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Declining nitrogen (primarily nitrate) concentrations in the Upper Floridan aquifer within the Santa Fe River Basin, Florida (2014–2024)

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Abstract

Since the 1950s, land use applications of nitrogen have resulted in increased nitrate ($NO_3 + NO_2$ as N) concentrations in waters of the Santa Fe River Basin. In 2008, the Florida Department of Environmental Protection declared the waters impaired. A restoration plan was enacted to lower concentrations to a threshold of 0.35 mg/L and monitor restoration progress. For springs and surface water, nitrate-loading data are used for tracking. For groundwater nitrate concentrations are used. To assist the Department, Alachua County Environmental Protection Department, AquiferWatch, and Florida LAKEWATCH are now monitoring groundwater. The latter entities use volunteers to sample. Assessment of historical data in the basin indicates that nitrate is the predominate nitrogen species. Trend analysis revealed that on a decadal scale, since 2014 in the lower basin, nitrogen (mostly nitrate) levels decreased. Reductions are tied to increase rainfall and groundwater dilution but not necessarily to modifications in land use. Once informed of these findings, the Department adjusted its monitoring strategies to better track NO_3 loading changes and correlate them with changes in nitrate concentrations in groundwater and potentially other indicators. The actions will improve its ability to track restoration progress. Finally, volunteers obtained reliable data at reduced monitoring costs.

Introduction

Since the 1950s, there has been an increase in the sources of nonpoint-source nitrogen contributing to Florida's groundwater resources (Harrington et al. 2010; Spellman et al. 2022). The major nitrogen sources are from land use activities: (1) application of inorganic fertilizers, (2) animal wastes, especially large animal feeding operations (e.g. poultry and dairy farms), (3) domestic wastewater (e.g. spray fields, rapid infiltration basins), and (4) high density residential areas with septic tanks, and (5) atmospheric deposition. Excess nitrogen at land surface can migrate with

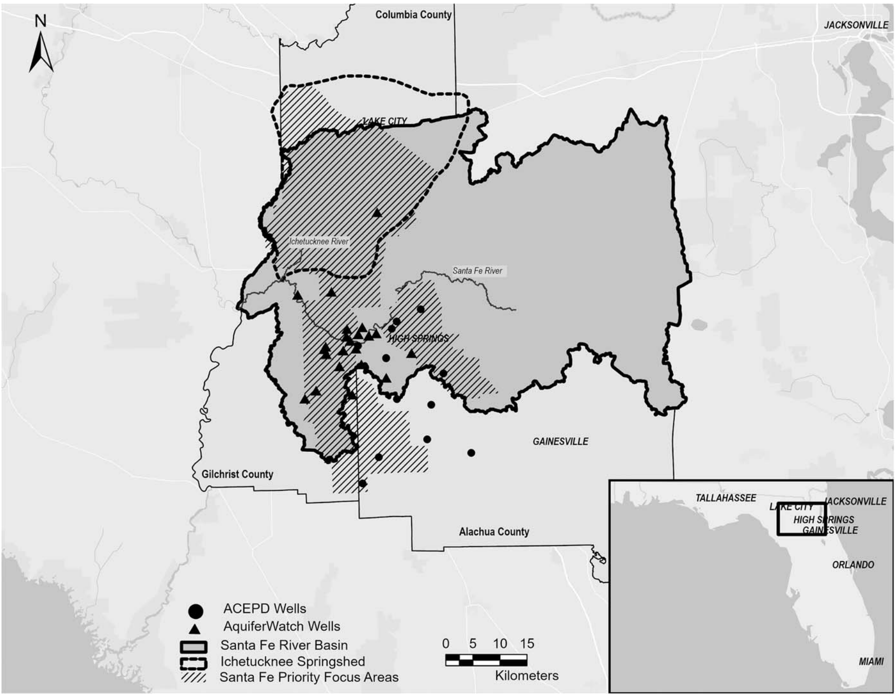

Figure 1. The Santa Fe River Basin.

rainwater into the soil. Once in the soil, nitrogen bonds with oxygen form nitrate (by analytical convention is expressed as $NO_3 + NO_2$ as N) through the chemical process of nitrification (Upchurch et al. 2019). Since nitrite is a minor constitute, for brevity, nitrate is abbreviated NO_3. With recharge, NO_3 enters underlying aquifers. Once it is in an aquifer, nitrate-rich groundwater flows downgradient and discharges directly into surface waterbodies, most notably into springs. Elevated NO_3 concentrations in spring runs are considered the most significant contributor to algal imbalance in spring runs (Harrington et al. 2010; Spellman et al. 2022). Under natural conditions, concentrations of NO_3 in Florida's aquifers are less than 0.05 mg/L (Upchurch 1992). By the early 1990s, the median nitrate concentrations in groundwater over much of Florida exceeded 1.00 mg/L (Harrington et al., 2010). By 2001, Harrington et al. noted that over 40% of Florida's major springs had NO_3 concentrations exceeding this level.

