Table 5 - Continued

Contaminants	Health Effects	MCL[1]	Sources
Methoxychlor	Nervous system/kidney effects	.1	insecticide used on fruit trees, vegetables
2.4-D	Liver/kidney effects	.1	herbicide used to control broad-leaf weeds in agriculture, used on forests, range, pastures, and aquatic environments
2.4.5-TP Silvex	Liver/kidney effects	.01	herbicide (cancelled in 1984)
Toxaphene	Cancer risk	.005	insecticide used on cotton, corn, grain
Benzene	Cancer	.005	fuel (leaking tanks), solvent commonly used in manufacture of industrial chemicals, pharmaceuticals, pesticides, paints and plastics
Carbon tetrachloride	Possible cancer	.005	common in cleaning agents, industrial wastes from manufacture of coolants
p-Dichlorobenzene	Possible cancer	.075	used in insecticides, moth balls, air deodorizers
1.2-Dichloroethane	Possible cancer	.005	used in manufacture of insecticides, gasoline
1.1-Dichloroethylene	Liver/kidney effects	.007	used in manufacture of plastics, dyes, perfumes, paints SOCs
1.1.1-Trichloroethane	Nervous system problems	.2	used in manufacture of food wrappings, synthetic fibers
Trichloroethylene (TCE)	Possible cancer	.005	waste from disposal of dry cleaning materials and manufacture of pesticides, paints, waxes and varnishes, paint stripper, metal degreaser
Vinyl Chloride	Cancer risk	.002	polyvinylchloride pipes and solvents used to join them, waste from manufacturing plastics and synthetic rubber
Total trihalomethanes (TTHM) (chloroform, bromoform, bromodichloromethane, dibromochloromethane	Cancer risk	.1	primarily formed when surface water containing organic matter is treated with chlorine

[1] In milligrams per liter, unless otherwise noted

Table 6. EPA Secondary Drinking Water Standards (from EPA, 1991)

Contaminants	Suggested Levels	Contaminant Effects
pH	6.5 -8.5	Water is too corrosive
Chloride	250 mg/l	Taste and corrosion of pipes
Copper	1 mg/l	Taste and staining of porcelain
Foaming agents	0.5 mg/l	Aesthetic
Sulfate	250 mg/l	Taste and laxative effects
Total dissolved solids (hardness)	500 mg/l	Taste and possible relation blow hardness and cardiovascular disease; also an indicator or corrosivity (related to lead levels in water); can damage plumbing and limit effectiveness of soaps and detergents
Zinc	5 mg/l	Taste
Fluoride	2.0 mg/l	Dental flourishes (a brownish discoloration of the teeth)
Color	15 color units	Aesthetic
Corrosivity	non-corrosive	Aesthetic and health related (Corrosive water can leach pipe materials, such as lead, into drinking water.)
Iron	0.3 mg/l	Taste and staining of laundry
Manganese	0.05 mg/l	Taste and staining of laundry
Odor	3 threshold odor number	Aesthetic

Secondary Drinking Water Standards are unenforceable federal guidelines regarding the taste, odor, color - and certain other non-aesthetic effects - of drinking water. EPA recommends them to the States as reasonable goals, but Federal law does not require water systems to comply with them. States may, however, adopt their own enforceable regulations governing these concerns. To be safe, check your State's drinking water rules.

5.0 Wellhead Protection Program

Minimum requirements for WHP Programs were established by the EPA as a result of the 1986 Safe Drinking Water Act (SDWA). As a minimum, the SDWA requires each state's WHP to:

- Specify the roles of state and local governments and public water suppliers;
- Delineate wellhead protection areas for each well or wellfield;
- Identify sources of contaminants within each WHP area;
- Develop management approaches to protect the water supply within WHP areas from those contaminants;
- Develop contingency plans for each public water supply system in the event of well or wellfield contamination;
- Locate new wells properly to minimize potential contamination; and
- Ensure public participation in WHP program development.

Because these requirements were set up for state and local authorities, the first and last requirements would not necessarily apply to MCB. However, it is important that MCB participate at the local level when and if local WPAs are formulated.

5.1 Delineation of MCB Wellhead Protection Area

Prior to the introduction of the Wellhead Protection Programs by the EPA in 1986, the term "wellhead" was applied to the above-ground physical structure of the well, including piping and valves.

The EPA redefined the term "wellhead" to include the surface and subsurface within which contaminants are likely to move to a water-supply well or well field, and thus refers to "the surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are likely to move toward and reach such water well or well field" (US EPA, 1987, p. 1-2).

The EPA recognized that the source of water for all wells ultimately comes from infiltration by surface water into the water table aquifer as it passes across the land surface and through the soil zone.
Consequently, the condition of the soil and shallow subsurface materials greatly affects the quality of water found in the water table aquifer. Surface spills of chemicals and petroleum products may eventually migrate into the groundwater system and later show up in drinking water.

The purpose of a WPA program is to delineate the area where primary infiltration occurs and, through some plan, regulate or control the release of substances within this zone. Substance control methods suggested by the EPA include: (1) land-use planning within the WPA, (2) zoning, or (3) some other method of restrainment. EPA and the State of North Carolina intended to have local governments manage wellhead protection policy through restriction of certain development activities within the WPA (NC Wellhead Protection Program, Draft Document, 1991). During the process of establishing a WPA at MCB, an inventory of existing potential contamination sources was completed by Geophex. Based on the results of this survey, several groupings of wells were found to be located within a 10-year zone of travel (ZOT) of potential contaminant sources (Figure 15).

Under the WMP, one of three following options are suggested to protect the wellhead area: (1) abandon the well, (2) move the potential contamination source to an area outside of the WPA, or (3) create a monitoring program designed to detect the potential contamination in the event of a leak.

If the monitoring alternative is selected, the frequency of monitoring should be determined by the location of the potential contamination with respect to the well (EPA, 570/9-91-008).

The protection goals proposed by Geophex for MCB are similar to the goals suggested by EPA and NC DEM, and include one or more of the following elements.

1. Provide a zone of protection around wells or well fields that affords adequate time to react to incidents of unexpected contamination. The "Time of Travel" protection strategy is based upon the time necessary to identify and cleanup contaminants before they reach a well. This goal is accomplished by delineating a protection area large enough to attenuate potential contaminants to target levels.

2. Protecting all or part of the zone of contribution from contamination by prohibiting threatening activities to take place in defined zones surrounding the wells. This is a form of zoning or land-use planning.

5.1.1 Strategy for Establishment of WPA at MCB

The EPA (EPA 1987) proposed five criteria to be used as a basis for establishing the zone of protection surrounding wells or well fields. These criteria are, in part, based upon the hydrodynamics of the aquifer system, and are described in the following sections.

- Distance

  North Carolina regulations (NCAC Title 15 Subchapter 2C Section .0100) currently employ a fixed radius concept where no public water-supply well may be constructed within 100 feet of any sewer or septic system. The EPA recommends the use of distance criteria only as a temporary measure until a better-founded basis can be established following a more complete analysis. To determine minimum required distance between a well and a sewer or septic system, a circle with an arbitrary fixed radius is drawn around each well. The radius of the circle may or may not have any relationship to pumping rates, aquifer conditions, or topographic position.

- Drawdown

  The areal extent over which drawdown occurs within an aquifer due to withdrawals from wells is commonly referred to as the zone of influence, or the cone of depression.

  In a region where regional gradient is negligible, the extent of the cone of depression coincides with the area of downward leakage and is generally circular in shape. Regional gradients tend to complicate the shape of the zone of influence by stretching the circle into an ellipse up-gradient from the well. The extent of the stretch is determined by the rate of regional groundwater flow. In this case the hydraulic potential for vertical leakage decreases rapidly away from the well. However, vertical leakage may be less than the potential if the confining unit is considered "tight." Vertical leakage into the Castle Hayne Aquifer can be accelerated by a lack of a "tight" confining unit and/or vertical geologic structures including ancient stream channels, and man-made structures such as deep ditches and poorly constructed water and monitor wells.

- Time of Travel

  The time-of-travel criterion is used to establish the time for groundwater or hypothetical contaminant to flow from a point of interest (or concern) to a well. A collection of common travel times define an isochron (contours of equal time) wherein a ZOT is established.

  ZOT provide a graphic representation of the extent of areas that would be included in a particular well or well field's zone of capture for a given time interval. Such a representation is useful in establishing the minimum acceptable distance in which a well should be located with respect to potential contaminants. The minimum acceptable distance is, in part, determined by the type of potential contaminant and the speed and effectiveness with which they can be detected, contained, and removed from the nearest WPA.

- Flow Boundaries

  Hydrogeologic mapping is utilized to establish hydrogeologic boundaries, including such natural physical boundaries such as rivers, groundwater divides, and man-induced boundaries such as those created by pumping wells. Hydrologic mapping can be useful where these boundary conditions can be clearly defined, for example, in the Piedmont and mountain regions. In the case of MCB, because the relief is low, groundwater divides are poorly defined, thus the extent of the a hydrologic cell cannot be accurately mapped.

- Assimilative Capacity

  The assimilative capacity refers to the concept that contaminants are assimilated as they pass through the saturated and/or unsaturated section of an aquifer. The extent of assimilation can be quite variable and largely depends on the mineral composition of the soils, the chemical characteristics of the aquifer, and the composition of the contaminant. Because the assimilative capacity of the water table aquifer and the Castle Hayne Aquifer is not known, it is not considered in this plan. Eliminating this factor promotes a more conservative approach to defining WPAs.

For the reasons cited below the following criterion were determined to be an inappropriate basis to found the MCB WPA Plan upon:

- The use of distance criterion would not adequately or accurately characterize the true aquifer recharge zone.
- Use of flow-boundary criterion is not used because groundwater divides in a confined and semi-confined aquifer in low relief areas such as MCB are difficult to define.
- Assimilative capacity is too poorly understood to be considered a valid option, and its exclusion only assures that the criterion employed is somewhat conservative.

- The drawdown method is not utilized because the zone of contribution surrounding a well field given a long periods of pumping can be unrealistically large and unmanageable. In addition, sufficient hydrogeologic information is not currently available to adequately describe drawdown at MCB given the complex nature of the existing well field and pumping scenarios.

Therefore, we recommend utilizing the time-of-travel criterion as the primary basis for establishing the MCB WPA. Utilization of the time of travel criterion requires the calculation of an appropriate ZOT around each well based upon know or assumed geologic and hydrologic conditions, a inventory of known contaminants or potential contaminants within the ZOT and the establishment of a routine monitoring system that is designed to detect the presense of contaminants within the ZOT.

