NUTRIENT FINGERPRINTING IN GROUNDWATER SOURCES

Guiding Groundwater BMPs for the Restoration of the Indian River Lagoon

2023 FLORIDA STORMWATER ASSOCIATION

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June 15, 2023

PRESENTATION OUTLINE

1. Project Background and Objectives
2. Project Design
3. Project Methodology
4. Results
    a. Groundwater Concentrations by Treatment Type
    b. Source Tracking: Isotopic Fingerprinting
    c. Groundwater BMPs
5. Conclusions & Next Steps

PROJECT BACKGROUND

- Pollution is entering the IRL also via groundwater
- Save Our Indian River Lagoon (SOIRL) Sales Tax
- Upgrades to wastewater treatment, reclaimed irrigation systems, & septic systems
- Groundwater pilot study in **2017** funded by legislative funding
- Project expanded in **2018** to guide the SOIRLPP program

Category	Annual Total Nitrogen Load (pounds per year)
Stormwater and Baseflow Loading	248,233
Atmospheric Deposition Loading	22,371
Point Sources Loading	0
Total Loading	270,604
Target Percent Reductions	18.0%
Targeted Reductions	48,709

PROJECT OBJECTIVES

GOAL: Understand environmental drivers of wastewater pollution in Brevard County's groundwater

- **Describe groundwater sources** of nutrients to the lagoon
- **Refine** pollution load models (watershed models)
- **Prioritize** areas with high groundwater contamination for retrofit projects
- **Inform management** efforts to restore the estuary
- **Evaluate** success

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PROJECT DESIGN

TREATMENT TYPES

- Communities (residential) on:
  - Septic
  - Sewer
  - Sewer with Reclaimed (high nutrient effluents)
- Control Sites (undeveloped/natural areas)

SPATIAL REPRESENTATION

- North, Central, and South Mainland (2 controls)
- Barrier Island (1 control)

TEMPORAL REPRESENTATION

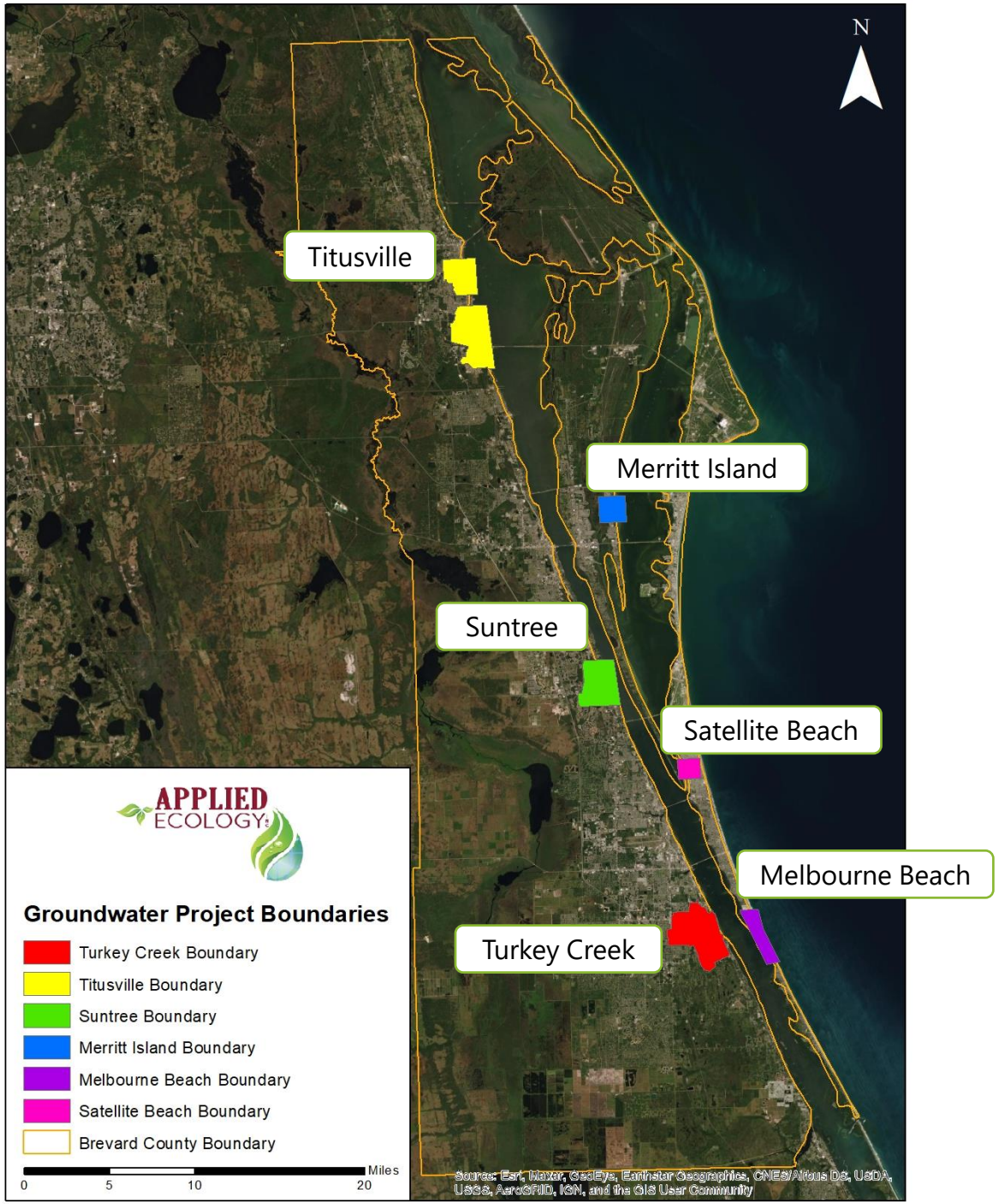
- Monthly monitoring independent of rainfall and other conditions

ESTABLISHING A LONG – TERM MONITORING NETWORK

PROJECT LOCATIONS

- # of Monitoring Wells = 43 (originally 45)
- Five areas of interest (from N-S):
  - Titusville (Mainland North)
  - Suntree (Mainland Central
  - Turkey Creek (Mainland South) *
  - Merritt Island (Barrier Central)
  - Beaches (Barrier South) *

**** Includes all treatment types***



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STEP 1: PRIORITIZATION OF COMMUNITIES

Single Family Homes (SFH)

SFH within Subdivisions (clustered)

Classify by Type (Septic, Sewer, Reclaimed, Vacant)

Determine Key Pollution Predictors

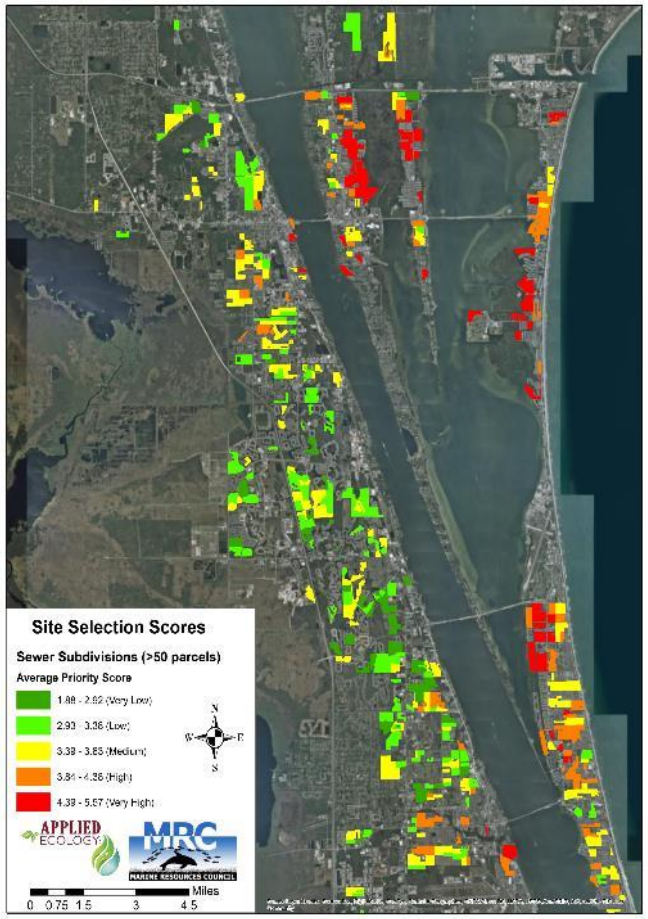
Rank Subdivisions for each Predictor

Final Prioritization Score

POLLUTION PREDICTORS

1. Housing density
2. Housing age (year built)
3. Minimum distance to an open channel (excluding IRL)
4. Minimum distance to the IRL
5. Mean elevation
6. Mean % organic matter
7. Mean hydrologic group value
8. Mean hydraulic conductance
9. Mean porosity
10. Mean depth to water

STEP 1: PRIORITIZATION OF COMMUNITIES



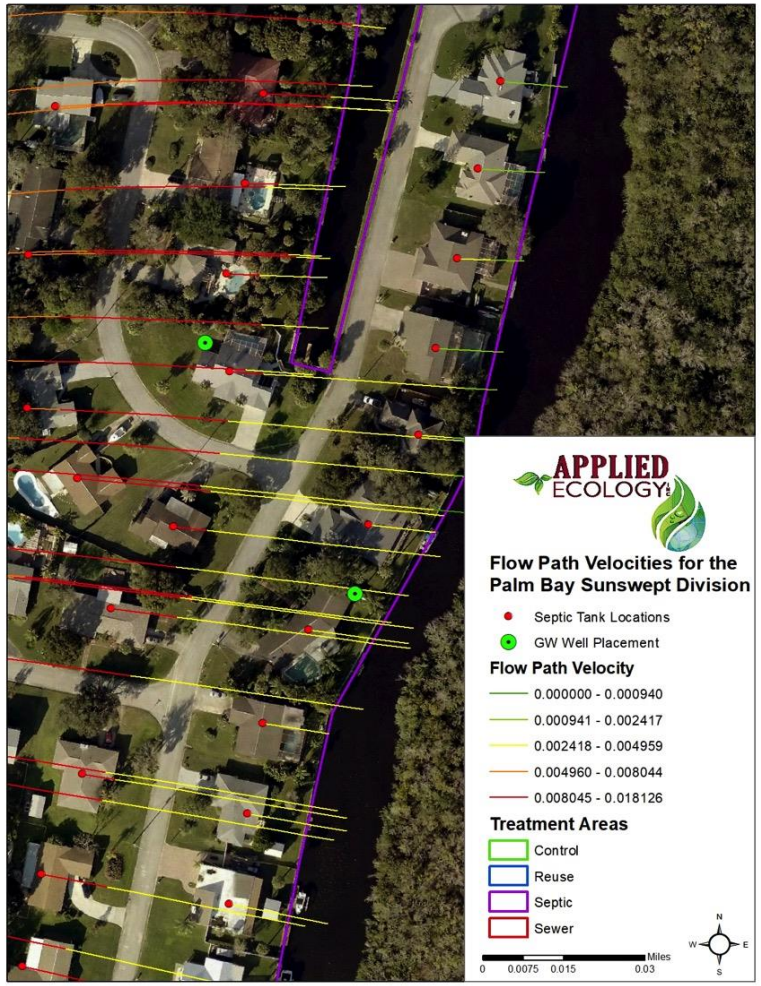
- Selected top 5% ranked septic communities
- Highest ranked sewer, reclaimed areas within 1 mile from septic communities
- Closest natural area (control)

Not all areas included all treatment types

STEP 2: WELL SITING AND INSTALLATION

CONTRAINTS

- Modeled flow paths
- Representative of treatment type (especially in septic communities)
- Provides space/access for a drill rig
- Homeowner agreements (huge ongoing recruitment/retention effort)



Installation of a groundwater well using a Geoprobe

STEP 3: ONGOING MONITORING AND ANALYSIS

MONTHLY SAMPLING

- Total nitrogen, NO_x, NH_3, TKN, total phosphorus, and orthophosphate.
- Stable Isotope samples from NO_3^-
    - δ15N
    - δ18O

ANALYSIS & REPORTING

- Quarterly Reporting of Trends
- Annual Statistical Analyses

Sampling of a groundwater well

FIVE YEARS OF MONTHLY SAMPLING

Region	Total Wells	Septic Wells	Sewer Wells	Reclaimed Wells	Natural Wells	Sampling Events
Beaches	11	3	3	3	2	**47**
Merritt Island	5	3	2	-	-	**47**
Suntree	9	3	3	3	-	**47**
Titusville	7	-	2	3	2	**47**
Turkey Creek	11	3	3	3	2	**59**
Totals	**43**	**12**	**13**	**12**	**6**	**-**

- Additional wells to be installed
  - 1 sewer well in Merritt Island
  - 1 natural well in Turkey Creek

FIVE YEARS OF MONTHLY SAMPLING

Region	Total Wells	Septic Wells	Sewer Wells	Reclaimed Wells	Natural Wells	Total Samples
Beaches	11	3	3	3	2	**657**
Merritt Island	5	3	2	-	-	**335**
Suntree	9	3	3	3	-	**543**
Titusville	7	-	2	3	2	**441**
Turkey Creek	11	3	3	3	2	**781**
Total Samples	**2,757**	**744**	**863**	**766**	**384**	**-**

