DELINEATION OF GROUND WATER SUPPLY MANAGEMENT AREAS

5

SECTION 5: DELINEATION OF GROUND WATER SUPPLY MANAGEMENT AREAS

INTRODUCTION

HWH approached the issue of protection of the ground water of the Eastern Shore by first examining the geologic and hydrologic conditions of the region, drawing upon existing technical literature. Appropriate criteria for aquifer and wellhead protection were explored, utilizing accepted EPA-approved criteria coupled with the hydrogeologic realities of the area. After appropriate criteria were selected, a methodology was determined and implemented to map the protection zones.

SELECTION OF GROUND WATER PROTECTION CRITERIA

The three-dimensional character of the ground water flow system to the confined aquifer governed the choice of the aquifer and wellhead protection area criteria. Initially, a criterion of time of travel (TOT) was evaluated. With TOT, a distance is calculated from the well or wellfield that corresponds to the amount of time it would take a particle of water (or contaminant) to move to the supply source within a designated threshold (10-year TOT, 25-year TOT, etc.). TOT is an extremely effective criteria in some hydrogeologic environments, particularly in unconfined aquifers in which the time it takes precipitation to recharge the saturated zone is quite short. In that situation, recharge of water is assumed to follow a piston-like pattern of flow downward through the unsaturated zones in a relatively short time frame. TOT distance thresholds are then based on the time of travel of a particle of water within the saturated zone, moving horizontally with the average velocity of the ground water under pumping conditions.

On the Eastern Shore the character of ground water flow assumes more of a three-dimensional rather than a two-dimensional nature. To obtain an accurate TOT calculation for a given well in a confined system would have to account for the time taken for recharge water to pass through the unsaturated zone, the time it takes to move both vertically and horizontally within the overlying unconfined aquifer to the uppermost confining layer, the time it takes to move through that confining layer and the time it takes to move horizontally to a well screened in the confined aquifer. When a three layer system such as the Yorktown-Eastover aquifer is considered, the problems of determining TOT become extremely difficult to solve with any degree of certainty. The data requirements and qualifying assumptions to determine the length of time it would take to move through such a complex pathway is extensive; TOT is not an appropriate protection criterion in this hydrogeologic environment.

Criteria were selected for aquifer and wellhead protection based upon the unique hydrogeologic conditions found on the Eastern Shore. The conceptual model indicates that the recharge area to the most important aquifer (the Yorktown-Eastover aquifer) lies along the center of the peninsula. Accordingly, protection criteria were determined to address this particular situation. Radial distance was used for Zone 1, while hydrogeologic flow boundaries were used for Zones 2 and 3. Each ground water supply management area is explained below along with the method used to map the protection zones.

Zone 1

Criteria:	200-foot radial distance around a well.
Rationale:	The need for a protective zone immediately around a well has more to do with human error than to hydrogeologic conditions. This zone is employed to maintain an area

around the well to prevent potential contaminants from moving into the aquifer via a poorly constructed or faulty annular seal at the well. Wells that are poorly built or are old may lack the concrete or bentonite clay seal designed to prevent leakage from the surface down along the well casing into the aquifer. In addition, properly constructed seals may also break down over time and create a pathway for water an contaminants to flow into the well. A 200-foot radius around each well where virtually all activity is banned offers a measure of protection against accidental spills.

Method: The radial distance is established by drawing a scaled circle around the well on a map.

Zone 2 - Spine Recharge Area

Criteria: Hydrogeologic boundaries based on recharge areas.

Rationale: The conceptual model of the hydrogeology of the Eastern Shore indicates that the primary recharge area for the Yorktown-Eastover aquifer is located along the center of the peninsula. Assuming that precipitation falling on the surface of the Eastern Shore follows the flowpaths displayed in Figures 2-6 and 2-7, water falling along the center will penetrate vertically through the confining layer and recharge the confined aquifer. Recharge to the unconfined aquifer (the Columbia) has been estimated at between 12 and 26 inches per year (see below and Appendix E). Recharge through the uppermost confining layer to the Yorktown-Eastover is much slower, governed by the low permeability of the confining clays and silts. That recharge rate is estimated at only about 0.10 feet per year (see below and Appendix E).

Using the principle of conservation of mass, the amount of water that seeps through the uppermost confining layer to a pumping well at a low recharge rate over a large area must be balanced by an equal volume of water that recharges the unconfined aquifer at a higher rate. The volumes of water will be the same, but the recharge rates and the area required will differ. The land surface from which recharge flows into the unconfined aquifer is much smaller that the area through which recharge flows into the confined aquifer. Optimally, a full three-dimensional ground water flow model that accounts for the various differing permeabilities and thicknesses would be used to determine the recharge areas in the unconfined and confined aquifer and use particle tracking to back-track the starting points for water particles that are discharged by the pumping wells. That modelled contributing area would then be a logical choice for a protection zone.

Without such a sophisticated model, a simpler solution was derived. Using a moderately conservative recharge rate of 9 inches per year for the Columbia aquifer, the amount of area within each of five areas (described below) to produce the permitted volume discharged was determined. That area was then divided equally on either side of the peninsula to form Zone 2. For this study, average values were used for recharge across the entire study area. Once the USGS model is available (see page 6-4), aquifer properties can be varied, and the model rerun.

Method: The largest users of ground water on the Eastern Shore were located and mapped. This group of twenty-six wells or wellfields (Appendix E) accounts for most of the total ground water discharge permitted on the Eastern Shore. The drawdown of the pumping wells was modelled analytically using a standard ground water solution to the flow equation, the Cooper-Jacob method. The individual drawdowns were then added to model the interference effects from neighboring wells throughout the Eastern Shore. The area of the peninsula was divided into five regions based on the grouping of wells, the amount of permitted pumpage and the contributing areas defined by contour mapping of the modelled drawdowns (Figure 5-1).

The protection zone for each of the five areas was determined on the basis of recharge. The total amount of permitted pumping was determined for each area. The amount of land area required to balance that volume of pumping with a 9 in/yr recharge rate was calculated. The 9 inches was chosen as a conservative value to account for drought years. Since the recharge area was determined to be located along the center of the peninsula, the length of the spine was measured in each zone of contribution, and the width of the protection zone determined by dividing the recharge area necessary by the length of the spine available. This width ranges from 1,530 feet to 4,660 feet but, to remain conservative, a larger 5,000-foot strip (2,500 feet on each side) was plotted along the spine throughout the entire peninsula (Figure 5-2).

The 5,000-foot strip represents the size of surface area that contributes water to the wells in the Yorktown-Eastover aquifer. As the recharge flows downward in the Columbia aquifer it also moves horizontally towards the coasts (see Figure 2-7). The contributing area at the base of the Columbia has therefore grown wider. The transfer rate from the Columbia to the Yorktown-Eastover aquifers is then lower in order to maintain the same volume of water passing through the confining unit.

Zone 3 - Wellhead Protection Areas

Criteria: Hydrogeologic boundaries using contributing areas of flow.

Rationale: The moderate to low transmissivities found within the Yorktown-Eastover aquifer coupled with high levels of permitted discharge on the part of a number of major users creates substantial drawdowns in individual wells. These drawdowns interfere with one another, and since individual cones of depression are additive, the interference patterns serve to exacerbate the problems of excessive water level drop. Pumping from the confined Yorktown-Eastover aquifer produces a gradient on the overlying confining unit and the unconfined Columbia aquifer. In those areas, patterns of recharge and downward vertical flow occurring primarily along the central spine will be modified to some extent by the increased gradients, particularly where the confining unit possesses relatively high hydraulic conductivity or where the clays and silts are missing altogether. Those conditions could apply especially where the documented paleochannels cross the Eastern Shore peninsula. In such locales, recharge will occur from areas other than the central spine under conditions of substantially higher gradients created by pumping.

To address this issue on a peninsula-wide basis, Zone 3 is proposed. Zone 3, based on ground water divides created by the superpositions of pumping patterns upon the ambient potentiometric surface, covers virtually the entire peninsula. The

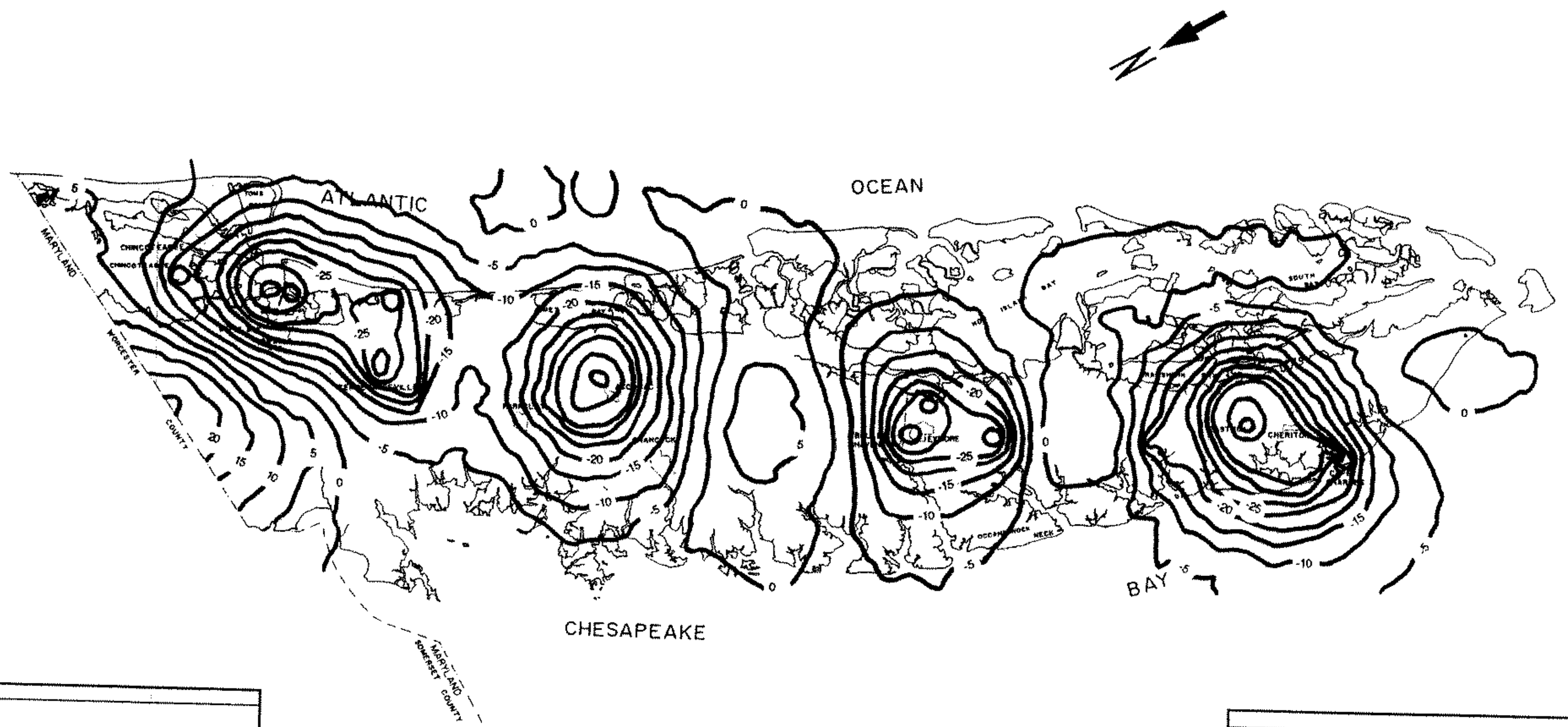


FIGURE 5-1

EASTERN SHORE POTENTIOMETRIC MAP:

Pemitted Pumping

HMH

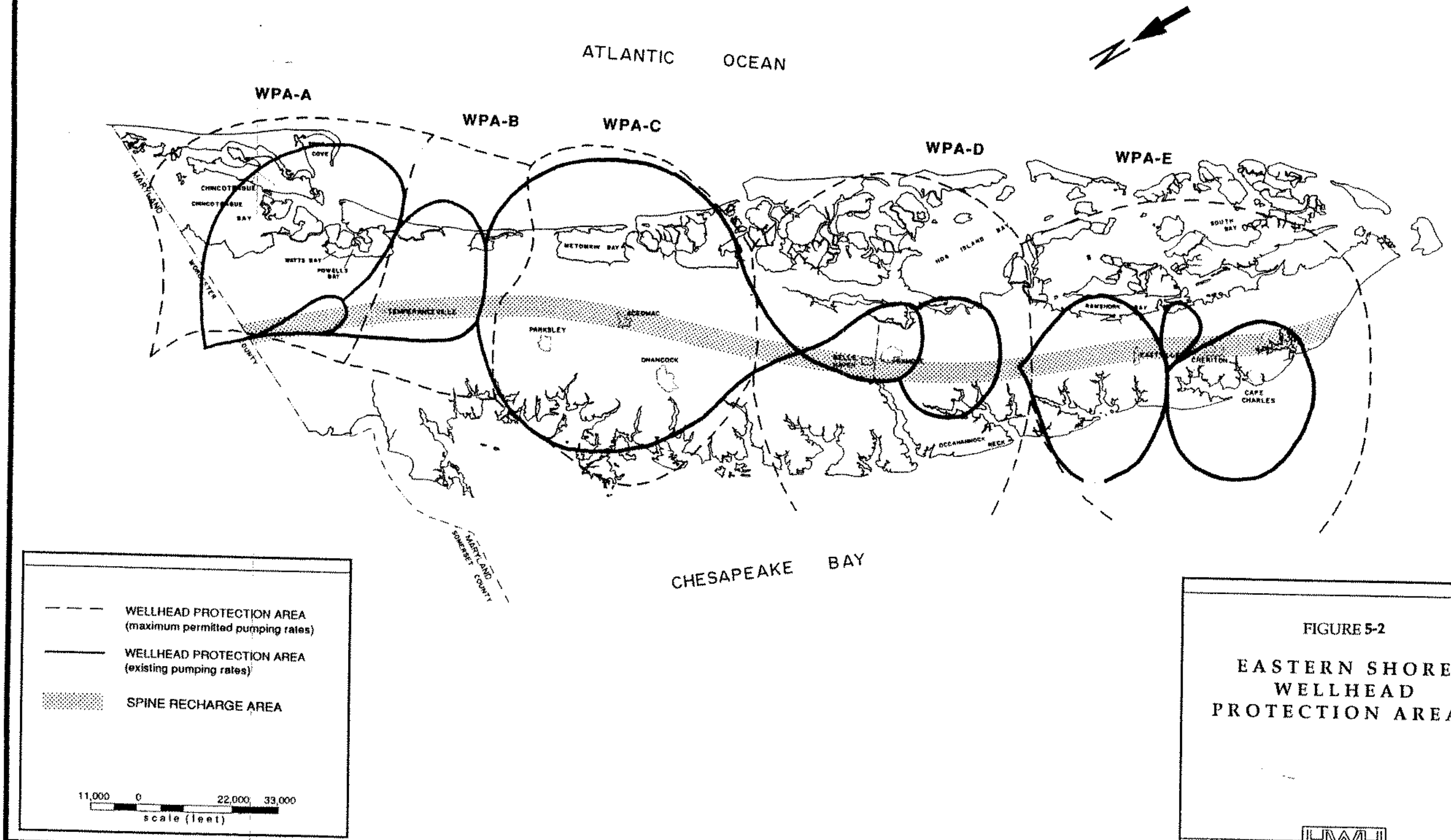


FIGURE 5-2

EASTERN SHORE
WELLHEAD
PROTECTION AREAS

employment of such a zone serves to establish formally how widespread the impact of ground water withdrawals has been on the hydrogeologic system of the Eastern Shore. Creating a zone of protection at the scale of Zone 3 re-emphasizes the dependence of the area on its ground water supply and how activities throughout the region, not simply along the central corridor, affect the quality and quantity of ground water.

Method: The results of the analytical modelling to determine the amount of drawdown caused by pumping the major producing wells on the Eastern Shore were combined with a map of the pre-pumping conditions taken from the numerical flow modelling conducted by Bal, 1977. The resultant water level surface was then analyzed to ascertain ground water divides that form the boundaries to the zones of contribution to the Eastern Shore. See Figure 5-1 for the potentiometric map for permitted pumping rates. The zones of contribution constitute Zone 3 (Figure 5-2).

PHYSICAL DESCRIPTION OF EACH WELLHEAD PROTECTION AREA

The Wellhead Protection Areas (WPA's, Zone 3 ground water supply management areas), reflect the contributing areas to existing wells under permitted pumping rates. Below is a breakdown of certain activities within each WPA, along with a general geographical description. Please refer to Figure 5-2 for the location of each WPA.

Wellhead Protection Area A - Chincoteague Area

Area: 27,000 acres
Number of Wells: 13
Number of VPDES dischargers: 17
Landfills: 2 closed
Lagoons: none

Of the WPA's, this wellhead protection area covers the least extent of upland. It includes Chincoteague Island to the east, Captain's Cove to the north, Oak Hall to the south, and includes the town of New Church and the NASA Wallops Station. The old northern landfill in Accomack County (now closed) is located within this area, and apparently there is a closed landfill on Chincoteague. Large wells serve Captain's Cove, the Town of Chincoteague, NASA Wallops Main Station, and New Church Energy Association. These facilities also have discharge permits to dispose of liquid wastes in the area. Water taken from the tap at Stoney Point Decoys, NASA Wallops Flight Center, and NASA Wallops Island have all tested above 5 mg/l for nitrate-nitrogen, with readings ranging from 7.11 to 11.5 mg/l.

Wellhead Protection Area B - Holly Farms (Tyson Foods) Area

Area: 43,000 acres
Number of Wells: 9
Number of VPDES dischargers: 6
Landfills: 1
Lagoons: 1

The towns of Withams, Hallwood, Nelsonia, and most of Wallops Island are located in this wellhead protection area. To the east, it extends into the Atlantic Ocean, and to the west it reaches as far as Route 698 near the Saxis area. This wellhead protection area contains the greatest visible contamination threat. Directly on the spine recharge area is the Northern Landfill for Accomack County and one of the two Bundick septage lagoons, which is unlined. Any contamination which reaches the ground water within this recharge area could eventually contaminate the Yorktown-Eastover aquifers. Water withdrawers and septage dischargers located in this area are Holly Farms, which is second to Perdue in its permitted water withdrawal rate, Taylor Packing Company, and the NASA Wallops Island facility. The Atlantic Fire House is the only known facility in WPA B to have nitrate-nitrogen levels above a negligible amount; a sample taken in 1981 measured 5 mg/l.

Wellhead Protection Area C - Perdue Area

Area: 76,000 acres
Number of Wells: 15
Number of VPDES dischargers: 7
Landfills: none
Lagoons: 1

This is the contributing area created by pumping from Perdue, Byrd Foods, the towns of Onancock and Parksley, and the Accomack County Nursing Home. Because of large amounts of industrial water withdrawals, this wellhead protection area is the largest one on the peninsula. The current pumping rates, dominated by Perdue Inc., show a drawdown area almost as large as the drawdown expected for the maximum, permitted pumping rates. The WPA extends into both the Bay and the Atlantic, and includes Bloxom to the north and Melfa to the south, and Accomac, Parksley, Onley, and Onancock in the central portions. WPA C contains the Boggs septage lagoon. Two public water supply wells for the Town of Parksley have had nitrate nitrogen levels ranging from 5.65 to 8.5 mg/l during testing intervals between 1974 and 1989. An observation well sampled in 1980 measured 10 mg/l for nitrate-nitrogen.

Wellhead Protection Area D - Exmore Area

Area: 65,000 acres
Number of Wells: 9 and 1 proposed
Number of VPDES dischargers: 9
Landfills: 1
Lagoons: 1

WPA D covers the border of Accomack and Northampton Counties. The southern landfill for Accomack County and a Bundick Lagoon is located within its boundaries. To the east, the boundaries cover most of Paramore Island and Hog Island, and it extends far out into the Chesapeake Bay on the west side. The villages of Keller and Johnsontown are the north and south extents of wellhead protection area B, respectively. Also included are Pungoteague, Wachapreague, Exmore, and Nassawadox. Wells are in use for the town of Exmore, Virginia Landing Campground, the Accomack-Northampton Hospital, and American Original Foods. Peaceful Beach Campground plans to install a well in this wellhead protection area. An observation well on Churchneck has measured very high nitrate nitrogen levels, ranging from 13.0 to 24.0 mg/l.

Wellhead Protection Area E - Cape Charles Area

Area: 52,000 acres
Number of Wells: 17 plus 7 proposed
Number of VPDES dischargers: 13
Landfills: 1
Lagoons: none

This wellhead protection area is the most southern on the peninsula, not quite reaching Fisherman's Island. Similar to WPA D, its boundaries include most of the marshland on the east, and extend out to a large distance into the Bay. Machipongo is the northernmost town, and Eastville, Cheriton, Cape Charles, and Townsend are all included in the protection area. Major wells in the area are presently proposed but permitted, and include wells for the DiCanio and Brown & Root communities near Cape Charles. Current water withdrawers are the towns of Eastville and Cape Charles, America House Motor Inn, Sea Watch International, KMC Foods, and Bayshore Concrete Products. The Northampton County Landfill is also located within this area. A Brown and Root well sampled in 1977 had a nitrate-nitrogen level of 17.0 mg/l, and an observation well near Oyster exhibited nitrate-nitrogen levels ranging from 6.9 to 9.0 mg/l.

WATER BUDGET/BALANCE

6

SECTION 6: WATER BALANCE

Because aquifer and wellhead protection is so intimately tied to the issues of water quality and quantity, some quantification of the amount of recharge both to the unconfined and confined aquifer systems was needed. The estimate of the available water could then be compared to the amount extracted in terms of current, permitted and future yields.

RECHARGE TO THE COLUMBIA AQUIFER

An estimate of the amount of water recharging the unconfined Columbia aquifer as made using a standard water budget calculation (Appendix E) following the approach detailed in Dunne and Leopold, 1978. A water budget is calculated by creating a "balance sheet" of hydrologic inputs and outputs to the system. The input to the system is precipitation. Average values for monthly precipitation from the weather station at Painter, Virginia were used, representing six years of record (1985-1990). Outputs from the system include the amount of water evaporated directly or transpired indirectly to the atmosphere, estimated using an approach from Thornthwaite and Mather (1955) (Appendix E). The Thornthwaite and Mather approach is designed for use in temperate and humid environments and is an appropriate choice to estimate potential evapotranspiration (ET) on the Eastern Shore. Where ET is greater than precipitation, a potential water loss develops and accumulates during the dry months (June, July and August). The amount of moisture held in the soil (a function of soil type and plant rooting depth) will be reduced because of this accumulated water loss. Calculations are then made to estimate the actual ET and to determine the amount of water available for runoff and recharge. The water budget approach resulted in an estimate of 17 inches per year of recharge to the unconfined Columbia aquifer on the Eastern Shore, assuming 50 % runoff, 12 inches per year with 60% runoff and 26 inches per year with 40% runoff.

The water budget modelling is fairly robust with regard to most of its components. Temperature and precipitation records show only moderate scatter, characteristic of a temperature climate. The fact that relatively little soil moisture deficit develops is typical with the climatic regime of the Eastern Shore. Where the model does show sensitivity is in the estimate of the amount of runoff that takes place. The Soil Conservation Service (SCS) models of runoff calculations are only applicable to small catchments, and empirical estimates for runoff percentages are difficult to obtain at the scale of the entire peninsula. Given the permeable nature of soils on the Eastern Shore, a 50% estimate is reasonable (Dunne and Leopold, 1978). If 40% is estimated to run off, the recharge estimate jumps to approximately 26 inches per year. If 60 percent runoff is estimated, about 12 inches per year recharges the aquifer.

The volumetric amount of recharge is determined by multiplying the recharge rate by the area of the peninsula. Using an area of 400 square miles and 17 inches of recharge per year, the volumetric recharge to the unconfined aquifer is approximately 324 million gallons per day. Most of the withdrawals from the surficial aquifer consist of agricultural extractions, and many are undocumented. However, it can be fairly safely maintained that the withdrawals do not approach even within an order of magnitude of the amount being recharged. The quantity of water within the Columbia aquifer appears to be of little concern.

RECHARGE TO THE YORKTOWN-EASTOVER AQUIFER

The clays and silts separating the unconfined Columbia and the confined Yorktown-Eastover aquifers range in thickness from 20 to 100 feet. The permeability of this confining layer is low, but precisely how low is difficult to determine empirically. To calculate the flux across the confining layer for transient (time-dependent) conditions using Darcy's Law, some value for hydraulic conductivity (permeability) has to be used. To avoid this problem, and to obtain a conservative estimate of recharge to the Yorktown-Eastover aquifer, HWH used as steady state approach to calculate recharge. Recharge was determined via a cross-sectional model for the confined ground water system. The governing differential equation for one-dimensional flow at steady state was integrated and boundary conditions appropriate to the Eastern Shore used to determine the constants of integration. The result was an equation that could be solved for a recharge rate (see Appendix E). The recharge rate was multiplied by the area of the confining layer receiving recharge to determine the volumetric quantity of water reaching the confined system.

