SUSCEPTIBILITY OF SOURCE WATER TO COMMUNITY WATER SUPPLY WELLS IN NEW JERSEY TO CONTAMINATION BY PESTICIDES

Summary

A susceptibility assessment model was developed to predict the potential susceptibility of the source water from 2,237 community water supply (CWS) wells in New Jersey to contamination by pesticides. Susceptibility is defined by variables describing hydrogeologic sensitivity and contaminant-use intensity within the area contributing water to a well. The models were calibrated by using concentrations of pesticides in water samples from two sets of wells monitored for pesticides at various minimum reporting levels (MRLs). These data were from (1) 229 CWS wells sampled and analyzed by various groups and (2) 436 unconfined wells of all types sampled and analyzed by the U.S. Geological Survey (USGS).

Results indicate that concentrations of regulated pesticides in water from CWS wells infrequently exceeded 10 percent of a Maximum Contaminant Level (MCL). Water samples from only four CWS wells contained a regulated pesticide concentration that exceeded 10 percent of an MCL—dinoseb in two wells and atrazine and lindane each in one well. Metabolites of dacthal, an unregulated pesticide, were detected above 10 percent of the Health Advisory (HA) of the parent compound in four CWS wells. One or more of four regulated pesticides (alachlor, atrazine, carbofuran, and simazine) were detected above 10 percent of their respective MCL in 18 wells sampled and analyzed by the USGS: these wells included 1 CWS well and 17 other well types, such as observation and domestic.

Variables used to estimate hydrogeologic sensitivity in the susceptibility model are if the well is open to a confined or unconfined aquifer, and the conceptual variables depth to the top of the open interval and length of the open interval for wells in unconfined aquifers. Variables used to estimate pesticide-use intensity in wells screened in unconfined aquifers are the percentages of agricultural land in 1986 and minimum distance to agricultural land in 1995, and the conceptual variables percentage of urban land in 1995 and minimum distance to a golf course. Results of the model indicate that 29 percent of CWS wells are open to a confined Coastal Plain aquifer and are not susceptible, whereas, in unconfined aquifers the susceptibility is low for 48 percent and moderate for 23 percent of the CWS wells (figs. 1 and 2).

Introduction

The 1996 Amendments to the Federal Safe Drinking Water Act require all states to establish a Source Water Assessment Program (SWAP). New Jersey Department of Environmental Protection (NJDEP) elected to evaluate the susceptibility of public water systems to contamination by inorganic constituents, nutrients, volatile organic and synthetic organic compounds, pesticides, disinfection byproduct precursors, pathogens, and radionuclides. Susceptibility to contamination in ground water is a function of many factors, including contaminant presence or use in or near the water source, natural occurrence in geologic material, changes in ambient conditions related to human activities, and location of the well within the flow system. The New Jersey SWAP includes four steps: (1) delineate the source water assessment area of each ground- and surface-water source of public drinking water, (2) inventory the potential contaminant sources within the source water assessment area, (3) determine the NJDEP in decisions concerning monitoring of public sources of water.

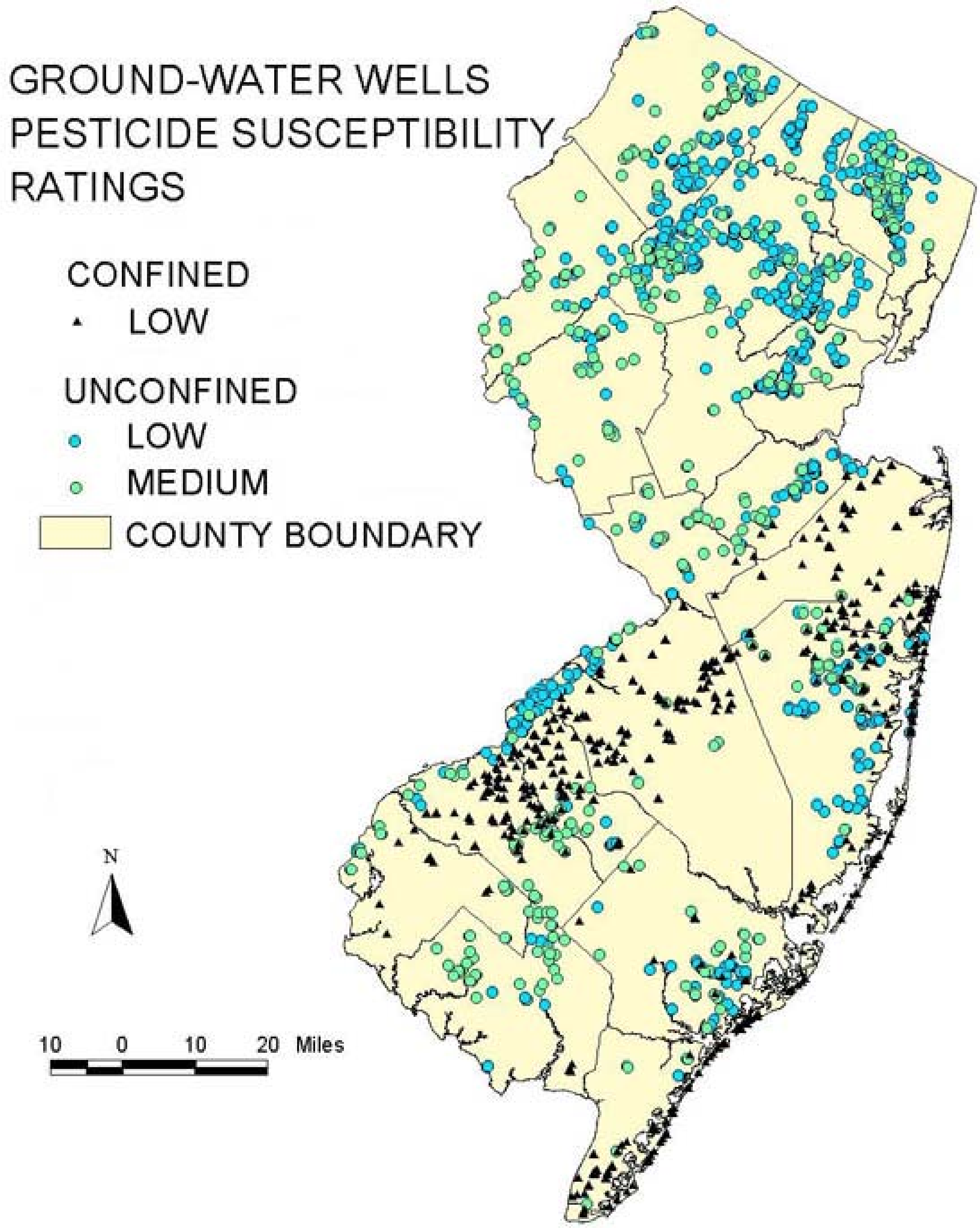

Figure 1. Susceptibility of 2,237 community water-supply wells in New Jersey to contamination by pesticides.

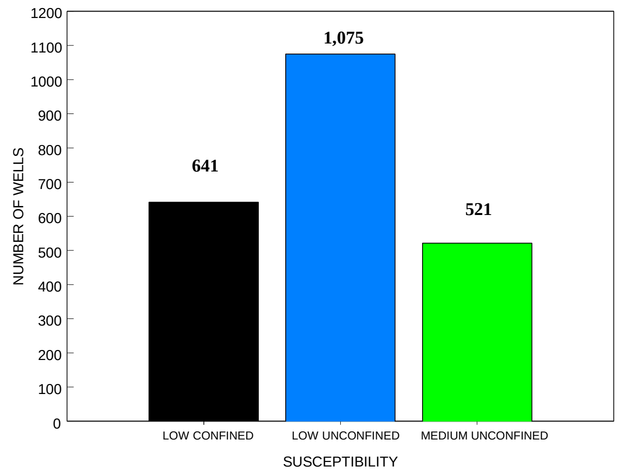

Figure 2. Number of community-water-supply wells in New Jersey by pesticide susceptibility group.

public water system's susceptibility to contaminants, and (4) incorporate public participation and education (http://www.state.nj.us/dep/swap).

Susceptibility assessment models were developed to rate each public ground-water source as having low, medium, or high susceptibility for groups of constituents. This report (1) describes methods used to develop the susceptibility assessment model for pesticides, (2) presents results of application of the susceptibility model to estimate the susceptibility of source water to CWS wells to pesticides, and (3) documents the distribution of pesticides in water from CWS wells in New Jersey. The results of the model are intended to be a screening tool to guide water managers in decisions concerning monitoring of public sources of water.

Background

Pesticides are defined as agents used to kill or control pests and include insecticides, herbicides, fungicides, algaecides, nematocides, bactericides, and rodenticides. Pesticides are regulated at the Federal level by the U.S. Environmental Protection Agency (USEPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). In New Jersey, the NJDEP Pesticide Contamination Program regulates pesticide use (**http://www.state.nj.us/dep/enforcement/pcp/index.html**).

Pesticides generally are considered a nonpoint source of contamination from broad areas where the source is difficult to identify on a map. Examples of pesticide sources and uses are agricultural crop management and nurseries, golf courses, residential lawn care, rights of way (roads and railroads), commercial/industrial, and the atmosphere from wet and dry deposition. Pesticides are grouped by their chemical composition and include organochlorine, organophosphorus, and carbamate insecticides and the triazine, acetanilide, and chlorophenoxy acid herbicides. Some volatile organic compounds are used as fumigants.

Currently 23 pesticides are regulated by the USEPA and the NJDEP in drinking water and MCLs have been set. In addition NJDEP has included aldicarb and its breakdown products of aldicarb sulfone and aldicarb sulfoxide on their list but no MCLs have been set although routine monitoring is required. HAs, Action Levels, and minimum stream water-quality criteria concentrations have been set for a number of other pesticides.

