



MONITORING NITROGEN REMOVAL BY FLORIDA'S INGROUND NITROGEN – REDUCING BIOFILTERS

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Florida Department of Environmental Protection

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OUTLINE

- Acknowledgement.
- Introduction.
- Nitrogen reducing onsite sewage treatment and disposal systems.
- In-ground nitrogen-reducing biofilter (INRB) sampling methods.
- Results and discussion.





ACKNOWLEDGEMENTS

- The project is partially funded by:
 - The federal multipurpose fund from the U.S. Environmental Protection Agency (EPA).
 - The Spring and Aquifer Protection Fund from the Florida Department of Environmental Protection (DEP).
- The monitored INRB systems in Leon and Citrus Counties were constructed by:
 - Apalachee Backhoe and Septic.
 - Ace Septic and Waste.
- Special thanks to Ms. Debby Tipton, Ms. Tanya Welborn, Mr. Martin Schumann, and Dr. Xueqing Gao for their continuous support throughout the monitoring and sampling process of the INRB systems.



INTRODUCTION

- Onsite sewage treatment and disposal systems (OSTDSs), commonly known as septic systems, are used by approximately 30% of Florida's establishments.
- Florida's estimated 2.6 million OSTDSs in operation represent approximately 12% of the septic systems in the U.S.
- Groundwater provides 90% of Florida's drinking water; therefore, it is important to properly plan, design, install, operate and maintain OSTDSs.

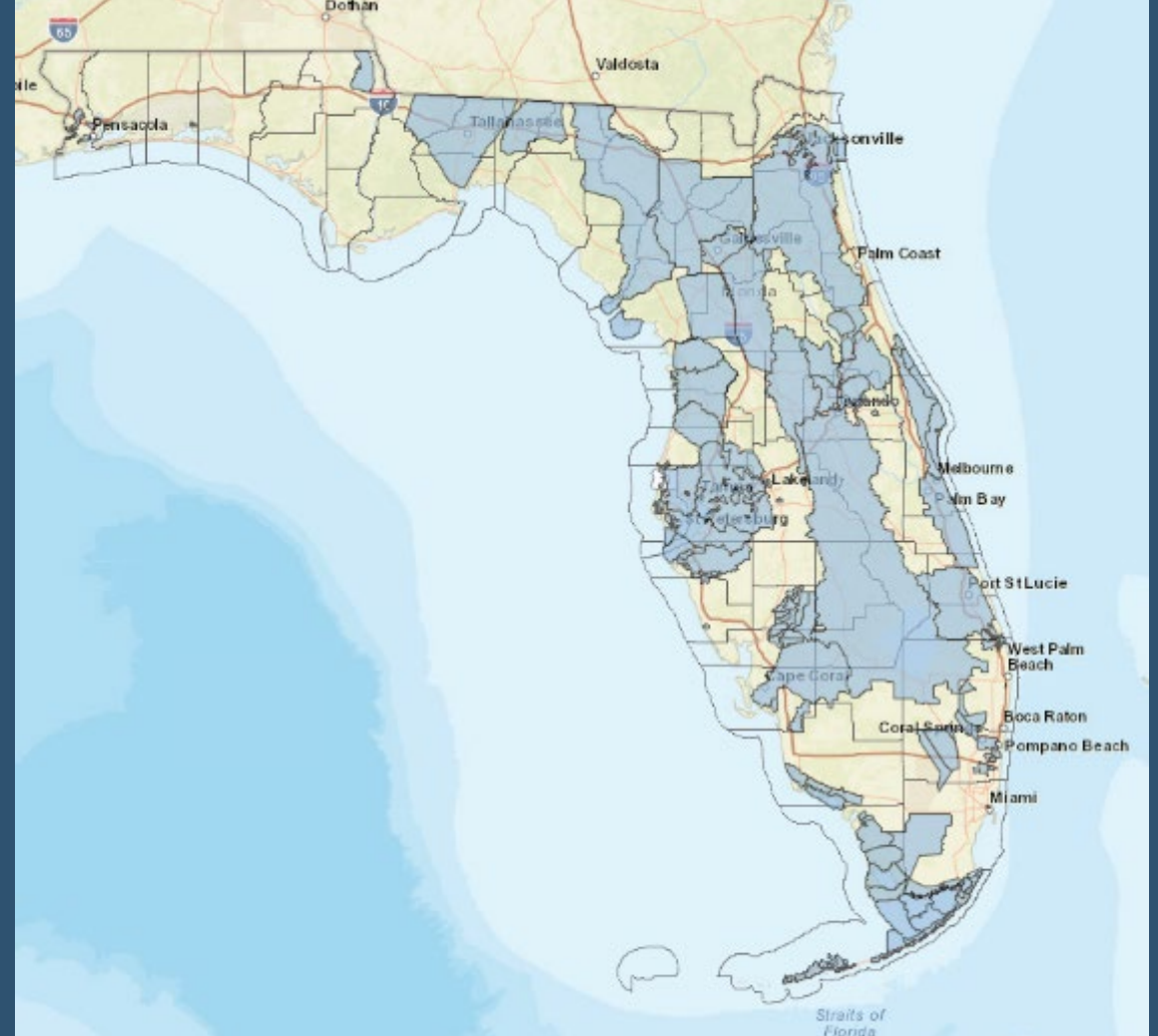
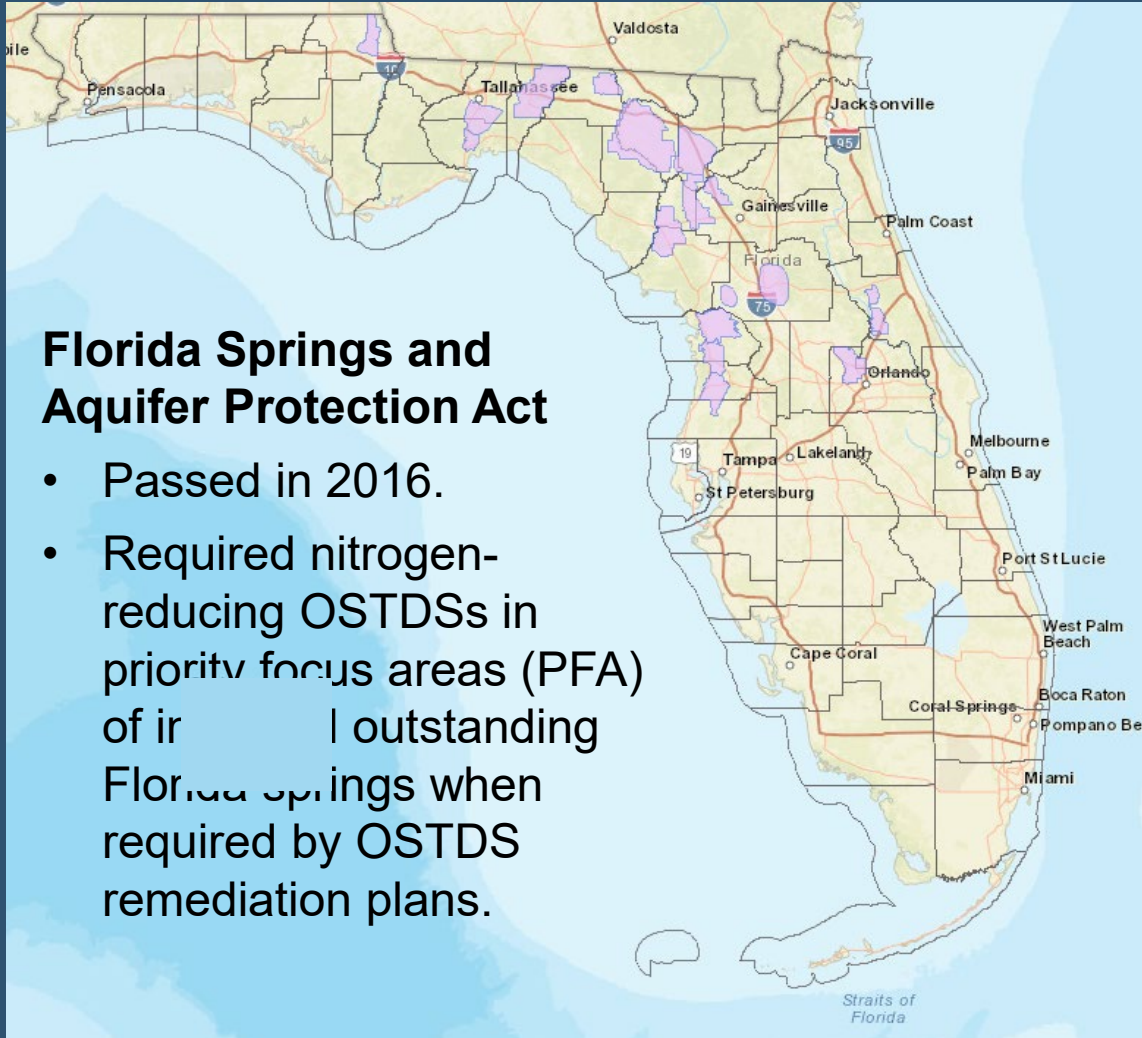


FLORIDA STATUTORY REQUIREMENTS

ENHANCED NUTRIENT-REDUCING OSTDSs

Florida Springs and Aquifer Protection Act

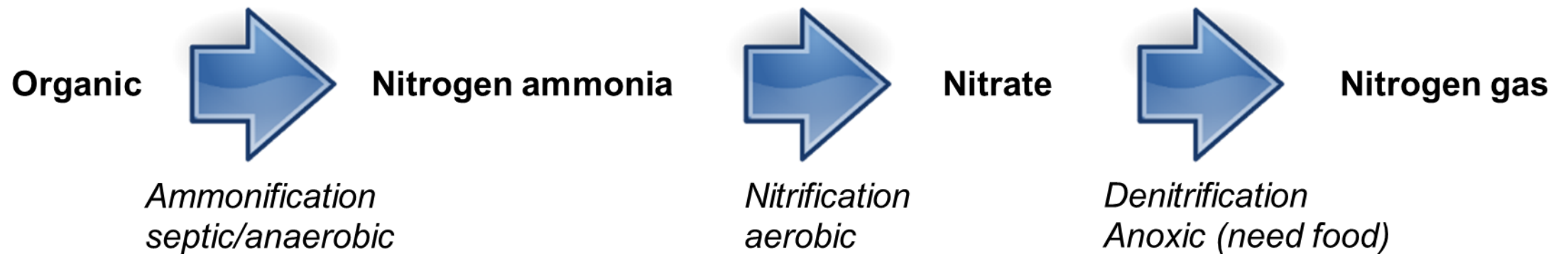
- Passed in 2016.
- Required nitrogen-reducing OSTDSs in priority focus areas (PFA) of impaired outstanding Florida Springs when required by OSTDS remediation plans.





REMOVING NITROGEN FROM DOMESTIC WASTEWATER

- Nitrogen exists in various forms and must generally be dealt with sequentially in each form to ensure removal.





ADVANCED SEPTIC SYSTEMS

TYPES OF ADVANCED SEPTIC SYSTEMS

- Nitrogen-reducing OSTDSs include:
 - Aerobic treatment units (ATU) certified as meeting NSF/American National Standards Institute (ANSI) Standard 245.
 - Nitrogen-reducing performance-based treatment systems (PBTS).
 - INRBs.



NITROGEN-REDUCING OSTDSs FOR SPRINGS

- More than 20,000 nitrogen-reducing OSTDS were installed in areas influenced by nitrogen-reducing requirements between Jan. 1, 2019, and April 19, 2025.
 - New systems required under springs OSTDS remediation plans.
 - New systems required in other areas by 2023 House Bill 1379.
 - Repairs and modifications required under springs OSTDS remediation plans (DeLeon, Wakulla, Wekiva).
 - Voluntary upgrades during repairs and modifications (some funded by DEP).

Type of Nitrogen-reducing OSTDS	Number of Systems Installed
ATU certified to NSF 245 standard	13,872
Nitrogen-reducing PBTS	692
INRB	5,561

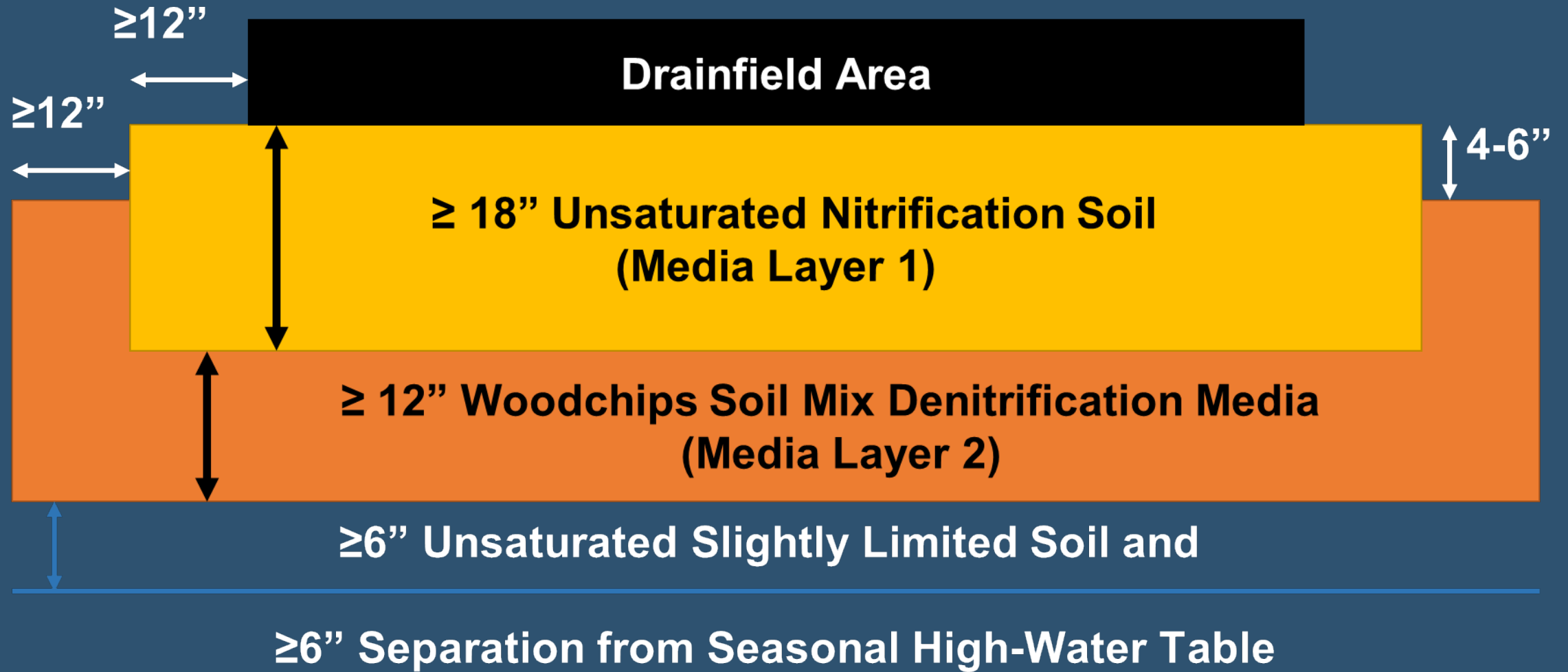


INRB COMPONENTS

- The INRB consists of:
 - Drainfield.
 - Media layer 1: unsaturated sandy media layer.
 - Nitrification: convert ammonia to nitrate.
 - Media layer 2: nitrogen-reducing media layer, mix of woody (lignocellulosic) material and fine aggregate.
 - Denitrification: convert nitrate to nitrogen gas.



INRB COMPONENTS (2)





OBJECTIVES

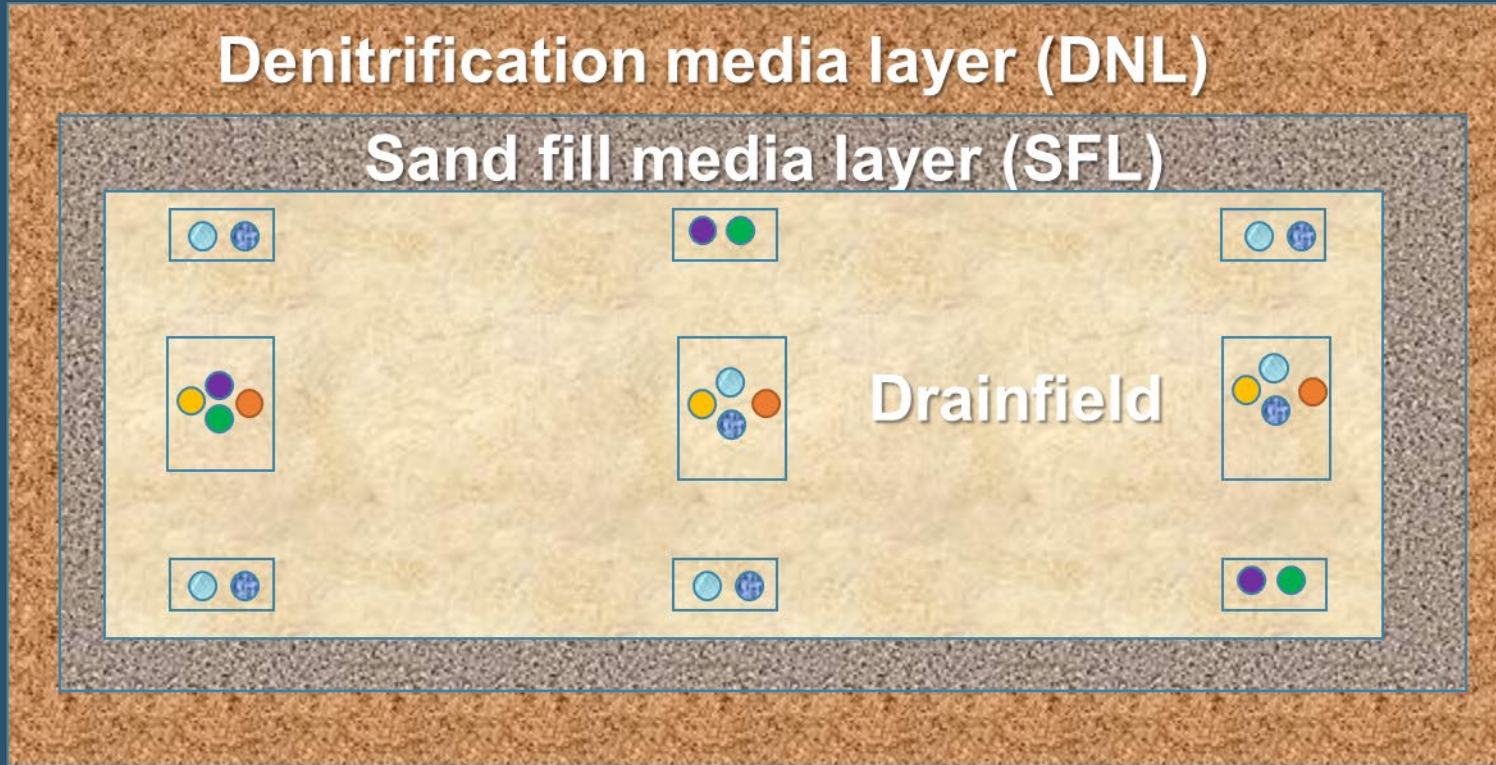
- Install and monitor INRBs.
 - Previously monitored two in Leon County.
 - Currently monitoring a third in Leon County and one in Citrus County.
 - Install monitoring equipment to obtain water samples.
 - Pan lysimeters (collect percolating water).
 - Suction lysimeters (collect soil moisture).
 - Install reference observation ports to monitor settling of materials over time.
 - Monitor at approximately quarterly intervals for two years (ongoing).



INRB MONITORING

TOP VIEW

Beginning of the drainfield



End of the drainfield

● DNL-SL ● SFL-SL ● DNL-PL ● SFL-PL ● SFL-OP ● DNL-OP

SL: suction lysimeter.

