Appendix A-16
Land Use and Ground-Water Quality in the Pine Barrens of Southampton

Water Resources Program, Center for Environmental Research
Cornell University

November 1983

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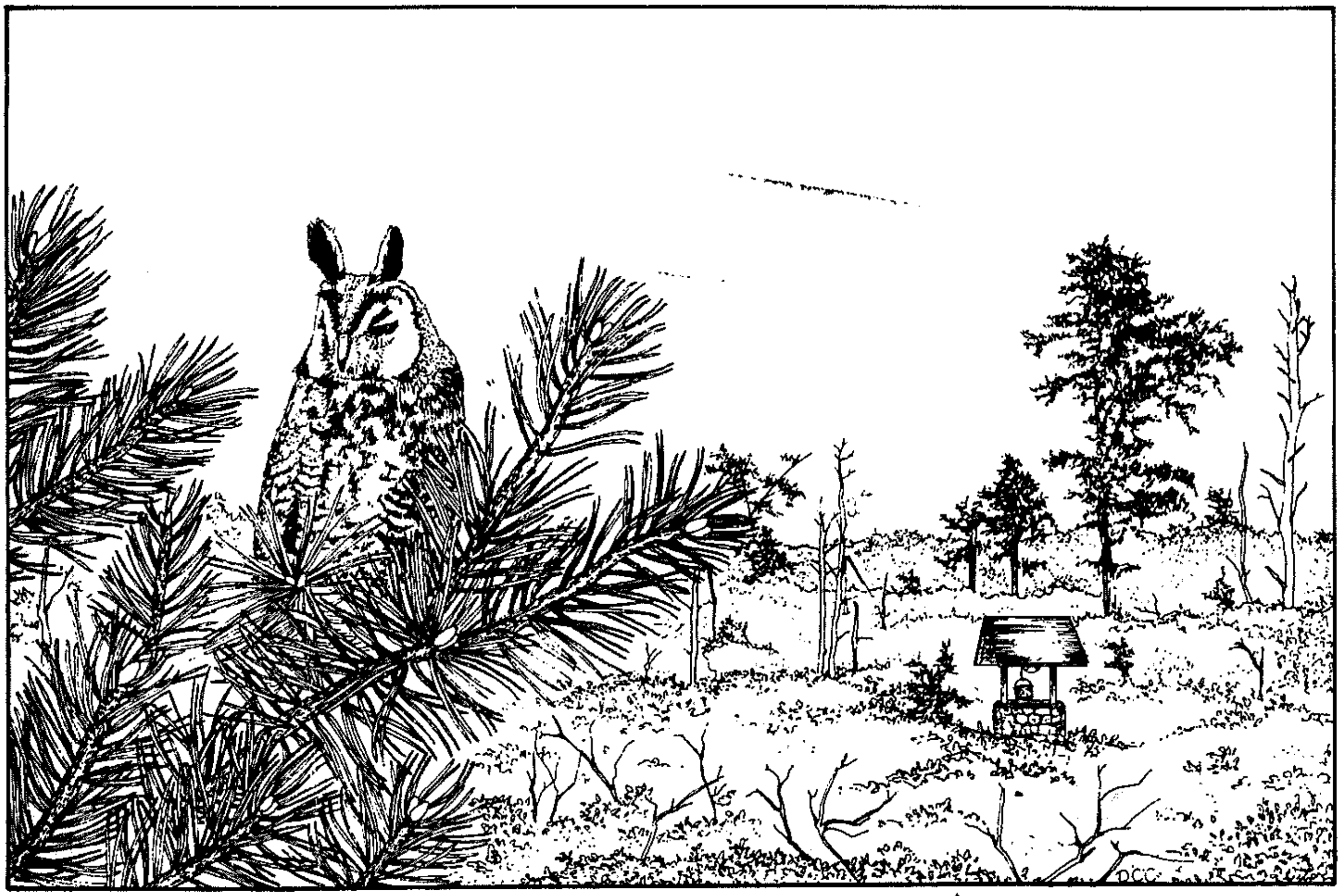

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Contents

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Revised Edition

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Chapter 1
Introduction

1.1 The Context for this Study

Ground water is an important water resource throughout much of the United States with approximately half of the population relying on ground water for drinking water. On Long Island, New York, ground water is the sole source of drinking water for the two counties of Nassau and Suffolk. Unfortunately many of the uses of land on Long Island have adversely affected the quality of the ground water beneath the land. This dilemma has led the environmental and health agencies at many levels of government on Long Island to seek ways of halting the contamination which threatens the Island's only fresh water supply.

The Pine Barrens on Long Island are a relatively undisturbed woodland area and the ground water beneath the Pine Barrens is likewise undisturbed, retaining its naturally high quality. It has been suggested by environmentalists and public officials alike, that preventing the contamination of this presently high quality water is an important step in the overall management of ground water on Long Island.

This study examined the relationship between land use and water quality in the undisturbed Pine Barrens and in the agricultural and residential land adjoining the Pine Barrens. This report then suggests what limits need to be imposed on future development of land in the Pine Barrens to prevent severe contamination of the ground water.

The technical methods which were demonstrated in this study can be applied to other areas where similar ground water concerns exist.

1.2 The Pine Barrens of Long Island

The Pine Barrens, which have been called Long Island's Secret Wilderness, contrast sharply with the heavily populated suburbs that characterize much of Long Island. This pine and oak forest earned the name Pine Barrens after early settlers failed in their efforts to make agriculture worthwhile on the sandy acid soils. The largest area remaining in the Pine Barrens covers approximately 100,000 acres in the center of Suffolk County (Figure 1.1).

Naturalists have discovered that the Pine Barrens is a unique and fascinating ecological system. According to some historical accounts, the region supported a thriving cord-wood industry until the mid-1800's. This industry was severely damaged when steam locomotives on the newly constructed railroad ignited catastrophic fires. The Pine Barrens are now regarded as a fire climax ecosystem — fires are an integral part of its existence and the plants and animals that inhabit the Pine Barrens are adapted to survive fires. Fire preserves the unusual character of the Pine Barrens by suppressing non-fire resistant species which might otherwise encroach.

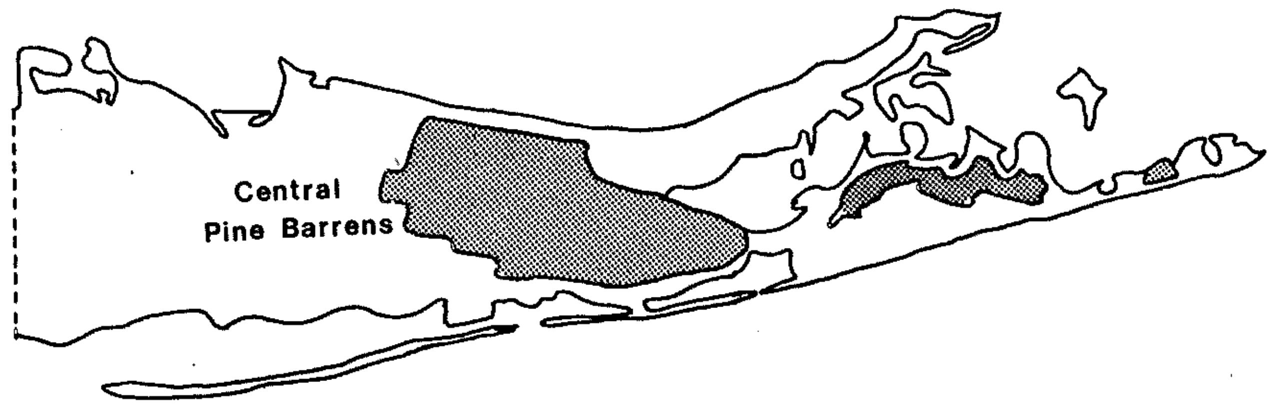


Figure 1.1
Forested areas in Suffolk County (mostly pine barrens) which are considered critical recharge areas (from Greenberg and others, 1982).

1.3 Ground Water and the Pine Barrens

Long Island's climate and geology result in plentiful and easily obtainable ground water throughout the Island. The bedrock base of the Island is overlain by deep glacial deposits of sand and gravel. These deposits are quite porous and therefore provide much storage space for ground water. Since the bedrock slopes from north to south, sand and gravel deposits are deeper on the southern part of the Island.

Figure 1.2 illustrates the flow of ground water at a typical cross section. About 50% of the water which falls on the surface of the Island as precipitation drains down through the unsaturated soil to the water table. Below the water table, in the saturated zone, water moves down and out toward one of the shores. Water which is recharged in the middle of the Island goes to the deepest part of the aquifer and takes the longest time to reach the shore. The point dividing north-flowing and south-flowing water (termed a ground-water divide) occurs near the center of the cross section.

Most contamination of ground water occurs when chemicals are released to the environment at or near the land surface. The contaminants are then carried with recharge water to the aquifer. The chemical contaminants which have been found on Long Island and are of most concern belong to the following three groups:

1. *Nitrate.* Primary sources of nitrate are human wastewater and nitrogen fertilizers. Nitrate is a health hazard to infants less than 6 months of age because it can cause an illness termed methemogobanemia. The State Health Standard limits the allowable nitrate concentration in drinking water to 10 mg/l (measured as milligrams of nitrogen per liter of water).
2. *Pesticides.* Aldicarb, which was used on potato fields from 1975 through 1979, is the only pesticide currently found to contaminate ground water adjoining the Pine Barrens in significant amounts. It is very toxic to humans at high doses, and the State guideline for the maximum allowable concentration of aldicarb in drinking water is 7 ug/l (.007 mg/l). Other pesticides may potentially contaminate ground water in the future.
3. *Organic chemicals*, used in households and industries. Many different chemicals are included in this category as described in Chapter 4. The major reason for health concern regarding these chemicals is because of their known or suspected carcinogenicity.

The concentration of these contaminants in ground water is directly related to the amounts released at the land surface where the water was recharged. Water recharged from agricultural land frequently contains nitrate and pesticides. Residential area recharge is usually contaminated with nitrate and organic chemicals used in household cleaning products. Water recharged from commercial and industrial land may contain chemicals used by the particular establishments at the site.

The ground water beneath the Pine Barrens is pure because the level of human activity in the area is low and few contaminating chemicals are used or disposed of in the Pine Barrens. Since the Pine Barrens cover the central parts of the island, the water in the deepest part of the aquifer to the north and south is recharged from the Pine Barrens and remains relatively pure. In order to maintain the high quality of water in the deep sections of the aquifer it is necessary to prevent contaminants from entering at the land surface in the center of the Island. For these reasons the Pine Barrens are critical recharge areas and deserve special management for the purpose of maintaining high water quality.

On Long Island there is much pressure to develop areas which are currently vacant. This pressure is especially heavy in the Pine Barrens areas. Because of the potential for conflict between those who want to develop the land and those who want to preserve the water, it is important for government decision makers to know what types of land use in the Pine Barrens are consistent with preserving water quality.

1.4 Selection of a Study Area

The present study is part of New York State's Ground Water Management Program. The initial purpose of this study was to address some of the specific questions facing local government officials and to demonstrate methods which could be used as tools for managing the Pine Barrens and similar critical recharge areas by applying systems analysis techniques collectively referred to as WALRAS (Water and Land Resource Analysis System) to the Pine Barrens situation.

A demonstration site in the Town of Southampton was selected for detailed application of the systems analysis techniques. The Southampton site was chosen because the Southampton Town Board is in the process of updating the Town Master Land Use Plan and wanted to include water quality considerations in land use planning for Pine Barrens areas. The specific site selected (shown on Figure 1.3) is representative of other parts of Southampton in terms of land use and water quality.

The study area contains two test wells where water quality is regularly tested, two adjacent public water-supply wells and many private house wells where water quality data were available. The boundaries of the study area include all of the recharge areas for water reaching these wells of interest. Thus the northern boundary of the study area is the approximate location of the ground water divide and any water recharged north of the divide flows away from the wells of interest.

The major land uses in the detailed study area include natural Pine Barrens, agricultural land, and residential land. The Pine Barrens occupy the northern section of the study area. Several potato and vegetable farms and a nursery are located in the center of the study area and residential developments are concentrated along the coast.

The quality of ground water in the Pine Barrens part of the study area is excellent, with very low concentrations of nitrate. In the agricultural and residential areas, somewhat higher levels of nitrate have been found. The severest existing water quality problem in the detailed study area is the contamination of some private wells by the pesticide aldicarb, used by potato farmers from 1975 through 1979. The manufacturer of the pesticide has provided home treatment units to those homeowners whose private wells have been found to have levels greater than 7 ug/l thus far.

1.5 Project Approach

The main objective of this project is to provide a sound technical basis so that management decisions in the Pine Barrens can be based on preservation of the quality of the recharge to ground water. The project focuses on determining:

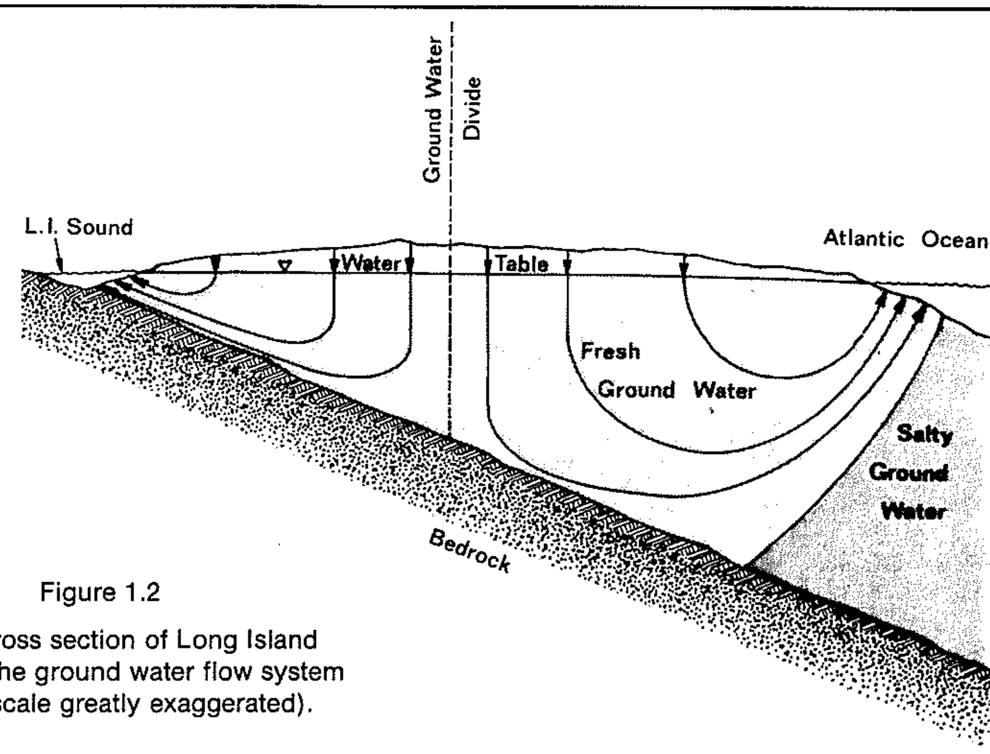


Figure 1.2

Typical cross section of Long Island illustrating the ground water flow system (vertical scale greatly exaggerated).

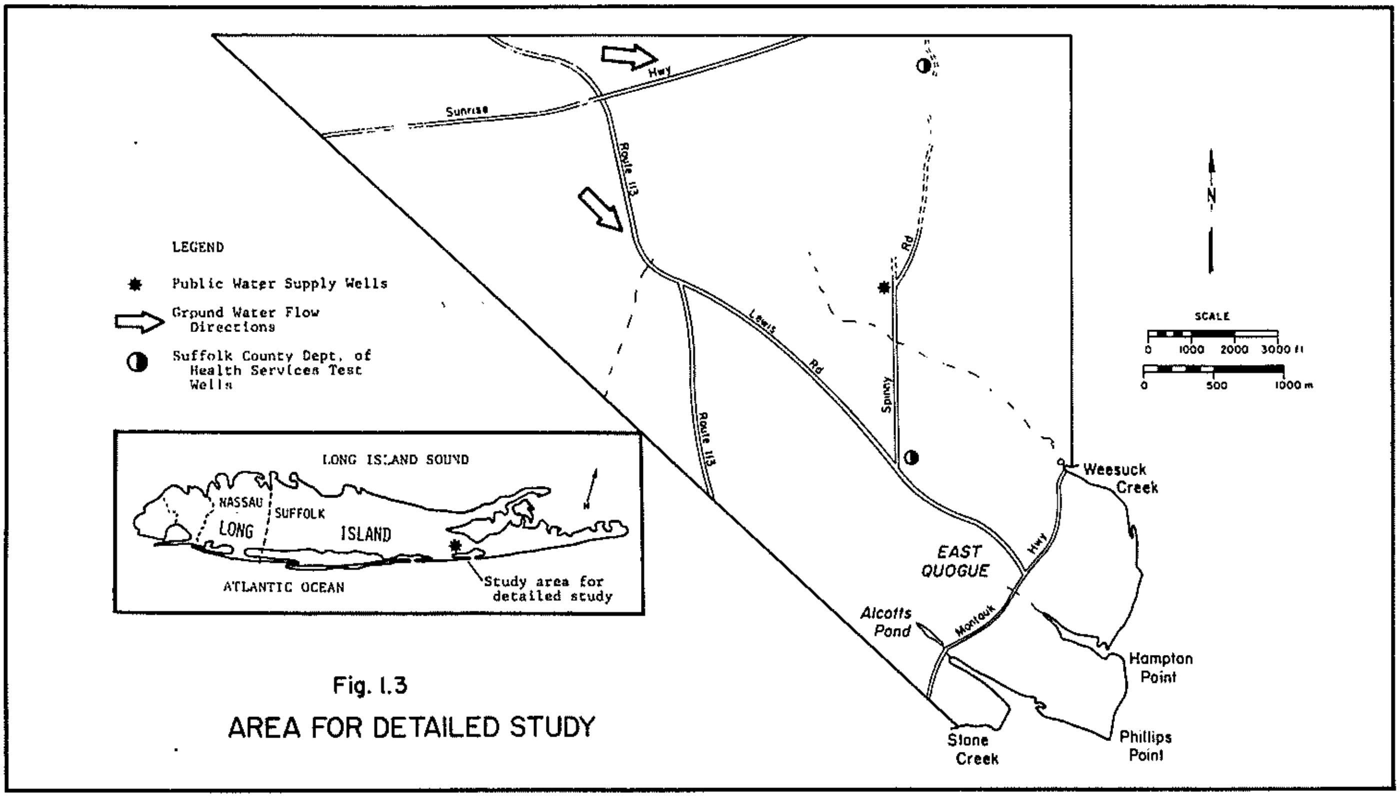


Fig. I.3
AREA FOR DETAILED STUDY

(1) the present extent and cause of ground-water contamination in the study area, (2) the potential for future contamination resulting from changes in management and in land use, and (3) the management options available for protection of the ground water resource. It is hoped that the methods of evaluation demonstrated as part of this project can be used in evaluating similar situations elsewhere.

