Trends of Nitrate Concentrations in Waters of the Suwannee River Water Management District, 2007

Prepared for

Suwannee River Water Management District
Live Oak, Florida

By
Sam B. Upchurch, Ph.D., P.G.
Jian Chen, P.G.
Crystal R. Cain

SDII Global Corporation
Tampa, Florida

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Endorsement

This report was submitted to the Suwannee River Water Management District by SDII Global Corporation under District contract No. 06/07-116. All work was performed under the supervision of the undersigned.

SDII Global Corporation

Sam B. Upchurch, Ph.D., P.G.
Vice President and Principal Geologist
Florida Registration No. 4

SDII Global Corporation Project Number

3017076

Cover Photograph

Hornsby Spring, Alachua County, Florida, in November, 2006. While nitrate concentrations vary considerably over time, they appear to be declining in this spring (Figure 9).

The image to the left is of filamentous algae growing on rock exposures at Hornsby Spring, Alachua County, Florida. Algal growth, such as shown in the photograph, results from excess nitrate in water discharging from the spring. Nitrate concentrations in the spring are highly variable (Figure 9), but a trend of declining concentrations appears to be developing.

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Introduction

The Suwannee River Water Management District (District) monitors water quality and quantity throughout the District on a regular basis. Water resources monitored include lakes, rivers and streams, springs, and ground water. The monitoring networks used by the District are collectively known as the Water Assessment Regional Network (WARN). The purpose of this report is to document the status and changes in nitrate concentrations in these water resources within the District.

Why Elevated Nitrate Concentrations Are A Problem

Nitrate (NO_3^-) is part of the nitrogen cycle (Figure 1). Nitrogen is the dominant gas in

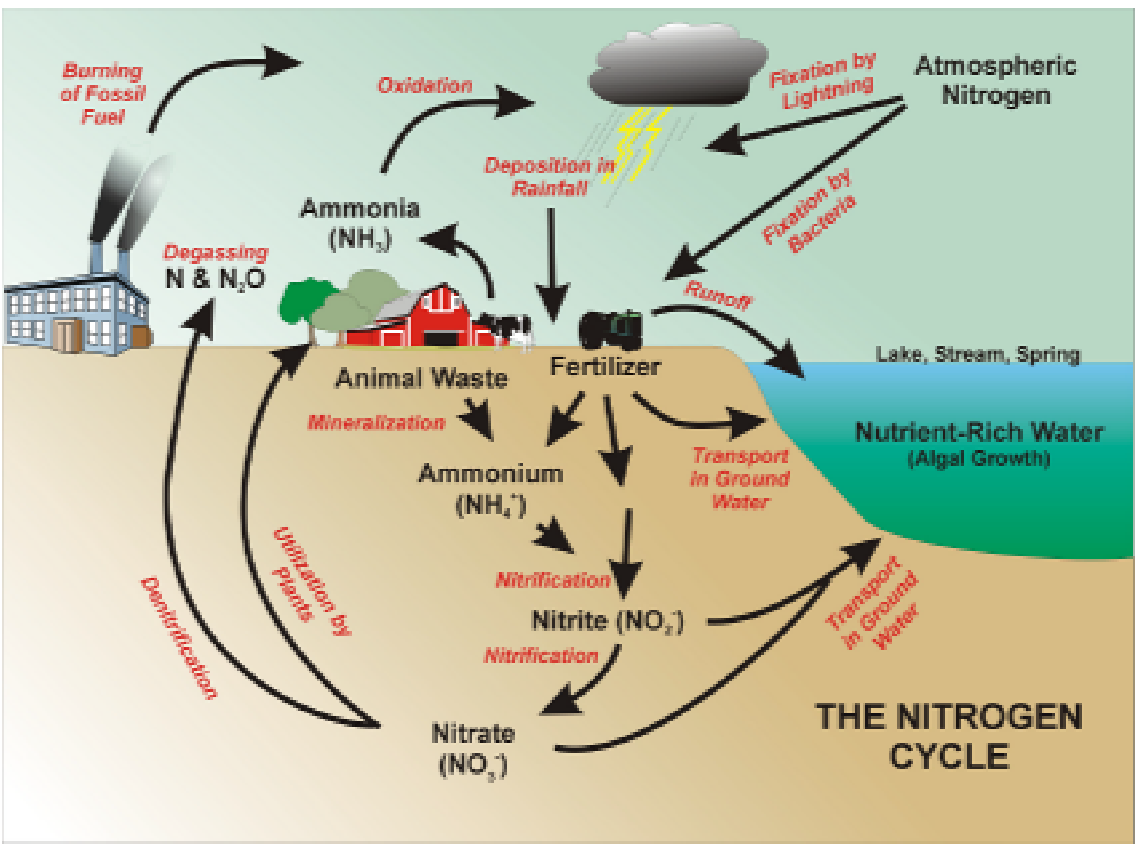

Figure 1 - The nitrogen cycle. The important part of this cycle is the link between surface-water quality and nitrate in groundwater derived from agricultural and domestic fertilizers, septic tanks, industrial activity and animal wastes.

Earth's atmosphere. It undergoes many transformations in the atmosphere, at the Earth's surface, and in soils and aquifers.

Figure 2 - Convict Spring, which is located in Lafayette County, has nitrate concentrations in excess of 8 mg/l, as N. Increasing nitrate concentrations in springs is a major concern of the District. (Photograph by the District.)

Nitrate is a plant nutrient that, in combination with other nutrients, such as phosphorus, iron, carbon, and potassium, contributes to plant growth. Because plants utilize nitrate efficiently, background concentrations of nitrate in rainwater, surface water, and ground water are near, or below, analytical detection limits.[1] When nitrate is introduced to surface water where light and other nutrients are abundant, excess nitrate may cause an overall deterioration of the ecosystem within the water body. Some of the consequences of nutrient enrichment include excessive growth of algae[2], including some that are noxious or toxic, reduction in the number of different species that inhabit the water body, changes in the plant and animal species that inhabit the water body, loss of oxygen in the water as a result of the decay of algae, and loss of water clarity as a result of floating algae and other particles.

There are state and federal drinking-water standards for nitrate because of human health risks of a syndrome known as *methemoglobinemia*, or "blue-baby" syndrome. "Blue-baby" syndrome is a loss of the ability of blood to carry oxygen, resulting in a bluish tint to the skin and potential illness or fatality, especially in infants whose circulation systems cannot tolerate lowered oxygen levels. The human-health based, drinking water standard for nitrate is 10 mg/L, as N (milligrams per liter expressed as nitrogen). Much lower concentrations have the potential for causing unwanted deterioration of surface-water ecosystems, however.[2]

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[1] The term background refers to natural concentrations of nitrate in areas that have been unaffected by human activity. In Florida, nitrate concentrations in ground water that has clearly not been affected by human activities are near or below current laboratory detection limits (i.e., 0.05 mg/L NO_3^-, as N).

Today, atmospheric fallout of nitrate and other nitrogen compounds has raised the ambient background concentrations in rivers and streams, lakes, and shallow, unconfined ground water to levels above the detection limit even without contributions from local, land-based sources. Upchurch (1992) showed that average nitrate concentrations in Florida rainfall was 0.97 mg/L.

[2] The amount of nitrate required to trigger excess algal growth varies from water body to water body and there is no accepted threshold concentration above which algal growth becomes a problem. Data on the problem in Florida, however, indicate that threshold concentrations are low and well below the drinking water standard (Stevenson and others, 2004).

Sources of nitrate today (Figure 1) include:

- Application of fertilizers to croplands (row crops, pastures, groves, etc.) and turf (lawns, golf courses, etc.);
- Animal wastes, including wastes from feedlots, septic tanks, wastewater treatment, and other sources; and,
- To a lesser extent, atmospheric deposition.

To reduce the flux of nitrate to ground- and surface-water bodies, it is necessary to reduce and better manage the application of nitrogen-bearing materials.

Many of the water bodies within the District are fed by ground water, so lakes, rivers, and springs have been affected by increases in nitrate concentrations in ground water. Ground water has shown significant increases in nitrate concentrations over the last 30 years throughout much of Florida, including the District (Hornsby and others, 2002, 2004). As a result, some springs routinely discharge water with elevated nitrate concentrations (Figure 2). In a few, scattered locations, nitrate concentrations have exceeded the drinking-water standard (Figure 2) and several springs and reaches of rivers fed by springs have developed algae problems (Hornsby and others, 2004).

What Is Being Done To Reduce Nitrate Concentrations

The District, working with members of the Suwannee River Partnership[3], numerous state, federal and local agencies and the public, has taken measures to begin to reduce nitrate in ground water through a number of programs designed to assist those who operate potential nitrate sources. Best management practices (BMPs), assistance grants to improve agricultural practices and waste management, an active monitoring and research program, and numerous other initiatives have been implemented to address concerns with nitrate in ground and surface waters of the District.

The goal of the Suwannee River Partnership and District is to reduce nutrient concentrations in waters of the District through wise stewardship of the land and management of wastes and fertilizers. Research efforts have been implemented in order to define the extent of the nitrate problem. These efforts have been funded by the Florida Springs Initiative and Florida Department of Environmental Protection. Development of BMPs and improvements of agricultural infrastructure have been funded by the Florida Department of Agriculture and Consumer Services and the National Resources Conservation Service.

One of the research efforts to identify the sources of nitrate and determine how nitrate

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[3] There are too many participants in the Suwannee River Partnership to name them all in this report. The results of the WARN monitoring are a testimony to the dedication and commitment of these agencies, industries, and citizens.

Funding support for WARN monitoring and development of the partnership include the District, the Florida Department of Environmental Protection Springs Initiative, Natural Resources Conservation Service, Florida Department of Agriculture and Consumer Services, and Florida Institute of Food and Agricultural Sciences.

moves through the ground water concerned dating of nitrate-rich water emerging from District springs. This work, a joint effort of the U.S. Geological Survey (USGS) and the District and authored by Katz and others (1999), has determined that the water from springs within the District entered the ground decades ago. This finding is important for understanding the results of monitoring presented in this report.

