**Division of Watershed Management**
**Bureau of Environmental Analysis and Restoration**
**Technical Report**

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# Nitrate as a Surrogate for Assessing Impact of Development Using Individual Subsurface Sewage Disposal Systems on Ground Water Quality

## Introduction:

Individual Subsurface Sewage Disposal Systems (ISSDSs) discharge numerous constituents including nutrients, bacteria, dissolved solids and organic compounds (USEPA, 2002). Some constituents are present in significant and predictable amounts while others are present in minute and/or variable amounts based on user behavior. Some constituents are significantly attenuated by the physical, chemical and biological reactions that occur in the soil through which the effluent travels, including dilution with the ground water over time and space. Others, such as nitrate and dissolved solids like sodium and chloride, are attenuated almost exclusively by dilution. Due to the large number of constituents in ISSDS effluent, which can occur in variable concentrations and are subject to numerous fate/transport responses after discharge, the Department has investigated the use of one component to act as a surrogate for all parameters of concern as a scientifically sound approach that can be implemented effectively through regulation. After careful consideration detailed in this report, nitrate was selected as the most appropriate parameter. This parameter is then used with a mass balance dilution model to identify the density of ISSDSs, or the equivalent use flow or mass conversions, that can be accommodated and maintain the Statewide ambient nitrate concentration in ground water of 2 mg/L.

## Selection of Parameter:

Nitrogen, phosphorus and total dissolved solids were selected as parameters to test as potential surrogates because they are present in septic effluent in relatively large and predictable amounts (Tables 1 and 2). Nitrogen as nitrate is assessed because nitrogen in other forms is readily converted to nitrate as the result of processes that occur in the soil. This is illustrated by the concentrations of total Kjeldahl nitrogen (TKN), which measures organic nitrogen and ammonia, and nitrate, the main inorganic form of nitrogen, in septic effluent compared to concentrations at 0.6 meters as shown in Table 1. Total phosphorus is the form of phosphorus for which data is available with respect to septic effluent quality. However, ground water sampling data is provided only for the dissolved or ortho-phosphate forms of phosphorus. For the purposes of the Department's

analyses, total phosphorus is assumed to be equivalent to both dissolved and ortho-phosphate as most, if not all, of the phosphorus that will be present in a ground water quality sample will be in the form of dissolved phosphorus, and ortho-phosphate generally makes up ~90% of dissolved phosphorus. Thus, comparing both these forms to total phosphorus is reasonable for the purpose of this analysis.

**Table 1. Quality of septic tank effluent and in soil water quality[1].**

| Parameter (units) | Statistics | Septic tank effluent quality | Soil water quality [2] at 0.6 meter | Soil water quality [2] at 1.2 meters |
|---|---|---|---|---|
| BOD (mg/L) | Mean<br>Range<br># samples | 93.5<br>46-156<br>11 | <1<br><1<br>6 | <1<br><1<br>6 |
| TOC (mg/L) | Mean<br>Range<br># samples | 47.4<br>31-68<br>11 | 7.8<br>3.7-17.0<br>34 | 8.0<br>3.1-25.0<br>33 |
| TKN (mg/L) | Mean<br>Range<br># samples | 44.2<br>19-53<br>11 | 0.77<br>0.40-1.40<br>35 | 0.77<br>0.25-2.10<br>33 |
| $NO_3$-N (mg/L) | Mean<br>Range<br># samples | 0.04<br>0.01-0.16<br>11 | 21.6<br>1.7-39.0<br>35 | 13.0<br>2.0-29.0<br>32 |
| TP (mg/L) | Mean<br>Range<br># samples | 8.6<br>7.2-17.0<br>11 | 0.40<br>0.01-3.8<br>35 | 0.18<br>0.02-1.80<br>33 |
| TDS (mg/L) | Mean<br>Range<br># samples | 497<br>354-610<br>11 | 448<br>184-620<br>34 | 355<br>200-592<br>32 |
| Cl (mg/L) | Mean<br>Range<br># samples | 70<br>37-110<br>11 | 41<br>9-65<br>34 | 29<br>9-49<br>31 |
| F. coli (log # per 100 mL) | Mean<br>Range<br># samples | 4.57<br>3.6-5.4<br>11 | nd<br><1<br>24 | nd<br><1<br>21 |
| F. strep (log # per 100 mL) | Mean<br>Range<br># samples | 3.60<br>1.9-5.3<br>11 | nd<br><1<br>23 | nd<br><1<br>20 |

[1] The soil matrix consisted of a fine sand; the wastewater loading rate was 3.1 cm per day over 9 months.
[2] Soil water quality measured in pan lysimeters at unsaturated soil depths of 2 feet (0.6 meter) and 4 feet (1.2 meters).

BOD = biochemical oxygen demand; TOC = total organic carbon; TKN = total Kjeldahl nitrogen; NO3 = nitrate; TP = total phosphorus; TDS = total dissolved solids; Cl = chlorides; F. coli = fecal coliforms; F. strep = fecal streptococci; nd = none detected.

Taken from Table 3-18, *USEPA: Onsite Wastewater Treatment Systems Manual* (2002); Case study: septic tank effluent and soil water quality. Source: Adapted from Anderson, *et al*. 1994.

**Table 2. Wastewater constituents of concern and representative concentrations in the effluent of various treatment units.**

| Constituents of concern | Example direct or indirect measures (Units) | Tank-based treatment unit effluent concentrations | | | | | SWIS percolate into ground water at 3-5 ft depth (% removal) |
|---|---|---|---|---|---|---|---|
| | | Domestic STE [1] | Domestic STE with N-removal recycle [2] | Aerobic unit effluent | Sand filter effluent | Foam or textile filter effluent | |
| Oxygen demand | $BOD_5$ (mg/L) | 140-200 | 80-120 | 5-50 | 2-15 | 5-15 | >90% |
| Particulate solids | TSS (mg/L) | 50-100 | 50-80 | 5-100 | 5-20 | 5-10 | >90% |
| Nitrogen | Total N (mg N/L) | 40-100 | 10-30 | 25-60 | 10-50 | 30-60 | 10-20% |
| Phosphorus | Total P (mg P/L) | 5-15 | 5-15 | 4-10 | $<1$-$10^3$ | 5-15[3] | 0-100% |
| Bacteria (e.g., *Clostridium perfrigens, Salmonella, Shigella*) | Fecal coliform (organisms per 100 mL) | $10^6$-$10^8$ | $10^6$-$10^8$ | $10^3$-$10^4$ | $10^1$-$10^3$ | $10^1$-$10^3$ | >99.99% |
| Virus (e.g., hepatitis, polio, echo, coxsackie, coliphage) | Specific virus (pfu/mL) | 0-$10^5$ (episodically present at high levels) | 0-$10^5$ (episodically present at high levels) | 0-$10^5$ (episodically present at high levels) | 0-$10^5$ (episodically present at high levels) | 0-$10^5$ (episodically present at high levels) | >99.9% |
| Organic chemicals (e.g., solvents, petrochemicals, pesticides) | Specific organics or totals (µg/L) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | 0 to trace levels (?) | >99% |
| Heavy metals (e.g., Pb, Cu, Ag, Hg) | Individual metals (µg/L) | 0 to trace levels | 0 to trace levels | 0 to trace levels | 0 to trace levels | 0 to trace levels | >99% |

[1] Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant STE is markedly higher particularly in $BOD_5$, COD, and suspended solids while concentrations in graywater STE are noticeably lower in total nitrogen.

[2] System with N-removal cycle: N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.

[3] P-removal by adsorption/precipitation is highly dependent on media capacity, P loading, and system operation.

SWIS = Subsurface Wastewater Infiltration System

Taken from: Table 3-19 from *USEPA: Onsite Wastewater Treatment Systems Manual* (2002); Wastewater constituents of concern and representative concentrations in the effluent of various treatment units. Source: Siegrist, 2001 (after Siegrist, *et al*. 2000).

An initial screening was performed to evaluate the behavior of the three components with respect to ambient quality using a spreadsheet dilution model based on *A Recharge-Based Nitrate-Dilution Model for New Jersey*, which was simplified for this

purpose. *A Recharge-based Nitrate-dilution Model for New Jersey* and its "Technical Manual" (NJGS Open-File Report 04-1: *A Recharge-Based Nitrate-Dilution Model for New Jersey* (Hoffman and Canace, 2004)) can be found on the Department's website at http://www.njgeology.org/pricelst/pricelst.htm. This model calculates the number of acres needed to dilute a pollutant load, based on the simplifying assumption that the pollutant becomes mixed with the ground water over the area identified, in order to achieve a concentration target in the groundwater. The model was developed to determine density needed to dilute nitrate, hence the title, but works equally well to predict the dilution of other parameters. The model has as inputs 1) the recharge capabilities that have been derived for a wide range of soil types, 2) a climate factor assigned to each municipality that is based on precipitation data for the State, 3) the pollutant load per person, expressed either as a mass over a unit time or a concentration and flow rate, 4) the number of persons per dwelling unit, and 5) the target concentration in the ground water. The model derives a value for impervious cover using an algorithm that relates lot size and the associated percent of impervious cover to refine the output of the model, which is in acres per unit needed to achieve the designated target. This algorithm is extrapolated from the Natural Resources Conservation Service's (NRCS) Technical Release 55 (TR-55: Urban Hydrology for Small Watersheds (USDA, 1986)), which presents procedures for estimating stormwater runoff and peak rates of discharge.

For the purpose of comparing the three components, only the relative behavior of each constituent is important and so a single recharge condition is illustrative. Therefore, *A Recharge-Based Nitrate-Dilution Model for New Jersey* was simplified by assigning a recharge factor of 11.8 inches, the Statewide average recharge rate, as a fixed constant for annual recharge volume in place of the soil type and climate factor variables and with no adjustment for impervious cover. As mentioned above, the spreadsheet requires an input of persons per dwelling unit and either a load or a concentration and flow contributed by each person to establish the parameter load. To establish a household occupation rate, the Department examined the latest U.S. census data to determine a representative residential density. Based on the 2000 census, the average household-size in New Jersey is 2.68 people (U.S. Census Bureau, 2006; U.S. Census Bureau data can be accessed at www.census.gov). Therefore, the Department rounded this number to 3.

In order to determine the appropriate input and target concentrations for each component, the Department reviewed available literature sources as well as available ground water quality data. Two distinct datasets were utilized, one from the United States Geological Survey (USGS) that includes data collected over several decades from over 1000 wells and the other from a USGS/NJDEP cooperative project, the Ambient Ground Water Quality Monitoring Network (AGWQMN), which is a subset of the larger USGS data base with recent data from wells selected to represent a range of land uses and geographic regions. These datasets are contained in the Appendix section of this report.

Description of Datasets:

The USGS National Water Information System (NWIS) is a comprehensive database that supports the acquisition, processing, and long-term storage of national water data, and incorporates both chemical and physical data for streams, lakes, springs, and wells. One of the datasets utilized for the Department's septic density analyses was compiled by USGS personnel and provided to the Department on CD. Ground water quality data from the NWIS database was retrieved for a broad period of record, and the USGS program *Weedpoint* was then used to sort and select the maximum number of wells without overlapping a 500-meter buffer area around each well. This was done in order to prevent excessive redundancy of data from wells situated near each other. Given the large number of wells in the data base and the variations in land use, topography, and soil characteristics, a buffer area of 500-meters was selected as adequately representative of surrounding variables and prevalent inputs. All wells in confined units were automatically deleted as they are not expected to represent recent impacts from surface activities. Where there were multiple data records, only the most recent data record was automatically selected in order to provide the most current picture. Where wells were sampled at multiple depths, the shallowest sampling depth was automatically selected to best reflect the direct influence of surface inputs. This *Weedpoint* "filtering" of the NWIS database resulted in a refined dataset of 1,315 wells, sampled between December 8, 1926 and September 1, 2004. Of these 1,315 wells: 1,112 sampled for nitrate from February 16, 1978 through September 1, 2004, and 380 sampled for dissolved phosphorus from February 16, 1978 through March 21, 2002. Therefore, the periods of record assessed using the USGS/*Weedpoint*-refined dataset approximates the last 30 years and is considered representative of "modern" conditions. USGS also delineated and quantified the total area of each well's 500-meter buffer area by Anderson (1976) Level I Land Use/Land Cover (LULC) classifications, (e.g., Agricultural, Barren, Forest, Water, Wetlands, and Urban), in order to assess and differentiate analyses based on differences in land use.