In 2008, the Florida Department of Environmental Protection (FDEP) declared the Santa Fe River Basin (SFRB) (Figure 1) impaired for NO_3 (Hallas and Magley 2008). Required basin management action plans (BMAPs) were then implemented by FDEP to restore water quality in the springs, surface water, and groundwater within the springsheds (FDEP 2012). The primary goal of the plan is to restore NO_3 concentrations to below a set threshold, which is 0.35 mg/L. Early restoration priorities included development of methods for reducing NO_3 loading and identification of priority focus areas (PFAs) (Figure 1). A PFA can represent an area most vulnerable to contamination or an area where the most NO_3-loading exists. It can also be an area where FDEP and other entities investigate NO_3-loading mitigation practices. If successful, similar practices can be implemented elsewhere.

Since the primary source of nitrogen is land use activities, and since groundwater discharges into spring runs and other surface water bodies, the BMAP stresses the need to monitor groundwater quality, along with NO_3-loading in spring runs and key surface water sites. During the first years of BMAP initiatives in the SFRB, monitoring efforts emphasized spring vents, the Santa Fe River, and wells in the PFAs, but not the entire springshed. Installation of new wells within the PFAs was occasionally required. For these reasons, it took years to fully implement an SFRB monitoring plan.

The monitoring of the impaired springsheds stretches the financial and personnel resources of FDEP. As such, the Department encourages monitoring entities to supply relevant data to the Watershed Information Network (WIN), a statewide repository of water quality data (FDEP 2025a). Groundwater data are not available in the WIN database prior to 2017 (FDEP 2025a). In response to the interest of FDEP, three entities have been monitoring NO_3 in groundwater within the SFRB: the Alachua County Environmental Department (ACEPD), (2) AquiferWatch (AW), and (3) Florida LAKEWATCH (LW). This study covers the period 2014 through 2024. Data obtained from 2017-2024 are available via the WIN database.

Regarding ACEPD, two of its goals are to protect and prevent pollution in its water resources (ACEPD 2025). AW is a 501(c3) volunteer groundwater monitoring organization. One of its goals is to involve volunteers in monitoring Florida's groundwater resources. LW is part of the School of Forests, Fisheries, and Geomatic Sciences, and the Institute of Food and Agricultural Sciences at the University of Florida. Two of its goals are to track long-term temporal water quality changes and bolster citizen science volunteer participation in management of aquatic systems (Florida LAKEWATCH 2025a).

The purposes of this investigation are to determine if nitrate concentrations in groundwater in the SFRB changed during 2014-2024 and if citizen scientist can assist in monitoring. If changes occurred, what are the relationships with potential nitrate loading changes?

Hydrogeologic Overview

Three fresh-water aquifer systems (Southeastern Geological Society 1986) underly the SFRB (Figure 2). They are composed of sediments ranging in age from Paleogene to present (Scott 2016). The deepest is the Floridan aquifer system (FAS), primarily composed of limestone. It contains two major aquifers: the upper and lower Floridan aquifers. The Upper Floridan aquifer (UFA) is the source groundwater for most springs of Florida. Confining beds composed of relatively impermeable carbonates and gypsum separate the two aquifers. The Lower Floridan aquifer is not a major source of water within the SFRB.

Where it exists in the SFRB, the intermediate confining unit (ICU) is composed mostly of clay and silty clay (Figure 2). The ICU sediments overlie and confine the FAS in the eastern portion of the SFRB (Figure 2). Within the ICU there are