5.1.2 Establishment of Time of Travel WHP

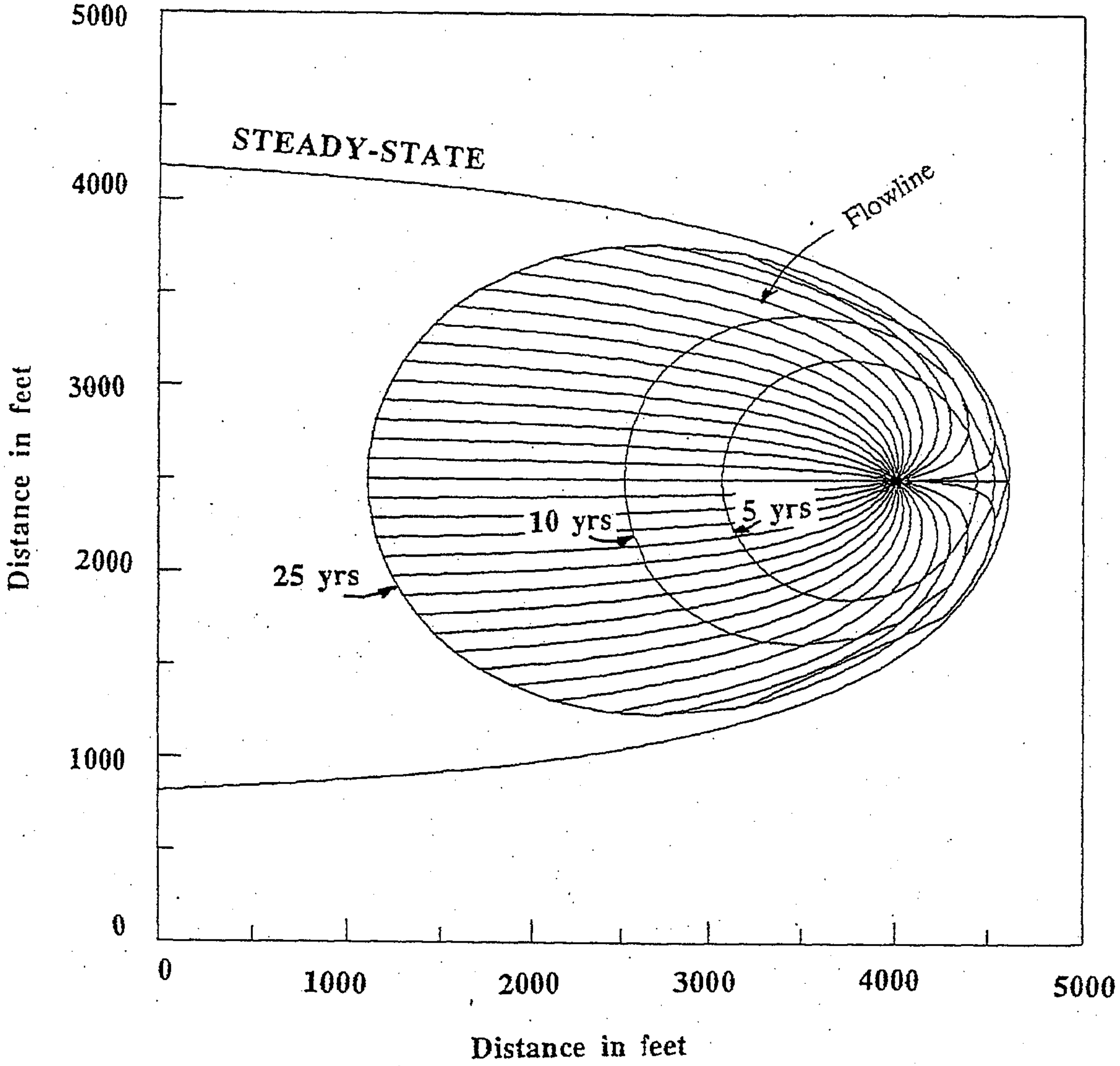
In an effort to standardize MCB's wellhead protection program to a format developed by the EPA, the reverse-path calculation method was employed using EPA's Wellhead Protection Area computer program, version 2.0 (Blanford and Huyokorn, 1991). This public domain software package has been installed on computer located at EMD, along with the two model simulations run by Geophex to determine the ZOTs used at MCB. Because this computer simulation is sensitive to pumping rates, aquifer transmissivity, and regional groundwater flow patterns, it is not currently possible to adequately model all MCB wells simultaneously. As an alternative, a template ZOT was generated for the different hydrogeologic conditions found: (1) in the vicinity of Holcomb Boulevard and Hadnot Point, and (2) at Camp Geiger and MCAS. Hydrogeologic input data for the Blanford and Huyokorn models were obtained from the existing USGS publication (Harned and others, 1989) and MCB well logs (Holcomb Boulevard Water Treatment Facility), and are summarized in Table 7.

The results of the Holcomb-Hadnot Point and MCAS simulations are presented in Figures 12 and 13 as steady-state, 5-, 10-, and 25-year time-related capture zones. The approximate limits and areas of each ZOT are shown in Table 8.

Table 7. Input to WHPA-MWCAP Model (Version 2.0)

Parameter Simulation Options	Holcomb Boulevard and Hadnot Point	MCAS
Units (feet and days)		
Step Length	50	50
XMIN (feet)	0	0
XMAX (feet)	10,000	10,000
YMIN (feet)	0	0
YMAX (feet)	10,000	10,000
Number of Wells	1	1
Location X (feet)	6,000	6,000
Location Y (feet)	5,000	5,000
Pumping rate (cubic ft/day)	57,754	30,802
Transmissivity	15,000	8,000
Regional slope	0.001	0.001
Orientation (degrees)	0	0
effective porosity	0.25	0.25
number of pathlines	20	20
boundary conditions	none	none
mode of calculation	Time-Related	Time-Related
Capture zone plotted	yes	yes

Zone Of Travel for Holcomb Boulevard-Hadnot Point Onslow Beach, and Rifle Range Wells



Geophex

Figure 12. Steady-State, 5-, 10-, and 25-Year, Zone of Travel (ZOT) For Typical Holcomb Boulevard-Hadnot Point, Onslow Beach, and Rifle Range Wells.

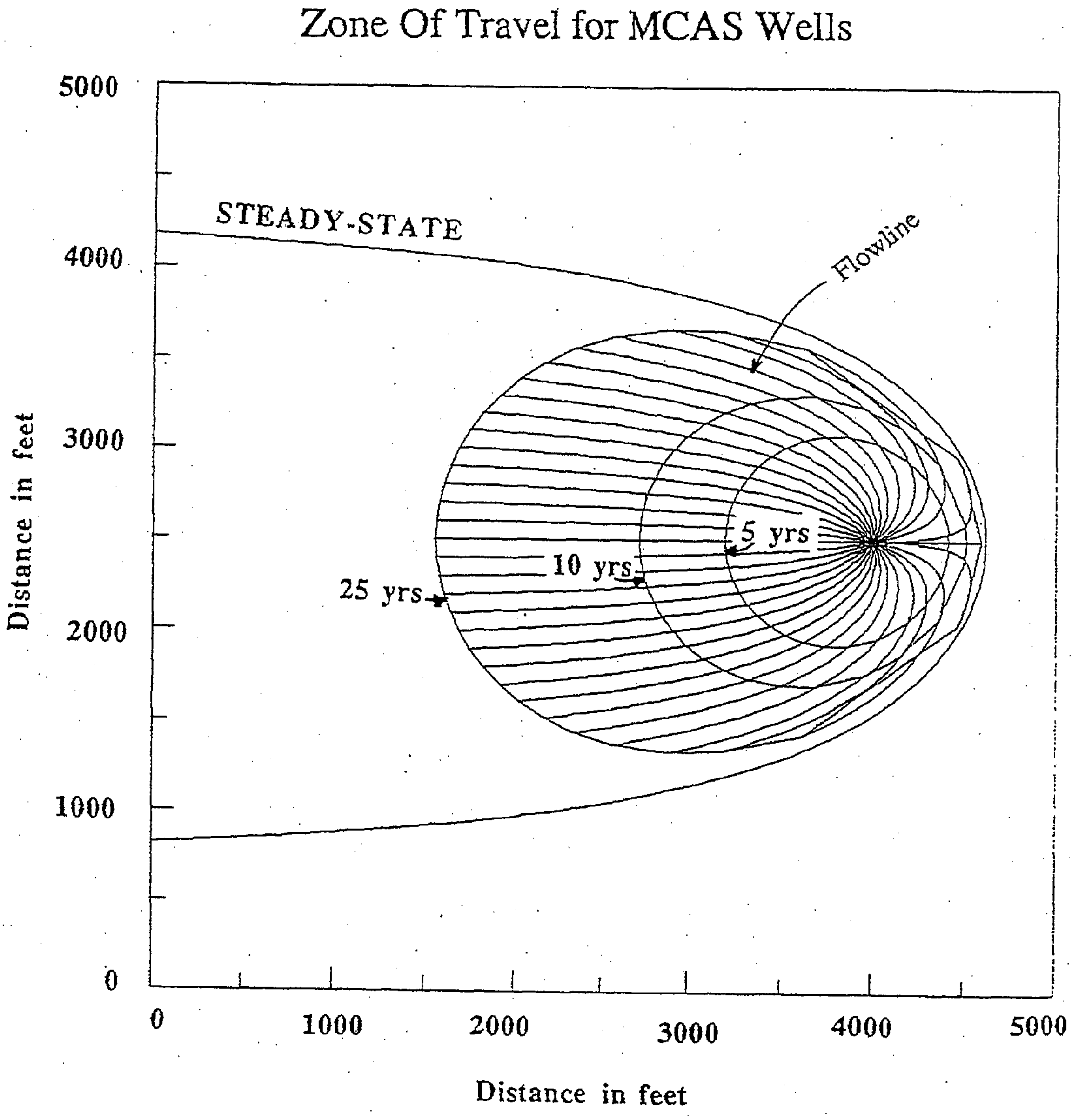


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Figure 13. Steady-State, 5-, 10-, And 25-Year, Zone of Travel (ZOT) for Typical MCAS Wells.

Table 8. Estimated Zone of Travel (ZOT) for Holcomb Boulevard-Hadnot Point and MCAS.

Location	Holcomb Boulevard -Hadnot Point	MCAS
Calculated 5 Year ZOT dimension:		
Length (feet)	1,350	1,100
Width (feet)	1,250	950
Approximate area (acres)	31	19
Calculated 10 Year ZOT dimension:		
Length (feet)	2,100	1,400
Width (feet)	1,700	1,350
Approximate area (acres)	65	34
Calculated 25 Year ZOT dimension:		
Length (feet)	3,200	2,600
Width (feet)	2,350	2,150
Approximate area (acres)	139	102

As an example, the 10-year ZOT for MCAS is elliptical in shape, approximately 1,400 x 1,350 feet in dimension and covers an area of 34 acres. In comparison, the 10-year ZOT for Holcomb-Hadnot Point is larger, measuring 2,100 x 1,700 feet and covering 65 acres. The 10-year ZOT is proposed because: (1) the 5-year ZOT does not provide adequate time for EMD to discover, conduct an RI, and then complete rehabilitative action, and (2) the 25-year ZOT consumes too much area and, at least for MCB planning purposes, is too conservative. The 10-year ZOT is proposed for MCB because it provides adequate time for discovery and clean-up of accidental contamination events, or will permit adequate time to install new wells if clean-up is not feasible.

The MCB WPA map (Figure 14) was compiled by appropriately orienting the 10-year ZOT template over each well location, and then circumscribing an inclusive boundary line around groups of wells that make up a well cluster. The composite of all ZOTs describes the 10-year WPA.

A comparison of the 10-year WPA map and the location of potential contamination sources shows that approximately one-third of MCB wells (including MCAS) are located such that potential contamination sources fall within their 10-year WPA. Two AOCs, located at the HPIA and MCAS, contain wells that have already been contaminated (Figure 15).

5.2 Potential On-Site Contamination Sources

Groundwater contamination is related to numerous activities at MCB and can be classified into the following categories: (1) oil pollution and hazardous substances, (2) leaking underground storage tanks, (3) waste management activities (e.g., land fills, surface impoundments, waste piles), (4) certain industrial activities (e.g., vehicle maintenance, metal fabrication, machine shops, etc.), and (5) surface water runoff from contaminated areas, including roads and parking lots.

In addition, MCB conducts various military training activities which have an unknown impact on regional groundwater quality. Related training activities include: (1) bombing and/or shelling of targets in G-10, K-2 and 1/BT-3 Impact Areas, (2) abandonment of unexploded ordnance in various training areas, and (3) logistic operations involving ammunition and/or weapons at various storage sites..

An inventory of potential on-site contamination sources supplied by MCB was reviewed. In general, these contamination sources include the following.

- Twenty-two sites where groundwater and/or soils have been contaminated and remedial investigations (RI) have or are being conducted. An inventory of these sites was prepared by Environmental Science and Engineering, Inc. (1990) for MCB and serves as a reference to all RI's considered in this study.
- Active solid waste disposal areas, including land fills and burn areas;
- Stormwater run-off;
- Chemical usage and storage;
- Underground petroleum storage, and
- Military training activities.

5.2.1 Underground Petroleum Storage

A inventory of approximately 458 underground storage tanks (USTs) was completed by Geraghty and Miller, Inc in 1989. EMD provided Geophex with a copy of the Geraghty and Miller tank locations. A shortened version of these data are presented in Appendix E. According to EMD, the Geraghty and Miller inventory of approximately 458 USTs represents only a portion of the total USTs located at MCB. Most of these USTs are associated with a building or service site provided by MCB, and are generally found within developed regions of the base. MCB currently is bringing all USTs up to compliance with current NC UST requirements for underground storge tanks (NCGS 143-215.94). An additional 1705 USTs were suspected to have existed and presumeably abandoned by removing the contents and filling with sand. Many of these USTs were associated with individual dwellings and duplexs supplied by MCB for military personnel and dependents. Because the extent of contamination, if any, associated with these USTs is not known, and the effectiveness of the tank closure to prevent groundwater and soil contamination has not been assessed these USTs should be viewed as potential sources of contamination.