The coefficients necessary to solve the derived equation are aquifer transmissivity, hydraulic head (water level), and the width of the peninsula. To examine the sensitivity of the analytical model, a range of values were used to determine an estimate for recharge. The average width of the peninsula is about 8 miles in Accomack County and about 6 miles in Northampton County, although sections exist that are considerably narrower. Calculations were made for widths of 4, 6, and 8 miles. Transmissivity values found in geologic reports of the Eastern Shore varied considerably, ranging from less than 1000 ft^2 per day to over 5000 ft^2 per day. The modelling incorporated a range of transmissivity from 500 to 5000 ft^2 per day. Values from the potentiometric surface map of Bal, 1977 were used for hydraulic head at the ground water divide, varying from 15 to 26 feet above mean sea level.

The results show that recharge to the confined Yorktown-Eastover aquifer is very slow. Calculated rates ranged from 0.01 ft/yr under the worst case conditions to 0.85 ft/yr for a somewhat optimistic scenario of narrow peninsula width coupled with high transmissivity and high hydraulic head. The average recharge rates for the 6 and 8 mile wide peninsula scenarios was 0.13 and 0.07 ft/yr, respectively. These average recharge rates take into account the average widths of the two counties at the selected average transmissivity values, but do not account for the large variability (more than a factor of two) in each of these numbers as discussed in Appendix E (Page E-6). These average rates also coincide with the conceptual model of a fairly restrictive confining layer separating the Columbia and the Yorktown-Eastover aquifer.

Recharge in the model changes directly in proportion to transmissivity increases and hydraulic head increases, but reacts oppositely to changes in the width of the peninsula. The model is quite sensitive to differences in peninsula width. With a decrease of 2 miles (8 to 6 miles, or 6 to 4 miles) recharge more than doubles. The model is also sensitive to values of transmissivity. Over the anticipated range of 500 to 5000 ft^2/day, recharge values approximately double with each 1000 ft^2/day increase. The model is least sensitive to hydraulic head, primarily because of the restricted range of heads that are used. Each 2 foot increase in head translates to about 0.01 ft/yr increase in recharge.

While the rate of recharge is quite low, the volumetric total of water that enters the confined system is fairly large. However, the conceptual model demonstrates that recharge does not occur across the entire area of the confining layer. Rather, it occurs predominantly over the central portions (Figures 2-6 and 2-7). Therefore, multiplying the calculated recharge rate by the entire area of the peninsula on the assumption that all of the confining layer surface permits recharge would incorrectly inflate the volumetric total entering the confined system. A range of areas smaller than the entire Eastern Shore was used to estimate the volumetric recharge to the confined Yorktown-Eastover aquifer (Appendix E).

Using an area of 200 mi^2 and a recharge rate of 0.10 ft/yr (averaging 0.13 and 0.07 ft/yr), there is some cause for concern in terms of water quantity in the Yorktown-Eastover aquifer. At a 0.10 ft/yr recharge rate, pumping at the permitted amount of 15.6 MGD would create a deficit situation, in effect, mining the ground water of the confined system. Even when considering a recharge area of 300 mi^2, the volumetric total at 0.10 ft/yr is within 3 MGD of currently permitted use.

If the Yorktown-Eastover aquifer is receiving recharge at a rate of 11 MGD, and the maximum withdrawal volumes could reach 15.6 MGD according to VAWCB issued permits, then significant problems could develop in the future. Continuous drops in hydraulic head and increases in chloride levels have been observed in VAWCB test wells in the vacinity of the largest industrial withdrawal wells. If maximum withdrawals reach 15.6 MGD, then salt water intrusion (lateral and upconing), well interference and water quality degradation of the Yorktown-Eastover aquifer, already observed near major industrial users, will be aggravated.

In view of these results, serious consideration should be given to (a) better quantification of the amount and distribution of recharge that enters the confined system, (b) careful examination of additional permits for large volume water users that would increase the amount of pumpage significantly beyond current levels, and (c) reevaluation of existing permits relative to actual use and need.

SALT WATER INTRUSION

Serious questions exist relating to the issue of sheer water quantity that can be extracted from the Eastern Shore's confined system. Of equal importance to the amount of water being extracted is the issue of where the water is being taken from. In particular, consideration for the problem of salt water intrusion has to be considered.

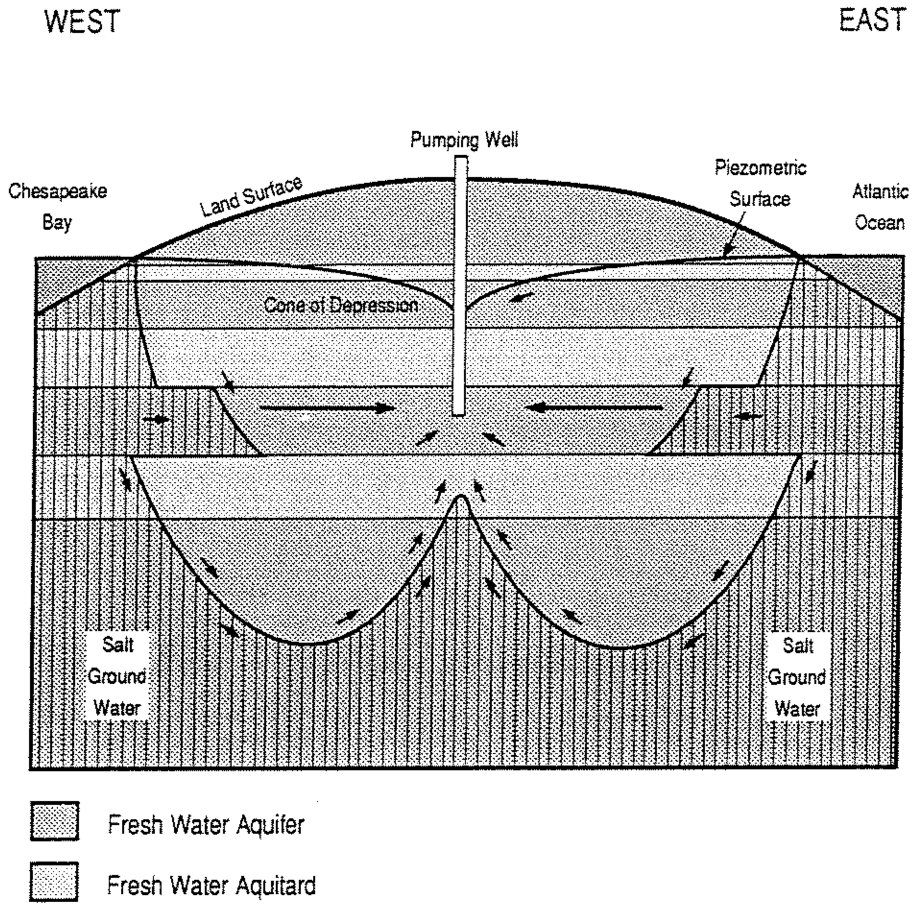
Salt water intrusion to a fresh water aquifer can occur in several ways. Intrusion can occur from lateral inflow of salt water into the fresh water zone. In this scenario, salt water is viewed as a wedge that pushes in to the fresh water lens as fresh ground water head declines because of a drop in areal recharge or from pumping of wells in the fresh water zone (Figure 6-1). Several analytical models have been developed for the analysis and description of flow in a fresh water zone overlying a static body of salt water including the standard Ghyben-Herzberg equation and an approach by Glover, 1959.

With confined aquifers, salt water can also intrude vertically through confining layers in response to reversals of gradient. As pumping proceeds or as areal recharge to the fresh water aquifer declines, the hydraulic head in the fresh water zone becomes less than that in the salt water zone. Flow that originally moved upward from the fresh water zone through the confining layer and discharging to the salt water zone reverses. As a result, salt water leaks through the confining layer into the fresh water zone. This problem particularly afflicts wells located along coastal areas.

The wedge-like movement of salt water into fresh water zones and the leakage through confining layers from gradient reversals was the subject of the recent U.S. Geological Survey study on the Eastern Shore, using the SHARP interface model (Richardson, in press). That report remains in the U.S.G.S review process and is not yet published. When the results do become available, they should be closely examined to assess the impact of lateral intrusion and intrusion through confining layers, particularly on high volume wells located near the coasts.

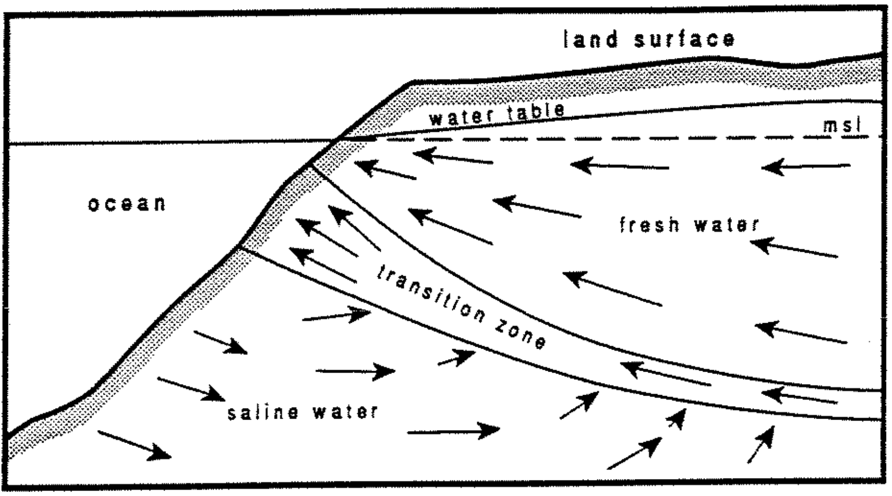
Figure 6-1

SALT WATER UPCONING FROM WELL



regardless of pumping rate, and a number of analytical equations have been developed to describe this movement of salt water (McWhorter and Sunada, 1977). If a well pumps at too high a rate, the salt water upcone will reach the well and contaminate the supply source. Therefore, pumping fresh water from an aquifer underlain by a salt water zone must be done using very small drawdowns to prevent upconing from reaching the well. It is possible to obtain an upconing of the salt/fresh interface that is stable for a given pumping rate, the thickness of fresh water zone and particular well construction. In practical terms, the salt/fresh interface is usually stable if the upcone rises less than one third of the distance between the bottom of the well and the original, non-pumping interface elevation.

Figure 6-2 Upward Vertical Migration of Salt Water



Several analytical solutions have has been developed to predict the maximum discharge a well can produce given a particular thickness of fresh water, hydraulic conductivity, and distance to a well screen. Three were examined for use on the Eastern Shore (Appendix E). The models are designed to predict the recommended maximum rate a well should pump to avoid the problem of moving the salt water upcone beyond the critical level of stability. Two of the models selected (McWhorter, 1972 and McWhorter and Sunada, 1977) are designed for cases of partial penetration of a well, in circumstances where the screened portion of the well is small in relation to the total depth, a common factor to virtually all wells on the Eastern Shore. The third approach (Bennett, 1968 in Reilly and others, 1987) incorporates a recharge factor into the calculations.

The upconing models were applied for conceptual purposes to obtain an idea of the magnitude of the problem of upconing. The aquifer was modelled as a single confined unit, ignoring intermediate confining and semi-confining layers to simplify the analysis. Parameters needed for the modelling (e.g.,thickness of the undisturbed fresh water zone, position of well screen, hydraulic conductivity, etc.) were determined for a high volume producing well, Perdue #2, taken from the literature. In particular, the elevation of the pre-pumping salt/fresh interface was designated at the elevation of the the 250 mg/l chloride level, calculated by subtracting the mapped 250 mg/l chloride surface elevation (Fennema and Newton, 1982) from the pre-pumping water level surface elevation (Bal, 1977). Water with more than 250 mg/l tastes salty and is generally unacceptable for most domestic and industrial uses. While the 250 mg/l chloride level does represent a limit of potable water, it is not a true salt/fresh water interface. The allowable discharges produced by all the upconing models are directly proportional to the difference in density between the salt (usually sea water) and fresh water, generally estimated at 0.025 mg/l. The density differences between fresh water and water with 250 mg/l chloride is negligible, resulting in trivially small allowable discharge rates. To make use of these analytical tools even for conceptual purposes, the density difference had to be maintained as that between sea and fresh water.

The results (Table 6-1) show the models predict considerably lower levels of pumping discharge rates than either permitted or existing rates in order to maintain a stable upcone. The predicted rates for this well range from a low of 20 gpm from an extremely conservative model to 80 gpm, using the Bennett and other, 1968 model that incorporates recharge. However, if a true salt water interface existed at the 320 foot level (with a chloride concentration of approximately 30,000 mg/l), this well and most all high volume wells on the Eastern Shore would have been contaminated at either their permitted or actual rates.