The second dataset the Department utilized, the New Jersey Ambient Ground Water Quality Monitoring Network (AGWQMN), is a subset of the NWIS database. Whereas the NWIS database contains water quality information for all manner of ground water wells, e.g., potable water supply wells, irrigation wells, non-contact cooling water wells, etc., all 150 wells in the AGWQMN were selected using a stratified random approach that considered land use and were drilled specifically to monitor the top of the water table to assess the status and trends in ground water quality throughout the State. A USGS computer program was used to divide the State into "cells" of equal area of targeted land uses: 60 Agricultural, 60 Urban, and 30 Undeveloped, and a well was installed in each cell. The wells are sampled on a rotational basis, 30 per year, so that each well is sampled once every 5 years. The first full round of sampling was completed in 2004, representing conditions from the summer of 1999 into the summer of 2004. This data was obtained from the New Jersey Geological Survey and the United States Geological Survey, who jointly administer the network.

In some instances in the above datasets, when testing of the sample produced no result for a particular component, meaning the actual value was below the detection level

for that component, the limit of detection was identified as the upper limit of the actual value. The Department opted to utilize the detection limit as the actual value, rather than abandon the data point, in order to maintain the fullest spatial representation of the State that these datasets were intended to portray. As a result, the averaging of the data can be expected to produce a somewhat higher result than the actual average concentrations. In fewer instances, some data points are noted as "estimated," indicating there was some question about the precision of the measurement. Again, rather than abandon this information the Department accepted these data points at face value. The only instance data points were abandoned was when a value entered was zero, because it was unknown if this was an accurate reading, a "non-detect" or some other situation. Of the 1,112 data records for wells that sampled for nitrate, 9 data records were entered as a value of zero. Including the zero values resulted in a mean of 2.65 mg/L nitrate, while excluding them resulted in the mean of 2.68 mg/L nitrate, a negligible difference.

Assessing Phosphorus as Surrogate for Ground Water Quality:

Phosphorus can be modified significantly by travel through soil, and concentrations from effluent can be reduced drastically within just the first few feet of contact with soils (USEPA, 2002). Phosphorus can adsorb to, in large part, iron and aluminum minerals and in a series of chemical reactions form precipitate compounds that become part of the soil profile. After filtration by two feet of soil, total phosphorous concentration can be reduced substantially, depending on soil characteristics, oxidation-reduction potential, and pH. After four feet of soil filtration, concentrations are further attenuated (refer to Table 1). To select an input concentration for use in the simplified dilution model, this soil attenuation effect must be considered. Therefore, the mean value of total phosphorus in septic effluent, listed as 8.6 mg/L from Table 1, was adjusted to the mean concentration recorded at 2-feet (0.40 mg/L) and 4-feet (0.18 mg/L), to represent a realistic range of inputs for testing.

To select an appropriate background concentration for phosphorus to serve as the target concentration, data available from a variety of publications and other sources were considered. One recent study (Serfes, 2004) sampled wells from the Highlands geologic province in northern New Jersey, resulting in a median of 0.02 mg/L dissolved phosphorus. Another study that focused on the Piedmont geologic province (Serfes, 1994) recorded a median concentration of 0.04 mg/L dissolved phosphorus.

The USGS/*Weedpoint*-refined database previously detailed was consulted. The number of wells from this dataset that yielded data for phosphorus was 380, for which the mean concentration was 0.034 mg/L of dissolved phosphorus (Appendix A, Table 1). There is no ground water quality standard for phosphorus, but because ground water eventually becomes surface water, the Department considered the criterion for phosphorus in the Surface Water Quality Standards (SWQS). Some of the values in the USGS *Weedpoint*-refined dataset ($n$ = 14) were in excess of the SWQS numeric criterion for phosphorus in rivers and streams, which is 0.1 mg/L total phosphorus. Under the construct that water quality that does not attain water quality standards should be

restored, the values that were in excess of 0.1 mg/L were reduced to the standard. This "amended" dataset resulted in a mean concentration of 0.026 mg/L of dissolved phosphorus (Appendix A, Table 1).

The AGWQMN dataset was also consulted. The mean concentration for phosphorus for these 150 wells was 0.028 mg/L, expressed as ortho-phosphate (Appendix A, Table 2). As was the case above, some of these data values ($n$ = 6) exceeded the SWQS for phosphorus and were thus reduced back down to 0.1 mg/L. The mean concentration of this amended dataset was 0.021 mg/L ortho-phosphate (Appendix A, Table 2).

The Department selected an ambient value of 0.027 mg/L phosphorus as the average of the literature values and the adjusted values from the data analyses. Recalling that the input values are mean concentrations at 0.6 and 1.2 meters taken from Table 1, the results of the model runs are shown below in Figures 1 and 2.

**Figure 1. Dilution model results using input of 0.4 mg/L (concentration at 0.6 m) and target of 0.027 mg/L phosphorus.**

| Phosphorous | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **0.4** | mg/l |
| target: | **0.027** | mg/l |
| | | |
| avg lot size | **3.8** | acres/home |

**Figure 2. Dilution model results using input of 0.18 mg/L (concentration at 1.2m) and target of 0.027 mg/L phosphorus.**

| Phosphorous | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **0.18** | mg/l |
| target: | **0.027** | mg/l |
| | | |
| avg lot size | **1.7** | acres/home |

Assessing Total Dissolved Solids (TDS) as Surrogate for Ground Water Quality:

Two values for the input TDS concentration were tested: the mean concentration for TDS in septic effluent of 497 mg/L and the highest concentration of 620 mg/L referenced in Table 1.

To determine ambient quality for TDS, the Department utilized the AGWQMN dataset, because it measured TDS directly and its data may be readily sorted by geologic province. Due to the potential differences in TDS that may be caused by various reactive tendencies inherent to differing chemical compositions of sediments and rock, it was determined to segregate the dataset based on geologic province. Statewide, these data produced a mean concentration of 316 mg/L based on 148 data points (2 wells out of the 150-well network had no value for TDS reported). Average TDS concentrations by geologic province are shown in Table 3 and exhibit a range of 193-528 mg/L. Data are provided in Appendix B.

**Table 3. Assessment of TDS concentration based on data from the AGWQMN database.**

| Geologic Province | TDS (mg/L) |
|---|---|
| Valley and Ridge | 323 |
| Highlands | 441 |
| Piedmont | 528 |
| Coastal Plain | 193 |

**Figure 3. Dilution model results using TDS input of 497 mg/L and target of 193 mg/L.**

| TDS | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **497** | mg/l |
| target: | **193** | mg/l |
| | | |
| avg lot size | **0.7** | acres/home |

Because the range for TDS based on the data records varies so widely, the Department assessed both the high and the low values for ambient TDS levels, 193 and 528 mg/L TDS, respectively, with the average and high values for TDS concentration in septic effluent, 497 and 620 mg/L, respectively . The results of these model runs are illustrated in Figures 3 through 6.

**Figure 4. Dilution model results using TDS input of 620 mg/L and target of 193 mg/L.**

| TDS | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **620** | mg/l |
| target: | **193** | mg/l |
| | | |
| avg lot size | **0.8** | acres/home |

**Figure 5. Dilution model results using TDS input of 497 mg/L and target of 528 mg/L.**

| TDS | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **497** | mg/l |
| target: | **528** | mg/l |
| | | |
| avg lot size | **0.2** | acres/home |

**Figure 6. Dilution model results using TDS input of 620 mg/L and target of 528 mg/L.**

| TDS | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| water use rate | **75** | gpd/person |
| input concentration | **620** | mg/l |
| target: | **528** | mg/l |
| | | |
| avg lot size | **0.3** | acres/home |

Assessing Nitrate as Surrogate for Ground Water Quality:

An annual loading rate of 10 pounds per person per year was used as the input to the ground water from the septic tank, as in *A Recharge-Based Nitrate-Dilution Model for New Jersey* nitrate-dilution model developed by the New Jersey Geological Survey, available at http://www.njgeology.org/geodata/dgs02-6.htm. The Department assessed background concentrations of nitrate both through published literature sources as well as

direct analysis of the two previously described datasets to determine a representative Statewide ambient nitrate concentration to be used as the target concentration.

Data referenced in the *N.J. Geological Survey Open-File Report 04-1: A Recharge-Based Nitrate-Dilution Model for New Jersey* (Hoffman and Canace, 2004), documents minimum, median, and maximum nitrate levels taken throughout all four major geologic provinces that transect New Jersey. The *N.J. Geological Survey Open-File Report 04-1: A Recharge-Based Nitrate-Dilution Model for New Jersey* (Hoffman and Canace, 2004) document can be found on the Department's NJGS website at http://www.njgeology.org/pricelst/pricelst.htm. Twenty-three studies were cited, with publication dates ranging from 1981-1997. Some of the studies categorized data dependent upon predominant land use, e.g., undeveloped, urban, and agricultural. The data was also categorized by geologic province: Valley and Ridge, Highlands, and Newark Basin, which are grouped together here as above the "Fall Line," which is the outer border of the Piedmont region and where streams pass from the more resistant rocks of northern New Jersey to the softer deposits of the Coastal Plain. In Table 4 mean nitrate levels were derived in multiple ways: using all the median data points statewide; by isolating the Coastal Plain due to its long history of crop production as a predominant land use; and by then removing those records based on agricultural areas which have disproportionately high levels of nitrate due to applied fertilizers. As Table 4 illustrates, where the result is influenced by agriculture and the historical deposition of nitrate fertilizers, nitrate levels are notably elevated.

**Table 4. Nitrate quality based on studies referenced in NJGS Open-File Report 04-1: *A Recharge-Based Nitrate-Dilution Model for New Jersey* (Hoffman and Canace, 2004).**

| | Statewide (All) | Statewide (Agricultural areas removed) | Coastal Plain (All) | Coastal Plain (Agricultural areas removed) | Above Fall Line* (All) |
|---|---|---|---|---|---|
| **# Studies** | 23 | | 18 | | 5 |
| **# Median (M) Values** | 41 | 34 | 32 | 25 | 9 |
| **Mean (nitrate levels from M-values (mg/L)**** | 1.95 | 0.93 | 2.18 | 0.85 | 1.15 |

* No agricultural areas were monitored above the Fall Line.

** 70% of the median levels were recorded as nitrate-nitrogen, 30 percent as nitrate + nitrite. Nitrite is a highly unstable ion that occurs in low concentrations. It is commonly assumed that by the time leachate reaches the water table nitrite concentrations are insignificant. Where both nitrate-nitrogen and nitrate + nitrite levels were recorded, the nitrate + nitrite records were omitted. Two studies monitored for nitrate + nitrite and total Kjeldahl nitrogen (a measure of organic nitrogen and ammonia); in these cases the nitrate + nitrite value was used.