Previous investigations

In a study of the susceptibility of CWS wells by pesticides in New Jersey, 90 CWS wells were sampled by the USGS and analyzed by a Rutgers University laboratory at an MRL of about 0.1 micrograms per liter (μg/L) (Clawges and others, 1998). Six of the 90 wells contained one or more pesticides above an MRL. Two wells contained dinoseb greater than 10 percent of the MCL but did not exceed the MCL of 7 μg/L. One well contained atrazine greater than 10 percent of the MCL but did not exceed the MCL of 3 μg/L**.** A numerical rating model was developed to rank the public supply wells into groups of low, medium, and high susceptibility to pesticide detection (Vowinkel, 1998, Vowinkel, 1997, and Vowinkel and others, 1996). Variables used in the rating model included distance of the well from the outcrop area, organic matter content of the soils, depth to the top of the open interval of the well, predominant land use surrounding the well, minimum distance to agricultural land, and minimum distance to a golf course. Pesticides were detected in water from wells in zero percent of the wells in the low vulnerability group, less than 5 percent in the medium group, and 19 percent in the high susceptibility group. Ayers and others, 2000, sampled wells in the Kirkwood-Cohansey aquifer system in southern New Jersey for pesticides at MRL concentrations approaching 0.001 μg/L. Results of this investigation indicate that many pesticides are reported above an MRL in water samples from public wells, however, the sum of these pesticide concentrations rarely exceeded 1 μg/L. Stackelberg and others, 2000 determined that one or more pesticides were detected at low concentrations in 76 and 80 percent of water samples from CWS and monitoring wells respectively in the Kirkwood-Cohansey aquifer system in southern New Jersey. None of the pesticides in this investigation exceeded 10 percent of their respective MCLs. In a study by the NJDEP, pesticides were analyzed in water samples from susceptible wells in New Jersey. Metabolites of dacthal were the most commonly detected pesticide in water from CWS wells (Louis J.L., 2003, NJDEP, written commun.).

Definition of Susceptibility

The susceptibility of a public water supply to contamination by a variety of constituents is defined by variables that describe hydrogeologic sensitivity and potential contaminant-use intensity in the area that contributes water to that source (fig. 3). The susceptibility assessment models were developed by using an equation whereby the susceptibility of the source water is equal to the sum of the values assigned to the variables that describe hydrogeologic sensitivity plus the sum of the values assigned to the variables that describe potential contaminant-use intensity within the area contributing water to a well.

Susceptibility = Hydrogeologic Sensitivity + Potential Contaminant-Use Intensity

The susceptibility models are intended to be a screening tool and are based primarily on water-quality data in the USGS National Water Information System (NWIS) database but other sources of water-quality data were considered. The objective is to rate all community water supplies as low, medium, or high susceptibility to contamination for the groups of constituents using, as guidance, the thresholds developed by NJDEP for use in the models. In general, the low-susceptibility category includes wells for which constituent values are not likely to equal or exceed one-tenth of New Jersey’s drinking-water MCL, the medium-susceptibility category includes wells for which constituent values are not likely to equal or exceed one-half the MCL, and the high-susceptibility category includes wells for which constituent values may equal or exceed one-half the MCL. The susceptibility rating for the pesticides constituent group is based on the frequency of detection of any pesticide in water from wells at 10 percent of an MCL or HA.

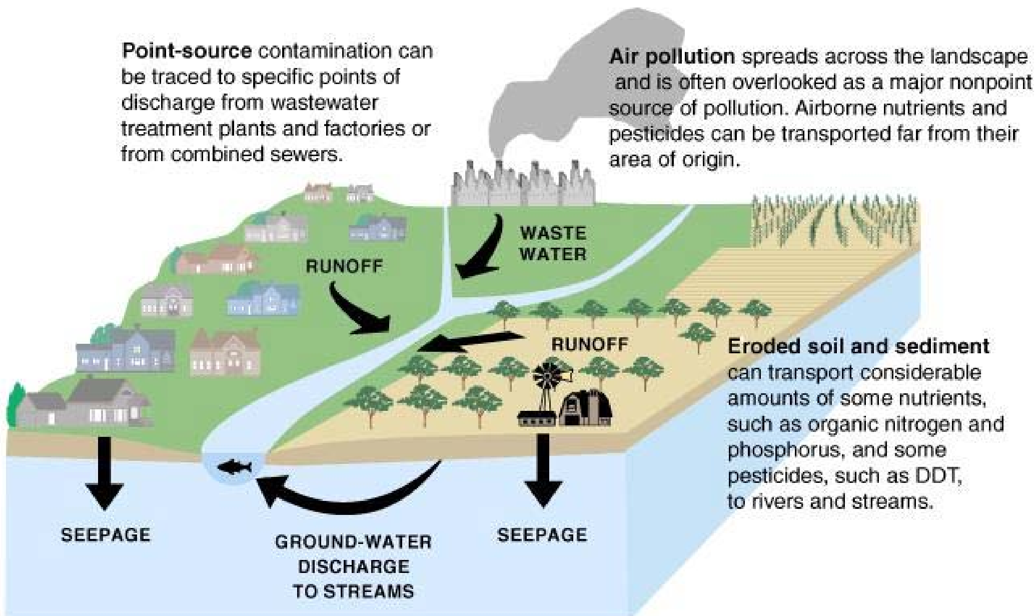

Figure 3. Schematic diagram showing point and nonpoint sources of contamination and how they can affect ground- and surface-water quality.

Susceptibility Model Development

The development of the susceptibility assessment model involved several steps (J.A. Hopple and others, U.S. Geological Survey, written commun., 2003): (1) development of source water assessment areas to community water supplies; (2) building of geographic information system (GIS) and water-quality data sets; (3) exploratory data analysis using univariate and multivariate statistical techniques, and graphical procedures; (4) development of a numerical coding scheme for each variable used in the models; and (5) assessment of relations of the constituents to model variables.

Development of Source Water Assessment Areas

The New Jersey Geological Survey (NJGS) estimated areas contributing water to more than 2,400 CWS wells in New Jersey and New York (fig. 4) by using the Combined Model/Calculated Fixed Radius method. These methods use well depth, water-table gradient, water-use data, well characteristics, and aquifer properties to determine the size and shape of the contributing area. The source water assessment area for a well open to an unconfined aquifer was divided into three tiers based on the time of travel from the outside edge to the wellhead: tier 1 (2-year time of travel), tier 2 (5-year time of travel), and tier 3 (12-year time of travel) (http://www.state.nj.us/dep/njgs/whpaguide.pdf). An unconfined aquifer is a permeable water-bearing unit where the water table forms its upper boundary at the interface between unsaturated and saturated zones. The source water assessment area for a well open to a confined aquifer was defined as the area within a 50-foot radius of the well (http://www.state.nj.us/dep/njgs/whpaguide.pdf). Confined aquifers are permeable water-bearing units between hydrogeologic units with low permeability known as confining units. Land use variables were estimated for unconfined wells that are not CWS wells by using 500 meter radius buffer zones surrounding each well similar to the USGS National Water Quality Assessment Program protocol.

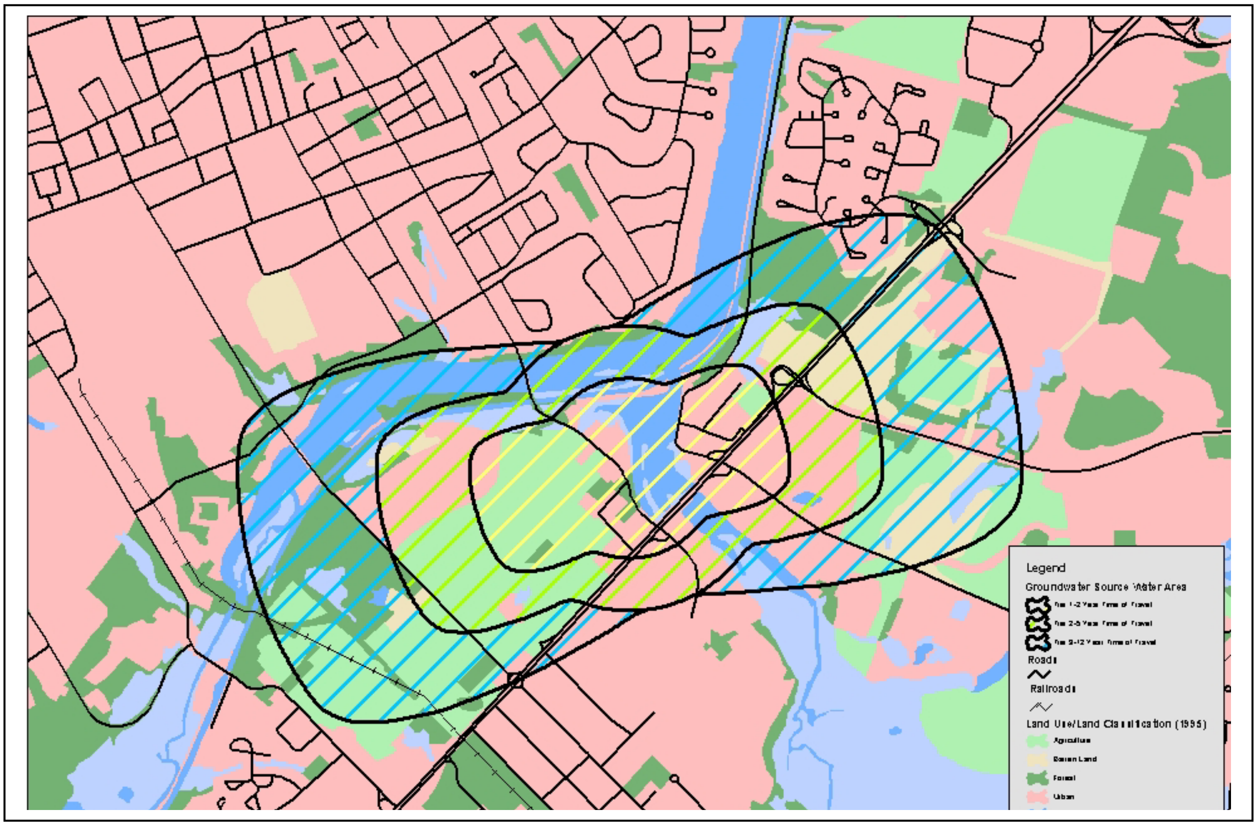

Figure 4. Example of delineated source water assessment area to a community water supply well showing time of travel (TOT), land use, roads, and railroads.