5.2.2 Other Contamination Sources

The EPA prepared a list of common sources or activities related to groundwater contamination (EPA, 1990). These sources or activities are presented in Table 9. Nearly all of the potential groundwater contaminant sources listed by the EPA exist at MCB. The distribution for all these potential sources of contamination are not mapped. However, a review of base facility activities and land use clearly demonstrates most of the common sources of groundwater contamination are located on the most developed areas at MCB. On the other hand, non-developed lands contain very few, if any, of these common sources. Figure 16, shows the distribution of developed lands at MCB, which correspond to those areas with the greatest number of potential sources of contaminants. The distribution of these areas is a critical consideration in delineating WPAs.

5.3 Land Usage

The training mission of MCB has been a major factor in the determination of how land is to be best utilized. The training requirement for large, unobstucted areas with suitable staging areas for troop deployment has resulted in the establishment of two very general settings.

Table 9. EPA List of Common Sources or Activities Related to Groundwater Contamination. (Source: EPA Guide to Groundwater Supply Contingency Planning for Local and State Governments, 1990)

AGRICULTURAL

Animal burial areas
Animal feedlots
Chemical application
  (e.g., pesticides, fungicides, and fertilizers)
Chemical storage areas
Irrigation
Manure spreading and pits

COMMERCIAL

Airports
Auto Repair Shops
Boat Yards
Construction Areas
Car Washes
Cemeteries
Dry Cleaning Establishments
Educational Institutions
  (e.g., labs, lawns, and chemical storage areas)
Gas Stations
Golf courses (chemical application)
Jewelry and Metal Plating
Laundromats
Medical Institutions
Paint Shops
Photography Establishments/Printers
Railroad Tracks and yards/Maintenance
Research Laboratories
Road Deicing Operations
  (e.g., road salt)
Road Maintenance Depots
Scrap and Junkyards
Storage Tanks
  (i.e., Above-Ground, Below-Ground, and Underground)

INDUSTRIAL

Asphalt Plants
Chemical Manufacture, Warehousing, and Distribution Activities
Electrical and Electronic Products Manufacturing
Electroplaters and Metal Fabricators
Foundries
Machine and Metalworking Shops
Manufacturing and Distribution Sites for Cleaning Supplies
Mining (Surface and underground) and Mine Drainage
Petroleum Products Production, Storage, and Distribution Centers
Pipelines
  (e.g., oil, gas, coal slurry)
Septage Lagoons and Sludge
Storage Tanks
  (i.e., Above-Ground, Below-Ground and Underground)
Toxic and Hazardous Spills
Wells -- Operating and Abandoned
  (e.g., oil, gas, water supply, injection, monitoring and exploration)
Wood Preserving Facilities

RESIDENTIAL

Furniture and Wood Strippers and Refinishers
Household Hazardous Products
Household lawn (chemical application)
Septic Systems, Cesspools, and Water Softeners
Sewer Lines
Swimming Pools
  (e.g., chlorine)

WASTE MANAGEMENT

Hazardous Waste Management Units (e.g., landfills, land treatment areas, surface impoundments, waste piles, incinerators)
Municipal Incinerators
Municipal Landfills
Municipal Wastewater and Sewer Lines
Open Burning Sites
Recycling and Reduction Facilities
Stormwater Drains, Retention Basins
Transfer Stations

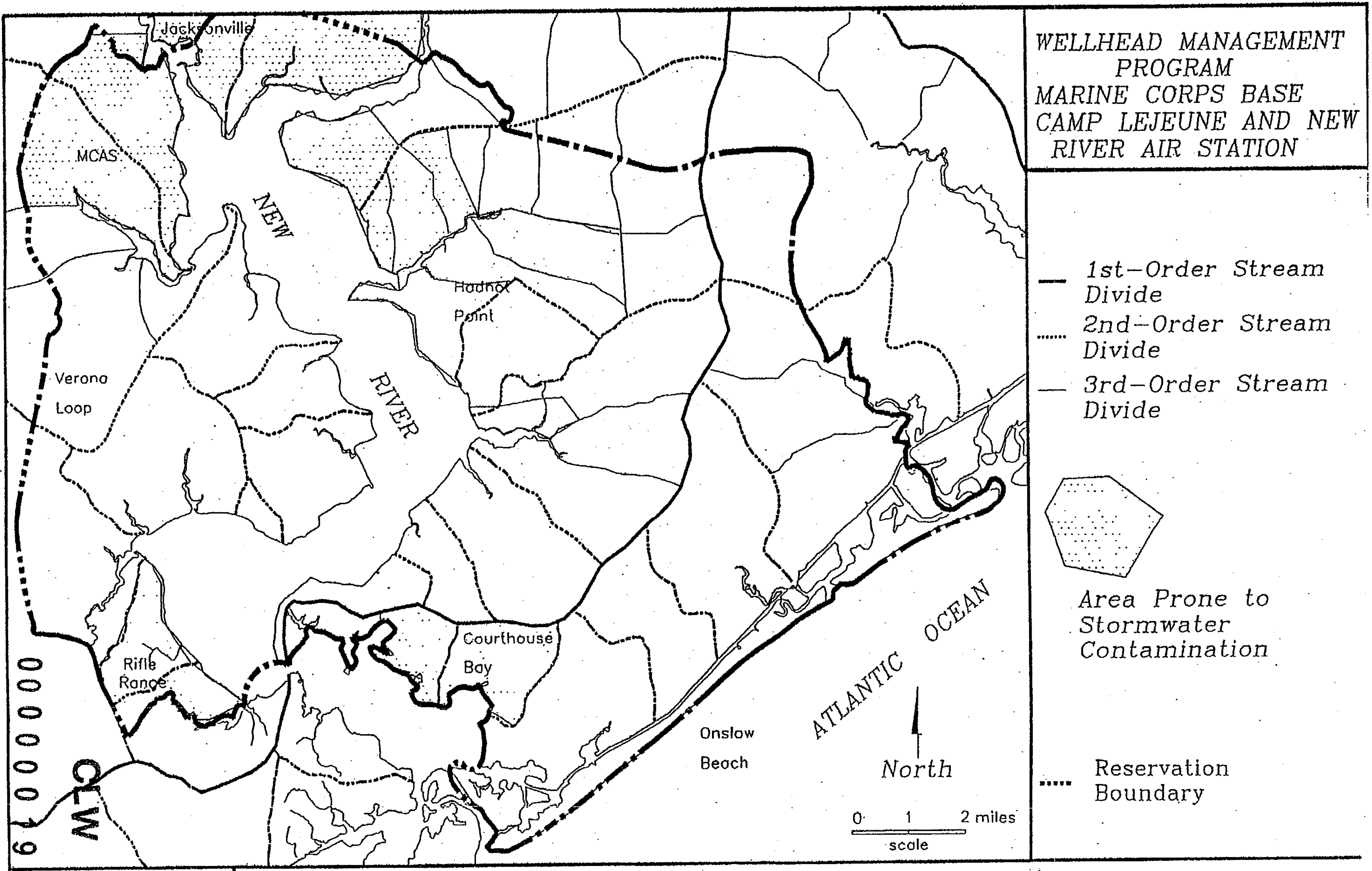

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Figure 16. Location of Developed Land Surfaces at MCB Containing Most Potential Contamination Sources.

A major portion of the base is undeveloped woodlands traversed by trails and semi-improved roads. A much smaller portion of the base is highly developed, containing services and structures to support the approximately 65,000 personnel associated with the base activities. The intense areas of development are conducive to surface and groundwater contamination. The following is a general description of the major sources of groundwater contamination identified at MCB.

5.3.1 Solid Waste Disposal

MCB maintains a single solid waste disposal site, with plans to expand the existing site by the addition of another fill layer. The site is located east of the HPIA along Sneeds Ferry Road adjacent to MCB water wells 606, 609, and 626. Water analysis from these wells indicates no VOC contamination at present, however a total chemical scan should be conducted to determine if leachate are present. An abandoned landfill was operated near the site of contaminated Well 651, west of Piney Green Road. Adjacent wells 636, 610, and 709 do not show similar contamination.

5.3.2 Storm Water Management

Storm water management is in early stages of development at MCB. Part I Group Stormwater permits were applied for in 1991 (Geophex, 1991). Chemical analyses characterizing runoff planned in Part II is not currently available, thus it was not possible to characterize the water quality between stream divides. Because water quality data was not available, a quantitative approach was not possible. First-, second- and third-order surface water drainage basins were constructed from MCB topographic maps (Figure 17). Drainage from developed regions is assumed to be contaminated, whereas drainage from undeveloped regions is assumed uncontaminated. The contaminated regions highlighted in Figure 17, show a potential adverse impact on wells in portions of the Hadnot Point and the MCAS wellfields.

5.3.3 Chemical Usage and Storage

The location of chemical usage and storage centers was not mapped in detail for this project. A review of the locations of activities involved with chemical processes provided by EMD indicates that nearly all chemical storage and user centers corresponds to previously identified developed regions of the base.

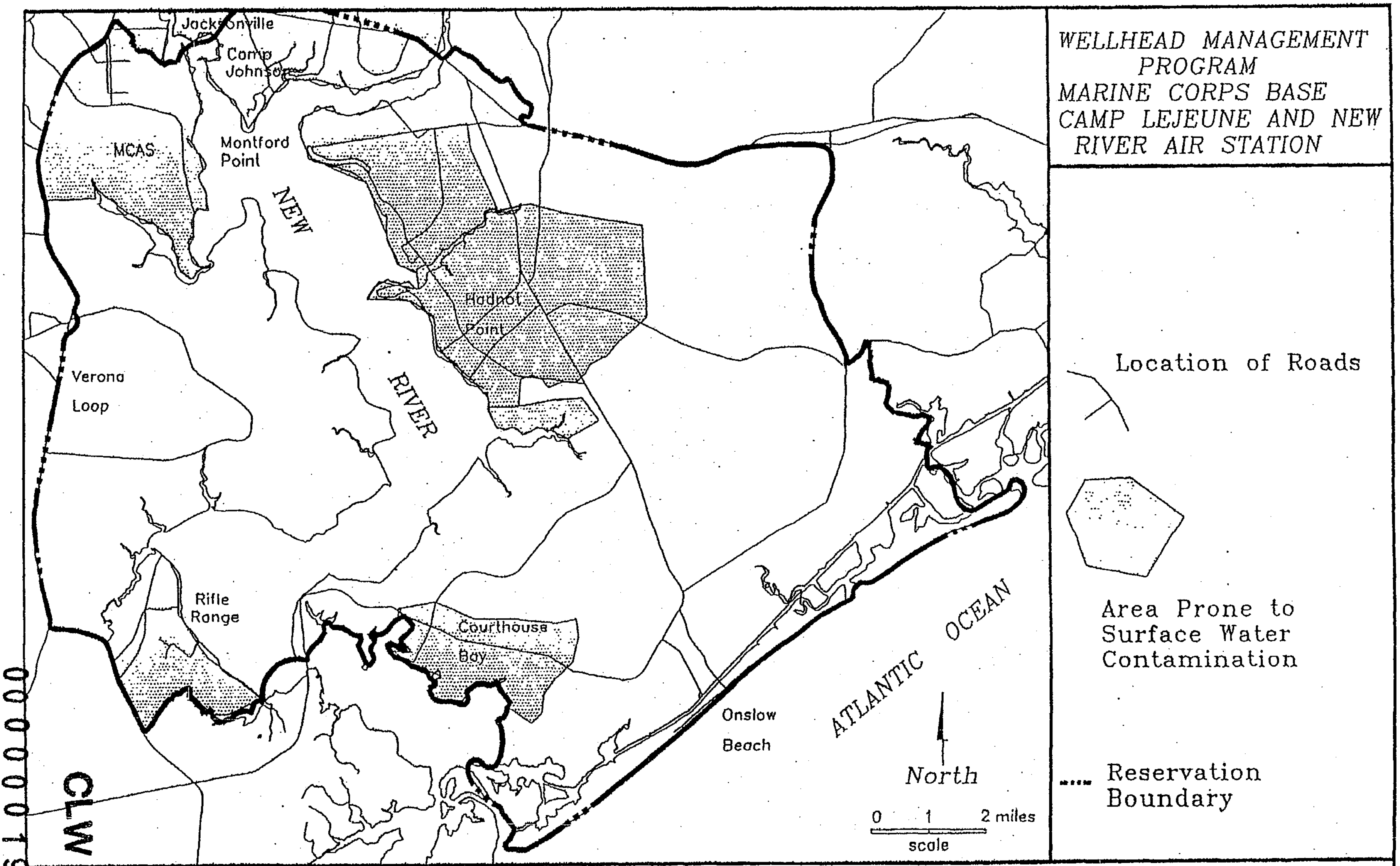

Figure 17. Location of Drainage Basins Most Likely to Contain Contaminated Surface Water Runoff.