District Nitrate Monitoring

The District's WARN monitoring is intended to evaluate the outcomes of the measures taken by members of the Suwannee River Partnership, District, and numerous others to reduce nitrogen loading in areas draining to the springs and Suwannee River system. As noted above, the WARN includes monitoring sites in lakes, streams, springs, and ground water (Mirti and others, 2006). The WARN network was implemented in 2000. However, many of the sites, especially surface water sites, have been monitored since 1989. Where data are available, this analysis includes all data from 1989 to early 2007.

The District analyzes for nitrate plus nitrite (NO_3^- + NO_2^-). The results are reported in milligrams per liter as nitrogen in order to adjust for the different masses of the two compounds. Typically, nitrite is an intermediate step in the process of nitrification (Figure 1) and is present in small quantities, if at all. In order to simplify the following discussion, the analyte nitrate plus nitrite is termed nitrate.

Surface-Water Monitoring - Surface water samples are collected for water-quality monitoring at 76 sites, including 22 springs. Sampling intervals are monthly, bi-monthly, and quarterly. In addition, 26 lake stations have been monitored for water quality on an *ad hoc* basis. Figures 3, 7, and 10 illustrate the locations of surface-water monitoring sites for which sufficient data exist for trend evaluation. Appendix A lists the surface-water sites.

Because springs represent the discharge of ground water into surface-water environments, the monitoring of water quality of springs detects conditions in both ground and surface water. District springs are important economic and ecologic resources, and they tend to reflect the cumulative effects of human activities in their drainage basins.

It is important to understand that research on age-dating of spring water by the USGS and District suggests that successful reductions of nitrate concentrations in ground water and spring discharge may take decades to realize and that short-term (5-10 year) measures of success will be indicated by

1. Cessation of trends showing increased nitrate concentrations in the springs, and
2. Beginnings of downward trends in nitrate concentrations of nitrate, especially in ground water.

Ground-Water Monitoring - The ground-water monitoring program within the WARN consists of two monitoring networks: the Status and Trend Networks (Mirti and others, 2006).

There are two purposes of the Status Network. It is used to identify and monitor regions of the District where ground-water quality issues may exist and to enable the District to report on the overall quality of ground water within the District. The Status Network consists of 147 wells scattered randomly throughout the District. These wells, which include monitoring and domestic wells, were randomly selected and are changed every five years. By randomly selecting the wells, all portions of the aquifers in the District have a statistical chance of being sampled, so the network enables the District to evaluate the overall ground-water quality throughout the area without bias (Copeland and others, 1999).

The purpose of the Trend Network is to monitor changes in ground-water quality through time at specific sites within the District. The Trend Network wells were purposefully located in areas where

- Background[1] conditions were thought to exist, or
- Water-quality problems were known to exist and measures were being taken to reduce nitrate loading.

The benefits of the Trend Network are that the District can specifically address known problem areas, evaluate new management strategies, and detect improvements (or degradation) in water quality as they develop.

Because the Trend and Status Networks have been monitored over the same time frame (2000-2006) so far, the results of the monitoring within the two networks are combined for the purposes of this report. Future reports will separate the results as the locations of Status Network wells change.

Figure 12 provides the locations of the WARN ground-water monitoring sites and Appendix B lists the sites.

Trend-Detection Methods

Methods – In order to detect statistically significant trends in the data for each sampling station, the following conditions were applied to all data:

- There had to be at least three samples spread over three or more years, and
- Any trend detected had to be statistically significant at an alpha level of 0.10 (P = 90%).[4]

The first criterion was necessary to allow for determination of statistical significance and sufficient time for a trend to be manifested. There is a problem with collection of a small number of samples over a long period of time because of a process known as

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[4] The alpha level (α) is the risk that a random sample of unrelated and uncorrelated data will, by chance, produce a spurious trend. An α of 0.10 was chosen in order to detect some of the weaker trends in the data that result from the natural variability of the data. 1 – α is the confidence probability (P). With an α = 0.10, one can state that the trends are statistically significant with a probability of 90% [100(1 – α)].

"aliasing" (Koopmans, 1995). Aliasing involves collection of samples in a time series that has cycles that are shorter than the sampling interval. There is a risk that the trend analysis will detect a false trend that results from sampling of different parts of the cyclic pattern.

There is also a concern about detecting trends when there is "serial correlation" within a time series of data (Ward and others, 2003). Serial correlation results when the data points are close enough in time that they are measuring the same event or process. When this occurs, the trend detected may be trivial and not meaningful. All that this serially correlated trend reflects is a repeat of the same data. There should be little risk of serial correlation because the data collection intervals range from monthly to semi-annually.

In order to investigate the possibilities of both aliasing and serial correlation, the data were stratified into quarters that correspond with segments of the hydrologic year. The quarters are:

- Quarter 1: September through November, relatively dry interval;
- Quarter 2: December through February, wet season in northern portions of District, relatively wet interval to south;
- Quarter 3: March through May, dry interval; and
- Quarter 4: June through August, relatively wet to the north, wet in southern part of District.

Data from each quarter were also tested for trends to determine if trends existed and to evaluate any possibilities for aliasing or serial correlations. In the end, it was determined that neither serial correlation nor aliasing was a problem, so the time-series data were considered as a whole for each period or record.

An alpha level[4] (α) of 0.10 was selected because of the known long-term, seasonal, and tidal variability in some of the data and to allow for other forms of variability that are known to occur in the data.

Methods utilized to determine if trends exist in the data included:

- Pearson product-moment correlation and simple linear regression,
- Kendall's tau and seasonal Kendall tests, and
- Sen's slope estimator.

These tests (Ward and others, 2003) were consistent in identifying trends. Because the correlation coefficients also allowed for evaluation of variability accounted for by linear regressions of the data versus time, they were used for the final evaluation of trends.

The site-specific results of the Pearson product-moment correlation analysis are presented in Appendices A and B. Testing by the other methods listed above provided similar results.

Uncertainties – Some data sets showed inflections with declining or increasing trends in nitrate concentrations within the time series. In most cases, the inflections were so recent that there was insufficient data to determine if they reflect the onset of a long-term trend or simply natural data variability. More time and data collection will be required to evaluate this uncertainty. For the purposes of this report, where insufficient data existed for trend evaluation, the determination of significance was based on the entire data set.

Also, care must be taken at this time relative to drawing conclusions about the causes of any trends detected or the absence thereof. The early 2000s were years of extreme to moderate drought followed in the mid-2000s by wet years. Changes in rainfall patterns over the period of the data time series may affect trends and several more multi-year rainfall intervals will be needed to evaluate the effects of rainfall on nitrate in the water bodies. Dilution and/or changes in discharge, therefore, may be masking some of the changes that have begun to develop.

Finally, as shown by the work of Katz and others (1999), response times are likely to be on the scale of decades. Unless a nitrate source is very near to a spring or monitoring well, one would not expect immediate improvements in water quality. Since the growth of the Suwannee River Partnership and implementation of BMPs was on-going during the sampling interval, it is unlikely that wide-spread and

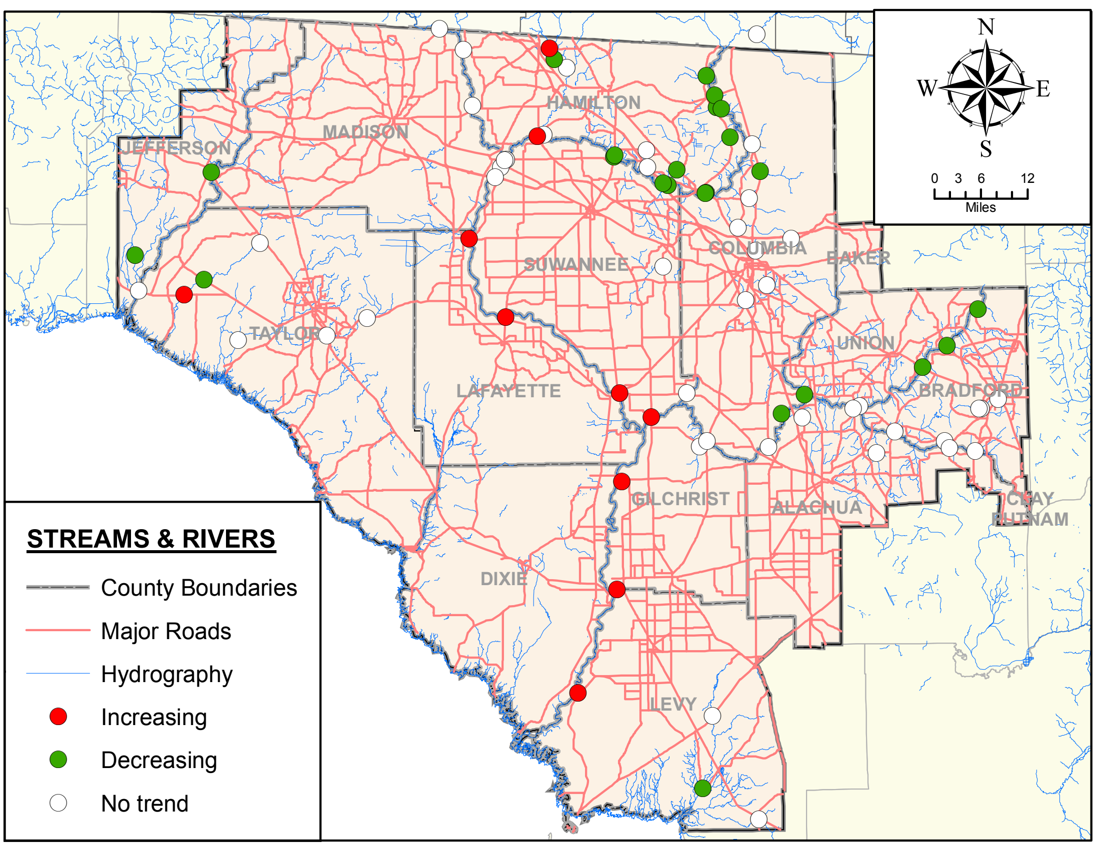

Figure 3 - Trends detected at river and stream sampling stations of the WARN.

significant changes will be detected.

