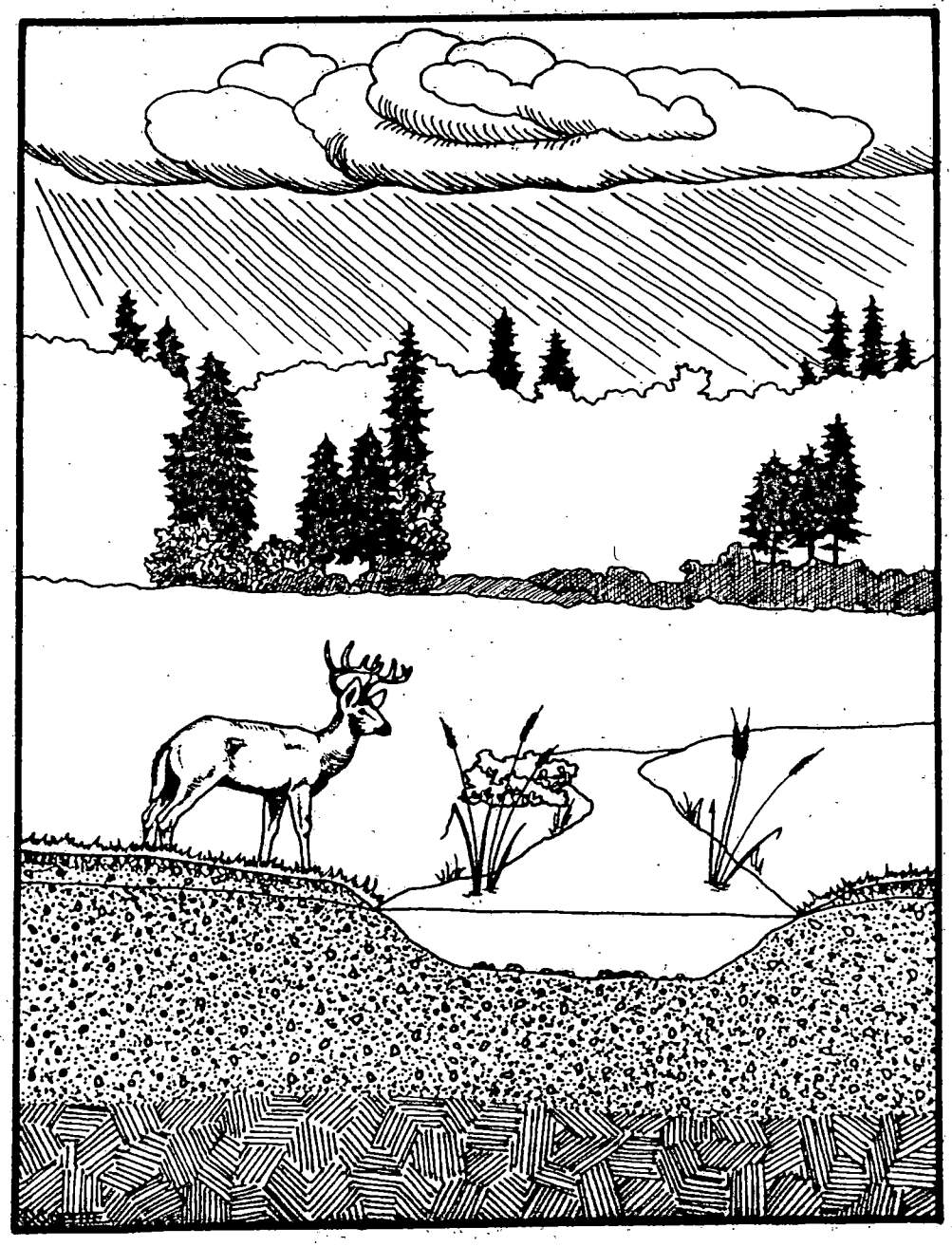
Aquifer Protection Planning for the Tug Hill Aquifer Communities

A Resource Collection and Final Report



Water Resources Program
Center for Environmental Research
Cornell University

Aquifer Protection Planning for the Tug Hill Aquifer Communities

A Resource Collection and Final Report

August 1985

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The Temporary State Commission on Tug Hill
Watertown, N.Y.

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The illustrations used in this report were drawn by Donna Curtin and Christine Cleveland.

Numerous other people contributed their time and energy to various aspects of this project and their efforts helped stretch the value of this modest effort.

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Introduction

This report is a collection of materials developed for Tug Hill communities to assist them with aquifer protection planning. They are compiled here for convenient use by circuit riders and planners in the Tug Hill Region. The synopsis series articles at the end of this report will eventually be part of a handbook for local officials which should be ready sometime in 1986.

The first four sections in this report were developed specifically for the Town of Adams. Much of the material in these sections would be useful to other Tug Hill communities interested in aquifer protection planning. The first section describes important watershed areas for the Town of Adams. Following this are three hypothetical case studies which illustrate the threat to groundwater quality posed by residential land, industrial or commercial land and agricultural land.

The fifth section describes the results of testing for nitrate and coliform bacteria in private wells in the Oswego County portion of the aquifer. The nitrate tests confirm the measurable impact that residential and agricultural land have on groundwater quality.

The last four sections are articles developed for a handbook for local officials which were also included in the Center for Environmental Research Synopsis Series. These articles cover the same subjects covered in the Adams material, but are more general in terms of describing the threat. These articles go into detail on what options local officials have for protecting their groundwater supplies from these threats.

WATERSHED AREAS IMPORTANT FOR PUBLIC WATER SUPPLY IN THE TOWN OF ADAMS

The quantity and quality of water available at a well or spring is influenced by human activities in the watershed supplying the well or spring with water. A recent study for the New York State Department of Health (Hennigan, 1981) specifies three types of land in a watershed which need to be considered to protect a ground water supply:

1. Well head area - the area right next to the well generally within 200 feet of the well or spring.

2. Aquifer recharge area upstream of well - the area of land directly over an aquifer where water from precipitation percolates directly through the soil to the aquifer and then passes through the aquifer to the well.

3. Watershed tributary to aquifer recharge area - if surface water or runoff flows into the aquifer recharge area and becomes recharge water, this is the watershed from which the surface water comes.

From the preliminary information provided by the aquifer project, we have delineated these areas for the two public water supplies in Adams on Figure 1. It is important to realize that the boundary of the aquifer recharge area upstream of the well can only be determined in an approximate manner. The exact area supplying recharge to a well at a particular time is influenced by underground features and by the weather. For example, the recharge area for a well may expand or even shift slightly during dry periods as compared with wet periods.

The three types of land differ in their importance to the water supply and in the appropriate level of protection:

1. Well head areas are the most important and these areas are usually owned by the water company or municipality. Control of this area is necessary to prevent bacterial or viral contamination.

2. The aquifer recharge area upstream of the well is next in importance since certain types of chemicals could contaminate the water supply if they were allowed to enter the aquifer in this area. A chemical release on the land surface in this area would travel toward the well underground and hence might not be detected before it reached the well.

3. The watershed tributary to the aquifer recharge area is important because it is also supplying water to the well. It is less critical than the first two areas since it is further away from the well and because the water it is supplying travels over the surface. It is more likely that a chemical release in this area could be detected and cleaned up before the water supply was affected than a release in the recharge area.

The **amount** of water available at a well is also dependent on land use within the watershed. A change in land use which involved paving large areas and draining the runoff directly into the streams would reduce the amount of water recharged and hence reduce the amount of water available to the well.

Some Notes About Adams

1. Wetland areas play an important role in the watershed for Adams' main supply wells. Wetlands remove many types of contaminants and these wetlands probably help to purify Adams' water to its current good quality. The wetland southeast of Adams Center, for example, serves as a buffer between the aquifer recharge area and the upland watershed. Also, the poor drainage just east of Adams' main wells, where the small stream goes underground, may help to keep the

water table higher in dry periods by holding back water which would runoff if the area were drained better.

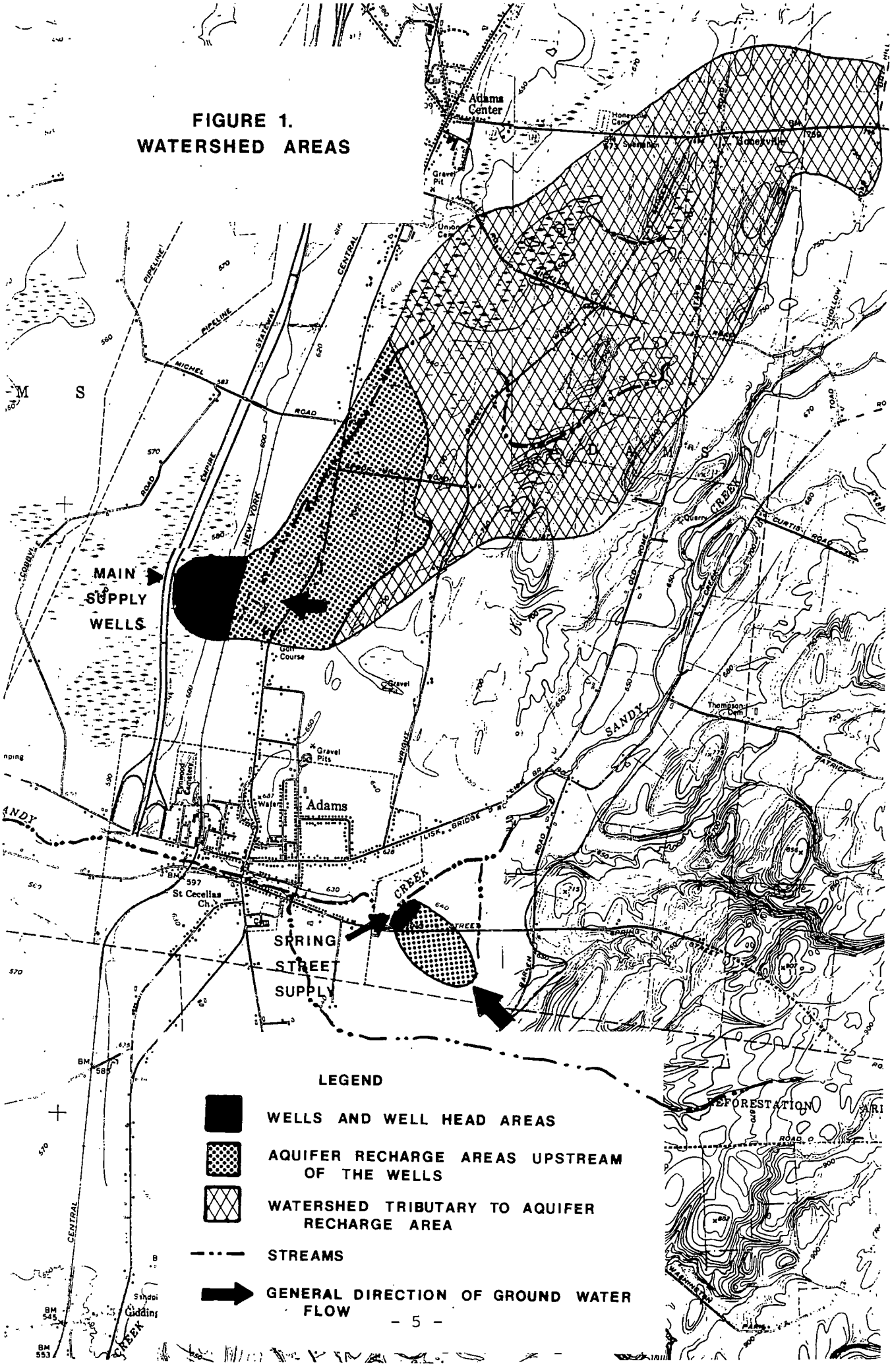
2. Preliminary geologic data from the aquifer project indicates that the aquifer is probably much thicker near the Spring Street supply than in the area of the main wells. If this is the case, it means there could be much water stored in the aquifer near Spring Street which is not currently being used.

3. Private wells provide water to many residents of Adams. While watersheds serving public supplies may warrant special protection, private wells should also be considered in planning to protect the aquifer.

Reference

Hennigan, Robert D. 1981. Water Supply Source Protection Rules and Regulations Project, Final Report. State University of New York, College of Environmental Science and Forestry. Syracuse, N.Y.

FIGURE 1.
WATERSHED AREAS



Tug Hill Aquifer Case Study 1

THE POTENTIAL IMPACT OF RESIDENTIAL DEVELOPMENT ON GROUND WATER QUALITY IN THE TOWN OF ADAMS

Residential development on land overlying the aquifer which feeds the public supply in Adams could affect the quality of the water. From studies of the impact of residential land on other aquifers in New York State we know what kind of problems come from residential developments and we can assess the likely impact in Adams.

Nitrate and some synthetic organic chemicals are the chemicals which are most likely to cause groundwater contamination in residential areas. The main sources of contamination in residential areas are septic tanks and cesspools, but chemicals applied or spilled on the land surface have also been known to cause problems.

Nitrate

Nitrate is a nitrogen compound which forms in septic tanks and cesspools when the organic matter in them decays. Since nitrate is very soluble, it is carried by leachate water into the ground water. Other possible sources of nitrate in residential areas are the nitrogen fertilizers applied to lawns and pet wastes.

Figure 1 shows how the average nitrate concentration in groundwater underneath a residential development would rise with increasing population density in Adams.

The nitrate concentration in drinking water is limited to 10 mg/l by the State Department of Health to protect infants. Nitrate has been observed to cause a sometimes serious blood disorder, methemaglobanemia, in infants. It is necessary to keep the average nitrate concentration in groundwater well below 10 mg/l to avoid occassional violations of the standard because concentrations tend to fluctuate.

Synthetic Organic Chemicals

Many modern household chemicals which are in the category of "synthetic organics" have been found to contaminate groundwater in residential areas. The worst problems are caused by drain cleaners and cesspool cleaners which are intended to be poured down the drain, and go directly into groundwater from the cesspool or septic tank. Waste oil or paint thinner which is dumped in the back yard can also be sources of contamination. Table 1 describes some common synthetic organic groundwater contaminants.

Because the suspected health effects of these chemicals are quite serious, it is very desirable to keep these chemicals out of drinking water.

Preventive Techniques

There are several techniques which can be used to prevent groundwater contamination from existing or planned residential developments. Some possibilities are:

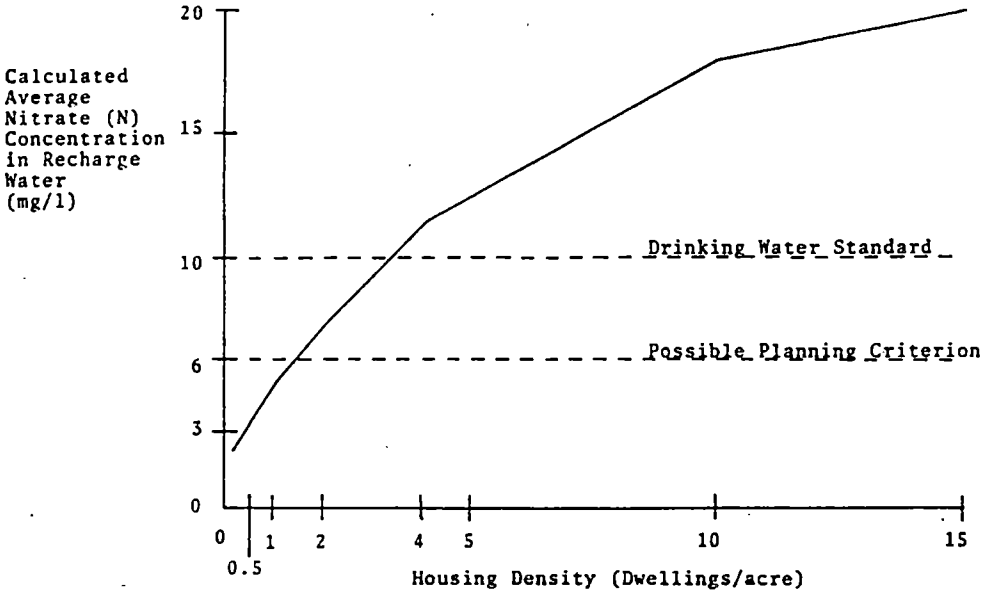
1. keeping housing densities low,

2. educating homeowners about septic tank maintenance and safe chemical disposal, and

3. sewering.

