APPENDIX 2 - WATER QUALITY ANALYSIS: NITRATE DILUTION MODEL

Warren County Strategic Growth Plan

Water Quality Analysis: Recharge-Based Nitrate Dilution Model

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Note – Appendices are available upon request from the Warren County Planning Department

WARREN COUNTY WATER QUALITY ANALYSIS

I. Introduction

The Warren County Strategic Plan is being developed to coordinate and guide land use planning by local municipalities. The Strategic Plan sets forth 11 goals for future development, one of which is the protection and enhancement of water quality and quantity. Thus, the New Jersey Geological Survey's "Recharge-Based Nitrate Dilution Model for New Jersey" was used to examine the potential impacts of minimum lot size on water quality for individual wastewater treatment systems.

The following report documents the methodology and assumptions used to apply this model to Warren County. The results of the analysis are then presented for each municipality. The potential application of alternative individual wastewater disposal systems is also reviewed.

By developing an understanding of environmental constraints, the County, Steering Committee members, municipalities and other interested parties can determine the feasibility of implementing the defined goals, refine goals that do not comply with established environmental initiatives, protect valuable environmental features, and plan upgrades or expansion to existing infrastructure.

II. Environmental Impacts of Onsite Waste Disposal Systems

The effluent from individual wastewater disposal systems has the potential to impair water quality if the systems. As noted by the NJGS "where these systems are too close together the cumulative impact may exceed the natural ability of the environment to clean and dilute the effluent…"[1]

Nitrate is one pollutant discharged from individual on-site waste disposal systems. Nitrate production is a result of the anaerobic conversion of ammonia by bacteria in the unsaturated zone.[2] Concentrations of nitrate in drinking water greater than 10mg/l can cause methemoglobinemia in infants and are a health threat to the elderly.[3] Nitrate contamination is also typically an indicator of other types of groundwater contamination.

Most developable properties within Warren County are located within the Northwest New Jersey Sole Source Aquifer. Sole source aquifers serve as primary drinking water sources and are irreplaceable should they become contaminated. Sole source aquifers typically provide more than 50% of the drinking water in a designated area.

III. Model Description

The Recharge-Based Nitrate-Dilution Model is a synthesis of two independent methods: the NJGS Groundwater Recharge Model and a modified version of the Trela-Douglas Nitrate Dilution Model. Each of the three models is explained below.

a. NJGS Groundwater Recharge Model

Onsite waste disposal systems allow development in rural areas not currently serviced by municipal sewer systems; however, they do discharge pollutants into the groundwater. In response to growth in rural areas of New Jersey, the New Jersey Geological Survey (NJGS) developed the Groundwater Recharge model (GSR-32) in 1993. The NJGS model calculates groundwater recharge per annum for a particular parcel as base on lot size, municipality, soil type and land use. As defined by the NJGS, groundwater recharge is the water that infiltrates through the soil, reaching the groundwater table. Therefore, lots located in undeveloped areas on very permeable soils will experience greater groundwater recharge than lots located in highly developed urban areas on clay, or other less permeable soils.

The NJGS model is represented by the following equation to calculate recharge:

$$R = s(1 - 0.179A^{-0.5708}) \qquad \text{Equation 1}$$

where:

s	=	Maximum recharge for soil type (in/year)
A	=	Area (acres)

b. Trela-Douglas Nitrate Dilution Model

The Trela-Douglas Nitrate Dilution Model was developed in 1978 to determine the lot size necessary to dilute the concentration of nitrate in groundwater. The Trela-Douglas Nitrate Dilution Model utilizes a user-defined nitrate concentration Standard to determine the area needed for each onsite waste disposal unit in order to reach this Standard. The following equation represents groundwater recharge in inches per year, using the Trela-Douglas model. Equation 2 represents the modified Trela-Douglas Nitrate Dilution Model, where recharge varies with respect to impervious surface on a subject property.

$$R = 0.0134HW_u \frac{C_e - C_q}{(A(1 - 0.179A^{-0.5708})C_q} \qquad \text{Equation 2}$$

where:

H	=	Household size
W_u	=	Water usage
C_e	=	Concentration of Nitrate in Effluent (mg/L)
C_q	=	Water Quality Standard (mg/L)
A	=	Lot Size (acres)

As illustrated by the Equation 1 and Equation 2, the NJGS Modelcalculates groundwater recharge by evaluating lot size and maximum recharge for given soil types. Alternately, the Trela-Douglas Nitrate Dilution Model calculates groundwater recharge by evaluating household size, land use and cover conditions, water consumption, and nitrate concentration before and after treatment.

c. NJGS Residential Carrying Capacity Model

The NJGS Model and the Trela-Douglas Nitrate Dilution Model both express expected groundwater recharge rates for, however, the determined rates are based on two independent sets of variables.