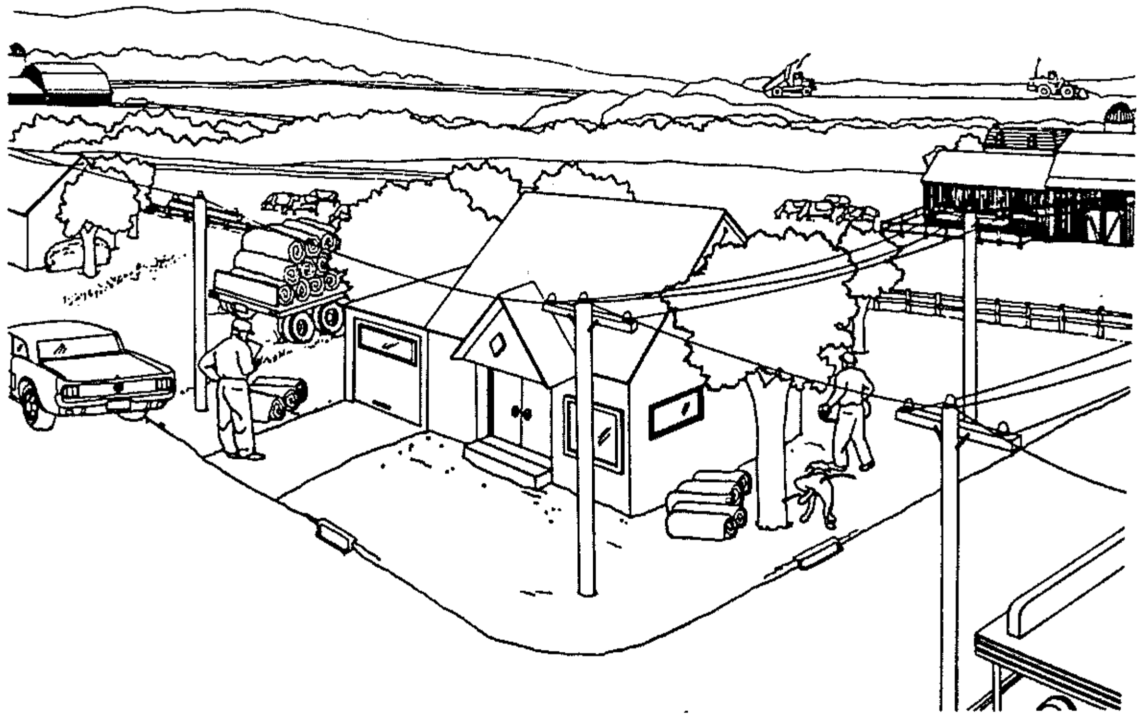
The Water and Land Resource Analysis System (WALRAS), a systematic technique for evaluating existing or potential ground-water contamination resulting from various land use activities, was implemented for this project. WALRAS was used to estimate the amount of nitrogen and the pesticide aldicarb which leach to the aquifer with recharge water from the types of land currently found in the detailed study area and for certain land uses which may be proposed in the future for the undeveloped Pine Barrens areas. Simulation models of the root zone are used to compute the effects that processes in the root zone, such as the breakdown of substances in soil and plant uptake, have on nitrogen and pesticides and then the quantity of the contaminant that leaches out of the root zone.

Below the root zone there is no removal of water by plants and very little biodegradation; hence, most chemicals leaving the root zone eventually reach the aquifer and move through the aquifer with the water until it is discharged to the bay. Nitrate has been observed to be quite conservative — its concentration diminishes little if at all once it has left the root zone. Since aldicarb may not be as conservative the degradation process below the root zone was simulated for aldicarb, using the limited available data on degradation rates.

The simulation results were compared with observations of water quality in wells. The simulations help explain the reasons for the observed nitrate and aldicarb levels.

Organic chemicals which are found in ground water recharged from commercial and residential land in other areas of Long Island were considered in a preliminary assessment. The processes which affect these chemicals have not been extensively measured in the field, but it is known that these chemicals pose a significant health threat. Largely due to the many uncertainties both about the effects of these chemicals and their transport into ground water, there is reason to be concerned that the worst effect that future residential developments might have on ground water is the addition of these organic chemicals. The available ground-water data on organic contamination from four Long Island communities was analyzed to help determine the magnitude of the threat that these chemicals represent.

The final phase of the project considered the impact on nitrate concentrations in ground water of a hypothetical new residential development in the Pine Barrens part of the detailed study area. The nitrogen simulation models were used to determine how much nitrate would leach into the ground water under several assumed scenarios for development.



Chapter 2
Data Describing the Study Area

The data describing the detailed study area needed for the project were collected from various existing compilations of data. The analysis of water and contaminant budgets in the soil system using WALRAS requires climatic, soils and land use data. Information about ground-water hydrology is necessary to track the movement of water and contaminants through the ground-water system. The ground-water quality data on observed nitrogen and pesticide concentrations was compared with simulation results as a check on the realism of the simulations.

2.1 Climate

The climate data for the detailed study area was obtained from the Riverhead weather station, located eight miles northeast of the study area. Precipitation, temperature and potential evapotranspiration data are needed to simulate the water budgets in the root zone. Average conditions were obtained by averaging simulation results for 1973, 1974, and 1976 since these years represent wet, dry, and average precipitation amounts and their average approximates the long term precipitation average. Potential evapotranspiration has been computed using Penman's method (Penman, 1948). Each year is simulated as 30 twelve-day timesteps to account for seasonal variations in climate. Table 2.1 summarizes the climatological data which was used for each timestep.

Time-step	Dates	1973 Precip. (inches)	1974 Precip. (inches)	1976 Precip. (inches)	Average Temp. (°F)	Potential Evapo-trans-piration (inches)
1	1/1-1/12	1.28	3.14	2.66	28.9	.004
2	1/13-1/24	0.82	0.91	1.33	27.0	.012
3	1/25-2/5	4.69	0.62	3.12	25.5	.004
4	2/6-2/17	1.35	1.36	0.40	26.4	.028
5	2/18-3/1	0.15	1.37	0.43	29.5	.043
6	3/2-3/13	1.60	0.50	1.02	42.6	.028
7	3/14-3/25	0.97	2.76	1.83	47.5	.071
8	3/26-4/6	3.05	1.78	1.61	50.0	.091
9	4/7-4/18	1.66	2.27	0.00	46.0	.118
10	4/19-4/30	2.54	0.14	0.83	62.6	.098
11	5/1-5/12	1.78	1.05	1.50	54.0	.110
12	5/13-5/24	2.03	1.27	2.08	59.5	.079
13	5/25-6/5	0.51	1.68	1.19	65.5	.102
14	6/6-6/17	0.17	0.23	0.09	60.1	.146
15	6/18-6/29	2.07	1.22	0.18	68.5	.130
16	6/30-7/11	2.56	0.44	2.02	72.5	.142
17	7/12-7/23	3.93	0.07	0.59	73.6	.130
18	7/24-8/4	1.96	0.10	2.00	75.0	.126
19	8/5-8/16	1.51	0.44	5.23	76.6	.091
20	8/17-8/28	0.28	0.79	1.99	72.5	.146
21	8/29-9/9	1.55	4.07	0.43	72.0	.102
22	9/10-9/21	1.33	0.31	1.44	65.1	.083
23	9/22-10/3	0.26	1.78	1.26	64.9	.039
24	10/4-10/15	0.05	0.00	2.96	62.6	.031
25	10/16-10/27	0.08	2.37	2.69	55.6	.040
26	10/28-11/8	2.17	0.24	1.17	53.1	.031
27	11/9-11/20	0.00	0.78	0.01	49.5	.031
28	11/21-12/2	1.75	3.21	0.44	46.6	.012
29	12/3-12/14	2.45	1.49	1.18	41.0	.008
30	12/15-12/31	4.98	2.45	1.21	33.1	.008
Total	1/1 - 12/31	50	39	43		

2.2 Soils

Figure 2.1 shows the distribution of soils in the detailed study area and Table 2.2 gives the hydraulic properties of these soils. In general the soils in the study area are sandy and drain quickly. Carver and Plymouth Sands are found in most of the areas still covered by Pine Barrens. Because of their low fertility, these sands have little agricultural value. Agricultural activity in the study area occurs where Riverhead Sandy Loam, a more fertile soil, predominates.

Table 2.2
Characteristics of Soils Found in the Detailed Study Area

Symbol	Series	Texture	Parent Material	Typical Landforms	Permea-bility cm/day	Hydrologic Group	Porosity*	Field* Capacity	Wilting* Point
At	Aston Sand	Sand & Loamy Sand	Glacial Outwash	Nearly Level	380	C	.4	14	.08
Cp	Carver & Plymouth Sands	Coarse Sand to Loamy Sand	Glacial Outwash	Level to Steep	380	A	.4	.10	.07
De	Deerfield Sand	Sand to Loamy Sand	Glacial Outwash	Nearly Level	380	B	.4	.13	.07
Ha	Haven Loam	Silt Loam to Very Fine Sandy Loam	Glacial Outwash and Till	Level to Rolling	0-18 in: 250 18-28 in: 120	B	.5	.24	.10
Pl	Plymouth Loamy Sand	Loamy Sand to Sand	Glacial Outwash	Level to Steep	380	A	.4	.12	.06
Rd	Riverhead Sandy Loam	Sandy Loam and Fine Sandy Loam	Glacial Outwash and Till	Level to Steep	250	B	.4	.25	.12

*volume fraction

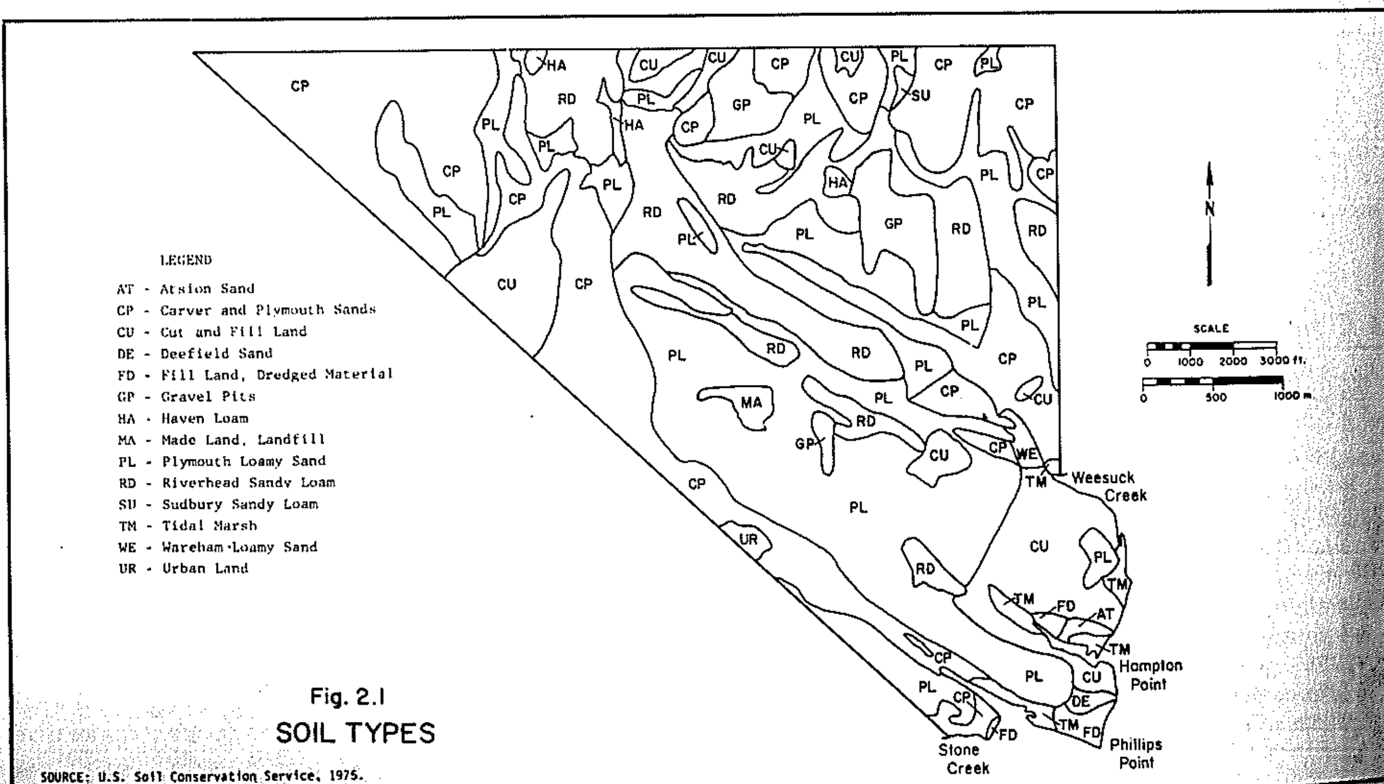


Fig. 2.1
SOIL TYPES

SOURCE: U.S. Soil Conservation Service, 1975.

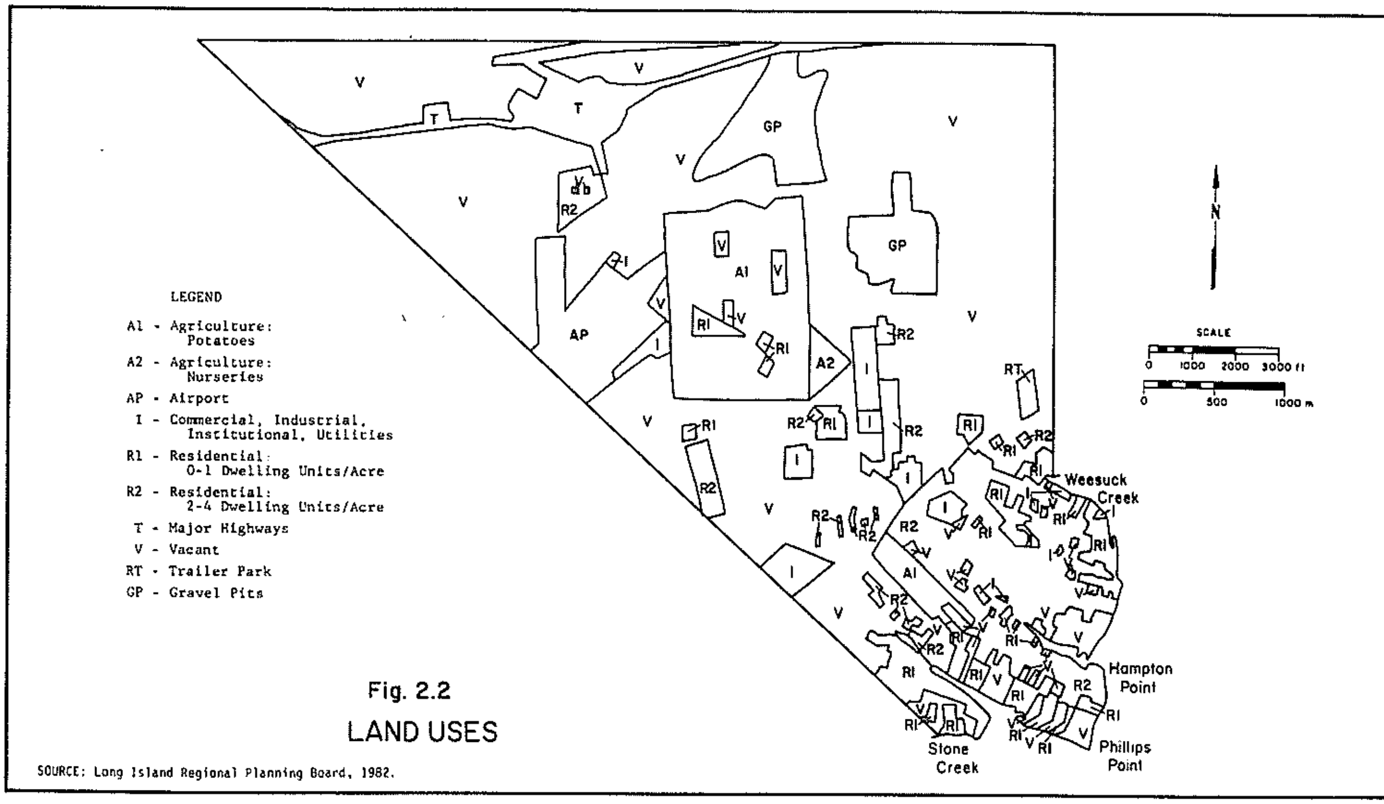


Fig. 2.2
LAND USES

2.3 Land Use

Figure 2.2 depicts the distribution of land uses in the detailed study area. The vacant land in the northern part of the study area remains mostly covered by the Pine Barrens. Some potato and vegetable farming takes place in the center of the study area and the coastal area in the southern part is predominantly residential. Tables 2.3 and 2.4 contain a detailed description of the data used to describe each land use.