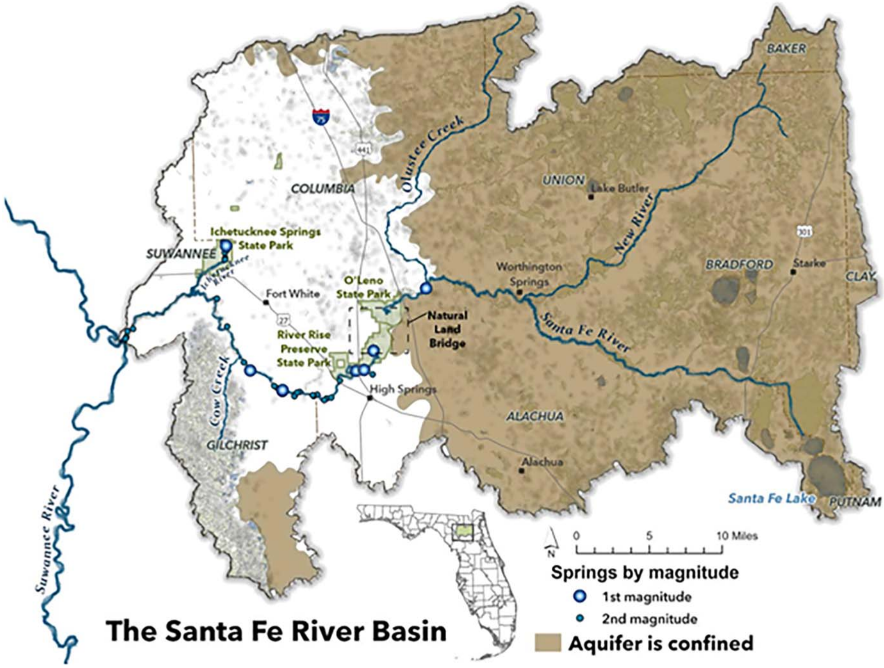

Figure 2. Upper Floridan aquifer confinement in Santa Fe River Basin (McKee, 2005).

occasional beds of sand and carbonates that are part of the intermediate aquifer system (IAS). Overlying the ICU is the surficial aquifer system (SAS). Present in the eastern region of the SFRB (Figure 2), it is composed mostly of quartz sand and clay.

In part of the western portion of the SFRB (Figure 2), clayey sediments of the ICU are incompletely eroded and only partially confine the UFA. An abundance of sinkholes and other karst features occur in this area. In Figure 2, note the Santa Fe River is captured by a swallet, travels underground several miles, and resurfaces at the Santa Fe Rise.

In the west-central portion of the SFRB (Figure 2), there is a sand veneer covering carbonate rocks of the unconfined UFA. The area comprising both the perforated and unconfined portions of the SFRB (Figure 2) is the Lower Santa Fe River Basin (HSW Engineering Inc 2021). The unconfined UFA is especially vulnerable to NO_3 contamination evidenced by concentrations often exceeding the 0.35 mg/L BMAP threshold. In the east, where the UFA is confined (Figure 2), NO_3 concentrations are often < 0.05 mg/L.

Methods

Quality Assurance. Groundwater collection procedures, along with field and laboratory analyses, are conducted in accordance with F.A.C. Chapter 62-160. For details regarding the ACEPD sampling and laboratory, contact the ACEPD (2025). AW has an in-house quality assurance plan, Prior to each sampling event, AW staff instructs volunteers on sampling procedures and the operation of field meters. AW staff calibrate meters at the beginning and end of each sampling day and divide volunteer samplers into AW-lead teams. Details regarding the Florida LAKEWATCH laboratory are available by contacting its scientific laboratory manager (Florida LAKEWATCH 2025b).

Statistical Analyses. Analyses were constructed in the packages of the R programing language platform (R Core Team 2024). R vignettes are often available to assist in understanding the commands. For TN trend analysis, the regional-Kendall (RK) test (Helsel and Frans 2006), was used. Each test was conducted in the rkt command in the rkt library in R. The Step-trend analyses used the Wilcoxon signed-rank (WSR) test (matched-pair, dependent data) discussed by Conover (1999). The test was conducted using the wilcox.test command in the standard stat library in R. For dependent data, the subcommand (paired = TRUE) is needed to initiate the WRS test. The null hypothesis (NH) is no change in slope for the RK and in the median value for the WSR tests.

For the RK test, each datum must be independent (Helsel and Frans 2006). The authors noted that the presence of either serial or spatial autocorrelation (AC) is an indication of data dependency. They also noted that both temporal and spatial AC can potentially affect the results of a hypothesis test by adversely lowering the resulting NH p-value. However, if there are 10 years or more of data, the RK test can make necessary adjustments.

For this study, if the resulting significant p-value of the statistical test is equal or less than a preset α level, an inference is made that the NH should be rejected and infers the existence of a trend. Most hypothesis tests use $\alpha = 0.05$. Wasserstein et al. (2019) stated that decisions based solely on a value of 0.05 should be used with caution. As a response, for this study a multiple set of threshold p-values were used: (A) ≤ 0.01 infers a very strong change, (B) > 0.01 to ≤ 0.05 infers a strong change, (C) > 0.05 to ≤ 0.10 infers a moderate change, and (D) > 0.10 indicates insufficient evidence of change. All reported p-values ≤ 0.10 are presented in **bold** font. In addition, final overall conclusions concerning changes in NO_3 concentrations within the SFRB were based on a series of tests, rather than just one.