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  - 1 sewer well in Merritt Island
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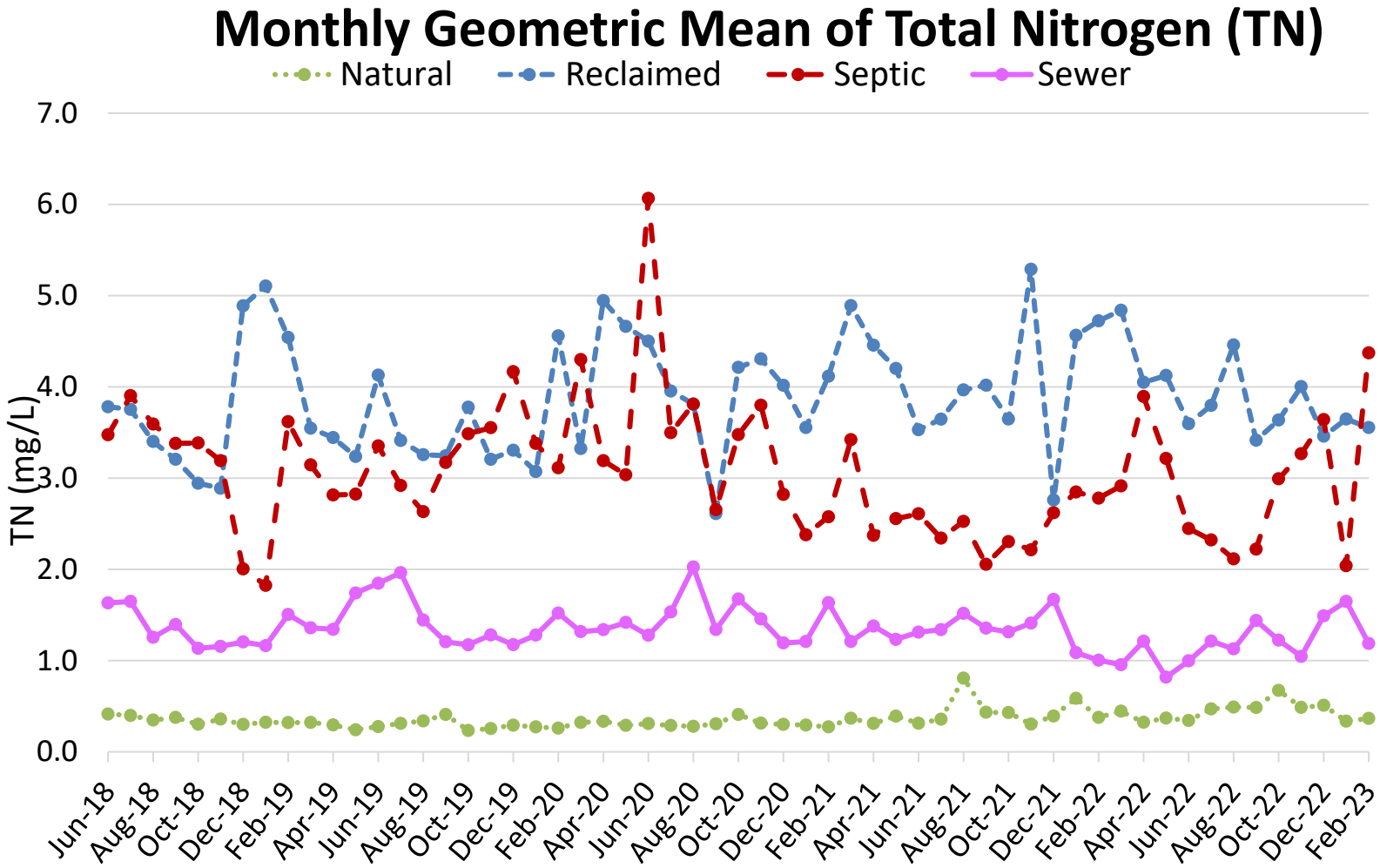
TOTAL NITROGEN (TN)

[GEOMETRIC MEAN]

Treatment	Geometric Mean (mg/L)
Reuse	**3.79**
Septic	3.05
Sewer	1.39
Natural/Control	0.36

Highest geometric mean concentration is in bold

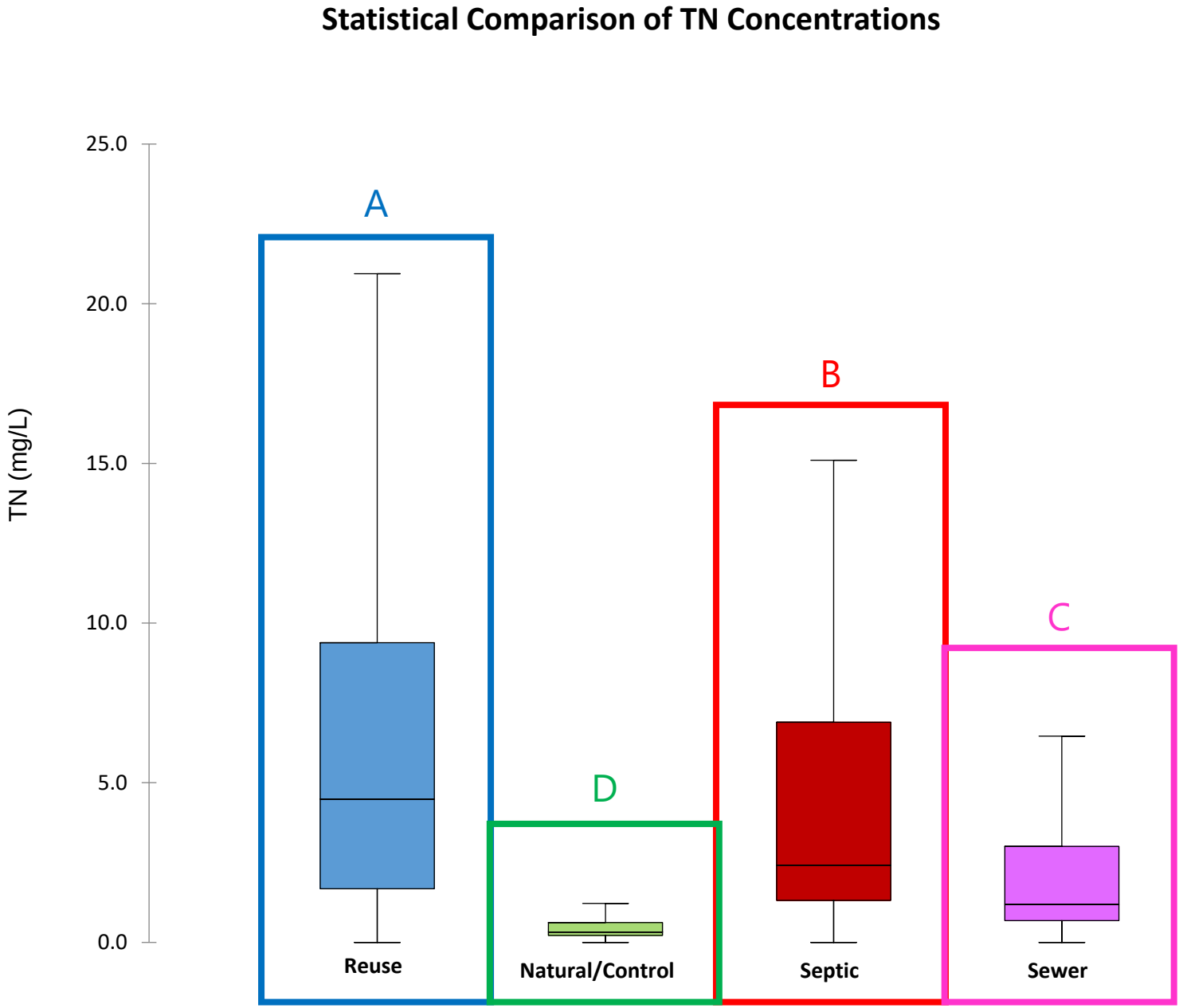


TOTAL NITROGEN (TN)

[MEDIAN]

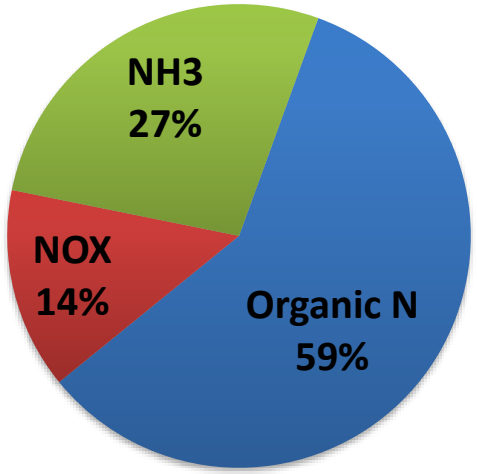
Treatment	Median (mg/L)
***Reuse**	**4.49_a**
*Septic	2.42_b
*Sewer	1.19_c
*Natural/Control	0.32_d

Significantly different median at p<0.001 using Kruskal-Wallis.



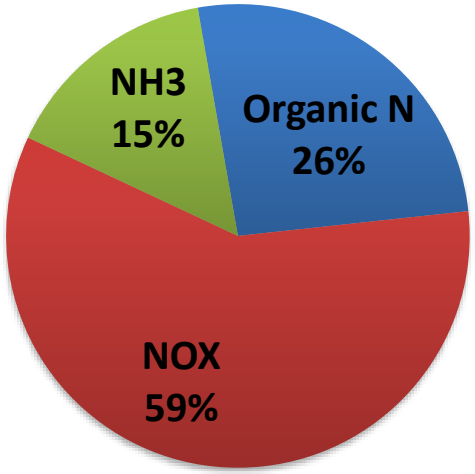
TOTAL NITROGEN COMPOSITION BY TREATMENT

Natural



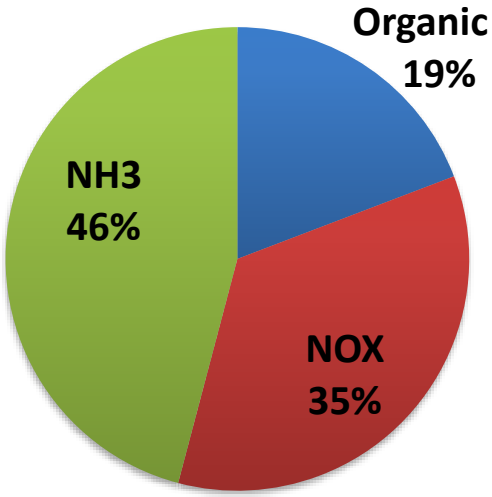
0.32 mg/L

Reuse



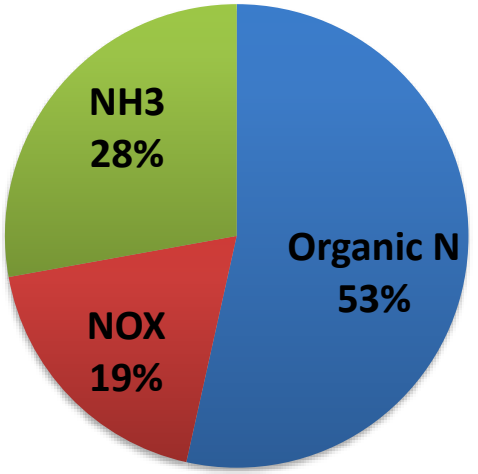
4.49 mg/L

Septic



2.42 mg/L

Sewer



1.19 mg/L

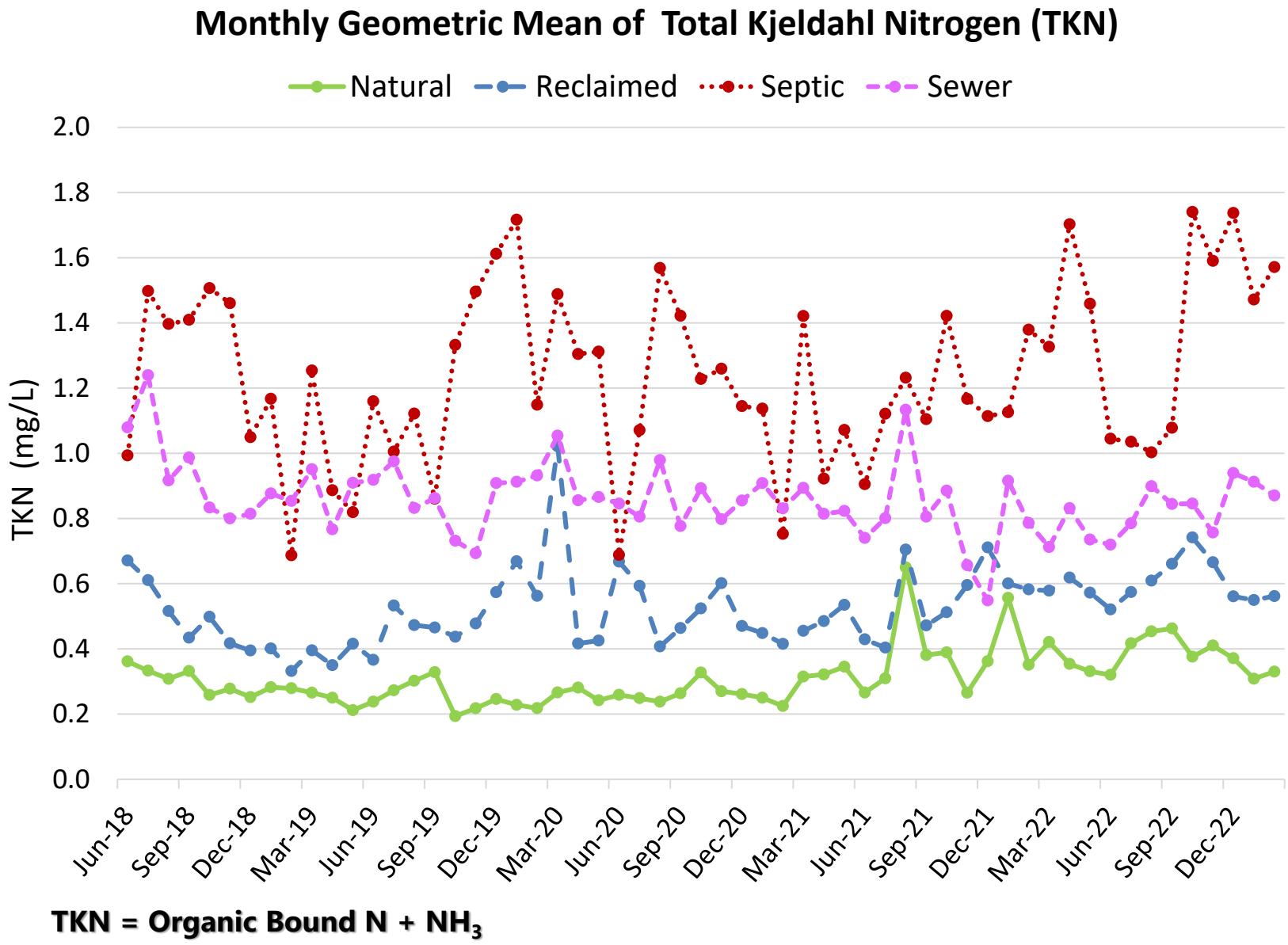
Average percent NO_x composition at **reuse sites** is highest of all treatment types

