Cover photo: Young burley tobacco plants in the Nolichucky River Basin, Washington County, Tennessee.

Shallow Ground-Water Quality Adjacent to Burley Tobacco Fields in Northeastern Tennessee and Southwestern Virginia, Spring 1997

By GREGORY C. JOHNSON and JOSEPH F. CONNELL

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http://water.usgs.gov/nawqa/nawqa_home.html

FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Associate Director for Water

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, WATER-QUALITY UNITS, AND ABBREVIATIONS

Multiply	By	To obtain
foot (ft)	0.3048	meter
square miles (mi^2)	2.590	square kilometers
acre	0.4047	hectare
pound (lb)	0.4536	kilogram
pounds per acre (lb/acre)	1.12	kilograms per hectare
milligrams per liter (mg/L)	0.001	grams per liter
micrograms per liter (µg/L)	10^{-6}	grams per liter

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C = (°F - 32) / 1.8

Sea level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water-quality units

mg/L	milligrams per liter
pCi/L	picocuries per liter
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter at 25° Celsius

Abbreviations and Acronyms

GIS	Geographic Information System
HAL	Health advisory limit
MCL	Maximum contaminant level
MRL	Method reporting limit
NAWQA	National Water-Quality Assessment Program
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTEN	Upper Tennessee River Basin
VOC	Volatile organic compound

Shallow Ground-Water Quality Adjacent to Burley Tobacco Fields in Northeastern Tennessee and Southwestern Virginia, Spring 1997

By Gregory C. Johnson *and* Joseph F. Connell

ABSTRACT

In 1994, the U.S. Geological Survey began an assessment of the upper Tennessee River Basin as part of the National Water-Quality Assessment (NAWQA) Program. A ground-water land-use study conducted in 1996 focused on areas with burley tobacco production in northeastern Tennessee and southwestern Virginia. Land-use studies are designed to focus on specific land uses and to examine natural and human factors that affect the quality of shallow ground water underlying specific types of land use.

Thirty wells were drilled in shallow regolith adjacent to and downgradient of tobacco fields in the Valley and Ridge Physiographic Province of the upper Tennessee River Basin. Ground-water samples were collected between June 4 and July 9, 1997, to coincide with the application of the majority of pesticides and fertilizers used in tobacco production. Ground-water samples were analyzed for nutrients, major ions, 79 pesticides, 7 pesticide degradation products, 86 volatile organic compounds, and dissolved organic carbon.

Nutrient concentrations were lower than the levels found in similar NAWQA studies across the United States during 1993-95. Five of 30 upper Tennessee River Basin wells (16.7 percent) had nitrate levels exceeding 10 mg/L while 19 percent of agricultural land-use wells nationally and 7.9 percent in the Southeast had nitrate concentrations exceeding 10 mg/L. Median nutrient concentrations were equal to or less than national median concentrations. All pesticide concentrations in the basin were less than established drinking water standards, and pesticides were detected less frequently than average for other NAWQA study units. Atrazine was detected at 8 of 30 (27 percent) of the wells, and deethylatrazine (an atrazine degradation product) was found in 9 (30 percent) of the wells. Metalaxyl was found in 17 percent of the wells, and prometon, flumetralin, dimethomorph, 2,4,5-T, 2,4-D, dichlorprop, and silvex were detected once each (3 percent). Volatile organic compounds were detected in 27 of 30 wells. Although none of the volatile organic compound concentrations exceeded drinking water standards, the detection frequency was higher than the average for the other NAWQA study units.

INTRODUCTION

In 1994, the U.S. Geological Survey (USGS) began an investigation to assess the water-quality conditions in the upper Tennessee River Basin (UTEN) as part of the National Water-Quality Assessment (NAWQA) Program. The NAWQA Program, designed to describe the status of and trends in the quality of the Nation’s surface- and ground-water resources and to relate the status and trends to natural and human factors (Hirsch and others, 1988), calls for spatial characterization of water-quality conditions of major aquifers through study-unit and land-use studies (Gilliom and others, 1995).

One component of the NAWQA Program is to evaluate the effect of various land uses on shallow ground-water quality within specific land-use settings. Adherence to nationally classified land-use categories allows comparisons to be made on a national scale. The focus on shallow ground water is intended to provide the earliest indication of potential contamination or other water-quality changes and to minimize the influence of factors other than land use on ground-water quality. Agricultural land-use studies examine the potential impacts of the widespread application of agricultural chemicals on shallow ground water in agricultural settings. One of the most important agricultural crops in the UTEN is burley tobacco; therefore, in 1996 a ground-water land-use study was conducted, which focused on areas of burley tobacco production in the UTEN.

Purpose and Scope

This report presents results regarding the quality of shallow ground water downgradient from burley tobacco fields in northeastern Tennessee and southwestern Virginia. Water samples were collected from 30 shallow wells for analysis of major ions, nutrients, pesticides, and volatile organic compounds. Water-quality results were compared with similar NAWQA study units on a national scale, and with other local and regional studies.

Description of the Upper Tennessee River Basin and the Study Area

The UTEN study unit (fig. 1) drains an area of about 21,390 square miles (mi^2), which includes the entire drainage of the Tennessee River and its tributaries upstream of Chattanooga, Tennessee. The basin includes parts of Tennessee (11,500 mi^2), North Carolina (5,480 mi^2), Virginia (3,130 mi^2), and Georgia (1,280 mi^2), and consists of parts of the Blue Ridge, Cumberland Plateau, and Valley and Ridge Physiographic Provinces (fig. 1). Forest covers about 64 percent of the basin; and agricultural land, which is predominantly pastureland, accounts for about 27 percent of the basin (fig. 2). Urban areas, water bodies, and barren land account for the remainder of the land use in the basin. The Valley and Ridge Physiographic Province has the highest percentage of agricultural land use of the three physiographic provinces in the UTEN.

The tobacco land-use study described in this report was conducted in a part of the Valley and Ridge Physiographic Province in northeastern Tennessee and southwestern Virginia (fig. 1). This part of the UTEN was delineated for the study because it has the largest concentration of tobacco production within the Valley and Ridge Physiographic Province. The tobacco study area covers 6,724 mi^2 with forest accounting for about 51 percent of the study area, agriculture about 41 percent, and urban areas and open water accounting for the remainder of the land use.

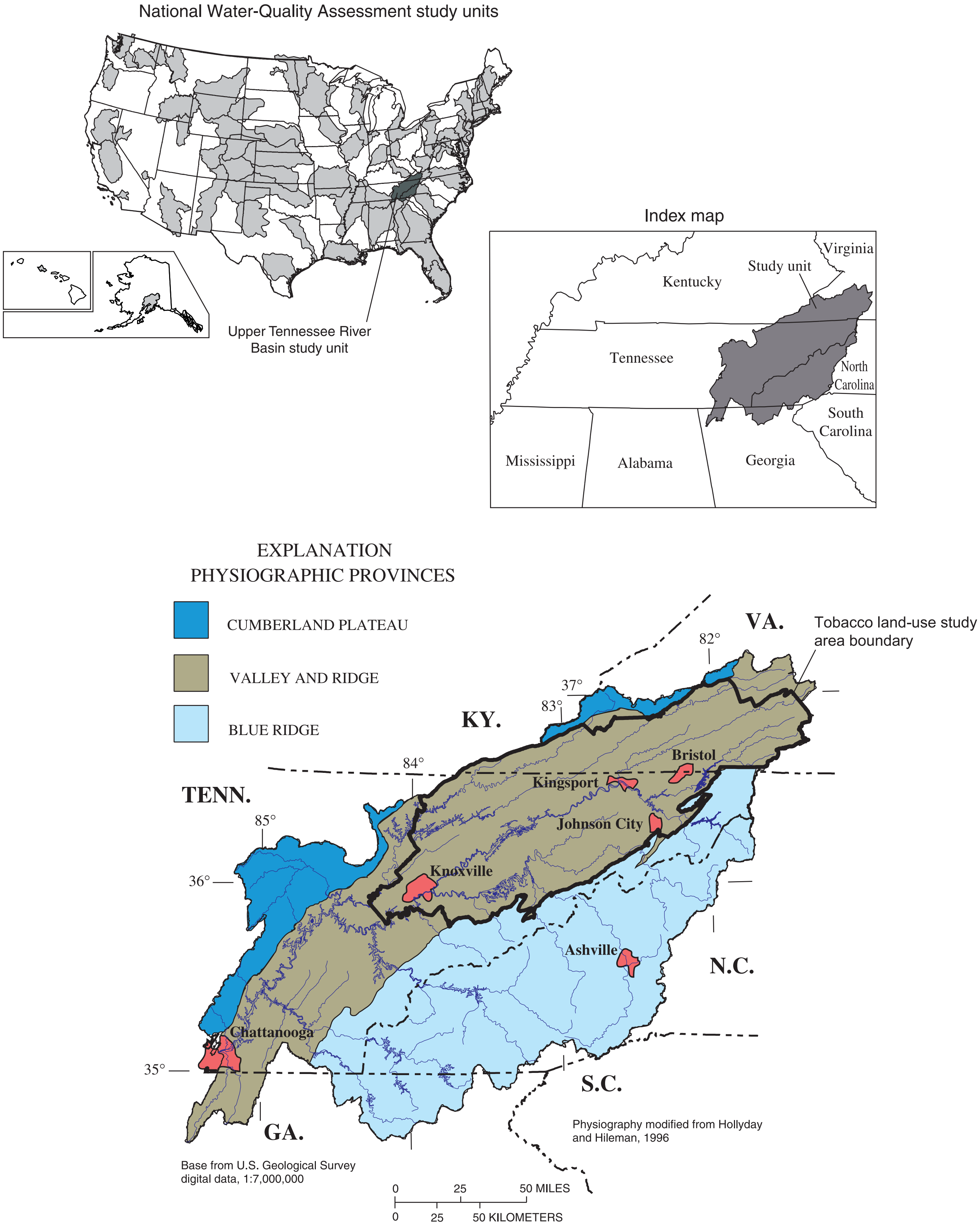
Geology and Geography

The Valley and Ridge Physiographic Province is a long narrow belt of faulted and folded Paleozoic sedimentary rocks. Predominant rock types are, in order of abundance, carbonate rock (dolomite and limestone), shale, and sandstone (Colton, 1970). For this study, the shale and sandstone units were grouped together as siliciclastic rocks (fig. 3).

Topographically, the Valley and Ridge is characterized by a succession of subparallel northeast-trending ridges that are made up of the less soluble cherty limestone, dolomite, and sandstones. The valleys have developed in the more soluble limestone, dolomite, and shale (DeBuchananne and Richardson, 1956). Topography largely dictates land use in the UTEN with most of the agricultural land located in stream valleys, on benches, and in the more gently rolling areas of the Valley and Ridge. Regolith in the Valley and Ridge ranges in thickness from 0 to 450 feet and varies in texture from clay to gravel. The regolith also varies in composition with the most common soil types consisting of silty clay and clay, followed by soils containing sand, silt, clay, and gravel. Regolith is either formed in place by weathering of the underlying bedrock (residuum) or deposited after being transported from the place of weathering (alluvium and colluvium) (Hollyday and Hileman, 1996). Shallow surficial aquifers in the regolith generally are not used for drinking-water supplies, but contaminants in the surficial aquifers can be transported to underlying bedrock aquifers through cracks and fissures or solution cavities, or can move through the saturated soil zone to adjacent surface-water features.

Tobacco Production

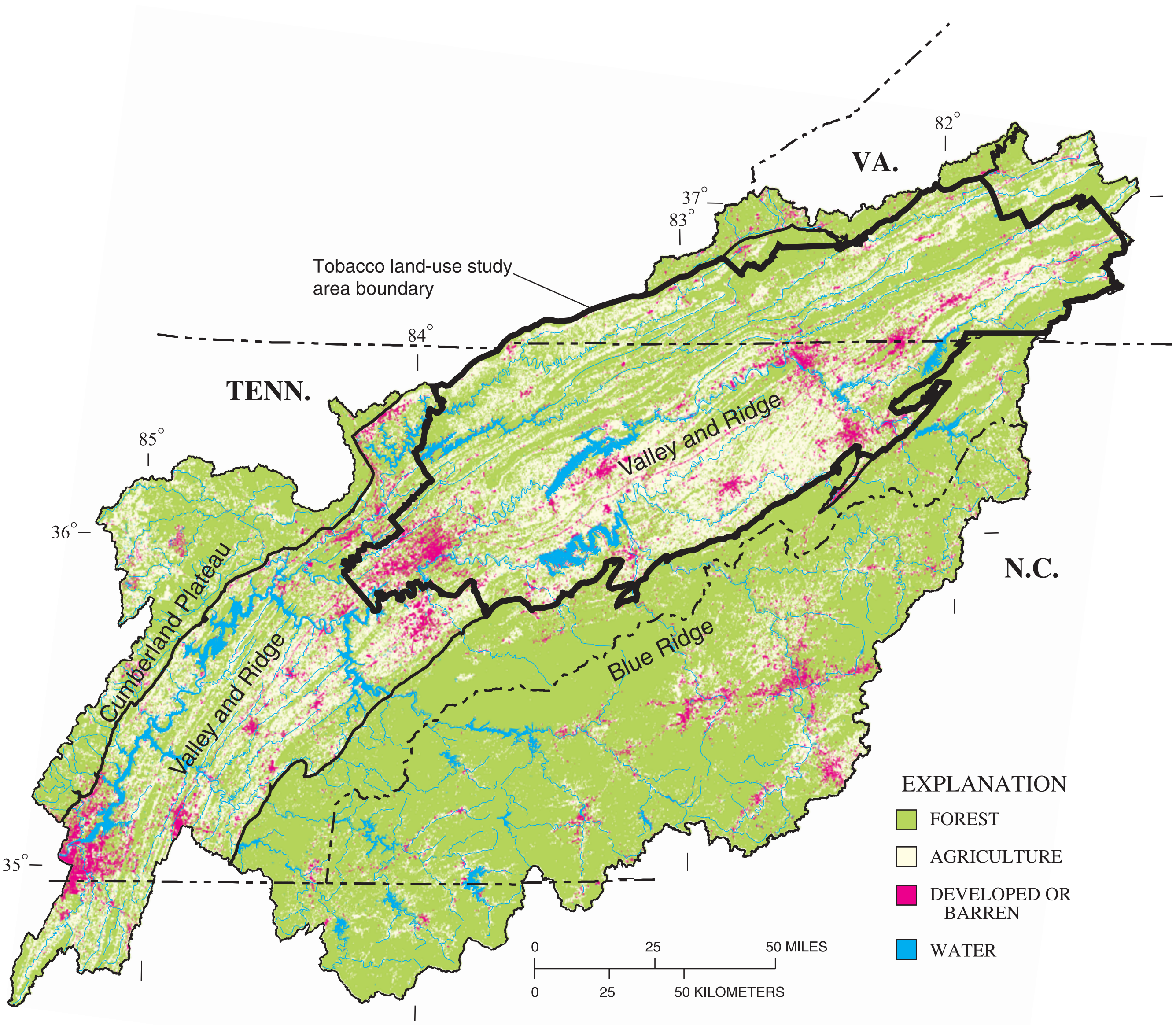
In 1996, approximately 1.57 billion pounds of flue-cured and burley tobacco were produced in the United States. Of this amount, 94 percent was grown in North Carolina, Kentucky, Virginia, South Carolina, Tennessee, and Georgia. Burley tobacco is a light, air-cured tobacco that is usually grown on smaller farms than flue-cured tobacco because of labor requirements and the local topography. Farms in Tennessee (mostly burley) average about 4 acres of tobacco, whereas



Physiography modified from Hollyday and Hileman, 1996

Base from U.S. Geological Survey digital data, 1:7,000,000

Figure 1. Location of the upper Tennessee River Basin study unit and the tobacco land-use study.



