from the furthest point in Nags Head to the bridge. The calculation is a simple division of maximum distance (15 miles) by average speed (35 MPH).

Travel time for Nags Head is under one-half hour.

4. Evacuation Capacity

The bottleneck for Nags Head evacuees is clearly the bridge and causeway which link the island to the mainland. This section calculates the amount of time required to move the evacuating vehicles through this bottleneck. First, the period during which evacuation takes place is calculated, then the demand for evacuation during that period is examined to evaluate the bottleneck:

Warning Time - The National Weather Service can be counted on to provide no more than a 12-hour warning which is accurate to within approximately 50 miles of the landfall of the eye.

Hazard Cutoff Time - Roads are inundated or high winds prevent evacuation four hours before the landfall of the hurricane eye.

Evacuation Period - The amount of time during which evacuation may take place, i.e 12 hour warning minus 4 hour hazard cutoff results in an 8 hour evacuation period.

Moving the total evacuation demand over the bridge and causeway takes over 12 hours; 9391 divided by 768. If fifteen percent of the vehicles leave before the order is given, this leaves over 1800 vehicles stranded on the island, after the 8 hour evacuation period. An additional 2.4 hours are needed to evacuate these remaining vehicles. The total time necessary for full evacuation is almost 15 hours, even if 15 percent of the population leaves prior to the warning. If no significant number of vehicles leaves prior to the warning, over 16 hours are necessary for full evacuation.

An example given in Stone's manuscript asserts that only 400 to 500 vehicles per hour can pass over a two-lane bridge during hurricane evacuation conditions. This results in a scenario far worse than that resulting from the 768 vehicles per hour estimated in this analysis.

In addition, this evacuation model merely evacuates vehicles from Nags Head and Hatteras Island to Roanoke Island. On Roanoke Island, the vehicles from the barrier islands will be joined by vehicles from Manteo and Wanchese, further aggravating evacuation to the mainland.

Table 8

Nags Head Evacuation Analysis

BRIDGE CAPACITY

Normal Flow	1000 veh/lane/hr	
Blockage Factor	0.85 (stalled cars,etc.)	
Weather Reduction Factor	0.65 (slick roads, etc.)	
Lane/Clearance Factor	0.77 (shoulder,sight distance)	
Oversize Vehicle Factor	0.95 (truck,trailer,RV)	
Emergency Vehicle Factor	0.90 (1 lane,10% use)	
Total Bridge Capacity using two lanes	(veh/hr)	768

EVACUATION DEMAND

Permanent Residential	1690 D.U.'s	
Tourist Residential	2238 D.U.'s	
Vehicles per Permanent D.U.	1.60	
Vehicles per Tourist D.U.	1.10	
Early Evacuators (%)	0.15	
Nags Head Vehicles		4391
Other Vehicles (areas outside Nags Head)		5000
Evacuation Demand at Peak Occupancy	(total vehicles)	9391

TRAVEL TIME

Average Speed	35.00 MPH
Maximum Distance	15.00 Miles
Travel Time	0.43 Hours

EVACUATION CAPACITY

NWS Warning Time	12.00 Hours
Hazard Cutoff Time	4.00 Hours
Evacuation Period	8.00 Hours
Vehicles Remaining Until Evacuation Order is Given	7982 Vehicles
Vehicles Which Can Be Evacuated in 8 Hours Over the Bridge	6143 Vehicles
Vehicles Stranded on the Island	1839 Vehicles
Additional Hours Needed to Evacuate These Vehicles	2.40 Hours

continued on next page

Table 8 (cont.)

TOTAL EVACUATION TIME
(time necessary before landfall of the eye, assuming that 15% leave early)

Hazard Cut-off Time	4.00 Hours
Evacuation Period	8.00 Hours
Travel Time	0.43 Hours
Add'l Hours Needed	2.40 Hours
Total	14.82 Hours

Time Necessary for Complete Evacuation (no vehicles leave before the order)	16.66 Hours

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