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5.3.4 Military Training

Large portions of the MCB are designated for military training. Some regions are set aside for particular training activities that are incompatible with the development of wells; for example, G-10 Impact Area is not suitable for well development because of potential damage from artillary or rifle fire. Military training facilities, including but not limited to firing ranges, field exercise areas, tactical aircraft landing areas, and ammunition and weapon storage facilities as outlined on MCB Combat Training Charts are also considered undesireable for wellfield development (Figure 18). Border regions surrounding these properties may be suitable for well construction provided assurances are made that the wells will not be damaged by training activities.

The potential of groundwater contamination from exploded or unexploded ordnance is not well understood. A potential source of lead in the environment, and thus the groundwater, comes from the lead fill of the brass-cased bullets. Lead contamination would likely be a problem where discharged bullets are concentrated, for example at a barrier, where stray bullets are arrested. Other discharged ordinances potentially harmful to groundwater include: unexploded ordnance, incendiary devices, and residues from discharge weapons. Although no site-specific study has been conducted at Camp Lejeune, environmental evaluations of target ranges at nearby Cherry Point Marine Air Station, at Havelock, North Carolina have been conducted (Sirrine Environmental, 1990). The Cherry Point target ranges differ from Camp Lejeune's in that they received bombs dropped from planes instead of artillary shells. No impact on the water quality was detected in this study.

Because the potential for groundwater contamination is generally believed to be greater for bombs, that carry more explosive chemicals than artillary shells, and because no adverse effects have been detected with bombs, the potential for large scale groundwater contamination is presumed to be minimal.

5.4 Groundwater Extraction Practices

Water supply systems generally adopt various pumping strategies so as to: (1) minimize maintenance, (2) routinely exercise each well, (3) reduce drawdown interference between wells, and (4) supply the correct combination of water quality and quantity to the water treatment plant. MCB regulates groundwater production by varying the number of pumping wells and the duration of pumping intervals.

The following procedure is used to set the production rate of each well (personal communication, MCB Facility Manager, Mr. Stanley Miller). The well is turned on and the drawdown level monitored until the level stabilizes. The flow from the well is adjusted upward by throttling open a gate valve located on the well discharge. As the valve is opened the withdrawal increases and the water level falls in the well. Proper flow is established when the water level falls to within 10 feet of the intake of the pump. The specific yields from wells were reviewed at varying pumping rates and found to be fairly consistent (less than 10 percent variation from low to high withdrawal rates suggesting that the aquifer is not being stressed and turbulent flow conditions are not being experienced). The consistent value can be viewed as evidence that the aquifer could yield more water if well construction can be improved.

Because the production rate of each well is held constant, increased demand for water is accomplished by turning on more wells or increasing the length of time each well is pumped. Because some of MCB wells produce less water than others, the combination of wells pumped and the demand for water determines the length of the pumping interval.

The current MCB pumping strategy for Hadnot Point, Holcomb Boulevard, Onslow Beach, and Rifle Range water treatment facilities accomplishes the four goals previously stated in Section 5.4. MCAS water production plan is different from the other MCB facilities as a result of varying production rates and degraded water quality from some wells. Four MCAS wells (TC-502, AS-131, AS-191, and AS-4140) produce water containing chloride concentrations in excess of 200 mg/l.

Elevated chloride content in these wells has been related to the inadvertant production of trihalomethanes at the water treatment plant (personal communication, Mr. Fred Hill, Regional Manager, NC Public Water Supply, Washington Regional Office). Currently, MCAS water treatment facility must pump wells in predetermined groupings, so as to maintain an overall low chloride concentration in water supplied to the treatment facility (personal communication, MCB Facility Manager, Mr. Stanley Miller).

The cause of the high chloride levels in groundwater at MCAS is not known. The USGS has suggested that high-volume pumping of wells has created conditions for saltwater intrusion from the New River (personal communication, Dr. Alex Cardinell, USGS, Raleigh, NC). They suggest a buried channel feature discovered in sub-bottom profiles near the Air Station (Cardinell, and others, 1990) has channeled saltwater from the river into selected wells at MCAS.

Analysis of surface waters from the New River at Jacksonville show varying levels of chloride content. The chloride content found in river water is sufficient to support a saltwater intrusion theory; however, historical records suggest another alternative (MCB Well Records, Holcomb Boulevard Water Treatment Facility). Well "A" drilled at Camp Geiger in 1941, and later abandoned, intersected two water bearing zones and produced water containing high-chlorides (>350 mg/l). The presence of high chloride levels in MCB wells prior to any high rates of water production indicates the saline waters are not related to high volume pumping. Instead, the presence of saline water in the first well is strong evidence that portions of the aquifer contain some connate water. During the construction of nearby well TC-325, a high-chloride aquifer was discovered at a depth of 125 to 175 feet underlying and separated by a clay unit from a low-chloride aquifer. Based upon historical records from well "A" and aquifer analysis from Well TC-325, it makes sense that high chlorides would be found in wells that intersect the deeper high-chloride aquifer. Unfortunately, existing well completion logs and water quality analysis are not sufficient to conclusively support the interpretation. However, it is important to know if two-aquifers bearing high- and low-chloride waters exists.

5.5 Aquifer Recharge Areas

The aquifer recharge areas are poorly understood in Onslow County. Regions of highest recharge can normally be delineated through a study of the regional aquifer pieziometric surface. Unfortunately these data do not exist, and thus, a detailed statement as to recharge area is not possible. However, it is generally known that groundwater recharge to the surficial aquifer in the coastal plain occurs on most land surfaces greater than five feet in elevation (Harned and others, 1990). Thus, the recharge area represents nearly the entire MCB land area.

The relative recharge rate over the region may be related to soil type and the relative vertical porosity penetrating the soil and other confining layers. Regions of relatively low and high recharge areas have been delineated from the Onslow County soil survey map (Figure 19) and serves only to point out areas where soil conditions provide relatively high degrees of protection from surface pollution sources. In this figure, areas containing clayey soils are contrasted with areas containing sandy soils. The eastern one-half of MCB is dominated by poorly drained, sandy soils. Clay soils marked by the hatched pattern (Figure 20) occur over less than 25% of the base land area. Clayey soil regions would have lower recharge rates and thus offer greater reaction time between the occurrence of a surface contamination event and possible groundwater contamination.

Recharge to the Castle Hayne Aquifer from the water table aquifer largely depends upon the thickness and permeability of the confining unit at the top of the Castle Hayne.

The detailed geology of the confining unit is not known; however, it is is suspected that the upper confining unit is quite variable in their extent and permeability over MCB. It is apparent from available information (Harned and others, 1990; and MCB Environmental Lab Records) that the confining unit is leaky. The degree of leakage is high in some regions as evidenced by the relatively short period of time needed for a surface spill to show up in a production well (e.g., Well HP-645). The ease in which the Castle Hayne Aquifer can be affected by water table conditions emphasizes the importance of maintaining high surface water quality.

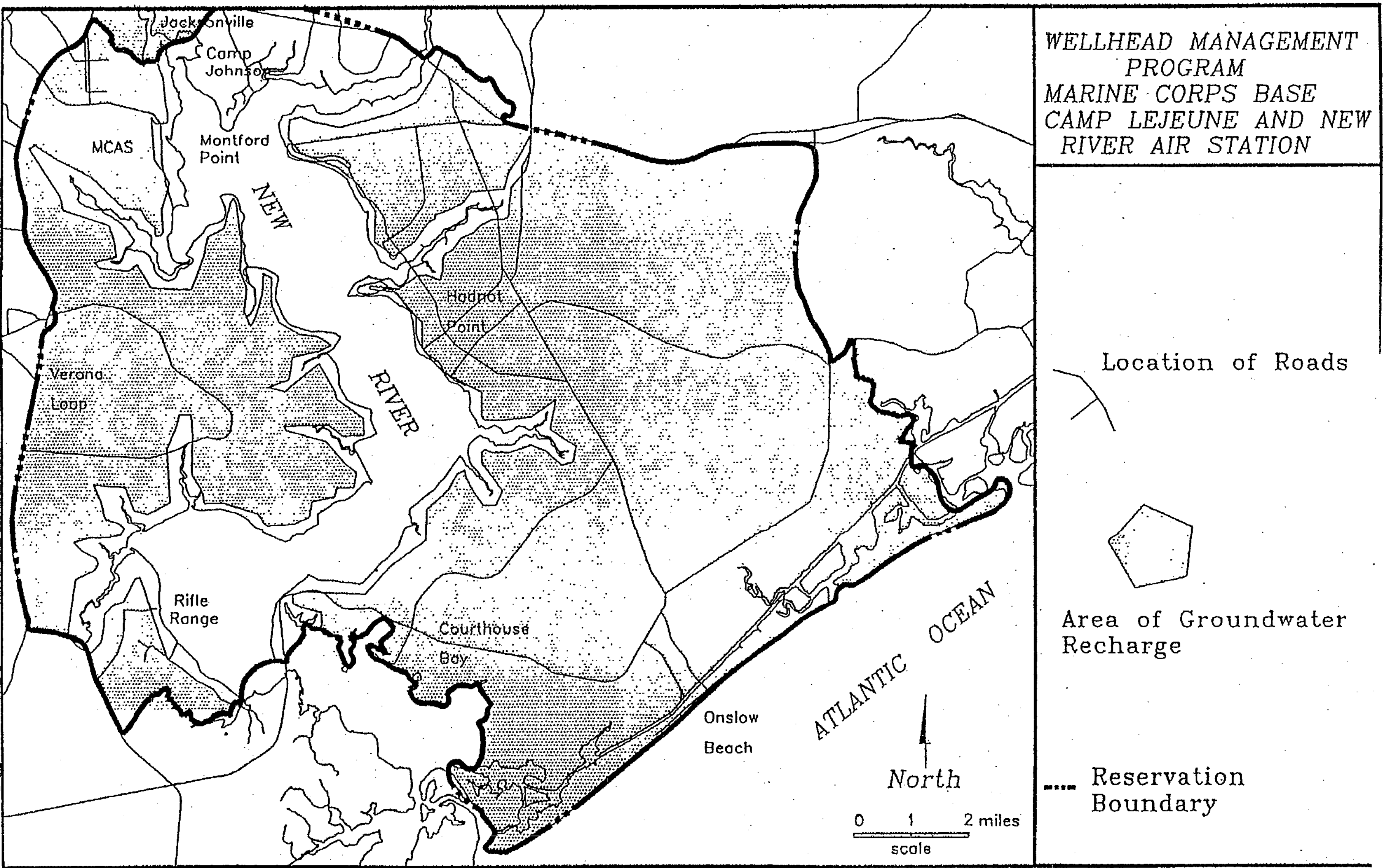

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Figure 19. Location of Groundwater Recharge Regions at MCB.

