SUSCEPTIBILITY OF SOURCE WATER TO COMMUNITY AND NONCOMMUNITY SURFACE-WATER SUPPLIES AND RELATED WELLS IN NEW JERSEY TO CONTAMINATION BY NITRATE

Summary

A susceptibility assessment model was developed to predict the susceptibility of source water to 46 public community and 3 non-community water supply intakes, and 11 public community supply wells under the direct influence of surface water (GWUDI) in New Jersey to contamination by nitrate. Susceptibility is defined by variables that describe hydrogeologic sensitivity and land-use intensity within the area contributing water to a sampling point. The models were calibrated by using concentrations of nitrate in samples collected by the U.S. Geological Survey (USGS) from 301 surface-water sites. Variables used to estimate susceptibility to contamination by nitrate at 50 percent of the Maximum Contaminant Level (MCL) are percentages of urban and agricultural land uses in 1995 and sewage treatment plant density within the contributing area of water to each site. Results of the rating model (figs. 1 and 2) for intakes placed 18 in the high, 24 in the medium, and 7 in the low susceptibility group and for GWUDI placed 4 in the high, 6 in the medium, and 1 in the low susceptibility group.

Introduction

The 1996 Amendments to the Federal Safe Drinking Water Act require all states to establish a Source Water Assessment Program (SWAP). The New Jersey Department of Environmental Protection elected to evaluate the susceptibility of public water systems to contamination by inorganic constituents, nutrients, volatile organic and synthetic organic compounds, pesticides, disinfectant byproduct precursors, pathogens, and radionuclides. Susceptibility to contamination in surface 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 source 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 used for public drinking water, (2) inventory the potential contaminant sources within the source water assessment area, (3) determine the public water system's susceptibility to contaminants, and (4) incorporate public participation and education (**www.state.nj.us/dep/swap**).

Susceptibility assessment models were developed to rate each public surface-water source as low, medium, or high susceptibility for five groups of constituents. This report (1) describes methods used to develop the susceptibility assessment model for nitrate, (2) presents results of application of the susceptibility model to estimate the susceptibility of source water to water supply intakes and ground-water sources under the direct influence of surface water (GWUDI), and (3) documents the distribution of nitrate in surface water in New Jersey. The models are intended to be screening tools to guide monitoring of public water supplies in New Jersey.

Background

The nitrogen cycle (fig. 3) describes the movement and microbial transformation of nitrogen in the environment. Nitrogen compounds occur naturally in some geologic materials such as lignite and in soil organic matter, but these materials probably contribute little nitrate to surface water. Consequently, most of the nitrogen species in surface water results from point and nonpoint sources of contamination (fig. 4). Point sources are discrete identifiable points, such as municipal or industrial wastewater-treatment-plant discharges and known contamination sites.

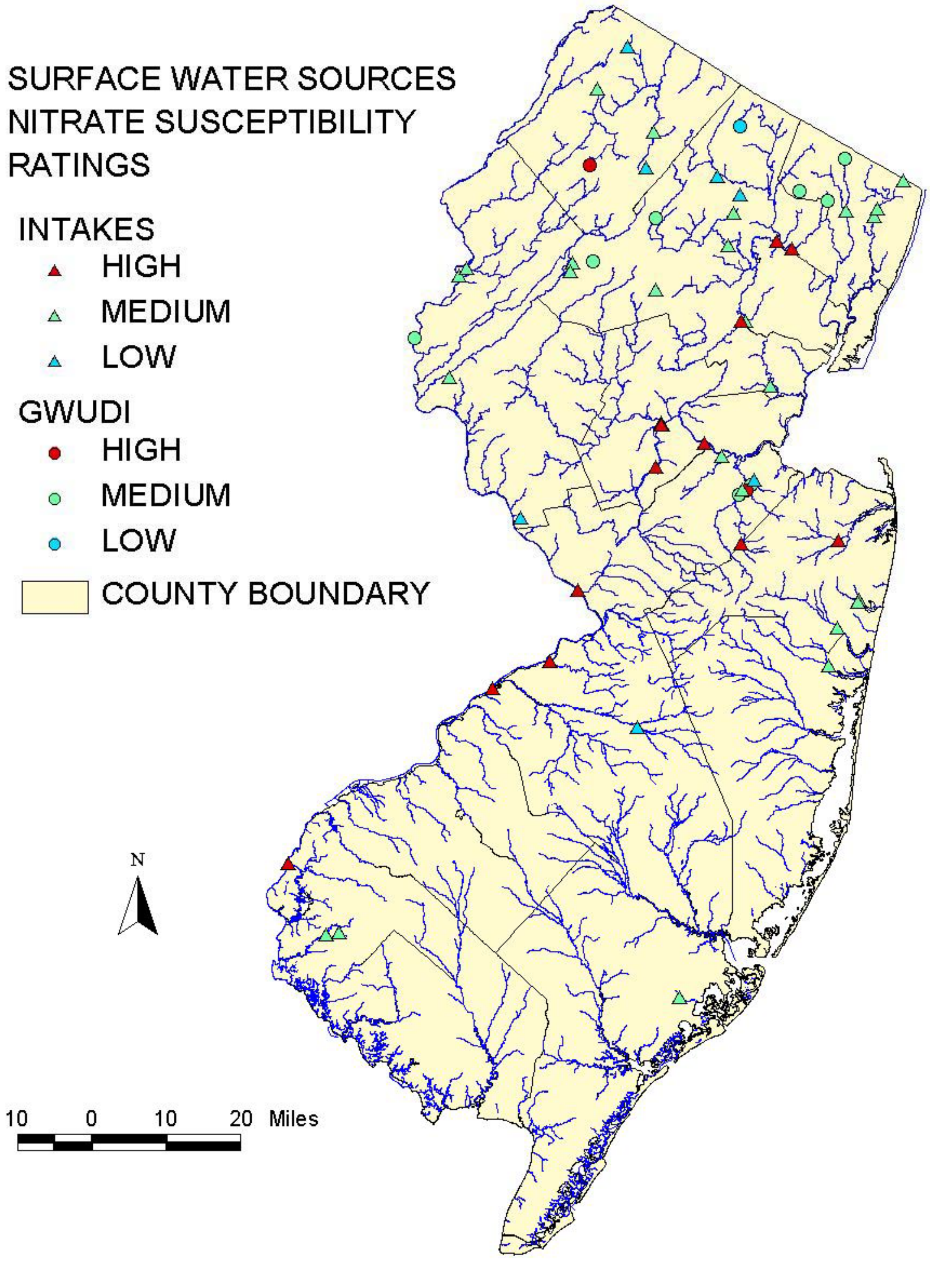


Figure 1. Susceptibility of 49 public surface-water intakes and 11 public community supply wells under the direct influence of surface water to contamination by nitrate.

