

Declining Nitrate Concentrations in the Groundwater in the Santa Fe River Basin (2014 – 2024)

Springs Forum, Newberry, FL

April 23, 2025

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Major Contributors

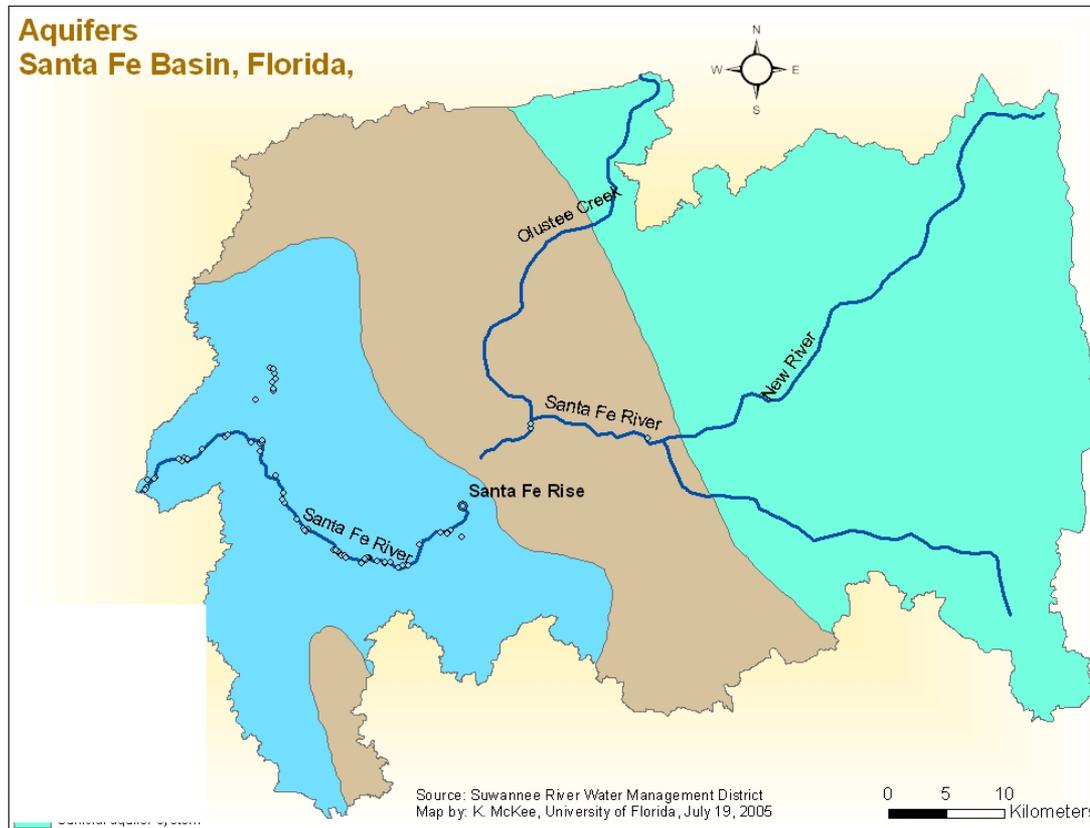
- **Rick Copeland: AquiferWatch (AW)**
- **Gary Maddox:AW**
- **Hailey Hall:AW**
- **Tommy Seal:AW**

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RC, GM, TS: Worked with the Florida Department of Environmental Protection (FDEP) for years

Nitrate ($\text{NO}_3 + \text{NO}_2$ as N) in the Santa Fe River Basin

- Elevated (Impaired) NO_3 (NO_x) in groundwater (GW) of the Floridan Aquifer System (FAS)
- Lower SFRB (Brown and Blue): LSFRB*



FAS in SFRB

Green:

Confined

(plus, Surficial Aq. Sys.)

Brown

**Partially Confined
(Perforated)**

Blue

Unconfined

***Emphasize LSFRB**

Modified from McKee (2006)

FDEP

- Through a Basin Management Action Plan (BMAP) FDEP is required to Restore Santa Fe River and Spring Water Quality (NO₃) down to 0.35 mg/L
- By monitoring both the SFR and spring water quality plus flow (e. g. N-Loading), FDEP measures progress of restoration
- Under normal conditions GW discharges into SW. If NO₃ concentration in GW > 0.35, then restoration will not occur. Need to monitor NO₃ concen. in wells

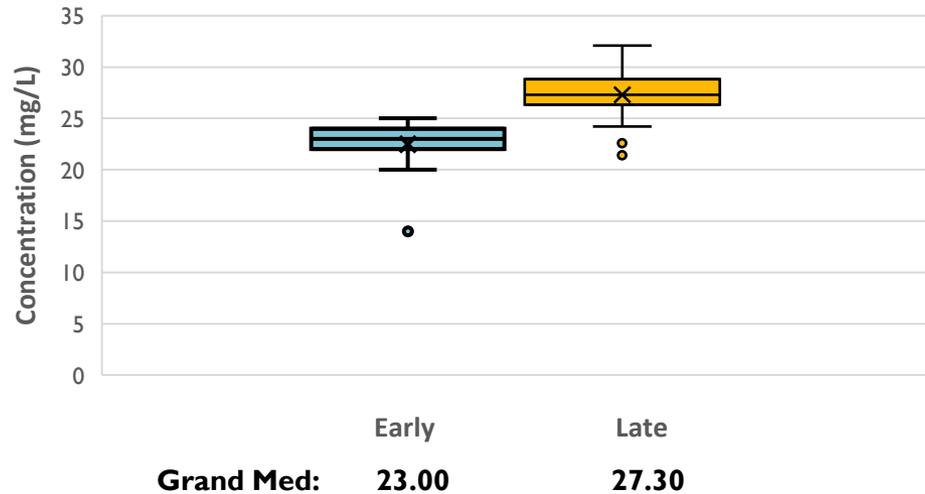
Results of Two Types of Monitoring of NO₃ in GW