Several analyses were performed using the USGS/*Weedpoint*-refined and AGWQMN datasets described above. The number of wells from the USGS/*Weedpoint*-refined dataset that yielded data points for nitrate was 1,103, for which the mean concentration was 2.68 mg/L as nitrate + nitrite (Appendix C, Table 1). As noted previously, based on land use and applications of fertilizing agents, nitrate levels may

often be elevated. For instance, the highest concentration of nitrate detected in this dataset was 72.4 mg/L, over 7 times the drinking water standard of 10 mg/L. In fact, 58 wells samples had values above 10 mg/L nitrate, with a mean concentration of nitrate for these 58 wells of 16.81 mg/L. Again, under the construct that water quality that does not attain standards should be restored to the standard, the levels for these 58 wells were reduced to the drinking water standard of 10 mg/L nitrate, and the mean concentration of nitrate for this amended 1,103-well database was 2.32 mg/L (Appendix C, Table 1) .

The AGWQMN dataset was also consulted. The mean concentration for these 150 wells was 3.58 mg/L nitrate (Appendix C, Table 2). Again, particularly in agricultural areas, nitrate levels were observed to be elevated—the 3 highest concentrations recorded in the AGWQMN database for ground water wells are 55.51, 24.20, and 21.75 mg/L nitrate, all from agricultural land uses. Therefore, a second analysis was performed whereby all data points from the agricultural land use category (n = 60, with a mean average for these wells of 6.79 mg/L nitrite and nitrate) were removed from the data set, which resulted in a mean concentration of 1.45 mg/L nitrate for the remaining 90 wells. Of the agricultural data points removed above, however, only a portion of them recorded nitrate concentrations greater than the drinking water standard, so another exercise was performed whereby the values in the full dataset ($n$ =150) that exceeded the standard were reduced to 10 mg/L ($n$ = 16). The result of this last exercise was a mean concentration of 2.88 mg/L nitrate (Appendix C, Table 2).

Lastly, the Department took a final look at agricultural land use within the USGS/*Weedpoint*-refined dataset. Within the 500-meter buffers of each well, the type of land cover was categorized using Anderson (1976) Level 1 land use designations, e.g., Agricultural, Barren, Forest, Water, Wetlands, and Urban. Under the assumption that if the immediate area around the well was equal to or greater than 50% agriculture there would be abnormally high loadings of nitrate, the well was removed from the database ($n$ = 161 wells, with a mean average for these wells of 6.93 mg/L nitrite and nitrate). This screening produced a mean concentration of 1.95 mg/L nitrite and nitrate for the remaining 942 wells. For a further selective comparison looking at land use, the Department also screened this dataset based on pristine conditions, defined as wells where the 500-meter buffer area surrounding each well contained at least 90% of land uses that are Forest, Wetlands, and Water. Only 83 of the 1,103 wells that tested for nitrate fit this criteria, which resulted in a mean concentration of only 0.3 mg/L nitrite and nitrate.

To select the ambient nitrate concentration, the Department evaluated the mean nitrate concentration from literature values and data analyses. In consideration of all of this information, an ambient nitrate concentration of 2 mg/L was selected as the best representation of ambient nitrate that has not been unduly influenced by high nitrate inputs. The preliminary dilution model result using the input load of 10 lbs/person and the target concentration of 2 mg/L is shown in Figure 7.

**Figure 7. Dilution model results using input of 10 lbs/person/year nitrate and target of 2 mg/L.**

| Nitrate | | |
|---|---|---|
| *parameter* | *value* | *units* |
| population density: | **3** | people/home |
| human nitrate loading rate | **10.0** | pounds/person/year |
| target: | **2** | mg/l |
| | | |
| avg. lot size: | **5.6** | acres/home |

Based on the preceding analyses, using nitrate as a surrogate for assessing the impact of all parameters in septic system effluent using a dilution model provides the most protective approach with respect to ground water.

**Other considerations:**

In that surficial ground water makes up base flow in streams, surface water quality data was also consulted. The Ambient Surface Water Quality Monitoring Network monitors surface water quality throughout the State through regular sampling and chemical analysis. As part of this effort, background sites are monitored, at least one per geologic province, as a reference for natural or historical conditions. Table 5 below summarizes nitrate levels in surface waters at these sites for the latest five-year round. There were a minimum of 20 samples for each site, collected seasonally from 1997-2002.

**Table 5. Background Nitrate Levels for Surface Waters observed by NJDEP/USGS Cooperative Network.**

| Location Name | Geologic Province | Maximum Nitrate Level (mg/L) |
|---|---|---|
| Dunnfield Creek at Dunnfield | Valley and Ridge | 0.41 |
| Double Kill at Wawayanda | Highlands | 0.17 |
| Spruce Run at Newport | Highlands | 0.879 |
| Morristown National Historic Park (Primrose Brook) | Highlands/Piedmont | 1.59 |
| Gravelly Run at Laurel Lake | Coastal Plain | 0.23 |
| Lebanon State Forest (McDonald's Branch) | Coastal Plain | 0.1 |

As the preceding table illustrates, documented ambient levels for nitrate concentrations at reference sites are generally below the selected target of 2 mg/L.

Studies relating nitrate to land use were consulted. A positive correlation between nitrate concentrations and other chemicals, primarily pesticides, has been well established for agricultural land uses (Vowinkel, 1993, USGS, 1999). This relationship has also been shown to exist between dissolved solids and nitrate concentrations (Szabo, 1993). Residential lawn care is the second largest user of pesticides, primarily herbicides (NJDEP, 1995). Therefore, it is reasonable to assume that this same positive correlation between intensity of land use and concentration of pollutants also exists for residential land use. Studies have already shown a relationship between volatile organic compounds (VOCs) and, to a lesser extent, pesticides and nitrate concentrations in residential and urban areas as well (Kish, 1986; USGS, 1999). Therefore, due to its stable and soluble nature, the concentration of nitrate in ground water is a reasonable surrogate for concentrations of pesticides, herbicides, paints and thinners, compounds used for health and personal care, cleaning products and other chemicals typically used in homes or applied to residential sites. These contaminants tend to occur at higher concentrations in shallow ground water (MacLeod, 1995). As stated above, shallow ground water makes up much of stream baseflow during periods of dry weather. While the concentrations at which these contaminants presently occur may not always pose a risk to human health, ecological receptors can exhibit a greater sensitivity to some compounds than humans (see New Jersey Surface Water Quality Standards, N.J.A.C. 7:9B; also Efroymson, 1997). For instance, both suspended solids and ammonia have more stringent SWQS criteria for streams classified as trout production and trout maintenance. The relationship between septic density and drinking water vulnerability has also been noted (USGS, 1996). As a result, placing limits on nitrate concentrations will help to protect the quality of ground water with respect to an array of contaminants of concern with respect to water used for drinking.

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# APPENDIX A

**Table 1. Complete USGS/*Weedpoint*-refined dataset of dissolved phosphorus concentrations (*n* = 380) utilized to determine mean background concentrations of 0.034 and 0.026[1] mg/L.**

| USGS Station ID Number | Date Sampled | Dissolved-P (mg/L) |
|---|---|---|
| 394531074435601 | 19780216 | 0.01 |
| 394834074471501 | 19780217 | 0.01 |
| 394431074494101 | 19780223 | 0.01 |
| 394224074471301 | 19780223 | 0.01 |
| 394812074403102 | 19780301 | 0.01 |
| 394050074303701 | 19780302 | 0.01 |
| 393809074334901 | 19780302 | 0.01 |
| 394940074314301 | 19780303 | 0.01 |
| 394208074403101 | 19780308 | 0.01 |
| 394226074394801 | 19780308 | 0.01 |
| 393944074371401 | 19780309 | 0.01 |
| 393945074384801 | 19780309 | 0.01 |
| 394204074492102 | 19780310 | 0.01 |
| 394143074282801 | 19780329 | 0.01 |
| 394312074282101 | 19780329 | 0.01 |
| 394148074481001 | 19780331 | 0.01 |
| 394329074371801 | 19780406 | 0.01 |
| 394300074383002 | 19780407 | 0.01 |
| 394104074344001 | 19780412 | 0.01 |
| 394106074362501 | 19780412 | 0.02 |
| 393832074360802 | 19780414 | 0.01 |
| 394848074365601 | 19780421 | 0.01 |
| 394636074373901 | 19780421 | 0.01 |
| 394406074412701 | 19780425 | 0.01 |
| 394438074483801 | 19780425 | 0.01 |
| 394536074354202 | 19780426 | 0.01 |
| 393748074381701 | 19780427 | 0.01 |
| 394223074415302 | 19780428 | 0.01 |
| 394608074405401 | 19780429 | 0.03 |
| 400051074165701 | 19811123 | 0.01 |
| 400100074163701 | 19811123 | 0.01 |
| 395722074231901 | 19811124 | 0.02 |
| 394511074183001 | 19811202 | 0.01 |
| 400013074174601 | 19811207 | 0.01 |
| **400022074140501** | **19811214** | **0.34** |
| 394551074191801 | 19811215 | 0.01 |
| 394039074155101 | 19811215 | 0.06 |
| 395325074121701 | 19811221 | 0.02 |
| 395332074114801 | 19811221 | 0.02 |

| **400641074211101** | **19811230** | **0.14** |
|---|---|---|
| 400241074131901 | 19820120 | 0.01 |
| 395734074224101 | 19820120 | 0.04 |
| 394629074124201 | 19820121 | 0.01 |
| 395230074125302 | 19820121 | 0.01 |
| 393955074165701 | 19820210 | 0.01 |
| 393653074194501 | 19820216 | 0.01 |
| 394533074224001 | 19820216 | 0.01 |
| 394242074171301 | 19820217 | 0.01 |
| 394153074150501 | 19820222 | 0.01 |
| 395020074114801 | 19820222 | 0.01 |
| 395430074104901 | 19820223 | 0.01 |
| 393534074202001 | 19820303 | 0.01 |
| 393827074183001 | 19820303 | 0.01 |
| 400341074302201 | 19820303 | 0.04 |
| 394744074145101 | 19820308 | 0.01 |
| 400223074173601 | 19820310 | 0.04 |
| 395528074160001 | 19820310 | 0.1 |
| 394600074125601 | 19820317 | 0.03 |
| **394118074143701** | **19820317** | **0.15** |
| **400457074092601** | **19820322** | **0.25** |
| 395459074090701 | 19820324 | 0.01 |
| 395646074211001 | 19820329 | 0.01 |
| 395704074222501 | 19820329 | 0.01 |
| 400330074105201 | 19820330 | 0.01 |
| 395204074115401 | 19820331 | 0.01 |
| 395656074065801 | 19820331 | 0.01 |
| 400138074242801 | 19820413 | 0.01 |
| **400416074270104** | **19820420** | **0.24** |
| 395748074215601 | 19820421 | 0.01 |
| **400549074051601** | **19820421** | **0.34** |
| 395046074114701 | 19820422 | 0.01 |
| 400102074104802 | 19820426 | 0.01 |
| 400044074185901 | 19820427 | 0.01 |
| 400107074182501 | 19820427 | 0.01 |
| **400511074102901** | **19820427** | **0.24** |
| 395654074233701 | 19820428 | 0.01 |
| 395756074083401 | 19820428 | 0.01 |
| 394728074120201 | 19820428 | 0.01 |
| 400710074171401 | 19820428 | 0.03 |
| 400652074044501 | 19820429 | 0.01 |
| 400214074080501 | 19820503 | 0.01 |
| 400352074081301 | 19820503 | 0.01 |
| 400415074053001 | 19820503 | 0.01 |
| 395615074205901 | 19820504 | 0.01 |
| 394134074091801 | 19820504 | 0.04 |
| 400102074085901 | 19820505 | 0.01 |
| 400730074075701 | 19820505 | 0.01 |