TOTAL KJELDAHL NITROGEN (TKN)

[GEOMETRIC MEAN]

Treatment	Geometric mean (mg/L)
Reuse	0.52
Septic	**1.24**
Sewer	0.91
Natural/Control	0.30

Highest geometric mean concentration is in bold



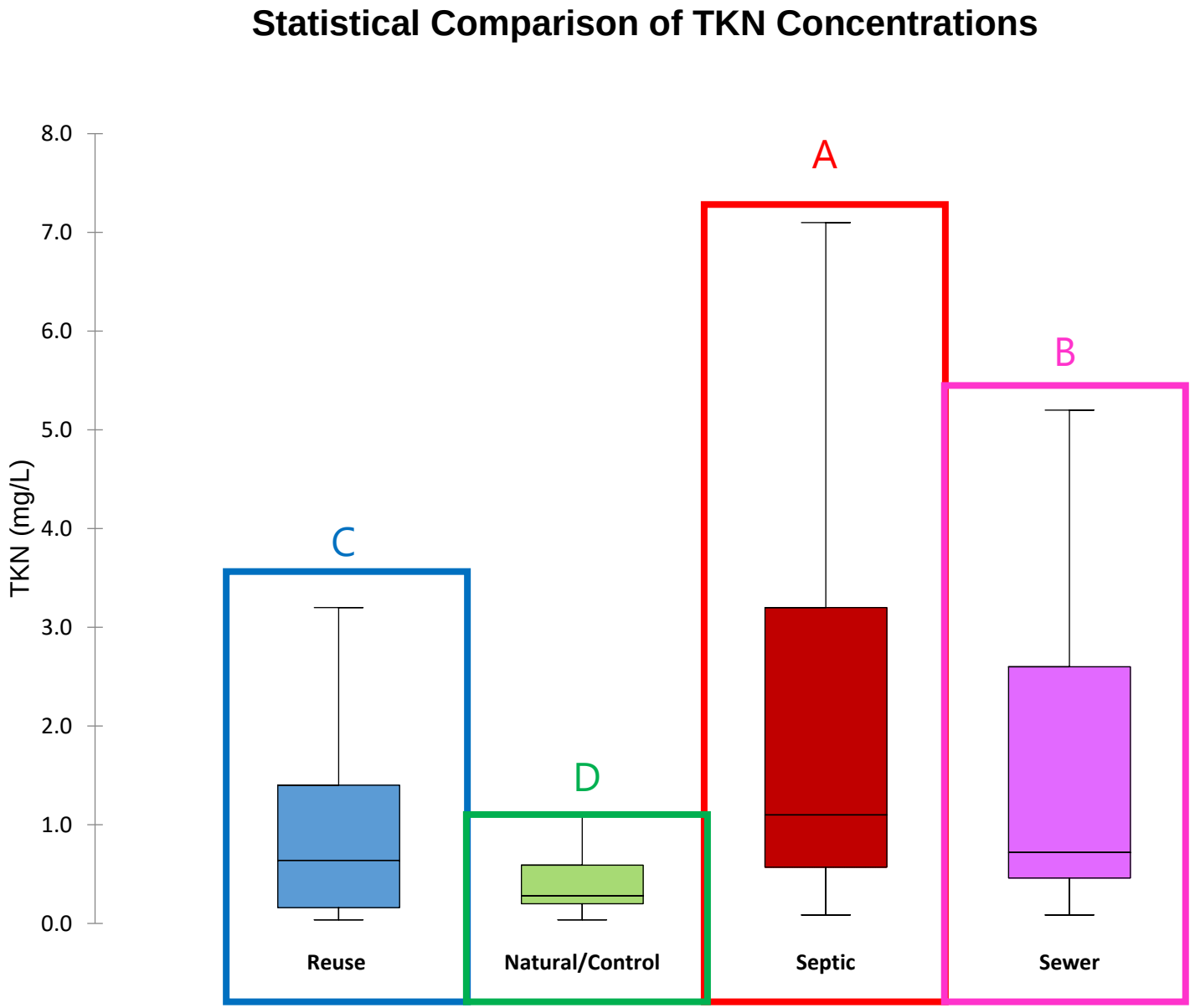
TKN = Organic Bound N + NH_3

TOTAL KJELDAHL NITROGEN (TKN)

[MEDIAN]

Treatment	Median (mg/L)
*Reuse	0.64_c
***Septic**	**1.10_a**
*Sewer	0.72_b
*Natural/Control	0.28_d

Significantly different median at p<0.001 using Kruskal-Wallis.

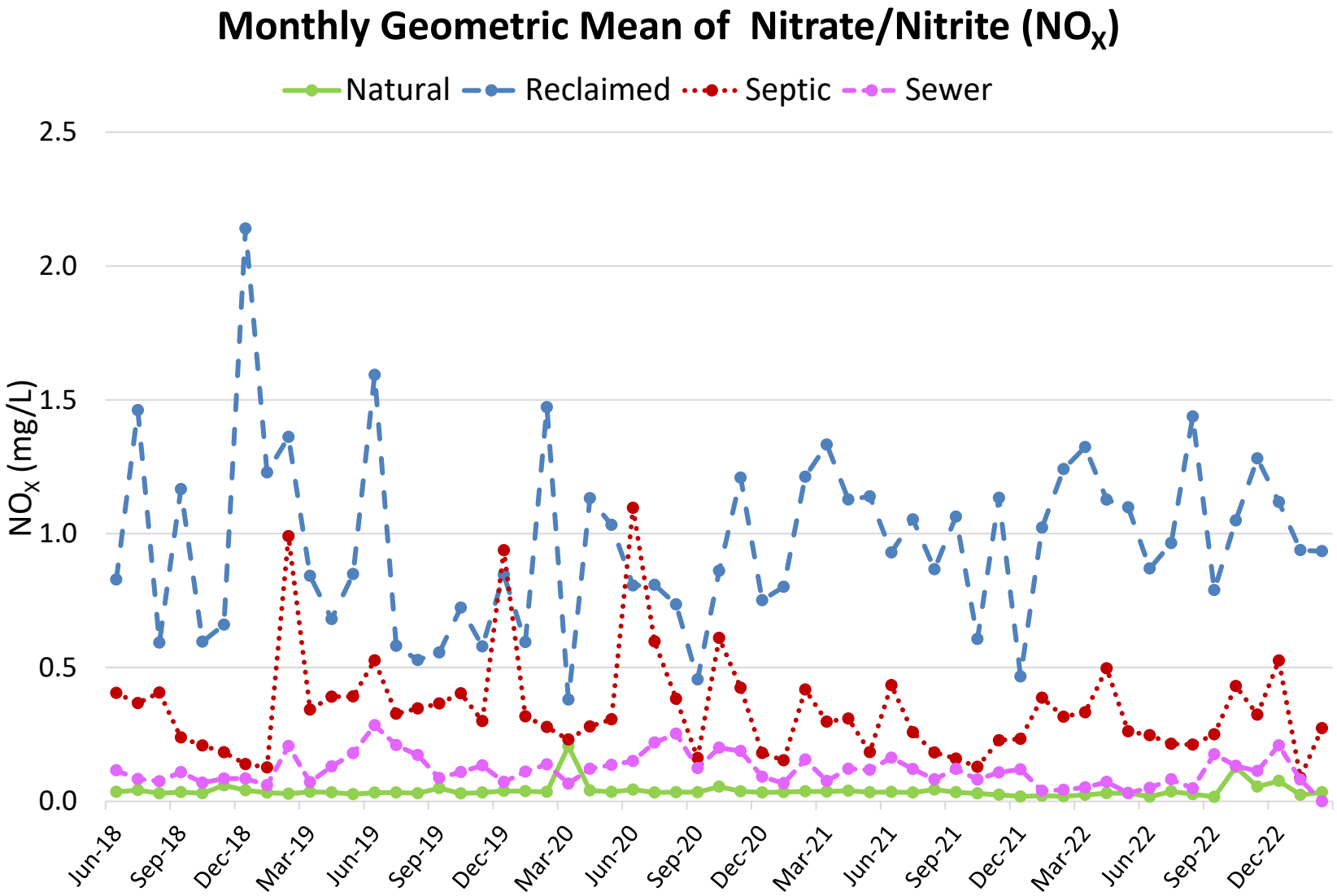


NITRATE + NITRITE (NOX)

[GEOMETRIC MEAN]

Treatment	Geometric mean (mg/L)
Reuse	**0.97**
Septic	0.29
Sewer	0.10
Natural/Control	0.04

Highest geometric mean concentration is in bold

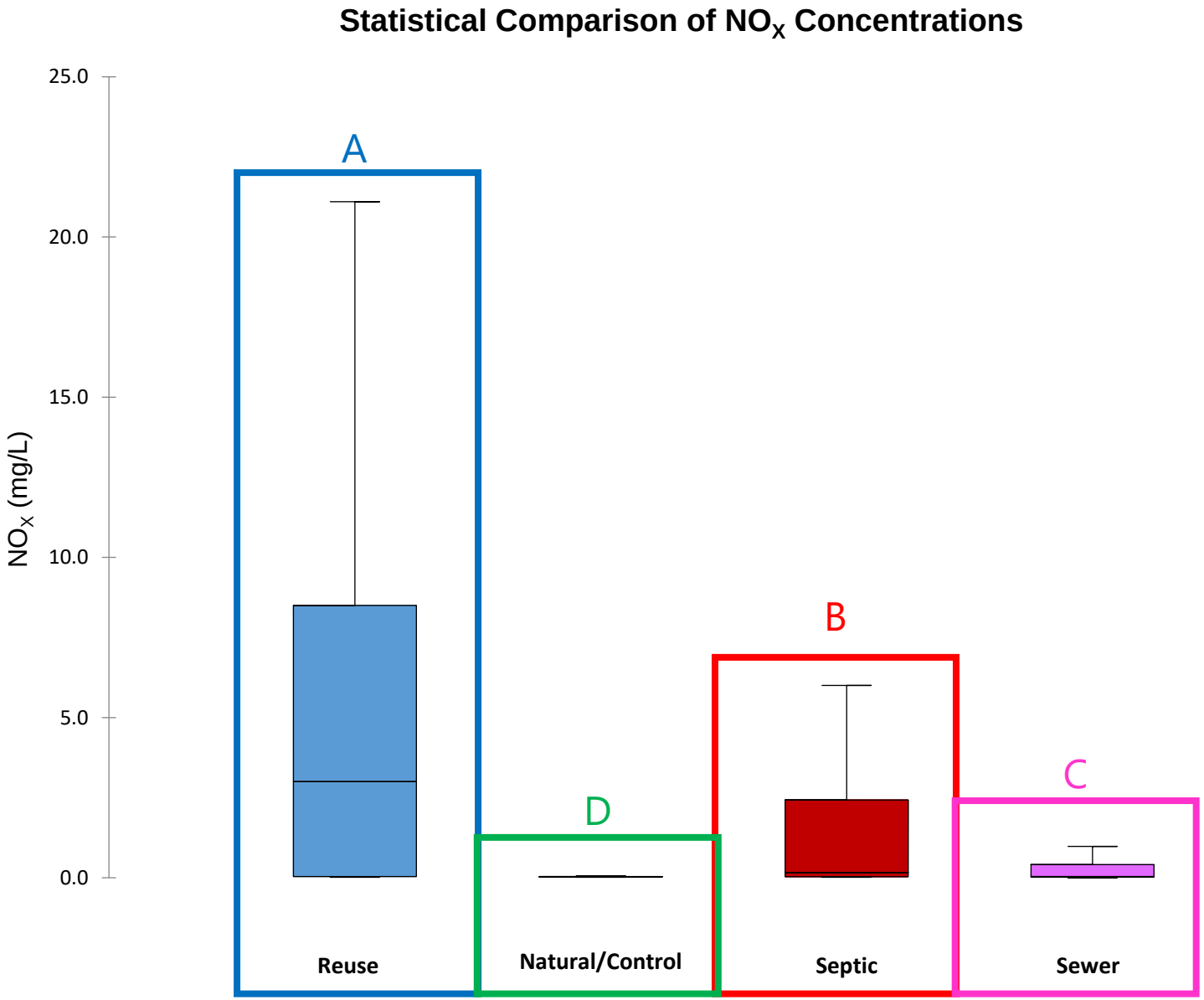


NITRATE + NITRITE (NO_X)

[MEDIAN]

Treatment	Median (mg/L)
***Reuse**	**3.00_a**
*Septic	0.17_b
*Sewer	0.03_d
*Natural/Control	0.04_c

Significantly different median at p<0.001 using Kruskal-Wallis.