Figure 1

The Impact of Housing Density on Nitrate Concentrations in Recharge Water in the Adams Area.



Calculated based on the following major assumptions:

1. There are 3.6 persons per house.
2. Each person contributes 10 lb of nitrogen per year to the cesspool and 50% of this ends up as nitrate in recharge water.
3. Lawns are not fertilized.
4. Water is recharged at a rate of 19 inches per year from lawns and 17 inches per year from natural vegetation areas (these rates are computed from climatic data).

Note: These calculations should be considered accurate to within about plus or minus 25%.

Table 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.

Tug Hill Aquifer Case Study 2
The Potential Effect of a Leaking Gasoline Storage Tank

Assume that a gasoline storage tank at a farm or a gasoline station was located over the aquifer and upstream from a public water supply well. What would happen in the aquifer and at the well if the tank developed a slow leak?

Assume that the water supply draws 530,000 gallons of water per day from the aquifer (as does the Adams supply), that the gas tank is located 1,700 feet upstream from the well and that the aquifer is similar to the Tug Hill Aquifer near Adams. The story might unfold like this:

- The tank grows old and develops a small leak at a rusty spot which goes unnoticed. A tenth of a gallon per day is lost.

- The gasoline seeps downward through the subsoil to the aquifer. If it is ten feet from the tank to the water table, and the gasoline moves at about the same speed as water it will take about 6 months for the gasoline to reach the aquifer.

- At the water table most of the gasoline constituents float on top of the water forming a slick. The soluble constituents, primarily benzene, xylene, and toluene dissolve in the water and begin to move through the aquifer.

- Benzene is known to cause cancer in humans so it is the chemical which usually receives the most concern. Under the conditions assumed here it will take about 3 years for the benzene and the other soluble constituents to reach the well.

- When the benzene reaches the well it will enter the drinking water supply at a concentration averaging 5 parts per billion, right at the guidline for drinking water. When the benzene was eventually discovered, testing results would show that the benzene concentration varied considerably from day to day violating the guideline about half the time.

- If the leak had been ten times the rate assumed above or 1 gallon per day, then the concentration would be ten times as high also or averaging 50 parts per billion.

- By the time the benzene was discovered in the water the tank would have been leaking for at least three and a half years and a plume of benzene would stretch from the well back to the tank.

- It would take about three and half years from the time the leak was stopped until the benzene concentration began to taper off.

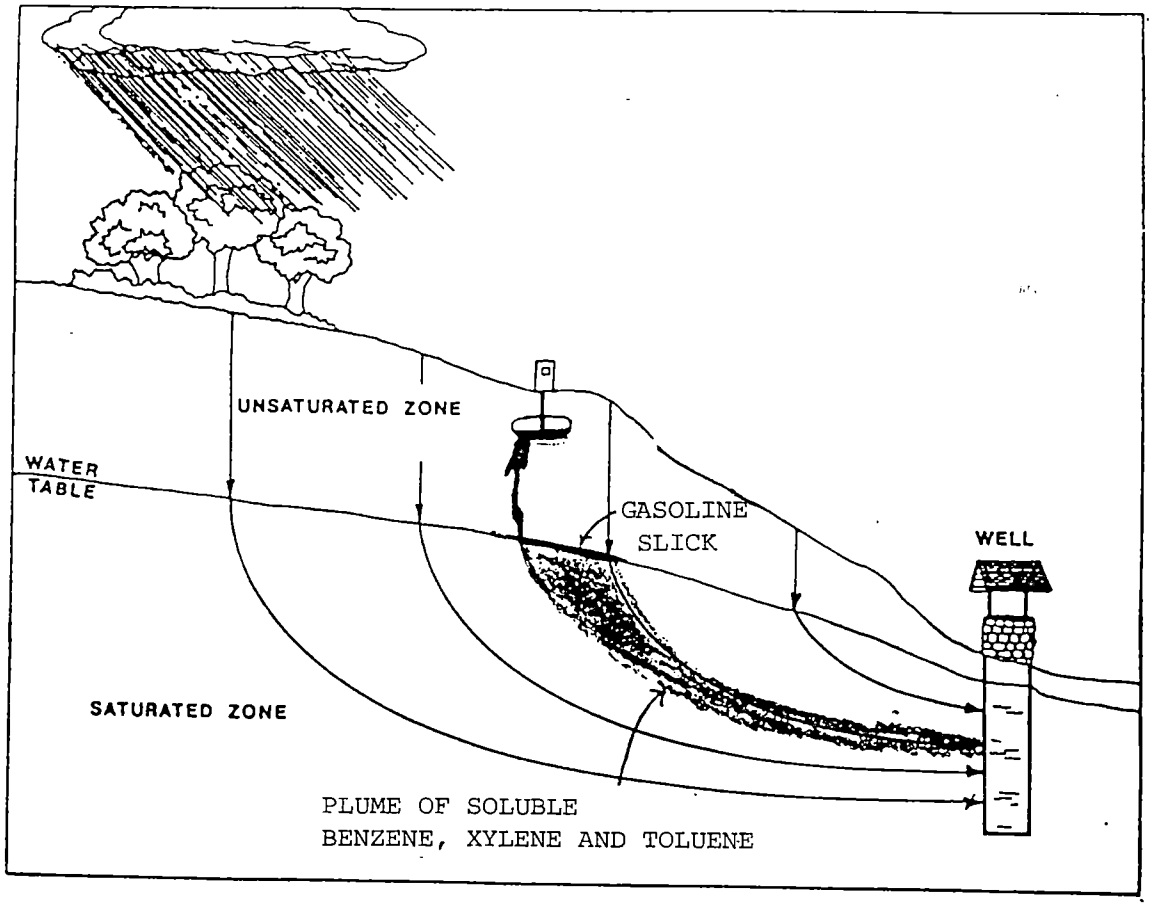
The travel times are highly dependent on aquifer properties and distances used for the case study. It is also assumed here that benzene would not break down or be adsorbed to any significant degree in the aquifer, a worst case assumption which is probably close to reality.

What could a local government do to prevent this situation from occurring in the first place ? Some options are:

- Adopt special land use controls for the recharge area supplying the well with water. These regulations could forbid the use of underground tanks for storage of gasoline and other hazardous chemicals.

- Adopt ordinances for the recharge area which require leak detection systems and or use of double walled tanks. The ordinance could be modeled after the New York State Petreleum Bulk Storage Law, but should not exempt small tanks.

- A monitoring program could be developed to test wells close to petroleum storage facilities to detect groundwater contamination before the contamination reaches public wells.



Tug Hill Aquifer - Case Study 3
Agricultural Impacts

Nitrate is a naturally occurring nitrogen compound which can cause groundwater contamination problems. Nitrate contamination from agricultural land has adversly affected groundwater supplies in New York State in such diverse areas as Long Island, the Southern Tier and the Finger Lakes area. In one case Upstate, a water supply has been closed indefinitely because of the nitrate contamination. The maximum allowable nitrate-nitrogen concentration in New York State public water supplies is 10mg/l. This health standard is designed to protect infants under the age of 6 months who are vulnerable to a serious blood disorder which can be caused by nitrate in drinking water.

Nitrate contamination can result from over fertilization of cropland or from the manure from large herds of farm animals confined to relatively small areas of land. Nitrate contamination at a public supply well is usually caused by a number of nitrogen sources in the well contribution zone. It is more likely that contamination will be caused by the combined effects of nitrogen fertilizer use and manure disposal than by either one alone. Nonagricultural sources of nitrogen such as onsite sewage disposal systems can also contribute to the problem.

Pesticide contamination of groundwater is less common in New York State, but has caused serious contamination on Long Island. An investigation of pesticide contamination in Upstate New York is currently being conducted by Cornell and the New York State Department of Environmental Conservation.

Per Acre Nitrogen Loads

To prevent the nitrate concentration from exceeding the 10 mg/l health standard in groundwater it is necessary to keep the concentration below 10 mg/l in the recharge water. Since farmers typically measure their nitrogen fertilizer and manure applications in terms of the pounds of nitrogen applied per acre, it is useful to view the potential for groundwater contamination in terms of the pounds of nitrogen per acre which may leach with recharge water.

The amount of nitrogen which can be allowed to leach with recharge water depends on the recharge rate which is determined by climate and soil type. Precipitation over the Tug Hill Aquifer averages about 40 inches per year and about half of this or 20 inches per year becomes recharge water over the aquifer. As shown on Figure 1, if 45 pounds per acre per year of nitrate-nitrogen are dissolved in this recharge water then the nitrate concentration in the recharge will be 10 mg/l, right at the health standard.

It is important to include a safety factor when planning for allowable nitrogen losses because seasonal fluctuations in nitrogen leaching rates can cause nitrate levels to periodically exceed the 10 mg/l standard when the average concentration is less than 10 mg/l. Six mg/l is a planning standard used in some parts of New York State to allow a 4 mg/l safety factor. Thus, for the Tug Hill Aquifer it makes sense to encourage agricultural practices which result in no more than 28 pounds of nitrogen leaching per year.

Computer simulations of the Tug Hill Aquifer conditions indicate that about 50 percent of nitrogen fertilizer applied in the spring would be expected to leach. Nitrogen applied later in the season, such as a side dress at cultivation would leach less. This is a rough estimate, but it is sufficient for the purpose of this discussion. If 50 percent of the fertilizer leaches then a fertilization rate of 90 pounds per acre per year on an agricultural field would produce a nitrate concentration in the recharge from the field of 10 mg/l.

This means that fields which receive less than 56 pounds of nitrogen per year would result in nitrate concentrations of less than 6 mg/l in the grundwater beneath them. Fields which receive much more than 90 pounds of nitrogen per acre per year on average would probably cause nitrate contamination in excess of the 10 mg/l standard in the groundwater beneath them.

Area Nitrogen Budgets

The recharge areas supplying large public wells in the Tug Hill area are not likely to contain just one land use. The nitrate concentration in a well is a result of the combined impact of all the land uses in the recharge area. Thus, the effect of land uses which have a high nitrogen load will be diluted by the recharge water from land where relatively little nitrogen leaches.

Private wells which withdraw less water are more likely to draw water which was recharged from just one land use.

Three Nitrate Contamination Scenarios

Outlined here are three possible ways that agricultural practices could result in the nitrate concentration going above the drinking water standard of 10 mg/l in the public well water supply for Adams. The recharge area serving Adams is about 430 acres and it is assumed that the land not used for agriculture is not contributing significant amounts of nitrogen.

1. A heavily fertilized crop such as potatoes which is fertilized at a rate of 150 pounds of nitrogen per year (a typical rate for potatoes) is grown on at least 250 acres (60 percent of the land) in the recharge area upstream of the Adams well. If the nitrogen were applied at planting then about 50% of the applied nitrogen would probably leach into groundwater. This amount of nitrogen leaching would cause the nitrate concentration to go above 10 mg/l in the Adams supply well.

2. A feedlot for at least 300 cattle is opened up somewhere in the recharge area. If the manure is not used for fertilizer, but is disposed of in a way that plants can not recover the nitrogen content, the nitrogen leached from the manure could cause the nitrate concentration in the Adams water to exceed 10 mg/l. Figure 2 shows the relationship between cow population density and the average nitrate concentration in recharge computed for the Tug Hill Aquifer.

3. A large dairy farm comes into being in the recharge area. There are at least 400 cows and at least 300 acres (70 percent of the land) used to grow corn fertilized with the manure and 60 pounds per acre of nitrogen fertilizer. Since the manure is used as fertilizer, less of the nitrogen from

manure leaches than in the feedlot case. The combined impact of fertilizer and manure would cause the nitrate concentration at the Adams well to exceed 10 mg/l.

These cases apply to a 430 acre recharge in the Tug Hill area where the recharge rate is about 20 inches per year. The cases can be adapted to other areas of the Tug Hill Aquifer by adjusting the number of fertilized acres or the number of cows in proportion to the size of the recharge area.