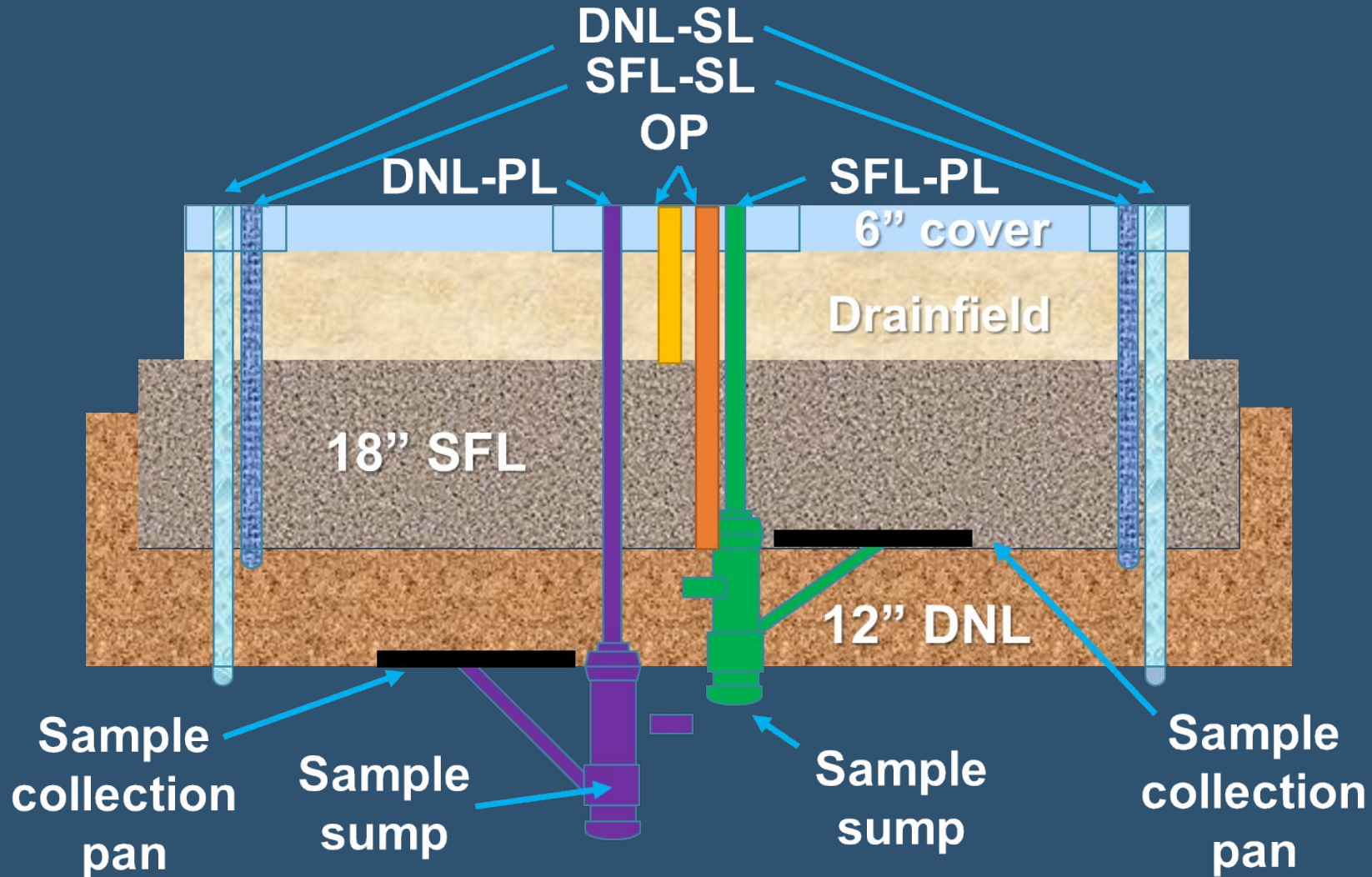
PL: pan lysimeter.

OP: observation port.



INRB MONITORING (2)

FRONT VIEW





MONITORING EQUIPMENT



Pan lysimeter (PL)



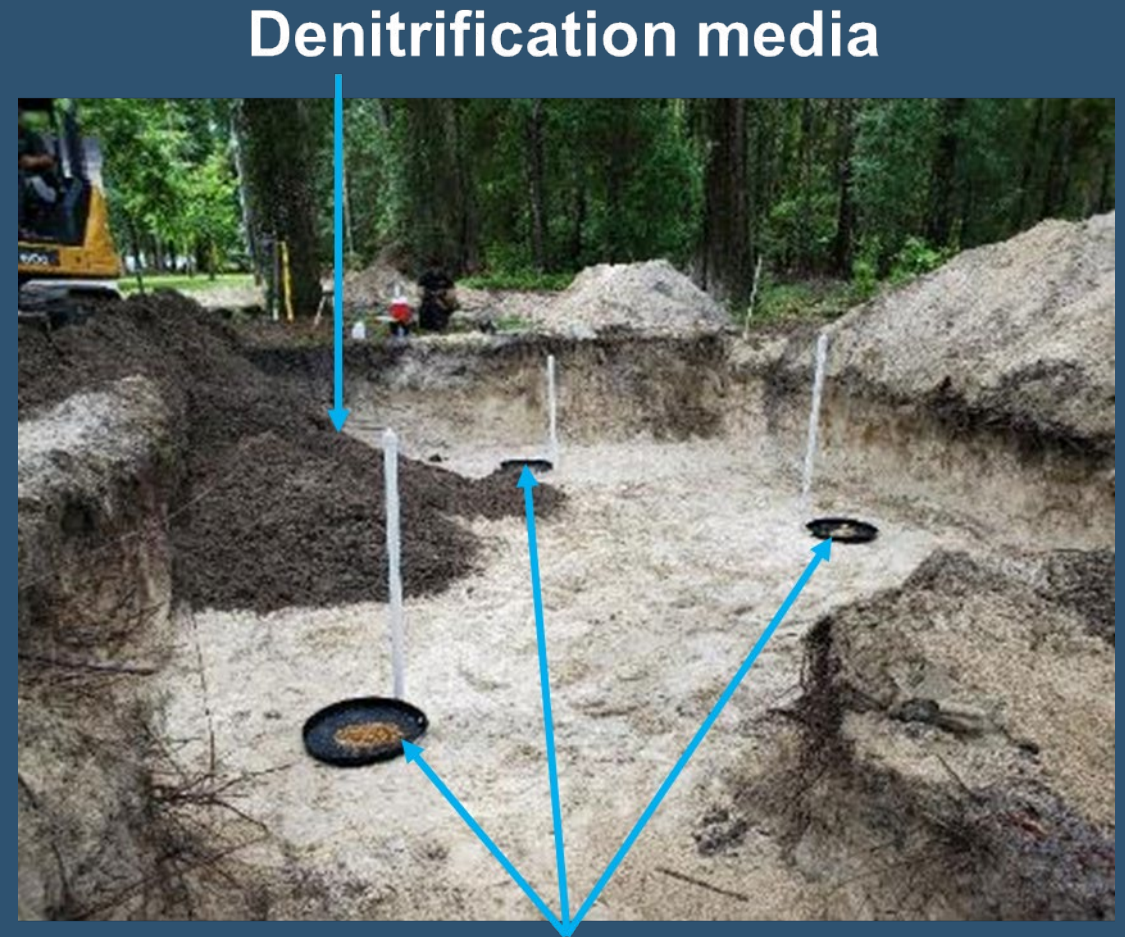
Suction lysimeter (SL)



MONITORING EQUIPMENT INSTALLATION



Bottom of INRB



PL at the bottom of INRB



MONITORING EQUIPMENT INSTALLATION (2)

PL at bottom of SFL



Top of DNL

SL at bottom of DNL



Sand fill media



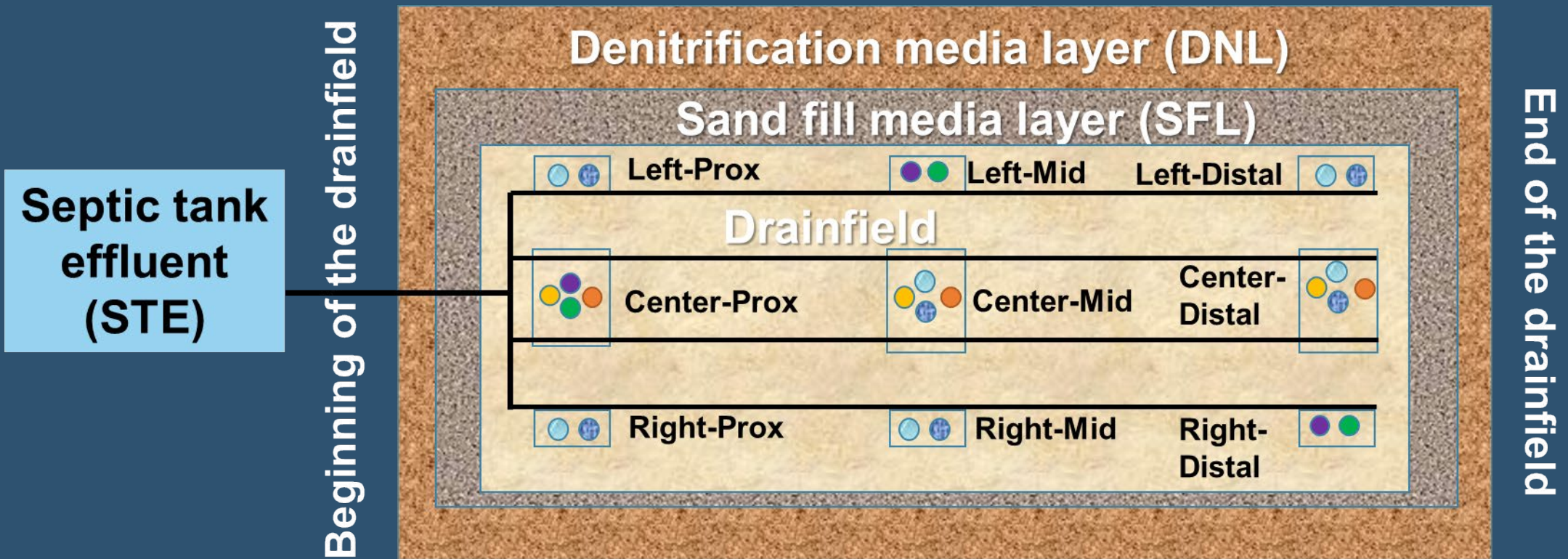
MONITORING EQUIPMENT INSTALLATION (3)



Top of sand fill media layer



MONITORING EQUIPMENT ARRANGEMENT



● DNL-SL ● SFL-SL ● DNL-PL ● SFL-PL ● SFL-OP ● DNL-OP

SL: suction lysimeter.

PL: pan lysimeter.

OP: observation port.



INRB SYSTEM MONITORING

- Inspect the systems to ensure proper function.
- Conduct elevation survey to evaluate change of depth of media layers.
- Collect samples for:
 - Total Kjeldahl nitrogen (TKN), ammonium nitrogen ($\text{NH}_4\text{-N}$), and nitrate/nitrite nitrogen (NOx-N).
 - Total phosphorus (TP).
 - Total organic carbon (TOC).
 - Fecal coliform.
 - Alkalinity and chloride.



INRB SYSTEM MONITORING (2)

- Collect field measurements.
 - Water temperature.
 - Dissolved oxygen (DO).
 - Specific conductivity.
 - pH.
 - Oxidation reduction potential (ORP).
 - Flowmeter reading.



ONGOING INRB MONITORING PROJECTS

- Experimental prototypes of INRBs previously installed showed approximately 65% nitrogen removal.
- More data is required from more systems to provide a more robust evaluation of the INRB performance in Florida.
- DEP's Onsite Sewage Program (OSP):
 - Monitored two INRBs in Leon County.
 - Currently monitoring one INRB in Leon County and one in Citrus County.



PREVIOUSLY MONITORED LEON COUNTY INRBS

Monitoring Nitrogen Removal by Florida INRBs



PROPERTY CHARACTERISTICS

SYSTEMS S3 AND S4

System	Estimated Sewage Flow (gallons per day [gpd])	Drainfield Size (square feet [ft ²])	Soil Type	# of Occupants	Mean Quarterly Average Daily Water Use (gpd)
S3	300	360	Fine Sand	1	18.0
S4	300	375	Fine Sand	4 - 5	446.9

- Monitoring of both INRBs began in December 2021.
- Eight quarterly samplings were conducted by September 2023.
- Neither property had an irrigation system (all water flow goes to system).



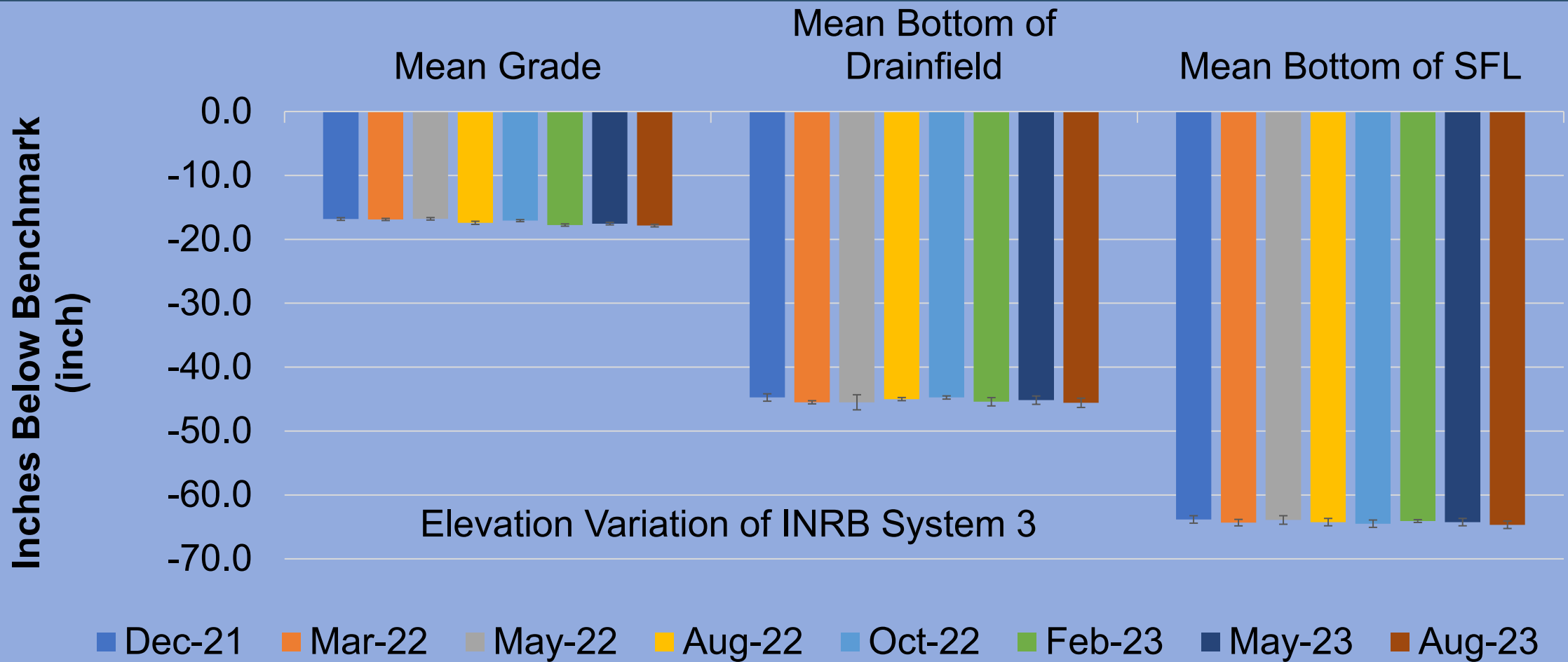
AVERAGE NITROGEN REDUCTION

SYSTEM 3

Sampling Events	STE (mg/L)	Left-Prox (mg/L)	Right-Prox (mg/L)	Left-Prox Percent Nitrogen Reduction	Right-Prox Percent Nitrogen Reduction
12/8/2021	230	2	160	99%	30%
3/2/2022	220	11	152	95%	31%
5/25/2022	220	3	39	99%	82%
8/24/2022	200	6	16	97%	92%
10/19/2022	200	2	21	99%	90%
2/22/2023	170	13	112	92%	34%
5/24/2023	190	2	3	99%	98%
8/23/2023	140	1	12	99%	92%
Mean	196	5	64	97%	69%
S.E.*	11	2	23	1%	11%

Overall average nitrogen reduction: **83%**.

*S.E.: Standard Error.



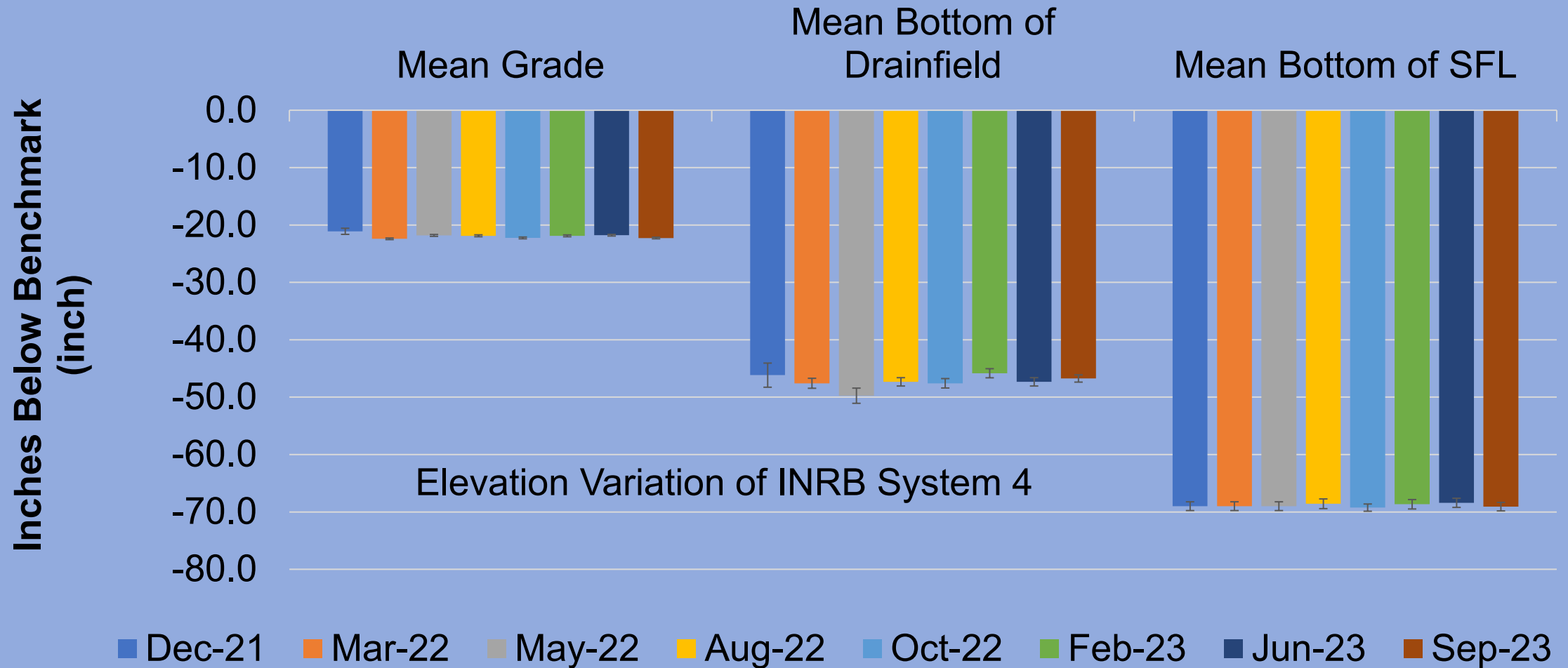


AVERAGE NITROGEN REDUCTION S4

SYSTEM 4

Sampling Location	All Sampling Event Mean	Up to Design Flow Sampling Event Mean
Left-Prox	52%	80%
Center-Prox	35%	62%
Right-Prox	51%	77%
Left-Mid	53%	80%
Center-Mid	33%	69%
Right-Mid	58%	83%
Left-Distal	12%	63%
Center-Distal	30%	72%
Right-Distal	54%	81%
Overall Mean	42%	74%