Base from Southern Appalachian Assessment 30 meter land use GIS data base, 1996.

Figure 2. Land use and land cover by physiographic province in the upper Tennessee River Basin.

farms in South Carolina (all flue-cured) average about 43 acres of tobacco (Capehart, 2000). In 1996 in Tennessee, the total burley tobacco production was 87.7 million pounds on 79,531 farms with an average yield of 1,830 lbs/acre (Tennessee State Farm Service Agency, 1998); in Virginia, production was 17.4 million pounds on 9,500 farms with an average yield of 1,835 lbs/acre. In the tobacco land-use study area of the UTEN, 52.8 million pounds of burley tobacco were produced in 1996 (U.S. Department of Agriculture, 1999). Burley tobacco production has been a staple source of income for farmers in eastern Tennessee and southwestern Virginia for more than 100 years. Tobacco contributed nearly 1 out of every 10 dollars in agricultural receipts in Tennessee in 1998, and leads all crops in cash receipts (Tiller, 1999). The potential for fertilizer and pesticides to move into nearby surface water is significant because of the high application rates of these chemicals used for growing tobacco (Taraba, 1997).

Acknowledgments

The authors thank the many farmers and the officials of agricultural research stations who allowed

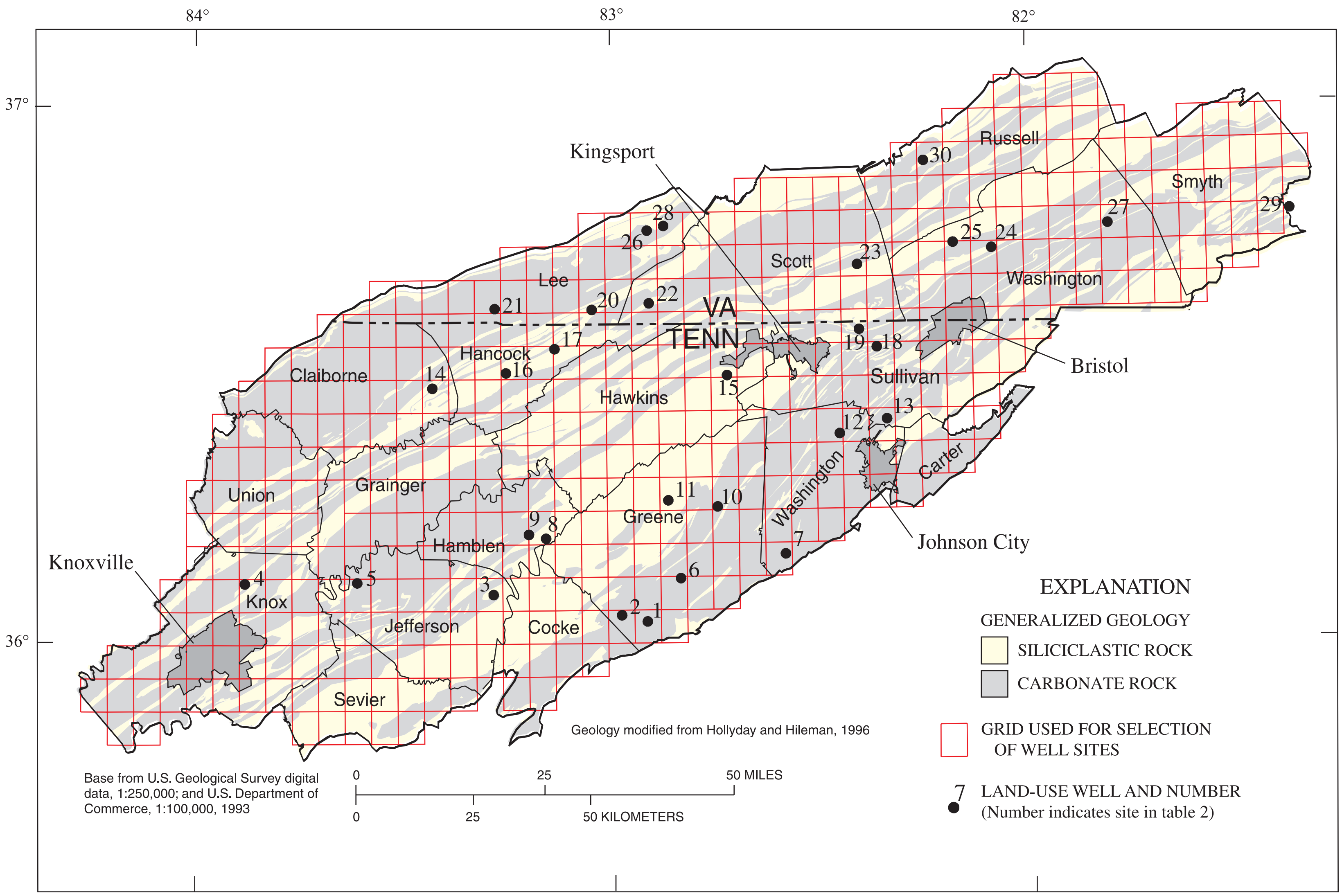


Figure 3. Generalized geology, county location, and the randomized well selection grid for the upper Tennessee River Basin tobacco land-use study.

USGS personnel to access their properties for the purpose of installing and sampling observation wells. In addition, the authors are grateful for the assistance of many Agricultural Extension Service Agents in Tennessee and Virginia for their introductions to numerous tobacco farmers in northeastern Tennessee and southwestern Virginia.

Methods and Approach

Thirty sites within the Valley and Ridge Physiographic Province of the UTEN study area were randomly selected in major tobacco-producing counties in northeastern Tennessee and southwestern Virginia. A geographic information system (GIS) map coverage of the tobacco study area was constructed and overlain with a grid and an outline of the county boundaries (fig. 3). The 1996 county tobacco-production values (U.S. Department of Agriculture, 1999) (table 1) and the percentage of the county area inside the tobacco land-use study area were used to assign a weighting factor to each cell, which consisted of one quarter of a 7.5-minute USGS quadrangle map. Cells were then randomly selected for well installation on the basis of the weighting factors. Selected cells were field checked for the presence of tobacco production and access to the fields. Tobacco fields underlain by shallow alluvium along the bottom of valleys and adjacent to surface-water bodies were preferentially selected to increase the chance of finding shallow ground water. Monitor wells were installed adjacent to the tobacco fields and downgradient from the tobacco fields.

Well Construction

Shallow monitoring wells were installed at locations and depths to collect representative water chemistry samples from the saturated soil zone. Wells were drilled adjacent to tobacco fields by the USGS in the fall of 1996 and early spring of 1997 in accordance with NAWQA protocols (Lapham and others, 1995). Thirty wells were completed in regolith or in the top of bedrock. Nineteen wells were completed in regolith in the top of carbonate rock units, and 11 wells were completed in the regolith in the top of siliciclastic rock units (table 2). Wells were constructed of threaded, 2-inch-diameter PVC pipe, with 5- or 10-ft-long screens; well bore annular spaces were sealed with bentonite and capped at the surface with cement seals (fig. 4). Wells ranged in depth from 7.5 to 61 feet (table 2) with a mean depth of 20 feet. Water levels in the wells at the time of sampling ranged from 0.81 to 34.1 feet below land surface with a mean depth of 7.4 feet. The wells were developed by bailing and by using a portable submersible pump.

Table 1. Tobacco production and acreage for the upper Tennessee River Basin land-use study, by county for 1996

[Data from the U.S. Department of Agriculture, 1999]

County	1996 Tobacco production (thousands of pounds)	Total acreage
	Tennessee	
Claiborne	5,060	2,540
Cocke	1,820	1,100
Greene	8,650	4,600
Grainger	3,205	1,650
Hamblen	1,915	600
Hancock	1,850	1,185
Hawkins	3,866	2,035
Jefferson	2,260	1,100
Knox	300	160
Sullivan	1,645	960
Unicoi	250	160
Union	1,145	630
Washington	4,900	2,430
	Virginia	
Lee	3,214	1,950
Russell	2,754	1,400
Scott	3,524	2,150
Smyth	1,489	735
Washington	4,934	2,355

Sample Collection and Analysis

Samples were collected using established NAWQA protocols (Koterba and others, 1995) that require using noncontaminating sampling equipment, purging wells prior to sample collection, and collecting quality-assurance samples. Prior to sampling, wells were purged to remove at least three casing

Table 2. Site identification, well depth, depth to water, and generalized geology for the upper Tennessee River Basin land-use study wells

[Depth to water measured at the time of the sampling]

Well no.	Site identification	Well depth (feet)	Depth to water (feet below land surface)	Generalized geology
1	360139082551801	30.0	22.6	Carbonate rock
2	360222082585801	24.0	8.05	Carbonate rock
3	360444083171701	9.5	2.05	Carbonate rock
4	360556083524901	18.3	1.45	Siliciclastic rock
5	360605083364601	16.0	5.85	Carbonate rock
6	360633082503101	13.0	4.00	Carbonate rock
7	360916082353401	43.0	5.85	Carbonate rock
8	361107083094601	14.5	2.10	Siliciclastic rock
9	361134083121301	13.8	1.95	Carbonate rock
10	361441082451101	61.0	34.1	Carbonate rock
11	361525082521501	28.0	6.18	Siliciclastic rock
12	362254082273601	7.5	0.90	Carbonate rock
13	362414082203801	10.5	2.40	Carbonate rock
14	362813083260001	18.0	5.12	Siliciclastic rock
15	362937082434201	21.0	8.55	Siliciclastic rock
16	362957083152601	21.0	1.95	Siliciclastic rock
17	363235083084501	19.0	9.20	Siliciclastic rock
18	363243082220901	10.0	2.98	Carbonate rock
19	363444082244101	9.1	0.81	Carbonate rock
20	363618083033401	8.0	1.84	Siliciclastic rock
21	363716083170201	32.0	25.7	Carbonate rock
22	363751082545201	16.0	4.00	Carbonate rock
23	364207082255101	8.5	5.00	Siliciclastic rock
24	364351082053001	20.5	1.26	Carbonate rock
25	364430082110201	20.5	16.8	Carbonate rock
26	364607082550601	13.0	9.20	Carbonate rock
27	364629081484201	33.0	11.9	Carbonate rock
28	364638082524301	25.0	4.40	Carbonate rock
29	364804081205701	11.0	1.65	Siliciclastic rock
30	365351082150901	27.5	14.9	Siliciclastic rock

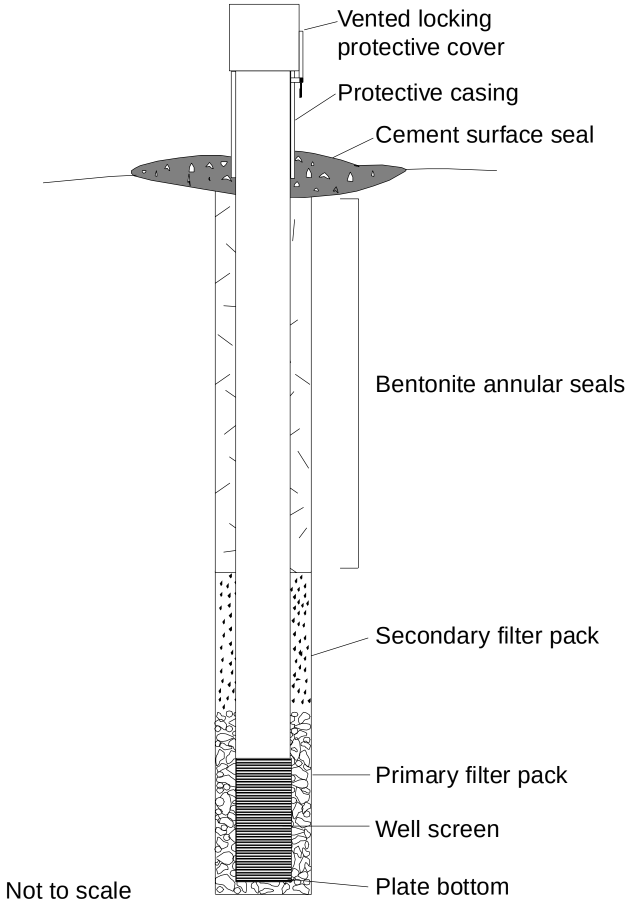


Figure 4. Typical monitoring-well design in unconsolidated material. (From Lapham and others, 1997.)

volumes of water from the well; purging continued until specific conductance, pH, and dissolved oxygen values stabilized to obtain representative ground-water samples from the surrounding aquifer. Wells with low recovery rates were pumped dry, allowed to recover to at least 90 percent of the original water column height, and then sampled within 24 hours.