Development of Data Sets

Data sets were developed for the GIS and water-quality data to assess the variables used to develop the susceptibility models. A relational database was used to store and manipulate water-quality, hydrogeologic-sensitivity, and intensity variables.

GIS

A GIS was used to quantify hydrogeologic-sensitivity and potential contaminant-use variables that may affect ground-water quality within areas contributing water to wells. The variables were calculated for each of the three ground-water tiers and for the entire source water assessment areas for wells open to unconfined aquifers. The variables were calculated for the entire source water assessment area for wells open to confined aquifers. Sensitivity variables used in the statistical analysis include soil properties, aquifer properties, physiographic province, and well-construction characteristics. Intensity variables include land use from coverages based in the early 1970's, 1986, and 1995-97; lengths of roads, railways, and streams; the number of potential contaminant sources; septic-tank, population, and contaminant-site densities; and minimum distances of the well to the various land uses and to potential contaminant sources.

Water-Quality Data

Ground-water-quality data from June 1980 through October 2002 were obtained from the USGS NWIS database. Data were imported into a relational database and a statistical software package used for exploratory data analysis, statistical testing, and plotting. All water-quality data are from water samples collected by the USGS prior to treatment, unless otherwise noted. Analyses that were determined by older, less accurate, less precise methods were excluded. Analyses with known contamination problems also were not used.

Five water-quality data sets were used to develop the susceptibility model (Tables 1 and 2, Fig. 5, and Appendices 1 and 2). The first two data sets consist of wells sampled and analyzed for pesticides by the U.S. Geological Survey. Data Set 1 consists of 75 CWS wells and Data Set 2 consists of 436 wells of all types. Data set 2 was evaluated because only one CWS well in Data Set 1 contained a pesticide greater than 10 percent of the MCL; this is too few in number to make a meaningful model. The most recent concentration measured at each well was used because (1) the sample reflects more recent conditions, (2) the sample probably was analyzed using a method with the lowest minimum reporting level (MRL) and greatest precision, and (3) selecting one sample avoided problems of averaging samples with different MRLs. Data Set 3 consisted of 90 CWS wells sampled by the U.S. Geological Survey and analyzed by a Rutgers University laboratory. Data Set 4 consists of 97 CWS determined to be susceptible in the previous USGS study and were sampled by NJDEP and analyzed by the NJ Department of Health (NJDOH). This data set was used because the metabolites of one particular pesticide (dacthal) were present above 10 percent of the HA for the parent compound in four wells. The numbers of detections relative to 10 percent, 50 percent, and 100 percent of the MCL for regulated and HAs for unregulated pesticides measured in water from CWS and all wells are listed in table 2.

Data sets 1, 3, and 4 were combined into data set 5 to increase the number of CWS wells containing one or more pesticides equal to or greater than 10 percent of an MCL or HA. Problems exist in collating the data in that (1) not all wells were analyzed for all of the same pesticides, (2) some water samples were unfiltered whereas others were filtered, (3) MRLs changed over time, (4) some of the regulated pesticides (dalapon, diquat, endothall, glyphosate, and pentachlorophenol) never were analyzed in any samples; (5) combining pesticides with different solubilites and other physical characteristics may bias statistical results. Also, different pesticides are used in different land-use settings so the same pesticides were not expected to be detected in all land use settings.

Table 1. Summary of data sets used in the statistical analysis

[CWS; community water supply; GE, greater than or equal to; %, percent; MCL, Maximum Contaminant Level; USGS/NWIS, U.S. Geological Survey National Water Information System; NJDEP, New Jersey Department of Environmental Protection; NJDOH, New Jersey Department of Health]

Data Set	Types of wells	Wells sampled by	Wells analyzed by	Number of wells	Number of detects GE 10% of MCL	Pesticides detected at concentrations GE than 10 percent of an MCL	Source of data
1	CWS	USGS	USGS	75	1	Lindane	USGS/NWIS
2	All types	USGS	USGS	436	18	Alachlor Atrazine Carbofuran Dinoseb Heptachlor epoxide Lindane Simazine	USGS/NWIS
3	CWS	USGS	Rutgers University	90	3	Dinoseb Atrazine	Clawges and others, 1998
4	CWS	NJDEP	NJDOH	97	4	Dacthal	Louis, J.L., NJDEP, 2003, written commun.
5	CWS	Both	All	229	8	Those in data sets 1,3, and 4	Combined sets 1, 3, and 4.

Table 2. Pesticides detected in water in water from wells at concentrations equal to or greater than 10 percent of a Maximum Contaminant Level or Health Advisory.

[F, filtered; U, unfiltered; MCL, Maximum Contaminant Level; HA, Health Advisory; µg/L, micrograms per liter; #, number; %, percent; NWIS, National Water Information System]

			Community water supply wells					All wells				
Constituent	**Sample type**	**MCL or HA in µg/L**	**Number sites at which data are available**	**Number sites at which constituent was detected**	**Number sites at which concentration meets criterion 1[1]**	**Number sites at which concentration meets criterion 2[2]**	**Number sites at which concentration exceeds standard**	**Number sites at which data are available**	**Number sites at which constituent was detected**	**Number sites at which concentration meets criterion 1[1]**	**Number sites at which concentration meets criterion 2[2]**	**Number sites at which concentration exceeds standard**
Wells sampled and analyzed by the U.S. Geological Survey (USGS): Source of data USGS NWIS database												
Data set 1: Community water supply wells								Data set 2: Any well type				
Pesticides with an MCL												
Alachlor	F	2	38	9	0	0	0	382	20	2	0	1
	U		11	0	0	0	0	119	7	4	0	1
Atrazine	F	3	38	14	0	0	0	382	106	4	0	0
	U		37	1	0	0	0	230	21	12	1	0
Carbofuran	F	40	38	4	0	0	0	370	14	0	0	0
	F		4	1	0	0	0	150	5	0	0	0
	U		2	0	0	0	0	63	7	1	0	0
Dinoseb	F	7	4	1	0	0	0	150	5	0	0	1
Heptachlor epoxide	F	0.2	2	0	0	0	0	82	4	2	0	0
	U		41	1	0	0	0	246	2	0	0	0
Lindane	F	0.2	40	0	0	0	0	381	1	0	0	0
	U		41	1	1	0	0	247	11	1	2	1
Simazine	F	4	38	12	0	0	0	370	80	5	0	0
	U		37	2	0	0	0	231	6	1	0	0
Any pesticide			75		1	0	0	436		18	0	1
Pesticides with an HA												
Dacthal	F	70	38	0	0	0	0	370	3	0	0	0
Dieldrin	F	0.5	40	11	0	0	0	381	42	2	2	3
	U		41	3	0	0	0	246	20	1	0	0
Data not in the USGS NWIS database												
Data set 3: Wells sampled by the U.S Geological Survey and analyzed by Rutgers University: Source of data—Clawges and others, 1998												
Atrazine	U	3	90	1	1	0	0					
Dinoseb	U	7	90	2	2	0	0					
Data set 4: Wells sampled by the N.J. Department of Environmental Protection and analyzed by the N.J. Department of Health												
Dacthal	U	70	97	23	3	0	1					

[1]Criterion 1: Concentration is a least equal to 10 percent of the standard, but is less than 50 percent of the standard.
[2]Criterion 2: Concentration is a least equal to 50 percent of the standard, but is less than the standard.