If the Equation 1 and Equation 2 are set equal to one another, Equation 3 results. The unknown variable in Equation 3 is A, or lot size. When Equation 3 is represented graphically, the minimum lot size necessary to dilute nitrate from the effluent generated by onsite waste disposal systems is equal to the point that the two curves, or two models intersect. Equation 3 is also known as "A Model of Residential Carrying Capacity for New Jersey Based on Water Quality". This model was developed in May of 2000 by the New Jersey Geological Survey and published by the New Jersey Department of Environmental Protection, Division of Science, Research and Technology. Figure 1 graphically illustrates the Water Quality Model for Allamuchy Township, in Zoning District SFR-1. This Example utilizes a 2mg/L water quality standard and recharge data available for Edneyville soils.

$$0.0134HW_u \frac{C_e - C_q}{A(1-0.179A^{-0.5708})C_q} = s(1-0.179A^{-0.5708}) \qquad \text{Equation 3}$$

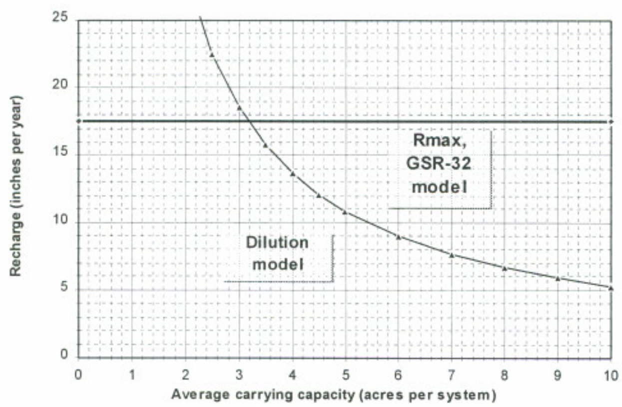

Figure 1 – Nitrate Dilution Model. Allamuchy Township, Zoning District SFR-1, 2 mg/L Water Quality Goal

IV. Water Quality Thresholds

The modeling described above was used to assess the ability of soils under existing zoning densities to adequately protect water quality. The modeling was performed at the two thresholds – 10 mg/l and 2 mg/l. The lot sizes recommended by the modeling are for overall density of a subdivision and do not necessarily apply to each lot within a subdivision.

The 10 mg/l threshold is based on several factors. The maximum contaminant level Standard (MCLG), a non-enforceable level, for nitrate in drinking water is 10 mg/L in accordance with the 1974 Safe Drinking Water Act. The Maximum Contaminant Level (MCL), which is the enforceable standard, has also been set at 10 mg/L. If water is consumed with concentrations of nitrate greater than this primary drinking water standard, it can cause health problems for infants and the elderly.

The State of New Jersey uses a more stringent standard of 2 mg/l to protect water quality. This standard represents a desired nitrate concentration found in groundwater at the property boundary of a particular lot. This concentration is typical of nitrate levels found naturally in groundwater in developed areas without agricultural land uses. Thus, this standard is consistent with the State's policy of non-degradation of water quality.

The 10 mg/l standard is useful for determining the minimum lots sizes for clustering in each community. The State's Realty Improvement Act establishes 8 mg/l as the minimum threshold for minimum lot sizes in cluster subdivisions. In order to further protect water quality in cluster subdivisions, the New Jersey Geological Survey recommends that deeper well casings be used and lots be arranged so that septic systems are down gradient of wells and the permanently protected open space replenishes the wells.

V. Basic Assumptions and Methodology

The model for Warren County was developed by generating a list of soil types available within a given municipality. The soil types located in each municipality were determined by analyzing existing soils data obtained from the Warren County Planning Department. An analysis of each soil was performed on developable land in each municipality within Warren County to determine the estimated recharge rate. Soils with the highest estimated recharge rate as well as the lowest recharge rate were selected for each municipality for use within the NJGS model. Soils with higher recharge rates require smaller lot sizes than soils with lower recharge rates. By utilizing the highest and lowest recharge rate values, a range of suggested lot sizes can be developed.