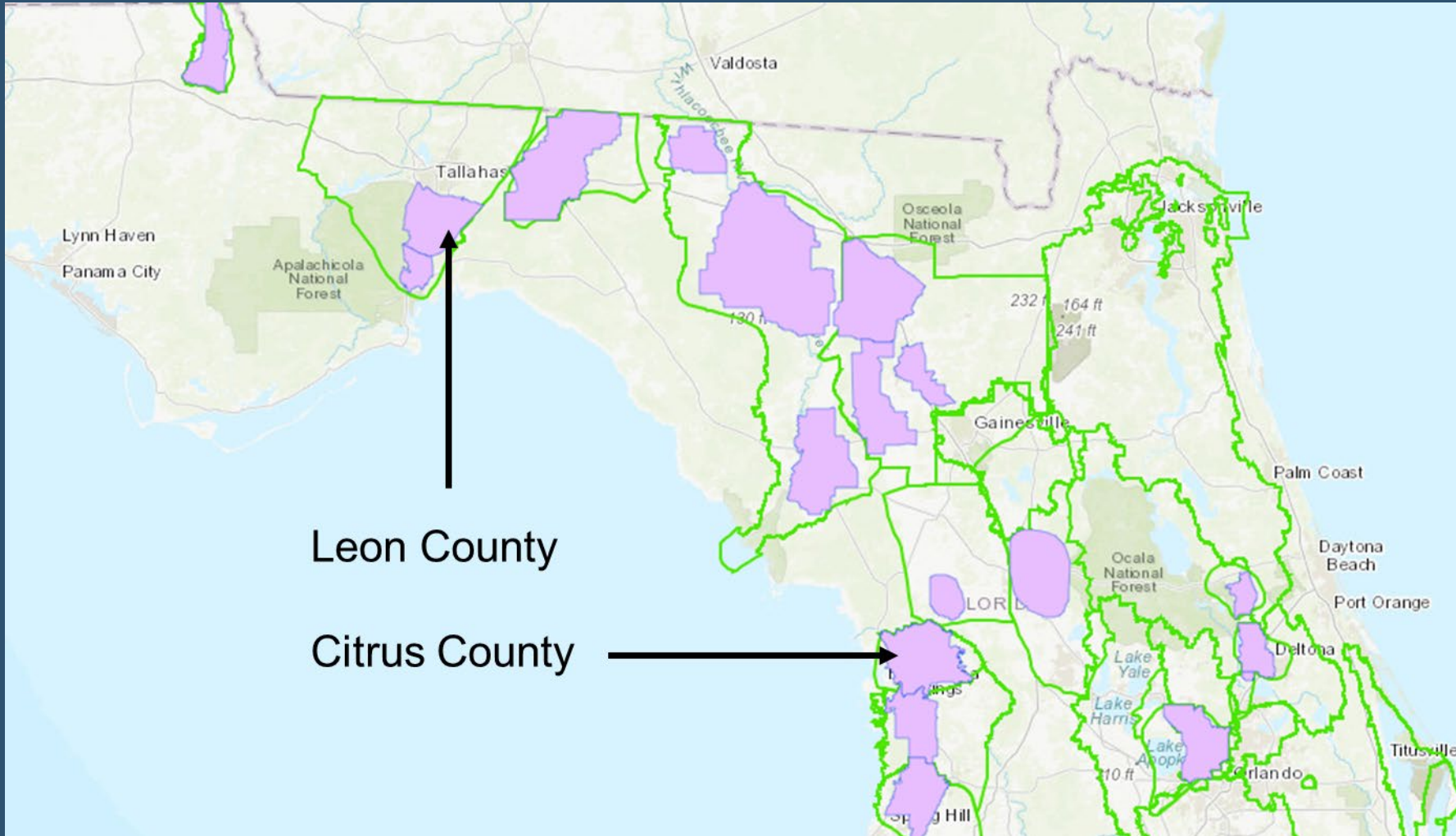
Note: Nitrogen-reduction calculated for each sampling event at each sampling site first, then averaged over events. Overall reduction was then calculated by averaging all locations.





PROJECT LOCATIONS

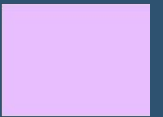
SYSTEMS 5 AND 6



BMAP area



PFA





PROPERTY CHARACTERISTICS S5 AND S6

SYSTEMS S5 AND S6

System	Estimated Sewage Flow (gallons per day [gpd])	Drainfield Size (square feet [ft ²])	Soil Type	# of Occupants	Mean Quarterly Average Daily Water Use (gpd)
S5 Leon County	300	375	Fine Sand	5	189
S6 Citrus County	400	500	Fine Sand	2-5	89

- Monitoring of Citrus County system INRB began in January 2024.
- Monitoring of Leon County system INRB began in November 2024.
- Neither property had an irrigation system (all water flow goes to system).



LEON COUNTY INRB

Monitoring Nitrogen Removal by Florida INRBs

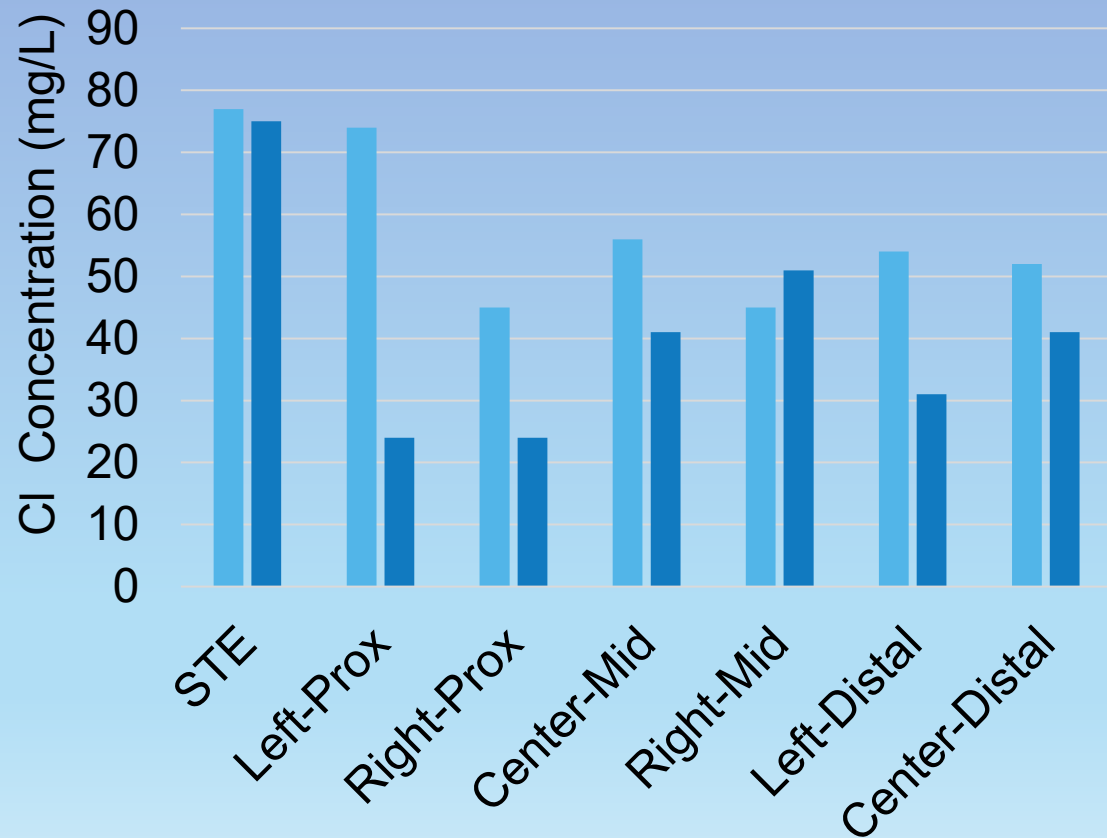


CHLORIDE CONCENTRATION

SYSTEM 5 – SFL MEDIA EFFLUENT

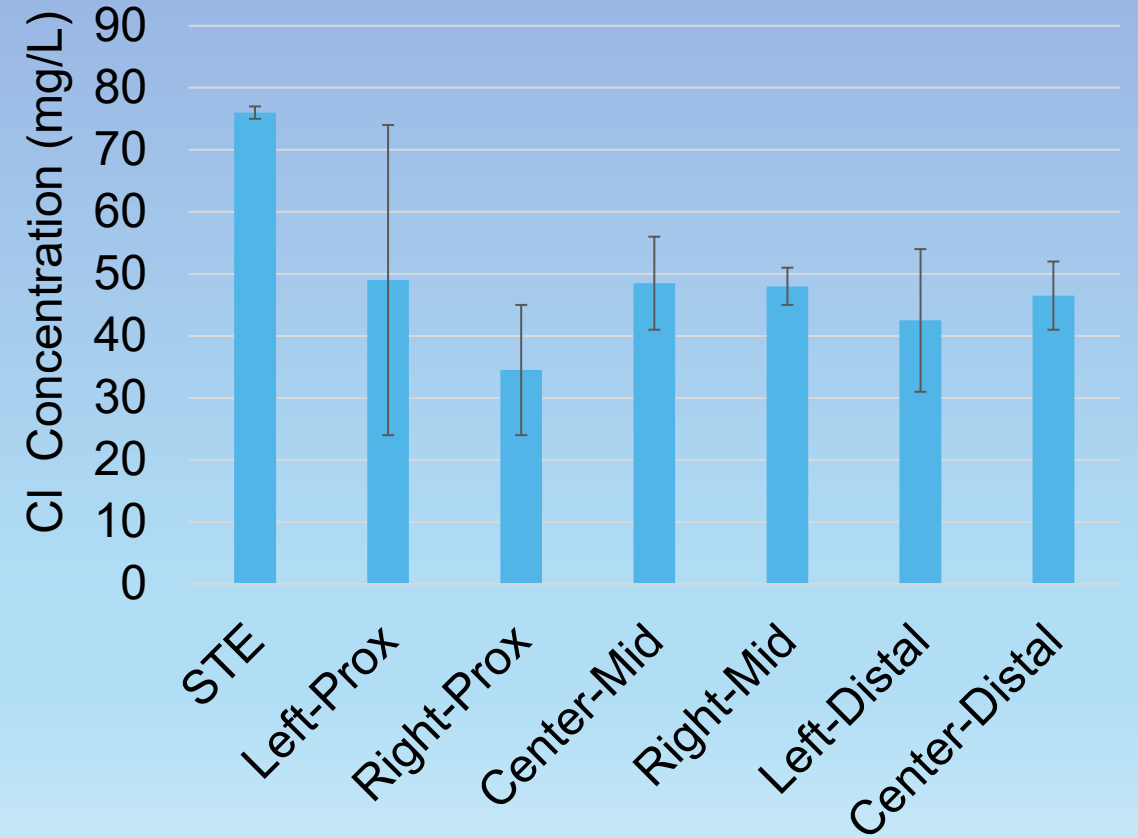
SFL Chloride (mg/L)

■ Event 1 ■ Event 2



Average SFL Chloride (mg/L)

■ Chloride (mg/L)