Figure 1

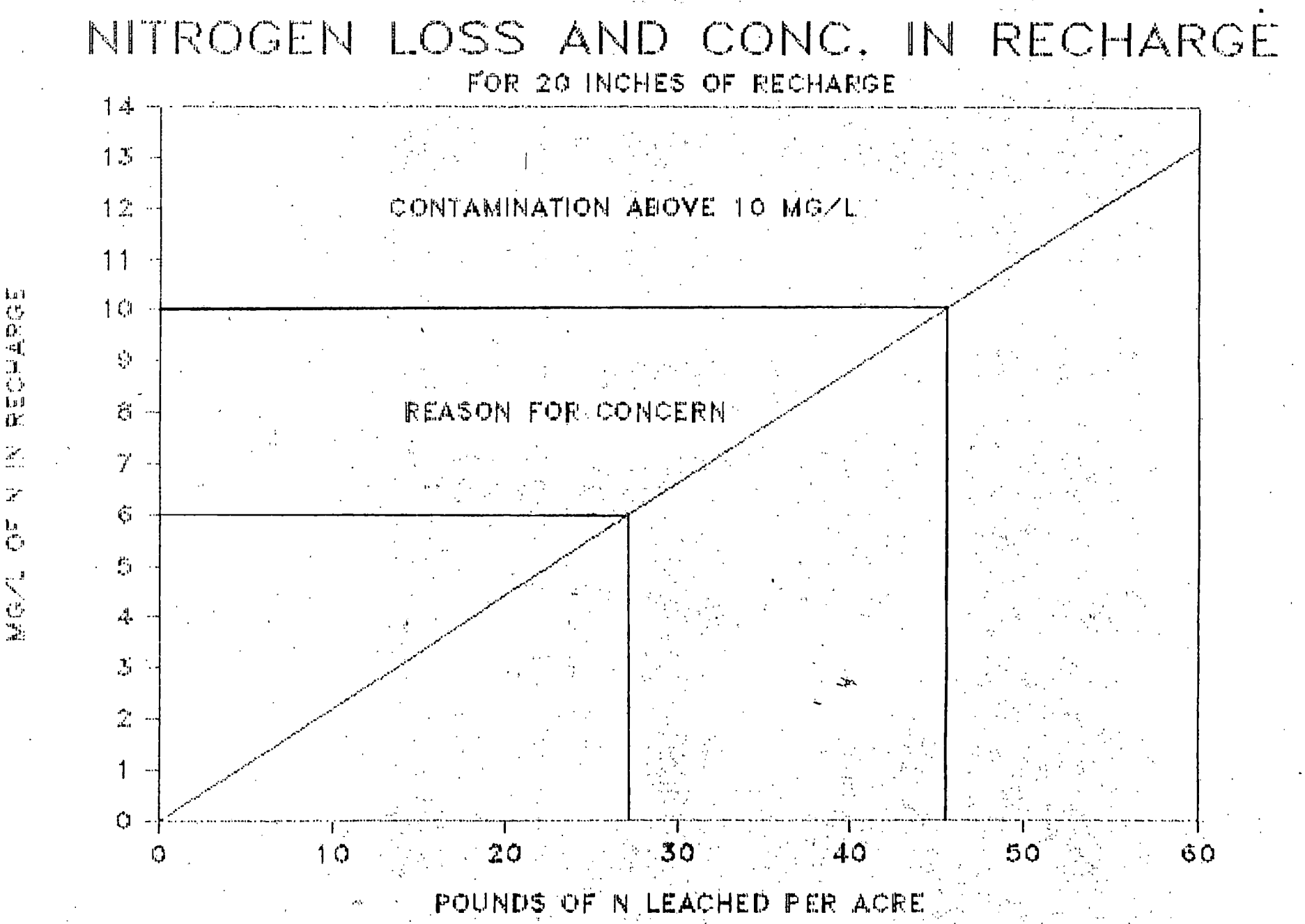
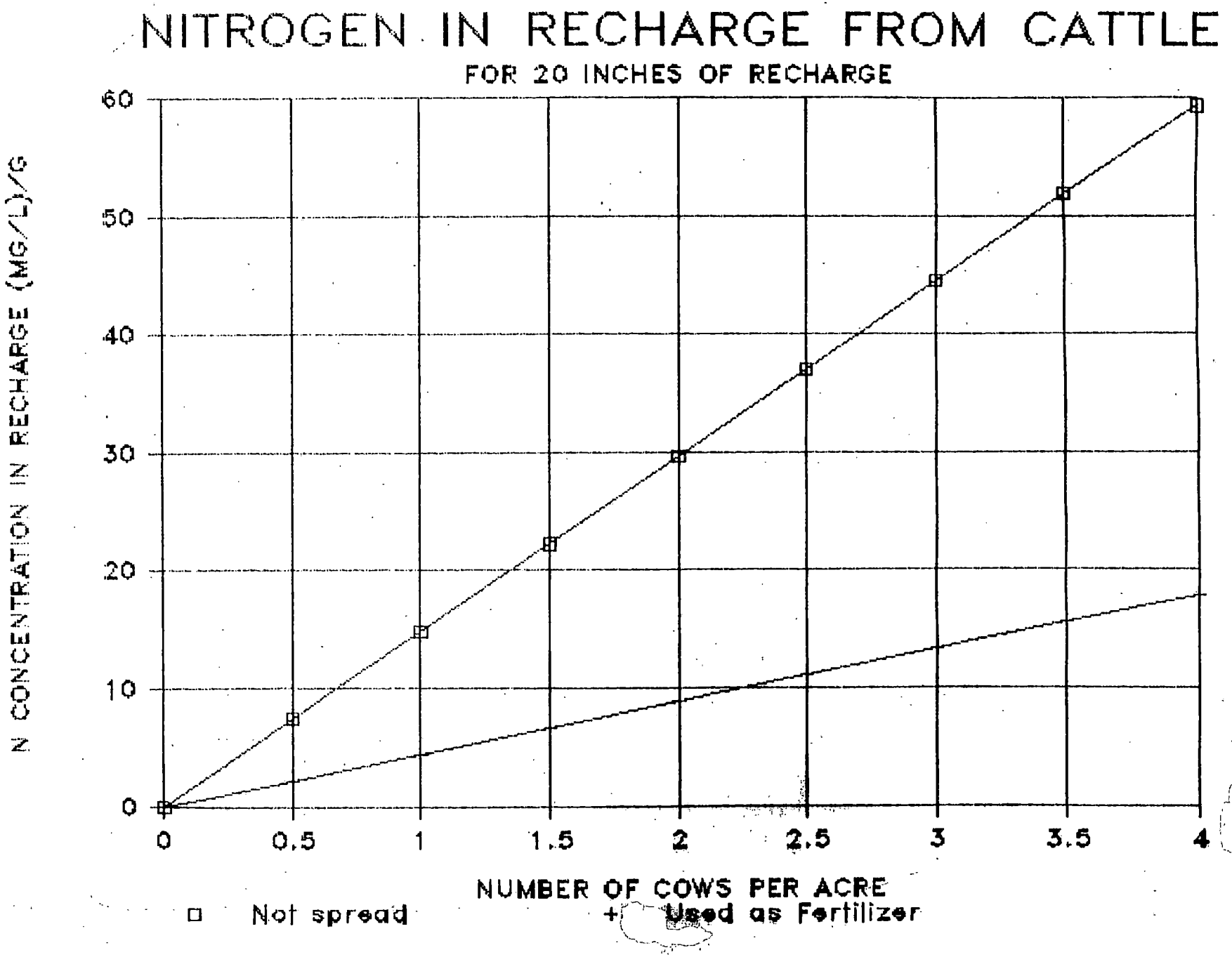

NITROGEN LOSS AND CONC. IN RECHARGE
FOR 20 INCHES OF RECHARGE
CONTAMINATION ABOVE 10 MG/L
REASON FOR CONCERN
MG/L OF N IN RECHARGE
POUNDS OF N LEACHED PER ACRE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
10
20
30
40
50
60

Figure 2


NITROGEN IN RECHARGE FROM CATTLE
FOR 20 INCHES OF RECHARGE
N CONCENTRATION IN RECHARGE (MG/L)/G
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
NUMBER OF COWS PER ACRE
Not spread
Used as Fertilizer

Tug Hill Aquifer
Oswego County Well Testing Results for
Nitrate and Coliform Bacteria

prepared by:
Henry B. F. Hughes
Cornell Center for Environmental Research

for:
The Temporary State Commission on Tug Hill

July 1985

Introduction

Water was collected from twenty private wells tapping the Oswego County portion of the Tug Hill Aquifer. The twenty wells were selected to give a representative set of wells over the aquifer from agricultural areas, residential areas and vacant areas. The water was collected by a Senior Sanitarian from the Oswego County Health Department. The water was tested for coliform bacteria by the Health Department and for nitrate by Cornell.

The well owners were asked to fill out a form with a description of the land use around the well, and a field inspection of some of the sites sampled was made. Based on the information provided by well owners, preliminary U.S.G.S. potentiometric surface maps and the field inspection, the wells were classified according to the type of land judged to be supplying recharge to the well. The three catagories used were agricultural, residential and vacant. The classifications are not perfect in every case since the direction of groundwater flow is not known precisely at each site and several land uses are often in the vicinity of a particular well.

The work was initiated by funding from the Tug Hill Commission. The Oswego County Health Department and Cooperative Extension Service contributed services. Personnel from the Tug Hill Commission, the Oswego County Health Department, Oswego County Cooperative Extension and the Cornell Center for Environmental Research participated in the project.

Nitrate Results

The Oswego County Health Department has a program for testing public wells for nitrate, and the data for public wells which tap the Tug Hill Aquifer were added to the data collected from private wells to provide for a more complete assessment. The public wells were sampled during the period of 1978 through 1982. The land use affecting the public wells was determined during the field inspection.

As expected, elevated nitrate levels can be observed in the agricultural and residential areas when compared to the vacant areas. See Table 1.

Table 1
Nitrate Concentration Summary
(milligrams of nitrogen per liter)

Type of Land	Number of Private Wells	Number of Public Wells	Nitrate Concentration (mg/l) Average	Minimum	Maximum
Agricultural	11	2	3.9	0.01	23.0
Residential	5	12	2.3	0.38	9.3
Vacant	4	3	0.28	0.04	0.95

Agricultural Impacts on Nitrate Concentrations

In general the highest nitrate concentrations were in wells influenced by agricultural land. Only one well had a nitrate concentration exceeding the 10 mg/l nitrate standard. This well was a developed spring on the side of a small knoll. On top of this knoll, in the recharge area for the well, is a large dairy operation with 400 cattle and corn fields. The manure from the barnyard and surrounding corn fields appears to be the major source of nitrate. Chemical fertilizer used on corn probably contributes a small fraction of the nitrate in the well water, since the farmer reported using very little chemical nitrogen fertilizer.

Another private well is located on the edge of a corn field and the water drawn from it was clearly recharged in the corn field. Its nitrate concentration was 5.7 mg/l. All other wells in agricultural areas had lower nitrate concentrations and many of them are either partially or wholly influenced by vacant land near the agricultural land.

The potato fields north of Williamstown are heavily fertilized with nitrogen, but there do not appear to be any wells downgradient of the fields which could be tested. The water recharged from the fields seems to drain directly into the streams adjoining the fields. The one well tested which was close to a potato field appears to receive recharge from vacant land accross the street, and its nitrate concentration was 0.87 mg/l.

Residential Impacts on Nitrate Concentrations

The average nitrate concentration in residential areas is higher than vacant areas, but lower than agricultural areas. Most of the nitrate in groundwater underlying residential areas is from onsite wastewater disposal systems.

The highest concentration (9.3 mg/l) was from a well which is downgradient from much of Village of Altmar. The second highest nitrate concentration in a residential area was 4.5 mg/l.

Coliform Bacteria

Table 2 summarizes the coliform test results according to land use type and well construction. Wells where the sample water had more than 1 coliform per 100 ml, the New York State Health Standard, are termed unsatisfactory. The unsatisfactory wells are fairly evenly distributed among the land uses and the drilled and dug wells.

Coliforms are harmless themselves, but serve as an indicator of other possible bacterial contamination. They can come from the soil or from human or animal waste. Since coliforms can not survive for very long underground they must come from within several hundred feet of the well. Coliform contamination is therefore a localized problem related to well placement and construction. The Oswego County Health Department is following up with the owners of wells which were found to be unsatisfactory.

Table 2
Coliform Bacteria Test Results Summary
Wells were Deemed Either Satisfactory or Unsatisfactory
by New York State Health Standards

Type of Land	Number of Wells Satisfactory	Number of Wells Unsatisfactory
Agricultural	7	4
Residential	2	3
Vacant	2	2
TOTAL	11	9

Well Construction	Number of Wells Satisfactory	Number of Wells Unsatisfactory
Drilled Wells	5	4
Dug Wells	6	5

Nitrate Results for Each Well Sampled

(HD = Health Dept. sample of public well; OS = private well sample)

Land Use	Well Code	Nitrate Conc. (mg/l)	Comments
Residential	HD-14	9.30	Altmar
	OS-17	4.50	Altmar
	HD-6	4.00	Williamstown
	HD-7	2.90	Williamstown
	HD-3	2.60	Richland
	HD-4	2.60	Richland
	HD-16	2.60	Altmar
	HD-17	1.90	Richland
	HD-2	1.80	Richland
	HD-5	1.70	Richland
	OS-2	1.65	Altmar
	OS-21	1.22	Richland
	HD-10	0.85	Williamstown
	OS-23	0.55	Sandy Creek, Town
	HD-15	0.50	Altmar
	HD-9	0.50	Williamstown
	OS-12	0.38	Altmar
Agricultural	OS-5	23.00	corn,dairy
	OS-20	5.70	corn
	HD-1	4.50	corn
	HD-11	4.30	corn and potatoes
	OS-9	3.60	corn,alfalfa,dairy
	OS-6	3.10	corn,beef cattle,pigs
	OS-8	1.95	strawberries,blueberries
	OS-18	1.82	strawberries,blueberries
	OS-13	0.87	potatoes
	OS-7	0.85	corn,hay,oats,dairy
	OS-19	0.31	corn,hay
	OS-14	0.09	corn,oats,hay,dairy
	OS-22	0.01	corn,alfalfa,dairy
Vacant	HD-13	0.95	
	OS-3	0.36	
	OS-15	0.30	
	OS-16	0.11	
	HD-8	0.10	
	HD-12	0.10	
	OS-10	0.04	

COOPERATIVE EXTENSION

Cornell University
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U.S. Department of Agriculture

Water Resources Program
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468 Hollister Hall, Ithaca, NY 14853-3501

File No. 85-5(C), June 13, 1985
Telephone 607-256-7535

Chemical Hazards in Our Groundwater
Options for Community Action
WELL CONTRIBUTION ZONES

SYNOPSIS:

The first step in stopping water well contamination is to find out where the water comes from. This information is rarely available. Until recently, there was usually little interest in tracing water supply well sources.

This lack of interest was fostered by (1) The belief that water wells were less susceptible to contamination than surface reservoirs, and (2) The difficulty in tracing the movement of underground water.

Recent contamination of drinking water wells in many areas of New York has led to an awakening interest in identifying groundwater supply sources. This is not merely a matter of examining a small area around the well. The water may have originated far from the well site.

The land area that channels precipitation to a water supply well is the well contribution zone. This zone extends outward on the upgradient side of the well. It may vary in size from hundreds of feet to miles in extent.

Well contribution zones normally consist of three parts: (1) The wellhead, an area extending a few hundred feet around the well site; (2) The recharge area, where soils allow precipitation to easily percolate underground; and (3) Tributary drainage into the recharge area.

Land uses--especially those using chemicals--in the contribution zone can result in contaminated groundwater that will eventually end up in the supply well. Due to the slowness of underground water movement, it may take years for contaminants to reach the well.

A community groundwater interest group, with the aid of local agencies, can often identify the general locations of high-yield groundwater formations (aquifers). This can provide a focus for gathering information on land uses that may cause groundwater contamination.

More refined groundwater information, including the location of likely contribution zones for water supply wells, can often be obtained through studies conducted by a local agency. This may be sufficient to develop protective regulations to maintain groundwater quality.

Detailed mapping of the boundaries and subsurface characteristics of well contribution zones requires professional hydrogeologic studies. This is by far the most costly type of study. Consequently, such studies are usually conducted only when strong reasons exist for doing so, such as suspected contamination from hazardous waste sites or industrial spills, for example.