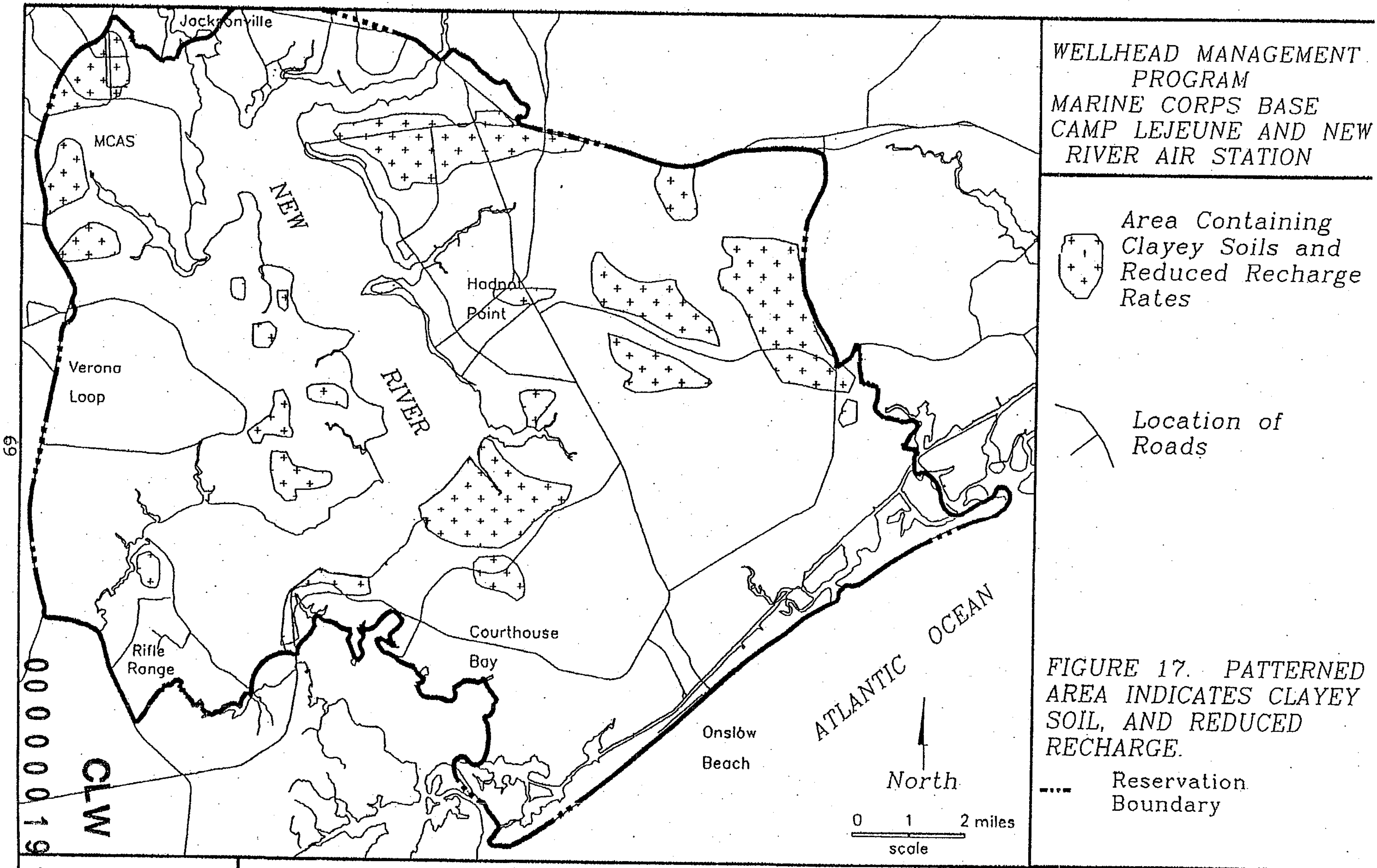

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Figure 20. Recharge potential Related to Soil Types.

Water Table Aquifer recharge for MCB is based upon an average rainfall of 56 inches (Narkunas, 1980) and an average recharge of approximately 30 percent, or an annual recharge of approximately 17 inches per year (Heath, 1991). The recharge rate far exceeds demand, thus MCB should be able to meet its own needs from within the confines of the base.

5.6 Groundwater Preservation Areas

MCB has no formally established groundwater preservation areas however, because the MCB controls more than 230 square miles of land, and because much of this land has remained undeveloped, much of these lands serve the function of groundwater preserves. The extent to which these regions have remained uncontaminated is not known. For example, G-10 Impact Area represents a large area which appears to be undeveloped; however, the potential for groundwater contamination from ordnance and residue are present. An extensive groundwater resource survey should be conducted if MCB should commit to developing a wellfield in this region. It is important that the surface areas overlying principal recharge areas remain relatively undeveloped so as to minimize contamination by accidental surface spills.

Outlines of proposed groundwater preservation areas are shown in Figure 21. These areas should be considered as potential wellfield sites, and thus, should be considered candidate sites for groundwater resource evaluation. The sites that are especially critical to WMP Program are located on Figure 22 and include the following.

- An area located approximately one mile south of MCAS along the abandoned Seaboard Coastline tracks offers an option to new well development at MCAS. This region is relatively undeveloped and should be free of surface contamination.
- A large area of land situated between NC Highway 24 and Holcomb Boulevard, in the general vicinity of the Holcomb Boulevard water treatment facility.
- A strip of land located on both sides of Sneeds Ferry Road and Courthouse Bay Road, south of the existing Hadnot Point wellfield.
- A strip of land located on both sides of NC Highway 172, between Onslow Beach and Courthouse Bay.

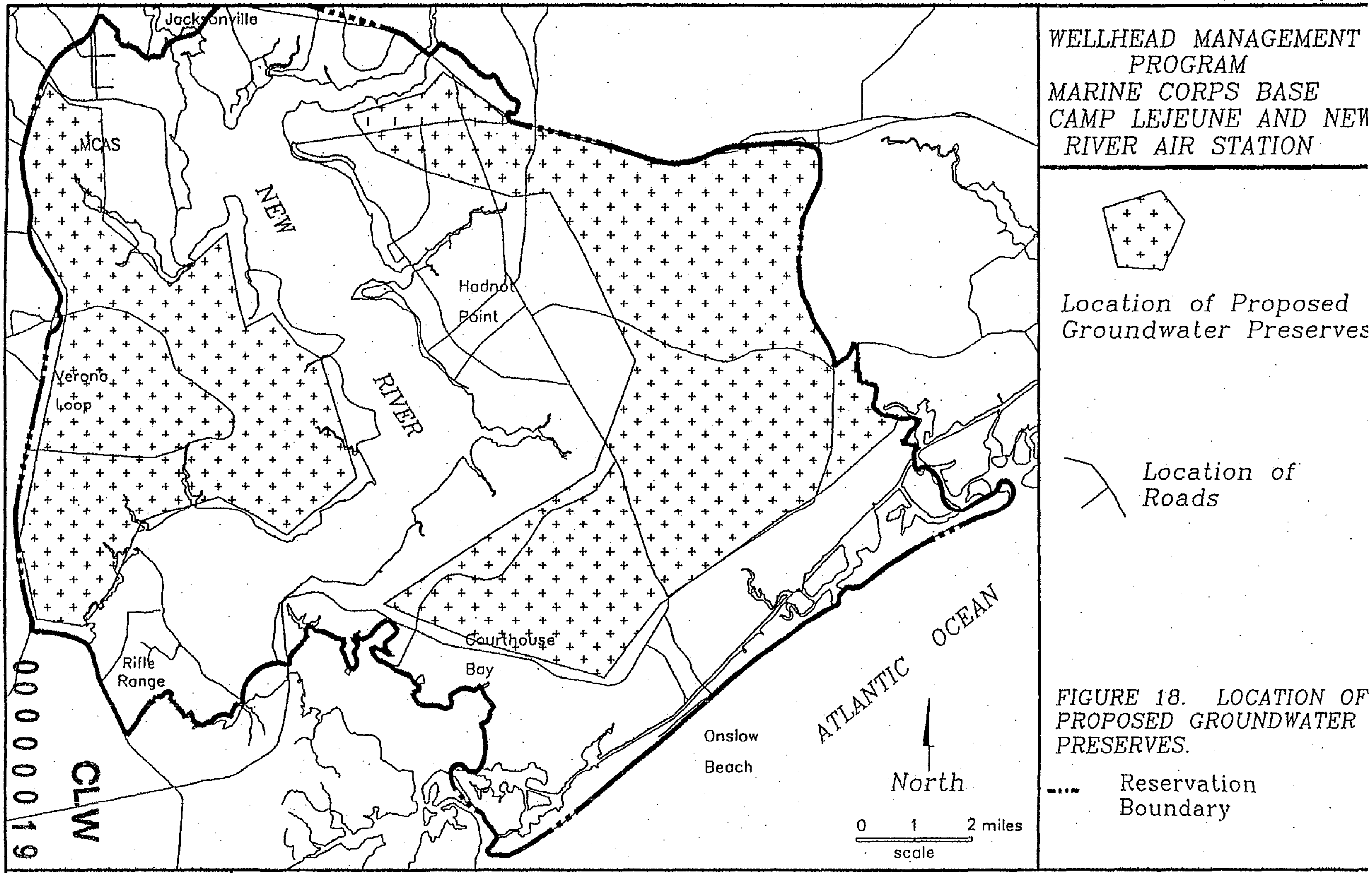

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Figure 21. Location of Proposed Groundwater Preserves.

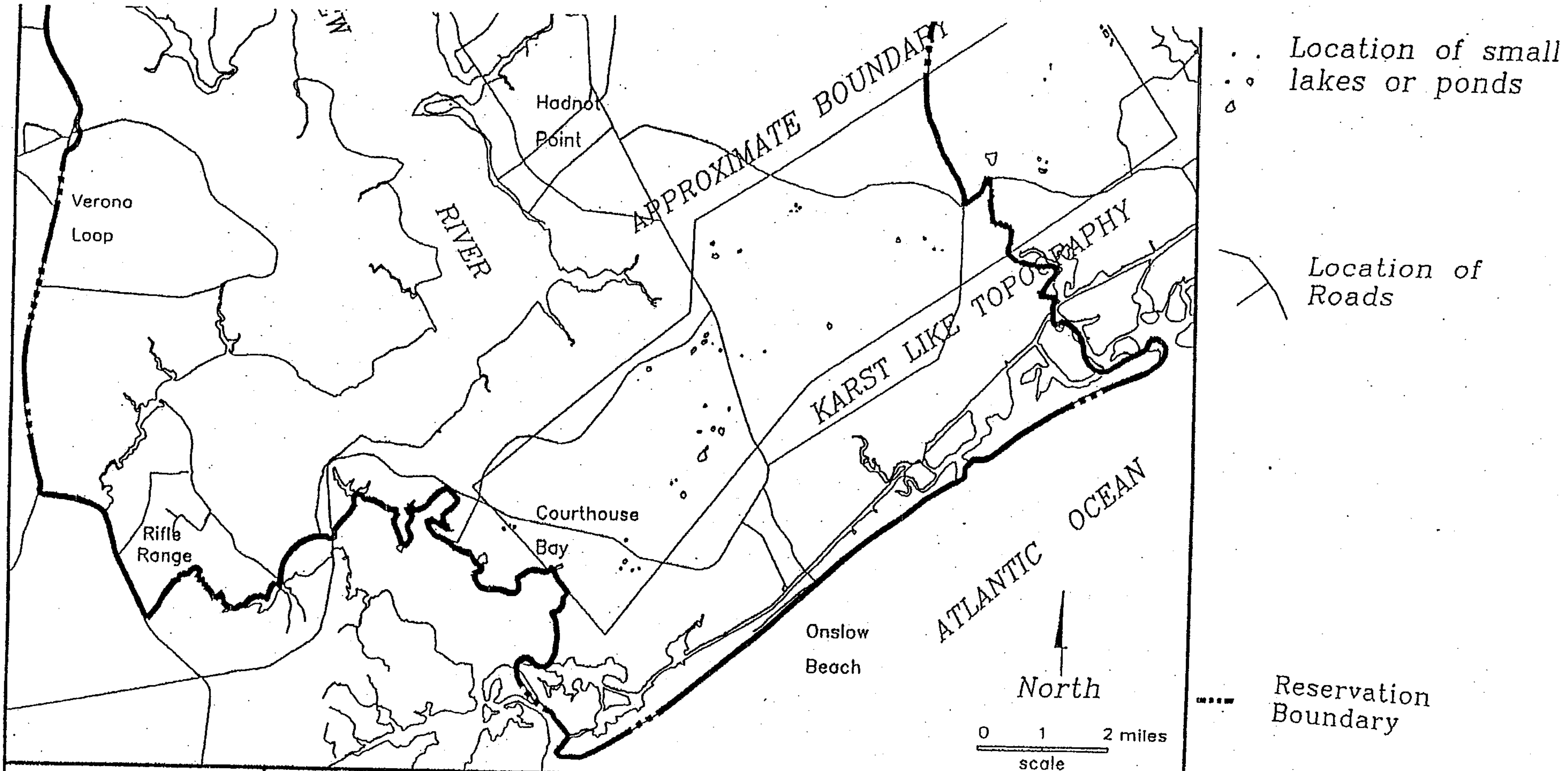

Figure 22. Location of Potentially High-Recharge Area Associtated with Karst-Like Topography.

