

## Ground Water Quality

### Ambient Ground Water Quality Monitoring Network

#### Background

The quality of shallow ground water is important because it is the water that typically recharges deeper aquifers and provides base flow to local streams and wetlands. The NJDEP, in partnership with the U.S. Geological Survey (USGS), monitors ground water quality with its Ambient Ground Water Quality Monitoring Network (AGWQMN). The goals of the AGWQMN are to assess ground water quality status and trends, evaluate contaminant sources, and identify emerging water quality issues.<sup>1</sup>

The network consists of 150 shallow wells that were sampled historically at the rate of 30 per year on a five-year cycle. The sampling frequency increased to once every three years starting with the fourth sampling cycle in 2014.<sup>1</sup> The wells cover a range of the State's geology and land-use patterns. Chemical and physical parameters analyzed in each well-water sample include pH, total dissolved solids, dissolved oxygen, temperature, alkalinity, major ions, trace elements, nutrients, gross-alpha particle activity, 34 volatile organic compounds (VOCs), and pesticides. Network wells are screened approximately 5 feet below the water table, so the sample water is therefore expected to be relatively young ground water. Monitoring younger ground water, rather than the older ground water in deeper systems, permits a better assessment of how current land-use activities are affecting ground water quality.

Four sampling cycles have been completed to date. The first sampling cycle was performed between 1999 and 2003, the second sampling cycle was performed between 2004 and 2008, and the third between 2009 and 2013. The most recent sampling cycle occurred between 2014 and 2016, but laboratory results are not yet available. A review of changes over time will allow for the analysis of trends.

Well locations, along with the corresponding geology and land-use category, are pictured in Figure 1. Two generalized physiographic provinces cover the State, designated as the bedrock (BR) region and Coastal Plain (CP) region. The sampling sites were selected in both provinces to cover three primary land-use designations, namely undeveloped (UND), agricultural (AG), and urban (URB). The distribution of wells as a function of land use is 30 in UND land-use areas, 60 in AG areas, and 60 in URB areas.<sup>1</sup> Land-use designations were determined using 1986 and 1995 land-use coverages, site visits, and estimations of ground water-flow directions (based on the local geologic framework and site-specific topographic controls) to ensure each well is down-gradient of the desired land use.<sup>1,2</sup>

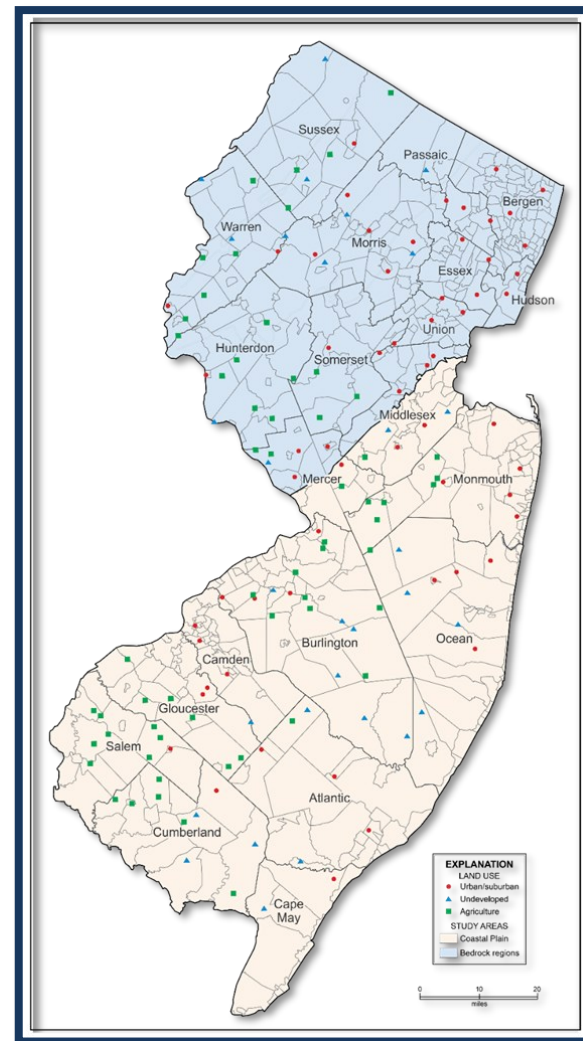


Figure 1. Ambient Ground Water Quality Monitoring Network Locations with land-use and location designations.

