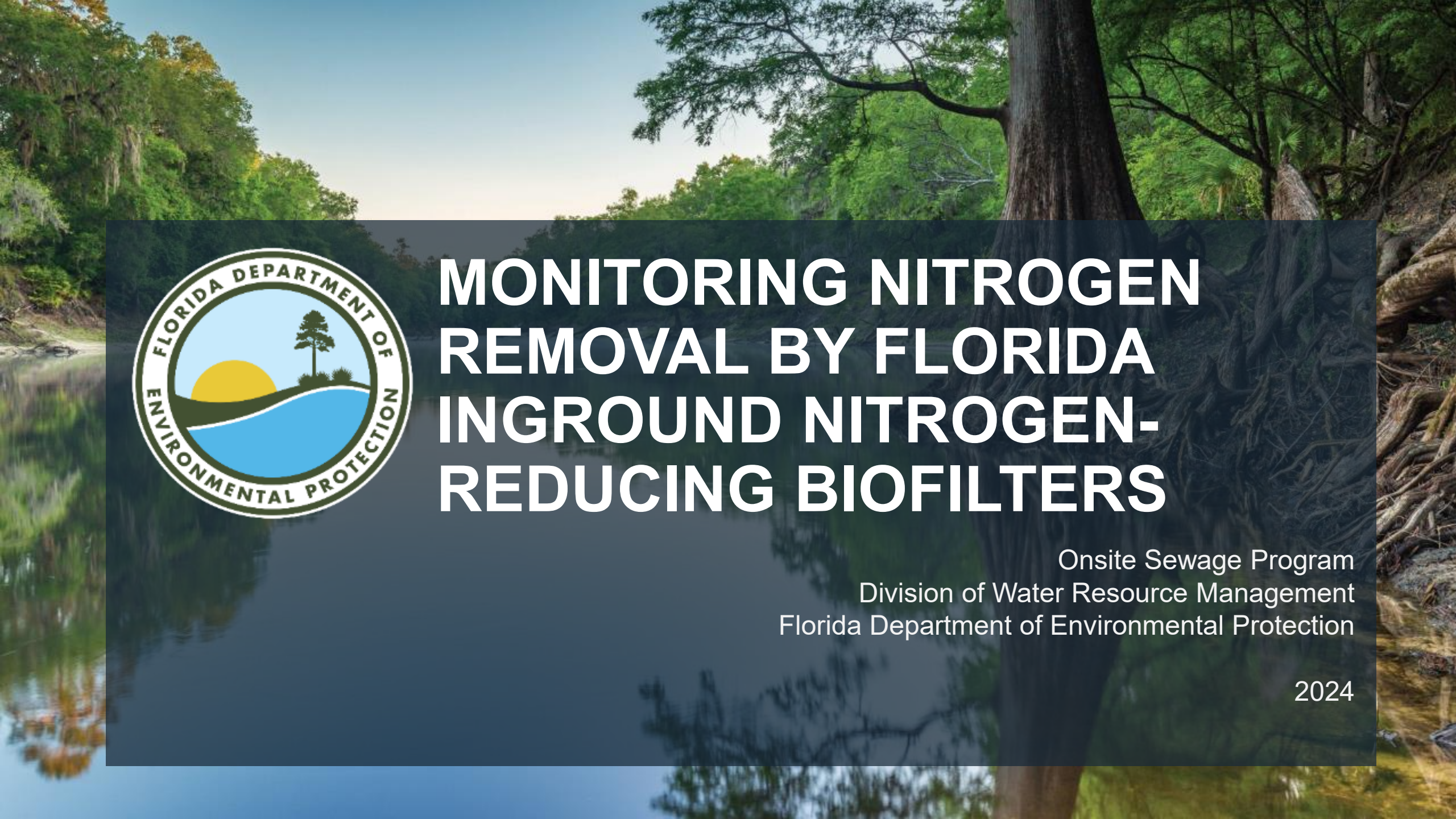


MONITORING NITROGEN REMOVAL BY FLORIDA INGROUND NITROGEN-REDUCING BIOFILTERS

Onsite Sewage Program
Division of Water Resource Management
Florida Department of Environmental Protection

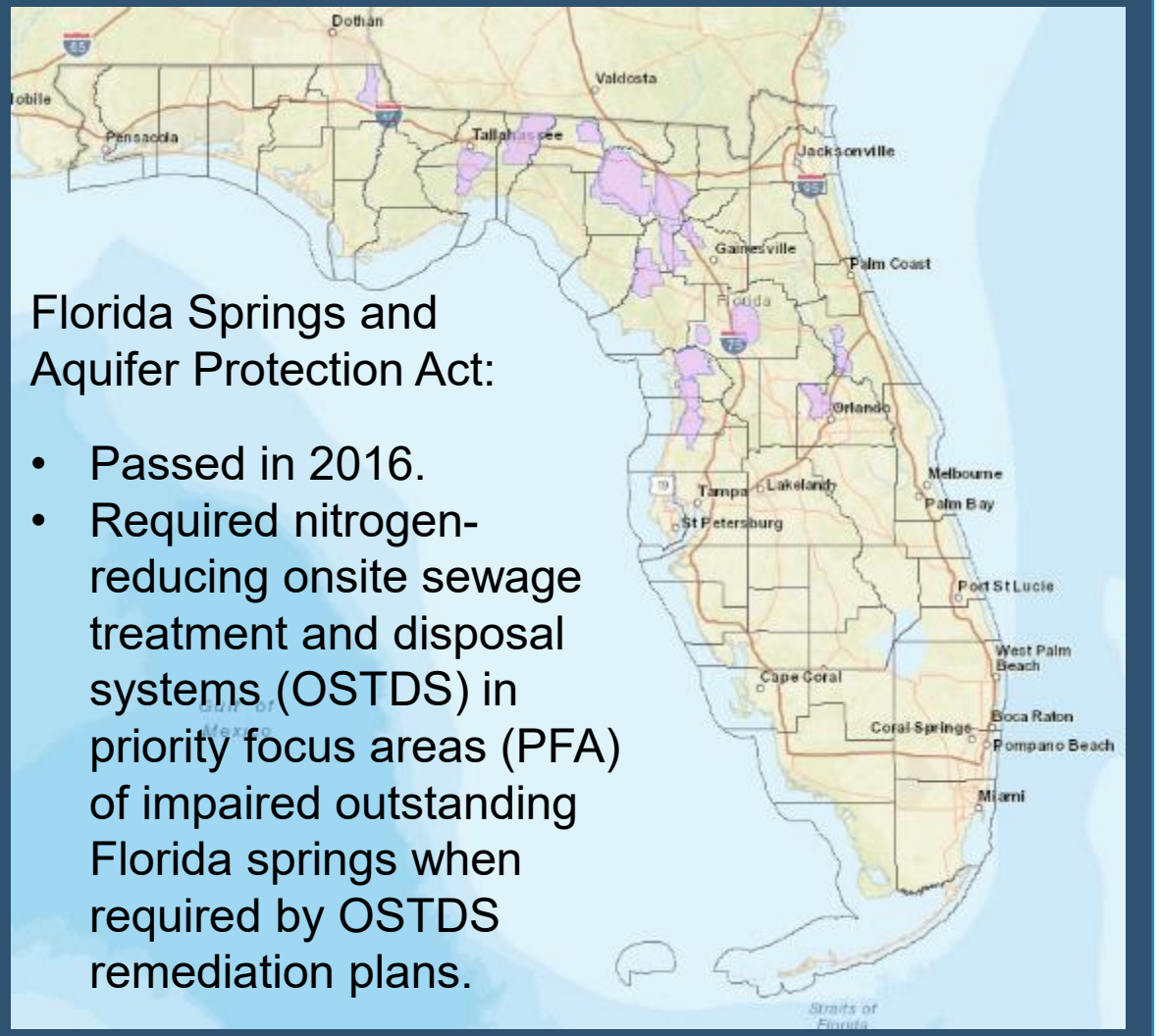
2024

ACKNOWLEDGEMENT

- This project was partially funded by the federal multipurpose fund from the U.S. Environmental Protection Agency (EPA) and the Spring and Aquifer Protection Fund from the Florida Department of Environmental Protection (DEP).
- The inground nitrogen-reducing biofilter (INRB) systems in Leon and Citrus Counties monitored in this project were constructed by the following companies.
  - Apalachee Backhoe and Septic.
  - Ace Septic and Waste.
- Special thanks to Ms. Tanya Welborn, Ms. Debby Tipton and Dr. Sol Park for helping with planning, preparing and conducting sampling on INRB systems.

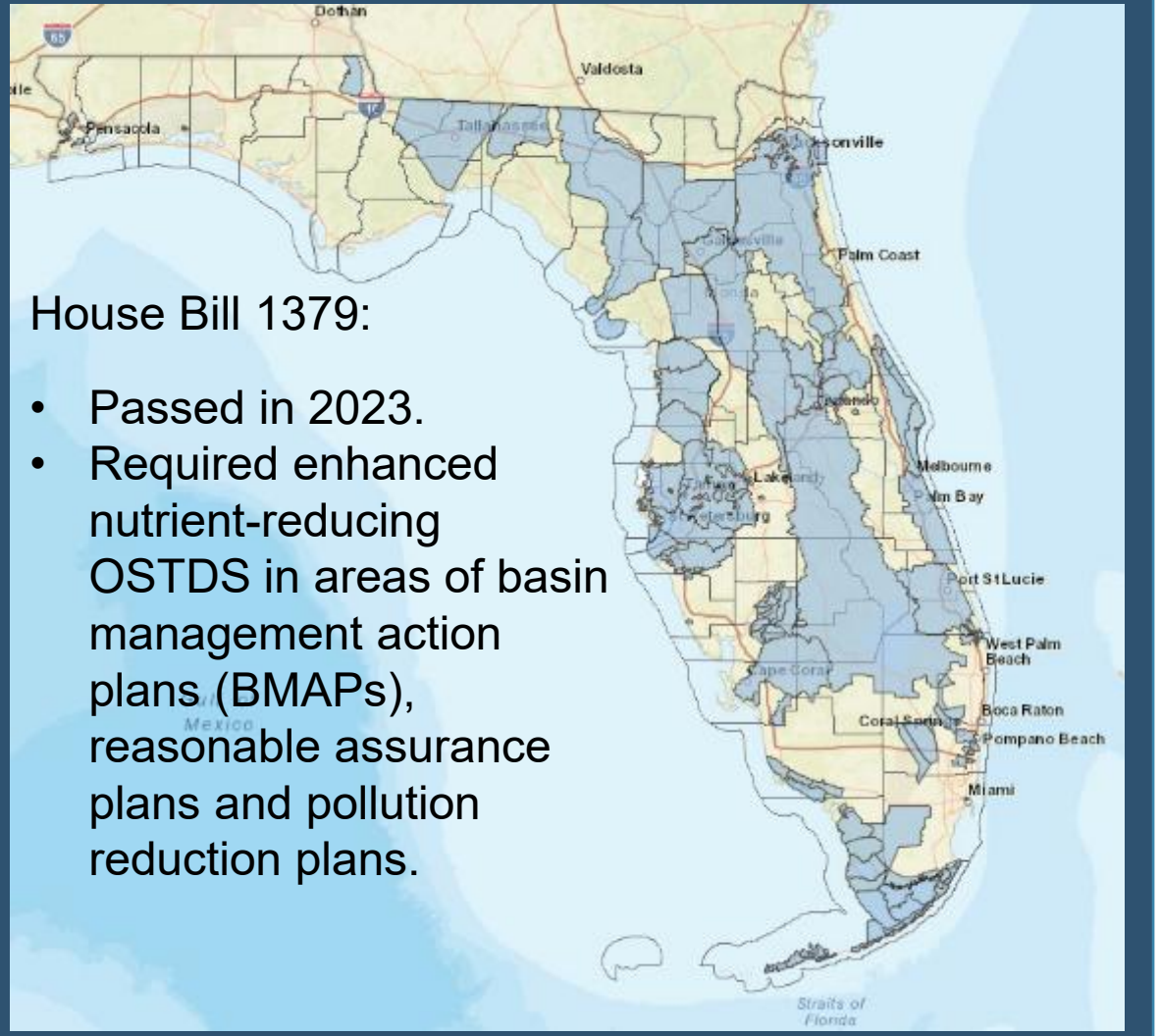
FLORIDA STATUTORY (F. S.) REQUIREMENTS

ENHANCED NUTRIENT-REDUCING OSTDS



Florida Springs and Aquifer Protection Act:

- Passed in 2016.
- Required nitrogen-reducing onsite sewage treatment and disposal systems (OSTDS) in priority focus areas (PFA) of impaired outstanding Florida springs when required by OSTDS remediation plans.



House Bill 1379:

- Passed in 2023.
- Required enhanced nutrient-reducing OSTDS in areas of basin management action plans (BMAPs), reasonable assurance plans and pollution reduction plans.

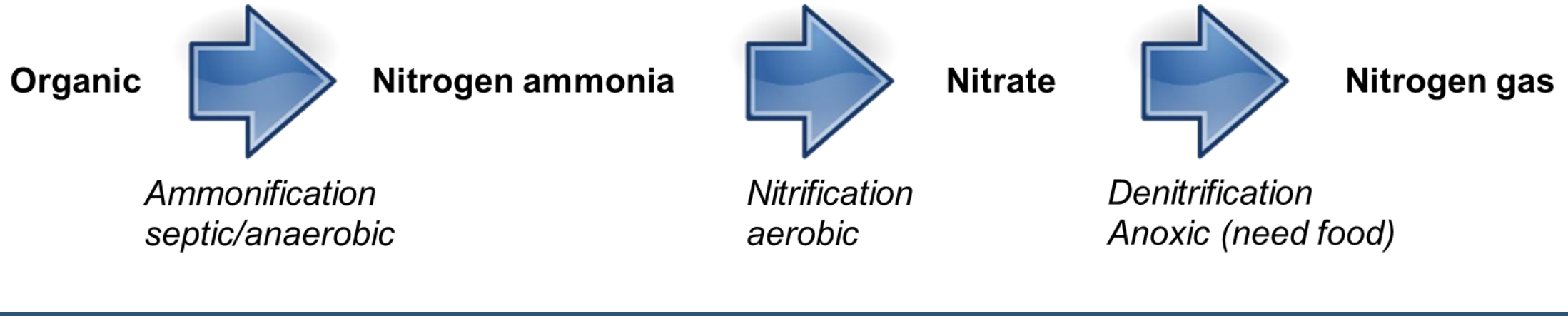
MODERN CONVENTIONAL OSTDS

- Modern conventional OSTDS effectively removes organic carbon (represented by biochemical oxygen demand [BOD]), total suspended solids (TSS), phosphorus and fecal coliform if the system is properly installed and maintained.

- However, conventional OSTDS is not designed to remove nitrogen with high efficiency.

REMOVING NITROGEN FROM DOMESTIC WASTEWATER

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



NITROGEN-REDUCING OSTDS

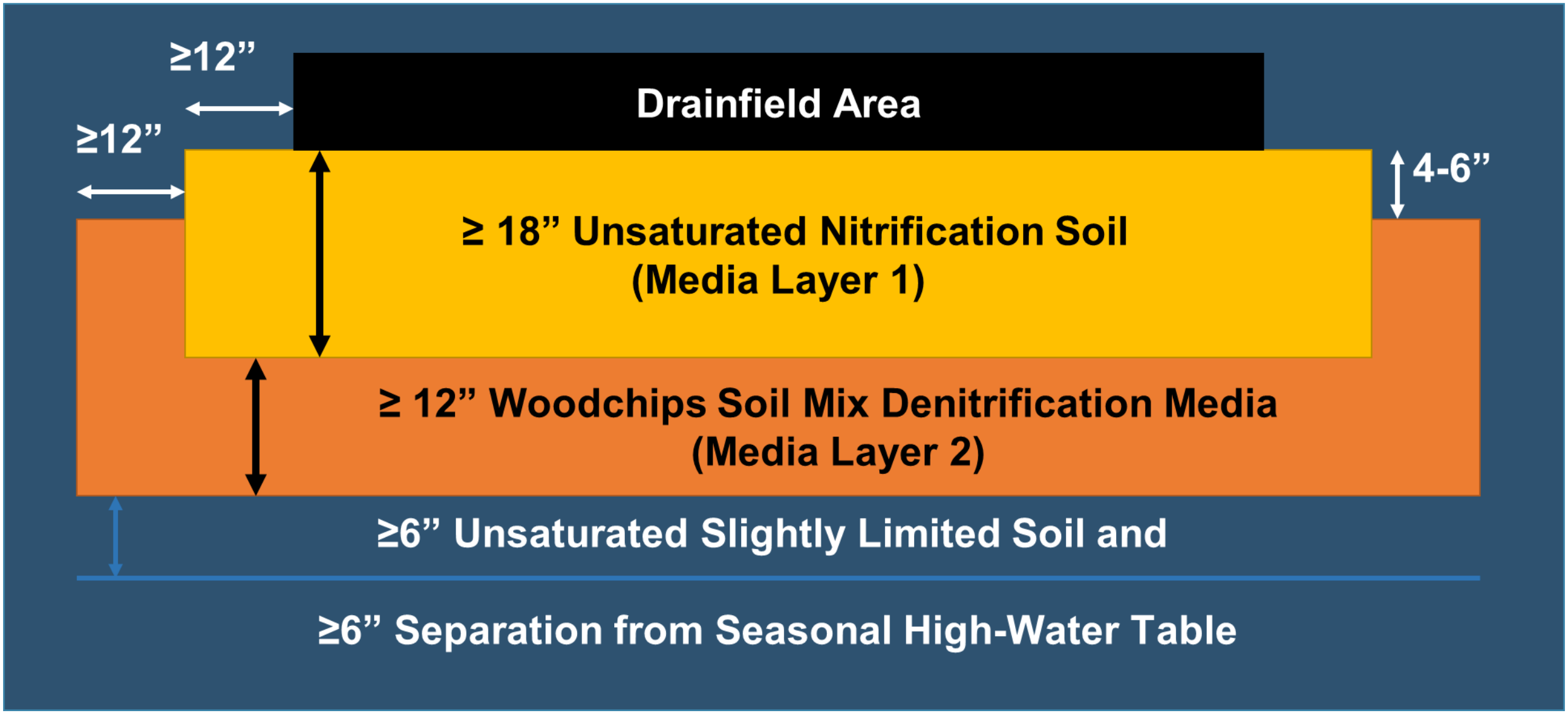
- Aerobic treatment units (ATU) certified as meeting the NSF 245 standard.
- Nitrogen-reducing performance-based treatment systems (PBTS).
- Inground nitrogen-reducing biofilters (INRB).

