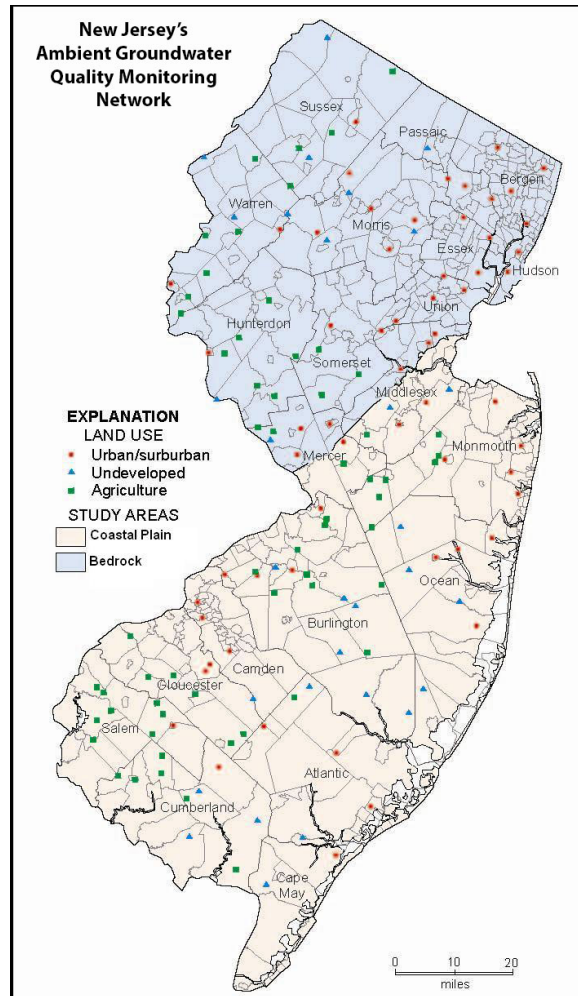


Ground Water Quality Monitoring Results

As a companion to its surface water monitoring program, New Jersey has developed and now maintains a cooperative ambient ground-water quality monitoring network with the United States Geological Survey (USGS), consisting of 150 wells screened at the water table. Initially, thirty wells were sampled annually creating a five-year monitoring cycle. Beginning in 2014, fifty wells were sampled annually creating a three-year monitoring cycle. However, 30 of the 150 wells, all wells classified as undeveloped land use, were not sampled during cycle 4 due to budget constraints. To date, five full sampling cycles have been completed (and will be referred to as sampling cycles 1 through 5 in this report). The sixth sampling cycle is currently underway but has not been completed, therefore the partial cycle data will not be included in this report. The primary goals of the New Jersey ambient ground-water quality monitoring network (AGWQMN) are to characterize shallow ground-water quality as a function of land use and to assess shallow ground-water quality trends.

Figure F1: Location and Land Uses Associated with Ambient Network Wells



The water table is the first and most significantly impacted part of the ground-water system. Network wells are screened or open just below the water table and therefore samples from them are generally expected to represent relatively young ground water. This is the ground water that interacts with and impacts surface water quality. Wells sites were located using a stratified-random site selection process as outlined by Scott (1990). The final distribution of wells as a function of land use is 60 in agricultural areas, 60 in urban/suburban areas, and 30 in undeveloped land use areas (see Figure F1).

Land use designations were determined using 1986 and 1995 land use coverages, 1995 aerial photographs and site visits. Well sites were selected using land use designations and estimations of ground-water flow directions based on the local geologic framework and site-specific topographic relationships. The 1986 and updated 1995 digital land use data categories were interpreted from 1986 and 1995 color infrared aerial photography. Parameters measured include conventional pollutants (pH, turbidity, temperature, DO), nutrients, metals, minerals, VOCs, radioactivity, and pesticides.