2.4 Ground Water Hydrology

Figure 2.3 shows the water table elevations as measured in 1980 and 1982 by the Suffolk County Department of Health Services. Ground water flows in the direction perpendicular to the water table contours; hence ground water in the study area flows generally from Northwest to Southeast.

Three major aquifers underly the study area in unconsolidated deposits at different depths. These aquifers are described in detail by McClymonds and Franke (1972). The upper glacial aquifer, uppermost of the three is composed mainly of sand and gravel with some clay deposits. This aquifer extends 100 to 200 feet below the water table in the detailed study area. Beneath the upper glacial is the magothy aquifer which is 800 to 900 feet thick in the study area and composed mainly of medium to coarse sand. Both of these aquifers are characterized by moderate to high permeability — they readily yield water to the wells which tap them. The Lloyd aquifer is beneath the Magothy and separated from it by a layer of clay. It is composed of sand and gravel and is 250 to 300 feet thick in the study area.

The upper glacial and the Magothy aquifers are most important for this study since they are the aquifers currently used for water supply in the area and are most vulnerable to contamination from the surface.

2.5 Existing Water Quality

Three categories of contaminants are important to ground water quality in the detailed study area; nitrate, pesticides and organic chemicals.

Nitrate occurs in varying amounts in the detailed study area. In general, nitrate concentrations are very low in the groundwater underlying the Pine Barrens section of the study area and increase gradually as one moves south. Table 2.5 summarizes the available nitrate data.

The pesticide aldicarb has been found at concentrations greater than 7 ppb (the guideline for drinking water established by the New York State Department of Health) in water from house wells tested by the Suffolk County Department of Health Services in the areas indicated in Figure 2.4. Health Department records show that at least eleven private wells and the two public water supply wells have been tested for aldicarb. As of March 1983 aldicarb had been found in four of the private wells with three of these having concentrations above the guideline, the highest being 18 ug/l. No aldicarb was detected in the public water supply wells.

The Department of Health Services has tested water from nine wells in the study area for organic chemicals other than pesticides. None were detected in any of the samples (for further discussion see Chapter 4).

Table 2.3 Summary of Assumptions Relating to Each Existing Land Use Type

Land Use Category		Assumption		Value	Information Source
R1.	Residential (0-2 dwellings/acre)	a.	Population density	2.7 persons/acre	All population density estimates were based on 1980 school district population estimates for East Quogue, revised by the Long Island Regional Planning Board to account for seasonal variations.
		b.	Percentage of land as natural cover	52%	All land cover percentage calculations were based on measurements from local low-altitude air and development plans done by the Long Island Regional Planning Board (1983) and the Center for Environmental Research (Hughes and others, 1980).
		c.	Percentage of land as turf	24%	
		d.	Percentage of land as impervious surface	24%	
R2.	Residential (2-5 dwellings/acre)	a.	Population density	9.5 persons/acre	
		b.	Percentage of land as natural cover	12%	
		c.	Percentage of land as turf	47%	
		d.	Percentage of land as impervious surface	41%	
RT.	Trailer Park	a.	Population density	39.4 persons/acre	The number of trailers per acre in the East Quogue Trailer Park was estimated from 1980 airphotos taken by the Agricultural Stabilization and Conservation Service.
		b.	Percentage of land in natural cover	8%	
		c.	Percentage of land in turf	30%	
		d.	Percentage of land in impervious surface	62%	
	Assumptions applying to all residential	a.	Per capita sewage nitrogen generated	(10 lbs/person/yr)	Porter and others, 1978
		b.	Per capita wastewater flow generated by persons served by on-site systems	(44 gallons/person/day)	NYS Department of Health, 1969; Porter and others, 1978
		c.	See Table 2.4 for assumptions relating to turf, impervious surface and natural cover		
A1.	Agriculture: Potatoes and vegetables in in rotation.		Potatoes		
		a.	Depth of root zone	24 inches (60 cm)	
		b.	Maximum plant nitrogen content if all growth conditions are optimal	180 lb/acre (200 kg/ha)	
		c.	Percentage of harvested plant biomass nitrogen returned to soil	30%	Suffolk County Cooperative Extension.
		d.	Percentage of harvested plant biomass nitrogen removed from field	70%	Suffolk County Cooperative Extension
		e.	Amount of inorganic nitrogen fertilizer applied	175 lb/acre/yr (192.5 kg/ha/yr)	Suffolk County Cooperative Extension
		f.	Irrigation water amount	3 inches/yr (7.5 cm/yr)	Suffolk County Cooperative Extension
			Vegetables		
		a.	Depth of root zone	30 cm	
		b.	Maximum plant nitrogen content if all growth conditions are optimal	135 lb/acre (150 kg/ha)	Based on cauliflower (Suffolk County Cooperative Extension personal communication; Singh and Rajput, 1976)

Table 2.3 Summary of Assumptions Relating to Each Existing Land Use Type (continued)

Land Use Category		Assumption	Value	Information Source
		Vegetables		
	c.	Percentage of harvested plant biomass nitrogen returned to soil	66%	Suffolk County Cooperative Extension
	d.	Percentage of harvested plant biomass nitrogen removed from field	34%	Suffolk County Cooperative Extension
	e.	Inorganic nitrogen fertilizer	140 lbs/acre/yr (154 kg/ha/yr)	Suffolk County Cooperative Extension
A2. Agriculture: Nurseries	a.	Depth of root zone	60 cm	
	b.	Maximum plant nitrogen content, if all growth conditions are optimal	450 lb/acre (500 kg/ha)	
	c.	Percentage of harvested plant biomass nitrogen returned to soil	0%	
	d.	Percentage of harvested plant biomass nitrogen removed from field	100%	Suffolk County Cooperative Extension
	e.	Number of harvests per year	2	Suffolk County Cooperative Extension
	f.	Percentage of total plant biomass nitrogen harvested at each harvest	20%	
	g.	Nitrogen fertilizer applied	250 lb/acre/yr (275 kg/ha/yr)	Suffolk County Cooperative Extension
	h.	Irrigation water amount	3 inches/yr (7.5 cm/yr)	
AP. Airports (Suffolk Co. Airport at Westhampton Beach)	a.	Percentage of land as vacant	60%	
	b.	Percentage of land as turf	5%	
	c.	Percentage of land as impervious surface	35%	
V. Vacant		Assumed to have natural cover year-round (see Table 2.3, natural cover)		
T. Major Highways (Smaller roads assumed to be part of adjacent lots.)	a.	Percentage of land as vacant	40%	
	b.	Percentage of land as impervious surface	60%	
GP. Gravel Pits	a.	Assumed to have no covering vegetation		

Table 2.4 Summary of Assumptions Relating to Land Cover Types Which Are Part of Several Land Use Types

Cover Type		Assumptions	Source
1. Turf	(a)	Half of the initial nitrogen content of animal waste is lost to the atmosphere	Porter (1975) and Lauer and others (1976)
	(b)	All pet waste was assumed to be deposited evenly over all turf in the study area. Pet population based on human population and dogs and cats per person for Long Island. This yields an estimated nitrogen loading on turf of 6.5 pounds per acre from pet waste	Rates based on data from Loehr (1974) and Porter and others (1978); Pet population from U.S.S.C.S. (1977)
	(c)	Turfgrass leaf density is assumed to vary during the year peaking in late spring and summer and being least in winter	
	(d)	Depth of root zone is 20 cm	
	(e)	Turf mowings were assumed to be bi-weekly during the summer and to each remove 10 percent of the biomass	
	(f)	75% of turf is fertilized and 25% is not.	Pike and others (1980)
	(g)	20 percent of the clippings are returned to the soil and 80 percent are removed on fertilized turf, and all clippings are returned to the soil on unfertilized turf.	Pike and others (1980)
	(h)	Fertilized turf receives 2.5 lbs of fertilizer nitrogen per 1000 sq. ft. (122 kg/ha) annually. Half the total was assumed to be in slow release compounds and the other half in fast release compounds	Pike and others (1980), average for Suffolk County
	(i)	Lawn irrigation is estimated to be about 5.5 inches (14 cm) annually	Nassau County Health Department (1977), estimate for their county
2. Impervious Surface	(a)	There is assumed to be no root zone	
	(b)	10% of the precipitation is assumed to evaporate	Mather (1979)
	(c)	90% of the water and all of the nitrogen is assumed to be recharged in recharge basins or adjacent pervious areas	
3. Natural Cover	(a)	Assumed to be Pine Forest	
	(b)	Root zone depth assumed to be 200 cm (79 inches)	
	(c)	Plant uptake and gaseous losses are assumed to remove 85% of the nitrogen entering in precipitation	Based on observed nitrogen concentrations in ground water in Pine Barrens areas as measured by the Suffolk County Department of Health Services

Table 2.5
Nitrate Nitrogen Concentrations in Water Samples
From the Study Area

Sampling Location	Average Concentration (mg/l)	Range of Concentrations (mg/l)	Time Period of Samples
Northern Test Well 48434	0.28	0.14–0.36	1974–1980
Southern Test Well 48435	2.3	1.2–2.9	1974–1981
Spinny Rd. Public Supply Wells	3.3	2.42–4.08	1979–1982
34 Private House Wells throughout East Quogue	2.8	(less than 0.4) –15.4	1974–1982

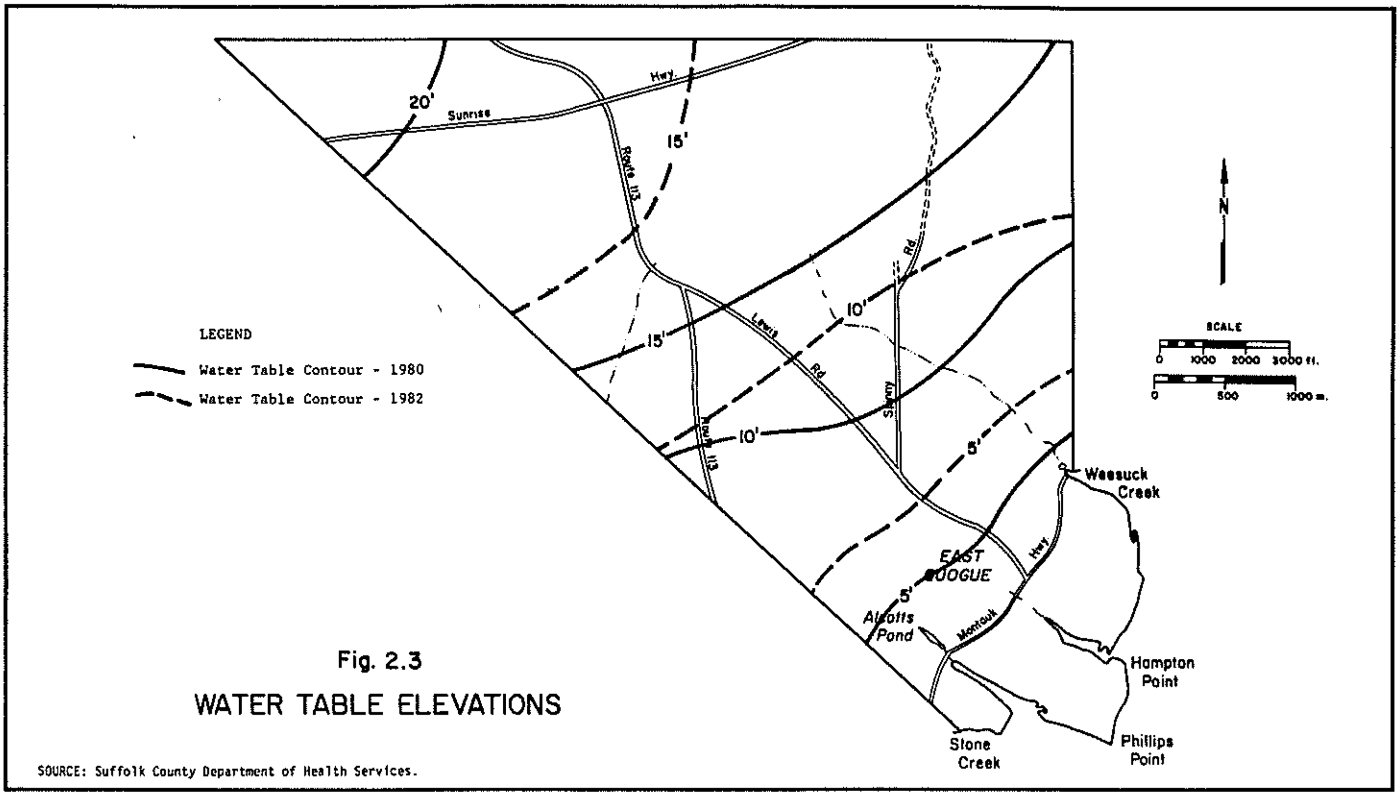


Fig. 2.3
WATER TABLE ELEVATIONS

SOURCE: Suffolk County Department of Health Services.

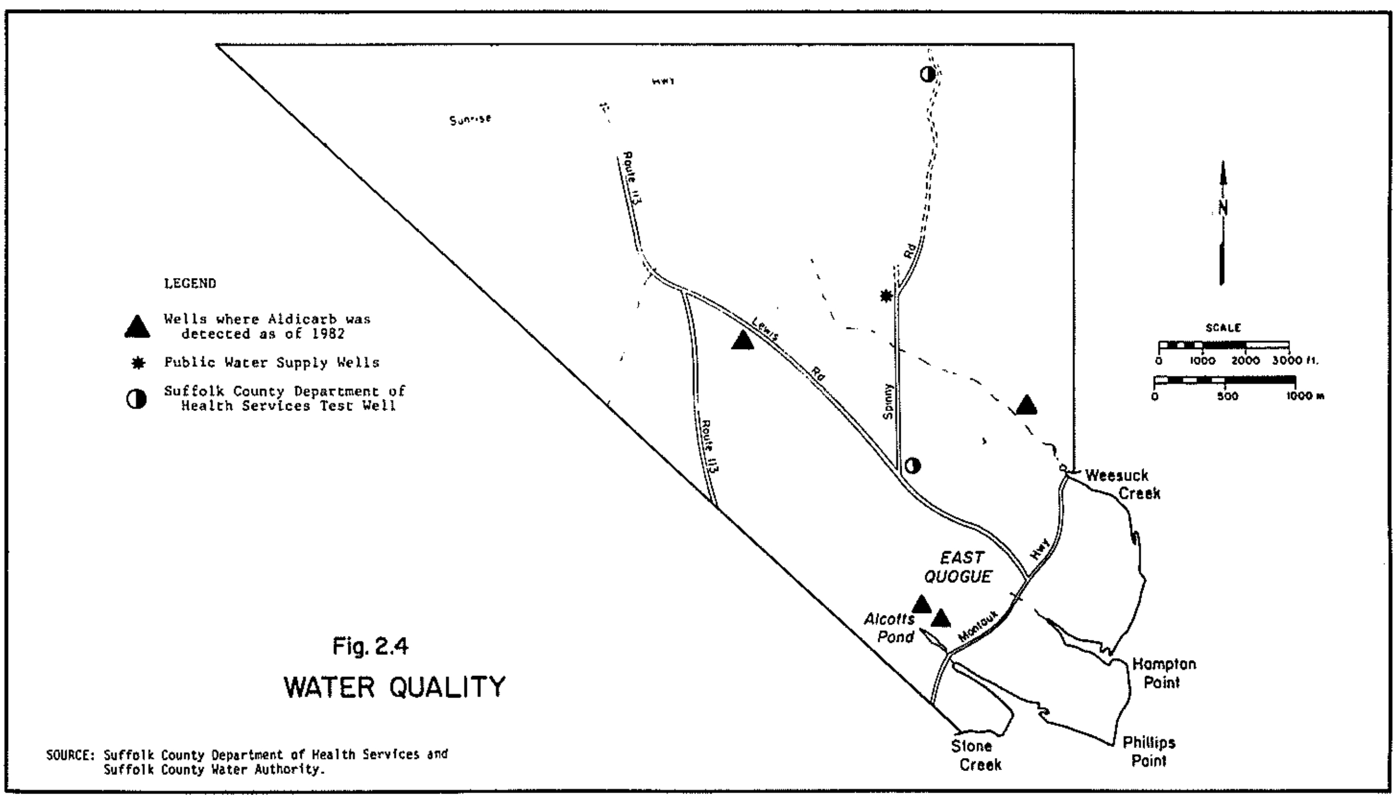


Fig. 2.4
WATER QUALITY

SOURCE: Suffolk County Department of Health Services and Suffolk County Water Authority.

