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Prepared in cooperation with the
Delaware Department of Natural Resources and Environmental Control
and the
Delaware Geological Survey

Occurrence and Distribution of Organic Chemicals and Nutrients and Comparison of Water-Quality Data from Public Drinking-Water Supplies in the Columbia Aquifer in Delaware, 2000–08

Scientific Investigations Report 2010–5206

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound, avoirdupois (lb)
	Pressure	
atmosphere, standard (atm)	101.3	kilopascal (kPa)
atmosphere, standard (atm)	760	millimeters of mercury (mmHg)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Glossary

Health-Based Screening Level (HBSL)

Benchmark concentrations of contaminants in water that may be of potential concern for human health, if exceeded. HBSLs are non-enforceable benchmarks that were developed by the U.S. Geological Survey (USGS) in collaboration with the U.S. Environmental Protection Agency (USEPA) and others using USEPA methodologies for establishing drinking-water guidelines and the most current, USEPA peer-reviewed, publicly available human-health toxicity information.

Health Advisory Limit (HAL)

A non-regulatory health-based reference level of chemical traces (usually in parts per million) in drinking water at which there are no adverse health risks when ingested over certain periods of time. Levels are established for 1 day, 10 days, long-term, and lifetime exposure periods. They contain a wide margin of safety, and are set forth by the Delaware Division of Public Health.

Maximum Contaminant Level (MCL) or Primary Maximum Contaminant Level (PMCL)

As used in this report, a USEPA drinking-water standard that is legally enforceable, and that sets the maximum permissible level of a contaminant in water that is delivered to any user of a public water system, at which no known or anticipated adverse effect on the health of persons occurs, and which allows an adequate margin of safety.

Secondary Maximum Contaminant Level (SMCL)

As used in this report, a USEPA secondary drinking-water standard, and non-enforceable guidelines regulating contaminants that may cause cosmetic or aesthetic effects (such as taste, odor, or color) in drinking water. USEPA recommends secondary standards for water systems but does not require compliance. However, states may choose to adopt them as enforceable standards.

Source Water

Source water is the raw (ambient) water collected at the supply well prior to water treatment. Following water treatment, source water is finished or drinking water.

Occurrence and Distribution of Organic Chemicals and Nutrients and Comparison of Water-Quality Data from Public Drinking-Water Supplies in the Columbia Aquifer in Delaware, 2000–08

By Betzaida Reyes

Abstract

The U.S. Geological Survey, in cooperation with the Delaware Department of Natural Resources and Environmental Control and the Delaware Geological Survey, conducted a groundwater-quality investigation to (a) describe the occurrence and distribution of selected contaminants, and (b) document any changes in groundwater quality in the Columbia aquifer public water-supply wells in the Coastal Plain in Delaware between 2000 and 2008. Thirty public water-supply wells located throughout the Columbia aquifer of the Delaware Coastal Plain were sampled from August through November of 2008. Twenty-two of the wells in the sampling network for this project were previously sampled in 2000. Eight new wells were selected to replace wells no longer in use. Groundwater collected from the wells was analyzed for the occurrence and distribution of selected pesticides, pesticide degradates, volatile organic compounds, nutrients, and major inorganic ions. Nine of the wells were analyzed for radioactive elements (radium-226, radium-228, and radon). Groundwater-quality data were compared for sites sampled in both 2000 and 2008 to document any changes in water quality.

One or more pesticides were detected in samples from 29 of the 30 wells. There were no significant differences in pesticide and pesticide degradate concentrations and similar compounds were detected when comparing sampling results from 2000 and 2008. Pesticide and pesticide degradate concentrations were generally less than 1 microgram per liter. Twenty-four compounds, 14 pesticides, and 10 pesticide degradates were detected in at least one sample; the pesticide degradates, metolachlor ethanesulfonic acid, deethylatrazine, and alachlor ethanesulfonic acid were the most frequently detected compounds, each found in more than 50 percent of samples. Almost 80 percent of the detected pesticides were agricultural herbicides, which reflects the prevalence and wide distribution of agriculture in sampled areas, as well the dominance of agricultural pesticides among the target analytes for this study. No concentration of a pesticide or pesticide degradate exceeded any regulatory standard. Dieldrin, an insecticide that has been banned for several decades, was detected at a concentration that exceeded a non-regulatory health-based screening level of 0.002 micrograms per liter at nine sites.

Volatile organic compounds (VOCs) were generally detected at concentrations of less than 1 microgram per liter, although 7 of the 31 detected VOCs had concentrations greater than 1 microgram per liter. There were no significant differences in VOC concentrations from 2000 to 2008; however, among the resampled wells, the mean number of VOCs detected per well was significantly different over the 8-year period. The number of VOCs detected per well decreased in 73 percent of the resampled wells; the decrease ranged from one to eight fewer detections in 2008 than in 2000. Chloroform and methyl *tert*-butyl ether were the most frequently detected VOCs, at 90 percent and 63 percent, respectively, among the 30 wells. Solvents were the most frequently detected class of VOCs. All measured concentrations of VOCs in groundwater were below established standards for drinking water and below other health-based guidelines.

There were no significant differences in nutrient or major-ion concentrations between 2000 and 2008, however, the medians of two field measurements, pH and dissolved oxygen, were significantly higher in 2008 than in 2000 in the resampled wells. Although pH and dissolved oxygen were higher, water was still acidic and predominantly oxic. Nitrate was the predominant nutrient species in the Columbia aquifer, with a 90-percent detection frequency. The median nitrate concentration in groundwater was 4.88 milligrams per liter, which was slightly lower than, but not significantly different from, the median of 5.23 milligrams per liter for the 2000 samples. Concentrations of nitrate exceeded the U.S. Environmental Protection Agency's Maximum Contaminant Level or Federal drinking-water standard of 10 milligrams per liter as nitrogen in samples from two wells. Eight of the 30 wells sampled had iron or manganese concentrations that exceeded the U.S. Environmental Protection Agency's Secondary Maximum Contaminant Level; nine samples exceeded the Health

Advisory Limit set by the Delaware Division of Public Health of 20 milligrams per liter for sodium in drinking water.

Two radiochemical isotopes, radium-226 and radon-222, were detected in all nine groundwater samples analyzed; five samples had detectable levels of radium-228 activity. None of the samples exceeded the U.S Environmental Protection Agency's Maximum Contaminant Level for radium or radon in drinking water. Although radioactive elements were more frequently detected in 2008 than in 2000, this increased detection frequency is more likely due to lower detection levels in 2008 than 2000.

The average age of groundwater entering the screens of the production wells sampled in 2008 ranged from 6 to 35 years, with a median groundwater age of 22 years. Groundwater age was positively correlated with well depth and negatively correlated with dissolved oxygen. Data from the 22 resampled wells indicate a significant positive difference in the average modeled groundwater-sample-age results. The average groundwater age from samples collected in 2008 was generally 7 years older than the average groundwater age from samples collected in 2000.

Introduction

The Columbia aquifer is an important drinking-water resource in the Coastal Plain of Delaware (Ferrari, 2002). A significant number of public drinking-water supply wells are screened in the Columbia aquifer. The Columbia aquifer consists primarily of sands and gravels of fluvial and marginal marine origin. Since it is largely unconfined, it is susceptible to contamination from applications or spills of chemicals on or near the land surface. The primary land uses surrounding these relatively shallow public-supply wells in the Coastal Plain of Delaware include agriculture, and low-density urban and suburban areas associated with small towns and communities.

A previous study of the Columbia aquifer in 2000 found that low concentrations of pesticides and volatile organic compounds (VOCs) were present in the source water for 30 randomly selected drinking-water wells throughout Delaware (Ferrari, 2002). Although concentrations of organic compounds were generally low (less than 1 µg/L/microgram per liter), at least one compound was detected in all water samples, and most samples had multiple detections. None of the organic compound concentrations were above the U.S. Environmental Protection Agency (USEPA) Federal drinking-water standards for Primary or Secondary Maximum Contaminant Levels (MCLs) or Health Advisory Levels (HALs). In addition, the median concentration of nitrate in water samples was about half (5.20 mg/L/milligrams per liter) of the Federal drinking-water standard for nitrate as nitrogen (10 mg/L). This concentration is significantly greater than the background concentration of nitrate in groundwater in the Delmarva Peninsula, which was estimated to be less than 0.4 mg/L (Hamilton and others, 1993). These results show that human effects on land use have impacted the quality of this important drinking-water resource.

State regulatory officials and water-resource managers are concerned with the overall quality of the drinking-water resource, and are interested in determining if there have been any broad changes in the characteristics of source waters since the initial sampling in 2000. This project was undertaken to allow for a direct comparison of chemical-quality results between samples collected in 2000 and 2008. These results will further supplement the public-well database for the State of Delaware, and provide information on the changes in concentration and distribution of chemical compounds that will assist officials responsible for implementing practices for protecting drinking-water resources in Delaware.

Purpose and Scope

The primary objectives of this report are to describe the occurrence and distribution of selected contaminants and to document any changes in groundwater quality in the Columbia aquifer public-supply wells in the Coastal Plain in Delaware between 2000 and 2008. Samples were collected from August through November of 2008. The same well network sampled in 2000 by Ferrari (2002) was resampled for this study to the extent possible. Of the original 30 wells, 22 were available for resampling and the remaining 8 wells were replaced with similar nearby wells.

All wells were sampled for the same suite of constituents that were sampled in 2000. As such, groundwater samples were collected and analyzed for pesticides, pesticide degradation products, VOCs, nutrients, major ions, and trace elements. Groundwater age was determined for each sample. A subset of nine wells was analyzed for radon and radium. Constituent concentrations were compared to the USEPA MCLs (U.S. Environmental Protection Agency, 2009), the Health Advisory Limits (HALs) set by the Delaware Division of Public Health (State of Delaware, 2002) and the U.S. Geological Survey (USGS) Health-Based Screening Levels (HBSLs) (Toccalino and others, 2004; Toccalino and others, 2008), where available. These comparisons were made for informational purposes and not for evidence of compliance or non-compliance with Federal regulations because these standards and guidelines are for public drinking water as supplied to customers and are not applied to raw water. Complete tables of analytical results for 2008 are included as appendixes B to G at the end of the report.

This study is part of the Source Water Assessment and Protection Program (SWAPP), which was created by Congress as part of the Safe Drinking-Water Act Amendments of 1996. The goal of the SWAPP is to better protect public-drinking water resources by providing local and State governments and the public with more information about these resources. The susceptibility of sources of public drinking water to various types of contamination was also determined and described.

Description of Study Area

The study area lies entirely within the Atlantic Coastal Plain Physiographic Province in Delaware (fig. 1a). This area is underlain by a seaward-dipping wedge of unconsolidated gravels, sands, silts, and clays that form a series of confined aquifers and confining beds overlain by a regional unconfined aquifer system that is referred to as the Columbia aquifer in Delaware (Benson and others, 1986). This study focuses on the Columbia aquifer, which is generally unconfined and consists of near-surface water-yielding sediments (Bachman, 1984; Bachman and Wilson, 1984; Andres, 1991, 1994; Talley, 1988). The aquifer, which ranges from 20 ft (feet) to over 100 ft in thickness, consists primarily of sands that occur as channel-fill deposits in the northern part of the study area and spread into sheet sands in Kent and Sussex Counties (Johnston, 1973). The aquifer's hydrologic characteristics and presence at the land surface render it particularly susceptible to contamination.

Land use is predominantly agricultural throughout Delaware, and the major crops are corn, soybeans, and small grains (U.S. Department of Agriculture, 1997; Denver, Ator, and Brayton, 2004). In 1997, approximately, 45 percent of Delaware's total available land area was used for farming (Blaier and Baxter, 2000). Most agricultural activity takes place in Kent and Sussex Counties and south of the Chesapeake and Delaware (C&D) Canal in New Castle County.

The Columbia aquifer is the primary source of water for domestic and agricultural use in Delaware, and an important source of public water supply (Denver and others, 2004). The aquifer is a source of recharge to underlying confined aquifers and the predominant source of base flow to streams (Debrewer and others, 2007).

Methods of Study

This study was designed to identify and quantify spatial and temporal changes in the groundwater quality in the Columbia aquifer in Delaware used for public drinking-water supply between 2000 and 2008. Groundwater was sampled for the same set of compounds in 22 original and 8 replacement wells.

Sampling Network

USGS personnel visited each site to determine if the original 30 wells were still suitable for sampling (See Ferrari, 2002 for additional information on the original well-network design). During this process, it was discovered that eight wells were no longer in use for a variety of reasons. The selection of replacement wells to complete the 30-well network was made by Delaware Department of Natural Resources and Environmental Control (DNREC) personnel on the basis of the following established criteria: located close to the original well (generally within 1 mile) with similar well construction, used as a public drinking-water supply, and screened in the unconfined aquifer (fig. 1b). A summary of the well-construction data, and modeled groundwater ages of groundwater samples is listed in table 1.

Samples from nine wells were analyzed for radium-226, radium-228, and radon-222. After reconnaissance, six of the original wells were determined to be suitable for resampling, and four wells needed to be replaced. One of the replacement wells could not be sampled due to scheduling problems.

Sample Collection and Analysis

All wells were sampled and analyzed for the same suite of organic contaminants and nutrients as in 2000. Water temperature, specific conductance, pH, dissolved oxygen, and alkalinity were determined in the field following the protocols outlined in Wilde and others (2005). All groundwater samples were collected from the raw-sample tap prior to any filtering or treatment, and are therefore representative of the available groundwater resource rather than drinking water. Wells were purged to remove standing water in the casing (generally three well volumes) before samples were collected. Purging continued until dissolved oxygen (±0.3 mg/L), pH (±0.1 units), specific conductance (±3 percent), water temperature (±0.2°C/degrees Celsius), and turbidity (±10 percent) stabilized. Water-quality samples were collected through Teflon tubing inside a sampling chamber. A subset of samples intended for dissolved analyses was passed through a 0.45-µm (micrometer) capsule filter (for inorganic constituents) or a 0.7-µm baked-glass fiber filter (for pesticides and pesticide degradates); selected trace elements and major-ion samples were preserved with nitric acid to a pH below 2. Bottles were chilled to maintain a temperature of 4°C during shipment to the laboratory.

Samples were analyzed for 48 pesticides and 35 pesticide degradates, 86 VOCs, nutrients (nitrogen and phosphorus), major ions, trace elements, dissolved organic carbon, age dating, and selected radioactive elements (radium-226 and radium-228, radon-222).

The majority of the analytical work (concentrations of inorganic ions, trace elements, selected pesticides and pesticide degradates, nutrients, and radon-222) for this study was performed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, using established procedures (Fishman, 1993; Zaugg and others, 1995; Connor and others, 1998). Additional analyses for pesticide degradates were performed at the USGS Organic Geochemistry Research Laboratory in Lawrence, Kansas (Zimmerman, and others, 2000; Lee and others, 2001). To determine groundwater age, concentrations of gaseous sulfur hexafluoride (SF_6) were determined at the USGS National Research Program Chlorofluorocarbon/Dissolved Gas Laboratory in Reston, Virginia (Plummer and Busenberg, 1999; Plummer and

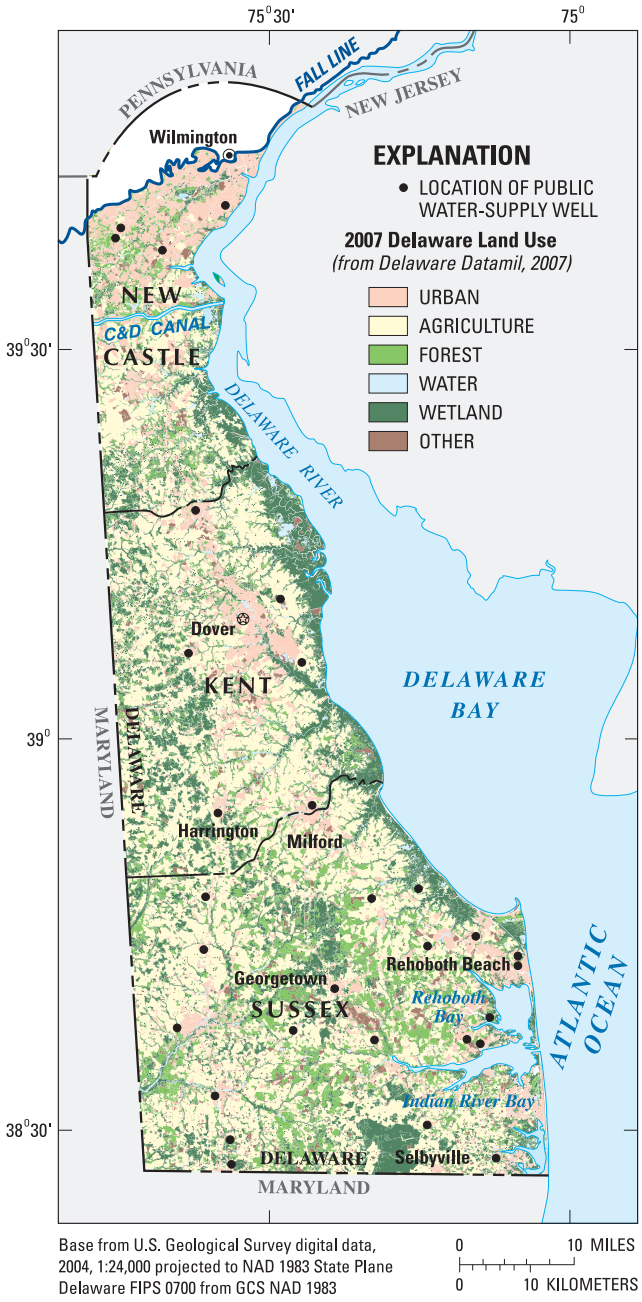

Figure 1a. Land use in the Atlantic Coastal Plain study area of Delaware.

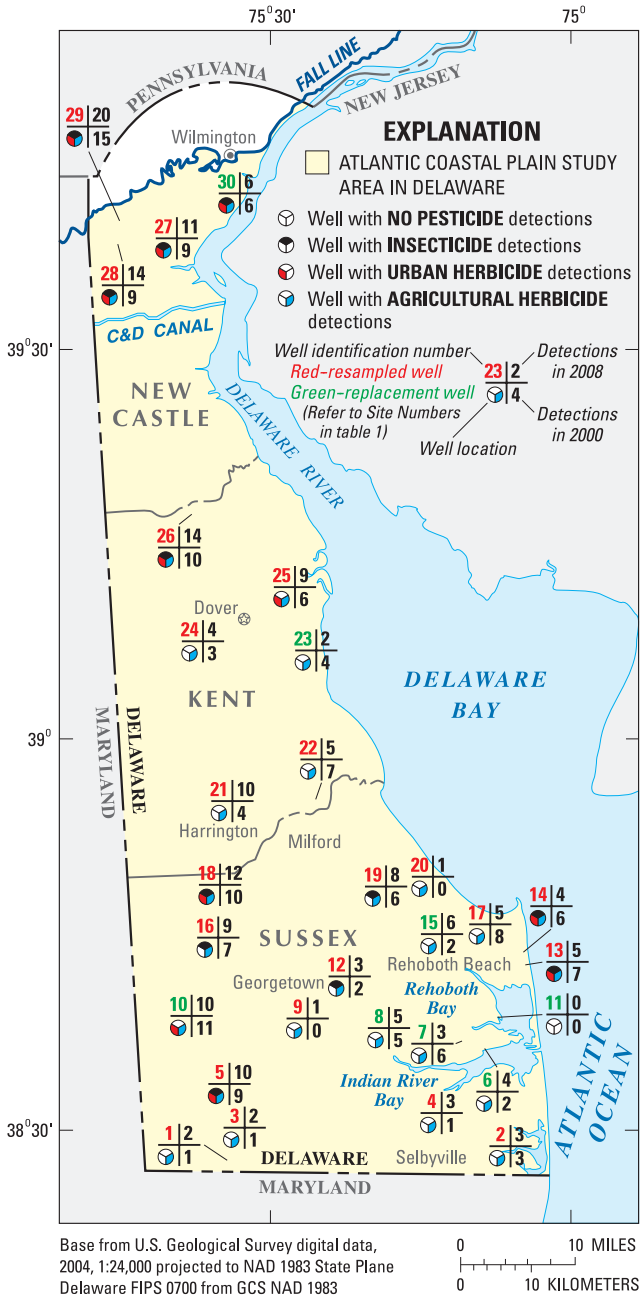

Figure 1b. Locations of public water-supply wells sampled in 2008 in the Columbia aquifer in Delaware and comparison of pesticide and degradate detection frequencies in groundwater, 2000 and 2008.

Friedman, 1999; Plummer and Busenberg, 2000; Busenberg and others, 2001). Radiochemical activities (radium-226 and -228) for the groundwater samples were performed at the Eberline Analytical Corporation Laboratory in Richmond, California following USEPA method 903.1 (U.S. Environmental Protection Agency, 1980a) and USEPA modified method 904.0 (U.S. Environmental Protection Agency, 1980b), respectively.

Data Analysis

Explanatory and nonparametric statistical tests were used to characterize water chemistry differences between sampling events in 2000 and 2008, to identify changes in groundwater quality from individual wells, and to identify patterns in groundwater chemistry during the 8-year study period in the Columbia aquifer. Correlation among continuous variables was evaluated through the use of scatter plots and correlation (Spearman's rho) matrices (Helsel and Hirsch, 1992; Conover, 1999). Plots of cumulative distribution frequency (CDF) of selected chemicals were used to view differences in the distribution of data between the two sampling periods. Wilcoxon Signed-Rank-Sum tests were used to determine if median concentrations were significantly different between time periods, and x-y plots of specific chemicals and factors such as groundwater age or well depth were prepared (Helsel and Hirsch, 1992). Twenty-two of the original wells were available for resampling and used for comparison between the 2000 and 2008 samples. Where laboratory reporting levels had changed since the initial samples were collected, data were censored to a common detection level for each compound (several compounds had multiple laboratory reporting levels) and censored data (less than the reporting limit) were set to zero before any analyses or ranks. All statistical tests were evaluated at the 95-percent confidence level (α=0.05). Statistical analyses were performed using Statistical Analysis Software (SAS), version 9.1.2 (SAS Institute Inc., SAS 9.1.2, 2004).

Quality-Control Sampling

Field blanks, sequential replicate samples, and spikes were collected following the protocols described in Koterba and others (1995) to determine uncertainty and variability. The number of samples collected for quality control was based on results and criteria reported in the previous study (Ferrari, 2002). Nineteen quality-control samples were collected: 10 replicates, 7 field blanks, and 2 laboratory spikes. Not all chemical constituents were analyzed in each quality-control sample, but as in 2000, particular suites of chemicals were targeted. The quality-control data are presented in Appendixes Ha through Hf.

Field blanks were collected to estimate the accuracy of concentrations and to ensure that sample collection and processing did not result in contamination. No nutrients, major ions, pesticides, or pesticide degradate compounds were detected in field blanks at concentrations exceeding laboratory reporting levels. Results of concentrations from VOC blanks were higher than their respective environmental sample results for a small group of compounds. All of these samples had concentrations estimated to be lower than their reporting limits or below detection limits, however. Field blanks indicated that reported concentrations of VOCs may contain minimal bias due to contamination during sample collection, processing, or shipment.

Replicate field samples measure the combined precision of sampling and laboratory analysis procedures. Most of the replicate samples had results similar to or consistent with their respective environmental samples. Six constituent replicates were the exception: metolachlor, alachlor ethanesulfonic acid second amide (alachlor ESA SA), total ammonia plus organic nitrogen, magnesium, iron, and radium-226. For each of these constituents, one of the samples had a reported concentration estimated to be lower than the reporting limit, whereas the associated environmental or replicate sample did not have a detectable concentration. These replicates are considered to be consistent because the reported concentrations were lower than the non-detection reporting levels.

Spikes were analyzed to determine the extent of degradation of the analyte concentration during sample processing and analysis, recovery bias, and variability (Koterba and others, 1995). In this study, samples were spiked in the laboratory with a known quantity of pesticides. Spike data are available upon request from the USGS Maryland-Delaware-D.C. Water Science Center in Baltimore, Maryland.

Age Dating

Average age dates for groundwater samples were estimated on the basis of measured concentrations of SF_6 (Busenberg and Plummer, 2000; Plummer and Friedman, 1999) (table 1, Appendix Ga). SF_6 is a colorless, odorless stable gas primarily of anthropogenic origin with a small concentration from natural sources. The SF_6 method can be used to date groundwater that is in equilibrium with atmospheric SF_6 during recharge and is not subsequently exposed to significant SF_6 from other sources. Dissolved-gas analyses also were performed on samples of each well as part of the age-dating analysis to determine the average recharge temperature of the water in the aquifer (Appendix Gb). Wells were screened over several feet of aquifer sediment; therefore, the recharge date represents the average age of water withdrawn from the well. The reported age was calculated by averaging the SF_6 ages estimated from each of two samples collected from each well.

Water-quality data described in this report were collected from 30 public-supply wells sampled during August through November 2008. These data were compared to data from previous sampling conducted in 2000 (Ferrari, 2002) to analyze differences in samples from the 22 wells sampled during both periods. Results were grouped according to the type of chemicals and include: pesticides and degradate compounds, VOCs, nutrients, major ions and trace elements, radium and radon, and age-dating data. Complete data tables for the current study are provided in Appendixes A through F.