Geology

The state of New Jersey can be separated in 4 geologically unique regions or Physiographic Provinces each with unique rock types, landforms and hydrogeological settings (see Figure 1). These geological variables affect natural ground water quality. From north to south the regions are:

- 1) The Valley and Ridge: mostly of a thick sequence of Paleozoic sedimentary rocks ranging in age from approximately 390 to 540 million years. Sedimentary rock types include dolomite, limestone, sandstone, shale (often metamorphosed to slate) and siltstone.
- 2) The New England Province (Highlands): ridges of more resistant Middle Proterozoic (~ 940 to 1600 Ma) metamorphosed igneous and sedimentary rocks. These rocks are in fault and unconformable contact with lenses and elongate belts of generally less resistant Paleozoic sedimentary rocks (like 1 above) comprise the valley floors.
- 3) The Piedmont: intersects and it mostly underlain by the Newark Basin, which is mainly comprised of lower Mesozoic aged (~230 to 190 Ma) red, gray and black (organic rich) shale and sandstone that are inter-layered with basic igneous intrusions.
- 4) The Coastal Plain (Southern New Jersey): a southeasterly dipping and thickening wedge of stratified unconsolidated sand, silt, clay and gravel sediments that vary in age from Cretaceous ~ 144-66 million years ago (Ma) to Tertiary (~ 1.6 Ma). Three glaciations have occurred within the last 2 million years. North of the maximum extent of the last glaciation (~ 20,000 years ago), the landscape is draped by unstratified and stratified unconsolidated glacial materials of various thicknesses.

The Valley and Ridge, Highlands, and Piedmont Physiographic Provinces for this report will be referred to as the bedrock provinces.

Ground-Water Quality

Ground water is mainly recharged by precipitation that percolates downward through the unsaturated zone into the zone of saturation. Ground-water quality is a reflection of: 1) the starting composition of precipitation; 2) the solubility and composition of the materials that the precipitation comes in contact with on the land surface, in the unsaturated zone, and in the saturated zone; and 3) the duration of that contact. Natural geologic materials impart a geochemical character to the water contacting it that is unique to those materials. Anthropogenic contaminants or pollutants in the form of dissolved gases, chemical constituents and possibly colloids and other particles can impact ground-water quality.

Sources of ground-water pollution can be separated into two general types: 1) point source pollution and 2) nonpoint source pollution. Point sources of pollution can be traced back to a single identifiable source, such as a chemical spill, leaking underground storage tank or an infiltration lagoon. In the AGWQMN, efforts were made to select wells that are not impacted by pollutants from known point sources.

Nonpoint source pollution is from diffuse sources that do not have a single identifiable point of origin. This type of pollution can adversely affect the quality of water in the hydrologic cycle over large areas. For example, the release of emissions to the atmosphere from the burning of fossil fuels, such as sulfur that produces acid rain, can alter the quality of precipitation that can in turn have a regional impact on surface and ground water quality. In addition, once precipitation contacts the land surface it can be further altered by dissolving nonpoint source pollutants associated with agricultural and urban land use activities; thereby impacting water quality on a regional scale.

Data summaries of samples collected and analyzed from the 150 AGWQMN wells between 1999 and 2019 are presented and discussed below. Samples from these wells were collected by the Department of Environmental Protection's (Department's) Bureau of Fresh Water and Biological Monitoring, New Jersey Geological and Water Survey (NJGWS) and USGS' New Jersey Water Science Center and analyzed at the USGS National Water Quality Laboratories in Denver, Colorado. VOCs and pesticides were analyzed using USGS methods O-3127-94 (Rose and Schroeder, 1995) and O-4127-96 (Zaugg and others, 1995), respectively. Data for water years 1999 to 2013 are reported in their respective USGS Water Resources Data Reports for New Jersey (DeLuca and others, 2000 – 2009) and can be obtained through NJGWS. Data and Water-Year Summaries for water years 2014 to present can be obtained through the USGS National Water Information System web interface (NWISWeb).