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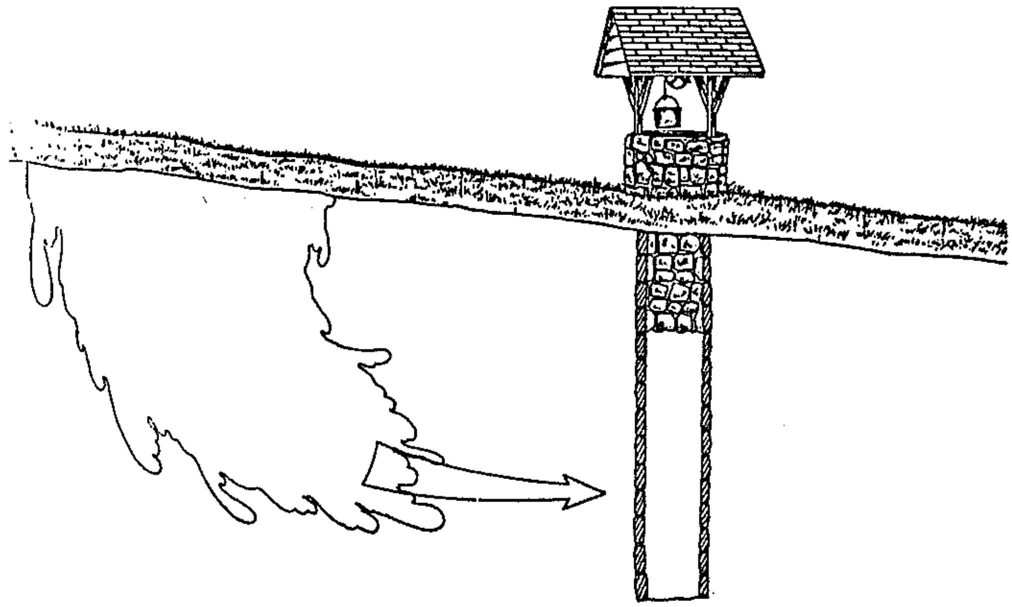


Chapter 3
The Impact of Existing Land Use on Ground Water Quality

Ground water in some parts of the study area contains nitrate and the pesticide aldicarb. The amount of these substances which is leached with recharge water from each land use in the study area was simulated using computer models. This information was then combined with basic hydrological knowledge to explain the source of nitrate and aldicarb at the specific wells where these were found.

3.1 Nitrogen Simulations for Each Land Use

3.1.1 Natural Pine Barrens

The observed ground-water quality under the Pine Barrens is excellent. The only contaminant found there is nitrate-nitrogen. A small amount of nitrogen is added to the soil in the Pine Barrens from precipitation, but most of it does not reach the ground water. Apparently plants and bacteria remove the nitrogen before the water leaves the root zone.

Table 3.1 summarizes the simulated water and nitrogen budgets for natural Pine Barrens conditions. Precipitation which falls on the Pine Barrens either drains through the soil, evaporates, or is taken up and transpired by plants. A negligible amount of water may run off during heavy rain storms. The simulated nitrogen budget for the root zone of the Pine Barren was calibrated to agree with observed water quality.

Table 3.1
Simulated Water and Inorganic Nitrogen Budgets
for the Root Zone of Natural Pine Barrens

Water (in/yr)	
Inputs	*Outputs*
Precipitation: 43.3	Evapotranspiration: 23.5 Drainage: 20.5 Runoff: .3 Change in storage during simulation: -1.2
Totals: 43.1	43.1
Inorganic Nitrogen (lb/acre/yr)	
Inputs	*Outputs*
Precipitation: 5 Mineralization of Soil Organic Matter: 27.3	Plant Uptake and Gaseous Loss: 30.9 Leaching: .8 Runoff: 0 Change in storage during simulation: +.6
Totals: 32.3	32.3

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

0.2 mg/l (as N)

3.1.2 Residential Land

Recharge from residential land can contaminate the ground water with nitrate and other chemicals used in residential areas. The two major sources of nitrate in residential areas are lawn fertilizers and human wastewater. These sources are discussed here. The other chemicals are discussed in Chapter 4.

Nitrogen from Lawn Fertilizers

The average effect of lawn fertilizers was assessed using data reflecting average turf management practices in Eastern Suffolk County. The results of the root zone water and nitrogen budgets simulation for turf are given in Table 3.2. This simulation model was calibrated to reflect the nitrogen uptake rates observed in turf experiments conducted by the Long Island Horticultural Research Laboratory (Selleck and others, 1980).

Table 3.2
Simulated Water and Inorganic Nitrogen Budgets
for the Root Zone of Fertilized Turf

Inputs	Outputs
Water (in/yr)	
Precipitation: 43.3	Evapotranspiration: 19.0
Irrigation: 5.5	Drainage: 28.8
	Runoff: 0.8
	Change in storage during simulation: +0.2
Totals: 48.8	48.8
Inorganic Nitrogen (lb/acre/yr)	
Precipitation and Irrigation: 8.8	Plant Uptake: 66.1
Inorganic Fertilizer: 55.5	Leaching: 64.0
Mineralization of soil organic matter and organic fertilizer: 65.5	Gaseous Loss: 6.6
Mineralization of Pet Waste: 6.5	Runoff: 0.2
	Change in storage during simulation: -0.3
Totals: 136.3	136.3

Resulting Nitrate Concentration in Recharge (Runoff and Leaching) 9.4mg/l (as N)

Nitrogen from Sewage

The average person excretes 10 pounds of nitrogen per year (Porter and others, 1978). When this nitrogen enters a septic system or cesspool it either leaches or is lost as a gas. Experiments indicate that about 50% of the nitrogen entering a normal system, operated on Long Island, is converted to gaseous nitrogen and the remainder leaches into the soil (Andreoli and others, 1977).

The total amount of nitrate leaching from a residential area is the sum of the nitrate leaching from domestic sewage disposal systems, from turf and from vacant land. Table 3.3 summarizes the nitrogent budgets on the three categories of residential land in the study area.

Table 3.3

Land Use	Substance	Nitrogen and Water Recharged From: Turf	Sewage	Other	Overall Nitrogen Concentration in Recharge (mg/l)
R1	Water (in)	6.9	1.6	19.4	4.7
	Nitrogen (lb/acre)	12.3	14.9	2.9	
R2	Water (in)	13.5	5.6	18.2	9.3
	Nitrogen (lb/acre)	24.0	52.4	4.2	
RT	Water (in)	8.6	23.4	25.7	17.9
	Nitrogen (lb/acre)	15.3	217.4	6.3	

3.1.3 Agricultural Land

Most of the agricultural land in the study area is managed using a rotation with potatoes for 2 or 3 years and then vegetables for one. A separate nitrogen budget was simulated for potato fields and vegetable fields. The potato simulation was calibrated to agree with field experiments conducted by the Long Island Horticultural Research Laboratory (Selleck and others, 1980). No field experiments were available to calibrate the vegetable simulations and they are therefore more hypothetical.

Since soil type makes a significant difference in the amount of nitrogen lost from fertilizers applied to potatoes and vegetables, separate simulations were done for the two dominant soil types used for agriculture. Riverhead Sandy Loam drains more slowly than the Carver and Plymouth Sands and hence leaching losses from Riverhead Sandy Loam are less than from the Carver and Plymouth Sands. This is because fetilizer nitrogen moves downward with the water and the faster the water drains out of the root zone the less chance plants have of absorbing the nitrogen. Table 3.4 gives the simulated water and nitrogen budgets for potatoes and vegetables on the two different types of soils.

Since a small nursery is located in the study area, a nitrogen budget for nurseries was also simulated. Little is known about the nitrogen budget for nursery crops, and no field experiments were available to calibrate the nursery simulations. For these reasons the simulation of the nitrogen budget for nursery plants is hypothetical only (Table 3.5).

The accuracy of the land use simulations was estimated using a sensitivity analysis. This analysis simulates the highest and the lowest possible impact of a particular land use by varying the parameters which control plant uptake and gaseous loss. The resulting confidence intervals represent a combination of individually estimated uncertainties. Figure 3.1 summarizes graphically the nitrogen impact of each land use and the associated confidence intervals.

Table 3.4
Simulated Water and Inorganic Nitrogen Budgets for
the Root Zone of Potatoes and Vegetables

Potatoes: Riverhead Sandy Loam

Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.9	Evapotranspiration: 13.6
Irrigation: 3.0	Drainage: 20.9
	Runoff: 11.4
	Change in Storage During Simulation: 0
Totals: 45.9	45.9

Inorganic Nitrogen (lb/acre/yr)

Inputs	*Outputs*
Precipitation and Irrigation: 7.7	Plant Uptake: 182.3
Inorganic Fertilizer: 175.0	Leaching: 50.0
Mineralization of soil organic matter and organic fertilizer: 65.5	Runoff: 9.5
	Gaseous Loss: 4.5
	Change in Storage During Simulation: 1.9
Totals: 248.2	248.2

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

7.96 mg/l (as N)

Potatoes: Plymouth Loamy Sand

Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.5	Evapotranspiration: 14.0
Irrigation: 3.0	Drainage: 25.4
	Runoff: 5.9
	Change in Storage During Simulation: .2
Totals: 45.5	45.5

Inorganic Nitrogen (lb/acre/yr)

Inputs	*Outputs*
Precipitation and Irrigation: 7.7	Plant Uptake: 109.5
Inorganic Fertilizer: 175.0	Leaching: 110.9
Mineralization of soil organic matter and organic fertilizer: 42.3	Gaseous Loss: 2.3
	Change in Storage During Simulation: 2.3
Totals: 225.0	225.0

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

15.59 mg/l (as N)

Vegetables: Riverhead Sandy Loam

Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.5	Evapotranspiration: 16.9
Irrigation: 3.9	Drainage: 23.0
	Runoff: 6.1
	Change in Storage During Simulation: .4
Totals: 46.4	46.4

Inorganic Nitrogen (lb/acre/yr)

Inputs	*Outputs*
Precipitation and Irrigation: 8.6	Plant Uptake: 158.6
Inorganic Fertilizer: 140	Leaching: 38.6
Mineralization of soil organic matter and organic fertilizer: 65.9	Runoff: 11.8
	Gaseous Loss: 5.5
	Change in Storage During Simulation: 0
Totals: 214.5	214.5

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

7.30 mg/l (as N)

Vegetables: Plymouth Loamy Sand

Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.5	Evapotranspiration: 16.9
Irrigation: 3.9	Drainage: 23.0
	Runoff: 6.1
	Change in Storage During Simulation: .4
Totals: 46.4	46.4

Inorganic Nitrogen (lb/acre/yr)

Inputs	*Outputs*
Precipitation and Irrigation: 8.6	Plant Uptake: 115
Inorganic Fertilizer: 140.0	Leaching: 69.1
Mineralization of soil organic matter and organic fertilizer: 42.3	Runoff: 3.6
	Gaseous Loss: 3.2
	Change in Storage During Simulation: 0
Totals: 190.9	190.9

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

10.73 mg/l (as N)

Table 3.5
Simulated Water and Inorganic Nitrogen Budgets for the Root Zone of Nurseries

Nurseries: Riverhead Sandy Loam
Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.9	Evapotranspiration: 23.0
Irrigation: 3.0	Runoff plus Drainage: 22.8
	Change in Storage During simulation: +.1
Totals: 45.9	45.9

Inorganic Nitrogen (lb/acre/yr)

Inputs	*Outputs*
Precipitation and Irrigation: 7.0	Plant Uptake: 180.7
Inorganic Fertilizer: 168.3	Runoff plus Leaching: 69.5
Mineralization of Soil Organic Matter and Organic Fertilizer: 84.5	Gaseous Loss: 12.8
	Change in Storage During Simulation: -3.2
Totals: 259.8	259.8

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)
13.20 mg/l (as N)

Nurseries: Plymouth Loamy Sand
Water (in/yr)

Inputs	*Outputs*
Precipitation: 42.5	Evapotranspiration: 22.5
Irrigation: 3.0	Runoff plus Drainage: 22.7
	Change in Storage During Simulation: +.3
Totals: 45.5	45.5

Inorganic Nitrogen (lb/acre/yr)

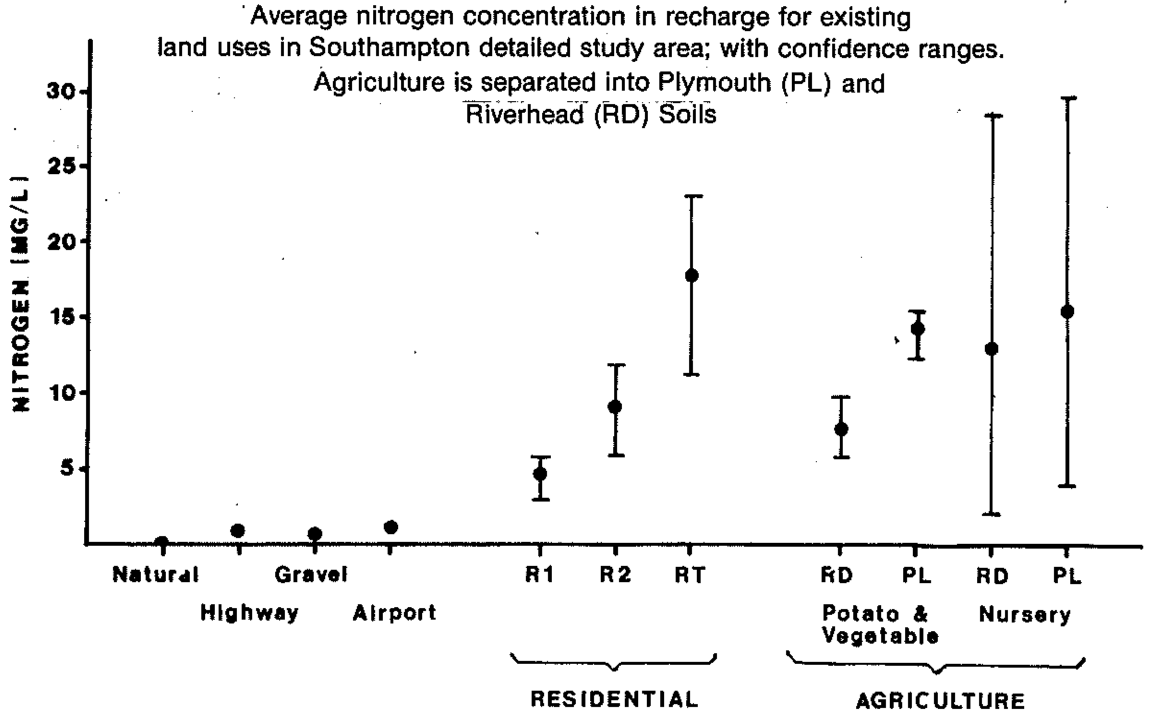
Inputs	*Outputs*
Precipitation and Irrigation: 6.9	Plant Uptake: 173.6
Inorganic Fertilizer: 168.3	Runoff plus Leaching: 81.0
Mineralization and Soil Organic Matter and Organic Fertilizer: 84.4	Gaseous Loss: 10.5
	Change in Storage During Simulation: -5.5
Totals: 259.6	259.6

Resulting Nitrate Concentration in Recharge (Runoff and Leaching)

15.49 mg/l (as N)

Figure 3.1

Average nitrogen concentration in recharge for existing land uses in Southampton detailed study area; with confidence ranges. Agriculture is separated into Plymouth (PL) and Riverhead (RD) Soils



3.2 Nitrogen Simulation of Entire Study Area

The simulations of individual land use types were combined to produce a composite picture. Figure 3.2 depicts the simulated nitrogen leached with recharge for each parcel of land in the study area. It was assumed that most runoff water is recharged at some place near to where it ran off. This assumption is reasonable for the types of soils and flat topography found in the study area. The simulated runoff water and nitrogen was added to the simulated recharge values to give the overall impact of a land use type.

To compare simulated nitrogen concentrations in recharge water with observed nitrogen concentrations in wells, it is necessary to know approximately where water in the wells was recharged. This land area which replenishes the water drawn by a well is termed the well catchment. Since ground water flow patterns vary yearly with changing weather conditions, the catchment of a well also varies. The depth at which a well obtains water (the depth of the screen) and rate of water removal also affect the size and location of the well catchment.

The approximate well catchment can be determined using a map of water table elevations and other basic geohydrologic information. Figure 3.3 illustrates the approximate well catchments of the two observation wells and the public water supply wells in the study area. The observation wells are shallow and only small amounts of water are removed for sampling.

Their well catchments are therefore small and include the land immediately around each well. The public supply wells are deeper (118 feet and 162 feet respectively) and have a large volume of water removed from them (a total of about five hundred thousand gallons of water per day). The catchment of the public supply well was calculated roughly by taking into account the depth of the wells and the volume of water removed.

Table 3.6 compares the simulated average nitrate concentration in recharge for the well catchments with the measured average nitrate concentration of the well water. The catchment area of the northernmost observation well is entirely within the Pine Barrens; as would be expected, observed nitrate levels there were very low. Higher concentrations of nitrates in the southern observation well are due to the residential land in its catchment. The catchment of the public water supply wells includes a large portion of the upstream agricultural land which accounts for the nitrate concentration in the water being greater than background levels.

For the residential area as a whole, the possible catchment is the entire study area. The location of each individual well catchment depends on the location and depth of the specific well. In the residential area 2.8 mg/l is the average nitrate concentration. The nitrate in the water comes from agricultural land, residential land or a combination of both.