Other assumptions used in this analysis include:

1. The model is only used to evaluate residential carrying capacity. Commercial development is not analyzed as part of this model.

2. It was assumed that zoning districts with lot sizes greater than 0.5 acre lots are not currently serviced with municipal sanitary sewer. It was then assumed that zoning districts less than 0.5 acres are serviced by municipal sanitary sewer.

3. All soils located within the municipality are also located within the identified developable areas.

4. This model did not account for potential impacts on individual wells. It was assumed that all on-site waste disposal systems will be installed with proper setbacks from all individual well systems.

5. Average household sizes for each municipality were obtained from the year 2000 United States Census.

7. Household size will remain consistent as growth occurs.

8. A nitrate-loading rate of 10 pounds per person per year was assumed for all municipalities.

9. Water usage occurs at a rate of 88 gallons per capita per date.

10. The nitrogen concentration of the effluent is 40 mg/L.

The Water Quality Model was utilized for each Township and Boro located in Warren County. Belvidere and Phillipsburg were removed from the model, since it can be assumed that all developable parcels are serviced by municipal sanitary sewer.

Each zoning district in each municipality was first analyzed to determine if it met basic criteria for onsite waste disposal. For example, there must be developable land within the zoning district and specified lot sizes within the district must be greater than 0.5 acres.

The model was then run using three separate nitrate dilution conditions. The first two conditions assumed traditional septic systems were used, namely, systems that utilize a concrete tank with an absorption field. One trial was run using the standard of 2 mg/L and the second was run using the 10 mg/L MCL for traditional individual wastewater disposal systems. The third nitrate dilution condition was analyzed for alternative wastewater disposal systems approved by the New Jersey Pinelands Commission.

The results of the Water Quality Model indicate the minimum lot size needed for each onsite waste disposal system given the variables described in preceding paragraphs. When compared with the minimum lot sizes assigned to zoning districts, the zoning regulations can be analyzed in terms of the impacts growth may have on the environment.

VI. Model Results

The model was performed for each municipality not entirely serviced by sanitary sewer within Warren County. Phillipsburg, Belvidere and Washington Boro are entirely serviced by sanitary sewer. It was not necessary to conduct the model on those municipalities. The results from this model can be used to identify possible zoning changes or deficiencies, identify areas where the extension of the municipal sewer system may be prudent or utilize alternative on site systems that have been proven to reduce the nitrogen in the effluent, thus allowing density to be increased.

For each water quality standard, the minimum and maximum lot sizes required to dilute nitrate from onsite waste disposal systems to the specified level for each zoning district was determined. A soil analysis was performed for each zoning district to determine which soils, located on developable land, provided the lowest and highest recharge rates. Those soils with the lowest recharge rates resulted in the largest area required to dilute nitrate to the specified level. Those soils with the highest recharge rates resulted in the smallest area required to dilute nitrate to the specified level.

Allamuchy

From the 2000 Census, a population density of 2.28 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 3.2 acres per system to 3.8 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.7 acres per system to 0.9 acres per system.

Allamuchy					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
SFR 1	1 Acre	3.2	3.8	0.7	0.9
RR	4 Acres		3.2		0.7
PPE	1 Acre		3.8		0.9

Soil Analysis		
Zoning	Soil Type	
	Highest Recharge Rate	Lowest Recharge Rate
SFR 1	Edneyville	Bartley
RR	Edneyville	Washington
PPE	Edneyville	Bartley

As illustrated in the table above, the minimum lot sizes required by the SFR 1 and PPE zoning districts are insufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The lot sizes, however, are sufficient to comply with the 10 mg/L Drinking Water MCL.

Alpha

From the 2000 Census, a population density of 2.5 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.1 acres per system to 4.8 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

Alpha					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-1	3 Acres	4.1	4.1	0.9	0.9
R-2	2 Acres		4.8		1.1

Soil Analysis		
Zoning	Soil Type	
	Highest Recharge Rate	Lowest Recharge Rate
R-1	Washington	Washington
R-2	Washington	Bartley

As illustrated in the table above, the minimum lot sizes required by the zoning districts analyzed are insufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The lot sizes, however, are sufficient to comply with the 10 mg/L Drinking Water MCL.

Blairstown

From the 2000 Census, a population density of 2.81 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.4 acres per system to 5.1 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.1 acres per system.