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These groundwater preservation areas represent sufficient acreage to adequately meet MCB's existing groundwater needs.

5.7 Alternate Water Supply Contingency Plan

As part of the WHP Program, a contingency plan for the location and provision of alternate drinking water supplies in the event of well or wellfield contamination is required. The alternate water supply proposed here does not include the case where the water treatment facility and distribution system is contaminated. An emergency water supply response plan should be developed by MCB in concert with other emergency response plans existing for MCB. An EPA guide to groundwater supply contingency planning for local and state governments has been provided to EMD by Geophex as a guideline for organizing this contingency plan (EPA, 440/6-90-003, 1990).

5.7.1 Short-Term, Alternate Water Sources

Options that are viable on an emergency or short-term basis may differ depending on the conditions that created the supply disruption.

Short-term alternate water supplies are designed to alleviate the immediate need for water. Short term indicates the period of time, between water loss and full restoration. It may vary from minutes to years, depending on the severity of the contamination event.
The following discussion of alternatives addresses solutions from within and outside the system.

- Management Alternatives - The MCB water collection system is designed so that any number of wells may be isolated from the remainder of the system. Proper management can control contamination by isolating contaminated wells and increasing production from non-contaminated wells. If the area of contamination is relatively small, and has affected only a few wells, then MCB's excess capacity within the system can provide sufficient alternate water. The use of water system management to provide an alternate water source should be the first course of action. Because it requires minimum effort, and relies on unused excess capacity, it is a low-cost alternative that minimizes service interruption .

- Water Conservation - In the event a substantial portion of the water supply must be isolated from the system but the entire system is not shut-down, water conservation practices must be enacted. Voluntary reduction of car washing, watering lawns, bathing, etc. will help to reduce consumption. Voluntary reduction of water consumption is attractive because it eliminates the need to supply alternative water supplies immediately.

- Interconnection of Treatment Facilities - The Holcomb Boulevard and Hadnot Point water treatment facilities are connected by a 24-inch water main which permits water sharing. This connection permits MCB to shut down water plants one at a time. Excess plant capacity exists such that a winter-time shut-down of a treatment plant is possible. A summer-time shut-down would most likely necessitate more stringent controls on water consumption. MCAS, Onslow Beach, Rifle Range, and Courthouse Bay water treatment facilities are not interconnected, thus loss of wells would pose a more serious threat to those water supplies. Outside water hook-ups to non-base water supplies, or increasing the capacity of the system would provide alternatives to the existing facilities.

- Use of Storage - In an emergency, MCB can utilize stored water. The life of stored water varies according to the season and how much is contained in tanks and lines. Because the water reserve in storage tanks can vary greatly, and may have already been contaminated, it should only be considered as a temporary supply and not a true alternative.

- Bottled Water - If an emergency situation should arise where all wells and treatment facilities have to be shut down, bottled water may offer the best alternative supply of drinking water. However, it is not feasible or economic to utilize bottled water for purposes other than food preparation and washing. The demand for bottled water is likely to be high and the availability low, thus, it is not considered a viable long-term water source.

- Tank Trucks (Water Mules) - Tank trucks offer a viable short-term alternative, but is not recommended as a long-term water source because it may be difficult to meet demand, and the cost of operating a fleet is likely to be high.

- Surface Water Supplies - Surface water alternatives do not exist at MCB. The waters of the New River are saline and would require desalination prior to use for drinking. Many tributaries of the New River have been designated as unhealthy for contact with humans.

- Interconnection With Outside Water Systems - Interconnection with another water supplier is a viable short-term alternative. MCB should consider establishing links with both the City of Jacksonville and Onslow County water systems. The establishment, and operation of water links, requires considerable planning and availability of appropriate equipment to connect alternate water supplies to the distribution system. A suggested hook-up plan may call for Tarawa Terrace I and II, and Montford Point (Camp Johnson) be linked to the City of Jacksonville; and MCAS, Rifle Range, Holcomb Boulevard and Hadnot Point linked to Onslow County water mains. The establishment of interconnection would mutually benefit the City or County in case of an emergency within their respective systems.

5.7.2 Long-Term Alternate Water Sources

Long-term alternate water sources differ for those sources previously discussed in two ways. First, the time available to evaluate and carryout alternatives is longer, allowing for a more pragmatic approach. Second, the number of alternatives is larger, and perhaps more cost effective. This underscores the importance of a viable short-term program capable of buying time to carryout a long-term program.

- Water System Management - The use of Water System Management is a realistic means to compensate for lost well production. However, if the contamination is moderate or severe, MCB will have to consider other options to be carried out in conjunction with water system management.

- Excess Capacity - The use of excess capacity to offset well loss is not a viable option for MCB. Presently, excess capacity for Hadnot Point does not exist. The other water systems have excess capacity, but many of the wells are old and may need replacing in the near future. Thus, any excess capacity that presently exists, will likely vanish in the next five to ten years.

- Surface Water Supplies - Long term development of surface water supplies would result in increased cost for water treatment. However, surface water development would yield an almost unlimited quantity of water. Development of surface water resources would require years of planning and construction before the first drop of water could be realized.
- Drilling New Wells - Construction of new wells in uncontaminated portions of the Castle Hayne Aquifer can be accomplished within a relatively short period of time, under emergency conditions. Drilling new wells into the Castle Hayne Aquifer offers MCB the most economic option to provide long-term water resources from outside the present system. New well development should not be placed near the site of contamination, and preferably away from other established wellfields.

- Alternate aquifers exist beneath MCB, including several aquifers in Cretaceous rocks beneath the Castle Hayne Aquifer. The Cretaceous aquifers contain varying concentrations of saltwater that would require desalinization as part of the water treatment plan. Despite the saline content of these aquifers, they would be less susceptible to contamination from surface spills than the Castle Hayne Aquifer.

- Aquifer Remediation - In the event of a contamination event, aquifer remediation is paramount. Contamination plumes, if left unchecked, may spread throughout the wellfield. Commonly, turning off contaminated wells accelerates the spread of the contaminants throughout the remainder of the aquifer. If the contamination is relatively small, then cleanup may offer the best long-term alternative to restoring the capacity of the water system, or in the very least, preventing large scale contamination of the aquifer.

5.7.3 Factors Affecting Future MCB Water Resources

Recharge into the Castle Hayne Aquifer is sufficient to maintain MCB water supplies provided present groundwater contamination is contained and remediated, and existing and future wellhead areas are protected. Several new factors have arisen recently that may affect existing and future water sources of MCB. The following is a brief overview of these factors.

5.7.3.1 Increased Competition for Water Resources

Increasing demand on water supplies from the City of Jacksonville and Onslow County has strained the production capacity of the Black Creek Aquifer (Narkunas, 1980). As a result both the City and County are considering obtaining water from the Castle Hayne Aquifer (personal communication, Mr. Bill Harvey, Onslow County Water System). Onslow County has the most ambitious program, which includes the completion of several exploratory wells near the communities of Hubert and Dixon.

Onslow County presently develops all of its water from Cretaceous aquifers underlying the region between Richlands and Jacksonville (Figure 23).

The County has immediate goals of developing water resources in the vicinity of Folkstone and Hubert (personal communication, Mr. Bill Harvey, Onslow County Water System). Both of these development sites will utilize treated groundwater from the Castle Hayne Aquifer. The proposed Hubert site is located near the existing Camp Lejeune water system and may impact future plans for replacement wells within the existing MCB system. The Folkstone site may be considered as a source of water for base expansion in the Fort Davis area as well as for new MCB acquisition areas. In all, Onslow County plans to expand its capacity by approximately 4.5 million gallons per day by the end of 1995. The County is seriously working towards the establishment of Wellhead Protection Areas through the mechanism of county or municipal land use zoning (personal communication, Mr. Bill Harvey, Onslow County Water System). These zoning changes could adversely impact the MCB. Enactment of the draft WHP regulations could give the County or City the power to control some of the water usage within the base property.

The City of Jacksonville, and the County, currently develops groundwater from the same aquifer and vicinity. The city plans to expand its system by three wells over the next three years. Groundwater currently produced by the City does not require treatment and is of high quality. The City of Jacksonville, like the County, cannot significantly increase water production from the Cretaceous Aquifers in order to meet the increasing needs stimulated by regional growth. In the near future, the City will have to expand its groundwater production to include either the water table aquifer or the Castle Hayne Aquifer.

5.7.3.2 Contamination

Groundwater contamination remains a problem at MCB. The problem is somewhat accentuated because a great portion of MCB wells are developed in areas which are prone to contamination by existing surface contaminants, incidental spills, roadway runoff, and underground storage facilities. It is apparent that the confining unit overlying the Castle Hayne Aquifer affords very little protection from surface and surficial aquifer contamination. Therefore, the WHP program should provide for the systematic replacement of existing wells in industrially active portions of the base, with wells constructed in non-developed, protected areas. The same plan should set out to begin immediate remediation of all contaminated waters. This action would significantly reduce the possibility of new contamination events as well as reduce the spread of existing contaminants.

6.0 Conclusions and Recommendations

6.1 Proposed Wellhead Protection Areas

WPAs for all active wellfields are proposed based on a 10-year ZOT surrounding each well. Development within the WPA should be controlled so as to minimize potential contaminant sources. The contaminant sources are commonly related to activities identified by the EPA and listed in Table 9. The proposed WPAs are described below.

Proposed WPAs cover approximately 4,500 acres of land surrounding existing wellfields. Approximately 30 percent of the designated land is impacted by existing or potential groundwater contamination. These areas should be considered for one or more of the following actions:

- Removal of present or potential contaminants for the 10-year ZOT;
- Remediation of contaminated groundwater;
- Permanent abandonment of contaminated water supply wells; and
- Relocation by attrition of existing wellfields into areas that can be easily maintained with a minimum impact on the mission of MCB.

6.2 Proposed Rehabilitation Studies

Based upon the distribution of known contaminant plumes and knowledge of contaminated wells, approximately 30 percent of the existing wellfield has been or has the potential to be contaminated from surface contamination sources. Present planned, new well-development programs are not sufficient to offset the potential loss of water production from existing or potential contamination sources. Rehabilitation of groundwater resources offers a viable option to drilling new wells. Three areas, discussed below, currently impacted are recommended for rehabilitation because of the apparent high probability of success.

6.2.1 Hadnot Point Industrial Area

Six wells within HPIA have been contaminated with varying levels of TCE (MCB Environmental Lab). Four of these six wells have reported concentrations near detection levels for TCE. In addition, several of these wells indicated the presence of TCE on two of three analyses. Retesting of these marginally contaminated wells is recommended to determine if the data are statistically valid. If so, the source of contamination should be determined, and a water treatment system recommended. Remediation of the surficial and Castle Hayne Aquifer should be expedited in order to limit the spread of contamination to adjacent wells.

6.2.2 Holcomb Boulevard

The Holcomb Boulevard well HP-645 should be retested to determine if the petroleum contamination persists. Because of the central location of the contamination with respect to adjacent wells, the potential for contamination of one or more wells exist. If petroleum contamination persists an RI program should be initiated.