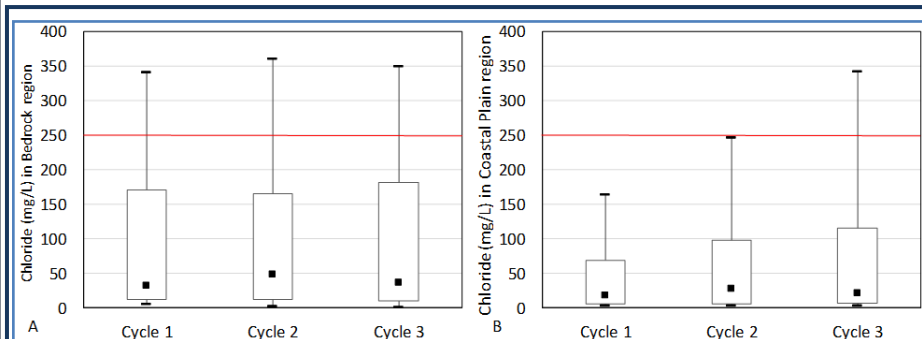
There are subtle differences in natural ground water quality between northern and southern New Jersey. Ground water in northern New Jersey tends to have a more neutral to basic pH, due in part to that region's bedrock geology. Concentrations of

calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, and silica ions are generally higher in the northern part of the State than in the southern part due to the regional geology. The ground water in the southern part of the State generally has a more acidic pH and lower total dissolved solids (TDS) levels, which is also reflective of the regional geology.<sup>1</sup> Anthropogenic activities, such as the application of road salt and lawn care and agricultural chemicals, contribute to higher TDS and ion levels in agricultural and urban land-use areas.<sup>1</sup>

## Status and Trends

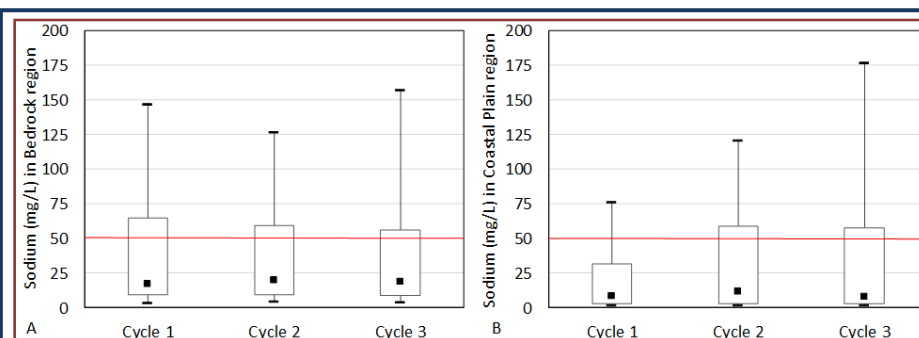
Trends in chloride, sodium, and nitrate-nitrite concentrations, as well as the occurrence of volatile organic compounds, over the three sampling cycles are presented below. The trends are evaluated for sites in the northern and southern parts of the State separately due to the differences in regional geologies. The influence of land use on major ions and nutrients, including those presented below, is discussed in a NJGWS report.<sup>1</sup>

The NJ Ground Water Quality Criterion (GWQC) for chloride is 250 mg/L. During sampling cycle 3, chloride concentrations in ground water exceeded the GWQC for 20% of the samples in the bedrock physiographic region and for 16% of the samples in the Coastal Plain physiographic region. There were no statistically significant differences in chloride concentrations in ground water over the sampling cycles for either the bedrock physiographic region<sup>4</sup> (Figure 2A) or the Coastal Plain physiographic region<sup>5</sup> (Figure 2B).