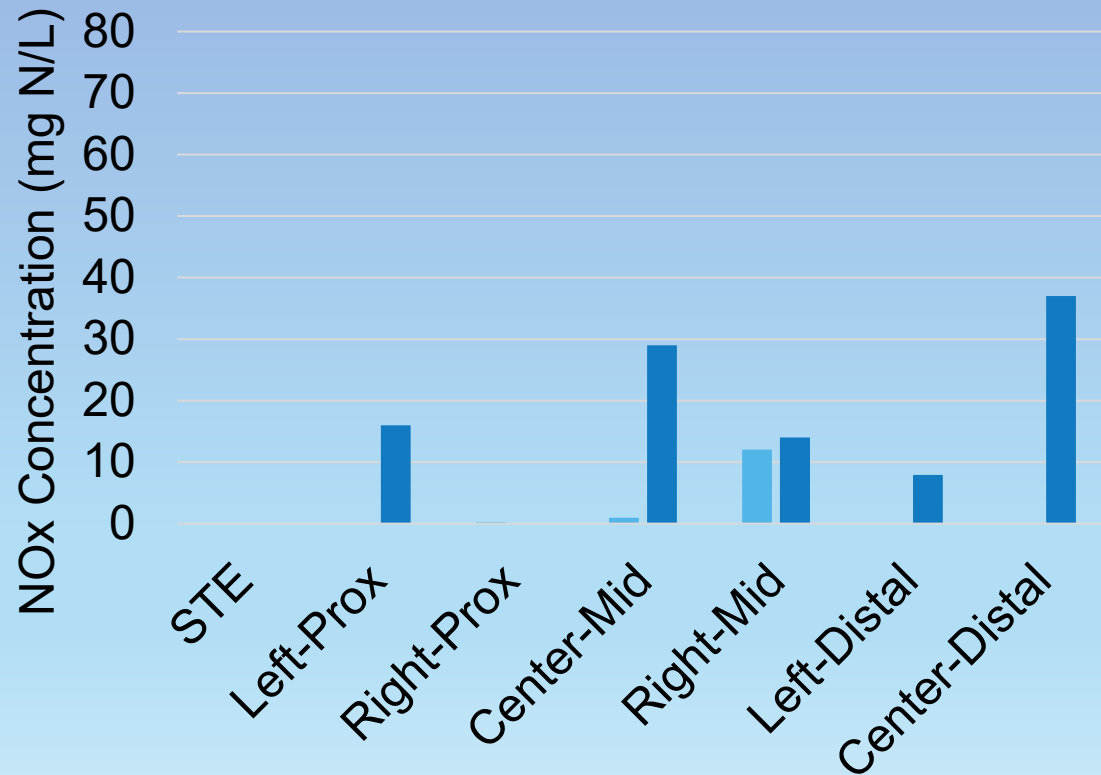


NO_x CONCENTRATION/EVENT

SYSTEM 5 – SFL EFFLUENT

SFL NO_x (mg N/L)
Dilution Unadjusted

■ Event 1 ■ Event 2



SFL NO_x (mg N/L)
Dilution Adjusted

■ Event 1 ■ Event 2

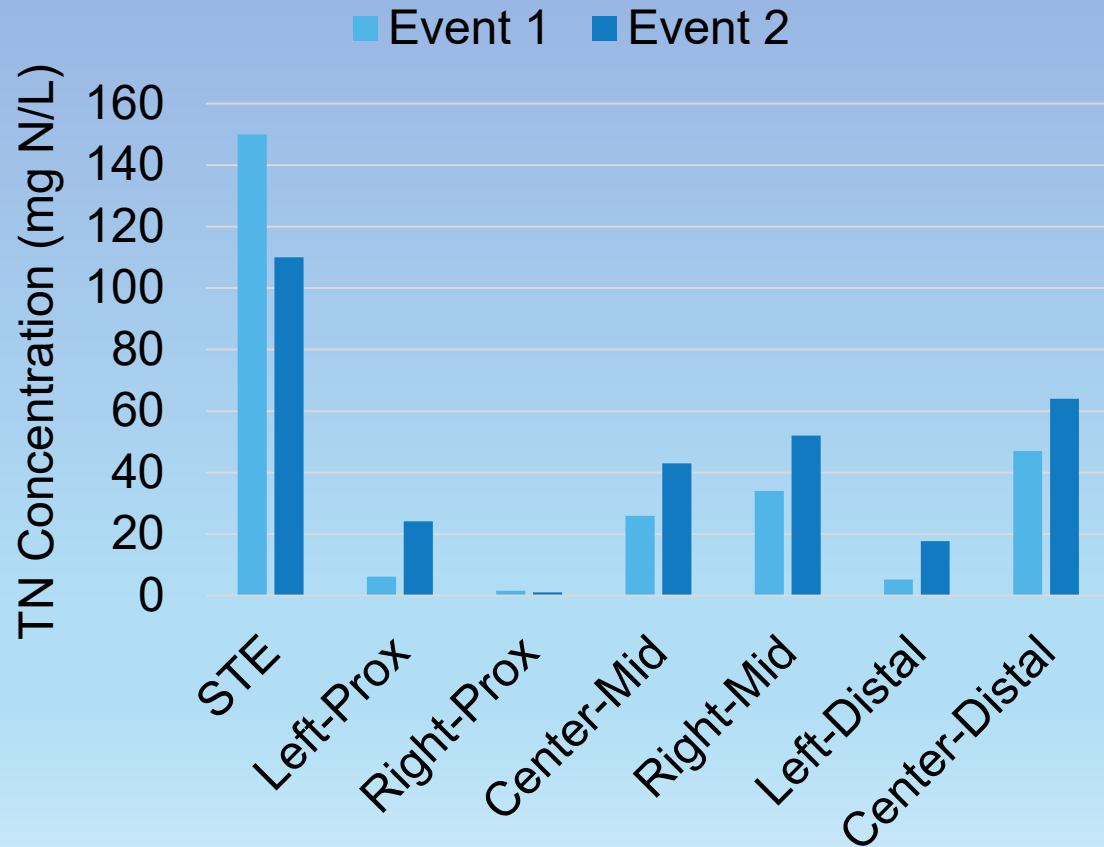




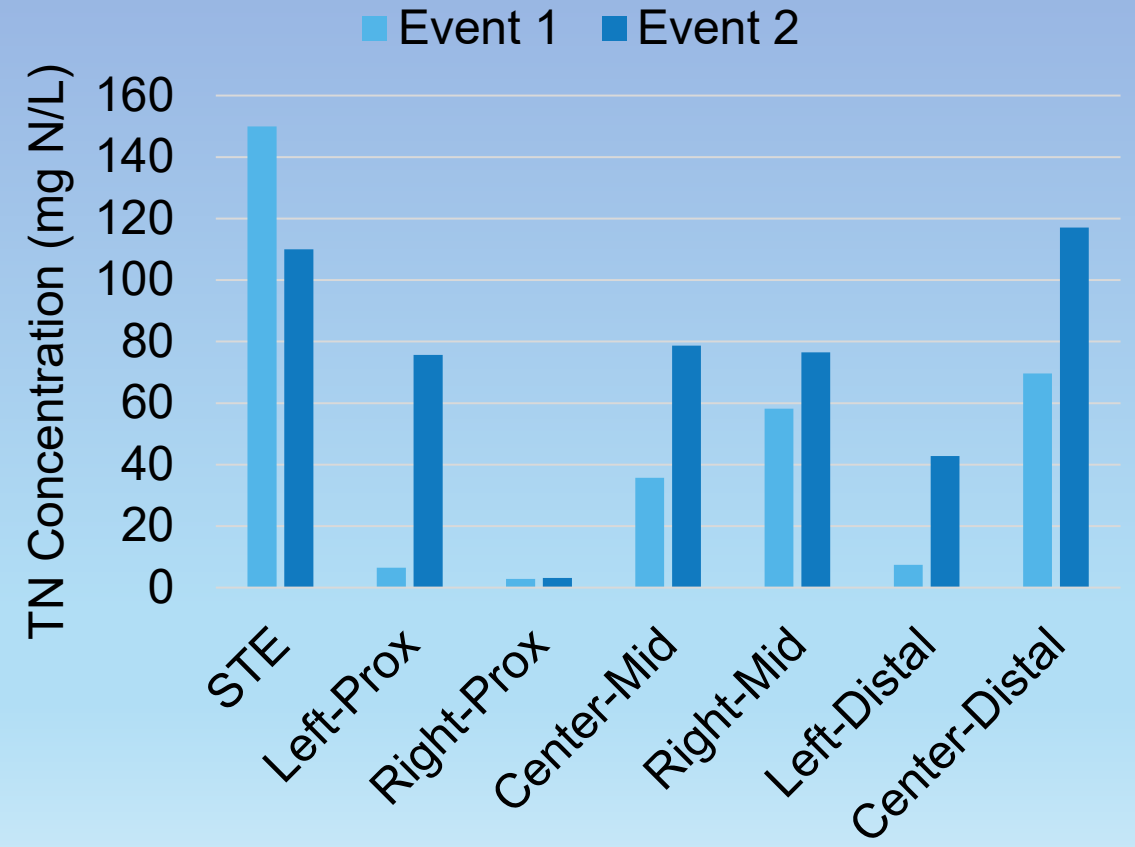
TOTAL NITROGEN CONCENTRATION/EVENT

SYSTEM 5 – SFL EFFLUENT

SFL TN (mg N/L)
Dilution Unadjusted



SFL TN (mg N/L)
Dilution Adjusted

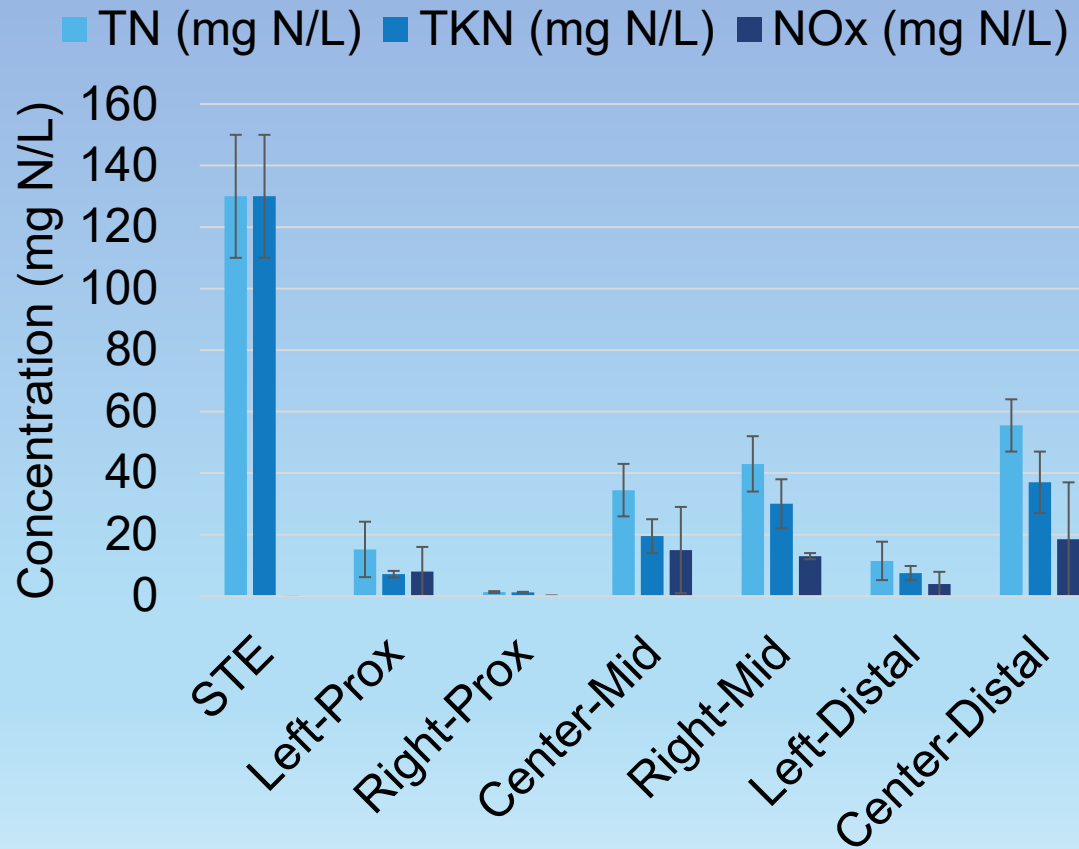




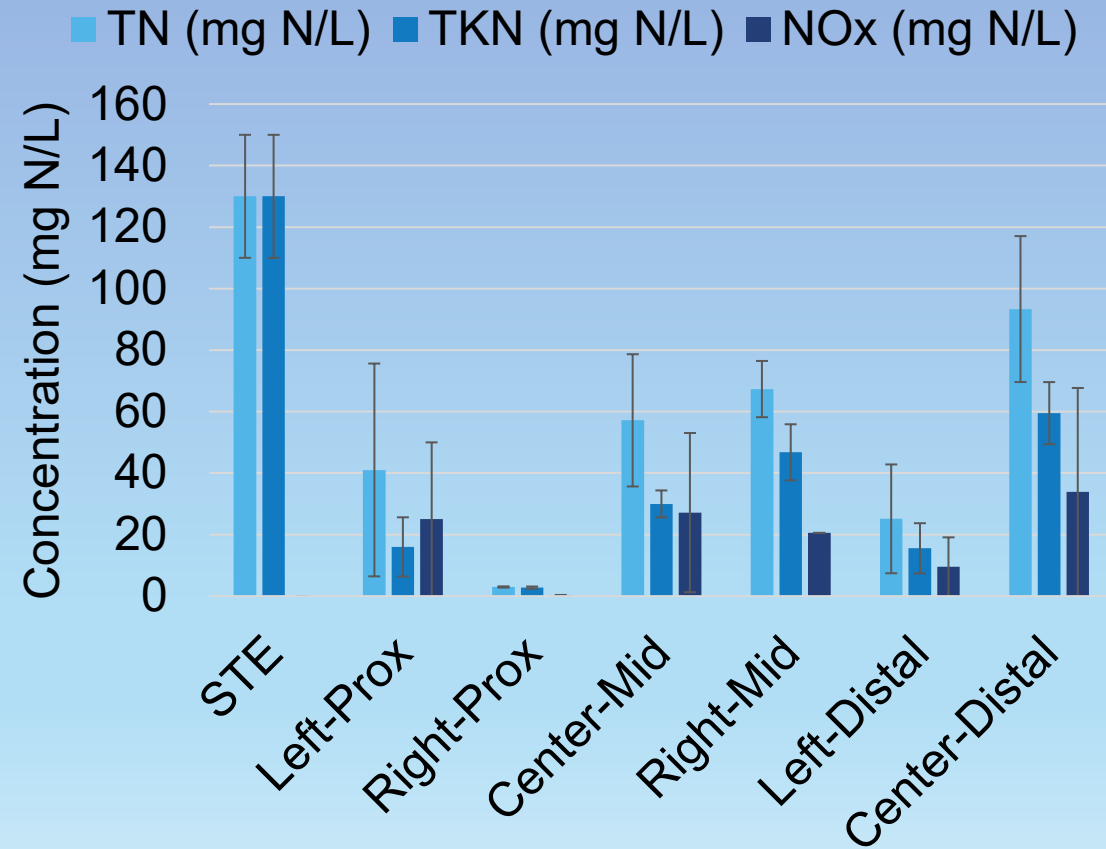
AVERAGE NITROGEN CONCENTRATIONS

SYSTEM 5 – SFL EFFLUENT

Average SFL Nitrogen (mg N/L)
Dilution Unadjusted



Average SFL Nitrogen (mg N/L)
Dilution Adjusted



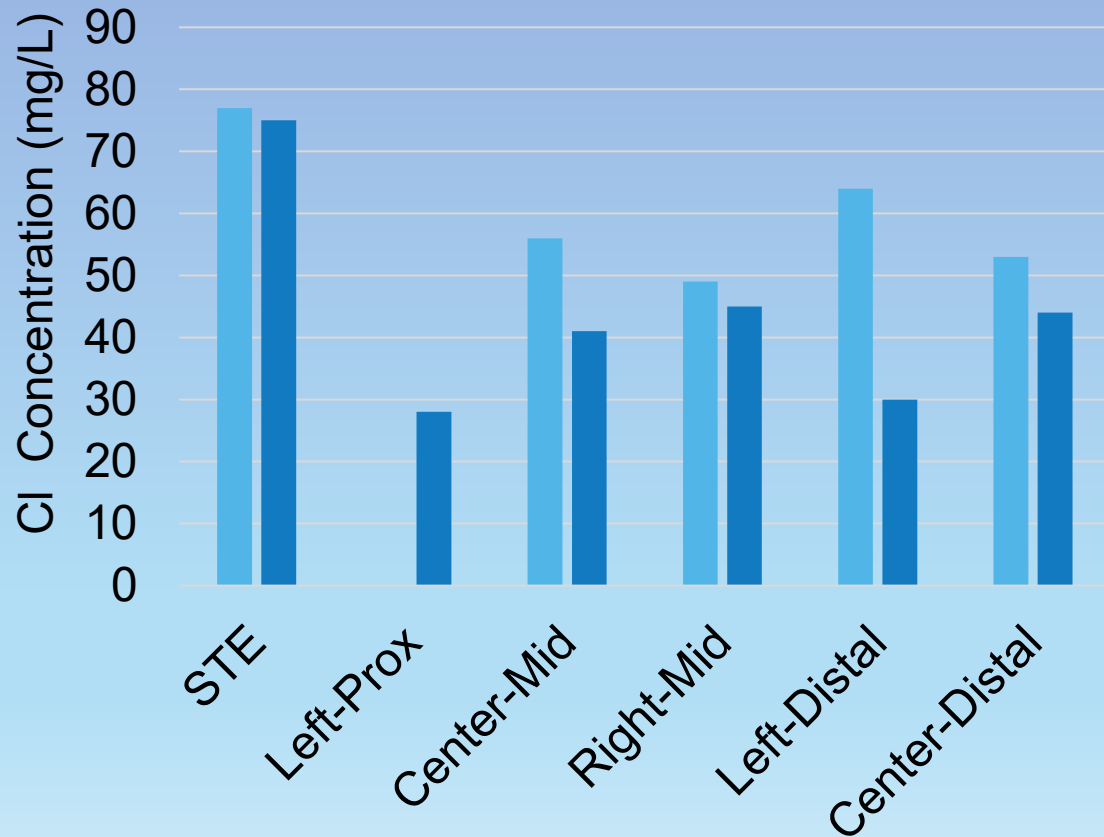


CHLORIDE CONCENTRATION S5

SYSTEM 5 – DNL MEDIA EFFLUENT

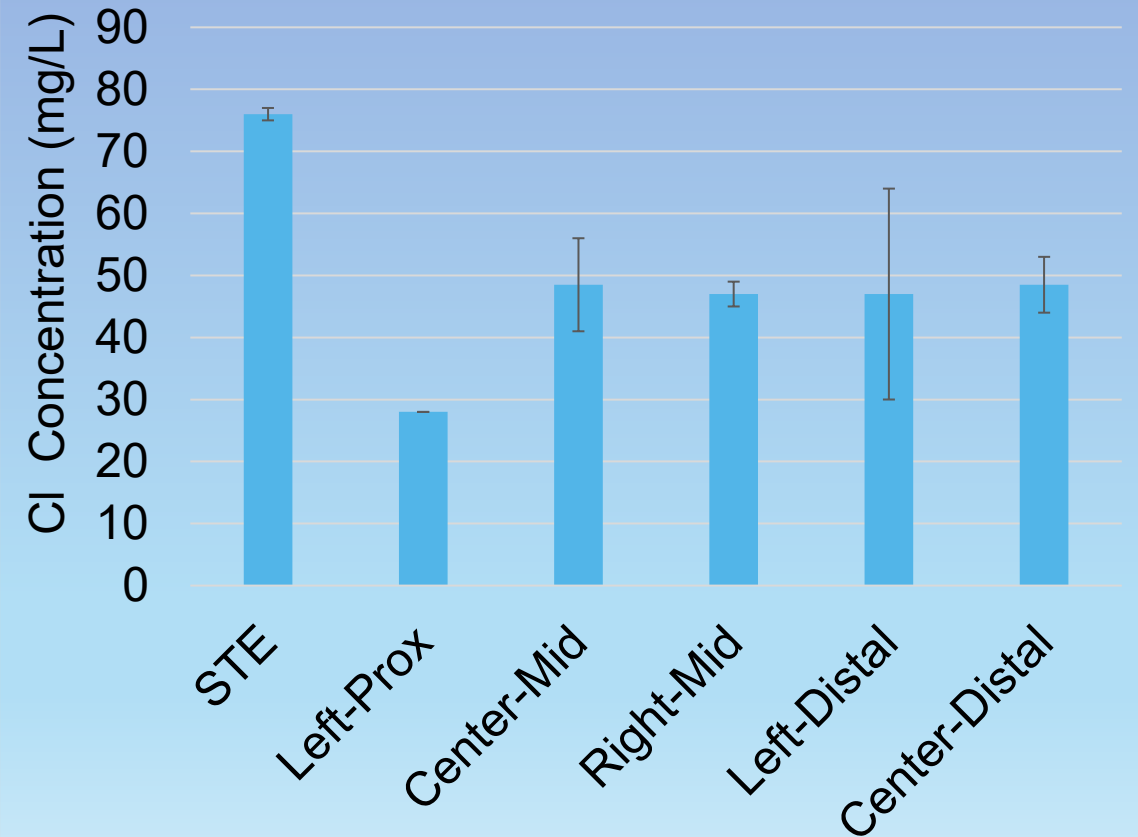
DNL Chloride (mg/L)

■ Event 1 ■ Event 2



Average DNL Chloride (mg/L)

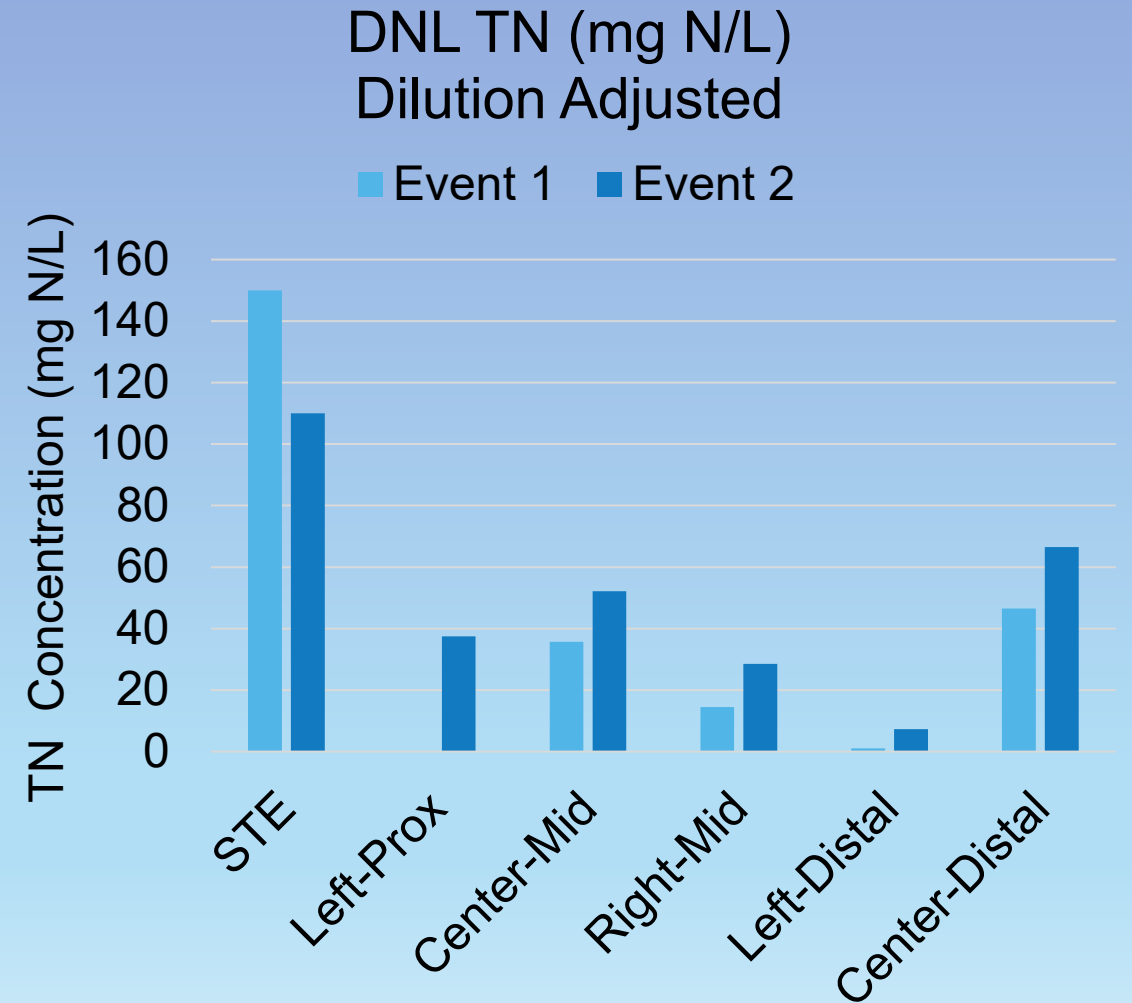
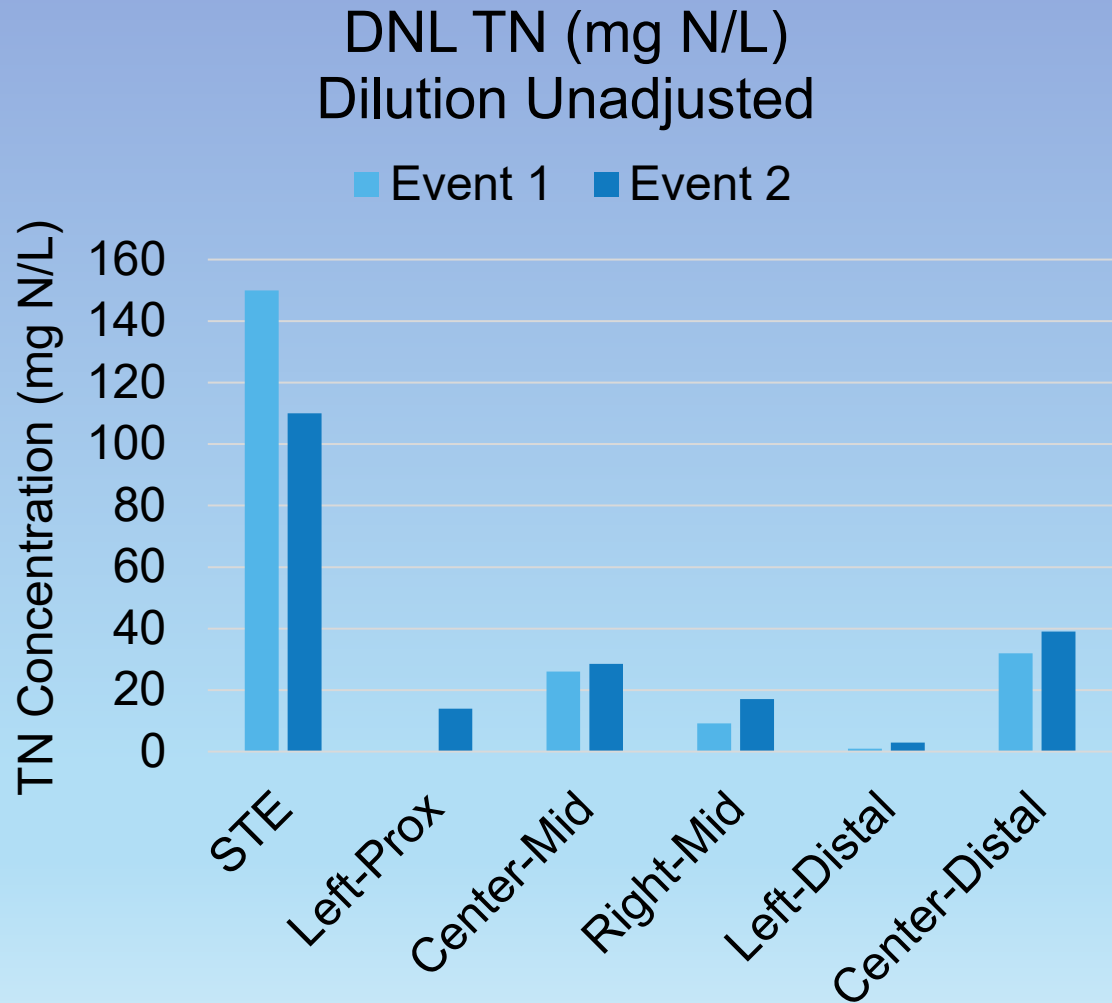
■ Chloride (mg/L)