- A. “Low” sampling frequency from a “Large” number of wells
A synoptic survey. Can be used to evaluate for a **Step Trend**
- B. “High” sampling frequency from a “Small” number of wells
To evaluate for a **Time-Series Trend**

Example of “Steps”

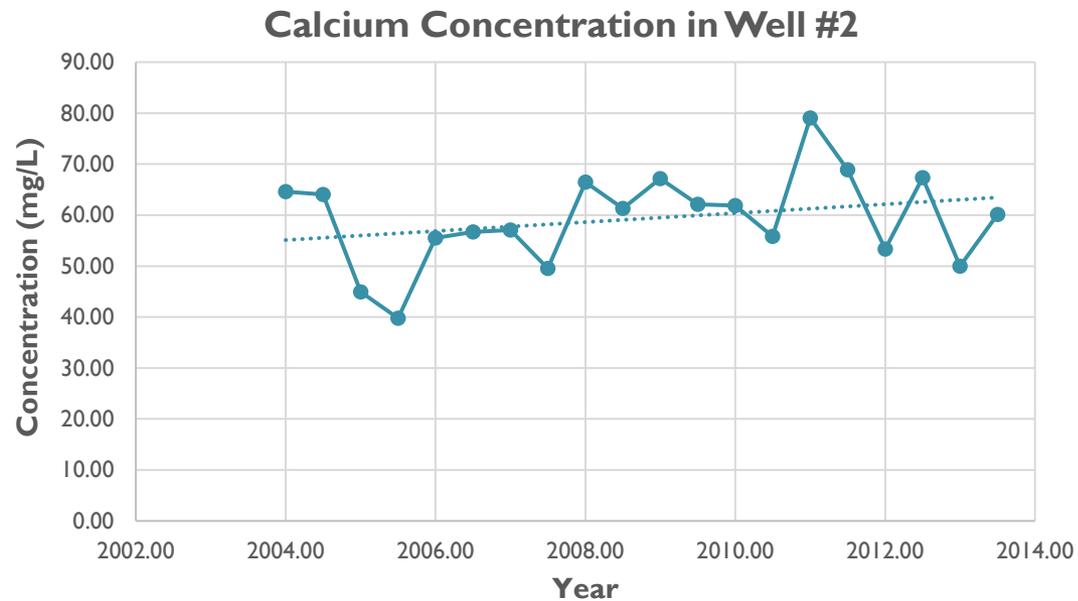
Hypothetical Box Plots of Calcium Concentrations from 20 Wells in Each of Two Periods.

Calcium Concentrations in 20 wells
E(1991-1997) to (2005-2011)



Example of “Time-Series”

Hypothetical Graph of Calcium Concentrations in a Well (2004-2013)





Alachua County (EPD) (Synoptic Survey)

Lower Santa Fe River Basin Groundwater Nitrate Assessment

Protect Florida Spring Tag Grant

-Funded by Wildlife Foundation of Florida

-Fiscal Year 2023-2024

-Lower Santa Fe River Basin
Groundwater Nitrate Assessment

-WFF \$8140

-ACEPD In-Kind contribution
\$10,618



Project Objective and Location

- NO3 assessment
- Lower Santa Fe River Basin
- Two sampling events:
 - Wet Season (November 2023)
 - Dry Season (May 2024)
- Counties: (Alachua, Gilchrist and Columbia)



Groundwater Sampled via Wells and Springs

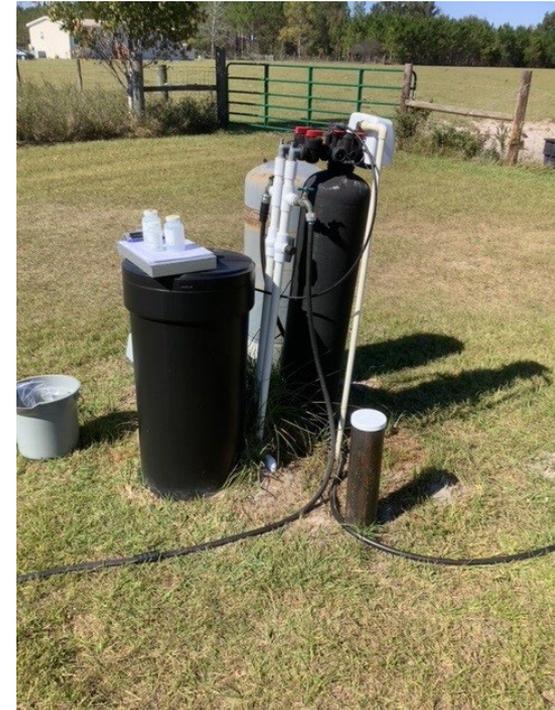
-ACEPD well network and previous projects.