Ground-water samples were collected between June 4 and July 9, 1997, to coincide with the application of fertilizer and pre-emergence herbicides. Abundant rainfall in spring 1997 delayed field preparation and tobacco transplanting for many farmers, which resulted in later-than-usual chemical applications. Ground-water samples were analyzed for nutrients, major ions, 79 pesticides, 7 pesticide degradation products, 86 volatile organic compounds (VOC's), and dissolved organic carbon (DOC). Pesticide analyses included three compounds specific to tobacco production: dimethomorph, flumetralin, and metalaxyl. All laboratory analyses were performed at the USGS National Water Quality Laboratory in Denver, Colorado.

In addition to the regular environmental samples, three different types of quality-assurance samples, which accounted for about 15 percent of all samples, also were collected. Quality-assurance samples included: field blanks using contaminant-free water, spiked samples (samples with known amounts of target analytes added to the environmental samples), and replicate samples collected with the environmental samples. Quality-assurance samples ensured that sampling procedures were noncontaminating, and provided information on bias and variability associated with the sampling procedure. The pesticide and nutrient field blanks showed no contamination, but the VOC field blanks had numerous low-level detections. Some VOC's were frequently present in the commercially available VOC-grade water used to collect the VOC blanks. Several of the VOC's present in the VOC-grade water and respective blanks also were frequently detected in environmental samples at similar concentrations. These concentrations were generally low, less than 0.1 microgram per liter (µg/L). Determining if detections in environmental samples were due to VOC's in the ground water was difficult because of similar VOC detections in VOC-grade water used for blanks (B.L. Taglioli, U.S. Geological Survey, written commun., 2000). No systematic VOC contamination of environmental samples between sites was evident; therefore, the environmental samples were assumed to be accurate.

SHALLOW GROUND-WATER QUALITY ADJACENT TO BURLEY TOBACCO FIELDS, SPRING 1997

Inorganic Water Quality

Concentrations for 11 inorganic constituents (table 3) and specific conductance, dissolved oxygen, alkalinity, and pH were measured in ground-water samples collected from each of the 30 shallow land-use wells. Concentrations of inorganic constituents can indicate the condition and mineralogy of the water-bearing unit. The presence of dissolved oxygen in water can indicate younger water not far removed from atmospheric contact. Field water-quality measurements were collected at all 30 wells. Specific

Table 3. Summary of inorganic water quality by generalized geology for the upper Tennessee River Basin land-use study wells

[P-value, smallest level of significance that rejects the hypothesis that carbonate water quality is similar to siliciclastic water quality; µg/L, micrograms per liter; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25° Celsius; <, less than]

Parameter	P-value	Generalized geology					
		Carbonate rocks (19 samples)			Siliciclastic rocks (11 samples)		
		Median	Mean	Maximum	Median	Mean	Maximum
Manganese (dissolved, µg/L)	0.641	22	573	3,570	184	417	2,380
Iron (dissolved, µg/L)	0.585	<3.0	1,787	13,200	42	2,653	13,900
Chloride (dissolved, mg/L)	0.682	5.1	10.8	47	10.0	9.2	16.0
Magnesium (dissolved, mg/L)	0.923	15	15	35	9.6	14.6	44
Fluoride (dissolved, mg/L)	0.779	0.17	0.17	0.30	0.16	0.18	0.34
Silica (dissolved, mg/L)	0.042	9.8	10.2	18	11	14.1	30
Sulfate (dissolved, mg/L)	0.011	7.8	14.5	48	27	46	140
Calcium (dissolved, mg/L)	0.624	76	67	100	49	59	110
Sodium (dissolved, mg/L)	0.647	4.1	8.5	30	4.9	10.3	37
Potassium (dissolved, mg/L)	0.990	2.3	2.3	13	1.8	2.4	6.1
Bromide (dissolved, mg/L)	0.076	0.04	0.04	0.09	0.06	0.06	0.12
Specific conductance (µS/cm)	0.751	504	487	813	430	460	891
Dissolved oxygen (mg/L)	0.100	3.2	3.1	8.5	0.7	1.4	5.7
Alkalinity, field (mg/L as $CaCO_3$)	0.150	233	210	421	105	150	359
pH (units)	0.098	6.7	6.7	7.1	6.4	6.3	7.1

conductance ranged from 78 to 891 microsiemens per centimeter (µS/cm) with a median value of 479 µS/cm. Dissolved oxygen ranged from 0.1 to 8.5 mg/L with a median value of 1.0 mg/L. Alkalinity ranged from 1.0 to 421 mg/L as $CaCO_3$ with a median value of 219 mg/L, and pH ranged from 4.7 to 7.1 with a median value of 6.6.

Water chemistry within the two geologic units was similar. The only statistically significant differences at a confidence level of p=0.05, using a standard two sample t-test (table 3), were that silica and sulfate concentrations were higher in water samples from siliciclastic wells. The higher silica levels may indicate more soluble forms of silicates in the siliciclastic units such as aluminosilicates found in clays. Because the wells were drilled in shallow regolith, the similarities in the water chemistry may be attributed to short flow paths and minimal contact with the deeper geologic units.

Nutrients

Burley tobacco requires large amounts of nitrogen fertilizer to produce high yields of good quality air-cured leaf. On well-drained soils, nitrogen fertilizer typically is applied as much as 4 weeks before tobacco plants are transplanted. This approach results in a delay of up to 9 weeks before the onset of rapid growth and nitrogen accumulation at about 5 weeks after transplanting. Abundant rainfall commonly occurs during this period and creates the potential for losses of soil and fertilizer (MacKown and Sutton, 1998). Because tobacco is a high-value cash crop, producers may be likely to overfertilize the crop. Excessive use of nitrogen fertilizer can be economically unfavorable and environmentally unsound (MacKown and Sutton, 1998). In Kentucky (Taraba, 1997), runoff concentrations of nitrate in water almost doubled

(4.5 to 8.6 parts per million for the high nitrate plots) between the first and second rainfall events, and were near background concentrations after the final rainfall.

Small concentrations of phosphorus and nitrogen can occur naturally in ground water, but elevated concentrations typically are associated with human activities. For example, nitrate concentrations in natural ground water are usually less than 2 milligrams per liter (mg/L) (Mueller and others, 1995). Natural or background nitrate concentrations, however, are highly variable and are dependent on many local and regional factors. Phosphorus and nitrogen are found in fertilizers, animal waste, and atmospheric deposition. Leaching of fertilizers from agricultural areas or infiltration of septic-system effluent can result in elevated phosphorus and nitrogen concentrations in ground water.

Water samples from the 30 wells in the tobacco study area were analyzed for ammonia, nitrite, ammonia plus organic nitrogen, nitrite plus nitrate, phosphorus, and orthophosphorus (table 4, Appendix A). Nitrite (NO_2) concentrations in ground water were less than 0.010 mg/L from 26 wells and were 0.026, 0.015, 0.031, and 0.031 mg/L from the other 4 wells. Because of the low nitrite concentrations, the nitrite plus nitrate concentration ($NO_2 + NO_3$ as N) is used to describe nitrate concentrations in water samples from the 30 land-use study wells.

Nitrate, a stable species of nitrogen in oxygenated subsurface environments, was the most commonly detected nutrient in ground water from the UTEN study area. Water from 24 wells had nitrate concentrations ($NO_2 + NO_3$ as N) ranging from less than 0.05 to 32.5 mg/L (fig. 5). Nitrate concentrations

Table 4. Comparison of nutrient concentrations and depth to water for the upper Tennessee River Basin (UTEN), regional, and national National Water-Quality Assessment (NAWQA) study units

[mg/L, milligrams per liter; N, nitrogen; <, less than]

Constituents	UTEN land-use survey wells (1997) (30 wells)			Southeast land-use survey wells (1993-95) (76 wells) (Hitt, 1999)			National NAWQA land-use survey wells (1993-95) (Hitt, 1999)			
	Min.	**Median**	**Max.**	**Min.**	**Median**	**Max.**	**Number of wells**	**Min.**	**Median**	**Max.**
Ammonia (NH_3), dissolved, mg/L as N.	<0.015	0.02	1.91	<0.015	0.02	2.70	929	<0.015	0.02	4.8
Nitrite (NO_2), dissolved, mg/L as N.	<0.01	<0.01	0.03	<0.01	0.01	0.18	929	<0.01	<0.01	0.60
Ammonia plus organic nitrogen (NH_3+ OrgN), dissolved, mg/L as N.	<0.20	<0.20	2.60	<0.20	<0.20	3.10	916	<0.02	<0.02	16.0
Nitrite plus nitrate (NO_2+NO_3), dissolved, mg/L as N.	<0.05	0.68	32.5	<0.05	1.10	25.0	929	<0.05	1.95	78.0
Phosphorus, dissolved, mg/L as P.	<0.01	<0.01	0.572	<0.01	<0.01	1.40	916	<0.02	0.02	13.0
Orthophosphorus (PO_4), dissolved, mg/L as P.	<0.01	<0.01	0.534	<0.01	<0.01	1.40	929	<0.01	0.01	2.90
Depth to water, in feet below land surface.	0.81	4.70	34.0	1.81	15.9	150	757	1.60	18.0	591

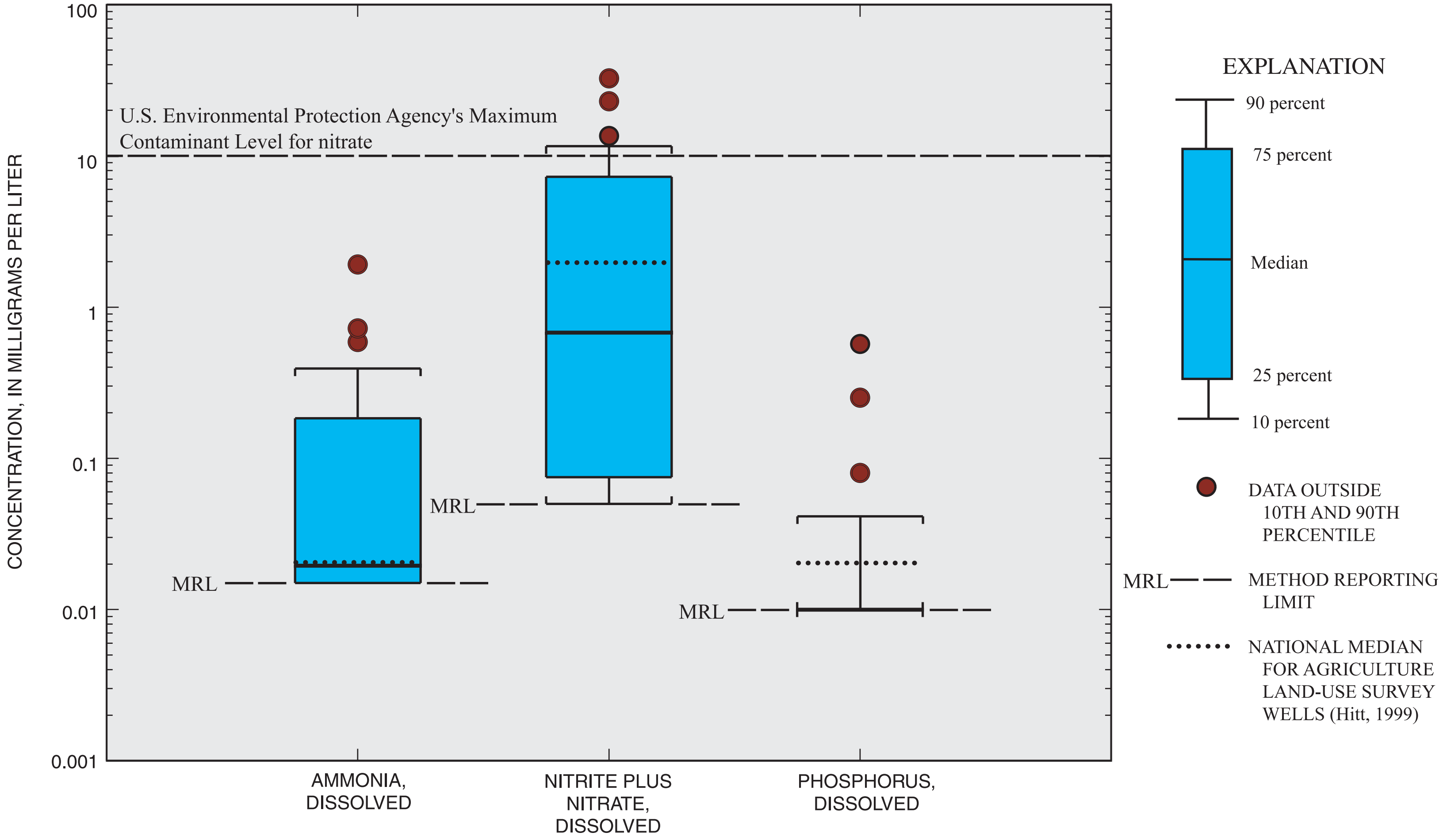
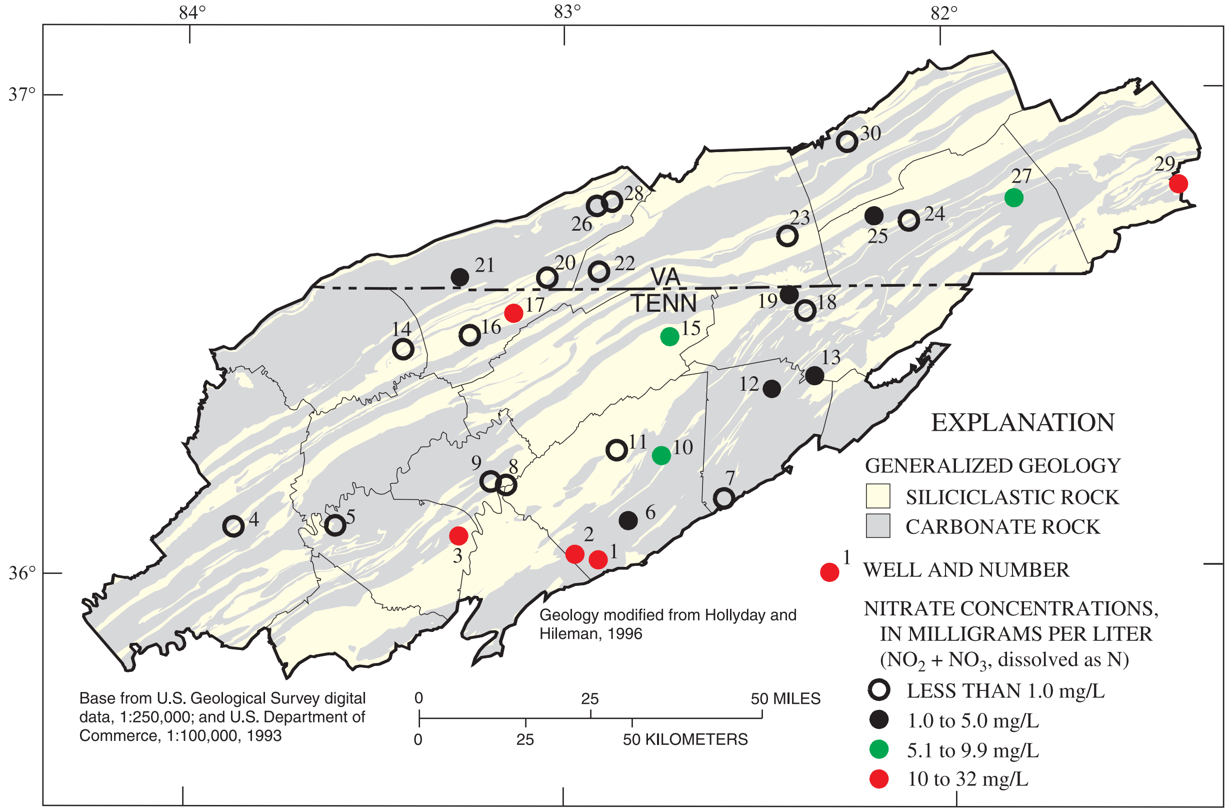