Blairstown					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-5	5 Acres	4.4	5.1	1.0	1.1
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
R-5		Washington		Bartley	

As illustrated in the table above, the minimum lot sizes required by the zoning districts analyzed are sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary if the soils on the property have recharge rates better than Bartley soils. The lot sizes are sufficient to comply with the 10 mg/L Drinking Water MCL.

In addition, approximately 52 acres are zoned VN and VR that require only 10,000 sf minimum lot size. This area does not meet the minimum area required to meet the Drinking Water MCL.

Franklin

From the 2000 Census, a population density of 2.84 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.6 acres per system to 5.5 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.2 acres per system.

Franklin					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
RC R-75	5 Acres 30,000 SF	4.6 4.7	5.5	1.0 1.1	1.2
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
RC R-75		Parker Washington		Bartley Bartley	

As illustrated in the table above, the minimum lot size required by the RC zoning district is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality

Standard at the property boundary if the soils on the property have recharge rates better than Bartley soils. The lot size required by the R-75 zoning district is insufficient to dilute nitrate from onsite waste disposal system effluent for either the 2 mg/L Water Quality Standard or the 10 mg/L Drinking Water MCL.

Freilinghuysen

From the 2000 Census, a population density of 2.81 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.1 acres per system to 4.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

Freilinghuysen					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
AR-4	4 Acres	4.1	4.9	0.9	1.1
AR-3	3 Acres		4.9		1.1
VN-2	2 Acres		4.2		0.9
VN-1	1 Acres		4.2		0.9
Soil Analysis					
Zoning		Soil Type			
		Highest Recharge Rate		Lowest Recharge Rate	
AR-4		Washington		Bartley	
AR-3		Washington		Bartley	
VN-2		Washington		Hazen	
VN-1		Washington		Hazen	

As illustrated by the table above, the minimum lot size required in zoning district AR-4 is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary if the soils on the property have recharge rates better than Bartley soils. The minimum lot sizes required for zoning districts AR-3, VN-2, and VN-1 are insufficient to comply with the 2 mg/L Water Quality Standard. The lot sizes in the these districts are large enough to dilute nitrate in onsite waste disposal system effluent to the 10 mg/L Drinking Water MCL.

Greenwich

From the 2000 Census, a population density of 3.07 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 5.0 acres per system to 5.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.1 acres per system to 1.3 acres per system.

As illustrated in the table on the following page, the minimum lot sizes required by the R-1 and R-2 zoning districts are insufficient to dilute nitrate from the 40 mg/L to the 2 mg/L

Water Quality Standard at the property boundary. The minimum lot sizes required in all three zoning districts are sufficient to comply with the 10 mg/L drinking water MCL.

Greenwich					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-7	10 Acres	5.0	5.2	1.1	1.2
R-2	2 Acres	5.0	5.9	1.1	1.3
R-1	1 Acre	4.9	5.9	1.1	1.3

Soil Analysis		
Zoning	Soil Type	
	Highest Recharge Rate	Lowest Recharge Rate
R-75	Washington	Hazen
R-2	Washington	Bartley
R-1	Parker	Annandale

Hackettstown

From the 2000 Census, a population density of 2.41 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 2.8 acres per system to 2.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.7 acres per system to 0.8 acres per system.

Hackettstown					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-30	30,000 SF	2.8	2.9	0.7	0.7

Soil Analysis		
Zoning	Soil Type	
	Highest Recharge Rate	Lowest Recharge Rate
R-30	Hazen	Washington

As illustrated in the table above, the minimum lot size required by the zoning districts R-30 is insufficient to dilute nitrate from the 40 mg/L to the 2 mg/L Water Quality Standard or the 10 mg/L MCL at the property boundary.

Hardwick

From the 2000 Census, a population density of 2.85 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.2 acres per system to 4.8 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

Hardwick					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
Low Density	5 Acres	4.2	4.8	0.9	1.1
Soil Analysis					
Zoning		Soil Type			
		Highest Recharge Rate		Lowest Recharge Rate	
Low Density		Washington		Swartswood	

As illustrated by the table above, the minimum lot size required in the Low Density zoning district is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary .

Harmony

From the 2000 Census, a population density of 2.68 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.3 acres per system to 5.1 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.1 acres per system.