Table 1. Well-construction data for sampled public water-supply wells screened in the Columbia aquifer in Delaware during 2000 and 2008, and modeled ages of groundwater sampled in 2008.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; DNREC, Delaware Department of Natural Resources and Environmental Control; Resampled, 22 public water-supply wells sampled in 2000 and 2008; --, replaced by, public water-supply wells sampled only in 2000, not active in 2008; Replacement, 8 public water-supply wells sampled only in 2008]

Site number	USGS site identification number	DGS local well number	Well network	DNREC permit number	County	Year well constructed	Casing material	Depth of well (feet)	Diameter of well (inches)	Depth to top of screen (feet)	Depth to bottom of screen (feet)	Average age in 2008 (years)
1	382805075330301	Rd22-01	Resampled	66041	Sussex	1986	Plastic	60	2	52	60	25.5
2	382830075073601	Ri23-04	Resampled	106344	Sussex	1995	Plastic	82	6	70	80	23.7
3	383000075326001	Qd52-09	Resampled	78054	Sussex	1989	Plastic	70	4	60	70	20.5
4	383101075141101	Frankford4	Resampled	10342	Sussex	1934	Unknown	85	8	69	81	29.2
5	383311075344401	Qd21-12	Resampled	35239	Sussex	1975	Steel	100	12	70	100	22.7
--	383649075090801	Pot Nets #1	Replaced by Pi32-15	10651	Sussex	1972	Unknown	Unknown	6	Unknown	85	24.5
--	383705075192801	Forest Hills	Replaced by Pg31-12	10700	Sussex	1975	Unknown	110	4	Unknown	110	Unknown
6	383713075085501	Pi32-15	Replacement	10653	Sussex	1972	Unknown	90	6	75	85	21.8
7	383729075101601	Ph35-25	Replacement	63104	Sussex	1986	Unknown	58	8	58	73	21.3
8	383732075191301	Pg31-12	Replacement	35113	Sussex	1975	Plastic	73	12	53	73	16.1
--	383736075092801	Pi31-02(pn5)	Replaced by Ph35-25	49713	Sussex	1986	Steel	70	8	55	70	15.5
--	383801075375701	Pc33-44	Replaced by Pc22-06	10369	Sussex	1988	Unknown	Unknown	12	82	97	12.5
9	383815075271001	Pe23-185	Resampled	72060	Sussex	1987	Plastic	120	4	100	110	34.6
10	383823075382101	Pc22-06	Replacement	74465	Sussex	1988	Steel	103	16	63	103	19.5
11	383914075080501	Pi12-11	Replacement	75500	Sussex	1988	Plastic	68	4	58	68	18.1
--	383947075083401	Pi12-08	Replaced by Pi12-11	32247	Sussex	1974	Plastic	55	4	45	55	12.0
12	384139075230101	Of42-01	Resampled	10325	Sussex	1948	Unknown	120	6	Unknown	120	26.7
13	384322075051101	Oi25-18	Resampled	93955	Sussex	1993	Plastic	38	4	23	38	8.0
14	384326075050801	Oi25-19	Resampled	93496	Sussex	1992	Unknown	37	4	27	37	14.7
15	384428075135501	Oh12-07	Replacement	181528	Sussex	2001	Plastic	118	4	108	118	22.4
16	384428075355701	Oc15-11	Resampled	10319	Sussex	1955	Unknown	119	12	100	119	25.0
17	384526075091601	Ni51-32	Resampled	55833	Sussex	1984	Plastic	139	16	85	135	27.1
--	384530075121101	Nh53-01	Replaced by Oh12-07	30657	Sussex	2001	Steel	110	4	100	110	17.0
18	384818075354101	Nc25-37	Resampled	72714	Sussex	1988	Steel	63	12	40	63	18.1
19	384819075190101	Ng21-03	Resampled	71704	Sussex	1987	Plastic	111	4	91	111	25.2
20	384856075151101	Ng25-04	Resampled	97993	Sussex	1994	Plastic	139	8	99	139	33.7
21	385448075341801	Md11-04	Resampled	65911	Kent	1986	Unknown	70	10	50	70	21.7
22	385522075251802	Le55-09	Resampled	31756	Kent	1974	Steel	91	10	71	91	23.9

Table 1. Well-construction data for sampled public water-supply wells screened in the Columbia aquifer in Delaware during 2000 and 2008, and modeled ages of groundwater sampled in 2008.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; DNREC, Delaware Department of Natural Resources and Environmental Control; Resampled, 22 public water-supply wells sampled in 2000 and 2008; --, replaced by, public water-supply wells sampled only in 2000, not active in 2008; Replacement, 8 public water-supply wells sampled only in 2008]

Site number	USGS site identification number	DGS local well number	Well network	DNREC permit number	County	Year well constructed	Casing material	Depth of well (feet)	Diameter of well (inches)	Depth to top of screen (feet)	Depth to bottom of screen (feet)	Average age in 2008 (years)
23	390617075261901	Je55-01	Replacement	85416	Kent	1991	Plastic	65	4	55	65	Unknown
--	390619075290901	Je41-08	Replaced by Je55-01	10735	Kent	1955	Unknown	40	4	Unknown	40	9.5
24	390652075370701	Jc43-05	Resampled	82964	Kent	1990	Plastic	70	4	60	70	18.4
25	391060075282801	Ie42-03	Resampled	85022	Kent	1991	Steel	70	16	49	64	16.4
26	391747075364202	Hc34-03	Resampled	10068	Kent	1948	Steel	100	16	80	95	18.0
27	393739075394202	Dc31-15	Resampled	10434	New Castle	1960	Unknown	76	17	50	70	7.6
28	393916075440802	Db11-28	Resampled	10003	New Castle	1956	Unknown	62	10	31	62	5.8
29	393928075440202	Db11-27	Resampled	10004	New Castle	1956	Steel	66	10	41	62	7.3
--	394060075334601	Cd52-15	Replaced by Cd42-18	10045	New Castle	1960	Steel	74	17	50	73	6.0
30	394102075334301	Cd42-18	Replacement	10046	New Castle	1958	Unknown	104	17	56	104	Unknown

Pesticides and Pesticide Degradates

A variety of pesticides and pesticide degradates were detected in groundwater samples from the Columbia aquifer in the Coastal Plain in Delaware, although concentrations were typically less than 1 µg/L. Of the more than 80 pesticides and degradate compounds (48 and 35, respectively) for which samples were analyzed, 24 (14 pesticides and 10 degradates) were detected at least once (table 2, fig. 1b). No samples contained concentrations above the Federal drinking-water standards or MCLs, however, standards currently exist for only 5 of the 14 pesticide compounds detected (table 3) (U.S. Environmental Protection Agency, 2009). None of the degradate compounds have established criteria or guidelines (U.S. Environmental Protection Agency, 2009; Toccalino and others, 2004). Several additional pesticides and pesticide degradates were analyzed in the 2008 samples that were not included in the 2000 analyses (table 2).

The pesticides that were most frequently detected above the reporting limits in groundwater were herbicides typically used for local agricultural applications and their degradates (fig. 2). Atrazine and metolachlor, the most commonly detected parent compounds, were detected in more than 40 percent of the samples. The pesticide degradates metolachlor ESA, deethylatrazine, and alachlor ESA were detected in more than half of the samples. The ESA and oxanilic acid (OA) degradates of metolachlor and alachlor are more soluble than their respective parent compounds and move readily in groundwater with little additional degradation (Phillips and others, 1999). Debrewer and others (2007) found that in groundwater from the Delmarva Peninsula, pesticide degradates were detected more frequently and generally at higher concentrations (at least one order of magnitude higher) than their parent compounds, metolachlor, atrazine, and alachlor, respectively (table 3). Herbicides commonly used for non-agricultural purposes and insecticides were detected much less frequently than

Table 2. Pesticides and pesticide degradates for which groundwater samples from public water-supply wells were analyzed in the Columbia aquifer in Delaware, 2000 and 2008.

[Compounds detected in 2008 are in **bold**; pesticide degradates are listed in *italics*; **, compounds not measured in 2000; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide]

2,6-Diethylaniline	Chlorpyrifos	***Fipronil sulfone*****[1]	Parathion
2-[(2-Ethyl-6-methylphenyl)amino]-2-oxoESA**[1]	Cyanazine	Flufenacet	Parathion methyl
Acetochlor	*DCPA (Clorthal-dimethyl)*	*Flufenacet ESA*	**Pebulate**[2]
Acetochlor ESA	*Dechloroacetochlor*	*Flufenacet OA*	Pendimethalin
Acetochlor OA	*Dechloroalachlor*	Fonofos	*cis*-Permethrin
Acetochlor SA	*Dechlorodimethenyl amide*	Glufosinate	Phorate
Acetochlor SAA	*Dechlorometolachlor*	Glyphosate	**Prometon**[2]
Alachlor[2]	***Deethylatrazine (CIAT)***[2]	*Hydroxyacetochlor*	*Propachlor ESA*
Alachlor ESA[2]	*Desulfinylfipronil amide*	*Hydroxyalachlor*	*Propachlor OA*
Alachlor ESA SA**[1]	*Desulfinylfipronil*	*Hydroxydimethenamid*	Propachlor
Alachlor OA[2]	Diazinon	*Hydroxymetolachlor*	Propanil
Alachlor SA	**Dieldrin**[2]	**Lindane**[2]	Propargite
Alachlor SAA	Dimethenamid	Linuron	Propyzamide
alpha-HCH[1]	*Dimethenamid ESA*	Malathion	**Simazine**[2]
Aminomethylphosphonic acid**[1]	*Dimethenamid OA*	**Metolachlor**[2]	**Tebuthiuron**[2]
Atrazine[2]	Disulfoton	***Metolachlor ESA***[2]	Terbacil
Azinphos-methyl	**EPTC (Eptam)**[2]	***Metolachlor OA***[2]	Terbufos
Benfluralin	Ethalfluralin	Metribuzin	Thiobencarb
Butylate[2]	Ethoprop	Molinate	Triallate
Carbaryl[3]	**Fipronil****[1]	Napropamide	Trifluralin
Carbofuran[2]	***Fipronil sulfide*****[1]	*p,p'-DDE*[3]	

[1] Detected only in 2008.

[2] Detected in 2008 and 2000.

[3] Detected only in 2000.

Table 3. Summary statistics for pesticides and pesticide degradates detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.

[**, compounds not measured in 2000; pesticide degradates are in *italics*; LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; nd, no data; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; --, no standard or guideline established; µg/L, micrograms per liter; number of detections in **bold** are detections above the MCL or (HBSL), where established]

Compound	Network	Number of detections	Minumum (µg/L)	Median (µg/L)	Maximum (µg/L)	Number of detections ≥0.1 µg/L	MCL[1] or (HBSL[2,3])
			Agricultural herbicides				
Metolachlor	Total (2000)	19	E0.001	0.009	0.185	3	(700)
	Total (2008)	13	E0.003	<0.012	0.087	0	(700)
	Resampled (2000)	14	E0.001	0.008	0.185	3	(700)
	Resampled (2008)	12	E0.003	<0.01	0.087	0	(700)
Metolachlor ESA	Total (2000)	20	<0.05	0.23	2.92	18	--
	Total (2008)	24	<0.02	0.195	3.95	18	--
	Resampled (2000)	16	<0.05	0.23	2.92	14	--
	Resampled (2008)	18	<0.02	0.22	3.21	16	--
Metolachlor OA	Total (2000)	9	<0.05	<0.05	0.7	5	--
	Total (2008)	14	<0.02	<0.02	0.98	9	--
	Resampled (2000)	9	<0.05	<0.05	0.7	5	--
	Resampled (2008)	11	<0.02	<0.02	0.98	7	--
Atrazine	Total (2000)	15	<0.001	<0.007	0.862	4	3
	Total (2008)	14	E0.005	<0.007	0.488	2	3
	Resampled (2000)	11	<0.001	<0.001	0.862	4	3
	Resampled (2008)	11	E0.005	<0.007	0.488	2	3
Deethylatrazine (CIAT)	Total (2000)	21	<0.002	E0.013	E0.455	4	--
	Total (2008)	23	E0.002	<0.014	E0.195	3	--
	Resampled (2000)	15	<0.002	E0.014	E0.455	4	--
	Resampled (2008)	17	E0.002	<0.014	E0.195	3	--
Alachlor	Total (2000)	7	E0.006	<0.006	0.055	0	2
	Total (2008)	6	<0.002	<0.002	0.054	0	2
	Resampled (2000)	4	<0.002	<0.002	0.054	0	2
	Resampled (2008)	5	E0.006	<0.006	0.055	0	2
Alachlor ESA	Total (2000)	20	<0.05	0.11	1.6	17	--
	Total (2008)	21	<0.02	0.14	2.11	17	--
	Resampled (2000)	15	<0.05	0.17	1.6	13	--
	Resampled (2008)	17	<0.02	0.17	2.09	14	--
Alachlor OA	Total (2000)	2	<0.05	<0.05	0.28	2	--
	Total (2008)	11	<0.02	<0.02	0.2	3	--
	Resampled (2000)	2	<0.05	<0.05	0.28	2	--
	Resampled (2008)	9	<0.02	<0.02	0.2	3	--

Table 3. Summary statistics for pesticides and pesticide degradates detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[**, compounds not measured in 2000; pesticide degradates are in *italics*; LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; nd, no data; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; --, no standard or guideline established; µg/L, micrograms per liter; number of detections in **bold** are detections above the MCL or (HBSL), where established]

Compound	Network	Number of detections	Minumum (µg/L)	Median (µg/L)	Maximum (µg/L)	Number of detections ≥0.1 µg/L	MCL[1] or (HBSL[2,3])
*Alachlor ESA SA***	Total (2000)	nd	nd	nd	nd	nd	--
	Total (2008)	4	0.02	<0.02	0.04	0	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	3	0.02	<0.02	0.04	0	--
*2-[(2-Ethyl-6-methylphenyl) amino]-2-oxoESA***	Total (2000)	nd	nd	nd	nd	nd	--
	Total (2008)	8	0.02	<0.02	0.39	1	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	8	0.02	<0.02	0.39	1	--
Fipronil**	Total (2000)	nd	nd	nd	nd	nd	--
	Total (2008)	7	E0.003	<0.02	<0.04	0	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	6	E0.003	<0.02	<0.04	0	--
*Fipronil sulfide***	Total (2000)	nd	nd	nd	nd	nd	--
	Total (2008)	1	E0.003	<0.013	<0.013	0	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	1	E0.003	<0.013	<0.013	0	--
*Fipronil sulfone***	Total (2000)	nd	nd	nd	nd	nd	--
	Total (2008)	4	E0.002	<0.024	<0.024	0	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	3	E0.002	<0.024	<0.024	0	--
Aminomethylphosphonic acid**	Total (2000)	nd	nd-	nd	nd	nd	--
	Total (2008)	4	<0.02	<0.02	0.28	1	--
	Resampled (2000)	nd	nd	nd	nd	nd	--
	Resampled (2008)	2	<0.02	<0.02	0.28	1	--
Lindane	Total (2000)	3	E0.002	<0.004	0.009	0	0.2
	Total (2008)	1	E0.006	<0.006	<0.014	0	0.2
	Resampled (2000)	3	E0.002	<0.004	0.009	0	0.2
	Resampled (2008)	1	E0.006	<0.006	<0.014	0	0.2
Butylate	Total (2000)	1	<0.002	<0.002	0.01	0	(400)
	Total (2008)	1	<0.002	<0.002	0.002	0	(400)
	Resampled (2000)	1	<0.002	<0.002	0.01	0	(400)
	Resampled (2008)	1	<0.002	<0.002	0.002	0	(400)

Table 3. Summary statistics for pesticides and pesticide degradates detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[**, compounds not measured in 2000; pesticide degradates are in *italics*; LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; nd, no data; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; --, no standard or guideline established; µg/L, micrograms per liter; number of detections in **bold** are detections above the MCL or (HBSL), where established]

Compound	Network	Number of detections	Minumum (µg/L)	Median (µg/L)	Maximum (µg/L)	Number of detections ≥0.1 µg/L	MCL[1] or (HBSL[2,3])
Alpha HCH**	Total (2000)	nd	nd	nd	nd	nd	(0.006-0.6)
	Total (2008)	1	<0.002	<0.002	<0.008	0	(0.006-0.6)
	Resampled (2000)	nd	nd	nd	nd	nd	(0.006-0.6)
	Resampled (2008)	1	<0.002	<0.002	<0.008	0	(0.006-0.6)
EPTC (Eptam)	Total (2000)	1	<0.002	<0.002	0.018	0	(200)
	Total (2008)	1	<0.002	<0.002	0.009	0	(200)
	Resampled (2000)	1	<0.002	<0.002	0.018	0	(200)
	Resampled (2008)	1	<0.002	<0.002	0.009	0	(200)
Pebulate	Total (2000)	1	<0.002	<0.004	0.004	0	(50)
	Total (2008)	1	<0.004	<0.004	<0.016	0	(50)
	Resampled (2000)	1	<0.002	<0.004	0.004	0	(50)
	Resampled (2008)	1	<0.004	<0.004	<0.016	0	(50)
Urban herbicides							
Simazine	Total (2000)	9	E0.004	<0.005	0.019	0	4
	Total (2008)	8	E0.004	<0.006	0.032	0	4
	Resampled (2000)	7	E0.004	<0.005	0.019	0	4
	Resampled (2008)	6	E0.004	<0.006	0.032	0	4
Prometon	Total (2000)	10	E0.003	<0.018	0.149	1	(400)
	Total (2008)	7	E0.005	0.009	0.049	1	(400)
	Resampled (2000)	9	E0.003	<0.018	0.149	1	(400)
	Resampled (2008)	6	E0.005	<0.008	0.049	1	(400)
Tebuthiuron	Total (2000)	6	E0.007	<0.01	0.039	0	(1,000)
	Total (2008)	4	<0.016	<0.016	0.047	0	(1,000)
	Resampled (2000)	4	E0.007	<0.01	0.039	0	(1,000)
	Resampled (2008)	4	<0.016	<0.016	0.047	0	(1,000)
Insecticides							
Dieldrin	Total (2000)	**9**	<0.001	<0.003	0.106	2	(0.002-0.2)
	Total (2008)	**9**	<0.009	<0.009	0.084	0	(0.002-0.2)
	Resampled (2000)	**7**	<0.001	<0.001	0.088	2	(0.002-0.2)
	Resampled (2008)	**8**	<0.009	<0.009	0.084	0	(0.002-0.2)
Carbofuran	Total (2000)	6	<0.003	<0.003	E0.17	4	40
	Total (2008)	3	E0.017	<0.02	<0.06	0	40
	Resampled (2000)	4	<0.003	<0.003	E0.17	3	40
	Resampled (2008)	3	E0.017	<0.02	<0.06	0	40

Table 3. Summary statistics for pesticides and pesticide degradates detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[**, compounds not measured in 2000; pesticide degradates are in *italics*; LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; nd, no data; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; --, no standard or guideline established; µg/L, micrograms per liter; number of detections in **bold** are detections above the MCL or (HBSL), where established]

Compound	Network	Number of detections	Minumum (µg/L)	Median (µg/L)	Maximum (µg/L)	Number of detections ≥0.1 µg/L	MCL[1] or (HBSL[2,3])
Carbaryl	Total (2000)	1	<0.003	<0.003	<0.041	0	(40-4,000)
	Total (2008)	0	<0.06	<0.06	<0.2	0	(40-4,000)
	Resampled (2000)	1	<0.003	<0.003	<0.041	0	(40-4,000)
	Resampled (2008)	0	<0.06	<0.06	<0.2	0	(40-4,000)
p,p'-DDE	Total (2000)	1	E0.001	<0.006	<0.006	0	(0.1-10)
	Total (2008)	0	<0.003	<0.003	<0.003	0	(0.1-10)

[1] U.S. Environmental Protection Agency, 2009.

[2] Toccalino and others, 2004.

[3] Toccalino and others, 2008.

agricultural herbicides. Only the urban herbicides prometon and simazine and the insecticide dieldrin were detected in more than 15 percent of these samples (fig. 2).

Of the 10 detected compounds for which non-regulatory health-based guidelines exist (Toccalino and others, 2004), 1 pesticide, dieldrin, exceeded the HBSL of 0.002 µg/L in all 9 samples from urbanized areas. Dieldrin is an insecticide that was primarily used for termite control, and its use was banned in most of the world, including Delaware, in 1978 (U.S. Environmental Protection Agency, 2003). It was originally developed in the 1940s as an alternative to DDT, and proved to be highly effective; it was very widely used from the 1950s to the early 1970s. It is resistant to degradation and tends to biomagnify in food webs (U.S. Department of Health and Human Services, 2002). Long-term exposure has proven toxic to humans and a very wide range of animals.

The occurrence and distribution of pesticide and pesticide degradate compounds and the number of detections in the Columbia aquifer in Delaware did not change significantly from 2000 to 2008 (figs. 1b and 2). A similar distribution was found between numbers of compounds detected in the three pesticide groups between 2000 and 2008 (fig. 2). Almost 80 percent of the detected compounds were agricultural herbicides, such as metolachlor and atrazine, or their respective degradates. These chemicals have been used for over 25 years in the study area (Debrewer and others, 2007; Denver and others, 2004). The predominance of the agricultural herbicides among the pesticides detected in groundwater reflects the prevalence and wide distribution of agriculture in sampled areas (fig. 1b), as well as the dominance of agricultural herbicides among the target analytes (table 2) (Denver and Ator, 2006). Ferrari (2002) noted the same pattern, where 63 percent (12 of 19) of the detected compounds were agricultural herbicides. Debrewer and others (2007) noted that atrazine and metolachlor concentrations in groundwater in the Delmarva Peninsula increased with an increasing proportion of agriculture near sampled wells.

Pesticides commonly used in urban areas, such as dieldrin, prometon, simazine, and tebuthiuron, were detected in nine wells from mainly urban areas, particularly in the northern part of the study area (fig. 1b). Rapid urban expansion in the areas directly north and south of the C&D Canal resulted in conversion of much of the remaining agricultural land to residential and commercial uses (Blaier and Baxter, 2000) (fig. 1b).

When present, pesticides commonly occur in mixtures in groundwater (Denver and Ator, 2006; Ator and Reyes, 2008). Mixtures of pesticides and pesticide degradates were found in 90 percent of the 30 wells sampled (from 2 to 20 pesticide compounds detected per well); two wells had one detection, and only one well (Pi12-11), a replacement well, had no detections (Appendixes D and E). The prevalence of pesticide mixtures in groundwater reflects similar patterns in usage; multiple compounds are often applied to the same area, often in mixed formulations, for greater pest control. In addition, many pesticides have similar chemical properties that control their fate and movement in the environment (Denver and Ator, 2006). The wells with one or no detectable pesticides are located either in predominantly forested areas, areas with poorly drained soils, or areas with highly organic soils that can limit (tend to adsorb) pesticide movement to groundwater.

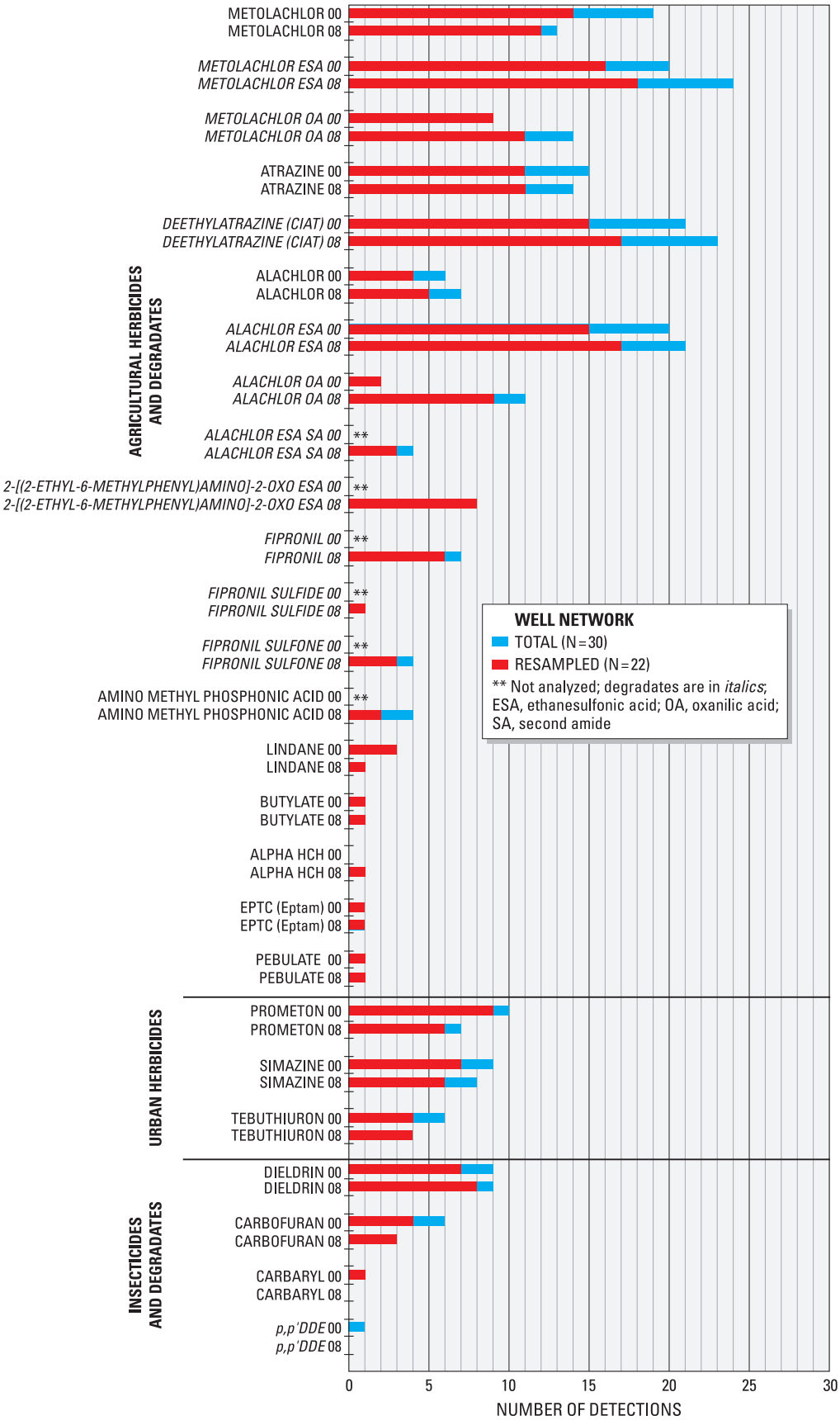

Figure 2. Pesticides and pesticide degradates in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, 2000 and 2008.

The widespread detection and distribution of pesticide compounds during 2000 and 2008 reflects their abundant use in Delaware, and is indicative of their chemical properties such as moderate to high water solubility and persistence. Aquifer characteristics, such as good soil drainage and sandy aquifer sediments, promote the movement of pesticides into groundwater (Debrewer and others, 2007). The relative magnitude of concentrations of selected degradates and parent compounds in Columbia aquifer groundwater reflects the fact that most pesticide degradation occurs in the soil zone, before infiltration reaches the water table (Barbash and Resek, 1996). Excluding metolachlor and lindane, the number of pesticides or degradate compounds detected per well increased or remained the same over the study period in more than 75 percent of the samples from the 22 resampled wells. A slight decrease in the number of pesticide or degradate detections occurred in four wells, and one well had the same number of detections as in 2000 (fig. 1b).

Groundwater responds more slowly than streams to changes in pesticide use—taking years and even decades for changes in quality to occur (Gilliom and others, 2006). A persistent pesticide or degradate can remain in groundwater long after its use has been discontinued or replaced because of the slow rates of groundwater flow and the resulting long residence time of water and contaminants in groundwater flow systems. This is evident from a number of studies in different parts of the U.S. (Gilliom and others, 2006; Denver and Ator, 2006). The effect of groundwater residence time on the occurrence of pesticides is further demonstrated by the detection of legacy compounds such as dieldrin and alachlor in groundwater (table 3, fig. 2). These pesticides either had their registration cancelled or they were replaced by other compounds many years ago, but they are still present nationwide in soils, streams, and groundwater (Gilliom and others, 2006).