AGWQMN wells in undeveloped areas yield ground water with a more natural quality than those in agricultural and urban areas and therefore provide a reference for water quality that is little affected by human activity. Shallow ground-water chemistry in undeveloped areas in the Coastal Plain (southern New Jersey) is different from that in the northern portion of New Jersey that is underlain by bedrock (northern New Jersey). For example, the median pH and total dissolved concentration (TDS) is lower in the Coastal Plain than in the bedrock provinces (see Table 1). Minerals comprising the bedrock aquifers are generally more reactive than those in the Coastal Plain because they are more soluble. For example, many of the northern aquifers contain the soluble mineral calcite (CaCO_3) that imparts alkalinity to ground water upon dissolution. That

reaction yields circum-neutral pH waters with calcium and bicarbonate ions as major ions. The quartz-rich less-reactive sands in the Coastal Plain are generally devoid of highly soluble minerals yielding little if any alkalinity and ground water is more dilute and acidic, similar to the rainwater that recharged it. Because the natural shallow ground-water quality is clearly different in the Coastal Plain in southern New Jersey than in the bedrock Physiographic Provinces to the north, the data in this report are separated into Coastal Plain and bedrock.

Water Quality Parameters

The water quality parameters or constituents such as temperature, dissolved oxygen, pH, and total dissolved solids (TDS) concentration values yield information about the general character of shallow ground water as a function of geology and land use (Table F1). Lower pH and TDS values in the Coastal Plain reflect the difference in geologic makeup. In addition, it is generally cooler in northern New Jersey, which is reflected in the cooler shallow ground-water temperatures relative to the Coastal Plain shallow ground-water temperature in the southern portion of the State. The lower dissolved oxygen concentration in urban areas in both the bedrock and Coastal Plain may result from the large percentage of heat absorbing impervious surface area and resulting in poorer exchange with atmospheric oxygen, and the higher surface temperature affects the density of air. A noticeable decrease in the median DO in the undeveloped land use monitoring wells in the Coastal Plain in sampling cycles 3 and 5 was observed. However, this decrease is not significant at the 95% confidence level when compared to the median DO concentrations in sampling cycle 1 and 2. Increased total dissolved solids concentrations in agricultural and urban areas are due to the road salt and agrochemical applications. Many wells in agricultural land use areas are also near roads and therefore their water quality can also be impacted by road salt.

Table F1: Ground-water Temperature, Dissolved Oxygen, pH, and Total Dissolved Solids

	Agricultural			Urban			Undeveloped		
	Min.	Median	Max.	Min.	Median	Max.	Min.	Median	Max.
Bedrock Cycle 1									
Water Temp. (°C)	10.3	13.3	23	6.8	12.9	18.3	10	12	13.9
DO (mg/L)	0.2	4.3	11	0.2	2.9	6.9	0.6	4.2	6.7
pH	6.5	7.4	8.1	4.7	6.9	8.4	5.8	7	8.1
TDS (mg/L)	167	269	938	132	476	2200	22	119	387
Bedrock Cycle 2									
Water Temp. (°C)	9.9	13	15.9	9.1	13.9	23.4	9.2	11.8	14.2
DO (mg/L)	0.2	3.6	10.7	0	2.9	6.7	0.9	6	8
pH	6.1	7.3	7.9	5.2	6.9	7.7	5	7	8.5
TDS (mg/L)	129	242	1270	149	480	3530	23	119	549
Bedrock Cycle 3									
Water Temp. (°C)	11.3	13.2	18	9.9	13.7	29.9	9.5	11	14
DO (mg/L)	0.1	4.1	9.2	0.1	2.6	7.3	0.6	5.8	8.2
pH	6	7.4	8	5.1	7	12.3	5.5	6.5	8.4
TDS (mg/L)	74	250	770	126	593	2260	27	111	464

Table F1 (continued): Ground-water Temperature, Dissolved Oxygen, pH, and Total Dissolved Solids