Figure 5. Nutrient concentrations for the upper Tennessee River Basin tobacco land-use study wells.

in 5 of the UTEN wells exceeded the U.S. Environmental Protection Agency (U.S. EPA) drinking-water maximum contaminant level of 10 mg/L (fig. 6). High concentrations of nitrate in ground water can pose a health threat, especially to infants and farm animals whose digestive systems convert the nitrate to nitrite, which reduces the oxygen-carrying capacity of blood and can result in the disease methemoglobinemia (“blue-baby syndrome”). Nitrate concentrations were below the laboratory method reporting limit of 0.05 mg/L for 6 wells that had dissolved oxygen concentrations of 1.0 mg/L or less (Appendix A); under these low dissolved oxygen conditions, nitrate likely would have been reduced to ammonia.

The presence of ammonia in ground water could result from urea or animal waste being applied to agricultural fields, from ammonia being used directly as fertilizer, from the reduction of nitrate, or from other sources. Urea, added to the soil, is rapidly converted to ammonium (NH_4^+) and bicarbonate ions (Vinten and Smith, 1993). In most natural waters, any ammonia nitrogen in solution is in the form of ammonium (Hem, 1985). Ammonia concentrations in water from the UTEN wells ranged from less than 0.015 to 1.91 mg/L with a median of 0.02 mg/L for all 30 wells. Ammonia concentrations greater than the 0.015-mg/L method reporting limit were detected in water samples at 16 sites (Appendix A). For these 16 sites, concentrations ranged from 0.015 to 1.91 mg/L with a median value of 0.176 mg/L. The presence of any significant ammonia concentrations, above 0.5 mg/L, in the UTEN wells was generally associated with dissolved oxygen levels below 1.0 mg/L.

Phosphorus is an essential plant nutrient that can be present in fertilizers, manures, and detergents. Phosphorus is a fairly common element in igneous rock, but concentrations present in natural water are normally no more than a few tenths of a milligram (Hem, 1985). Phosphorus concentrations in water from the UTEN wells ranged from less than 0.01 mg/L in 22 wells to 0.572 mg/L with a median of less than 0.01 mg/L for all 30 wells (table 4). Phosphorus was detected in ground water at only 8 of the 30 wells



Geology modified from Hollyday and Hileman, 1996

Base from U.S. Geological Survey digital data, 1:250,000; and U.S. Department of Commerce, 1:100,000, 1993

Figure 6. Nitrate concentrations for the upper Tennessee River Basin tobacco land-use study wells.

sampled (Appendix A). Phosphorus concentrations for the 8 wells ranged from 0.01 to 0.572 mg/L with a median value of 0.04 mg/L.

Ground-water nutrient data from the UTEN tobacco land-use study (table 4) were compared to nutrient data from 18 NAWQA study units collected during 1993-95 for 35 similar shallow land-use studies targeting agricultural crops (Hitt, 1999). Median nutrient concentrations in ground water from wells downgradient from tobacco fields in the UTEN generally were lower than median concentrations in NAWQA study units nationwide. The median depth to water for the UTEN wells also was less than the national median. The median is resistant to the effects of outliers; therefore, the median is used to compare the data sets. For the UTEN tobacco land-use study, 16.7 percent of the wells had nitrite plus nitrate concentrations exceeding the U.S. EPA drinking-water standard of 10 mg/L. Nationally, 19 percent of agricultural land-use wells had nitrate concentrations exceeding 10 mg/L (Tom Nolan, U.S. Geological Survey, written commun., 1999).

Median nutrient concentrations in the UTEN wells generally were similar or slightly lower (table 4) than median nutrient concentrations in four similar agricultural land-use studies in three NAWQA study units in the southeastern United States from 1993 to 1995 [Ozark Plateaus, Albemarle-Pamlico Drainage Basin, and Appalachicola-Chattahoochee-Flint River Basin (Hitt, 1999)]. The maximum nitrite plus nitrate concentration in the UTEN (32.5 mg/L) was higher than the maximum concentration (25.0 mg/L) in the other southeastern study units (table 4). Nitrate concentrations exceeded the U.S. EPA maximum contaminant level (MCL) of 10 mg/L in an average of 7.9 percent of the wells in the other southeastern NAWQA study units.

Pesticides

Approximately 1.1 billion pounds of pesticides are used each year in the United States (Barbash and Resek, 1996). In 1992, about 2.4 million pounds of pesticides were used in the UTEN (M. Majewski, U.S. Geological Survey, written commun., 1997). Ground-water samples collected from the UTEN wells were analyzed for 88 pesticides including 3 tobacco-specific compounds and 7 pesticide degradation products (Appendixes A and B). These pesticides include approximately 75 percent of the agricultural pesticides used in the United States and a substantial representation of urban and suburban use (Gilliom, 1999). Pesticides that were detected in water from the UTEN wells or that were used in the UTEN in 1992 (M. Majewski, U.S. Geological Survey, written commun., 1997) are listed in table 5. Samples were analyzed by gas chromatography/mass spectrometry (Zaugg and others, 1995) and by high performance liquid chromatography (Werner and others, 1996).

Ten pesticides or degradation byproducts were detected in samples from 13 wells (figs. 7 and 8). Of the 10 pesticides detected, 4 (atrazine, simazine, 2,4,5-T, and 2,4-D) have established MCL’s. All pesticide detections were below the drinking-water standards, and some detections were below the method reporting limit (MRL) (table 5 and Appendix A), which is the lowest concentration at which the pesticide can be identified, measured, and reported with 99-percent confidence that the concentration is greater than zero (Zaugg and others, 1995). All data reported below the MRL are believed to be reliable detections, but with greater than average uncertainty in quantification and are indicated in the text and Appendix A with “E” (estimated). For example, prometon, MRL of 0.018 μg/L (table 5), was detected at an estimated concentration of 0.0026 μg/L in well 13, and the result is listed as E0.0026 (Appendix A).

In the UTEN study, pesticides were detected in 13 (43 percent) of the wells. The most frequently detected pesticides in the UTEN ground-water samples (fig. 8) were atrazine (27 percent); deethylatrazine, an atrazine degradate (30 percent); and metalaxyl (13 percent). Other pesticides detected in the UTEN study wells were prometon, flumetralin, dimethomorph, 2,4,5-T, 2,4-D, dichlorprop, and silvex, all of which were detected only once (3-percent detection frequency). Because atrazine has a lower MRL than the other pesticides, more bias may exist towards detection of atrazine more frequently than other pesticides.

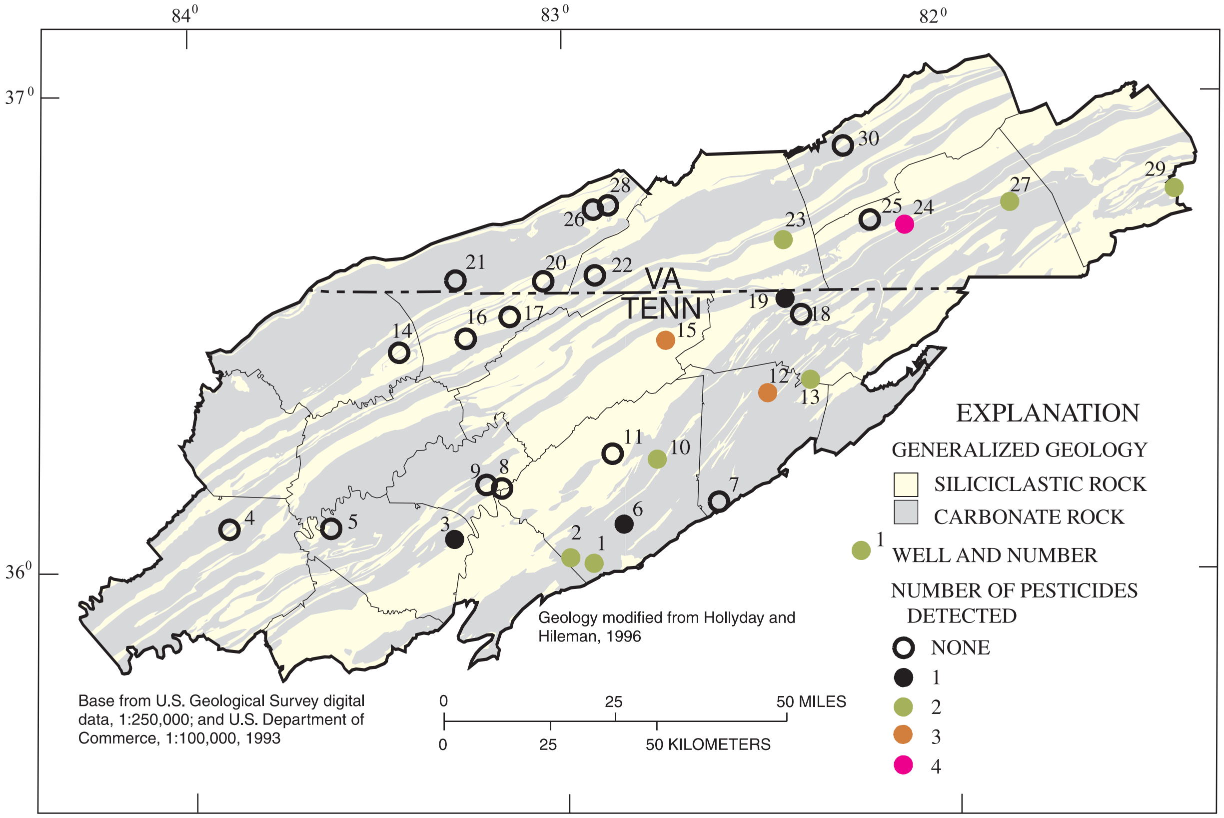
Pesticides were detected less frequently in the UTEN tobacco land-use study than in other NAWQA agricultural land-use studies. Nationally, one or more pesticides were detected at 56 percent of 813 agricultural land-use wells sampled during the first phase of the NAWQA program from 1993-95 (Kolpin and others, 1998). Nationally, the compounds detected most frequently were atrazine (45 percent), deethylatrazine (43 percent), simazine (22 percent), metolachlor (20 percent), and prometon (15 percent) (fig. 8).