| | | |
|---|---|---|
| 394122074151401 | 19820505 | 0.01 |
| 400126074160301 | 19820505 | 0.01 |
| 394205074165701 | 19820506 | 0.01 |
| 394802074104501 | 19820510 | 0.01 |
| 395554074173501 | 19820510 | 0.01 |
| 400416074071801 | 19820510 | 0.01 |
| 394424074140301 | 19820511 | 0.01 |
| 394453074143401 | 19820511 | 0.01 |
| 394615074121601 | 19820511 | 0.04 |
| 395003074113401 | 19820512 | 0.01 |
| 395158074105201 | 19820512 | 0.01 |
| **395550074072301** | **19820512** | **0.22** |
| **400259074071801** | **19820512** | **0.72** |
| 400134074102901 | 19820513 | 0.01 |
| 393608074210002 | 19820517 | 0.01 |
| 395925074224001 | 19820517 | 0.01 |
| 393805074185301 | 19820517 | 0.03 |
| 395326074095601 | 19820518 | 0.01 |
| 400229074144101 | 19820519 | 0.01 |
| 400426074145301 | 19820519 | 0.01 |
| 395021074051801 | 19820520 | 0.01 |
| 400459074153501 | 19820520 | 0.01 |
| 400412074280901 | 19820520 | 0.01 |
| 400413074280501 | 19820520 | 0.01 |
| 400142074063101 | 19820524 | 0.01 |
| 400009074140501 | 19820524 | 0.08 |
| 400622074130701 | 19820525 | 0.01 |
| 400500074034501 | 19820525 | 0.02 |
| 400440074083401 | 19820525 | 0.08 |
| 400113074160101 | 19820526 | 0.01 |
| 400228074275601 | 19820526 | 0.01 |
| 400709074152201 | 19820526 | 0.01 |
| 400557074185901 | 19820526 | 0.01 |
| 400525074080701 | 19820527 | 0.01 |
| 410158074091301 | 19840320 | 0.05 |
| 410046074074701 | 19840328 | 0.01 |
| 410508074133901 | 19840404 | 0.01 |
| 410557074095001 | 19840405 | 0.04 |
| 410013074143301 | 19840410 | 0.01 |
| 410610074085901 | 19840410 | 0.01 |
| 410318074110101 | 19840418 | 0.04 |
| 410414074071401 | 19840419 | 0.01 |
| 405929074130101 | 19840426 | 0.02 |
| 410403074090001 | 19840501 | 0.02 |
| **410328074074401** | **19840501** | **0.11** |
| 410334074113701 | 19840510 | 0.02 |
| 410203074150201 | 19840524 | 0.01 |
| 410337074134401 | 19840525 | 0.01 |

| | | |
|---|---|---|
| 410344074141601 | 19840525 | 0.01 |
| 410101074135001 | 19840606 | 0.01 |
| 410417074093901 | 19840606 | 0.04 |
| 410452074104601 | 19840607 | 0.02 |
| 410313074125901 | 19840611 | 0.01 |
| 410359074122101 | 19840611 | 0.01 |
| 394452074281901 | 19840613 | 0.01 |
| 394949074202901 | 19840614 | 0.01 |
| 405920074123901 | 19840614 | 0.01 |
| 410153074112701 | 19840614 | 0.01 |
| 395107074225501 | 19840614 | 0.01 |
| 405947074141401 | 19840614 | 0.05 |
| 410344074103701 | 19840615 | 0.01 |
| 395122074301702 | 19840619 | 0.01 |
| 410252074090101 | 19840619 | 0.02 |
| 405937074125001 | 19840621 | 0.02 |
| 410052074125401 | 19840627 | 0.01 |
| 405959074135801 | 19840628 | 0.01 |
| 392920074570001 | 19841115 | 0.01 |
| 402109074301301 | 19841204 | 0.01 |
| 403726074162401 | 19850702 | 0.09 |
| 405607074343205 | 19850821 | 0.01 |
| 405229074211101 | 19851125 | 0.01 |
| 405412074302801 | 19851125 | 0.01 |
| 405317074340402 | 19851126 | 0.01 |
| 405357074291501 | 19851126 | 0.03 |
| 405412074352601 | 19851126 | 0.03 |
| 405458074252801 | 19851126 | 0.05 |
| 405309074322901 | 19851126 | 0.06 |
| 405243074314801 | 19851126 | 0.07 |
| 405413074274101 | 19851126 | 0.07 |
| 405558074283901 | 19851127 | 0.01 |
| 405712074245701 | 19851127 | 0.01 |
| 405451074264101 | 19851127 | 0.02 |
| 405414074310901 | 19851127 | 0.03 |
| 410207074310401 | 19851127 | 0.06 |
| 405344074273901 | 19851204 | 0.07 |
| 404921074334901 | 19860107 | 0.02 |
| 405335074265001 | 19860107 | 0.02 |
| 405308074310601 | 19860114 | 0.1 |
| 405542074261701 | 19860117 | 0.03 |
| 405900074322501 | 19860127 | 0.03 |
| 403637074390701 | 19860127 | 0.1 |
| 405549074354901 | 19860219 | 0.04 |
| 403231074161601 | 19860529 | 0.02 |
| **392508075184601** | **19860729** | **1** |
| 402015074275701 | 19860807 | 0.01 |
| 394440074593101 | 19860822 | 0.01 |

| | | |
|---|---|---|
| 404749074252401 | 19860917 | 0.07 |
| **401105074120202** | **19871015** | **0.3** |
| 402207074434201 | 19880328 | 0.02 |
| 402128074494501 | 19880330 | 0.01 |
| 402446074490801 | 19880331 | 0.07 |
| 402556074443001 | 19880404 | 0.04 |
| 402430074464001 | 19880404 | 0.05 |
| 401819074502801 | 19880421 | 0.03 |
| 402123074452101 | 19880421 | 0.04 |
| 402215074413801 | 19880422 | 0.01 |
| 402023074450801 | 19880422 | 0.03 |
| 402351074505601 | 19880425 | 0.05 |
| **401951074401101** | **19880429** | **0.11** |
| 401910074500101 | 19880503 | 0.04 |
| 402208074505001 | 19880506 | 0.04 |
| 405047074101501 | 19880819 | 0.06 |
| 394232075012601 | 19880907 | 0.01 |
| 394021075082701 | 19880908 | 0.01 |
| 393428075024401 | 19880909 | 0.01 |
| 393448074560601 | 19880909 | 0.01 |
| 393828074565501 | 19880915 | 0.01 |
| 393634075041501 | 19880915 | 0.01 |
| 393917075014901 | 19880919 | 0.01 |
| 393934075103301 | 19880919 | 0.01 |
| 393322074595001 | 19880920 | 0.01 |
| 393633075063001 | 19880920 | 0.01 |
| 394025075054801 | 19880922 | 0.01 |
| 393411075002201 | 19880926 | 0.01 |
| 393708075014301 | 19880927 | 0.01 |
| 394020074561102 | 19880928 | 0.01 |
| 394114074590801 | 19880929 | 0.01 |
| 394246075015101 | 19880930 | 0.01 |
| 404915074474201 | 19881116 | 0.01 |
| 404900074462501 | 19881117 | 0.02 |
| 404244074515001 | 19881122 | 0.02 |
| 404835074465801 | 19881130 | 0.03 |
| 405348074441501 | 19890405 | 0.02 |
| 405140074422801 | 19890412 | 0.01 |
| 405020074380701 | 19890515 | 0.03 |
| 404621074352201 | 19890606 | 0.02 |
| 405140074431301 | 19890627 | 0.02 |
| 405520074345801 | 19890803 | 0.01 |
| 410545074224801 | 19890825 | 0.01 |
| 405909074351101 | 19890828 | 0.01 |
| 404204074531901 | 19890919 | 0.01 |
| 405236074404301 | 19890920 | 0.01 |
| 410639074233201 | 19890926 | 0.01 |
| 405258074410401 | 19890927 | 0.01 |

| | | |
|---|---|---|
| 405627074340701 | 19900516 | 0.02 |
| 403940074594001 | 19900827 | 0.02 |
| 404553074330001 | 19900904 | 0.04 |
| 404633074374001 | 19900905 | 0.01 |
| 404113074555301 | 19900906 | 0.01 |
| 410527074155301 | 19900911 | 0.02 |
| 411020074192701 | 19900912 | 0.01 |
| 411127074294001 | 19900912 | 0.01 |
| 404941074300601 | 19900912 | 0.02 |
| 404233074544701 | 19900914 | 0.01 |
| 405913074275301 | 19900918 | 0.02 |
| 411033074330001 | 19900919 | 0.02 |
| 404153074531301 | 19900925 | 0.03 |
| 404727074330001 | 19900926 | 0.01 |
| 404753074314001 | 19900927 | 0.07 |
| 405230074492501 | 19900928 | 0.01 |
| 404934074400501 | 19900928 | 0.04 |
| 410347074484301 | 19910424 | 0.01 |
| 405047074392901 | 19910507 | 0.01 |
| 410005074473801 | 19910509 | 0.01 |
| 410449074483301 | 19910515 | 0.01 |
| 410713074393701 | 19910909 | 0.02 |
| 411202074374001 | 19910910 | 0.01 |
| 403923074543301 | 19910911 | 0.02 |
| 410914074540401 | 19910918 | 0.01 |
| 404507074571801 | 19910930 | 0.04 |
| 401800074354901 | 19930908 | 0.02 |
| 405813074164502 | 19930921 | 0.01 |
| 405345074160102 | 19931201 | 0.01 |
| 402123074460501 | 19940831 | 0.01 |
| 393134074335202 | 19960730 | 0.01 |
| 394736074564201 | 19960918 | 0.01 |
| 394258075061101 | 19961015 | 0.02 |
| 394127075045601 | 19961022 | 0.01 |
| 394549075051401 | 19961028 | 0.01 |
| 394504075051001 | 19961104 | 0.03 |
| 395007074562501 | 19961119 | 0.01 |
| 394351075080101 | 19961120 | 0.01 |
| 394211075063701 | 19961121 | 0.01 |
| 393437075043001 | 19961209 | 0.01 |
| 393858075022501 | 19961209 | 0.01 |
| 394243075034401 | 19961210 | 0.01 |
| 394415075065601 | 19961212 | 0.01 |
| 394329074581201 | 19961217 | 0.01 |
| 392928075015901 | 19961218 | 0.01 |
| 392918075003301 | 19961218 | 0.04 |
| 394710075004001 | 19961219 | 0.01 |
| 393243075040601 | 19961222 | 0.02 |

| | | |
|---|---|---|
| 394447074580301 | 19970730 | 0.01 |
| 394052074582701 | 19970805 | 0.01 |
| 394657074554502 | 19971020 | 0.01 |
| 394501075020601 | 19971106 | 0.01 |
| 394137075000501 | 19971118 | 0.01 |
| 394820074570301 | 19971119 | 0.01 |
| 394321075015701 | 19980227 | 0.01 |
| 394225074580701 | 19980304 | 0.01 |
| 394538074581601 | 19980305 | 0.01 |
| 394058074592501 | 19980309 | 0.01 |
| 394639074590102 | 19980309 | 0.01 |
| 394253074550201 | 19980309 | 0.01 |
| 394358075012002 | 19980311 | 0.01 |
| 394523075060501 | 19980528 | 0.01 |
| 393903075055301 | 19980602 | 0.01 |
| 394710075144401 | 19980604 | 0.01 |
| 394034074482001 | 19980714 | 0.01 |
| 394918074442801 | 19980715 | 0.01 |
| 400326074115201 | 19980715 | 0.01 |
| 394415074174301 | 19980716 | 0.01 |
| **390805074500001** | **19980720** | **0.23** |
| 393117074484101 | 19980721 | 0.01 |
| 392824074272801 | 19980722 | 0.01 |
| 405708074450501 | 19980723 | 0.01 |
| 393053074344201 | 19980728 | 0.01 |
| 393328075121201 | 19980728 | 0.05 |
| 392028075020501 | 19980803 | 0.01 |
| 392813074321001 | 19980825 | 0.01 |
| 391953075115701 | 19980825 | 0.03 |
| 392533075151801 | 19980827 | 0.01 |
| 392434074483001 | 19980902 | 0.05 |
| 393807075030401 | 19980903 | 0.01 |
| 394113074164401 | 19980909 | 0.01 |
| 393035074533601 | 19980922 | 0.01 |
| 392335074410801 | 19980923 | 0.01 |
| 400122074113801 | 19980923 | 0.01 |
| 393823075071601 | 19981014 | 0.05 |
| 394416074544901 | 19981104 | 0.05 |
| 405715074441801 | 19981105 | 0.05 |
| 394351074321501 | 19981112 | 0.05 |
| 393300075011301 | 19981120 | 0.05 |
| 405647074453401 | 19981208 | 0.05 |
| 393001075130801 | 19981209 | 0.05 |
| 393302075041501 | 19981210 | 0.05 |
| 405722074442101 | 19981215 | 0.05 |
| 394329075053601 | 19990125 | 0.007 |
| 393643074543601 | 19990126 | 0.004 |
| 393941074574501 | 19990126 | 0.004 |