Nitrate Trends

Rivers and Streams – Figure 3 illustrates the locations of monitoring sites in rivers and streams of the District. The color of the symbol indicates whether a statistically significant (α = 0.10), trend was detected (red = trend of increasing nitrate concentrations, green = decreasing nitrate trend, and no color = no significant trend detected). All totaled, 10 (12%) of the 81 sampling stations reflected increasing nitrate concentrations and 23 (28%) showed decreasing trends.

Many, but not all, of the river and stream sites that show significant declining nitrate trends are located where the Floridan aquifer is confined (Figure 4; Suwannee River Water Management District, 1982; Grubbs, 1998) and stream-aquifer interactions are limited to the surficial aquifer. Nitrate concentrations in these systems are heavily affected by local land use and rainfall.

This is the case for the sites where trends of declining nitrate concentrations were

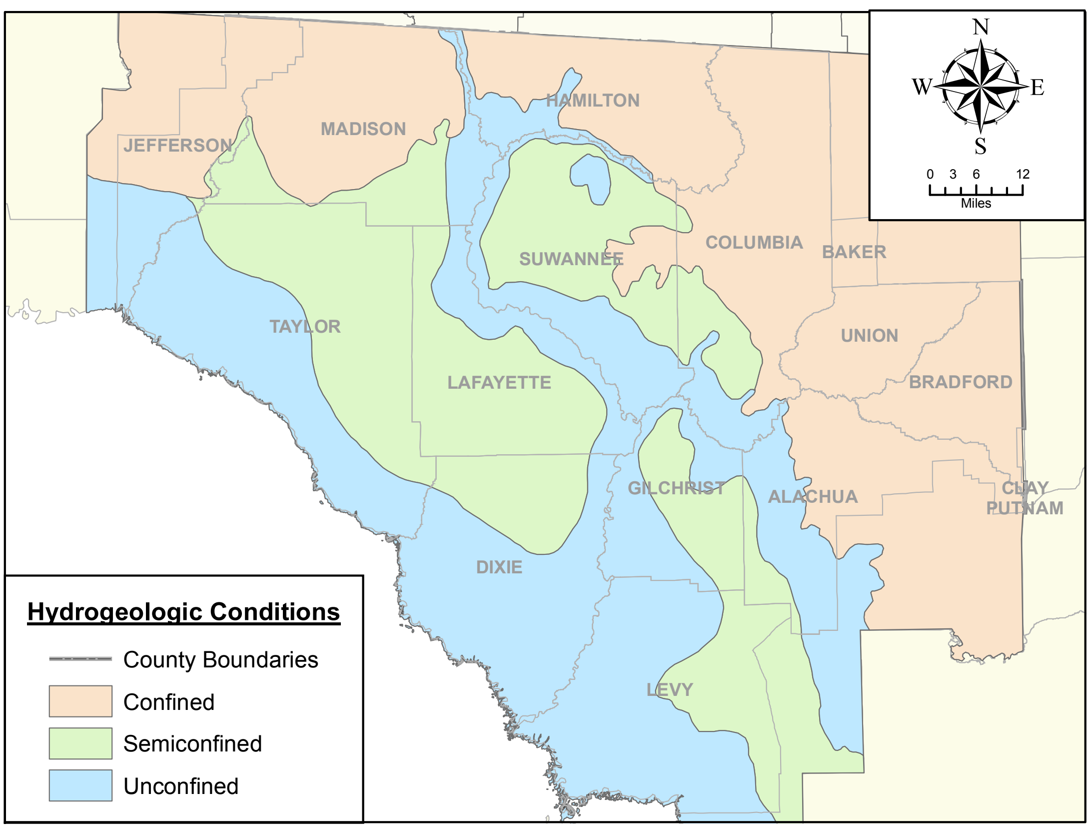

Figure 4 - Conditions of confinement of the Floridan aquifer in the Suwannee River Water Management District. Adapted from Suwannee River Water Management District (1982).

identified in the upper reaches of the Suwannee and Santa Fe Rivers (compare Figures 3 and 4). One would anticipate that water quality in these locations would respond rapidly to changes in rainfall and land use because the streams are typically dominated by runoff.

Figure 5 is an example of the behavior of nitrate concentrations with time in a stream (Swift Creek Station ID SWF010C1) that drains an area where the Floridan aquifer is typically confined and that is dominated by runoff. Nitrate concentrations at this site fluctuate with rainfall. Peaks occur during the winter months – the local rainy season – and lows are during the drier summer months. Even so, the data demonstrate a weak,

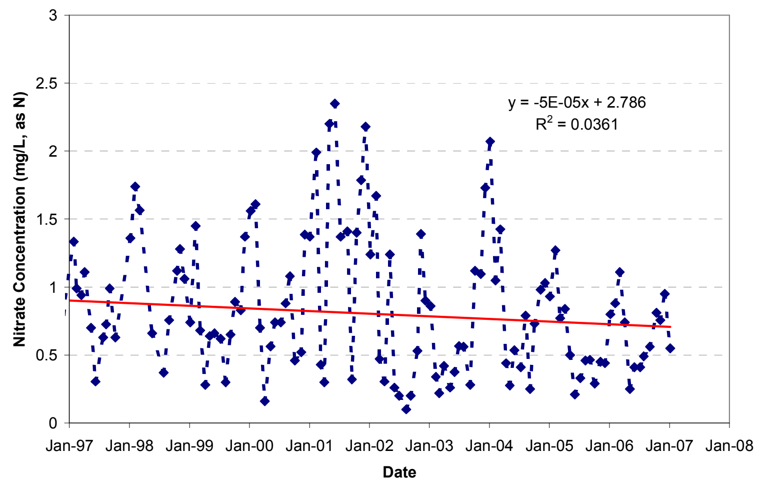

Figure 5 – Nitrate concentrations from 1997 to early 2007 at Swift Creek (Station ID SWF010C1), Hamilton County. Note that the correlation is low, but statistically significant, and that the regression line only accounts for about 4 percent of the variability in the data.

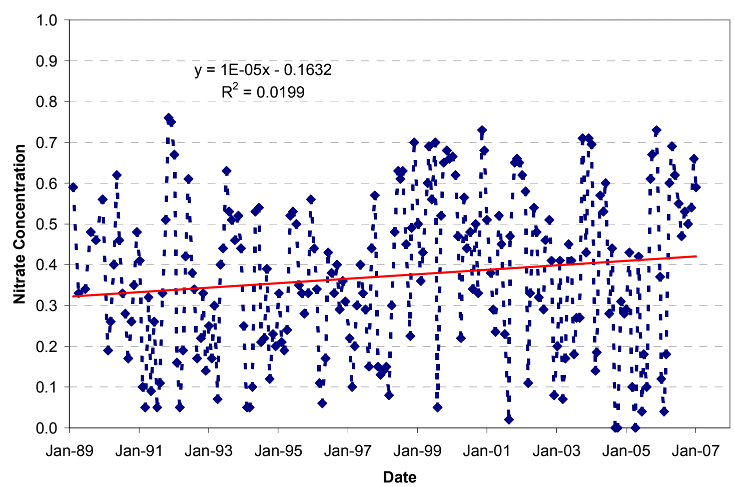

Figure 6 – Nitrate concentrations from 1989 to early 2007 in the Suwannee River at Dowling Park (Station SUW120C1), Lafayette County. Note that the correlation is low, but statistically significant, and that the regression line only accounts for about 2 percent of the data variability.

but statistically significant decline over the period from 1997 to 2007. Based on the R^2 value[5] of the regression, the line shown in Figure 5 accounts for approximately 4 percent of the data variability.

For contrast, Figure 6 illustrates nitrate behavior in the Suwannee River at Dowling Park (Station ID SUW120C1) from 1989 to 2007. Note the seasonal pattern and slight slope of the regression line, which reflects the statistically significant, increasing nitrate trend. While the trend is statistically significant, only about 2 percent of the data variability can be accounted for by the regression.[2] The remainder of the variability is accounted for by the seasonal fluctuations in concentrations.

As with the Swift Creek example, there is a strong seasonal signal in the Dowling Park data (Figure 6), but the high nitrate concentrations occur in dryer months and low nitrate concentration in wetter intervals. This pattern is reversed from the Swift creek example (Figure 5) and reflects the importance of ground water discharge to the river.

The Suwannee River near Dowling Park is located in a region where the Floridan aquifer is unconfined (Figure 4), so ground water is vulnerable to nitrate contamination, which results in high nitrate concentrations in affected areas and sustained flow of nitrate-rich water to the river as baseflow.

The Dowling Park sample site is located in an area where baseflow from ground water sustains river flow during dry periods. The springs in this area exhibit relatively high nitrate concentrations in discharge waters, and, at low flow, this spring discharge constitutes significant portions of the total river flow.

Springs - Figure 7 illustrates the locations of WARN monitoring sites in springs of the District. The color of the symbol indicates whether a statistically significant trend was detected (red = increasing nitrate trend, green = decreasing nitrate trend, and no color = no trend detected). All totaled, 14 (20%) of the 68 sampling stations[6] reflected trends of increasing nitrate concentrations and 17 (25%) showed decreasing trends.

Many of the springs illustrating increasing nitrate trends are located on the middle and lower Suwannee River. The District has been aware of the increases in nitrate concentration in these springs for several years (Katz and others, 1999). It is these springs that contribute to the elevated nitrate concentrations in the Suwannee River during low flows and that justified creation of the Suwannee River Partnership to

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[5] R^2 is the square of the correlation coefficient. In this case, the R^2 is 0.0361 and the correlation coefficient is 0.19, a weak correlation. The R^2 value multiplied by 100 is the percent of the variation in the data that can be accounted for by the line representing the correlation. In the case of the Swift Creek data (Figure 4), the R^2 value indicates that there is a significant amount of variability in the data and that the statistically significant negative trend is weak, but not likely a result of random variation.

[6] There were 68 springs that had been sampled by the District. This is a larger sample set than the 22 springs that are formally included in the WARN because it includes springs that were sampled for other purposes. As shown in Appendix A, trends could not be detected in 37 springs, partly because of low sample size.