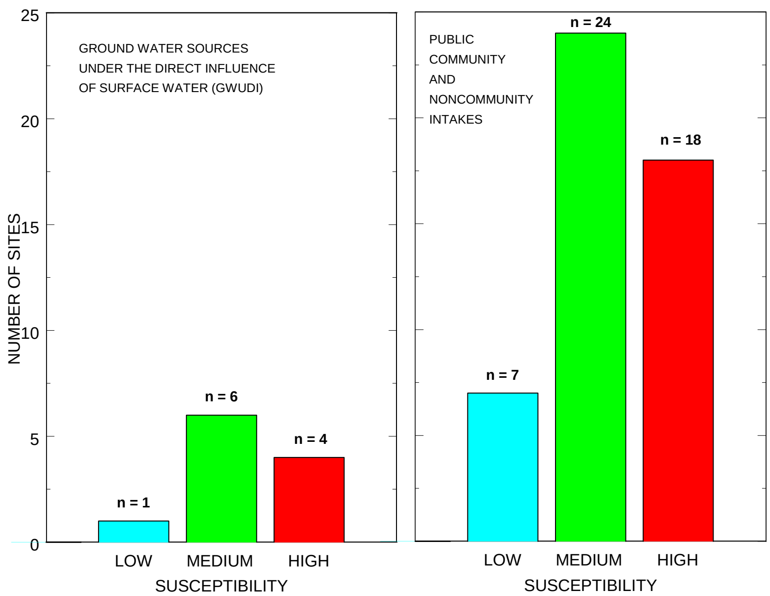


Figure 2. Number of public surface water intakes and related wells in New Jersey having low, medium, and high susceptibility to contamination by nitrate.

Nonpoint sources are from broad areas where the source is difficult to identify on a map. Examples of point and nonpoint sources of nitrogen are the atmosphere (wet and dry deposition); wildlife (birds, mammals, other); fertilizer use (residential and agricultural); domestic and farm animals; confined feedlot operations; septic-system waste (residential/industrial); and leaky sewer pipes especially from older piping systems.

Nitrogen species contributed by contaminant sources are either in an oxygenated form, such as nitrate, or in a reduced form, such as organic nitrogen or ammonia. The reduced forms can be oxidized to nitrite, and then to nitrate by soil bacteria. The nitrate is soluble and can leach into ground and surface water. In oxygenated water, nitrate tends to persist and is mobile, but in anoxic waters, it is converted to nitrous oxide or nitrogen gas by bacteria (Hem, 1989). More information on the distributions of nitrate in surface water in New Jersey and elsewhere in the United States can be found on the USGS NAWQA web site (http://water.usgs.gov/nawqa/nutrients/).

The MCL for nitrate as nitrogen (as N) in drinking water is 10 mg/L. Routine monitoring for nitrate at all community water systems is required by Federal and State Safe Drinking Water regulations. Increased monitoring for nitrate beyond the routine is required if the concentration exceeds 50 percent of the MCL. Concentrations equal to or greater than 10 percent of the MCL are considered here to be an indication of an emerging problem, but health effects at this level are of less concern. Various forms of nitrogen are measured in water samples collected and analyzed by the USGS, including ammonia, ammonia plus organic nitrogen, nitrite, and nitrate plus nitrite. Because nitrite rarely is present in surface water, the nitrate plus nitrite analysis is predominantly nitrate and hereafter will be referred to as nitrate. Most nitrate in surface water is dissolved and does not adsorb to particles.

Definition of Susceptibility

The susceptibility of a public water supply to contamination by various constituents is defined by variables that describe the hydrogeologic sensitivity of, and the potential contaminant-use intensity in, the area that contributes water to that source. The susceptibility assessment models were based on the equation whereby the susceptibility of the source water is equal to the sum of the variables that describe hydrogeologic sensitivity plus the sum of the variables that describe potential contaminant-use intensity within the area contributing water to a surface-water source. In general, surface water is assumed to be highly sensitive to contamination because of direct discharge from point sources, overland flow from precipitation events, and atmospheric deposition. No physical barriers prevent the discharge of contaminants into surface water from these sources. Also ground-water discharge to streams may contain contaminants. However, in some cases, documented research from existing studies and statistical methods of this study may indicate that a surface-water sensitivity variable has a significant relation to contaminant concentrations.

Susceptibility = Hydrogeologic Sensitivity + Potential Contaminant-Use Intensity

The susceptibility models are intended to be a screening tool and are based on water-quality data in the USGS National Water Information System (NWIS) database. The objective is to rate all community and noncommunity water supplies as low, medium, or high susceptibility to contamination for the groups of contaminants by using, as guidance, thresholds developed by NJDEP for use in the model. In general, the low-susceptibility category includes surface-water sources for which constituent values are not likely to equal or exceed one-tenth of the New Jersey's drinking-water MCL. The medium-susceptibility category includes surface-water sources for which constituent values are not likely to equal or exceed one-half of the MCL, and the high-susceptibility category includes surface-water sources for which constituent values may equal or exceed one-half of the MCL.

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 and noncommunity 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 model; (5) assessment of relations of the contaminants to model variables; and (6) use of an independent data set to verify the model. Multiple lines of evidence were used to select the final variables used in the model. Some of the components of the analysis were subjective, especially the coding scheme of the model ratings. The susceptibility rating represents a combination of both sensitivity and intensity and, in some cases, may be inconsistent with the results of water-quality analyses.