| | | |
|---|---|---|
| 405656074413701 | 19990817 | 0.05 |
| 401734074470301 | 19991012 | 0.012 |
| 405702074585201 | 20000517 | 0.004 |
| 411401074452901 | 20000605 | 0.012 |
| 411117074480401 | 20000606 | 0.013 |
| 410422074575101 | 20000607 | 0.019 |
| 411930074431401 | 20000719 | 0.008 |
| 403319074542801 | 20000821 | 0.05 |
| 403338074503101 | 20000822 | 0.07 |
| 402622074583901 | 20000822 | 0.08 |
| 394604075003601 | 20000824 | 0.006 |
| 394233074574401 | 20000824 | 0.006 |
| 392558075051901 | 20000825 | 0.035 |
| 403314074592301 | 20000831 | 0.05 |
| 411108074351901 | 20000908 | 0.05 |
| 401940074430801 | 20000914 | 0.05 |
| 402601074424601 | 20000914 | 0.05 |
| 394342075040301 | 20001107 | 0.006 |
| 402358074510301 | 20010601 | 0.06 |
| 402708074471401 | 20010607 | 0.04 |
| 410633074364601 | 20010614 | 0.06 |
| 411255074295101 | 20010614 | 0.06 |
| 403224074340601 | 20010621 | 0.06 |
| 402741074302801 | 20010621 | 0.07 |
| 404159075093401 | 20010712 | 0.06 |
| 405459074451201 | 20010717 | 0.035 |
| 393517074553901 | 20010802 | 0.06 |
| 393458075002701 | 20010802 | 0.06 |
| 393734075252901 | 20010803 | 0.03 |
| 394243074493201 | 20010807 | 0.06 |
| 392826074555801 | 20010807 | 0.06 |
| 393945074470301 | 20010808 | 0.06 |
| 402149074561001 | 20010814 | 0.06 |
| 405122074042201 | 20010823 | 0.06 |
| 402310074312301 | 20010824 | 0.06 |
| 404717074340201 | 20010828 | 0.06 |
| 402829074545601 | 20010828 | 0.06 |
| 394453075235101 | 20010830 | 0.06 |
| 410242074103501 | 20010905 | 0.06 |
| 404844074065101 | 20010906 | 0.06 |
| 401558074335102 | 20010911 | 0.06 |
| 402643074342601 | 20011002 | 0.04 |
| 405444074363601 | 20011016 | 0.06 |
| 401823074474301 | 20011023 | 0.06 |
| 401658074505001 | 20011206 | 0.03 |
| 400014074081601 | 20011206 | 0.06 |
| 402043074491201 | 20011210 | 0.07 |
| 405139074402701 | 20011217 | 0.06 |

| | | |
|---|---|---|
| 394838074533601 | 20011219 | 0.06 |
| 393856074493701 | 20011219 | 0.06 |
| 385950074554501 | 20011227 | 0.06 |
| 392719074292201 | 20020319 | 0.06 |
| 410159074102201 | 20020321 | 0.06 |

[1] Bolded entries denote those values ($n$=14) that exceed the SWQS of 0.1 mg/L for phosphorus, and which were then reduced to 0.1 mg/L for the 2nd averaging.

**APPENDIX A: Table 2. Complete AGWQMN dataset of ortho-phosphorus concentrations ($n$ = 150) utilized to determine mean background concentrations of 0.028 and 0.021[1] mg/L.**

| Geologic Province | USGS Station ID # | Sampling Date | Ortho-P (mg/L) |
|---|---|---|---|
| Valley and Ridge | 410053074441301 | 20010917 | 0.02 |
| | 405631074475001 | 20010917 | 0.02 |
| | 410049075045801 | 20010919 | 0.01 |
| | 404900075043601 | 20040623 | 0.02 |
| | 410033074544701 | 20030624 | 0.02 |
| | 410213074460901 | 20010918 | 0.02 |
| | 411853074403601 | 20010926 | 0.02 |
| | 404937074580501 | 20030625 | 0.02 |
| | 410433074394001 | 20021118 | 0.02 |
| Highlands | 410214074204501 | 20021120 | 0.02 |
| | 403719075091801 | 20010924 | 0.02 |
| | 405537074361401 | 20030911 | 0.02 |
| | 405220074482201 | 20010925 | 0.02 |
| | 405035074502201 | 20010927 | 0.02 |
| | 404828074403501 | 20030708 | 0.02 |
| | 405154074585701 | 20010924 | 0.02 |
| | 403951075075301 | 20021216 | 0.02 |
| | 404324075041801 | 20021204 | 0.02 |
| | 411348074273901 | 20010924 | 0.02 |
| | 403921074515901 | 20030624 | 0.03 |
| | 405827074360801 | 20040331 | 0.02 |
| | 404146075112101 | 20030626 | 0.02 |
| | 404936074423101 | 20021022 | 0.01 |
| | 410610074344801 | 20040617 | 0.02 |
| | 405309074315301 | 20021113 | 0.02 |
| Piedmont | 401619074462401 | 20010920 | 0.02 |
| | 401942074510101 | 20020523 | 0.01 |
| | 402018074540301 | 20010906 | 0.02 |
| | 402431075020801 | 20010919 | 0.02 |
| | 404944074232401 | 20021029 | 0.04 |
| | 401829074513301 | 20040617 | 0.01 |
| | 403121075003901 | 20030625 | 0.02 |

| | | | |
|---|---|---|---|
| | 402633074541301 | 20030910 | 0.06 |
| | 403347074575101 | 20030709 | 0.02 |
| | 402501074505001 | 20030701 | 0.03 |
| | 403100074464101 | 20030626 | 0.03 |
| | 402512074414301 | 20030115 | 0.06 |
| | 403200074420601 | 20021104 | 0.05 |
| | 402820074341501 | 20031014 | 0.02 |
| | **403129075034701** | **20030625** | **0.19** |
| | 402310074453801 | 20030116 | 0.02 |
| | 402051074400001 | 20040616 | 0.02 |
| | 403537074394401 | 20030630 | 0.01 |
| | 404704074281301 | 20040330 | 0.02 |
| | 402907074255801 | 20030616 | 0.02 |
| | 403451074294801 | 20030320 | 0.04 |
| | **403617074265601** | **20030114** | **0.32** |
| | 404303074173101 | 20040318 | 0.02 |
| | 403422074192001 | 20021022 | 0.02 |
| | 403946074193901 | 20021112 | 0.02 |
| | 405739074164201 | 20040324 | 0.02 |
| | 405128074231401 | 20031009 | 0.02 |
| | 404055074132901 | 20040311 | 0.06 |
| | **404332074104201** | **20030909** | **0.18** |
| | 405148074133601 | 20040427 | 0.02 |
| | 405632074131801 | 20040325 | 0.02 |
| | 404339074045401 | 20040504 | 0.02 |
| | 404844074082501 | 20040428 | 0.02 |
| | 405435074080201 | 20040317 | 0.01 |
| | 410218074065001 | 20040309 | 0.01 |
| | 404636074024701 | 20040623 | 0.02 |
| | 405050074011401 | 20040622 | 0.02 |
| | 405543074040901 | 20040323 | 0.02 |
| | 405909073574101 | 20040310 | 0.02 |
| **Coastal Plain** | **400954074302001** | **20000928** | **0.104** |
| | 395815074442101 | 19990831 | 0.01 |
| | 395928074502701 | 19990819 | 0.01 |
| | 400533074405101 | 19990929 | 0.01 |
| | 400525074314101 | 19990915 | 0.01 |
| | 400202074461301 | 19990902 | 0.01 |
| | 395836074542701 | 19990819 | 0.01 |
| | 395855074470701 | 20000913 | 0.02 |
| | 395643074295201 | 19990901 | 0.03 |
| | 395814075002201 | 20000925 | 0.02 |
| | 395806074540501 | 20000914 | 0.01 |
| | 395638074432501 | 19990907 | 0.01 |
| | 395532074504701 | 19990921 | 0.04 |
| | 395358075053701 | 20000911 | 0.01 |
| | 395341074345101 | 20000919 | 0.01 |

| | | |
|---|---|---|
| 395448074370701 | 19990922 | 0.01 |
| 395143075044101 | 20000816 | 0.01 |
| **394647074592701** | **19990908** | **0.18** |
| 394446075031001 | 19990920 | 0.03 |
| 394849075184501 | 20000816 | 0.01 |
| 394245075151001 | 20000822 | 0.01 |
| 394108075250401 | 20000815 | 0.01 |
| 394342075040301 | 19990908 | 0.01 |
| 394014075060001 | 20000822 | 0.01 |
| 394256075101001 | 19990922 | 0.01 |
| 394024075234701 | 19990909 | 0.01 |
| 392558075051901 | 19990920 | 0.04 |
| 393818075132401 | 19990923 | 0.01 |
| 393738075221401 | 19990908 | 0.01 |
| 393532075101201 | 19990927 | 0.01 |
| 393610075250001 | 19990928 | 0.03 |
| 393712075121201 | 19990914 | 0.01 |
| 393313075254101 | 19990923 | 0.01 |
| 393413075141901 | 19990927 | 0.01 |
| 393301074591601 | 19990914 | 0.01 |
| 393104075122201 | 19990915 | 0.01 |
| 392715075173101 | 19990913 | 0.01 |
| 391357074575501 | 19990923 | 0.01 |
| 392820075122601 | 19990928 | 0.01 |
| 392920075011901 | 19990913 | 0.01 |
| 392753075204701 | 20000920 | 0.02 |
| 392435075072801 | 19990920 | 0.01 |
| 391854075065501 | 20000810 | 0.01 |
| 391145074520401 | 20000928 | 0.01 |
| 391844074451501 | 20000809 | 0.01 |
| 391611074383801 | 20000815 | 0.01 |
| 392123074534801 | 20000920 | 0.01 |
| 394018074324701 | 20000912 | 0.01 |
| 392328074315401 | 20000914 | 0.01 |
| 393744074244101 | 20000913 | 0.01 |
| 394123074435101 | 20000927 | 0.01 |
| 393531074523901 | 20000802 | 0.01 |
| 393940074534201 | 20000801 | 0.01 |
| 393947074464501 | 20010726 | 0.02 |
| 393129074383201 | 20000918 | 0.01 |
| 394642074375401 | 20000809 | 0.01 |
| 394117074214001 | 20000801 | 0.01 |
| 394640074323201 | 20010731 | 0.02 |
| 393415074563601 | 20000808 | 0.01 |
| 395417074143401 | 20000803 | 0.01 |
| 395034074112101 | 20010801 | 0.02 |
| 395900074242801 | 20000731 | 0.01 |
| 400204074145401 | 20010806 | 0.02 |

| | | |
|---|---|---|
| 400346074081701 | 20010802 | 0.02 |
| 400529074260601 | 20000802 | 0.01 |
| 400052074191201 | 20010802 | 0.02 |
| 401021074030601 | 20010730 | 0.02 |
| 401335074042701 | 20010731 | 0.02 |
| 401531074172801 | 20010822 | 0.02 |
| 402412074073001 | 20010906 | 0.02 |
| 401732074022101 | 20010807 | 0.01 |
| 401229074290001 | 20010808 | 0.01 |
| 401233074320401 | 20010906 | 0.01 |
| 401809074371701 | 20010807 | 0.02 |
| 402323074280901 | 20010926 | 0.02 |
| 402623074154701 | 20010925 | 0.02 |
| 401508074193501 | 20010926 | 0.02 |
| 400634074403401 | 20030326 | 0.02 |
| 401454074371401 | 20030904 | 0.02 |
| 401916074324201 | 20030911 | 0.02 |
| **401917074183801** | **20040316** | **0.57** |
| 401606074183501 | 20020926 | 0.06 |
| 400811074414101 | 20020926 | 0.02 |
| 402046074261901 | 20030624 | 0.02 |
| 402403074210201 | 20021028 | 0.02 |
| 402831074171901 | 20021022 | 0.02 |

[1] Bolded entries denote those values ($n$=6) that exceed the SWQS of 0.1 mg/L for phosphorus, and which were then reduced to 0.1 mg/L for the 2nd averaging.