Table 6-1: Salt Water Upconing Modelling Results

Well:	Perdue #2			
Model Input Parameters			*Discharge Data*	
Screen bottom elevation	253	ft msl	Permitted discharge (gpm)	503
Salt/fresh interface	320	ft msl	Actual discharge (gpm)	278
Thickness of fresh water	340	ft		
Areal Recharge	0.10	ft/yr		
Hydraulic conductivity	37.5	ft/day		
Modelled allowable discharge to prevent upconing				
Model from McWhorter, 1972			**20**	**gpm**
Model from McWhorter and Sunada, 1977			**46**	**gpm**
Model from Bennett and others, 1968			**80**	**gpm**

The reasons why sea water does not flow from the wells of the Eastern Shore is a combination of several factors. The models assume a sharp interface between the salt and fresh water, a phenomenon that rarely occurs in field conditions, especially if pumping is intermittent. Instead, the salt/fresh interface usually forms a gradational zone from highly saline or brackish water to fresh water. Also, as indicated above, the interface position used in the modelling was not assumed to be a pre-pumping true interface (approximately 30,000 mg/l). The model instead used a post-pumping 250 mg/l chloride level, which is not a true salt water/fresh water interface. The actual position of salt water lies somewhat below the level used in the modelling, below the confining layer that separates the lower Yorktown-Eastover modelling was not assumed to be a pre-pumping true interface (approximately 30,000 mg/l). The model instead used a post-pumping 250 mg/l chloride level, which is not a true salt water/fresh water interface. The actual position of salt water lies somewhat below the level used in the modelling, below the confining layer that separates the lower Yorktown-Eastover aquifer from the underlying unit, the St. Mary's Formation. None of the models used incorporates a low permeability unit into the calculations, and salt water intrusion from upconing would be slowed by the presence of a lower boundary of silts and clays.

The results of this modelling should serve not as any sort of regulatory tool but as a warning that large discharges will promote salt water contamination from upconing unless pumping rates and intensities are regulated. Also, the primary issue at hand is not whether sea water with a chloride concentration of 30,000 mg/l is actively intruding into the fresh water aquifer. The more important question is whether water that possesses chloride concentrations of 250 mg/l and is essentially useless for direct consumption, either as drinking water or as industrial use water, will be drawn into the wells. In all likelihood, that is probably happening now in a number of wells on the Eastern Shore despite the fact that samples from most wells show lower overall concentrations. Most wells completed in the Yorktown-Eastover aquifer have screens in all three layers and draw water from all three. The lower Yorktown-Eastover is often the least transmissive of the three and contributes the least water. The overall result is that a mixing of water occurs, and samples taken from a given well represent the bulk chemical signature of all three layers. Water in the upper two layers is not likely to have been affected by high chlorides yet, and dilution masks the elevated concentrations of chloride from the lower section. Salt water upconing will occur with pumping, and careful management of the resource is required to avoid irreparable damage to the fresh water aquifers.

BUILDOUT/DEVELOPABLE LOT ANALYSIS

7

SECTION 7: BUILDOUT

DEVELOPABLE LOT/LAND USE ANALYSIS

Of the total land area on the Eastern Shore (about 537,000 acres), approximately 38 percent or 206,000 acres are wetlands and coastal islands, not suitable for residential, agricultural or industrial use. Approximately 53% of the land area on the Eastern Shore is under agricultural use or forestry. The remaining 9% of the land is under residential use (3.2%), commercial/industrial use (0.6%), in the public domain (2.4%), or other uses (2.3%) (Table 4-1, p. 4-3.).

With the exception of sewage treatment plants servicing the towns of Cape Charles and Onancock, existing development on the Eastern Shore relies on individual subsurface disposal systems for sewage treatment. No large-scale sewering is anticipated in the future. Residential development is scattered, with a low density pattern of development overall. Commercial and industrial development is concentrated along the center strip of both counties, following Route 13. Drinking water is supplied by a combination of public water supply and private wells.

Zoning requirements (dimensional and use) vary widely, both within the counties, and within the towns. Land use in Virginia is regulated at the county level, with the exception of the areas within incorporated towns. Land use in these areas is regulated by the towns themselves.

The authority for local governments to zone land in Virginia is granted by the Virginia General Assembly and can be found as Article 8 of the Code of Virginia. The Virginia Zoning Code cites ten general purposes for zoning including *"to protect surface water and groundwater"* (VA Code Ann. sec. 15.1-489). The Zoning Code also authorizes conditional zoning, site plan ordinances, and the provision for variances.

In addition, local governments are required to develop a comprehensive plan for *"the physical development of the territory within its jurisdiction"* (VA Code Ann., sec. 15.1-446.1). The comprehensive plan becomes the general plan for development and the basis for the formulation of zoning ordinances in the local jurisdiction. Specifically, the code requires local governments to include in their plans *"the designation of areas for the implementation of reasonable groundwater protection measures"* (VA Code Ann,. sec. 15.1-446.1).

Local control over development can also be found in the State's law controlling land subdivision (VA Code Ann. sec. 15.1-465). This authority can be particularly important in an area such as the Eastern Shore where very little land is currently subdivided into smaller residential lots.

A land use control measure that recently became available for use in Virginia is found in the Chesapeake Bay Preservation Act (VA Code Ann. sec. 10.1 -2100). This new law passed in 1988 requires that counties, cities, and towns of Tidewater Virginia incorporate general water quality protection measures into their comprehensive plans, zoning ordinances, and subdivision ordinances. This authority provides very general and broad powers to local governments in Virginia to control land uses that may impact on water quality.

Methods

The primary purpose of buildout, or developable lot, analysis was to evaluate the impacts of existing and potential land uses on ground water quality. The analysis therefore focused on the Zone 2 spine recharge area, as delineated in this study.

The buildout analysis followed a three step process. First, Zones 2 and 3, as delineated in this study, were transferred onto US Geological Survey 1:25,000 scale topographic quadrangles for Northampton County and Accomack County land use district maps, also at 1:25,000 scale.

Secondly, existing land uses within the spine were documented. The potential for further development was determined from future land use maps prepared for both counties, and the information was transferred onto the set of 1:25,000 scale maps. An example of future land use within the spine is shown on Figure 7-1.

The Soil Conservation Service (SCS) identified the Nimmo-Arapahoe soil association as the only upland soil type in the two counties that is considered undevelopable (R. Lewis, personal communication, 1991). Areas with these soils were identified on the land use maps, and analyses were conducted with and without inclusion of these areas. Small regions of hydric soils were not factored into analyses.

Finally, areal extent was measured for each future land use class, subdivided by county, ground water protection zone, and soil class. Fifteen percent (15%) of developable land was taken out for roads within each land use category.

All data used in the analysis was entered into a computerized spreadsheet program (Microsoft Excel), to aid sorting and analysis. The spreadsheet was programmed to perform the necessary calculations for the various buildout scenarios. The total future number of units was calculated by taking the total land area within each land use category in each protection zone, subtracting out 15% for roads and poorly drained soils. The remainder was divided by the permitted number of lots per acre under current zoning (Northampton) or recommended zoning (Accomack Comprehensive Plan, 1989). Table 7-1 lists parameters used.

Table 7-1: Minimum Lot Sizes Used in Buildout Analysis

Accomack County		Northampton County	
RR: Rural Residential	1 unit/acre	Residential	20,000 ft^2
R-1: Residential	3 units/acre	Agriculture	43,560 ft^2
R-2: Residential	2 units/acre		
Agriculture:	1 unit/5 acres		

Source: Accomack County Comp. Plan, 1989 Northampton County Zoning Ordinance, 1990

The analysis results have important implications for the assessment of nitrogen contamination of ground water and for the development of appropriate regulatory approaches in protecting ground water quality on the Eastern Shore.

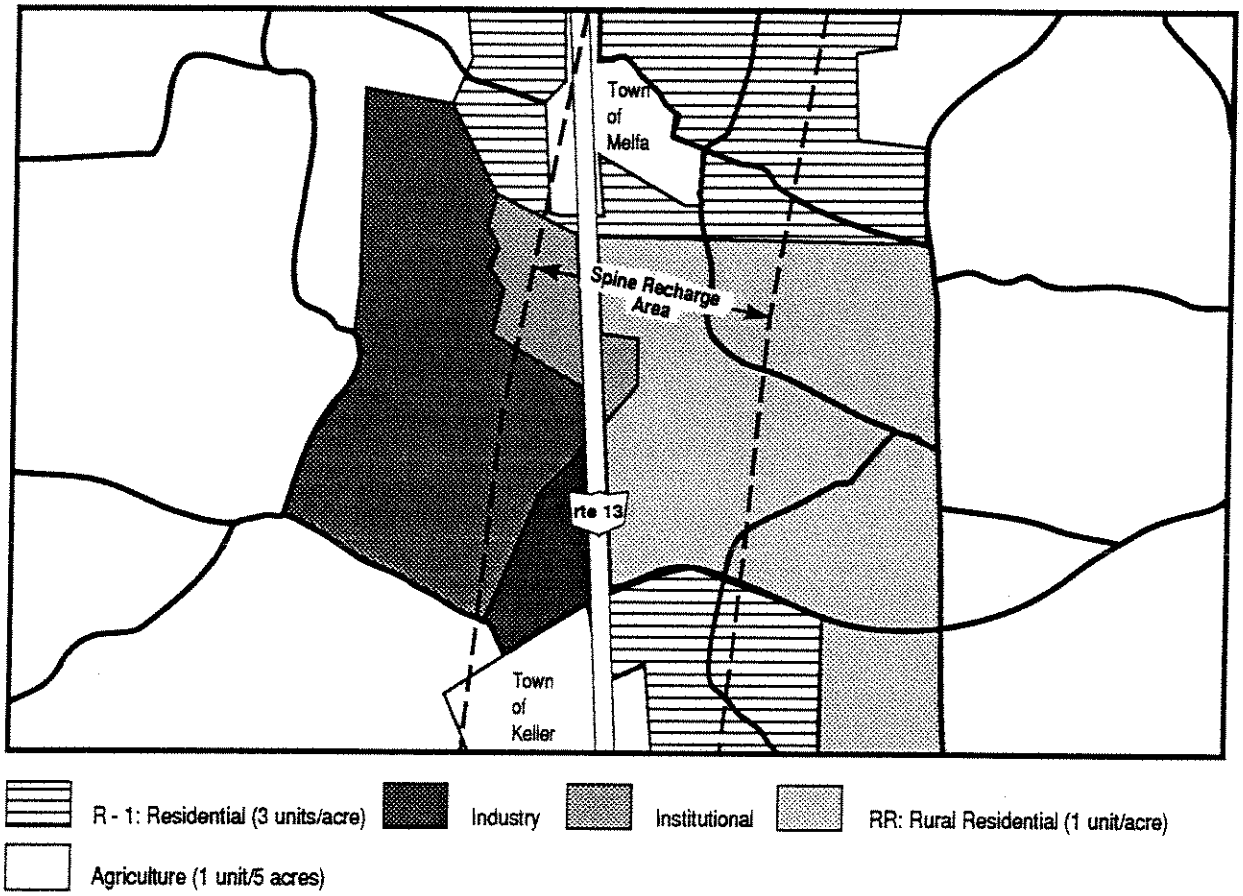
Buildout Assumptions

For incorporated towns in Accomack County certain assumptions were made in order to complete the buildout analysis. Each town has its own zoning which is not included in the Future Land Use Plan for the County. The following assumptions were made:

1) The percentage of the town which lies within the spine was determined by taking the ratio of acres of town within the spine to total acres of incorporated town.
2) The breakdown of land use types was assumed to be equivalent to that of the entire county, leaving out agriculture, parks, and marshland. In Accomack County, it was estimated that 75% is residential, 1.8% is trade, 17.5% is industrial, and 5.3% of is institutional. These percentages were

Figure 7-1:

Example of Future Land Use Within Spine Recharge Area



multiplied by the acres of each town which fall on the spine. An estimate of acreage by land use within the town was thus achieved.

3) Using the estimated potential residential acreage in each town from (2), the number of potential dwelling units was calculated. An average of 2 units per acre was used.

For Northampton County, there are two types of residential land delineated on the future land use map, Rural Residential (and village area) and Urban Development Area. In the Comprehensive Plan, each urban development area is broken down into residential, commercial, industrial, roads/railroads and public land areas. The maps showing the locations of these types are inadequate for transferral to the USGS quadrangle maps. Therefore, land use within the urban development areas was estimated. Proportions of each land use type within the spine were assumed to be equivalent to that of the area as a whole; and residential land was separated from other types within each urban development area.

Calculations within incorporated towns and Urban Development Areas are included in Tables 7-3 and 7-4.

BUILDOUT ANALYSIS RESULTS

Buildout results are summarized in Table 7-2; complete results are shown in Table 7-5.