Volatile Organic Compounds

In 2008, 29 of 30 wells had 1 or more VOCs detected; 3 wells had 10 VOCs detected (fig. 3). Out of the 85 VOCs analyzed in this study, 31 different VOCs were detected in at least one well (table 4). VOCs were divided into seven groups on the basis of common usage (Zogorski and others, 2006): Trihalomethanes (THMs; common by-products of water chlorination), solvents, gasoline oxygenates, gasoline hydrocarbons, refrigerants, fumigants, and organic synthesis compounds (compounds used in the formation of other organic compounds) (fig. 4). Chloroform, one of the THMs, was the most frequently detected VOC compound (90 percent of samples) and its source is attributed, in part, to the recycling of chlorinated waters to aquifers (Zogorski and others, 2006). The gasoline oxygenate methyl *tert*-butyl ether (MTBE) was the second most frequently detected VOC, in more than 60 percent of the samples. The solvents tetrachloroethene (or perchloroethene/PCE) and trichloroethylene (TCE) were the third and fourth most frequently detected VOCs, and were found in more than 35 and 25 percent of the samples, respectively. Zogorski and others (2006) also detected the same VOCs most frequently during their study of the Nation's groundwater and drinking water.

None of the VOC detections were above Federal drinking-water standards, although only 16 out of the 85 VOCs have established MCLs (table 5) (U.S. Environmental Protection Agency, 2009). Concentrations of eight detected VOC compounds that have non-regulatory health-based guidelines were all below levels of concern (Toccalino and others, 2004).

Overall, the concentrations of each VOC and the total concentration of all VOCs in a group were less than 1 µg/L. Solvents and THMs were the most common groups of compounds detected. Detection frequency of VOCs in groundwater is an important indicator of water quality in occurrence assessments (Zogorski and others, 2006). In order to compare detection frequencies for individual VOCs, groups of VOCs, or VOC data from different agencies with different reporting levels, Zogorski and others (2006) applied an assessment level of 0.2 µg/L, which was used in a similar manner in this report. An assessment level is a fixed concentration used as the basis for computing detection frequencies. Out of the 30 samples, 23 contained one or more VOCs at 0.2 µg/L or greater concentrations. Less than half, about 45 percent, of all VOCs detected (117 = total number of detections, see table 5) had concentrations above 0.2 µg/L. At the same assessment level and within each VOC group, MTBE and chloroform were the most frequently detected compounds above 0.2 µg/L. From the gasoline oxygenate detections (25), MTBE accounted for 56 percent, and from the THM detections (33), chloroform accounted for 36 percent (table 5).

The detections of specific compounds and the frequency of their detection in 2008 were similar to detections in 2000 (fig. 4; Ferrari, 2002). Solvents were the most frequently detected class of compounds, and chloroform, PCE, and MTBE, which were detected in 50 percent or more of samples in 2000, were the most frequently detected in 2008 as well (fig. 4). There were some differences in the compounds detected between the two sampling periods (table 5, fig. 4) but these differences were only evident in samples from one well.

Although there were no significant differences in VOC concentrations between the study periods, the difference in the mean number of VOCs detected per well decreased significantly ($p<0.002$) (fig. 3, inset). The number of VOC detections in 2008 decreased in 73 percent of the 22 resampled wells—from one to eight fewer detections than in 2000.

VOC contamination in aquifers is complex. VOC occurrence is determined not only by sources but also by natural factors or a mix of natural and anthropogenic factors that affect the fate and transport of VOCs in aquifers (Zogorski and others, 2006). VOCs are groundwater contaminants of concern because of very large environmental releases, human toxicity, and the tendency for some compounds to persist and migrate to drinking-water supply wells (Zogorski and others, 2006). The finding that one or more VOCs were detected in

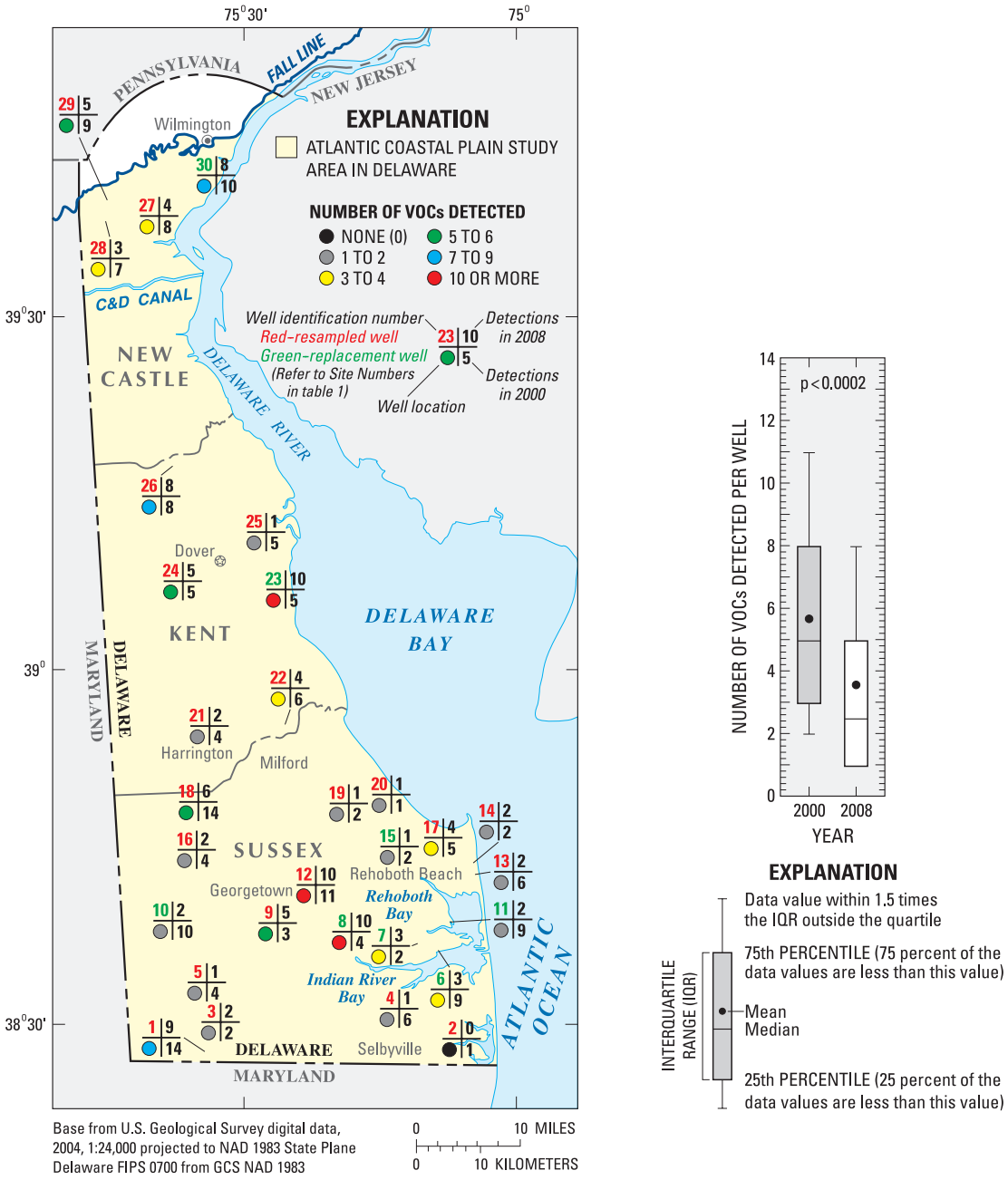

Figure 3. Locations of public water-supply wells sampled in 2008 in the Columbia aquifer in Delaware and comparison of volatile organic compound (VOC) detection frequencies in groundwater, 2000 and 2008.

Table 4. Volatile organic compounds for which groundwater samples from public water-supply wells were analyzed in the Columbia aquifer in Delaware, 2000 and 2008.

[Compounds detected in 2008 are in **bold**]

1,1,1-Trichloroethane[2]	Bromobenzene	Isodurene
1,1,2,2-Tetrachloroethane	Bromochloromethane	Isopropylbenzene[3]
1,1,2-Trichloroethane	**Bromodichloromethane**[2]	*m* and *p*-Xylene
1,1,2-Trichlorotrifluoromethane (CFC-113)[3]	Bromoethene	Methacrylonitrile
1,1-Dichloroethane[2]	**Bromoform (Tribromomethane)**[2]	Methyl acrylate
1,1-Dichloroethene[2]	Bromomethane	**Methyl ethyl ketone**[1]
1,2,4-Trichlorobenzene[1]	Butylmethylketone	Methyl methacrylate
1,2-Dibromoethane	**Carbon disulfide**[2]	**Methyl *tert*-pentyl ether**[2]
1,2-Dichlorobenzene[2]	**Carbon tetrachloride**[2]	**Methyl *tert*-butyl ether (MTBE)**[2]
1,2-Dichloroethane[3]	**Chlorobenzene**[2]	Naphthalene
1,2-Dichloropropane[2]	Chloroethane	*n*-butylbenzene
1,3-Dichlorobenzene[1]	**Chloroform (Trichloromethane)**[2]	*n*-propylbenzene
1,4-Dichlorobenzene[2]	**Chloromethane**[2]	*o*-Xylene
1,1,1,2-Tetrachloroethane	*cis*-1,3-Dichloropropene	*p*-Isopropyltoluene[3]
1,1-Dichloropropene	***cis*-1,2-Dichloroethene**[2]	Prehnitene (1,2,3,4-tetramethylbenzene)
1,2,3-Trichlorobenzene	**Dibromochloromethane**[2]	***sec*-butylbenzene**[2]
1,2,3-Trichloropropane	Dibromochloropropane	**Styrene**[1]
1,2,3-Trimethylbenzene	Dibromomethane	*tert*-Butylbenzene[3]
1,2,4-Trimethylbenzene	**Dichlorodifluoromethane (CFC-12)**[2]	**Tetrachloroethene (PCE)**[2]
1,3,5-Trimethylbenzene	**Dichloromethane**[2]	**Tetrahydrofuran**[2]
1,3-Dichloropropane	Diethyl ether	**Trichlorofluoromethane (CFC-11)**[2]
2,2-Dichloropropane	**Diisopropyl ether**[2]	**Toluene**[2]
2-Chlorotoluene	Ethyl benzene	*trans*-1,4-Dichloro-2-butene
2-Ethyltoluene	Ethyl methacrylate	*trans*-1,2-Dichloroethene
3-Chloropropene	Ethyl *tert*-butyl ether[3]	*trans*-1,3-Dichloropropene
4-Chlorotoluene	Hexachlorobutadiene	**Trichloroethene (TCE)**[2]
Acetone[3]	Hexachloroethane	Vinyl chloride
Acrylonitrile	Iodomethane	
Benzene[2]	Isobutylmethylketone	

[1] Detected only in 2008.

[2] Detected in 2008 and 2000.

[3] Detected only in 2000.

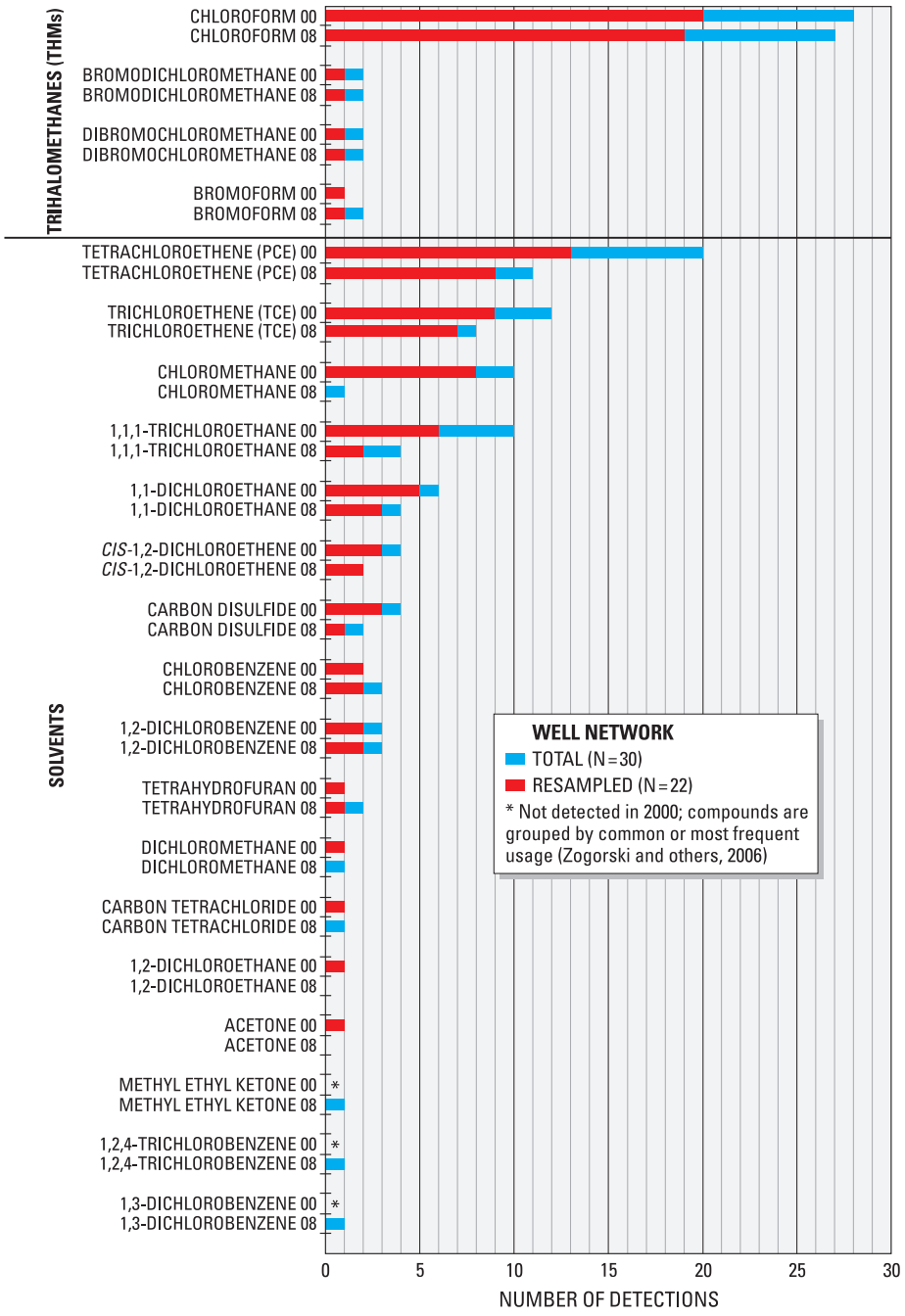

Figure 4. Volatile organic compounds (VOCs) detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, 2000 and 2008.

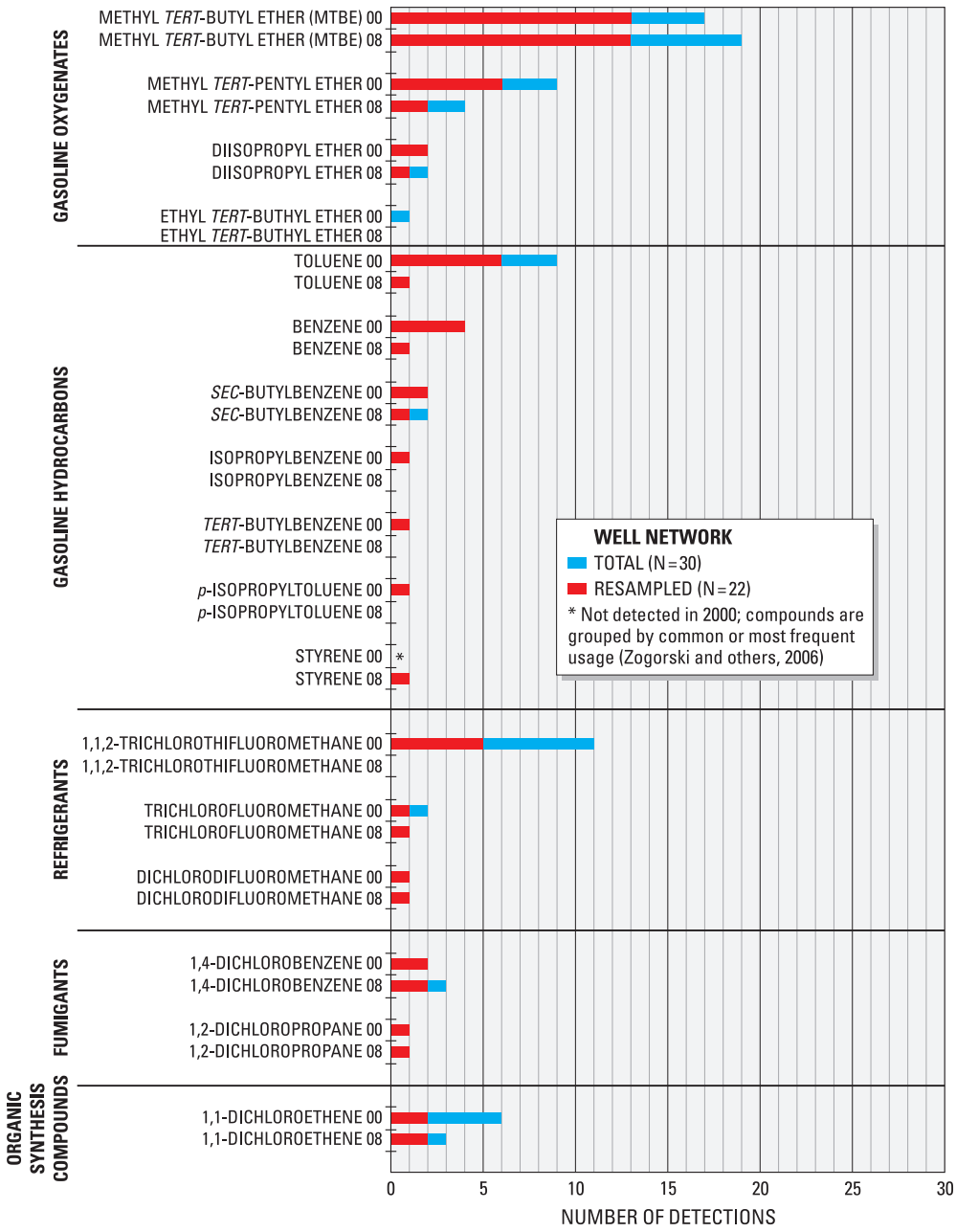

Figure 4. Volatile organic compounds (VOCs) detected in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, 2000 and 2008.—Continued

Table 5. Summary statistics for volatile organic compounds in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; *, MCL set forth by the Delaware Division of Public Health; HBSL, Health-Based Screening Level; µg/L, micrograms per liter; --, no standard or guideline established, none detected above the MCL or (HBSL), where established]

Compound groups[6]	Network	Number of detections	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	MCL[1] or (HBSL[2,3])	Assessment Level	
							<0.2 µg/L	≥0.2 µg/L
Trihalomethanes (THMs)								
Chloroform (Trichloromethane)	Total (2000)	28	E0.885	0.123	3.846	80[4]		
	Total (2008)	27	E0.02	0.118	1.126	80[4]	15	12
	Resampled (2000)	20	E0.885	E0.073	0.621	80[4]		
	Resampled (2008)	19	<0.02	E0.091	0.63	80[4]		
Bromodichloromethane	Total (2000)	2	<0.048	<0.048	0.233	80[4]		
	Total (2008)	2	<0.04	<0.04	0.371	80[4]	0	2
	Resampled (2000)	1	<0.048	<0.048	0.134	80[4]		
	Resampled (2008)	1	<0.04	<0.04	0.371	80[4]		
Dibromochloromethane	Total (2000)	2	E0.104	<0.18	<0.18	80[4]		
	Total (2008)	2	<0.12	<0.12	0.769	80[4]	0	2
	Resampled (2000)	1	E0.104	<0.18	<0.18	80[4]		
	Resampled (2008)	1	<0.12	<0.12	0.769	80[4]		
Bromoform (Tribromomethane)	Total (2000)	1	E0.051	<0.06	<0.06	80[4]		
	Total (2008)	2	<0.08	<0.08	0.632	80[4]	0	2
	Resampled (2000)	1	E0.051	<0.06	<0.06	80[4]		
	Resampled (2008)	1	<0.08	<0.08	0.632	80[4]		
Group detections (n=30, 2008)		33					15	18
Solvents								
Tetrachloroethene (PCE)	Total (2000)	20	E0.42	<0.1	1.911	5		
	Total (2008)	11	E0.026	<0.04	1.616	5	4	7
	Resampled (2000)	13	E0.468	<0.1	1.911	5		
	Resampled (2008)	9	E0.026	<0.04	1.616	5		
Trichloroethene (TCE)	Total (2000)	12	E0.012	<0.038	0.81	5		
	Total (2008)	8	E0.015	<0.02	0.581	5	5	3
	Resampled (2000)	9	E0.012	<0.038	0.81	5		
	Resampled (2008)	7	E0.015	<0.02	0.581	5		
Chloromethane	Total (2000)	10	E0.028	<0.25	<0.5	--		
	Total (2008)	1	E0.042	<0.1	<0.14	--	1	0
	Resampled (2000)	8	E0.028	<0.5	<0.5	--		
	Resampled (2008)	0	<0.1	<0.1	<0.14	--		
1,1,1-Trichloroethane	Total (2000)	10	E0.79	<0.032	2.437	200		
	Total (2008)	4	<0.02	<0.02	1.102	200	3	1
	Resampled (2000)	6	E0.79	<0.032	2.437	200		
	Resampled (2008)	2	<0.02	<0.02	1.102	200		

Table 5. Summary statistics for volatile organic compounds in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; *, MCL set forth by the Delaware Division of Public Health; HBSL, Health-Based Screening Level; µg/L, micrograms per liter; --, no standard or guideline established, none detected above the MCL or (HBSL), where established]

Compound groups[6]	Network	Number of detections	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	MCL[1] or (HBSL[2,3])	Assessment Level	
							<0.2 µg/L	≥0.2 µg/L
Solvents—Continued								
1,1-Dichloroethane	Total (2000)	6	E0.015	<0.066	0.149	--		
	Total (2008)	4	<0.04	<0.04	0.135	--	4	0
	Resampled (2000)	5	E0.015	<0.066	0.149	--		
	Resampled (2008)	3	<0.04	<0.04	0.135	--		
*cis*1,2-Dichloroethene	Total (2000)	4	E0.017	<0.038	E0.082	70		
	Total (2008)	2	<0.02	<0.02	1.268	70	1	1
	Resampled (2000)	3	E0.017	<0.038	E0.082	70		
	Resampled (2008)	2	<0.02	<0.02	1.268	70		
Carbon disulfide	Total (2000)	4	E0.018	<0.07	<0.07	(700)		
	Total (2008)	2	<0.04	<0.06	E0.065	(700)	2	0
	Resampled (2000)	3	E0.026	<0.07	<0.07	(700)		
	Resampled (2008)	1	<0.04	<0.06	<0.06	(700)		
Chlorobenzene	Total (2000)	2	<0.028	<0.028	0.488	1		
	Total (2008)	3	<0.02	<0.02	0.14	1	3	0
	Resampled (2000)	2	<0.028	<0.028	0.488	1		
	Resampled (2008)	2	<0.02	<0.02	0.14	1		
1,2-Dichlorobenzene	Total (2000)	3	<0.031	<0.048	1.466	6		
	Total (2008)	3	<0.02	<0.02	0.357	6	2	1
	Resampled (2000)	2	<0.031	<0.048	1.466	6		
	Resampled (2008)	2	<0.02	<0.02	0.357	6		
Tetrahydrofuran	Total (2000)	1	<2.2	<2.2	9.787	--		
	Total (2008)	2	E0.303	<1.4	2.113	--	0	2
	Resampled (2000)	1	<2.2	<2.2	9.787	--		
	Resampled (2008)	1	<1.4	<1.4	2.113	--		
Dichloromethane	Total (2000)	1	E0.018	<0.38	<0.38	5		
	Total (2008)	1	E0.016	<0.04	<0.04	5	1	0
	Resampled (2000)	1	E0.018	<0.38	<0.38	5		
	Resampled (2008)	0	E0.022	<0.04	<0.04	5		
Carbon tetrachloride	Total (2000)	1	E0.026	<0.06	<0.06	5		
	Total (2008)	1	E0.02	<0.08	<0.08	5	1	0
	Resampled (2000)	1	E0.026	<0.06	<0.06	5		
	Resampled (2008)	0	<0.06	<0.08	<0.08	5		
1,2-Dichloroethane	Total (2000)	1	<0.13	<0.13	0.133	5		
	Total (2008)	0	<0.06	<0.06	<0.06	5	0	0
	Resampled (2000)	1	<0.13	<0.13	0.133	5		
	Resampled (2008)	0	<0.06	<0.06	<0.06	5		

Table 5. Summary statistics for volatile organic compounds in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; *, MCL set forth by the Delaware Division of Public Health; HBSL, Health-Based Screening Level; µg/L, micrograms per liter; --, no standard or guideline established, none detected above the MCL or (HBSL), where established]

Compound groups[6]	Network	Number of detections	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	MCL[1] or (HBSL[2,3])	Assessment Level	
							<0.2 µg/L	≥0.2 µg/L
Solvents—Continued								
Acetone	Total (2000)	1	E5.829	<7	<7	(6,000)		
	Total (2008)	0	<4	<4	<4	(6,000)	0	0
	Resampled (2000)	1	E5.829	<7	<7	(6,000)		
	Resampled (2008)	0	<4	<4	<4	(6,000)		
Methyl ethyl ketone	Total (2000)	0	<1.6	<1.6	<1.6	(4,000)		
	Total (2008)	1	E0.441	<1.6	<1.6	(4,000)	0	1
	Resampled (2000)	0	<1.6	<1.6	<1.6	(4,000)		
	Resampled (2008)	0	<1.6	<1.6	<1.6	(4,000)		
1,2,4-Trichlorobenzene	Total (2000)	0	<0.19	<0.19	<0.19	70		
	Total (2008)	1	E0.037	<0.08	<0.08	70	1	0
	Resampled (2000)	0	<0.19	<0.19	<0.19	70		
	Resampled (2008)	0	<0.04	<0.08	<0.08	70		
1,3-Dichlorobenzene	Total (2000)	0	<0.03	<0.054	<0.054	(600)		
	Total (2008)	1	<0.02	<0.04	0.166	(600)	1	0
	Resampled (2000)	0	<0.03	<0.054	<0.054	(600)		
	Resampled (2008)	0	<0.02	<0.04	<0.04	(600)		
Group detections (n=30, 2008)		45					29	16
Gasoline oxygenates								
Methyl *tert*-butyl ether (MTBE)	Total (2000)	17	E0.048	0.204	12.03	10*[5]		
	Total (2008)	19	E0.028	0.117	2.554	10*[5]	5	14
	Resampled (2000)	13	E0.048	0.313	8.6	10*[5]		
	Resampled (2008)	13	E0.096	0.17	2.554	10*[5]		
Methyl *tert*-pentyl ether	Total (2000)	9	E0.036	<0.11	0.437	--		
	Total (2008)	4	E0.031	<0.06	E0.086	--	4	0
	Resampled (2000)	6	E0.044	<0.11	0.251	--		
	Resampled (2008)	2	<0.06	<0.06	E0.086	--		
Diisopropylether	Total (2000)	2	E0.053	<0.1	0.467	--		
	Total (2008)	2	E0.034	<0.06	E0.091	--	2	0
	Resampled (2000)	2	E0.053	<0.1	0.467	--		
	Resampled (2008)	1	<0.06	<0.06	E0.091	--		
Ethyl *tert*-butyl ether	Total (2000)	1	<0.054	<0.054	0.364	--		
	Total (2008)	0	<0.04	<0.04	<0.04	--	0	0
	Resampled (2000)	0	<0.054	<0.054	<0.054	--		
	Resampled (2008)	0	<0.04	<0.04	<0.04	--		
Group detections (n=30, 2008)		25					11	14