Development of Source Water Assessment Areas

The NJDEP estimated 60 areas contributing water to surface-water sources used for drinking water in New Jersey (fig. 5); 49 are associated with surface-water intakes, and 11 are associated with sources using ground water under the direct influence of surface water. For most surface-water sources, the source water assessment area includes the entire drainage area that contributes to the water that flows past the intake or source. These source water assessment areas include the headwaters and tributaries and are based on the USGS 14-digit hydrologic unit code (HUC 14) (Ellis and Price, 1995) (http://www.state.nj.us/dep/swap). For intakes or sources with extremely large contributing areas, the source water assessment area is based on the time of travel to the intake or source.

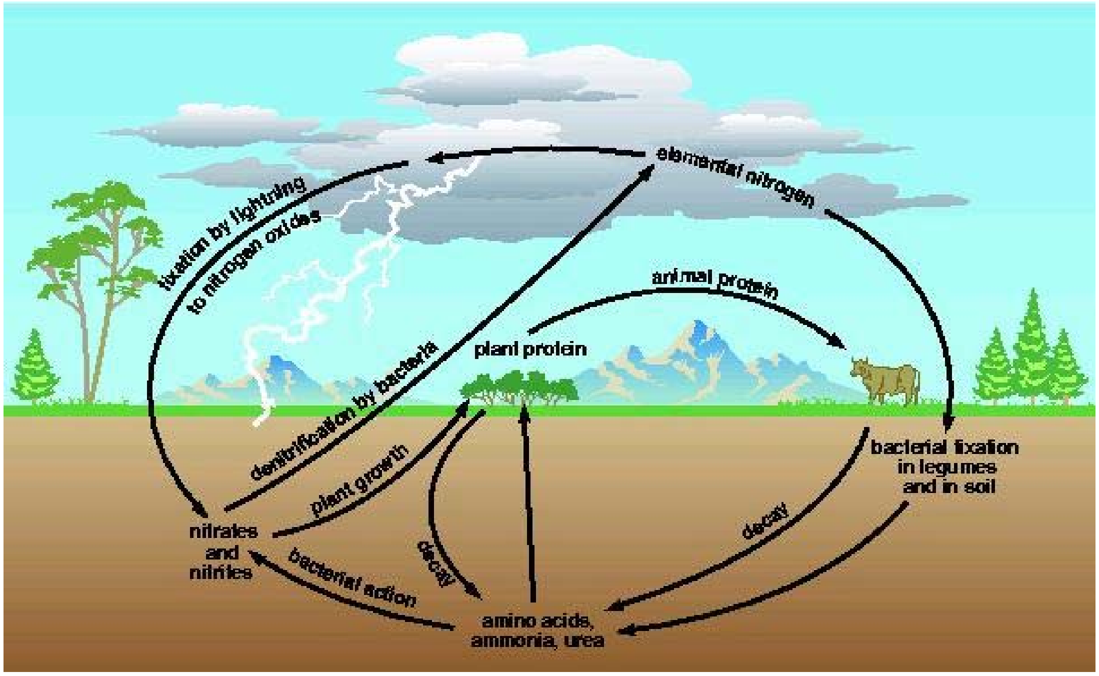


Figure 3. Schematic diagram of the nitrogen cycle.

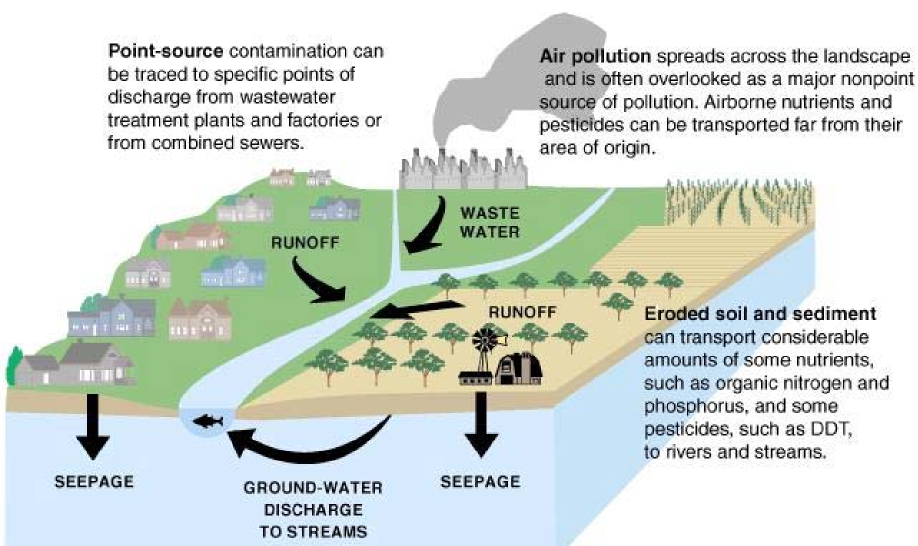


Figure 4. Schematic diagram of point and nonpoint sources of contamination showing how they can affect ground and surface-water quality**.**

The NJDEP has classified 55 wells as sources using ground water under the direct influence of surface water (GWUDI). Water from wells that are classified as GWUDI wells must meet specific water-quality criteria and is treated in a manner similar to water from surface-water intakes. To determine the susceptibility rating for these wells, NJDEP performed an integrated delineation combining the ground-water assessment area with the surface-water assessment area. The ground-water assessment area was delineated using the Combined Model/Calculated Fixed Radius Method (www.state.nj.us/dep/dsr/whpadel.pdf). The surface-water assessment area was delineated as the entire drainage area that contributes water to the well, with the 2-year time-of-travel demarcation of the ground-water assessment area determining the downstream boundary. A few GWUDI wells do not have an associated surface-water assessment area because no surface-water body is present within the 2-year ground-water time-of-travel area. In these instances, only the ground-water assessment area was used. Both the ground- and surface-water models were applied to these areas, and the higher of the two ratings was selected as the susceptibility rating for that well.