Estimating NO_3 from total nitrogen (TN). ACEPD samples are generally analyzed by their laboratory for both NO_3 and TN, but occasionally only one is analyzed. Florida LAKEWATCH analyzes AW samples for TN but not NO_3. Nitrite is a minor constituent in groundwater from the UFA (Upchurch 1992). Thus, whenever a sample is analyzed for both analytes, the proportion of NO_3 to the total can be obtained by dividing NO_3 by TN. AW acquired NO_3 and TN data from the Generalized Water Information System (FDEP 2024), a groundwater and surface water database maintained by FDEP. From a search box within the western portion of the SFRB, 205 groundwater samples (data available from the contributing author) were retrieved from the upper Floridan aquifer, the principal aquifer for water supply and river discharge. Each sample was analyzed for both NO_3 and TN. Although the proportion of NO_3 to TN ranged from <0.01 to >0.99, the median ratio was 0.92. From ACEPD data, 148 groundwater samples had TN and NO_3. The median ratio of NO_3 to TN was 0.97. During one sampling event in May 2024, 16 AW samples were analyzed by a commercial laboratory for both analytes. The ratio was 0.74.

Table 1. Annual median total nitrogen and estimated NO_3 concentrations[1] (2014-2024).

Year	TN (AW)	Estimated NO_3 (AW)	TN (ACEPD)	Estimated NO_3 (ACEPD)
2014	0.66	0.49	0.99	0.96
2015	0.61	0.45	1.30	1.26
2016			1.60	1.55
2017	0.78	0.58	1.45	1.41
2018	0.75	0.56	1.40	1.36
2019	0.88	0.65	0.93	0.90
2020	0.60	0.44	0.90	0.87
2021	0.62	0.46	0.79	0.77
2022	0.65	0.48	0.88	0.85
2023	0.55	0.40	0.90	0.87
2024	0.53	0.39	0.70	0.68

[1] Concentrations in mg/L

The ratios (0.97 (ACEPD) and 0.74 for (AW)) were used to estimate annual median SFRB NO_3 concentrations by organization (Table 1).

Groundwater Monitoring in the Santa Fe River Basin for this project

The ACEPD has monitored groundwater since the late 1980s. The network currently consists of 12 wells (Figure 1) with sufficient data for trend analysis. Sampling occurs semi-annually, during the wet and dry seasons (typically in February and August). Sampling follows FDEP groundwater sampling protocols (Florida Statutes 2200). Samples are analyzed at a National Environmental Laboratory Analysis Conference certified laboratory (ACEPD 2025). Periodically, ACEPD secures grants from the Fish and Wildlife Foundation of Florida (2024) to fund extended sampling during select periods.

AW currently monitors 23 private drinking water wells on a semi-annual basis (wet and dry seasons) (Figure 1). Each AW well taps groundwater from the UFA. In 2021, AW began monitoring a separate set of wells within the Ichetucknee River springshed (Figure 1). However, at the current time, data from the 16 Ichetucknee wells are insufficient for data analysis. AW also conducts a community science water screening program for private well water users called *Is Your Water Well?* AW also cooperates closely with ACEPD, as well as LW.

In 2014 ACEPD obtained a grant (Wildlife Foundation of Florida 2024) to conduct two synoptic groundwater quality surveys within the SFRB (November 2014 and May 2015). ACEPD sampled and analyzed groundwater data, including NO_3, from 38 and 40 wells respectively. In addition, ACEPD sampled its permanent network of wells. During this time, AW agreed to collect samples from its network, while LW agreed to analyze the samples for TN. The grant ended in late 2015 and no samples were collected in 2016. In 2017 AW/LW re-initiated their monitoring activities and have continued their efforts ever since. A total of 23 AW wells currently have sufficient data for analyses. During this period ACEPD continued to monitor wells semiannually. Of the monitored wells, data from 12 were used for time-series analyses. Note ACEPD also conducted additional synoptic surveys in 2020-2021 and 2023-2024.

Table 2. Regional-kendall test results (2014-2024).

Data Sets	[4]n(w), [5]n(s)	RK Score	Var Score	Corrected p-value	Sen [6]Slope	Direction
ACEPD	12, 240	−284	11529	[2]0.011	−0.041	Down
AW	23, 506	−127	6236	0.111		
ACEPD and AW	35, 746	−411	21810	[1]0.005	−0.016	Down
AW (Alachua)	5, 110	−78	1604	[3]0.055	−0.015	Down
AW (Columbia)	8, 176	−116	2131	[2]0.013	−0.020	Down
AW (Gilchrist)	10, 220	67	1292	[3]0.067	0.005	Up

[1] Very strong trend (p-val <0.01), [2]Strong trend ($0.01 \geq$ p-value < 0.05),[3] Moderate trend ($0.05 \geq$ p-value < 0.10), [4](w) = Number of wells, [5]n(s) = number of samples, [6]Slope = mg/L/yr.