TOTAL NITROGEN CONCENTRATION/EVENT S5

SYSTEM 5 – DNL EFFLUENT

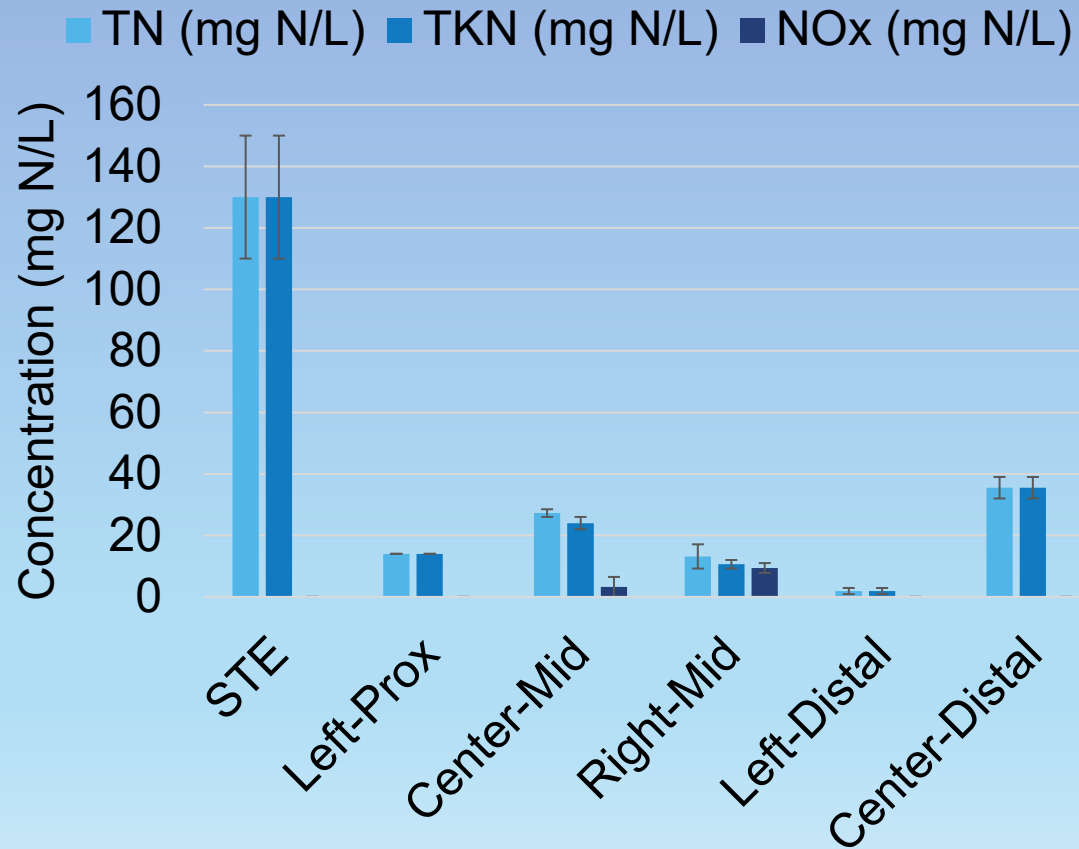




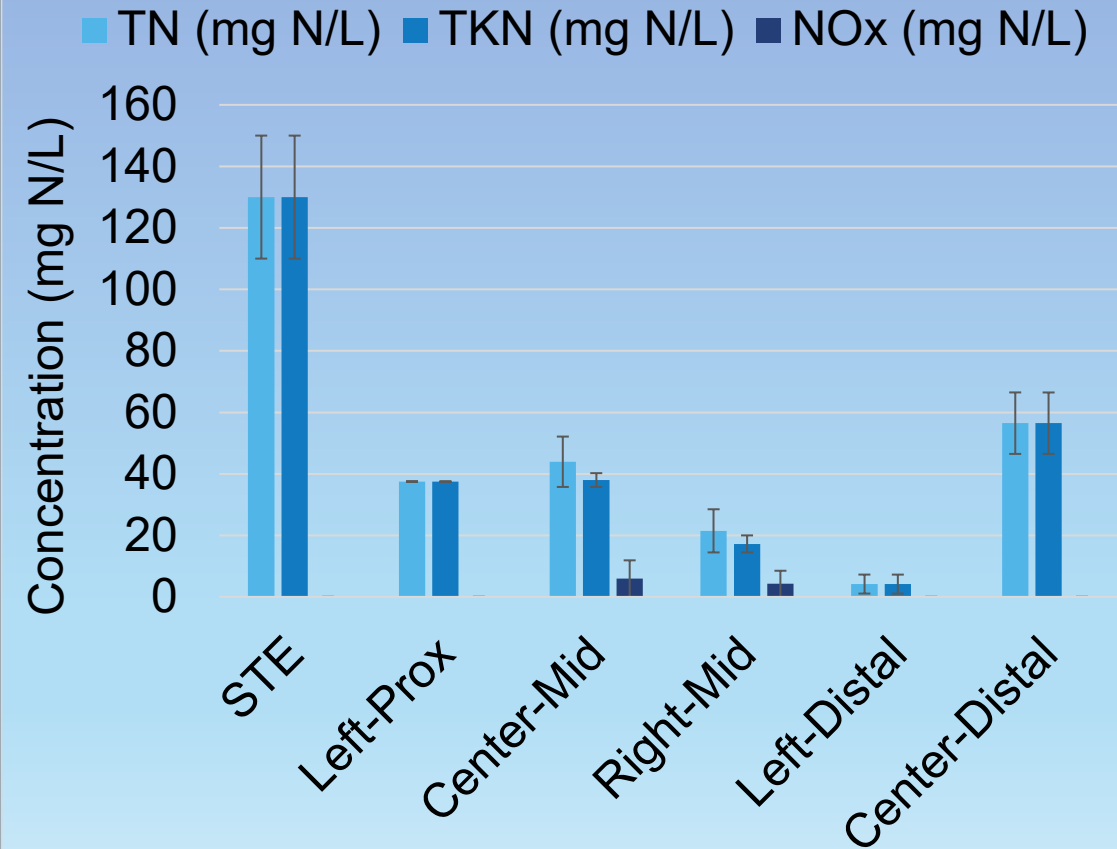
AVERAGE NITROGEN CONCENTRATIONS S5

SYSTEM 5 – DNL EFFLUENT

Average DNL Nitrogen (mg N/L)
Dilution Unadjusted



Average DNL Nitrogen (mg N/L)
Dilution Adjusted



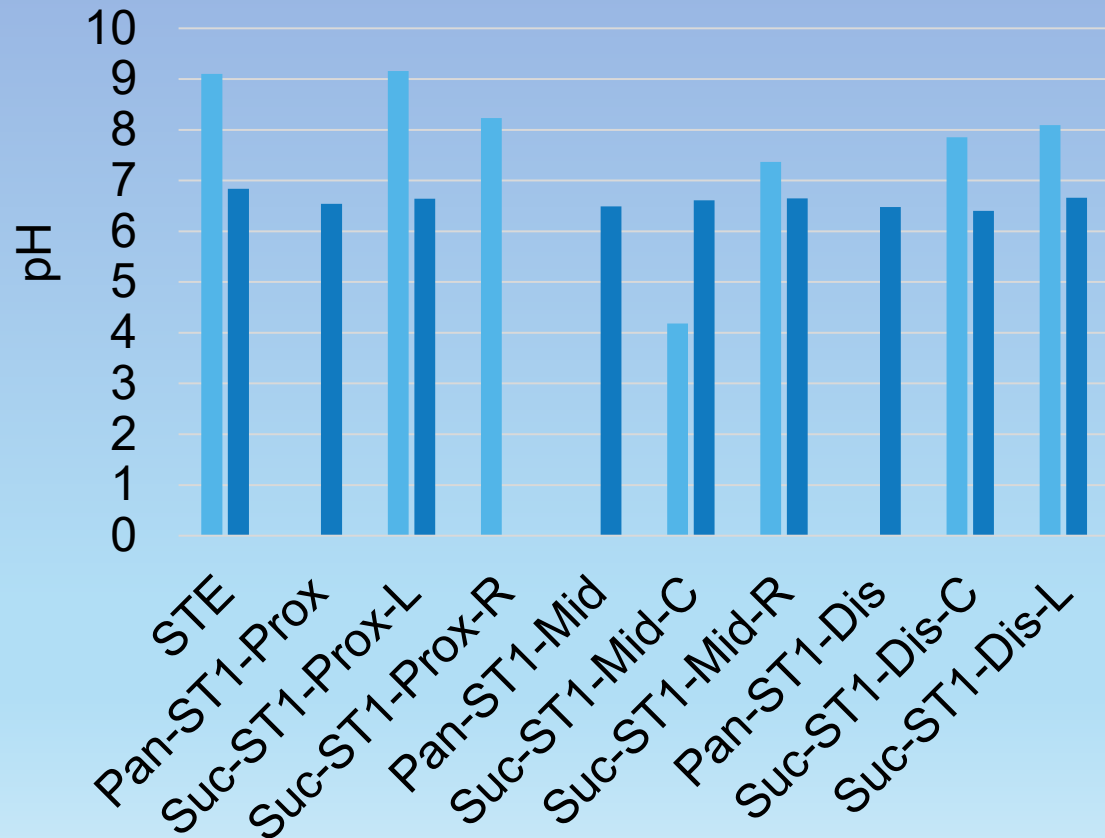


PH VALUES

SYSTEM 5 – SFL VERSUS DNL EFFLUENT

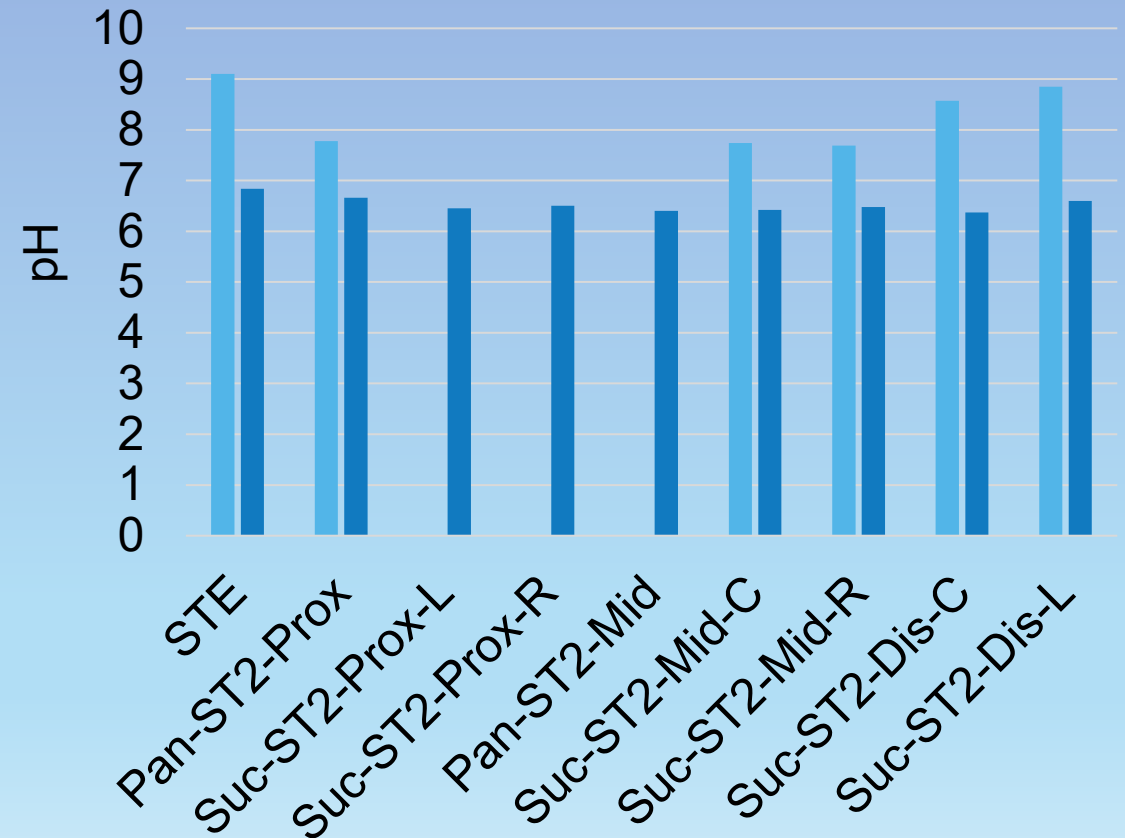
SFL pH

Event 1 Event 2



DNL pH

Event 1 Event 2



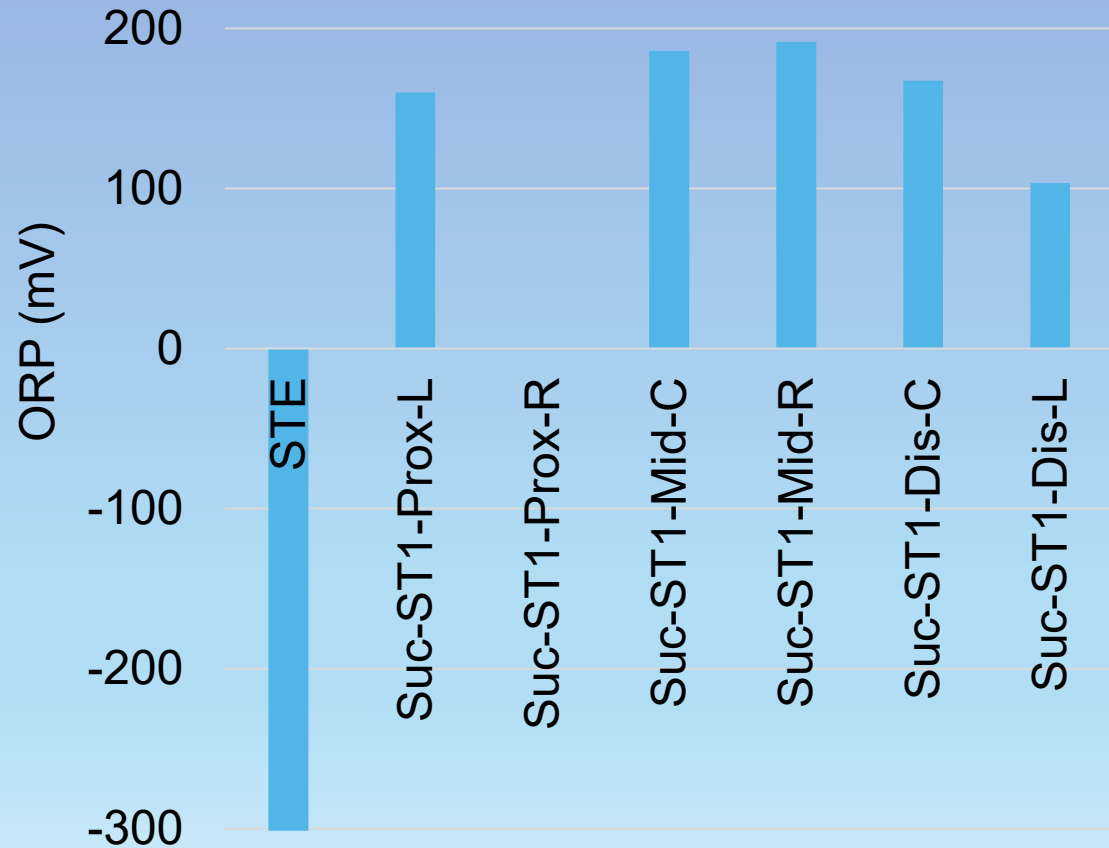


ORP VALUES

SYSTEM 5 – SFL VERSUS DNL EFFLUENT

SFL ORP

■ Event 2



DNL ORP

■ Event 2





AVERAGE NITROGEN REDUCTION S5

SYSTEM 5 – DNL – ADJUSTED

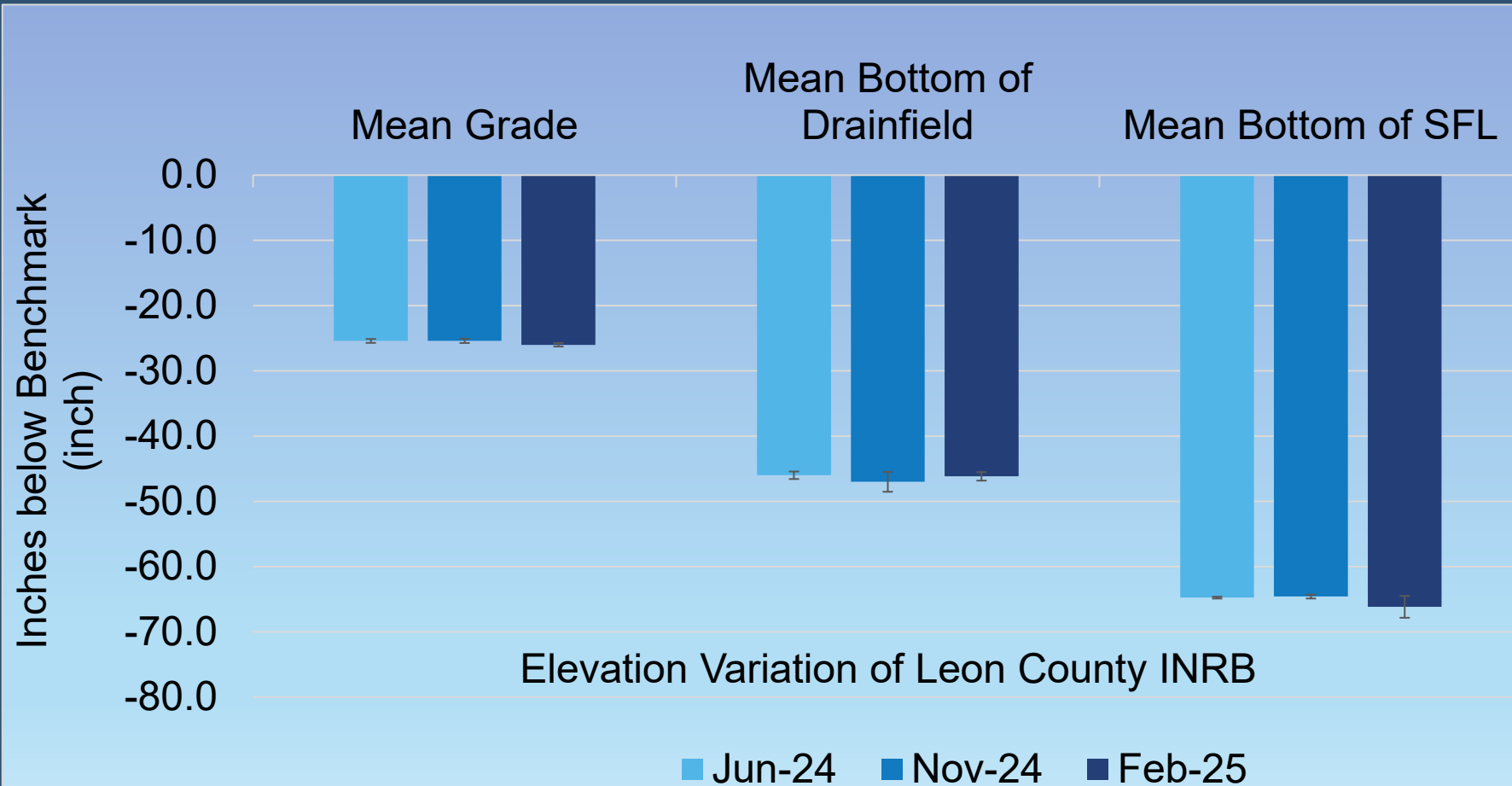
Location	Event 1	Event 2	Average	Percent Nitrogen Reduction	Percent Nitrogen Reduction	Average in Monitoring Location
STE (mg/L)	150	110	130	Event 1	Event 2	All events
Center-Mid (mg/L)	36	52	44	76%	53%	66%
Right-Mid (mg/L)	15	29	22	90%	74%	82%
Left-Distal (mg/L)	1	7	4	99%	94%	97%
Center-Distal (mg/L)	47	67	57	69%	39%	54%
Average for each event				84%	65%	

Overall average percent nitrogen reduction ~ 75%.