NITROGEN-REDUCING OSTDS FOR SPRINGS

- Between June 29, 2018, and March 19, 2024, more than 8,800 nitrogen-reducing OSTDS were installed in areas influenced by nitrogen-reduction requirements.
- Includes both new systems that were required by OSTDS remediation plans and 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	5,001
Nitrogen-reducing PBTS	302
INRB	3,578

INGROUND NITROGEN-REDUCING BIOFILTER



ONGOING INRB MONITORING PROJECTS

- Experimental prototypes of INRB installed previously showed about 65% nitrogen removal.
- Data from more systems are needed to provide more robust evaluation of the performance of the technology in Florida.
  - DEP's Onsite Sewage Program (OSP) is monitoring two INRB systems in Leon County and one INRB system in Citrus County.
  - OSP is working with DEP's Division of Environmental Assessment and Restoration (DEAR) to monitor four other INRBs in Leon County.
  - Monitoring equipment in an experimental INRB system installed in 2014 in Ichetucknee Springs State Park was replaced in May 2023 for renewed monitoring.
  - Continued monitoring on a passive nitrogen-reducing system installed during the Florida Onsite Sewage Nitrogen-Reduction Strategy (FOSNRS) study provided more data on an INRB using DEP 319 Grant funds.
  - OSP is looking for more volunteer INRB owners to participate in monitoring.

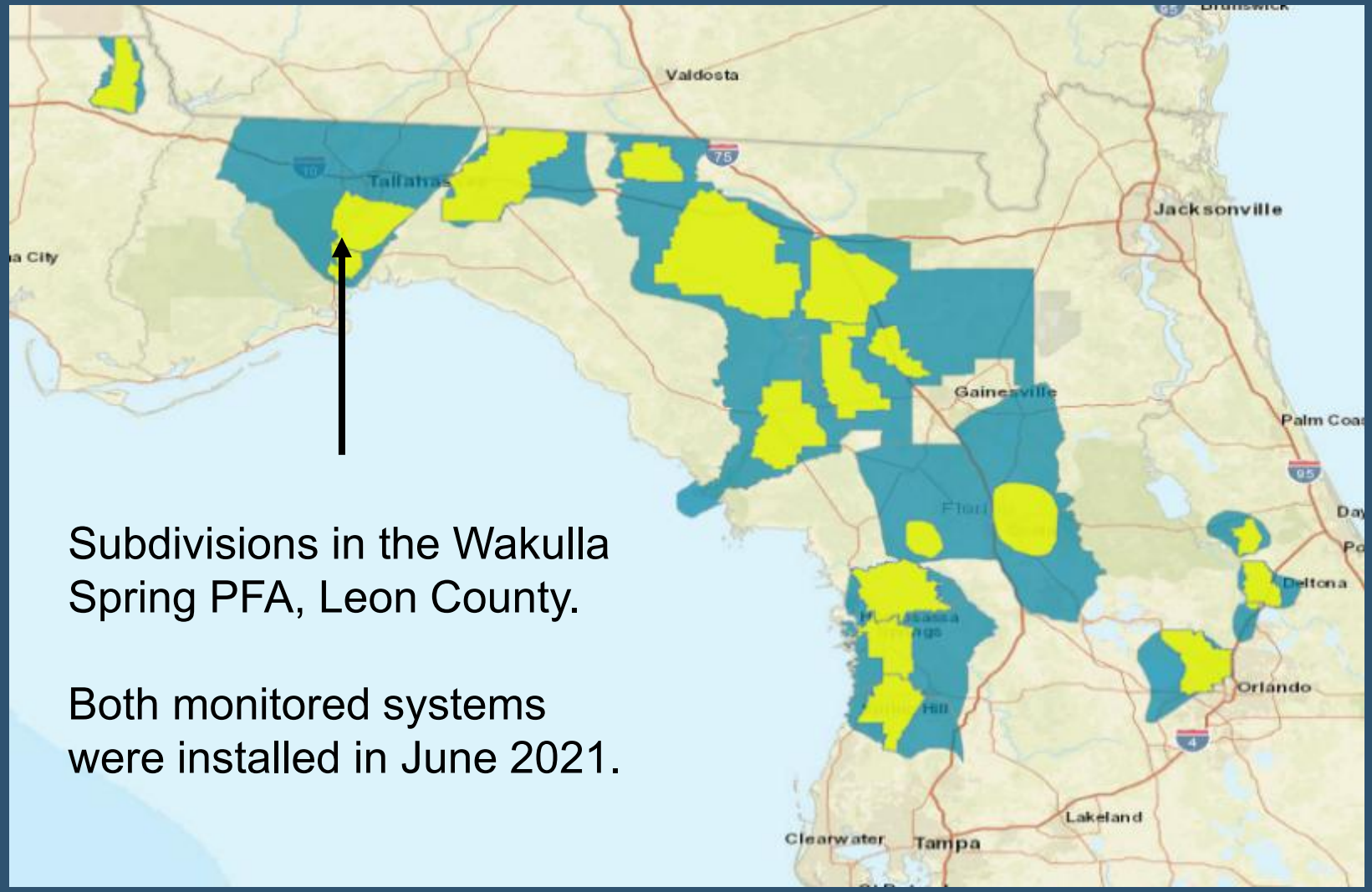
TWO LEON COUNTY INRBS MONITORED BY OSP

Monitoring Nitrogen Removal by Florida INRBs

TWO INRBS MONITORED BY OSP

- The two Leon County INRBs monitored by this project were installed in June 2021 in a subdivision located in the Wakulla Spring PFA.
- Monitoring of these two INRBs was funded through the multipurpose grant from EPA.
- Both systems were constructed by Apalachee Backhoe and Septic Tank.
- Monitoring equipment was installed when the two INRBs were constructed.
- Goals of this monitoring:
  - Evaluate the nitrogen-reducing efficiency of INRB systems.
  - Evaluate removal efficiency of phosphorus, fecal coliform and organic carbon.
  - Evaluate media decay through monitoring the change of elevations of media layers.

PROJECT LOCATION



Subdivisions in the Wakulla Spring PFA, Leon County.

Both monitored systems were installed in June 2021.

BMAP Area

PFA

INRB SYSTEM MONITORING

- Inspect the systems to observe proper function.
- Conduct elevation survey to evaluate change of depth of media layers.
- Collect samples:
  - Total Kjeldahl nitrogen (TKN).
  - Ammonium nitrogen (NH4-N).
  - Nitrate/nitrite nitrogen (NOx-N).
  - Total phosphorus (TP).
  - Total organic carbon (TOC).
  - Fecal coliform.
  - Alkalinity.
  - Chloride.

INRB SYSTEM MONITORING (2)

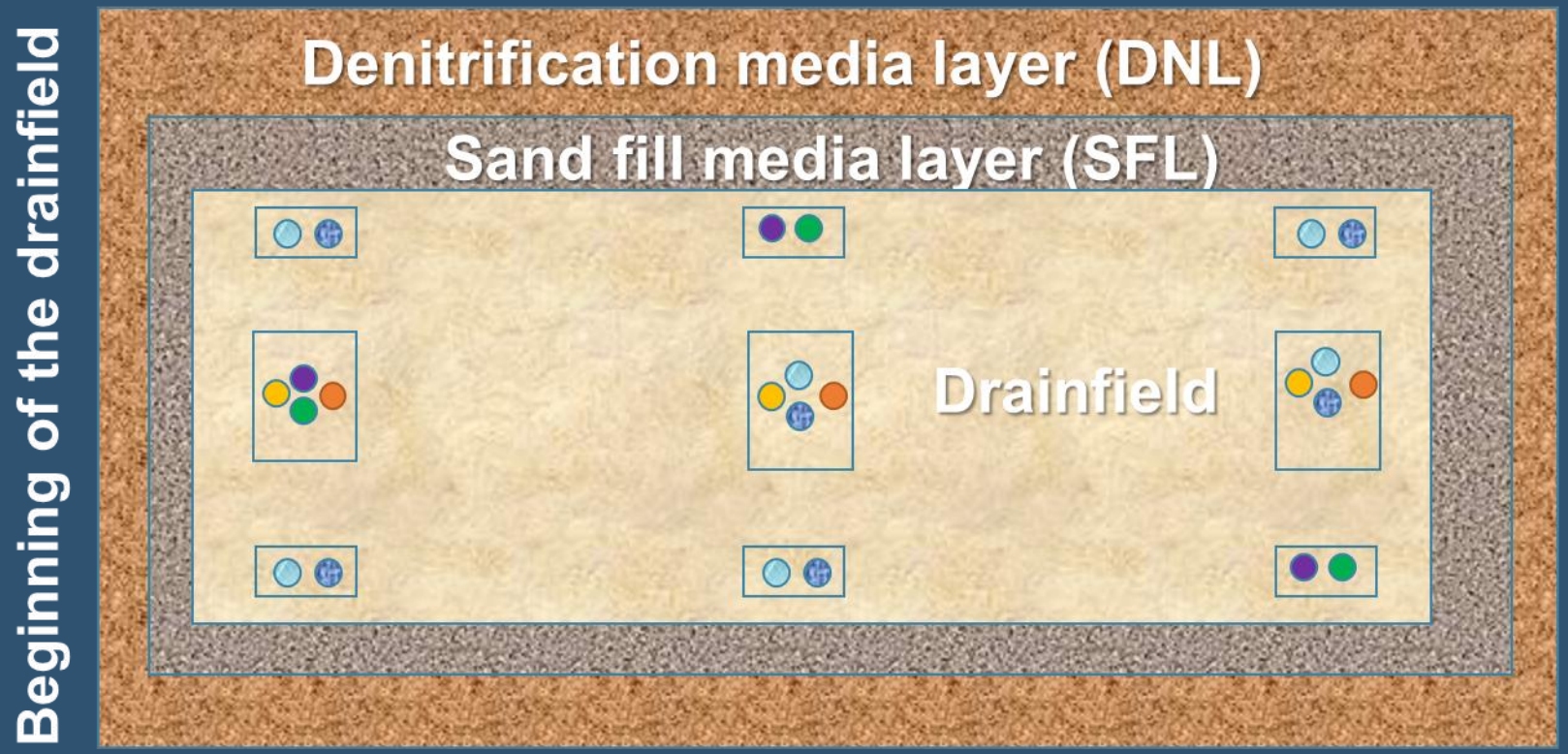
- Collect field measurements:
  - Water temperature.
  - Dissolved oxygen.
  - Specific conductivity.
  - pH.
  - Oxidation reduction potential (ORP).
  - Flowmeter reading.

MONITORING EQUIPMENT

Pan Lysimeter (PL)

Suction Lysimeter (SL)

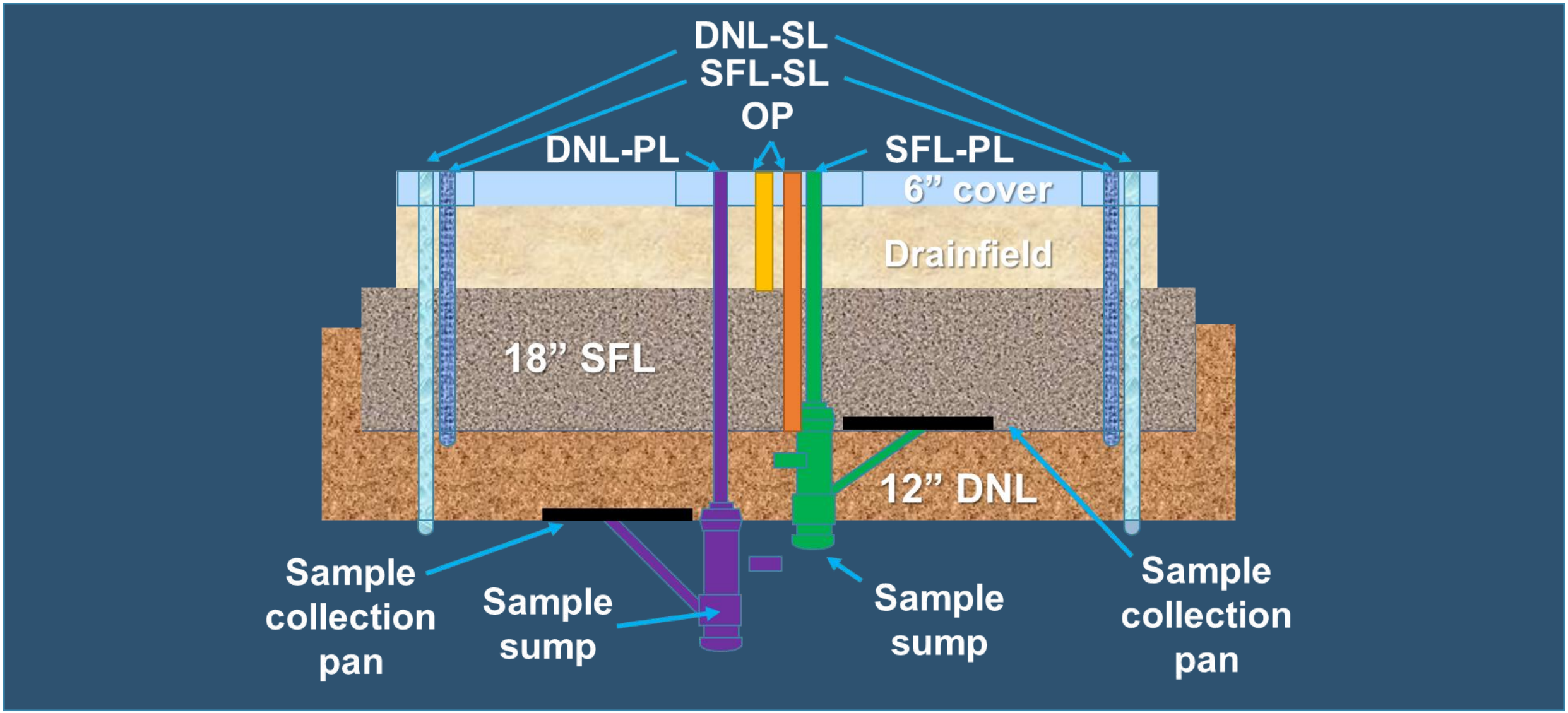
MONITORING EQUIPMENT ARRANGEMENT



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

SL: suction lysimeter. **PL**: pan lysimeter. **OP**: observation port.

MONITORING EQUIPMENT ARRANGEMENT (2)



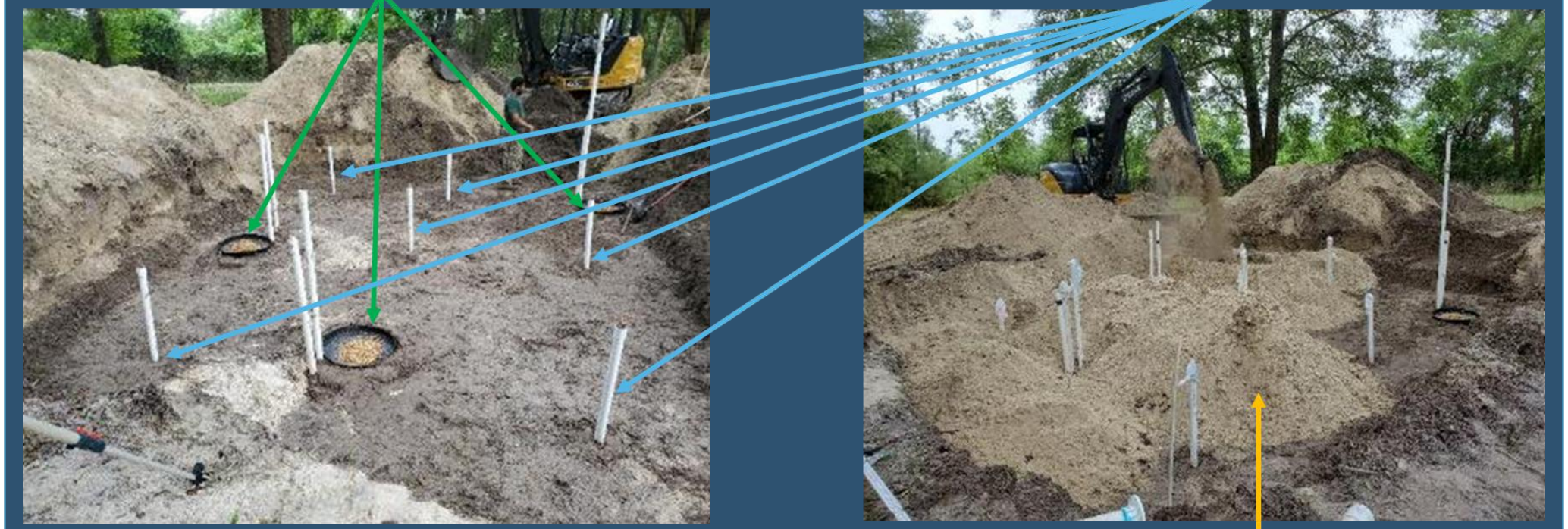
MONITORING EQUIPMENT INSTALLATION

Bottom of INRB

Denitrification media

PL at the bottom of INRB

MONITORING EQUIPMENT INSTALLATION (2)



MONITORING EQUIPMENT INSTALLATION (3)

Top of sand fill media layer

SYSTEM 3 (S3)