Analyses (2014-2024). TN data from the 12 ACEPD and 23 AW wells with sufficient data were used for time-series trend analysis. Table 2 displays the results of the RK tests. The Sen slope (Sen, 1968) and its direction is listed if the test indicated a trend. The corrected p-value is the p-value after adjustments were made by the RK test. For the ACEPD data (Row 2), the p-value was 0.011. Thus, TN concentrations in Alachua County trended strongly downward. The Sen slope was −0.041 mg/L/yr. For the AW data (Row 3) the p-value was 0.111, indicating insufficient evidence of a statistical trend. For the third test (Row 4), data from ACEPD and AW were combined (35 wells). The resulting p-value (0.005) indicated a very strong decrease in TN concentrations. The Sen Slope was −0.010 mg/L/yr. The remaining RK tests are restricted to AW wells in Alachua, Columbia, and Gilchrist Counties. TN concentrations decreased moderately in Alachua County (p-value = 0.055) and strongly in Columbia County (p-value = 0.013). Concentrations in Gilchrist County increased moderately (p-value = 0.067). Corresponding slopes were −0.015, −0.020, and 0.005 mg/L/yr, respectively.

Recall NO_3 is a proportion of TN. Thus, the changes in TN infer changes in NO_3.To visually evaluate basin-wide changes in NO_3 concentrations, Figure 3 displays estimated annual median NO_3 concentrations from 12 ACEPD wells for the period 2014-2024 and for the 23 AW wells in Alachua, Columbia, and Gilchrist Counties (FL) (Figure 1). There were net declines in both data sets over the 11-year period. Concentrations obtained from ACEPD wells were higher than those obtained from AW wells. The rate of decline in NO_3 was greater in ACEPD relative to AW wells.

Analyses (2017-2024). In BMAP groundwater monitoring efforts, FDEP does not use data older than 2017 from the WIN database (FDEP 2025a). The RK test cannot adjust for AC with less than 10 years of data. However, the WSR test is a matched-pair test. Thus, comparisons were made between median values in the Early (2017-2020) to the Late (L) (2021-2024) TN data sets. For each of the wells, the corresponding median matched-pair values of the four-year E period was compared to those of the four-year L period. Table 3 displays the results of the WSR tests. Note, the table only presents the direction of change if the p-value is <0.100.

For the ACEPD data (Row 2), there was a moderate downward change in TN concentrations (p-value = 0.077). For AW wells (Row 3), there is no statistical evidence of change (p-value = 0.111). For the combined ACEPD and AW data sets

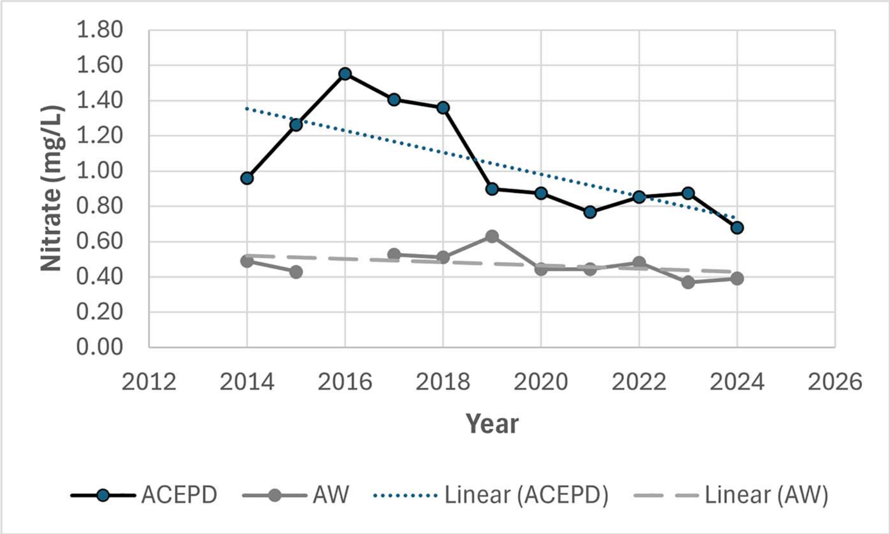

Figure 3. Estimated Annual Median (AM) Nitrate concentrations in samples from ACEPD and AW Wells (2014 – 2024). Estimated AM linear slope: ACEPD: AM = 126.41 – 0.06 * (Year), $R^2 = 0.49$, AW:AM = 22.48 – 0.01 * (Year), $R^2 = 0.19$.