	Agricultural			Urban			Undeveloped		
	Min.	Median	Max.	Min.	Median	Max.	Min.	Median	Max.
Bedrock Cycle 4									
Water Temp. (°C)	9.5	13.2	22.5	8.5	14.4	27.3	Not sampled		
DO (mg/L)	<0.1	4.1	9.4	<0.1	2.5	7.1			
pH	6.4	7.6	8.1	4.8	6.9	8.1			
TDS (mg/L)	75	256	1200	139	587.5	2760			
Bedrock Cycle 5									
Water Temp. (°C)	10.1	14.2	22.8	11.3	14.5	21.2	10.2	14.1	22.4
DO (mg/L)	0.2	4.4	9.4	0.1	2.1	7.7	0.3	5.4	7.8
pH	6.2	7.4	10.3	5	6.9	8	5.1	6.6	8.2
TDS (mg/L)	151	268	1630	213	591	2520	21	101	563
Coastal Plain Cycle 1									
Water Temp. (°C)	12	15.5	22.5	13.8	17.5	29	12	14.5	18
DO (mg/L)	<0.3	5.4	10.5	<0.2	2.1	10	<0.2	4.6	9.3
pH	3.9	5	7.91	3.8	4.9	7.8	3.7	4.7	6
TDS (mg/L)	35	214	690	56	150	816	15	28	170
Coastal Plain Cycle 2									
Water Temp. (°C)	11.1	14.8	19.9	12.2	14.9	21.8	8.5	12.7	15.3
DO (mg/L)	0.2	3.5	11.2	0.1	3.1	9.6	0.2	5.1	9.1
pH	3.8	4.8	7.9	3.6	4.9	8.1	4.1	4.5	5.8
TDS (mg/L)	45	208	2040	40	221	2310	19	27	147
Coastal Plain Cycle 3									
Water Temp. (°C)	8.3	13.7	19.4	12.7	15.6	18.2	9	10.7	20.1
DO (mg/L)	0.2	5	12.6	0.3	2.7	8.6	0.3	2.4	9.6
pH	3.7	5.2	7.9	4	5	8	4.2	4.6	6.2
TDS (mg/L)	26	230	1860	40	237	1230	14	31	171
Coastal Plain Cycle 4									
Water Temp. (°C)	8.4	13.8	20.6	9	14.6	16	Not sampled		
DO (mg/L)	<0.1	5.7	10.8	<0.1	1.7	9			
pH	3.8	5.2	7.9	4.2	4.8	7.6			
TDS (mg/L)	51	181.5	8170	95	323.5	1680			
Coastal Plain Cycle 5									
Water Temp. (°C)	10.5	15.15	21.8	11.5	15.4	22.5	11.2	13.5	18.7
DO (mg/L)	<0.1	5	10.5	<0.1	2.4	8.8	0.2	2.7	9.7
pH	3.7	5.1	7.8	3.8	4.9	7.8	3.9	4.4	6.1
TDS (mg/L)	29	177	3170	78	350.5	1690	21	37	516

Trace Elements

Ground-water samples were analyzed for the following 15 trace elements (metals): aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and selenium. Of these, eight trace elements (arsenic, beryllium, cadmium, iron, lead, manganese, nickel, and aluminum) have been detected at concentrations greater than the New Jersey Ground Water Quality Standards (GWQS) in all five sampling cycles except nickel not being detected above the GWQS in cycles 1 and 3.

Arsenic detection and concentrations in the bedrock regions are natural in origin with the number of detections that exceed the NJ Ground Water Quality Standard dropping between sampling cycles. The one well that exceeded the arsenic standard in undeveloped land use during the second sampling cycle had a concentration of 3.4 µg/L, which is just above the GWQS of 3 µg/L. Iron and manganese detections and concentrations have a strong urban association and possibly a weak agricultural association. The reducing conditions found in the agricultural and urban land use areas, indicated by the lower dissolved oxygen concentrations found in these land use areas, are conducive to iron and manganese mobility.