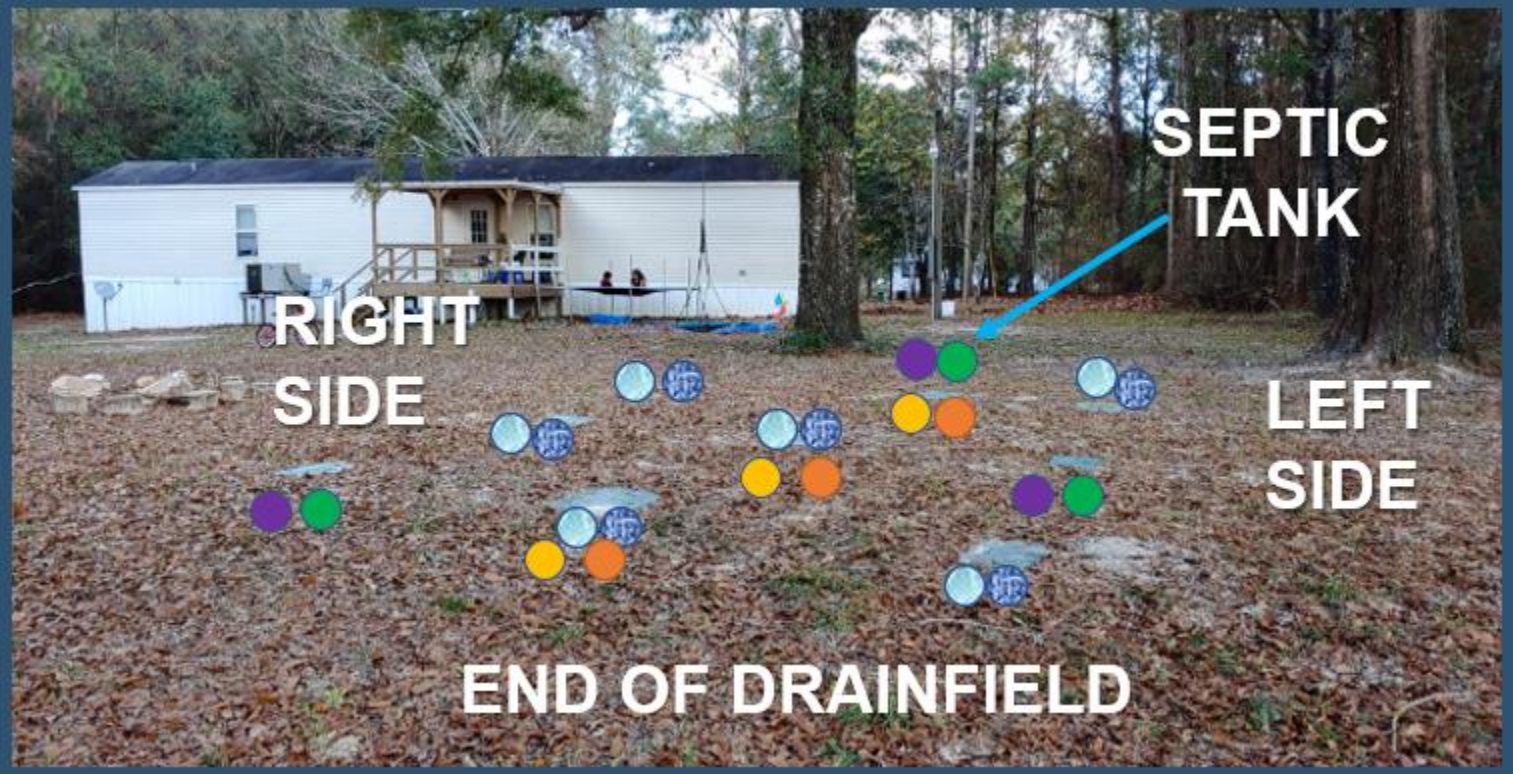
INSTALLED JUNE 2021

DNL	SFL
SL	SL
PL	PL
OP	OP

No irrigation.

SYSTEM 4 (S4)

INSTALLED JUNE 2021



DNL	SFL
SL	SL
PL	PL
OP	OP

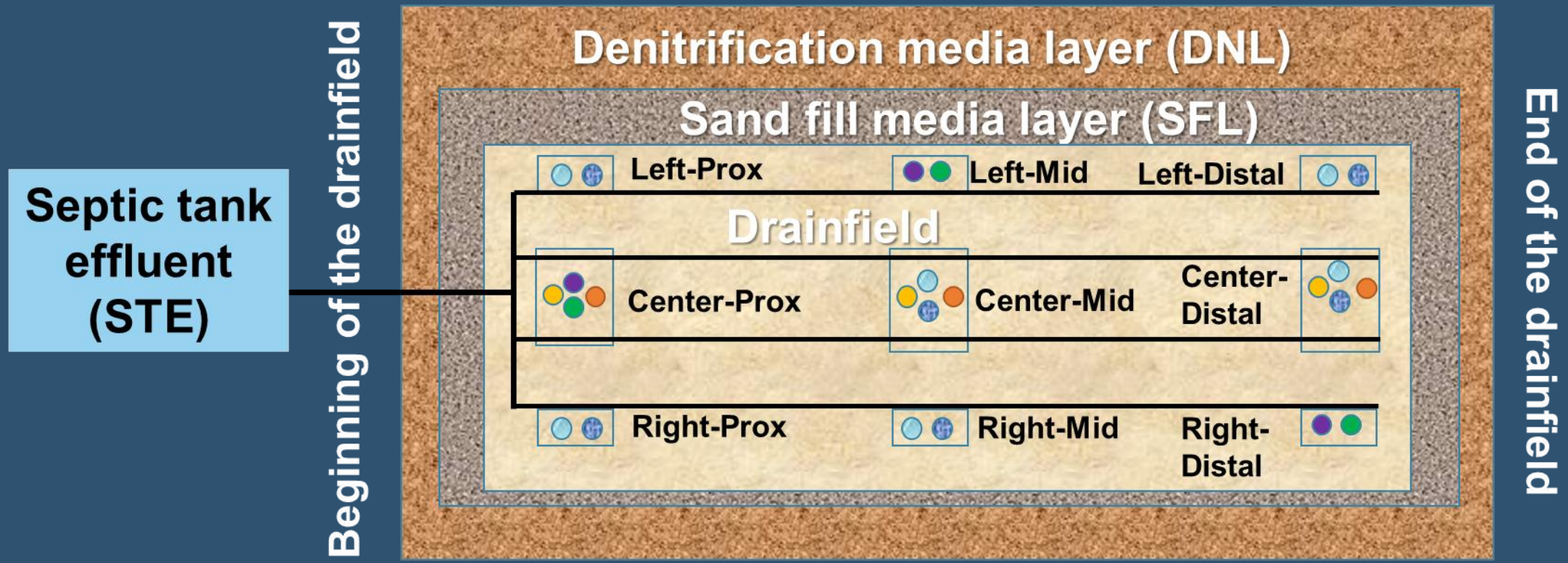
No irrigation.

PROPERTY CHARACTERISTICS

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

MONITORING EQUIPMENT ARRANGEMENT (1)

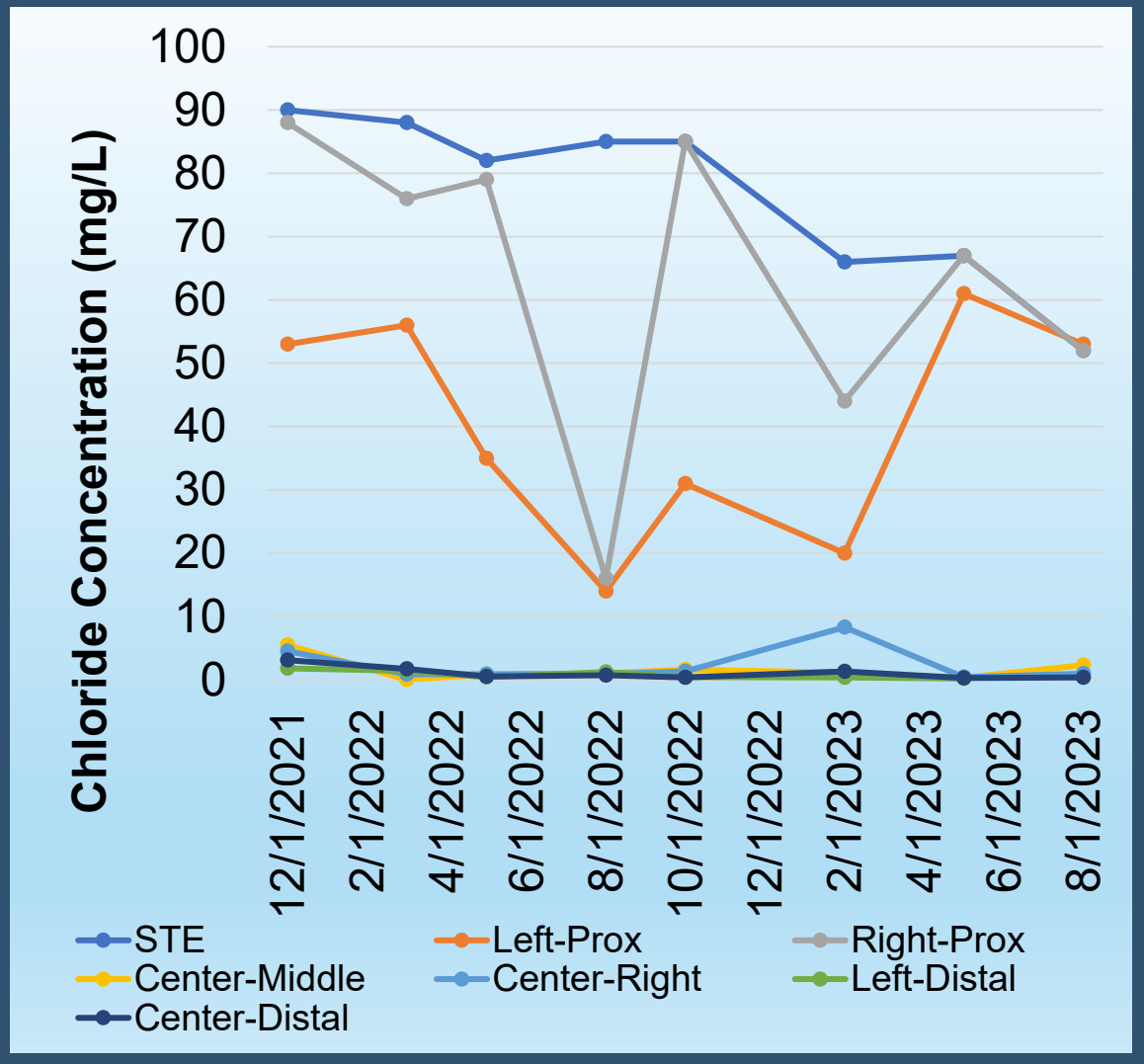


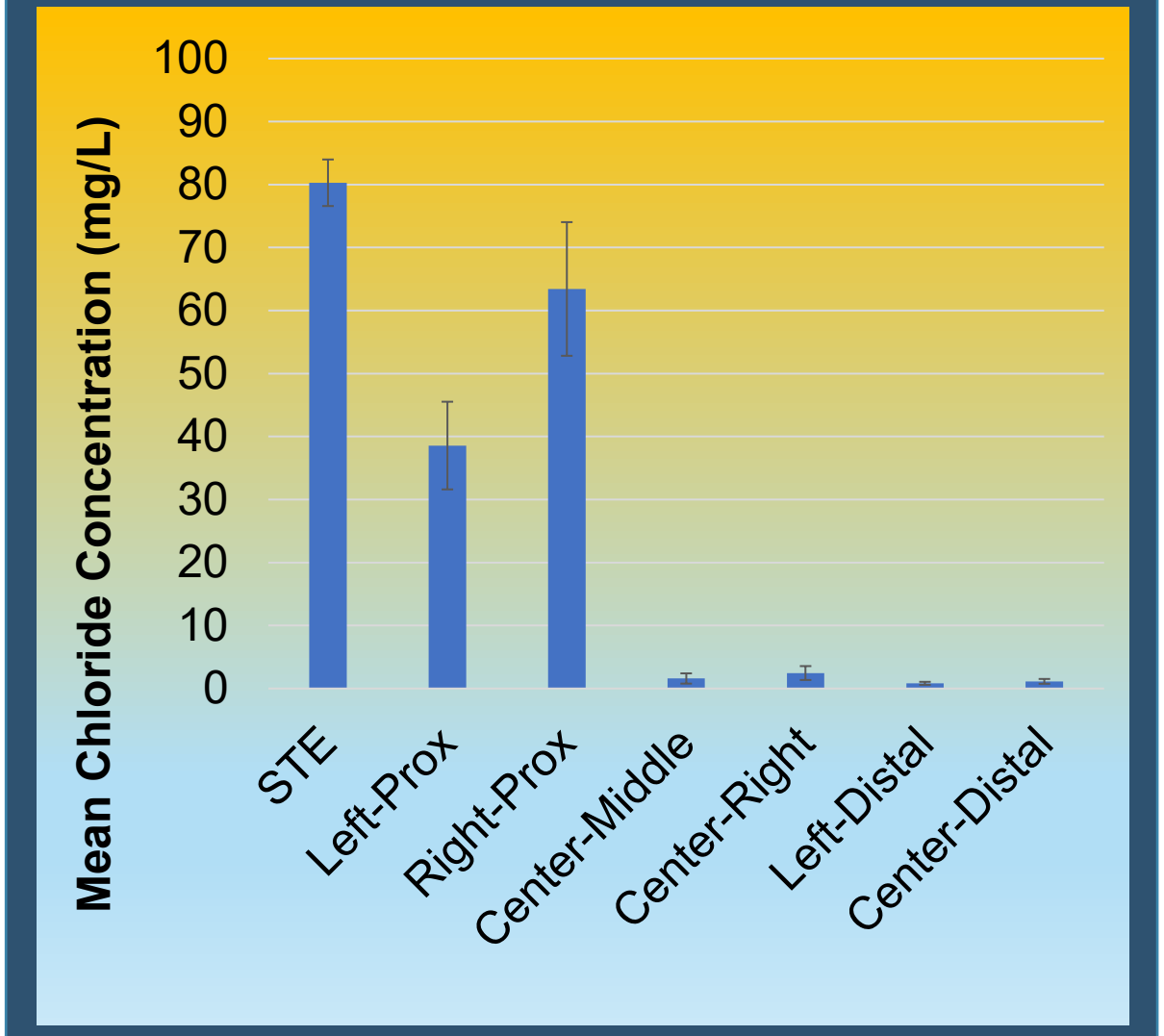
DNL-SL SFL-SL DNL-PL SFL-PL SFL-OP DNL-OP

SL: suction lysimeter. **PL**: pan lysimeter. **OP**: observation port.