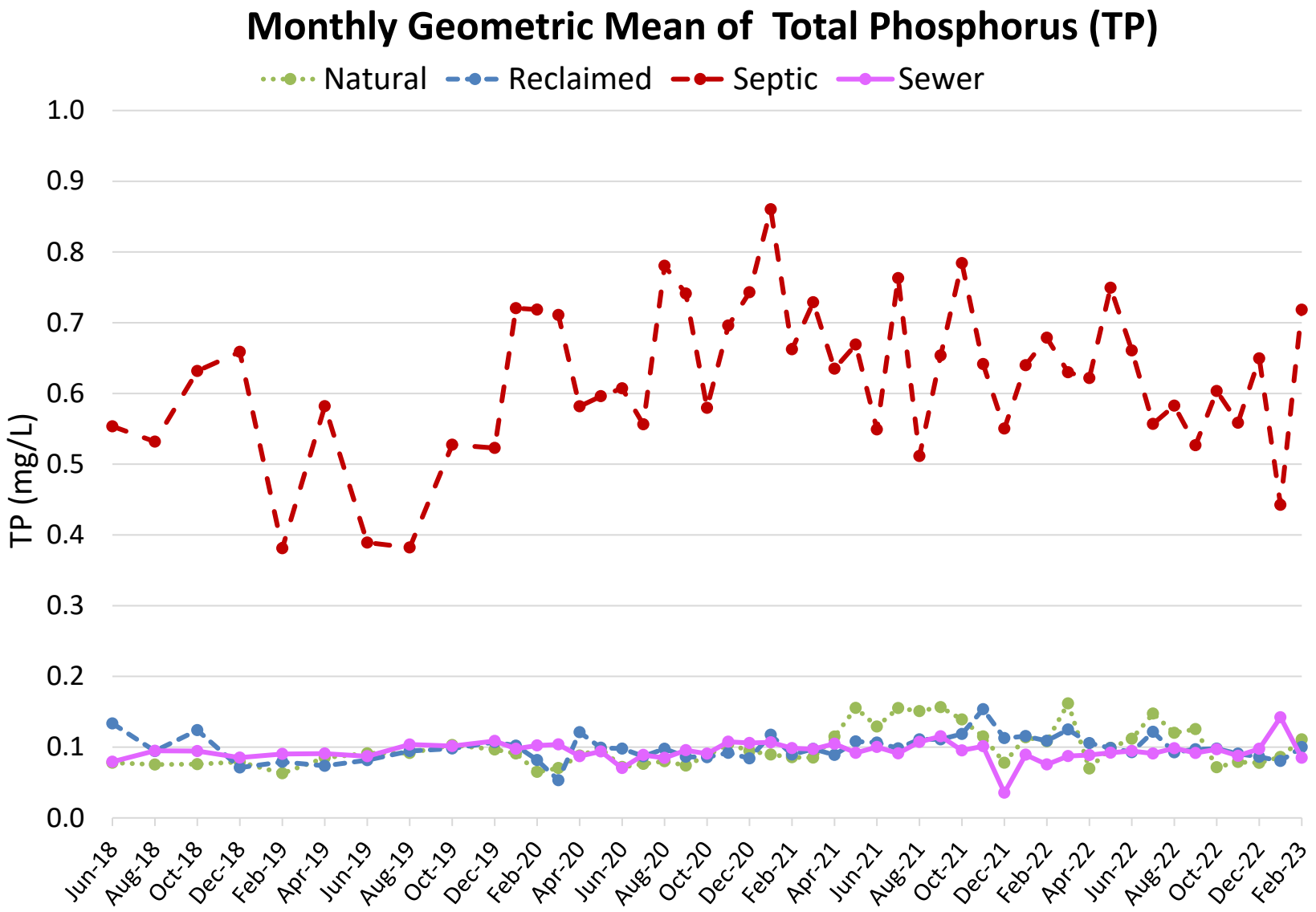


TOTAL PHOSPHORUS (TP)

[GEOMETRIC MEAN]

Treatment	Geometric mean (mg/L)
Reuse	0.10
Septic	**0.62**
Sewer	0.09
Natural/Control	0.10

Highest geometric mean concentration is in bold



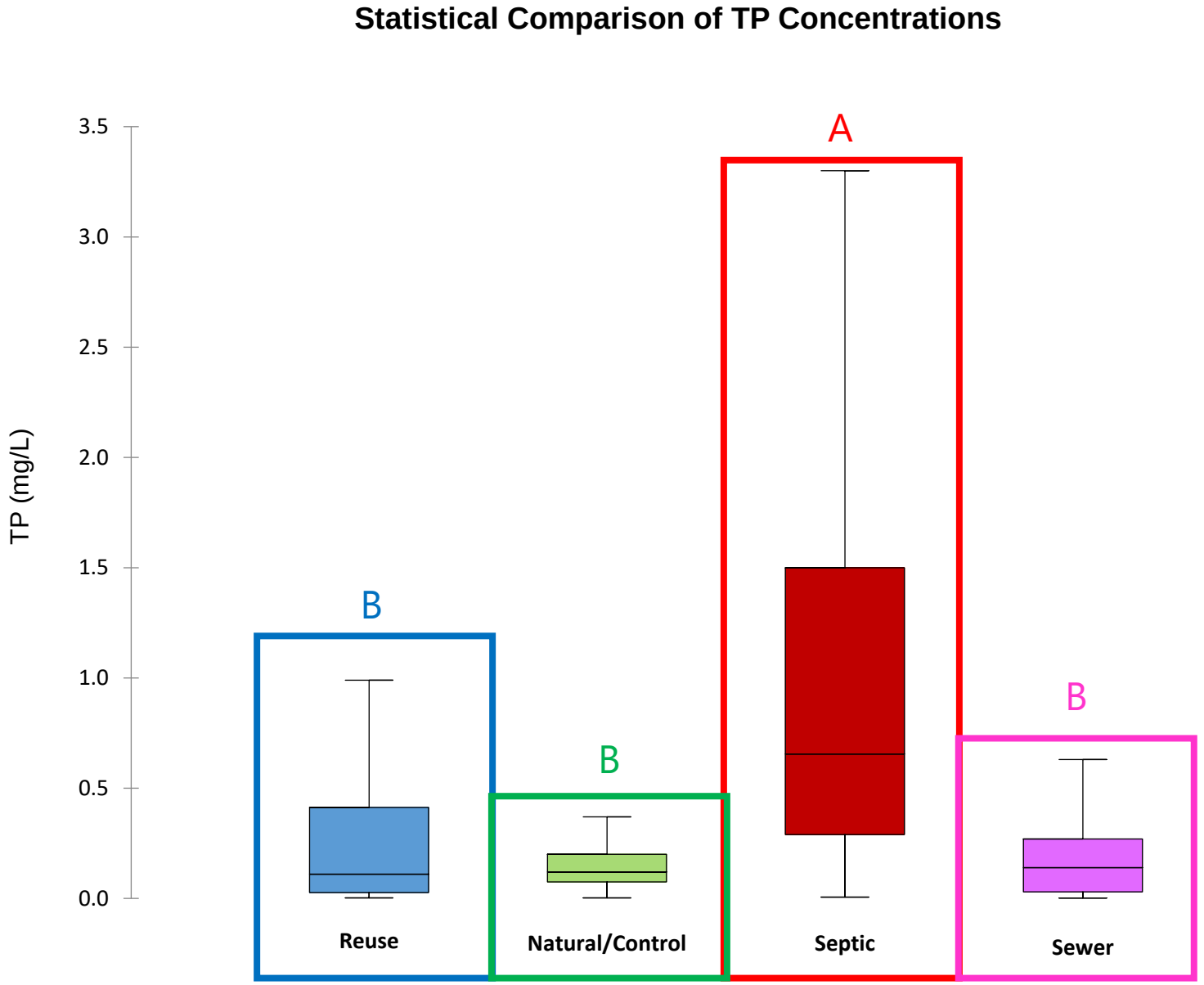
Geometric mean TP at **septic sites** is **6x** other treatment types

TOTAL PHOSPHORUS (TP)

[MEDIAN]

Treatment	Median (mg/L)
Reuse	0.11_b
***Septic**	**0.66_a**
Sewer	0.14_b
Natural/Control	0.12_b

Significantly different median at p<0.001 using Kruskal-Wallis.



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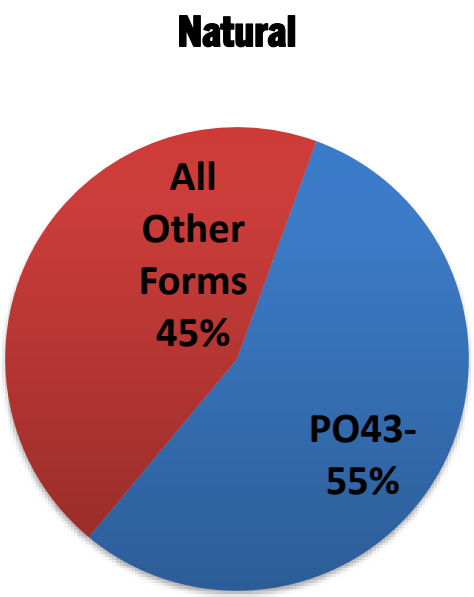
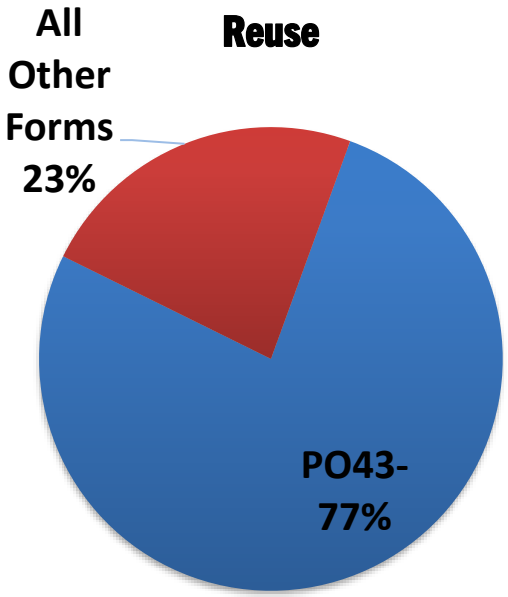
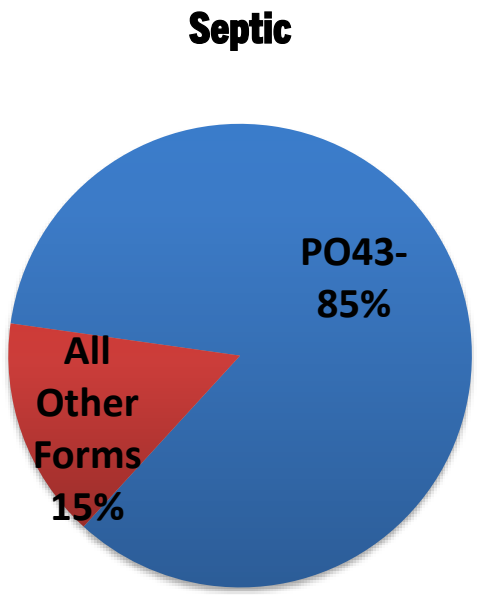


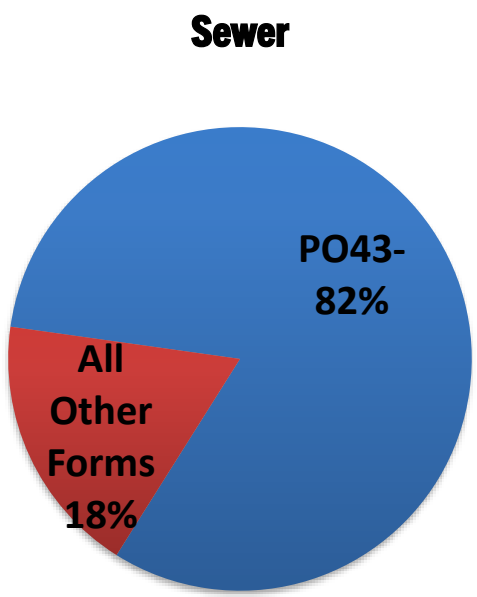
0.12 mg/L



0.11 mg/L



0.66 mg/L

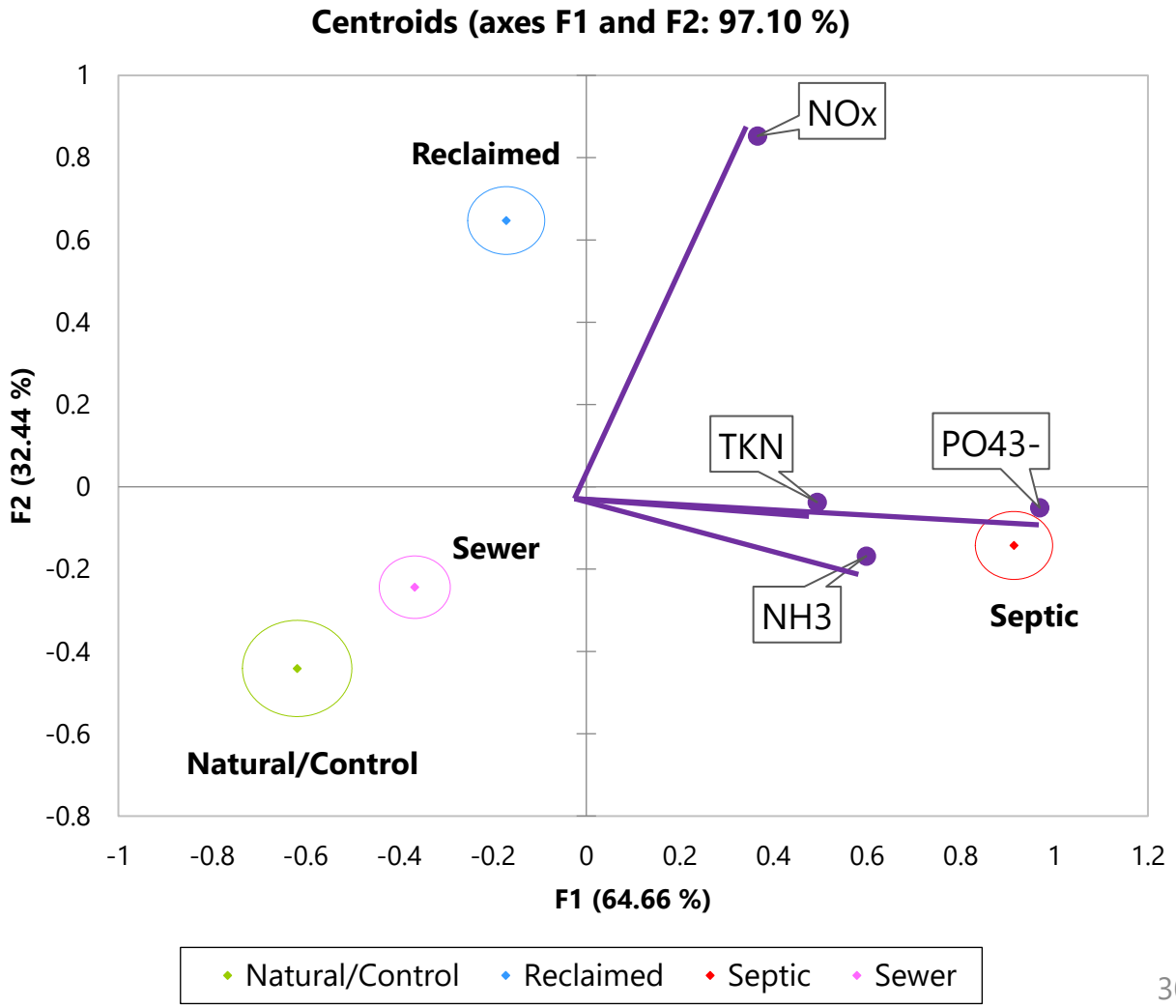


0.14 mg/L

Average percent PO_4^{3-} composition is lowest at **natural sites,** highest at **septic sites**