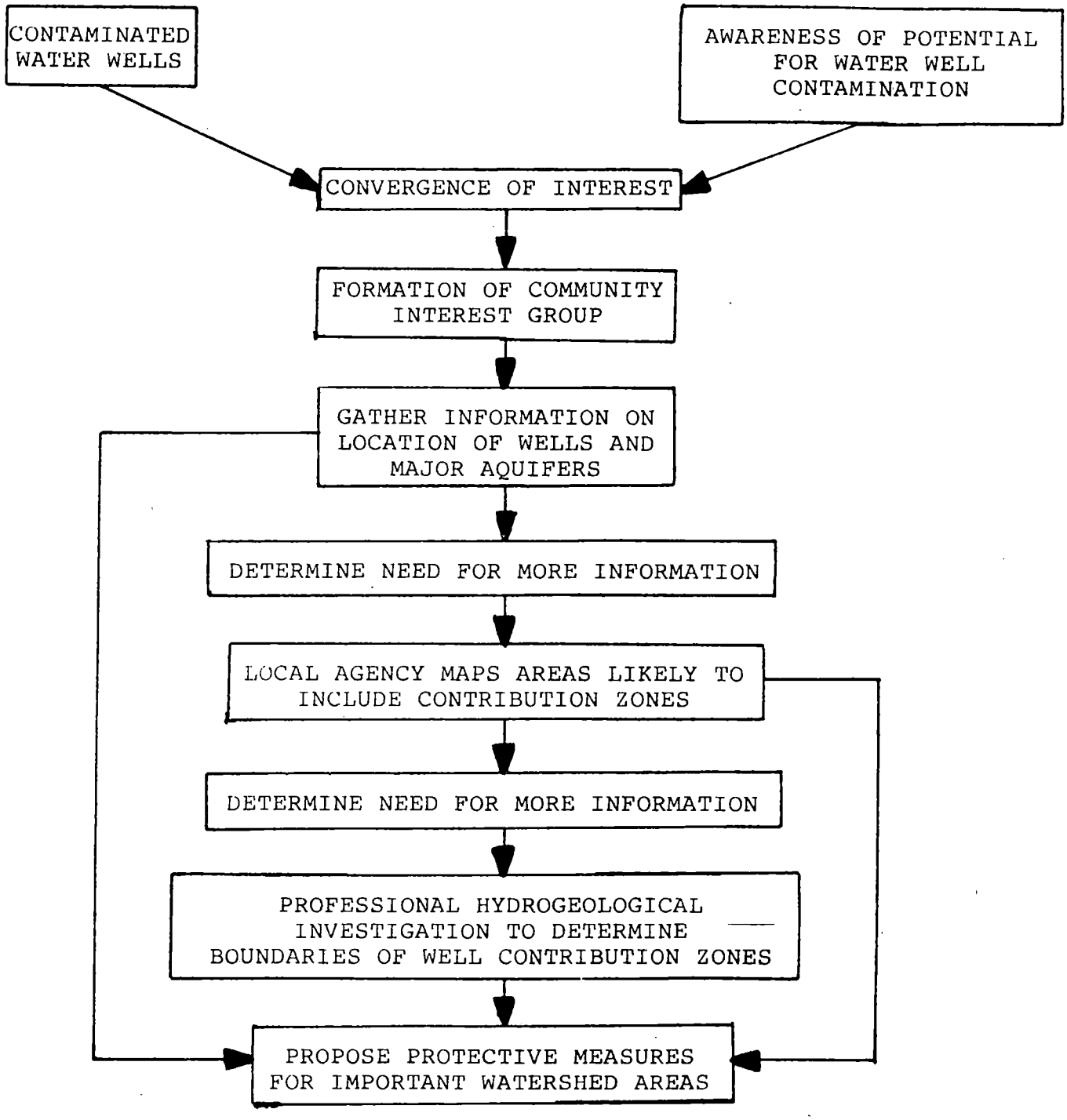
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Lyle S. Raymond Jr.
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Options for Community Action
LOCATING WELL CONTRIBUTION ZONES



Chemical Hazards in Our Groundwater
Options for Community Action
Well Contribution Zones

Henry B.F. Hughes
Lyle S. Raymond

The principle task in protecting water supply wells from contamination is to find out where the water comes from and protect that area. A community interest group, with local agency assistance, can often locate likely source areas. Precise mapping of well contribution zones may be a necessary input for decisions significantly impacting the community, and this requires a professional hydrogeological investigation. This article defines well contribution zones and outlines the methods a community may employ for locating them.

What is a Contribution Zone?

Groundwater in the Northeast comes from precipitation which infiltrates the land surface, as recharge, and enters a water bearing soil or rock formation called an aquifer where it may be withdrawn by a well. The area of land which supplies water to a well is the contribution zone for the well. [1] This area is sometimes called the well catchment. Activities at the land surface within the contribution zone determine, to a large extent, the quality of the water arriving at the well.

A well contribution zone can include three types of land. These areas are termed Watershed Protection Zones in a recent New York State Health Department study. [2] The three types of land are:

1. The well head area which is the area immediately surrounding the well (Termed Watershed Protection Zone I),

2. The recharge area upgradient from the well consisting of land directly over the aquifer which the well taps (Termed Watershed Protection Zone II), and

3. The tributary watershed which includes any land from which surface water drains to the recharge area (Termed Watershed Protection Zone III).

Are They Important?

Groundwater pollution has only recently been recognized as a major problem in the United States. The widespread use of modern industrial chemicals and the development of methods for detecting these chemicals in water at low concentrations have both led to the discovery of these chemicals in groundwater. Certain of these chemicals are suspected of causing health problems at the low concentrations found in groundwater. Since they can travel long distances underground without being filtered out by the soil, the traditional method of protecting only the area right around a well is not sufficient to prevent contamination.

A typical response to a contaminated public well is to abandon the well and drill a new one. The cost and trouble of drilling a new well is usually much less than locating and cleaning up a source of contamination. In fact, once the contamination has been discovered in a public well the contamination may be so

widespread that it would take years after the source of contamination is stopped before the well could be used. It is possible to treat water to remove chemical contaminants, but such treatment may be very costly for a small community to install and operate.

No community is blessed with an unlimited number of new supplies of water which can be tapped when the current one goes bad. The fact that once a well is contaminated it may be too expensive to clean it up, means that the best way to deal with the groundwater contamination problem is to prevent contamination in the first place. This requires locating the zone of contribution for a well and taking steps to prevent the release of chemical contaminants in the zone.

The generalized experience of communities on Long Island with groundwater contamination is relevent. [3],[4] The aquifer system on Long Island is very deep, so when shallow wells became contaminated deeper wells were drilled to tap the still uncontaminated water from the deeper parts of the aquifer. Eventually the contamination caught up with the new wells so even deeper ones were installed. Recently, contaminants started reaching even the deepest wells and it was not possible to go any deeper. Now treatment units are being installed on some contaminated wells to remove the contaminants. At the same time an effort is being made to protect recharge areas to prevent further contamination as much as possible. A community which presently enjoys the benefits of an uncontaminated groundwater supply can benefit from this experience by taking steps to protect recharge areas before contamination occurs.

Locating a Contribution Zone

Locating a well contribution zone can be aproached at several levels of detail depending on the purpose for the information. [5]

1. For the purpose of educating the community about groundwater, the community well and the contribution zone, a volunteer or intern for a community agency or interest group may be able to gather existing information on the location and use of important aquifers and put it on a map. Such a person can also locate likely areas of groundwater recharge. This is the low budget approach and may be a preliminary step before undertaking a detailed study.

2. For the purpose of locating probable contribution zones for specific wells as part of an official protection plan, a more professional approach will be needed. This will require an agency person or consultant with some hydrogeologic experience or who can be given an opportunity to obtain such knowledge. This type of project should make use of existing information but may require some test drilling to fill in gaps in current knowledge about the aquifer.

3. For the purpose of dealing with an existing contamination problem or as a basis for stringent regulations likely to have significant impacts on private land uses, a more high powered approach may be required. In this case a consulting firm would usually be employed to thoroughly map the aquifer and other subsurface features in the area of the well and the well contribution zone. If the well is contaminated they would attempt to trace contaminants from the well back to their source or sources at the land surface. These

projects usually involve much drilling of test wells and hence are quite costly.

Some agencies which can usually provide some assistance to communities undetaking any of the above levels of study are

- State Environmental or Health Agencies,
- a local or regional health or planning agency,
- the United States Geological Survey,
- the State Cooperative Extension Service or University, and
- the Soil and Water Conservation District or Soil Conservation Service.

Principles Governing the Contribution Zone

There are certain principles about a well contribution zone which will help in understanding how it can be located. The well head area is defined in New York State as the area which is within 200 feet of the well. This is the distance judged from experience to provide protection from bacterial and viral contamination. In the past, it was felt that protecting the wellhead area was sufficient for protecting the water quality in the well.

The most difficult but most important area to locate is the upgradient recharge area. Once the recharge area has been located it is a simple matter to locate the tributary watershed, if there is one. Any area of land which drains surface water into the recharge area where it can be recharged is part of the trubutary watershed.

Locating The Recharge Area

- The first step in locating a recharge area is to identify the extent of the aquifer which the well taps. If the aquifer has not been mapped, a person with groundwater experience can probably determine its approximate extent from existing soils maps, well logs and other geologic information.

- The next step is to find out which way water is flowing in the aquifer. Groundwater flows in the "downhill" direction of the water table's slope. To determine the direction of the flow one needs to map the elevation of the water table if the aquifer is unconfined. If the aquifer is confined under impermeable layers the level measured would be the level to which water rises in a well (technically referred to as the potentiometric surface). Test wells and existing wells which tap the aquifer are used to determine the water table or potentiometric surface elevations throughout the aquifer.

- From the direction of flow in the aquifer the location of the area supplying the well may be apparant, but it will still require some experienced interpretation. The depth of the well has an effect on whether the well draws water that was recharged nearby or far away, for example. While an aquifer is a fixed geologic feature, the size and location of the recharge area supplying the well can change with varying climatic conditions. For example, during a prolonged drought the well may draw in water from a much larger area than during normal climatic conditions.

Several factors make it difficult to locate a well's recharge area accurately. The fact that we can only obtain spotty information from test wells about the aquifer contributes most to this uncertainty. The fact that the pumping rate of the well and the climatic conditions also affect the size of the area drawn from adds to the uncertainty. One can spend a lot of money on consultants trying to pin down the recharge area. It is probably best to start with an inexpensive investigation, using readily available information, and then purchase a more detailed study only if it is really needed.

Groundwater Movement Rates

One aspect of groundwater which distinguishes it from surface water is the slowness with which it travels. Water in a stream may move several feet per minute but water in an aqifer may only move several feet per month. In terms of water quality concerns, this difference is significant. A surface water contamination event happens rapidly but a groundwater contamination event may start years before it is detected in a well. The consequence of such slow movement is that by the time contamination is detected it may be widespread, and it will take as many years for the aquifer between the source and the well to purge itself of contaminants as it did for the contaminants to reach the well in the first place.

Consider the movement of water from the land surface where it may pick up contaminants to a well where it is withdrawn for drinking. The water starts as precipitation. Some of it percolates into the soil and eventually becomes groundwater. This water must first travel through the upper soil layer or unsaturated zone to get to the water table which is the top of the aquifer or saturated zone. It then moves through the aquifer to the well. Water travel in these two underground zones is fundamentally different, and occurs at different speeds.

In the unsaturated zone, above the water table, water moves basically straight down. The speed of water movement is determined by the water holding properties of the soil and the precipitaion rate. A typical rate of water movement in the unsaturated zone in the Northeast is from 5 to 20 feet per year.

Water movement in the saturated zone or aquifer is usually primarily horizontal. The speed of this movement is a function of how much water is provided by precipitation and the properties of the rock material through which the water must move. In a typical sand and gravel aquifer in the Northeast groundwater will travel at a speed of several hundred feet per year.

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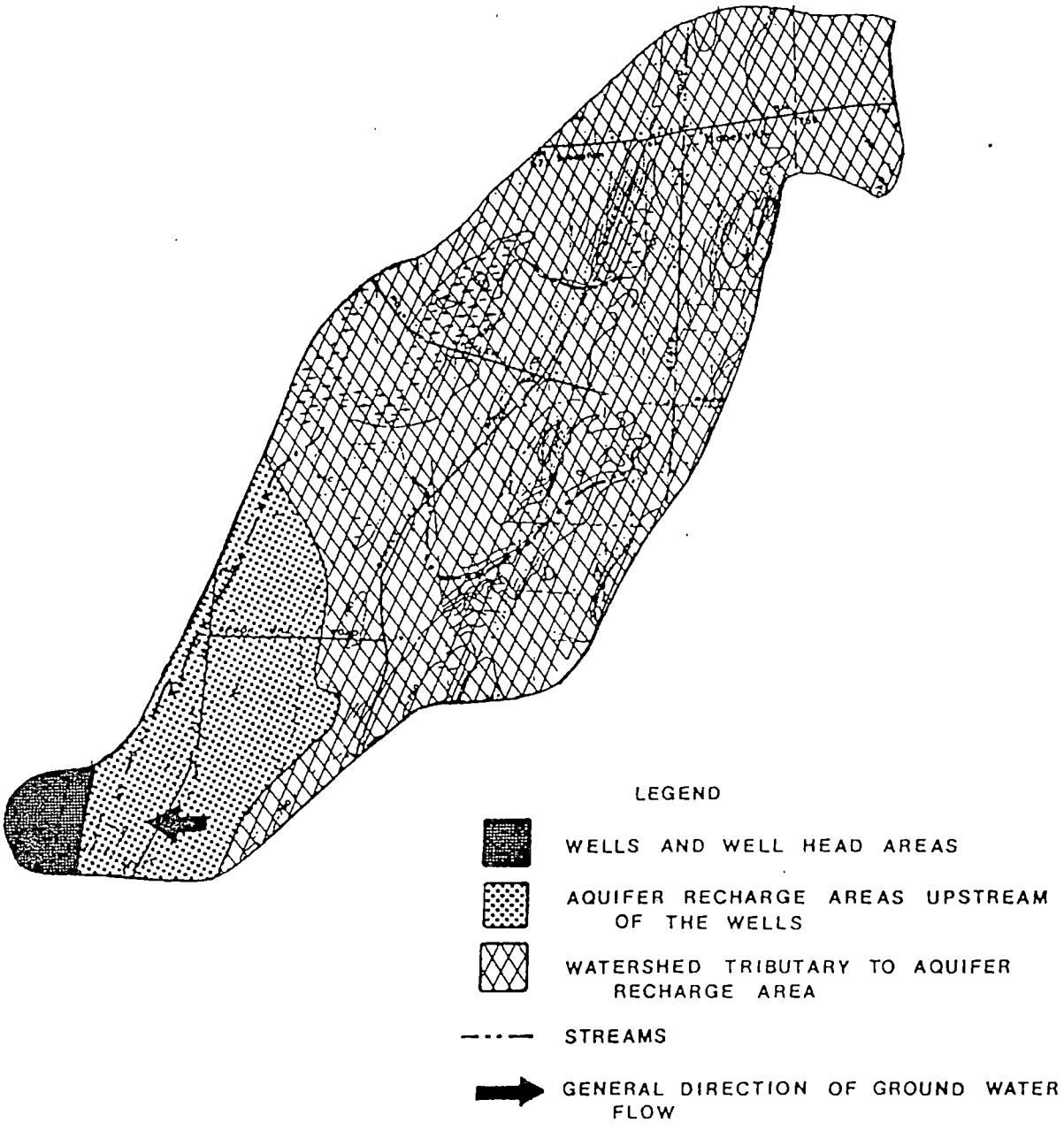
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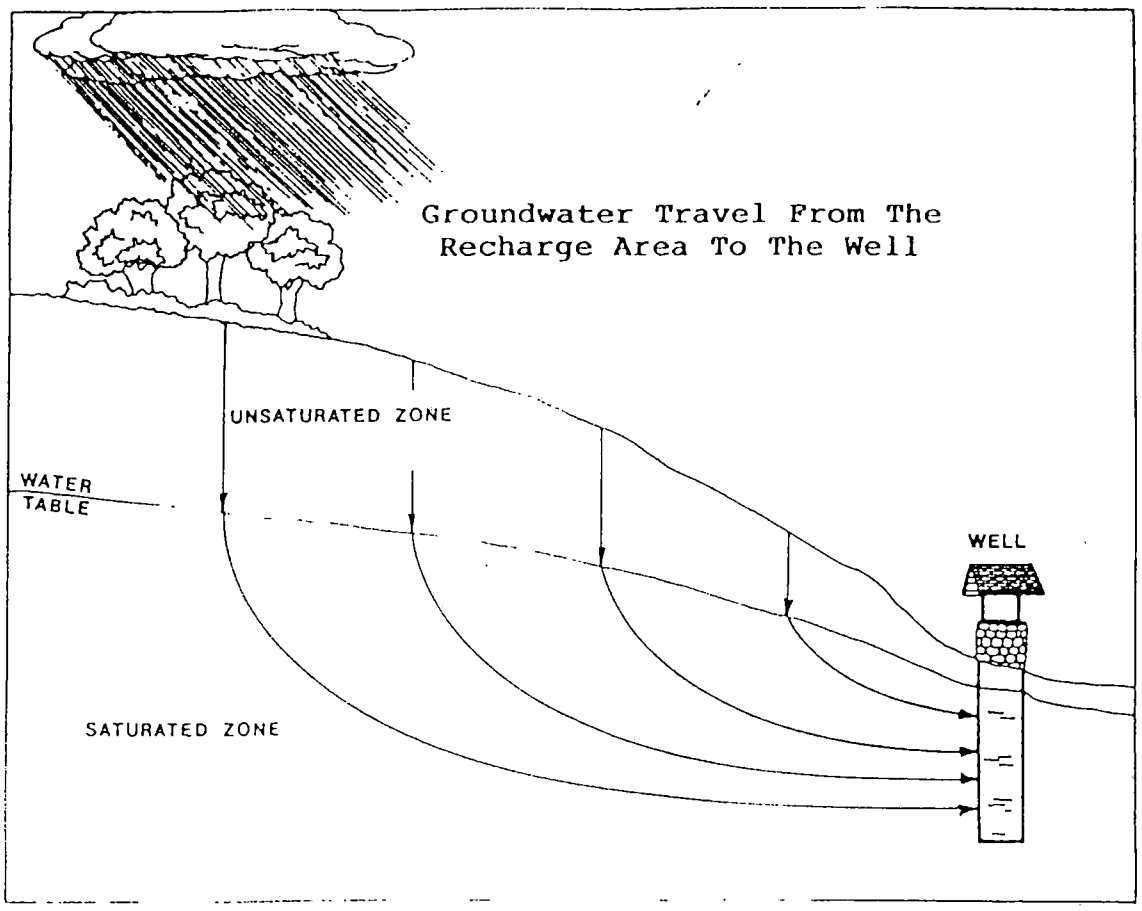
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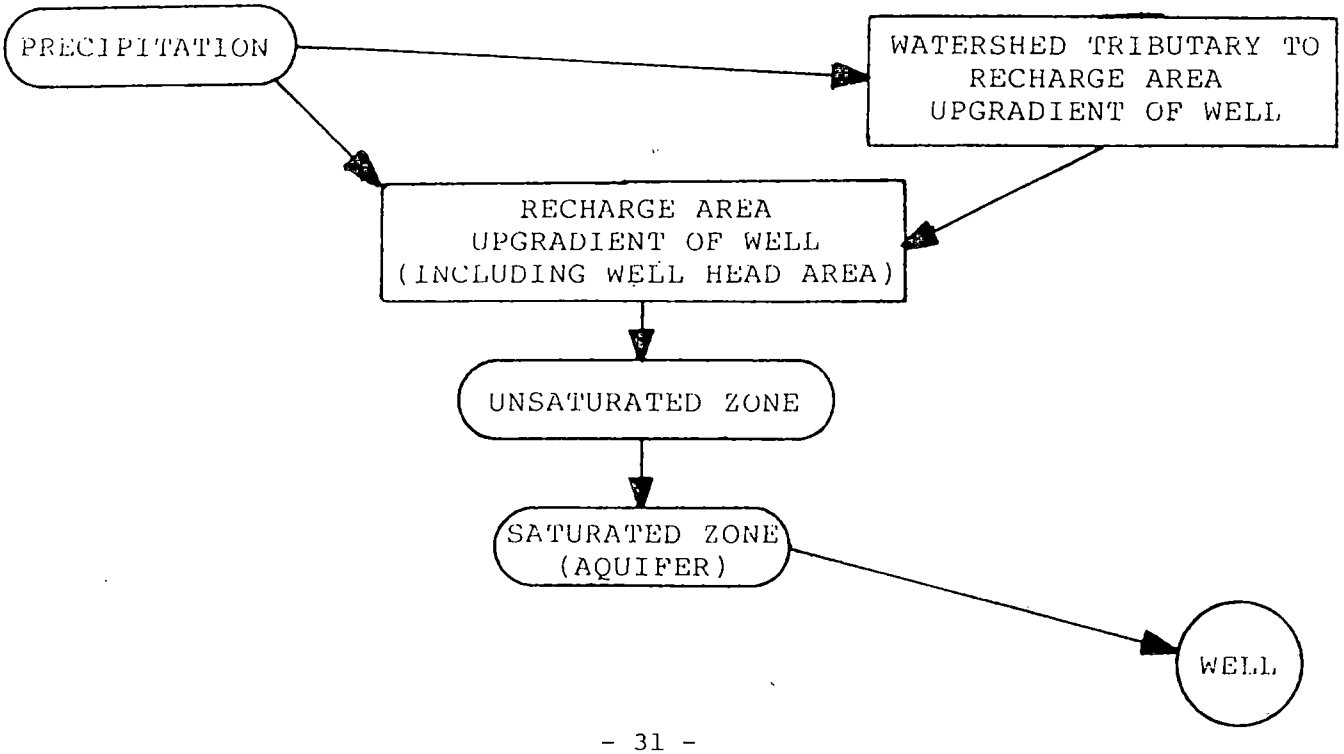
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Typical Well Contribution Zone