CHLORIDE CONCENTRATION

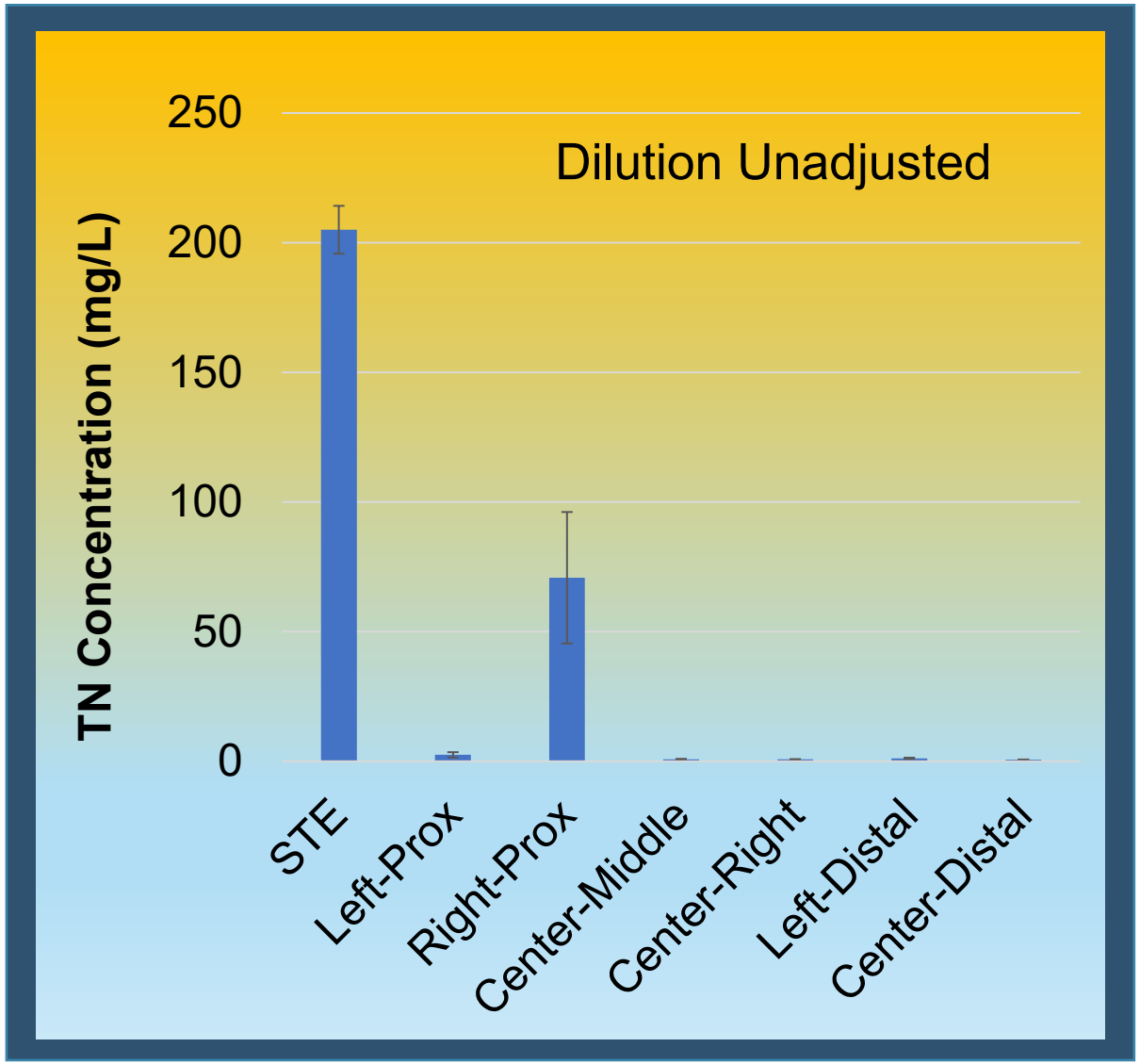
SYSTEM 3 – DNL MEDIA EFFLUENT

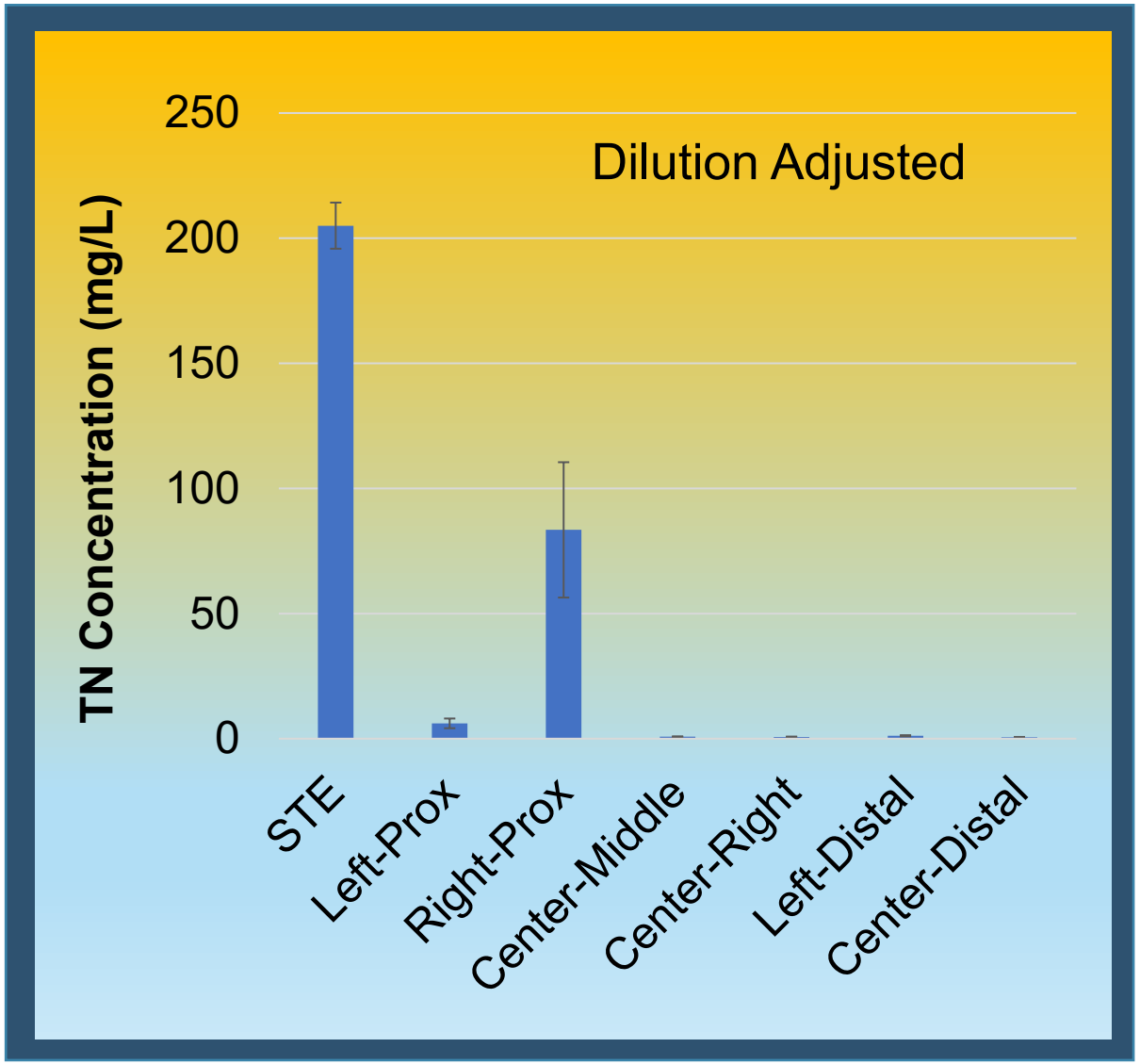




AVERAGE NITROGEN CONCENTRATIONS

SYSTEM 3 – DNL EFFLUENT





AVERAGE NITROGEN REDUCTION EFFICIENCY

SYSTEM 3

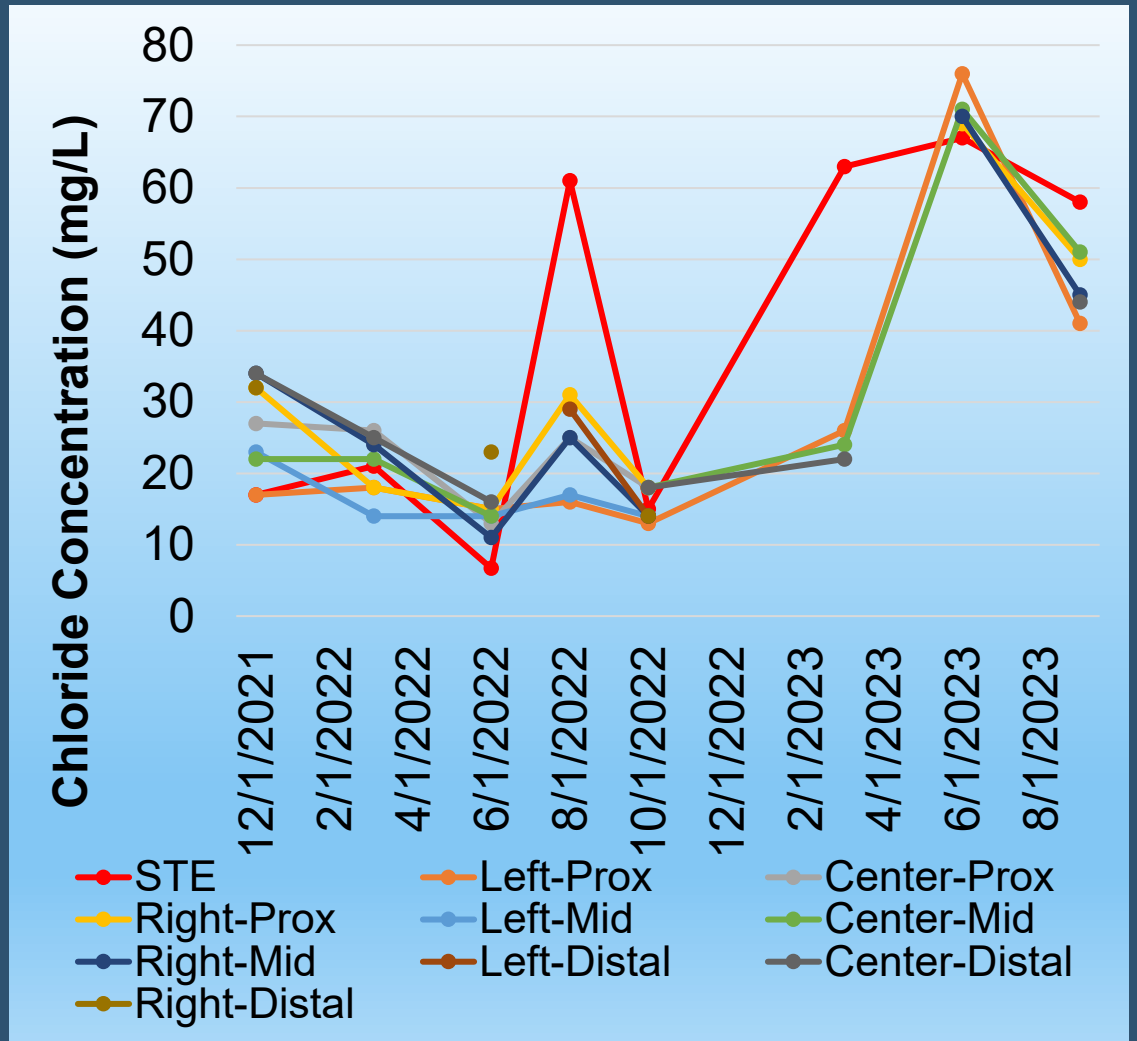
Sampling Events	STE (mg/L)	Left-Prox (mg/L)	Right-Prox (mg/L)	Left-Prox N-Removal Efficiency	Right-Prox N-Removal Efficiency
12/8/2021	230	2	160	99%	30%
3/2/2022	220	11	152	95%	31%
5/25/2022	220	3	39	99%	82%
8/24/2022	200	6	16	97%	92%
10/19/2022	200	2	21	99%	90%
2/22/2023	170	13	112	92%	34%
5/24/2023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

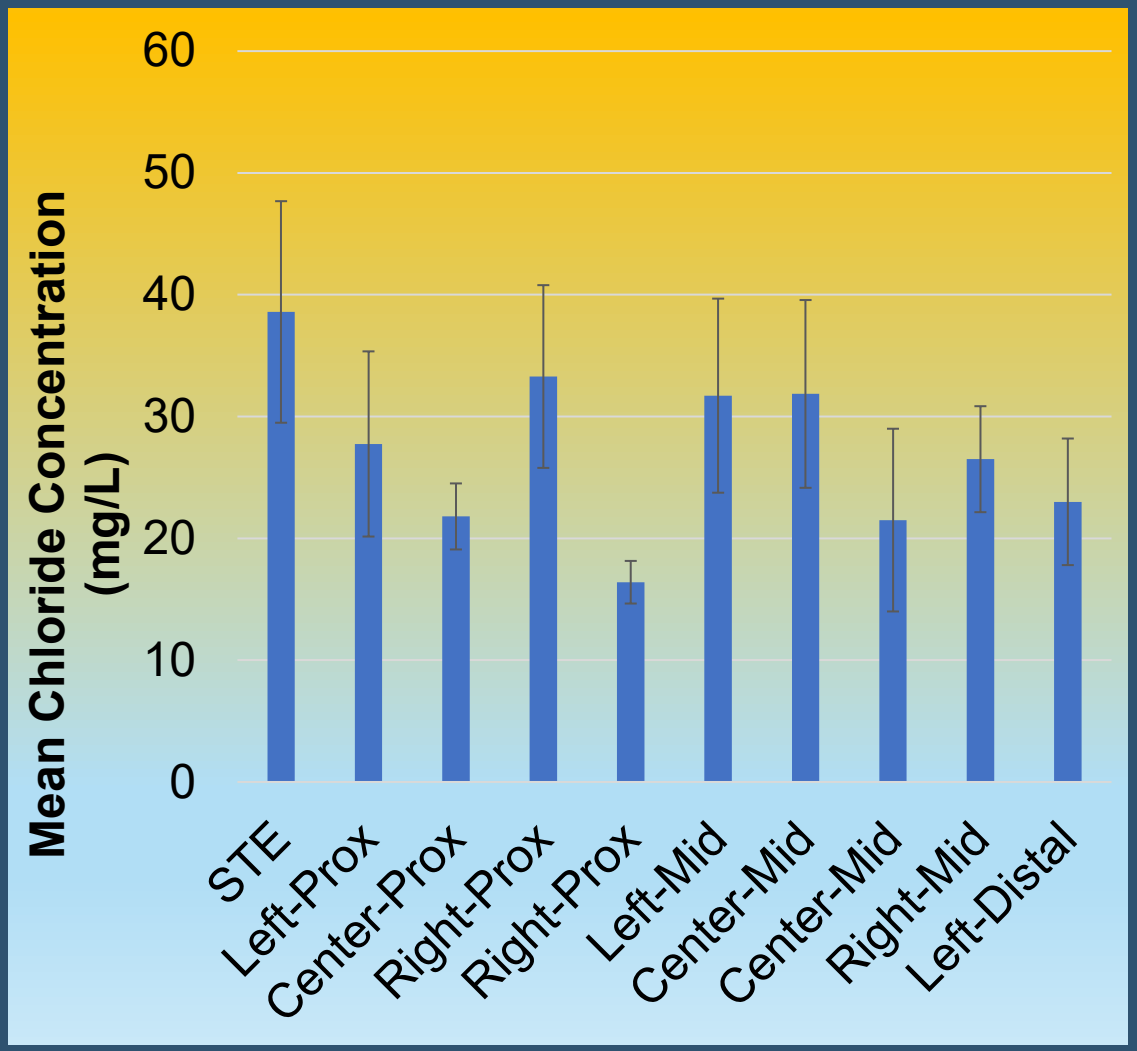
Overall mean nitrogen reduction efficiency: **83%.**

*SE: Standard Error.

CHLORIDE CONCENTRATIONS (2)

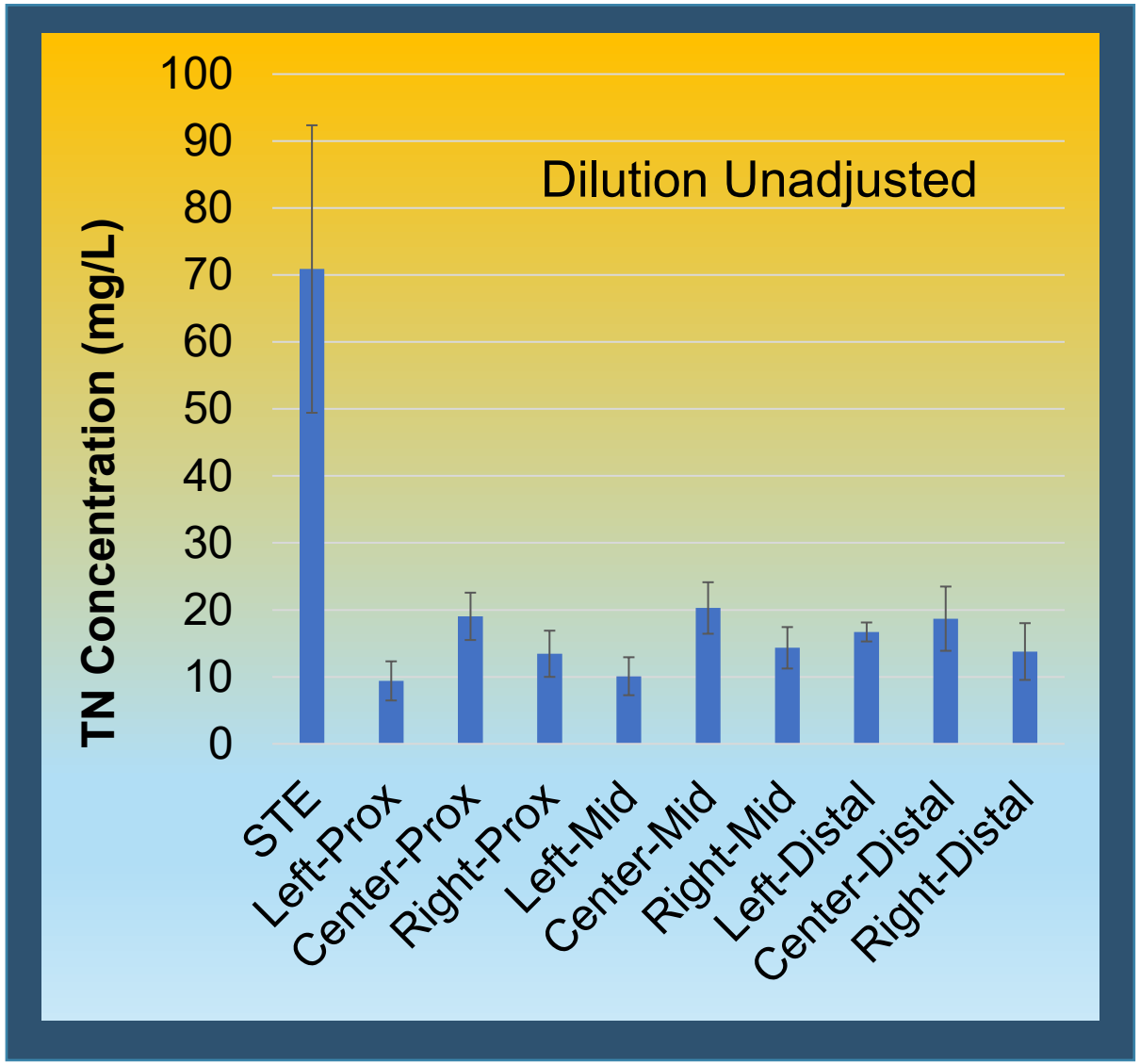
SYSTEM 4 – CHLORIDE CONCENTRATION FROM DNL MEDIA