Figure 5. Example of a delineated source water assessment area to a water-supply intake

The USGS estimated areas contributing water to 388 surface-water-quality sites in New Jersey for model development and verification. Of these 388 sites, 301 were sampled and analyzed for nitrogen species. Drainage areas contributing water to a surface-water-quality site were delineated using a GIS macro language program that determines basin area from a digital elevation model (DEM) based on a 1:24,000 scale and 30-meter resolution to contour intervals (L.J. Kauffman, U.S. Geological Survey, written commun. 2002).

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 surface-water quality within areas contributing water to surface-water sources. The variables were calculated for the source water assessment area. Sensitivity variables used in the statistical analysis include soil properties and site-specific information, such as major watershed, hydrologic unit, and physiographic province. Intensity variables include land use from coverages based in 1995-97; lengths of roads, railways, and streams; the number of potential contaminant point sources; septic-tank and contaminant-site densities; and minimum distances between the surface-water source and various land uses and between the surface-water source and potential contaminant sources.

Water Quality Data

Surface-water quality data from June 1980 through October 2002 were obtained from the USGS's NWIS database. Analyses that were determined by older, less accurate, less precise methods, and those with high reporting levels were excluded. 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, or less precise methods were excluded. Analyses of water from sites with known contamination problems also were not used. Sites in northern New Jersey with more than 20 percent of the contributing area in New York State were eliminated because comparable sensitivity and intensity variables were unavailable.

Two data sets were used in the modeling process. The sets consist of (1) 301 sites analyzed for nitrate, including all sampling rounds since 1982 and (2) a subset consisting of all 301 sites with the maximum concentration measured at each site (fig. 6). Many of these sites are part of ambient networks that were monitored four times per year during various seasons and hydrologic conditions. The sampling sites, for the most part, are neither near site-specific contamination sites nor sewage-treatment-plant outfalls; therefore, the results of models could under represent the effects of point sources on surface-water quality. Stream discharge measurements and field characteristics such as dissolved oxygen concentration, pH, and specific conductance were measured and only filtered nitrate is considered in the analysis.

Data Analysis

Federal and State Safe Drinking Water Regulations require routine monitoring for nitrate at community water systems. For the purpose of modeling, NJDEP determined that concentrations greater than one-half the MCL would be of greatest concern. Concentrations equal to or above 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 nitrate model was 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 and one-half of the MCL.

Statistical tests were used to determine those variables that best describe the presence or absence of nitrate in source waters at 5 and 1 mg/L. 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, 2002). Correlation coefficients were calculated between the nitrate 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 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).

Relation of Nitrate in Surface Water to Susceptibility Variables

Relations of concentrations of nitrate in surface water to hydrogeologic sensitivity factors were explored. Concentrations of nitrate in surface water are related to stream discharge (fig. 7). Concentrations tend to increase as the discharge rate increases from 1 to about 300 ft^3/s (cubic feet per second), possibly as a result of runoff from precipitation events and increased discharge from sewage-treatment plants and storm sewers. Concentrations tend to decrease at discharge rates greater than 300 ft^3/s because the nitrate concentration is diluted and dispersed by the increased ground- and surface-water recharge from precipitation. This analysis is important even though stream discharge is not used in the final model. These results indicate that the concentration of nitrate in surface water is dependent on the stream discharge rate; typically the maximum concentration at a site occurs during low flow. Use of the maximum concentration at each site implies that the sample was collected during low flow. During low flows, the effects of concentrations of nitrate in ground-water discharge and sewage-treatment-plant discharge are the greatest. Also, flow data usually are unavailable in most data sets; therefore, the data user does not know whether the concentration is representative of a particular flow condition at that site.