Three tobacco-specific compounds were detected at five wells in the UTEN land-use study. Metalaxyl (trade name Ridomil, used to control blue mold and soil-borne pathogens) was detected at 4 of

Table 5. Pesticides used or detected in the upper Tennessee River Basin land-use study

[MRL, method reporting limit in micrograms per liter; --, not reported; *, from M. Majewski, U.S. Geological Survey, written commun., 1997; **, pesticides used on tobacco from Thelin, 1997; #, tobacco specific]

Pesticide	Type	MRL	Total pounds applied in 1992*
2,4,5-T	Herbicide	0.035	--
2,4-D	Herbicide	0.035	55,600
2,4-DB	Herbicide	0.035	5,340
Aldicarb **	Insecticide	0.016	9,910
Bentazon	Herbicide	0.014	1,720
Bromoxynil	Herbicide	0.035	8
Chloramben	Herbicide	0.011	366
Chlorothalonil	Fungicide	0.035	12,900
Dicamba	Herbicide	0.035	5,750
Dichlobenil	Herbicide	0.02	287
Dichlorprop	Herbicide	0.032	--
Diuron	Herbicide	0.02	3,340
Esfenvalerate	Insecticide	0.019	311
MCPA	Herbicide	0.05	2
Methomyl **	Insecticide	0.017	7,930
Norflurazon	Herbicide	0.024	390
Oryzalin	Herbicide	0.019	933
Oxamyl	Insecticide	0.018	686
Silvex	Herbicide	0.021	--
Triclopyr	Herbicide	0.05	2020
Alachlor	Herbicide	0.002	40,900
Atrazine	Herbicide	0.001	116,000
Butylate	Herbicide	0.002	24,800
Carbaryl	Insecticide	0.003	27,200
Carbofuran **	Insecticide	0.003	17,000
Chlorpyrifos **	Insecticide	0.004	71,500
Cyanazine	Herbicide	0.004	14,700
Deethylatrazine	Degradate	0.002	--
Diazinon **	Insecticide	0.002	2,590
Disulfoton **	Insecticide	0.017	2,570
Ethalfluralin	Herbicide	0.004	486
Ethoprop **	Insecticide	0.003	7,760
Fonofos **	Insecticide	0.003	298
Lindane	Insecticide	0.004	15
Linuron	Herbicide	0.002	1,136
Malathion **	Insecticide	0.005	1,218
Methyl parathion	Insecticide	0.006	2,970
Metolachlor	Herbicide	0.002	46,300
Metribuzin	Herbicide	0.004	2,600
Napropamide **	Herbicide	0.003	12,500
Pebulate **	Herbicide	0.004	31,400
Pendimethalin **	Herbicide	0.004	27,200
Permethrin	Insecticide	0.005	1,610
Phorate	Insecticide	0.002	578
Prometon	Herbicide	0.018	--
Propargite	Insecticide	0.013	2,400
Simazine	Herbicide	0.005	23,800
Terbacil	Herbicide	0.007	1,790
Terbufos	Insecticide	0.013	8,990
Trifluralin	Herbicide	0.002	3,300
Dimethomorph ** #	Growth control	0.03	--
Flumetralin ** #	Fungicide	0.03	--
Metalaxyl ** #	Fungicide	0.03	28,100



Geology modified from Hollyday and Hileman, 1996

Base from U.S. Geological Survey digital data, 1:250,000; and U.S. Department of Commerce, 1:100,000, 1993

Figure 7. Pesticide detections for the upper Tennessee River Basin tobacco land-use study wells.

30 wells with values ranging from E0.02 to 1.56 µg/L. Dimethomorph (trade name Acrobat, a systemic fungicide also used to control blue mold) was detected at E0.01 µg/L in one well. Flumetralin (trade name Prime Plus, used to control sucker growth on tobacco) was detected at E0.005 µg/L in one well. Because flumetralin usually is applied just after topping the tobacco plant in the summer, this detection most likely was from the tobacco crop from the previous year. Concentrations detected below the method reporting limit for a compound are marked with an “E.”

A study on flue-cured tobacco in North Carolina (Harned, 1994) showed metalaxyl, isopropalin, and flumetralin in 7 percent or less of the samples from two wells in a shallow unconfined aquifer about 16 feet below ground surface. Pesticides also were monitored in the soil at 3-, 6-, and 9-inch depths and in surface runoff. Concentrations of pesticides were higher and were detected more frequently in the surface-water and soil samples. Adsorption in the shallow soils was apparently an effective sink for some of the pesticides monitored by Harned (1994).

Atrazine has been the pesticide used most extensively in the United States since the early 1970’s, and has been detected most frequently in ground water during many previous State, regional, and national studies (Kolpin and others, 1998). Atrazine is a herbicide used on corn, sorghum, Christmas trees, and other crops to control broadleaf and grassy weeds. Atrazine also is used as a nonselective herbicide on noncropped industrial lands and on fallow lands (Meinster and Sine, 1995). Nationally, atrazine and deethylatrazine were present in 44 and 43 percent, respectively, of 925 shallow agricultural land-use wells (Kolpin and others, 1998). Atrazine was detected at 8 of 30 (27 percent) of the UTEN shallow agricultural land-use wells, and deethylatrazine was present in 9 of 30 (30 percent) wells. Atrazine and its degradation byproducts are the most commonly detected pesticide compounds in the surface waters of the UTEN, present at over 90 percent of the surface-water sites.

Some detected compounds are detrimental for tobacco production; for example, atrazine can reduce tobacco yields. Silvex, 2,4,5-T, 2,4-D, and dichlorprop, herbicides harmful to tobacco and used for defoliation and broadleaf control, were detected in water from one well. Distribution of silvex and 2,4,5-T was discontinued for use in the United States in 1985.

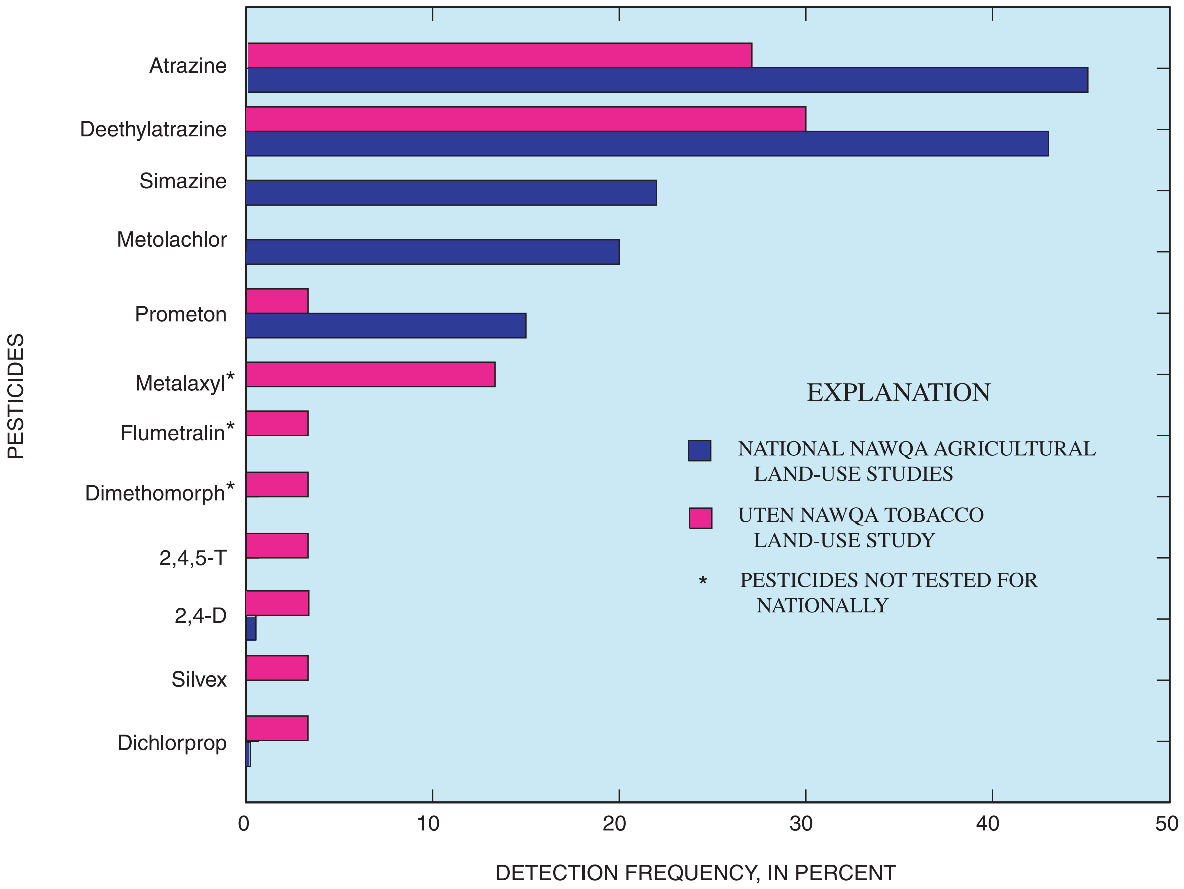


Figure 8. Comparison of pesticide dectection frequency between the upper Tennessee River Basin (UTEN) tobacco land-use study and national National Water-Quality Assessment (NAWQA) agricultural land-use studies, 1993-95.

Generally 2,4-D is biodegraded in the environment and has low to moderate mobility in the soil. Silvex degrades slowly and strongly adsorbs to sediment (U.S. Environmental Protection Agency, 1999). The herbicide 2,4,5-T is biodegraded in the environment and has medium to high mobility in the soil. The occurrence of pesticides harmful to tobacco production in wells downgradient of the tobacco fields may be attributed to ground-water flow from corn or other crops upgradient of the tobacco fields, from spray drift, or from inadequate washing of sprayers between applications of different compounds.

Volatile Organic Compounds

VOC's include components of petroleum products, metal degreasers, solvents, refrigerants, cleaning compounds, and agricultural fumigants. Methyl bromide is a common soil fumigant used in tobacco transplant beds. VOC's also are present in fuels and in exhaust from fuel combustion. Direct industrial and wastewater discharges into surface water and the atmosphere and accidental fuel and oil spills are likely sources of VOC's in ground water. VOC's in rainfall may originate from vehicle and industrial emissions. Stormwater runoff introduces the aquifer to another possible source of VOC contamination. Relating a particular land use to a specific compound is difficult because of the varied and widespread use of VOC's, as well as the possibility of atmospheric deposition.

Ground-water from the tobacco field wells were analyzed for 86 VOC's. Thirty-one VOC's were detected in water samples from 27 of the 30 wells (figs. 9 and 10), with as many as 17 different VOC's detected at a single well (fig. 9). The majority of the detections were below the MRL and are believed to be

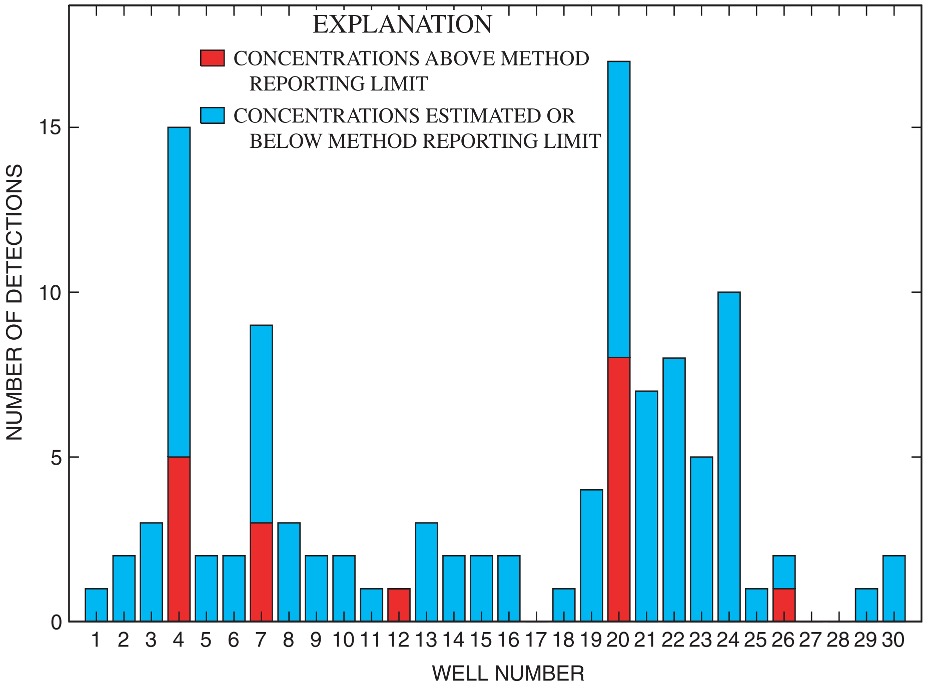


Figure 9. Number of volatile organic compound detections for the upper Tennessee River Basin land-use study.

reliable detections, but with greater than average uncertainty in quantification. Some of the compounds detected were more than an order of magnitude smaller than the MRL (table 6); detections below the MRL are reported as estimated (E) values. The MRL's vary on the basis of the individual compound characteristics; therefore, comparison of compounds based on the MRL may lead to some bias for compounds with lower MRL's. Detection of many of the VOC's is a result of improved gas chromatography/mass spectrometry techniques that measure low concentrations, with detection levels as low as 0.01 µg/L (0.01 parts per billion) (Connor and others, 1998).

VOC's found in the highest concentrations were carbon disulfide, acetone, toluene, benzene, o-xylene, and meta/para-xylene. The most frequently detected VOC was carbon disulfide, which was found in 12 wells and exceeded the MRL at 3 wells. Chloroform, toluene, and benzene were detected at 10 or more wells (table 6), and exceeded the MRL at 2 to 3 wells each (fig. 11). Dichlorodifluoromethane was detected at nine wells, but all of the concentrations were estimated (table 6, Appendix A). Drinking-water standards have been established for 12 of the 31 compounds detected, but none of the VOC's detected exceeded these standards. The detection frequency for VOC's above the MRL in the UTEN is higher than the detection frequency for VOC's in similar NAWQA agricultural land-use studies from 1993 to 1995 (fig. 11). VOC's that were not detected, even at estimated concentrations, in any of the UTEN wells are listed in Appendix B.

Acetone, carbon disulfide, toluene, and other VOC's are used in industrial processes in the UTEN (U.S. Environmental Protection Agency, 1999) (table 7). The presence of industrial compounds in the shallow ground water at higher detection frequencies than in other agricultural land-use studies possibly could be attributed to deposition from atmospheric releases in the UTEN (fig. 11). Benzene, toluene, and xylene are components of fuel, and the presence of these compounds could possibly be explained by spills at farm refueling stations, improper disposal of waste oil or solvents, or by diesel fuel being used as a carrier for pesticides in previous years. No obvious point sources were identified for any of the wells with multiple VOC detections.