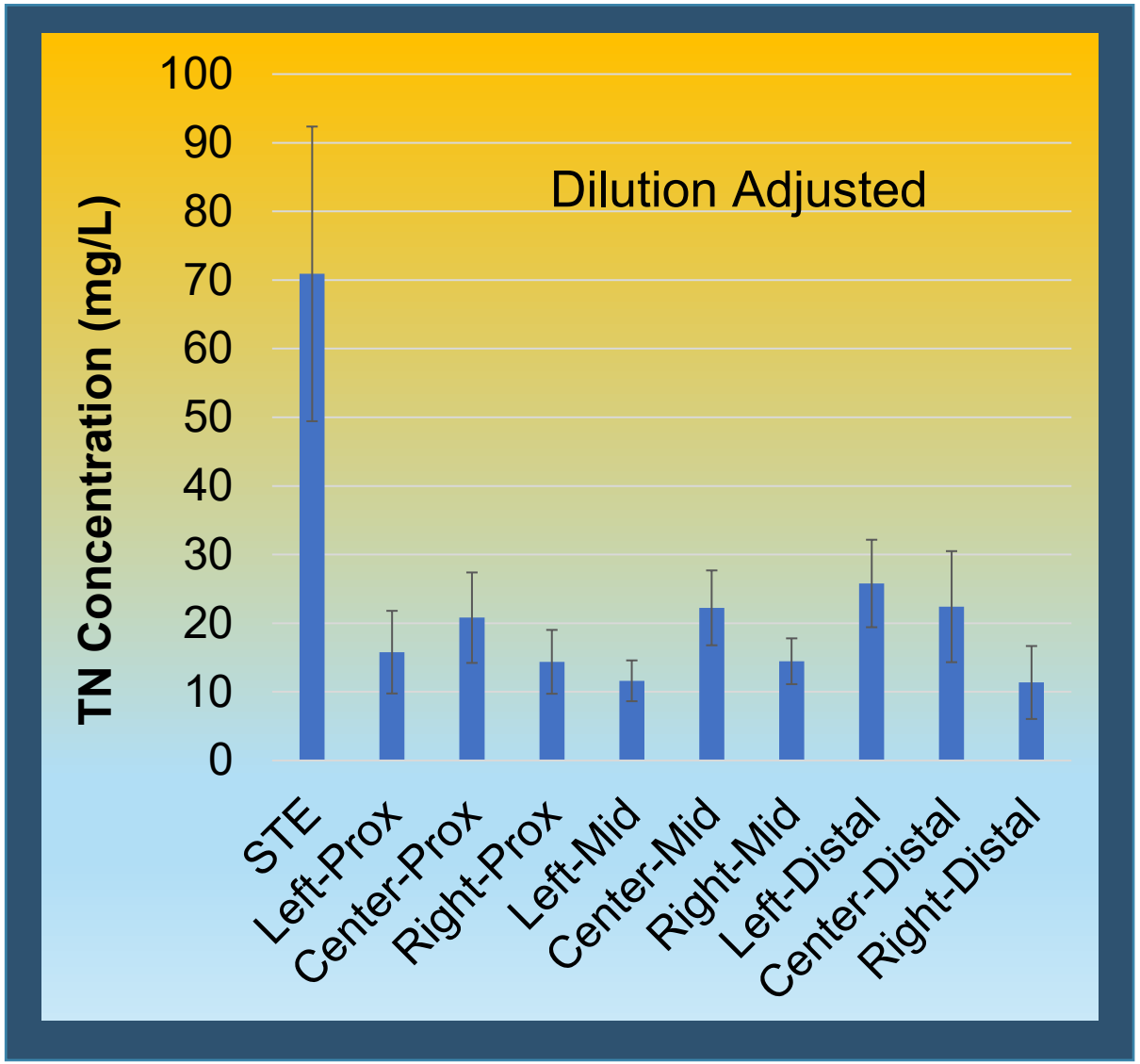




NITROGEN CONCENTRATIONS

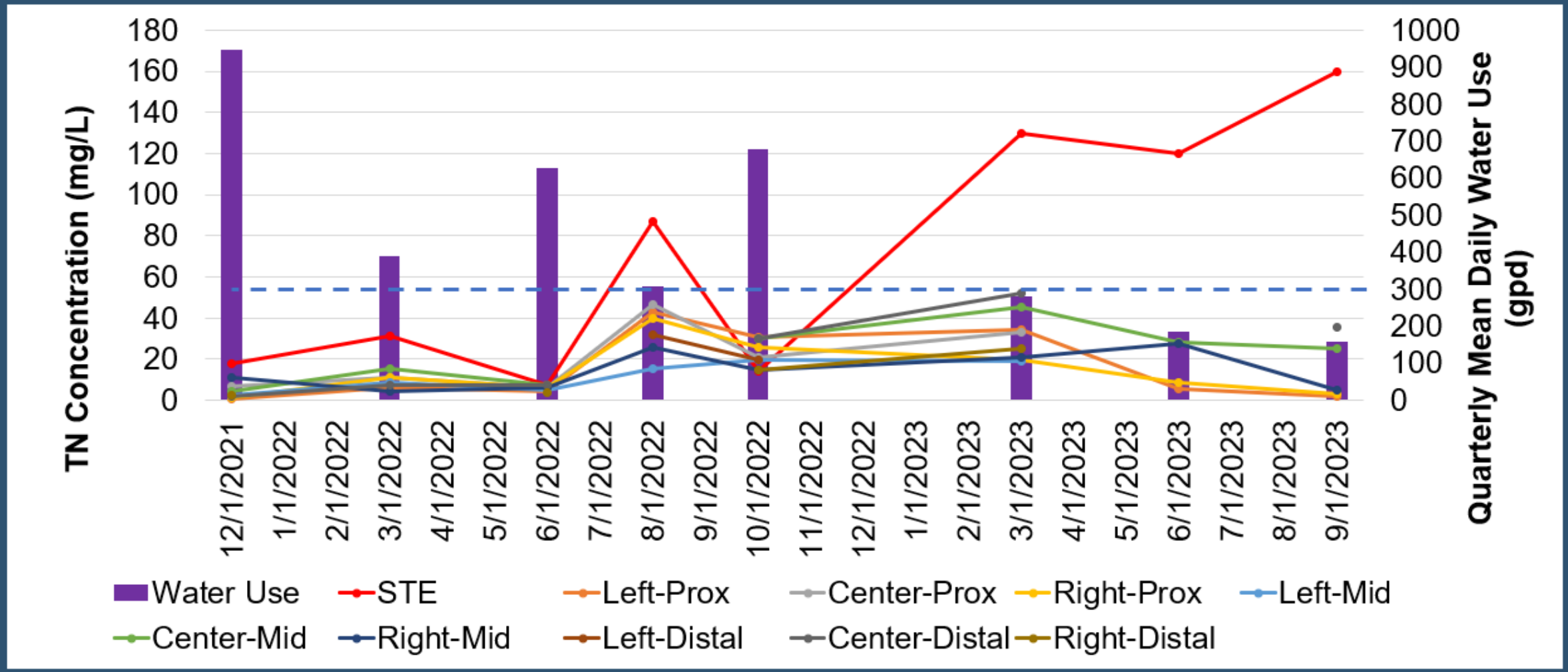
SYSTEM 4 – DNL EFFLUENT





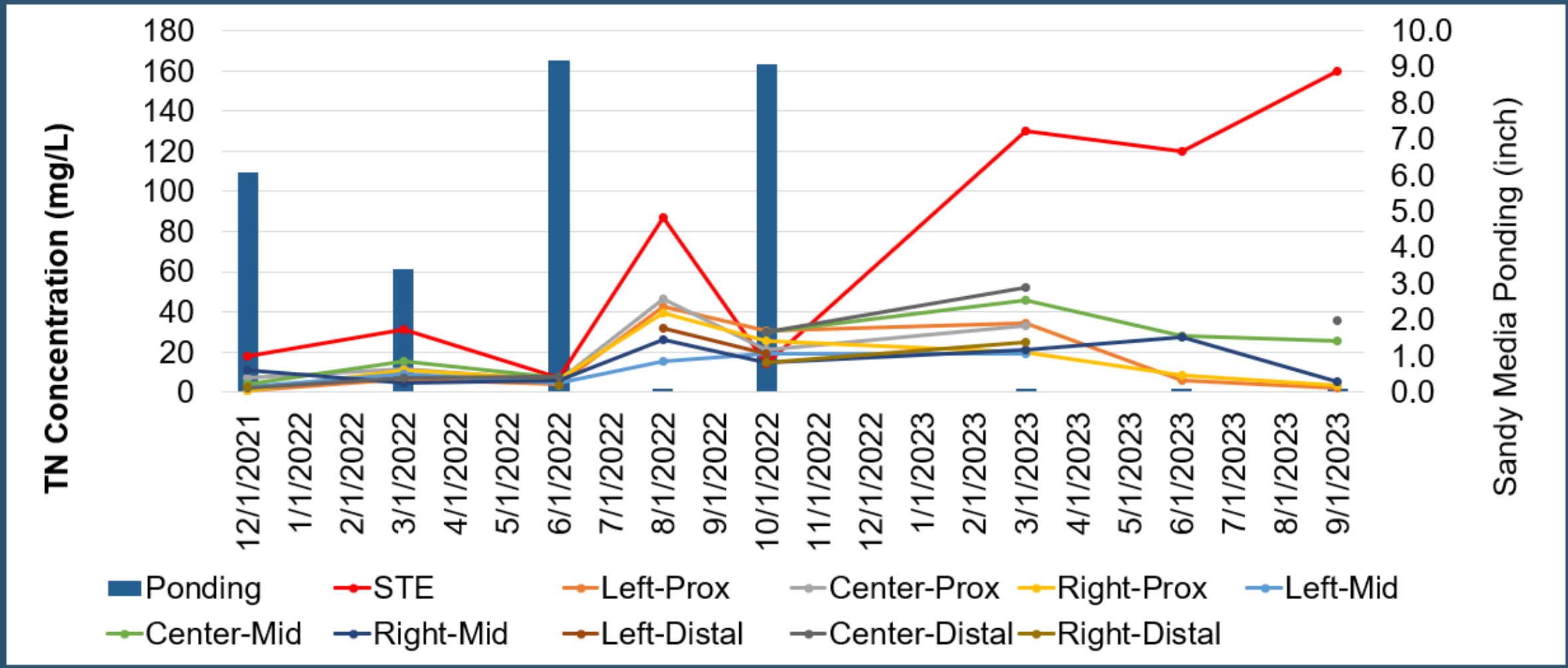
NITROGEN CONCENTRATIONS V. WATER USE

SYSTEM 4 – DILUTION ADJUSTED DNL TN CONCENTRATION



NITROGEN CONCENTRATIONS V. SFL PONDING

SYSTEM 4 – DILUTION ADJUSTED DNL TN CONCENTRATION



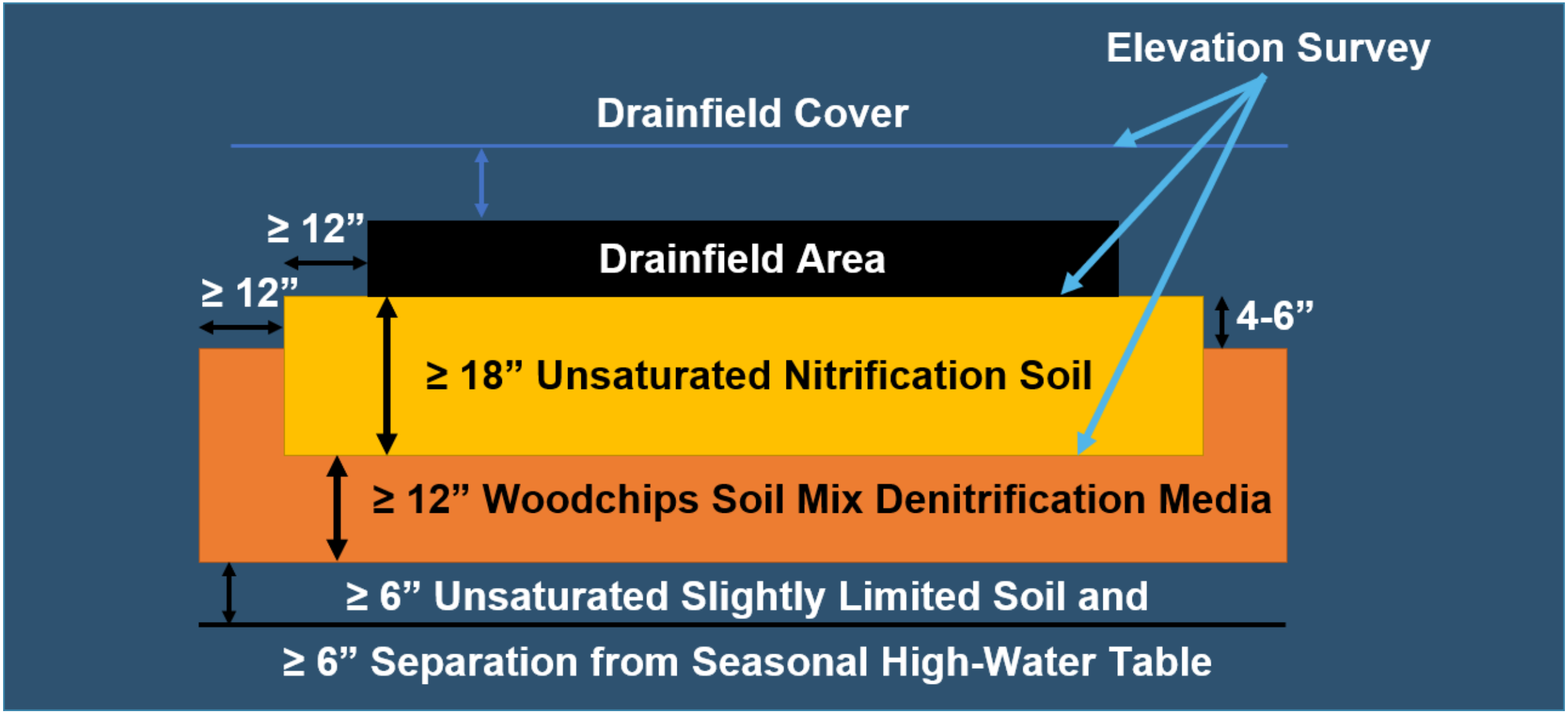
NITROGEN REDUCTION EFFICIENCY

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%**

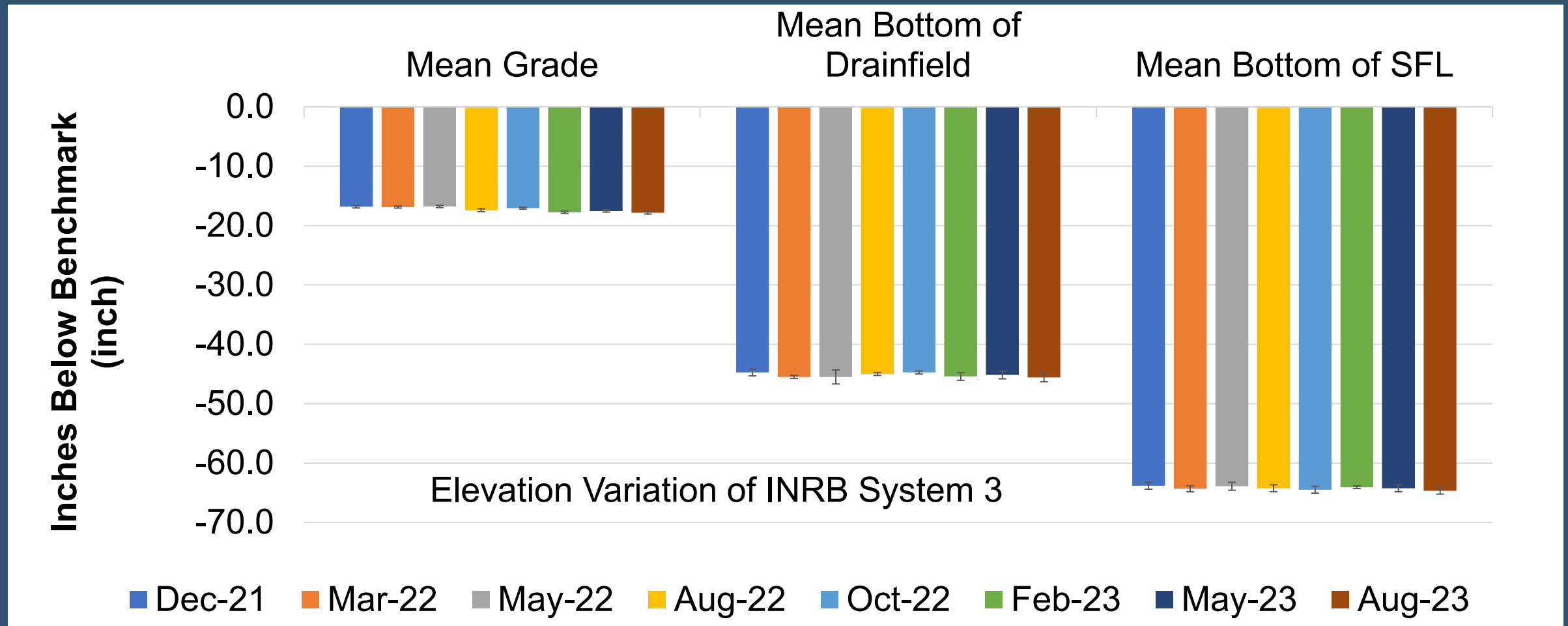
Note: Nitrogen-reduction calculated for each sampling event at each sampling site first, then averaged over events. Overall reduction was then calculated by averaging all locations.

ELEVATION CHANGE OF SYSTEM LAYERS



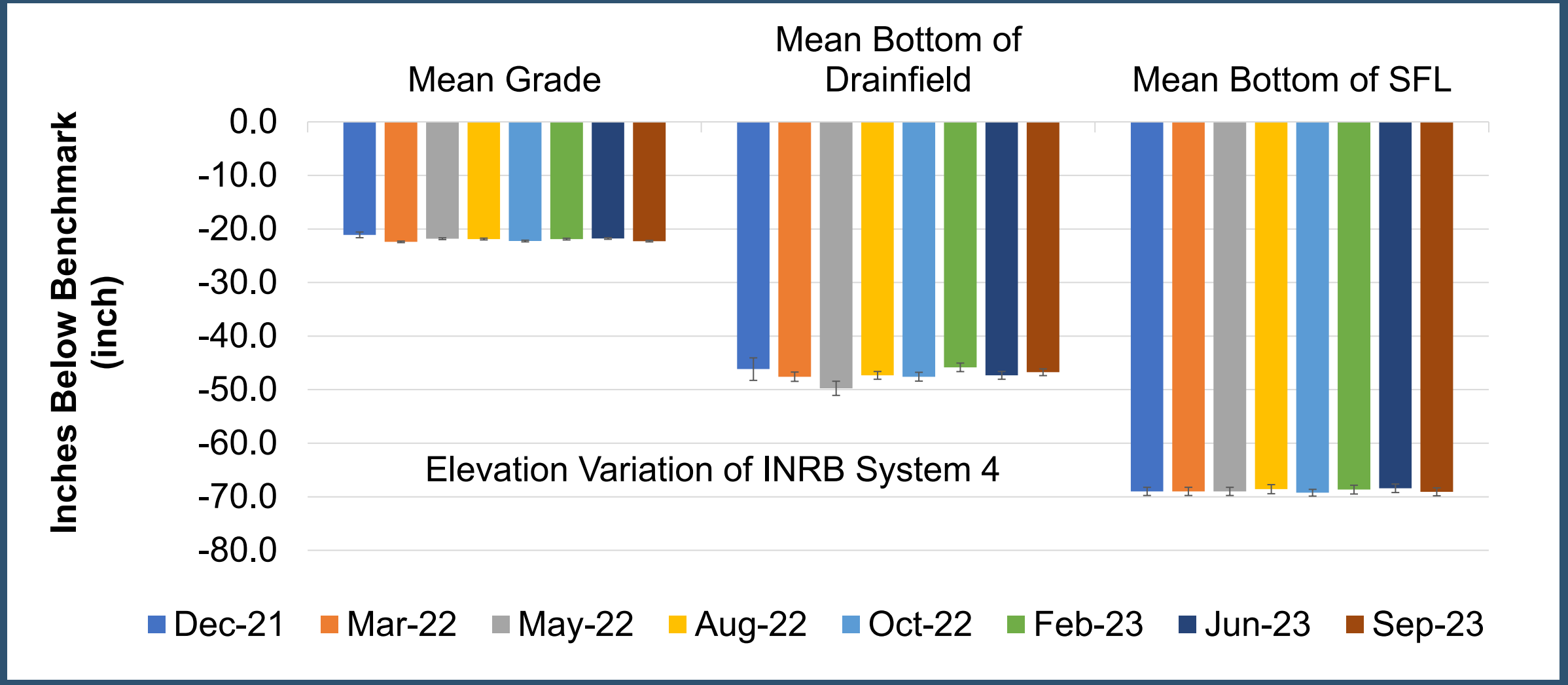
ELEVATION CHANGE OF SYSTEM LAYERS S3

SYSTEM 3



ELEVATION CHANGE OF SYSTEM LAYERS (3)