-AquiferWatch well network

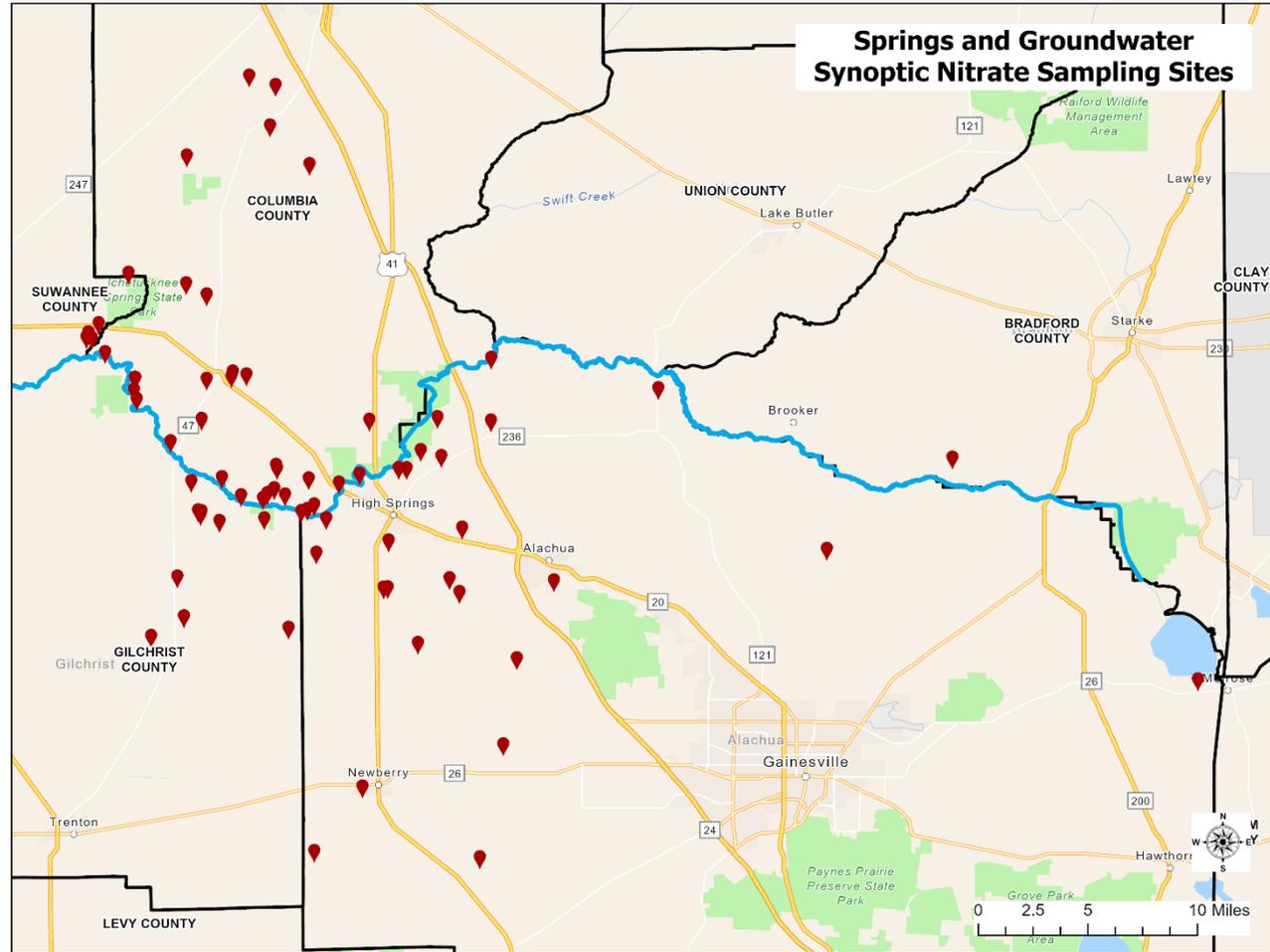
-Springs

-November 2023
(80 wells and springs)

-May 2024
(73 wells and springs)



EPD Wells/Springs Sampled November 2023 and May 2024



Sampling Method and Analysis

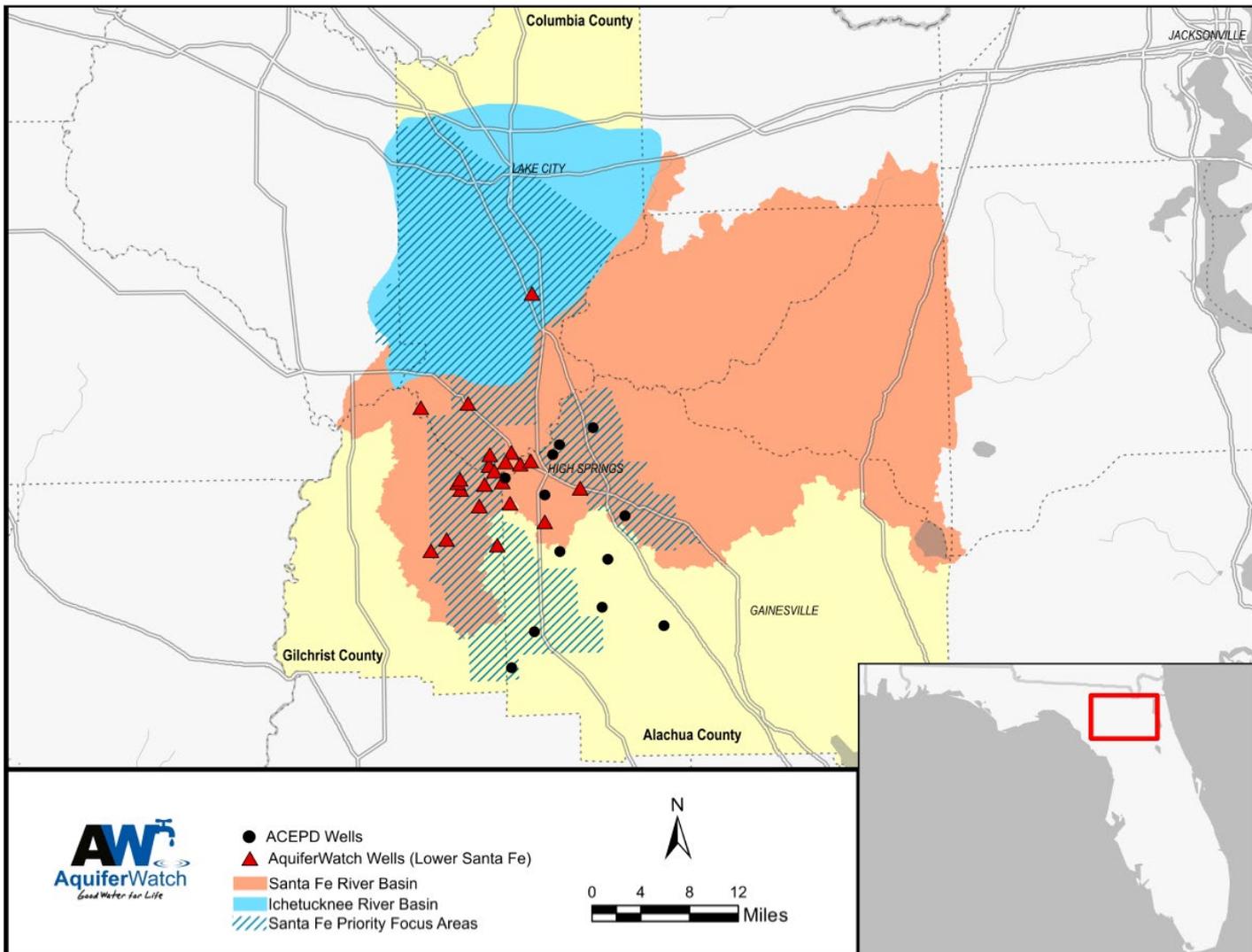
- 15 minutes purging time
- Water collection and preservation
- Delivered to AEL
- Analysis (NO_x (nitrate + nitrite), potassium, Total Phosphorous and chloride)
- AquiferWatch statistical analysis