Flow of Water Through the
Contribution Zone to a Well



COOPERATIVE EXTENSION

Cornell University
State University of New York
U.S. Department of Agriculture

Water Resources Program
Center for Environmental Research
468 Hollister Hall, Ithaca, NY 14853-3501

File No. 85-6(C), July 12, 1985
Telephone 607-256-7535

SYNOPSIS:

Chemical Hazards in Our Groundwater
Options for Community Action
LEAK AND SPILL PREVENTION

Hazardous chemicals are the greatest danger to human health from contaminated water supply wells. Solvents and degreasers are the principal chemicals found in public wells. In individual home wells, petroleum products are the most common contaminants.

Leaking storage tanks are one of the most frequent sources of groundwater pollution. A very small, unnoticed leak in a gasoline tank can contaminate a water supply for several thousand people with benzene beyond New York State public health guidelines.

Many industries use solvents such as tricholoroethylene (TCE) to clean metals and fabrics. Even the corner dry cleaner or gas station easily handles enough solvents or other hazardous chemicals to contaminate a large public water well.

Solvents are present in many household products, including oven cleaners, paint products, and some septic tank cleaners. Careless use and disposal of these materials can also contaminate groundwater.

Other chemicals that have caused groundwater contamination are chloride from salt piles or road salting; nitrate from fertilizers or decaying wastes; pesticides; and heavy metals.

Local water well contamination prevention should consider (1) Proper enforcement of federal and state laws regulating hazardous chemical use; and (2) Local actions to protect groundwater recharge areas and well contribution zones from chemical leaks and spills not regulated by other laws.

Initial steps in a local protection program include collecting information on (1) Chemical storage tanks; (2) Chemicals used in commercial and industrial activities; and (3) Principal groundwater aquifers and well contribution zones.

Local groundwater interest groups can play an important role in collecting this information and fostering community recognition of the need for preventive action. Prevention is much cheaper than cleanup, but unless a contamination incident has occurred, complacency may be the biggest obstacle to overcome.

Options for local actions include (1) Regulation of land uses in undeveloped areas over critical groundwater recharge zones to prevent use of hazardous chemicals; and (2) Regulation of storage, handling and disposal of chemicals by existing users in developed areas.

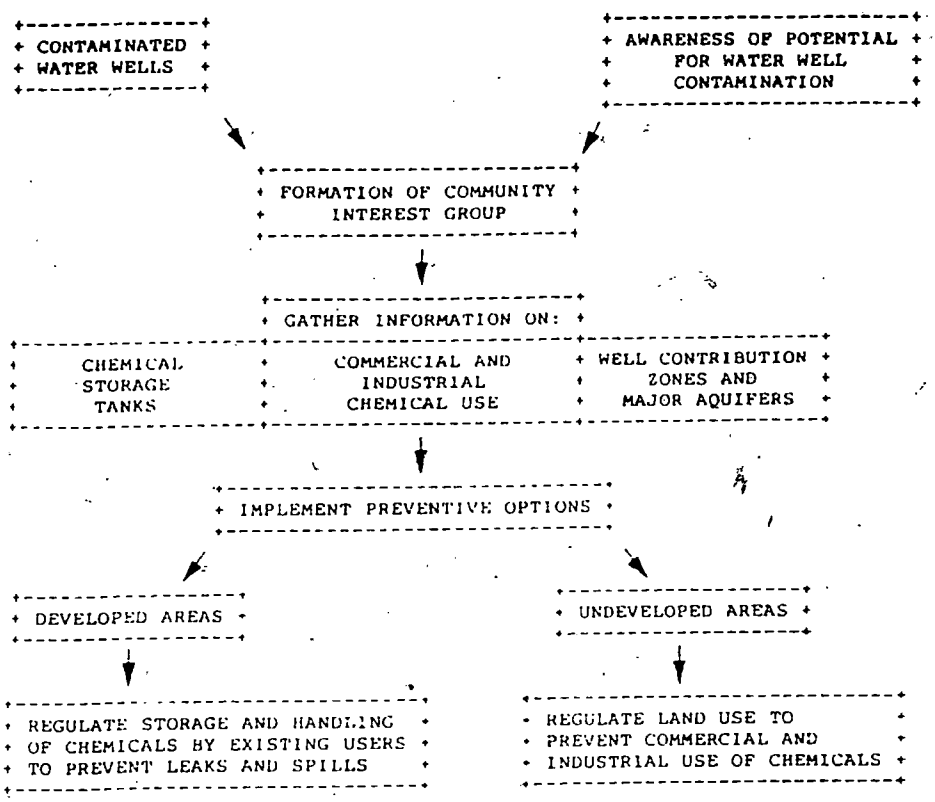
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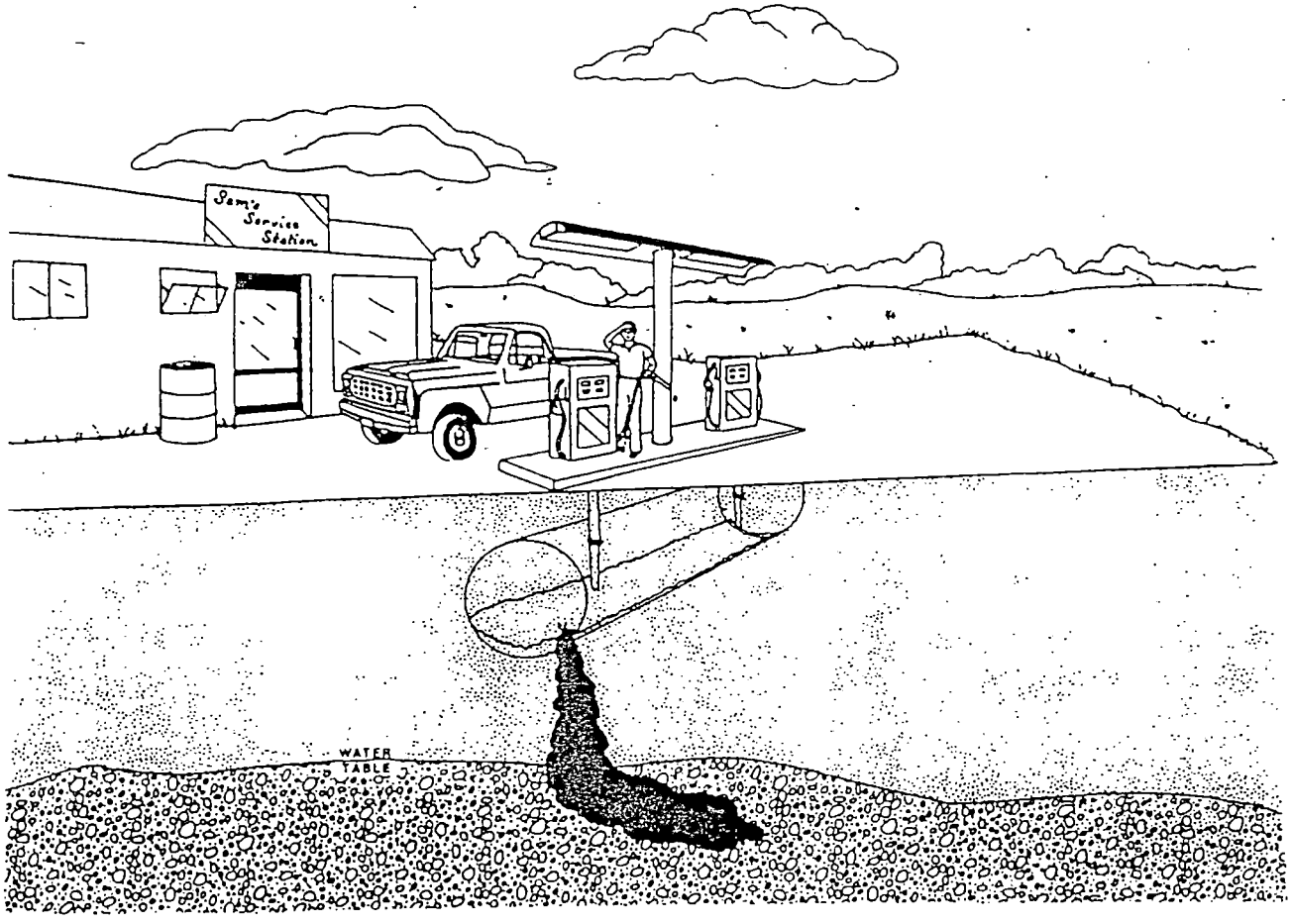
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Options for Community Action
LEAKS AND SPILLS





Chemical Hazards in Our Groundwater
Options for Community Action
LEAK AND SPILL PREVENTION

Henry B.F. Hughes, Water Resources Specialist

Leaking chemical storage tanks and careless handling of solvents are frequent causes of groundwater pollution. Gasoline tanks are a frequent source of leaks. Steps leading to local action to prevent water supply well contamination include collecting information on: (1) Chemical storage tanks; (2) Chemicals used in commercial and industrial establishments; and (3) Principal groundwater aquifers and contribution zones. Local groundwater interest groups can play an imporant role in collecting this information and fostering community recognition of the need for preventive action.

The Hazardous Chemical Threat

Industrial and commercial chemicals such as petroleum products and modern solvents currently pose the most serious threat to groundwater quality. Hazardous chemicals can get into groundwater through accidental leaks and spills and through careless disposal of hazardous wastes. The Environmental Protection Agency considers hazardous chemicals from leaking storage tanks the most serious risk to human health in groundwater[1]. Many chemicals are stored in tanks, but most of the tanks in use contain gasoline. In New York State alone it is estimated that 24,000 of these gasoline storage tanks are leaking at the present time. [2]

EXAMPLE: A Leaking Gasoline Storage Tank

Assume that a gasoline storage tank at a farm or a gasoline station was located over a groundwater supply recharge area and upgradient from a public water supply well. What would happen to the groundwater supply and the well if the tank developed a slow leak? What would happen to people near the leak?

Assume that groundwater conditions are typical of sand and gravel aquifers in the northeast. The situation might unfold like this:

- The tank grows old and develops a small leak at a rusty spot which goes unnoticed because the leak is insignificant from the owners perspective.

- The gasoline seeps downward through the subsoil to the water table which defines the top of the groundwater supply or aquifer. If it is twenty feet from the tank to the water table, and the gasoline moves at about the same speed as water it will take about 1 to 2 years for the gasoline to reach the aquifer.