STATISTICAL SUMMARY

- Discriminant Analysis (DA) of the measured nutrient concentrations
- Natural treatment clearly lowest nutrients of all treatments
- Septic dominated by highest PO_4^{3-}, NH_3, and TKN
- Reclaimed dominated by highest NO_x



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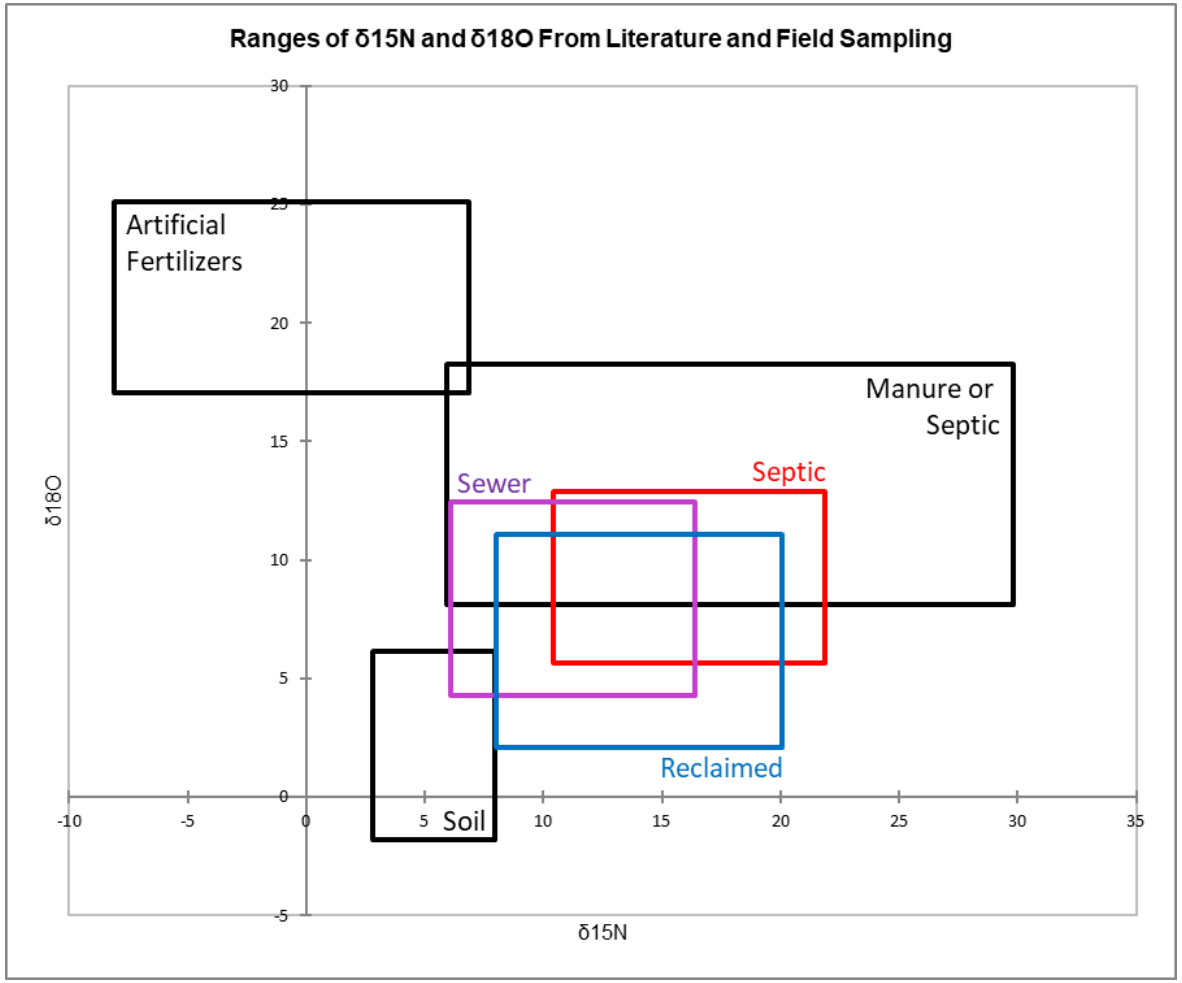
NITROGEN AND OXYGEN ISOTOPES AS TRACERS

We use stable isotopes of nitrate (NO_3^-) to understand sources in groundwater

- δ^{15} Nitrogen
  - Low ranges are signatures of artificial NH_3 fertilizers
  - High enrichment ranges signature of manure, sewage, or biosolids
- δ^{18} Oxygen
  - Low δ^{18} signature of surficial groundwater as the rainfall recharge is δ^{18} depleted
    - Low δ^{18} reclaimed likely due to more oxygen exchange with ambient water
  - High δ^{18} representative of reactions utilizing atmospheric O_2

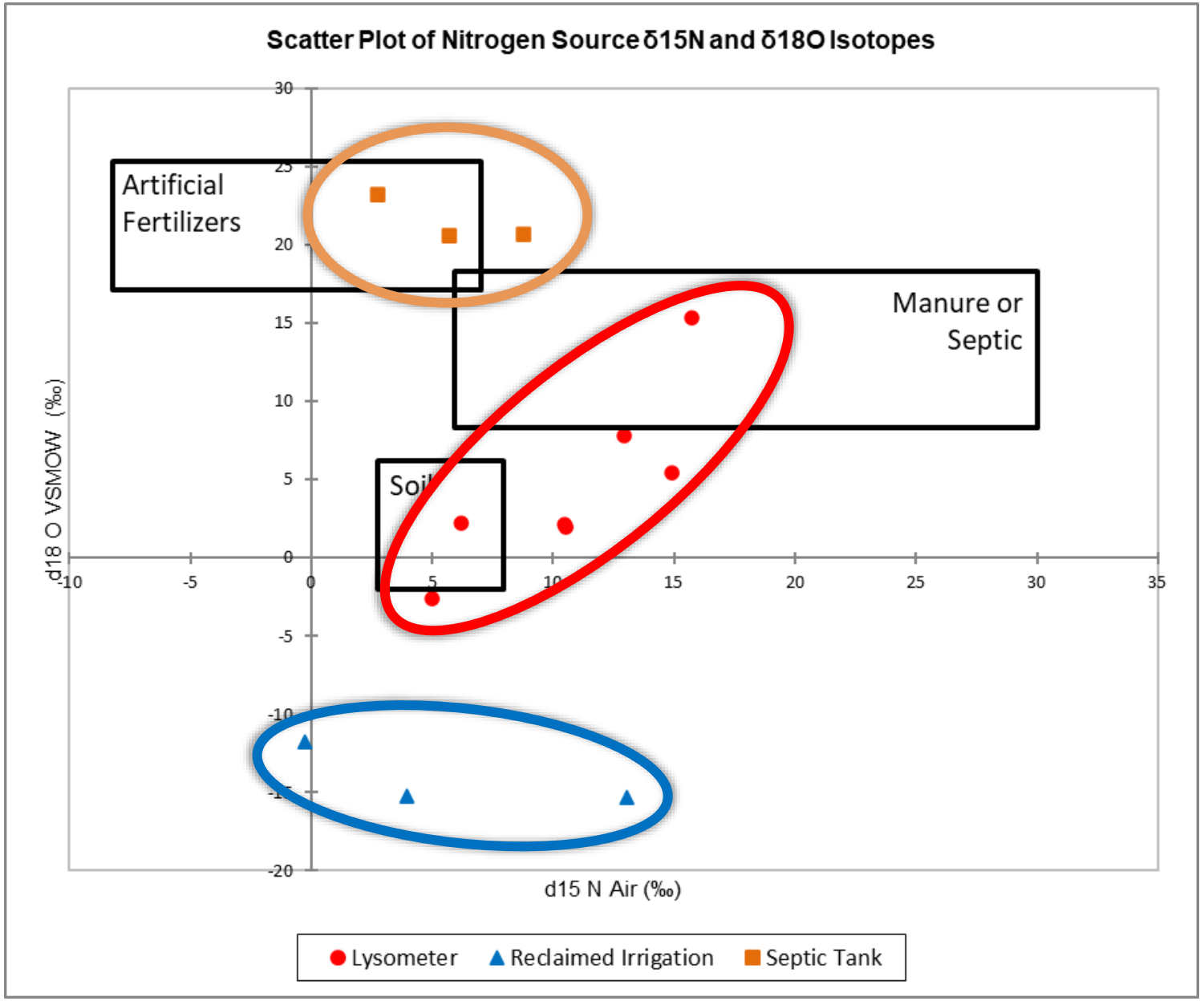


Nikolenko, Olha, et al. "Isotopic composition of nitrogen species in groundwater under agricultural areas: a review." *Science of the Total Environment* 621 (2018): 1415-1432.

4b. ISOPTOPIC FINGERPRINT

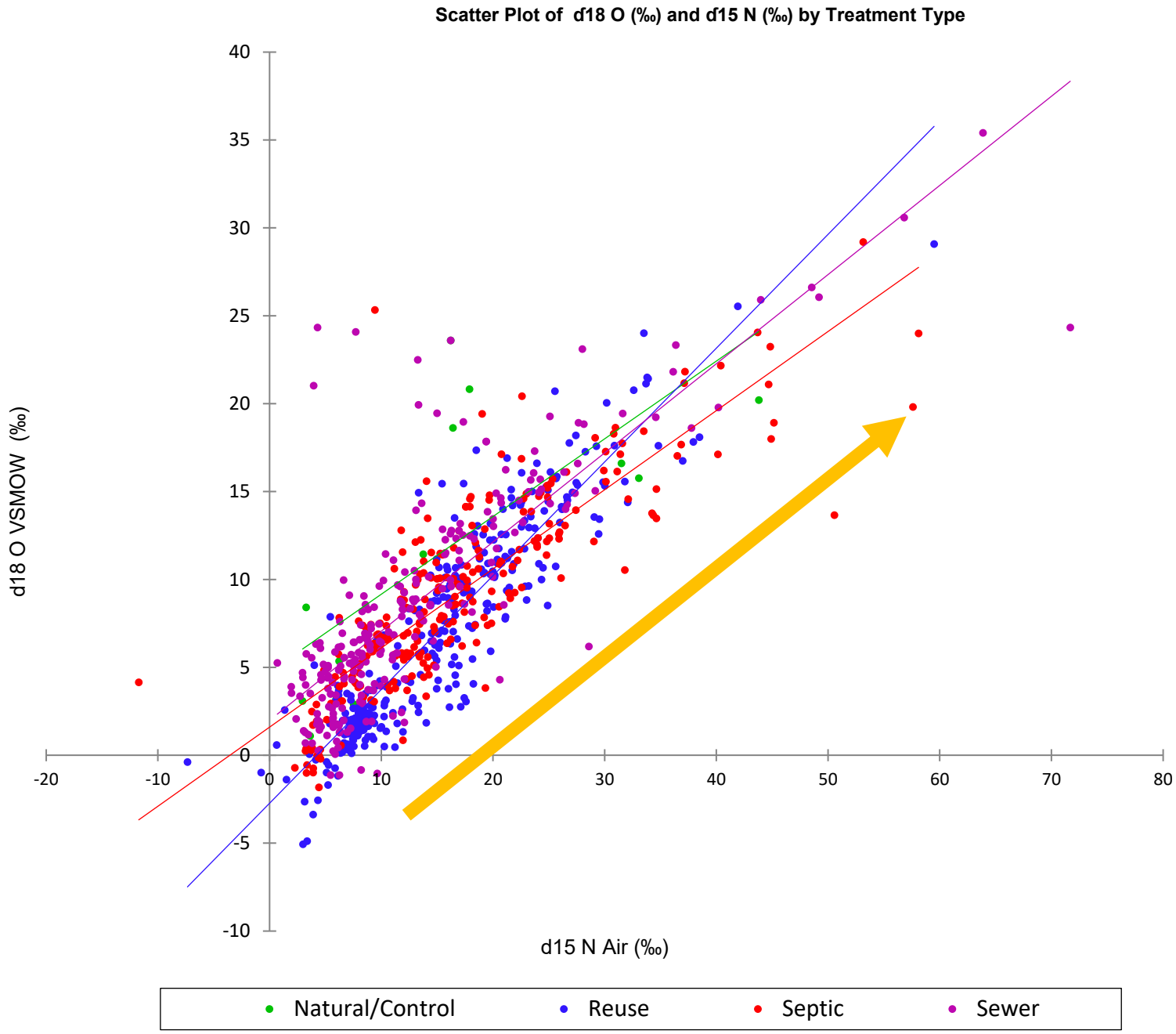
FINGERPRINTING SOURCES

- Samples collected directly from:
  - Septic tanks
  - Septic drain fields (lysimeter)
  - Reclaimed Irrigation
- Fingerprints don't match the literature