In the Coastal Plain of New Jersey (southern NJ), iron and aluminum are most likely natural in origin. As observed in the bedrock provinces monitoring wells, manganese has an urban and agricultural land use association. Acidic and reducing ground-water conditions will mobilize the iron, aluminum, and manganese. In undeveloped land use, the fluctuations of the median concentrations for these compounds cannot be attributed to a change in pH values, which have remained consistent. They could be attributed to the natural fluctuation of concentrations.

One undeveloped well had an arsenic concentration that exceeded the GWQS of 3 µg/L in sampling cycle 1 and 2. Its concentration was 3.3 µg/L during both sampling events, which is just above the standard, and may be attributed to a high degree of iron-oxide dissolution. During all sampling cycles, the same two urban wells were observed to have arsenic concentrations that exceeded the ground water standard with a maximum concentration of 111.53 µg/L. The ultimate source of this arsenic is unknown. Mercury is detected at low levels, generally less than 1 µg/L with the exception of one well in sampling cycle 5 with a detection of 7.14 µg/L, which exceeds the GWQS of 2 µg/L. Fertilizers, agrochemicals, and lawn care products could be the source or mobilization agent for the beryllium, cadmium, lead, and nickel observed in the Coastal Plain.

Nutrients

Nutrient concentrations are dominated by nitrate, and the frequency and concentration by land use in both the bedrock provinces (northern NJ) and the Coastal Plain (southern NJ) are agricultural greater than urban, which is greater than undeveloped (Table F2) in all of the sampling cycles. The majority of concentrations of nitrite plus nitrate as milligrams per liter (mg/L) of nitrogen that exceed the GWQS of 10 mg/L were observed in the agricultural land use monitoring wells. The use of nitrogen-based fertilizers in agricultural and urban areas and possibly septic system and sewer system leakage are considered to be the major sources. In the first four sampling cycles, orthophosphate concentrations were all less than 1.0 mg/L. In cycle 5, three monitoring wells had concentrations greater than 1.0 mg/L with a maximum concentration of 2.58 mg/L as phosphorous. Two of these wells were in agricultural land use areas while the third classified as urban land use.

Table F2: Ground-water Nitrite plus Nitrate by Land Use and Sampling Cycle

Sampling Cycle - Coastal Plain or Bedrock - Land Use	Number of Wells Sampled	Percentage of Detected Values	Percentage of Values above the GWQS of 10 mg/L	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)
1 - CP - Ag	39	87.18	28.21	0.02	55.51
2 - CP - Ag	39	79.49	25.64	0.07	51.7
3 - CP - Ag	39	84.62	23.08	0.03	38.3
4 - CP - Ag	39	79.49	17.95	0.057	26.7
5 - CP - Ag	39	76.92	20.51	0.051	28.7
1 - CP - Urb	28	75	3.57	0.029	14.404
2 - CP - Urb	28	71.43	0	0.03	5.22
3 - CP - Urb	28	78.57	0	0.077	9.46
4 - CP - Urb	28	82.14	3.57	0.062	11.9
5 - CP - Urb	28	82.14	3.57	0.05	10.6
1 - CP - Und	19	15.79	0	0.077	0.779
2 - CP - Und	19	10.53	0	0.05	0.84
3 - CP - Und	19	42.11	0	0.02	1.75
4 - CP - Und	0	Not sampled			
5 - CP - Und	19	36.84	0	0.045	2.12
1 - BR - Ag	21	95.24	19.05	0.66	24.2
2 - BR - Ag	21	100	9.52	0.03	16.1
3 - BR - Ag	21	95.24	14.29	0.043	14.3
4 - BR - Ag	21	95.24	9.52	0.135	28.3
5 - BR - Ag	21	95.24	14.29	0.064	19.4
1 - BR - Urb	32	81.25	0	0.033	7.44
2 - BR - Urb	32	81.25	0	0.02	5.52
3 - BR - Urb	31	80.65	0	0.073	5.64
4 - BR - Urb	32	78.13	0	0.075	4.93
5 - BR - Urb	31	80.65	0	0.105	5.91
1 - BR - Und	11	100	0	0.027	1.978
2 - BR - Und	11	81.82	0	0.04	3.46
3 - BR - Und	11	90.91	0	0.03	4.15
4 - BR - Und	0	Not sampled			
5 - BR - Und	11	72.73	0	0.047	6.41