ELEVATION CHANGE OF SYSTEM LAYERS S5

SYSTEM 5





CITRUS COUNTY INRB

Monitoring Nitrogen Removal by Florida INRBs

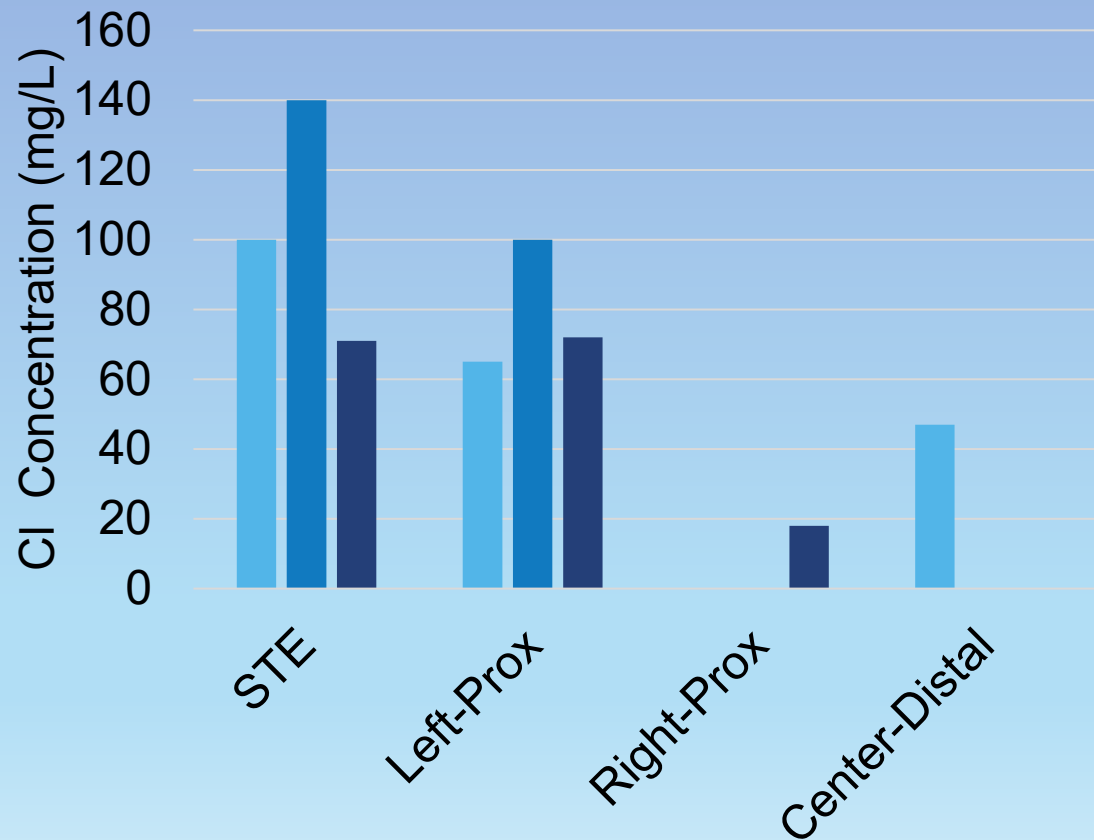


CHLORIDE CONCENTRATION S6

SYSTEM 6 – SFL MEDIA EFFLUENT

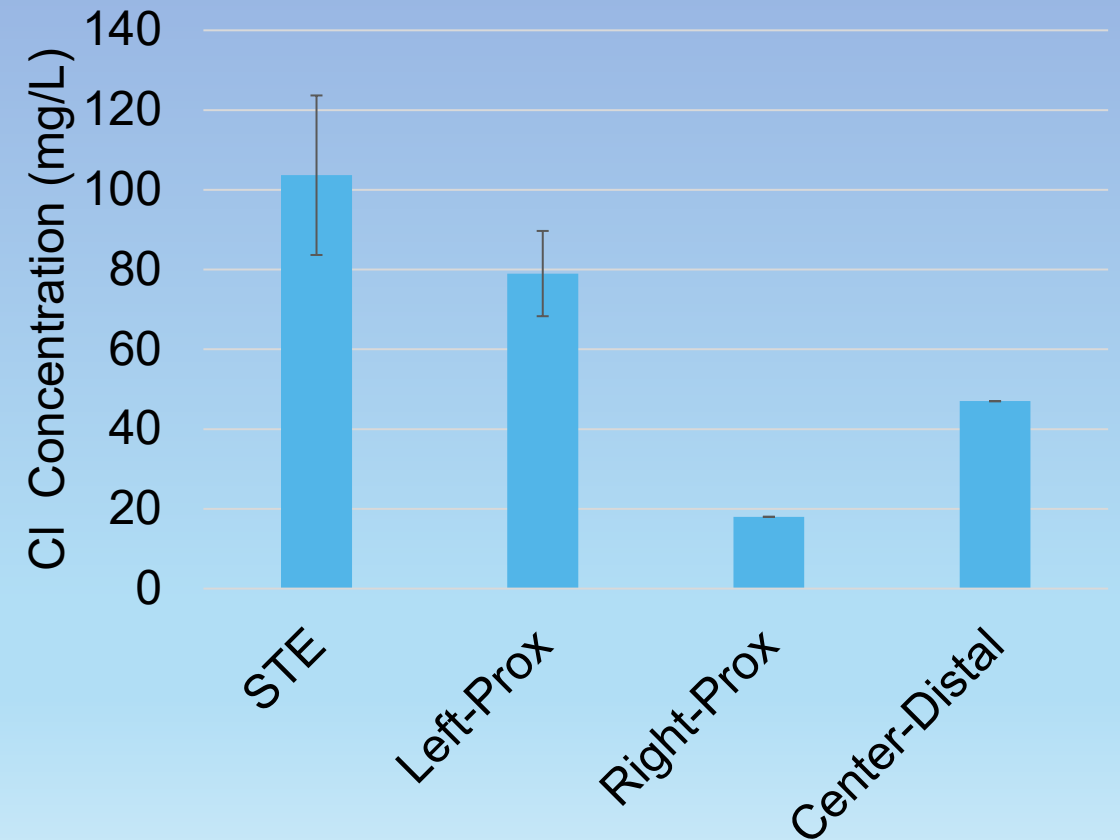
SFL Chloride (mg/L)

Event 1 Event 2 Event 3



Average SFL Chloride (mg/L)

Chloride (mg/L)