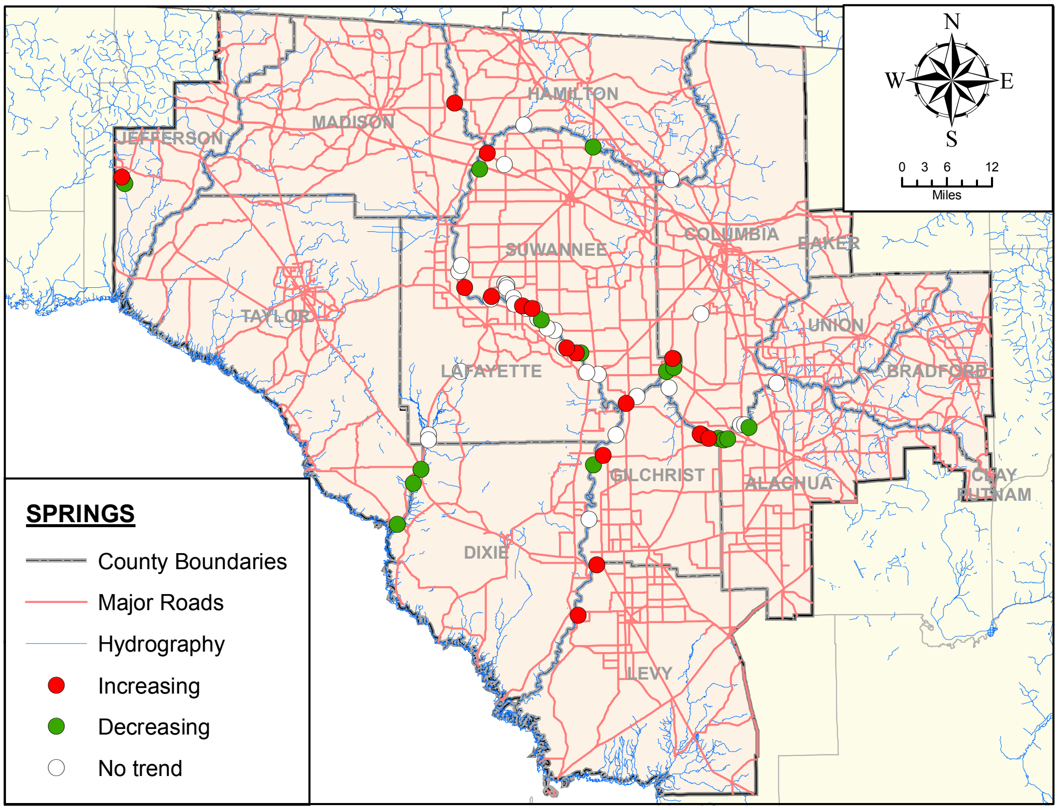

Figure 7 - Trends detected in springs monitored as part of the WARN.

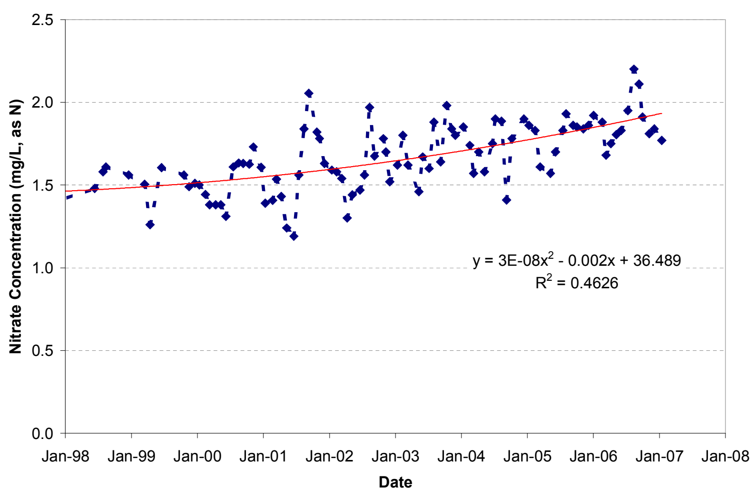

Figure 8 - Nitrate concentrations (mg/L, as N) in Manatee Spring (Sampling Station MAN010C1) discharge for the period from 1998-2007. Note the muted seasonal fluctuations and statistically significant slope. Approximately 46 percent of the nitrate variability can be accounted for by the regression line.

assist in reducing nitrate concentrations.

Figure 8 illustrates the statistically significant trend of increasing nitrate in water discharging from Manatee Spring (Station ID MAN010C1) in Levy County. This statistically significant trend is superimposed over muted seasonal and tidal cycles. The linear regression accounts for approximately 46 percent of the data variability.

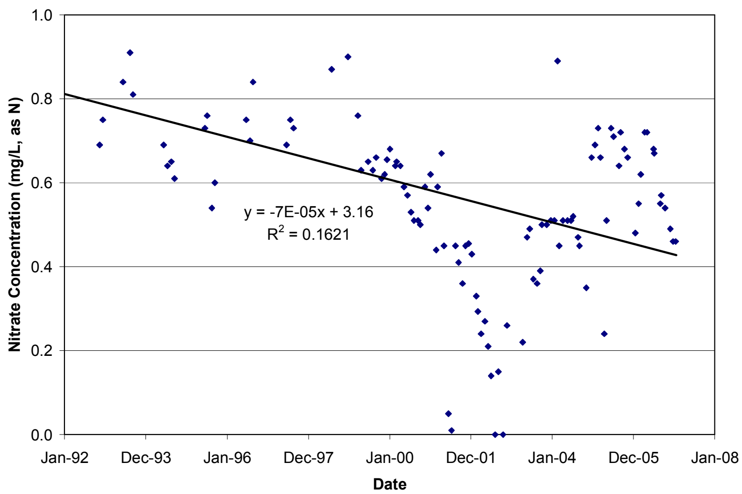

Figure 9 - Statistically significant, declining trend in nitrate, as N, concentrations at Hornsby Spring (HOR010C1), Alachua County.

Hornsby Spring (HOR010C1; Alachua County) illustrates an example of a spring with a statistically significant, declining trend in nitrate concentrations (Figure 9). Note that the pattern suggests fluctuations resulting from major climatic events, such as the el Niño rainfall event of 1997-1998 and the record drought of 1998-2002. Note also that the trend is evident even though there are major, multi-year excursions away from the weak, long-term trend. The regression illustrated in Figure 9 accounts for approximately 16 percent of the data variability. Many of the springs that revealed negative trends (declining nitrate concentrations; Figure 7) are the smaller springs (moderate to low, second magnitude[7] springs, such as Ginnie and Guaranto springs). This pattern is to be expected because spring discharge is typically directly related to drainage basin (springshed) area.[8] The smaller the springshed and spring magnitude, the shorter the flow paths of ground water within the springshed and more likely the nitrate concentrations in spring discharge will respond to land-use practices in the short term.

[7] Second magnitude springs exhibit long-term median discharge of 10 to 100 cubic foot per second (cfs) (Meinzer, 1927; Copeland, 2003).
[8] Faulkner (1971) argued that the discharge from a spring is proportional to springshed size. The “rule of thumb” he suggested is that a spring averages about 1 cfs for each square mile of drainage basin size.

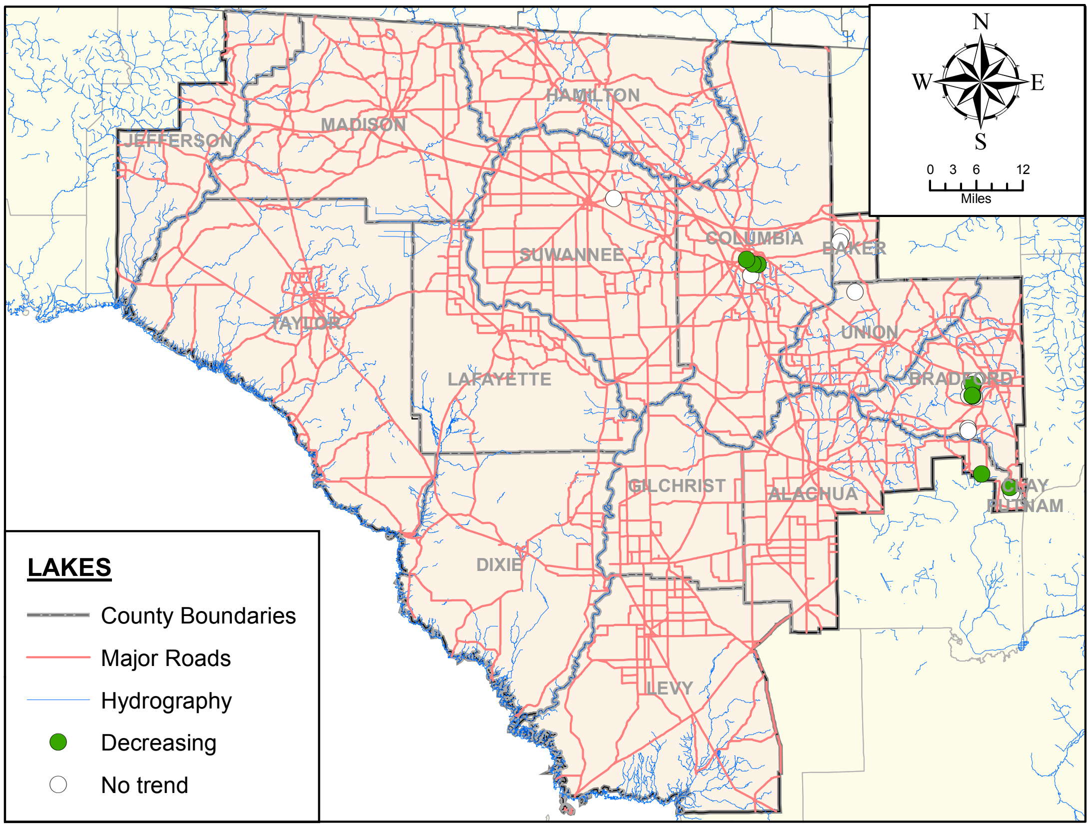

Figure 10 - Trends in nitrate concentrations at WARN sample stations in lakes.