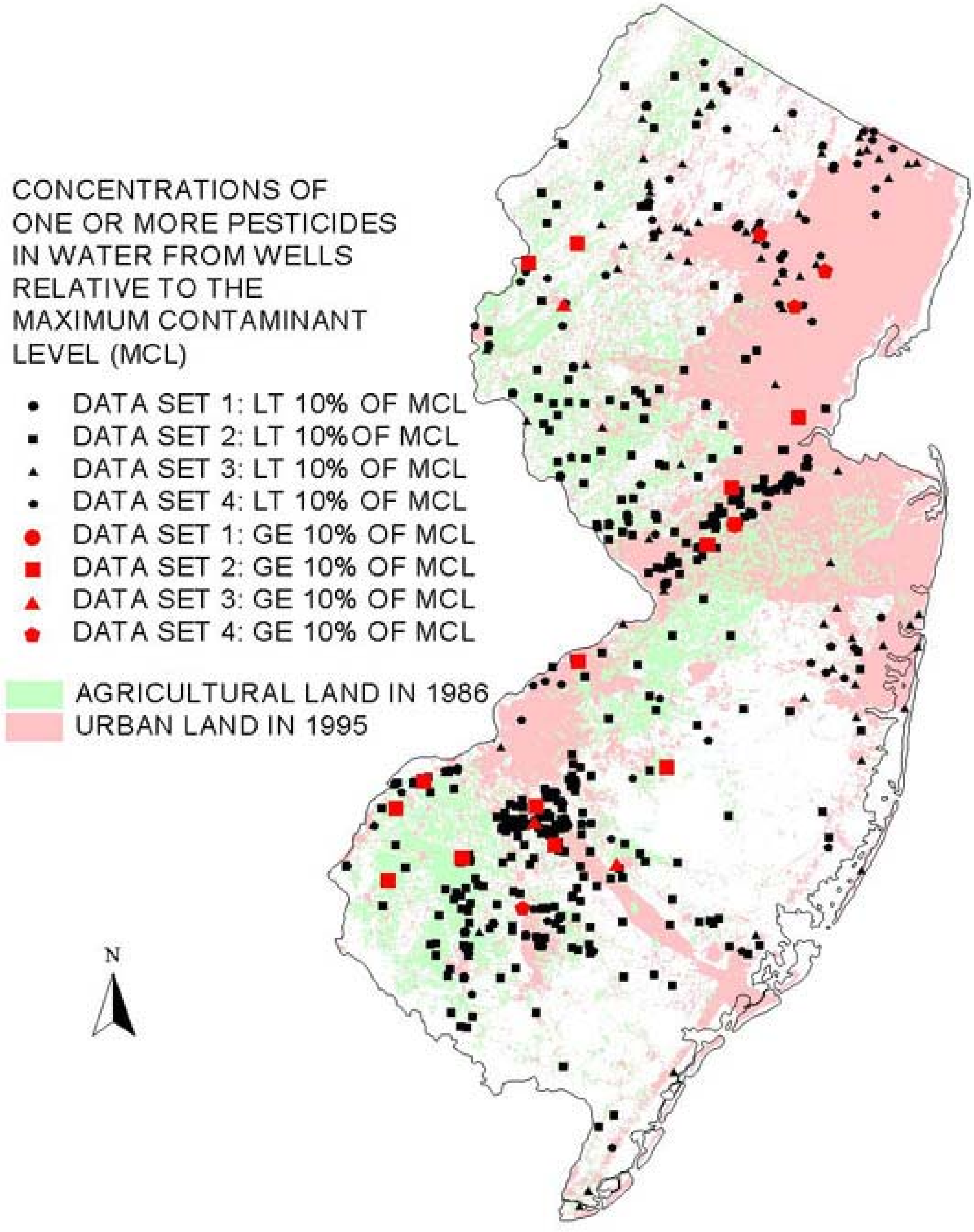

Figure 5. Concentrations of pesticides in water from wells relative to 10 percent of the MCL and potential land-use intensity variables used in model development.

[GE, equal to or greater than; LT, less than; %, percent; MCL, Maximum Contaminant Level]

Data Analysis

Federal and State Safe Drinking Water Regulations require routine monitoring for many pesticides at community water systems. For the purpose of modeling, NJDEP determined that concentrations greater than one-half of the MCL would be of greatest concern. Concentrations equal to or greater than one-tenth of the MCL also are considered in this report as an indication of an emerging problem, but health effects at this level are of less concern. The pesticide models were developed to determine the variables that best describe the presence or absence of constituents in source waters at concentrations equal to or greater than one-tenth of the MCL.

Statistical tests were used to determine those variables that best describe the presence or absence of pesticides in source waters at 10 percent of the MCL (table 3). The size of the Kruskal-Wallis test statistic and corresponding p-value are used as a measure of the strength of differences between the groups. Spearman’s rho, the nonparametric equivalent of a correlation coefficient, was used to evaluate linear trends between ranked explanatory and response variables because environmental variables rarely are normally distributed (Helsel and Hirsch, 1992). Correlation coefficients were calculated between the pesticide value and all hydrogeologic-sensitivity and intensity variables, and many water-quality variables. Scatter plots of each variable in relation to the total pesticide value were generated to confirm the results of statistical tests. Boxplots were used to compare the distributions of variables among groups.

In some cases, variables thought to be a good predictor of contamination did not produce a significant univariate statistical relation. In this report, conceptual variables are variables with possible graphical relations for which results of univariate statistical tests were not significant but that have been shown in a previous scientific investigation to be related to the concentrations of a constituent. Conceptual variables also are variables for which results of univariate statistical tests were or were not significant but that improve the model and may represent a surrogate for other unidentified variables associated with the concentration of a constituent, although no evidence was found in previous investigations of a relation. Conceptual variables that did not produce significant univariate statistical relations may, however, produce a significant relation when used with other variables in multivariate statistical tests. Selected sensitivity and intensity variables that were either conceptually or significantly related to the presence or absence of a particular constituent were tested for covariance by using Principal Components Analysis. Logistic regression analysis was used to determine the best combination of variables to predict the presence or absence of a constituent at a given concentration. Variables were included in the susceptibility models were used only if there was a physical basis or explanation for their inclusion, plots showed an apparent graphical relation, or they improved the results of the model.

Some variables that proved to be statistically significant were not used in the model. Some possible reasons for exclusion were (1) the variable was not a known source of the constituent modeled, (2) use of the variable in the model was not supported by scientific investigations, (3) the variable did not show a graphical relation to the constituent, or (4) the variable was found to have a similar relation to the constituent as another variable. Also, problems exist related to closure when percentages are used in statistical analyses. Results of statistical analyses that include percentages are used with caution. Since all surface-water-quality sites were used in the statistical analysis, overlapping buffers could bias results because of double accounting of land uses (Barringer and others, 1990).

Results of univariate and multivariate statistical analyses indicate that concentrations of pesticides in water from CWS wells are not significantly related to various hydrogeologic-sensitivity variables, including aquifer type and well-construction characteristics and potential land-use intensity variables (table 3). The poor statistical relations are mostly because a small percentage of wells contained one or more pesticides equal to or greater than 10 percent of an MCL in water samples from wells. Only 8 of 229 CWS wells (3.5 percent) in data set 5 and 18 of 436 (3.7 percent) of unconfined wells sampled and analyzed by USGS in data set 2 contained one or more pesticides equal to or greater than the respective pesticide MCL. Not all wells were sampled for of the same pesticides, therefore, each data set did not have comparable numbers of pesticides and minimum reporting levels associated with them. These low frequencies of detection do not allow for significant statistical relations. Also, different pesticides are used in different land use areas, therefore, statistical tests using land use may be confounded when different pesticides are grouped to try to increase the number of detections. Several variables were selected for further examination based on previous results from other studies or results of other variables. Exploratory graphical analyses of the data show some trends that may be useful in the susceptibility analysis.

Table 3. Results of univariate statistical tests showing the relation of hydrogeologic and land use variables to the presence or absence of pesticides at 10 percent of Maximum Contaminant Level.

[CWS, community water supply; USGS, U.S. Geological Survey; --, not enough data to compute test statistic; NA, no data available for statistical analysis]

	Data set 5: CWS wells			Data set 2: USGS wells		
	Kruskal-Wallis rank test			Kruskal-Wallis rank test		
Variable[1]	Kruskal-Wallis score	p-value	Con-ceptual variable	Kruskal-Wallis score	p-value	Con-ceptual variable
Well screened in confined or unconfined aquifer	--	--	No	NA	NA	No
Depth to top of open interval, in feet	0.25	0.62[2]	Yes[3]	0.01	0.90[2]	Yes[3]
Length of open interval, in feet	0.88	0.35[2]	Yes[3]	0.01	0.91[2]	Yes[3]
Percent urban land use in 1995	0.34	0.56[2]	Yes[3]	0.30	0.58[2]	Yes[3]
Percent agricultural use in 1986	0.77	0.38[2]	Yes[3]	3.97	0.05	No
Distance to agricultural land use in 1995, in feet	1.36	0.24[2]	Yes[3]	4.80	0.03	No
Distance to golf course, in feet	0.24	0.62[2]	Yes[3]	NA	NA	Yes[5]

[1]Only the 421 wells open to unconfined aquifers were tested for hydrogeologic sensitivity and potential land-use variables.
[2] Not significant at the alpha 0.05 level.
[3] This conceptual variable shows a graphical relation, improves the model, and is supported by scientific investigations.
[4]This conceptual variable shows a graphical relation and improves the model.
[5]Statistical tests could not be used because variable was unavailable for this data set.

RATING SCHEME

A scoring method was developed that assigned every variable a value from 0 to 5 (table 4). The graphs presented in this report were used as the starting point for devising the numerical code. First, if a well is screened in a confined aquifer (more than 1 mile downdip from the outcrop area of the aquifer that water is withdrawn) then the well was given zero sensitivity and zero intensity points because the water from the well has a small chance of being affected by contamination at the land surface above the well or from sources upgradient. No other hydrogeologic sensitivity or contaminant-use intensity variables are calculated for these confined wells because they would have no effect on the concentration of pesticides in the water from the well. Wells in unconfined aquifers were assigned a five to indicate maximum sensitivity.

For unconfined aquifers, the depth to the top of open interval and length of open interval were selected to characterize the vertical extent of contamination. The top of the open interval is an indication of the minimum vertical distance that a pesticide used at the land surface would have to travel to enter a well. The length of open interval is an indicator of the thickness of the aquifer that needs to be contaminated at that concentration or a measure of the possible dilution of higher concentrations by mixing deeper, older and probably less contaminated ground water with shallower, younger, and probably more contaminated ground water. A similar coding scheme used for nitrate sensitivity variables was used for pesticide sensitivity variables because a significant relation between pesticide detection and nitrate concentration in ground water. Over 300 wells do not have adequate top of open interval, depth, and length of open interval data and therefore were given the largest sensitivity scores for depth to top and length of open interval.

If a land-use percentage (agricultural or urban) was equal to zero within the source water assessment area then a score of zero was assigned and the resultant pesticide concentration should then be zero if that were the only source of contamination. The value assigned to the percent land use increases as the percentage of land use increases based on the relation observed in the graph. Likewise, the nearer well to agricultural land or a golf course the larger the points assigned. Where the distance is zero the maximum score is assigned.