**Figure 2A–B. Chloride concentrations (mg/L) in ground water by sampling cycle for the bedrock physiographic region (A) and Coastal Plain physiographic region (B). The boxplot shows the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup> and the 90<sup>th</sup> percentiles. The red horizontal line represents the NJ Ground Water Quality Criterion (GWQC) for chloride of 250 mg/L.**

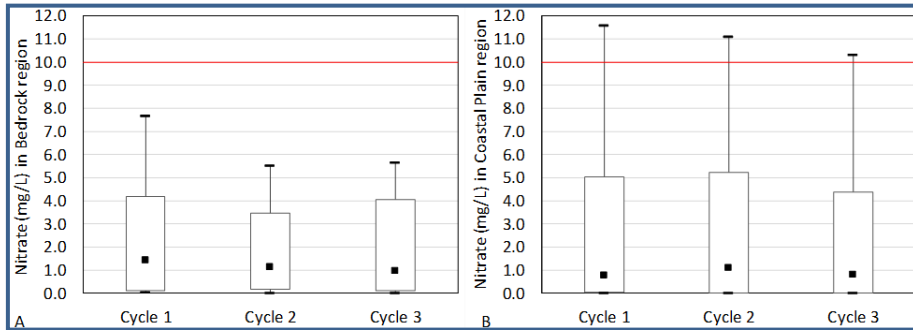
The NJ Ground Water Quality Criterion for sodium is 50 mg/L.<sup>3</sup> During sampling cycle 3, sodium concentrations in ground water exceeded the GWQC for 26% of the samples in the bedrock physiographic region and for 27% of the samples in the Coastal Plain physiographic region. There were no statistically significant differences in sodium concentrations in ground water over the sampling cycles for either the bedrock physiographic region<sup>6</sup> (Figure 3A) or the Coastal Plain region<sup>7</sup> (Figure 3B).



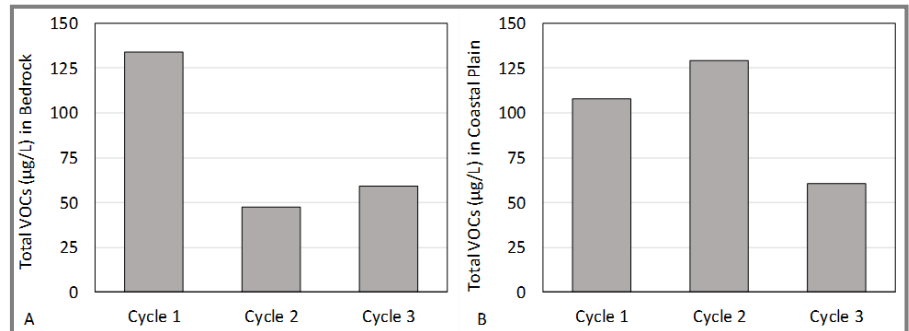
**Figure 3A–B. Sodium concentrations (mg/L) in ground water by sampling cycle for the bedrock physiographic region (A) and Coastal Plain physiographic region (B). The boxplot shows the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup> and the 90<sup>th</sup> percentiles. The red horizontal line represents the NJ Ground Water Quality Criterion (GWQC) for sodium of 50 mg/L.**

Nitrate plus nitrite measured as nitrogen (nitrate-nitrite) is one of the most widely spread ground water contaminants found across the Northern Atlantic Coastal Plain Surficial Aquifer System.<sup>8</sup> Potential sources in ground water include fertilizers and manure management,<sup>9</sup> as well as septic systems and leaking sewer systems. The NJ Ground Water Quality Criterion for nitrate is 10 mg/L.<sup>3</sup> During sampling cycle 3, nitrate-nitrite concentrations in ground water exceeded the GWQC for approximately 5% of the samples in the bedrock physiographic region and for approximately 11% of the samples in the Coastal Plain physiographic region. There were no statistically significant differences in nitrate-nitrite concentrations in ground water over the sampling cycles for either the bedrock physiographic region<sup>10</sup> (Figure 4A) or the Coastal Plain region<sup>11</sup> (Figure 4B). Because some of the results were below the laboratory reporting limit (i.e., non-detect or censored values), Kaplan-Meier survival analysis<sup>12</sup> was applied to the nitrate-nitrite dataset rather than substituting or setting values below the reporting limit.