Harmony					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
AR-500	5 Acres	4.3			1.1
AR-300	3 Acres	4.4	5.1	1.0	1.0
AR-200	2.5 Acres	4.3			1.1
Soil Analysis					
Zoning		Soil Type			
		Highest Recharge Rate		Lowest Recharge Rate	
AR-500		Parker		Califon	
AR-300		Edneyville		Califon	
AR-200		Parker		Califon	

As illustrated by the table above, the minimum lot size required in zoning district AR-500 is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot sizes required for zoning districts AR-300 and AR-200 are insufficient to comply with the 2 mg/L Water Quality Standard. The lot sizes in the three districts are large enough to dilute nitrate in onsite waste disposal system effluent to the 10 mg/L Drinking Water MCL.

Hope

From the 2000 Census, a population density of 2.71 people per home was utlized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.5 acres per system to 5.2 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.2 acres per system.

Hope					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
LDAR	5 acre	4.5	5.2	1.0	1.2
LDAR-H	5 acre	4.6			
HMHC	40,000	4.6			
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
LDAR		Edneyville		Bartley	
LDAR-H		Hazen		Bartley	
HMHC		Wassaic		Bartley	

As illustrated by the table above, the minimum lot size required in zoning district HM HC is insufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard and is slightly below the 10 mg/L Drinking Water MCL threshold.

Independence

From the 2000 Census, a population density of 2.61 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 3.2 acres per system to 3.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.7 acres per system to 0.9 acres per system.

Independence					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
AR	10 Acres	3.2	3.9	0.7	0.9
R-30	3 Acres				
R-2	2 Acres				
R-1	1 Acres				
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
AR		Palmyra		Annandale	
R-30		Edneyville		Annandale	
R-2		Edneyville		Annandale	
R-1		Palmyra		Bartley	

As illustrated by the table above, the minimum lot size required in zoning district AR is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot sizes required for zoning districts R-30, R-2 and R-1 are not large enough dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard. All lot sizes are sufficient to dilute nitrate in onsite waste disposal system effluent to the 10 mg/L Drinking Water MCL.

Knowlton

From the 2000 Census, a population density of 2.87 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.7 acres per system to 5.5 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.1 acres per system to 1.2 acres per system.

Knowlton					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
FPD AR-1	5 Acres 1 Acre	4.7	5.5	1.1	1.2
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
FPD		Pope		Bartley	
AR-1		Pope		Bartley	

As illustrated by the table above, the minimum lot size required in zoning district FPD is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot size required for zoning district AR-1 is insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard or 10 mg/L Drinking Water MCL.

Liberty

From the 2000 Census, a population density of 2.79 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.7 acres per system to 5.4 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.1 acres per system to 1.2 acres per system.

As illustrated by the table below, the minimum lot size required in zoning district A-G is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot sizes required for the R2 and R3 are insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard, however, they satisfy the 10 mg/L Drinking Water MCL.

Liberty					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
A-G	6 Acres	4.8	5.4	1.1	1.2
R2	2 Acres	4.7	5.3	1.1	1.2
R3	3 Acres	4.7	5.3	1.1	1.2
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
A-G		Hazen		Bartley	
R2		Palmyra		Annandale	
R3		Palmyra		Annandale	

Lopatcong

From the 2000 Census, a population density of 2.55 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.1 acres per system to 4.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

Lopatcong					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-2	2 Acres	4.1	4.9	1.0	1.1
R-3/2	3 Acres	4.1		0.9	
R-5/2	5 Acres	4.1		0.9	
R-10/2	10 Acres	4.1		0.9	
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
R-2		Parker		Bartley	
R-3/2		Parker		Annandale	
R-5/2		Parker		Annandale	
R-10/2		Parker		Annandale	

As shown above, zoning district R-MF requires lot sizes sufficient in size to dilute nitrate in effluent from onsite waste disposal systems from 40 mg/L to the 2 mg/L Water Quality Standard. Districts R-2 and R-3/2require lots insufficient in size to comply with the 2 mg/L Water Quality Standard, however, lots in each zoning district are in compliance with the 10 mg/L Drinking Water MCL.

Mansfield

From the 2000 Census, a population density of 2.76 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 3.5 acres per system to 4.2 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.8 acres per system to 0.9 acres per system.

Mansfield					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
A R-1	6 Acres 3 Acres	3.5	4.2	0.8	0.9
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
A		Edneyville		Annandale	
R-1		Washington		Annandale	

As illustrated by the table above, the minimum lot size required in zoning district A is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot size required for zoning district R-1 is insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard, however, it does satisfy the 10 mg/L Drinking Water MCL.