Table 5. Summary statistics for volatile organic compounds in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

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Compound groups[6]	Network	Number of detections	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	MCL[1] or (HBSL[2,3])	Assessment Level	
							<0.2 µg/L	≥0.2 µg/L
Gasoline hydrocarbons								
Toluene	Total (2000)	9	E0.698	<0.05	<0.05	1,000		
	Total (2008)	1	<0.018	<0.02	E0.036	1,000	1	0
	Resampled (2000)	6	E0.698	<0.05	<0.05	1,000		
	Resampled (2008)	1	<0.018	<0.02	E0.036	1,000		
Benzene	Total (2000)	4	E0.011	<0.035	0.293	5		
	Total (2008)	1	<0.016	<0.02	0.14	5	1	0
	Resampled (2000)	4	E0.011	<0.035	0.293	5		
	Resampled (2008)	1	<0.016	<0.02	0.14	5		
sec-Butylbenzene	Total (2000)	2	E0.875	<0.032	0.235	--		
	Total (2008)	2	E0.014	<0.04	E0.099	--	2	0
	Resampled (2000)	2	E0.875	<0.032	0.235	--		
	Resampled (2008)	1	<0.02	<0.04	E0.099	--		
Isopropylbenzene	Total (2000)	1	E0.871	<0.032	<0.032	(700)		
	Total (2008)	0	<0.04	<0.04	<0.04	(700)	0	0
	Resampled (2000)	1	E0.871	<0.032	<0.032	(700)		
	Resampled (2008)	0	<0.04	<0.04	<0.04	(700)		
tert-butylbenzene	Total (2000)	1	E0.045	<0.06	<0.06	--		
	Total (2008)	0	<0.06	<0.06	<0.06	--	0	0
	Resampled (2000)	1	E0.045	<0.06	<0.06	--		
	Resampled (2008)	0	<0.06	<0.06	<0.06	--		
p-Isopropyltoluene	Total (2000)	1	E0.583	<0.07	<0.07	--		
	Total (2008)	0	<0.06	<0.08	<0.08	--	0	0
	Resampled (2000)	1	E0.583	<0.07	<0.07	--		
	Resampled (2008)	0	<0.06	<0.08	<0.08	--		
Styrene	Total (2000)	0	<0.042	<0.042	<0.042	100		
	Total (2008)	1	<0.04	<0.04	0.257	100	0	1
	Resampled (2000)	0	<0.042	<0.042	<0.042	100		
	Resampled (2008)	1	<0.04	<0.04	0.257	100		
Group detections (n=30, 2008)		5					4	1
Refrigerants								
1,1,2-Trichlorotrifluoromethane (CFC-113)	Total (2000)	11	E0.016	<0.06	0.233	(200,000)		
	Total (2008)	0	<0.04	<0.04	<0.042	(200,000)	0	0
	Resampled (2000)	5	E0.022	<0.06	0.233	(200,000)		
	Resampled (2008)	0	<0.04	<0.04	<0.042	(200,000)		

Table 5. Summary statistics for volatile organic compounds in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels and Health-Based Sceening Levels in 2000 and 2008.—Continued

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; ≥, greater than or equal to; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; *, MCL set forth by the Delaware Division of Public Health; HBSL, Health-Based Screening Level; µg/L, micrograms per liter; --, no standard or guideline established, none detected above the MCL or (HBSL), where established]

Compound groups[6]	Network	Number of detections	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	MCL[1] or (HBSL[2,3])	Assessment Level	
							<0.2 µg/L	≥0.2 µg/L
Refrigerants—Continued								
Trichlorofluoromethane (CFC-11)	Total (2000)	2	E0.015	<0.09	0.155	(2,000)		
	Total (2008)	1	E0.02	<0.08	<0.08	(2,000)	1	0
	Resampled (2000)	1	<0.09	<0.09	0.155	(2,000)		
	Resampled (2008)	1	E0.02	<0.08	<0.08	(2,000)		
Dichlorodifluoromethane (CFC-12)	Total (2000)	1	<0.27	<0.27	E1.618	(1,000)		
	Total (2008)	1	<0.1	<0.14	E1.327	(1,000)	0	1
	Resampled (2000)	1	<0.27	<0.27	E1.618	(1,000)		
	Resampled (2008)	1	<0.1	<0.14	E1.327	(1,000)		
Group detections (n=30, 2008)		2					1	1
Fumigants								
1,4-Dichlorobenzene	Total (2000)	2	E0.018	<0.05	0.511	75		
	Total (2008)	3	<0.02	<0.02	0.237	75	2	1
	Resampled (2000)	2	E0.018	<0.05	0.511	75		
	Resampled (2008)	2	<0.02	<0.02	0.187	75		
1,2-Dichloropropane	Total (2000)	1	<0.029	<0.068	E0.073	5		
	Total (2008)	1	<0.02	<0.02	E0.071	5	1	0
	Resampled (2000)	1	<0.029	<0.068	E0.073	5		
	Resampled (2008)	1	<0.02	<0.02	E0.071	5		
Group detections (n=30, 2008)		4					3	1
Organic synthesis compounds								
1,1-Dichloroethene	Total (2000)	6	E0.942	<0.04	0.498	7		
	Total (2008)	3	<0.02	<0.02	0.236	7	2	1
	Resampled (2000)	2	E0.036	<0.04	0.498	7		
	Resampled (2008)	2	<0.02	<0.02	0.236	7		
Group detections (n=30, 2008)		3					2	1
Total VOC detections, among 30 wells		117					65	52

[1] U.S. Environmental Protection Agency, 2009.

[2] Toccalino and others, 2004.

[3] Toccalino and others, 2008.

[4] MCL is for total THMs.

[5] MCL set in the State of Delaware 2002 Watershed Assessment Report 305(b).

[6] Zogorski and others, 2006.

more than 95 percent of the samples analyzed using a low-level detection method (lower than 0.2 µg/L) demonstrated the vulnerability of the Columbia aquifer in Delaware to low-level VOC contamination (Zogorski and others, 2006).

Field Parameters, Nutrients and Major Ions, and Trace Elements

Summary statistics for selected field parameters, nutrients, major ions, and trace elements in groundwater samples from public-supply wells are shown in table 6. Only three constituents have established MCLs: two nutrients (nitrate and nitrite) and one major ion (fluoride). Two wells out of the 30 wells sampled had nitrate (NO_3^-) concentrations above the Federal drinking-water standard of 10 mg/L as nitrogen; both wells were in Sussex County (fig. 5). Concentrations of nitrite and fluoride did not exceed their MCLs.

Non-enforceable guidelines (SMCLs or HALs) exist for eight of the sampled inorganic constituents (table 6). No sample fell within the range of the SMCL for pH, which is between 6.5 and 8.5; 29 of 30 samples were more acidic and the remaining sample was more basic (table 6). Both iron and manganese exceeded their SMCLs in four and six samples, respectively. Iron and manganese concentrations above their SMCLs were most frequently detected in Sussex and Kent Counties (fig. 5). Only one constituent, sodium, has a HAL (20 mg/L) for drinking water set by the Delaware Division of Public Health (table 6) (State of Delaware, 2002). Thirty percent of the 30 samples exceeded the HAL for sodium (table 6, fig. 5).

More than 85 percent of the 30 wells sampled had dissolved oxygen levels greater than or equal to 1 mg/L (fig. 6), which was considered a threshold for oxic conditions in this study, following Denver and others (2004). Four samples had dissolved oxygen levels below 1 mg/L, and all were in Sussex County in predominantly poorly drained areas (fig. 5). The presence or absence of dissolved oxygen in groundwater is important as some chemicals of concern are stable and persistent under oxic conditions, most notably nitrate, and some are more prominent under reducing conditions, such as iron and manganese.

Nitrate was the predominant nutrient species detected in the Columbia aquifer, with 90 percent detection (table 6). Under natural conditions, nitrate concentrations rarely exceed 0.4 mg/L in groundwater on the Delmarva Peninsula (Hamilton and others, 1993); concentrations greater than the natural background level are likely impacted by anthropogenic activities. The major anthropogenic sources of nitrogen and phosphorus on the Peninsula are inorganic fertilizers and manure applications (Debrewer and others, 2007; Denver and others, 2004). Inputs from nitrogen fertilizer applications have increased since the 1940s, whereas data show that nutrient inputs from manure have recently decreased. Manure application still contributes significantly to total nutrient inputs, however (Debrewer and others, 2007; Denver and others, 2004).

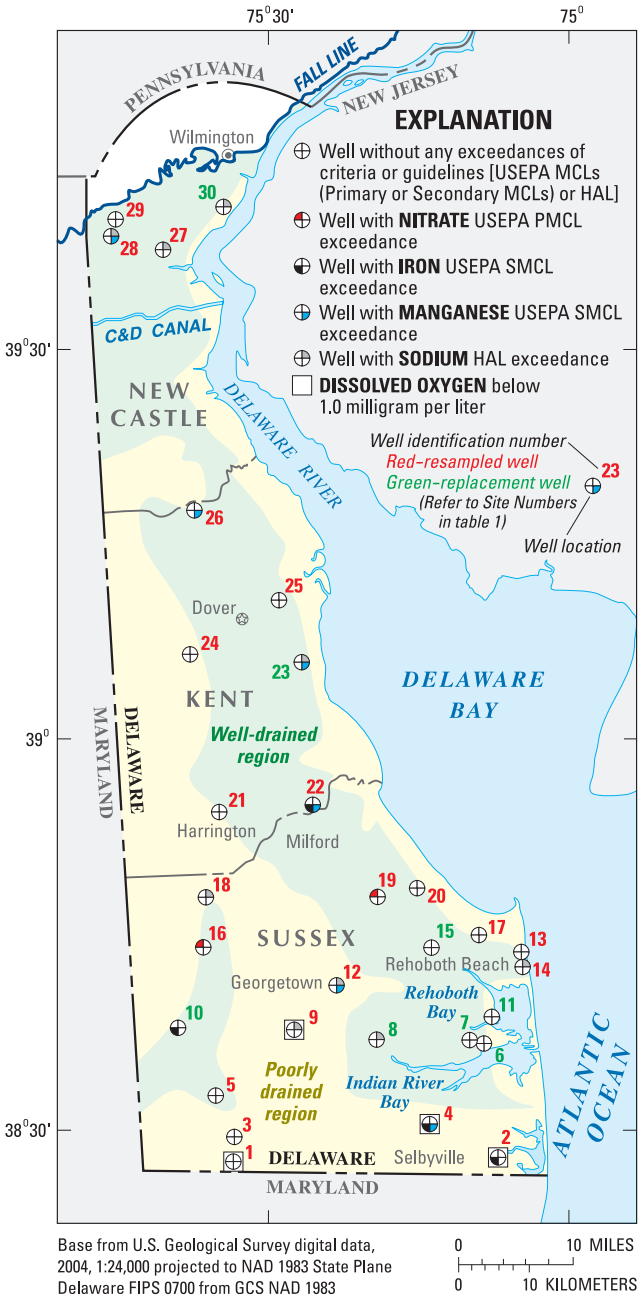

Figure 5. Locations of public water-supply wells sampled in 2008 in the Columbia aquifer in Delaware with exceedances of criteria and guidelines for nutrients and major ions detected in groundwater. [USEPA, U.S. Environmental Protection Agency; MCLs, Maximum Contaminant Levels; PMCL, Primary MCL; SMCL, Secondary MCL; HAL, Health Advisory Limit set by the Delaware Department of Public Health.]

Table 6. Summary statistics for selected field parameters, nutrients, major ions, and trace elements in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Primary and Secondary Maximum Contaminant Levels and Health Advisory Limits, 2000 and 2008.

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level; HAL, Health Advisory Limit set forth by the Delaware Division of Public Health; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no standard or guideline established; †, pH detections below SMCL; *, 29 pH detections below SMCL and 1 pH detection above SMCL in 2008]

Constituent	Network	Number of detections	Minimum	Median	Maximum	MCL[1]	Detections above MCL	SMCL[1] or (HAL[2])	Detections above SMCL[1] or (HAL[2])
Field parameters									
Water temperature (°C)	Total (2000)	30	14	15.3	23.5	--	--	--	--
	Total (2008)	30	13.5	15.8	24	--	--	--	--
	Resampled (2000)	22	14	15.5	23.5	--	--	--	--
	Resampled (2008)	22	13.5	15.8	24	--	--	--	--
Specific conductance (µS/cm)	Total (2000)	30	63	149	389	--	--	--	--
	Total (2008)	30	62	176	343	--	--	--	--
	Resampled (2000)	22	63	173	389	--	--	--	--
	Resampled (2008)	22	62	178	331	--	--	--	--
Dissolved oxygen (mg/L)	Total (2000)	30	0.1	4.6	10	--	--	--	--
	Total (2008)	30	0.11	4.6	10.1	--	--	--	--
	Resampled (2000)	22	0.1	4.3	10	--	--	--	--
	Resampled (2008)	22	0.11	4.2	10.1	--	--	--	--
pH (pH units)	Total (2000)	30	4.5	5.4	6.9	--	--	6.5-8.5	29†
	Total (2008)	30	4.5	5.5	8.7	--	--	6.5-8.5	30*
	Resampled (2000)	22	5	5.5	6.9	--	--	6.5-8.5	22†
	Resampled (2008)	22	5.2	5.5	6.4	--	--	6.5-8.5	22†
Alkalinity (as mg/L of $CaCO_3$)	Total (2000)	29	3	13	41	--	--	--	--
	Total (2008)	30	0.5	11.5	44	--	--	--	--
	Resampled (2000)	22	5	15	41	--	--	--	--
	Resampled (2008)	22	3	14	44	--	--	--	--
Nutrients									
Nitrate (mg/L)	Total (2000)	26	<0.05	5.204	11.314	10	1	--	--
	Total (2008)	27	<0.04	4.884	12.114	10	2	--	--
	Resampled (2000)	19	<0.05	5.204	11.314	10	1	--	--
	Resampled (2008)	19	<0.04	4.884	12.114	10	2	--	--
Nitrite (mg/L)	Total (2000)	1	<0.006	<0.01	0.024	1	--	--	--
	Total (2008)	6	E0.001	<0.002	<0.006	1	--	--	--
	Resampled (2000)	1	<0.006	<0.01	0.024	1	--	--	--
	Resampled (2008)	5	E0.001	<0.002	<0.006	1	--	--	--

Table 6. Summary statistics for selected field parameters, nutrients, major ions, and trace elements in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Primary and Secondary Maximum Contaminant Levels and Health Advisory Limits, 2000 and 2008.—Continued

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level; HAL, Health Advisory Limit set forth by the Delaware Division of Public Health; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no standard or guideline established; †, pH detections below SMCL; *, 29 pH detections below SMCL and 1 pH detection above SMCL in 2008]

Constituent	Network	Number of detections	Minimum	Median	Maximum	MCL[1]	Detections above MCL	SMCL[1] or (HAL[2])	Detections above SMCL[1] or (HAL[2])
Nutrients—Continued									
Ammonia (mg/L)	Total (2000)	5	<0.02	<0.02	0.167	--	--	--	--
	Total (2008)	9	E0.011	<0.02	0.798	--	--	--	--
	Resampled (2000)	5	<0.02	<0.02	0.167	--	--	--	--
	Resampled (2008)	7	E0.011	<0.02	0.263	--	--	--	--
Total phosphorus (mg/L)	Total (2000)	12	E0.002	<0.008	2.098	--	--	--	--
	Total (2008)	13	E0.004	<0.012	0.127	--	--	--	--
	Resampled (2000)	11	E0.004	<0.008	2.098	--	--	--	--
	Resampled (2008)	12	E0.004	0.01	0.127	--	--	--	--
Major ions									
Calcium (mg/L)	Total (2000)	30	1.99	8.05	19.22	--	--	--	--
	Total (2008)	30	0.05	10.50	21.29	--	--	--	--
	Resampled (2000)	22	2.80	9.57	19.22	--	--	--	--
	Resampled (2008)	22	0.05	11.08	21.29	--	--	--	--
Magnesium (mg/L)	Total (2000)	30	0.73	3.91	12.40	--	--	--	--
	Total (2008)	30	E0.01	4.44	13.59	--	--	--	--
	Resampled (2000)	22	0.73	4.24	12.40	--	--	--	--
	Resampled (2008)	22	E0.01	4.51	13.59	--	--	--	--
Sodium (mg/L)	Total (2000)	30	5.3	11.7	25.9	--	--	(20)	(1)
	Total (2008)	30	5.2	14.2	34.5	--	--	(20)	(9)
	Resampled (2000)	22	5.3	11.7	25.9	--	--	(20)	(1)
	Resampled (2008)	22	5.2	14.2	34.5	--	--	(20)	(6)
Potassium (mg/L)	Total (2000)	30	1.05	2.23	16.45	--	--	--	--
	Total (2008)	30	E0.02	2.54	11.68	--	--	--	--
	Resampled (2000)	22	1.05	2.27	16.45	--	--	--	--
	Resampled (2008)	22	E0.02	2.54	11.68	--	--	--	--
Chloride (mg/L)	Total (2000)	30	4.62	18.28	60.75	--	--	250	--
	Total (2008)	30	4.50	18.62	56.86	--	--	250	--
	Resampled (2000)	22	4.62	18.91	60.75	--	--	250	--
	Resampled (2008)	22	4.50	20.91	56.86	--	--	250	--

Table 6. Summary statistics for selected field parameters, nutrients, major ions, and trace elements in groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Primary and Secondary Maximum Contaminant Levels and Health Advisory Limits, 2000 and 2008.—Continued

[LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; Total, 30 public water-supply wells sampled in 2000 or 2008; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level; HAL, Health Advisory Limit set forth by the Delaware Division of Public Health; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no standard or guideline established; †, pH detections below SMCL; *, 29 pH detections below SMCL and 1 pH detection above SMCL in 2008]

Constituent	Network	Number of detections	Minimum	Median	Maximum	MCL[1]	Detections above MCL	SMCL[1] or (HAL[2])	Detections above SMCL[1] or (HAL[2])
Major ions—Continued									
Sulfate (mg/L)	Total (2000)	29	E0.18	13.83	44.36	--	--	250	--
	Total (2008)	30	E0.11	18.53	35.33	--	--	250	--
	Resampled (2000)	21	<0.31	17.59	44.36	--	--	250	--
	Resampled (2008)	22	E0.11	20.56	33.22	--	--	250	--
Fluoride (mg/L)	Total (2000)	1	E0.09	<0.1	<0.2	4	--	2	--
	Total (2008)	1	<0.08	<0.12	0.59	4	--	2	--
	Resampled (2000)	0	<0.1	<0.1	<0.2	4	--	2	--
	Resampled (2008)	1	<0.08	<0.12	0.59	4	--	2	--
Silica (mg/L)	Total (2000)	30	9.41	17.65	39.23	--	--	--	--
	Total (2008)	30	10.85	18.34	35.53	--	--	--	--
	Resampled (2000)	22	9.41	18.78	39.23	--	--	--	--
	Resampled (2008)	22	10.85	19.71	35.53	--	--	--	--
Total dissolved solids (mg/L)	Total (2000)	27	55.50	116.00	221.00	--	--	500	--
	Total (2008)	30	E46.16	E115.94	200.97	--	--	500	--
	Resampled (2000)	21	55.50	122.00	221.00	--	--	500	--
	Resampled (2008)	22	E46.16	122.61	E192.82	--	--	500	--
Bromide (mg/L)	Total (2000)	29	<0.01	0.053	0.115	--	--	--	--
	Total (2008)	28	E0.017	0.047	0.194	--	--	--	--
	Resampled (2000)	21	<0.01	0.053	0.115	--	--	--	--
	Resampled (2008)	21	E0.017	0.046	0.194	--	--	--	--
Trace elements									
Iron (µg/L)	Total (2000)	20	E5.3	11.3	10,053	--	--	300	5
	Total (2008)	21	E3.6	<8	14,110	--	--	300	4
	Resampled (2000)	16	E6.0	12.8	10,053	--	--	300	5
	Resampled (2008)	16	<4	<8	14,110	--	--	300	3
Manganese (µg/L)	Total (2000)	27	E1.85	11.62	326.92	--	--	50	6
	Total (2008)	30	1.76	15.66	275.90	--	--	50	6
	Resampled (2000)	20	E2.10	13.60	326.92	--	--	50	6
	Resampled (2008)	22	1.76	20.25	275.90	--	--	50	5

[1] U.S. Environmental Protection Agency, 2009.

[2] State of Delaware 2002 Watershed Assessment Report 305(b).

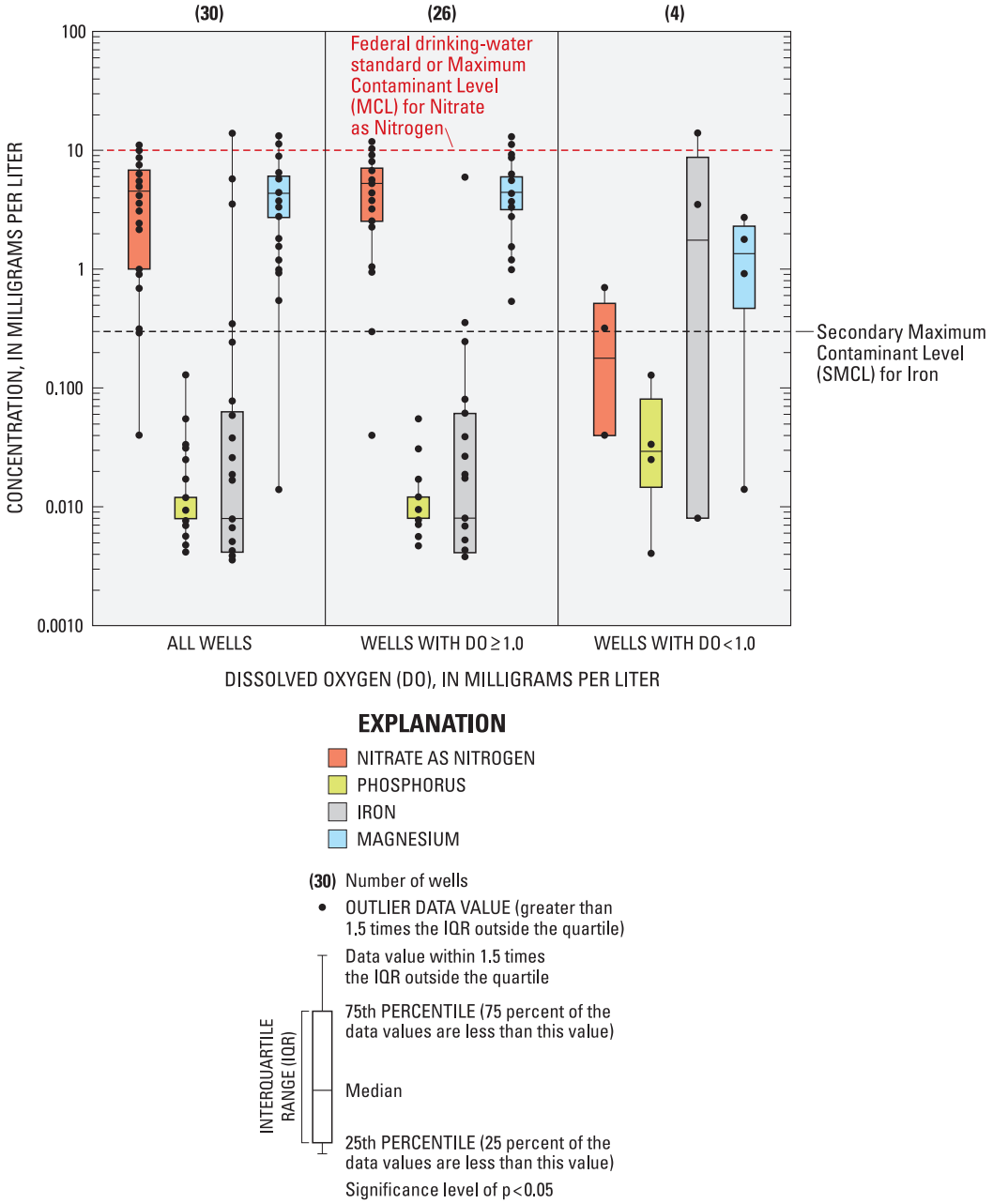

Figure 6. Distribution of nutrients (nitrate as nitrogen and total phosphorus), major ions (magnesium), and trace elements (iron) concentrations in different oxidation-reduction (redox) environments in the Columbia aquifer among the 30 public water-supply wells sampled in 2008.

Current 2008 data show that nitrate occurred at concentrations exceeding background concentrations in 83 percent of the 30 wells (Appendix B), with a median concentration of 4.88 mg/L as nitrogen (table 6). Although the median concentration of nitrate was slightly lower in 2008 than the median concentration in 2000 (5.20 mg/L; Ferrari, 2002), these differences are not statistically significant (table 6). Debrewer and others (2007) also found that overall nitrate concentrations tended to be higher in oxic environments, such as upland regions, where soils are generally well-drained (figs. 5 and 6). Ator and Reyes (2008) found that nitrate concentrations greater than 3 mg/L in groundwater were most likely in areas with agricultural land use. Much of the nitrate in groundwater in the Delaware Coastal Plain is attributed to agricultural sources, as that is the predominant land use (Debrewer and others, 2007).

Nitrate concentrations were positively correlated with dissolved oxygen in the Columbia aquifer (R^2=0.6998, p<0.0001) (fig. 7). In addition, median concentrations of nitrate and magnesium were significantly higher in oxic environments than in low-oxygen environments (p=0.0050 and p=0.0283, respectively) (fig. 6). Debrewer and others (2007) and Denver and others (2004) found similar results on the Delmarva Peninsula.