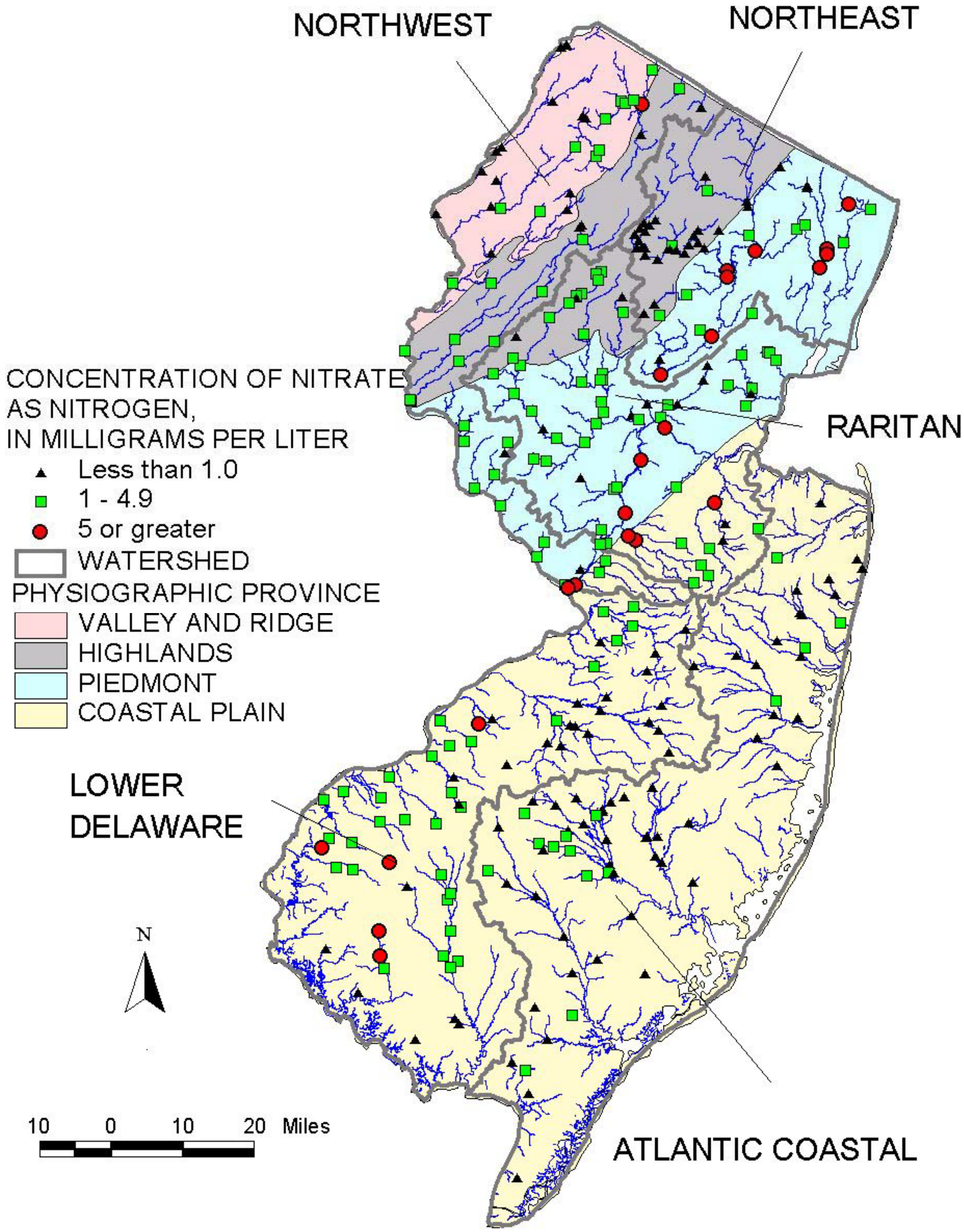


Figure 6. Maximum concentration of nitrate plus nitrite in filtered water from 301 surface-water-quality sites in New Jersey used for model development.

Maximum concentrations of nitrate in surface water differ among watersheds and physiographic provinces (fig. 8). Concentrations are largest in the Raritan and Passaic watersheds (fig. 8A) mostly because these basins have the largest percentage of developed land use and have higher density of sewage-treatment plants than the other basins. Maximum concentrations are smallest in the Atlantic Coastal watershed (fig.8A) because much of the area encompasses the undeveloped Pine Barrens where sources of nitrogen from human activities are uncommon. Maximum concentrations are largest in the Piedmont Physiographic Province (fig. 8B) probably because this province has large percentages of urban and agricultural land and a high density of sewage-treatment plants than other provinces. This analysis is important even though these variables are not included in the final model because the results indicate that land use is more influential factor for concentrations of nitrate in streams than the characteristics of the watershed or physiographic province.

Relations between concentrations of nitrate in surface water and potential contaminant land-use intensity variables linked to nonpoint and point sources were explored. Maximum concentrations of nitrate in surface water are related to percentages of land use (fig. 9). The percentage of developed land is the sum of the percentages of urban plus agricultural land uses, which are sources of nitrate to surface water. Areas that are undeveloped include forested areas and wetlands that typically are not sources of nitrate. Concentrations tend to increase as the percentage of developed land use in 1995 increases (fig. 9A). Nitrate concentrations are typically less than 1 mg/L where the developed land is less than 10 percent; atmospheric sources probably contribute less than 1 mg/L of nitrate as N to streams in undeveloped areas. Concentrations of nitrate as N exceeded 5 mg/L at only two sites where the percentage of developed land use is less than 40 percent. This analysis is important even though the percent developed land use is not used in the final model because the results indicate that the effects of percentages of urban and agricultural land on concentrations of nitrate in streams are additive. The next step is to determine how much nitrate in streamwater results from either urban or agricultural land uses.

Maximum concentrations of nitrate in streamwater tend to increase as the percent of urban land (fig. 9B) increases from zero to 50 percent but tends to level off or decrease, when the percent of urban land is greater than 50 percent. Concentrations of nitrate as N exceeded 5 mg/L in water in areas where urban land use accounted for 20 to 50 percent of the land use, reflecting the effect of areas that changed from agricultural to urban land use. The lower concentrations of nitrate at higher percentages of urban land use probably occur because areas that have greater than 50 percent urban land use are more likely to use sewers than septic systems. In areas where wastewater is sewered the nitrogen is transported to the sewage treatment plant, where some of the nitrogen is partially removed before wastewater is discharged to streams. In areas serviced by septic systems, the nitrogen is treated underground near the site and any untreated nitrogen is oxidized to nitrate in the unconfined aquifers, which typically contain dissolved oxygen.

Maximum concentrations of nitrate are large where agricultural land use is below 20 percent because of effects of urban land use predominate, but concentrations tend to increase as the percentage of agricultural land increases (fig. 9C). As the percentage of agricultural land increases from 20 to 30 percent, the likelihood that nitrate concentrations as N in surface water exceed 5 mg/L increases.

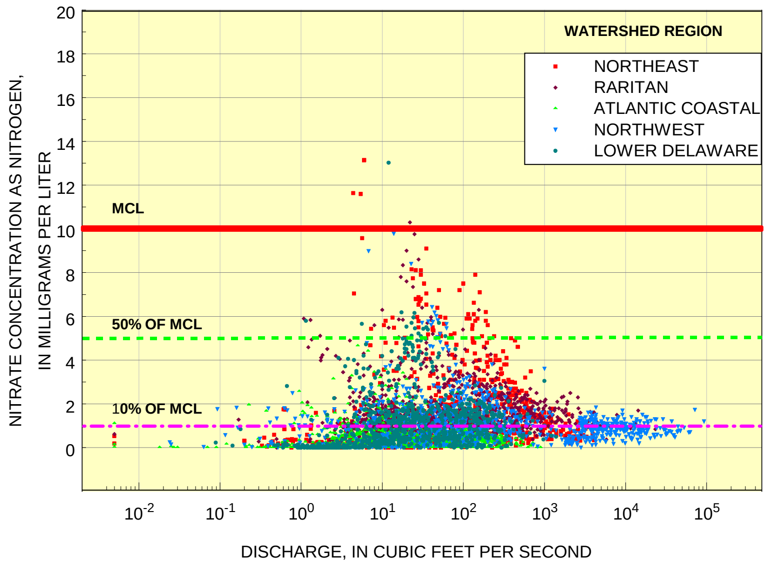


Figure 7. Relation of all concentrations of nitrate in filtered water to stream discharge at 301 surface-water sites in New Jersey, by major watershed.