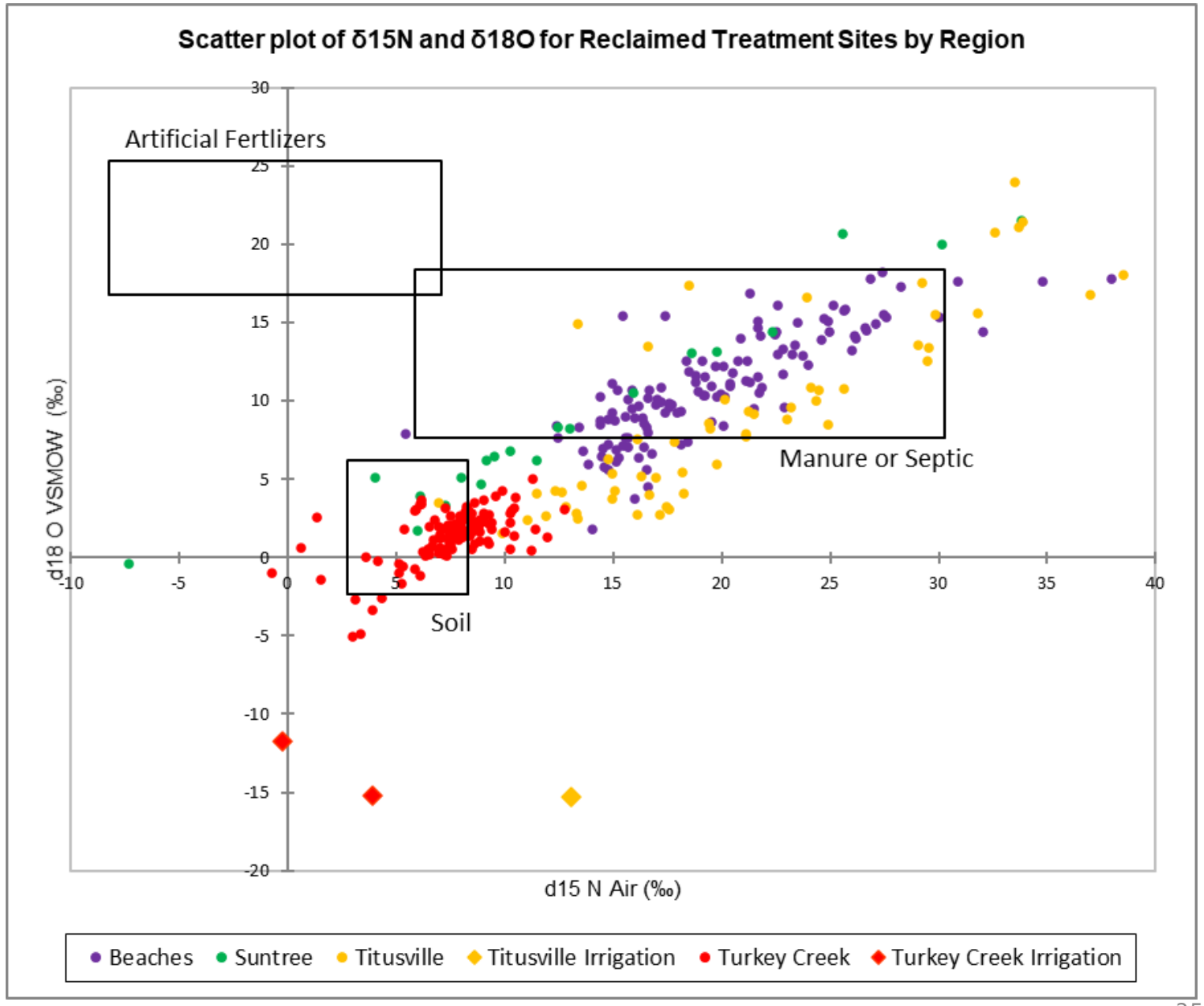
GROUNDWATER- ALL TREATMENT TYPES

- Variability seen in all treatment types
- Similar trends between treatment types, but some distinct differences
- Lowest enrichment seen in reuse sites
- **Number of Isotope samples analyzed**
  - **Natural – 13**
  - **Reclaimed – 336**
  - **Septic – 254**
  - **Sewer 240**



GROUNDWATER - RECLAIMED SITES

- Beaches, Suntree, and Titusville show signatures of septic
- Turkey Creek low enrichment, similar to soil
- Turkey Creek samples collected prior to WWTF upgrades



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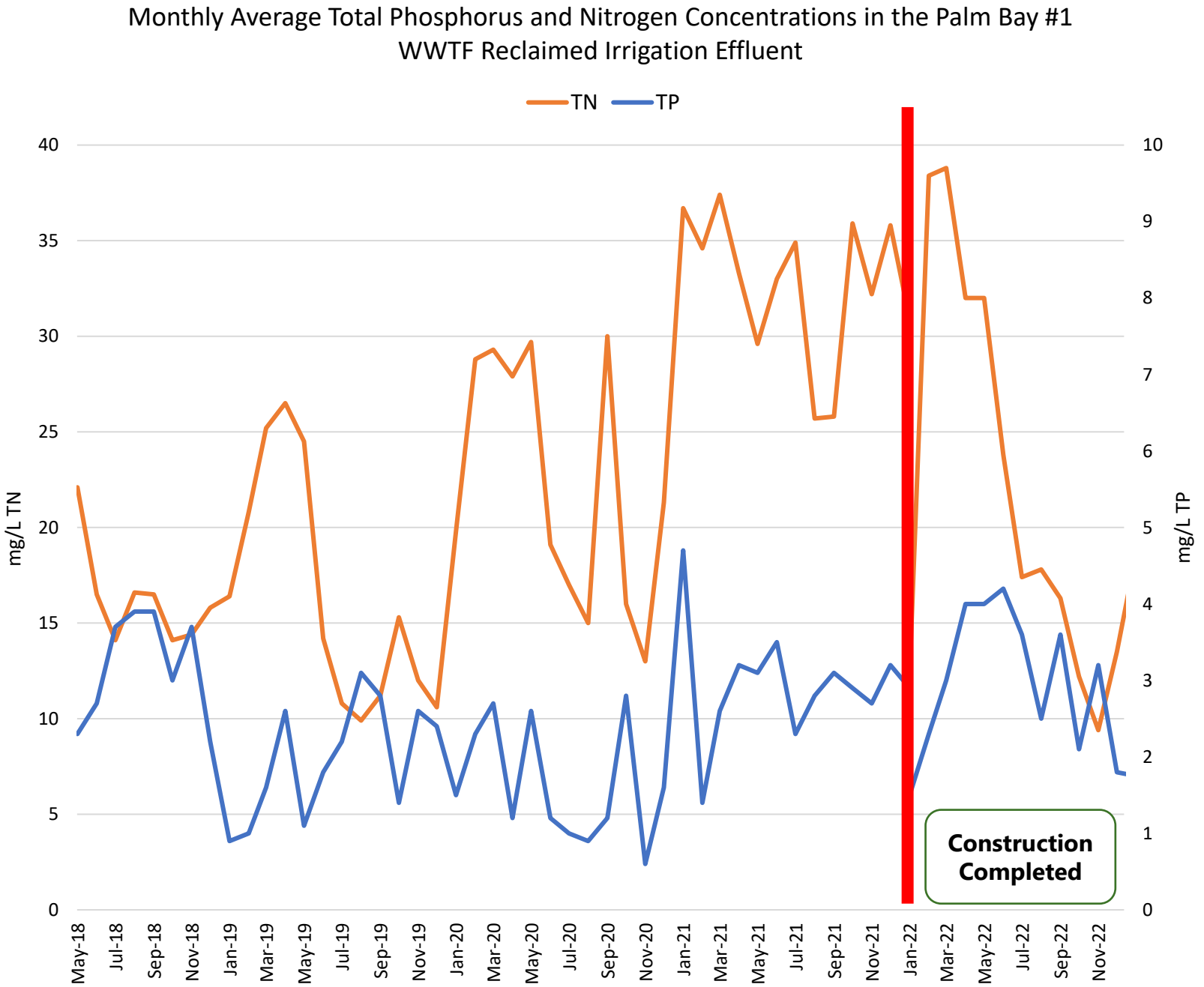
PALM BAY WRF

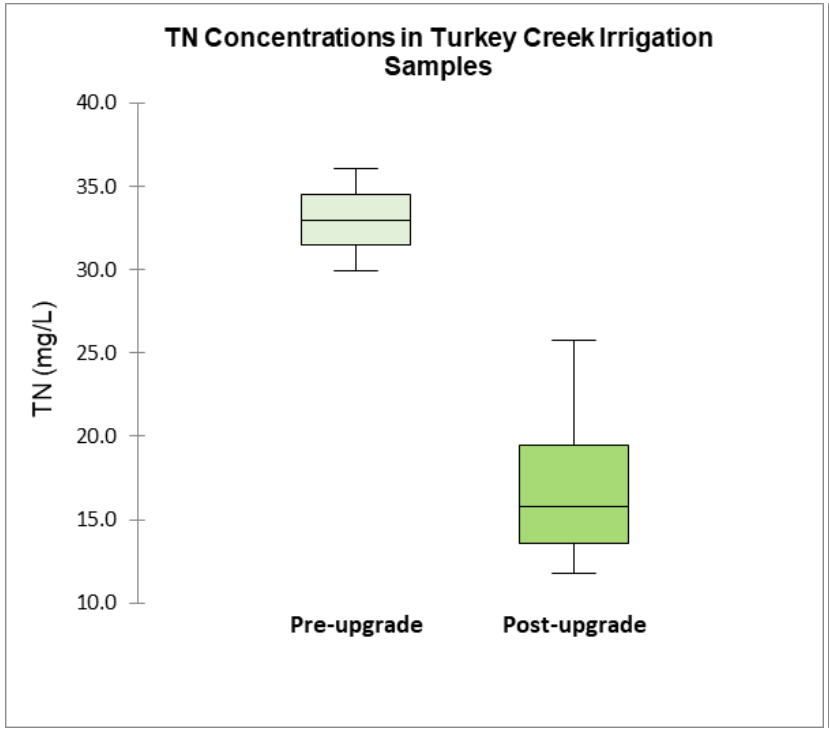
- Construction completed in January 2022
- Upgrades started yielding reduction in effluent concentrations in June/July 2022

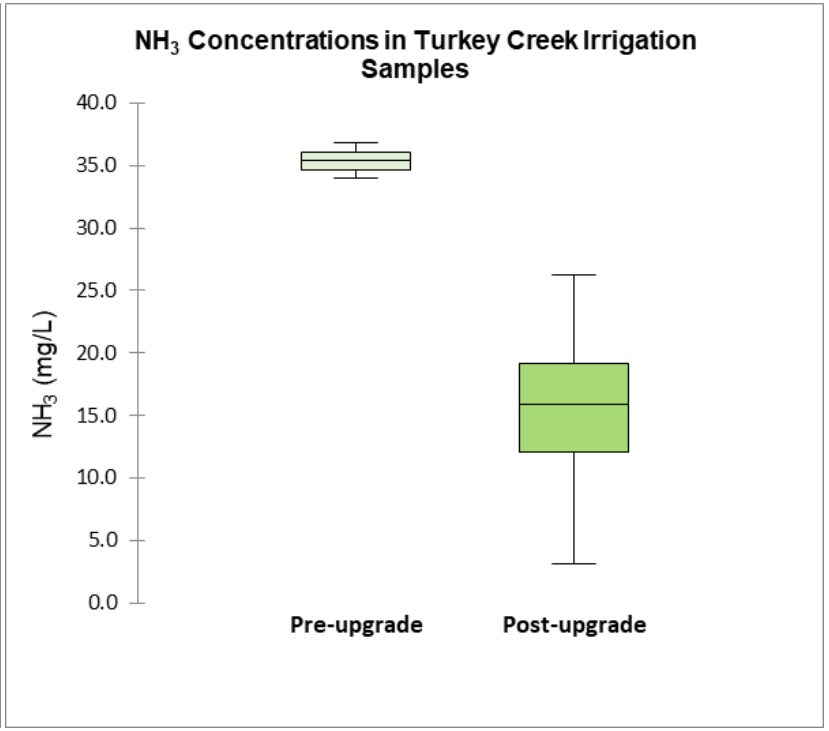


PALM BAY WRF

TN IN TURKEY CREEK IRRIGATION SAMPLES

- AEI monitored post upgrade nutrient concentration in irrigation
- Small sample size, however **large concentration differences**
- More long-term post-upgrade data to be collected