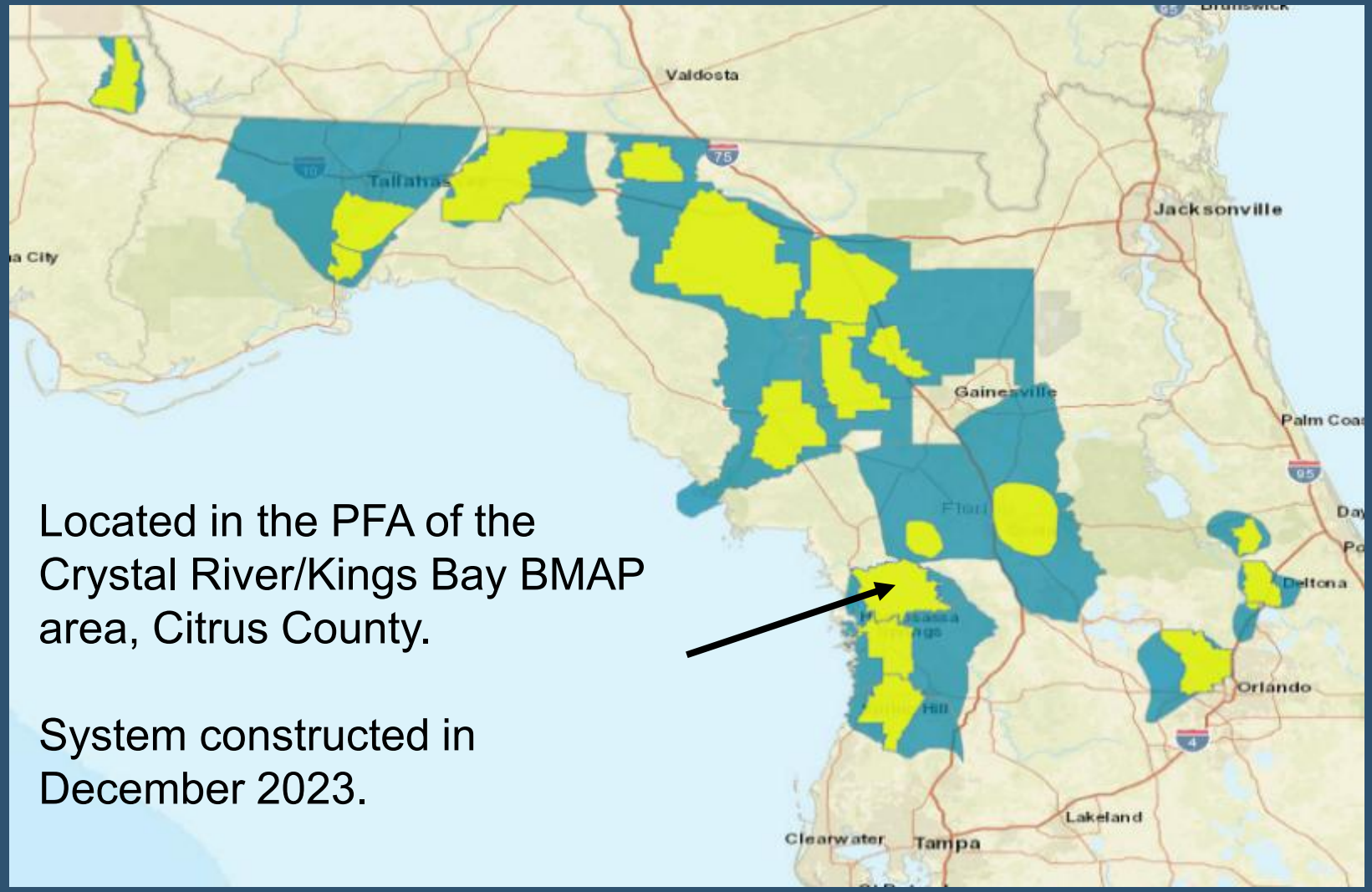
SYSTEM 4



CITRUS COUNTY INRB MONITORED BY OSP

Monitoring Nitrogen Removal by Florida INRBs

PROJECT LOCATION (1)



Located in the PFA of the Crystal River/Kings Bay BMAP area, Citrus County.

System constructed in December 2023.

BMAP Area

PFA

INRB IN CITRUS COUNTY MONITORED BY OSP

- Construction was a repair funded by the DEP Septic Upgrade Incentive Fund.
- The estimated sewage flow for the system is 400 gpd with a drainfield size of 500 square feet (slightly limited soil in trench configuration).
- The INRB and monitoring equipment were installed by Ace Septic and Waste.
- The types, arrangement and number of monitoring equipment installed in this system and the chemical parameters, field parameters and locations of elevation measurements taken are the same as for the two Leon County systems.
- The first sampling event was conducted in January 2024. The second sampling event is schedule for May 2024.
- OSP is working with the University of South Florida to sample the system.

CITRUS COUNTY INRB SYSTEM

Bottom of Denitrification Media

Top of Denitrification Media

CITRUS COUNTY INRB SYSTEM (2)

Adding Nitrification Media

Top of Nitrification Media

CITRUS COUNTY INRB SYSTEM (3)

Adding Native Soil Fill

Finished System

CITRUS COUNTY INRB SYSTEM (4)

Meter Box

Observation Ports and Suction Lysimeter

NITROGEN REDUCTION EFFICIENCY - CITRUS

CITRUS COUNTY INRB FIRST SAMPLING EVENT

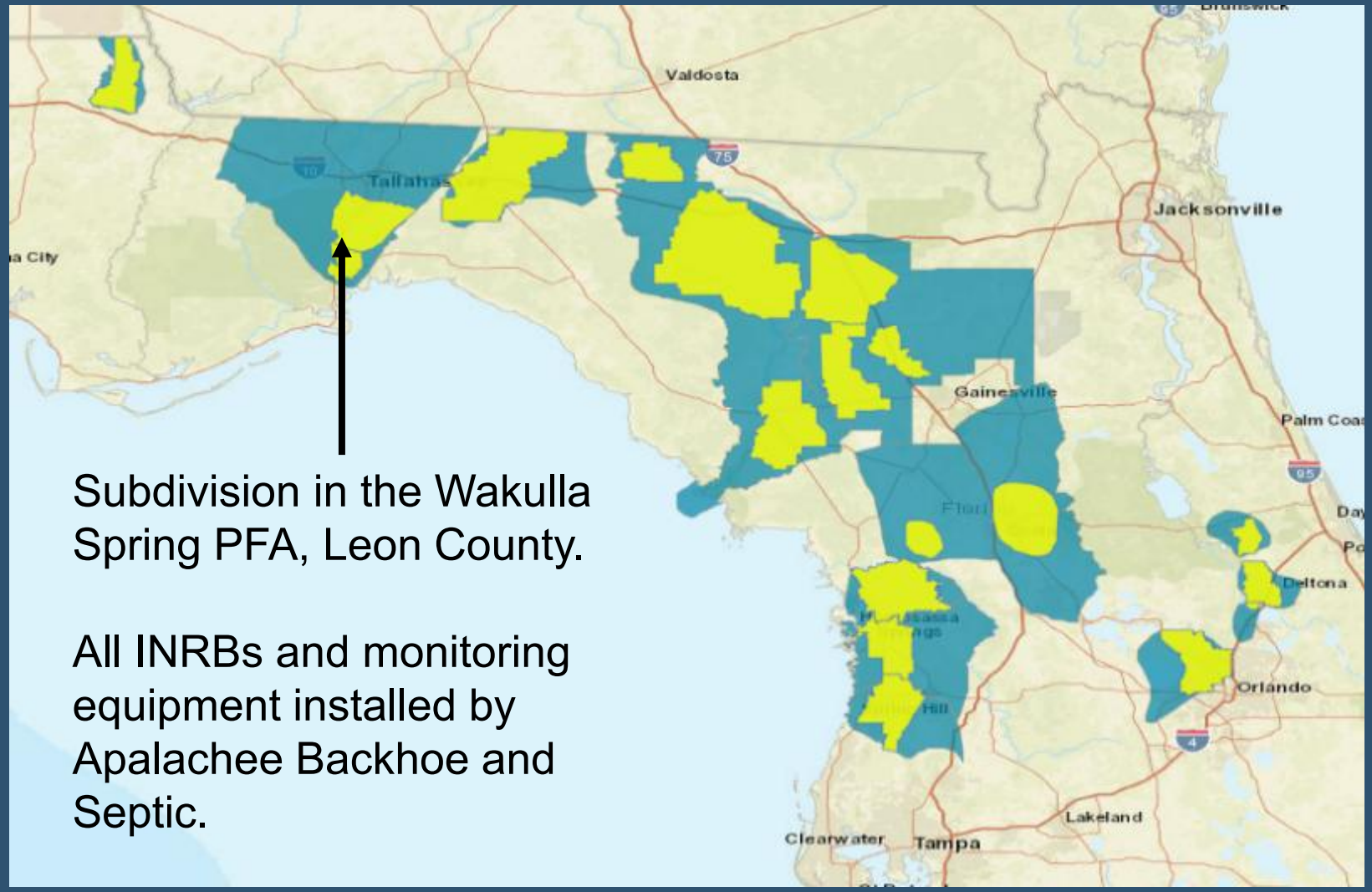
Parameter	STE	Left-Prox	Right-Prox	Center-Mid	Right-Mid	Left-Dist	Center-Dist
TN (mg/L)	190	48	8	3	2	4	3
TKN (mg/L)	190	48	7	3	2	4	3
NH4 (mg/L)	160	46	0	0	1	0	0
NOx (mg/L)	0	0	1	0	0	0	0
Chloride (mg/L)	100	75	180	47	31	18	47
Dilution Adjusted TN (mg/L)	190	64	4	6	6	22	6
Percent Reduction		**66%**	**98%**	**97%**	**97%**	**88%**	**97%**

Overall mean nitrogen percent reduction is 90% with a standard error of 5%.

LEON COUNTY INRBS MONITORED WITH DEAR

Monitoring Nitrogen Removal by Florida INRBs

PROJECT LOCATION



Subdivision in the Wakulla Spring PFA, Leon County.

All INRBs and monitoring equipment installed by Apalachee Backhoe and Septic.

BMAP Area

PFA

INRB SYSTEM MONITORING WITH DEAR

- Inspect the systems to ensure proper function.
- Conduct elevation survey to evaluate change of depth of media layers.
- Collect samples.
  - TKN.
  - NH4-N.
  - NOx-N.
  - TOC.
  - TP.
  - Chloride.

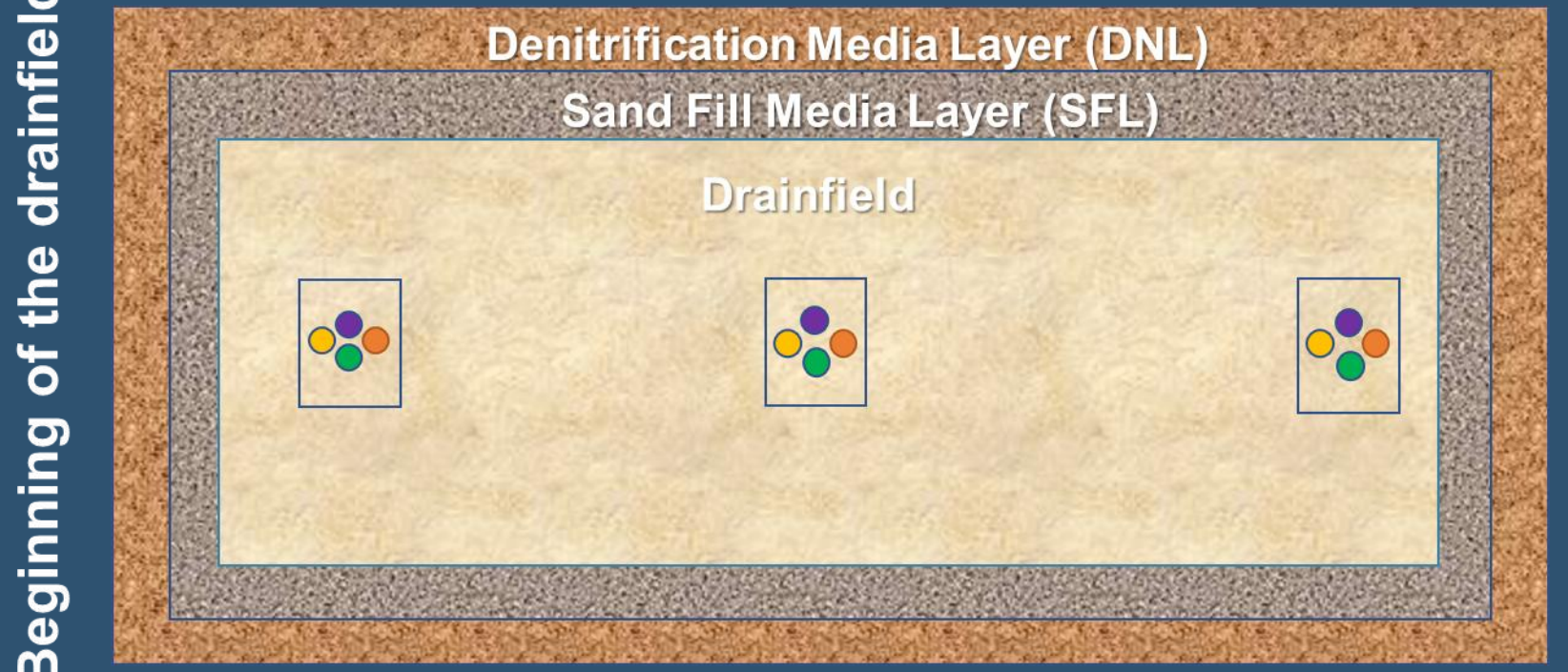
INRB SYSTEM MONITORING FIELD (2)

- Collect field measurements.
  - Water temperature.
  - Dissolved oxygen.
  - Specific conductivity.
  - pH.
  - ORP.

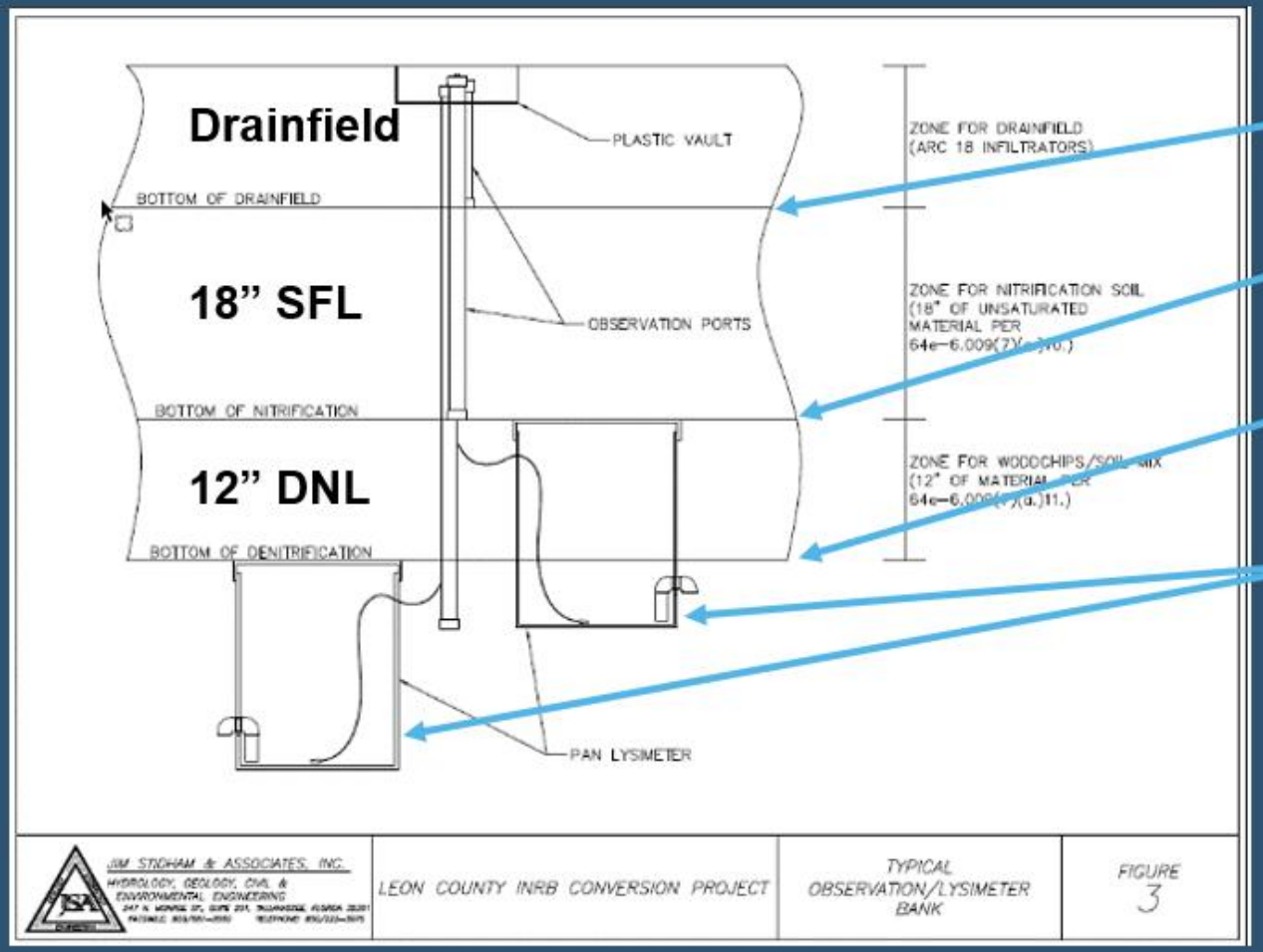
PROPERTY CHARACTERISTICS (DEAR)

System	# of Bedrooms	Drainfield Size (square feet [ft^2])	Soil Type	# of Occupants
DEAR-S1	4	500	Fine Sand	4
DEAR-S2	3	444	Fine Sand	2-3
DEAR-S3	3	580	Fine Sand	2
DEAR-S4	3	384	Fine Sand	1