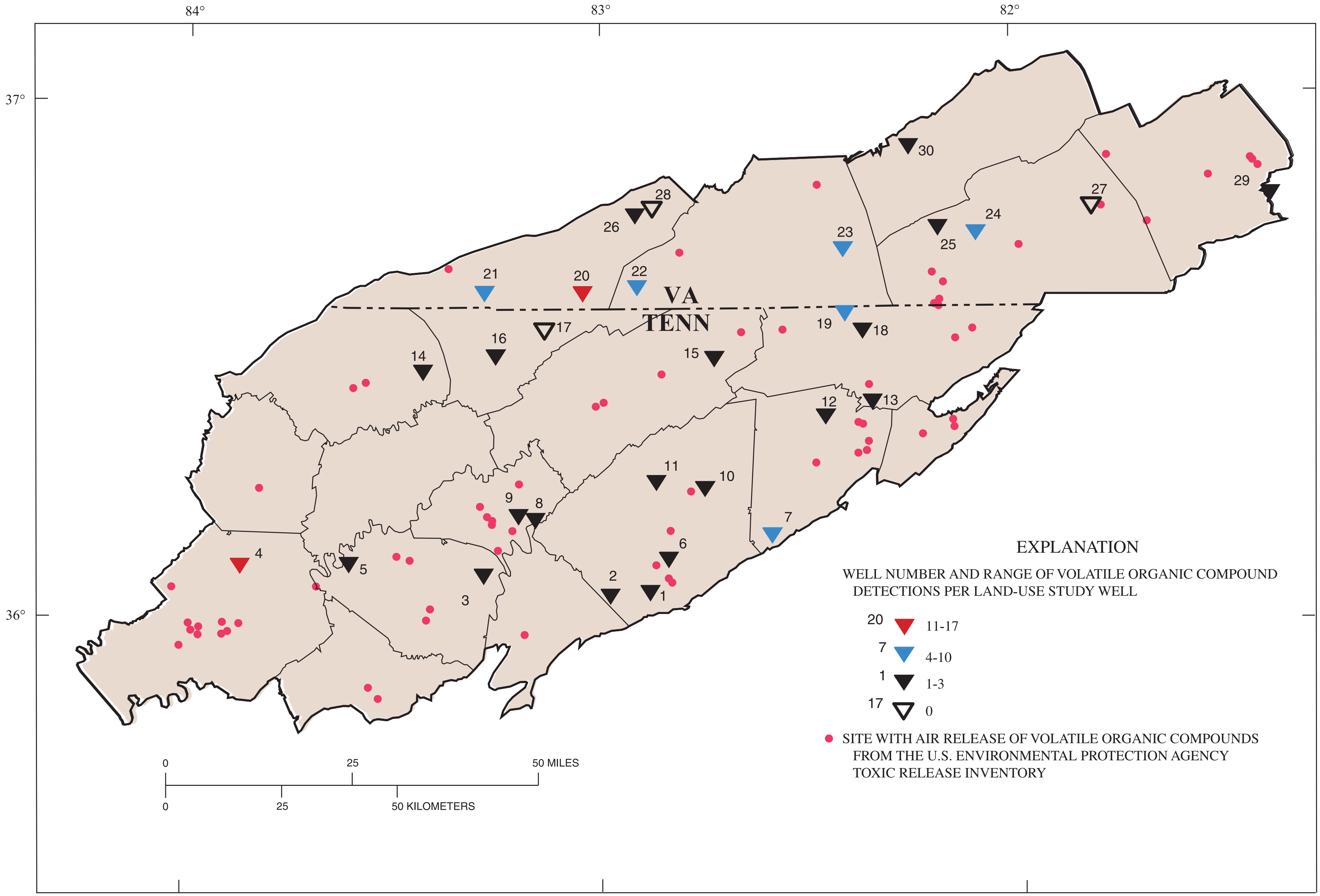


Figure 10. Volatile organic compound detections in wells in the upper Tennessee River Basin land-use study and U.S. Environmental Protection Agency (U.S. EPA) toxic inventory release sites.

Table 6. Summary of volatile organic compounds detected for 30 monitoring wells, 1997

[Units are in micrograms per liter; --, no applicable standard; MRL, method reporting limit; MCL, maximum contaminant level; HAL, health advisory limit; E, estimated; +, total for all trihalomethanes combined cannot exceed the 100 μg/L level]

Constituent	Total number of detections (detections above MRL)	Maximum concentration	Method reporting limit	Lifetime HAL[a,b]	MCL[a,c]	Cancer group[d]
Carbon disulfide	12 (3)	1.03	0.08	--	--	--
Chloroform	11 (2)	0.398	0.052	--	100+	B2
Toluene	11 (3)	0.726	0.038	1,000	1,000	D
Benzene	10 (2)	0.808	0.032	--	5	A
Dichlorodifluoromethane	9 (0)	E0.3	0.096	1,000	--	D
Styrene	6 (0)	E0.4	0.042	100	100	C
Meta/para-xylene	6 (2)	1.00	0.064	10,000	10,000[e]	D
1,2,4-Trimethylbenzene	5 (1)	0.251	0.056	--	--	--
Ethylbenzene	4 (1)	0.481	0.03	700	700	D
p-Isopropyltoluene	4 (0)	E0.10	0.11	--	--	--
Chloroethane	2 (0)	E0.05	0.12	--	--	B
Methylchloride	2 (0)	E0.05	0.254	--	--	--
Tetrachloroethylene	2 (0)	E0.01	0.038	--	5	--
o-ethyl Toluene	2 (1)	0.121	0.1	--	--	--
1,2,3-Trimethylbenzene	2 (1)	0.148	0.124	--	--	--
Isopropylbenzene	2 (0)	E0.09	0.032	--	--	--
n-Propylbenzene	2 (0)	E0.07	0.042	--	--	--
1,3,5-Trimethylbenzene	2 (0)	E0.03	0.044	--	--	--
n-Butylbenzene	2 (0)	E0.008	0.186	--	--	--
Methyl ethyl ketone	2 (0)	E1.0	1.65	--	--	D
Chlorobenzene	1 (0)	E0.06	0.028	100	--	--
Methylene chloride	1 (0)	E0.5	0.382	5	--	--
o-Dichlorobenzene	1 (0)	E0.007	0.048	600	600	D
1,3-Dichlorobenzene	1 (0)	E0.009	0.054	--	600	--
1,4-Dichlorobenzene	1 (0)	E0.003	0.05	75	--	--
Prehnitene	1 (0)	E0.03	0.23	--	--	--
o-Xylene	2 (2)	0.955	0.064	10,000[e]	10,000[e]	D
Methyl iodide	1 (0)	E0.01	0.076	--	--	--
Freon-113	1 (0)	E0.01	0.032	--	--	--
Acetone	1 (0)	E1.00	4.9	--	--	--
Ethylether	1 (0)	E0.10	0.17	--	--	--

[a] U.S. Environmental Protection Agency drinking-water regulations and health advisories (1996).

[b] Drinking Water Health Advisory limit (HAL). The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety.

[c] Maximum contaminant level (MCL). Maximum permissible level of a contaminant in water which is deliverable to any user of a public water supply system (U.S. Environmental Protection Agency, 1996).

[d] Cancer group: A-Human carcinogen; B-Probable human carcinogen; B1- Probable human carcinogen, limited epidemiological studies; B2 -Probable human carcinogen, sufficient evidence from animal studies; C-Possible human carcinogen; D-Not classifiable (U.S. Environmental Protection Agency, 1996).

[e] Guidelines are for total xylene.

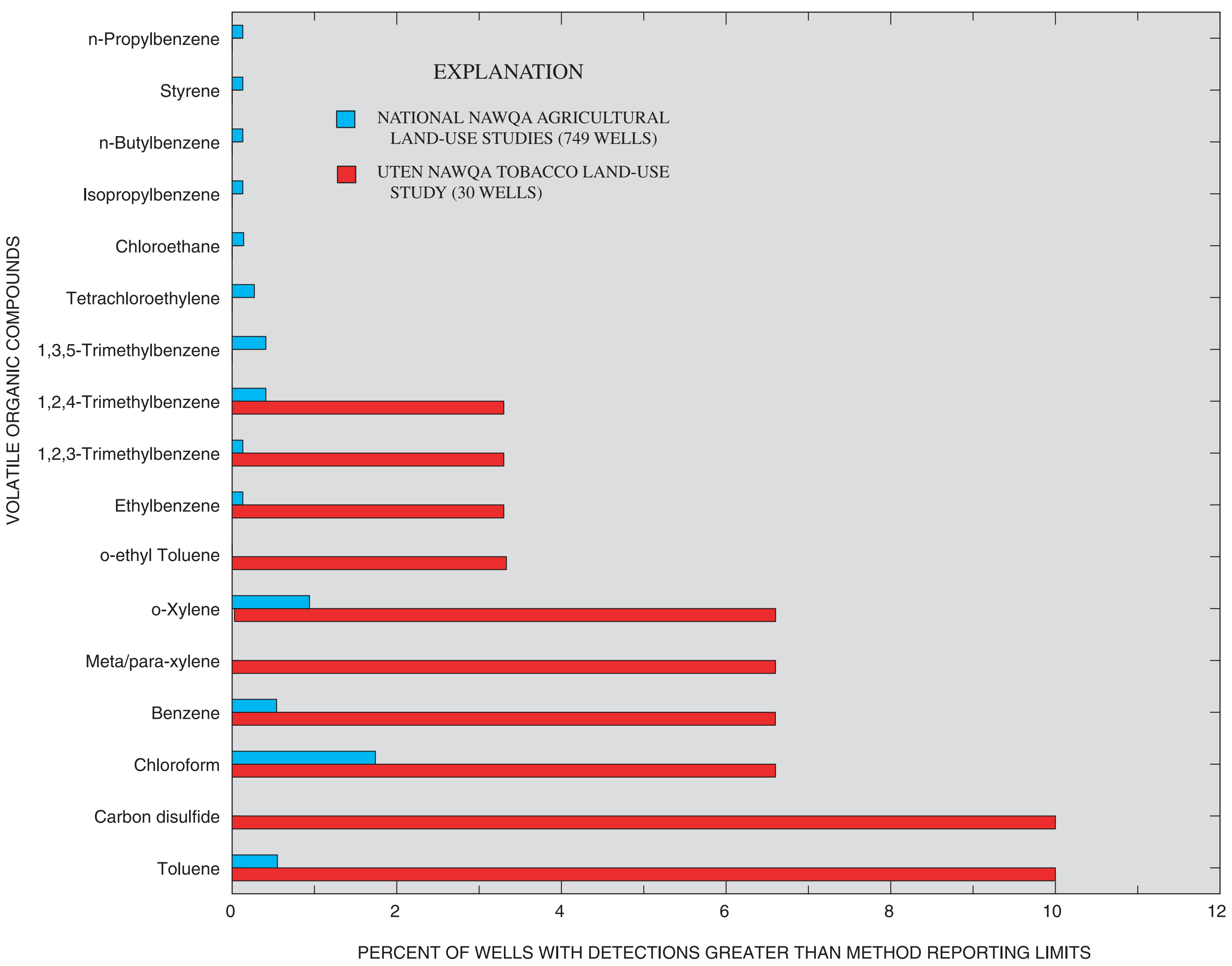


Figure 11. Volatile organic compound detections greater than the method reporting limit in wells from the upper Tennessee River Basin (UTEN) tobacco land-use study and the national National Water-Quality Assessment (NAWQA) agricultural land-use studies, 1993-95.

Table 7. Quantity of select volatile organic compounds released to the air by industry in the upper Tennessee River Basin, 1992

[Data from the U.S. Environmental Protection Agency Toxic Release Inventory (U.S. Environmental Protection Agency, 1999)]

Volatile organic compound	Total quantity released to air (pounds per year)	Number of facilities reporting releases
Acetone	27,830,000	21
Carbon disulfide	24,120,000	2
Toluene	5,680,000	36
Methyl ethyl ketone	984,000	24
Xylene	631,000	26
Styrene	295,000	11
Chloroform	40,000	1
Benzene	30,000	2
Freon-113	45,000	2
Dichlorodifluoromethane	17,000	1
Ethylbenzene	2,400	1

SUMMARY AND CONCLUSIONS

In 1994, the USGS began an investigation to assess the water-quality conditions in the upper Tennessee River Basin as part of the NAWQA Program. One component of the NAWQA Program is the evaluation of the effect of various land uses on shallow ground-water quality within specific land-use settings. Burley tobacco production for 1996 in Tennessee and Virginia was 87.7 and 17.4 million pounds, respectively. In 1996, a ground-water land-use study focusing on burley tobacco production was conducted in the UTEN.

Nineteen wells were drilled into regolith or the top of carbonate rock units and 11 wells were drilled into the regolith or top of siliciclastic rock units. Generally, ground water from the carbonate and siliciclastic rock units had similar water chemistry. The only statistically significant differences were that silica and sulfate were higher in water from siliciclastic rock wells than in water from regolith wells. For all wells, specific conductance ranged from 78 to 891 µS/cm with a median value of 479 µS/cm. Dissolved oxygen ranged from 0.1 to 8.5 mg/L with a median value of 1.0 mg/L. Alkalinity ranged from 1.0 to 421 mg/L as $CaCO_3$ with a median value of 219 mg/L, and pH ranged from 4.7 to 7.1 with a median value of 6.6.

Generally, burley tobacco production has little effect on shallow ground-water quality. The greatest effect is from fertilizer application, but nutrient concentrations recorded in this study were lower than the levels found in similar NAWQA land-use studies during 1993 to 1995 at various locations across the United States. Five of 30 UTEN wells (17 percent) had nitrate levels exceeding 10 mg/L, whereas nationally, 19 percent of agricultural land-use wells exceeded 10 mg/L. The nutrient levels in samples from wells in the UTEN generally were slightly lower than four other similar agricultural land-use studies in the Southeastern United States from 1993 to 1995 (Ozark Plateaus, Albemarle-Pamlico Drainage Basin, and Apalachicola-Chattahoochee-Flint River Basin), with the exception of the number of high nitrite plus nitrate values in the UTEN (17 percent), compared to 7.9 percent exceeding 10 mg/L for the southeastern studies.