AquiferWatch (AW)

- AW: a 501(c)(3) nonprofit, volunteer GW organization
- AW indirectly tied to Florida Lakewatch (LW), a lake volunteer monitoring org. (Univ. of FL.)
 - AW: Collects samples
 - LW: Chemically analyzes samples in their lab for Total Nitrogen (TN)
(More on this issue shortly)

Time-Series Monitoring in LSFRB

- AW monitors GW in wells; from FAS (Currently **23** in LSFRB and 16 in Ichetucknee Basin)
 - Data analyzed (2014-2015, 2017-2024)
- EPD currently monitors 21 wells of various types,
 - **12** Have sufficient data to analyze for (2014-2024)



Orange/Blue (SFRB), **Blue** (Ichetucknee River Basin)
 Yellow (Columbia, Gilchrist, and Alachua Counties)
Black Circles (EPD Wells); **Red Triangles** (AW wells)
 Wells are monitored on regular basis

LSFRB GW Monitoring

- EPD samples for TN and NO₃ (but not always both)
- AW samples only for TN
- For this project, want NO₃
- If sample is analyzed for both TN and NO₃, then an estimate NO₃ is the proportion of NO₃ to TN (NO₃/TN)

LSFRB GW Monitoring (NO₃ and TN)

- AW obtained data from **201 FDEP wells** from unconfined FAS in a search box around SFRB (1991-2023)
- Median **ratio** of NO₃/TN = **0.95** (Range: 0.06 -1.00)

EPD; **21** samples, NO₃/TN **ratio = 0.96.**

AW; 16 samples analyzed both NO₃ & TN (Commercial Lab)
Ratio = 0.97.

AW/EPD (2014-2024)