Concentrations of other nutrient species were generally lower than concentrations of nitrate in the Columbia aquifer in Delaware. Data from Denver and others (2004) and current 2008 data indicated that concentrations of dissolved phosphorus in groundwater rarely exceeded 0.1 mg/L (see Appendix B) in spite of relatively large applications of phosphorus in inorganic fertilizers and manure (Denver and others, 2004). This finding is in large part explained by the chemical properties and mobility of phosphorus. Specifically, phosphorus readily attaches to soil particles under oxidizing conditions; it does not dissolve and move readily to the groundwater system. Under reducing conditions (where dissolved oxygen is absent), however, phosphorus is mobilized more readily in shallow groundwater and can be detected at concentrations greater than 0.1µg/L (Denver and others, 2004). Current 2008 data from the Columbia aquifer follow this pattern; median phosphorus

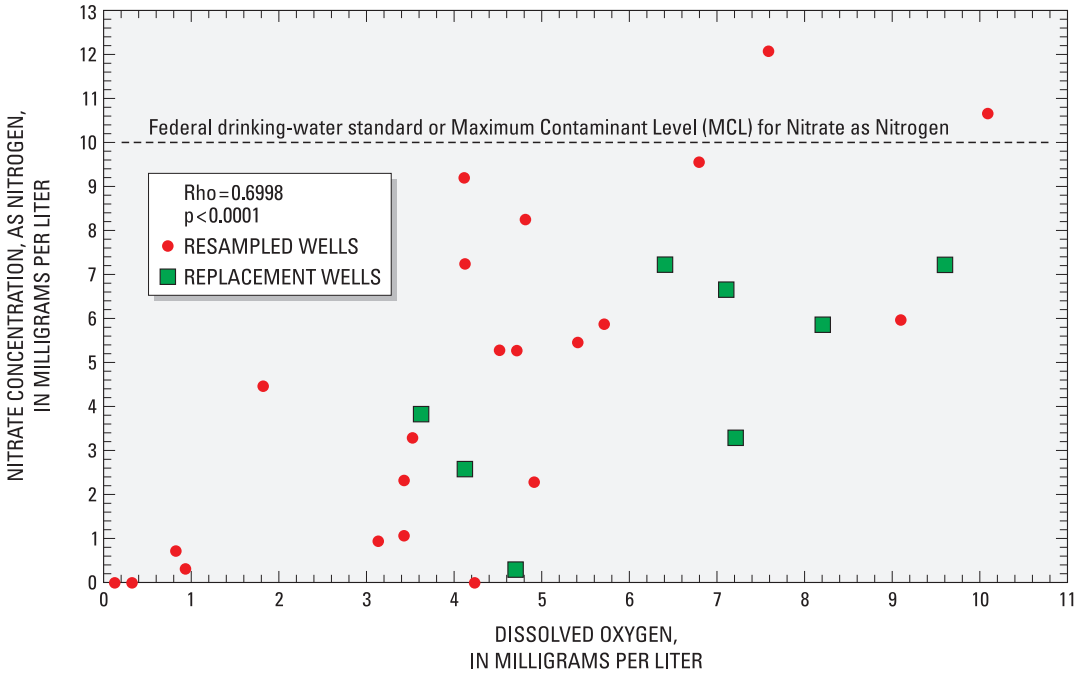

Figure 7. Relation of nitrate concentrations to dissolved-oxygen concentrations in the Columbia aquifer in Delaware, 2008.

concentrations were significantly higher in low-oxygen environments than in oxic environments (p=0.0033) (fig. 6).

Dissolved iron is often a major component of natural groundwaters associated with reducing conditions (Shedlock and others, 1999). Median iron concentrations were significantly higher in low-oxygen environments than oxic environments (p=0.0036) (fig. 6). The median concentration of iron in water with low dissolved oxygen levels exceeded the SMCL of 300 µg/L for iron in drinking water.

No differences in nutrients or major ions were found between samples collected in 2000 and 2008. Two field parameters, pH and dissolved oxygen, however, were both significantly higher in 2008 than in 2000. Although pH and dissolved oxygen were significantly higher in 2008, the average pH was still moderately acidic (median of 5.5) (table 6) and most groundwater samples were oxic.

Radium and Radon

Radon and radium-226 had a 100-percent detection rate in nine samples collected; five samples also had detectable levels of radium-228 (table 7). Radium isotopes and radon sampling distribution are shown in figure 8; most of the wells are in New Castle and Sussex Counties. Wells were selected for sampling in New Castle County (Bachman and Ferrari, 1995) in areas with aquifer characteristics similar to those in areas of Maryland (Bolton, 2000) and New Jersey (Szabo and DePaul, 1998), where radium was detected in groundwater (fig. 8). The remainder of the wells sampled were mainly in agricultural areas. Szabo and DePaul (1998) previously found an apparent relation between radium concentration and agricultural land use in New Jersey, and Bolton (2000) found a relation between sodium chloride and radiochemical activities

Table 7. Radiochemical activities for groundwater samples from public water-supply wells screened in the Columbia aquifer in Delaware, and comparisons to U.S. Environmental Protection Agency Maximum Contaminant Levels in 2000 and 2008.

[DGS, Delaware Geological Survey; LTMDL, long-term method detection limit; MRL, method reporting level; E, value is greater than the LTMDL but less than MRL and is coded as estimated because of lower precision in this value; <, less than; --, no data; Resampled, 22 public water-supply wells sampled in 2000 and 2008, active wells; Replaced by, public water-supply well sampled only in 2000, not active in 2008; Replacement, public water-supply well sampled only in 2008; MCL, Maximum Contaminant Level; all units in picocuries per liter; **bold**, public water-supply well sampled in 2000 with detection above the MCL.]

DGS local well number	Type of well	Radium-226		Radium-228		Radon-222	
		2000	2008	2000	2008	2000	2008
Cd42-18	Replacement	--	0.16	--	0.43	--	175
Cd52-15	Replaced by Cd42-18	<1.00	--	<1.00	--	192	--
Db11-27	Resampled	<1.00	0.08	<1.00	<-0.04	246	237
Db11-28	Resampled	<1.00	0.16	<1.00	0.28	222	200
Dc31-15	Resampled	<1.00	0.08	<1.00	0.28	260	286
Forest Hills1	Replaced by Pg31-12	<1.00	--	<1.00	--	220	--
Pg31-12	Replacement	--	0.13	--	0.30	--	204
Hc34-03	Resampled	<1.00	0.39	1.13	0.85	167	132
Ng25-04[3]	Resampled	--	0.09	--	<0.20	--	71
Pc33-44	Replaced by Ng25-04	1.29	--		--	155	--
Pe23-185	Resampled	<1.00	0.02	<1.00	<0.07	79	73
PN1	Replaced by Pi32-15	<1.00	--	<1.00	--	**343**	--
Qd52-09	Resampled	<1.00	0.04	<1.00	<0.12	221	182
Number of radiochemical activities among all 9 wells		1	9	1	5	1	9
Number of radiochemical activities among resampled wells (6)		0	7	1	3	6	7
MCL[1]		5[2]		5[2]		300	

[1] U.S. Environmental Protection Agency, 2009.

[2] MCL for combined radium-226 and radium-228.

[3] Well not sampled for radiochemical activities in 2000.

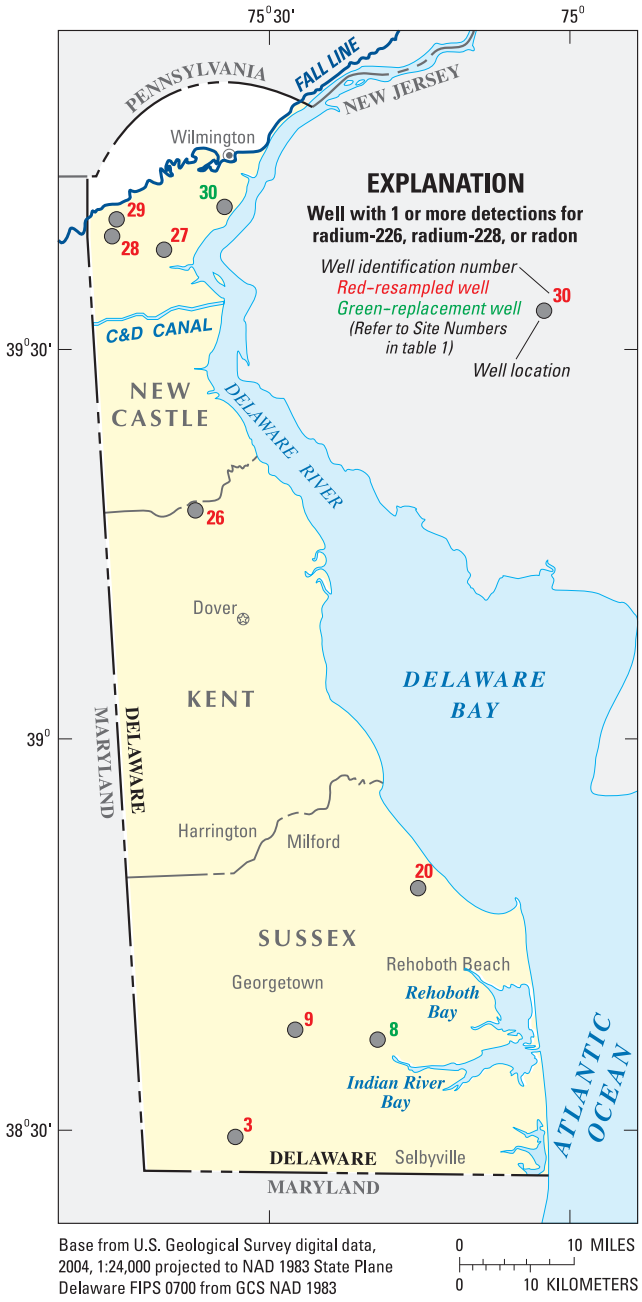

Figure 8. Locations of public water-supply wells sampled in 2008 in the Columbia aquifer in Delaware for radiochemical activities.

including radium-226, radium-228, gross-alpha-particle activity and gross-beta-particle activity. Radium occurs naturally in groundwater and is a daughter product from the decay of uranium and thorium, but can be mobilized by processes similar to those that mobilize other alkaline earth metals. Although some radionuclides were detected, none were found at concentrations above applicable drinking-water standards in 2008 (table 7).

Temporal differences in radioactive elements were difficult to determine with the available data. Even though recent data indicate a higher number of detections, the frequency of detection was affected by the change in detection limits between 2008 and 2000. The activities for radium isotopes still remain below 1 picocurie per liter.

Groundwater Age Results

Average groundwater age ranged from 6 to 35 years, with a median of 21.5 years among the 30 wells sampled in 2008. Groundwater ages are positively correlated with well depth (fig. 9a) and negatively correlated with dissolved-oxygen concentrations (fig. 9b) in the Columbia aquifer.

Comparison of the data (fig. 10a) from resampled wells indicates that the average groundwater age was significantly different; samples collected in 2008 were on average 7 years older than samples collected in 2000 ($p<0.0001$) (fig. 10b). In 2000, the median age of groundwater was 15 years, and ranged from 7 to 23 years; in 2008, the median age of groundwater in the resampled wells was 22 years, and ranged from 6 to 34.6 years. Groundwater age represents a mixture of older and younger groundwater because well screens in public-supply wells are relatively long and pumping enhances the mixing of waters of disparate groundwater ages (Dunkle and others, 1993). The reason for the difference in groundwater age in the samples from 2000 and 2008 is unknown. Gholam and others (2006) indicated that this age difference could reflect a higher proportion of water drawn from slow-moving storage, possibly due to pumping for longer periods of time, or an increase in pumpage that caused more water from older, deeper, or more distant sources to be drawn into the well.

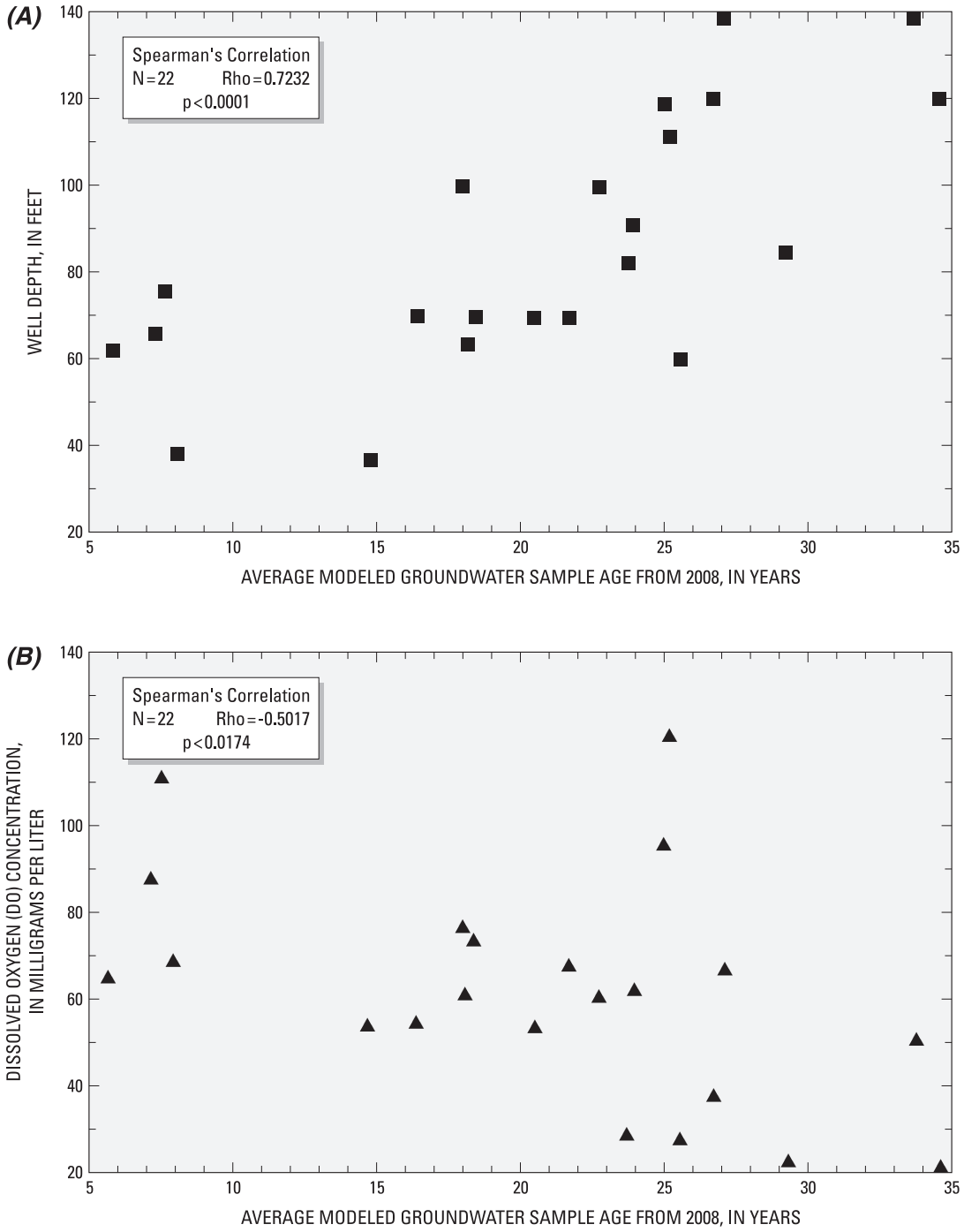

Figure 9. Relation of average modeled groundwater sample to *(A)* well depth, and *(B)* dissolved-oxygen concentrations in the Columbia aquifer in Delaware, 2008.

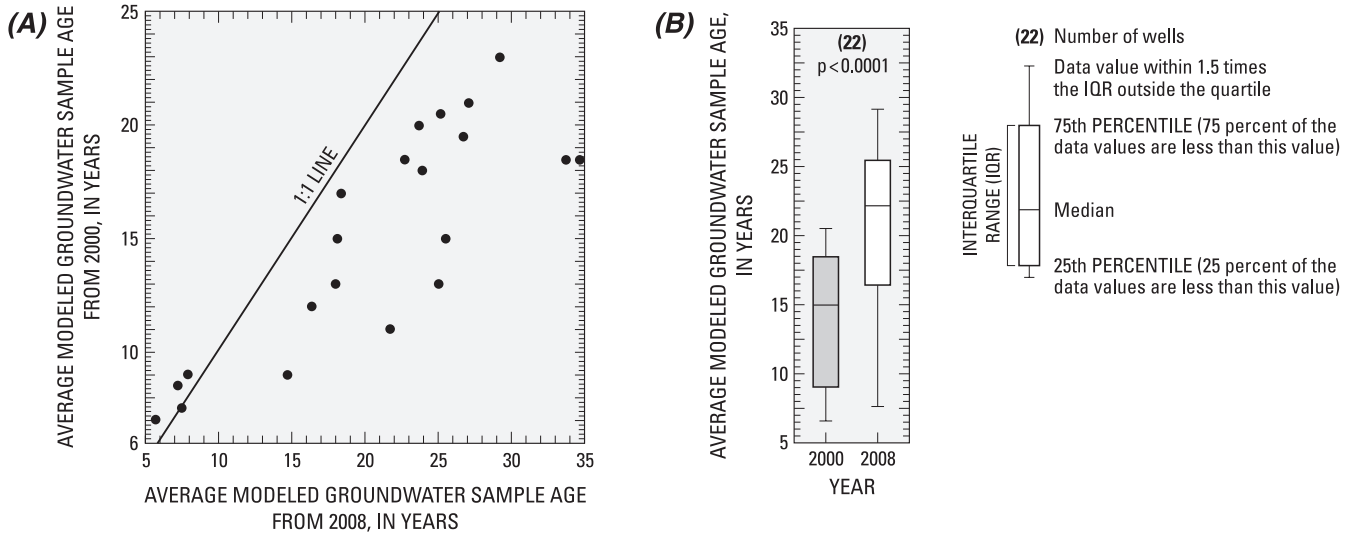

Figure 10. *(A)* comparison and *(B)* distribution of average modeled groundwater sample age over the 8-year study period from the 22 sampled wells in the Columbia aquifer in Delaware, 2000 to 2008.

Summary

The U.S. Geological Survey collected water-quality sampling data from 30 public-supply wells screened in the Columbia aquifer in Delaware from August through November of 2008. The data indicate that human influences are apparent in groundwater. Dissolved contaminants appear to be derived mainly from agricultural practices, and influenced by natural and anthropogenic factors. A comparison of average modeled groundwater age indicates that the actual groundwater age in 2008 samples was significantly older than the groundwater age in samples from 2000. The average groundwater age difference between the study periods among the resampled wells was 7 years.

There were no significant differences in water-quality data during the 8-year period for either pesticides or pesticide degradates; similar patterns existed for the number of compounds detected per well in both sampling rounds. A variety of pesticides and degradate compounds were detected in groundwater of the Columbia aquifer at low levels. Metolachlor, atrazine, and alachlor, and their degradates, were the most commonly detected pesticide compounds; degradation products were detected more frequently and at higher concentrations than their parent compounds. Almost 80 percent of the 24 pesticide and pesticide degradate compounds detected were agricultural herbicides. Mixtures of pesticides were prevalent in 90 percent of the groundwater samples, which reflects similar usage patterns; multiple compounds are often applied to the same area (often in mixed formulations) for greater pest control. None of the pesticides or pesticide degradates exceeded U.S. Environmental Protection Agency Maximum Contaminant Levels (MCLs). Dieldrin exceeded the non-regulatory Health-Based Screening Level (HBSL) (0.002 µg/L/micrograms per liter) in all nine samples with detected concentrations.

Even though there were no significant differences in volatile organic compound (VOC) concentrations, the mean number of VOCs detected per well decreased significantly in 73 percent of the resampled wells. Of the 85 VOCs analyzed in this study, 31 were detected at concentrations that were generally less than 1 µg/L; only one well had no detectable concentration of any VOC. VOCs were classified in seven groups, trihalomethanes (THMs), solvents, gasoline oxygenates, gasoline hydrocarbons, refrigerants, fumigants, and organic synthesis compounds; the greatest number of detections occurred in the solvents group. Chloroform—a THM—and Methyl-*tert* butyl ether (MTBE)—a gasoline oxygenate—were present in more than 50 percent of the samples. None of the VOCs exceeded USEPA MCLs or non-regulatory HBSLs.

Median values for pH and dissolved oxygen, respectively, from 2000 and 2008 differed. Almost all of the samples (29 of 30) were moderately acidic and fell below the lower

Secondary Maximum Contaminant Level (SMCL) for pH (6.5); the only sample that was not acidic exceeded the upper limit of the SMCL (8.5). More than 85 percent of the 30 wells sampled showed oxidizing aquifer conditions with dissolved-oxygen concentrations above 1 mg/L (milligram per liter); four samples had dissolved-oxygen concentrations below 1 mg/L—these wells were in poorly drained areas of Sussex County.

Nitrate, the predominant nutrient species detected in samples from the Columbia aquifer in Delaware, had a median concentration of 4.88 mg/L, which was not significantly different from the median nitrate concentration in 2000 (5.20 mg/L). Samples from two wells exceeded the MCL for nitrate (10 mg/L). Differences in nitrate concentrations over the 8-year study period in the same well were small and increased in some wells or decreased in others. Overall, nitrate concentrations were positively correlated with dissolved oxygen in the Columbia aquifer and higher in upland regions where soils are generally well-drained and agriculture is more prevalent than in poorly drained regions of Delaware.

Median concentrations of phosphorus and iron were significantly higher in low-oxygen environments than oxic environments; the median concentration of iron from wells in low-oxygen environments exceeded the SMCL (300 µg/L). Several samples had detections of major ions above the USEPA SMCL for iron or manganese (50 µg/L) or the Health Advisory Level (HAL) for sodium (20 mg/L) in drinking water set by the Delaware Division of Public Health.

Radon and radium-226 had a 100-percent detection rate in the nine samples collected at the six resampled wells. Radium-228 had a 50-percent detection rate in the nine samples collected at the six resampled wells. In 2008, none of the radiochemical activities were above any established drinking-water standards or MCLs.

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References Cited

Andres, A.S., 1991, Results of the coastal Sussex County, Delaware, ground-water quality survey: Delaware Geological Survey Report of Investigations No. 49, 28 p.

Andres, A.S., 1994, Geohydrology of the Seaford area, Delaware: Delaware Geological Survey Hydrologic Map Series No. 9, scale 1:24,000, 1 sheet.

Ator, S.W., and Reyes, B., 2008, Pesticides in ground water of central and western Maryland: U.S. Geological Survey Fact Sheet 2008–3068, 6 p., available online at *http://pubs.usgs.gov/fs/2008/3068/*.

Bachman, L.J., 1984, Nitrate in the Columbia aquifer, central Delmarva Peninsula, Maryland: U.S. Geological Survey Water-Resources Investigations Report 84–4322, 51 p.

Bachman, L.J. and Ferrari, M.J., 1995, Quality and geochemistry of ground water in southern New Castle County, Delaware: Delaware Geological Survey Report of Investigations No. 52, 31 p.

Bachman, L.J., and Wilson, J.M., 1984, The Columbia aquifer of the Eastern Shore of Maryland: Maryland Geological Survey Report of Investigations No. 40, 144 p.

Barbash, J.E., and Resek, E.A., 1996, Pesticides in groundwater: Distribution, trends, and governing factors: Chelsea, Michigan, Ann Arbor Press, 588 p.

Benson, R.N., Andres, A.S., Roberts, J.H., and Woodruff, K.D., 1986, Seismic stratigraphy along three multichannel seismic reflection profiles off Delaware's coast: Delaware Geological Survey Miscellaneous Map No. 4, with discussion, 1 sheet.

Blaier, S.C., and Baxter, S.J., 2000, The occurrence and distribution of several agricultural pesticides in Delaware's shallow ground water: Delaware Geological Survey Report of Investigations No. 61, 23 p.

Bolton, D.W., 2000, Occurrence and distribution of radium, gross alpha-particle activity, and gross beta-particle activity in ground water in the Magothy Formation and Potomac Group aquifers, upper Chesapeake Bay area, Maryland: Maryland Geological Survey Report of Investigations No. 70, 97 p.

Busenberg, Eurybiades, and Plummer, L.N., 2000, Dating young ground water with sulfur hexafluoride: Natural and anthropogenic sources of sulfur hexafluoride: Water Resources Research, v. 36, no. 10, p. 3,011–3,030.

Busenberg, Eurybiades, Plummer, L.N., and Bartholomey, R.C., 2001, Estimated age and source of the young fraction of ground water at the Idaho National Engineering and Environmental Laboratory: U.S. Geological Survey Water-Resources Investigations Report 01–4265, 145 p.

Connor, B.F., Rose, D.L., Abney, S.R., and Raese, J.W., 1998, Laboratory method for analysis of small concentrations of Methyl *tert*-Butyl Ether and other ether gasoline oxygenates in water: U.S.Geological Survey Fact Sheet 98–086, 6 p.

Conover, W.J., 1999, Practical nonparametric statistics, 3d ed.: New York, John Wiley & Sons, Inc., 584 p.

Debrewer, L.M., Ator, S.W., and Denver, J.M., 2007, Factors affecting spatial and temporal variability in nutrient and pesticide concentrations in the surficial aquifer on the Delmarva Peninsula: U.S. Geological Survey Scientific Investigations Report 2005–5257, 45 p., available online at *http://pubs.usgs.gov/sir/2005/5257/*.

Delaware DataMIL Web Site, 2007, 2007 Land Use Land Cover: ESRI:102257, NAD_1983_HARN_StatePlane_ Delaware_FIPS_0700, scale 1:2,400, accessed October 26, 2009 at *http://datamil.delaware.gov/geonetwork/srv/en/main.home*.

Denver, J.M., and Ator, S.W., 2006, Pesticides in ground water of the Maryland Coastal Plain: U.S. Geological Survey Fact Sheet 2006–3119, 8 p., available online at *http://pubs.usgs.gov/fs/2006/3119/*.

Denver, J.M., Ator, S.W., and Brayton, M.J., 2004, Hydrologic and geochemical controls on pesticide and nutrient transport to two streams on the Delmarva Peninsula: U.S. Geological Survey Scientific Investigations Report 2004–5051, 34 p., available online at *http://pubs.usgs.gov/sir/2004/5051/SIR2004-5051.pdf*.

Denver, J.M., Ator, S.W., Debrewer, L.M., Ferrari, M.J., Barbaro, J.R., Hancock, T.C., Brayton, M.J., and Nardi, M.R., 2004, Water quality in the Delmarva Peninsula, Delaware, Maryland, and Virginia, 1999-2001: U.S. Geological Survey Circular 1228, 36 p., available online at *http://pubs.usgs.gov/circ/2004/1228/*.

Dunkle, S.A., Plummer, L.N., Busenberg, Eurybiades, Phillips, P.J., Denver, J.M., Hamilton, P.A., Michel, R.L., and Coplen, T.B., 1993, Chlorofluorocarbons (CCl_3F and CCl_2F_2) as dating tools and hydrologic tracers in shallow groundwater of the Delmarva Peninsula, Atlantic Coastal Plain, United States: Water Resources Research, v. 29, no.12, p. 3,737–3,860.

Ferrari, M.J., 2002, Occurrence and distribution of selected contaminants in public drinking-water supplies in the surficial aquifer in Delaware: U.S. Geological Survey Open-File Report 01–327, 62 p., available online at *http://pubs.usgs.gov/of/2001/ofr01-327/pdf/ofr-01-327.pdf*.

Fishman, M.J., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory: determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Gholam, A., Kazemi, G.A., Lehr, J.H., and Perrochet, P., 2006, Groundwater age: Hoboken, New Jersey, John Wiley & Sons, Inc., 325 p.

Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, Naomi, Nowell, L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P., and Wolock, D.M., 2006, The quality of our Nation's waters—Pesticides in the Nation's streams and ground water, 1992-2001: U.S. Geological Survey Circular 1291, 172 p., available online at *http://pubs.usgs.gov/circ/2005/1291/*.

Hamilton, P.A., Denver, J.M., Phillips, P.J., and Shedlock, R.J., 1993, Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia—Effects of agricultural activities on, and distribution of, nitrate and other inorganic constituents in the surficial aquifer: U.S. Geological Survey Open-File Report 93–40, 87 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Netherlands, Elsevier Science Publishers, Studies in Environmental Science, v. 49, 522 p.

Johnston, R.H., 1973, Hydrology of the Columbia (Pleistocene) deposits of Delaware: An appraisal of a regional water-table aquifer: Delaware Geological Survey Bulletin No. 14, 78 p.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program—Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95–399, 113 p.

Lee E.A., Strahan, A.P., and Thurman, E.M., 2001, Methods of analysis by the U.S. Geological Survey Organic Geochemistry Research Group—Determination of glyphosate, aminomethylphosphonic acid, and glufonsinate in water using online solid-phase extraction and high-performance liquid chromate: U.S. Geological Survey Open-File Report 01–454, 13 p., available online at *http://ks.water.usgs.gov/pubs/reports/ofr.01-454.html*.

Phillips, P.J., Eckhardt, D.A., Terracciano, S.A., and Rosenmann, L., 1999, Pesticides and their metabolites in wells of Suffolk County, New York, 1998: U.S. Geological Survey Water-Resources Investigations Report 99–4095, 12 p.

Plummer, L.N., and Busenberg, Eurybiades, 1999, Chlorofluorocarbons: Tools for dating and tracing young groundwater *in* Cook, P., and Herczeg, A., eds., Environmental tracers in subsurface hydrology: Boston Massachusetts, Kluwer Academic Publishers, chapter 15, p. 441–478.

Plummer, L.N., and Busenberg, Eurybiades, 2000, Data on the crystal growth of calcite from calcium bicarbonate solutions at 34 degrees C and CO_2 partial pressures of 0.101, 0.0156, and 0.00102 atmospheres: U.S. Geological Survey Open-File Report 99–247, 13 p.

Plummer, L.N, and Friedman, L.C., 1999, Tracing and dating young ground water: U.S. Geological Survey Fact Sheet 134–99, 4 p., accessed March 31, 2010 at *http://pubs.usgs.gov/fs/FS-134-99/pdf/fs-134-99.pdf*.

SAS Institute Inc., 2004, SAS® 9.1.2 Qualification tools user's guide: Cary, North Carolina, SAS Institute Inc.

Shedlock R.J., Denver J.M., Hayes, M.A., Hamilton, P.A., Koterba, M.T., Bachman, L.J., Phillips P.J., and Banks, W.S.L., 1999, Water-quality assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia: Results of investigations, 1987–91: U.S. Geological Survey Water Supply Paper 2355–A, 41 p.

State of Delaware, 2002, Watershed Assessment Report 305(b), Department of Natural Resources and Environmental Control, August 1, 2002, 169 p., accessed March 31, 2010 at *http://www.dnrec.state.de.us/water2000/Sections/Watershed/TMDL/2002_305b.pdf*.

Szabo Z., and DePaul, V.T., 1998, Radium-226 and radium-228 in shallow ground water, southern New Jersey: U.S. Geological Survey Fact Sheet, FS–062–98, 6 p.

Talley, J.H., 1988, Geohydrology of the southern coastal area, Delaware: Delaware Geological Survey Hydrologic Map No. 7, sheet 2, Geohydrology of the Columbia aquifer, scale 1:24,000.

Toccalino, P.L., Norman, J.E., Booth, N.L, and Zogorski, J.S., 2008, Health-based screening levels: A tool for evaluating what water-quality data may mean to human health: U.S. Geological Survey, National Water-Quality Assessment Program, accessed August 20, 2010 at *http://water.usgs.gov/nawqa/HBSL/*.

Toccalino, P.L., Norman, J.E., Phillips, R.H., Kauffman, L.J., Stackelberg P.E., Nowell, L.H., Krietzman, S.J., and Post, G.B., 2004, Application of health-based screening levels to ground-water quality data in a state-scale pilot effort: U.S. Geological Survey Scientific Investigations Report 2004–5174, 64 p., available online at *http://pubs.usgs.gov/sir/2004/5174/sir20045174.pdf*.

U.S. Department of Agriculture, 1997 Census of Agriculture—v.1, National, state, and county tables: U.S. Department of Agricultural Statistics Service, accessed March 31, 2010 at *http://www.nass.usda.gov/Statistics_by_State/Delaware/About_Us/index.asp*.

U.S. Department of Health and Human Services, 2002, Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile for Aldrin/Dieldrin (Update): Atlanta, Georgia, 2 p., accessed May 24, 2010 at *http://www.atsdr.cdc.gov/tfacts1.pdf*.

U.S. Environmental Protection Agency, 1980a, Prescribed procedures for measurement of radioactivity in drinking water, method 903.1, EPA, 600/4–80–032, radium-226 in drinking water—radon emanation technique, method ID: EPA 903.1, document no. PB 80-224744, 11 p., accessed September 1, 2010 at *http://www.epa.gov/waterscience/ methods/method/files/903_1.pdf*.

U.S. Environmental Protection Agency, 1980b, Prescribed procedures for measurement of radioactivity in drinking water, method 904.0 EPA, 600/4–80–032, radium-228 in drinking water (with modification), method ID: EPA 904.0, document no. PB 80-224744, accessed September 2, 2010 at *http://www.epa.gov/safewater/methods/pdfs/methods/methods_radionuclides.pdf*.

U.S. Environmental Protection Agency, 2003, Health effects support document for Aldrin/Dieldrin: Office of Water, EPA 822–R–3–001, February 2003, accessed March 31, 2010 at *http://water.epa.gov/action/advisories/drinking/upload/2004_1_16_ support_cc1_aldrin-dieldrin_healtheffects.pdf*.

U.S. Environmental Protection Agency, 2009, National primary drinking-water standards and health advisories: Office of Water, last updated on Friday, September 11, 2009, accessed October 15, 2009 at *http://water.epa.gov/action/advisories/drinking/upload/dwstandards2009.pdf*.

Wilde, F.D., Radtke, D.B., Gibs, J., and Iwatsubo, R.T., 2005, National field manual for the collection of water-quality data: U.S. Geological Survey Handbooks for Water-Resources Investigations, book 9, [variously paged].

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory— Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 95–181, 49 p.

Zimmerman, L.R., Hostetler, K.A., and Thurman, E.M., 2000, Methods of analysis of the U.S. Geological Survey Organic Geochemistry Research Group—Determination of chloroacetanilide herbicide metabolites in water using high-performance liquid chromatography-diode array detection and high-performance liquid chromatography/ mass spectrometry: U.S. Geological Survey Open-File Report 00–182, 28 p.

Zogorski, J.S., Carter, J.M., Ivahnenko, T., Lapham, W.W., Moran, M.J., Rowe, B.L., Squillace, P.J., and Toccalino, P.L., 2006, The quality of our Nation's waters—Volatile organic compounds in the Nation's groundwater and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.

Appendixes A–H

Appendix A. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Field parameters.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; mm Hg, millimeters of mercury; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; --, no data]

USGS site identification number	DGS local well number	Sample date	Sample time	Field parameters						
				Water temperature (°C)	Air pressure (mm Hg)	Dissolved oxygen (mg/L)	pH (field units)	Alkalinity (mg/L as $CaCO_3$)	Specific conductance, field (µS/cm)	Air temperature (°C)
382805075330301	Rd22-01	9/10/2008	1430	17	762	0.8	5.5	21	91	--
382830075073601	Ri23-04	9/10/2008	1030	15.5	762	0.9	5.9	28	166	--
383000075326001	Qd52-09	9/9/2008	0930	16.5	759	3.4	5.6	13	83	23
383101075141101	Frankford4	8/27/2008	1100	16	762	0.3	6	30	236	22
383311075344401	Qd21-12	9/23/2008	1130	16	769	4.1	5.5	8	137	19.5
383713075085501	Pi32-15	10/21/2008	1030	15	762	7.2	5.5	9	120	12
383713075085501	Pi32-15	10/21/2008	1100	--	--	--	--	--	--	--
383729075101601	Ph35-25	10/21/2008	1430	16	762	4.1	5.6	8	92	14
383732075191301	Pg31-12	10/14/2008	1100	16	765	9.6	8.7	7	199	16.5
383815075271001	Pe23-185	8/7/2008	1200	24	757	0.11	6.4	44	102	31
383815075271001	Pe23-185	8/7/2008	1215	--	--	--	--	--	--	--
383823075382101	Pc22-06	9/8/2008	1330	17		6.4	4.5	0.5	165	29
383914075080501	Pi12-11	10/20/2008	1130	14	765	4.7	5.5	7	141	11
384139075230101	Of42-01	9/9/2008	1430	16	759	1.8	5.3	21	268	21
384322075051101	Oi25-18	9/25/2008	1330	15.5	767	4.9	5.6	20	197	18.5
384326075050801	Oi25-19	9/25/2008	1030	15	767	3.4	5.5	16	250	18
384428075135501	Oh12-07	11/13/2008	1030	14.5	766	7.1	5.5	6	117	13
384428075135501	Oh12-07	11/13/2008	1100	--	--	--	--	--	--	--
384428075355701	Oc15-11	8/26/2008	1100	16	763	7.6	5.3	3	175	23
384526075091601	Ni51-32	10/8/2008	1100	15	762	4.7	5.5	9	162	18.5
384818075354101	Nc25-37	8/21/2008	1100	18	767	4.1	6.4	39	269	27
384819075190101	Ng21-03	9/16/2008	1200	15	764	10.1	5.2	3	164	23.5
384856075151101	Ng25-04	9/17/2008	1100	15.5	763	3.1	5.5	7	62	19
385448075341801	Md11-04	8/28/2008	1100	16.5	763	4.8	5.6	13	255	24
385522075251802	Le55-09	11/12/2008	1100	15	771	4.2	5.8	11	182	11
390617075261901	Je55-01	11/6/2008	1030	16	757	3.6	5.2	12	240	16.5
390652075370701	Jc43-05	8/5/2008	1100	16	761	5.4	5.3	8	177	29.5
390652075370701	Jc43-05	8/5/2008	1115	--	--	--	--	--	--	--
391060075282801	Ie42-03	8/19/2008	1100	15.5	762	3.5	5.4	6	178	29.5
391747075364202	Hc34-03	9/2/2008	1100	15.5	764	5.7	5.4	11	174	26.5
393739075394202	Dc31-15	10/7/2008	1030	13.5	769	9.1	5.6	16	311	13
393916075440802	Db11-28	10/2/2008	1400	17	752	4.5	5.5	15	328	11.5
393928075440202	Db11-27	10/2/2008	1100	15	752	6.8	5.5	16	331	13
394102075334301	Cd42-18	10/7/2008	1400	15	769	8.2	5.6	22	343	16

Appendix B. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Nutrients.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in milligrams per liter; E, estimated; --, not detected; N, nitrogen]

USGS site identification number	DGS local well number	Nutrients						
		Ammonia as N	Dissolved ammonia plus organic nitrogen as N	Total ammonia plus organic nitrogen as N	Nitrite as N	Nitrite plus nitrate as N	Dissolved phosphorus	Total phosphorus
382805075330301	Rd22-01	--	--	--	--	0.718	E0.005	E0.004
382830075073601	Ri23-04	0.032	--	E0.07	0.002	0.322	0.020	0.025
383000075326001	Qd52-09	--	--	--	E0.001	2.322	0.007	E0.008
383101075141101	Frankford4	0.263	0.385	3.30	0.003	--	0.121	0.127
383311075344401	Qd21-12	E0.013	E0.074	--	--	7.260	E0.004	E0.006
383713075085501	Pi32-15	--	--	--	--	3.305	E0.004	--
383729075101601	Ph35-25	--	--	--	--	2.585	E0.005	--
383732075191301	Pg31-12	--	--	--	--	7.263	--	--
383815075271001	Pe23-185	--	--	--	--	0.000	0.034	0.034
383823075382101	Pc22-06	E0.011	--	--	--	7.261	--	--
383914075080501	Pi12-11	--	--	--	--	0.299	--	--
384139075230101	Of42-01	0.034	E0.134	E0.11	E0.001	4.485	0.017	0.017
384322075051101	Oi25-18	0.024	E0.087	E0.08	--	2.298	--	--
384326075050801	Oi25-19	--	--	--	--	1.058	E0.004	--
384428075135501	Oh12-07	--	E0.062	--	--	6.696	--	--
384428075355701	Oc15-11	--	--	--	--	12.114	--	--
384526075091601	Ni51-32	--	E0.072	E0.05	E0.001	5.282	E0.005	--
384818075354101	Nc25-37	--	E0.087	--	--	9.224	--	--
384819075190101	Ng21-03	--	--	--	--	10.695	--	--
384856075151101	Ng25-04	--	--	--	--	0.955	--	E0.005
385448075341801	Md11-04	--	E0.105	E0.08	--	8.276	0.006	0.001
385522075251802	Le55-09	0.107	0.150	0.13	--	0.000	0.049	0.055
390617075261901	Je55-01	0.798	0.968	0.92	E0.001	3.839	--	E0.007
390652075370701	Jc43-05	--	--	E0.08	--	5.486	--	--
391060075282801	Ie42-03	--	--	E0.10	--	3.302	0.032	0.031
391747075364202	Hc34-03	--	--	--	--	5.887	0.015	0.017
393739075394202	Dc31-15	--	--	--	--	6.006	--	--
393916075440802	Db11-28	E0.011	E0.061	E0.06	--	5.304	--	--
393928075440202	Db11-27	--	--	E0.06	--	9.584	E0.003	--
394102075334301	Cd42-18	--	--	--	--	5.904	--	--

Appendix C. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Major ions and trace elements.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Major ions and trace elements													
		Bicarbonate (mg/L)	Bromide (mg/L as Br)	Calcium (mg/L as Ca)	Chloride (mg/L as Cl)	Fluoride (mg/L as F)	Magnesium (mg/L as Mg)	Manganese (µg/L as Mn)	Potassium (mg/L as K)	Silica (mg/L as SiO_2)	Sodium (mg/L as Na)	Sulfate (mg/L as SO_4)	Dissolved noncarbonate hardness (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Total Iron (µg/L as Fe)
382805075330301	Rd22-01	26	0.044	3.86	9.64	--	0.94	45.47	1.31	35.5	12.3	3.65	--	13.49	--
382830075073601	Ri23-04	34	0.044	8.60	17.42	--	2.83	36.31	1.41	32.3	15.6	20.75	5.24	33.14	3,528.0
383000075326001	Qd52-09	16	0.030	3.72	8.01	--	1.02	4.28	1.41	25.3	10.3	3.76	0.34	13.47	--
383101075141101	Frankford4	37	0.047	11.17	33.28	--	1.84	74.86	1.58	26.4	19.7	15.01	5.10	35.46	14,110.0
383311075344401	Qd21-12	10	0.079	10.26	12.43	--	4.54	17.11	2.82	19.8	9.6	17.31	36.09	44.30	18.8
383713075085501	Pi32-15	11	0.071	4.75	17.08	--	2.83	7.01	2.00	19.7	11.0	4.66	14.49	23.53	--
383729075101601	Ph35-25	10	0.059	3.17	12.70	--	1.22	14.82	1.45	19.4	11.2	2.42	4.75	12.96	--
383732075191301	Pg31-12	9	--	6.81	15.29	--	3.92	6.44	3.07	15.8	27.6	1.91	25.75	33.15	--
383815075271001	Pe23-185	53	E0.018	0.05	4.50	--	E0.01	30.16	E 0.02	29.2	25.6	0.40	--	E 0.17	--
383823075382101	Pc22-06	0.6	0.030	9.01	13.51	--	4.54	46.37	3.49	13.3	5.6	19.75	40.71	41.21	353.0
383914075080501	Pi12-11	9	0.114	3.49	29.53	--	2.80	6.44	1.88	15.2	17.2	7.38	12.84	20.23	60.1
384139075230101	Of42-01	25	0.194	14.63	29.49	--	5.79	82.75	11.68	21.6	20.2	31.49	39.87	60.39	80.4
384322075051101	Oi25-18	24	0.077	11.21	26.22	--	6.64	5.50	2.12	10.9	14.6	22.17	35.63	55.32	E 6.8
384326075050801	Oi25-19	19	0.124	9.03	40.82	--	9.71	3.18	2.66	14.1	21.5	30.48	46.95	62.54	26.3
384428075135501	Oh12-07	7	0.047	6.76	11.53	--	1.58	2.86	1.60	22.3	9.9	3.89	17.64	23.39	E 3.6
384428075355701	Oc15-11	4	0.040	12.61	18.66	--	3.30	5.36	3.48	21.4	11.2	E 0.11	41.80	45.09	E 5.1
384526075091601	Ni51-32	11	0.070	8.10	18.57	--	3.65	8.61	2.23	17.3	13.7	13.68	26.24	35.27	--
384818075354101	Nc25-37	48	--	11.16	24.17	0.59	5.62	32.41	3.29	19.6	34.5	4.90	11.61	50.99	E 4.2
384819075190101	Ng21-03	3	0.044	10.73	14.95	--	4.40	9.54	5.73	12.6	5.2	3.20	42.44	44.91	E 5.3
384856075151101	Ng25-04	8	0.043	1.60	10.86	--	0.55	1.76	1.28	14.5	8.3	0.87	--	6.24	77.5
385448075341801	Md11-04	16	0.047	19.73	27.10	--	5.64	16.49	1.86	25.5	16.6	26.75	59.36	72.49	62.7
385522075251802	Le55-09	13	0.056	11.03	23.15	--	3.39	193.20	2.42	21.0	12.0	33.22	30.84	41.52	5,804.0
390617075261901	Je55-01	15	0.057	5.40	27.08	--	4.58	176.80	3.28	12.7	32.9	35.33	20.03	32.34	59.3
390652075370701	Jc43-05	10	0.036	13.05	14.74	--	4.47	24.74	1.98	26.3	9.9	25.55	42.80	51.01	244.2
391060075282801	Ie42-03	7	0.078	11.13	16.47	--	6.11	23.39	3.96	15.6	9.6	32.85	47.22	52.97	16.9
391747075364202	Hc34-03	14	0.042	10.96	23.16	--	6.17	62.55	4.11	15.3	11.3	20.38	41.27	52.77	--
393739075394202	Dc31-15	19	0.043	15.83	49.28	--	8.84	3.92	3.67	13.8	24.8	24.39	60.33	75.93	--
393916075440802	Db11-28	19	0.063	17.40	56.86	--	9.68	275.90	3.28	14.0	24.7	21.15	67.70	83.30	38.1
393928075440202	Db11-27	20	0.050	21.29	44.06	--	13.59	2.91	2.76	13.7	15.0	30.07	92.71	109.13	4.4
394102075334301	Cd42-18	27	0.078	19.72	53.04	--	11.62	4.52	2.80	14.8	25.8	33.63	74.94	97.10	4.0

Appendix D. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticides.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Pesticides													
		Atrazine	Alachlor	alpha-HCH	Butylate	Carbofuran	Dieldrin	EPTC (Eptam)	Fipronil	Lindane	Metolachlor	Pebulate	Prometon	Simazine	Tebuthiuron
383311075344401	Qd21-12	E0.005	--	--	--	--	0.017	--	--	--	0.087	--	--	E0.004	--
383713075085501	Pi32-15	0.007	--	--	--	--	--	--	--	--	--	--	--	--	--
383815075271001	Pe23-185	--	--	--	--	--	--	--	E0.003	--	--	--	--	--	--
383823075382101	Pc22-06	0.049	0.049	--	--	--	--	--	--	--	0.034	--	0.009	E0.006	--
384139075230101	Of42-01	--	--	--	--	--	0.011	--	--	--	--	--	--	--	--
384322075051101	Oi25-18	--	--	--	--	--	0.084	--	E0.004	--	--	--	0.034	--	--
384326075050801	Oi25-19	--	--	--	--	--	0.026	--	--	--	--	--	E0.005	--	--
384428075135501	Oh12-07	--	0.030	--	--	--	--	--	--	--	--	--	--	--	--
384428075355701	Oc15-11	--	0.055	--	--	E0.056	--	--	--	--	0.024	--	--	--	--
384526075091601	Ni51-32	0.021	--	--	--		--	--	--	--	E0.007	--	--	--	--
384818075354101	Nc25-37	0.022	0.011	--	--	E0.017	--	--	--	--	0.053	--	E0.005	--	--
384819075190101	Ng21-03	0.488	0.000	--	--	E0.017	--	--	--	--	E0.003	--	--	--	--
385448075341801	Md11-04	0.044	E0.006	--	--	--	--	--	--	--	0.083	--	--	--	--
390652075370701	Jc43-05	0.009	--	--	--	--	--	--	--	--	E0.003	--	--	--	--
391060075282801	Ie42-03	0.052	--	--	--	--	--	--	--	--	E0.008	--	--	E0.005	--
391747075364202	Hc34-03	0.028	0.010	--	--	--	0.053	--	E0.004	--	0.028	--	0.010	0.011	0.029
393739075394202	Dc31-15	0.067	--	--	--	--	0.036	--	E0.009	--	E0.007	--	--	0.018	0.047
393916075440802	Db11-28	0.096	--	--	--	--	0.037	--	E0.011	--	E0.005	--	0.049	0.013	E0.018
393928075440202	Db11-27	0.203	E0.006	E0.002	0.002	--	0.074	0.009	E0.018	E0.006	0.055	E0.005	0.013	0.032	0.026
394102075334301	Cd42-18	0.027	--	--	--	--	0.083	--	E0.009	--	--	--	--	0.022	--

Appendix E. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticide degradates.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Pesticide degradates									
		Alachlor ESA	Alachlor ESA SA	Alachlor OA	Aminomethyl phosphonic acid	Deethylatrazine (CIAT)	Fipronil sulfide	Fipronil sulfone	Metolachlor ESA	Metolachlor OA	2-[(2-Ethyl-6-methylphenyl)amino]-2-oxoESA
382805075330301	Rd22-01	0.06	--	--	--	--	--	--	0.03	--	--
382830075073601	Ri23-04	0.45	0.02	--	--	--	--	--	0.22	--	--
383000075326001	Qd52-09	--	--	--	--	E0.005	--	--	0.15	--	--
383101075141101	Frankford4	0.18	--	0.03	--	--	--	--	0.19	--	--
383311075344401	Qd21-12	0.2	--	0.02	--	E0.013	--	--	1.23	0.61	0.05
383713075085501	Pi32-15	0.08	--	--	--	E0.032	--	--	0.09	--	--
383729075101601	Ph35-25	--	--	--	--	E0.005	--	--	0.05	0.04	--
383732075191301	Pg31-12	2.11	--	--	0.03	E0.051	--	--	3.95	0.13	--
383823075382101	Pc22-06	0.41	--	0.05	--	E0.091	--	--	1.72	0.33	--
384139075230101	Of42-01	0.02	--	--	--	E0.005	--	--	--	--	--
384322075051101	Oi25-18	--	--	--	--	E0.002	--	--	0.05	--	--
384326075050801	Oi25-19	--	--	--	--	E0.002	--	--	0.1	--	--
384428075135501	Oh12-07	0.31	--	0.03	0.16	E0.028	--	--	0.07	--	--
384428075355701	Oc15-11	0.27	--	0.1	--	E0.195	--	--	2.77	0.09	0.02
384526075091601	Ni51-32	0.03	--		--	E0.039	--	--	0.22	--	--
384818075354101	Nc25-37	0.51	0.02	0.13	--	E0.076	--	--	3.21	0.26	0.03
384819075190101	Ng21-03	2.09	--	0.02	--	E0.112	--	--	1.25	0.15	
384856075151101	Ng25-04	--	--	--	--	E0.003	--	--	--	--	--
385448075341801	Md11-04	0.48	--	0.07	0.03	E0.059	--	--	0.58	0.19	0.02
385522075251802	Le55-09	0.21	--	0.2	0.28	--	--	--	0.2	0.03	
390617075261901	Je55-01	--	0.03	--	--	--	--	--	0.03	--	--
390652075370701	Jc43-05	0.16	--	--	--	E0.009	--	--	--	--	--
391060075282801	Ie42-03	0.37	--	0.02	--	E0.082	--	--	2.28	0.3	0.02
391747075364202	Hc34-03	0.3	--	0.02	--	E0.013	--	E0.002	0.3	0.08	
393739075394202	Dc31-15	0.1	--	--	--	E0.068	--	--	0.55	0.08	0.03
393916075440802	Db11-28	0.12	--	--	--	E0.038	E0.003	E0.006	0.91	0.18	0.03
393928075440202	Db11-27	0.21	0.04	--	--	E0.171	--	E0.004	3.15	0.98	0.39
394102075334301	Cd42-18	--	--	--	--	E0.011	--	0.003	--	--	--

Appendix F. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Volatile organic compounds							
		Benzene	Bromo-dichloro-methane	*sec*-Butyl-benzene	Carbon disulfide	Chloro-benzene	Chloro-methane	Dibromo-chlorometh-ane	1,2-Dichlo-robenzene
382805075330301	Rd22-01	--	--	--	--	0.14	--	--	0.357
383000075326001	Qd52-09	--	--	--	--	--	--	--	--
383101075141101	Frankford4	--	--	--	--	--	--	--	--
383311075344401	Qd21-12	--	--	--	--	--	--	--	--
383713075085501	Pi32-15	--	--	--		--	--	--	--
383729075101601	Ph35-25	--	--	--	--	--	--	--	--
383732075191301	Pg31-12	--	0.255	--	E0.065	--	E0.042	0.453	--
383815075271001	Pe23-185	--	--	--	E0.057	--	--	--	--
383823075382101	Pc22-06	--	--	--	--	--	--	--	--
383914075080501	Pi12-11	--	--	--	--	--	--	--	--
384139075230101	Of42-01	--	--	E 0.099	--	E0.062	--	--	E0.042
384322075051101	Oi25-18	--	--	--	--	--	--	--	--
384326075050801	Oi25-19	--	--	--	--	--	--	--	--
384428075135501	Oh12-07	--	--	--	--	--	--	--	--
384428075355701	Oc15-11	--	--	--	--	--	--	--	--
384526075091601	Ni51-32	--	--	--	--	--	--	--	--
384818075354101	Nc25-37	--	0.371	--	--	--	--	0.769	--
384819075190101	Ng21-03	--	--	--	--	--	--	--	--
384856075151101	Ng25-04	--	--	--	--	--	--	--	--
385448075341801	Md11-04	--	--	--	--	--	--	--	--
385522075251802	Le55-09	0.140	--		--	--	--	--	--
390617075261901	Je55-01		--	E0.014	--	0.044	--	--	0.149
390652075370701	Jc43-05	--	--	--	--	--	--	--	--
391060075282801	Ie42-03	--	--	--	--	--	--	--	--
391747075364202	Hc34-03	--	--	--	--	--	--	--	--
393739075394202	Dc31-15	--	--	--	--	--	--	--	--
393916075440802	Db11-28	--	--	--	--	--	--	--	--
393928075440202	Db11-27	--	--	--	--	--	--	--	--
394102075334301	Cd42-18	--	--	--	--	--	--	--	--