- At the water table most of the gasoline constituents float on top of the water forming a slick. The soluble constituents, primarily benzene, xylene, and toluene, dissolve in the water and begin to move through the aquifer.

- At this point people who live near the leak may discover gasoline fumes in their basements. If basements flood because of a seasonally high water table, the gasoline floating on the water may seep into basements filling entire houses with fumes and forcing people to evacuate. If no houses are near the leak it would probably go undetected.

- In the aquifer, the soluble constituents will move toward the public supply well. Benzene is known to cause cancer in humans, so it is the chemical which usually receives the most concern. If the leaking tank is located many hundreds of feet upgradient from the well, it will probably take the benzene and other soluble constituents in the gasoline a year or more to reach the well.

- After the benzene reached the well it would eventually be detected in the water. Even a small leak from the gasoline tank could contaminate the water to the point where it was considered unsafe to drink. As shown on the chart, a leak of one tenth of a gallon per day could contaminate a water supply of 500,000 gallons per day to the 5 part per billion guideline used in New York State.

- By the time the benzene was discovered in the water the tank would have been leaking for a number of years and a plume of benzene would stretch from the well back to the tank. It would take at least an equal number of years from the time the leak was stopped until the benzene concentration began to taper off in the well water if no cleanup steps were taken.

- A municipality would have few options at this point. An investigation and cleanup of an aquifer is costly, and could take many months or years. In the mean time, either the water would have to be treated or a new water supply located.

Other Hazardous Material Users

Although thousands of chemicals are used in industry, two classes of chemicals are responsible for most of the problems. In Upstate New York, solvents and degreasers are responsible for most of the contamination incidents at public supply wells, while petroleum products are responsible for most of the contamination problems reported in individual home wells. Some of the other chemicals which have caused groundwater contamination at commercial or industrial sites are: chloride from salt piles or road salting, nitrate from fertilizers or decaying wastes, pesticides, and heavy metals. [3]

The common solvents, such as trichloroethylene (TCE) and related chemicals, are used to clean metals and fabrics and are widely used by many industries, large and small. Dry cleaner's use solvents to clean clothes. Manufacturers of electrical components use them as do metal working industries. These chemicals are also contained in some household chemical mixtures including oven cleaners, paint products, and some septic tank cleaners.

If we limit our image of contamination sites to large industries, we will overlook the most important sources in many areas. The corner dry cleaner or gas station easily handles enough hazardous material to contaminate a large public supply well. Even careless use of these materials around the home can contaminate the neighborhood groundwater.

Federal and State Programs

There are a number of Federal and state programs which can be taken advantage of at the local level. These programs do not in any way diminish the need for local groundwater management. In fact, local action is important to make sure regulations are properly enforced and to take advantage of grant

programs for cleanup of contamination. Some of the major state or Federal programs for protecting groundwater from hazardous industrial and commercial chemicals are listed here. [4]

- States and EPA regulate the generation, transportation and disposal of hazardous wastes to provide "cradle to grave" management of hazardous waste.

- Federal and State "Superfunds" provide money for cleanup of sites of existing contamination.

- Some States, such as New York are implementing bulk storage regulations to deal with the problem of leaking tanks.

- Most states have a permit program which regulates large industrial discharges of wastewater. These programs were designed with point discharges to surface water in mind but may be applied to underground discharges as well.

- Citizens may petition EPA to designate an aquifer as a sole-source aquifer which then means that EPA reviews all Federally assisted projects which may affect the aquifer.

Prevention at the Local Level

Local governments, with authority over land use, are in the best position to prevent hazardous chemical contamination of groundwater supplies. The first step in deciding how to deal with industrial and commercial chemicals is to determine where they are used and stored. It is important to locate abandoned storage tanks as well as existing ones since abandoned tanks are often left with chemicals in them. For discussion purposes a community could divide its jurisdiction into three categories of varying degrees of importance for preventing hazardous chemical contamination of groundwater. If possible, a community could channel the users of chemicals into areas where they pose the least risk to human health.

1. Probably the most important area is the well contribution zone for public supply wells. A contamination incident in this area would be likely to ruin all or part of the water supply for a large number of people.

2. Other priority areas would be those where individual home owners depend on private wells for drinking water. While it might be easier and less expensive to respond effectively to contamination of a few private wells than to contamination of a public well, it can still be traumatic for the well owners.

3. Areas where groundwater contamination would have little impact on human health would be those far removed from houses or areas served by public water with a deep water table (so basements do not flood) and which are not in the contribution zone.

A community may find itself in one of two positions with respect to the important groundwater recharge areas. The recharge areas may be relatively free of land uses which involve the use of hazardous chemicals. For example, the recharge areas may be natural vegetation, low intensity agricultural or low density residential in nature. Alternatively the recharge areas may already be built up with enterprises which use hazardous chemicals such as gasoline stations, dry

cleaners, and various types of manufacturing.

In either case, community involvement programs could be an important tool for building support for preventive measures. Prevention is much cheaper than cleanup, but without a contamination incident to draw attention, it will take a certain amount of effort to overcome complacency. Users of hazardous chemicals need to be aware of the potential contamination problems since their willing cooperation will greatly help preventive programs. Many preventive measures will require understanding and support from the general public as well.

Options for Protecting Undeveloped Recharge Areas

Rural communities are likely to be in a position where the land over the recharge areas is not occupied by users of hazardous chemicals. They are in a position to maintain the current low risk situation through planning. These are often the same communities that are not in a position to operate expensive regulatory programs. Land use controls, which are relatively simple to implement, are an attractive option from that perspective also. Some likely options are given below. [5]

- Purchase of critical parcels of land in the recharge area gives the community the most control over it. This option may be desirable if the community also wants the land for recreational uses or open space.

- Zoning can be used to keep users of hazardous chemicals out of the recharge areas. Uses which should be prohibited are commercial or industrial uses of hazardous chemicals. Land uses such as agriculture and large lot residential development could be permitted instead.

- Watershed protection districts can be created in many states for giving special protection to the public well contribution zones. In New York, for example, a community may adopt watershed rules and regulations with the help of the Department of Health. These regulations may extend across municipal boundaries.

Options for Preventing Contamination in Developed Areas

If the recharge area is largely developed with commercial or industrial users of hazardous chemicals, an approach which minimizes the risk from the existing uses can be followed. Some approaches which can be followed are:

- Adopt ordinances for the recharge areas which regulate the storage and handling of hazardous materials. Local regulations can often be adopted as an extension of state or Federal laws, but they will have to be much stricter to be effective in protecting important recharge areas. The state and Federal programs often exempt "small" users which could be significant users if located over a recharge area.[6],[7]

- A monitoring program could be developed to install test wells in between the chemical use areas and the wells. The test wells would be tested regularly for the chemicals in use to give warning of contamination before it reached the wells.

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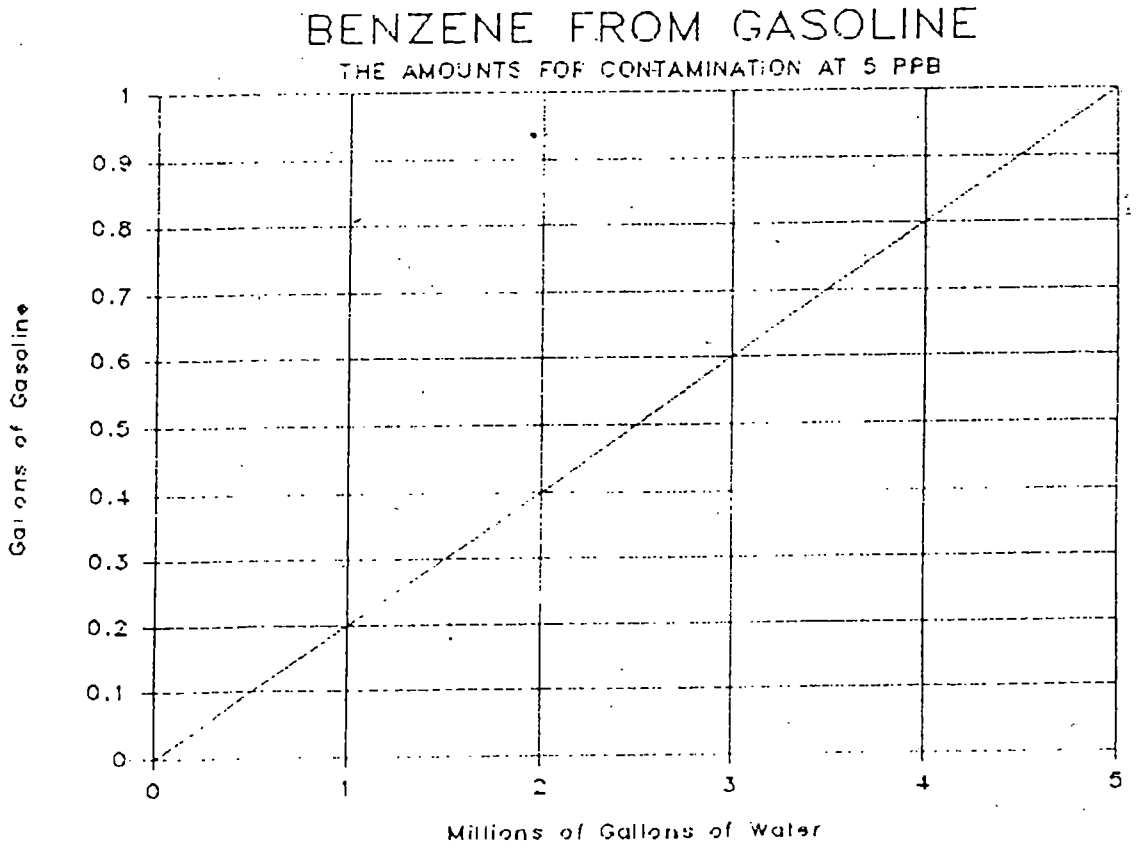
ASSESSMENT OF GROUND-WATER CONTAMINATION BY NITROGEN AND SYNTHETIC ORGANICS IN TWO WATER DISTRICTS IN NASSAU COUNTY, N.Y. 1985. Henry B.F. Hughes, James Pike and Keith S. Porter, Water Resources Program, Center for Environmental Research, Ithaca, N.Y.

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How Little It Takes

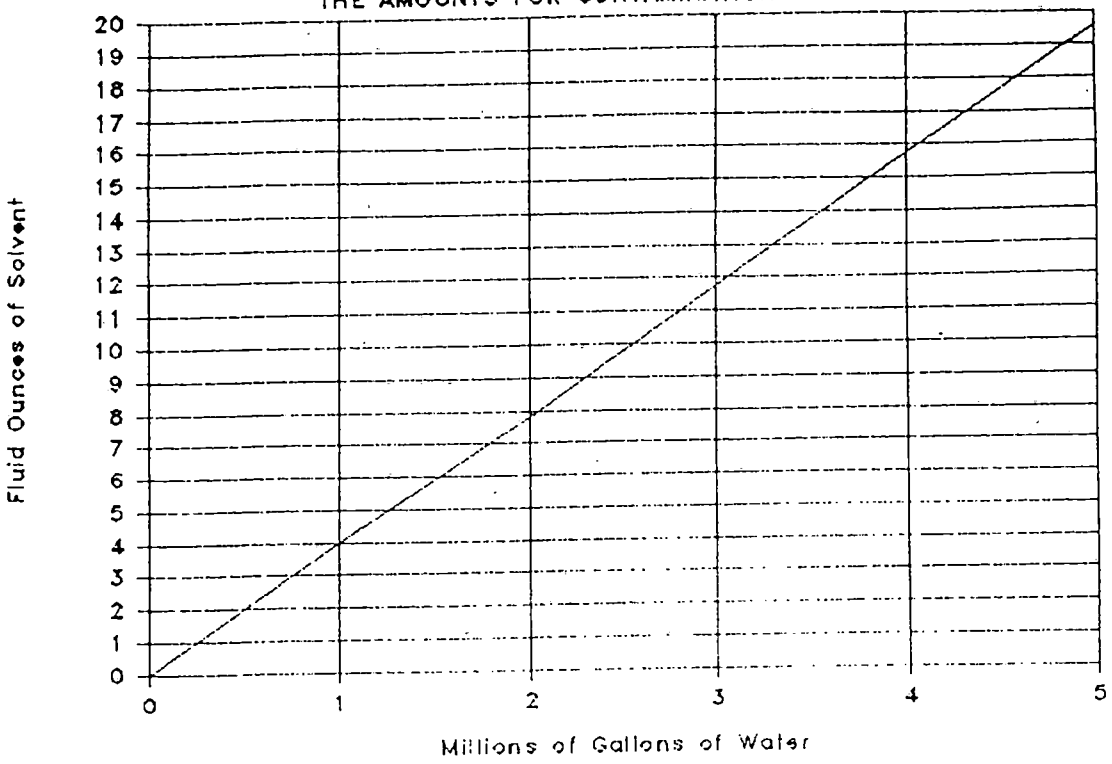
It only takes a very small amount of gasoline or solvent to contaminant water from a large public supply well, so that it violates the guidelines for drinking water. In New York State the Department of Health uses a guideline of 5 parts per billion for benzene in drinking water and a guideline of 50 parts per billion for solvents such as TCE. It is a simple matter to compute how much gasoline it would take to contaminate your drinking water supply so that it violated this guideline.

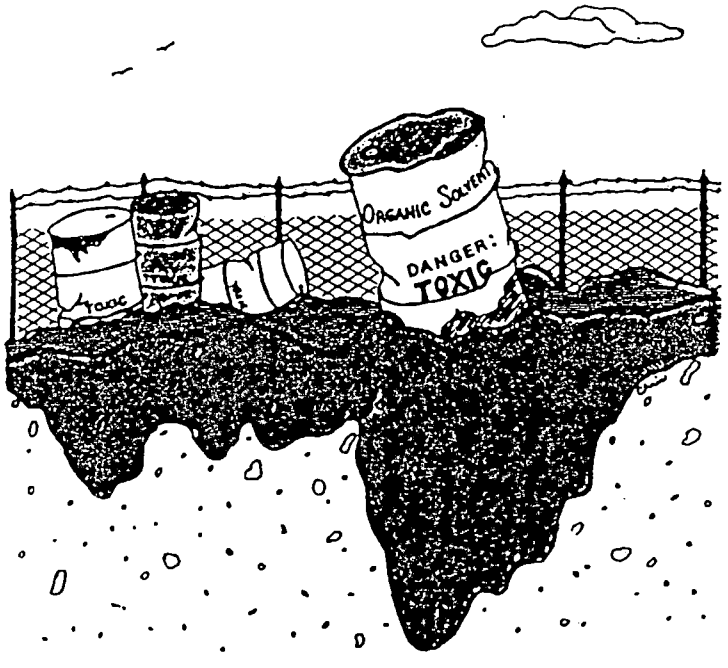
Gasoline usually contains between 3 and 5 percent benzene by weight [8]. This means that 1 gallon of gasoline has enough benzene to contaminate 5 million gallons of drinking water. It takes even less of a straight solvent to cause contamination above the guidelines. The charts below can be used to compute the amount of chemical which can cause contamination above the New York State guidielines in a particular water supply.



SYNTHETIC ORGANIC SOLVENTS (TCE)

THE AMOUNTS FOR CONTAMINATION AT 50 PPB





COOPERATIVE EXTENSION

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SYNOPSIS:

Chemical Hazards in Our Groundwater
Options for Community Action

PREVENTING AGRICULTURAL CONTAMINATION

Recently a village in a rich agricultural section of upstate New York lost the use of its water supply due to nitrate contamination. The high nitrate levels in the village wells were traced to nitrogen fertilizer used on corn in the groundwater recharge area for the wells.