Lakes – The District has sampled 26 lake stations for water quality in the 1998-2007 time period. Figure 10 depicts the locations of sampling stations and trends in nitrate concentrations identified at the lake stations. None of the lake station data exhibited statistically significant, increasing nitrate trends and 9 stations (66% of the sample set) showed decreasing trends.

Alligator Lake (ALL010C1) is an example (Figure 11) of a lake with a declining nitrate concentration trend. There was an apparent outlier (1.5 mg/L sample collected in November, 1990), that further skewed the trend and regression. This data point was removed to produce the figure and regression shown (Figure 11). The declining trend in nitrate concentrations is evident, as is a change in detection limits of the analytical method. Prior to 1993, the detection limit was 0.1 mg/L, as N, which resulted in the cluster of data points on the 0.1 mg/L line. By 1997, the detection limit had been lowered to 0.05 mg/L, as N, which resulted in the cluster of data points shown at the bottom of the graph from 2001 forward. Based on the R^2 value of the regression, the regression line shown in Figure 11 accounts for approximately 29 percent of the data variability.

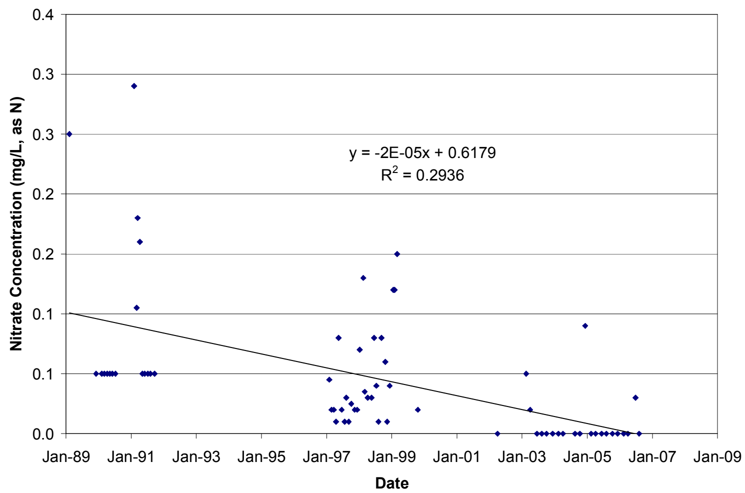

Figure 11 - Nitrate concentrations in Alligator Lake (Station ALL010C1), Columbia County, from 1989 to 2007. A data outlier (1.5 mg/L from November, 1990) has been removed from the chart and regression.

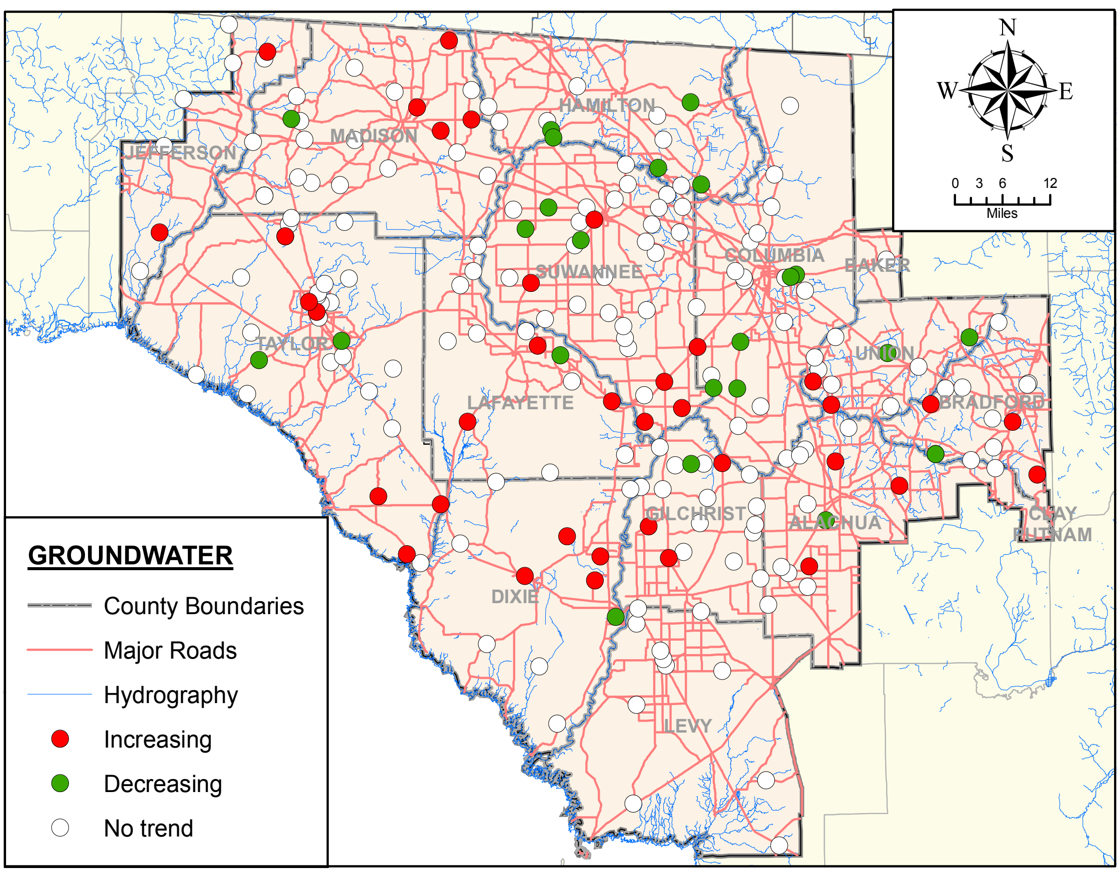

Figure 12 - Locations of and ground-water-quality trends detected in wells of the WARN.

Ground-Water Systems - Figure 12 illustrates the locations of wells in the WARN, including Status and Trend Networks. As noted above, both networks were initiated at the same time (2000) and they were monitored until 2006. Therefore, for this interval only, the two networks can be combined. The Status Network has been re-randomized and it incorporates new wells, so future reports will have to separate the two networks because of the different time frames of sampling.

Figure 12 also depicts the statistically significant trends in data from the ground-water monitoring (Appendix B). Green dots indicate decreasing nitrate concentrations over time and red dots indicate increasing nitrate concentrations. Well locations with colorless dots are locations where there was no significant trend. Sen's slope evaluation indicates that there are weak changes in nitrate concentrations at many of

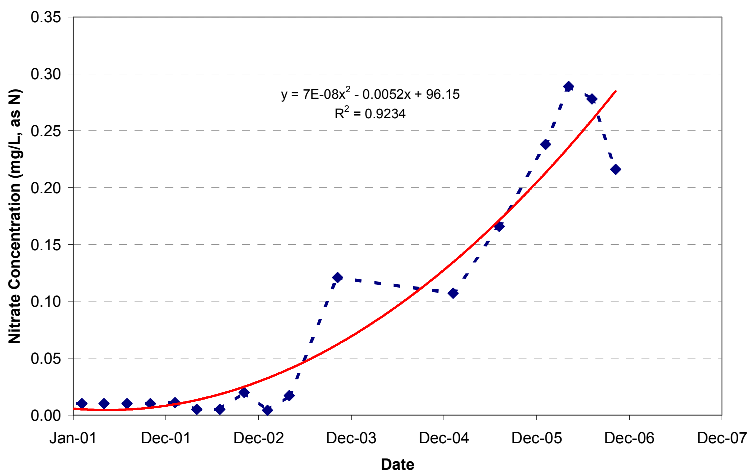

Figure 13 – Data from Well -021322008 showing a statistically significant positive trend in nitrate concentrations.

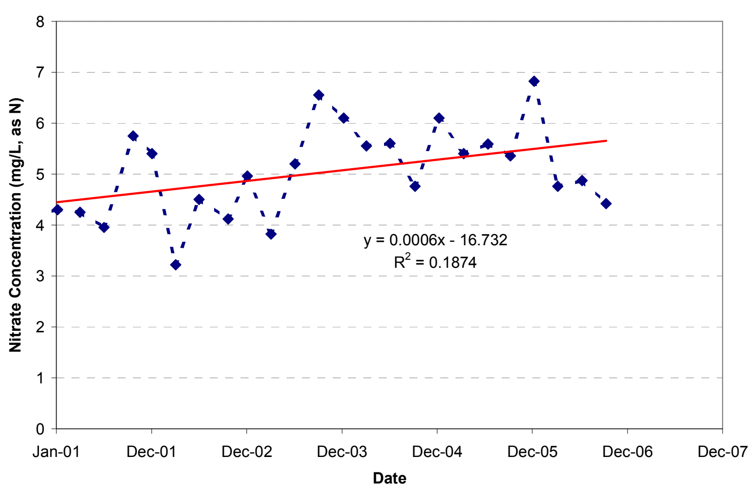

Figure 14 – Data from Well -081434001 illustrating a statistically significant, positive trend in high nitrate concentrations.

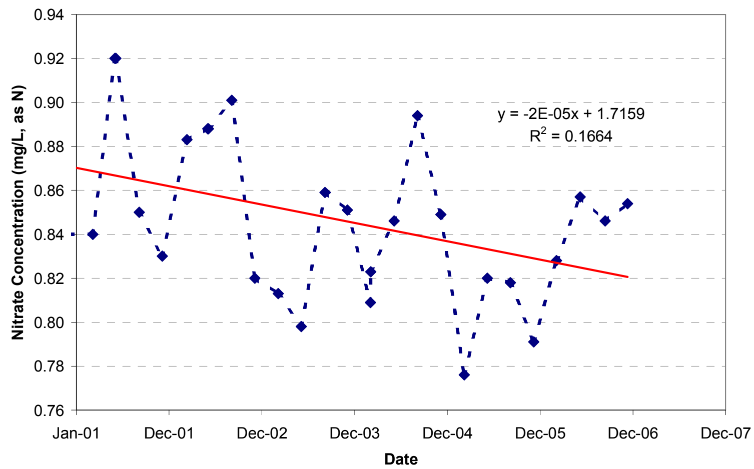

Figure 15 – Declining trend in nitrate concentrations at a well (Well -061607001) with low initial concentrations.