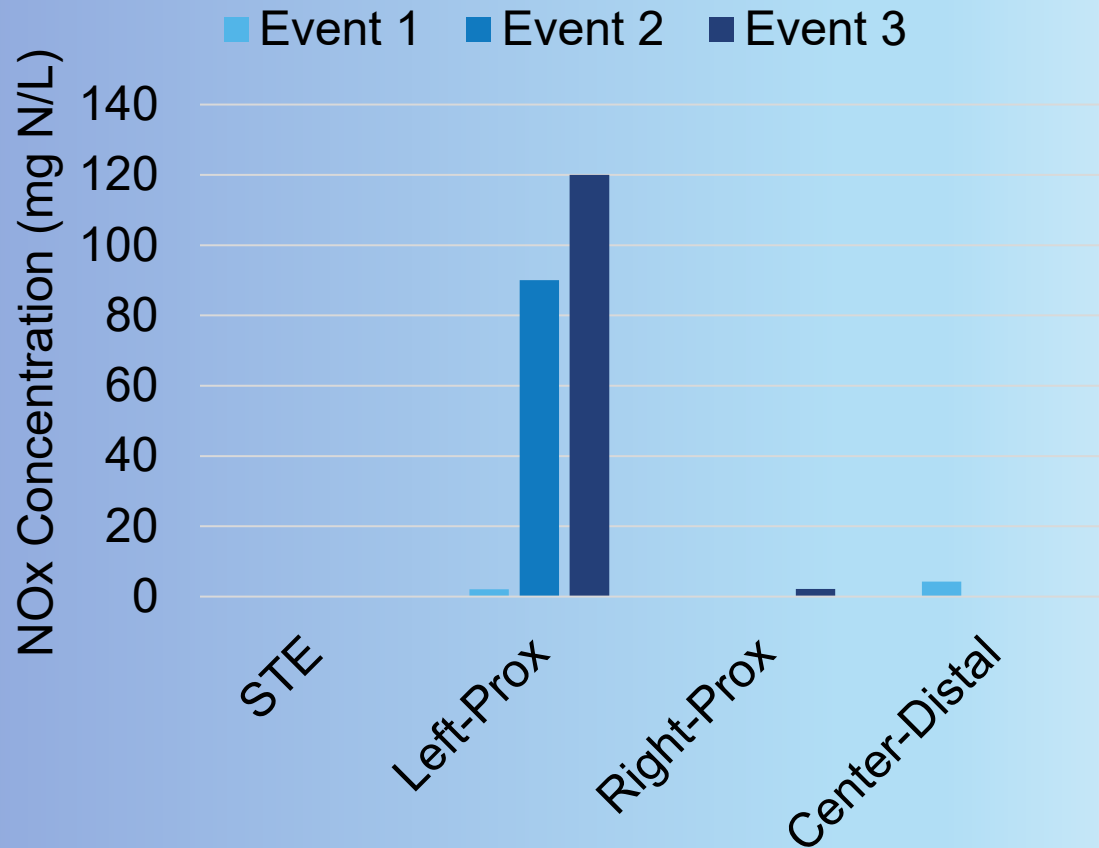




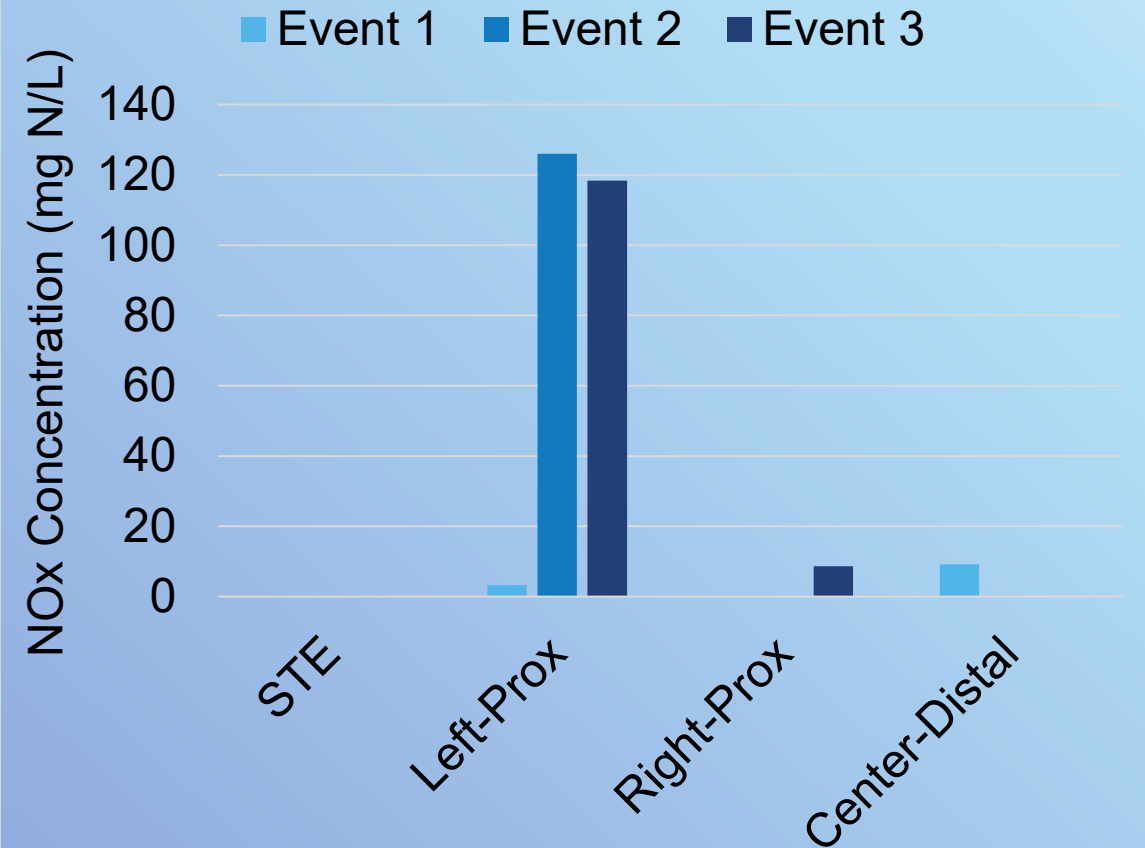
NO_x CONCENTRATION/EVENT S6

SYSTEM 6 – SFL EFFLUENT

SFL NO_x (mg N/L)
Dilution Unadjusted



SFL NO_x (mg N/L)
Dilution Adjusted

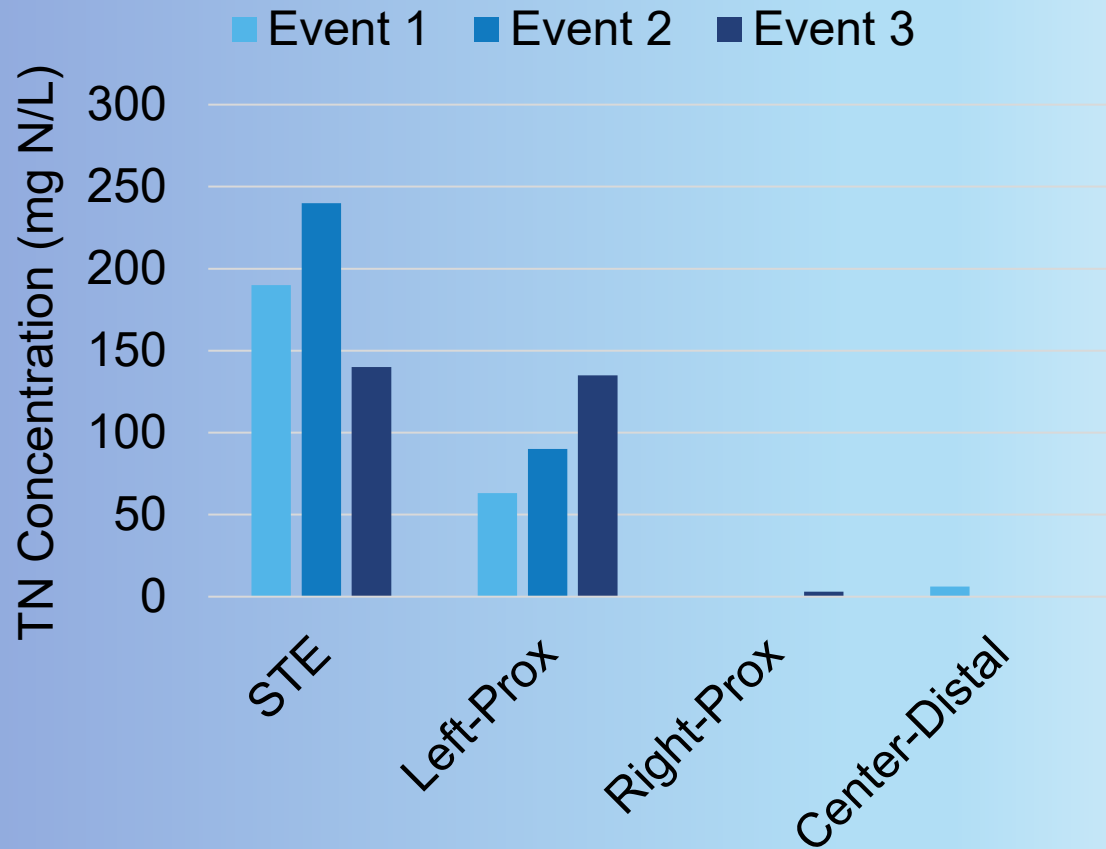




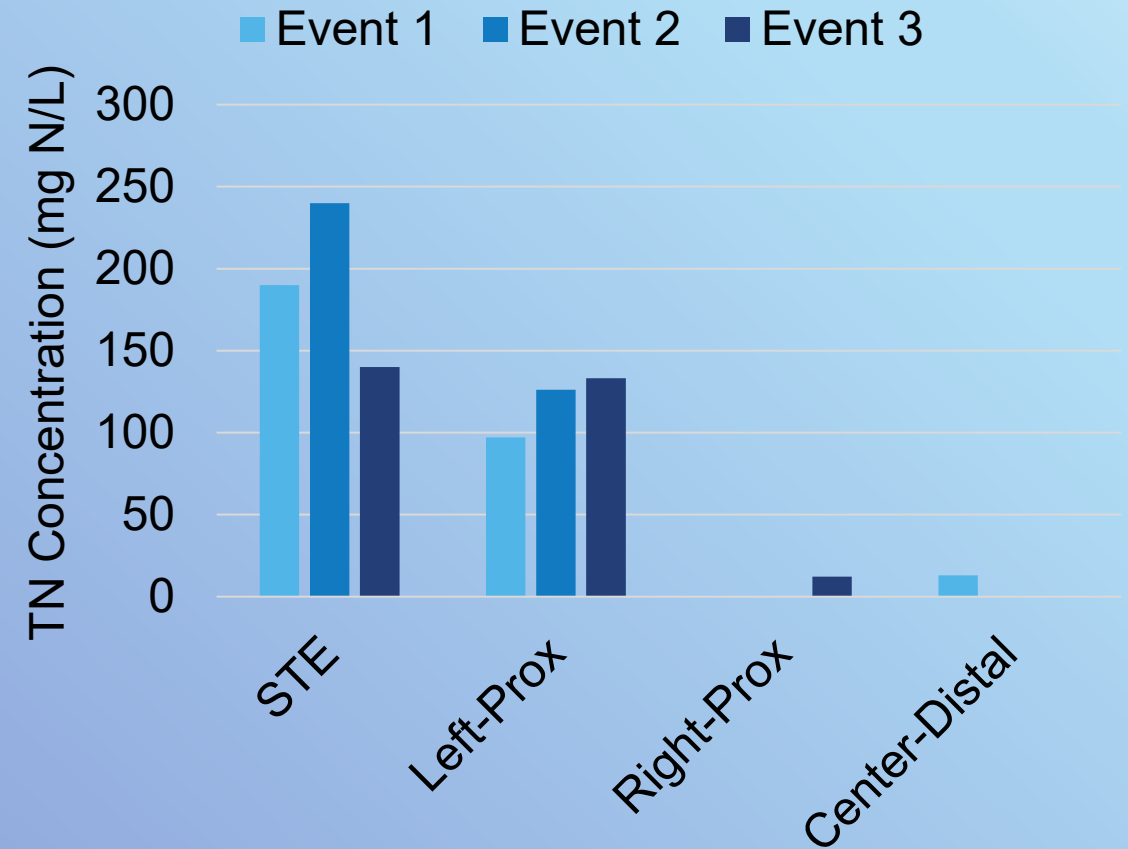
TOTAL NITROGEN CONCENTRATION/EVENT S6

SYSTEM 6 – SFL EFFLUENT

SFL TN (mg N/L)
Dilution Unadjusted



SFL TN (mg N/L)
Dilution Adjusted

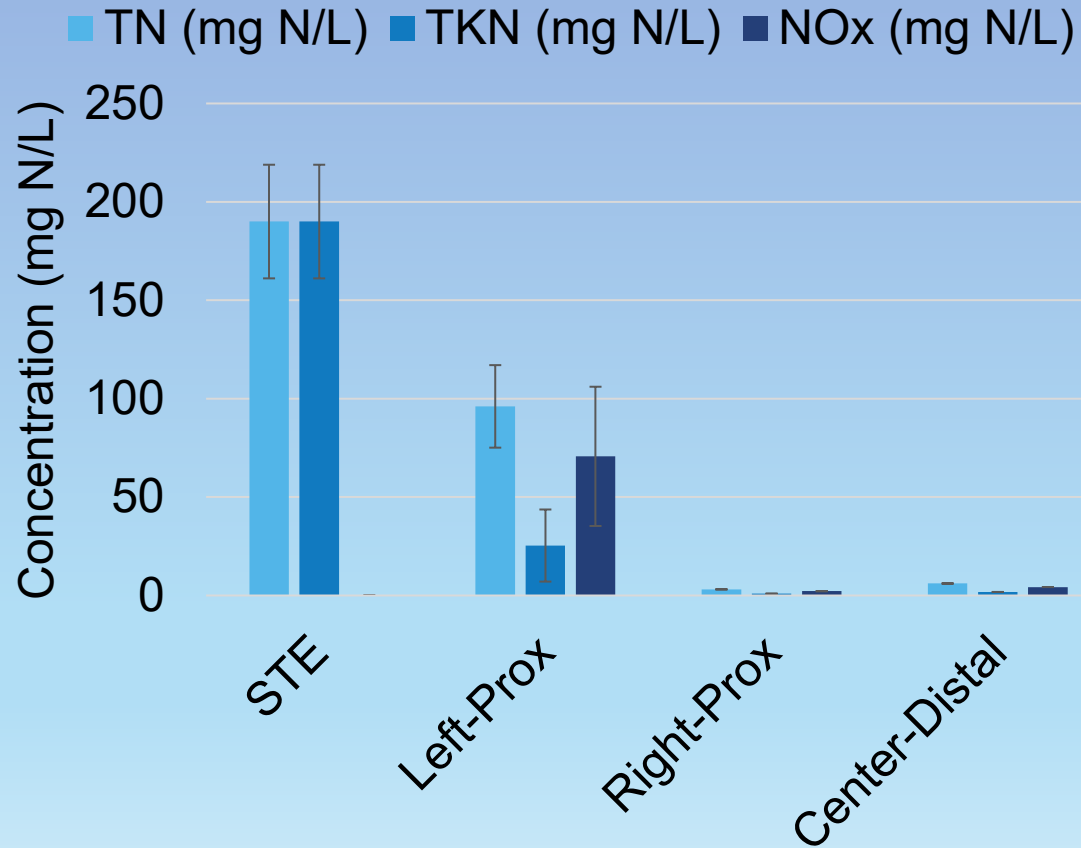




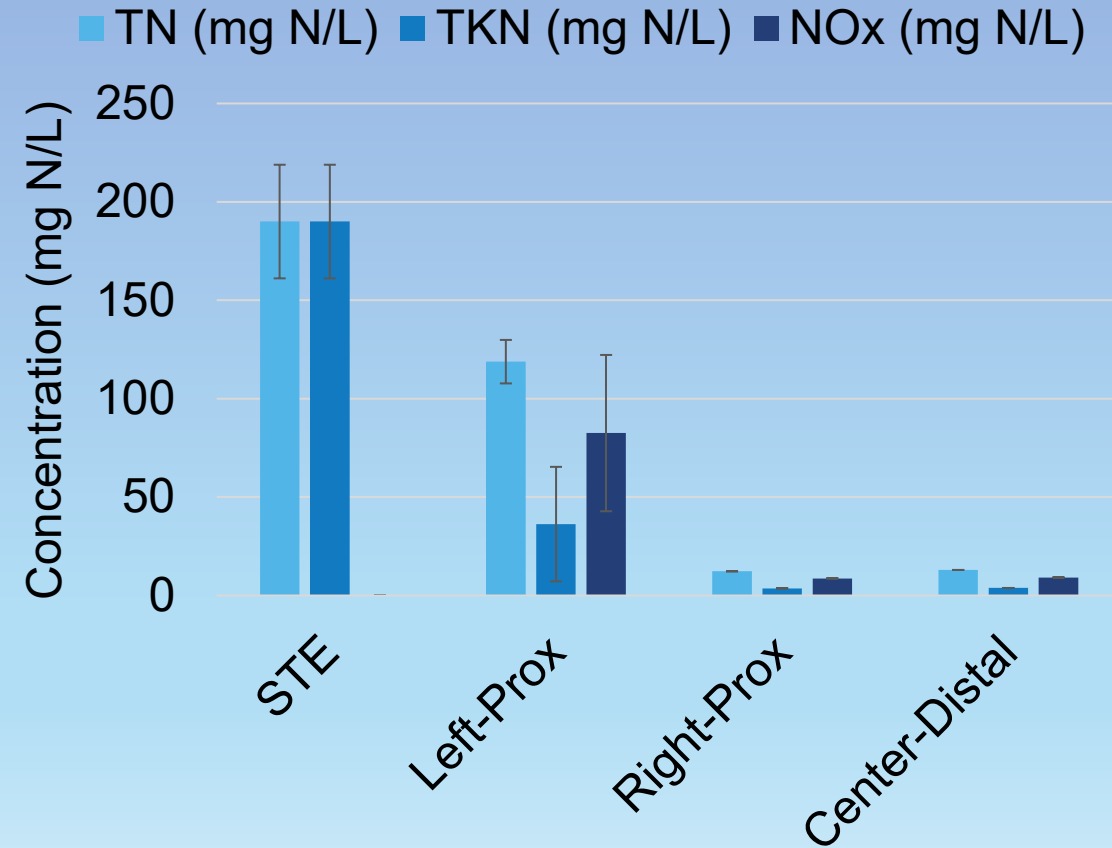
AVERAGE NITROGEN CONCENTRATIONS S6

SYSTEM 6 – SFL EFFLUENT

Average SFL Nitrogen (mg N/L)
Dilution Unadjusted



Average SFL Nitrogen (mg N/L)
Dilution Adjusted



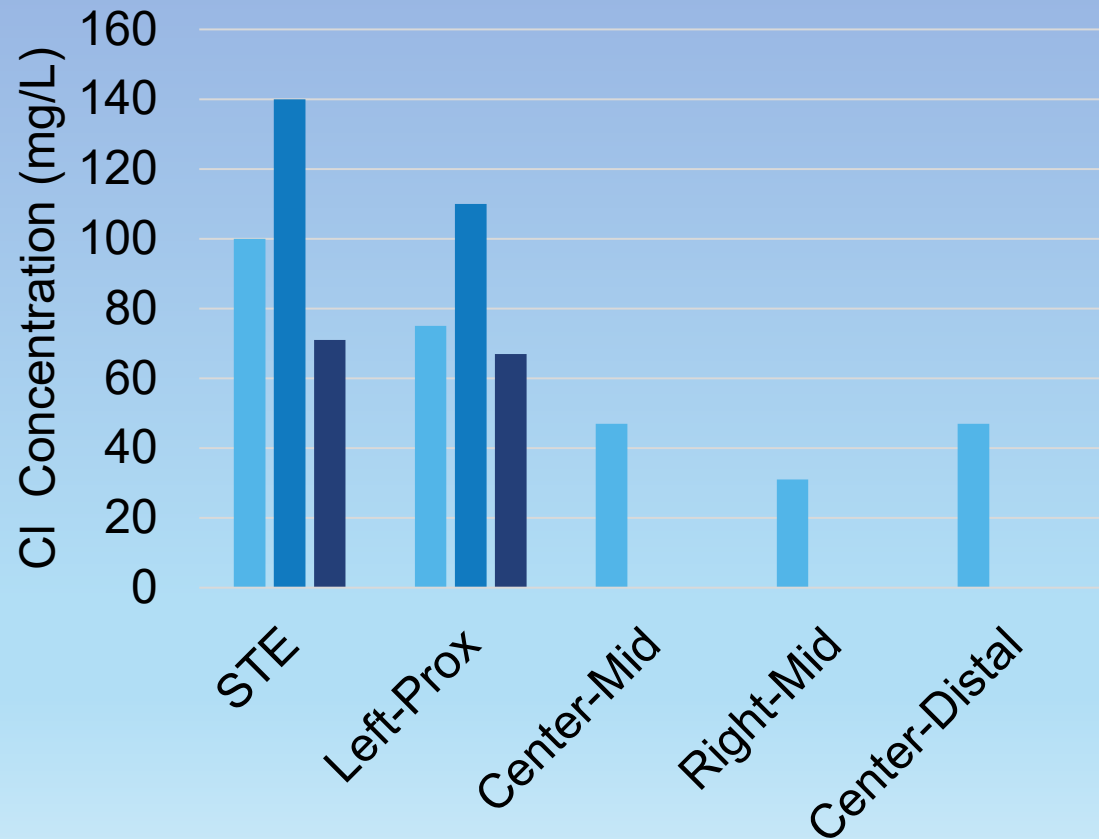


CHLORIDE CONCENTRATION S6 DNL

SYSTEM 6 – DNL MEDIA EFFLUENT

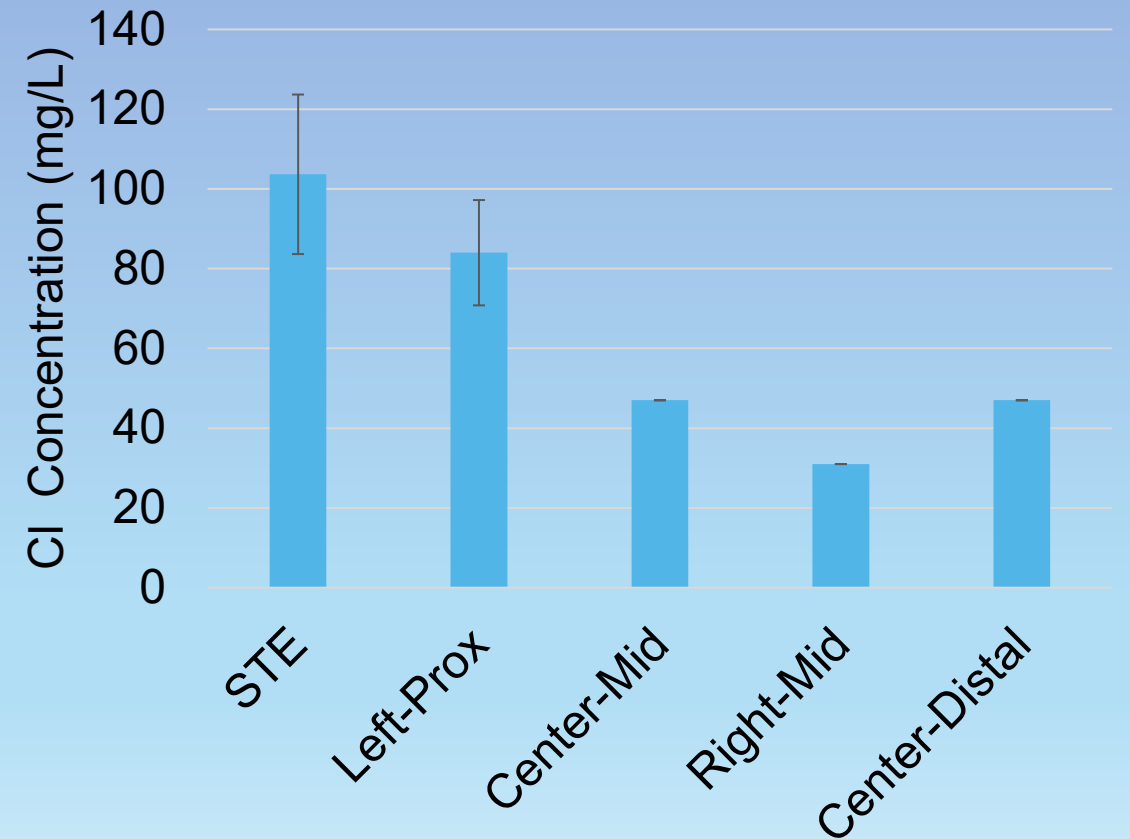
DNL Chloride (mg/L)

Event 1 Event 2 Event 3



Average DNL Chloride (mg/L)

Chloride (mg/L)