Table 4. Susceptibility coding scheme for pesticides in water from Public Community Water Supply wells. [>, greater than; ≥, greater than or equal to; <, less than]

Susceptibility Rating Group Scores: Confined Low, 0; Unconfined Low, 5 to19; Unconfined Medium, 20 to 35

	Hydrogeologic sensitivity points						Con-cep-tual
Hydrogeologic sensitivity variable[1]	0	1	2	3	4	5	
Well open to confined aquifer (Yes or No)	Yes	--	--	--	--	No	No
Depth to top of open interval, in feet	≥400	<400	<300	<200	<100	<50	Yes
Length of open interval, in feet	≥200	<200	<100	<50	<20	<10	Yes
	Contaminant-use intensity points						
Potential contaminant-use intensity variable[1]	0	1	2	3	4	5	
Percent urban land in 1995	0	>0-9	≥10-19	≥20-29	≥30-49	≥50	Yes
Percent agricultural land in 1986	0	>0-4	≥5-9	≥10-19	≥20-29	≥30	No
Minimum distance to agricultural land in 1995	>5000	≥2500	≥1000	≥500	>0	0	No
Minimum distance to a golf course	>5000	≥2500	≥1000	≥500	>0	0	Yes

[1]Only wells in unconfined aquifers are assigned points for hydrogeologic sensitivity and potential contaminant-use intensity variables

Relation of Pesticides in Ground Water to Susceptibility Variables

Only 12 CWS wells in confined Coastal Plain aquifers were sampled and analyzed for pesticides. Ten of these wells were sampled as part of the previous pesticide vulnerability analysis (Vowinkel, 1997) (data set 3) and 2 wells as part of the NJDEP study that included dacthal (data set 4). Pesticides were not detected in water samples from any of the 12 confined CWS wells in the Coastal Plain probably because the age of water is too old to have been affected by human activities (fig. 6). Results of a 3-dimensional ground-water flow model of the Potomac-Raritan-Magothy aquifer system indicated that the age of water downdip from the outcrop area of the aquifer system increased as the distance from the outcrop area increased (Vowinkel, 1997). Results of other investigations for the SWAP studies suggest that other constituents, such as nitrate and volatile organic compounds originating from human activities at the land surface rarely are detected or are below 10 percent of their respective MCL in water from CWS wells in confined aquifers. For these reasons, it is strongly suspected that water samples from wells in confined aquifers in the Coastal Plain are unlikely to contain pesticides equal to or greater than 10 percent of the MCL if at all.

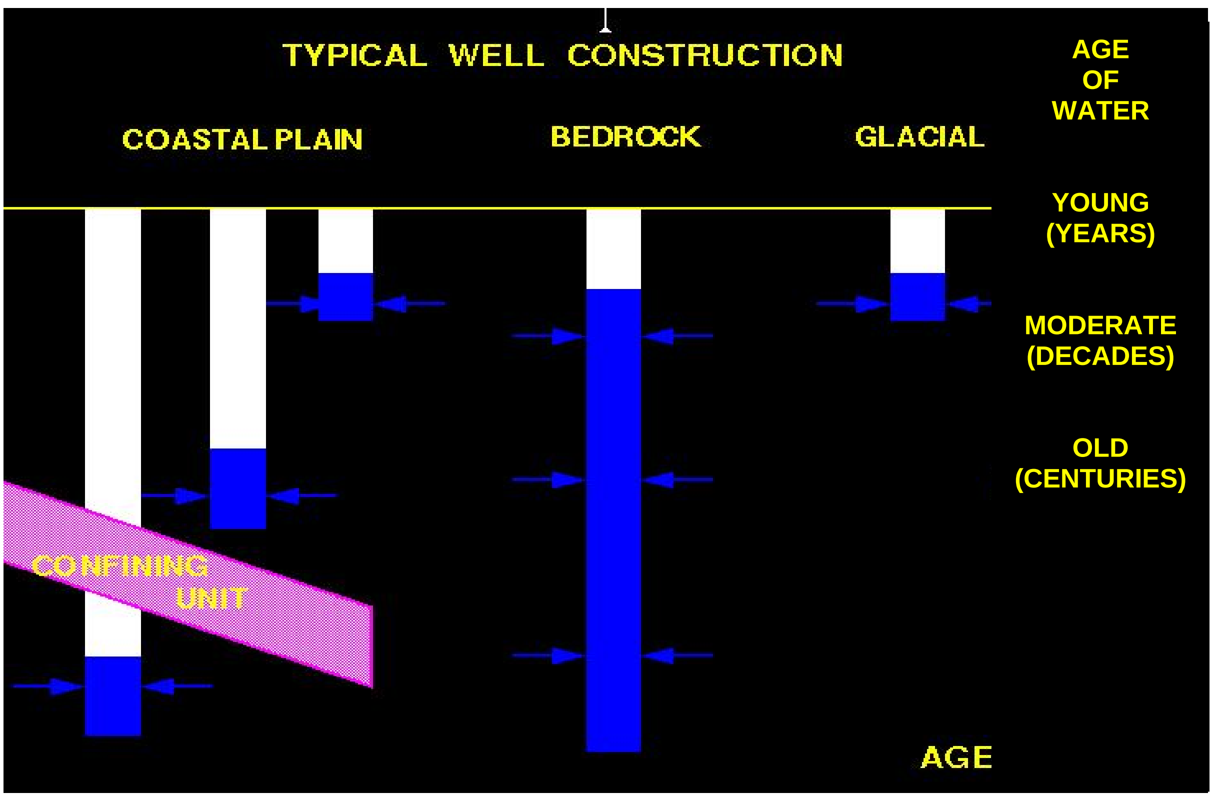

Figure 6. Schematic diagram of relation of aquifer type to well-construction characteristics and age of water, by aquifer type.

The age of water from the time the water recharged at the land surface is on the order of years for young, decades for moderate, and centuries to millennia for old water. Arrows denote direction of ground water flow to a well.

In unconfined aquifers, the depth to top of the open interval may determine if a well is potentially sensitive to contamination by pesticides at 10 percent of the MCL (fig. 7). In general, the age of ground water tends to increase as the depth within the aquifer increases (Szabo and others, 1994). The depth to top of open interval is typically shallower in water from wells containing one or more pesticides greater than or equal to 10 percent of an MCL. Pesticides were above 10 percent of the MCL in water from 8 CWS wells with depths to the top of open intervals that ranged from 25 to 185 feet below land surface with a median depth of about 100 feet below land surface (fig. 7A). Pesticides concentrations were above 10 percent of the HA for metabolites of dacthal in water from 4 CWS wells; depths to the top of open intervals ranged from 25 to 110 feet. In water from other wells sampled and analyzed by the USGS, the depth to the top of open interval is typically less than 50 feet below land surface (fig. 7B). Most of these other wells are observation wells that were open to the aquifer just below the water table. CWS wells containing water with one or more pesticides equal to or greater than 10 percent of an MCL were deeper than other wells possibly because of the vertical pumping pressures from CWS wells caused the pesticides to be transported deeper into the aquifer especially in bedrock aquifers in northern New Jersey. Many wells less than 150 feet did not contain a pesticide equal to or above 10 percent of an MCL. This may result partly because pesticides were not used in the area or the types of pesticides analyzed may not match those pesticides used in the area.

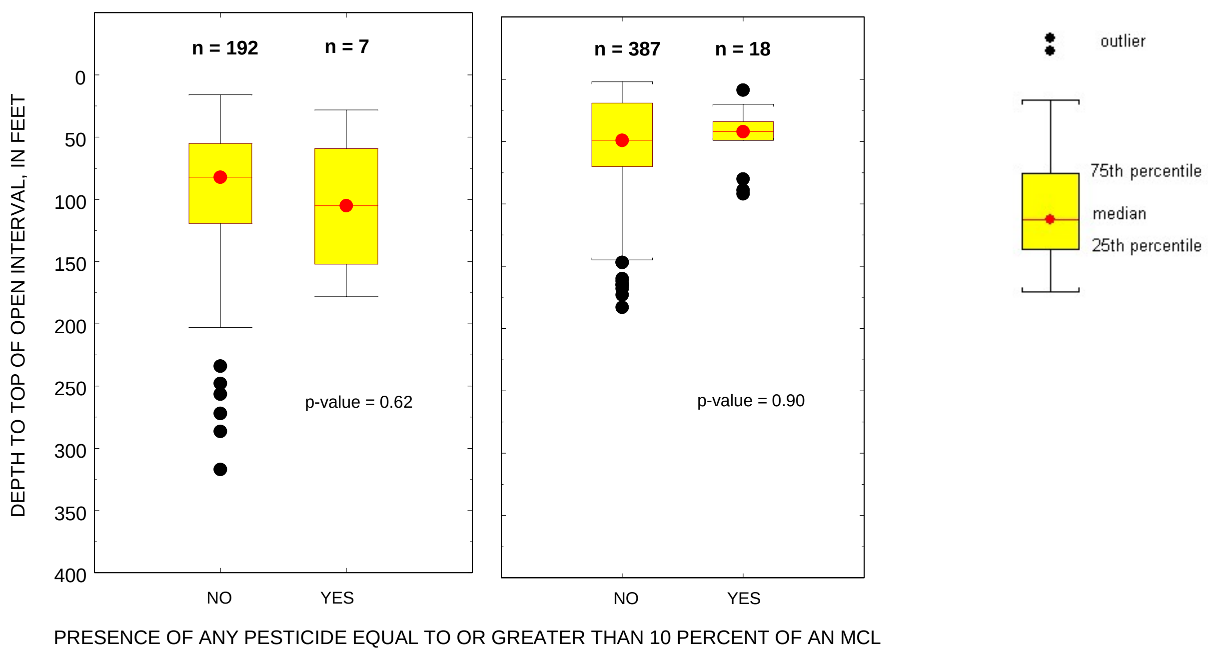

Figure 7. Distributions of depth to top of open interval relative to the presence of pesticides at 10 percent of the respective maximum contaminant level: (A) data set 5 and (B) data set 2.

The length of open interval may determine if the water from a CWS well open to an unconfined aquifer contains a pesticide equal to or greater than 10 percent of an MCL (fig. 8). CWS wells with long open intervals pump water partly from shallow young (years to decades) water and partly from deep older (centuries to millennia) water. The mixing of the shallow and deep water may dilute the pesticides in the water withdrawn from the bedrock wells. The median length of the open interval for those CWS wells containing one or more pesticides equal to or greater than 10 percent of the respective MCL was less than 50 feet (fig. 8A) and was less than 10 feet for other wells (fig. 8B). Many of these wells were shallow observation wells screened just below the water table and had narrow open intervals. Pesticides were above 10 percent of the MCL for dacthal in wells with lengths of open intervals ranging from 10 to 40 feet. The length of open interval was longer than 50 feet for some CWS wells in bedrock aquifers in northern New Jersey that contained pesticides equal to or greater than 10 percent of an MCL. The results of this analysis indicate that wells with a combination of a short depth to the top of open interval and short length of open interval probably are more likely to contain a pesticide equal to or greater than 10 percent of an MCL than a well with a long depth to top of open interval and a long length of open interval.