(MCL, Maximum contaminant level; %, percent)

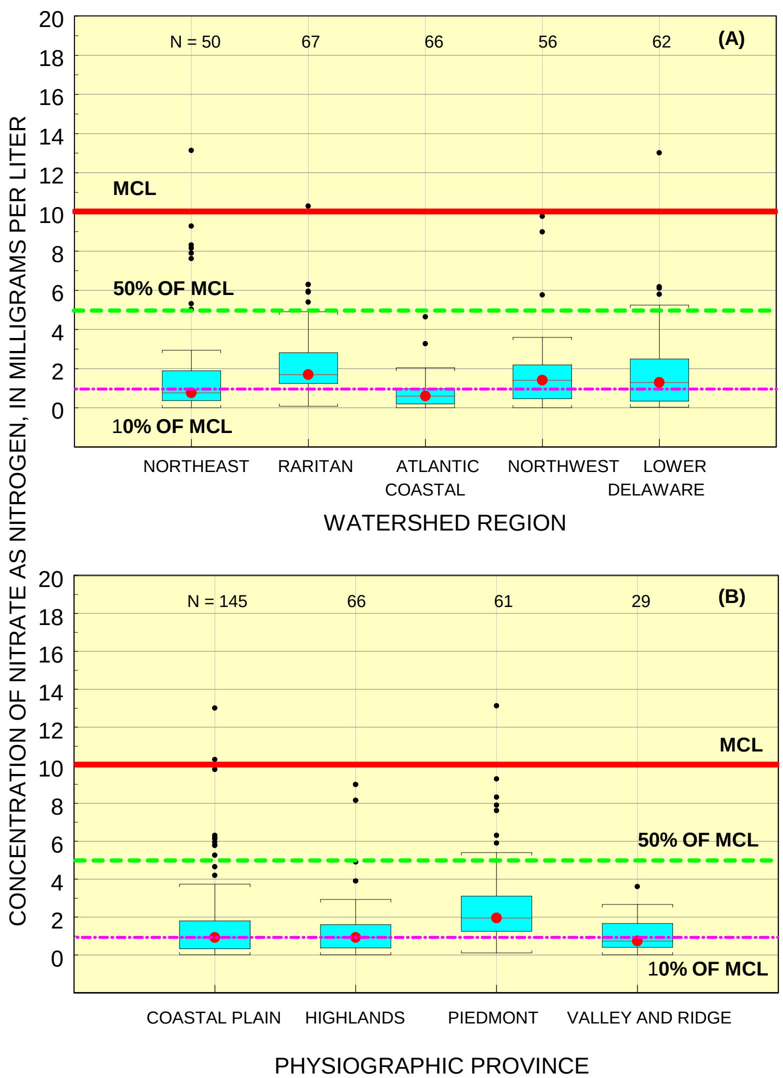
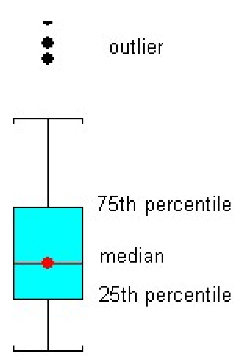


Figure 8. Distributions of the maximum concentrations of nitrate in filtered water from 301 surface-water sites in New Jersey by (A) major watershed region and (B) Physiographic Province.

(MCL, Maximum Contaminant Level; %, percent)



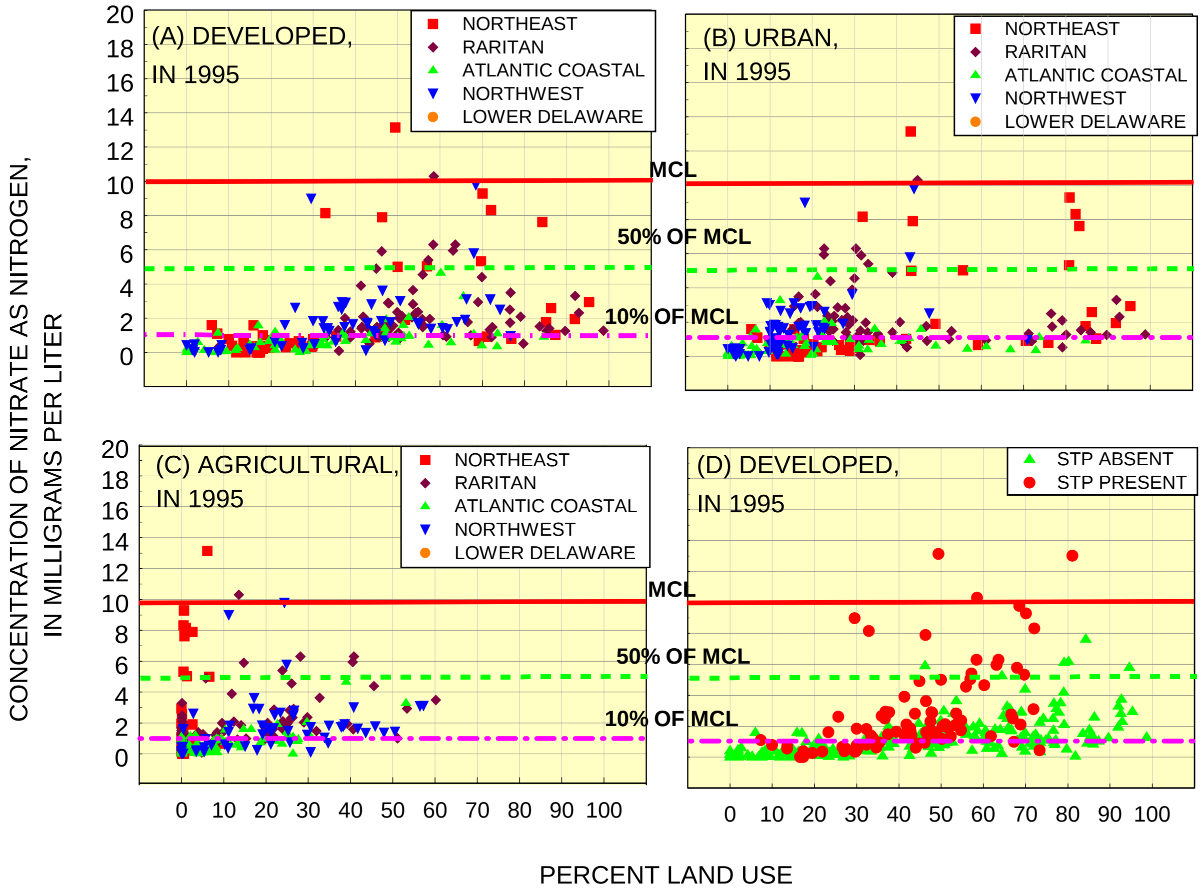


Figure 9. Relation of maximum concentration of nitrate in filtered water from 301 surface-water sites to percent of (A) developed land in 1995, (B) urban land in 1995, and (C) agricultural land in 1995, by major watershed; and (D) to percent developed land in 1995, by presence or absence of sewage treatment plants. (STP, sewage treatment plant, MCL, Maximum Contaminant Level)