Table 7-2: Buildout Summary

	Existing Units County-wide	Total Acres within spine	Res./Ag. Acres within spine	**Potential Units within spine**
Accomack County				
developable soils		17,140	16,561	15,893
all soils	15,840	22,147	19,901	16,470
Northampton County				
all soils	6,183	16,921	15,535	21,207

In both counties, the potential number of single-family dwelling units within the spine recharge area, according to current plans, is greater than the number of units that currently exist within the *entire* two counties. While the number of potential housing units may be striking, development is currently slow on the Eastern Shore of Virginia. Indeed, the population has actually decreased in the past decade. Consequently, there is opportunity to enact management tools to control future development and thereby protect ground water quality and quantity.

BUILDOUT ANALYSIS SUMMARY

The buildout analysis used a computerized spreadsheet approach to determine the maximum number of future residential units in both counties. The buildout focused on land areas within the delineated spine recharge zone (Zone 2) to the Yorktown-Eastover aquifer, since this area would most likely affect public water supply quality. Using minimum lot size requirements according to each county's comprehensive plan, the maximum number of units or houses that could be possibly built was calculated. In Accomack County this resulted in 16,470 potential units in the spine recharge area. For Northampton County, the maximum potential number of units was calculated to be 21,207 (Table 7-2). As discussed previously, this results in more potential units than that which currently exist within each county.

Table 7-3: Calculations for Buildout Within Incorporated Towns, Accomack County

CALCULATIONS OF CURRENT DWELLING UNITS WITHIN SPINE

Incorporated Town	Acres within spine	Total acres of town	% of town within spine	1990 census # dwelling units	Estimated dwelling units in spine
Accomac	173	262	66	205	136
Onley	83	486	17	276	47
Melfa	154	177	87	191	166
Keller	211	214	98	107	105
Painter	184	415	44	113	50
Belle Haven	408	820	50	245	122

CALCULATIONS OF LAND USE WITHIN TOWNS

Land Use	Acreage in county (%)	Estimated acreage within towns (%)	Estimated Acres					
			Accomac	Onley	Melfa	Keller	Painter	Belle Haven
Residential	4.3	75	131	63	116	159	138	308
Trade	0.1	2	3	2	3	4	3	7
Industrial	1.0	18	30	15	27	37	32	71
Institutional	0.3	5	9	4	8	11	10	22
Total	5.7	100	173	84	154	211	184	408

MAXIMUM POTENTIAL DWELLING UNITS WITHIN SPINE

Town	Estimated residential acres within spine	Residential acres subtracting 15% for roadways	Average units/acre	Potential dwellings in spine	Existing dwellings in spine	Maximum Additional Units Possible
Accomac	131	111	2	222	136	86
Onley	63	54	2	107	47	60
Melfa	116	99	2	197	166	31
Keller	159	135	2	270	105	165
Painter	138	118	2	235	50	185
Belle Haven	308	261	2	523	122	401

Table 7-4: Calculations for Buildout Within Urban Development Areas, Northampton County

CALCULATIONS OF CURRENT DWELLING UNITS WITHIN SPINE

Urban Development Area	Acres within spine	Total acres of area	% of area within spine	Current Population (Comp. Plan)	Estimated Pop. in spine	# persons/ dwelling (1990 census)	Est. number of dwelling units in spine
Exmore/Willis Wharf	1,164	4,225	28	2,684	740	2.1	350
Nassawadox	1,230	1,860	66	1,775	1,174	2.1	556
Eastville	1,423	2,277	63	800	500	2.1	237
Cheriton/Cape Charles	1,448	5,428	27	4,274	1,140	2.1	540

LAND USE WITHIN URBAN DEVELOPMENT AREAS ACCORDING TO COMPREHENSIVE PLAN

Land Use	Exmore/ Willis Wharf	Nassawadox	Eastville	Cheriton/ Cape Charles
Residential	65	88	77	66
Commercial	5	7	3	4
Industrial	6	2	2	7
Roads/Railroads	17	1	15	19
Public	7	2	2	5

MAXIMUM POTENTIAL DWELLING UNITS WITHIN SPINE

Urban Development Area	Estimated residential acres within spine	Minimum lot size (acres)	Potential dwellings in spine	Estimated existing dwellings in spine	Maximum Additional Units Possible
Exmore/Willis Wharf	759	0.46	1,650	350	1,300
Nassawadox	1,076	0.46	2,340	556	1,784
Eastville	1,096	0.46	2,382	237	2,146
Cheriton/Cape Charles	948	0.46	2,061	540	1,522

This buildout has important implications for wastewater disposal impacts and future water supply needs. Obviously, not every possible unit will be developed in the near future, however the buildout assessment expresses the "blue print" that has been established for growth by both counties. If this development were to occur, then significant water demands and wastewater disposal needs would have to be addressed. For the combined total number of units of 37,677, a water demand of 5.65 MGD (37,677 units x 150 gallons per day) would be needed. As of 1990 only 1.2 MGD is supplied by public water sources. Public water withdrawals would have to increase by over 4.5 times. Regarding wastewater disposal, if all of these units were allowed to be built, then a total of 6.22 MGD of wastewater (37,677 units x 165 gallons per day) would have to be either treated and disposed to the ocean or Bay, or be discharged to the ground water through septic systems. Further analysis of wastewater impacts under buildout conditions is discussed in Section 8.

The numbers generated in the buildout were used in the nitrogen loading model to determine maximum nitrogen loading under the planned densities and land use types for both counties. The buildout numbers for maximum number of units, agricultural areas, etc. are used to predict nitrogen loading under the current land use plans, and to allow for scenario testing of different land use patterns.

This buildout analysis can be used as a predictive tool to help assess the impacts of future development on the many community services that would be needed to support this level of development and to help plan for changes in development densities and patterns of future development. In reality, the near future will only see a fraction of this buildout potential due to market conditions and other factors. Buildout analyses such as this one can be used to identify potential land use conflicts and to begin to plan for changes to address these conflicts.

Table 7-5: Developable Lot Analysis, Accomack and Northampton Counties

ACCOMACK COUNTY

Measurements in acres

Permitted WPA A

Land Use Type	Developable Acres	Undevel. Acres	Total Acres	Units/ Acre	Potential Units Dev. soils	Potential Units All soils
RR: Rural Residential		12	12	1	0	10
R-1: Residential						
R-2: Residential						
Trade		60	60			
Industry						
Institutional						
Parks & Recreation						
Agriculture	161	3,183	3,344	1/ 5 acres	27	569
Total	161	3,256	3,417		27	579

Permitted WPA B

Land Use Type	Developable Acres	Undevel. Acres	Total Acres	Units/ Acre	Potential Units Dev. soils	Potential Units All Soils
RR: Rural Residential	733		733	1	623	623
R-1: Residential				3		
R-2: Residential	29		29	2	50	50
Trade	626		626			
Industry	187		187			
Institutional	29		29			
Parks & Recreation						
Agriculture	3,164	145	3,309	1/5 acres	538	563
Total	4,769	145	4,915		1,211	1,236

	Permitted WPA C			Permitted WPA D		
Land Use Type	Developable Acres	units/ acre	Potential Units	Developable Acres	units/ acre	Potential Units
RR: Rural Residential	1,220	1	1,037	401	1	341
R-1: Residential	2,985	3	7,612	899	3	2,292
R-2: Residential	205	2	349	312	2	530
Trade	585					
Industry	197			71		
Institutional	181			10		
Parks&Recreation	0					
Agriculture	3,726	1/5 acres	633	1,811	1/5 acres	308
Incorporated Town	410			802		
residential	310	2	526	605	2	1,028
trade	7			14		
industrial	72			140		
institutional	22			43		
Totals by area	9,509		10,157	4,306		4,498

NORTHAMPTON COUNTY

	Permitted WPA D			Permitted WPA E		
Land Use Type	Developable Acres	units/ acre	Potential Units	Developable Acres	units/ acre	Potential Units
Rural Resid. & Village Area	628	2.178	1,163	2,218	2.178	4,105
Urban Development Area	2,394			2,871		
residential	1,836	2.178	3,998	2,044	2.178	4,452
commercial	151			111		
industry	96			128		
roads/railroads	206			490		
public	170			98		
Agricultural or Forestral Area	3,102	1	2,637	5,707	1	4,851
Total by Area	6,125		7,798	10,796		13,409

NITROGEN LOADING

8

SECTION 8: NITROGEN LOADING

INTRODUCTION

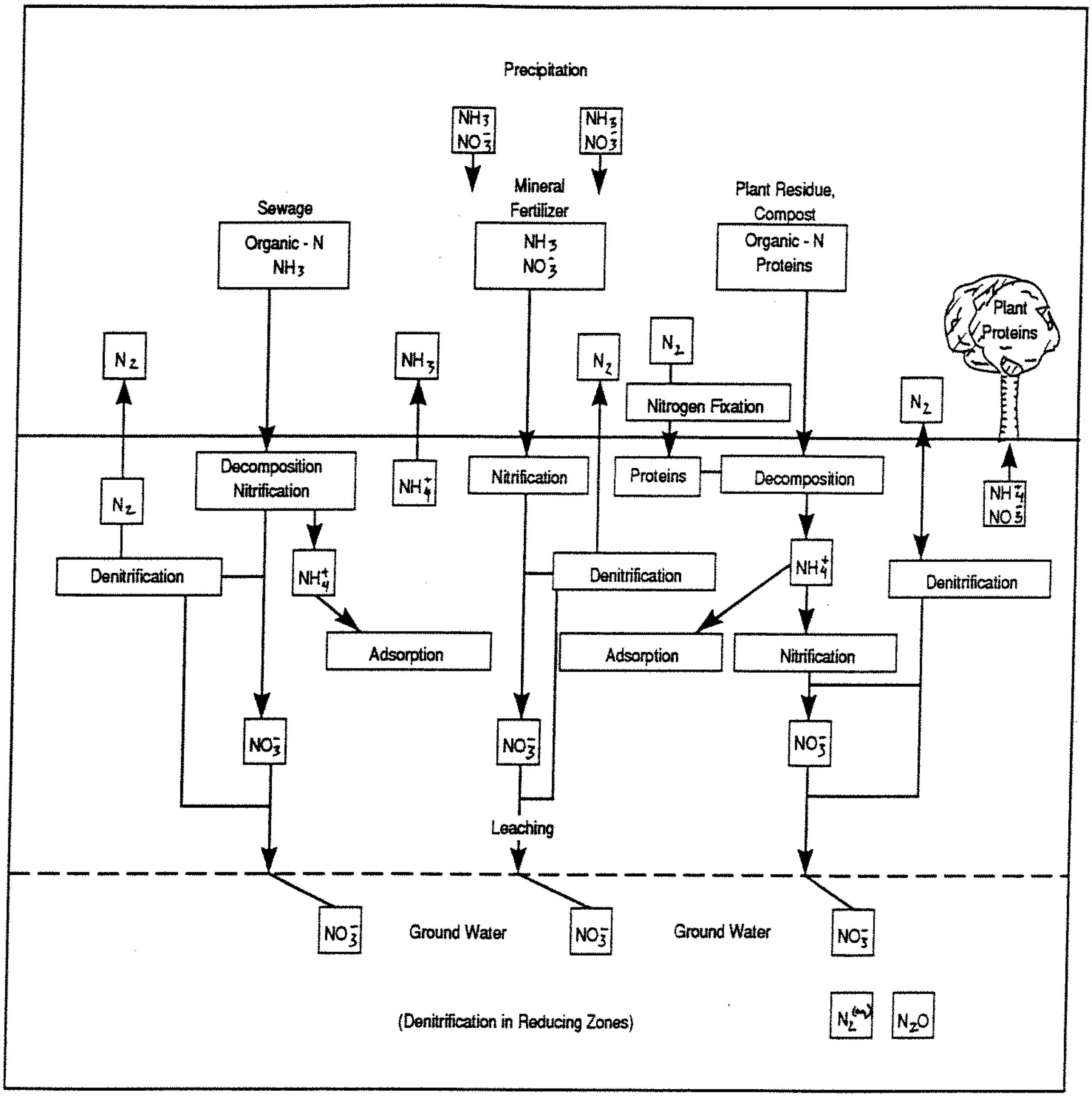
Nitrogen is present in surface and ground water environments in four primary forms. The forms are organic nitrogen, ammonium-nitrogen, nitrite-nitrogen and nitrate-nitrogen. Organic nitrogen consists of a variety of soluble, colloidal and particulate forms. Ammonium-nitrogen (NH_4^+) is characteristic of poorly oxygenated (anaerobic) conditions and is readily adsorbed by soil particles in the unsaturated, oxygenated zone above the water table where it is rapidly converted to nitrate-nitrogen. However, ammonium-nitrogen may travel long distances in areas where the saturated zone is anaerobic. Ammonium-nitrogen is the primary form of nitrogen in septic system effluent and in wetland soils. Nitrite-nitrogen (NO_2) is an unstable form which is rapidly transformed into nitrate-nitrogen, and so is usually present in very small quantities. Nitrate-nitrogen (NO_3) is characteristic of oxygenated (aerobic) conditions and is highly mobile in ground water. In this form, nitrogen may travel long distances with little attenuation. (Freeze and Cherry, 1979; Canter and Knox, 1986)