Ten pesticides were detected in the UTEN tobacco land-use study wells. Three of the 10 pesticides detected were tobacco-specific compounds (dimethomorph, flumetralin, and metalaxyl) that were not sampled in the national land-use studies. All pesticide concentrations were less than established drinking-water standards. Deethylatrazine, an atrazine degradation compound, was the most commonly detected pesticide, occurring in 30 percent of the wells, followed by atrazine (27 percent) and metalaxyl (13 percent). The remainder of the pesticides were detected in ground water only once. Pesticides were detected less frequently in the UTEN than in other similar national land-use studies; metalaxyl and flumetralin were detected in a similar frequency at a tobacco study in North Carolina.

Volatile organic compounds (VOC's) were detected in 27 of 30 wells, however, no concentrations exceeded drinking-water standards. The detection frequency for VOC's in the UTEN was somewhat higher than in other NAWQA study units. Most of the detections were at very low levels (less than 0.01 μg/L). Although no clear source of the VOC's was identified, the presence of these compounds may be attributed to atmospheric deposition from factories in the UTEN or from localized spills.

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Appendixes

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study

[°C, degrees Celsius; mm, millimeter; NTU, nephelometric turbidity units; µS/cm; microsiemens per centimeter; mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated; pCi/L, picoCurie per liter; <, less than; --, no data]

Well number	Local identifier	Station number	Pump or flow period prior to sampling (in minutes)	Depth of well, total (feet)	Depth to top of sample interval (feet)	Depth below land surface (water level) (feet)	Date	Temperature water (°C)	Barometric pressure (mm of Mg)
1	UTEN97-15	360139082551801	193	30.0	24	22.65	06-10-97	18.8	737
2	UTEN97-14	360222082585801	80	24.0	18	8.05	06-10-97	20.0	733
3	UTEN97-08	360444083171701	70	9.5	4.5	2.05	06-16-97	19.1	736
4	UTEN97-51	360556083524901	60	18.3	17	1.45	06-05-97	19.5	737
5	UTEN97-02	360605083364601	105	16.0	7.3	5.85	06-23-97	19.5	738
6	UTEN97-18	360633082503101	120	13.0	6.0	4.00	06-09-97	15.0	734
7	UTEN97-22	360916082353401	137	43.0	32	5.85	06-11-97	18.0	728
8	UTEN97-46	361107083094601	260	14.5	4.1	2.10	06-04-97	20.5	735
9	UTEN97-09	361134 83121301	90	13.8	7.4	1.95	07-09-97	20.3	737
10	UTEN97-19	361441082451101	122	61.0	50	34.1	06-11-97	14.8	724
11	UTEN97-21	361525082521501	80	28.0	16	6.18	06-17-97	18.5	732
12	UTEN97-23	362254082273601	60	7.5	2.0	.90	06-12-97	16.5	715
13	UTEN97-25	362414082203801	120	10.5	3.5	2.40	06-12-97	17.5	725
14	UTEN97-47	362813083260001	75	18.0	12	5.12	06-19-97	21.0	734
15	UTEN97-40	362937082434201	150	21.0	14	8.55	06-19-97	18.9	735
16	UTEN97-07	362957083152601	150	21.0	14	1.95	06-23-97	20.9	740
17	UTEN97-43	363235083084501	85	19.0	12	9.20	06-24-97	20.2	740
18	UTEN97-26	363243082220901	132	10.0	5.5	2.98	06-26-97	20.4	718
19	UTEN97-24	363444082244101	125	9.1	4.8	.81	07-02-97	22.5	722
20	UTEN97-12	363618083033401	150	8.0	4.5	1.84	06-30-97	22.8	731
21	UTEN97-53	363716083170201	190	32.0	30	25.70	06-30-97	29.1	736
22	UTEN97-29	363751082545201	--	16.0	12	4.00	07-01-97	24.0	728
23	UTEN97-50	364207082255101	29	8.5	7.0	5.00	06-26-97	21.2	725
24	UTEN97-37	364351082053001	100	20.5	8.5	1.26	07-02-97	28.9	714
25	UTEN97-34	364430082110201	105	20.5	18	16.80	07-01-97	18.4	727
26	UTEN97-42	364607082550601	40	13.0	12	9.20	06-25-97	18.2	734
27	UTEN97-38	364629081484201	150	33.0	22	11.90	06-18-97	18.7	708
28	UTEN97-31	364638082524301	160	25.0	13	4.40	06-24-97	24.1	725
29	UTEN97-39	364804081205701	70	11.0	6.5	1.65	06-18-97	17.5	690
30	UTEN97-36	365351082150901	225	27.5	17	14.90	06-25-97	23.2	726

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Turbidity (NTU)	Specific conductance (μS/cm at 25 °C)	Oxygen, dissolved (mg/L)	pH water whole field (standard units)	pH water whole lab (standard units)	Bicarbonate water, dissolved (mg/L as HCO_3)	Ammonia, (NH_3) dissolved (mg/L as N)	Nitrite, (NO_2) dissolved (mg/L as N)	Ammonia plus organic nitrogen, dissolved (mg/L as N)
1	1.2	612	6.6	6.7	7.1	325	<.015	<.010	<.20
2	21	813	8.5	7.1	7.6	306	<.015	<.010	<.20
3	.82	716	.8	6.5	7.1	285	<.015	.026	.25
4	440	430	1.0	7.1	7.8	127	.024	<.010	<.20
5	1.4	525	.3	6.8	7.2	328	.723	<.010	.66
6	.10	448	4.9	6.9	7.3	282	<.015	<.010	<.20
7	18	86	4.2	6.4	7.0	57	.015	.015	<.20
8	17	891	5.7	6.9	7.3	438	<.015	<.010	<.20
9	--	499	.2	7.0	7.6	264	.184	<.010	.23
10	.35	436	5.0	7.1	7.4	227	<.015	<.010	<.20
11	.37	855	.1	6.8	7.2	395	.158	<.010	<.20
12	1.4	477	.7	6.8	7.1	284	<.015	<.010	<.20
13	.28	581	.9	6.6	7.1	317	<.015	<.010	<.20
14	2.7	381	.2	6.4	6.7	128	.393	<.010	.43
15	.31	242	1.7	5.6	6.2	68	<.015	<.010	<.20
16	1.3	147	.1	6.2	6.7	73	.176	<.010	<.20
17	4.9	499	4.6	6.2	6.7	188	<.015	<.010	<.20
18	.65	504	.1	6.6	6.9	318	.261	<.010	.27
19	2.3	747	.2	6.7	7.4	514	.587	<.010	.63
20	8.2	223	.2	5.7	6.0	34	.108	<.010	<.20
21	190	609	3.2	6.7	7.1	288	.044	.031	<.20
22	--	294	4.4	6.5	7.0	176	.343	<.010	.39
23	1.4	559	1.1	6.6	7.1	307	.143	<.010	<.20
24	350	720	.4	7.1	7.0	359	1.91	.031	2.6
25	2.4	416	8.2	7.0	7.8	212	<.015	<.010	<.20
26	35	78	3.7	4.9	5.5	13	<.015	<.010	<.20
27	1.9	536	6.4	7.1	7.6	271	<.015	<.010	<.20
28	10	152	.2	6.1	6.3	43	.368	<.010	.37
29	.85	386	.7	4.7	5.1	1	<.015	<.010	<.20
30	24	446	.2	6.8	7.1	256	.046	<.010	<.20

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Nitrite plus nitrate, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Orthophosphorus, dissolved (mg/L as P)	Carbon, organic dissolved (mg/L as C)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)
1	10.6	<.010	<.010	.20	94	20	5.8	1.6	8.5
2	23.0	<.010	.012	.70	89	35	24	.99	20
3	11.0	.041	<.010	2.3	100	19	5.0	1.4	38
4	<.050	<.010	<.010	.80	68	8.6	4.9	2.7	5.3
5	<.050	<.010	<.010	.80	76	23	2.1	1.9	6.8
6	1.32	<.010	<.010	.30	68	16	1.1	1.9	2.1
7	.651	<.010	<.010	.50	11	2.1	2.5	1.6	2.1
8	.075	<.010	<.010	1.0	110	44	18	1.5	15
9	<.050	.010	.010	.50	61	15	22	.87	7.3
10	7.33	<.010	.018	.40	77	6.4	1.6	3.3	6.1
11	.106	<.010	<.010	.70	110	35	15	1.4	3.2
12	3.69	<.010	<.010	1.7	65	21	1.3	1.2	3.5
13	2.11	<.010	<.010	5.7	95	6.7	12	2.5	23
14	.083	<.010	<.010	.60	37	19	3.7	2.5	12
15	7.27	<.010	<.010	.80	36	4.0	1.6	1.2	13
16	<.050	.252	.222	.40	6.4	2.6	14	3.1	1.8
17	11.6	.028	.014	.60	80	13	2.2	.18	10
18	<.050	<.010	<.010	.80	88	7.0	1.9	2.9	3.3
19	1.42	<.010	<.010	3.7	66	35	25	13	47
20	.083	<.010	<.010	.50	12	9.6	3.3	1.8	12
21	1.49	<.010	<.010	.50	100	7.4	9.1	.71	4.2
22	<.050	.080	.069	.70	21	9.6	30	3.2	5.1
23	.703	<.010	<.010	.80	110	3.7	2.1	.23	5.4
24	.444	<.010	.015	2.4	96	27	8.1	3.0	16
25	4.32	.027	.012	.30	79	2.0	1.5	.77	3.7
26	.084	<.010	<.010	.40	7.6	1.8	2.4	1.0	.64
27	9.69	<.010	<.010	3.6	62	28	2.3	1.1	4.8
28	<.050	.572	.534	.70	12	3.4	4.1	1.5	3.9
29	32.5	<.010	<.010	1.8	26	14	11	6.1	16
30	.216	.024	.032	.70	49	6.9	37	5.2	7.2

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SIO_2)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Prometon, dissolved (µg/L)	Deethyl-atrazine, dissolved (µg/L)	Tritium (pCi/L)	Chloroform (µg/L)
1	18	.14	13	<3.0	<1.0	<.0180	E.0076	--	<.052
2	43	.22	8.5	<3.0	<1.0	<.0180	E.108	--	E.010
3	31	.12	10	<3.0	7.0	<.0180	<.0020	--	E.010
4	13	.13	15	42	25	<.0180	<.0020	62	.137
5	4.9	<.10	9.0	3,600	3,570	<.0180	<.0020	--	<.052
6	5.1	<.10	9.6	<3.0	<1.0	<.0180	E.0031	--	E.010
7	.47	.13	10	38	774	<.0180	<.0020	--	.398
8	130	.34	11	<3.0	181	<.0180	<.0020	--	<.050
9	48	.29	11	40	44	<.0180	<.0020	--	<.208
10	2.3	.27	18	<3.0	1.1	<.0180	E.0080	--	E.010
11	140	.20	12	180	21	<.0180	<.0020	--	<.052
12	7.6	.30	6.6	<3.0	2.6	<.0180	E.0087	--	<.052
13	7.8	.15	9.3	<3.0	1.1	E.0026	E.0080	--	E.030
14	63	.22	30	6,900	251	<.0180	<.0020	--	<.052
15	8.0	<.10	7.2	3.7	66	<.0180	E.0286	--	<.052
16	8.4	.16	20	7,700	679	<.0180	<.0020	--	<.052
17	33	<.10	8.4	<3.0	4.0	<.0180	<.0020	--	<.052
18	7.7	.19	9.8	5,500	812	<.0180	<.0020	--	<.104
19	28	.14	7.2	<3.0	228	<.0180	<.0020	--	<.052
20	53	<.10	23	13,900	472	<.0180	<.0020	--	<.052
21	4.7	.17	11	15	22	<.0180	<.0020	--	<.052
22	19	.18	12	1,800	1,550	<.0180	<.0020	--	E.010
23	27	.11	11	430	2,380	<.0180	E.0019	--	E.006
24	4.1	.18	12	9,700	1,100	<.0180	<.0020	--	<.052
25	9.9	.10	7.3	<3.0	<1.0	<.0180	<.0020	--	<.052
26	19	<.10	12	44	509	<.0180	<.0020	--	<.052
27	12	.20	8.6	<3.0	8.7	<.0180	E.0134	--	<.052
28	3.1	.18	9.3	13,200	2,260	<.0180	<.0020	--	<.052
29	21	.25	6.8	<3.0	184	<.0180	<.0020	--	E.050
30	9.5	.26	11	16	326	<.0180	<.0020	--	E.008

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Toluene (µg/L)	Benzene (µg/L)	Chlorobenzene (µg/L)	Chloroethane (µg/L)	Ethylbenzene (µg/L)	Methylchloride (µg/L)	Methylene chloride (µg/L)	Tetrachloroethylene (µg/L)	o-Dichlorobenzene (µg/L)	Metolachlor, dissolved (µg/L)
1	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
2	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
3	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
4	.456	.176	<.028	<.120	E.060	<.254	<.382	<.038	<.048	<.002
5	E.006	E.007	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
6	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
7	.726	E.070	<.028	<.120	E.030	<.254	E.500	<.038	<.048	<.002
8	E.050	E.080	<.050	<.100	<.050	<.200	<.100	<.050	<.050	<.002
9	<.152	<.128	<.112	<.480	<.120	<1.02	<1.53	<.152	<.192	<.002
10	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
11	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
12	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
13	<.038	<.032	<.028	<.120	<.030	<.254	<.382	E.004	<.048	<.002
14	E.020	E.020	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
15	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
16	E.006	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
17	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
18	<.076	<.064	<.056	<.240	<.060	E.050	<.764	<.076	<.096	<.002
19	E.010	<.032	<.028	E.020	<.030	E.040	<.382	<.038	<.048	<.002
20	.672	.808	<.028	E.050	.481	<.254	<.382	<.038	<.048	<.002
21	E.040	<.032	<.028	<.120	<.030	<.254	<.382	E.010	<.048	<.002
22	E.030	E.010	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
23	<.038	E.050	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
24	E.030	E.060	E.060	<.120	E.008	<.254	<.382	<.038	E.007	<.002
25	<.038	E.010	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
26	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
27	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
28	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
29	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002
30	<.038	<.032	<.028	<.120	<.030	<.254	<.382	<.038	<.048	<.002