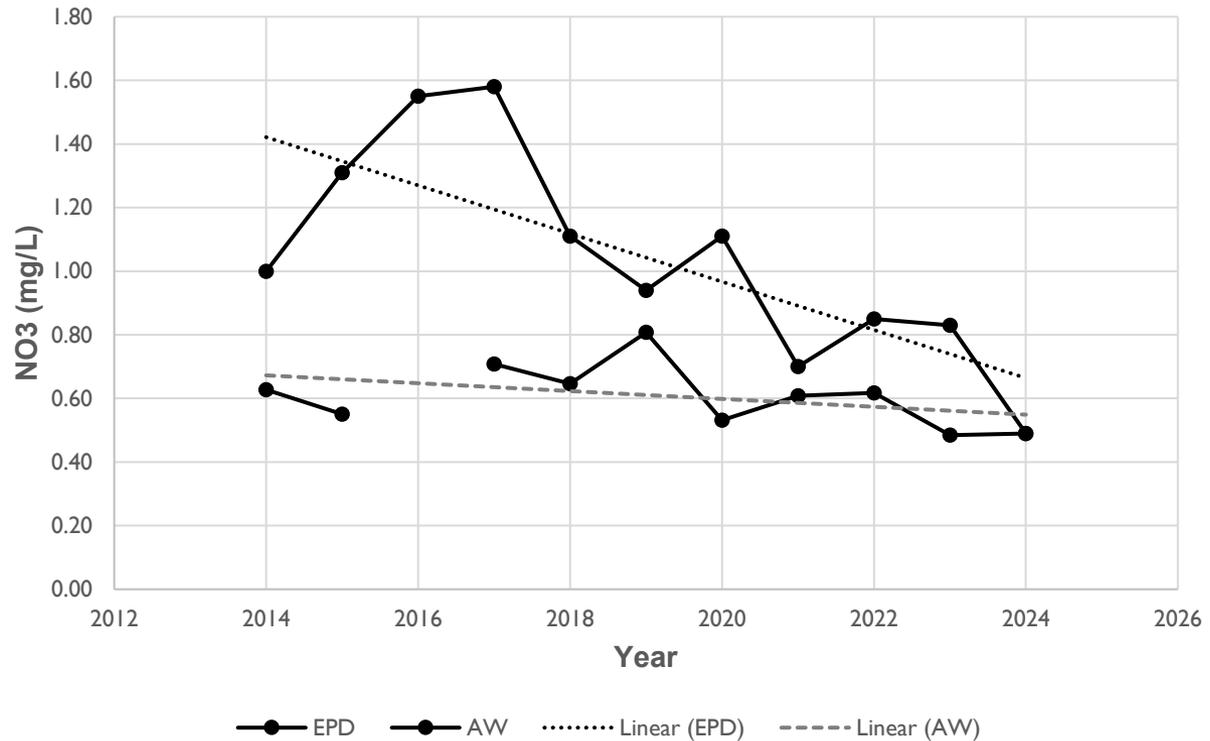
Time-Series Trend Analyses

Regional Kendall (Helsel and Frans, 2006)

Needs minimum of 10 years of data;

- AW (23 wells with sufficient data; 10 years)
- EPD (12 wells with sufficient data; 11 years)

NO3 Annual Medians (2014-2024)



Top: EPD Bottom:AW

Regional-Kendall Test Results (2014-2024)

Time Series

Wanted to be >90% confident of Trend

If p-value < 0.10, then a trend is considered to exist

Data Sets	n(w), n(S)	*Slope	P-value	Direction
EPD	12,240	-0.038	0.027	Down
AW	23,506		0.101	
EPD and AW	35,746	-0.012	0.009	Down
AW (Ala)	5,112	-0.015	0.054	Down
AW (Col)	8,176	-0.019	0.011	Down
AW (Gil)	10,220	0.004	0.067	<u>Up</u>

w:wells s:samples

*Sen Slope (mg/L/Yr)

EPD: Three Synoptic Surveys

Wilcoxon Test (Conover, 1989) used to evaluate step trends.

1. Sign-Rank Test: Only if same wells in two periods
2. Rank-Sum Test: If different wells in two periods

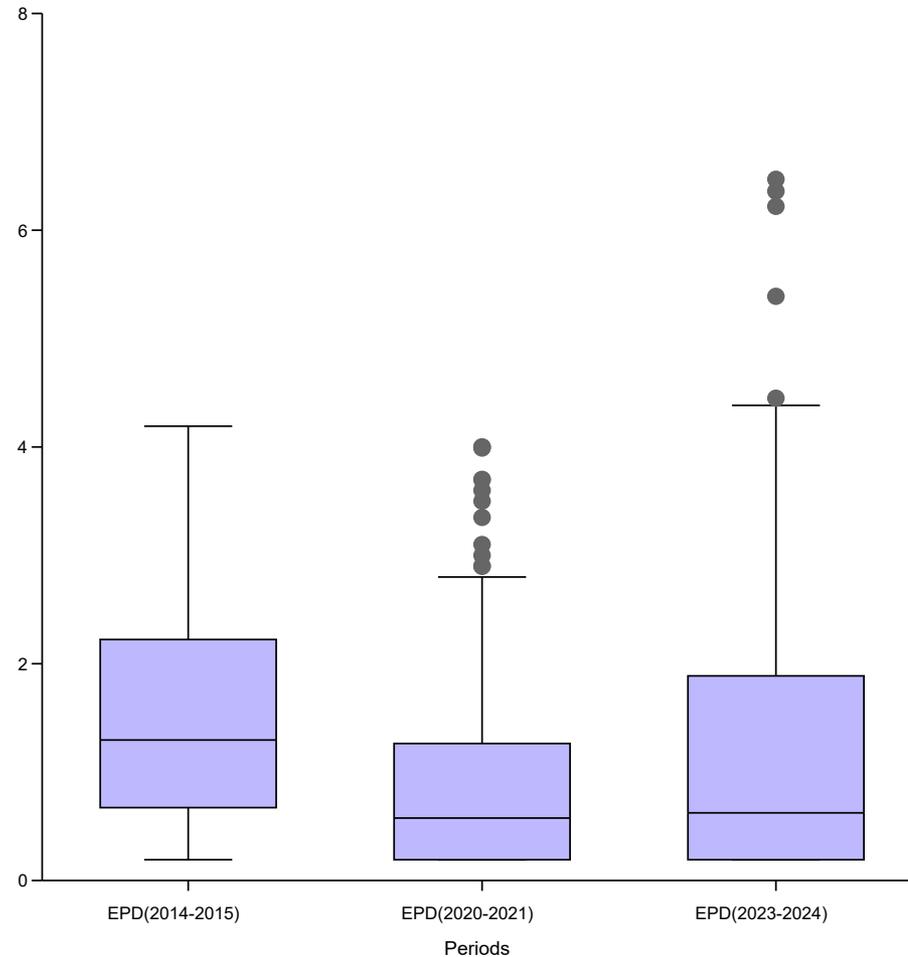
- 2014 (Fall) and 2015 (spring)
 - $n = 40$ $n = 38$
- 2020 (Fall) and 2021 (spring)
 - $n = 86$ $n = 81$
- 2023 (Fall) and 2024 (spring)
 - $n = 80$ $n = 73$