Nitrogen transformations are complex, bio-physio-chemical processes. Figure 8-1 illustrates some of the common nitrogen transformations, described below. The process by which organic nitrogen is transformed to ammonium-nitrogen is called *mineralization* or *ammonification,* and occurs under both aerobic and anaerobic conditions. The process whereby ammonium-nitrogen is transformed to nitrate-nitrogen is called *nitrification* and occurs under aerobic conditions. *Denitrification* is the process by which nitrate-nitrogen is converted to gaseous forms such as N_2 and released to the atmosphere. Denitrification occurs under anaerobic conditions, particularly within wetland soils. The opposite transformation, whereby atmospheric nitrogen is converted to ammonium nitrogen is called *nitrogen fixation,* and is performed by bacteria and blue-green algae (cyanobacteria). (Freeze and Cherry, 1979; Canter and Knox, 1986)

NITROGEN AS A CONTAMINANT

Although all forms of nitrogen are critical components of natural systems, nitrogen can cause water quality degradation if present in excessive quantities. In drinking water supplies, elevated nitrate-nitrogen levels can cause an illness known as infant cyanosis, methemoglobinemia, or "blue-baby syndrome" in infants, caused by the alteration of hemoglobin and subsequent problems with oxygen transport. In addition, high nitrate-nitrogen levels have been linked to the formation of carcinogenic nitrosamines (Porter, 1978). To reduce potential health risks, the U.S. EPA has established a drinking water standard of 10 milligrams per liter (mg/l) for nitrate-nitrogen. A statistical analysis of ground water samples collected on Long Island, New York, demonstrated that when median nitrate-nitrogen concentrations were 6 mg/l, 10 percent of the samples exceeded the 10 mg/l drinking water standard (Porter, 1978). To account for this variability, the Cape Cod Planning and Economic Development Commission (CCPEDC) and several towns across the state of Massachusetts have adopted a more conservative concentration of 5 mg/l, as a planning guideline. The Virginia State Water Control Board adopted a ground water standard of 5 mg/l for nitrate-nitrogen in the early 1970's. Since then, the anti-degradation policy supersedes these standards. In the case of Virginia, the numeric limits are meant as guidance and are for permitted discharge. The ground water standards are different and separate from drinking water standards, and are not levels that have to be reached should a clean-up be necessary. (T. Wagner, SWCB, personal communication, 1991).

Figure 8-1: Nitrogen Transformations



Adapted from Freeze and Cherry, 1979.

SOURCES OF NITROGEN

Nitrogen originates from a variety of natural and anthropogenic sources, including sewage, fertilizers (residential and agricultural), road runoff, precipitation, landfills, and wildlife. A discussion of published loading rates for these various sources is provided below.

Sewage

Sewage-derived nitrogen may be produced by a variety of sources, including sewage treatment plants, septage lagoons, on-site sewage disposal systems, exfiltration from leaking sewer mains and combined sewer overflows (CSO's). On the Eastern Shore, on-site sewage disposal systems are the primary source of nitrogen to the ground water.

The quantity of nitrogen produced by a given on-site sewage disposal system is a function of the volume and concentration of the effluent discharged, which, in turn, is dependent on the per capita water usage and the occupancy rate. Daily rates of water use may range from 36 to 150 gallons per person per day (EPA, 1980; Nelson et al., 1988) with average rates on the order of 50 to 75 gallons per day (gpd). In estimating sewage flow rates, however, it is important to differentiate between the amount of water actually used and the amount ultimately discharged to ground water as sewage flow. Typically, 20% of the water used may be lost through evaporation or transpiration during irrigation and other outside uses (Nelson et al., 1988). For the purpose of this study, a ground water discharge rate of 55 gpd per capita was used for sewage flow.

Quantification of household populations is very difficult, particularly in seasonal communities such as the Eastern Shore, where summer populations may be significantly higher than winter populations. For the purpose of this investigation, an average annual occupancy rate of three people per household was used, based on average occupancy rates as determined for Northampton County. However, a sensitivity analysis was conducted to evaluate household populations ranging from two to four people.

A review of the literature indicates that nitrogen concentrations in raw sewage may range from 20 to 100 mg/l. Once sewage enters a properly functioning septic system, however, some removal of this nitrogen occurs both within the septic tank and in the soils below the leaching area. Studies have indicated that between 30 to 60% of the nitrogen may be removed in this way (Porter, 1978; Andreoli et al., 1979). Thus, in estimating loading rates from on-site sewage disposal systems, it is important to use nitrogen concentrations in effluent discharging from the leaching area. Data on total nitrogen concentrations in effluent sampled either from the leaching area or from ground water immediately below the leaching area are summarized in Table 8-1.

Table 8-1: Total Nitrogen Concentrations in Septic System Effluent

Source	Concentration
Bouma et al., 1972	30 mg/l
Walker et al., 1973	40 mg/l
Dudley and Stevenson, 1973	14 mg/l
Magdoff, 1974	31 mg/l
Magdoff, 1974	41 mg/l
Reneau, 1977	23 mg/l
Brown and Assoc, 1980 (summary)	37 mg/l
Ellis, 1982	34 mg/l
Canter and Knox, 1986 (summary)	40 mg/l
Nelson et al., 1988 (summary)	34 mg/l

A critical review of these reports, particularly the more recent ones, suggests that an average effluent concentration of 40 mg/l is a conservative yet defensible value to use in evaluating water quality impacts of on-site sewage disposal. This value was used in our analyses. Using a flow rate of 55 gallons/capita/day and an average effluent concentration of 40 mg total nitrogen/l, the average loading rate per capita is 6.72 lbs N/year.

Fertilizers

Agricultural fertilizers are usually the primary nitrogen source to ground water in heavily farmed areas. Accomack and Northampton Counties are predominantly agricultural, with land in farms accounting for approximately 53% of the total land area. In Accomack County, poultry production is the main industry. The predominant crop grown in the two counties is soybeans, a plant which is a nitrogen-fixer and so does not require nitrogen fertilization. The remaining acreage of crop land requires a significant amount of fertilizer (see Table 3-5). For Accomack County this averages 89 lbs/acre and in Northampton County the average agricultural nitrogen application is 79 lbs/acre.

Fertilizer and manure applications and poultry production may contribute large quantities of nitrogen to the underlying aquifer depending upon the agricultural management practices in use. The application, production, and storage of fertilizers and animal wastes result in the most important nitrogen contributions.

From the Cooperative Extension Agents in both counties, information was gathered regarding crop type acreage and fertilizer application rates. This was used to calculate an average fertilizer application rate of 84 lbs N/acre/year, for all agricultural areas in both counties. An average leaching rate of 25% was assumed for farm fertilizers. Many researchers have documented nitrogen leaching rates that range from 1%-47%(Ritter, and Manger,1985; Bouk, 1984; Bacon, 1989; Bower, 1989; Owens, 1987; and Hubbard, 1986). Nitrogen leaching rates to ground water can be affected by many factors including: crop type, application rates, irrigation, soil types, application timing, fertilizer formulations, and climate. As such, the literature shows a wide range of nitrogen loading values. The value of 25% was chosen since it represents a value most often selected in modelling studies of nitrogen movement, and also because it represents a mid range of the values from the literature.

Animal Wastes

Given the high levels of organic and ammonium-nitrogen in manure, animal waste may function as both point and non-point sources of nitrogen contamination. Chicken manure, in particular, has a high nitrogen availability rate, making it easily leachable into ground water.

If wastes are produced or stored on open ground at poultry houses, rainwater can transport nitrogen by percolation through the wastes and into the soil and ground water. All poultry waste is assumed to be used as agricultural fertilizer for the purpose of this study. Prior to application as fertilizer, most manure remains in the poultry houses until it is cleaned out once or twice per year (J. Belote, personal communication, 1991). Storage of poultry wastes is usually thought to be a source of nutrients and pathogens that contaminate ground water. For this reason, on the Eastern Shore in Maryland, efforts are being made to construct storage sheds for poultry manure, rather than continue the current practice of letting manure pile up uncovered outside.

Natural mortality accounts for many tons of dead poultry birds. As explained in Section 3, the practice on the Eastern Shore of Virginia is to either bury or compost the chickens. The majority of chickens which die before being sent to the processing plant die within the first two weeks of life, and it is estimated that given the 1990 population, a total of 1.8 million pounds of dead birds had to be disposed. At 3.3% nitrogen (Keeton, 1980), dead chickens contributed 60,638 pounds of nitrogen to Accomack County in 1990.

Lawn Fertilizers

Fertilizers applied to residential lawns and golf courses contribute nitrogen to ground and surface waters. The pathway may be either direct, via surface runoff, or indirect, via gradual leaching to ground water. The amount of fertilizer that ultimately leaches into ground water is a function of the type of ground cover, soil characteristics, climate, type of fertilizer used, application rate, and the degree of irrigation/rainfall. A literature review of experiments conducted primarily on turf plots suggests that leaching rates may vary from less than 1% to 80%, depending on site specific conditions (see Table 8-2). Leaching rates rarely exceeded 30%, however, unless extremely high fertilization and irrigation rates were used (e.g. Nelson et al., 1980).

Table 8-2: Leaching Rates for Fertilizers Applied to Turf Areas

Reference	% Leached
Brown, 1977	2-27%
Brown, 1982	1-18%
Chichester, 1977	1-8%
Dowdell and Webster, 1980	2-5%
Hesketh, 1986	0-31%
Mancino, 1980	0-4%
Morton, 1988	2-14%
Nelson, 1980	5-81%
Petrovic, 1988	0-17%
Starr and DeRoo, 1981	<1%

Based on a review of this data, with particular emphasis on regional similarities, a leaching rate of 30% was selected as a conservative (worst case) average value for nitrogen applied as fertilizer to residential lawns within the study area.

The typical lawn size for a given lot will vary widely depending on overall lot size, residential character, and individual preferences. Few quantitative studies have been conducted of average lawn sizes. The Long Island, New York and the Barnstable County, Massachusetts 208 studies both used an average lawn area of 5,000 square feet. More recently, a survey conducted as part of the Yarmouth Water Resources Protection Plan documented an average lawn size of 4,350 square feet on half acre lots (Nelson et al., 1988). There have been no known studies on the Eastern Shore of Virginia regarding lawn sizes and application rates of fertilizers. For this study, an average lawn size of 5,000 square feet was used.

Fertilizer application rates are similarly difficult to quantify. The Cape Cod and Long Island 208 studies used an average annual application rate of three pounds per 1,000 square feet. The Yarmouth survey documented a similar annual application rate for homeowners (2.8 lbs/1,000 sq. ft.) and a higher annual application rate for professional lawn maintenance companies (4.7 lbs/1,000 sq. ft.). For this study, an average annual application rate of 3 lbs/1,000 sq. ft., equivalent to 39 lbs N/acre, and a leaching rate of 30% was used. Although lawn fertilization is not a widespread practice on the Eastern Shore of Virginia, these studies are the only means of taking into account any turf maintenance.

Landfills

Unlined landfills contribute large quantities of nitrogen to ground water through the decomposition of buried organic matter. Nitrogen loading from landfills was based on nitrogen concentrations in typical leachate, 218 mg/l (Patrick and Quarles, 1983). The area of the landfills was obtained from the Accomack-Northampton Planning District Commission, and an annual recharge rate of 24 inches per year was used (no vegetation/transpiration). This yielded a loading rate of 1184 lbs N/acre/year for landfills.

Septage Lagoons

Three septage lagoons are located on the Eastern Shore. These lagoons primarily receive the contents of septic tanks, pumped out according to proper maintenance procedures.

The nitrogen loading to ground water from septage lagoons is a product of the raw sewage load minus the amount attenuated in the septic tank, gaseous losses from the lagoon, and attenuation in the soil during percolation from the lagoon. The nitrogen concentration in raw sewage can vary from 20 to 100 mg/l (Metcalf & Eddy, 1979; Laak, 1980; Douglas, 1986), but the total load depends on the associated sewage flow. Nitrogen loads in untreated waste water have been reported from 8 to 13 lb/capita/year (Porter, 1978; Brandes, 1978; Laak, 1980; Camp and Meserve, 1974). Porter (1978) summarized a number of studies which found an average septic tank influent concentration of 65 mg/l, an average septic tank effluent concentration of 45 mg/l and an average removal of 31%.

Additional reduction occurs from gaseous losses from the lagoon and during percolation of septage into the soil. The estimated nitrogen concentration of septage reaching ground water can conservatively be set at 45 mg/l.