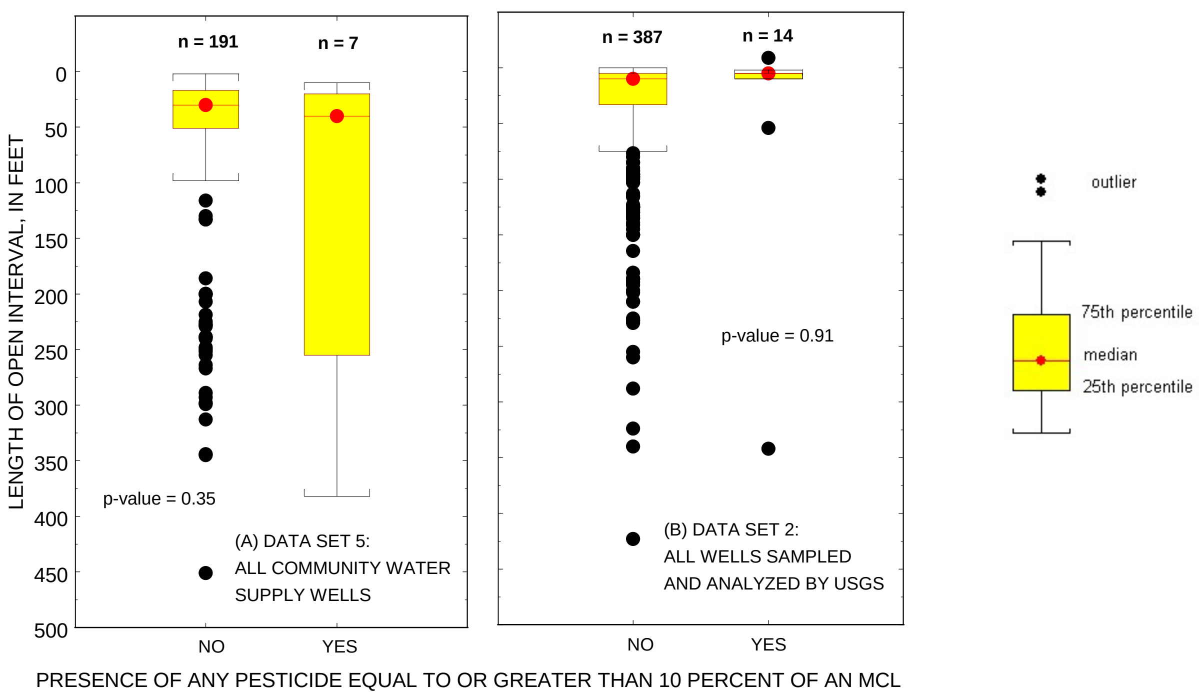

Figure 8. Distributions of the length of open interval relative to the presence of pesticides at 10 percent of a respective maximum contaminant level: (A) data set 5 and (B) data set 2.

The relation of potential sources of pesticides to concentrations of pesticides equal to or greater than 10 percent of an MCL in water from unconfined CWS and other wells were evaluated. It is hypothesized that the presence of pesticides in water from unconfined CWS wells is positively related to the intensity of the source of pesticides and negatively related to the distance from a source. Because of land-use change from agricultural to urban over the past several decades, past land uses also were evaluated.

For data set 2, the percentage of agricultural land in the source water assessment area was larger in those CWS wells containing pesticides equal to or greater than 10 percent of an MCL than in those wells not containing a pesticide at that level (fig. 9). The relation between percentage of agricultural land and the presence of a pesticide at the 10 percent MCL level was greater for the 1986 data set than the 1995 data set. The median percentage of agricultural land in 1986 was about 20 for CWS wells. For data set 2, only 1995 land-use data were available for analysis, In data set 2, the percentage of agricultural land use in the contributing area was significantly larger in those wells containing a pesticide at the 10 percent MCL level than wells that did not contain a pesticide. From analysis of these data it is hypothesized that as the percentage of agricultural land use increases the potential increases for one or more pesticides to be above the 10 percent of the MCL. For all unconfined CWS wells, the percentage of agricultural use within the source water assessment area in 1986 was greater than or equal to 30 percent for 121 wells and equal to or greater than 20 percent for an additional 112 wells.

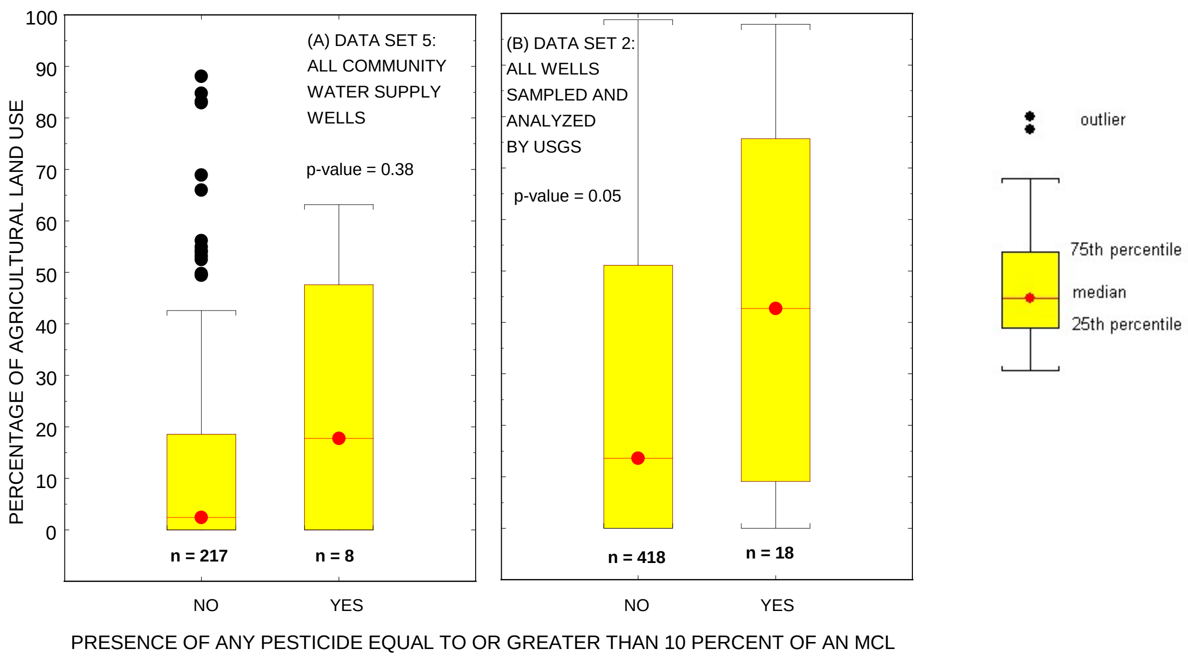

Figure 9. Distributions of percentage of agricultural land use in the source water assessment area relative to the presence of pesticides at 10 percent of the respective maximum contaminant level: (A) 1986 land use for data set 5 and (B) 1995 land use for data set 2.

It was hypothesized that the minimum distance from the wellhead to agricultural land use may affect if the well would contain a pesticide equal to or greater than 10 percent of the MCL. Only 1995 land use data were used in the analysis. The minimum distance of the wellhead to agricultural land in 1995 was shorter for eight CWS wells containing pesticides equal to or greater than 10 percent of the MCL than for those CWS wells not containing a pesticide at 10 percent of the MCL (figs. 10A). The minimum distance of the wellhead to agricultural land was less than 1,000 feet for all 8 CWS wells containing one or more pesticides equal to or greater than 10 percent of and MCL. The median distance to agricultural land was zero for the 16 wells in data set 2 that contained one or more pesticides equal to or greater than 10 percent of the MCL. The types of pesticides analyzed by the USGS for data set 2 are often used in agricultural areas. The wellhead of 31 of the 1,596 unconfined CWS wells is in agricultural land, an additional 217 wells are within 500 feet and another 153 are within 1,000 feet of agricultural land in 1995. The reason that both percentage of and minimum distance to agricultural land were considered as variables is because some wells may have a low percentage of agricultural land in the source area but may be close to agricultural land and thus be susceptible. Conversely, some wells may have large percentages of agricultural land in the source water area but the agricultural land may be far from the wellhead.

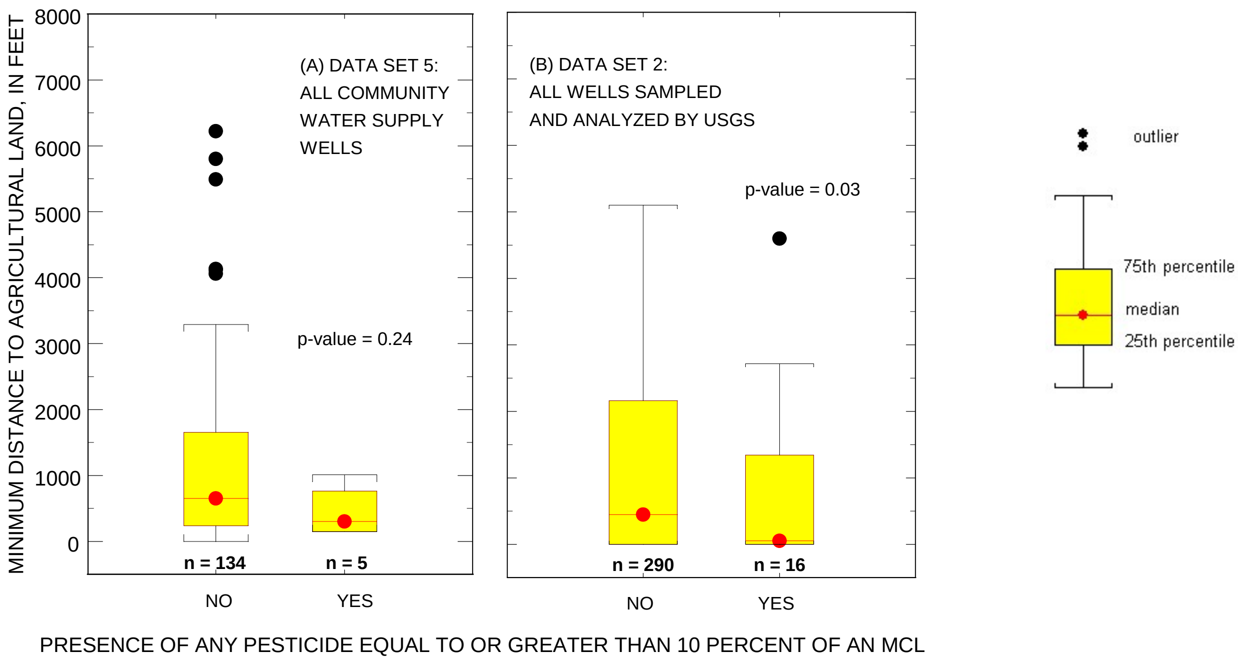

Figure 10. Distributions of minimum distance to agricultural land use in 1995 in the source water assessment area relative to the presence of pesticides at 10 percent of the respective maximum contaminant level: (A) data sets 5 and (B) data set 2.