NO₃ concentrations

2014-2015, 2020-2024

Nitrate Concentrations in ACEPD Samples

During Three Periods



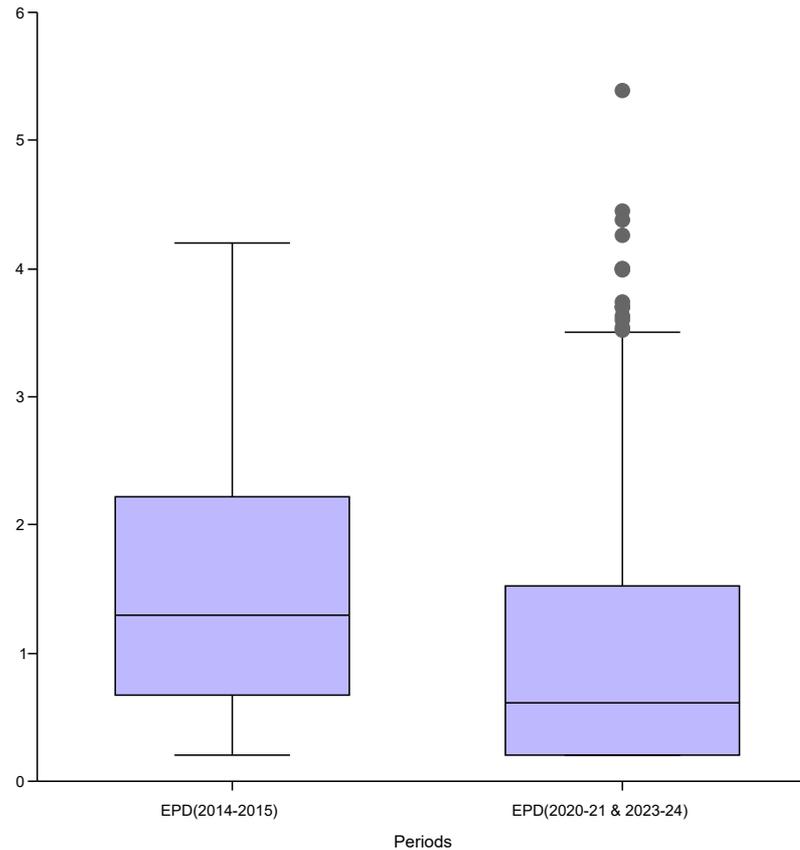
Compared
2020-2021 to
2023-2024 data.
Wilcoxon Test
p-value = 0.136

**Can treat two
periods as one.**

Analyses of EPD Early to Late “Step” Data

Nitrate Concentrations in ACEPD Samples

During Two Periods



Med = 1.30

Med = 0.61

“Wilcoxon” Test Results

Data Set	Median (mg/L)	P-value
(2014-2015) to	1.30	
(2020-2021) & (2023-2024)	0.61	<0.001

AW/EPD (2017-2024)

Using Step-Trend Analyses

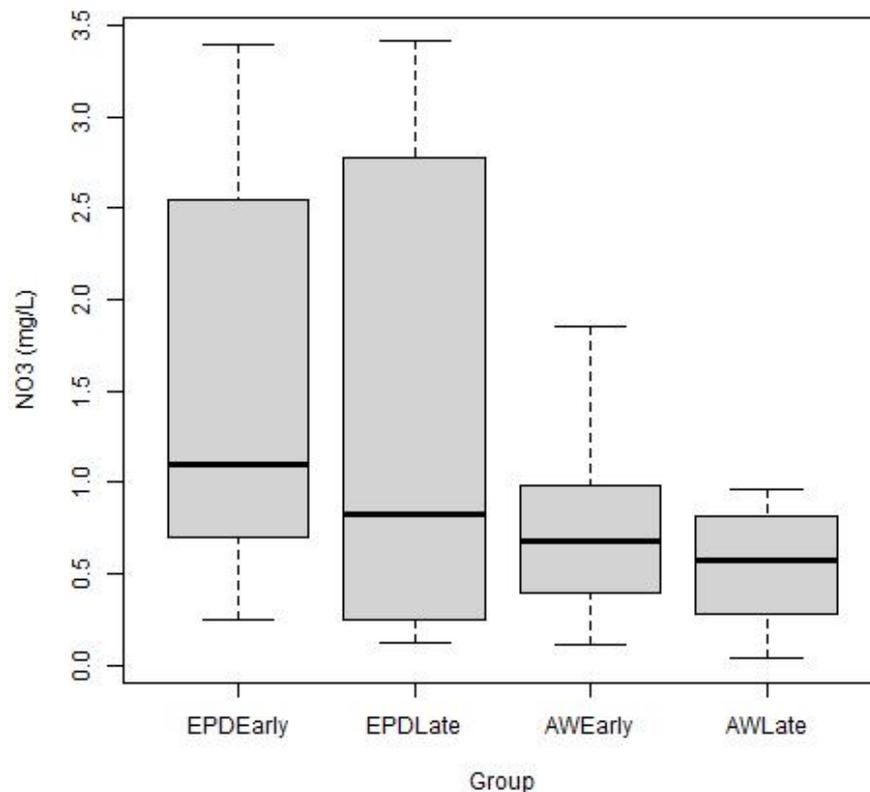
Note, data are from the 35 wells previously used in Time-Series analyses

Why start at 2017? Because FDEP does not use data prior to 2017

Compared NO₃ well medians in two periods
Compared (2017-2020) to (2021-2024)

NO3 Annual Medians

Early(E)(2017-2020) Late (L) (2020-2024)



**NO3 Concentrations from EPD and AW wells:
Early (2017-2020) and L (2021-2024)**

EPD

AW

Wilcoxon Sign-Rank Test Results, Comparing Annual Median NO₃ Concentrations Early (2017-2020) and Late (2021-2024)

Data Sets	n	Med Early (2017-2022)	Med Late (2021-2024)	P-value	Direction
EPD (Ala)	12	1.10	0.82	0.077	Down
AW (Ala, Col, Gil)	23	0.67	0.57	0.117	
EPD and AW	35	0.75	0.57	0.026	Down
AW (Ala, Col)	13	0.68	0.61	0.017	Down
AW (Gil)	10	0.55	0.52	1.000	