Pavement and Roof Runoff

Sources of nitrogen in pavement runoff include precipitation, soil erosion, leaf litter, street dirt, garbage, and animal waste. Nitrogen concentrations in road runoff can vary by an order of magnitude, depending on spacing between storms, the intensity and duration of a storm, and the timing of sample collection. The highest nutrient concentrations are generally found in the "first flush". A summary of typical road runoff values published in the literature is provided below:

Table 8-3: Total Nitrogen Concentrations in Road Runoff

Reference	Total Nitrogen Concentration
Koppelman, 1982	1.49 mg/l
Howie and Waller, 1986	1.13-2.15 mg/l
Lager et al., 1968	3-10 mg/l
Loehr, 1973	3 mg/l
Schmidt and Spencer, 1986	2.04 mg/l
Valiela and Costa, 1988	0.38 mg/l (27 um)*

*Dissolved Inorganic Nitrogen only

For the purposes of this analysis, a nitrogen concentration of 2.0 mg/l in road runoff was used. For roof-runoff, a nitrogen concentration of 0.75 mg/l was selected (Nelson et al., 1988).

ESTIMATION OF PAVED AREA/ROOF AREA

HWH estimated the total paved road area to be 15% of all land area (Nelson et al., 1988), multiplied by 55% since a typical 40 foot right of way includes a 22 foot width of actual pavement.

Driveway surface area was estimated to be 500 square feet and roof area to be 1500 square feet per residential unit (Nelson et al., 1988).

Businesses/Industrial/Institutional

The nitrogen loading from business, industrial, and institutional facilities was calculated to average the design sewage flow per acre for all current land uses in these areas. From the community, non-community, and non-transient non-community water supply list, population information was obtained for the number of persons served in motels, restaurants, campgrounds, trailer parks, hospitals, and nursing homes, as well as the number of employees working in offices and the number of students attending the schools. These data were then totaled per category and multiplied by the design flow per person, employee, or student, as estimated by the Virginia Water Control Board. From this, the total sewage flow for business, industrial, and institutional areas was obtained for each of the two counties. This number was divided by the number of acres currently under these land uses to obtain an average sewage flow of 423 gal/acre/day. The assumption was made that the sewage from these uses has a similar nitrogen concentration (40 mg/l) to residential sewage.

Precipitation

Nitrogen concentrations in precipitation vary regionally. As precipitation falls on vegetated areas much of the dissolved nitrogen is taken up by vegetative cover and within the root zone, and thus does not leach into the underlying aquifer. Based upon scientific literature, natural background levels on nitrate-nitrogen in ground water are typically 0.05 mg/l or less. This value was used in our analysis as a representation of natural background conditions.

NITROGEN LOADING ANALYSIS

The nitrogen loading rates used in our analyses were selected on the basis of the literature review outlined above, and also to correspond with a recently calibrated nitrogen loading model developed for the Town of Yarmouth, Massachusetts (Nelson et al., 1988). The loading rates for sewage and fertilizers originally used in this model have been slightly adjusted to reflect recent findings, which suggest that loading from on-site sewage disposal systems may be higher and loading from lawn fertilizers may be lower than previously thought. The loading rates used in our analysis are summarized in Table 8-4 below.

Once nitrogen has entered the ground water system, ultimate nitrate-nitrogen concentrations can be calculated using a simple mass balance equation, in which nitrogen levels are a function of the annual rate of nitrogen loading and the annual rate of dilution through recharge. Sources of recharge to ground water include precipitation, surface runoff from impervious areas and artificial recharge from on-site sewage disposal. Recharge rates used in the nitrogen loading analysis are summarized in Table 8-4. The nitrogen loading under existing conditions is presented in Tables 8-5 and 8-6.

Table 8-4: Nitrogen Loading Values

Source	Concentration	Loading Rate	Flow/Recharge
Sewage	40 mg N/liter	(6.72 lbs N/Person-yr)	55 gallons/person-day (165 gal/dwelling)
Business/Industrial/ Institutional	40 mg/l		423 gal/lot
Fertilizer (Lawns)		(0.9 lbs N/1000 sq ft-yr)	17 inches/year
Fertilizer (Agriculture)		84 lbs N/acre-yr, avg.	17 inches/year
Pavement Runoff	2.0 mg N/liter	(0.42 lbs N/1000 sq ft-yr)	34 inches/year
Roof Runoff	0.75 mg N/liter	(0.15 lbs N/1000 sq ft-yr)	34 inches/year
Landfills		1184 lbs N/acre-yr	24 inches/year
Septage Lagoons	45 mg/l		
Precipitation	0.05 mg/l		17 inches/year

Source: Adapted from Nelson et al., 1988

NITROGEN MODELLING RESULTS

Tables 8-5 and 8-6 present the results of the nitrogen loading model used by HWH to predict nitrogen concentrations in the ground water as a result of existing land use activities. The tables show that for Accomack, the total nitrogen from all sources is expected to result in a ground water concentration of 2.0 mg/l N. The results for Northampton show a similar average concentration of 1.9 mg/l N. These results represent an average nitrogen concentration across the entire county and do not reflect nitrogen concentrations at any specific location in the study area.

In Accomack County the majority of the loading of nitrogen is from agriculture (1,055,095 lbs per year). Septic system loading is the second highest source of nitrogen reaching the ground water. These findings reveal that on the average, across the entire county the nitrogen concentrations in the shallow ground water are acceptable. What the analysis does not reveal is that in order for the average conditions to reach 2 mg/l of nitrogen that there are many areas that will have significantly higher ground water nitrogen values.

Northampton County results show that the same categories of nitrogen inputs are contributors to the overall concentration of nitrogen in the ground water, however there are no septage lagoon and animal burial inputs. Even though the total nitrogen load in Northampton County is lower than in Accomack County (406,258 vs. 1,055,095 lbs/year) the resulting final recharge nitrogen loading concentration is approximately because the total recharge to the ground water is lower in Northampton County.

The results show that based on existing land use conditions, nitrogen concentrations in the shallow ground water are on the average acceptable and within state and local drinking water standards. These results are compared with existing water quality testing in the next section.

Table 8-5: Nitrogen Loading Calculations, Accomack Existing

INPUT FACTORS	
Number of Residential units	15,840
Sewage flow per house (gal/day)	165
Commercial/Industrial land (acres)	3,701
Com./Ind. sewage flow per acre (gal/day)	423
N-conc. in sewage effluent (mg/l)	40
Lawn area per house (square feet)	5,000
Pavement per house (square feet)	500
Road area (square feet)	130,680,000
Roof area per house (square feet)	1,500
Agricultural area (acres) [those acres that are fertilized]	47,420
Landfills (acres)	125
Septage lagoons (gallons/yr)	1,170,000
Septage N concentration (mg/l)	45
Animal burial (lbs /yr)	1,837,500
Total recharge area (acres)	234,269
Recharge rate for pervious area (in/yr)	17
Recharge rate for impervious area (in/yr)	34

INPUT	CALCULATIONS	RESULTS
Sewage (gal/day)		CALCULATED LOADING (LBS/YR)
3,929,123	x N-conc (mg/l) x 3.785 l/gal x 365 days/yr : 454000 mg/lb	478,254
Lawn area (sq ft)		
79,200,000	x 0.0009 lb N/sq ft	71,280
	application rate 3 lb/1000 sq ft x 30% leaching rate	
Pavement area (sq ft)		
138,600,000	x 0.00042 lb N/sq ft	58,212
Roof area (sq ft)		
23,760,000	x 0.00015 lb N/sq ft	3,564
Natural area (acres)		
177,478	x 43560 sq ft/acre x 0.000005 lb N/sq ft	38,655
Other Sources		
Agriculture (acres)		
47,420	x 89 lbs N/acre/year x 25% leaching rate	1,055,095
Landfills (acres)		
125	1184 lbs N/acre/year	148,000
Septage Lagoons (gal/year)		
1,170,000	x N-conc (mg/l) x 3.785 l/gal: 454000 mg/lb	634
Animal burial (lbs/year)		
1,837,500	x 3.3 % N concentration	60,638
	TOTAL NITROGEN LOADING (LBS/YR)	1,914,331
		TOTAL RECHARGE (MG/YR)
Recharge from sew/septage (gal/day)		
3,929,123	x 365 days/yr : 1,000,000 gal/million gal	1,435
Total pervious area (sq ft)		
9,956,344,860	x 17 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	105,504
Total impervious area (sq ft)		
Without landfills	x 34 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	5,149
242,967,780		
Landfills (sq ft)	x 24 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	81
5,445,000		
	TOTAL RECHARGE (MGAL/YR)	112,170
TOTAL NITROGEN LOAD/TOTAL RECHARGE X 454,000 MG/LB : 3,785,000 L/MGAL		
	=RECHARGE NITROGEN CONCENTRATION (mg/l or ppm)	2.0

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Table 8-6: Nitrogen Loading Calculations, Northampton Existing

INPUT FACTORS

Number of Residential units	6,183
Sewage flow per house (gal/day)	165
Commercial/Industrial land (acres)	940
Com./Ind. sewage flow per acre	423
N-conc. in sewage effluent (mg/l)	40
Lawn area per house (square feet)	5,000
Pavement per house (square feet)	500
Road area (square feet)	109,117,800
Roof area per house (square feet)	1,500
Agricultural area (acres) [those acres that are fertilized]	20,570
Landfills (acres)	78
Septage lagoons (gallons/yr)	0
Septage N concentration (mg/l)	45
Animal burial (lbs /yr)	0
Total recharge area (acres)	94,447
Recharge rate for pervious area (in/yr)	17
Recharge rate for impervious area (in/yr)	34

INPUT	CALCULATIONS	RESULTS
Sewage (gal/day)		CALCULATED LOADING (LBS/YR)
1,167,815	x N-conc (mg/l) x 3.785 l/gal x 365 days/yr : 454000 mg/lb	142,147
Lawn area (sq ft)		
30,915,000	x 0.0009 lb N/sq ft	27,824
	application rate 3 lb/1000 sq ft x 30% leaching rate	
Pavement area (sq ft)		
112,209,300	x 0.00042 lb N/sq ft	47,128
Roof area (sq ft)		
9,274,500	x 0.00015 lb N/sq ft	1,391
Natural area (acres)		
69,360	x 43560 sq ft/acre x 0.000005 lb N/sq ft	15,107
Other Sources		
Agriculture (acres)		
20,570	x 79 lbs N/acre x 25% leaching rate	406,258
Landfills (acres)		
78	1184 lbs N/acre/year	92,352
Septage Lagoons (gal/year)		
0	x N-conc (mg/l) x 3.785 l/gal: 454000 mg/lb	0
Animal burial (lbs/year)		
0	x 3.3 % N concentration	0
	TOTAL NITROGEN LOADING (LBS/YR)	732,206
		TOTAL RECHARGE (MG/YR)
Recharge from sew/septage (gal/day)		
1,167,815	x 365 days/yr : 1,000,000 gal/million gal	426
Total pervious area (sq ft)		
3,968,756,640	x 17 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	42,056
Total impervious area (sq ft)		
Without Landfills	x 34 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	3,009
141,957,000		
Landfills (sq ft)	x 24 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	51
3,397,680		
	TOTAL RECHARGE (MGAL/YR)	45,490
TOTAL NITROGEN LOAD/TOTAL RECHARGE X 454,000 MG/LB : 3,785,000 L/MGAL		
	=RECHARGE NITROGEN CONCENTRATION (mg/l or ppm)	1.9

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EXISTING WATER QUALITY TESTING RESULTS

The following section summarizes four studies or data bases which include test results for nitrogen content. These sources were researched in order to determine the extent of nitrate-nitrogen present in wells The majority of wells sampled, show low nitrate concentrations, although several results show very high nitrogen values that are probably related to a specific high nitrogen loading source.

Virginia Department of Health, Public Water System Inventory

The Virginia Department of Health tests public water supply wells regularly for several contaminants. The facilities included in this inventory fall under the categories of community, non-community, and non-transient non-community water supplies. Sample analysis dates generally fall within the years 1988 to 1990. The Table 8-7 is a synopsis of the information obtained from the VDH data base.

In general, the nitrate concentrations from these samples are low, especially in Northampton County. In Accomack County, three facilities had samples which tested above 5 mg/l. Four readings taken for a Town of Parksley well had nitrate nitrogen levels of 6.6, 6.9, 5.65, and 6.2 mg/l. A NASA facility, Charles G. Ward Building F-16, registered the highest nitrate levels of the testing group. Eight samples from that facility ranged between 7.27 and 11.5 mg/l. Finally, a well at Stoney Point Decoys was measured to have a nitrate nitrogen concentration of 7.11 mg/l. Most of these wells draw water from the deeper confined aquifer where nitrogen concentrations are expected to be very low. The higher readings reflected in this data base are probably the result of influences from the shallow aquifer system.