Other frequently detected VOCs in New Jersey's AGWQMN include tetrachloroethene (PCE), trichloroethene (TCE), toluene, and MTBE. Similar to chloroform, these constituents are frequently detected in ground water on a national level.<sup>7</sup> There were select instances when wells exceeded the Ground Water Quality Criteria (class IIA) for individual contaminants.



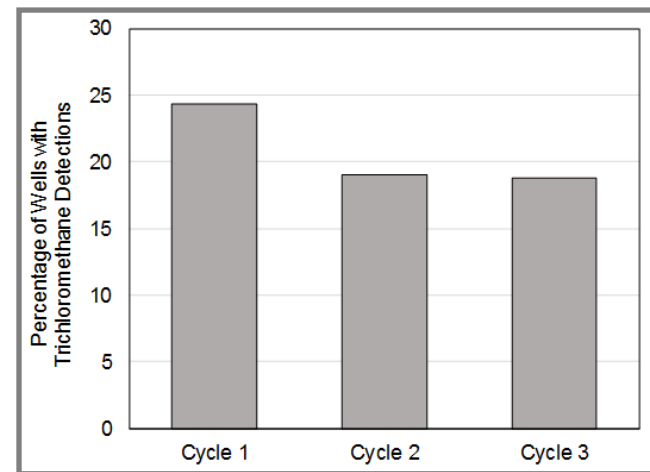
**Figure 4A–B. Nitrate-nitrite concentrations (mg/L) in ground water for the bedrock physiographic region (A) and Coastal Plain physiographic region (B). The boxplot shows the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup> and the 90<sup>th</sup> percentiles. The red horizontal line represents the NJ Ground Water Quality Criterion (GWQC) for nitrate of 10 mg/L.**



**Figure 5. Total concentration of 34 volatile organic compounds (VOC) in ground water by sampling cycle for the bedrock physiographic region (A) and Coastal Plain physiographic region (B).**

Although not shown graphically in this report, data on pesticide concentrations were evaluated as part of the AGWQMN, including detection frequency and summed (total) concentrations. During cycle 3, a more robust pesticide sampling schedule was implemented that included the addition of numerous pesticide metabolites. Statewide, the number of monitoring wells that had detections for a single pesticide remained consistent between sampling cycles 1 and 2 (74 wells (49.3%) and 75 wells (50%) wells, respectively). The frequency of pesticide or pesticide metabolite detections has increased in cycle 3 to 85 (56.7%) monitoring wells, but this increase may be due to the expansion of the analyte list. The most common chemicals observed were the herbicides atrazine, metolachlor, prometon, simazine, and the atrazine metabolite deethylatrazine.

Total VOC concentration has decreased from the first sampling cycle to the third sampling cycle for both physiographic regions (Figure 5). An example of a VOC is trichloromethane (also known as chloroform), which is the most widely detected VOC in the network. Detections of trichloromethane appear to have remained relatively stable over the sampling cycles (Figure 6). New Jersey's high frequency of detection of trichloromethane is consistent with national studies conducted by the USGS, which found chloroform to be the most frequently detected VOC in both public and domestic wells.<sup>13,14</sup> Natural sources of chloroform include volcanic gases, marine algae, and soil fungi.<sup>8</sup> Anthropogenic sources of chloroform in the environment include air emissions, past production of CFCs, and chlorination of water for disinfection purposes.<sup>8</sup>



**Figure 6. Percentage of wells with trichloromethane (chloroform) concentrations in ground water above the reporting limit (\*reporting limit varied from 0.052–1 µg/L).**

## Outlook and Implications

In New Jersey, approximately 30% of the drinking water supply is ground water (see “Water Supply” in the NJDEP Environmental Trends series). Anthropogenic activities are known to impact shallow ground water quality, and protecting this resource is critical. The AGWQMN work will continue and additional data will aid in the identification of important ground water-quality trends. The data provide insight for policy makers to assess current ground water-quality policies and to help shape future policies.