MONITORING EQUIPMENT ARRANGEMENTS



MONITORING EQUIPMENT PROFILE



Bottom of Drainfield

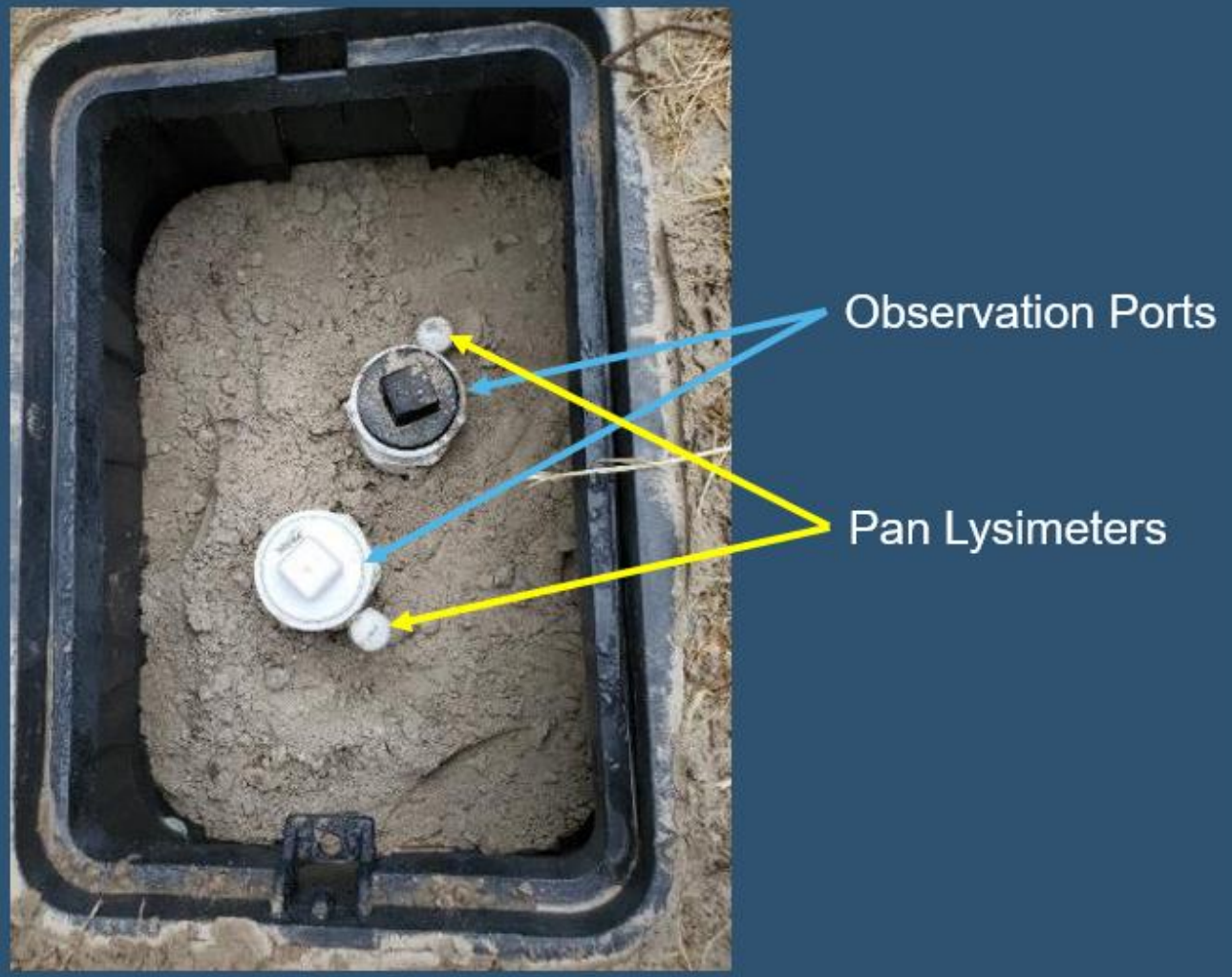
Bottom of SFL

Bottom of DNL

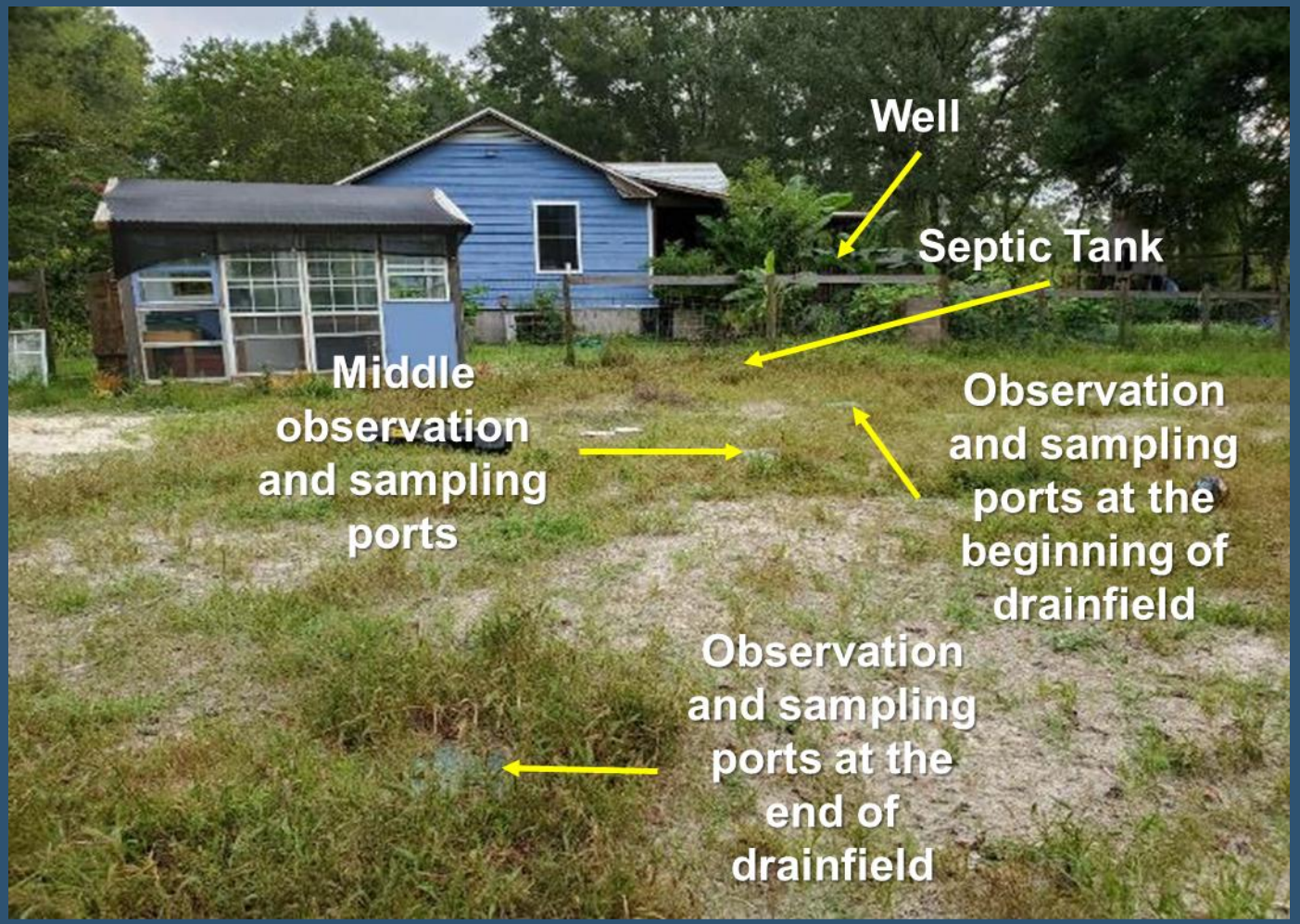
Pan Lysimeters

DEAR PAN LYSIMETERS COMPONENTS

DEAR PAN LYSIMETERS INSTALLATION

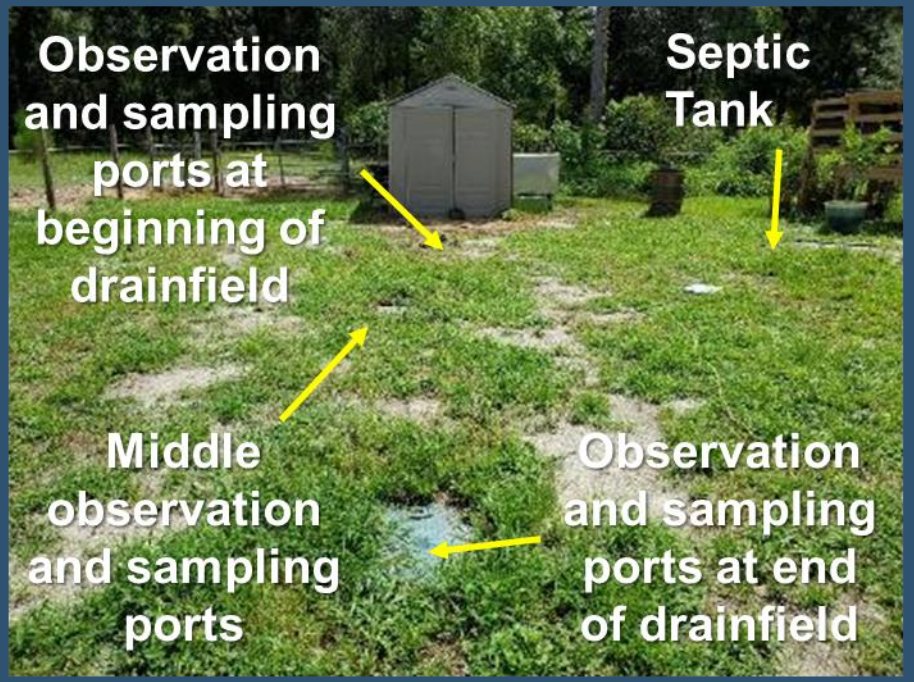


SYSTEM DEAR – S1

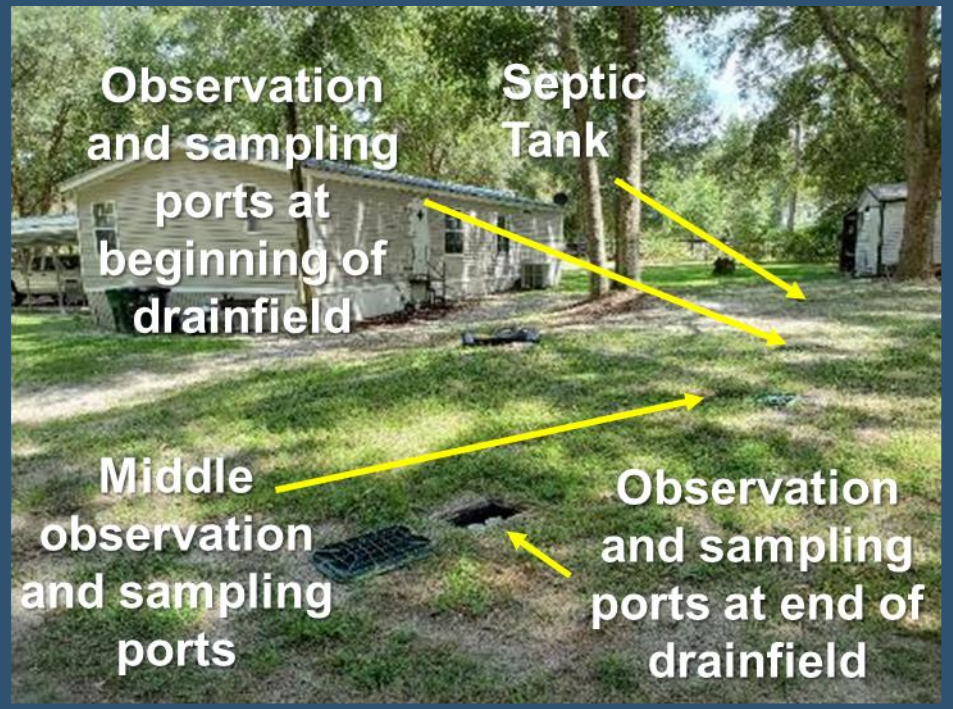


- House occupied by a couple and two children.
- Has a vegetable garden.
- No lawn irrigation.

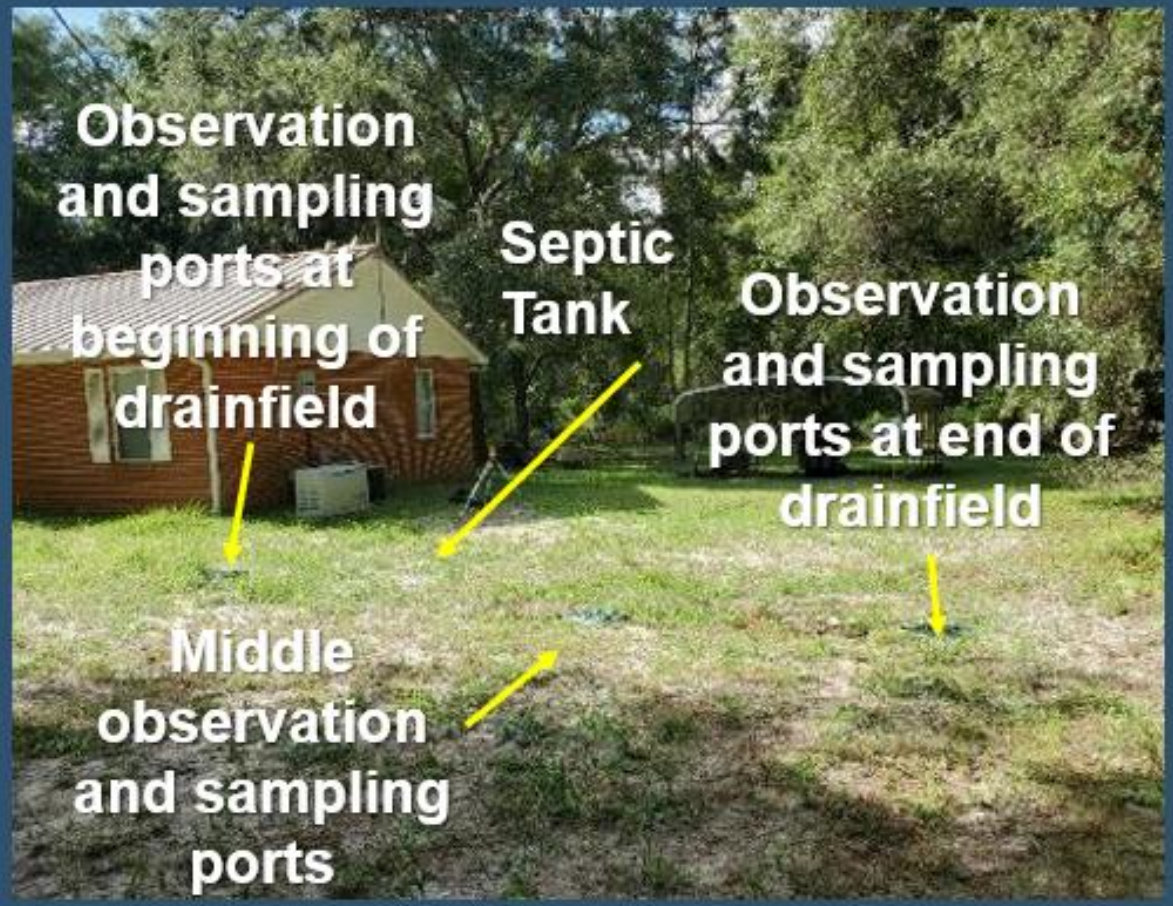
SYSTEM DEAR – S2



SYSTEM DEAR – S3



SYSTEM DEAR – S4



RETRIEVABLE SAMPLE VOLUME (2023): ML

INRBs	Drainfield	# of	Location of Pan	5/	15/	2023	5/	16/	2023	5/	19/	2023
Title	Size (SF)	Occupants	Lysimeter	Prox	Mid	Dist	Prox	Mid	Dist	Prox	Mid	Dist
DEAR-S1	500	4	SFL	250	1000	0	0	0	0	250	750	0
DEAR-S1	500	4	DNL	2000	0	0	1000	1500	0	0	0	0
DEAR-S2	444	2-3	SFL	0	0	0	0	0	0	0	1850	1750
DEAR-S2	444	2-3	DNL	1000	0	1000	5	1000	0	1	10	50
DEAR-S3	580	2	SFL	0	0	1500	0	0	0	0	0	0
DEAR-S3	580	2	DNL	20	2000	0	0	10	0	20	0	0
DEAR-S4	384	1	SFL	0	0	0	---	---	---	---	---	---
DEAR-S4	384	1	DNL	0	0	0	---	---	---	---	---	---

NITROGEN CONCENTRATION FOR DEAR – (1)

CHLORIDE UNADJUSTED

Sampling Sites	STE	STE	STE	DNL-Prox	DNL-Prox	DNL-Prox	DNL-Mid	DNL-Mid	DNL-Mid
Date	5/15	5/16	5/19	5/15	5/16	5/19	5/15	5/16	5/19
TN (mg/L)	95	120	85	29	10	---	---	43	---
TKN (mg/L)	95	120	85	2	1	---	---	2	---
NH4 (mg/L)	66	61	66	0	0	---	---	0	---
NOx (mg/L)	0	0	0	27	8	---	---	41	---
Chloride (mg/L)	45	46	45	63	56	---	---	58	---

NITROGEN CONCENTRATION FOR DEAR – (2)

CHLORIDE ADJUSTED

Sampling Sites	STE	STE	STE	DNL-Prox	DNL-Prox	DNL-Prox	DNL-Mid	DNL-Mid	DNL-Mid
Date	5/15	5/16	5/19	5/15	5/16	5/19	5/15	5/16	5/19
TN (mg/L)	95	120	85	21	8	---	---	34	---
TKN (mg/L)	95	120	85	1	1	---	---	2	---
NH4 (mg/L)	66	61	66	0	0	---	---	0	---
NOx (mg/L)	0	0	0	19	7	---	---	33	---

Sampling Site	DNL-Prox	DNL-Prox	DNL-Prox	DNL-Mid	DNL-Mid	DNL-Mid	Average Percent TN Reduction
Date	5/15	5/16	5/19	5/15	5/16	5/19	
Percent TN Reduction	78%	93%	---	---	72%	---	**81%**