# APPENDIX B

**Complete AGWQMN dataset of TDS concentrations (*n* = 148) utilized to determine a range of mean background concentrations of 193 - 528 mg/L.**

| Geologic Province | USGS Station ID # | Sampling Date | TDS (mg/L) |
|---|---|---|---|
| Valley and Ridge | 410053074441301 | 20010917 | 387 |
| | 405631074475001 | 20010917 | 229 |
| $\bar{x}$ = 323 | 410049075045801 | 20010919 | 128 |
| | 404900075043601 | 20040623 | 727 |
| | 410033074544701 | 20030624 | 331 |
| | 410213074460901 | 20010918 | 213 |
| | 411853074403601 | 20010926 | 22 |
| | 404937074580501 | 20030625 | 225 |
| | 410433074394001 | 20021118 | 645 |
| Highlands | 410214074204501 | 20021120 | 126 |
| | 403719075091801 | 20010924 | 194 |
| $\bar{x}$ = 441 | 405537074361401 | 20030911 | 100 |
| | 405220074482201 | 20010925 | 242 |
| | 405035074502201 | 20010927 | 272 |
| | 404828074403501 | 20030708 | 41 |
| | 405154074585701 | 20010924 | 118 |
| | 403951075075301 | 20021216 | 938 |
| | 404324075041801 | 20021204 | 301 |
| | 411348074273901 | 20010924 | 394 |
| | 403921074515901 | 20030624 | 269 |
| | 405827074360801 | 20040331 | 1950 |
| | 404146075112101 | 20030626 | 245 |
| | 404936074423101 | 20021022 | 426 |
| | 410610074344801 | 20040617 | 624 |
| | 405309074315301 | 20021113 | 820 |
| Piedmont | 401619074462401 | 20010920 | 208 |
| | 401942074510101 | 20020523 | 307 |
| $\bar{x}$ = 528 | 402018074540301 | 20010906 | 188 |
| | 402431075020801 | 20010919 | 117 |
| | 404944074232401 | 20021029 | 368 |
| | 401829074513301 | 20040617 | 119 |
| | 403121075003901 | 20030625 | 250 |
| | 402633074541301 | 20030910 | 172 |
| | 403347074575101 | 20030709 | 167 |
| | 402501074505001 | 20030701 | 285 |
| | 403100074464101 | 20030626 | 290 |
| | 402512074414301 | 20030115 | 222 |
| | 403200074420601 | 20021104 | 200 |
| | 402820074341501 | 20031014 | 293 |

| | | |
|---|---|---|
| 403129075034701 | 20030625 | 266 |
| 402310074453801 | 20030116 | 302 |
| 402051074400001 | 20040616 | 291 |
| 403537074394401 | 20030630 | 800 |
| 404704074281301 | 20040330 | 2060 |
| 402907074255801 | 20030616 | 415 |
| 403451074294801 | 20030320 | 238 |
| 403617074265601 | 20030114 | 455 |
| 404303074173101 | 20040318 | 735 |
| 403422074192001 | 20021022 | 237 |
| 403946074193901 | 20021112 | 225 |
| 405739074164201 | 20040324 | 800 |
| 405128074231401 | 20031009 | 795 |
| 404055074132901 | 20040311 | 306 |
| 404332074104201 | 20030909 | 1170 |
| 405148074133601 | 20040427 | 854 |
| 405632074131801 | 20040325 | 232 |
| 404339074045401 | 20040504 | 776 |
| 404844074082501 | 20040428 | 476 |
| 405435074080201 | 20040317 | 637 |
| 410218074065001 | 20040309 | 640 |
| 404636074024701 | 20040623 | 1310 |
| 405050074011401 | 20040622 | 779 |
| 405543074040901 | 20040323 | 2200 |
| 405909073574101 | 20040310 | 405 |

| | | | |
|---|---|---|---|
| Coastal Plain | 400954074302001 | 20000928 | 284 |
| | 395815074442101 | 19990831 | 72 |
| $\bar{x}$ = 193 | 395928074502701 | 19990819 | |
| | 400533074405101 | 19990929 | 682 |
| | 400525074314101 | 19990915 | 181 |
| | 400202074461301 | 19990902 | 105 |
| | 395836074542701 | 19990819 | 325 |
| | 395855074470701 | 20000913 | 296 |
| | 395643074295201 | 19990901 | 59 |
| | 395814075002201 | 20000925 | 361 |
| | 395806074540501 | 20000914 | 102 |
| | 395638074432501 | 19990907 | 162 |
| | 395532074504701 | 19990921 | 260 |
| | 395358075053701 | 20000911 | 455 |
| | 395341074345101 | 20000919 | 35 |
| | 395448074370701 | 19990922 | 19 |
| | 395143075044101 | 20000816 | 274 |
| | 394647074592701 | 19990908 | 139 |
| | 394446075031001 | 19990920 | 90 |
| | 394849075184501 | 20000816 | 279 |
| | 394245075151001 | 20000822 | 166 |
| | 394108075250401 | 20000815 | 140 |

| | | |
|---|---|---|
| 394342075040301 | 19990908 | 78 |
| 394014075060001 | 20000822 | 148 |
| 394256075101001 | 19990922 | 103 |
| 394024075234701 | 19990909 | 214 |
| 392558075051901 | 19990920 | 32 |
| 393818075132401 | 19990923 | 169 |
| 393738075221401 | 19990908 | 690 |
| 393532075101201 | 19990927 | 181 |
| 393610075250001 | 19990928 | 156 |
| 393712075121201 | 19990914 | 319 |
| 393313075254101 | 19990923 | 244 |
| 393413075141901 | 19990927 | 372 |
| 393301074591601 | 19990914 | 221 |
| 393104075122201 | 19990915 | 96 |
| 392715075173101 | 19990913 | 492 |
| 391357074575501 | 19990923 | 246 |
| 392820075122601 | 19990928 | 194 |
| 392920075011901 | 19990913 | 132 |
| 392753075204701 | 20000920 | 323 |
| 392435075072801 | 19990920 | 134 |
| 391854075065501 | 20000810 | 27 |
| 391145074520401 | 20000928 | 24 |
| 391844074451501 | 20000809 | 56 |
| 391611074383801 | 20000815 | 57 |
| 392123074534801 | 20000920 | 15 |
| 394018074324701 | 20000912 | 18 |
| 392328074315401 | 20000914 | 348 |
| 393744074244101 | 20000913 | 21 |
| 394123074435101 | 20000927 | 38 |
| 393531074523901 | 20000802 | 134 |
| 393940074534201 | 20000801 | 24 |
| 393947074464501 | 20010726 | 140 |
| 393129074383201 | 20000918 | 59 |
| 394642074375401 | 20000809 | 22 |
| 394117074214001 | 20000801 | 29 |
| 394640074323201 | 20010731 | 35 |
| 393415074563601 | 20000808 | 397 |
| 395417074143401 | 20000803 | 68 |
| 395034074112101 | 20010801 | 80 |
| 395900074242801 | 20000731 | 82 |
| 400204074145401 | 20010806 | 285 |
| 400346074081701 | 20010802 | 816 |
| 400529074260601 | 20000802 | 21 |
| 400052074191201 | 20010802 | |
| 401021074030601 | 20010730 | 163 |
| 401335074042701 | 20010731 | 161 |
| 401531074172801 | 20010822 | 245 |
| 402412074073001 | 20010906 | 205 |

| | | |
|---|---|---|
| 401732074022101 | 20010807 | 133 |
| 401229074290001 | 20010808 | 87 |
| 401233074320401 | 20010906 | 113 |
| 401809074371701 | 20010807 | 124 |
| 402323074280901 | 20010926 | 170 |
| 402623074154701 | 20010925 | 152 |
| 401508074193501 | 20010926 | 550 |
| 400634074403401 | 20030326 | 430 |
| 401454074371401 | 20030904 | 651 |
| 401916074324201 | 20030911 | 310 |
| 401917074183801 | 20040316 | 81 |
| 401606074183501 | 20020926 | 222 |
| 400811074414101 | 20020926 | 118 |
| 402046074261901 | 20030624 | 56 |
| 402403074210201 | 20021028 | 322 |
| 402831074171901 | 20021022 | 132 |

# APPENDIX C

**Table 1. Complete USGS/*Weedpoint*-refined dataset of nitrate concentrations (*n* = 1,103) utilized to determine mean background concentrations of 2.68 and 2.32[1] mg/L.**

| USGS Station ID Number | Date Sampled | NO3 + NO2-N (mg/L) |
|---|---|---|
| 394531074435601 | 19780216 | 0.02 |
| 394834074471501 | 19780217 | 0.01 |
| 394224074471301 | 19780223 | 0.02 |
| 394431074494101 | 19780223 | 0.27 |
| 394812074403102 | 19780301 | 0.28 |
| 394050074303701 | 19780302 | 0.01 |
| 393809074334901 | 19780302 | 0.03 |
| 394940074314301 | 19780303 | 0.01 |
| 394208074403101 | 19780308 | 0.01 |
| 394226074394801 | 19780308 | 0.02 |
| 393944074371401 | 19780309 | 0.01 |
| 393945074384801 | 19780309 | 0.10 |
| 394204074492102 | 19780310 | 0.02 |
| 394312074282101 | 19780329 | 0.01 |
| 394143074282801 | 19780329 | 0.04 |
| 394148074481001 | 19780331 | 0.01 |
| 394329074371801 | 19780406 | 0.02 |
| 394300074383002 | 19780407 | 0.02 |
| 394104074344001 | 19780412 | 0.01 |
| 394106074362501 | 19780412 | 0.44 |
| 393832074360802 | 19780414 | 0.01 |
| 394636074373901 | 19780421 | 0.02 |
| 394848074365601 | 19780421 | 0.03 |
| 394406074412701 | 19780425 | 0.02 |
| 394438074483801 | 19780425 | 0.06 |
| 394536074354202 | 19780426 | 0.01 |
| 393748074381701 | 19780427 | 0.01 |
| 394223074415302 | 19780428 | 0.10 |
| 394608074405401 | 19780429 | 0.01 |
| 401048074403601 | 19800604 | 0.02 |
| 400909074422801 | 19800605 | 0.00 |
| 400934074401901 | 19800605 | 0.00 |
| 400606074473401 | 19800606 | 0.00 |
| 400641074461301 | 19800606 | 0.00 |
| 400540074484701 | 19800606 | 5.00 |
| 400447074482001 | 19800611 | 0.01 |
| 400326074493501 | 19800612 | 0.01 |
| 400158074571001 | 19800617 | 6.10 |
| 400324074515201 | 19800619 | 0.02 |
| 400333074550501 | 19800619 | 5.90 |