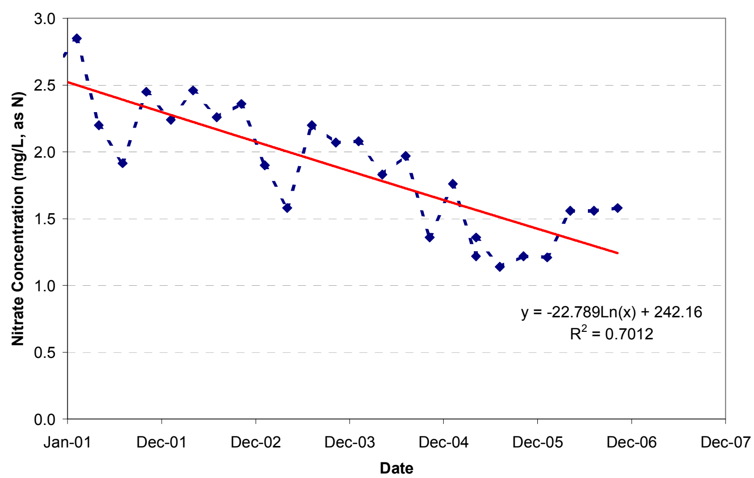

Figure 16 – Trend in declining nitrate concentrations at Well -021231001. Nitrate concentrations in water from this well are relatively high.

these locations. With additional time and monitoring, these changes may become significant.

All totaled, there are 199 wells with sufficient data to evaluate. Of these, 37 (19 percent of the data set) indicate significant positive trends and 23 (12 percent) have negative trends. A positive trend indicates that nitrate concentrations are increasing through time and a negative trend indicated decreasing nitrate concentrations.

Comparison of Figure 12 with the Floridan aquifer confinement map (Figure 4) shows little correspondence of the locations where a trend exists with degree of confinement. Wells located in highly confined areas typically show negative (decreasing) or no trends. Areas where the aquifer is semi-confined or unconfined and, therefore vulnerable also contain locations where statistically significant, decreasing trends exist, as well as areas where there is no trend. The locations where increasing nitrate trends were detected also occur where semi–confined to unconfined conditions exist (Figure 4). The facts that (1) decreasing trends have been documented and (2) many areas show no trend appear to suggest that reduction in nitrate loading has some affect on ground-water quality.

Figure 13 is an example of data from a well that contains water with relatively low nitrate concentrations. Figure 14 illustrates data from a well with heavily impacted water quality, as indicated by the high nitrate concentrations. Both have time trends that are significant and positive. The variability in nitrate concentrations in Well - 081434001 (Figure 14) with time is suggestive of responses to wet and dry seasons.

Figures 15 and 16 illustrate examples of wells where water quality improved over time. These data also show variability that reflects seasonal and year-to-year rainfall and recharge patterns.

The fact that all of these examples depict apparent seasonal and annual variations in nitrate concentrations speaks to two factors. First, the wells are located in areas where rainfall and recharge can affect nitrate concentrations. Therefore, they are in regions where the Floridan aquifer is semi- to unconfined and vulnerable to contamination. Second, response to rainfall is a result of year-to-year differences in nutrient loading, such as fertilizer use, and leaching and flushing of nitrogen compounds into the ground-water system from soils.

Summary and Conclusions

This is the first to report on trends in nitrate concentrations of the surface- and ground-water in the District based on data collected as part of the WARN (Water Assessment Regional Network). The purposes of the WARN data collection effort are to

- Track changes in water quality concurrent with efforts to reduce nitrate loading and
- Identify areas where problems relating to water quality are emerging.

The WARN began operation in 2000; the same time that members of the Suwannee River Partnership began efforts to reduce nitrogen loading and contamination in area rivers and springs.

Not all participants in the District's efforts began nitrogen loading reductions at the beginning of the effort in 2000. Efforts have been increasing with time as a result of identification of new participants, development of BMPs, construction of infrastructure for fertilizer and waste management, and growing awareness of the need to reduce nitrogen loading. As a result, one would not expect that trends of declining nitrate concentrations would begin instantly in 2000. Rather, some areas would be expected to show early on-set of nitrate concentration reductions while others may not yet show improvement.

Similarly, the 2000 to 2007 time period included major droughts in 2000-2001 and again in 2006-2007. The middle period (2002-2005) exhibited near-normal to moderately high rainfall. Therefore, the monitoring interval does not reflect the range of climatic events that are expected to occur through time within the District.

Finally, the work of Katz and others (1999) clearly indicates that there is a delay between nutrient loading events on the land surface and arrival of the affected water at area springs. In fact, it is likely that decades may be required to achieve significant reductions in nitrate contamination in springs and their receiving waters (rivers and streams) given the nature of the ground-water flow systems. Changes in nitrogen-compound use and loading near the springs may have a rapid effect on nitrate concentrations in the springs, but changes that are distant from the spring will require many years for their effects to be realized.

This analysis demonstrates that a trend study five or six years after a nitrogen-loading reduction program began is not likely to definitively prove proof of the effectiveness of the measures taken to reduce nitrogen loading. In order to document the outcome of the nitrogen loading reduction effort, many years of monitoring will be required. To rush to any conclusion as to whether the nitrogen-reduction program is working or not is premature.

There is, however, some positive evidence in this early data analysis. First, many of the sampled surface- and ground-water sites show an absence of statistically significant trends. It is unclear if the lack of trends means that increasing nitrate concentrations existed at these sites prior to on-set of monitoring and that this trend has been arrested, or not. We do know that the over-all pattern since monitoring began in the 1970s has been for nitrate concentrations to rise and the areas affected by elevated nitrate concentration to increase. It will be instructive to determine if additional or stronger trends develop over the next five years.

Second, there are locations where statistically significant increases and decreases in nitrate concentrations exist in both ground- and surface-water bodies. Many of the significant trends can be explained by ground-water/surface-water interactions, springshed sizes, and other physical processes. For example, negative trends were identified in some smaller springs, which suggest that the shorter flow paths and residence times of water in these springsheds allow for more rapid changes in response to climate, nitrate loading and/or other factors. Variability in nitrate data in ground water, streams, and other media also appear to reflect climatic variability. Other trends cannot be readily explained, especially with respect to ground-water quality. The areas where patterns are not discernable may well reflect local successes, failures, or slow responses of the system to nutrient loading reductions.

Variability in the data suggest that nitrate concentrations in all media respond to changes in rainfall, recharge, flow, and other hydrologic factors. Sampling should continue through enough time to incorporate sufficient climatic variability that the trend analysis can account for any effects of these hydrologic events.

While the results of this trend analysis are mixed, there are indications that positive outcomes are emerging. It is strongly recommended that monitoring of the WARN continue at the design locations and with the same sampling intervals for at least another five years. This will allow the data to include more climatic variability, perhaps detect delayed responses to use of BMPs and other nutrient loading techniques, and account for some of the delays resulting from slow ground-water transport rates.

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Appendices

The following appendices present the site names, Pearson product-moment correlation coefficients of a linear regression of nitrate concentration versus time, the alpha level of the regression, and the number of samples for each water body. Rows that are highlighted in yellow represent statistically significant ($\alpha \leq 0.10$) correlations.

The sign of the correlation coefficient (+ or -) indicates whether the best fit regression line has a positive (+) or negative (-) slope. A positive slope suggests a trend of increasing nitrate concentrations with time. A negative slope suggests a trend of declining nitrate concentrations with time.

The value of the correlation coefficient ranges from -1.0 to 0 to +1.0. Coefficients of +1 or -1 indicate that all of the data points fell on the line and variation in the data is completely accounted for by the line. A coefficient near 0 indicates that the line does not fit the data, that there is no trend in the data, and that there is no simple relationship of nitrate concentrations with time.

The square of the correlation coefficient (r) is R^2, which is a measure of goodness of fit of the line to the data. The R^2 value, which as discussed in the body of the report, can be used to consider the ability of the best-fit line to reproduce the data. Therefore, a R^2 value of 0.5 means that about half of the variation in the data can be accounted for by the line and about half is variability that falls off the line and is not accounted for.

The number of samples (n) is important because it indicates the number of data points used to determine whether a trend exists or not. The more data used in the regression, the stronger the conclusions as to the presence of a trend. For example, cases where there are only 2 data points always define a line, but the n value is so low that significance cannot be established. When n is large and a trend can be detected, great confidence can be placed in the trend.