In general, the higher nitrogen concentrations found in ground water in the southern part of the study area can be attributed to the agricultural and residential land located there. The public supply wells receive enough water that was recharged in the Pine Barrens to keep the nitrate concentrations in the water below the 10 mg/l standard. The nitrogen concentrations in private well water varies considerably but

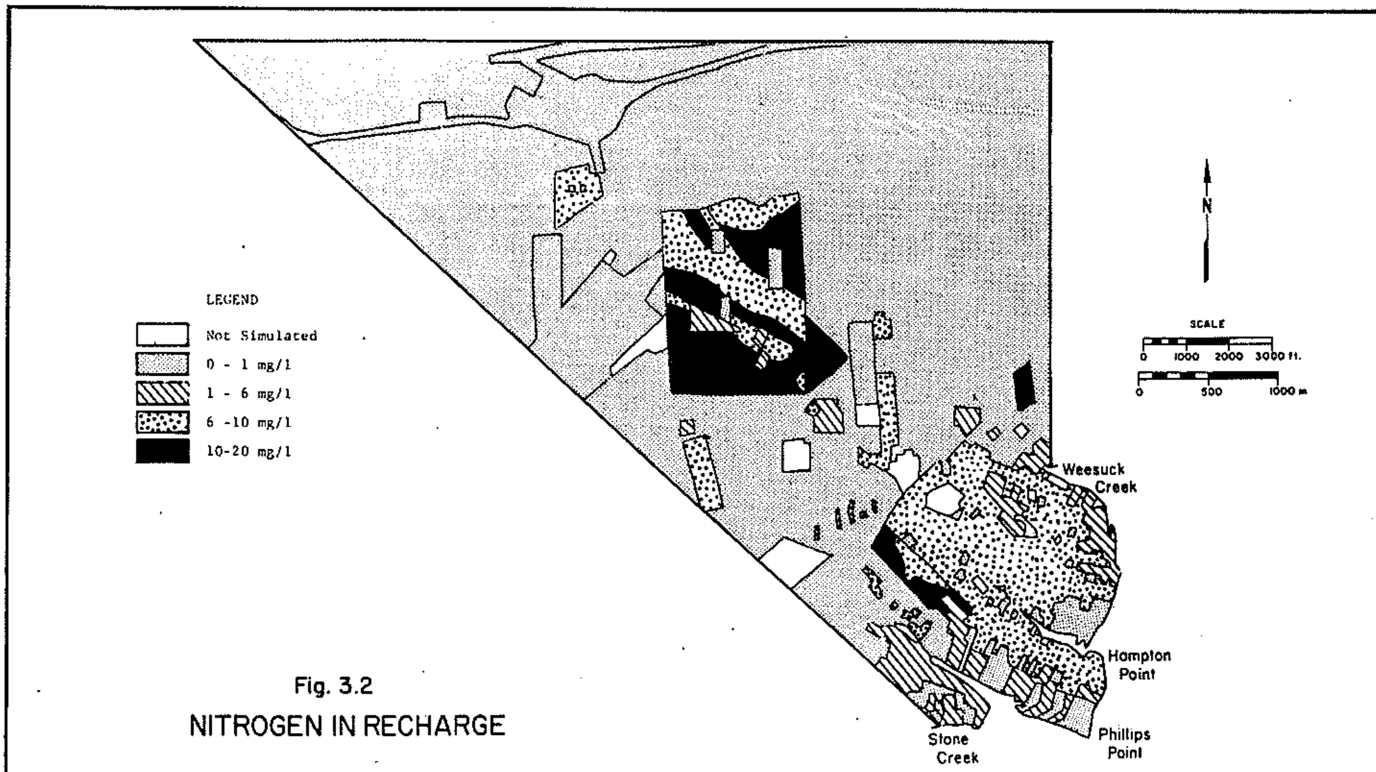


Fig. 3.2
NITROGEN IN RECHARGE

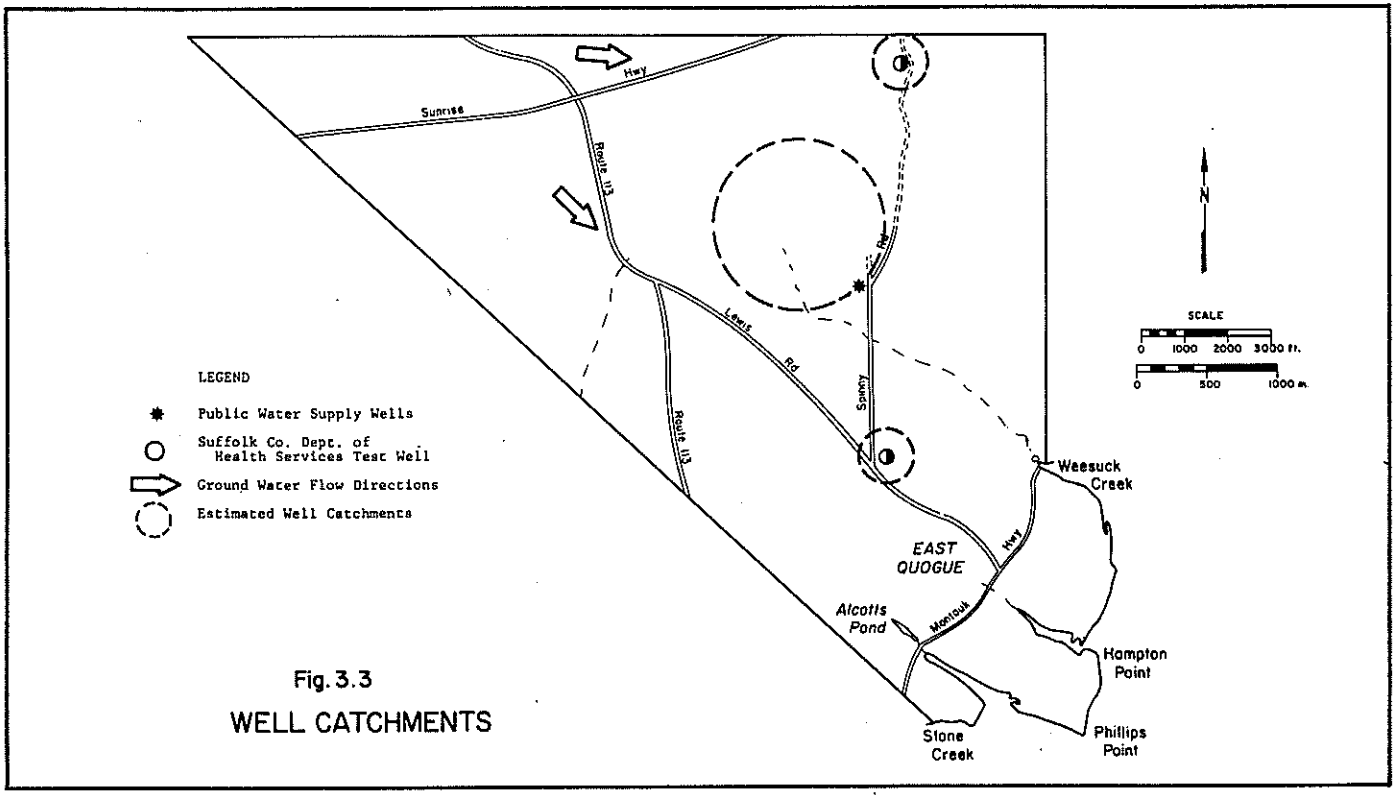


Fig. 3.3
WELL CATCHMENTS

most wells have water with low concentrations which is probably because they draw water which was recharged in the Pine Barrens. The generally low nitrate levels in water throughout the study area is the result of the largely undisturbed Pine Barrens land in the northern section where deep recharge occurs.

Table 3.6
Simulated vs. Measured Nitrate Concentrations in Recharge for Well Catchments

Well	Land Uses in the Well Catchment	Nitrogen Concentration in Recharge, Simulated	Nitrogen Concentration Measured in Well
North Test Well (48434)	Vacant - 100%	0.2 mg/l	0.3 mg/l
South Test Well (48435)	R2 = 21% Vacant - 31% I (treated as vacant)* - 48%	2.1 mg/l	2.3 mg/l
Public Supply Wells Spinney Rd. #1&2	Agriculture - 18% (Riverhead Sandy Loam) Agriculture - 17% (Plymouth Loamy Sand) Gravel Pit - 18% Vacant - 47%	4.3 mg/l	3.3 mg/l

*Most of this particular site is in fact vacant.

3.3 Assessment of Aldicarb Contamination in the Study Area

Aldicarb was applied to potato fields in the study area from 1975 through 1979 when potatoes were planted. Farmers report that potatoes are rotated with one year of vegetables every 2 or 3 years. This means aldicarb would have been applied to each field 3 or 4 years out of the 5. Most of the potato fields are in the center of the study area near Lewis Road and there is one small field located closer to the Bay.

A model which simulates pesticide movement and decay in the subsurface environment was used to assess the eventual fate of aldicarb in the study area and the potential for further contamination of water supply wells (Steenhuis and Trautmann, 1982). The calculations performed by the model are rough approximations of the most important processes affecting aldicarb movement. For this reason the results are only an approximate indicator of possible future problems. This model was calibrated on field data from the Long Island Horticultural Research Laboratory and other field data used by Intera (1980).

The field data indicate that about 15% of the applied aldicarb leached below the root zone and that the decay of aldicarb to nontoxic substances below the root zone was very slow.

An uncertain aspect of assessing the fate of aldicarb is how fast it breaks down to harmless substances once it is beneath the root zone. Preliminary results by Union Carbide indicate that it may decay with a half life of 2 or 3 years, meaning half of the initial concentration would decay in 2 or 3 years, half of the remaining decays during the next 2 or 3 years and so on. Intensive work is now underway to estimate, with a greater degree of confidence, what the half life is under Long Island conditions. A worst case would be if aldicarb doesn't decay at all in which case it would flow through the ground water system the whole way to the Shinnecock Bay. Figure 3.4 shows the areas which may be afected by the main parts of the aldicarb plumes, and be subject to concentrations greater than the 7 ug/l health guideline assuming either a 3 year half life or an infinite half life.

From this analysis it appears that the public water supply wells on Spinny Road will be affected by aldicarb regardless of which half life is assumed. The calculations indicate that the plume should take about ten years to reach the public supply well. This includes four years of travel from the land surface to the water table and six years of travel through the aquifer. These travel times would result in the plume arriving at the well in the mid-1980's. No attempt was made to estimate the concentration which would be found since it will be affected by mixing caused by pumping as well as the decay of the aldicarb as it travels.

Much of East Quogue could potentially be affected by the aldicarb plumes. If the three year half life in the aquifer proves to be realistic then most of East Quogue would not be affected by aldicarb concentrations of greater than 7 ug/l. Whether or not a specific well is affected will also depend on the depth of the well relative to the depth of the aldicarb plume.

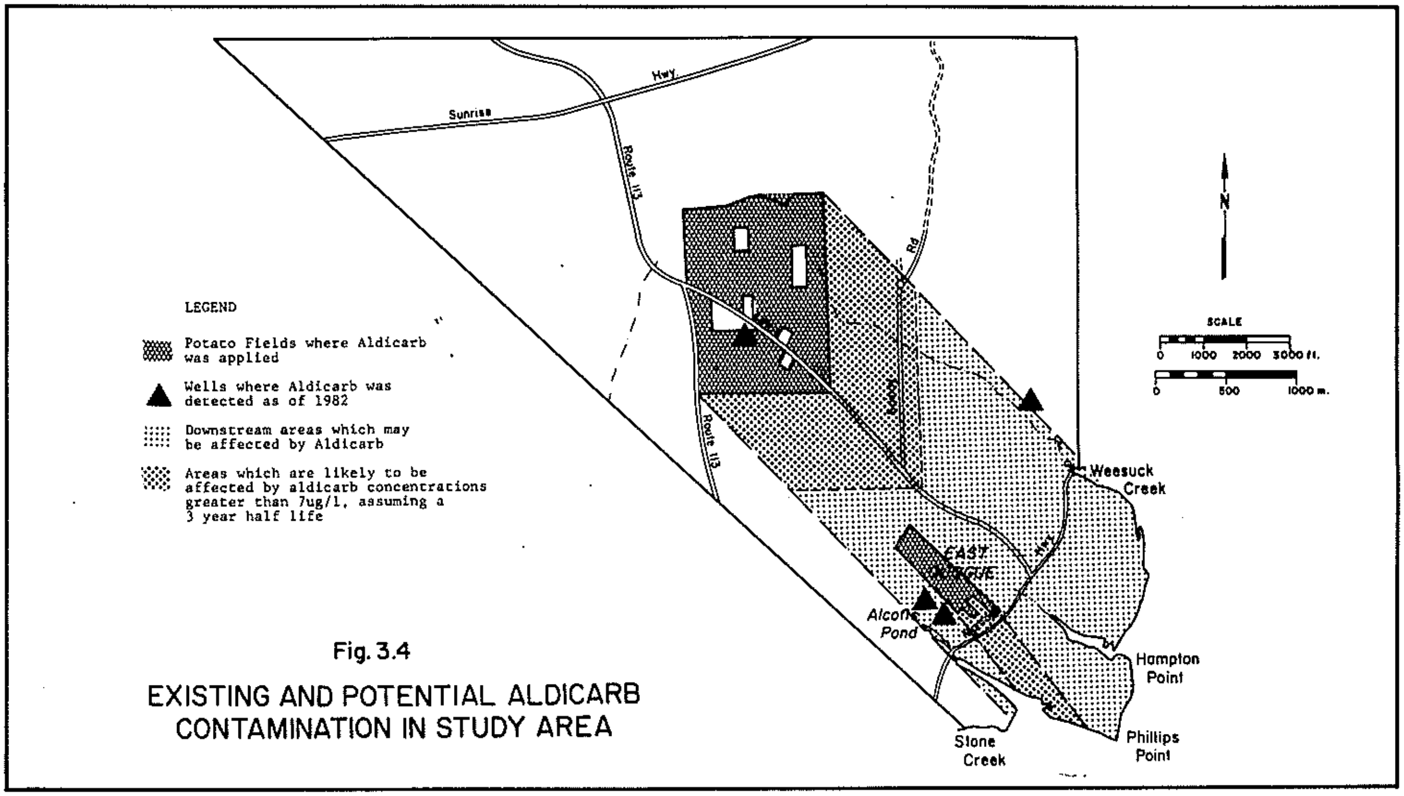


Fig. 3.4

EXISTING AND POTENTIAL ALDICARB CONTAMINATION IN STUDY AREA

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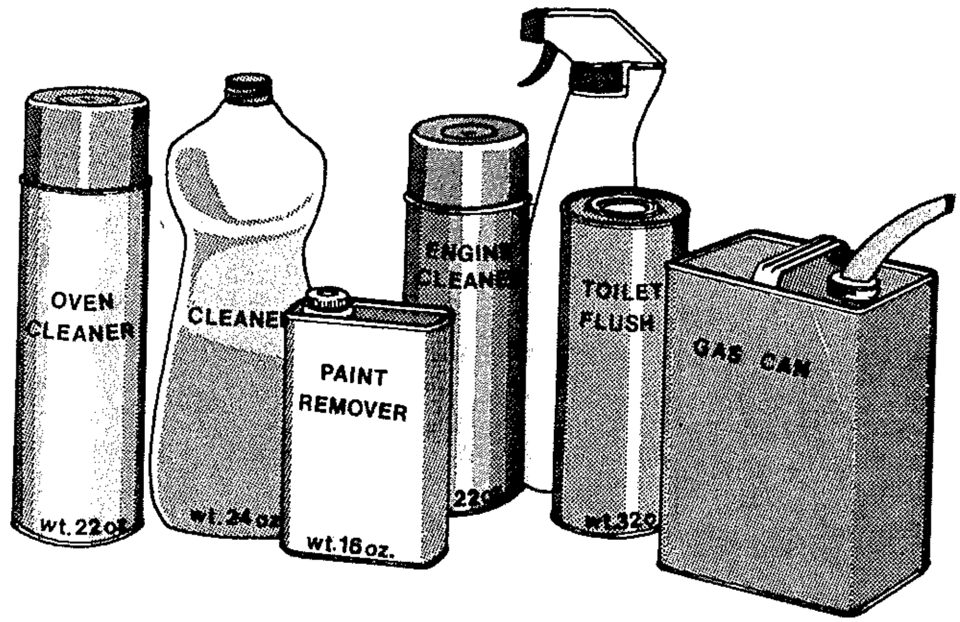


Chapter 4
Potential Contamination by Organic Chemicals

Organic chemicals contained in certain household products have been observed to contaminate the ground water underlying residential areas on Long Island. The main way that these chemicals get into ground water is probably through the on-site domestic wastewater disposal systems. Leaks from underground storage tanks and spills on the surface are other possible ways that the chemicals could get into ground water.

In order to assess the impact of these chemicals on ground water beneath residential areas, the four Long Island communities of Mastic, Mastic Beach, Wading River and Rocky Point where organic contamination has been observed were selected for study. (Figure 4.1). These communities were selected because on-site domestic waste water disposal systems are used throughout each and there is little or no industry in these communities so the organic contamination in each must be due to the residential and commercial activities. Most residents of these communities rely on private house wells for their water supply. Much of the water drawn from wells in each community is water that was recharged from land in the same community, although to some degree, water recharged outside of each community is also being used. Rocky Point and Wading River are located on the north shore and do not extend very far inland. Hence some of the deeper wells in these communities are probably withdrawing water which was recharged further inland and flows under the community (see Chapter 1, Figure 1.1 for a description of flow patterns). Mastic and Mastic Beach are adjoining communities - Mastic Beach is located on the South shore and Mastic is located inland of Mastic Beach. Most of the wells in Mastic probably draw water which was recharged in Mastic and wells in Mastic Beach may draw water which was recharged in either Mastic or Mastic Beach.

The Suffolk County Department of Health Services began testing water from individual home wells for these chemicals in the late 1970's and since 1981 has tested for the presence of 15 organic contaminants (Benzene, toulene, m-xylene, p-xylene, o-xylene, chloroform, bromoform, bromodichloromethane, chlorodibromomethane, carbon tetrachloride, methylene chloride, trichloroethylene, tetrachloroethylene, trichlorotrifluoroethane, 1,1,1trichloroethane). In 1981 and 1982 the County Health Department collected and tested approximately 1000 water samples from these four communities for organics. The assessment used in this study is based on the 1981, 1982 data set.