| | | |
|---|---|---|
| 400612074485301 | 19800626 | 1.70 |
| 400105074573402 | 19800630 | 6.20 |
| 395713075051301 | 19800701 | 1.20 |
| 395608075042601 | 19800701 | 4.80 |
| 395258075064101 | 19800707 | 0.06 |
| 395752075041102 | 19800710 | 0.05 |
| 395652075030702 | 19800710 | 3.10 |
| 400355074480901 | 19800717 | 0.01 |
| 395857075034401 | 19800728 | 0.00 |
| 395715075051901 | 19800821 | 5.40 |
| 395358075044701 | 19800822 | 0.01 |
| 395806075004601 | 19800825 | 2.60 |
| 395107075094601 | 19800826 | 0.00 |
| 400241074554601 | 19800829 | 0.01 |
| 400213074551301 | 19800829 | 2.80 |
| 395216075073901 | 19800902 | 0.00 |
| 395743075044801 | 19800905 | 0.01 |
| **395027075181001** | **19800912** | **16.00** |
| 395044075124201 | 19800918 | 0.04 |
| 395020075134001 | 19800925 | 0.00 |
| 394648075231801 | 19801001 | 2.90 |
| 393750075313101 | 19801002 | 0.09 |
| 394542075251001 | 19801003 | 0.02 |
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| 400352074081301 | 19820503 | 1.50 |
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| 400415074053001 | 19820503 | 6.10 |
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| 395107074225501 | 19840614 | 0.65 |
| 410153074112701 | 19840614 | 0.73 |
| 405920074123901 | 19840614 | 2.60 |
| 405947074141401 | 19840614 | 3.10 |
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| 405937074125001 | 19840621 | 1.70 |
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| 405959074135801 | 19840628 | 2.90 |
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| 401339074430701 | 19850311 | 3.80 |
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| 401354074411401 | 19850312 | 5.30 |
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| 401455074410001 | 19850314 | 3.00 |
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| 402248074295501 | 19850418 | 1.20 |
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| 402127074221401 | 19850718 | 0.10 |
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| 393025074381601 | 19850904 | 8.00 |
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| 392350074495601 | 19851003 | 0.16 |
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| 392731074533601 | 19851016 | 0.21 |
| 392911074563901 | 19851018 | 5.10 |
| 392653074275501 | 19851024 | 0.22 |
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| 392841074322501 | 19851031 | 1.60 |
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| 392613074420302 | 19851120 | 0.51 |
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| 405542074261701 | 19860117 | 0.10 |
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| 394207075264501 | 19860717 | 5.50 |
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| 402802074202201 | 19870505 | 0.10 |
| **393319075081301** | **19870629** | **15.00** |
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| 401819074502801 | 19880421 | 3.60 |
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| 403130074450301 | 19880701 | 2.10 |
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| 403356075013901 | 19980817 | 0.47 |
| 392813074321001 | 19980825 | 0.05 |
| 391953075115701 | 19980825 | 0.05 |
| 400009074114901 | 19980826 | 3.23 |
| 392533075151801 | 19980827 | 4.97 |
| 400112074123201 | 19980901 | 3.01 |
| 392434074483001 | 19980902 | 0.08 |
| 393807075030401 | 19980903 | 2.97 |
| 394113074164401 | 19980909 | 0.14 |
| 393035074533601 | 19980922 | 0.09 |
| 392335074410801 | 19980923 | 0.07 |
| 400122074113801 | 19980923 | 1.77 |
| 393823075071601 | 19981014 | 1.34 |
| 394416074544901 | 19981104 | 0.44 |
| 405715074441801 | 19981105 | 3.99 |
| 394351074321501 | 19981112 | 0.08 |
| 393300075011301 | 19981120 | 4.96 |
| 405647074453401 | 19981208 | 0.41 |
| 393001075130801 | 19981209 | 5.94 |
| 393302075041501 | 19981210 | 5.32 |
| 405722074442101 | 19981215 | 0.17 |
| 394329075053601 | 19990125 | 0.85 |
| 393941074574501 | 19990126 | 0.07 |
| 393643074543601 | 19990126 | 7.12 |
| 394218075002701 | 19990527 | 0.75 |
| 400339074122201 | 19990809 | 1.11 |
| 405656074413701 | 19990817 | 1.49 |
| 404527074583701 | 19990824 | 3.63 |
| 404721074355401 | 19990831 | 1.61 |

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|---|---|---|
| 403557074275503 | 19991007 | 2.95 |
| 401734074470301 | 19991012 | 0.12 |
| 394257075004901 | 19991115 | 2.11 |
| 394226075001701 | 19991118 | 2.00 |
| 405702074585201 | 20000517 | 7.20 |
| 411401074452901 | 20000605 | 0.05 |
| 394755075210802 | 20000605 | 3.99 |
| 411117074480401 | 20000606 | 0.05 |
| 410422074575101 | 20000607 | 0.05 |
| 411930074431401 | 20000719 | 0.46 |
| 404432074210501 | 20000725 | 0.33 |
| 395900074242801 | 20000731 | 0.05 |
| 392001074352201 | 20000731 | 1.62 |
| 392119074342401 | 20000731 | 3.51 |
| 393940074534201 | 20000801 | 0.05 |
| 394117074214001 | 20000801 | 0.75 |
| 400529074260601 | 20000802 | 0.05 |
| 392306074352001 | 20000802 | 1.23 |
| **393531074523901** | **20000802** | **14.40** |
| 395417074143401 | 20000803 | 0.05 |
| 392854074342901 | 20000808 | 0.60 |
| 392530074371501 | 20000808 | 1.10 |
| **393415074563601** | **20000808** | **55.50** |
| 391844074451501 | 20000809 | 0.05 |
| 392254074343201 | 20000809 | 0.40 |
| 391854075065501 | 20000810 | 0.05 |
| 395929074592202 | 20000815 | 4.42 |
| **394108075250401** | **20000815** | **10.10** |
| 395143075044101 | 20000816 | 0.05 |
| 394849075184501 | 20000816 | 0.32 |
| 403319074542801 | 20000821 | 0.05 |
| 404909075033501 | 20000821 | 3.64 |
| 403338074503101 | 20000822 | 1.67 |
| 402622074583901 | 20000822 | 5.45 |
| **394014075060001** | **20000822** | **10.90** |
| **394245075151001** | **20000822** | **13.00** |
| 395906075000601 | 20000823 | 4.63 |
| 394233074574401 | 20000824 | 2.41 |
| 394604075003601 | 20000824 | 2.96 |
| 392558075051901 | 20000825 | 0.05 |
| 404724074412301 | 20000828 | 2.86 |
| 405220074455301 | 20000828 | 4.15 |
| 403314074592301 | 20000831 | 9.27 |
| 411108074351901 | 20000908 | 6.01 |
| 395358075053701 | 20000911 | 0.05 |
| 404339074324201 | 20000911 | 0.13 |
| 394018074324701 | 20000912 | 0.05 |
| 403110074281202 | 20000913 | 0.01 |

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|---|---|---|
| 393744074244101 | 20000913 | 0.05 |
| 394535075205401 | 20000913 | 0.05 |
| 395855074470701 | 20000913 | 7.91 |
| 401940074430801 | 20000914 | 0.05 |
| 402601074424601 | 20000914 | 0.05 |
| 395806074540501 | 20000914 | 0.54 |
| 392328074315401 | 20000914 | 1.42 |
| 393129074383201 | 20000918 | 0.44 |
| 395341074345101 | 20000919 | 0.05 |
| 392123074534801 | 20000920 | 0.05 |
| **392753075204701** | **20000920** | **12.20** |
| 395814075002201 | 20000925 | 0.05 |
| 400002075004401 | 20000926 | 3.20 |
| 394123074435101 | 20000927 | 0.05 |
| 394608075212801 | 20000927 | 0.48 |
| 394629075224501 | 20000927 | 4.34 |
| 391145074520401 | 20000928 | 0.05 |
| 392158074331701 | 20001003 | 2.37 |
| 405351074433201 | 20001004 | 0.08 |
| 394342075040301 | 20001107 | 2.89 |
| 402358074510301 | 20010601 | 3.70 |
| 402708074471401 | 20010607 | 3.44 |
| 410633074364601 | 20010614 | 3.07 |
| 411255074295101 | 20010614 | 3.16 |
| 402741074302801 | 20010621 | 2.52 |
| 403224074340601 | 20010621 | 3.51 |
| 404159075093401 | 20010712 | 6.23 |
| 405459074451201 | 20010717 | 0.14 |
| 393947074464501 | 20010726 | 8.69 |
| 401021074030601 | 20010730 | 5.92 |
| 401335074042701 | 20010731 | 0.03 |
| 394640074323201 | 20010731 | 0.04 |
| 395034074112101 | 20010801 | 2.75 |
| 400346074081701 | 20010802 | 3.14 |
| 400052074191201 | 20010802 | 3.27 |
| 393458075002701 | 20010802 | 3.67 |
| 393517074553901 | 20010802 | 8.40 |
| **393734075252901** | **20010803** | **10.90** |
| 400204074145401 | 20010806 | 0.56 |
| 401732074022101 | 20010807 | 1.17 |
| 401809074371701 | 20010807 | 1.65 |
| 392826074555801 | 20010807 | 4.88 |
| **394243074493201** | **20010807** | **25.70** |
| 401229074290001 | 20010808 | 3.86 |
| 393945074470301 | 20010808 | 4.52 |
| 402149074561001 | 20010814 | 4.07 |
| 402053074260301 | 20010820 | 1.45 |
| 401531074172801 | 20010822 | 4.41 |

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|---|---|---|
| 405122074042201 | 20010823 | 4.71 |
| 402310074312301 | 20010824 | 4.72 |
| 400318074543801 | 20010827 | 0.05 |
| 402829074545601 | 20010828 | 2.35 |
| 404717074340201 | 20010828 | 5.66 |
| **394453075235101** | **20010830** | **18.40** |
| 410242074103501 | 20010905 | 5.66 |
| 402412074073001 | 20010906 | 0.03 |
| 402018074540301 | 20010906 | 3.02 |
| 401233074320401 | 20010906 | 3.78 |
| 404844074065101 | 20010906 | 4.81 |
| 404911074584901 | 20010910 | 2.40 |
| **401558074335102** | **20010911** | **72.40** |
| 410053074441301 | 20010917 | 0.07 |
| **405631074475001** | **20010917** | **10.50** |
| 410213074460901 | 20010918 | 3.67 |
| 401619074462401 | 20010920 | 0.03 |
| 405154074585701 | 20010924 | 0.03 |
| 411348074273901 | 20010924 | 1.85 |
| 403719075091801 | 20010924 | 3.86 |
| 405220074482201 | 20010925 | 0.11 |
| 402623074154701 | 20010925 | 0.78 |
| 411853074403601 | 20010926 | 0.04 |
| 402323074280901 | 20010926 | 0.05 |
| 401508074193501 | 20010926 | 0.95 |
| 405035074502201 | 20010927 | 0.90 |
| 402643074342601 | 20011002 | 3.79 |
| 395643074044302 | 20011010 | 0.05 |
| 405444074363601 | 20011016 | 6.59 |
| 401823074474301 | 20011023 | 4.48 |
| 401658074505001 | 20011206 | 0.83 |
| 400014074081601 | 20011206 | 1.04 |
| 402043074491201 | 20011210 | 0.57 |
| 405139074402701 | 20011217 | 3.16 |
| 393856074493701 | 20011219 | 2.13 |
| 394838074533601 | 20011219 | 5.91 |
| 385950074554501 | 20011227 | 0.35 |
| 392719074292201 | 20020319 | 1.03 |
| 410159074102201 | 20020321 | 2.45 |
| 394747074555001 | 20020709 | 0.05 |
| 393050074412501 | 20020718 | 0.70 |
| 395618074223501 | 20020806 | 0.05 |
| **394939074414701** | **20020806** | **13.30** |
| 390643074522501 | 20020807 | 7.04 |
| 404430074222201 | 20021211 | 1.12 |
| 393359075172801 | 20030910 | 6.32 |
| 395448074370701 | 20040615 | 0.06 |
| 395815074442101 | 20040616 | 7.81 |

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|---|---|---|
| 395643074295201 | 20040617 | 0.06 |
| 392435075072801 | 20040622 | 5.07 |
| 400202074461301 | 20040623 | 0.36 |
| 393301074591601 | 20040624 | 5.42 |
| 394647074592701 | 20040630 | 1.65 |
| 393313075254101 | 20040630 | 9.58 |
| 400525074314101 | 20040701 | 0.06 |
| 395638074432501 | 20040707 | 0.06 |
| 400533074405101 | 20040713 | 0.06 |
| **394024075234701** | **20040714** | **10.80** |
| 392715075173101 | 20040715 | 6.34 |
| 393738075221401 | 20040720 | 0.17 |
| **393610075250001** | **20040721** | **11.60** |
| 391357074575501 | 20040727 | 4.24 |
| **392820075122601** | **20040727** | **34.00** |
| 395532074504701 | 20040901 | 2.16 |

[1] Bolded entries denote those values ($n$ = 58) that exceed the SWQS of 10.0 mg/L for nitrate, and which were then reduced to 10.0 mg/L for the 2nd averaging.