Interpretation of Graphs

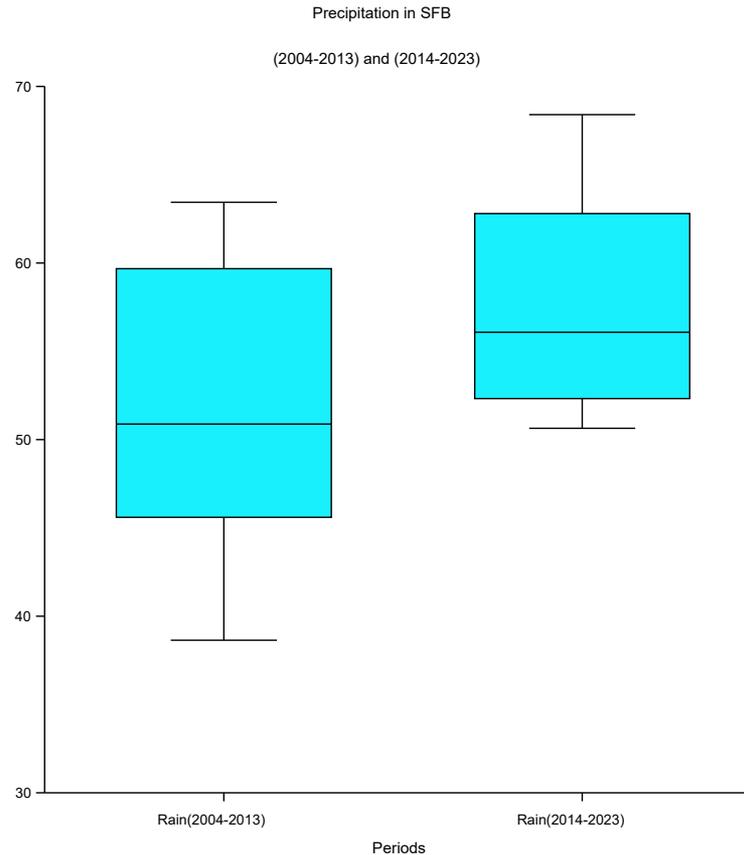
- Increasing Trends
“Bad” News
- **Decreasing Trends**
“Good” News
- Insufficient Evidence:
“Not Bad News, but could be better”

Plausible Drivers of Decreasing NO₃ Concentrations

(Modified from Upchurch, 1992; Upchurch et al. , 2019)

- 1. Decrease in N-Loading from land surface
- 2. Sufficient increase in Rainfall, followed by dilution of NO₃ concentrations
(More likely to occur in unconfined aquifers)

Comparison of Two Periods of LSB Precipitation (Col, Gil and Ala Co)