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	1,3-Dichloro-benzene (µg/L)	1,4-Dichloro-benzene (µg/L)	Dichlorodi-fluoromethane (µg/L)	Alkalinity, field mg/L as $CaCO_3$	Atrazine, dissolved (µg/L)	2,4-D, dissolved (µg/L)	2,4,5-T, dissolved (µg/L)	Silvex, dissolved (µg/L)	Dichlorprop, dissolved (µg/L)	Simazine, dissolved (µg/L)
1	<.054	<.050	E.060	266	.004	<.035	<.0350	<.0210	<.0320	<.0050
2	<.054	<.050	<.096	251	.144	<.035	<.0350	<.0210	<.0320	<.0050
3	<.054	<.050	E.010	234	<.001	<.035	<.0350	<.0210	<.0320	<.0050
4	<.054	<.050	E.300	104	<.001	<.035	<.0350	<.0210	<.0320	<.0050
5	<.054	<.050	<.096	269	<.001	<.035	<.0350	<.0210	<.0320	<.0050
6	<.054	<.050	E.080	231	<.001	<.035	<.0350	<.0210	<.0320	<.0050
7	<.054	<.050	<.096	47	<.001	<.035	<.0350	<.0210	<.0320	<.0050
8	<.050	<.050	<.200	359	<.001	<.035	<.0350	<.0210	<.0320	<.0050
9	<.216	<.200	<.384	216	<.001	<.035	<.0350	<.0210	<.0320	<.0050
10	<.054	<.050	E.050	186	.006	<.035	<.0350	<.0210	<.0320	<.0050
11	<.054	<.050	<.096	324	<.001	<.035	<.0350	<.0210	<.0320	<.0050
12	<.054	<.050	<.096	233	.006	<.035	<.0350	<.0210	<.0320	<.0050
13	<.054	<.050	E.060	260	.012	<.035	<.0350	<.0210	<.0320	<.0050
14	<.054	<.050	<.096	105	<.001	<.035	<.0350	<.0210	<.0320	<.0050
15	<.054	<.050	E.010	56	.032	<.035	<.0350	<.0210	<.0320	<.0050
16	<.054	<.050	<.096	60	<.001	<.035	<.0350	<.0210	<.0320	<.0050
17	<.054	<.050	<.096	154	<.001	<.035	<.0350	<.0210	<.0320	<.0050
18	<.108	<.100	<.192	261	<.001	<.035	<.0350	<.0210	<.0320	<.0050
19	<.054	<.050	<.096	421	<.001	<.035	<.0350	<.0210	<.0320	<.0050
20	<.054	<.050	<.096	28	<.001	<.035	<.0350	<.0210	<.0320	<.0050
21	<.054	<.050	<.096	236	<.001	<.035	<.0350	<.0210	<.0320	<.0050
22	<.054	<.050	E.040	144	<.001	<.035	<.0350	<.0210	<.0320	<.0050
23	<.054	<.050	<.096	252	E.003	<.035	<.0350	<.0210	<.0320	<.0050
24	E.009	E.003	<.096	294	<.001	E4.54	.610	.0600	.400	<.0050
25	<.054	<.050	<.096	174	<.001	<.035	<.0350	<.0210	<.0320	<.0050
26	<.054	<.050	<.096	10	<.001	<.035	<.0350	<.0210	<.0320	<.0050
27	<.054	<.050	<.096	222	.091	<.035	<.0350	<.0210	<.0320	<.0050
28	<.054	<.050	<.096	35	<.001	<.035	<.0350	<.0210	<.0320	<.0050
29	<.054	<.050	<.096	1	<.001	<.035	<.0350	<.0210	<.0320	<.0050
30	<.054	<.050	E.040	210	<.001	<.035	<.0350	<.0210	<.0320	<.0050

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Prehnitene (μg/L)	Solids, residue at 180 °C, dissolved (mg/L)	Bromide, dissolved (mg/L as Br)	Tritium 2 sigma (pCi/L)	RN-222 2 sigma (pCi/L)	Carbon disulfide (μg/L)	Styrene (μg/L)	o-xylene (μg/L)	1,2,3-trimethyl-benzene (μg/L)
1	<.230	359	.034	--	26	<.080	<.042	<.064	<.124
2	<.230	488	.052	--	20	E.020	<.042	<.064	<.124
3	<.230	447	.053	--	--	<.080	E.007	<.064	<.124
4	<.230	234	.056	5.1	25	<.080	<.042	.143	E.040
5	<.230	292	<.010	--	36	<.080	<.042	<.064	<.124
6	<.230	259	.032	--	28	<.080	<.042	<.064	<.124
7	<.230	55	<.010	--	34	.133	<.042	<.064	<.124
8	<.050	580	.12	--	30	E.020	<.050	<.050	<.050
9	<.920	311	.037	--	18	<.320	<.168	<.256	<.496
10	<.230	274	.049	--	29	<.080	<.042	<.064	<.124
11	<.230	477	.036	--	24	E.020	<.042	<.064	<.124
12	<.230	275	.038	--	46	1.03	<.042	<.064	<.124
13	<.230	336	.054	--	39	<.080	<.042	<.064	<.124
14	<.230	237	.12	--	23	<.080	<.042	<.064	<.124
15	<.230	152	.040	--	40	<.080	E.004	<.064	<.124
16	<.230	99	.060	--	20	<.080	E.008	<.064	<.124
17	<.230	305	.060	--	33	<.080	<.042	<.064	<.124
18	<.460	289	.057	--	36	<.160	<.084	<.128	<.248
19	<.230	440	.060	--	22	E.300	<.042	<.064	<.124
20	E.030	130	.12	--	--	E.050	<.042	.955	.148
21	<.230	370	.071	--	20	E.060	E.040	<.064	<.124
22	<.230	195	.092	--	22	E.300	<.042	<.064	<.124
23	<.230	334	.025	--	30	E.010	E.010	<.064	<.124
24	<.230	435	.064	--	31	E.020	<.042	<.064	<.124
25	<.230	258	.026	--	36	<.080	<.042	<.064	<.124
26	<.230	58	<.010	--	31	.183	E.010	<.064	<.124
27	<.230	294	.019	--	19	<.080	<.042	<.064	<.124
28	<.230	92	.022	--	30	<.080	<.042	<.064	<.124
29	<.230	226	.018	--	33	<.080	<.042	<.064	<.124
30	<.230	253	.031	--	23	<.080	<.042	<.064	<.124

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	1,2,4-trimethyl-benzene (µg/L)	Isopropyl-benzene (µg/L)	n-Propyl-benzene (µg/L)	1,3,5-trimethyl-benzene (µg/L)	n-Butyl-benzene (µg/L)	o-ethyl Toluene (µg/L)	p-Isopropyl-toluene (µg/L)	Methyl iodide (µg/L)	Freon-113 (µg/L)
1	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
2	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
3	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
4	E.090	E.010	E.010	E.030	<.186	E.010	E.004	<.076	E.010
5	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
6	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
7	E.010	<.032	<.042	<.044	E.005	<.100	<.110	<.076	<.032
8	<.050	<.050	<.050	<.050	<.050	<.050	<.050	<.050	<.050
9	<.224	<.128	<.168	<.176	<.744	<.400	<.440	<.304	<.128
10	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
11	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
12	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
13	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
14	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
15	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
16	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
17	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
18	<.112	<.064	<.084	<.088	<.372	<.200	<.220	<.152	<.064
19	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
20	.251	E.090	E.070	E.020	E.008	.121	E.009	<.076	<.032
21	E.010	<.032	<.042	<.044	<.186	<.100	E.003	<.076	<.032
22	E.008	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
23	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
24	<.056	<.032	<.042	<.044	<.186	<.100	E.100	E.010	<.032
25	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
26	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
27	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
28	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
29	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032
30	<.056	<.032	<.042	<.044	<.186	<.100	<.110	<.076	<.032

Appendix A. Water-quality data for the upper Tennessee River Basin tobacco land-use study—Continued

Well number	Acetone (µg/L)	Ethylether (µg/L)	Methyl ethyl ketone (µg/L)	Radon 222 (pCi/L)	Meta/para-xylene (µg/L)	Metalaxyl (µg/L)	Flumetralin (µg/L)	Dimethomorph (µg/L)
1	<4.90	<.170	<1.65	652	<.064	<0.03	<0.03	<0.03
2	<4.90	<.170	<1.65	224	<.064	<0.03	<0.03	<0.03
3	<4.90	<.170	<1.65	--	<.064	0.16	<0.03	<0.03
4	<4.90	<.170	<1.65	583	.310	<0.03	<0.03	<0.03
5	<4.90	<.170	<1.65	1,485	<.064	<0.03	<0.03	<0.03
6	<4.90	<.170	<1.65	720	<.064	<0.35	<0.03	<0.03
7	<4.90	<.170	<1.65	1,221	E.040	<0.03	<0.03	<0.03
8	<5.00	<.100	<5.00	972	<.050	<0.03	<0.03	<0.03
9	<19.6	E.100	E1.00	100	<.256	<0.03	<0.03	<0.03
10	<4.90	<.170	<1.65	756	<.064	<0.03	<0.03	<0.03
11	<4.90	<.170	<1.65	322	<.064	<0.03	<0.03	<0.03
12	<4.90	<.170	<1.65	2,516	<.064	<0.03	<0.03	E0.01
13	<4.90	<.170	<1.65	1,739	<.064	<0.03	<0.03	<0.03
14	<4.90	<.170	<1.65	258	<.064	<0.03	<0.03	<0.03
15	<4.90	<.170	<1.65	1,451	<.064	0.09	<0.03	<0.03
16	<4.90	<.170	<1.65	265	<.064	<0.03	<0.03	<0.03
17	<4.90	<.170	<1.65	1,188	<.064	<0.03	<0.03	<0.03
18	<9.81	<.340	<3.30	1,432	<.128	<0.03	<0.03	<0.03
19	<4.90	<.170	<1.65	308	<.064	E0.02	<0.03	<0.03
20	E1.00	<.170	<1.65	--	1.00	<0.03	<0.03	<0.03
21	<4.90	<.170	<1.65	269	E.020	<0.03	<0.03	<0.03
22	<4.90	<.170	E.600	365	E.020	<0.03	<0.03	<0.03
23	<4.90	<.170	<1.65	832	E.030	<0.03	<0.03	<0.03
24	<4.90	<.170	<1.65	955	<.064	<0.03	<0.03	<0.03
25	<4.90	<.170	<1.65	1,555	<.064	<0.03	<0.03	<0.03
26	<4.90	<.170	<1.65	962	<.064	<0.03	<0.03	<0.03
27	<4.90	<.170	<1.65	154	<.064	<0.03	<0.03	<0.03
28	<4.90	<.170	<1.65	880	<.064	<0.03	<0.03	<0.03
29	<4.90	<.170	<1.65	1,054	<.064	1.56	E0.005	<0.03
30	<4.90	<.170	<1.65	397	<.064	<0.03	<0.03	<0.03

Appendix B. Pesticides and volatile organic compounds sampled for but not detected

Pesticides

1-Naphthol
2,4-DB
3-Hydroxy-carbofuran
Acifluorfen
Aldicarb
Aldicarb sulfone
Aldicarb sulfoxide
Bentazon
Bromacil
Bromoxynil
Chloramben
Chlorothalonil
Clopyralid
Dacthal, monoacid
Dicamba
Dichlobenil
Dinoseb
Diuron
DNOC
Esfenvalerate
Fenuron
Fluometuron
MCPA
MCPB
Methiocarb
Methomyl
Neburon
Norflurazon
Oryzalin
Oxamyl
Picloram
Propham
Propoxur
Triclopyr
2,6-Diethylaniline
Acetochlor
Alachlor
Alpha BHC
Benfluralin
Butylate
Carbaryl
Carbofuran
Chlorpyrifos
Cyanazine
DCPA
P, P’ DDE
Diazinon
Dieldrin
Disulfoton
EPTC
Ethalfluralin
Ethoprop
Fonofos
Lindane
Linuron
Malathion
Methyl azinphos
Methyl parathion
Metribuzin
Molinate
Napropamide
Parathion
Pebulate
Pendimethilin
cis-Permethrin
Phorate
Pronamide
Propchlor
Propanil
Propargite
Tebuthiuron
Terbacil
Terbufos
Thiobencarb
Triallate
Trifluralin

Volatile Organic Compounds

Dibromomethane
Bromodichloromethane
Tetrachloromethane
1,2-Dichloroethane
Tribromomethane
Dibromochloroethene
2-Propenenitrile
1,1,1,2,2,2-Hexachloroethane
Bromomethane
Trichlorofluoromethane
1,1-Dichloroethane
1,1-Dichloroethene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,2-Dichloroethene
1,2,4-Trichlorobenzene
Naphthalene
trans-1,3-Dichloropropene
cis-1,3-Dichloropropene
Chloroethene
Trichloroethene
Hexachlorobutadiene
Methyl acrylate
1,2,3,5-Tetramethylbenzene
Bromoethene
Ethyl *tert*-butyl ether
tert-Amyl methyl ether
trans-1,4-Dichloro-2-butene
Vinyl Acetate
Ethenyl ethanoate
cis-1,2-Dichloroethene
2-Hexanone
1,1-Dichloropropene
2,2-Dichloropropane
1,3-Dichloropropane
1-Chloro-2-methylbenzene
1-Chloro-4-methylbenzene
Bromochloromethane
(1-Methylpropyl)benzene
(1,1-Dimethylethyl)benzene
1,2,3-Trichloropropane
1,1,1,2-Tetrachloroethane
1,2,3-Trichlorobenzene
1,2-Dibromoethane
Methyl *tert*-butyl ether
3-Chloro-1-propene
4-Methyl-2-pentanone
Bromobenzene
Diisopropyl ether
Tetrahydrofuran
Methyl methacrylate
1,4-Epoxybutane
1,2-Dibromo-3-chloropropane