The ten chemicals listed on Table 4.1 were detected in one or more water samples from these communities. All of these chemicals can produce immediate adverse effects in humans if ingested in large doses (National Research Council, 1977). These chemicals may also be carcinogenic in small doses. Doses which a person would receive from drinking ground water contaminated to the levels found during the Health Department's sampling program would not induce accute toxic effects but might cause cancer or birth defects (National Research Council, 1977).

Table 4.2 shows the number of wells where each chemical was found. Twenty-four percent of the well-water samples contained detectable amounts of at least one organic chemical

Table 4.1
Description of Organic Chemicals Found in Ground Water Underlying Residential Communities on Long Island, New York

Contaminant	Possible Sources	Guideline for Maximum Concentration in Drinking Water	Known or Suspected Adverse Health Effects*
Benzene	Gasoline, Other Petroleum Products Paint Remover Solvents and Cleaning Fluids	5 ug/l**	Observed to cause cancer (leukemia) Toxic at high doses
Toluene	Gasoline, Other Petroleum Products Paint Remover Driveway Degreaser Solvents and Cleaning Fluids Engine Degreasers	50 ug/l	Narcotic effects at high doses Insufficient data on long term effects
Chloroform		50 ug/l	Suspected of causing cancer Toxic at high doses
Trichloroethylene	Solvents and Cleaning Fluids Dry Cleaning Fluids	50 ug/l	Suspected of causing cancer Toxic at high doses
Tetrachloroethylene	Solvent	50 ug/l	Toxic at high doses Insufficient data on long term effects
1,1,1-Trichloroethane	Cesspool Cleaners Oven Cleaner Solvents and Cleaning Fluids	50 ug/l	Insufficient data on long term effects
Carbon Tetrachloride	Solvents and Cleaning Agents	50 ug/l	Suspected of causing cancer Toxic at high doses
Xylene	Gasoline Garage Degreasers Cleaning Fluids Lacquer Thinner Tar Remover	50 ug/l	Toxic at high doses May cause birth defects
Chlorodibromomethane	Unknown	50 ug/l	Insufficient data on long term effects
Methylene Chloride	Paint Remover Cesspool Cleaners Oven Cleaners Cleaning Fluids Engine Degreasers	50 ug/l	Insufficient data on long term effects

* Source: National Research Council, 1977.
** Micrograms per liter (ug/l) is the same as parts per billion.

Table 4.2
Number of Wells Affected by Organic Chemical Contamination in Wading River, Rocky Point, Mastic and Mastic Beach

Contaminant	Number (and Percent) of Wells Where Detected	Number of Wells Where Detected Above Guideline	Highest Concentration Found
Benzene	4 (.4%)	4 (.4%)	170 ug/l
Toluene	5 (.5%)	2 (.2%)	62 ug/l
Chloroform	14 (1.4%)	0	29 ug/l
Trichloroethylene	17 (1.7%)	1 (0.1%)	110 ug/l
Tetrachloroethylene	51 (5.1%)	4 (0.4%)	1100 ug/l
1,1,1-Trichloroethane	203 (20.3%)	23 (2.3%)	330 ug/l
Carbon Tetrachloride	2 (0.2%)	0	7 ug/l
O-Xylene	1 (0.1%)	0	8 ug/l
Chlorodibromomethane	1 (0.1%)	0	2 ug/l
Methylene Chloride	1 (0.1%)	1 (0.1%)	80 ug/l

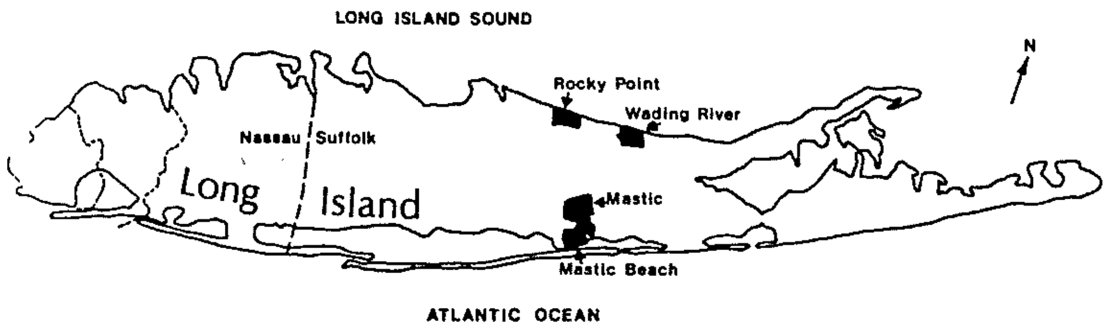


Figure 4.1

The four Long Island communities studied to assess organic chemical contamination of ground water from residential areas.

and 3.7% contained one or more chemical at concentrations greater than the State Department of Health guideline for the maximum concentration allowable in drinking water. The chemical found most often was 1,1,1 trichloroethane, a major ingredient in cesspool cleaners. Xylene, chlorodihromomethane, and methylene chloride were each found in one sample. Benzene, a known carcinogen and the contaminant with the strictest guideline, was found in 0.4% of the samples.

The four communities studied are of different average housing densities. Figure 4.2 graphs housing density versus both the percentage of wells tested where organics were found and the percentage of wells tested where organics were found at concentrations greater than the guideline for drinking water. Table 4.3 presents the data on which the graphs were based. From the graph it appears that the percentage of wells affected in a community is directly proportional to the housing density. This observation supports the theory that each house with its own on-site sewage disposal system is a potential source of organic contamination.

Table 4.3 also shows the average nitrogen concentration measured in each community over the same period. As is expected the average nitrate level increases with housing density. However the presence and concentrations of these chemicals in individual samples are not correlated with nitrate concentrations in the samples. Many of the water samples contained high concentrations of organics and a low concentration of nitrate. This means that even though the average nitrogen concentration in an area may be a rough indication of the percentage of wells affected by organics, land use planning based only on nitrogen loadings will not necessarily provide adequate protection from organic contamination.

The data set is not large enough to make any general conclusions about the percentage of wells contaminated *in excess of the guideline*. Mastic Beach has a higher percentage of wells with contamination in excess of the guideline than the other communities, and this may be related to several factors including the high density and the fact that there is no non-residential area adjoining Mastic Beach from which uncontaminated water could come.

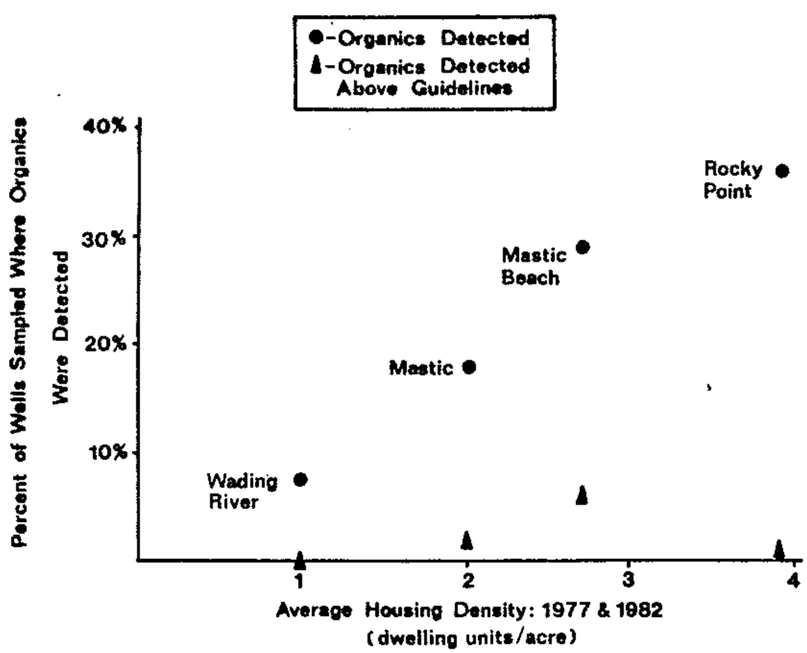
Table 4.3

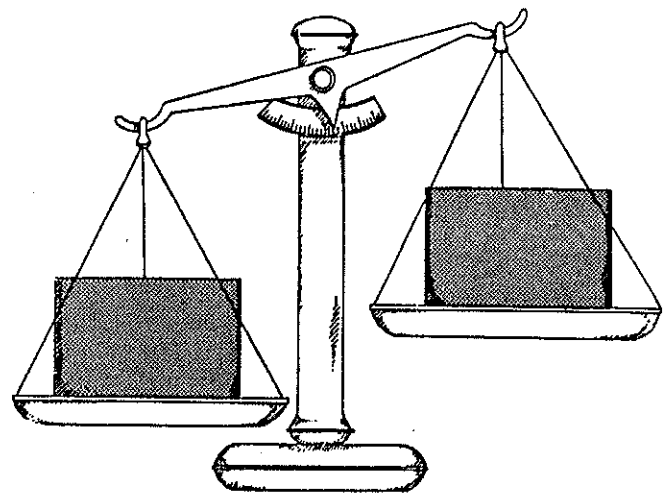
Summary of Organic Chemical Contamination and Nitrogen Concentrations in Private Wells in Four Long Island Communities

Community	Average Housing Density 1977-1982 (Houses/acre)	Number of Wells Sampled for Organics 1981-1982	Percentage (and number) of Wells Sampled Where Organics Were Detected	Percentage of Wells Sampled Where Organics Were Detected at Concen-centrations in Excess of the Guideline	Number of Wells Sampled for Nitrogen 1981-1982	Average Nitrogen (Nitrate plus Ammonia) Concentration (mg/l)
Wading River	1.0	67	8% (5)	0% (0)	120	3.1
Mastic	2.0	317	18% (57)	2% (6)	316	3.8
Mastic Beach	2.7	508	29% (147)	6% (31)	502	3.8
Rocky Point	3.9	97	36% (35)	1% (1)	109	4.4

Figure 4.2

The relationship between average housing density and the percentage of wells in a community affected by organic chemical contamination.





Chapter 5
Water Quality Criteria for Planning

5.1 Discussion of Criteria

In order to effectively maintain the high quality of water in critical aquifer recharge areas, it is necessary to develop criteria which define the desired quality. These criteria should be stringent enough to ensure that the water is of high enough quality for all expected water uses, but not so stringent as to prevent all use of the land, or to impose unreasonable restraints on potential sources of contamination.

Ground water recharged in the Pine Barrens is used for:

(1) Drinking and other human needs, and for
(2) Maintaining the ecological integrity of the surface water bodies to which the ground water is discharged, including streams, wetlands and the Shinnecock Bay.

The New York State Department of Health drinking water standards and the New York State Department of Environmental Conservation Effluent Standards for discharges to ground water can serve as a starting point for developing criteria (see Table 5.1)

The drinking water standards and guidelines apply to public water supply systems and were established to protect human health. The D.E.C. effluent standards apply to discharges to aquifers which are best suited to providing drinking water. Domestic on-site waste water disposal systems and agricultural practices are exempt from the effluent standards provided that these activities do not preclude the use of the ground water for drinking.

In reviewing these and other sources it is highly desirable to keep in mind the current high quality of water in the Pine Barrens. Therefore, we suggest that planning efforts in the Pine

Table 5.1
State Standards for Water Quality for
Contaminants Considered in This Report

Contaminant	NYS DOH Health Standard or Guideline	NYS DEC Effluent Standard (if more stringent*)
Nitrate	10 mg/l	—
Aldicarb	7 ug/l	0.35 ug/l
Benzene	5 ug/l	not detectable
Carbon Tetrachloride	50 ug/l	5 ug/l
Chlorodibromomethane	50 ug/l	—
Chloroform	50 ug/l	—
Methylene Chloride	50 ug/l	—
Tetrachloroethylene	50 ug/l	—
Toluene	50 ug/l	—
1,1,1 Trichloroethane	50 ug/l	—
Trichloroethylene	50 ug/l	10 ug/l
Xylene	50 ug/l	—

* The effluent standard is defined to be the health standard unless a more stringent standard is specified.

Barrens should incorporate a margin of safety sufficient to ensure the continuing high quality of the water in the aquifer. For this purpose, the planning activity must take into account the variability of ground water quality over space and time in order to ensure water of drinkable quality throughout the aquifer virtually all the time.

In order to ensure that concentration of any contaminant is below the standard more than half of the time, the average concentration of the contaminant must be less than the standard. This means that planning standards should be lower than the health standards by an amount that guarantees meeting the health standard a high percentage of the time. This is particularly important for groundwater where relatively little mixing takes place and the benefits of dilution are much less than they are in surface water systems. Porter (1982) evaluated the relationship between the mean concentration of nitrate found in a set of ground water samples from areas in Nassau County and the percentage of samples which violated the 10.0 mg/l standard. He found that if the average nitrate concentration in an area was 5.8 mg/l, then 10% of the samples from that area had nitrate concentrations exceeding 10 mg/l. The areas used for this analysis were about four square miles in area and one could expect the variability to be less if smaller areas were considered.

Given uncertainties about the effects of some organic contaminants, either singly or in combination, it may be argued that it is desirable to have water which is of higher quality than that required by the health standards where practicable. For example, in evaluating the toxicity of benzene the United States Environmental Protection Agency (1981), following the "no-threshold" theory, assumed that the less benzene a person consumed, the less chance a person had of getting cancer caused by benzene. This implies that no level of benzene could be considered entirely safe. The same conclusion would also be true for the other chemicals known or suspected to cause diseases after long term low level exposures. Such an argument for prudence may apply with particular force to the high quality ground water in the Pine Barrens.

5.2 Suggested Criteria

Health standards are normally specified in terms of maximum permissible levels for the contaminants. We suggest that the planning criteria expressed as averages should explicitly provide for the lowest reasonable detectable amounts of chemicals to be discharged in the critical recharge area.

Since nitrate is a background constituent of the water in the Pine Barrens and poses little or no health threat at very low concentrations, the planning criterion, as an average, should be set at some level between the background concentration of 0.2 mg/l and the drinking water standard of 10.0 mg/l, taking into account both ecological and health considerations.

Stedinger (1981) expanded Porter's analysis of the relationship between average nitrate concentrations and the percentage of time that the 10.0 mg/l standard was met. He developed a statistical formula for estimating the percentage of time the health standard was met, given an average nitrate concentration (see Table 5.2).

Table 5.2

Probability of Not Exceeding 10 mg/l	Average Nitrate Concentration
90%	6 mg/l
99%	3 mg/l
99.9%	2 mg/l

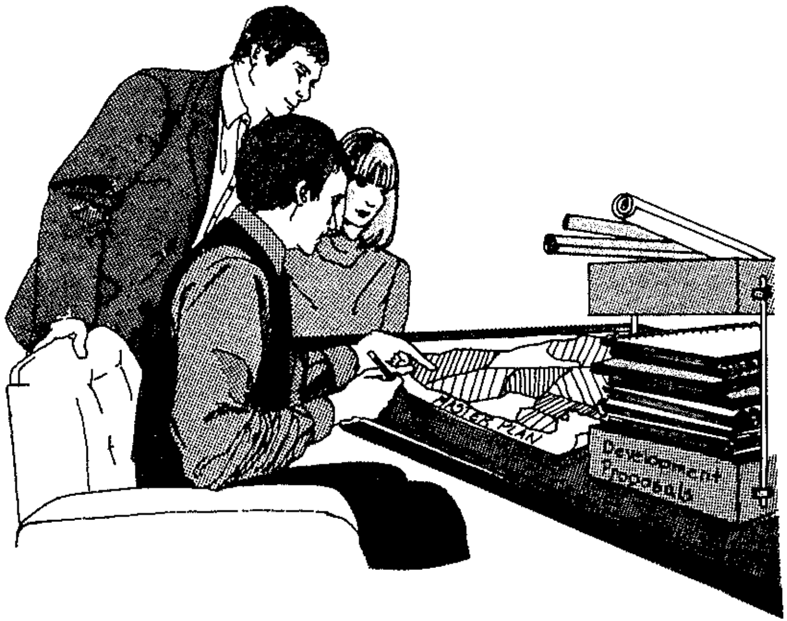
Six mg/l has been used as a planning standard in areas where significant degradation has occurred and expensive remedial measures such as sewering are being considered. However, this criterion still allows 1 water sample in 10 to violate the standard. In a critical aquifer recharge area the goal of planning is to keep all of the water drinkable virtually all of the time. Therefore, in this case, a more stringent criterion seems appropriate.

With respect to ecological considerations, the major threat posed by nitrogen is eutrophication of surface waters, especially the Shinnecock Bay where fishing is an economic and recreational resource. The regional 208 Study (L.I.R.P.B., 1978) notes that bays such as the Shinnecock Bay are particularly susceptible to eutrophication and the resultant low oxygen levels because of increased nitrogen levels. Tetra Tech estimated for the 208 Study that nitrogen concentrations above 0.4 mg/l could lower the oxygen content of the water enough to harm fish. However, since the Bay is flushed with ocean water by the tides quite frequently, it is not possible without further study to estimate the level of nitrogen concentration in ground water that would be consistent with maintaining a healthy aquatic environment.

The New Jersey Pinelands Commission adopted a standard of 2 mg/l for discharges to ground water in the New Jersey Pinelands (an ecological system similar to the Long Island Pine Barrens), with the intent of preventing eutrophication of fresh water wetlands.

Taking all these factors into account, we suggest that either 2 or 3 mg/l would make a reasonable planning criterion for nitrogen discharges to ground water. This will ensure that the health standard is met an estimated 99 or 99.9% of the time. It will allow for some increase in nitrate levels associated with future land use. Further study is necessary to determine how much protection this standard would give to ecological systems.