1.00 in = 2.54 cm

Mean: 51.84
Med: 50.89

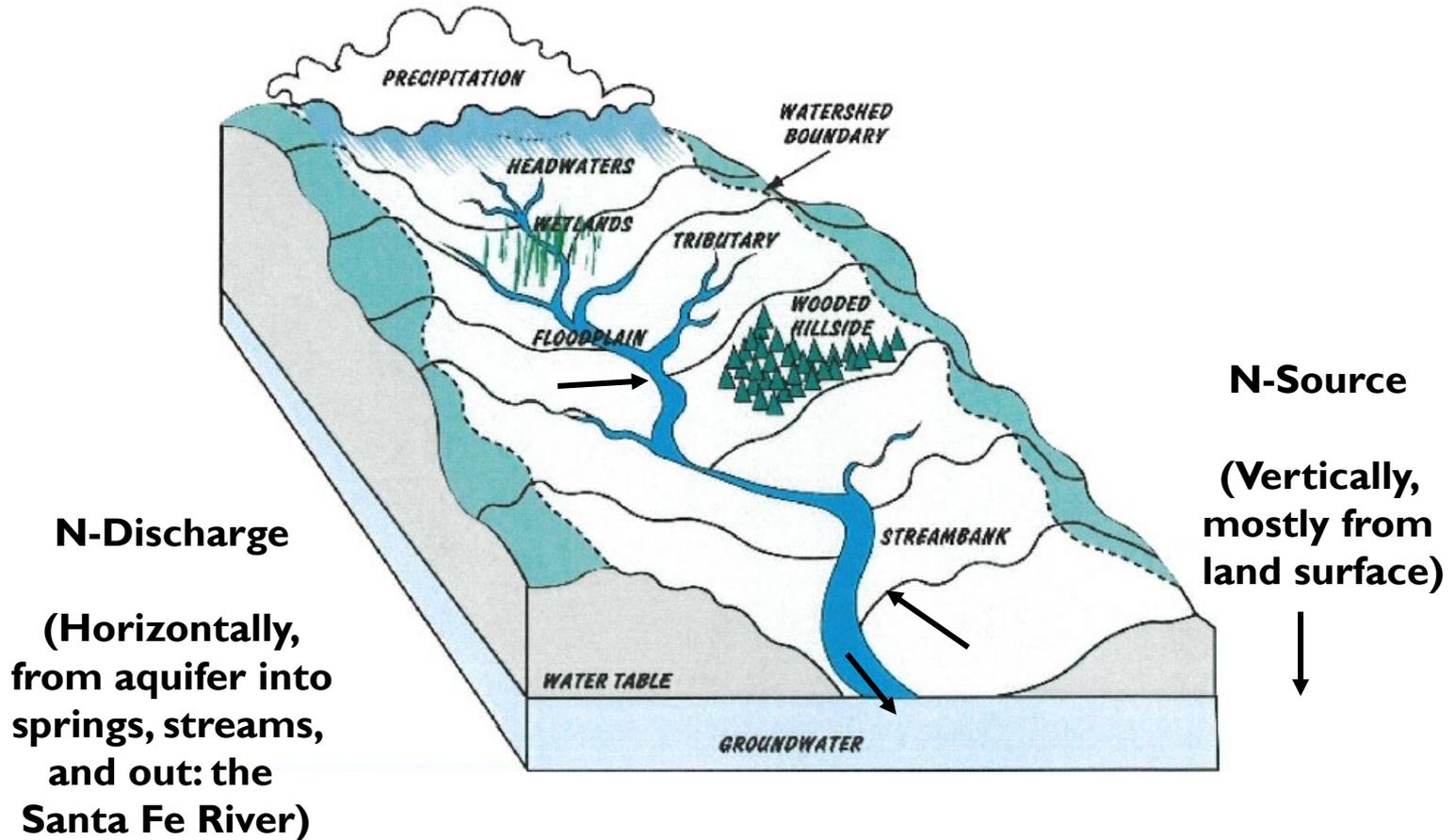
57.88
56.06

Data from SRWMD (2024)

Next Steps

- Suggested to FDEP to modify its N-Loading network (FDEP agrees)
- Also suggested FDEP obtains N-Loading measurements at regular intervals (e. g. time series) (FDEP agrees)
- Note, modification may be limited by available FDEP resources

Cartoon of Santa Fe Basin



N-Loading

Simplified Version Example

$$\text{Loading} = \text{NO}_3 \times \text{Discharge}$$

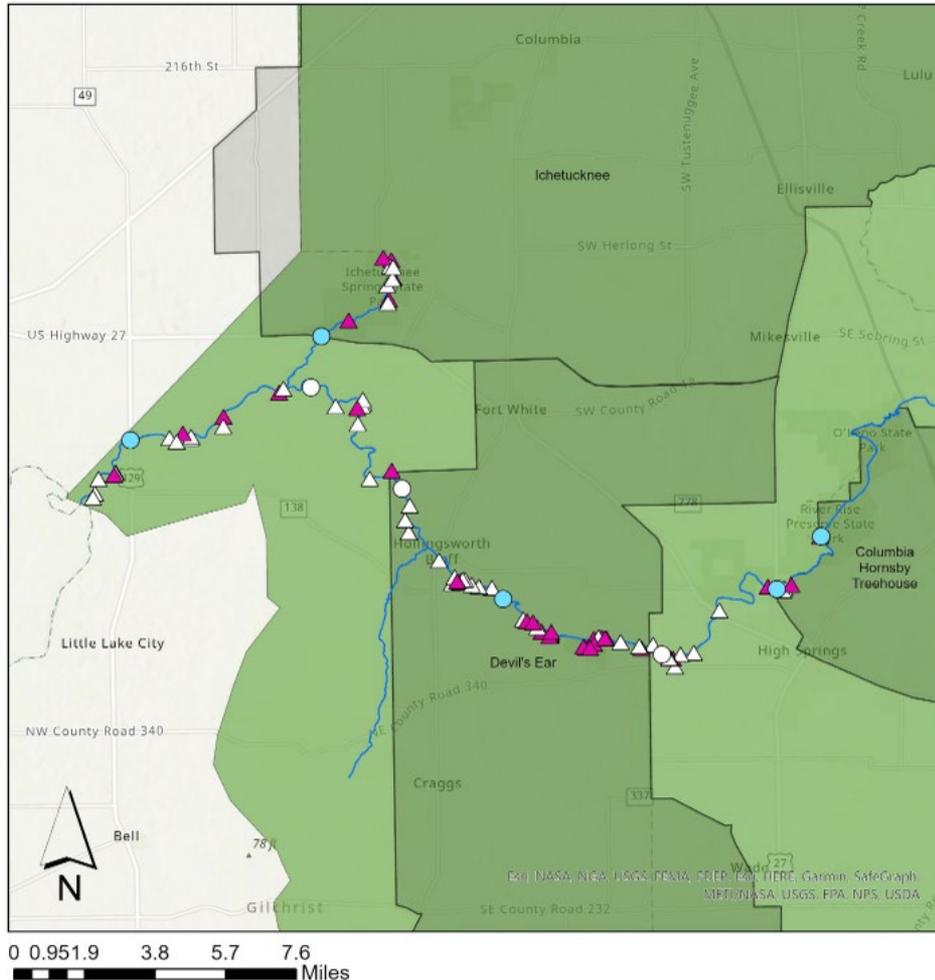
Pounds of N per Day

- Important for Total Maximum Daily Load
- TMDL

New FDEP Project that will Likely be Funded

One time N-loading measurements of up to 60 sites along Santa Fe River

Santa Fe Monitoring Sites



Circles
Surf. Wat. Sites

Triangles
Spring Sites

Anticipated Results of Survey

- Determine N-Loading at each site.
- Sites with greatest loading become targets for time-series monitoring
- Depending on available resources, modify N-Loading Network
 - Time-Series Network and periodic synoptic surveys (Steps)
- More accurately monitor restoration success

Summary

- SFRB impaired for NO₃ (>0.35mg/L)
- EPD & AW monitor GW [NO₃ (2014-2024)]
 - Evaluate Data for Time-Series and Step Trends
- Results: NO₃ Concentrations in GW are Decreasing
 - Driver (1). Increase Rain and dilution of NO₃ in FAS. Likely
 - Driver (2). Reduction in N-Loading. Cannot tell
- Need to modify N-Loading monitoring (FDEP agrees)
- FDEP to conduct synoptic N-Loading of 60 sites
- Results to be used to modify a N-Loading network



• Questions?

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