Pesticides are used at the land surface to control weeds and insects in urban areas for residential, rights-of-ways, and industrial/commercial areas. It was hypothesized that as the area of urban land use increases that the potential would increase for ground water to contain a pesticide equal to or greater than 10 percent of an MCL. However, the statistical and graphical relation between the presence of pesticides equal to or greater than 10 percent of an MCL and the percentage of urban land use in the source water assessment area for data sets 5 and 2 are not strong (table 3). Samples collected and analyzed for pesticides by the USGS did not show a strong relation to the percentage of urban land use in the source area. This may result from the fact that the types of pesticides analyzed by the USGS are used more in agricultural areas than in urban areas. In water samples collected and analyzed by the NJDEP and analyzed by NJDOH (data set 3), only one of the four wells containing dacthal above 10 percent of the HA had any agricultural land use in the source water assessment area. Between 20 and 80 percent of the land use within Tiers 1-3 of the source water assessment area to the these four wells that contained dacthal was urban land use with a mixture of both residential and industrial/commercial land use. If more unregulated pesticides that are typically used in urban areas, it is assumed that more samples from CWS wells would contain a pesticide equal to or greater than 10 percent of an MCL. It is assumed that as the percentage of urban land use increases, the potential for regulated or unregulated pesticides to equal or exceed 10 percent of the MCL should increase. The percentage of urban land use in 1995 within Tiers 1-3 of the source water assessment area was equal to or greater than 50 percent for 410 wells and equal to or greater than 30 percent for an additional 436 wells.

Pesticides are used on golf courses to control weeds on fairways, greens, and tee boxes. Most pesticides used in golf course areas are unregulated. It is hypothesized that the nearer a CWS wells is located to a golf course the greater the probability of having one or more pesticides in ground water equal to or greater than 10 percent of an MCL or HA. Unfortunately, little pesticide concentration data are available for water samples from CWS or other wells near golf courses. Two of the eight CWS wells containing a pesticide equal to or greater than 10 percent of an MCL or HA are either in or within 1,800 feet of a golf course (fig. 12). One of the four sites containing metabolites of dacthal equal to or greater than 10 percent of the HA of the parent compound was beneath a golf course. Five of the 18 wells in Data set 2 that contained one or more pesticides equal to or greater than 10 percent of an MCL had some part of a golf course within the 500-meter-radius buffer zone of the wellhead. Since little is known about the presence of regulated and unregulated pesticides in ground water near golf courses in New Jersey, it was assumed that water from CWS wells in unconfined aquifers beneath or near a golf course would be susceptible to contamination by pesticides used at the golf course. The wellheads at 12 CWS wells in unconfined aquifers are located within the boundaries of a golf course: an additional 22 CWS wells are within 500 feet, and another 40 CWS wells are within 1,000 feet.

Susceptibility of Community Water Supply Wells

Variables used to estimate hydrogeologic sensitivity are if a CWS well is open to a confined or unconfined aquifer, and for wells in unconfined aquifers the conceptual variables depth to the top of the open interval and length of the open interval. Variables used to estimate pesticide-use intensity for CWS wells in unconfined aquifers are percent of agricultural land in 1986 and minimum distance to agricultural land in 1996, and the conceptual variables percent of urban land in 1995 and minimum distance to a golf course. The sum of the hydrogeologic sensitivity and land-use intensity variables was computed. Wells in confined aquifers had a score of zero and were have low susceptibility to contamination by pesticides. Wells in unconfined aquifers with scores of 1-19 were considered low susceptibility, and those wells with scores of 20 or greater were considered moderate susceptibility. No CWS wells were considered highly susceptibility because few wells of any kind contained one or more pesticides in water samples in excess of 50 percent of an MCL or HA.

Results of the model indicate that about 29 percent of CWS wells are in confined aquifers, whereas, in unconfined aquifers the susceptibility is low for 48 percent and moderate for 23 percent (figs. 1 and 2). The frequency of detection of one or more pesticides at 10 percent of an MCL (fig. 11) was zero percent for CWS wells screened in confined aquifers, 2.9 percent for the unconfined low group and 5.1 percent for the unconfined medium group. These results for pesticides in conjunction with results of analyses of nitrate and other contaminants introduced by human activities at the land surface indicate that the 641 wells screened in confined Coastal Plain aquifers are unlikely to be contaminated by pesticides. Well-construction characteristics play a lesser but important role in the distribution of concentration of pesticides in water from unconfined CWS wells. Pesticides generally were detected in water from wells with shallow depths to top of open intervals that have short open intervals. The percentage of and minimum distance to agricultural land use are significant predictors of pesticides in water from CWS wells. Although pesticide use at golf courses is significant, few CWS wells located near golf courses were sampled for pesticides. To be conservative, wells located near golf courses were coded as susceptible.

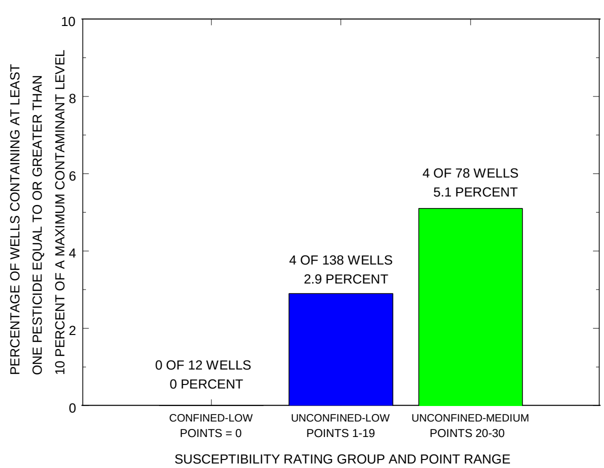

Figure 11. Frequency of detection of regulated and unregulated pesticides in water from Community Water Supply Wells by susceptibility group.

Discussion

The statistical analysis and numerical rating models developed as part of the SWAP project will provide guidance to water managers at the NJDEP as they determine impacts of hydrogeology and land use on the quality of source waters to CWS wells. The relations shown in figures, graphs, and tables will be useful in determining monitoring requirements for water purveyors to ensure public health.

There are several limitations to these models that should be noted. Because well construction data were unavailable for over 300 wells, these wells were given the maximum scores for depth to the top of open interval and length of open interval that automatically puts a well near the high susceptibility group. Different numbers of pesticides analyzed and different MRLs for pesticides make the comparison difficult between data sets. Pesticide sampled from wells near golf courses and rights of way are scarce. These models should only be used as screening tools for potential contamination problems. Most recent concentrations were used in the analysis and concentrations could have been higher in the water from the well. Some of the components of the analysis were subjective especially for the coding scheme for the numerical rating model. Problems exist in the interpretation of data at a local scale and projecting to statewide scales. Using different scales for various GIS layers may bias statistical results and land-use changes may cause spurious relations. The methods used to determine source water assessment areas of water to wells and tiers representing times of travel of water to the well are estimates and do not reflect changes in withdrawals over time or effects of pumpage from other nearby wells.

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Appendix 1. Detections of pesticides with Maximum Contaminant Levels in water from wells sampled and analyzed by the USGS.

[F, filtered; U, unfiltered; MCL, Maximum Contaminant Level; µg/L; micrograms per liter#, number; %, percent]

			Community water supply wells					All wells				
Constituent[3]	MCL In µg/L	Sample type	Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard	Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard
2,4-D	70	F	4	0	0	0	0	150	1	0	0	0
		U	10	0	0	0	0	151	1	0	0	0
Alachlor	2	F	38	9	0	0	0	382	20	2	0	1
		U	11	0	0	0	0	119	7	4	0	1
Aldicarb	3	F	4	0	0	0	0	116	0	0	0	0
Aldicarb sulfone	3	F	3	0	0	0	0	147	0	0	0	0
Aldicarb sulfoxide	4	F	4	0	0	0	0	150	1	0	0	0
Atrazine	3	F	38	14	0	0	0	382	106	4	0	0
		U	37	1	0	0	0	230	21	12	1	0
Carbofuran	40	F	38	3	0	0	0	370	14	0	0	0
		F	4	1	0	0	0	150	5	0	0	0
		U	2	0	0	0	0	63	7	1	0	0
Chlordane	0.5	F	2	0	0	0	0	82	1	0	0	0
		U	41	0	0	0	0	246	0	0	0	0
Dinoseb	7	F	4	1	0	0	0	150	5	0	0	1
Endrin	2	F	2	0	0	0	0	82	0	0	0	0
		U	41	0	0	0	0	254	2	0	0	0
Heptachlor epoxide	0.2	F	2	0	0	0	0	82	4	2	0	0
		U	41	1	0	0	0	246	2	0	0	0
Heptachlor	0.4	F	2	0	0	0	0	82	0	0	0	0
		U	41	0	0	0	0	246	1	0	0	0
Hexachlorobenzene	1	U	4	0	0	0	0	32	0	0	0	0
Lindane	0.2	F	40	0	0	0	0	381	1	0	0	0
		U	41	1	1	0	0	247	11	1	2	1
Oxamyl	200	F	3	0	0	0	0	149	2	0	0	0
		U	2	0	0	0	0	63	1	0	0	0
p,p'-Methoxychlor	40	F	2	0	0	0	0	82	0	0	0	0
		U	41	0	0	0	0	254	1	0	0	0
Picloram	500	F	4	0	0	0	0	150	1	0	0	0
Silvex	50	F	3	0	0	0	0	138	1	0	0	0
		U	10	0	0	0	0	151	0	0	0	0
Simazine	4	F	38	12	0	0	0	370	80	5	0	0
		U	37	2	0	0	0	231	6	1	0	0
Toxaphene	3	F	2	0	0	0	0	82	0	0	0	0
		U	41	0	0	0	0	247	1	0	0	0