Oxford

From the 2000 Census, a population density of 2.6 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.2 acres per system to 5.0 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.1 acres per system.

Oxford					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
AR-200	200,000 SF	-	-	-	-
R-120	120,000 SF	4.2	5.0	1.0	1.1
R-80	80,000 SF	4.3	5.0	1.0	1.1
R-40	40,000 SF	4.3	5.0	1.0	1.1
Soil Analysis					
Zoning		Soil Type			
		Highest Recharge Rate		Lowest Recharge Rate	
AR-200		-		-	
R-120		Parker		Bartley	
R-80		Edneyville		Bartley	
R-40		Parker		Annandale	

As illustrated by the table above, the minimum lot size required in zoning district AR-200 is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot size required for zoning districts R-120 and R-80 is insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard, however, it does satisfy the 10 mg/L Drinking Water MCL. The minimum lot size required in zoning district R-40 is insufficient in size to satisfy the requirements of the 2 mg/L Water Quality Standard as well as the 10 mg/L Drinking Water MCL.

Pohatcong

From the 2000 Census, a population density of 2.54 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.1 acres per system to 4.9 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

Pohatcong					
Zoning		Water Quality Model			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-1	5 Acres	4.1	4.9	0.9	1.1
R-2	2.5 Acres	4.2	4.9	0.9	1.1
Soil Analysis					
Zoning		Soil Type			
		Highest Recharge Rate		Lowest Recharge Rate	
R-1		Parker		Annandale	
R-2		Pope		Bartley	

As illustrated by the table above, the minimum lot size required in zoning district R-1 is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary. The minimum lot size required for zoning districts R-2 is insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard, however, it does satisfy the 10 mg/L Drinking Water MCL.

Washington Township

From the 2000 Census, a population density of 2.95 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.7 acres per system to 5.6 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 1.0 acres per system to 1.2 acres per system.

As illustrated by the table below, the minimum lot size required in zoning district MR is sufficient to dilute the nitrate from effluent from 40 mg/L to the 2 mg/L Water Quality Standard at the property boundary if the soils on a subject property exhibit recharge rates greater than Annandale Soils. The minimum lot size required for zoning districts R40 and VR is insufficient to dilute nitrate in onsite waste disposal system effluent to the 2 mg/L Water Quality Standard, however, it does satisfy the 10 mg/L Drinking Water MCL.

Washington Township					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R40	1 Acre	4.7			
VR	4 Acres	4.6	5.5	1.0	1.2
MR	5 Acres	4.7			
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
R40		Washington		Annandale	
VR		Parker		Annandale	
MR		Washington		Annandale	

White

From the 2000 Census, a population density of 2.47 people per home was utilized. Using a 2 mg/l NO_3 Water Quality Standard, the minimum recharge areas needed to dilute the nitrate ranges from 4.0 acres per system to 4.2 acres per system. If the 10 mg/l NO_3 MCL is used, the minimum recharge area ranges from 0.9 acres per system to 1.1 acres per system.

White					
Zoning		**Water Quality Model**			
		2mg/L Water Quality Goal		10 mg/L Drinking Water MCL	
District	Min Lot Size	Min Lot Size	Max Lot Size	Min Lot Size	Max Lot Size
R-1	3 Acres	4.0	4.7	0.9	1.1
R-1C	65,000 SF	4.1	4.2	0.9	1.0
Soil Analysis					
Zoning		**Soil Type**			
		Highest Recharge Rate		Lowest Recharge Rate	
R-1		Parker		Hazen	
R-1C		Pope		Venango	

The table above illustrates that the lot size required by zoning districts R-1 and R-1C is insufficient to dilute nitrate from onsite waste disposal systems from 40 mg/L to the 2 mg/L Water Quality Standard. The lot size, however, is sufficient to comply with the 10 mg/L Drinking Water MCL.

VII. Model Summary – Traditional Systems

As illustrated in the Water Quality, the density of most zoning districts is greater than the minimum lot size needed to dilute the nitrate in the effluent to the 2 mg/l water quality Standard. If the nitrate dilution standard is increased to 10 mg/l or the water quality standard, a greater number of zoning districts are of an adequate density to sustain drinking water quality. The 2 mg/l water quality Standard provides an adequate factor of safety to ensure that MCL is obtained.

One of the Standards of the Sustainable Development Study is to increase density and establish identified Town Centers. As a result of this NJGS model analysis, it is recommended that the establishment of Town Centers should be coupled with upgrades to municipal infrastructure, or alternative waste disposal methods should be researched.