In 1980 it was discovered that more than 1,000 private wells had been contaminated with the pesticide Aldicarb in Long Island's potato growing area. Long Island's sandy soil failed to hold the pesticide in the root zone long enough for it to degrade, allowing it to leach to the underground water table.

These cases illustrate the potential for agricultural contamination of groundwater supplies. Most modern farm operations involve the use of nitrate fertilizers and pesticides. Large animal herds also generate wastes which can result in nitrate contamination of the groundwater.

Nitrate fertilizers and pesticides are a significant portion of the crop production cost for a farmer. Loss of these chemicals to groundwater is an economic loss as well as a health hazard.

Educational and technical assistance can be effective in increasing awareness of practices that prevent groundwater contamination—and save the farmer money. This type of program is best done through a local organization with farmers among its members.

Traditional incentive programs to encourage farmers to adopt beneficial soil conservation management practices suggest similar incentive programs for practices that protect groundwater. These programs are carried out by county soil and water conservation districts.

Buffer zones to protect well recharge areas from contamination can be established by land purchase, through easements, or by methods that allow only uses with low potential for nitrate or pesticide contamination. Local land use regulations have been enacted on Long Island to prevent nitrate and pesticide contamination of groundwater supplies.

Providing a safe means of disposing of unused pesticides is another local option. County pesticide cleanup days are already a well established activity in New York. This can be coupled with an educational program to ensure that local, state and federal regulations are adhered to.

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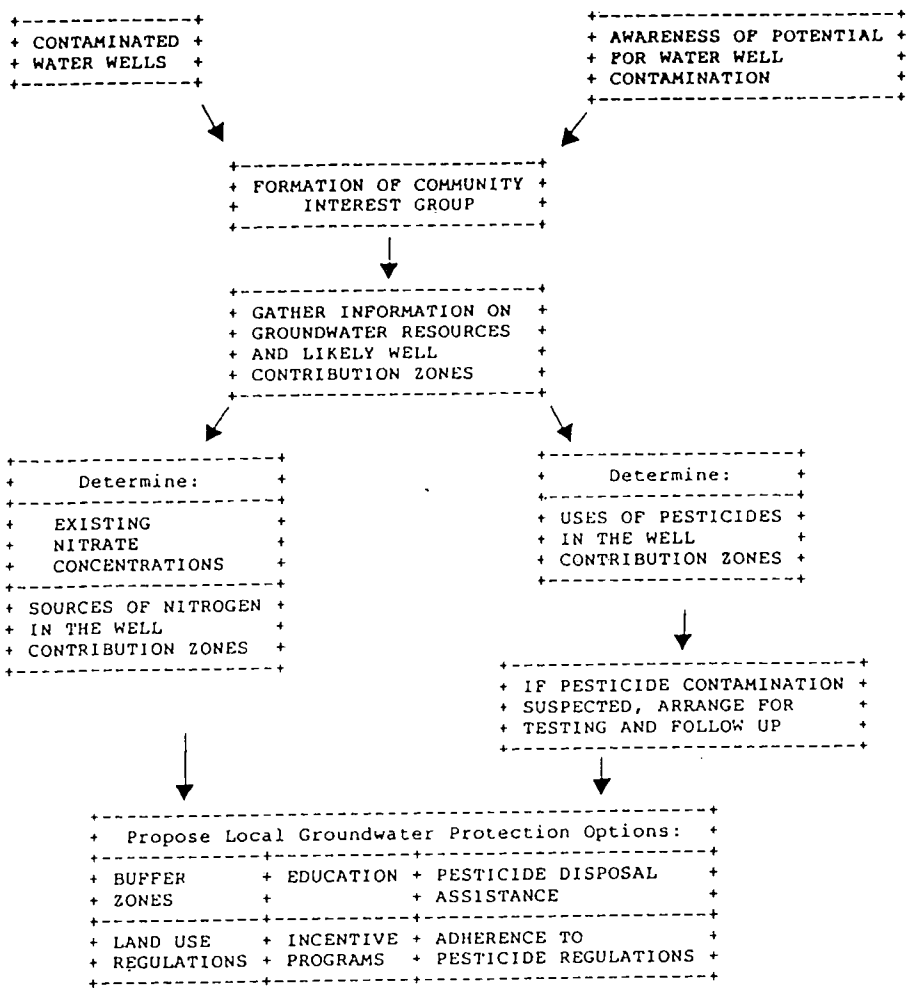
The attached article is to be included in a handbook for local officials and groups [in preparation]. Comments on articles in this series are welcome.

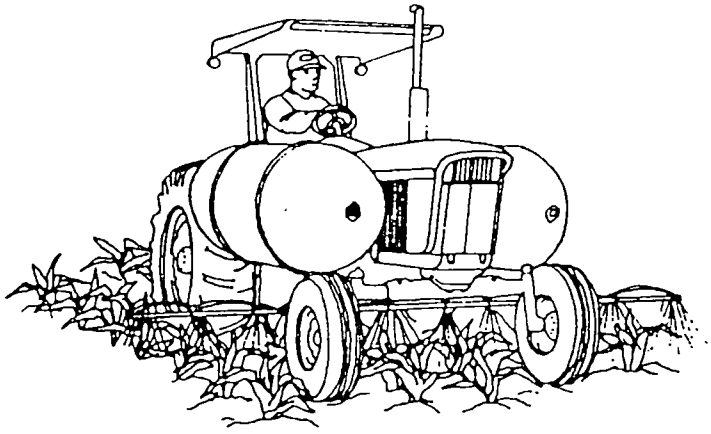
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Options for Community Action
PREVENTING AGRICULTURAL CONTAMINATION





Chemical Hazards in Our Groundwater
Options for Community Action

PREVENTING AGRICULTURAL CONTAMINATION

Henry B. F. Hughes and Lyle S. Raymond

Common groundwater contaminants in agricultural areas are nitrate from fertilizers or animal wastes and pesticides. Options for local preventive actions include: (1) Education; (2) Special incentive programs to encourage practices that protect groundwater; (3) Buffer zones to protect water supply wells; (4) Providing assistance for disposing of unused chemicals such as pesticide cleanup days and (5) Encouraging strict adherence to federal and state chemical use regulations. Education and incentive programs may be quite effective since loss of valuable agricultural chemicals to groundwater represents an economic loss to farmers.

Agricultural Contamination

Recently a village in a rich agricultural section of Upstate New York lost use of its water supply wells because of nitrate contamination. Nitrogen fertilizer used on corn in the recharge area upgradient of the well was identified as the major source of nitrate. [1] In 1980 it was discovered that more than 1,000 private wells in Long Island's potato growing areas had been contaminated with the pesticide aldicarb. [2] The high rate of aldicarb use on potatoes and the inability of Long Island's sandy soil to "filter out" the pesticide, contributed to aldicarb showing up in groundwater.

These cases illustrate the emerging problem that nitrate and pesticides from modern agricultural operations can cause in groundwater.

Nitrate

Nitrate is a naturally occurring nitrogen compound, and very important plant nutrient. It comes from precipitation, decaying organic matter and nitrogen fertilizers. Nitrate is readily carried by recharge water into groundwater, and hence excess nitrogen in the soil which is not used by plants can cause nitrate contamination of the underlying groundwater. Nitrate concentrations in water above 10 mg/l are potentially harmful to infants. [3] Numerous private and public water supplies throughout the northeast have nitrate levels approaching or exceeding the nitrate standard.

Nitrogen fertilizer is used on many crops to supplement the nitrogen released naturally from the soil. It allows farmers to get a large increase in crop yield in relation to the cost of the investment. It is also used on lawns to help grass grow in soils where it normally would not do very well, or to make lawns look greener.

Nitrate also results from the decay of animal manure. This manure can be a problematic source of nitrate in groundwater. Herds of animals confined to a small area of land such as feedlots can be concentrated sources of groundwater contamination.

All agricultural land uses do not cause nitrate contamination, although some elevation of nitrate concentrations in groundwater can be observed in most agricultural areas when compared to undisturbed forests. It is the intensity of the

agricultural operation and the amount of nitrogen wasted that determine whether or not contamination will occur. A large herd of cattle confined to a small area and surrounded by heavily fertilized crop land is one formula for nitrate contamination. [4]

Nitrate contamination at a public well often occurs gradually, as the result of several sources of nitrogen in the well contribution zone. Agriculture may be only one of the potential nitrate contamination sources. Since nitrate is a common contaminant and a nitrate analysis is inexpensive, it makes sense to test public supplies regularly for nitrate and watch for increasing trends.

A useful way to keep tabs on the various sources of nitrate in a well contribution zone is to compute a nitrogen budget. [5],[6] A nitrogen budget is an estimate of the proportion of nitrate in the well water coming from each source in the contribution zone. This makes it possible to concentrate control efforts on the most significant sources of nitrogen. A nitrogen budget could in most cases be computed by a local agency staff person with some assistance from a university, state agency or consultant. The amount of outside assistance required would depend on the complexity of the sources of nitrogen in a well contribution zone and the precision required.

Options for Controlling Nitrate

Methods of controlling the most significant agricultural sources of nitrogen in a groundwater protection area must be adaptable to individual agricultural operations in order to be effective. Control programs will need to be personalized and will require a large degree of voluntary compliance. Here are some suggestions for local nitrogen management for groundwater protection.

- **Education and technical assistance for land owners** is a low cost noncontroversial way to minimize nitrate contamination. Since nitrogen is a valuable fertilizer for farmers, it is in their interest to keep it out of the groundwater. An awareness of the potential for problems and ways of preventing them will help farmers prevent contamination. An education program conducted through a local interest group with farmers in the membership and local agency technical assistance may be the best overall approach to the problem. A number of agencies exist to assist farmers including Soil and Water Conservation Districts, Cooperative Extension, the Agricultural Stabilization and Conservation Service and the Soil Conservation Service. Professional staff from one or more of these agencies should be involved in any educational effort.

- **Incentive programs** are set up to compensate farmers for adopting particular practices. These programs have been used to promote practices which will protect surface waters from pollution, and can be adapted for groundwater protection. The Soil and Water Conservation Districts administer these programs which are usually funded with federal money. Local money can also be made available to Soil and Water Conservation Districts to develop and administer special incentive programs for groundwater protection. [7]

- **Establishing buffer zones** can be a way to offset nitrate contamination from high impact land uses with low impact ones. A buffer zone would consist of particularly sensitive land in the well contribution zone, such as the portion of

the recharge area closest to the well. Land in the buffer zone would be maintained in uses which contributed little nitrate to groundwater. Ideally the land would be kept in natural vegetation and not fertilized. The buffer could be established through outright purchase of land, purchase of easements or other mechanisms which guarantee a low impact use.

- **Regulations** could be implemented to prevent land uses which would cause nitrate concentrations to go above the health standard. These can also apply to the use and handling of chemicals and wastes. The regulations must be enforceable, and many aspects of agricultural nitrogen management are not amenable to regulation. The concentrating of farm animals could be regulated more easily, for example, than fertilization practices. The Towns and Countes on Long Island have a number of these types of regulations. [8]

Pesticides

Pesticide contamination of groundwater from agricultural uses in certain areas is a relatively recent discovery. The discovery of a few pesticides has led to investigations of others, and many questions about pesticides in groundwater have yet to be answered.

Modern pesticides are designed to degrade to harmless substances in the soil after they have accomplished their purpose. Most pesticides are held in the surface layer of the soil so that this degradation can take place. However, under some circumstances, pesticides have not been held by the soil and have moved into groundwater before they degraded. Researchers have found certain conditions which lead to pesticide contamination: [9],[10]

- Pesticides which are not readily filtered out by soil because of their chemical nature are more likely to contaminate groundwater.

- Soils which are low in organic matter, such as sands, are more conducive to contamination.

- Wells which are close to fields where pesticides are used are more likely to become contmainated than wells which are further away.

- Shallow wells are also more vulnerable to contamination than deep wells.

Improper or careless handling of pesticides can also cause contamination. Disposng of containers with pesticides still in them in recharge areas may allow the leftover pesticides to leach into groundwater. Washing equipment used for application over a recharge area or in surface waters in a well contribution zone could also lead to pesticide contamination at a well.

Local individuals or interest groups can play a role in uncovering contamination. An interest group can collect information on likely contribution zones for water supply wells, land uses in those areas that use pesticides, and the type of pesticides used. A group that suspects pesticide contamination in local well supplies can encourage testing and action by the state, the federal government, or others. Aldicarb contamination was discovered in Upstate New York groundwater as a result of one farmer requesting that the manufacturer test his private well for the pesticide after he had used it on his potato crop for a

number of years. [11] Personnel from a university, state agency or Cooperative Extension may be able to assist a local group in determining whether or not pesticide contamination is likely under local conditions.

Options for Preventing Pesticide Contamination

The pesticide registration process, administered by the Environmental Protection Agency, is supposed to prevent pesticide contamination of groundwater, but state and federal regulations will not necessarily cover every local situation. Therefore, it seems prudent for communities to give some consideration to avoiding pesticide contamination of water supply wells as a precautionary measure. Local options for preventing pesticide contamination are similar to the options for preventing nitrate contamination. Four options are:

- **Establishing buffer zones** since the greater the distance between the place of pesticide application and the well the greater the chance that the pesticides will be filtered out and degraded in the soil.

- **Education of Pesticide Applicators** to alert them to the importance of complying with all federal, state and local regulations. They should also be informed about methods for disposing of residues in tanks and containers that will not lead to contamination of water supplies.

- **Provide means for safe disposal** of pesticide containers and unused stocks of pesticides. A number of counties in the northeast have conducted successful pesticide cleanup days where a local agency arranges for a collection site and a licensed waste hauler on the cleanup day. [12] These may need to be conducted on a regular basis. New York State recently adopted rules to help communities conduct such events safely. [13]

- **Incentive programs** to promote soil management practices that minimize potential pesticide contamination of groundwater supplies can be developed with local funding through Soil and Water Conservation Districts.

Long Range Strategies

Community leaders in communities that have delt with groundwater contamination, such as the aldicarb affected areas of Long Island, are suggesting that the present chemically intensive farming practices need to be reevaluated. [14] The trend toward one crop farming for major crops may increase efficiency in the short term, but it also increases the need for chemical fertilizers and pesticides. It may be desirable to encourage crop diversification to reduce pest pressures and maintain soil fertility. Biological pest controls should be encouraged to replace chemical controls as much as possible. Groups that explore this issue will find that it is a complex one involving agricultural economics and marketing strategy as well as chemical use practices.