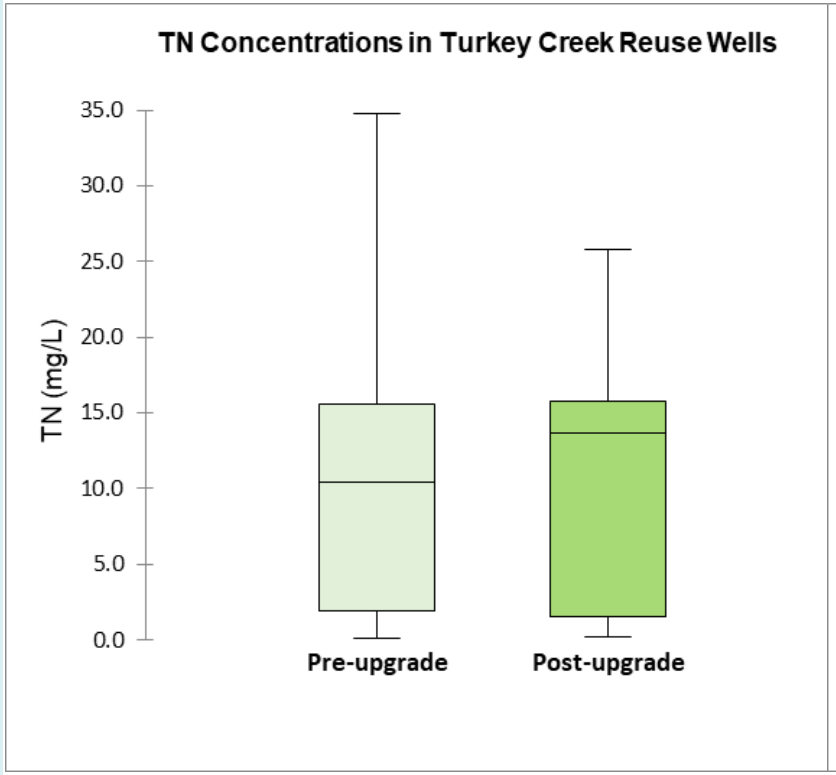


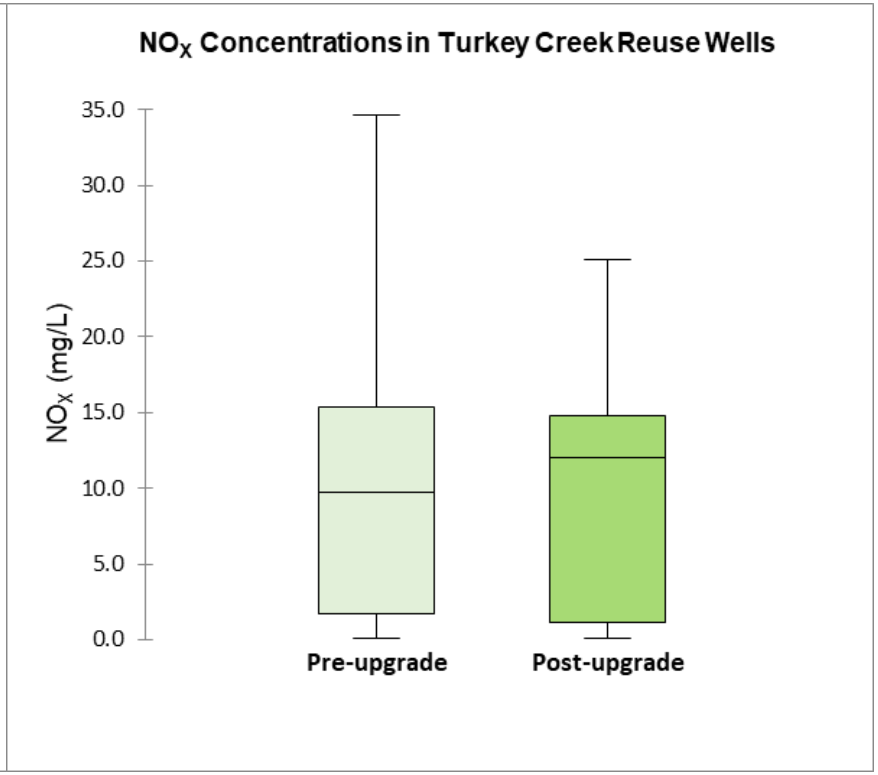
Geometric Mean Concentrations in Turkey Creek Irrigation Samples (mg/L)		
	Pre-upgrade n=2	**Post-upgrade** n=4
TN	32.85	16.56
NO_x	0.98	3.87
TKN	31.87	11.40
NH_3	35.37	11.96

PALM BAY WRF

TN IN TURKEY CREEK REUSE WELLS

- No notable reductions in groundwater thus far
- Continue collecting post-upgrade data to see effects within groundwater



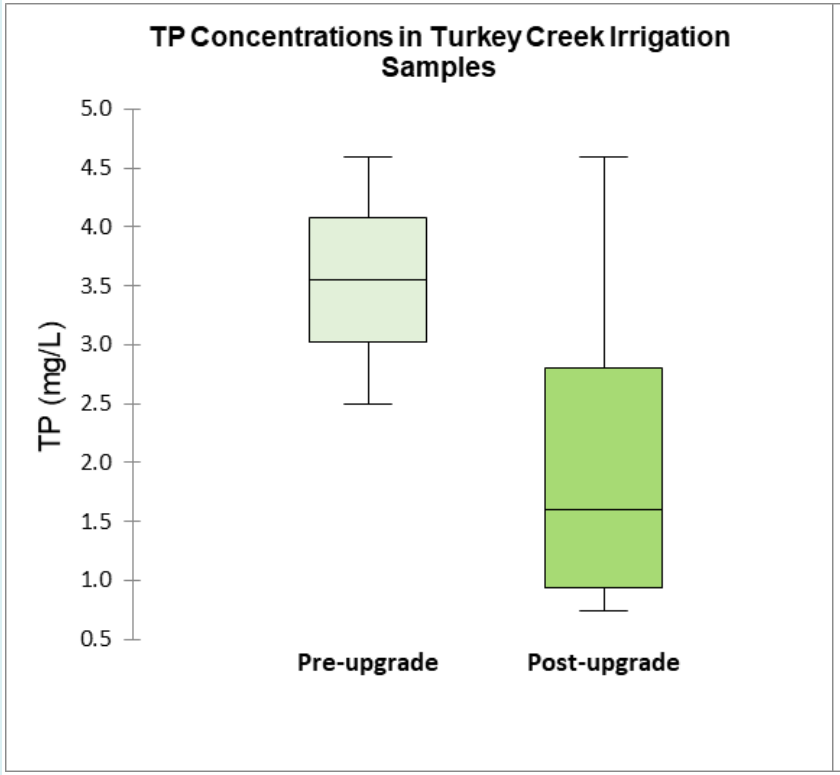


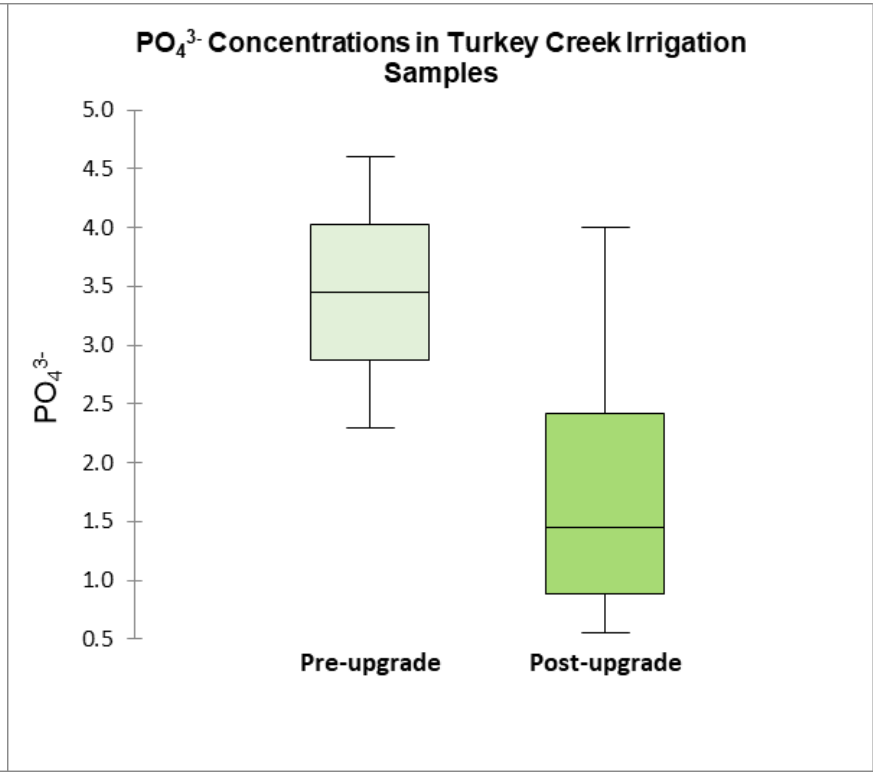
Geometric Mean Concentrations in Turkey Creek Reuse Wells (mg/L)		
	Pre-upgrade n=180	**Post-upgrade** n=27
TN	5.09	4.77
NO_x	0.13	0.18
TKN	0.139	0.304
NH_3	0.03	0.04

PALM BAY WRF

TP IN TURKEY CREEK IRRIGATION SAMPLES

- Small sample size, however **large concentration differences**
- More long-term post-upgrade data to be collected



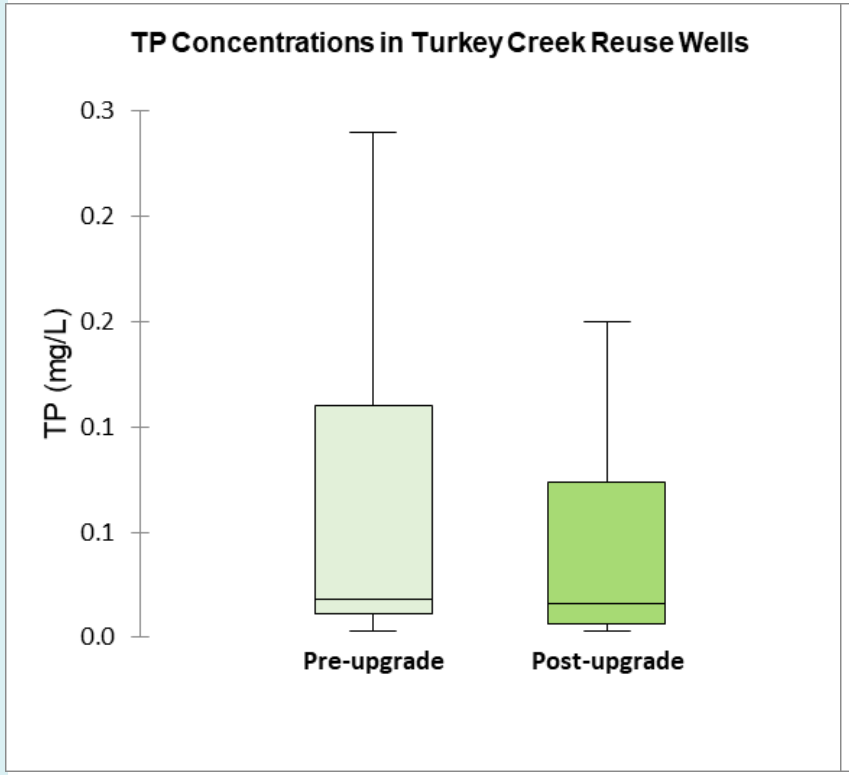


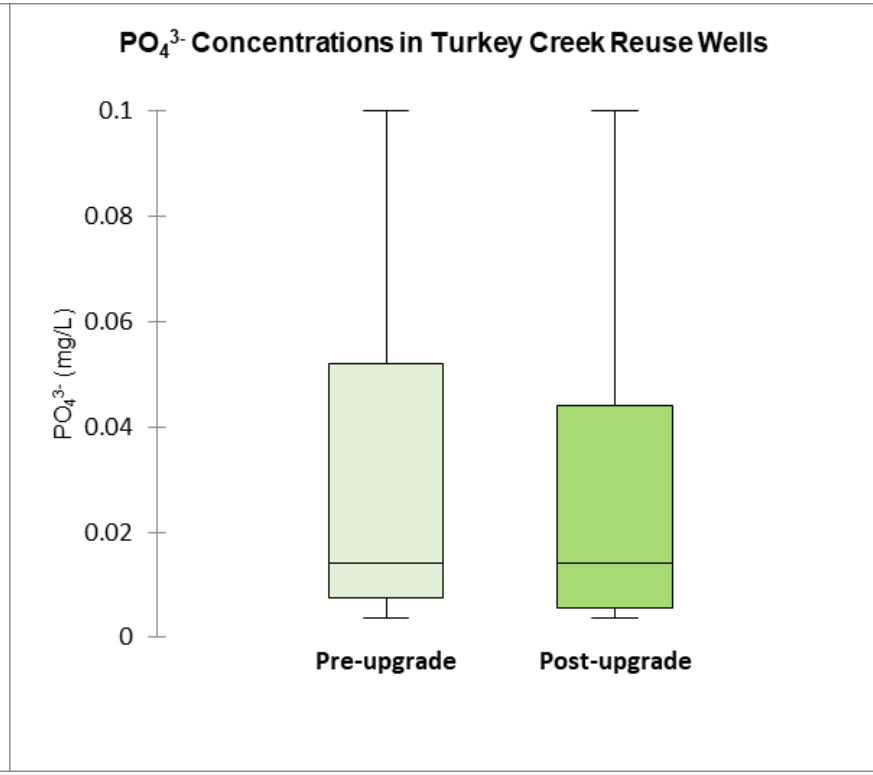
Geometric Mean Concentrations in Turkey Creek Irrigation Samples (mg/L)		
	Pre-upgrade n=2	**Post-upgrade** n=3
TP	3.39	1.65
PO_4^{3-}	0.13	0.18

PALM BAY WRF

TP IN TURKEY CREEK REUSE WELLS

- Some initial TP reduction in groundwater, but no notable PO43- reductions in groundwater thus far
- Continue collecting post-upgrade data to see effects within groundwater