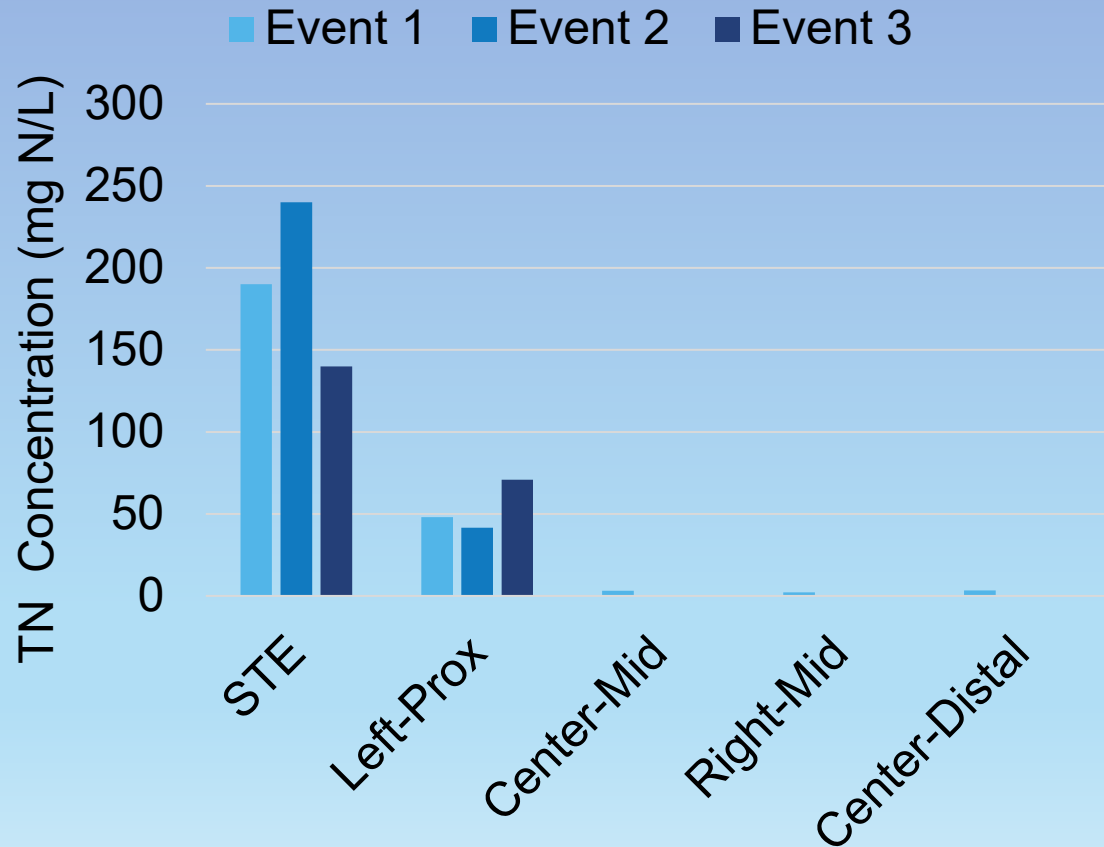




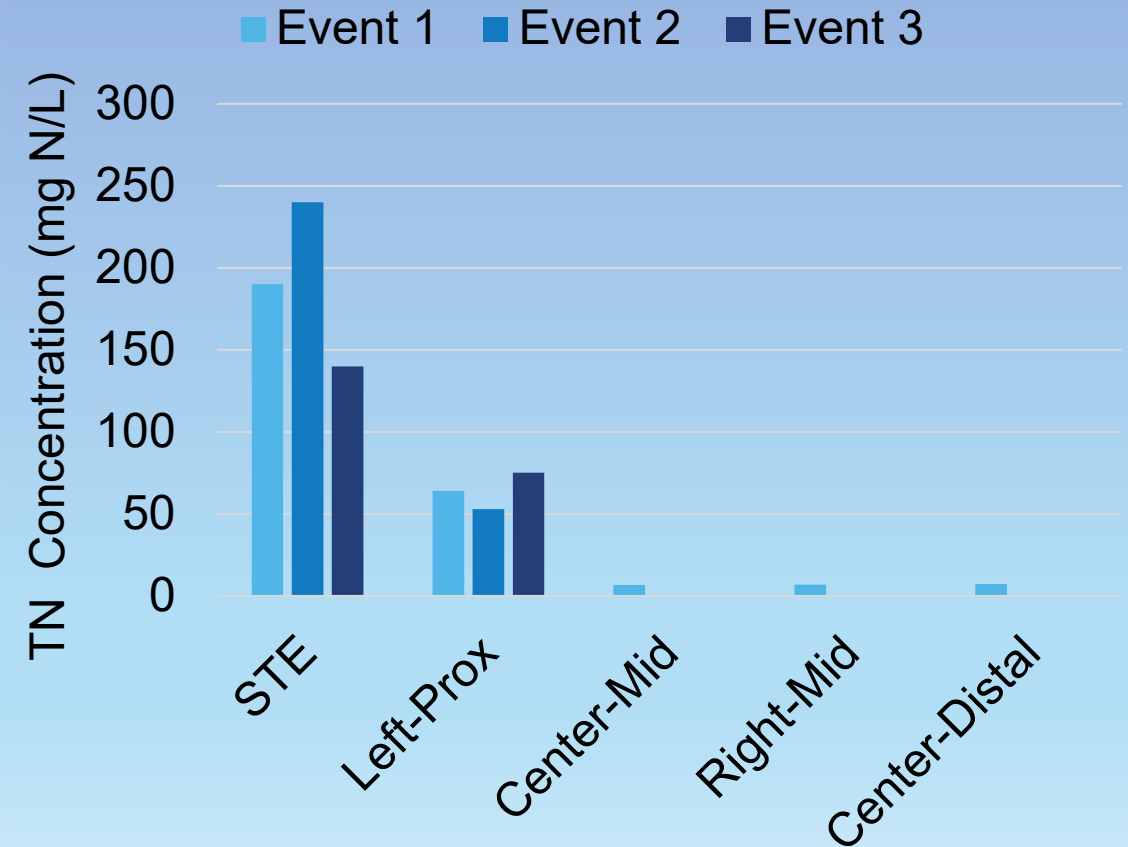
TOTAL NITROGEN CONCENTRATION/EVENT S6

SYSTEM 6 – DNL EFFLUENT

DNL TN (mg N/L)
Dilution Unadjusted



DNL TN (mg N/L)
Dilution Adjusted

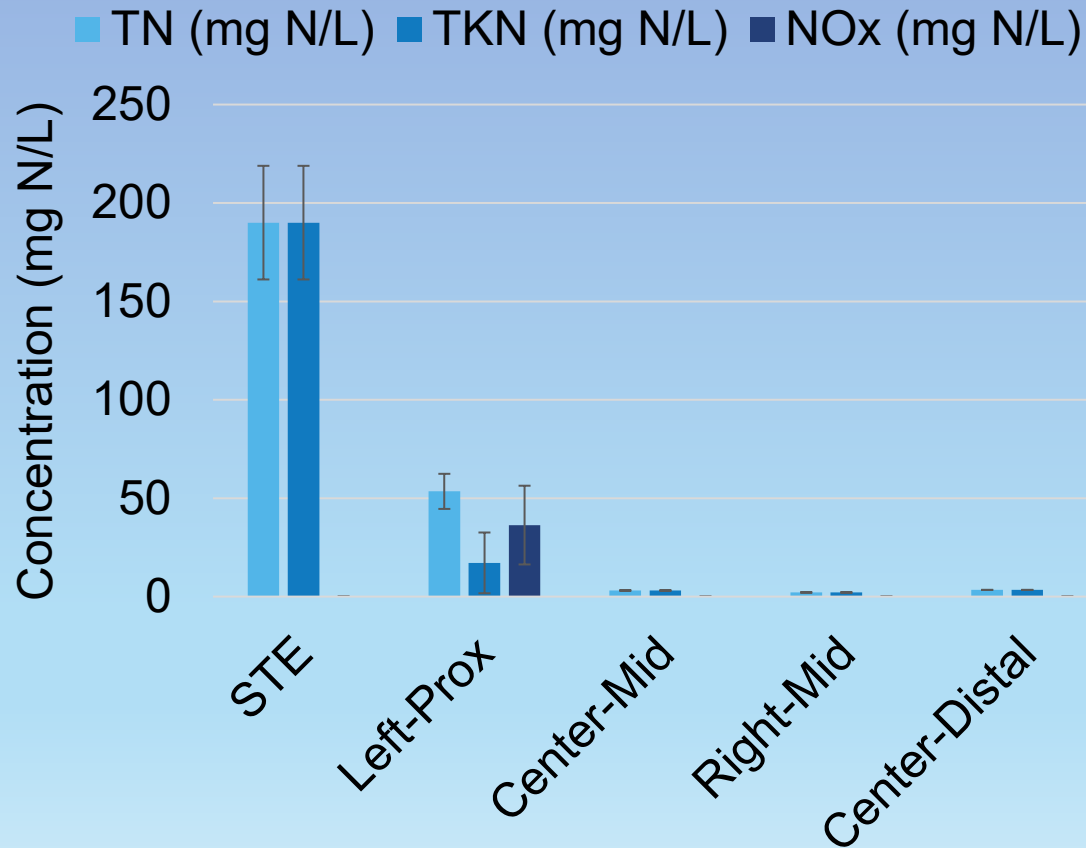




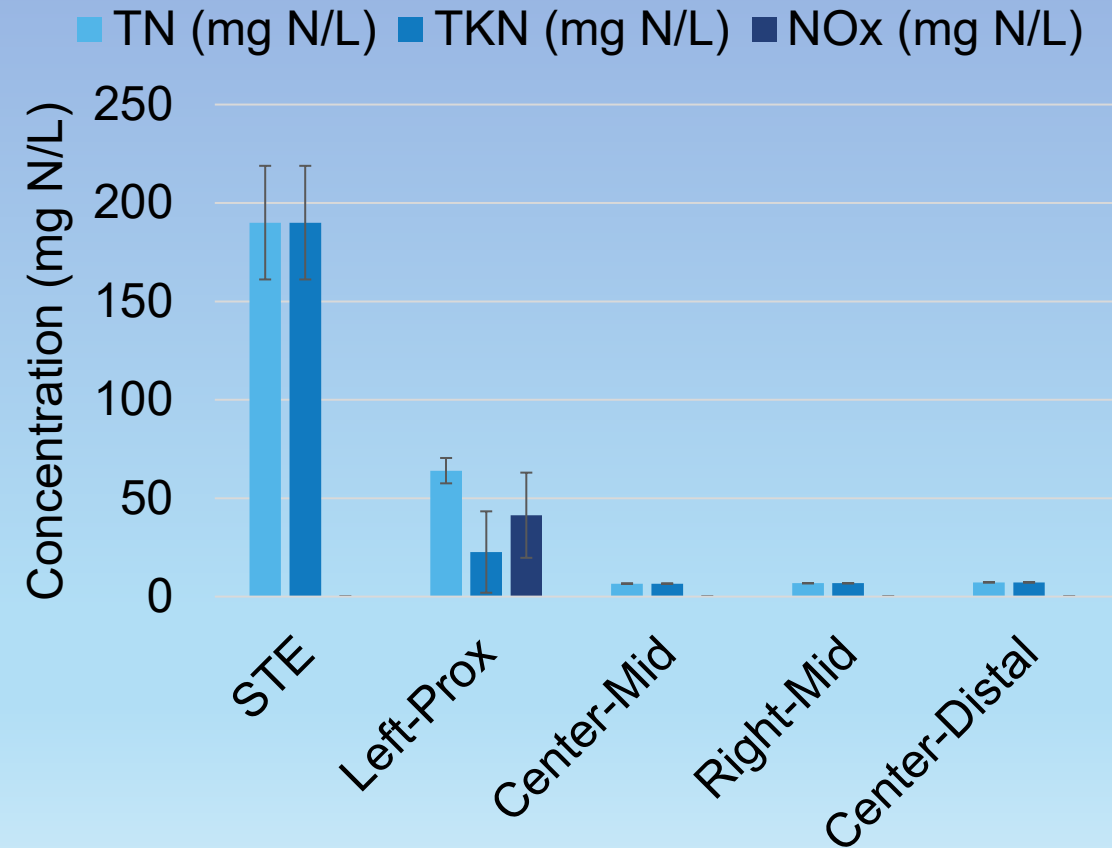
AVERAGE NITROGEN CONCENTRATIONS S6

SYSTEM 6 – DNL EFFLUENT

Average DNL Nitrogen (mg N/L)
Dilution Unadjusted



Average DNL Nitrogen (mg N/L)
Dilution Adjusted

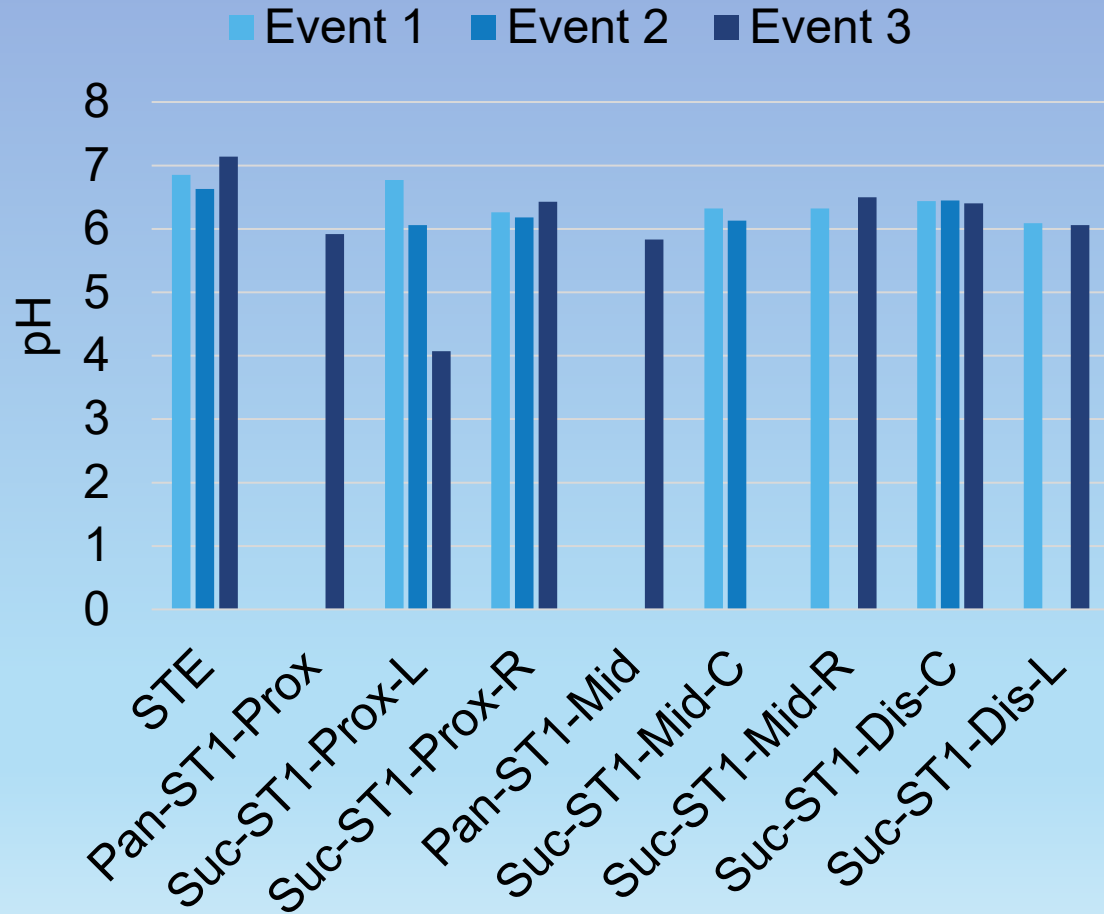




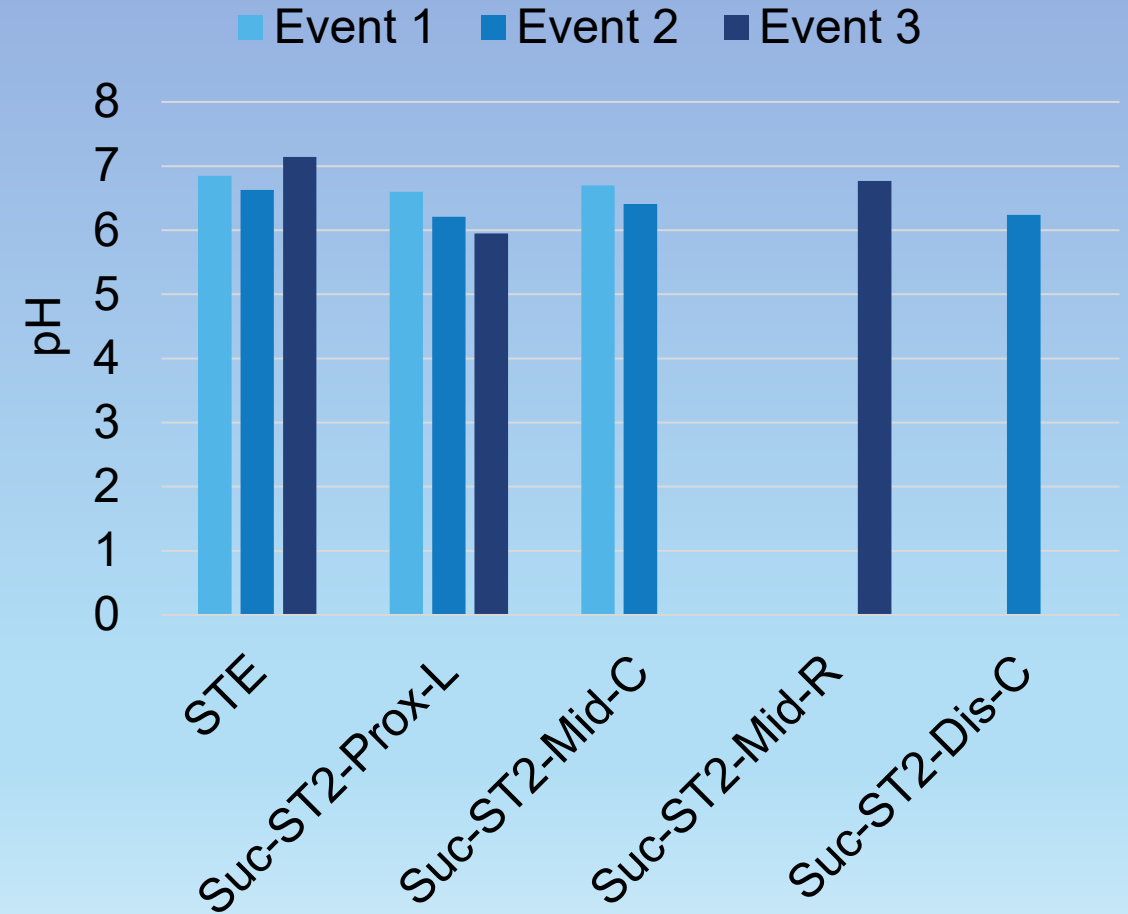
PH VALUES S6

SYSTEM 6 – SFL VERSUS DNL EFFLUENT

SFL pH



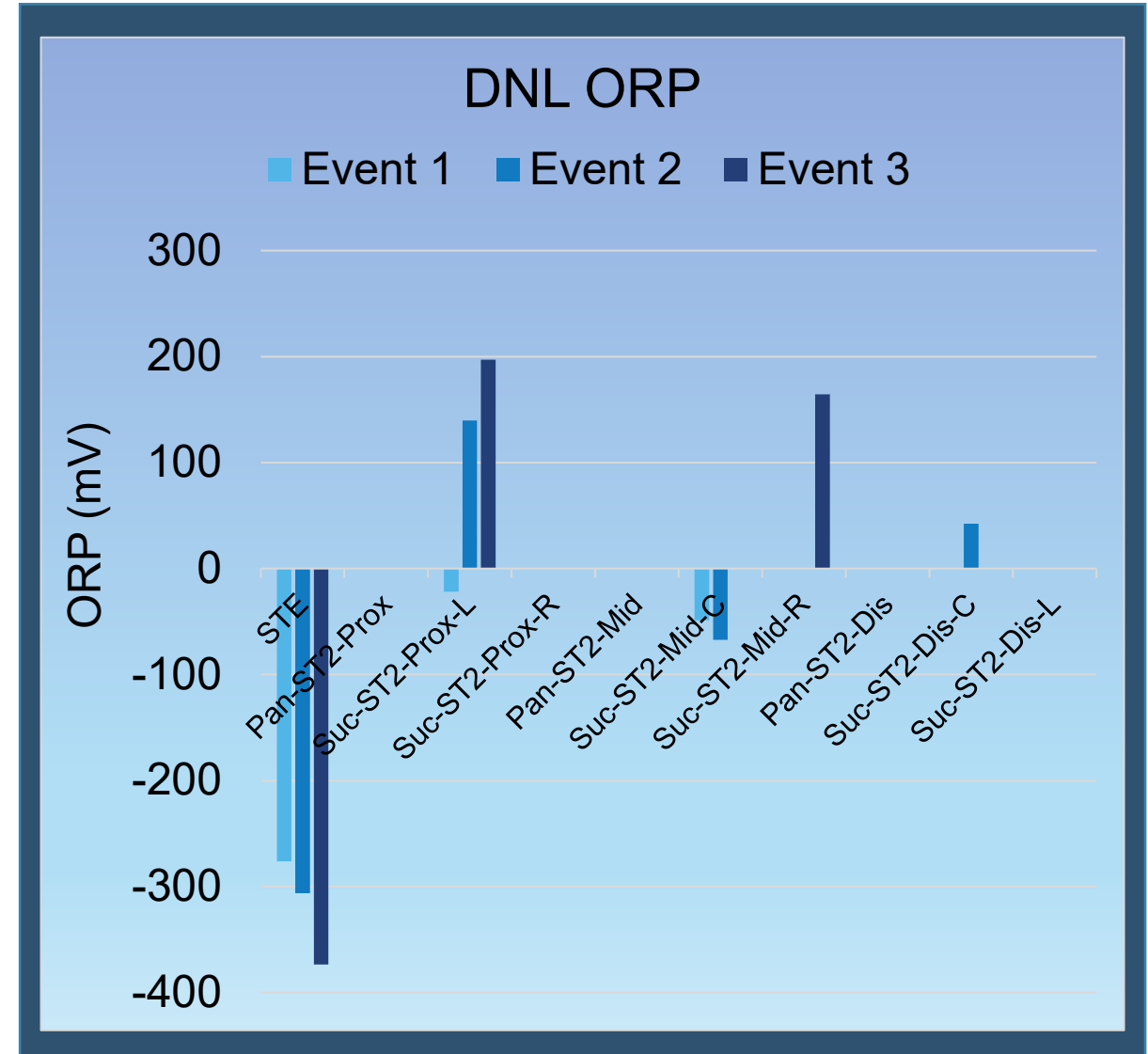
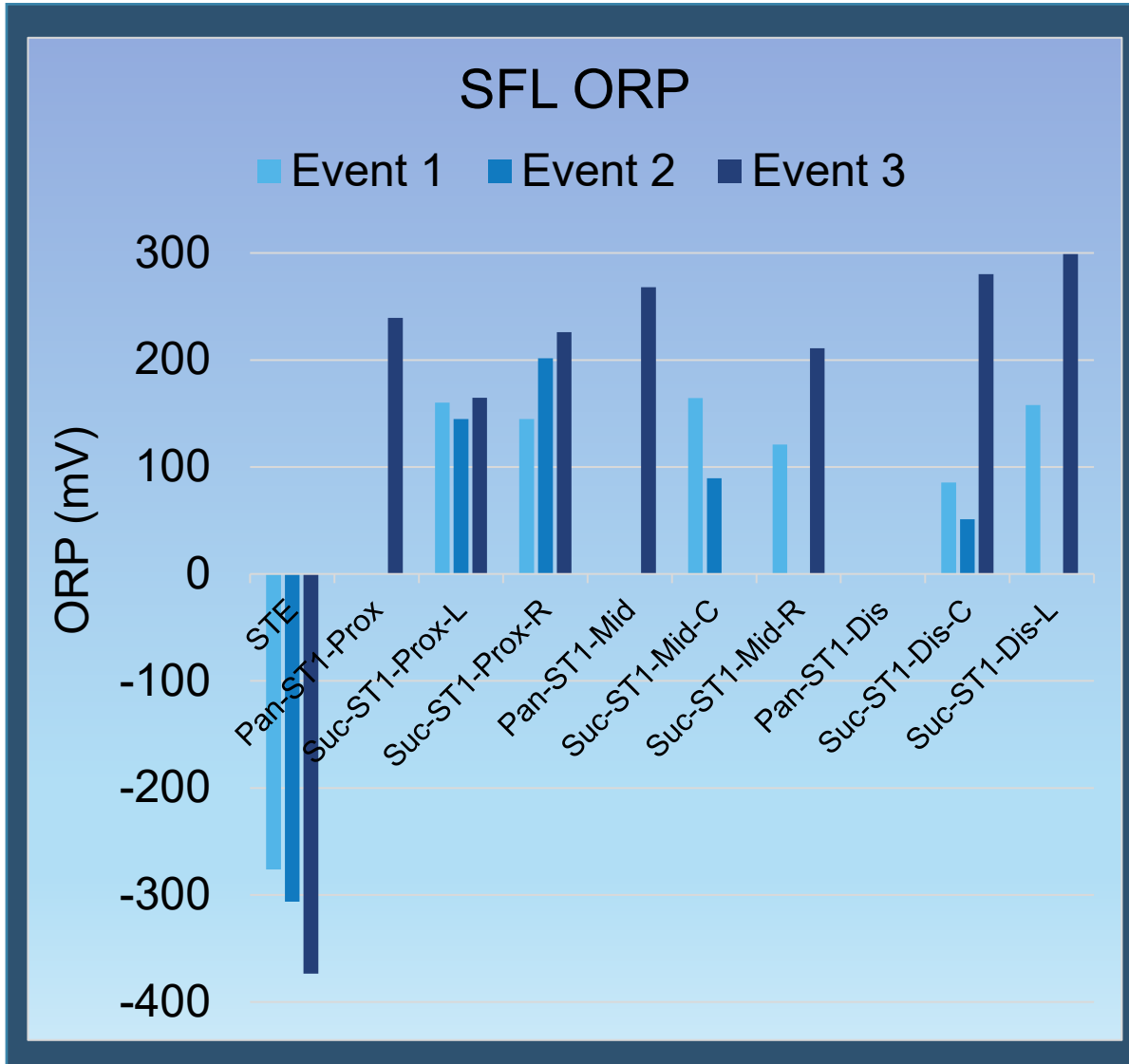
DNL pH





ORP VALUES S6

SYSTEM 6 – SFL VERSUS DNL EFFLUENT





AVERAGE NITROGEN REDUCTION S6

SYSTEM 6 – DNL – ADJUSTED

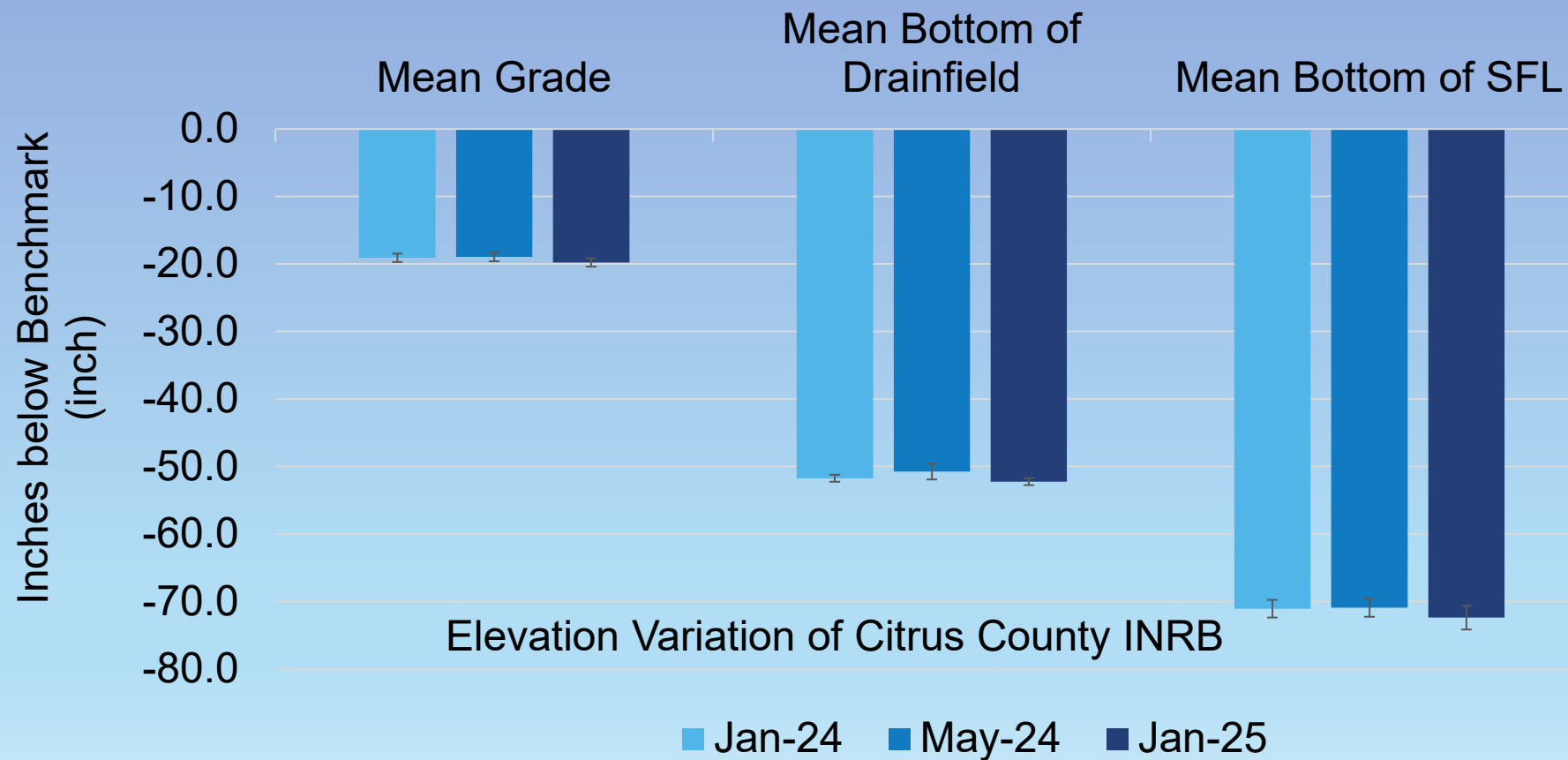
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STE (mg/L)	190	240	140	190	Event 1	Event 2	Event 3	All events
Left-Prox (mg/L)	64	53	75	64	66%	78%	46%	63%
Center-Mid (mg/L)	7	N/A	N/A	7	96%	N/A	N/A	96%
Right-Mid (mg/L)	7	N/A	N/A	7	96%	N/A	N/A	96%
Center-Distal (mg/L)	7	N/A	N/A	7	96%	N/A	N/A	96%
Average for each event					89%	78%	46%	

Overall percent nitrogen reduction ~ 71%.



ELEVATION CHANGE OF SYSTEM LAYERS S6

SYSTEM 6





SUMMARY

- Presented results of monitoring from two INRBs in Leon County and initial results from two additional INRBs.
- After adjusting for dilution, estimates for nitrogen reduction were as follows:
 - INRB S3: 83%.
 - INRB S4: 42% (up to design flow: 74%).
 - INRB S5 (two events): 75%.
 - INRB S6 (three events): 71%.
- Nitrogen reduction is consistent with expectations.
- Monitoring of elevations did not show settling of drainfields over time.



SUMMARY AND OUTLOOK

- Distribution of effluent in the drainfield is uneven.
 - For higher flows more sampling points detect effluent.
- Pan lysimeters were rarely successful in recovering effluent.
- Media layer 1 (nitrification layer) does sometimes not completely nitrify (turn TKN into NO_x) effluent.
 - This may be influenced by low pH and ORP.
 - Some nitrogen reduction occurs in this layer.
- Media layer 2 (denitrification layer) does sometimes not completely denitrify (remove NO_x from) effluent.
 - This may be influenced by relatively high ORP in those locations.
- Further monitoring of this and other systems is planned.



THANK YOU

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