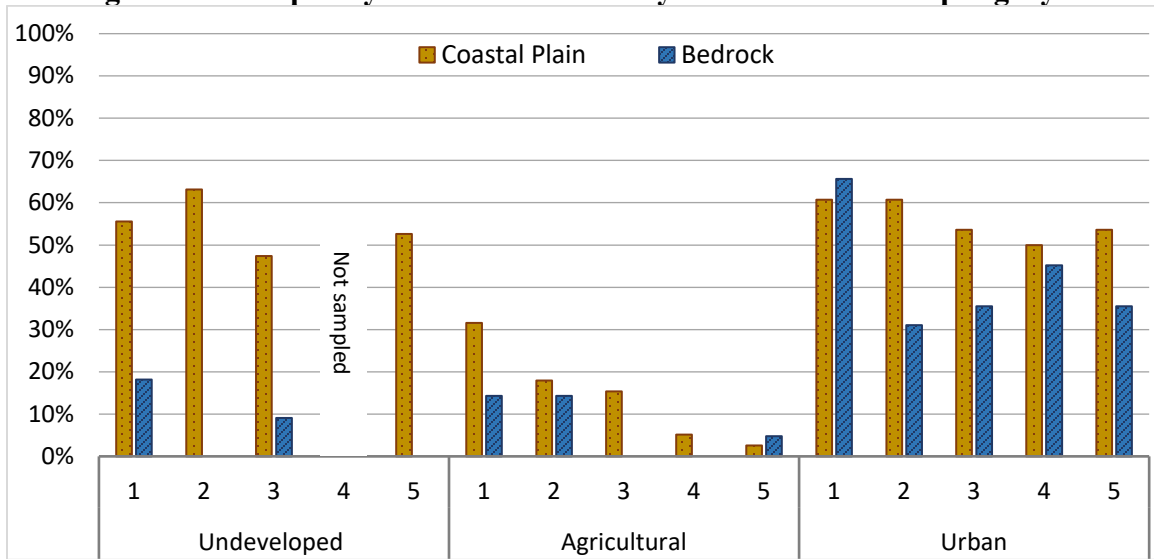
Volatile Organic Compounds

The ground-water samples were analyzed for 35 volatile organic compounds (VOCs). The frequency of VOC detection is a function of land use. Figure F2 shows the percentage of monitoring wells per sampling cycle that had at least one VOC detection. Of the three land uses, the samples from the urban land use monitoring wells generally had the highest frequency of detection of VOCs. It should be noted that a high percentage of undeveloped wells in the Coastal Plain had detections for one compound, chloroform (trichloromethane). Aside from chloroform detections, the frequency of VOC detection in undeveloped land use areas is relatively low. The presence of chloroform in groundwater can be potentially attributed to atmospheric deposition, septic systems, leaking sewers and water lines, or chlorinated drinking water being used to water lawns and gardens and to fill up swimming pools. In addition to these anthropogenic sources, chloroform can potentially be produced through natural processes in soil.

Methyl tertiary-butyl ether (MTBE), an additive in gasoline, showed a steep decline in the frequency of detection, especially in the bedrock provinces between sampling cycles 1 and 2. There were no detections above the GWQS of 70 µg/L in the Coastal Plain or bedrock provinces and the maximum detected concentration was 47.13 µg/L in sampling cycle 1. The frequency of detection remained steady between sampling cycle 2 and 5 with one detection in the bedrock provinces. During the first round of sampling 50% of the urban wells, 14% of agricultural wells, and 9% of the wells in undeveloped land use had detections for MTBE. In sampling cycle 2 through 5 there were only one detection of MTBE in each sampling cycle, but the detection was observed in a different well in each of cycles 2 to 4, one from each land use.