Similar arguments can be posed for contaminants other than nitrate, but more careful consideration of the circumstances surrounding contamination by these chemicals is needed first. Although detailed statistical analyses have not yet been performed for organic chemicals, such as those listed in Table 5.1, it would appear prudent to establish permissible average loading levels which are less than 50% of the drinking water guideline. The levels actually set should explicitly allow for the variations around the average that normally occur. The possibility of accidental spills of organic chemicals would also have to be considered.



Chapter 6
Assessment of Potential Nitrogen Contamination From Future Land Use Patterns

The Pine Barrens in the northern part of the study area are currently a much needed source of clean water. It is important that future development of this land keep the quality of water recharged within strict criteria, such as those suggested in the previous chapter.

This chapter assesses the nitrogen impact on water quality of various types of residential development in the currently undeveloped Pine Barrens areas, Figure 6.1. The assessment is based on the simulation model which was used to assess the existing residential land uses. This assessment considered the impact of residential development of different densities assuming average residential characteristics. The benefits of reductions in turf fertilizer use and size of turfed area were also assessed.

6.1 Residential Development at Different Densities

Residential development at densities ranging from 4 houses per acre to 1 house per 5 acres were assessed. The data and assumptions are the same as were used for existing residential developments with the following exceptions:

1. The percentage of land devoted to turf, vacant and impervious surface within each land use category were taken from the Long Island Regional Planning Board (1982).
2. All turf was assumed to be fertilized at the rate of 2.5 pounds of nitrogen per thousand square feet. Although it is likely that 25% of the turf would not be fertilized, as in existing developments, it is also likely that there would be entire neighborhoods where virtually all turf was fertilized. For planning purposes it is important to plan for the worst case which would be areas where all turf was fertilized.
3. Population densities were calculated by assuming an average of 2.7 persons per dwelling unit as described in Chapter 2.

Table 6.1 and Figure 6.2 summarize the simulations. As housing density decreases so does the average nitrogen concentration in recharge. At the lower densities, turf is the major source of nitrogen in recharge and in order to obtain lower nitrogen concentrations of recharge at these low densities it will be necessary to reduce the impact of turf.

6.2 Reducing Nitrogen Leached from Turf

It is apparent from Figure 6.2 that reducing the amount of nitrogen leached from turf would significantly reduce the total amount of nitrogen leached from low density residential land. There are two possible ways to limit the nitrogen leached from turf:

1. To limit the amount of land devoted to turf and,
2. To limit the amount of nitrogen fertilizer applied to turf.

Limiting the amount of land devoted to turf can be mandated by an ordinance and is therefore the more practical method for a governmental authority to control nitrogen

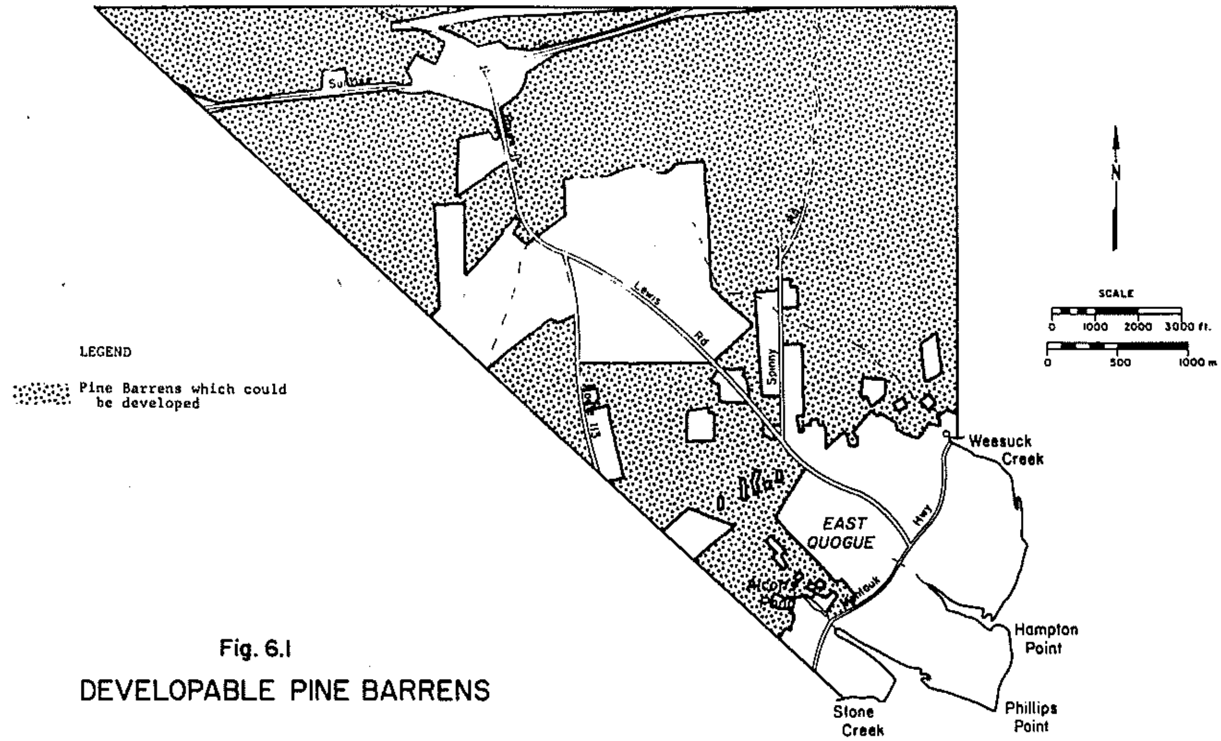


Fig. 6.1
DEVELOPABLE PINE BARRENS

Table 6.1

Simulation of Nitrogen Concentrations in Recharge for Residential Developments on Carver and Plymouth Sands

Housing Density	Percent Coverage by Natural	Percent Coverage by Turf	Percent Coverage by Impervious	Population Density (Persons/acre)	Nitrogen Concentration in Recharge (mg/l)	Confidence Range (mg/l)
4 Houses/acre	8%	57%	35%	10.8	10.9	(6.4-13.9)
2 Houses/acre	31%	44%	25%	5.4	8.0	(4.8-10.0)
1 House/acre	34%	46%	20%	2.7	6.8	(3.9-8.1)
1/2 House/acre	47%	40%	13%	1.4	5.6	(3.2-6.6)
1/5 House/acre	53%	40%	7%	0.5	5.2	(2.9-5.9)

leaching from turf. Reducing the amount of fertilizer applied to turf can also be beneficial in terms of limiting the amount of nitrogen leached, but fertilizer regulations would be very difficult to enforce. An educational effort would be a more practical way to achieve limitations in fetilizer use.

Figure 6.3 illustrates the relationship between the percentage of land devoted to turf and the total nitrogen leaching for residential densities of 1/2 house per acre and 1/5 house per acre. Land not used for ornamental turf is assumed to have a natural vegetative cover. All other characteristics of these land uses categories are assumed to be constant, and are as described on Table 6.1

Table 6.2

Rate of Fertilization and Nitrogen Leached

Fertilization Rate lb/1000ft²/yr	Number of Applications	Simulated Nitrogen Leached (lb/1000ft2/yr)	Simulated Nitrogen Leached (lb/1000ft²/yr)
1.0	1	0.6	3.7
2.0	2	1.1	7.1
2.5	3	1.4	9.4
3.0	3	1.8	11.9

Table 6.2 illustrates the relationship between fertilization rate and nitrogen leaching from turf. All other aspects of the turf system such as clipping disposal and irrigation rate, were held constant as described on Table 2.4. The timing of fertilizer applications for the different rates were according to Cooperative Extension recommendations. These results are very sensitive to these assumptions about management practices other than amount of fertilizer, and thus these numbers apply only to the particular conditions assumed.

6.3 Potential Impact of a Golf Course

A golf course is a land use which could be part of a residential development. Golf courses are made up of several types of turf which are maintained in special ways to facilitate the playing of golf. Table 6.3 summarizes the simulated impact that a golf course would have in the study area.

The fertilization rates and mowing rates for the various types of turf were obtained from surveys of several golf course owners and discussions with turf experts at Cornell. Since management practices vary, an "average" set of practices was chosen. Since there were no field measurements available of plant uptake or leaching of nitrogen or other parts of the nitrogen budget under these conditions, the simulation results must be considered approximate. It is reasonable to conclude from these results that the average nitrogen concentration in recharge water from a golf course located on Carver and Plymouth sands would be greater than 3 milligrams per liter.

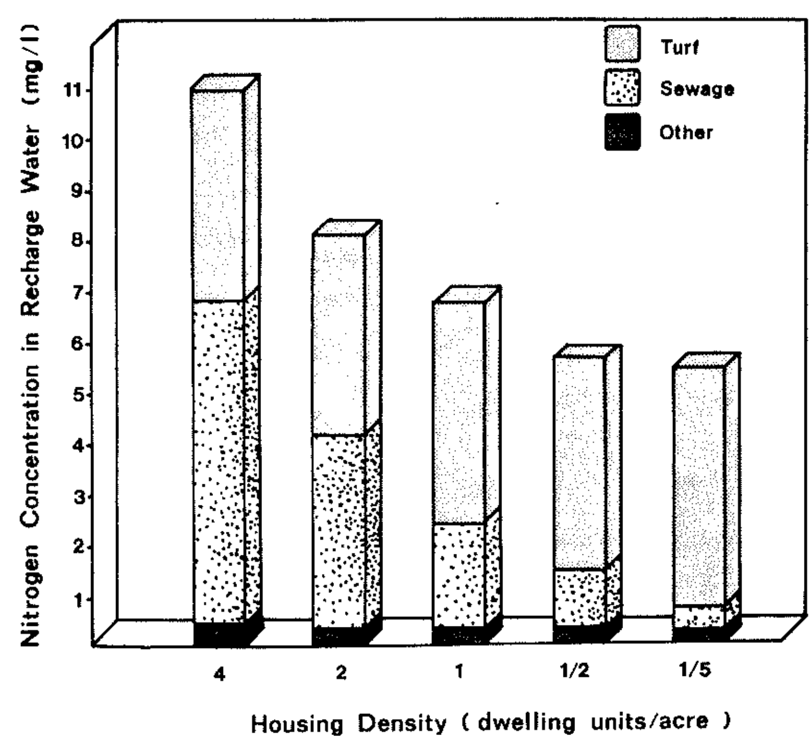


Figure 6.2

Simulated nitrogen concentration in recharge for future residential developments of various densities. Total nitrogen leached is broken down by percentage of nitrogen from turf, sewage and other.

Table 6.3

Potential Nitrogen Impact of a Golf Course

Land Type	Land Use Data: Percentage of Typical Golf Course	Land Use Data: Fertilization Rate (lb/1000 sq. ft./yr)	Nitrogen Removed with Clippings (lb/1000 sq. ft./yr)	Nitrogen Leached (lb/1000 sq. ft./yr)
Vacant	10%	0.0	0.0	0.02
Impervious	5%	0.0	0.0	0.11
Fairways*	60%	2.0	0.0	1.9
Tees	2%	4.5	2.6	2.3
Greens	3%	4.5	2.7	2.3
Roughs and Grounds	20%	1.25	0.0	0.7

Overall Average Nitrogen Concentration in Recharge Water: 7.5 mg/l (as N)

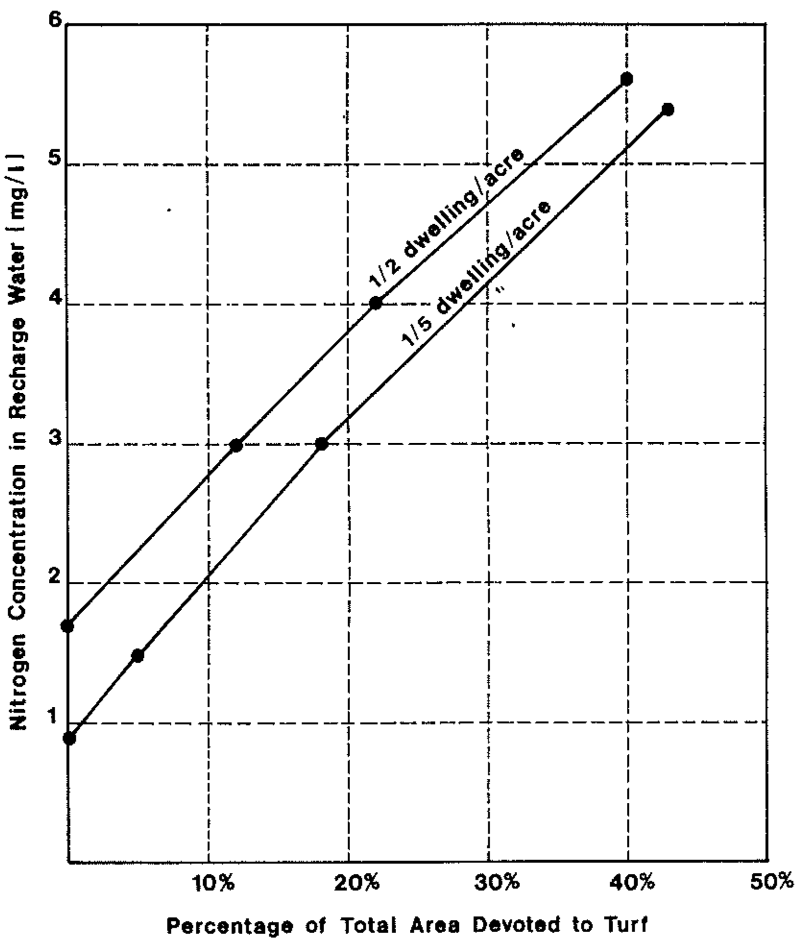
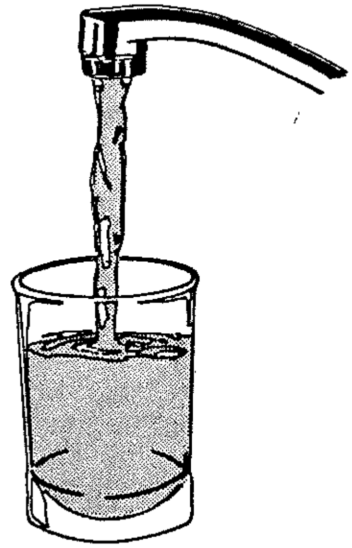


Figure 6.3

The relationship between the amount of land devoted to turf and the total amount of nitrogen leached from residential land with 1/2 dwelling /acre and 1/5 dwelling/acre.

Land not in turf or impervious surface is assumed to have unfertilized natural vegetation



Chapter 7
Summary and Conclusions

The Pine Barrens in the Town of Southampton on Long Island overlie large parts of the critical recharge areas for the regions ground water supply which is the sole source of fresh drinking water. This study concentrated on a representative part of Southampton around the community of East Quogue and related existing land use to observed water quality using the Water and Land Resource Analysis System (WALRAS). Potential ground water contamination problems were identified and potential methods for preventing these problems are suggested below.

The contaminants considered in this study can be divided into three categories: (1) nitrate-nitrogen, (2) pesticides, and (3) other organic contaminants. These contaminants are the ones which are most likely to cause future water quality problems if preventive measures are not taken.

Several conclusions can be drawn from this study and the work which preceded it about the impact of existing land use on ground water quality in the study area:

1. Nitrogen concentrations in ground water recharged from undisturbed Pine Barrens are quite low because the natural Pine Barrens vegetation remove some of the nitrogen from precipitation before it is recharged to ground water. Apparently this is due to the processes of plant uptake of nitrogen and denitrification.
2. Nitrate-nitrogen concentrations in ground water underlying residential and agricultural land in the study area are substantially higher than in the undisturbed areas. Nitrogen from fertilizers and on-site wastewater disposal systems are the major sources of this nitrogen.
3. The pesticide aldicarb which was used on potato fields in the study area from 1975 through 1979 has been found in some private wells adjoining the potato fields. Aldicarb is likely to be found in many more wells downstream of the potato fields including the public supply wells on Spinney Road before it decays to harmless substances. The total extent and severity of the potential contamination problem depends on the decay rate of aldicarb in ground water which is still unknown.
   Continued monitoring by the Suffolk County Department of Health Services will be needed to track the plume so that treatment units can be provided to homeowners whose wells are affected. The Suffolk County Water Authority should continue to test for aldicarb at its wells on Spinney Road so that appropriate measures can be taken if aldicarb contaminates these wells at some time in the future. It might be useful to place a monitoring well upstream from the public supply wells to get information about the position and concentration of the aldicarb plume before it reaches the public supply wells. Since the Water Authority does have excess capacity at its other wells that would allow it to immediately close down and do without the Spinney Road wells as soon as contamination were detected, the advance warning is not absolutely necessary.
4. Organic chemicals which are disposed of on residential, commercial and industrial land have been found in other Long Island communities and the percentage of wells affected in a community was found to be proportional to housing density in four residential communities. Although no organics have been reported found in the study area this may be because very few water samples from the study area have been tested for organics.

Because the Pine Barrens in Southampton overly critical recharge areas, and because the quality of the water recharged from the Pine Barrens is currently very good, several agencies have suggested that the Pine Barrens areas be protected from land uses which would seriously degrade the quality of the recharge.

The ideal policy for protecting the ground water would be to allow no degradation of quality. However, this would preclude any use of the Pine Barrens land other than maintaining it in its natural state, and therefore in order to implement a nondegradation policy the land would almost certainly have to be purchased and maintained by a public agency. Since sufficient public funds are not currently available to purchase all of the Pine Barrens land in critical recharge areas, ground-water protection will have to rely on regulated or voluntary management of private land. The following conclusions can be drawn from this study with regard to preserving the water quality in the Pine Barrens.