(Row 4), the p-value (0.055) denotes a moderate downward change. Results from analysis of a combined set of AW data from Alachua and Columbia Counties (Row 5) indicate a strong downward change in TN concentrations (p-value = 0.038). Finally, data from AW wells in Gilchrist County (Row 6) provide no statistical evidence of change (p-value = 0.554). For the 2017-2024 data sets, comparison of the late to the early medians (Columns 3 and 4), signifies concentrations decreased in Alachua and Columbia Counties. There was no indication of change for Gilchrist County. Recall there was a moderate increase from 2014 through 2024 (Table 2).

Figure 4 displays boxplots of estimated NO_3 concentrations from the four groups of ACEPD and AW wells. The left two boxplots represent estimated concentrations from ACEPD wells during the E and L periods and the two right ones display analogous information for the AW wells. For each boxplot, the lower end of

Table 3. Results of wilcoxon sign-rank tests, comparing annual median tn concentrations during two periods (Concentrations in mg/L).

Data Sets	n	Median TN [7]E (2017-2020)	Median TN [8]L (2021-2024)	p-value	Direction
ACEPD ([4]Ala)	12	1.13	0.85	[3]0.077	Down
AW (Ala, [5]Col, [6]Gil)	23	1.01	0.76	0.111	
ACEPD and AW	35	0.77	0.56	[3]0.055	Down
AW (Ala, Col)	13	1.00	0.76	[2]0.038	Down
AW (Gil)	10	0.74	0.63	0.554	

[1] Very strong trend (p-value <0.01), [2]Strong trend (0.01 ≥ p-value < 0.05), [3]Moderate trend (0.05 ≥ p-value < 0.10), [4]Ala=Alachua [5]Col=Columbia, [6]Gil=Gilchrist, [7]E = Early, [8]L = Late.

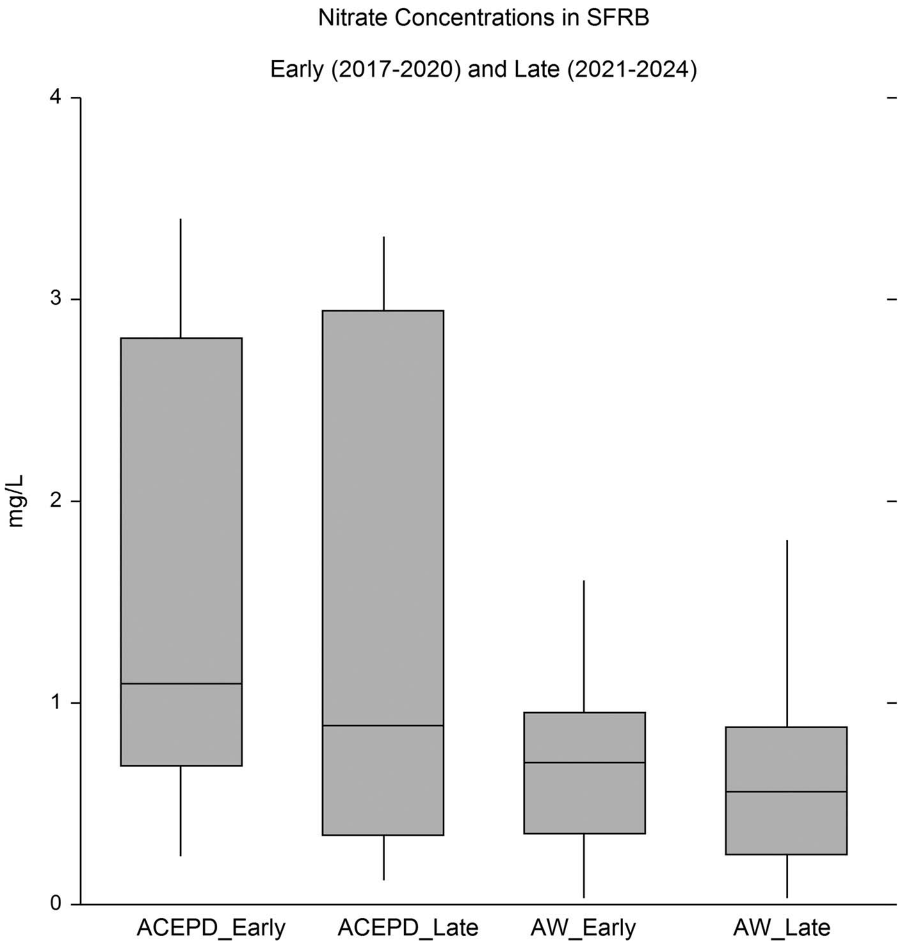

Figure 4. Estimated nitrate concentrations in samples from ACEPD from ACEPD and AW wells in early (2017-2020) and late (2021-2024).

the lower whisker represents the 5th percentile (P_{05}) of the corresponding data set. The upper end of the upper whisker represents the 95th percentile (P_{95}). The lower and upper horizontal bars of the boxes represent the P_{25} and P_{75} concentrations, respectively. The middle horizontal bars represent the median (P_{50}) values. To emphasize the differences in the medians, outliers (all upper) were not displayed. Concentrations were lower in the recent period for both the ACEPD and the AW wells.