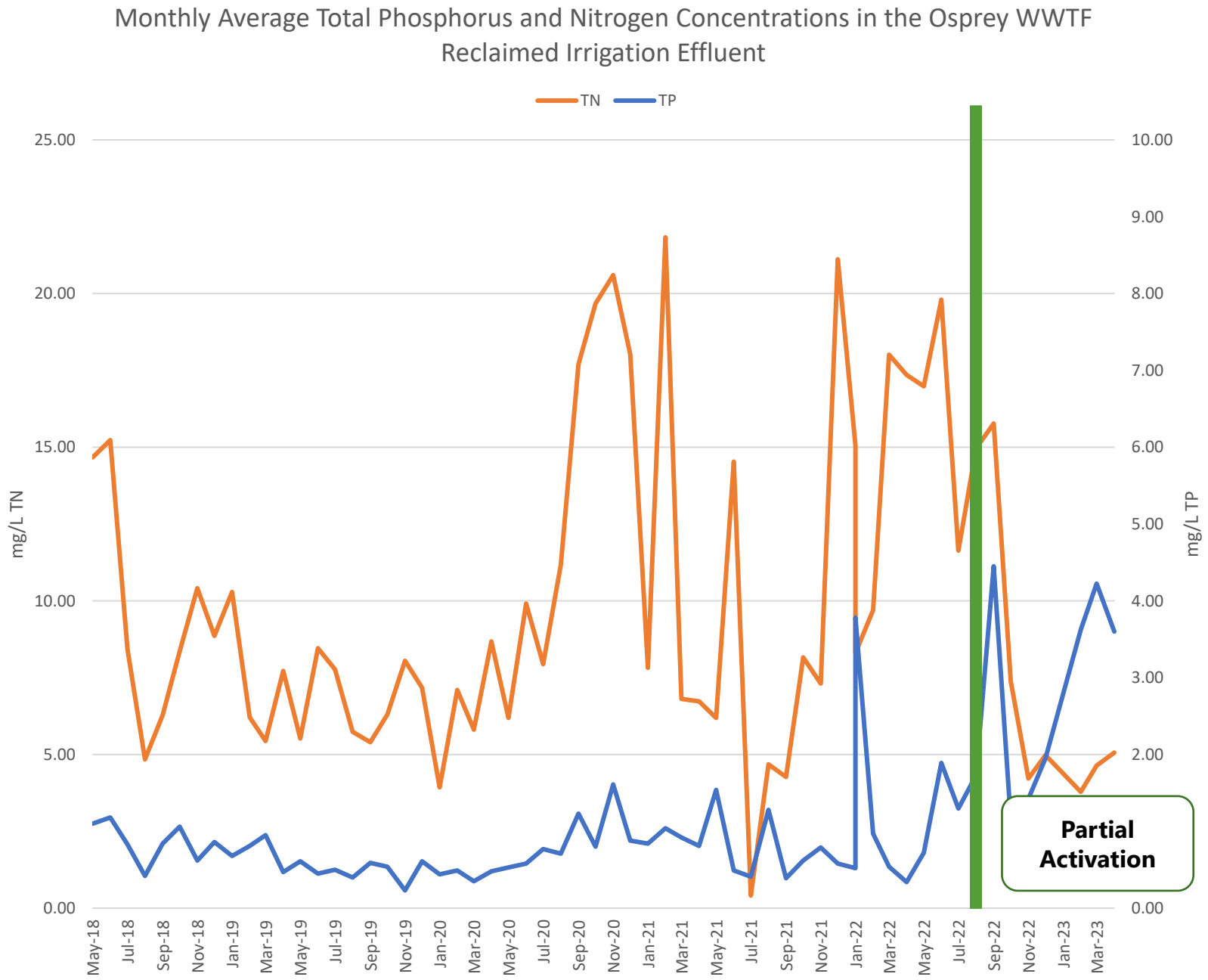




Geometric Mean Concentrations in Turkey Creek Reuse Wells (mg/L)		
	Pre-upgrade n=129	**Post-upgrade** n=27
TP	0.031	0.019
PO_4^{3-}	0.018	0.016

TITUSVILLE OSPREY WATER RECLAMATION FACILITY (WRF)

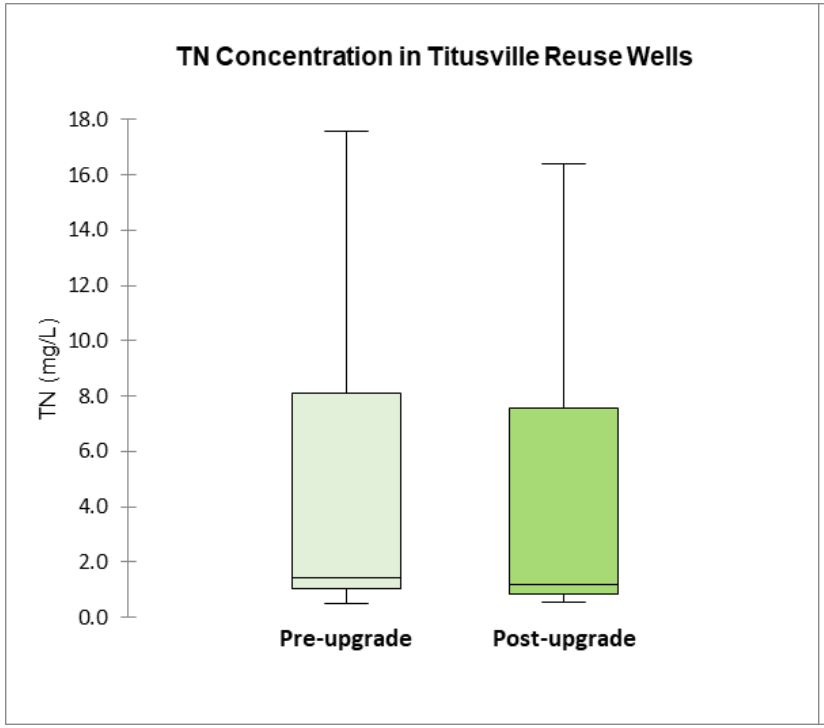
- Partial implementation of the BNR train in August 2022
- Reductions visible by November

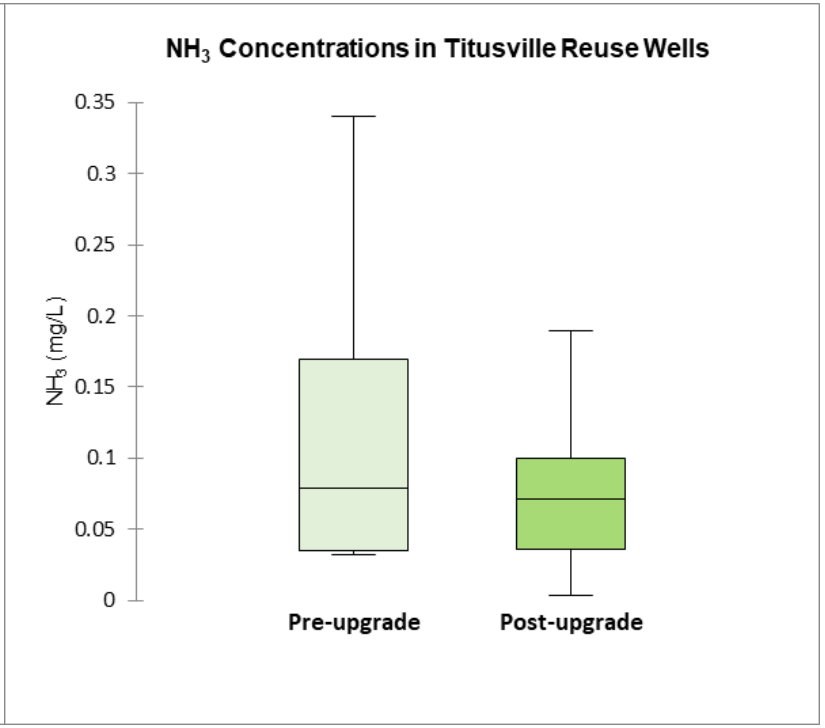


TITUSVILLE OSPREY WATER RECLAMATION FACILITY (WRF)

TN IN TITUSVILLE REUSE WELLS

- No notable reductions in groundwater concentrations yet



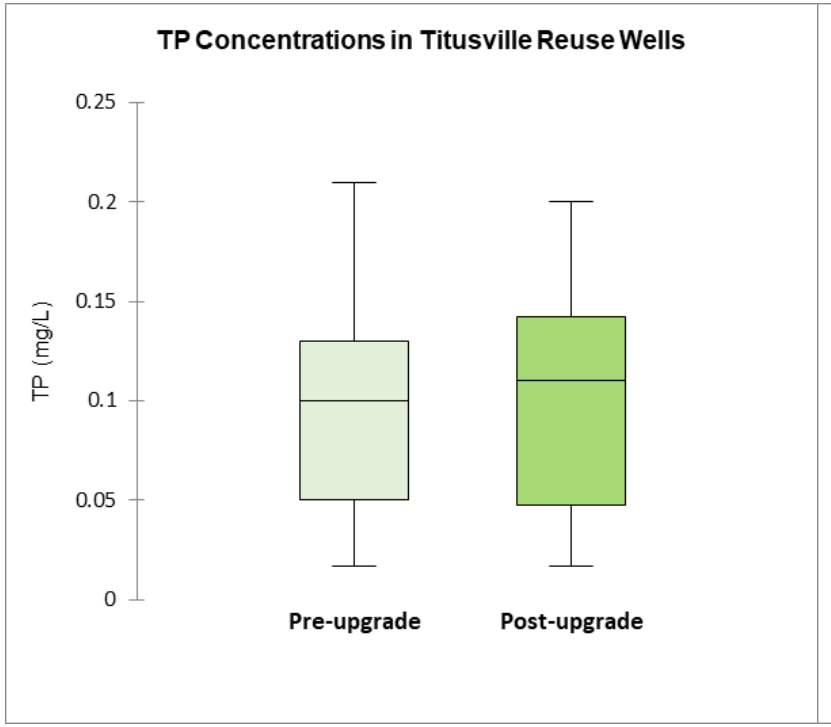


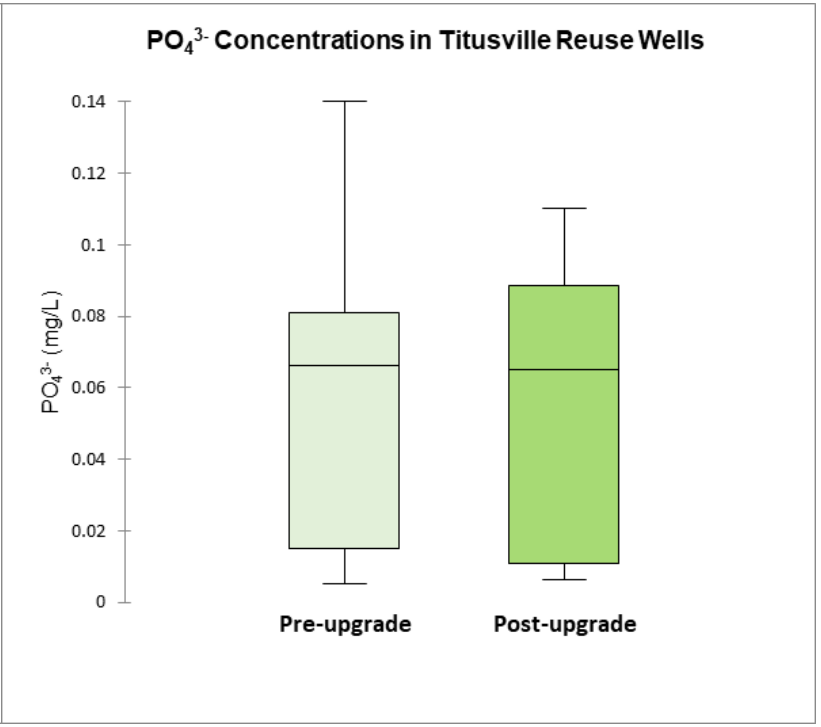
Geometric Mean Concentrations in Titusville Reuse Wells (mg/L)		
	Pre-upgrade n=153	**Post-upgrade** n=24
TN	2.52	2.21
NO_x	0.38	0.33
TKN	1.08	0.98
NH_3	0.09	0.06

TITUSVILLE OSPREY WATER RECLAMATION FACILITY (WRF)

TP IN TITUSVILLE REUSE WELLS

- No notable reductions in phosphorus after upgrades





Geometric Mean Concentrations in Titusville Reuse Wells (mg/L)		
	Pre-upgrade n=123	**Post-upgrade** n=24
TP	2.52	2.21
PO_4^{3-}	0.38	0.33

SEWER CONNECTIONS

- Septic-to-sewer construction was recently completed in the Suntree region
  - Delay in connections due to lift station supplies on back order
- Merritt Island Septic community ready to bid

Construction of septic-to-sewer conversions in Suntree

PRESENTATION OUTLINE

1. Project Background and Objectives
2. Project Design
3. Project Methodology
4. Results
    a. Groundwater Concentrations by Treatment Type
    b. Source Tracking: Isotopic Fingerprinting
    c. Groundwater BMPs
5. Conclusions & Next Steps

CONCLUSIONS: GROUNDWATER INPUTS

1) Loading and composition of nitrogen into Brevard County groundwater varies by source of wastewater.
2) Reclaimed monitoring sites have highest TN comprised of mostly NO_x, followed by septic comprised of mostly TKN
3) TN at septic and sewer sites are dominated by TKN, while NO_x was dominant at reclaimed sites
4) Septic monitoring sites have TP concentrations >6X higher than any other treatment types

CONCLUSIONS: ISOTOPIC SIGNATURES & BMP IMPLEMENTATION

1) There are significant differences between the isotopic composition of NO_3^- between septic and reclaimed irrigation treatments
   - Reclaimed irrigation NO_3^- has a unique isotopic composition which is likely the result of the WWTF treatment systems.
2) Robust Brevard County dataset (n=844) illustrates both N and O enrichment increases over time
3) Using static literature values of isotopic ratios to assume nitrogen sources can be misleading
4) Monitoring of post-WWTF upgrades must continue to identify differences in groundwater
   - Concentration differences observed in irrigation samples
   - More data needed for statistical trends in groundwater quality improvements, but initial trends are promising
5) Groundwater quality from long-term datasets should be used to guide BMPs/models

THANK YOU!

Save our Indian River Lagoon Program

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- *Lusk, M., Toor, G. S., & Obreza, T. (2011). Onsite Sewage Treatment and Disposal Systems: Phosphorus. University of Florida IFAS extension.*
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