Table 8 -7: Virginia Department of Health Public Water Test Results

	Accomack County	Northampton County
Average Nitrate-Nitrogen concentration	1.27 mg/l	0.04 mg/l
Range, Nitrate-Nitrogen concentration	0.01-11.5 mg/l	0.01-1.63 mg/l
Number of samples	92	31
Number of facilities	24	11
Number of samples above 5.0 mg/l NO_3	13	0
Number of samples above 10.0 mg/l NO_3	3	0

State Water Control Board, EPA STORET Database

The EPA maintains a database which contains a summary of ground water test results for public water supplies. This information is available to all states. Due to budget limitations, recent data has not been entered into the system, and the available information includes results from the late 1970's to late

1980's. Again, nitrate-nitrogen levels were low on average. Out of approximately 500 wells in Accomack and 150 in Northampton, only seven (7) wells reported nitrate-nitrogen levels above 5.00 mg/l. Table 8-8 summarizes results for the wells which tested high.

Most wells which tested high for nitrate-nitrogen are shallow; therefore they draw water from the unconfined Columbia aquifer. The one exception is the town of Parksley Well #1, which has a screen depth of 160 feet. In the Virginia Department of Health database, as described above, Parksley also reported high nitrate-nitrogen levels. The results from these two sources may be cause for further investigation into the quality of the drinking water supply for the town of Parksley.

Observation Well #103A is located on Church Neck, an area devoted mainly to agricultural practices (as delineated in the Northampton County Comprehensive Plan, 1990). The high nitrate levels here may indicate a correlation between fertilizer use and elevated nitrate-nitrogen levels in the ground water. However, the majority of wells in the two counties showed no contamination and it is likely that many were likewise located in agricultural areas.

Table 8-8: Nitrate-Nitrogen Levels Above 5 mg/l in STORET (EPA) File, Accomack and Northampton Counties

Facility	Date sampled	Nitrate -nitrogen level (mg/l)	Screen Depth (Feet)
Accomack County			
Town of Parksley #1	6/27/77	8.00	160
	11/14/77	6.50	
	2/23/78	6.00	
Town of Parksley #2	12/9/74	8.50	64
Observation Well #114S	2/13/80	9.50	40, 30, 40
	2/13/80	10.00	
	2/13/80	10.00	
	7/9/84	7.00	
Atlantic Fire House	8/4/81	5.00	69, 63, 69
Northampton County			
Observation Well #103A	9/28/77	13.00	40, 27, 37
	9/28/77	11.00	
	5/11/79	17.60	
	6/26/84	24.00	
Observation Well #104S	10/3/77	6.90	36, 26, 36
	10/3/77	6.90	
	8/18/80	7.50	
	8/19/80	9.00	
	8/4/86	8.25	
Brown &Root ST1 0-5	12/1/77	17.00	20, 40

Virginia Department of Health, Eastern Shore Health District

The Eastern Shore Health District conducted a shallow well baseline monitoring project in April of 1990. The testing was done in response to studies completed by the United States Geological Survey which indicate that wells installed at shallow depths may be at risk of having high levels of nitrates and pesticides. The Health Department intends to confirm or deny these results, and if necessary, change regulations to prohibit the use of water supplies proven to be at risk.

The written report of the baseline study is not yet available. Lab results were obtained, and are summarized below in Table 8-9. Present information available does not include the location of sampling sites. Twelve samples were taken in Accomack County, and ten in Northampton County. Wells sampled were domestic drinking wells drilled to a depth of 30 to 50 feet.

Table 8-9: Eastern Shore Health District, Shallow Well Monitoring Results

	Accomack County	Northampton County
Average Nitrate-nitrogen concentration	1.11 mg/l	4.36 mg/l
Number of samples	12	10
Number of samples above 5.0 mg/l NO_3	1	4
Number of samples above 10.0 mg/l NO_3	0	2

Average concentrations for nitrate nitrogen were much higher in Northampton County in this study than in the deeper wells in the county tested by the state. Although the sample size was small for this monitoring project, some of the levels of nitrogen were high, and the test should serve as a warning for residents with wells dug in the shallow aquifer. With knowledge of the locations of these sites, origins of the nitrate-nitrogen (agriculture, septic tanks, etc.) could be better determined and assessed. Two types of pesticides, triazines and carbanates, were tested, and none were detected in the 22 samples.

A baseline study of deeper wells was also conducted by the Eastern Shore Health District. At the time of publication of this report, no information about the baseline study has been made available. This Ground Water Management and Protection Plan is primarily concerned with large withdrawals from and preservation of the deeper Yorktown-Eastover aquifer. However, studies of the kind that the Eastern Shore Health District has conducted are invaluable as documentation for future use and for the determination of present contamination which may reach the lower aquifers at a later date.

USGS Water Quality Sampling

The United States Geological Survey is currently involved in a water quality study of shallow wells on the Delmarva Peninsula as a continuation of a water quality analysis through 1987 (USGS Open File Report 89-34). Table 8-10 presents the unpublished results of nitrate-nitrogen levels along two transects, and isolated locations along the mainland. Samples have been taken from August 1988 to

Table 8-10: USGS Nitrogen Sampling

ID	Lat	Long	Depth	Sample Date-1	NO3-N	Sample Date-2	NO3-N	Sample Date-3	NO3-N	Sample Date-4	NO3-N	Sample Date-5	NO3-N	Sample Date-6	NO3-N
Creek-Up	371151	755725	0.0									Jun-90	4.70		
Creek-Dn	371147	755700	0.0									Jun-90	5.30	Nov-90	4.80
Well 1	371145	755659	6.6									Jun-90	14.00	Nov-90	13.00
Well 2	371143	755658	8.9									Jun-90	6.60	Nov-90	13.00
Well 4A	371125	755702	16.8	Aug-88	9.70	Dec-88	10.00	Jun-89	9.60						
Well 4B	371125	755702	26.0	Aug-88	9.60			Jun-89	9.20					Nov-90	9.60
Well 4C	371125	755702	41.5	Aug-88	9.20									Nov-90	7.10
Well 4D	371125	755702	61.5	Aug-88	0.37			Jun-89	-					Nov-90	0.10
Well 4E	371125	755702	16.8											Nov-90	19.00
Well 5A	371121	755650	9.5	Aug-88	8.90	Dec-88	10.00	Jun-89	8.90					Nov-90	6.20
Well 5B	371121	755650	28.0	Aug-88	31.00									Nov-90	10.00
Well 6	371128	755721	15.0			Dec-88	34.00	Jun-89	29.00						
Well 7A	371136	755802	12.0	Aug-88	9.10	Dec-88	9.40	Jun-89	15.00						
Well 7B	371136	755802	31.0	Aug-88	3.50			Jun-89	2.60						
Well 8	371136	755748	12.0			Dec-88	18.00								
Well 11	371301	755844	13.0	Aug-88	12.00					Aug-89	7.80				
Well 12	371302	755832	13.0	Aug-88	38.00										
Well 13	371118	755635	6.6	Aug-88	0.10	Dec-88	0.15	Jun-89	0.10						
Well 14	371117	755631	6.7	Aug-88	0.10										
AC 201D	375744	753536	42.0							Sep-89	-				
AC 204S	375535	753249	22.5							Sep-89	0.13				
AC 204D	375535	753249	48.5							Sep-89	0.10				
AC 205S	375552	753018	22.0							Sep-89	9.60				
SOW 110S	375723	753444	36.0							Jan-90	0.10				
P32 D	373049	754841	30.0	Aug-88	11.00										
P32 S	373049	754841	22.0	Aug-88	9.20										
P31 D	373330	754946	40.0	Aug-88	0.10										
P31 S	373330	754946	13.0	Aug-88	15.00										
P31AD	373916	754108	30.0	Aug-88	6.20										
P31AS	373916	754108	13.0	Aug-88	8.10										
P30 D	374755	753710	28.0	Aug-88	0.10										
P30 S	374755	753710	15.0	Aug-88	0.29										

November 1990. The depth of the wells range from 6.6 to 61.5 feet. Nitrate-nitrogen levels are generally high. Out of a total of 51 samples, 69% of them have nitrate-nitrogen levels of 5 mg/l or greater, and 31% are greater than or equal to the recommended limit of 10 mg/l. The average of all the samples is 9.2 mg/l, with the highest reading at 38.0 mg/l.

The nitrate-nitrogen levels here are on average much higher than in the three studies previously described. Again, full analysis cannot be conducted because the USGS report has not yet been published.

NITROGEN LOADING ANALYSIS UNDER FUTURE BUILDOUT CONDITIONS

A nitrogen loading analysis was conducted in the spine recharge area of each of the five wellhead protection areas (WPA's) under permitted pumping conditions. This was done to predict the future nitrogen concentration in the ground water which can be expected if the land area in the spine is built out under the current regulations. A summary of the results of this analysis are presented in Table 8-11. The more detailed computer spreadsheets per area can be found in Appendix F. The nitrogen loading analysis indicates that the nitrogen concentrations in all but one WPA exceed the EPA drinking water standard of 10 mg/l nitrate-nitrogen.

Table 8-11: Nitrogen Concentration By Wellhead Protection Area

Wellhead Protection area	Predicted Average Nitrogen Concentration (mg/l)
A, all soils	5.6
A, w/o Arapahoe soils	5.5
B, all soils	13.5
B, w/o Arapahoe soils	13.5
C	8.3
D	7.8
E	7.1

A breakdown of the nitrogen loading by source and WPA are presented in Table 8-12. The major sources of nitrogen vary depending upon the land use in that area.

Table 8-12: Nitrogen Loading Under Future Buildout Conditions In Spine Of Wellhead Protection Areas Per Source (Percent of Total)

Wellhead Protection Area	load from sewage	load from lawns	load from agriculture	load from landfills	load from animal burial	TOTAL
A, all soils	20	4	65	0	10	99
A, w/o Arapahoe soils	5	0	83	0	10	98
B, all soils	20	2	16	58	3	99
B, w/o Arapahoe soils	20	2	16	58	3	99
C	67	12	14	0	5	98
D	69	14	9	0	6	98
E	77	17	4	0	0	98

Note: pavement, roofs, natural area and septage lagoons were left off this summary table because these sources contributed less than one percent of the total nitrogen load

The main sources of nitrogen under future buildout conditions are residential and commercial sewage, agriculture, and chicken burial. The actual percentage that these sources contribute vary by WPA.

In those WPA's where composting of dead chickens occurs, it can be a significant source of nitrogen, up to 10% of the total load. Agriculture contributes between 4 and 83 percent of the nitrogen load depending on the wellhead area. The landfill located within in the spine of WPA B is predicted to contribute 58 percent of the nitrogen concentration under future buildout conditions in this wellhead protection area. This analysis demonstrates that a landfill located on the spine recharge area has the potential to have a significant effect on water quality, assuming that the landfill is unlined.

In WPA E, in Northampton County residential sewage is the main source of nitrogen, comprising 77 percent of the nitrogen load. Sewage is the main source of nitrogen in this area because there are no poultry farms in Northampton County, and under future buildout conditions, the agriculturally zoned area can be completely subdivided into house lots, which was the scenario tested in this buildout. Considering the low residential growth rate and the current high level of agriculture, this may be an unlikely scenario.

Nitrogen loading scenarios discounting soils poorly suited to development (Arapahoe) were analyzed for northern Accomack County. Though the overall loading of nitrogen does not change, the major contributor (agriculture) increases from 65% to 83% when residential development is lowered. Thus, if agriculture is a more dominant land use in the future than residential development, nitrogen loading from farming will become the most significant contributor of this contaminant.

The future nitrogen loading results indicate that, nitrogen concentrations in the shallow Columbia aquifer are expected to increase to levels approaching the drinking water standard of 10 mg/l. In WPA B the concentration is expected to exceed this value (13.5 mg/l). Since these values are average recharge concentrations, individual measurements of ground water quality will most likely result in much higher concentrations at locations near major sources of nitrogen use or loading. The landfill located in WPA B should be assessed in more detail to determine its potential impact on water quality and nitrogen loading. In addition, the implementation of agricultural nutrient management plans will help to lower the average nitrogen concentration in the ground water. Other than sewering, little can be done to reduce the load from septic systems. Guiding development and sanitary wastewater discharges away from the spine recharge will help to reduce the nitrogen load from this source. As the area develops and more residential units are constructed, loading from lawns is expected to increase. Public education on the proper use of lawn fertilizers is the major mechanism to control this potential source of nitrogen.

These results indicate that under current conditions, nitrogen values in the ground water on the average are very good due to the large amounts of open and forested land found on the Eastern Shore. In addition, nitrogen concentrations in the vicinity of agricultural operations can be expected to be higher than background levels. More water quality testing and analysis in the Columbia aquifer is needed to obtain a better representation of water quality and how it changes across the Eastern Shore.