Appendix F. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Volatile organic compounds							
		1,3-Dichlorobenzene	1,1-Dichloroethane	1,1-Dichloroethene	*cis*-1,2-Dichloroethene	Dichlorofluoromethane	Dichloromethane	1,4-Dichlorobenzene	1,2-Dichloropropane
382805075330301	Rd22-01	--	0.135	E0.028	--	--	--	0.187	--
383000075326001	Qd52-09	--	--	--	--	--	--	E0.035	--
383101075141101	Frankford4	--	--	--	--	--	--	--	--
383311075344401	Qd21-12	--	--	--	--	--	--	--	--
383713075085501	Pi32-15	--	--	--	--	--	--	--	--
383729075101601	Ph35-25	--	E 0.053	--	--	--	--	--	--
383732075191301	Pg31-12	--	--	--	--	--	E 0.016	--	
383815075271001	Pe23-185	--	--	--	--	--	--	--	E0.071
383823075382101	Pc22-06	--	--	--	--	--	--	--	--
383914075080501	Pi12-11	--	--	--	--	--	--	--	--
384139075230101	Of42-01	--	E0.088	--	--	E1.327	--		--
384322075051101	Oi25-18	--	--	--	--	--	--	--	--
384326075050801	Oi25-19	--	--	--	--	--	--	--	--
384428075135501	Oh12-07	--	--	--	--	--	--	--	--
384428075355701	Oc15-11	--	--	--	--	--	--	--	--
384526075091601	Ni51-32	--	--	--	--	--	--	--	--
384818075354101	Nc25-37	--	--	--	--	--	--	--	--
384819075190101	Ng21-03	--	--	--	--	--	--	--	--
384856075151101	Ng25-04	--	--	--	--	--	--	--	--
385448075341801	Md11-04	--	--	--	--	--	--	--	--
385522075251802	Le55-09	--	--	--	--	--	--	--	--
390617075261901	Je55-01	0.166	--	--	--	--	--	0.237	--
390652075370701	Jc43-05	--	--	--	1.268	--	--	--	--
391060075282801	Ie42-03	--	--	--	--	--	--	--	--
391747075364202	Hc34-03	--	E0.066	0.236	--	--	--	--	--
393739075394202	Dc31-15	--	--	--	--	--	--	--	--
393916075440802	Db11-28	--	--	--	--	--	--	--	--
393928075440202	Db11-27	--	--	--	E0.053	--	--	--	--
394102075334301	Cd42-18	--	--	E0.031	--	--	--	--	--

Appendix F. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Volatile organic compounds							
		Diisopropylether	Methyl ethyl ketone	Methyl *tert*-butyl ether	Methyl *tert*-pentyl ether	Styrene	Tetrachloroethene	Tetrachloromethane	Tetrahydrofuran
382805075330301	Rd22-01	--	--	E0.096	--	--	E0.040	--	--
383000075326001	Qd52-09	--	--	--	--	--	--	--	--
383101075141101	Frankford4	E0.091	--	--	--	--	--	--	--
383311075344401	Qd21-12	--	--	--	--	--	--	--	--
383713075085501	Pi32-15	--	--	E0.069	--	--	--	--	--
383729075101601	Ph35-25	--	--	E0.028	--	--	--	--	--
383732075191301	Pg31-12	--	E0.441	--	--		--	E0.0196	E0.303
383815075271001	Pe23-185	--	--	--	--	0.257	--	--	2.113
383823075382101	Pc22-06	--	--	0.835	--	--	--	--	--
383914075080501	Pi12-11	--	--	E0.082	--	--	--	--	--
384139075230101	Of42-01	--	--	--	--	--	0.974	--	--
384322075051101	Oi25-18	--	--	0.733	--	--	--	--	--
384326075050801	Oi25-19	--	--	0.303	--	--	--	--	--
384428075135501	Oh12-07	--	--	--	--	--	--	--	--
384428075355701	Oc15-11	--	--	0.205	--	--	--	--	--
384526075091601	Ni51-32	--	--	0.134	--	--	E0.026	--	--
384818075354101	Nc25-37	--	--	0.626	--	--	1.616	--	--
384819075190101	Ng21-03	--	--	--	--	--	--	--	--
384856075151101	Ng25-04	--	--	--	--	--	--	--	--
385448075341801	Md11-04	--	--	0.717	--	--	--	--	--
385522075251802	Le55-09	--	--	0.751	--	--	0.544	--	--
390617075261901	Je55-01	--	--	0.913	E0.073	--	E0.090	--	--
390652075370701	Jc43-05	--	--	1.845	E0.086	--	--	--	--
391060075282801	Ie42-03	--	--	--	--	--	--	--	--
391747075364202	Hc34-03	--	--	2.554	E0.086	--	0.855	--	--
393739075394202	Dc31-15	--	--	0.267	--	--	E0.038	--	--
393916075440802	Db11-28	--	--	0.966	--	--	0.208	--	--
393928075440202	Db11-27	--	--	0.298	--	--	1.013	--	--
394102075334301	Cd42-18	E 0.034	--	1.470	E0.031	--	0.391	--	--

Appendix F. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations are in micrograms per liter; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Volatile organic compounds						
		Toluene	Tribromo-methane	1,2,4-Trichloro-benzene	1,1,1-Trichloro-ethane	Trichloro-ethene	Trichloro-fluorometh-ane	Trichloro-methane
382805075330301	Rd22-01	--	--	--	--	E0.031	--	0.106
383000075326001	Qd52-09	--	--	--	--	--	--	0.184
383101075141101	Frankford4	--	--	--	--	--	--	--
383311075344401	Qd21-12	--	--	--	--	--	--	0.103
383713075085501	Pi32-15	--	--	--	E0.021	--	--	1.126
383729075101601	Ph35-25	--	--	--	--	--	--	0.411
383732075191301	Pg31-12	--	0.352	--	--	--	--	0.325
383815075271001	Pe23-185	--		--	--	--	--	E0.026
383823075382101	Pc22-06	--	--	--	--	--	--	E0.020
383914075080501	Pi12-11	--	--	--	--	--	--	0.242
384139075230101	Of42-01	E0.036	--	--	E0.030	E0.071	--	E0.074
384322075051101	Oi25-18	--	--	--	--	--	--	E0.076
384326075050801	Oi25-19	--	--	--	--	--	--	E0.607
384428075135501	Oh12-07	--	--	--	--	--	--	0.499
384428075355701	Oc15-11	--	--	--	--	--	--	E0.091
384526075091601	Ni51-32	--	--	--	--	E0.015	--	E0.080
384818075354101	Nc25-37	--	0.632	--	--	--	--	0.136
384819075190101	Ng21-03	--	--	--	--	--	--	E0.043
384856075151101	Ng25-04	--	--	--	--	--	--	0.630
385448075341801	Md11-04	--	--	--	--	--	--	E0.067
385522075251802	Le55-09	--	--	--	--	0.229	--	--
390617075261901	Je55-01	--	--	E0.037	--		--	E0.029
390652075370701	Jc43-05	--	--	--	--	0.581	--	0.228
391060075282801	Ie42-03	--	--	--	--		--	E0.044
391747075364202	Hc34-03	--	--	--	1.102	0.519	--	0.131
393739075394202	Dc31-15	--	--	--	--	--	E0.020	0.380
393916075440802	Db11-28	--	--	--	--	--	--	0.443
393928075440202	Db11-27	--	--	--	--	E0.090	--	0.321
394102075334301	Cd42-18	--	--	--	E0.062	0.152	--	0.325

Appendix Ga. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Age dating: sulfur hexafluoride data.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; NOAA, National Oceanic and Atmospheric Administration; mL, milliliters; fmol/L, fentomoles per liter; °C, degrees Celsius; --, no data]

USGS site identification number	Sample number	DGS local well number	Sampling date	Sulfur hexafluoride (SF_6) data					
				NOAA Scale (fmol/L)	Excess air (mL)	Recharge temperature (°C)	Recharge elevation (feet)	Estimated date of recharge[1]	Estimated age of groundwater[1] (year)
382805075330301	1	Rd22-01	9/10/2008	0.58957	2.3	10.6	34	1983.0	25.7
382805075330301	2	Rd22-01	9/10/2008	0.60782	2.3	10.6	34	1983.5	25.2
382830075073601	1	Ri23-04	9/10/2008	0.99633	6	12.4	0	1985.5	23.2
382830075073601	2	Ri23-04	9/10/2008	0.88429	6	12.4	0	1984.5	24.2
383000075326001	1	Qd52-09	9/9/2008	0.88420	3.2	9.5	25	1986.0	22.7
383000075326001	2	Qd52-09	9/9/2008	1.33546	3.2	9.5	25	1990.5	18.2
383101075141101	1	Frankford 4	8/27/2008	0.40367	3.8	14.5	20	1979.5	29.2
383101075141101	2	Frankford 4	8/27/2008	0.41111	3.8	14.5	20	1979.5	29.2
383311075344401	1	Qd21-12	9/23/2008	0.87228	3.9	16.3	13	1987.0	21.7
383311075344401	2	Qd21-12	9/23/2008	0.73475	3.9	16.3	13	1985.0	23.7
383713075085501	1	Pi32-15	10/21/2008	0.76403	1.9	13.2	0	1986.5	22.3
383713075085501	2	Pi32-15	10/21/2008	0.81491	1.9	13.2	0	1987.5	21.3
383729075101601	1	Ph35-25	10/21/2008	0.87477	2.2	12.7	0	1987.5	21.3
383732075191301	1	Pg31-12	10/14/2008	1.39857	1.6	11.4	15	1993.5	15.3
383732075191301	2	Pg31-12	10/14/2008	1.26434	1.6	11.4	15	1992.0	16.8
383815075271001	1	Pe23-185	8/7/2008	0.19091	1.9	8.8	32	1974.0	34.6
383815075271001	2	Pe23-185	8/7/2008	0.18601	1.9	8.8	32	1974.0	34.6
383823075382101	1	Pc22-06	9/8/2008	1.54345	4.6	16.2	9	1993.0	15.7
383823075382101	2	Pc22-06	9/8/2008	0.79793	4.6	16.2	9	1985.5	23.2
383914075080501	1	Pi12-11	10/20/2008	1.10721	2.4	13.6	6	1990.5	18.3
383914075080501	2	Pi12-11	10/20/2008	1.16846	2.4	13.6	6	1991.0	17.8
384139075230101	1	Of42-01	9/9/2008	1.15175	2.7	14.2	34	1991.0	17.7
384139075230101	2	Of42-01	9/9/2008	0.48750	2.7	14.2	34	1982.0	26.7
384322075051101	1	Oi25-18	9/25/2008	2.07005	1.8	13.4	1	2001.0	7.7
384322075051101	2	Oi25-18	9/25/2008	1.98991	1.8	13.4	1	2000.5	8.2
384326075050801	1	Oi25-19	9/25/2008	1.63052	3	12.9	1	1994.5	14.2
384326075050801	2	Oi25-19	9/25/2008	1.52406	3	12.9	1	1993.5	15.2
384428075135501	1	Oh12-07	11/13/2008	1.22347	3.8	10.4	25	1989.0	19.9
384428075135501	2	Oh12-07	11/13/2008	0.75440	3.8	10.4	25	1984.0	24.9
384428075355701	1	Oc15-11	8/26/2008	0.54585	1.6	12.2	26	1983.5	25.2
384428075355701	2	Oc15-11	8/26/2008	0.57407	1.6	12.2	26	1984.0	24.7
384526075091601	1	Ni51-32	10/8/2008	0.44781	2.2	12.8	0	1981.5	27.3
384526075091601	2	Ni51-32	10/8/2008	0.48956	2.2	12.8	0	1982.0	26.8
384818075354101	1	Nc25-37	8/21/2008	0.96967	3	13	32	1988.0	20.6
384818075354101	2	Nc25-37	8/21/2008	1.47106	3	13	32	1993.0	15.6
384819075190101	1	Ng21-03	9/16/2008	0.53207	1.3	12.4	4	1983.5	25.2

Appendix Ga. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Age dating: sulfur hexafluoride data.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; NOAA, National Oceanic and Atmospheric Administration; mL, milliliters; fmol/L, fentomoles per liter; °C, degrees Celsius; --, no data]

USGS site identification number	Sample number	DGS local well number	Sampling date	Sulfur hexafluoride (SF_6) data					
				NOAA Scale (fmol/L)	Excess air (mL)	Recharge temperature (°C)	Recharge elevation (feet)	Estimated date of recharge[1]	Estimated age of groundwater[1] (year)
384819075190101	2	Ng21-03	9/16/2008	0.54356	1.3	12.4	4	1983.5	25.2
384856075151101	1	Ng25-04	9/17/2008	0.23269	2.8	8.5	0	1975.0	33.7
384856075151101	2	Ng25-04	9/17/2008	0.23337	2.8	8.5	0	1975.0	33.7
385448075341801	1	Md11-04	8/28/2008	1.19391	2.5	10.6	41	1990.0	18.7
385448075341801	2	Md11-04	8/28/2008	0.67789	2.5	10.6	41	1984.0	24.7
385522075251802	1	Le55-09	11/12/2008	1.05971	2.9	12.1	10	1989.0	19.9
385522075251802	2	Le55-09	11/12/2008	0.47403	2.9	12.1	10	1981.0	27.9
390617075261901	1	Je55-01	11/6/2008	3.25897	4	10.3	25	- -	- -
390617075261901	2	Je55-01	11/6/2008	2.91202	4	10.3	25	- -	- -
390652075370701	1	Jc43-05	8/5/2008	1.27289	3.9	14.3	45	1990.5	18.1
390652075370701	2	Jc43-05	8/5/2008	1.21453	3.9	14.3	45	1990.0	18.6
391060075282801	1	Ie42-03	8/19/2008	1.46191	3.5	13.5	3	1992.5	16.1
391060075282801	2	Ie42-03	8/19/2008	1.37572	3.5	13.5	3	1992.0	16.6
391747075364202	1	Hc34-03	9/2/2008	1.13423	2.5	15.2	32	1991.0	17.7
391747075364202	2	Hc34-03	9/2/2008	1.08487	2.5	15.2	32	1990.5	18.2
393739075394202	1	Dc31-15	10/7/2008	2.04715	2.3	13.5	5	2000.0	8.8
393739075394202	2	Dc31-15	10/7/2008	2.31614	2.3	13.5	5	2002.5	6.3
393916075440802	1	Db11-28	10/2/2008	2.35528	2.1	12.4	55	2003.0	5.8
393916075440802	2	Db11-28	10/2/2008	2.35932	2.1	12.4	55	2003.0	5.8
393928075440202	1	Db11-27	10/2/2008	1.93110	1.3	13.9	65	2001.5	7.3
393928075440202	2	Db11-27	10/2/2008	1.94034	1.3	13.9	65	2001.5	7.3
394102075334301	1	Cd42-18	10/7/2008	3.04283	3.5	14.7	20	- -	- -
394102075334301	2	Cd42-18	10/7/2008	3.38003	3.5	14.7	20	- -	- -

[1] Model ages corrected for excess air.

Appendix Gb. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Age dating: dissolved gas data.

[DGS, Delaware Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; --, no data; CH_4, methane; CO_2, carbon dioxide; N_2, nitrogen; O_2, oxygen; Ar, argon]

DGS local well number	Sampling date	Field temperature (°C)	Recharge elevation (feet)	Dissolved gas data										Comments
				Concentration (mg/L)					Partial pressures at field temperatures (atmospheres)					
				CH_4	CO_2	N_2	O_2	Ar	CH_4	CO_2	N_2	O_2	Ar	
Rd22-01	9/10/2008	17.00	34.0	0.0087	100.2128	20.0875	1.0910	0.7148	0.000329	0.053231	0.9786	0.0232	0.01110	
Rd22-01	9/10/2008	17.00	34.0	0.0084	99.8936	20.0095	1.3580	0.7138	0.000320	0.053062	0.9748	0.0289	0.01109	
Ri23-04	9/10/2008	15.50	-0.2	0.0109	64.5619	24.0141	0.2863	0.7506	0.000398	0.032735	1.1384	0.0059	0.01132	
Ri23-04	9/10/2008	15.50	-0.2	0.0102	63.9917	24.1814	0.2694	0.7511	0.000373	0.032445	1.1463	0.0056	0.01133	
Qd52-09	9/9/2008	16.50	25.0	0.0013	62.5480	21.3505	2.3737	0.7479	0.000049	0.032717	1.0308	0.0501	0.01150	
Qd52-09	9/9/2008	16.50	25.0	0.0018	62.8038	21.4075	2.2745	0.7471	0.000067	0.032851	1.0336	0.0480	0.01149	
Frankford 4	8/27/2008	15.50	20.0	0.9368	73.2647	22.5811	0.2411	0.6815	0.034350	0.037147	1.0704	0.0050	0.01028	
Frankford 4	8/27/2008	15.50	20.0	0.9399	73.8947	22.6952	0.2123	0.6838	0.034462	0.037467	1.0759	0.0044	0.01031	
Qd21-12	9/23/2008	15.50	13.0	0.0000	44.3896	19.8792	1.9075	0.6640	0.000000	0.022507	0.9424	0.0394	0.01001	
Qd21-12	9/23/2008	15.50	13.0	0.0000	45.6913	19.7219	2.3957	0.6641	0.000000	0.023167	0.9349	0.0495	0.01001	
Pi32-15	10/21/2008	14.50	-6.0	0.0000	51.6142	18.8927	0.4972	0.6724	0.000000	0.025355	0.8790	0.0101	0.00993	
Pi32-15	10/21/2008	14.50	-6.0	0.0000	48.7292	18.7874	4.1131	0.6720	0.000000	0.023938	0.8741	0.0833	0.00993	
Ph35-25	10/21/2008	15.50	-3.0	0.0000	53.8325	19.2608	2.7115	0.6839	0.000000	0.027294	0.9131	0.0561	0.01031	
Ph35-25	10/21/2008	15.50	-3.0	0.0000	53.7814	19.1999	2.6350	0.6807	0.000000	0.027269	0.9102	0.0545	0.01026	
Pg31-12	10/14/2008	15.50	15.0	0.0000	38.4966	19.1450	3.9647	0.6922	0.000000	0.019519	0.9076	0.0820	0.01044	
Pg31-12	10/14/2008	15.50	15.0	0.0000	37.6421	19.0691	4.7004	0.6902	0.000000	0.019086	0.9040	0.0972	0.01041	
Pe23-185	8/7/2008	24.00	32.0	0.6319	37.9154	20.4065	0.2714	0.7356	0.027519	0.024682	1.1157	0.0066	0.01298	
Pe23-185	8/7/2008	24.00	32.0	0.6459	38.2216	20.4172	0.2599	0.7395	0.028127	0.024881	1.1163	0.0063	0.01305	
Pc22-06	9/8/2008	16.50	9.0	0.0000	45.8845	20.4104	1.9371	0.6749	0.000000	0.024001	0.9854	0.0409	0.01038	
Pc22-06	9/8/2008	16.50	9.0	0.0000	46.6216	20.4040	0.2544	0.6741	0.000000	0.024386	0.9851	0.0054	0.01037	
Pi12-11	10/20/2008	14.00	6.0	0.0000	44.0289	19.2668	0.2391	0.6765	0.000000	0.021285	0.8879	0.0048	0.00989	
Pi12-11	10/20/2008	14.00	6.0	0.0000	40.6238	18.9027	3.1034	0.6692	0.000000	0.019639	0.8711	0.0622	0.00978	
Of42-01	9/9/2008	16.50	34.0	0.0101	154.3689	20.7353	0.2405	0.6770	0.000377	0.080745	1.0011	0.0051	0.01041	
Of42-01	9/9/2008	16.50	34.0	0.0100	154.1243	19.6640	0.2413	0.6609	0.000376	0.080618	0.9494	0.0051	0.01017	
Oi25-18	9/25/2008	15.50	1.0	0.0000	91.4324	18.6765	2.9556	0.6676	0.000000	0.046359	0.8854	0.0611	0.01007	
Oi25-18	9/25/2008	15.50	1.0	0.0000	88.1889	18.4988	2.7086	0.6640	0.000000	0.044714	0.8769	0.0560	0.01001	
Oi25-19	9/25/2008	15.00	1.0	0.0000	96.3512	20.1073	0.2417	0.6931	0.000000	0.048089	0.9444	0.0049	0.01035	
Oi25-19	9/25/2008	15.00	1.0	0.0000	99.3025	19.8207	0.2685	0.6925	0.000000	0.049562	0.9309	0.0055	0.01034	
Oh12-07	11/13/2008	14.50	25.0	0.0000	30.0754	21.7041	5.4840	0.7451	0.000000	0.014774	1.0098	0.1111	0.01101	
Oh12-07	11/13/2008	14.50	25.0	0.0000	30.3703	21.6117	4.7638	0.7434	0.000000	0.014919	1.0055	0.0965	0.01098	

Appendix Gb. Groundwater-quality data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Age dating: dissolved gas data.—Continued

[DGS, Delaware Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; --, no data; CH_4, methane; CO_2, carbon dioxide; N_2, nitrogen; O_2, oxygen; Ar, argon]

DGS local well number	Sampling date	Field temperature (°C)	Recharge elevation (feet)	Dissolved gas data										Comments
				Concentration (mg/L)					Partial pressures at field temperatures (atmospheres)					
				CH_4	CO_2	N_2	O_2	Ar	CH_4	CO_2	N_2	O_2	Ar	
Oc15-11	8/26/2008	16.00	26.0	0.0000	43.5592	18.7055	4.2949	0.6795	0.000000	0.022434	0.8949	0.0897	0.01035	
Oc15-11	8/26/2008	16.00	26.0	0.0000	47.4307	18.9626	0.2457	0.6802	0.000000	0.024428	0.9072	0.0051	0.01036	
Ni51-32	10/8/2008	15.00	-3.0	0.0000	45.7027	20.0689	0.2537	0.6774	0.000000	0.022810	0.9425	0.0052	0.01011	
Ni51-32	10/8/2008	15.00	-3.0	0.0000	46.9392	20.3014	2.6958	0.6841	0.000000	0.023427	0.9535	0.0552	0.01021	
Nc25-37	8/21/2008	18.00	32.0	0.0000	40.4983	20.7306	1.9072	0.7034	0.000000	0.022177	1.0279	0.0414	0.01114	
Nc25-37	8/21/2008	18.00	32.0	0.0000	41.5356	18.9584	0.2124	0.6761	0.000000	0.022745	0.9401	0.0046	0.01071	
Ng21-03	9/16/2008	15.00	4.0	0.0000	31.2095	18.4494	5.2418	0.6719	0.000000	0.015577	0.8665	0.1073	0.01003	
Ng21-03	9/16/2008	15.00	4.0	0.0000	32.8372	18.3829	3.5046	0.6701	0.000000	0.016389	0.8634	0.0717	0.01000	
Ng25-04	9/17/2008	15.50	-0.6	0.0000	37.7009	21.6460	3.0128	0.7630	0.000000	0.019115	1.0261	0.0623	0.01150	
Ng25-04	9/17/2008	15.50	-0.6	0.0000	36.7198	21.3868	2.8705	0.7568	0.000000	0.018618	1.0138	0.0593	0.01141	
Md11-04	8/28/2008	16.50	41.0	0.0000	71.9824	20.1331	4.1502	0.7139	0.000000	0.037652	0.9720	0.0875	0.01098	
Md11-04	8/28/2008	16.50	41.0	0.0000	72.9209	20.3540	3.7288	0.7216	0.000000	0.038143	0.9827	0.0787	0.01110	
Le55-09	11/12/2008	15.00	10.0	0.0000	50.1526	24.2301	0.3732	0.7040	0.000000	0.025031	1.1380	0.0076	0.01051	
Le55-09	11/12/2008	15.00	10.0	0.0000	48.1338	24.0938	0.4144	0.7034	0.000000	0.024024	1.1316	0.0085	0.01050	
Je55-01	11/6/2008	15.86	25.0	0.0000	139.7348	23.7339	0.6823	0.7450	0.000000	0.071652	1.1326	0.0142	0.01131	
Je55-01	11/6/2008	15.86	25.0	0.0000	138.8549	24.1470	0.9299	0.7535	0.000000	0.071201	1.1523	0.0194	0.01144	
Jc43-05	8/5/2008	16.00	45.0	0.0000	90.2122	20.6527	5.0703	0.6939	0.000000	0.046461	0.9881	0.1059	0.01057	
Jc43-05	8/5/2008	16.00	45.0	0.0000	88.9382	19.9153	4.3215	0.6789	0.000000	0.045805	0.9528	0.0902	0.01034	
Ie42-03	8/19/2008	15.50	3.0	0.0000	61.4376	23.1291	0.2584	0.6924	0.000000	0.031150	1.0964	0.0053	0.01044	
Ie42-03	8/19/2008	15.50	3.0	0.0000	60.5011	23.3337	0.2679	0.6935	0.000000	0.030676	1.1061	0.0055	0.01046	
Hc34-03	9/2/2008	15.50	32.0	0.0000	72.7466	20.2010	0.2424	0.6539	0.000000	0.036884	0.9576	0.0050	0.00986	
Hc34-03	9/2/2008	15.50	32.0	0.0000	70.3832	20.1238	2.7503	0.6515	0.000000	0.035686	0.9540	0.0569	0.00982	
Dc31-15	10/7/2008	13.50	5.0	0.0000	79.3186	19.1076	2.0357	0.6737	0.000000	0.037732	0.8721	0.0404	0.00975	
Dc31-15	10/7/2008	13.50	5.0	--	--	--	--	--	--	--	--	--	--	Sample lost
Db11-28	10/2/2008	17.00	55.0	0.0000	137.1960	19.2160	3.5000	0.6844	0.000000	0.072876	0.9361	0.0746	0.01063	No duplicate submitted
Db11-27	10/2/2008	15.00	65.0	0.0000	105.6206	18.0066	0.2308	0.6519	0.000000	0.052715	0.8457	0.0047	0.00973	
Db11-27	10/2/2008	15.00	65.0	0.0000	101.4155	17.9318	0.2379	0.6488	0.000000	0.050616	0.8422	0.0049	0.00968	
Cd42-18	10/7/2008	15.00	20.0	0.0000	97.7822	19.7802	5.6107	0.6744	0.000000	0.048803	0.9290	0.1148	0.01007	
Cd42-18	10/7/2008	15.00	20.0	0.0000	97.9240	19.8032	6.6744	0.6765	0.000000	0.048874	0.9301	0.1366	0.01010	