One way that local groups can influence this long term trend in their community is by helping to open up local markets to local produce which will encourage diversity. The Cornucopia Project at Rodale Press in Emmaus, Pennsylvania is a good source of ideas for local groups wishing to influence local agricultural trends. [15]

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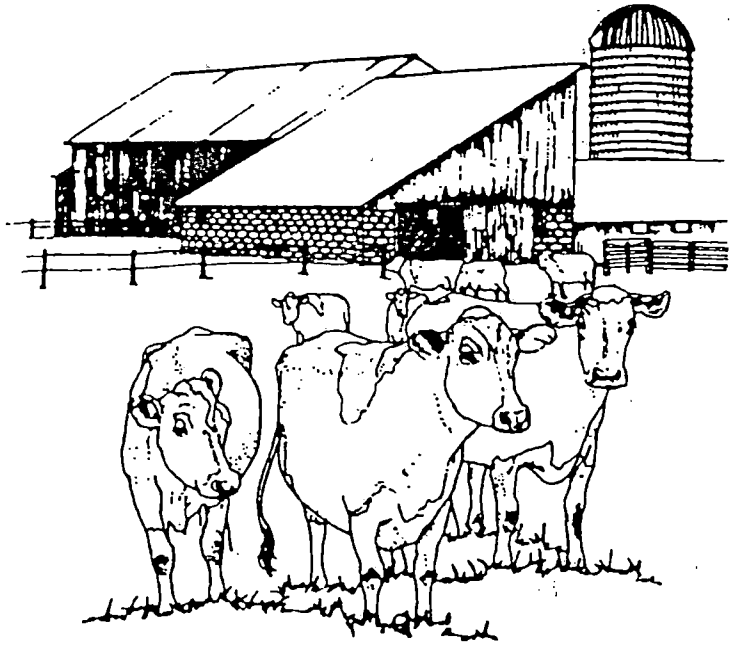
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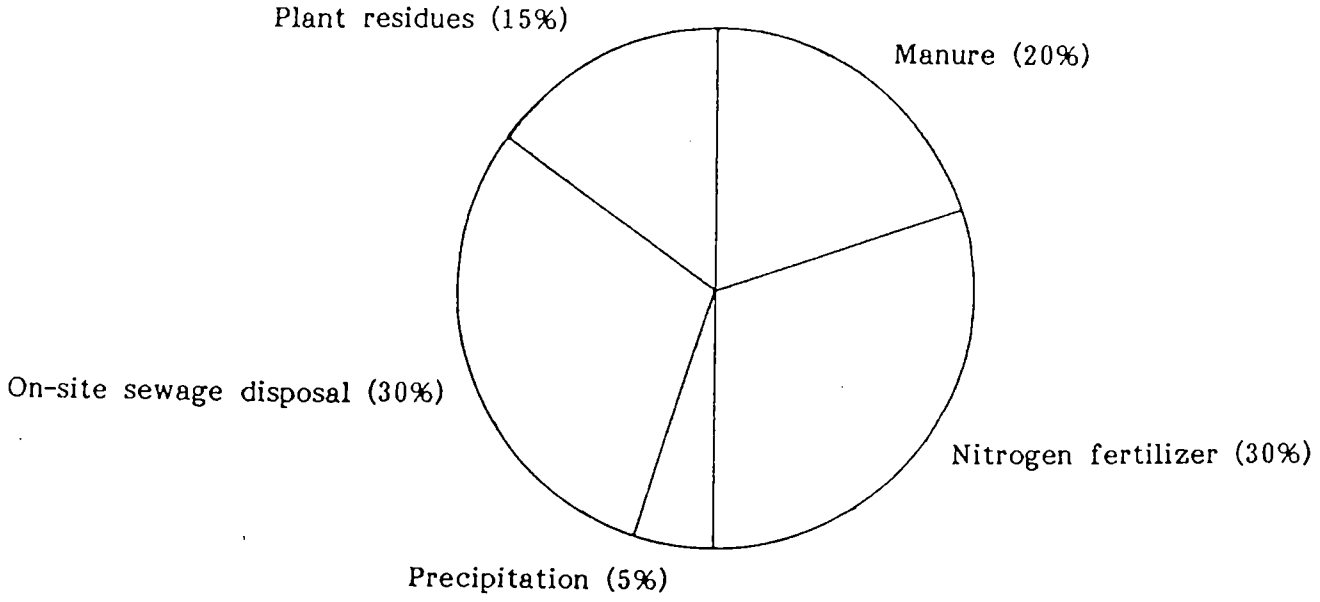
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Nitrogen Budgets

There are usually a number of sources of nitrogen in a groundwater protection area such as a well contribution zone. Computing a nitrogen budget is a useful device for determining which sources of nitrogen are the most significant contributors to nitrate in groundwater. A pie chart, such as the example one below, is a convenient way to summarize the nitrogen budget results.

NITRATE INPUTS TO GROUNDWATER
IN AN EXAMPLE WELL CONTRIBUTION ZONE



Chemical Hazards in Our Groundwater
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Preventing Household Contamination

Henry B.F. Hughes and Lyle S. Raymond

This article focuses on water well contamination from activities in and around the home. Hazardous chemicals that enter the home in consumer products and nitrates from on-site sewage disposal systems and lawn fertilizers are the principal chemical contaminants from households. Local prevention actions include: (1) Education; (2) Zoning; (3) Sewering; (4) Proper disposal; (5) Lawn management; and (6) Product bans. Local interest groups can play an important role in collecting information on household contamination hazards and fostering community recognition of the need for preventive action.

Hazardous Household Chemicals

The adverse impact that residential development can have on groundwater first became apparent in places like the suburbs of Long Island, where intense development took place over major groundwater aquifers which were the source of drinking water. Nitrate from on-site sewage disposal systems and from lawn fertilizers began showing up in wells at levels exceeding the health standard. Later, modern household chemicals from detergents and cesspool cleaners also began to contaminate the water. [1] Further studies showed that a variety of household chemicals including cleaning products, paint thinners, automotive chemicals and lawn care products posed a potential threat to the water. [2]

Poor development planning, the use of hazardous chemicals in consumer products, home owner ignorance about the potential for contamination, and the lack of safe alternatives for disposing of unused chemicals all contribute to the problem of groundwater contamination from residential areas. Even concerned consumers can find it difficult to assess the impacts their actions will have on the environment because of the general lack of information available about chemicals.

Communities that have had contaminated water supply wells have demonstrated how costly and troublesome it can be to solve contamination problems after they have occurred. Local groups can help prevent groundwater contamination in well contribution zones or other important recharge areas by working for (1) Greater awareness of groundwater resources, critical recharge areas and well contribution zones; (2) Proper planning of residential developments in important recharge areas; and (3) By educating homeowners about the potential impact of careless chemical use.

Nitrate

Nitrate is a naturally occurring nitrogen compound which is released into the soil from decaying organic matter, nitrogen fertilizers and precipitation. Nitrate concentrations in excess of 10 mg/l are potentially harmful to infants. The major sources of nitrate contamination of groundwater in residential areas are leachate from on-site sewage disposal systems and nitrogen fertilizers used on lawns.

Constructing a nitrogen budget for a well contribution zone is a convenient way to assess the amount of nitrate in groundwater coming from each source. [3] It can be particularly important in residential areas to know whether controls should be targeted at sewage systems, lawn fertilizers or something else.

Lawn fertilizer use varies from community to community. Soil properties and cultural factors influence the amount of fertilizer that homeowners use. A survey of homeowners to determine fertilization practices is a way to determine how much of a threat lawn fertilization poses to groundwater. [4] Using a nitrogen budget, it is possible to predict the nitrate concentration in groundwater resulting from a particular population density and fertilization scheme. A simple computer program to assist planners in assessing the nitrogen impact of residential development has been developed at Cornell. [5]

Options for Controlling Nitrate

There are two basic options for controlling nitrate contamination from sewage:

- **Low density zoning** can be used before development takes place to insure that there will be enough water from natural recharge to dilute the nitrate from on-site sewage disposal systems or lawn fertiizers. Towns on Long Island have used densities of from two to five acres to protect important groundwater recharge areas. [6] Nitrogen budgets have been used to calculate nitrogen impacts and recommend appropriate housing densities. [7],[8].

- **Sewering** an existing or new development removes most of the nitrate from the recharge area to a treatment plant. Sewering is a logical control measure for existing dense developments, but it has some disadvantages which may make it less desirable than other options for new developments. Sewer line leakage, for example, can itself become a source of groundwater contamination. Sewers may also encourage more intense development and are generally more expensive than other options. [9]

There are several options for controlling nitrate contamination from lawns if controls are deemed necessary:

- **Encouraging alternative ground covers** may be the best way to help homeowners prevent contamination from fertilizers where grass is difficult to grow. Native vegetation is one possibility. Local Cooperative Extension services often have recommendations for alternative ground covers. [10]

- **Encouraging low intensity lawn maintenance** is also helpful. Returning clippings to the lawn after mowing allows nitrogen from the clippings to be reused by the grass. If clippings are removed, it will create a need for chemical fertilizers which are more subject to leaching. Further, the unwanted clippings may be taken to a landfill where the nitrogen from the clippings may leach into groundwater. Use of low nitrogen grass species can also be encouraged. [11]

- **Lawn size regulations** have been used by some Long Island Towns to preserve native vegetation and reduce the impact of nitrogen fertilizers on groundwater. The regulations specify the maximum percent of a lot which can be cleared of native vegetation. [12]

Chemicals

Many of the chemicals which contaminate groundwater in industrial areas also enter households in a variety of products. A number of studies have been done to list all the possible hazardous chemicals around the home. [13] The attached table lists the chemical contaminants which were found in groundwater underlying residential areas in four communities.

Solvents are used in many consumer products which are responsible for many groundwater contamination incidents. Solvents may be used around the home to dissolve grease in clothing, clogged drains, dirty ovens or engine parts. They are also used to thin paints, waxes and finishes. These can get into groundwater when they are flushed into a septic system or poured on the ground. This might even be a part of the intended use of a product such as a septic tank degreaser.

Petroleum products contain a number of chemicals which can cause groundwater contamination. Heating oil, waste motor oil and gasoline are often present around homes. If these chemicals are disposed of or spilled on the ground or into an on-site waste disposal system they can contaminate groundwater.

Pesticides have been found to cause groundwater contamination in some agricultural areas. The pesticides available to homeowners are generally less toxic. Nonetheless, they pose a potential threat to groundwater and it is important that homeowners apply pesticides carefully and only when they are needed to solve an identifiable problem. [14]

There may be no easy way to dispose of unused chemicals or empty containers containing residues that does not endanger groundwater. Many people resort to dumping such products in their yard or down the drain where they are likely to leach into groundwater. Disposal of such products in the garbage is another common practice, but if the garbage is taken to a landfill the chemical may eventually leach out into the groundwater.

Used motor oil is one product which can be recycled, and there are service stations which will accept used oil. Unfortunately, few people realize that the oil can be recycled or they are not willing to take the time to take it to a recycling center. A local group can play a large role in educating the public and facilitating safe disposal of such hazardous wastes.

Options for Controlling Hazardous Household Chemicals

Local groups can pursue a number of tactics:

- **Educational programs** should be part of any overall strategy. Homeowners need to be aware of the connection between the use of chemicals and groundwater contamination. Alternatives to their use can be promoted as well as increased awareness about safe methods for their use and disposal.

- **Hazardous waste cleanup days** have been conducted by a number of Counties and Towns in the northeast. A local agency arranges for a collection site and a licensed waste hauler on the cleanup day. Home owners are encouraged to bring their unused hazardous chemicals to the cleanup day and are charged a small fee for disposal. [15], [16]

- **Product bans** can be effective in preventing the sale of chemical products for which the danger of use clearly outways the benefits. Organic solvent cesspool cleaners are now banned from Nassau and Suffolk Counties to protect groundwater. [17]

- **Proper management of on-site disposal systems** can help to prevent system failures, and provide for regular cleaning. This in turn will reduce the chance that people will turn to chemical degreasers to unclog the system. Educational programs can be used to increase proper management through voluntary action. A local government could even take over the management responsibility in a particularly critical area. This has been proposed in one Town in New York. [18]

- **Low Density Zoning** can be used to limit the overall impact of residential development in critical groundwater resource areas. Obviously fewer houses and on-site disposal systems would lead to less chance for chemical contamination from improper household disposal of hazardous chemicals.

Lifestyle and Risk Management Issues

It is disturbing that modern residential settlements can so easily contaminate the water we drink (and the air we breath). This concern raises the question of whether the health risks of using certain chemicals outweigh the benefits. Researchers and regulators are still seeking logical ways of managing these risks. Local groups need to be aware of the larger issues here and try to make educational programs as open and objective as possible to facilitate informed decision making by other members of their community.

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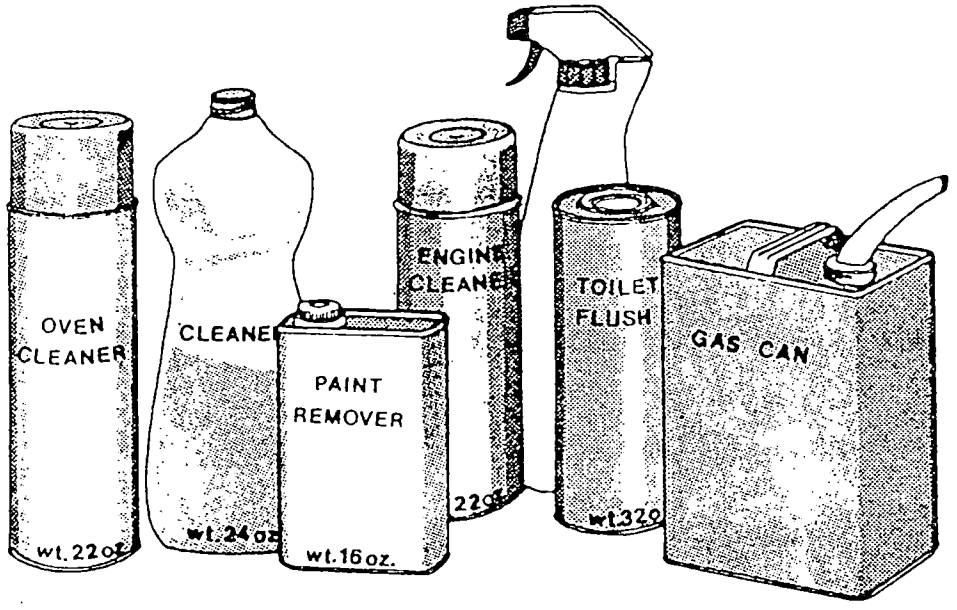
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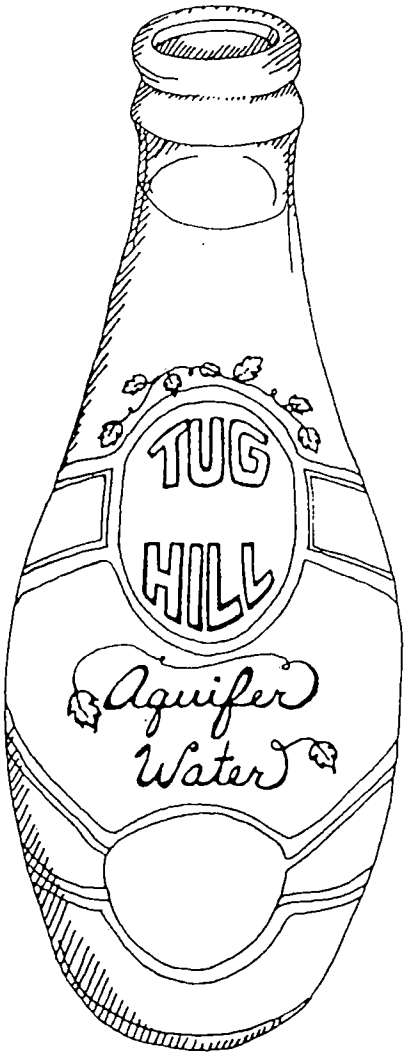
Description of Organic Chemicals Found In Ground Water Underlying Residential Communities on Long Island, New York

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.




TUG
HILL
Aquifer
Water