Appendix A

LISTING OF SURFACE-WATER MONITORING SITES WITH PEARSON PRODUCT-MOMENT CORRELATION DATA

(Rows highlighted in yellow represent statistically significant ($\alpha \leq 0.10$) correlations)

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Lakes				
Alligator Lake, N. Lobe	ALL010C1	-0.326	0.007	68
Alligator Lake, N. Lobe	ALL020C1	-0.358	0.001	79
Alligator Lake, S. Lobe	ALL030C1	-0.155	0.125	100
Lake Altho	ALT001C1	-0.951	0.200	3
Lake Altho at Waldo	ALT010C1	-0.342	0.036	38
Lake Butler	BUT001C1	-0.996	0.058	3
Lake Crosby	CRS001C1	0.533	0.642	3
Lake Crosby	CRS005C1	-0.403	0.597	4
Lake Crosby	CRS010C1	-0.288	0.080	38
Lake Crosby	CRS015C1	-0.896	0.104	4
Lake Hampton	HAM001C1	-0.943	0.216	3
Hampton Lake	HMP010C1	-0.208	0.211	38
Little Lake Santa Fe	LLS010C1	-0.354	0.029	38
Lake Santa Fe	LSF001C1	-0.963	0.174	3
Santa Fe Lake nr. Keystone Heights	LSF010C1	-0.309	0.056	39
Lake Sampson	LSM001C1	-0.909	0.274	3
Lake Sampson	LSM005C1	-0.006	0.994	4
Lake Sampson	LSM010C1	-0.359	0.029	37
Lake Sampson	LSM015C1	0.199	0.801	4
Lake Sampson	LSM025C1	0.404	0.596	4
Lake Sampson	LSM035C1	-0.633	0.367	4
Lake Montgomery	MON001C1	-0.994	0.072	3
Ocean Pond	OCP001C1	-0.129	0.918	3
Ocean Pond at Olustee	OCP010C1	-0.714	0.286	4
Lake Palestine	PAL001C1	-0.952	0.198	3

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Lakes (cont.)				
Lake Rowell	ROW001C1	-0.996	0.060	3
Lake Rowell nr. Alligator Creek	ROW005C1	-0.495	0.505	4
Lake Rowell	ROW010C1	-0.331	0.043	38
Lake Rowell nr. Outfall	ROW025C1	-0.585	0.415	4
Suwannee Lake	SWL001C1	-0.979	0.131	3
Springs				
Unnamed Spring	ALA112971	-0.195	0.340	26
Unnamed Spring	ALA930971	-0.999	0.029	3
Alapaha Rise	ALR010C1	0.155	0.404	31
Allen Mill Pond	AMP010C1	0.475	0.140	11
Anderson Spring	ANS010C1	-0.915	0.029	5
Betty Springs	BET010C1	0.776	0.434	3
Madison Blue Spring	BLM010C1	0.474	0.000	51
Gilchrist Blue Spring	BLU010C1	0.286	0.004	98
Branford Spring	BRA010C1	0.609	0.147	7
Bath Tub Springs	BTS010C1	0.994	0.071	3
Charles Spring	CHS010C1	0.150	0.580	16
Columbia Springs	COL010C1	-0.016	0.939	26
Unnamed Spring	COL61981	0.263	0.262	20
Convict Spring	CON010C1	0.105	0.602	27
Devils Ear Spring	DER010C1	-0.894	0.106	4
Dogwood Spring	DOG010C1	0.739	0.471	3
Ellaville Springs	ELL010C1	1.000	0.018	3
Falmouth Springs	FAM010C1	-0.109	0.510	39
Fanning Springs	FAN010C1	0.602	0.000	99

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Springs (cont.)				
Unnamed Spring	GIL917971	0.471	0.529	4
Ginnie Springs	GIN010C1	-0.416	0.039	25
Guaranto Spring	GUA010C1	-0.766	0.045	7
Hart Springs	HAR010C1	0.119	0.524	31
Hornsby Spring	HOR010C1	-0.403	0.000	111
Ichetucknee Head Spring	ICH001C1	0.327	0.096	27
Blue Hole Spring	ICH002C1	-0.158	0.461	24
Mission Spring	ICH003C1	-0.201	0.357	23
Devils Eye Spring	ICH004C1	-0.334	0.110	24
Mill Pond Spring	ICH005C1	-0.307	0.144	24
Cedar Head Spring	ICH006C1	-0.921	0.000	12
Grassy Hole Spring	ICH007C1	-0.719	0.008	12
Coffee Spring	ICH008C1	-0.650	0.022	12
July Spring	JUL010C1	-0.865	0.135	4
Unnamed Spring	LAF718971	-0.380	0.620	4
Unnamed Spring	LAF718972	-0.834	0.372	3
Unnamed Spring	LAF919972	-0.738	0.262	4
Unnamed Spring	LAF924971	-0.945	0.212	3
Lafayette Blue Springs	LBS010C1	0.425	0.000	80
Lilly Spring	LIL010C1	-0.977	0.023	4
Little River Springs	LRS010C1	-0.309	0.003	93
Manatee Springs	MAN010C1	0.658	0.000	98
Mearson Springs	MEA010C1	-0.202	0.529	12
Orange Grove Spring	ORG010C1	0.828	0.172	4
Owens Spring	OWN010C1	0.225	0.561	9

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Springs (cont.)				
Peacock Springs	PEA010C1	-0.056	0.843	15
Poe Springs	POE010C1	-0.515	0.000	97
Rock Bluff Spring	RKB010C1	0.310	0.003	92
Ruth Spring	RLS010C1	0.383	0.000	84
Royal Spring	ROY010C1	0.365	0.061	27
Rum Island Spring	RUM010C1	-1.000	0.012	3
Running Springs	RUN010C1	0.294	0.308	14
Suwannee Blue Spring	SBL010C1	0.057	0.605	85
Suwannee Springs	SSS010C1	-0.777	0.000	23
Steinhatchee Spring	STN015C1	-0.287	0.195	22
Sunbeam Springs	SUB010C1	-0.585	0.602	3
Unnamed Spring	SUW718971	-0.121	0.366	58
Unnamed Spring	SUW725971	-0.706	0.050	8
Unnamed Spring	SUW919971	0.170	0.830	4
Telford Spring	TEL010C1	0.407	0.000	95
Trail Spring Group	TRA010C1	0.602	0.014	16
Troy Springs	TRY010C1	0.274	0.007	97
Turtle Spring	TUR010C1	-0.489	0.266	7
Wacissa Head Spring	WAS100C1	0.995	0.065	3
Big Spring, Wacissa River	WAS101C1	-1.000	0.019	3
Cassida Spring	WAS104C1	-0.528	0.646	3
Wekiva Springs, Levy County	WEK100C1	-0.017	0.989	3
White Springs	WHS010C1	0.476	0.524	4
Karst window, Peacock Springs S.P.	WIN010C1	-0.711	0.497	3

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Rivers and Streams				
Alapaha River, Jennings	ALA010C1	0.274	0.000	210
Alligator Creek, US 301	ALC002C1	-0.717	0.283	4
Alligator Creek at Lake Rowell	ALC005C1	0.302	0.698	4
Alligator Creek	ALC010C1	0.017	0.921	36
Aucilla River at US27	AUC050C1	-0.250	0.009	108
Aucilla River at US98	AUC100C1	0.339	0.144	20
Cannon Creek	CAN010C1	0.140	0.487	27
Camp Branch	CMP010C1	-0.041	0.657	120
Deep Creek	DEP010C1	-0.313	0.001	105
Cow Creek	DSF003C1	-0.206	0.227	36
Pareners Branch	DSF028C1	0.001	0.996	35
Rocky Creek	DSF901C1	0.636	0.175	6
Bethel Creek	DSU008C1	0.000	1.000	6
Little Suwannee Creek, Georgia	DSU010C1	-0.646	0.166	6
Little Creek	DSU031C1	0.385	0.452	6
Sugar Creek	DSU035C1	-0.809	0.051	6
Econfina River at US27	ECN005C1	0.253	0.282	20
Econfina River nr Perry	ECN010C1	-0.495	0.000	112
Econfina River at US98	ECN015C1	0.478	0.033	20
Falling Creek at C-250	FAL010C1	-0.123	0.675	14
Falling Creek at Double Run Rd.	FAL015C1	0.165	0.514	18
Falling Creek at C-131	FAL020C1	-0.211	0.125	54
Fenholloway River nr. US27	FEN010C1	-0.082	0.533	60
Fenholloway River at US27	FEN020C1	-0.070	0.600	58
Fenholloway River below Spring Creek	FEN030C1	0.074	0.562	64

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Rivers and Streams (cont.)				
Hunter Creek	HNT010C1	-0.255	0.003	139
Hamilton Turpentine Creek nr. Gov. Cabin	HTC010C1	-0.778	0.222	4
Hamilton Turpentine Creek at sinkhole	HTS010C1	-0.988	0.012	4
Ichetucknee River N. of bridge	ICH010C1	-0.080	0.260	199
Jerry Branch	JER010C1	-0.616	0.193	6
Little River at C-137	LRP010C1	-0.832	0.374	3
Little River at C-252	LRP020C1	0.000	1.000	3
Little River at C-49	LRP030C1	0.000	1.000	3
Little River at Mt. Pisgah Rd.	LRP050C1	0.000	1.000	3
New River at SR-125	NEW007C1	-0.631	0.000	99
New River at SR-229	NEW008C1	-0.293	0.020	63
New River at SR-100	NEW009C1	-0.258	0.005	117
New River nr. Worthington Springs	NEW010C1	0.099	0.313	105
Cane Creek	OKE010C1	0.183	0.591	11
Suwannee Creek	OKE020C1	0.052	0.860	14
Gum Slough	OKE030C1	-0.047	0.836	22
Suwannee Sill	OKE040C1	0.235	0.281	23
Olustee Creek ar SR-18	OLS010C1	-0.349	0.000	137
Price Creek	PRI010C1	0.033	0.924	11
Price Creek	PRI050C1	-0.208	0.131	54
Robinson Branch	ROB010C1	-0.143	0.135	111
Rocky Creek	ROK010C1	-0.393	0.000	128
Roaring Creek	ROR010C1	-0.554	0.000	104
Rose Creek sinkhole	ROS010C1	-0.820	0.180	4
Santa Fe River at US-301	SFR005C1	0.663	0.151	6

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Rivers and Streams (cont.)				
Santa Fe River nr. Graham	SFR010C1	-0.169	0.285	42
Santa Fe River at SR-231	SFR020C1	0.076	0.279	206
Santa Fe River at Worthington Springs	SFR030C1	0.014	0.843	209
Santa Fe River at O'Leno	SFR040C1	-0.127	0.067	210
Santa Fe River at US-441	SFR050C1	-0.044	0.522	210
Santa Fe River at SR-47	SFR060C1	0.006	0.932	210
Santa Fe River at US-27	SFR070C1	0.160	0.020	210
Sampson River at CR-18	SMR010C1	0.062	0.429	165
Steinhatchee River at Bee Pond	STN010C1	0.182	0.318	32
Steinhatchee River nr. Steinhatchee	STN020C1	-0.094	0.326	110
Steinhatchee River nr. Cross City	STN030C1	-0.364	0.000	102
Steinhatchee River above Steinhatchee Falls	STN031C1	-0.512	0.000	127
Steinhatchee River at Steinhatchee	STN040C1	-0.404	0.000	83
Steinhatchee River mouth	STN050C1	-0.929	0.071	4
Suwannee River at SR-6	SUW010C1	-0.359	0.000	210
Suwannee River below Hunter Creek	SUW020C1	-0.342	0.041	36
Suwannee River above White Springs	SUW030C1	-0.333	0.041	38
Suwannee River at US-41	SUW040C1	-0.356	0.000	209
Suwannee River above Swift creek	SUW050C1	-0.301	0.070	37
Suwannee River nr. I-75	SUW060C1	-0.365	0.026	37
Suwannee River at Suwannee Springs	SUW070C1	-0.253	0.000	210
Suwannee River above Alapaha Rise	SUW080C1	-0.095	0.571	38
Suwannee River below Alapaha River	SUW085C1	0.277	0.076	42
Suwannee River above Withlacoochee River	SUW090C1	-0.020	0.827	121