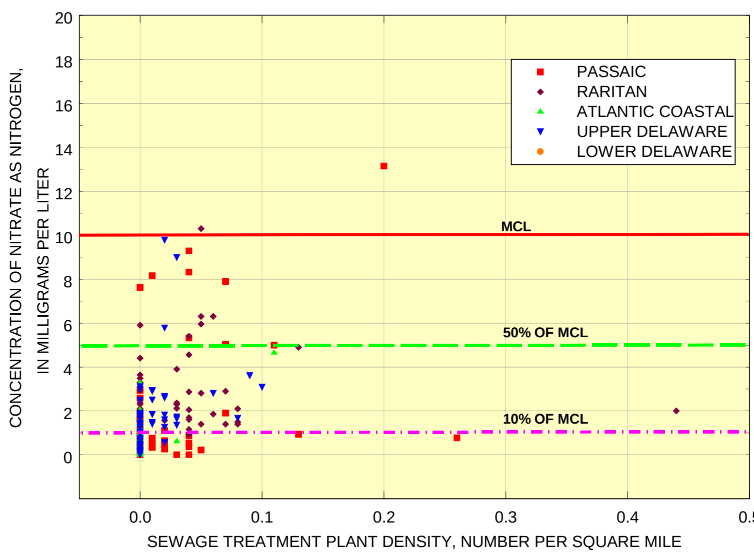


Figure 10. Relation of maximum concentration of nitrate in filtered water from 301 surface water sites to sewage treatment plant density, by watershed.

(MCL, Maximum Contaminant Level; %, percent)

Table 1. Results of univariate statistical tests showing the significance of the relation of the distribution of land-use variables to nitrite concentrations at the 1-mg/L and 5-mg/L-cutoff levels

	1-mg/L-cutoff level		5-mg/L-cutoff level	
Variable	Kruskal-Wallis test statistic	Kruskal-Wallis p-value	Kruskal-Wallis test statistic	Kruskal-Wallis p-value
Percent developed land in 1995	88.98	<0.0001	14.64	<0.001
Percent urban land in 1995	26.15	<0.0001	8.97	0.003
Percent agricultural land in 1995	49.18	<0.0001	1.66	0.198
Sewage-treatment-plant density	20.08	<0.0001	27.20	<0.001

Table 2. Results of logistic regression statistical tests showing the significance of the relation of the distribution of land-use variables to nitrite concentrations at the 1-mg/L and 5-mg/l-cutoff levels.

	1-mg/L-cutoff level		5 mg/L-cutoff level	
Variable	3-factor t-value	p-value	3-factor t-value	p-value
Percent urban land in 1995	6.74	<0.0001	3.75	<0.001
Percent agricultural land in 1995	7.44	<0.0001	3.38	0.001
Sewage-treatment-plant density	2.92	0.0035	2.74	0.006

Concentrations of nitrate tend to be larger than expected relative to the percentage of developed land when sewage treatment plants are present than when they are absent (fig. 9D). Maximum concentrations in developed areas are less than 5 mg/L, although concentrations of nitrate at two sites where the sewage treatment plants are absent, and the surrounding areas are in transition between moderately agricultural and urban land (fig. 10). Concentrations of nitrate tend to increase as the sewage-treatment-plant density increases in urban areas (fig. 10). The greater densities of sewage treatment plants are in the Piedmont Physiographic Province.

Results of univariate statistical tests (table 1) and multivariate logistic regression models (table 2) were used to predict contamination of surface water by nitrate. At the 1-mg/L-cutoff level, agricultural land use is a better predictor than urban land use. At the 5-mg/L-cutoff level, urban land use is a better predictor than agricultural land use. At the 5-mg/L-cutoff level, the best 3-parameter model includes percent urban land use in 1995, percent agricultural land use in 1995, and sewage-treatment-plant density. At the 5-mg/L-cutoff level agricultural land use is a significant predictor in the multivariate model, indicating that source water assessment areas with a combination of urban land and agricultural land greater than 40 percent could cause nitrate in surface water above that level. Those drainage sites with large sewage-treatment-plant densities are more likely to have concentrations of nitrate as N in surface water greater than 5 mg/L.

Rating Scheme

A scoring method was developed that rated variables on a scale of 0 to 5 (table 3). The graphs presented in this report were used as the starting points for the development of the numerical code. If the percentage of land-use within the contributing area was equal to zero, a score of zero was assigned; the associated nitrate concentration should be zero if the land use represented the only source of contamination. For instance, if no agricultural land is present in the area contributing water to the sampling site, then the effect of agricultural land use should be zero. The concentration of nitrate as N generally was not greater than 5 mg/L where urban land was greater than 50 percent; therefore, the maximum intensity points were set at 3.

Table 3. Susceptibility coding scheme for nitrates in surface water

[#/sq.mi., number per square mile; $\geq$, equal to or greater than]
Susceptibility group point range: Low, 0-2; Medium, 3-7; High, 8-12

	Land-use Intensity Points					
Variable	0	1	2	3	4	5
Percent urban land in 1995	0	1-19	20-49	$\geq$50	--	--
Percent agricultural land in 1995	0	1-9	10-19	20-29	30-49	$\geq$50
Sewage-treatment-plant density (#/sq.mi.)	0	$\geq$0.01	$\geq$0.02	$\geq$0.03	$\geq$0.04	$\geq$0.05

Susceptibility of Surface-Water Sources

Maximum concentrations of nitrate as N exceeded the MCL of 10 mg/L at two surface-water sampling sites, 5 mg/L at 23 sites, and 1 mg/L at 160 sites out of a total of 301sites. The largest concentrations of nitrate in surface water were typically measured during low flows. These larger concentrations during low flows in areas where sewage treatment plants are absent indicate that land use affects the quality of ground-water discharge to streams, and nitrate concentrations associated with land uses and sewage-treatment-plant discharges are not diluted by increased runoff from rainfall.