Figure 2 summarizes compliance with the 2 mg/L Water Quality Standard as well as the 10 mg/L MCL for each zoning district.

Figure 2

Municipality	District	Satisfies 2 mg/L Water Quality Standard	Satisfies 10 mg/L Drinking Water MCL
Allamuchy	SFR1		X
	RR	X	X
	PPE		X
Alpha	R-1		X
	R-2		X
Municipality	District	Satisfies 2 mg/L Water Quality Standard	Satisfies 10 mg/L Drinking Water MCL
Blairstown	R-5	*	X
Franklin	RC	*	X
	R-75		X
Freilinghuysen	AR-4		X
	AR-3		X
	VN-2		X
	VN-1		X
Greenwich	R-7	X	X
	R-2		X
	R-1		
Hackettstown	R-30		
Hardwick	LD	X	X
Harmony	AR-500	*	X
	AR-300		X
	AR-200		X
Hope	LDAR	*	X
	LDAR-H	*	X
	HMHC		X

Independence	AR	X	X
	R-30		X
	R-2		X
	R-1		X
Knowlton	FPD	*	X
	AR-1		
Liberty	L-G	X	X
	R2		X
Lopatcong	R-2		X
	R-3/2		X
	R-5/2		X
	R-10/2	X	X
	R-MF	X	X
Mansfield	A	X	X
	R-1		X
Oxford	AR-200	X	X
	R-120		X
	R-80		X
	R-40		X
Pohatcong	R-1	X	X
	R-2		X
Washington Twp.	R40		*
	VR		X
	MR	*	X
White	R-1		X
	R-1C		X

* Satisfies criteria on some lots, based on soil type

VIII. Alternative Systems

Alternative waste disposal systems have been approved by the New Jersey Pinelands Commission that reduce the nitrate levels in effluent from onsite wastewater disposal systems. The 2001 Final Report from the New Jersey Pinelands Ad Hoc Committee on Alternative Septic Systems researched several systems that can reduce the nitrate concentrations in effluent from onsite waste disposal systems. Examples of systems are listed below.

Technology	Expected Effluent Concentration
FAST	14 mg/L
Cromaglass	14 mg/L
Bioclere	14 mg/L
Amphidrome	14 mg/L
Ashco AFSIII	20 mg/L

The systems were analyzed to assess their ability to achieve a Standard of 2mg/l.

FAST – Fixed Activated Sludge Treatment

FAST wastewater treatment systems can be used for individual residences or for clustered subdivisions. FAST wastewater treatment systems can effectively reduce nitrate in effluent by fostering the growth of microorganisms that process wastewater.

Cromaglass

Wastewater enters the system and flows through a screen - liquid waste flows through the screen while solids remain behind the screen. Mixed liquor is pumped through the screen to degrade solids by turbulence. Wastes are aerated and mixed by submersible pumps and aspirators. Denitrification occurs by cutting off the air supply while mixing continues. Liquids are then transferred into a clarifier where settlement occurs. After settlement is complete, effluent is discharged from the clarifier. Sludge is transferred from the Clarifier into the main Aeration sections.

Bioclere

The Bioclere system is a modified trickling filter over a clarifier. They are appropriate for both smaller flows and large flows from clustered subdivisions. An anoxic tertiary upflow filter may be installed to reduce the nitrogen in the effluent.

Amphidrome

The Amphidrome system is a sequencing batch aerated/anoxic biofilter. The Amphidrome system consists of two tanks and a bioreactor. Wastewater enters the system through the first tank. This tank provides equalization, settling and sludge storage. The biochemical reactions that process wastewater occur within the Amphidrome reactor.

The Pinelands Commission examined the cost implications of alternative systems compared to conventional systems.(Final Report – Adhoc Committee on Alternative Septic Systems (2001)). The installation costs vary by alternative system (excepting the Ashco RFS system) but range from $13,000 to $21,000. The ASCHO system ranges from $15,000 to $25,000. A similar sized conventional system would cost $15,000. Maintenance costs for alternative systems range from $150 to $400 per year.

Should communities wish to maintain existing zoning to preserve water quality, alternative septic systems could be required as a provision to new construction. Assuming the alternative systems can reduce nitrate in the effluent from 40 mg/L to 15 mg/L, minimum lot sizes for each zoning district within each municipality in Warren County will be reduced as follows in order to achieve the 2 mg/L standard.