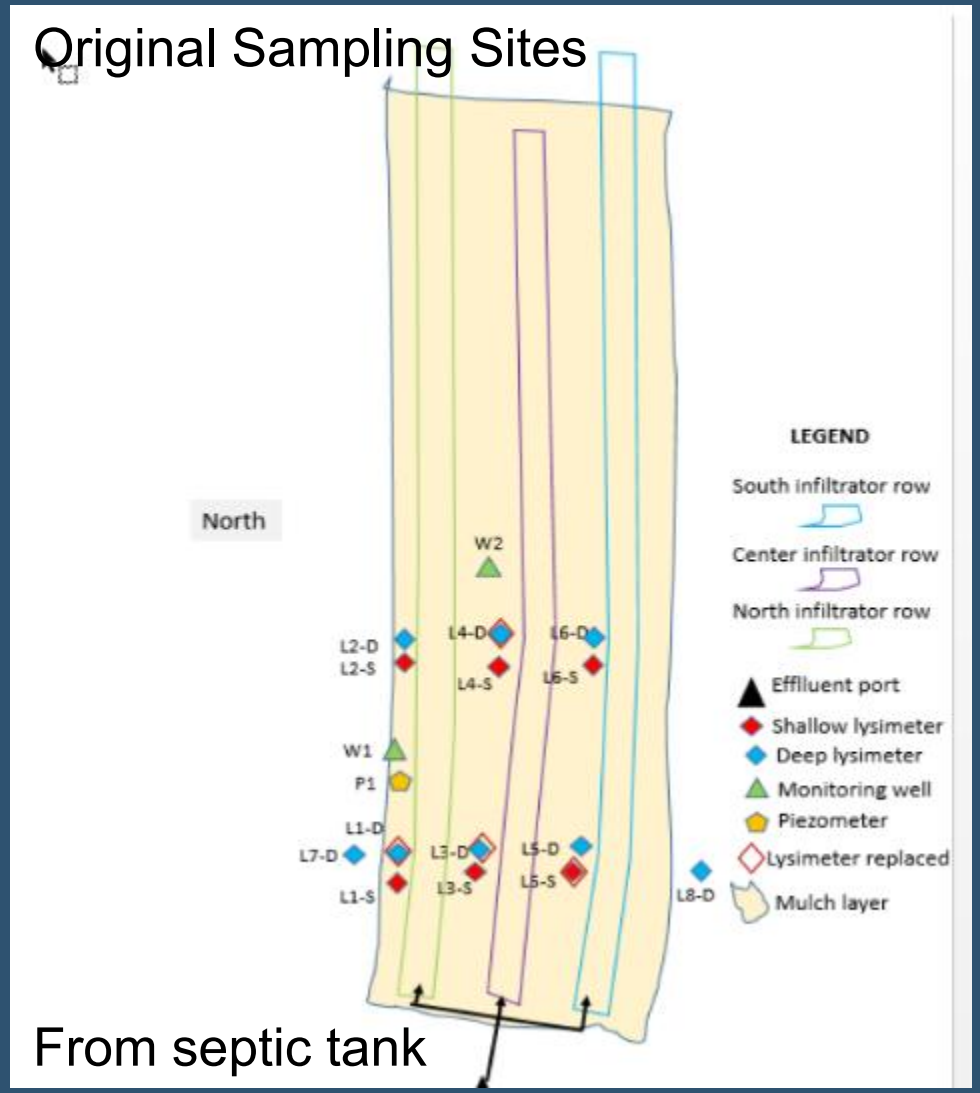
ICHETUCKNEE INRB CONTINUED MONITORING

Monitoring Nitrogen Removal by Florida INRBs

ICHETUCKNEE INRB SYSTEM INSTALLED IN 2014

- The experimental prototype INRB system was originally installed in Ichetucknee Springs State Park in 2014. Denitrification layer consists of wood only.
- The estimated flow from the property is 300 gpd (3 bedrooms). Drainfield size is 375 sqft. Drainfield sizing soil texture is fine sand.

ICHETUCKNEE INRB ORIGINAL MONITORING



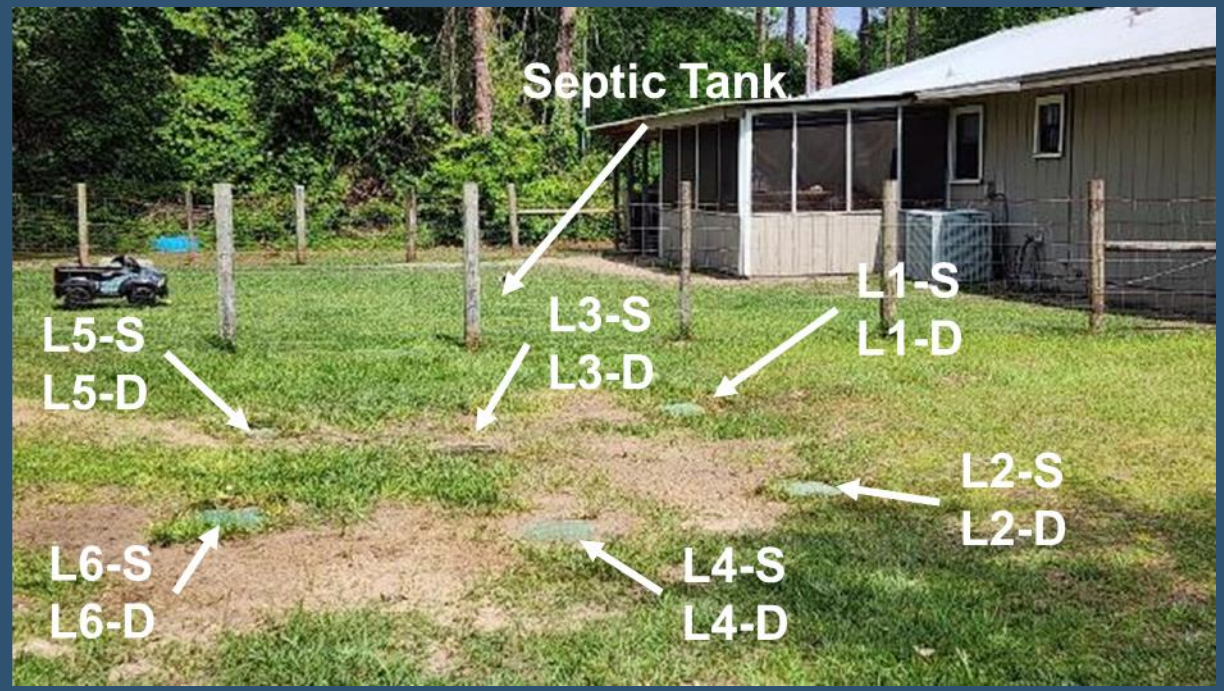
- Suction lysimeters, piezometers and monitoring wells were included in the original monitoring network.
- Lysimeters were installed at both the bottom of sand fill layer (L1-S to L6-S) and the bottom of denitrification layer (L1-D to L6-D).
- The system was monitored until 2019 when lysimeters stopped functioning.
- Percent nitrogen-reduction previously determined was about 65%.

ICHETUCKNEE INRB CONTINUED MONITORING (2)

All suction lysimeters were replaced during May and July 2023.

Continued monitoring on the system resumed in August 2023.

Second sampling conducted in November 2023.



NITROGEN CONCENTRATION (ML) (1)

ICHETUCKNEE INRB – 8/3/2023

Sampling Sites	STE	L1-D	L2-D	L3-D	L4-D	L5-D	L6-D
TN	58	8	1	36	10	34	---
TKN	58	2	1	1	2	1	---
NH4	57	0	0	0	0	0	---
NOx	0	7	1	35	8	33	---
Chloride	31	7	6	33	24	34	---
TN – Dilution Adjusted	58	35	5	34	13	31	---
Percent TN Reduction		36%	90%	42%	78%	47%	

Average TN percent reduction is 59% with a standard error of 11%.

NITROGEN CONCENTRATION (ML) (2)

ICHETUCKNEE INRB – 11/31/2023

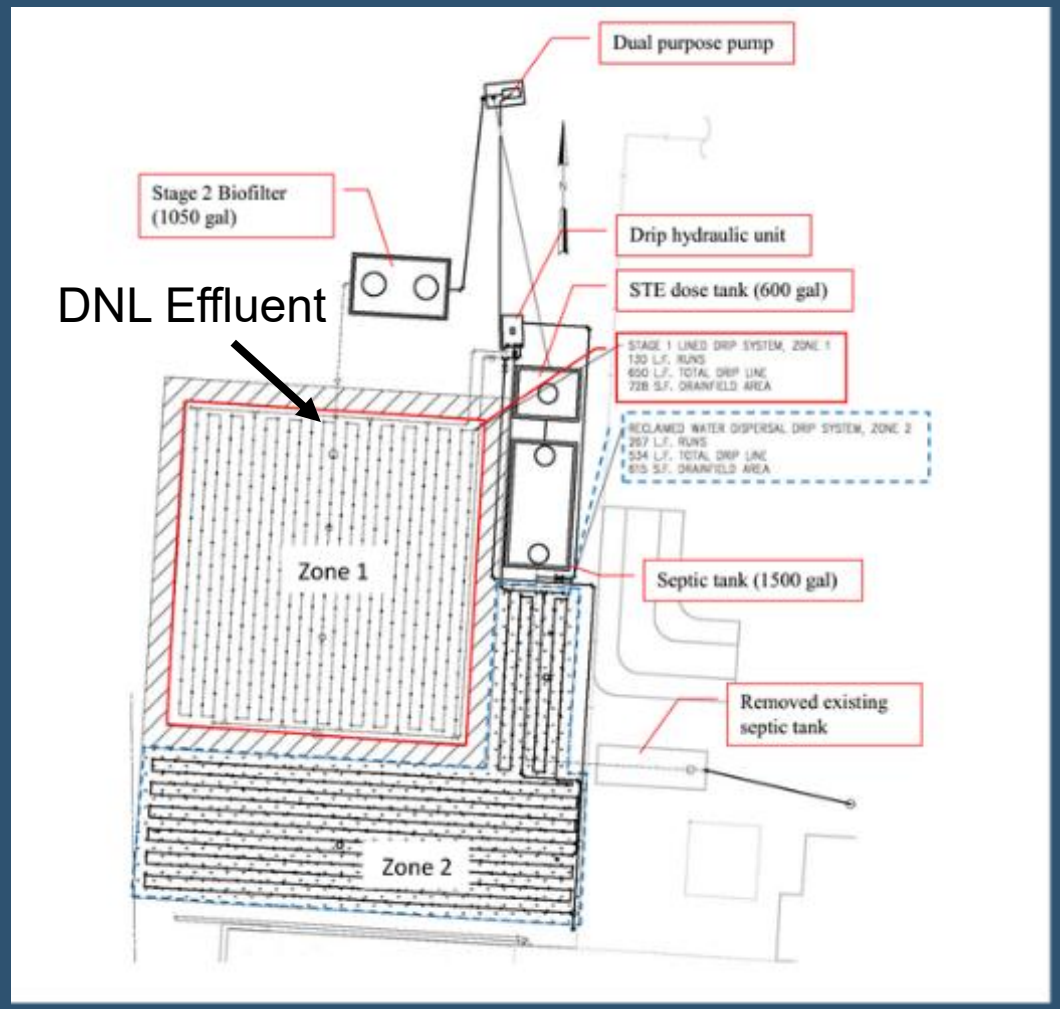
Sampling Sites	STE	L1-D	L2-D	L3-D	L4-D	L5-D	L6-D
TN	57	4	2	24	2	27	25
TKN	57	1	1	1	1	0	0
NH4	48	0	0	0	0	0	0
NOx	0	2	1	23	2	27	25
Chloride	34	22	14	29	28	28	31
TN – Dilution Adjusted	57	6	5	28	2	33	27
Percent TN Reduction		91%	93%	51%	95%	42%	39%

Average TN percent reduction is 68% with a standard error of 11%.

FOSNRS STUDY EXPERIMENTAL SYSTEM

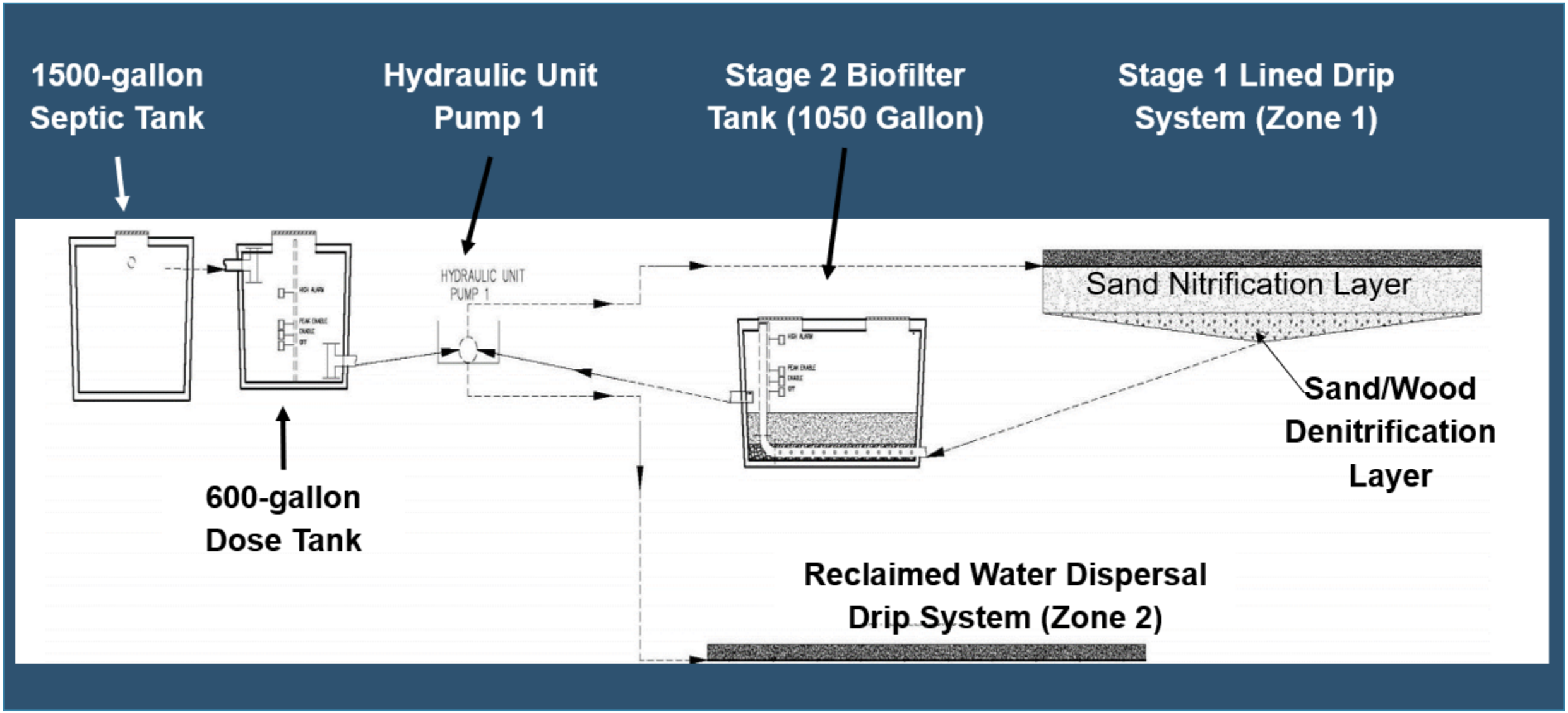
Monitoring Nitrogen Removal by Florida INRBs

INRB AS PART OF FOSNRS SYSTEM CONTINUED MONITORING – PLAN VIEW



- The experimental prototype system was installed in June 2013 during the FOSNRS study.
- The system included a lined INRB treatment drip irrigation drainfield (Zone1) with a sand nitrification layer over a sand/wood denitrification layer.
- Effluent from lined drainfield was further treated in a sulfur denitrification media tank and a dispersal drip irrigation drainfield.
- System was originally monitored by Hazen and Sawyer from September 2013 through December 2014.

INRB AS PART OF FOSNRS SYSTEM CONTINUED MONITORING – SECTION VIEW



INRB AS PART OF FOSNRS SYSTEM CONTINUED MONITORING

OSP resumed monitoring of this system in March 2017 and monitored the system eight times through December 2019.

TN CONCENTRATION OF EFFLUENT FROM SEPTIC TANK AND SAND/WOOD LAYER

Sampling Date	3/15/2017	11/9/2017	4/19/2018	11/13/2018	2/19/2019	5/14/2019	7/31/2019	12/3/2019
STE	54	66	68	57	32	53	60	74
Bottom of INRB	23	8	26	8	19	13	3	11
Percent TN Reduction	57%	88%	62%	86%	41%	75%	95%	85%

The overall average percent nitrogen-reduction is 74% with 7% standard error.

SUMMARY

1. Overall percent nitrogen-reducing efficiency ranged between 38% to 90%.
   - INRB S3: 81%.
   - INRB S4.
     - When measured flow far higher than the design flow was included: 38%.
     - When flow was up to approximately the design flow: 72%.
   - INRB Citrus County: 90% (one sampling event).
   - DEAR-S1: 81% (one sampling event).
   - Ichetucknee system continued monitoring: 58% and 68% (two sampling events).
   - FOSNRS lined system continued monitoring: 74%.

SUMMARY (2)

2. Hydraulic condition had impact on nitrogen treatment efficiency.
   - The low-flow INRB (S3) showed uneven distribution of wastewater.
     - Denitrification was limited in the area receiving the most wastewater.
     - Possibly a result of low pH (denitrification).
   - Very limited denitrification in the wood chip layer was observed from the high-flow INRB (S4).
     - Incomplete nitrification likely resulted from SFL ponding caused by high water use.
     - Higher nitrogen reducing efficiencies were observed when the water use decreased to close to the rule-based estimated sewage flow for property (300 gpd).
     - When no ponding was observed during periods of lower water use, more complete nitrification and higher nitrogen removal were observed.

SUMMARY (3)

3. Results suggest nitrogen reducing efficiency of at least 65% is achievable when hydraulic loading to the drainfield does not cause ponding of the SFL.
   - Ensuring household water use does not exceed the estimated flow from the property and using a pressurized distribution system may improve the nitrogen treatment efficiency.

4. To get accurate percent nitrogen results, measuring the water use and chloride concentration are important.

5. Two years after the INRB S3 and S4 systems were constructed, no obvious settling was observed for either the SFL or the DNL layers.
   - This suggests that the organic carbon in the DNL has not been substantially consumed or oxidized even when there is no impervious liner.

SUMMARY (4)

6. Sampling of more systems and longer sampling periods are needed to evaluate more thoroughly the performance of INRBs.

7. OSP is now making efforts to recruit more INRB owners to participate in INRB monitoring.

THANK YOU

Division of Water Resource Management
Onsite Sewage Program
Florida Department of Environmental Protection