1. *Organic chemical* contamination which could result from industrial, commercial or residential development poses the most serious threat to ground water quality in the Pine Barrens, because of the severe health hazard that some of these chemicals represent. More study is needed to determine the quantities of these chemicals which are used and the fate of these chemicals before they enter ground water. Discharges of organic chemicals may often be accidental, or intentional but illegal, and this is an added uncertainty which must be considered when dealing with organic chemicals. When and if an adequate understanding exists it may be possible to develop loading criteria which would ensure a certain level of compliance with the guidelines. At that time land use decisions could be based on these criteria. At present, only preliminary suggestions can be made about ways of preventing organic contamination:
   a. Major potential sources of organic contamination should not be located in the critical recharge areas unless adequate systems are designed to detect and clean up any discharge before ground water is contaminated. This would include all industrial and commercial operations which involve handling or storage of organic chemicals or petroleum products.
   b. Residential dwellings, which are also potential sources should be limited to the lowest feasible density to minimize the number of potential sources. This study found that as housing density increases, so does the percentage of wells which are contaminated by organics. Thus, limiting residential land to the 1/5 house per acre density would be a prudent first step toward preventing organic contamination. This step alone, however, would not guarantee that organic contamination would be contained within acceptable levels.
   c. Efforts should be made to prevent the discharge of organic chemicals from residential dwellings. The Suffolk County ban on organic septic tank and cesspool cleaners will prevent many discharges. As more is learned about the sources of these chemicals in ground water, other actions may be warranted.
2. New *pesticides* should be screened to determine which are likely to leach. Thorough analysis of such higher risk pesticides by Federal, State and local agencies before registration is necessary to prevent future contamination incidents by pesticides.
3. *Nitrate* contamination could become severe if Pine Barrens areas were converted to intense agricultural or residential uses. Because the soils are relatively infertile in the Pine Barrens areas, agricultural expansion is unlikely. The simulations of nitrogen leached from agricultural land, including potatoes, vegetables and nurseries, conducted for this study do indicate that nitrogen losses to ground water are likely to be high on the Pine Barrens soils for these types of agriculture. The simulations also indicate that much nitrogen could leach from golf courses to ground water.
   We recommend that for critical recharge areas in the Pine Barrens, a criterion for nitrogen concentration in recharge water of an average of 2 or 3 mg/l be selected as a basis for ← land use ordinances, and that every house lot be required to be designed so that the average nitrogen concentration from that lot be less than the criterion. Nitrate contamination from residential land at 1/5 house/acre density can be held to a level of 3 mg/l or 2 mg/l as long as provisions are taken to limit the amount of nitrogen which leaches from turf. One way to accomplish this is by restricting the percent of land devoted to turf to 18% or 10% depending on whether a 3 mg/l or 2 mg/l criterion is used, provided that the remaining pervious land is covered by unfertilized natural vegetation.

Further study would be necessary to determine the impacts that golf courses and nurseries would have on ground water under various management schemes. The average management practices assumed for this study resulted in simulated nitrogen concentrations in recharge which were higher than 3 mg/l. An evaluation of other management practices using data from field experiments would be desirable to determine if these land uses might be able to meet the nitrogen criterion with particular management practices.

4. Ultimately, the quality and quantity of groundwater under the Pine Barrens will be determined by the actions of people who live, work or play within its area. Therefore, it is essential that individuals have sufficient understanding of the resource so that "good housekeeping" practices are followed. For this purpose, a continuing educational program is strongly recommended.

Although this study concentrated on a small section of Pine Barrens, the results regarding the impact of future land uses on ground water quality can be applied to other parts of Long Island's Pine Barrens where Carver and Plymouth Sands are the dominant soils. However, it should be emphasized that the conclusions of this report are derived from the evaluation of the East Quogue study area and, we stress that transferring the results to other areas should be done only after ensuring that the extrapolation is valid. Where other areas have characteristics different from East Quogue, further evaluations of such areas is necessary for the development and application of management policies to them. Also, this study was limited in scope and only addressed the land use situations which seemed most likely to occur in the Pine Barrens in the near future. More study will be needed to address different land uses or management schemes which may be proposed.

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Appendix
Turf Nitrogen Simulations

One of the major concerns on Long Island is the contamination of ground water due to nitrates and the contribution that nitrogen fertilizers used on turf adds to this contamination. The assessment of nitrogen leaching from turf described in this report is based on a detailed simulation of water and nitrogen movement in the turf root zone using the WALRAS root zone nitrogen simulation model. The model computes the amount of nitrogen that leaches out of the root zone and gets into ground water, taking into account all of the significant environmental and management factors such as soil properties, climate, fertilization timing and rate, pet waste deposited on turf and irrigation. The details of the WALRAS simulation models can be found in manuals written by the Center for Environmental Research.

This appendix describes:

1. how the model was calibrated to be consistent with field experiments on turf uptake of nitrogen,
2. a comparison of simulated nitrogen leached with observed nitrogen in ground water, and
3. an assessment of the uncertainty of the simulation results.

Calibration

The two most significant fates of nitrogen in the turf root zone are uptake by the plants and leaching (gaseous loss and runoff also remove nitrogen from the root zone.) Plant uptake by turf has been extensively measured in field experiments in a way which allows a direct comparison with simulated plant uptake. Therefore we were able to calibrate the plant uptake simulation using these field results which were conducted by the Long Island Horticultural Research Laboratory, L.I.H.R.L. (Selleck and others, 1980).

Between 1974 and 1976 the eight fertilization treatments described in Table 1 were tested on experimental turf plots at the Long Island Horticulutral Research Laboratory. At the end of the experimental period the nitrogen content of the plants was measured. The amount of nitrogen fertilizer taken up by plants was determined by subtracting the nitrogen content of unfertilized turf on control plots from the nitrogen content of fertilized turf.

These experimental conditions were simulated using the WALRAS model and the field results and the simulation results were compared. Minor adjustments were made to the parameters which control the plant uptake simulation to make uptake results measured on sod farms as part of the same L.I.H.R.L. study.

Figure 1 shows a comparison of the simulated and observed nitrogen uptake by turf. Line A represents the amount of nitrogen which would be in the plants if their uptake of fertilizer nitrogen was 100% efficient. Line B represents the actual amount of fertilizer nitrogen retained in the plants. The simulation results compare well with the observed results.

Comparison with Well Data

In order to test the accuracy of the simulations for predicting ground water quality underneath turf, simulation results were compared with water quality data from shallow observation wells in the Twelve Pines subdivision in Medford, N.Y. (Figure 2).

Table 1. Rates and dates of fertilizer N aplied to turf (Selleck and others, 1980)

Treatment	Fertilization Rate per Application (lb N/1000 sq ft)	Dates of Application	Total N /32 mos.	Total N /yr
1	0		0	0
2	.260	1974: 5/26,6/24,9/2 9/24,10/9,11/5 1975 and 1976: 4/1,4/21 5/7,6/1,9/1 9/21,10/7, 11/1	5.64	1.89
3	1.03	1974: 5/26,9/2 1976 and 1977: 4/1,9/1	6.15	2.05
4	.51	as in 2 (above)	11.28	3.75
5	1.03	1974: 5/26,6/24,9/2 10/9 1975 and 1976: 4/1,9/1	12.3	4.10
6	2.05	1974: 5/26,9/2 1975 and 1976: 4/1,9/1	12.3	4.10
7	1.03	as in 2 (above)	22.55	7.50
8	2.05	as in 5 (above)	24.60	8.2

The subdivision was constructed on previously-wooded lands starting in 1970. Fourteen shallow observations wells were installed by USGS and Suffolk County in the Spring of 1972. The water table at that time was about forty feet below the land surface.

During the 1972 to 1978 period, data were collected to estimate the amount of nitrogen added to the soil. Since the area serviced by collective sewers which export sewage from the start, sewage was not a significant source. This allowed for closer analysis of the nitrogen sources associated with turf management, rainfall, and pets. Table 2 summarizes the data used in the WALRAS simulations. Turf simulations were combined with water and nitrogen simulations of forested land and impervious surface to calculate the overall nitrogen content of recharge water. The simulation results are summarized on Table 3.

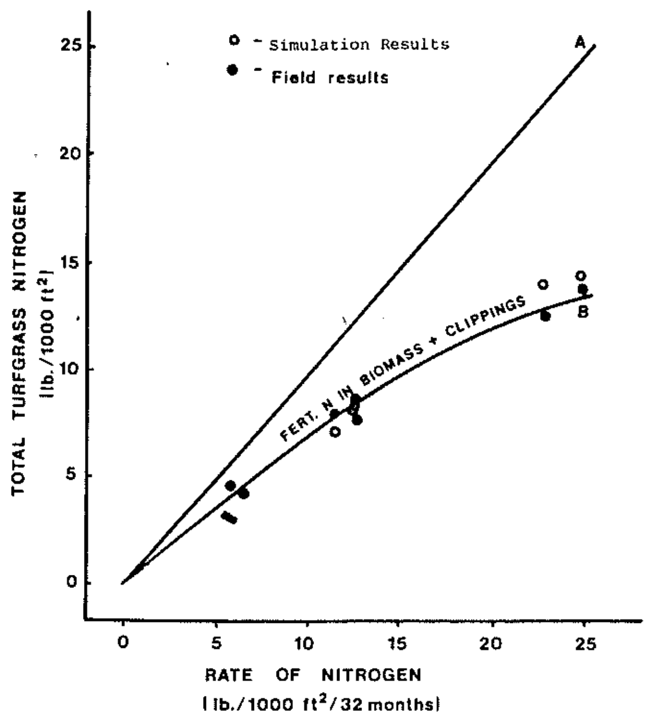

Figure 1.

Comparison of field data with Walras simulations of nitrogen uptake by turf.

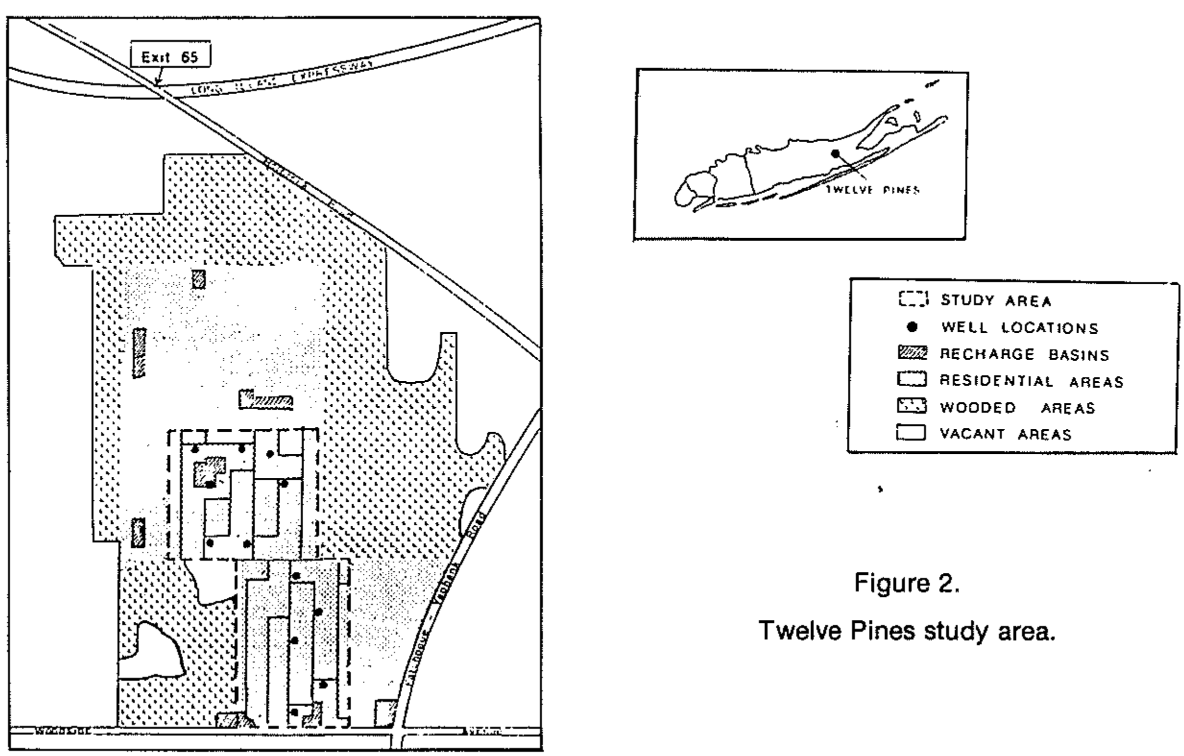

Figure 2.

Twelve Pines study area.

Table 2
Basic Data for the Twelve Pines Subdivision

Parameter	Value(s)	Remarks(22)
Fraction of area occupied by turf.	0.50	Estimated by measure ments of low-altitude aerial photos and at site.
Fraction of area covered by impervious surface.	0.16	As above.
Nitrogen concentration in precipitation.	1 mg/l	Based on samples by Suffolk County Dept. of Env. Control.
Nitrogen concentration in water supply water (mean).	2.1 mg/l	Based on samples of tap water.
Lawn fertilizer rate.	106 N/ha/yr (95 lbs/acre/yr, 2.2 lbs/1000 ft²/yr)	From Porter and others (1978). 1976 data.
Pest waste nitrogen application rate.	16 kg/ha/yr	
Fraction of lawn clippings removed.	0.75	1976 homeowner survey

Table 3
Simulated Nitrogen in Recharge*
Twelve Pines Study Area

Year	Water Recharged (in)	Nitrogen Recharged (lb/acre)	Nitrogen Concentration (mg/l)
1972	45.7	17.9	1.7
1973	28.1	13.3	2.1
1974	18.2	10.9	2.7
1975	28.4	16.5	2.6
1976	15.6	7.2	2.0

*Simulations include vacant land and impervious surface which contribute small amounts of nitrogen as well as turf which is the main source of nitrogen in recharge. All runoff water is assumed to be recharged through recharge basins.

Table 4
Summary of Twelve Pines Well Data

Total Nitrogen Wells 1,4,5,6,8,9,10,11,13,14

Year	Number of Samples	Mean (mg/l)	Standard Deviation (mg/l)
1972	40	1.58	1.14
1973*	8	1.05	0.64
1974	36	1.47	1.34
1975	40	2.17	1.49
1976	30	2.15	1.20
1977	20	2.19	1.36
1978	41	2.55	1.03

*Samples not representative of the year. Data for May or June, one sample per well, only.

which contribute small amounts of nitrogen as well as turf which is the main source of nitrogen in recharge. All runoff water is assumed to be recharged through recharge basins.

Four of the observation wells were located in areas which received some recharge from outside of the study area, so data from these wells were not used. Data from the ten remaining wells (1,4,5,6,8,9,10,11,13,14) are summarized in Table 4 for each year.

The time it takes for recharge water to travel the 40 feet from the surface to the water table is approximately 2 years (assuming general sand and gravel subsurface conditions). The simulated recharge nitrogen concentrations should thus be compared with nitrogen concentrations measured in wells two years later. Because flow in the unsaturated zone is variable, subsurface water mixes and the nitrogen concentrations observed in wells will actually represent a mixture of recharge water from several years. The simulation results are compared with the field measurements in Table 5. The simulated concentrations correspond closely to the observed concentrations.

Table 5
Comparison of Observed and Simulated Nitrogen Concentrations in Ground Water, Twelve Pines Subdivision

Year Wells Sampled	Average Nitrogen Concentration in Wells (mg/l)	Simulated Average Nitrogen in Recharge (mg/l)	Year Root Zone Simulated
(1974)	1.47	1.7	(1972)
(1975)	2.17	2.1	(1973)
(1976)	2.15	2.7	(1974)
(1977)	2.19	2.6	(1975)
(1978)	2.55	2.0	(1976)
average:	2.11	2.22	

Assessment of Uncertainty

A sensitivity analysis was conducted on the turf simulations to determine the margin of error in the results, caused by the uncertainty of the accuracy of the way turf is represented by the model. The model was constructed by using the best estimated value for each parameter in order to accurately represent the system. For the sensitivity analysis the parameters were changed to represent the range of possible impacts that the system might have on nitrogen concentrations in recharge. The parameters were varied systematically to represent the maximum possible impact that the turf system would have on ground water nitrate levels and the minimum possible impact. Table 6 shows the ranges of parameters that were used and the simulation results.

The maximum impact simulation resulted in a nitrogen concentration 10% greater than the medium impact; the nitrogen concentration of the minimum impact simulation was 46% less than the medium impact. The comparison of simulated nitrogen concentrations with observed concentrations on Table 5 showed that in that case the amount that the simulated concentrations differed from the observed concentrations was well within this range. These ranges were used in computing confidence intervals for land uses involving turf.

Table 6
Summary of Sensitivity Analysis of the WALRAS
Root Zone Water and Nitrogen Simulations for Turf
For Conditions Representing Southampton, N.Y.

Parameter*	Maximum Impact on Ground Water	Medium Impact on Ground Water**	Minimum Impact on Ground Water
Depth of root zone:	10 cm (3.9 in)	20 cm (7.9 in)	30 cm (11.8 in)
Maximum allowable plant nitrogen content	75 kg/ha (68.2 lb/acre)	300 kg/ha (272.7 lb/acre)	300 kg/ha (272.7 lb/acre)
Parameter allowing increased N uptake via diffusion:***	0	0	0.5
Denitrification rate:	0.0003 1/day	0.0005 1/day	0.001 1/day
Fraction of inorganic fertilizer which is lost as a gas:	0.025	0.05	0.1
Simulated Nitrogen Concentration in Recharge Water:	10.3 mg/l	9.4 mg/l	5.1 mg/l

*The parameters are described in detail in the WALRAS manuals.
**The medium impact parameters are the best estimates of these parameters determined from literature and the calibration.
***The larger this parameter the faster the plants will take up nitrogen in the simulations.