Figure 3

Municipality	Zoning		Alternative Septic Systems 2 mg/L Water Quality Standard	
	Designation	Min. Lot Size	Minimum Lot Size	Maximum Lot Size
Allamuchy	SFR1	1 Acre	1.49	1.73
	RR	4 Acres	1.49	1.49
	PPE	1 Acre	1.49	1.73
Alpha	R-1	3 Acres	1.89	1.89
	R-2	2 Acres	1.89	2.15
Belvidere	-	-	-	-
Blairstown	R-5	5 Acre	1.97	2.25

Municipality	Zoning		Alternative Septic Systems 2 mg/L Water Quality Standard	
	Designation	Min. Lot Size	Minimum Lot Size	Maximum Lot Size
Franklin	RC	5 Acre	2.05	2.4
	R-75	30,000 SF	2.09	2.4
Freilinghuysen	AR-4	4 Acres	1.86	2.15
	AR-3	3 Acres	1.86	2.15
	VN-2	2 Acres	1.86	1.90
	VN-1	1 Acre	1.86	1.90
Greenwich	R-7	10 Acres	2.23	2.29
	R-2	2 Acres	2.23	2.55
	R-1	1 Acre	2.19	2.53
Hackettstown	R-30	30,000 SF	1.36	1.57
Hardwick	Low Density	5 Acres	1.89	2.12
Harmony	AR-500	5 Acres	1.96	2.25
	AR-300	3 Acres	1.96	2.25
	AR-200	2.5 Acres	1.98	2.25
Hope	LDAR	5 Acres	2.00	2.29
	LDAR-H	5 Acres	2.07	2.29
	HMHC	40,000 SF	2.07	2.29
Independence	AR	10 Acres	1.52	1.77
	R-30	3 Acres	1.52	1.77
	R-2	2 Acres	1.52	1.77
	R-1	1 Acre	1.52	1.77
Knowlton	FPD	5 Acres	2.11	2.41
	AR-1	1 Acre	2.11	2.41
Liberty	A-G	6 Acre	2.11	2.35
	R2	2 Acres	2.10	2.35
	R-3	3 Acres	2.10	2.35
Lopatcong	R-2	2 Acres	1.95	2.19
	R-3/2	2 Acres	1.88	2.17
	R-5/2	2 Acres	1.88	2.17
	R-10/2	2 Acres	1.88	2.17
	R-MF	5 Acres	1.91	2.19
Mansfield	A	5 Acre	1.63	1.90
	R-1	3 Acres	1.64	1.90
Oxford	AR-200	200,000 SF	-	-
	R-120	120,000 SF	1.91	2.21
	R-80	80,000 SF	1.93	2.21
	R-40	40,000 SF	1.93	2.21
Phillipsburg	-	-	-	-
Pohatcong	R-1	5 Acre	1.87	2.16
	R-2	2.5 Acres	1.89	2.18
Washington Boro	N/A	-	-	-
Washington Twp.	R40	1 Acre	2.09	2.45
	VR	4 Acres	2.05	2.45
	MR	5 Acres	2.09	2.45
White	R-1	3 Acres	1.83	2.11

Municipality	Zoning		Alternative Septic Systems 2 mg/L Water Quality Standard	
	Designation	Min. Lot Size	Minimum Lot Size	Maximum Lot Size
	R-1C	65,000 SF	1.86	1.91

IX. Conclusions

Individual subsurface waste disposal systems are a viable means of managing residential sanitary sewage in rural areas not serviced by municipal systems. For drinking water quality to be maintained, it is necessary to analyze the existing zoning regulations to ensure lot sizes are adequate to dilute nitrate from sewage to an assigned post-treatment level. If zoning regulations permit densities greater than those indicated by the nitrate dilution model, municipalities should reassess the validity of their existing regulations and take immediate action to ensure development does not occur that will sacrifice overall groundwater quality.

Groundwater is an important natural resource that is integral to the sustainability of development in most rural communities. Groundwater within Warren County is particularly important since most of Warren County is located within the Northwest New Jersey Sole Source Aquifer. Because of its geographical location, it is even more important to implement development practices that sustain this natural resource.

By assessing the density of development in the rural areas of the county, and the ability of the groundwater system to dilute pollutants that are associated with development, County officials can focus key growth areas where capital improvements to the municipal sanitary sewer systems are feasible. In addition, County Officials can better understand the environmental constraints associated with development.

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