**APPENDIX C: Table 2. Complete AGWQMN dataset of nitrate concentrations ($n$ = 150) utilized to determine mean background concentration of 3.58 and 2.88[2] mg/L.**

| Geologic Province | USGS Station ID Number | Sampling Dates | NO3+NO2-N (mg/L) | Land Use[3] |
|---|---|---|---|---|
| Valley and Ridge | 410053074441301 | 20010917 | 0.07 | UND |
| | **405631074475001** | **20010917** | **10.54** | AG |
| | 410049075045801 | 20010919 | 0.23 | UND |
| | **404900075043601** | **20040623** | **14.00** | AG |
| | 410033074544701 | 20030624 | 0.66 | AG |
| | 410213074460901 | 20010918 | 3.67 | AG |
| | 411853074403601 | 20010926 | 0.04 | UND |
| | 404937074580501 | 20030625 | 4.20 | AG |
| | **410433074394001** | **20021118** | **24.20** | AG |
| | | | | |
| Highlands | 410214074204501 | 20021120 | 0.14 | UND |
| | 403719075091801 | 20010924 | 3.86 | AG |
| | 405537074361401 | 20030911 | 0.04 | UND |
| | 405220074482201 | 20010925 | 0.11 | UND |
| | 405035074502201 | 20010927 | 0.90 | URB |
| | 404828074403501 | 20030708 | 0.05 | UND |
| | 405154074585701 | 20010924 | 0.03 | UND |
| | 403951075075301 | 20021216 | 4.81 | AG |
| | **404324075041801** | **20021204** | **11.20** | AG |
| | 411348074273901 | 20010924 | 1.85 | AG |
| | 403921074515901 | 20030624 | 9.18 | AG |
| | 405827074360801 | 20040331 | 0.48 | URB |

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|---|---|---|---|---|
| | 404146075112101 | 20030626 | 4.28 | URB |
| | 404936074423101 | 20021022 | 0.65 | URB |
| | 410610074344801 | 20040617 | 0.69 | URB |
| | 405309074315301 | 20021113 | 0.14 | URB |
| | | | | |
| Piedmont | 401619074462401 | 20010920 | 0.03 | URB |
| | 401942074510101 | 20020523 | 1.02 | AG |
| | 402018074540301 | 20010906 | 3.02 | AG |
| | 402431075020801 | 20010919 | 1.98 | UND |
| | 404944074232401 | 20021029 | 0.03 | UND |
| | 401829074513301 | 20040617 | 0.41 | UND |
| | 403121075003901 | 20030625 | 3.42 | AG |
| | 402633074541301 | 20030910 | 4.25 | AG |
| | 403347074575101 | 20030709 | 1.77 | AG |
| | 402501074505001 | 20030701 | 5.79 | AG |
| | 403100074464101 | 20030626 | 8.84 | AG |
| | 402512074414301 | 20030115 | 7.67 | AG |
| | 403200074420601 | 20021104 | 2.43 | AG |
| | 402820074341501 | 20031014 | 0.06 | AG |
| | 403129075034701 | 20030625 | 3.41 | URB |
| | 402310074453801 | 20030116 | 0.13 | URB |
| | 402051074400001 | 20040616 | 3.19 | URB |
| | 403537074394401 | 20030630 | 5.69 | URB |
| | 404704074281301 | 20040330 | 5.42 | URB |
| | 402907074255801 | 20030616 | 0.06 | URB |
| | 403451074294801 | 20030320 | 2.47 | URB |
| | 403617074265601 | 20030114 | 4.12 | URB |
| | 404303074173101 | 20040318 | 0.06 | URB |
| | 403422074192001 | 20021022 | 0.06 | URB |
| | 403946074193901 | 20021112 | 0.55 | URB |
| | 405739074164201 | 20040324 | 0.73 | URB |
| | 405128074231401 | 20031009 | 0.44 | URB |
| | 404055074132901 | 20040311 | 4.34 | URB |
| | 404332074104201 | 20030909 | 7.44 | URB |
| | 405148074133601 | 20040427 | 0.06 | URB |
| | 405632074131801 | 20040325 | 1.06 | URB |
| | 404339074045401 | 20040504 | 6.77 | URB |
| | 404844074082501 | 20040428 | 3.63 | URB |
| | 405435074080201 | 20040317 | 0.04 | URB |
| | 410218074065001 | 20040309 | 1.42 | URB |
| | 404636074024701 | 20040623 | 0.06 | URB |
| | 405050074011401 | 20040622 | 0.06 | URB |
| | 405543074040901 | 20040323 | 3.30 | URB |
| | 405909073574101 | 20040310 | 1.45 | URB |
| | | | | |
| Coastal Plain | 400954074302001 | 20000928 | 0.17 | AG |
| | 395815074442101 | 19990831 | 2.59 | AG |
| | 395928074502701 | 19990819 | 0.05 | UND |

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|---|---|---|---|---|
| | 400533074405101 | 19990929 | 0.05 | AG |
| | 400525074314101 | 19990915 | 0.05 | AG |
| | 400202074461301 | 19990902 | 1.64 | AG |
| | **395836074542701** | **19990819** | **11.58** | AG |
| | 395855074470701 | 20000913 | 7.91 | URB |
| | 395643074295201 | 19990901 | 0.05 | AG |
| | 395814075002201 | 20000925 | 0.05 | URB |
| | 395806074540501 | 20000914 | 0.54 | URB |
| | 395638074432501 | 19990907 | 0.05 | AG |
| | 395532074504701 | 19990921 | 7.24 | AG |
| | 395358075053701 | 20000911 | 0.05 | URB |
| | 395341074345101 | 20000919 | 0.05 | UND |
| | 395448074370701 | 19990922 | 0.05 | UND |
| | 395143075044101 | 20000816 | 0.05 | URB |
| | 394647074592701 | 19990908 | 0.05 | URB |
| | 394446075031001 | 19990920 | 0.05 | URB |
| | 394849075184501 | 20000816 | 0.32 | AG |
| | **394245075151001** | **20000822** | **13.03** | AG |
| | **394108075250401** | **20000815** | **10.05** | AG |
| | 394342075040301 | 19990908 | 2.62 | URB |
| | **394014075060001** | **20000822** | **10.90** | AG |
| | 394256075101001 | 19990922 | 7.83 | AG |
| | **394024075234701** | **19990909** | **12.46** | AG |
| | 392558075051901 | 19990920 | 0.05 | UND |
| | 393818075132401 | 19990923 | 9.36 | AG |
| | 393738075221401 | 19990908 | 0.18 | AG |
| | 393532075101201 | 19990927 | 3.08 | URB |
| | **393610075250001** | **19990928** | **10.96** | AG |
| | 393712075121201 | 19990914 | 8.83 | AG |
| | 393313075254101 | 19990923 | 8.18 | AG |
| | **393413075141901** | **19990927** | **16.92** | AG |
| | 393301074591601 | 19990914 | 4.07 | AG |
| | 393104075122201 | 19990915 | 8.91 | AG |
| | 392715075173101 | 19990913 | 3.69 | AG |
| | 391357074575501 | 19990923 | 5.03 | AG |
| | **392820075122601** | **19990928** | **21.75** | AG |
| | 392920075011901 | 19990913 | 2.77 | URB |
| | **392753075204701** | **20000920** | **12.21** | AG |
| | 392435075072801 | 19990920 | 2.55 | AG |
| | 391854075065501 | 20000810 | 0.05 | UND |
| | 391145074520401 | 20000928 | 0.05 | UND |
| | 391844074451501 | 20000809 | 0.05 | UND |
| | 391611074383801 | 20000815 | 1.74 | URB |
| | 392123074534801 | 20000920 | 0.05 | UND |
| | 394018074324701 | 20000912 | 0.05 | UND |
| | 392328074315401 | 20000914 | 1.42 | URB |
| | 393744074244101 | 20000913 | 0.05 | UND |
| | 394123074435101 | 20000927 | 0.05 | UND |

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|---|---|---|---|---|
| | **393531074523901** | **20000802** | **14.40** | URB |
| | 393940074534201 | 20000801 | 0.05 | UND |
| | 393947074464501 | 20010726 | 8.69 | AG |
| | 393129074383201 | 20000918 | 0.44 | URB |
| | 394642074375401 | 20000809 | 0.08 | UND |
| | 394117074214001 | 20000801 | 0.75 | UND |
| | 394640074323201 | 20010731 | 0.04 | AG |
| | **393415074563601** | **20000808** | **55.51** | AG |
| | 395417074143401 | 20000803 | 0.05 | UND |
| | 395034074112101 | 20010801 | 2.75 | URB |
| | 395900074242801 | 20000731 | 0.05 | UND |
| | 400204074145401 | 20010806 | 0.56 | URB |
| | 400346074081701 | 20010802 | 3.14 | URB |
| | 400529074260601 | 20000802 | 0.05 | UND |
| | 400052074191201 | 20010802 | 3.27 | URB |
| | 401021074030601 | 20010730 | 5.92 | URB |
| | 401335074042701 | 20010731 | 0.03 | URB |
| | 401531074172801 | 20010822 | 4.41 | URB |
| | 402412074073001 | 20010906 | 0.03 | URB |
| | 401732074022101 | 20010807 | 1.17 | URB |
| | 401229074290001 | 20010808 | 3.86 | AG |
| | 401233074320401 | 20010906 | 3.78 | AG |
| | 401809074371701 | 20010807 | 1.65 | URB |
| | 402323074280901 | 20010926 | 0.05 | UND |
| | 402623074154701 | 20010925 | 0.78 | UND |
| | 401508074193501 | 20010926 | 0.95 | AG |
| | 400634074403401 | 20030326 | 0.21 | AG |
| | 401454074371401 | 20030904 | 0.59 | AG |
| | **401916074324201** | **20030911** | **16.50** | AG |
| | 401917074183801 | 20040316 | 0.06 | AG |
| | 401606074183501 | 20020926 | 0.02 | AG |
| | 400811074414101 | 20020926 | 0.33 | URB |
| | 402046074261901 | 20030624 | 3.24 | URB |
| | 402403074210201 | 20021028 | 0.06 | URB |
| | 402831074171901 | 20021022 | 0.06 | URB |

[2] Bolded entries denote those values ($n$ = 16) that exceed the SWQS of 10 mg/L for nitrate, and which were then reduced to match the SWQS for the 2nd averaging.

[3] AG = Agricultural; UND = Undeveloped; URB = Urban