The AGWQMN was one of the first networks to provide data to the National Ground Water Monitoring Network. It provides historic and new data to be used by external agencies, such as the USGS, to assess ground water quality in various geological formations. The data are also used by Licensed Site Remediation Professionals (LSRPs) to estimate regional background water-quality conditions. The data are also used to help set ground water rules and/or standards within the State. Along with other sources of data, the AGWQMN data have also been used to produce models for estimating septic densities for the Highlands Regional Master Plan.

It must be noted, however, that the AGWQMN was designed to cover the entire State based on land use, independent of any designated uses such as drinking water. Data to assess a localized or regional issue would require more monitoring wells to provide adequate coverage. Any new wells added to the network must be installed to the same rigorous criteria as the existing wells to ensure that the data are comparable.

## References

- <sup>1</sup>Bousenberry, R., New Jersey Geological and Water Survey, New Jersey Department of Environmental Protection. 2016 (revised). Information Circular, New Jersey Ambient Ground Water Quality Monitoring Network: New Jersey Shallow Ground-Water Quality, 1999-2008. Available at [www.state.nj.us/dep/njgs/enviroed/infocirc/NJAGWQMN.pdf](http://www.state.nj.us/dep/njgs/enviroed/infocirc/NJAGWQMN.pdf)
- <sup>2</sup>Scott, J.C. 1990. Computerized stratified random site-selection approaches for design of a ground-water-quality sampling network, U.S. Geological Survey, WRI Report 90-4101.
- <sup>3</sup>N.J.A.C. 7:9C, Ground Water Quality Standards, readopted without change on March 4, 2014 (see April 7, 2014 New Jersey Register).
- <sup>4</sup>Kruskal-Wallis test  $\chi^2 = 0.01$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>5</sup>Kruskal-Wallis test  $\chi^2 = 1.82$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>6</sup>Kruskal-Wallis test  $\chi^2 = 0.04$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>7</sup>Kruskal-Wallis test  $\chi^2 = 1.52$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>8</sup>Denver, J.M., Ator, S.W., Fischer, J.M., Harned, D.C., Schubert, C., and Szabo, Z. 2014. The Quality of Our Nation's Waters—Water Quality in the Northern Atlantic Coastal Plain Surficial Aquifer System, Delaware, Maryland, New Jersey, New York, North Carolina, and Virginia, 1988–2009: U.S. Geological Survey Circular 1353, 88 p.
- <sup>9</sup>Puckett, Larry J., Tesoriero, Anthony J., Dubrovsky, Neil M. 2011. Nitrogen Contamination of Surficial Aquifers—A Growing Legacy, *Environmental Science and Technology*, 45, p. 839-844.
- <sup>10</sup>Wilcoxon Peto-Prentice test  $\chi^2 = 0.1$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>11</sup>Wilcoxon Peto-Prentice test  $\chi^2 = 0.1$ ,  $df = 2$ ,  $p\text{-value} > 0.05$ .
- <sup>12</sup>Helsel, D. R. 2012. Statistics for Censored Environmental Data Using Minitab and R, Second Edition. John Wiley & Sons, Inc., Hoboken, New Jersey.
- <sup>13</sup>Zogorski, J.S., Carter, J.M., Ivahnenko, T., Lapham, W.W., Moran, M. J., Rowe, B.L., Squillace, P.J., and Toccalino, P.L. 2006. The quality of our Nation's water—Volatile organic compounds in the Nation's ground water and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.
- <sup>14</sup>Ivahnenko, T., and Zogorski, J.S. 2006. Sources and occurrence of chloroform and other trihalomethanes in drinking-water supply wells in the United States, 1986–2001: U.S. Geological Survey Scientific Investigations Report 2006–5015, 13 p.