Appendix Ha. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Nutrients.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in milligrams per liter; E, estimated; <, less than; N, nitrogen]

USGS site identification number	DGS local well number	Sample type	Nutrients						
			Ammonia as N	Dissolved ammonia plus organic nitrogen as N	Total ammonia plus organic nitrogen as N	Nitrite plus nitrate as N	Nitrite as N	Dissolved phosphorus	Total phosphorus
382830075073601	Ri23-04	Blank	<0.02	<0.14	<0.14	<0.04	<0.002	<0.006	<0.008
383713075085501	Pi32-15	Replicate	<0.02	<0.1	<0.1	3.3	<0.002	E0.003	<0.012
384428075135501	Oh12-07	Blank	<0.02	<0.1	<0.1	<0.04	<0.002	<0.006	<0.012
385448075341801	Md11-04	Replicate	<0.02	E0.08	E0.08	8.19	<0.002	0.007	0.009
390652075370701	Jc43-05	Replicate	<0.02	<0.14	<0.14	5.48	<0.002	<0.006	<0.008

Appendix Hb. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Major ions and trace elements.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Major ions and trace elements					
			Bromide (mg/L as Br)	Calcium (mg/L as Ca)	Chloride (mg/L as Cl)	Fluoride (mg/L as F)	Magnesium (mg/L as Mg)	Manganese (µg/L as Mn)
383713075085501	Pi32-15	Replicate	0.08	4.64	17.20	<0.08	2.77	6.94
383815075271001	Pe23-185	Replicate	E0.019	E0.03	4.50	<0.12	<0.02	29.61
384428075135501	Oh12-07	Blank	<0.02	<0.02	<0.12	<0.08	<0.012	<0.2
390652075370701	Jc43-05	Replicate	0.03	12.90	14.72	<0.12	4.46	25.16

USGS site identification number	DGS local well number	Sample type	Major ions and trace elements					
			Potassium (mg/L as K)	Silica (mg/L as SiO_2)	Sodium (mg/L)	Sulfate (mg/L as SO_4)	Total Hardness (mg/L as $CaCO_3$)	Total Iron (µg/L as Fe)
383713075085501	Pi32-15	Replicate	1.96	19.60	10.73	4.66	23.01	<4
383815075271001	Pe23-185	Replicate	0.04	29.35	25.92	0.40	--	E4.2
384428075135501	Oh12-07	Blank	<0.06	<0.02	<0.12	<0.18	--	<4
390652075370701	Jc43-05	Replicate	1.96	26.31	9.88	25.56	50.57	252.5

Appendix Hc. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticides.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter (µg/L); E, estimated; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Acetochlor	Alachlor	Atrazine	Benfluralin	Butylate
383311075344401	Qd21-12	Replicate	<0.006	<0.006	E0.005	<0.004	<0.002
384326075050801	Oi25-19	Blank	<0.006	<0.006	<0.007	<0.004	<0.002
384818075354101	Nc25-37	Replicate	<0.006	0.012	0.023	<0.004	<0.002
384856075151101	Ng25-04	Blank	<0.006	<0.006	<0.007	<0.004	<0.002
391060075282801	Ie42-03	Replicate	<0.02	< 0.02	--	--	--
393928075440202	Db11-27	Replicate	<0.01	E0.0059	0.204	<0.004	0.002

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Carbaryl	Carbofuran	Chlorpyrifos	Cyanazine	Diazinon
383311075344401	Qd21-12	Replicate	<0.06	<0.02	<0.005	<0.02	<0.005
384326075050801	Oi25-19	Blank	<0.06	<0.02	<0.005	<0.02	<0.005
384818075354101	Nc25-37	Replicate	<0.06	E0.019	<0.005	<0.02	<0.005
384856075151101	Ng25-04	Blank	<0.06	<0.02	<0.005	<0.02	<0.005
391060075282801	Ie42-03	Replicate	--	--	--	--	--
393928075440202	Db11-27	Replicate	<0.2	<0.06	<0.01	<0.04	<0.005

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Dieldrin	Dimethenamid	Disulfoton	Eptam (Eptam)	Ethalfluralin
383311075344401	Qd21-12	Replicate	0.017	<0.02	0.04	<0.002	<0.009
384326075050801	Oi25-19	Blank	<0.009	<0.02	0.04	<0.002	<0.009
384818075354101	Nc25-37	Replicate	<0.009	<0.02	0.04	<0.002	<0.009
384856075151101	Ng25-04	Blank	<0.009	<0.02	0.04	<0.002	<0.009
391060075282801	Ie42-03	Replicate	--	<0.02	--	--	--
393928075440202	Db11-27	Replicate	0.075	--	0.04	0.009	<0.009

Appendix Hc. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticides.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; E, estimated; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Ethoprop	Fipronil	Flufenacet	Fonofos	Glufosinate
383311075344401	Qd21-12	Replicate	<0.012	0.02	<0.02	<0.01	<0.02
384326075050801	Oi25-19	Blank	<0.012	<0.02	<0.02	<0.01	<0.02
384818075354101	Nc25-37	Replicate	<0.012	<0.02	<0.02	<0.01	<0.02
384856075151101	Ng25-04	Blank	<0.012	<0.02	<0.02	<0.01	<0.02
391060075282801	Ie42-03	Replicate	--	--	<0.02	--	<0.02
393928075440202	Db11-27	Replicate	<0.016	E0.018	--	<0.01	--

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Glyphosate	alpha-HCH	Lindane	Linuron	Malathion
383311075344401	Qd21-12	Replicate	<0.02	<0.002	<0.006	<0.06	<0.016
384326075050801	Oi25-19	Blank	<0.02	<0.002	<0.006	<0.06	<0.016
384818075354101	Nc25-37	Replicate	<0.02	<0.002	<0.006	<0.06	<0.016
384856075151101	Ng25-04	Blank	<0.02	<0.002	<0.006	<0.06	<0.016
391060075282801	Ie42-03	Replicate	<0.02	--	--	--	--
393928075440202	Db11-27	Replicate	--	E0.002	E0.006	<0.06	<0.02

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Metolachlor	Metribuzin	Molinate	Napropamide	Parathion
383311075344401	Qd21-12	Replicate	0.092	<0.012	<0.002	<0.018	<0.01
384326075050801	Oi25-19	Blank	<0.01	<0.012	<0.002	<0.018	<0.01
384818075354101	Nc25-37	Replicate	0.056	<0.012	<0.002	<0.018	<0.01
384856075151101	Ng25-04	Blank	<0.01	<0.012	<0.002	<0.018	<0.01
391060075282801	Ie42-03	Replicate	<0.02	--	--	--	--
393928075440202	Db11-27	Replicate	0.055	<0.016	<0.002	<0.018	<0.02

Appendix Hc. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticides.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; E, estimated; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Pesticides					
			Parathion methyl	Pebulate	*cis*-Permethrin	Phorate	Prometon	Propachlor
383311075344401	Qd21-12	Replicate	<0.008	<0.004	<0.01	<0.04	<0.008	<0.006
384326075050801	Oi25-19	Blank	<0.008	<0.004	<0.01	<0.04	<0.008	<0.006
384818075354101	Nc25-37	Replicate	<0.008	<0.004	<0.01	<0.04	E0.0055	<0.006
384856075151101	Ng25-04	Blank	<0.008	<0.004	<0.01	<0.04	<0.008	<0.006
391060075282801	Ie42-03	Replicate	--	--	--	--	--	<0.02
393928075440202	Db11-27	Replicate	<0.008	E0.005	<0.014	<0.02	0.0124	<0.012

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Propanil	Propargite	Propyzamide	Simazine	Tebuthiuron
383311075344401	Qd21-12	Replicate	<0.006	<0.04	<0.004	E0.004	<0.016
384326075050801	Oi25-19	Blank	<0.006	<0.04	<0.004	<0.006	<0.016
384818075354101	Nc25-37	Replicate	<0.006	<0.04	<0.004	<0.006	<0.016
384856075151101	Ng25-04	Blank	<0.006	<0.04	<0.004	<0.006	<0.016
391060075282801	Ie42-03	Replicate	--	--	--	--	--
393928075440202	Db11-27	Replicate	<0.014	<0.02	<0.004	0.031	0.025

USGS site identification number	DGS local well number	Sample type	Pesticides				
			Terbacil	Terbufos	Thiobencarb	Triallate	Trifluralin
383311075344401	Qd21-12	Replicate	<0.018	<0.018	<0.01	<0.006	<0.006
384326075050801	Oi25-19	Blank	<0.018	<0.018	<0.01	<0.006	<0.006
384818075354101	Nc25-37	Replicate	<0.018	<0.018	<0.01	<0.006	<0.006
384856075151101	Ng25-04	Blank	<0.018	<0.018	<0.01	<0.006	<0.006
391060075282801	Ie42-03	Replicate	--	--	--	--	--
393928075440202	Db11-27	Replicate	<0.04	0.018	<0.016	<0.006	<0.012

Appendix Hd. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticide degradates.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; SAA, sulfinyl acetic acid; E, estimated; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			Acetochlor SA	Acetochlor ESA	Acetochlor OA	Acetochlor SAA	Alachlor SA	Alachlor ESA SA
383311075344401	Qd21-12	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384326075050801	Oi25-19	Blank	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384818075354101	Nc25-37	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384856075151101	Ng25-04	Blank	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
391060075282801	Ie42-03	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
393928075440202	Db11-27	Replicate	--	--	--	--	--	--

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			Alachlor ESA	Alachlor OA	Alachlor SA	Aminomethyl-phosphonic acid	DCPA (Clorthal-dimethyl)	Deethyltrazine
383311075344401	Qd21-12	Replicate	0.2	0.02	<0.02	<0.02	<0.003	E0.013
384326075050801	Oi25-19	Blank	<0.02	<0.02	<0.02	<0.02	<0.003	<0.014
384818075354101	Nc25-37	Replicate	0.59	0.16	<0.02	<0.02	<0.003	E0.079
384856075151101	Ng25-04	Blank	<0.02	<0.02	<0.02	<0.02	<0.003	<0.014
391060075282801	Ie42-03	Replicate	0.35	0.02	<0.02	<0.02	--	--
393928075440202	Db11-27	Replicate	--	--	--	--	<0.006	E0.166

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			Dechloro-dimethen-amide	Desulfinyl-fipronil-amide	Dechloro-acetochlor	Dechloroala-chlor	Dechloro-metolachlor	Desulfinyl-fipronil
383311075344401	Qd21-12	Replicate	<0.02	<0.029	<0.02	<0.02	<0.02	<0.012
384326075050801	Oi25-19	Blank	<0.02	<0.029	<0.02	<0.02	<0.02	<0.012
384818075354101	Nc25-37	Replicate	<0.02	<0.029	<0.02	<0.02	<0.02	<0.012
384856075151101	Ng25-04	Blank	<0.02	<0.029	<0.02	<0.02	<0.02	<0.012
391060075282801	Ie42-03	Replicate	<0.02	--	<0.02	<0.02	<0.02	--
393928075440202	Db11-27	Replicate	--	<0.029	--	--	--	<0.012

Appendix Hd. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Pesticide degradates.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; ESA, ethanesulfonic acid; OA, oxanilic acid; SA, second amide; SAA, sulfinyl acetic acid; E, estimated; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			2,6-Diethylaniline	Dimethenamid ESA	Dimethenamid OA	2-[(2-Ethyl-6-methylphenyl) amino]-2-oxoESA	Fipronil sulfide	Fipronil sulfone
383311075344401	Qd21-12	Replicate	<0.002	<0.02	<0.02	0.04	<0.013	<0.024
384326075050801	Oi25-19	Blank	<0.002	<0.02	<0.02	<0.02	<0.013	<0.024
384818075354101	Nc25-37	Replicate	<0.002	<0.02	<0.02	0.02	<0.013	<0.024
384856075151101	Ng25-04	Blank	<0.002	<0.02	<0.02	<0.02	<0.013	<0.024
391060075282801	Ie42-03	Replicate	- -	<0.02	<0.02	0.03	- -	- -
393928075440202	Db11-27	Replicate	<0.006	- -	- -	- -	E0.001	E0.004

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			Flufenacet ESA	Flufenacet OA	Hydroxyacetochlor	Hydroxyalachlor	Hydroxydimethenamid	Hydroxymetolachlor
383311075344401	Qd21-12	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384326075050801	Oi25-19	Blank	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384818075354101	Nc25-37	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
384856075151101	Ng25-04	Blank	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
391060075282801	Ie42-03	Replicate	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
393928075440202	Db11-27	Replicate	- -	- -	- -	- -	- -	- -

USGS site identification number	DGS local well number	Sample type	Pesticide degradates					
			Metolachlor ESA	Metolachlor OA	Pendimethalin	*p,p'*-DDE	Propachlor ESA	Propachlor OA
383311075344401	Qd21-12	Replicate	1.24	0.61	<0.012	<0.003	<0.05	<0.02
384326075050801	Oi25-19	Blank	<0.02	<0.02	<0.012	<0.003	<0.05	<0.02
384818075354101	Nc25-37	Replicate	3.43	0.31	<0.012	<0.003	<0.05	<0.02
384856075151101	Ng25-04	Blank	<0.02	<0.02	<0.012	<0.003	<0.05	<0.02
391060075282801	Ie42-03	Replicate	2.25	0.28	- -	- -	<0.05	<0.02
393928075440202	Db11-27	Replicate	- -	- -	<0.012	<0.003	- -	- -

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Acetone	Acrylonitrile	Benzene	Bromobenzene	Bromochloro-methane
382805075330301	Rd22-01	Replicate	<4	<0.4	<0.016	<0.02	<0.06
384326075050801	Oi25-19	Blank	<4	<0.4	<0.045	<0.02	<0.06
384818075354101	Nc25-37	Replicate	<4	<0.4	<0.02	<0.02	<0.06
385522075251802	Le55-09	Blank	6.9	<0.4	<0.057	<0.02	<0.06
390617075261901	Je55-01	Blank	<4	<0.4	<0.016	<0.02	<0.06
391747075364202	Hc34-03	Replicate	<4	<0.4	<0.02	<0.02	<0.06

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Bromodichlo-romethane	Bromoethene	Bromo-methane	*n*-Butylbenzene	*sec*-Butylbenzene
382805075330301	Rd22-01	Replicate	<0.04	<0.12	<0.4	<0.14	<0.04
384326075050801	Oi25-19	Blank	<0.04	<0.12	<0.4	<0.14	<0.04
384818075354101	Nc25-37	Replicate	0.373	<0.12	<0.4	<0.14	<0.04
385522075251802	Le55-09	Blank	<0.052	<0.12	<0.4	<0.08	<0.02
390617075261901	Je55-01	Blank	E0.045	<0.12	<0.4	<0.08	<0.02
391747075364202	Hc34-03	Replicate	<0.04	<0.12	<0.4	<0.14	<0.04

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			trans-Butyl-benzene	Ethyl-*tert*-Butyl ether	Butyl methyl ketone	Carbon disulfide	Chlorobenzene
382805075330301	Rd22-01	Replicate	<0.06	<0.04	<0.6	<0.06	0.156
384326075050801	Oi25-19	Blank	<0.06	<0.04	<0.6	<0.06	<0.02
384818075354101	Nc25-37	Replicate	<0.06	<0.04	<0.6	<0.06	<0.02
385522075251802	Le55-09	Blank	<0.06	<0.04	<0.6	<0.04	<0.02
390617075261901	Je55-01	Blank	<0.06	<0.04	<0.6	<0.04	<0.02
391747075364202	Hc34-03	Replicate	<0.06	<0.04	<0.6	<0.06	<0.02

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Chloroethane	Chloromethane	3-Chloropropene	2-Chlorotoluene	4-Chlorotoluene
382805075330301	Rd22-01	Replicate	<0.1	<0.1	<0.08	<0.04	<0.04
384326075050801	Oi25-19	Blank	<0.1	<0.1	<0.08	<0.04	<0.04
384818075354101	Nc25-37	Replicate	<0.1	<0.1	<0.08	<0.04	<0.04
385522075251802	Le55-09	Blank	<0.1	<0.14	<0.08	<0.02	<0.02
390617075261901	Je55-01	Blank	<0.1	<0.14	<0.08	<0.02	<0.02
391747075364202	Hc34-03	Replicate	<0.1	<0.1	<0.08	<0.04	<0.04

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Dibromochloromethane	Dibromochloropropane	1,2-Dibromoethane	Dibromomethane	*trans*-1,3-Dichloropropene
382805075330301	Rd22-01	Replicate	<0.12	<0.5	<0.04	<0.04	<0.1
384326075050801	Oi25-19	Blank	<0.12	<0.5	<0.04	<0.04	<0.1
384818075354101	Nc25-37	Replicate	0.82	<0.5	<0.04	<0.04	<0.1
385522075251802	Le55-09	Blank	<0.12	<1	<0.04	<0.04	<0.1
390617075261901	Je55-01	Blank	<0.12	<1	<0.04	<0.04	<0.1
391747075364202	Hc34-03	Replicate	<0.12	<0.5	<0.04	<0.04	<0.1

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			trans-1,4-Dichloro-2-butene	1,2-Dichlorobenzene	1,3-Dichlorobenzene	1,4-Dichlorobenzene	1,1-Dichloroethane
382805075330301	Rd22-01	Replicate	<0.6	0.391	<0.04	0.2056	0.12
384326075050801	Oi25-19	Blank	<0.6	<0.02	<0.04	<0.02	<0.04
384818075354101	Nc25-37	Replicate	<0.6	<0.02	<0.04	<0.02	<0.04
385522075251802	Le55-09	Blank	<0.4	<0.02	<0.02	<0.02	<0.04
390617075261901	Je55-01	Blank	<0.4	<0.02	<0.02	<0.02	<0.04
391747075364202	Hc34-03	Replicate	<0.6	<0.02	<0.04	<0.02	E0.06

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			1,2-Dichloroethane	1,1-Dichloroethene	*cis*-1,2-Dichloroethene	*trans*-1,2-Dichloroethene	Dichlorofluoromethane
382805075330301	Rd22-01	Replicate	<0.06	E0.03	<0.02	<0.02	<0.14
384326075050801	Oi25-19	Blank	<0.07	<0.02	<0.02	<0.02	<0.14
384818075354101	Nc25-37	Replicate	<0.06	<0.02	<0.02	<0.02	<0.14
385522075251802	Le55-09	Blank	0.28	<0.02	<0.02	<0.018	<0.1
390617075261901	Je55-01	Blank	<0.06	<0.02	<0.02	<0.018	<0.1
391747075364202	Hc34-03	Replicate	<0.06	0.22	<0.02	<0.02	<0.14

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Dichloromethane	1,2-Dichloropropane	1,3-Dichloropropane	2,2-Dichloropropane	1,1-Dichloropropene
382805075330301	Rd22-01	Replicate	<0.04	<0.02	<0.06	<0.06	<0.04
384326075050801	Oi25-19	Blank	<0.04	<0.02	<0.06	<0.06	<0.04
384818075354101	Nc25-37	Replicate	<0.04	<0.02	<0.06	<0.06	<0.04
385522075251802	Le55-09	Blank	E0.097	<0.02	<0.06	<0.06	<0.04
390617075261901	Je55-01	Blank	<0.04	<0.02	<0.06	<0.06	<0.04
391747075364202	Hc34-03	Replicate	<0.04	<0.02	<0.06	<0.06	<0.04

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			cis-1,3-Dichloropropene	Diethylether	Diisopropylether	Ethylbenzene	Ethylmethylacrylate
382805075330301	Rd22-01	Replicate	<0.1	<0.12	<0.06	<0.04	<0.14
384326075050801	Oi25-19	Blank	<0.1	<0.12	<0.06	<0.04	<0.14
384818075354101	Nc25-37	Replicate	<0.1	<0.12	<0.06	<0.04	<0.14
385522075251802	Le55-09	Blank	<0.1	<0.13	<0.06	<0.04	<0.14
390617075261901	Je55-01	Blank	<0.1	<0.12	<0.06	<0.04	<0.14
391747075364202	Hc34-03	Replicate	<0.1	<0.12	<0.06	<0.04	<0.14

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Ethyl-methyl-ketone	2-Ethyl-toluene	Iodomethane	Isobutyl-methyl ketone	Isodurene
382805075330301	Rd22-01	Replicate	<1.6	<0.04	<0.4	<0.4	<0.12
384326075050801	Oi25-19	Blank	4.51	<0.04	<0.4	<0.4	<0.12
384818075354101	Nc25-37	Replicate	<1.6	<0.04	<0.4	<0.4	<0.12
385522075251802	Le55-09	Blank	31.61	<0.02	<0.8	<0.4	<0.08
390617075261901	Je55-01	Blank	<1.6	<0.02	<0.8	<0.4	<0.08
391747075364202	Hc34-03	Replicate	<1.6	<0.04	<0.4	<0.4	<0.12

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Isopropyl-benzene	4-Isopropyl-toluene	Hexachloro-butadiene	Hexachloro-ethane	Methacrylonitrile
382805075330301	Rd22-01	Replicate	<0.04	<0.08	<0.06	<0.14	<0.2
384326075050801	Oi25-19	Blank	<0.04	<0.08	<0.06	<0.14	<0.2
384818075354101	Nc25-37	Replicate	<0.04	<0.08	<0.06	<0.14	<0.2
385522075251802	Le55-09	Blank	<0.04	<0.06	<0.06	<0.14	<0.2
390617075261901	Je55-01	Blank	<0.04	<0.06	<0.06	<0.14	<0.2
391747075364202	Hc34-03	Replicate	<0.04	<0.08	<0.06	<0.14	<0.2

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Methyl-acrylate	Methyl meth-acrylate	Methyl-*tert*-pentyl ether	Methyl-*tert*-butyl ether	*n*-Propylbenzene
382805075330301	Rd22-01	Replicate	<0.6	<0.2	<0.06	E0.096	<0.04
384326075050801	Oi25-19	Blank	<0.6	<0.2	<0.06	0.173	<0.04
384818075354101	Nc25-37	Replicate	<0.6	<0.2	<0.06	0.628	<0.04
385522075251802	Le55-09	Blank	<0.6	<0.2	<0.06	0.778	<0.04
390617075261901	Je55-01	Blank	<0.6	<0.2	<0.06	<0.1	<0.04
391747075364202	Hc34-03	Replicate	<0.6	<0.2	E0.07	2.470	<0.04

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Naphthalene	Prehnitene (1,2,3,4-tetra-methylbenzene)	Styrene	Tetrachloro-ethene	Tetrachloro-methane
382805075330301	Rd22-01	Replicate	<0.2	<0.14	<0.04	E0.04146	<0.08
384326075050801	Oi25-19	Blank	<0.2	<0.14	<0.04	<0.04	<0.08
384818075354101	Nc25-37	Replicate	<0.2	<0.14	<0.04	1.611	<0.08
385522075251802	Le55-09	Blank	<0.2	<0.08	<0.04	<0.04	<0.06
390617075261901	Je55-01	Blank	<0.2	<0.08	<0.04	<0.04	<0.06
391747075364202	Hc34-03	Replicate	<0.2	<0.14	<0.04	0.852	<0.08

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Tetrahydro-furan	Toluene	1,1,1,2-Tetra-chloroethane	1,1,2,2-Tetra-chloroethane	Tribromo-methane
382805075330301	Rd22-01	Replicate	<1.4	<0.02	<0.04	<0.1	<0.08
384326075050801	Oi25-19	Blank	<1.4	<0.02	<0.04	<0.1	<0.08
384818075354101	Nc25-37	Replicate	<1.4	<0.02	<0.04	<0.1	0.6
385522075251802	Le55-09	Blank	E0.772	E0.026	<0.04	<0.1	<0.1
390617075261901	Je55-01	Blank	<1.4	<0.018	<0.04	<0.1	<0.1
391747075364202	Hc34-03	Replicate	<1.4	<0.02	<0.04	<0.1	<0.08

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			1,2,3-Trichlo-robenzene	1,2,4-Trichloro-benzene	1,1,1-Trichlo-roethane	1,1,2-Trichloro-ethane	Trichloro-ethene
382805075330301	Rd22-01	Replicate	<0.08	<0.08	<0.02	<0.06	E0.027
384326075050801	Oi25-19	Blank	<0.08	<0.08	<0.02	<0.06	<0.02
384818075354101	Nc25-37	Replicate	<0.08	<0.08	<0.02	<0.06	<0.02
385522075251802	Le55-09	Blank	<0.06	<0.04	<0.02	<0.06	<0.02
390617075261901	Je55-01	Blank	<0.06	<0.04	<0.02	<0.06	<0.02
391747075364202	Hc34-03	Replicate	<0.08	<0.08	1.04	<0.06	0.52

Appendix He. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Volatile organic compounds.—Continued

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all concentrations in micrograms per liter; <, less than; E, estimated; --, not detected]

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			Trichlorofluoromethane	Trichloromethane	1,2,3-Trichloropropane	1,1,2-Trichlorotrifluoromethane	1,2,3-Trimethylbenzene
382805075330301	Rd22-01	Replicate	<0.08	E0.0990	<0.12	<0.04	<0.08
384326075050801	Oi25-19	Blank	<0.08	0.1375	<0.12	<0.04	<0.08
384818075354101	Nc25-37	Replicate	<0.08	0.1416	<0.12	<0.04	<0.08
385522075251802	Le55-09	Blank	<0.08	0.3504	<0.12	<0.04	<0.08
390617075261901	Je55-01	Blank	<0.08	0.1251	<0.12	<0.04	<0.08
391747075364202	Hc34-03	Replicate	<0.08	0.1228	<0.12	<0.04	<0.08

USGS site identification number	DGS local well number	Sample type	Volatile organic compounds				
			1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	Vinyl chloride	*m-p*-Xylene	*o*-Xylene
382805075330301	Rd22-01	Replicate	<0.04	<0.04	<0.08	<0.08	<0.04
384326075050801	Oi25-19	Blank	<0.04	<0.04	<0.08	<0.08	<0.04
384818075354101	Nc25-37	Replicate	<0.04	<0.04	<0.08	<0.08	<0.04
385522075251802	Le55-09	Blank	<0.04	<0.04	<0.08	<0.08	<0.04
390617075261901	Je55-01	Blank	<0.04	<0.04	<0.08	<0.08	<0.04
391747075364202	Hc34-03	Replicate	<0.04	<0.04	<0.08	<0.08	<0.04

Appendix Hf. Quality-control data for sampled public water-supply wells in the Columbia aquifer in Delaware, August through November, 2008—Radiochemical activities.

[USGS, U.S. Geological Survey; DGS, Delaware Geological Survey; all activities are in picocuries per liter; <, less than; --, not detected]

USGS site identification number	DGS local well number	Sample type	Radiochemical activities		
			Radium-226	Radium-228	Radon-222
383815075271001	Pe23-185	Replicate	<0.01	<-0.03	58.5
391747075364202	Hc34-03	Blank	--	--	<3.2
391747075364202	Hc34-03	Replicate	0.47	0.8	--

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