[1]Criterion 1: Concentration is a least equal to 10 percent of the standard, but is less than 50 percent of the standard.
[2]Criterion 2: Concentration is a least equal to 50 percent of the standard, but is less than the standard.
[3]Samples were never analyzed for 5 pesticides with MCLs: dalapon, diquat, endothall, glyphosate, and pentachlorophenol.

Appendix 2. Detection of pesticides with Health Advisories in water from wells sampled and analyzed by the USGS
[F, filtered; U, unfiltered; HA, Health advisory; #, number; %, percent]

			Community Water Supply wells					All wells				
Constituent	HA in µg/L	Sample type	Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard	Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard
1-Naphthol		F	3	0				104	1			
2,4,5-T	70	F	3	0	0	0	0	138	0	0	0	0
		U	10	0	0	0	0	151	0	0	0	0
2,4-DB		F	4	0				150	0			
2,6-Diethylaniline		F	38	0				370	2			
2-Methyl-4,6-dinitrophenol		F	3	0				138	0			
3-Ketocarbofuran		F	1	0				23	0			
Acetochlor		F	38	1				370	2			
Acifluorfen	2000	F	4	1	0	0	0	150	1	0	0	0
alpha-Endosulfan		F	2	0				82	0			
alpha-HCH		F	38	0				370	0			
Azinphos-methyl		F	38	0				370	0			
Bendiocarb		F	1	0				24	0			
Benfluralin		F	38	0				370	1			
Benomyl		F	1	0				24	0			
Bensulfuron		F	1	0				24	0			
Bentazon	200	F	4	1	0	0	0	150	3	0	0	0
Bromacil	90	F	4	0	0	0	0	150	2	0	0	0
Bromoxynil		F	4	0				150	0			
Butylate	350	F	38	0	0	0	0	370	1	0	0	0
Carbaryl	700	F	4	0	0	0	0	150	5	0	0	0
Carbaryl		F	38	1	0	0	0	370	18	0	0	0
Carbaryl		U	19	0	0	0	0	169	0	0	0	0
Chloramben methyl ester		F	4	0				150	0			
Chlorimuron		F	1	0				24	0			
Chlorothalonil	150	F	4	0	0	0	0	150	0	0	0	0
Chlorpyrifos	20	F	38	0	0	0	0	370	1	0	0	0
cis-Permethrin	2	F	38	0	0	0	0	370	0	0	0	0
Clopyralid		F	4	0				150	0			
Cyanazine	1	F	38	1	0	0	0	370	3	0	0	0
Cycloate		F	1	0				24	0			
DCPA monoacid		F	4	0				150	0			
DCPA (Dacthal)	70	F	38	0	0	0	0	370	3	0	0	0
Deethyl atrazine		F	38	17				370	122			
Deethyldeisopropyl		F	1	0				24	8			

Constituent	HA in µg/L	Sample type	Community Water Supply wells: Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard	All wells: Number of sites at which data are available	Number of sites at which constituent was detected	Number sites at which concentration meets criterion 1[1]	Number sites at which concentration meets criterion 2[2]	Number sites at which concentration exceeds standard
atrazine												
Deisopropyl atrazine		F	1	0				24	4			
Diazinon	0.6	F	40	0	0	0	0	373	4	0	0	0
Diazinon		U	37	0	0	0	0	214	3	0	0	0
Dicamba	200	F	4	0	0	0	0	150	1	0	0	0
Dichlobenil		F	3	0				104	0			
Dichlorprop		F	4	0				150	0			
		U	10	0				151	0			
Dieldrin	0.5	F	40	11	0	0	0	381	42	2	2	3
		U	41	3	0	0	0	246	20	1	0	0
Diphenamid	200	F	1	0				24	0			
Disulfoton	0.3	F	38	0	0	0	0	370	0	0	0	0
Diuron	10	F	4	0	0	0	0	150	7	2	0	0
EPTC		F	38	0				369	4			
Esfenvalerate		F	3	0				104	0			
Ethalfluralin		F	38	0				370	0			
Ethoprop		F	38	0				370	0			
Fenuron		F	4	0				149	1			
Flumetsulam		F	1	0				24	0			
Fluometuron	90	F	4	0	0	0	0	150	1	0	0	0
Fonofos	10	F	38	0	0	0	0	370	0	0	0	0
Hydroxy atrazine		F	1	1				24	4			
Imazaquin		F	1	1				24	4			
Imazethapyr		F	1	0				22	0			
Imidacloprid		F	1	0				24	0			
Linuron		F	4	0				150	0			
		F	38	1				370	1			
Malathion	100	F	40	0	0	0	0	373	1	0	0	0
		U	37	0	0	0	0	222	0	0	0	0
MCPA	4	F	4	0	0	0	0	150	0	0	0	0
MCPB		F	4	0				150	0			
Metalaxyl		F	1	1				24	2			
Methiocarb		F	4	0				150	0			
Methomyl oxime		F	1	0				23	0			
Methomyl	200	F	3	0	0	0	0	149	2	0	0	0
Methyl parathion	2	F	38	0	0	0	0	370	0	0	0	0
		U	37	0	0	0	0	217	0	0	0	0
Metolachlor	70	F	38	15	0	0	0	382	89	0	0	0
		U	12	0	0	0	0	133	4	0	0	0
Metribuzin	100	F	38	2	0	0	0	382	9	0	0	0

			Community Water Supply wells					All wells				
Constituent	HA in µg/L	Sam-ple type	Number of sites at which data are avail-able	Number of sites at which constit-uent was detected	Number sites at which concen-tration meets criterion 1[1]	Number sites at which concen-tration meets criterion 2[2]	Number sites at which concen-tration exceeds standard	Number of sites at which data are avail-able	Number of sites at which constit-uent was detected	Number sites at which concen-tration meets criterion 1[1]	Number sites at which concen-tration meets criterion 2[2]	Number sites at which concen-tration exceeds standard
		U	12	0	0	0	0	133	3	0	0	0
Metsulfuron		F	1	0				24	0			
Mirex		F	2	0				82	0			
Molinatere		F	38	0				370	1			
Napropamide		F	38	0				370	4			
Neburon		F	4	0				150	0			
Nicosulfuron		F	1	0				24	0			
Norflurazon		F	4	0				150	2			
Oryzalin		F	4	0				133	0			
Oxamyl oxime		F	1	0				23	0			
p,p'-DDD		F	3	0				83	0			
		U	41	0				254	4			
p,p'-DDE	1	F	2	0	0	0	0	82	0	0	0	0
p,p'-DDE		F	38	2	0	0	0	370	13	0	0	0
p,p'-DDE		U	41	1	0	0	0	254	6	0	0	0
p,p'-DDT		F	2	0				82	0			
		U	41	1				254	6			
Parathion		F	40	0				373	0			
Pebulate		F	38	0				370	1			
Pendimethalin		F	38	0				370	1			
Perthane		F	2	0				82	0			
Phorate		F	38	0				370	0			
Prometon	100	F	38	6	0	0	0	370	63	0	0	0
Pronamide	50	F	38	0	0	0	0	370	0	0	0	0
Propachlor	90	F	38	0	0	0	0	370	0	0	0	0
Propanil		F	38	0				370	1			
Propargite		F	38	0				370	0			
Propham	100	F	4	0	0	0	0	150	0	0	0	0
		U	11	0	0	0	0	104	0	0	0	0
Propiconazole,		F	1	0				24	1			
Propoxur		F	4	0				149	0			
Siduron		F	1	0				24	1			
Sulfometuron		F	1	0				24	0			
Tebuthiuron	500	F	38	3	0	0	0	370	11	0	0	0
Terbacil	90	F	38	4	0	0	0	368	17	0	0	0
		F	1	0	0	0	0	24	1	0	0	0
Terbufos	0.9	F	38	0	0	0	0	370	0	0	0	0
Thiobencarb		F	38	0				370	0			
Triallate		F	38	0				370	0			
Tribenuron			1	0				21	0			

			Community Water Supply wells					All wells				
Constituent	HA in μg/L	Sam-ple type	Number of sites at which data are avail-able	Number of sites at which constit-uent was detected	Number sites at which concen-tration meets criterion 1[1]	Number sites at which concen-tration meets criterion 2[2]	Number sites at which concen-tration exceeds standard	Number of sites at which data are avail-able	Number of sites at which constit-uent was detected	Number sites at which concen-tration meets criterion 1[1]	Number sites at which concen-tration meets criterion 2[2]	Number sites at which concen-tration exceeds standard
Triclopyr		F	4	0				150	0			
Trifluralin	5	F	38	0	0	0	0	370	6	0	0	0

[1]Criterion 1: Concentration is a least equal to 10 percent of the Health Advisory (HA), but is less than 50 percent of the HA.
[2]Criterion 2: Concentration is a least equal to 50 percent of the HA, but is less than the HA.