The results of the numerical rating model using the 301 surface-water sites indicate that as the percentages of agricultural and urban land use and density of sewage-treatment plants within the contributing area increase, the likelihood that the maximum concentration of nitrate as N in surface-water will exceed 5 mg/L (figs. 11). Concentrations of nitrate as N in water from the 38 surface water sites rated as low susceptibility were less 2 mg/L with a median of 0.5 mg/L (fig. 11). The drainage areas had less than 10 percent urban and agricultural land use, and sewage treatment plants were absent. The median concentration of nitrate as N at the 182 sites rated as medium susceptibility was 1.5 mg/L; nitrate concentration exceeded 5 mg/L at only 5 sites. Concentrations of nitrate as N at the 81 surface-water sites rated as high susceptibility were the largest with a median of 2.1 mg/L and a maximum of 13.1 mg/L.

Results of the susceptibility model (figs. 1 and 2) rated 19 intakes as high susceptibility, 20 as medium, and 10 as low and 4 GWUDI as high, 6 as medium, and 1 as low. Most of the high susceptibility sites are in the Piedmont Physiographic Province and in the Raritan and Passaic watersheds, probably because the percentages of urban and agricultural land uses are the greatest in those areas and the sewage treatment plant densities are high.

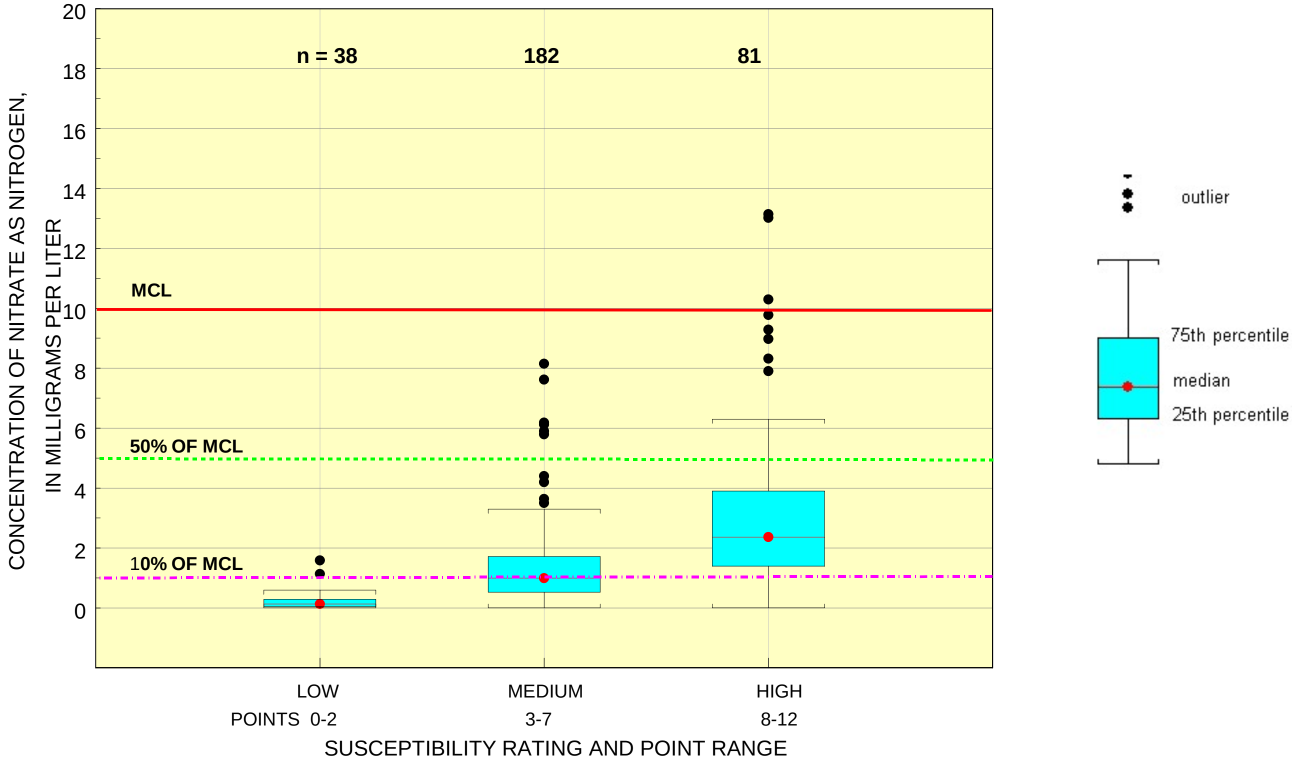


Figure 11. Distributions of concentrations of nitrate in filtered water from 301 surface-water sites in New Jersey, by susceptibility group. (n =, number of sites)

Discussion

The source water assessment models developed by the USGS as part of the SWAP project can provide guidance to scientists and managers as they determine effects of hydrogeology and land use on the quality of source waters to community water supply 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. These models are intended as screening tools for potential contamination problems. Maximum concentrations at each sampling site were used in the analysis and, therefore, could bias the results toward higher susceptibility. This bias is desirable for a susceptibility model because it is better to err on the higher concentrations than on the average concentration. All of the water-quality samples were collected from streams; and none were collected from reservoirs or ponds. The relation of land use to water quality in reservoirs could differ from the relation of land use to stream-water quality in rivers. Loads of nitrogen discharged from sewage treatment plants were not considered in the analyses. Some of the components of the analyses were subjective, especially the coding scheme for the numerical rating model. Projecting the relation of water-quality data and land use at a local scale to a statewide scale is difficult. The use of different scales for various GIS layers could bias statistical results, and land-use changes could cause spurious relations.

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