Discussion

During the 2014-2024 and 2017-2024 time periods, trends in TN, along with estimated NO_3 concentrations in groundwater in the SFRB generally declined. There are at least two potential drivers of the NO_3 concentration change. Upchurch (1992), Katz et al. (1999), and Upchurch et al. (2019) stated that decreases in NO_3

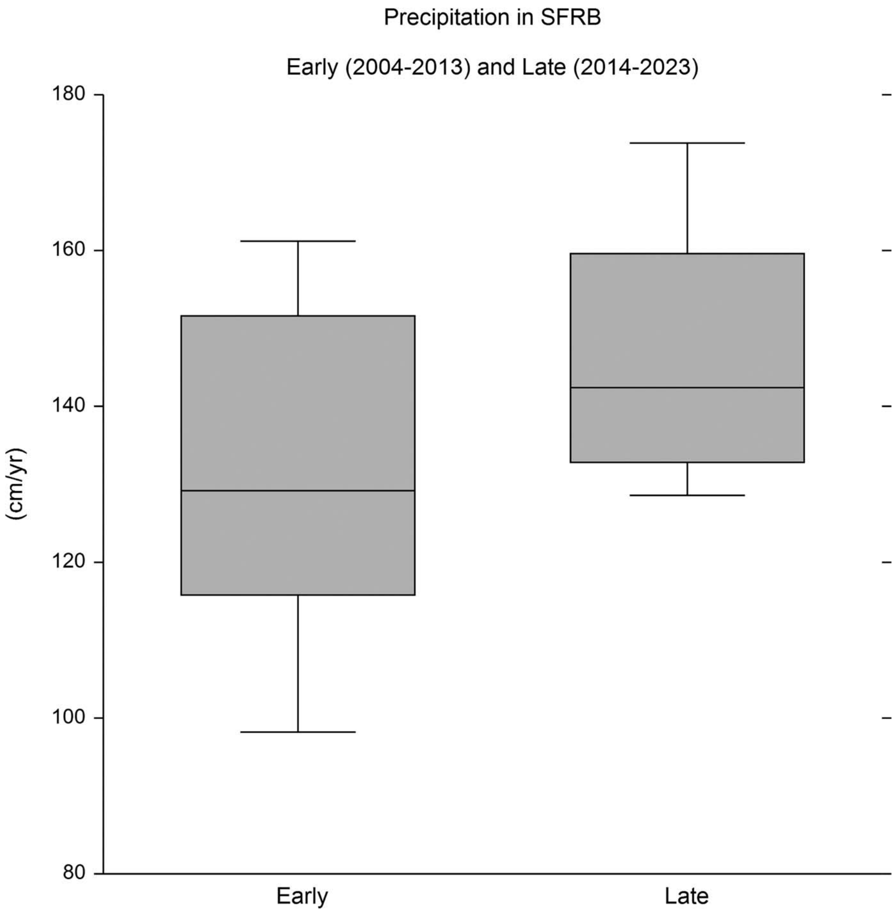

Figure 5. Annual rainfall in the Lower SFRB in a second set of early (2003-2013) and late (2014-2023).

concentrations can occur from a prolonged increase in rainfall, along with subsequent increases in recharge. A second, and the most important driver from the perspective of restoration efforts, is a decline in NO_3 loading from land use activities.

Figure 5 is a boxplot of precipitation/rainfall in the SFRB for two periods: early (2004-2013) and late (2014-2023). Data were supplied by the Suwannee River Water Management District and are from precipitation stations in Alachua, Columbia, and Gilchrist Counties. Data were not available for 2024. For this exercise, a late period (2014-2023) corresponds to the time of the study, minus 2024. An early period represents the 10 years prior to the current study. In centimeters, the median annual rainfall during the second early and late periods were 129.26 and 142.39, respectively, a 131.13 cm/yr increase. It should be noted that during the last five years of the late period, there was a net decrease in annual rainfall. However, from a practical perspective the 131.30 centimeters of extra rainfall, and a presumed increase in recharge, provide strong evidence that rainfall was a probable driver of decreasing NO_3 concentrations.