Well 707 should be examined for the presence of iron precipitation around the screens using a down-hole camera. The presense of buildup over the screens would explain why production was poor. Normally treatment with chlorine solves the bacterial problems. If the screens do not appear to be covered by growth, then the well was probably constructed incorrectly, and little can be done to improve productivity, short of repacking the well.

6.2.3 Tarawa Terrace

Although the Tarawa Terrace wells are inactive, the feasiblity of re-establishing a link to Holcomb Boulevard Water Treatment Facility should be investigated as a contingent source of water in the event of a large scale contamination south of Northeast Creek. The size and distribution of the TCE contaminant plume should be further investigated to determine the potential impact on non-contaminated wells and derrive clean-up alternatives.

6.2.4 MCAS VOC Contamination

Two wells have been contaminated by low-level VOCs at MCAS. Wells AS-106 and AS-4150 should be retested to determine if the data are statiscally valid. If they remain contaminated, the source of contamination should be identified and potential impact on the wellfield assessed. Feasiblity of a water treatment system should be addressed.

6.2.5 MCAS Saltwater Contamination

Since their completion over the course of 50 years, seven water production wells have been contaminated by groundwater with elevated levels of chloride. Presently, five of these wells have chloride levels in excess of 200 mg/l. Sufficient well construction data do not exist in MCB files to determine in every case, the source of high-chloride water.

Well construction records from the responsible driller should be compared with water quality data to determine the source of saline waters. The potential cross-contamination of saline waters should be evaluated and a plan should be developed to reduce saline waters in wells and protect the low chloride aquifer form saltwater contamination.

6.2.6 Rifle Range Wells

Because the TCE content in well RR-229 was near analytical detection limits, additional testing of the water is recommended to determine if the finding is statistically valid. In addtion, adjacent wells should be sampled to determine if the contaminant has spread to other wells.

6.3 Proposed Monitoring Program

A regularly scheduled monitoring program is recommended for all existing wellfield areas. The monitoring plan should be developed in concert with other MCB water-quality monitoring programs. In addition, future well areas should be evaluated for water quality prior the construction of water supply wells. All water quality data should be maintained on the EMD mapping system so that contaminated areas can be avoided.

6.3.1 Monitoring of Existing Wells

Groundwater from all existing water supply wells should be tested for EPA Primary and Secondary Drinking Water Standards (Tables 5 and 6) (EPA, 1990). A one-time broad-based testing will generate baseline data from which subsequent changes in water quality can be compared. The baseline analysis of well-water should be conducted over a relatively short period of time (one month) during a period of relatively low rainfall and be coordinated with the routine pumping of water supply wells. Results of these analysis should be used to establish a long-term sampling and testing program that is aimed at: (1) acquiring sufficient geologic data to model drawdown and water quality over the entire wellfield region, and (2) sampling production wells at intervals sufficient to allow for timely detection of potential wellhead contamination.

The following is proposed as an initial water sampling plan to establish a baseline data set. The baseline data set should be used to design a cost-effective monitoring program.

- Sample and analyze in duplicates, all producing wells, for EPA Primary and Secondary Drinking Water Standards. This is a one-time sampling program that will establish a background data base that will describe the condition of the aquifer. Wells exceeding any of the standards should be reviewed to determine if the contaminant is the result of normal cultural activity or from natural sources.
- A sampling and analysis schedule for each well should be devised such that wells containing contaminants that marginally exceed primary or secondary drinking water standards are sampled more frequently than those wells with no contaminants. A distinction should be made between cultural and natural contaminants. Cultural contamination is likely to be much more variable than natural contaminants. For example, cultural VOC contamination requires more frequent monitoring than dissolved iron, which is usually determined by natural levels in geologic formations and do not vary substantially.
- Measure water levels and temperature for all wells. Water samples should be drawn from all wells and where suspected, analysed for contaminants.
- Locate and gather geologic and/or well completion logs for all MCB wells. Many wells have been drilled but no record exists in either EMD or Holcomb Water Treatment Plant offices. All wells should be physically inspected to determine compliance with state construction requirements. Wells not meeting state requirements should be brought into compliance or should be permanently abandoned. Wells not containing the required identification plate should have identification plates installed, and completion reports submitted to NC DEM WiRO. Existing wells, without logs or completion records, should be logged using geophysical tools to determine construction parameters and then properly identified and reported submitted to NC DEM WiRO.

6.3.2 New Monitor Wells

Existing monitor well data should be compiled in the MCB water quality data base. Monitor wells should be constructed within and around existing and proposed wellfield areas. The purpose of these monitor wells is to provide early warning of contamination that might be entering the WPA, and to help establish the baseline conditions of the aquifer before and after well development.

6.3.3 Evaluation of New Wellfield Areas

New well construction should be located in areas where Castle Hayne Aquifer waters are uncontaminated and suitable for processing in existing MCB water treatment plants. In addition, land-use activities should be limited to exclude all potential groundwater contamination sources (see Table 9). The physical siting of the well should include a walk-over of the general area to determine the existance of unknown structures or potential contaminants. Monitor wells should be completed in advance of supply wells and analyzed for contaminants. The strategy is to determine water quality in the general vicinity of a proposed wellfield before expensive supply wells are constructed. If contamination is present, the site should be re-evaluated or a new location for the well selected.

6.3.4 Wellfield Design

After the new well sites have been selected and water quality found to be satisfactory, the wellfield layout should be designed so as to achieve the target water capacity for the least cost. The actual cost of the wellfield requires analysis of two factors: (1) capital cost - the money needed to design and install the wells, pumps, pipeline, and monitoring/control systems; and (2) operating cost - which includes maintenance and electric utility charges. Capital cost can be substantial, and is paid up-front. Thus, the real value is amortized over the life of the wells. Operating cost is paid on an as-used basis, and thus commonly is not factored in during the construction phase. Most of the operating cost of wellfields comes from electric power usage. Power usage is affected by: (1) volume of water moved - the more water pumped the more electricity used, and (2) well efficiency - defined as the ratio of the drawdown in the aquifer next to the well to the drawdown observed in the well (Figure 24). The volume of water moved is determined by the needs of the base, and thus can be regulated by turning wells on and off. Well efficiency is best maximized at the time of well construction and should be a primary consideration at well completion.

The drawdown in wells is a function of well efficiency, A properly constructed screened well may achieve efficiencies of 80 percent however, an efficiency of 50 precent to 60 percent is more normal, especially in wells that are not fully screened, as are the wells at

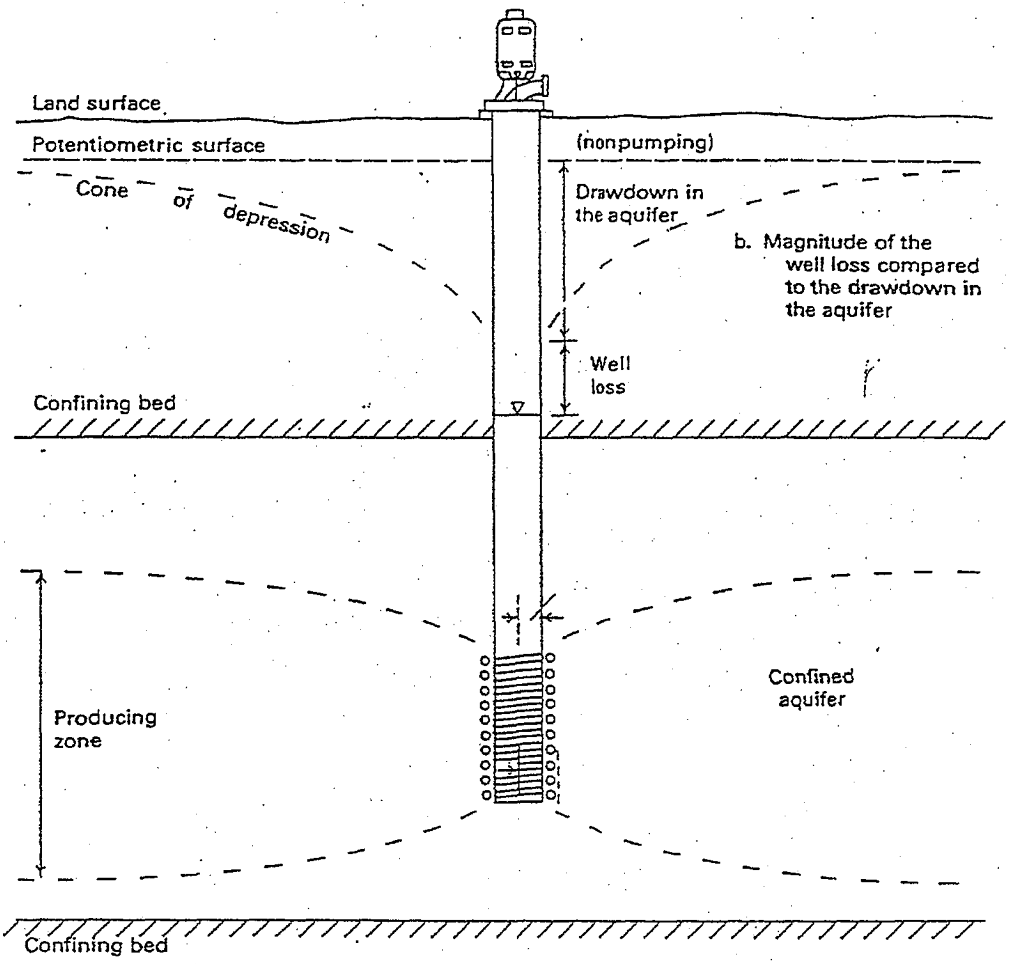

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Figure 24 Diagram showing the relationship between aquifer drawdown, drawdown in a well, and well efficiency (from Heath, 1980)

MCB. Well efficiency typically declines over the life of the well and must be considered in long-term planning. New wells should be designed to limit drawdown interference between wells.

6.4 Proposed Drilling Strategy

New water wells should be drilled to maximize water production. Enhanced water production may be achieved by: (1) completing wells throughout the entire thickness of the Castle Hayne Aquifer, (2) completing wells as open holes when possible, and (3) screening wells to achieve a well efficiency of 80 percent or better.

6.4.1 Drilling Specifications

MCB drilling specifications used for competitive bids should be changed to reflect the above needs. The approved design of water wells should be made after the construction of the pilot hole, geophysical testing, and water quality analysis. Geophysical testing should include: (1) caliper log, (2) spontaneous potential/resistance or resistivity logs, and (3) natural gamma log. The USGS and NCGS provide well logging services, and have volunteered to log MCB wells if the contractor cannot provide these services (Dr. Alex Cardinell of USGS, and Mr. Perry Nelson of NC Groundwater).

6.4.2 Wellhead Development

Enhanced production of water from wells should be investigated. The most common production enhancement techniques used in the Castle Hayne include surging of well water using compressed air or mechanical piston, and acidulation and purging of the well using corrosion inhibited hydrochloric acid.

6.5 Groundwater Areas of Concern

The two natural groundwater areas of concern identified at MCB are: (1) a suspect karst-like area that may represent a region of high recharge, and (2) a general region of elevated chloride levels found in some wells at MCAS.

6.5.1 Karst Region

Suspected karst topography was noted along a sandy relict beach ridge extending from Queens Creek to the New River. It is important to determine if the observed surface features acutally reflect near-surface solution activity. If solution is active, then local groundwater recharge is likely to be high in these areas. Regions of high recharge typically impact wellfield design and merit further investigation.

6.5.2 Saltwater Upconing Potential

The USGS proposes that saltwater infiltration causes high chloride content in wells at MCAS. Saltwater infiltration can result in a general reduction of aquifer quality, and may lead to a reclassification of groundwater by the State. The cause of high chloride conditions in MCAS wells needs to be identified, and plans to reverse the trend formulated.