Water Body	Site Name	Correlation Coefficient	Alpha (α) Level	Number of Samples
Rivers and Streams (cont.)				
Suwannee River at Ellaville	SUW100C1	0.012	0.861	210
Suwannee River below Goldkist Discharge	SUW110C1	-0.149	0.379	37
Suwannee River at Dowling Park	SUW120C1	0.141	0.041	210
Suwannee River at Luraville	SUW130C1	0.126	0.068	209
Suwannee River at Branford	SUW140C1	0.208	0.003	210
Suwannee River nr. Rock Bluff	SUW150C1	0.200	0.004	210
Suwannee River nr. Wilcox	SUW160C1	0.145	0.036	209
Suwannee River at Fowler Bluff	SUW240C1	0.224	0.001	210
Suwannee River at Gopher River	SUW275C1	0.245	0.001	178
Swift Creek	SWF010C1	-0.190	0.006	205
Tenmile Creek	TEN010C1	-0.226	0.311	22
Waccasassa River at SR-24	WAC005C1	0.776	0.224	4
Waccasassa River	WAC006C1	-0.720	0.280	4
Waccasassa River at SR-326	WAC010C1	-0.216	0.015	126
Wacissa River nr. Wacissa	WAS010C1	-0.384	0.000	96
Withlacoochee River at C-145	WIT010C1	0.075	0.278	210
Withlacoochee River nr. Pinetta	WIT020C1	-0.012	0.902	118
Withlacoochee River at SR-6	WIT030C1	-0.181	0.276	38
Withlacoochee River above Suwannee River	WIT040C1	0.042	0.589	172

Appendix B

LISTING OF GROUND-WATER MONITORING SITES WITH PEARSON PRODUCT-MOMENT CORRELATION DATA

(Rows highlighted in yellow represent statistically significant ($\alpha \leq 0.10$) correlations)

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-101336025	-0.712	0.001	19
-101303003	0.521	0.032	17
-91736001	0.370	0.069	25
-91733001	0.660	0.225	5
-91628005	0.275	0.204	23
-91611003	0.807	0.193	4
-91602005	0.160	0.797	5
-91530005	0.638	0.001	25
-91520003	-0.900	0.287	3
-91323001	0.498	0.026	20
-91231001	0.692	0.018	11
-91212003	0.662	0.007	15
-91011004	0.311	0.170	21
-90925014	-0.327	0.673	4
-90922003	0.882	0.048	5
-82202001	0.664	0.013	13
-82102001	0.734	0.158	5
-81912004	0.672	0.000	25
-81833003	-0.671	0.000	25
-81724001	0.589	0.296	5
-81624004	0.043	0.837	25
-81513001	-0.330	0.670	4
-81434001	0.433	0.031	25

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-81412001	0.349	0.186	16
-81409005	-0.038	0.861	24
-81408009	-0.639	0.361	4
-81104001	-0.106	0.895	4
-81016006	0.821	0.089	5
-80907003	0.587	0.011	18
-72205001	0.589	0.027	14
-72132001	-0.488	0.676	3
-72123006	-0.924	0.251	3
-72022002	-0.894	0.296	3
-72022001	-0.923	0.077	4
-71827009	0.452	0.068	17
-71801001	-0.006	0.994	4
-71727002	-0.869	0.330	3
-71724007	0.217	0.286	26
-71723003	0.250	0.219	26
-71635001	-0.777	0.122	5
-71630002	0.514	0.017	21
-71529002	0.160	0.454	24
-71528002	-0.946	0.054	4
-71526002	0.278	0.650	5

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-71419006	-0.015	0.991	3
-71413002	0.014	0.976	7
-71234001	0.288	0.279	16
-62210009	0.620	0.380	4
-62210002	-0.918	0.260	3
-62135004	0.513	0.377	5
-62118005	0.898	0.290	3
-62021004	0.923	0.077	4
-62014001	0.419	0.581	4
-61923002	0.746	0.148	5
-61821007	0.999	0.032	3
-61809003	-0.801	0.199	4
-61806003	0.756	0.082	6
-61634003	0.480	0.520	4
-61624001	0.587	0.298	5
-61610001	-0.620	0.032	12
-61607001	-0.408	0.031	28
-61521005	0.783	0.000	25
-61434006	0.573	0.065	11
-61410001	0.642	0.358	4
-61401003	0.686	0.000	26
-61313006	0.472	0.075	15
-61025003	0.566	0.018	17

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-60933001	-0.918	0.260	3
-60801001	-0.208	0.737	5
-60608001	-0.886	0.308	3
-52108003	-0.855	0.065	5
-52101001	-0.911	0.270	3
-52032004	-0.854	0.348	3
-51922001	-0.695	0.018	11
-51832002	0.402	0.429	6
-51819002	0.407	0.496	5
-51810004	-0.940	0.222	3
-51610006	-0.365	0.079	24
-51536001	0.510	0.490	4
-51511002	0.715	0.000	26
-51408002	-0.515	0.485	4
-51405002	0.040	0.848	25
-51331002	0.049	0.832	21
-51214008	-0.751	0.000	25
-51209001	0.664	0.000	25
-51004001	-0.887	0.113	4
-50928004	0.359	0.157	17
-50819002	0.935	0.231	3

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-50817001	-0.037	0.953	5
-50805006	-0.970	0.006	5
-50615002	-0.738	0.000	23
-50529001	-0.063	0.960	3
-41734002	-0.075	0.699	29
-41712004	0.322	0.597	5
-41523001	-0.606	0.279	5
-41431001	0.777	0.122	5
-41422011	0.410	0.494	5
-41324005	-0.770	0.128	5
-41317001	0.110	0.585	27
-41231002	-0.033	0.874	25
-41227001	-0.014	0.946	25
-41131002	0.394	0.511	5
-40807010	-0.298	0.626	5
-40723014	-0.685	0.315	4
-40723011	0.514	0.060	14
-40712013	-0.221	0.779	4
-40711006	0.626	0.570	3
-40710011	0.899	0.015	6
-40702007	0.625	0.375	4
-31923004	-0.219	0.493	12
-31735009	-0.917	0.084	4

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-31734029	0.003	0.998	3
-31734011	-0.639	0.019	13
-31635028	-0.820	0.388	3
-31634020	0.677	0.209	5
-31628004	0.060	0.940	4
-31611001	-0.926	0.247	3
-31413001	0.544	0.456	4
-31403007	0.333	0.667	4
-31335002	0.044	0.832	26
-31307004	0.310	0.612	5
-31305005	-0.682	0.000	25
-31232002	0.521	0.004	29
-31135002	0.121	0.846	5
-31130004	0.782	0.118	5
-31107004	0.553	0.448	4
-31035001	0.336	0.137	21
-30736008	-0.116	0.884	4
-30629002	-0.127	0.919	3
-30419001	0.613	0.580	3
-21717009	-0.875	0.321	3
-21636001	-0.876	0.321	3

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-21533004	0.897	0.292	3
-21516003	-0.911	0.271	3
-21507001	-0.859	0.342	3
-21507001	0.271	0.248	20
-21504001	-0.171	0.784	5
-21426004	0.757	0.243	4
-21413001	-0.876	0.320	3
-21329016	-0.058	0.942	4
-21322008	0.923	0.000	18
-21316001	0.658	0.228	5
-21312012	-0.886	0.114	4
-21231001	-0.837	0.000	26
-21215001	-0.703	0.000	26
-21113001	-0.366	0.544	5
-20828002	0.864	0.136	4
-20731003	-0.760	0.136	5
-20731002	0.468	0.067	16
-20729001	-0.111	0.929	3
-20720003	-0.265	0.829	3
-20603003	-0.555	0.445	4
-20603002	-0.682	0.136	6
-20603001	0.924	0.250	3
-20433001	0.823	0.000	16

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
-11729002	-0.905	0.280	3
-11535004	-0.761	0.004	12
-11506001	-0.874	0.323	3
-11432004	0.574	0.611	3
-11424003	-0.999	0.031	3
-11420006	0.311	0.224	17
-11129001	-0.322	0.101	27
-11011002	0.174	0.417	24
-10920002	-0.125	0.599	20
-10832002	0.060	0.923	5
-10734003	-0.701	0.506	3
-10729001	0.225	0.280	25
-10604003	0.720	0.280	4
-10403005	-0.180	0.772	5
-8153500	0.637	0.026	12
-4063300	0.317	0.683	4
10401003	-0.356	0.556	5
10704001	-0.031	0.917	14
10720006	-0.921	0.026	5
10721014	0.333	0.584	5
10733003	-0.079	0.764	17

Site ID	Correlation Coefficient	Alpha (α) Level	Number of Samples
10834001	0.418	0.582	4
10904001	0.076	0.887	6
10912001	0.851	0.015	7
11028003	0.677	0.000	27
11109001	-0.681	0.136	6
11119004	0.975	0.001	6
11122002	-0.193	0.346	26
11222001	-0.642	0.243	5
11226001	-0.934	0.020	5
11235006	-0.919	0.081	4
11424011	0.752	0.249	4
11510003	-0.885	0.002	9
11714002	-0.467	0.173	10
20611002	0.358	0.072	26
20611005	0.440	0.710	3
20618002	-0.589	0.296	5
20822002	-0.210	0.419	17
21036001	0.025	0.899	29
21332004	-0.198	0.403	20
30524002	0.501	0.312	6
31034003	0.770	0.000	25