Obtaining land use nitrogen application rates has been a priority since the implementation of BMAP initiatives. Application rates of fertilizer, manure, and human waste are sometimes documented by producers and waste disposal personnel as part of compliance with industrial waste permits. However, complete data sets are not always available. For this reason, FDEP developed the Nitrogen Source Inventory and Loading Tool (NSILT) (FDEP 2025b). It estimates nitrogen inputs from land surface based on the best available land use data. The tool is updated as new data becomes available. A second available nitrogen loading tool is the Blue Water Audit (Florida Springs Institute 2019) which uses data from a variety of sources to estimate the impact of nitrogen loading and groundwater withdrawals for land parcels. It tracks the impact of site-specific land use activities in the spring region; much of the north and central portion of Florida. It was last updated in 2019. Evaluating changes in nitrogen-loading with either tool is on a periodic basis.

The tools above are used for estimate rates of nitrogen loading from land surface. Direct measurements of NO_3-loading data are obtained from springs, spring runs, and along streams. They represent estimates leaving the SFRB. Ideally, NO_3-loading estimates are obtained by multiplying NO_3 concentrations (mass/volume) by discharge (volume/time) to obtain flow in units of mass/time. Unfortunately, obtaining NO_3 water samples and discharge measurements are often project driven. This often, but not always, results in water quality samples and corresponding discharge measurements not being obtained in a coordinated manner. Appropriate data are often obtained at different times, and the frequencies of data collection cannot be used as a time series.

It should be noted that once FDEP became aware that the decreasing NO_3 concentrations in groundwater could not be directly tied to NO_3-loading, it is initiating efforts to improve data collection efforts. NO_3 loading data are to be obtained at frequencies compatible with groundwater sampling of nitrate. The improvements will enable the Department to monitor changes in nitrate loading and nitrate concentrations over time, and to be able to correlate the relationships with the changes. In turn, the effort will improve the Department's ability track restoration progress.

Summary

Once in the soil, nitrogen bonds with oxygen to form nitrate through nitrification. Precipitation and subsequent recharge can mobilize NO_3 from the land surface to underlying aquifers. Nitrate-rich groundwater flows downgradient and discharges into springs and surface water bodies. In spring runs, elevated NO_3 concentrations contribute to an overabundance of algae.

Natural background NO_3 concentrations in Florida's groundwater are less than 0.05 mg/L. Since the 1950s, NO_3 concentrations in many of Florida's springsheds have risen due to changes in land use activities. By 2008 FDEP declared water in the SFRB impaired for NO_3. To restore water quality to 0.35 mg/Lin the SFRB, a series of BMAP initiatives were implemented by FDEP.

Restoration requires monitoring to track the effectiveness of BMAP initiatives. To alleviate monitoring costs, FDEP encourages data sharing by other monitoring entities. To assist, three such entities, ACEPD, AW, and Florida LAKEWATCH conduct nitrogen monitoring in groundwater within the SFRB.

Trend analyses were conducted for TN concentrations based on data from 35 ACEPD and AW monitoring wells within the SFRB for two periods: 2014-2024 and 2017-2024. Analyses revealed that concentrations decreased in Alachua and Columbia Counties in both periods. In Gilchrist County concentrations increased during the first period, but neither increased nor decreased during the second period. One possible driver of the observed change is increased rainfall and subsequent recharge, which can dilute NO_3 in groundwater. During this study, there was a net increase of about 131 centimeters of rainfall, relative to the 10 years immediately preceding it, providing strong evidence dilution of NO_3 concentrations occurred in groundwater within the SFRB.

Efforts to account for nitrogen loading from land use activities have been a high priority since the BMAPs were initiated. FDEP developed the Nitrogen Source Inventory and Loading Tool, while the Florida Springs Institute created the Blue Water Audit. Both tools use data from a variety of sources but can only be updated periodically.

The most obvious method to track restoration success is to monitor NO_3-loading in springs and surface waters leaving the springsheds. This is accomplished by obtaining loading data from springs, spring runs, and key surface-water sites. Efforts are currently being made to modify the collection of, NO_3-loading data to frequencies compatible with those obtained for NO_3 concentrations in groundwater. This will increase FDEP's ability to monitor the progress of its restoration efforts. Serendipitously, the study demonstrates that since citizen volunteers collect data at minimum cost. Their assistance can reduce FDEP's cost of monitoring BMAP restoration success.

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Data Availability AquiferWatch information and data supporting the findings of this study are openly available in Figshare.com at https://figshare.com/search?q=10.6084%2Fm9.figshare.30740294.

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