6.6 Abandonment of Wells

Inactive wells should be secured against possible vandalism and sealed with a water-tight cap or seal compatible with casing and installed so that it cannot be removed easily by hand. If the well has been shutdown because of contamination, a determination as to its future utility in a remediation plan should be determined. If the well is no longer needed, it should be permanently abandoned. Well abandonment should be completed by a licensed driller, and should follow state regulations for well abandonment as stated in NCAC Title 15, Subchapter 2c, Well Construction Standards, Section .0100. MCB should complete the following tasks prior to abandonment:

- All materials should be removed from the well so as not to constrict the placement of the neat cement plug.
- Each well should be video-logged to determine integrity of well casing, well screen, screen placement, and extent to which the casing has been filled with sediment. A compilation of these data will help evaluate the effectiveness of well construction practices and the effective life of the well casing.
- If possible, the entire well screen and casing should be pulled as the abandoned well is plugged to preclude any future vertical migration of contaminants.

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Appendix A

Summary of Well Completion Logs for MCB Water Wells

EXPLANATION

"Well No." - indicates well number or MCB Building Number.

"Yr. Drilled" - indicates year in which well construction was completed.

"Total Depth" - indicates total depth of well below land surface in feet.

"Diameter" - indicates inside diameter of well casing at top of well in inches.

"Type of Finish" - indicates the well completion method used to prepare the aquifer for production:

- Gravel Pack - indicates wells are completed with stainless steel or brass screens packed with gravel material.
- Screen - indicates well is completed with stainless steel or brass screens but the packing material is not known.
- Open Hole - indicates the well is completed without screens or gravel packing.

"Screened Intervals" - indicates depth of top and bottom screens placed in the well (depths are given in feet).

"Elevation" - elevation at top of well casing.

"Water Level" - elevation of water level in well (given in feet below top of well casing).
Water
levels following by a "P" indicates the well was operating at the time of measurement.

Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	pump cap casing depth
A-5	1942	116	8	Gravel pack	46.5-61.5	12.71	8.3	
					101-116			
BA-164	--	110	--	--	--	17*	4.5	
							7.2	
BA-190	1977	105	8	Screen	55-70	12*	3.6	
					80-100		5.6	
BB-43	1942	60	8	Gravel pack	30-60	13.1	10.4	
							13.4	
BB-44	1942	62	8	Gravel pack	32-62	17.8	13.4	
							14.8	
BB-45	1983	150	--	Screen	40-55	13*	10.1	
					102-125			
BB-220	1975	150	--	Gravel pack	55-70	37*	10.2	
					85-95		42P	
					130-145			
BB-221	--	200	--	--	60-80	40*	33.5	
					135-155			
BB-222 ✓	1985	185	10	Gravel pack	64-94	40*	55 P	
					148-168		20.0	
CCC-1 ✗	1941	103	10	Open hole	24	21*		
CCC-2 ✗	1942	102	8	Screen Gravel pack	50-60	22*	15.5	
					70-75			
					85-90			
HP-601	1941	195	8	Gravel pack	45.0-60.0	22*	11.3	
					95-100			
					115-130			
					175-195			
HP-602	1941	160	8	Gravel pack	70-80	25*	8.7	
					100-105		11.0	
					120-125			
					145-150			
					155-160			
HP-603	1941	195 ✓	8	Gravel pack	70-80	24.8	51 P	150 gpm
					100-110		43 P	70 ft
					130-140			
					160-170			
					190-195			
HP-606	1941	210 ✓	8	Gravel pack	80-90	30.4	13.7	345 gpm
					110-120		32 P	80 ft
					140-150			
					170-180			
					220-210			

* elevation estimated from USGS topographic map

add 607 210 ft 8" unk 50ft/29

Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	
HP-608 X	1941	162	8	Gravel pack	61.5-81.5	29.7	19.4	gone
					91.5-101.5		21.1	
					121.5-131.5			
		145			151.5-161.5			
HP-609	1942	~~150~~ ✓	8	Gravel pack	65-80	33*	9.7	65 ft/16 gp
					100-10		38 P	
					130-150			
HP-610 X	1942	190	8	Gravel pack	60-70	20*	14.1	
					90-110		16.9	
					130-140			
					180-190			
HP-611 X	1942	161	8	Gravel pack	61-71	31	16.3	
					91-101		21.9	
					121-136			
					156-161			
HP-612 X	1942	190	8	Gravel pack	60-70	31.8	22.2	
					90-95			
					115-120			
					140-145			
					155-160			
					170-175			
					185-190			
HP-613	1942	150 ✓	8	Gravel pack	60-70	24*	33 P	60 ft/20 gpm
					90-95		13.4	
					115-120			
					130-135			
					145-150			
HP-614 X	--	235	8	Gravel pack	105-120	31.4	18.2	
					150-170			
					217-227			
HP-615 X	1942	158	8	Gravel pack	58-68	32	16.0	
					88-89			
					108-128			
		147			148-158			
HP-616	1942	~~170~~	8	Gravel pack	95-115	33.3	47 P°	95ft/200
					130-140		41 P°	
		52			160-170			
HP-620	1944	~~54~~	18	Open hole	--	35*	29 P°	46 ft/160g
							27 P°	
HP-621 X	1942	77	8	Gravel pack	57-77	40.8	--	
							CLW	

* elevation estimated from USGS topographic map

623
622

197
227

50/300
50ft/310g

Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	
HP-626	--	159	8	Screen	58-63	28.3	15.0	
					82-92			
					108-123			
					144-154			
					154-159			
HP-627	--	163	8	Screen	65-75	30.7	--	
					92-102			
					117-122			
					133-158			
HP-628	1984	200 ✓	8	Gravel pack	60-70	26*	12.0	50ft/150gp
					85-89		56 P	
					110-120			
					135-145			
HP-629	1982	~~240~~ 230	8	Gravel pack	60-70	41*	22.6	50ft/150gpm
					125-140		20.3	
					160-170			
					220-230			
HP-630	--	176	8	Gravel pack	62-67	26*	14.4	
					87-92		13.5	
					107-117			
					127-142			
					152-162			
HP-632	1957	~~75~~ 200	--	--	--	34*	38 P	63ft/240gpm
							44 P	
HP-633	1959	205	8	Screen	55-65	23*	16.9	55/250gpm
					75-80		19.1	
					95-105			
					123-133			
					138-143			
					158-168			
					178-183			
					195-205			
HP-634	1959	225	8	Gravel pack	65-70	31*	8.6	
					73-78		12.4	
					83-88			
					93-98			
					107-117			
					124-129			
					135-140			
					153-163			
					170-175			
					195-200			
					215-225			

CLW

* elevation estimated from USGS topographic map

Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	
HP-635	1959	215 ✓	8	Gravel pack	65-75	17*	3.1	65/200gpm
					93-108		18.7	
					122-127			
					136-146			
					150-155			
					170-175			
					185-190			
					210-215			
HP-636 ✗	1959	225 ~~227~~	8	Gravel pack	90-100	28*	11.8	90/154gpm
					115-125			
down due to landfill					130-135			
					140-150			
					158-163			
					170-175			
					185-190			
					200-210			
					222-227			
HP-637 ✗	1971	180 ~~172~~	8	Gravel pack	90-98	31*	16.1	90/130gpm
out now					102-114		20.6	
					120-128			
					140-148			
					156-172			
HP-638 ✗	1969	196	8	Gravel pack	106-114	24*	99 P	
					126-134		20.1	
					150-158			
					162-170			
					176-184			
					188-196			
HP-639 ✗	1969	176	8	Gravel pack	62-70	23*	3.4	
					85-93		5.2	
					120-132			
					136-148			
					155-163			
					168-176			
HP-640	1969	179 ~~176~~	8	Gravel pack	64-72	30*	3.1	64ft/214 ~~290~~ gpm
					76-80		28 P	
					92-100			
					112-120			
					130-134			
					140-148			
					157-165			
					172-176			
							CLW	

* elevation estimated from USGS topographic map

Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	
HP-641	1971	178 ✓	8	Gravel pack	108-118	32*	19.5	52/281 gpm
					128-150			
					158-168			
HP-642	1971	210 ✓	8	Gravel pack	112-124	29	9.8	40ft/156g
					136-144			
					157-163			
					174-178			
		240			188-196			
HB HP-643	1971	~~250~~	10	Gravel pack	90-100	28*	16.0	88ft/269g
					138-148		47 P	
					230-240			
HB HP-644	1971	255 ✓	10	Gravel pack	85-100	26*	21.0	85ft/230g
					235-250		52 P	
HB HP-645 X	1971	245	10	Gravel pack	90-100	25*	15.9	
benzene					138-148		47 P	
		266			230-240			
HB HP-646	1971	~~270~~	10	Gravel pack	90-100	26*	23.0	50ft/425
					240-250			
					255-265			
HB HP-647	1970	200 ✓	10	Gravel pack	105-115	33*	18.4	105ft/302
					138-143		38 P	
		260			175-190			
HB HP-648	1971	~~265~~	10	Gravel pack	107-122	36*	9.4	107ft/280gp
		279			245-260		76 P	
HB HP-649 X	1971	~~284~~	10	Gravel pack	126-136	37*	13.0	126/100gp
Caved in					159-164		19.7	
					205-210			
					232-237			
					274-279			
HB HP-650	1971	179 ✓	10	Gravel pack	128-133	38*	12.2	50ft/480g
					140-150		78 P	
					155-165			
					169-174			
HP-651 X	1971	199	10	Gravel pack	125-135	32*	16.1	
					140-155		17.9	
					189-194			
HP-652	1971	183 ✓	10	Gravel pack	120-130	30*	4.9	50ft/146 ~~200~~ gpm
					148-158		9.0	
					163-168			
					173-178			
HP-653 X	1978	270	--	–	--	32*	65 P	
							65 P	
							150 CLW	

* elevation estimated from USGS topographic map

	Well No.	Yr. drilled	Total depth (ft)	Diameter (in)	Type of finish	Screened intervals (ft)	Elevation (msl)	Water level (ft below surf)	
	HP-654	1978	~~250~~ 183	--	--	--	32*	36 P	50ft/~~300~~ 119 gpm
								51 P	
								15.0	
	HP-655 X	1980	145	8	--	--	26*	10.3	
								12.4	
	HP-661	1983	~~140~~ ✓ 135	10	Gravel pack	50-65	30*	61 P	50ft/269 gpm
						87-102		17.9	
						125-135			
	HP-662	--	230 ~~100?~~	--	--	--	20*	71 P	50ft/146 gpm
	HP-663	1986	180 ✓	10	Gravel pack	130-180	35*	64 P	50ft/210
								20.1	
HB	HP-698	1985	124 ✓	10	Gravel pack	84-124	26*	66 P	50ft/244g
			108					13.2	
HB	HP-699	1985	~~124~~	10	Gravel pack	84-124	23*	57 P	50ft/267g
								11.1	
HB	HP-700	1985	130 ✓	10	Gravel pack	100-130	20*	69 P	50ft/140gp
			105					15.7	
HB	HP-701	1985	~~110~~	10	Gravel pack	70-100	24*	27 P	50ft/172g
			115	10"				18.0	
HB	HP-703	1985	--	--	--	--	31*	59 P	50ft/192g
								20.5	
HB	HP-704	1985	124 ✓	10	Gravel pack	84-114	26*	20.9	50ft/159g
HB	HP-705	1986	160 ✓	10	Gravel pack	120-160	34*	26.7	50ft/185g
			185					24.7	
HB	HP-706	1985	~~176~~ ✓	10	Gravel pack	126-176	41*	86 P	50ft/199g
			130					19	
HB	HP-707	1986	~~150~~	10?	Gravel pack?	80-140	27*	28 P	50ft/130gp
HB	HP-708	1986	176 ✓	10	Gravel pack	126-176	41*	74 P	50ft/219gp
								9.9	
	HP-709	1985	140 ✓	10	Gravel pack	70-90	28*	56 P	50ft/172g
						110-140		14.5	
	HP-710	1985	140 ✓	10	Gravel pack	70-90	32*	46 P	50ft/105g
						110-140		19.6	
	HP-711	1985	150 ✓	10	Gravel pack	60-80	36*	44 P	50ft/100g
						110-150		19.4	
	LCH-4006 X	--	140	8	Gravel pack	90-114	33*	19.2	
						116-134		23.3	
	LCH-4007	--	~~145~~ 100	8	Gravel pack	50-60	41*	25.1	51ft/150
						69-99		28.4	
						120-130			
						140-145			

CLW

Midway 4009 134 8

5186 160 10"

50ft/350 gp

50 /350

* elevation estimated from USGS topographic map