In the Coastal Plain, the frequency of MTBE detection decreased between sampling cycles from 18% of wells with detections in cycle 1 to 7% of wells with detections in cycle 5. The decrease in detections of MTBE can be attributed to a ban on using MTBE in the State of New Jersey. The Coastal Plain has more detections of MTBE than the bedrock provinces, which could possibly be due to atmospheric deposition. The predominant wind patterns are from the north-west, and the heavily urbanized areas of New Jersey's bordering States to the west could be one reason for the observed higher detections of MTBE in the Coastal Plain than in the bedrock provinces. In the agricultural land use wells in the Coastal Plain, the frequency of detection of MTBE decreases to 0 in sampling cycles 4. Figure F2 shows a decreasing trend of VOC detection frequency in agricultural land use wells in the Coastal Plain. In sampling cycle 5, there was only one well with a VOC detection, which was of a single compound, toluene.

Figure F2. Frequency of VOC Detection by Land Use and Sampling Cycle



Pesticides

The concentration and frequency of detections of pesticides Statewide is land use driven with agricultural land use the primary source. The number of compounds detected fluctuates over the five sampling cycles. During sampling the bedrock provinces monitoring wells in cycle 2, there was a change in the pesticide parameter list. The new parameter list contains more metabolite compounds that were not previously analyzed for. As of sampling cycle 5, 80 pesticide compounds are included in the analysis. There were detections of 33 of the 80 compounds in cycle 5. Atrazine and its degradation product 2-chloro-4-isopropylamino-6-amino-s-triazine (deethylatrazine), metolachlor, prometon, and simazine are herbicides used to control grasses and broadleaf plants that are frequently detected compounds in all sampling cycles.

Radionuclides

Gross alpha particle activity was analyzed within 48 hours after sample collection. This ensures that the radioactive decay of short-lived radium-224 (half-life of 3.64 days) is measured along with the other alpha emitters. The Federal and New Jersey drinking water standard of 15 pCi/L gross alpha particle activity still applies even though the shorter holding time results in increased activity if significant radium-224 is present. Generally, higher radium activity is found in the Coastal Plain Physiographic Province versus the bedrock provinces in all land use. This is most likely due to the greater abundance of radium-224 and the low pH of the ground water in the Coastal Plain. The low pH can increase radium's mobility. In both the combined bedrock and Coastal Plain provinces, and in both sampling cycles, the highest activity is associated with agricultural and urban land use areas. The application of agricultural and lawn chemical products can compete with naturally occurring radium for adsorption sites thereby mobilizing more into the ground-water system. In the Coastal Plain, the frequency of gross alpha concentrations above the standard ranged between 11% and 20% over the five sampling cycles with a generally increasing trend. In the bedrock provinces, there was only one monitoring well sample that exceeded the standard in sampling cycles 2 and 4, but these were not at the same well. No samples from monitoring wells in bedrock provinces exceeded the standard in sampling cycles 1, 3, and 5.

Conclusion

In agricultural and urban land uses, total dissolved solids concentrations, as well as the concentration, frequency, and variety of major ions, trace elements, nutrients, volatile organic compounds, and pesticides, are found at higher levels than in wells located in undeveloped areas. While nitrite plus nitrate median concentrations fluctuated slightly in urban and agricultural land uses, the concentrations were still higher than those in undeveloped land use with the highest concentration and frequency of detection being in agricultural land use. Atrazine and its degradation product 2-chloro-4-isopropylamino-6-amino-s-triazine, metolachlor, prometon, and simazine were frequently detected pesticides in both the bedrock provinces and the Coastal Plain and in all sampling cycles. Of the VOCs detected, MTBE (methyl tertiary-butyl ether) showed the steepest decline in the frequency of detection. Agrochemicals and lawn care products could be promoting the mobilization of radium in both the Coastal Plain and bedrock provinces, along with the reducing conditions found in the Coastal Plain.

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