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Passive Systems: History, function, promise, and optimization

Christopher J Gobler, Ph.D
SoMAS, Stony Brook University
NYS Center for Clean Water Technology

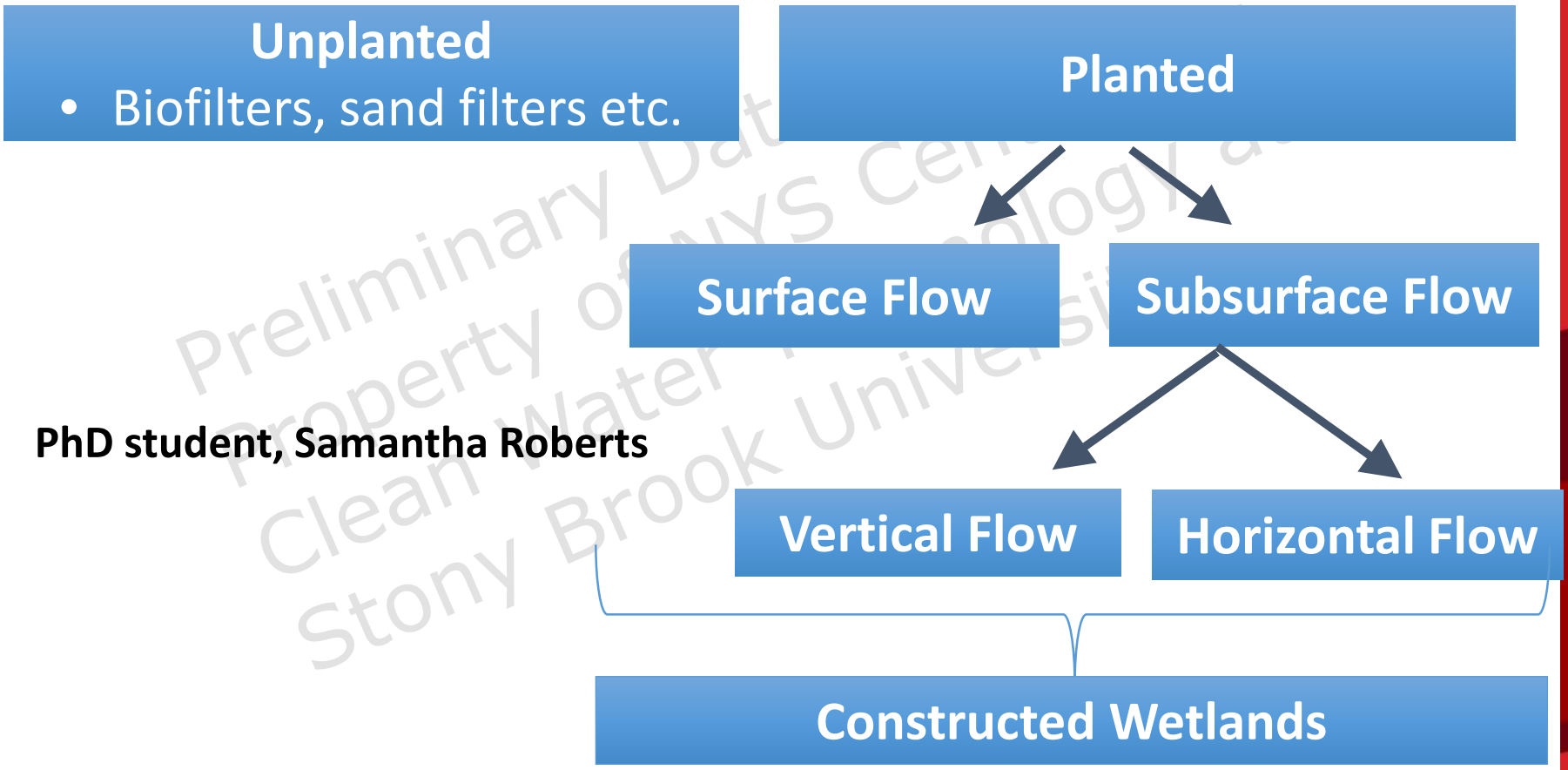
FAR BEYOND

What is a passive system?

- FL DoH: “a type of onsite wastewater treatment system that utilizes no mechanical components other than **one effluent pump** and uses a **reactive media for denitrification**”.
- Consistent, reliable, low-energy, and low-maintenance.
- CCWT is investigating three types of passive systems: Wetlands, permeable reactive barriers, and nitrogen removing Biofilters (NBRs).

Wetlands

- Designed to improve the quality of effluent

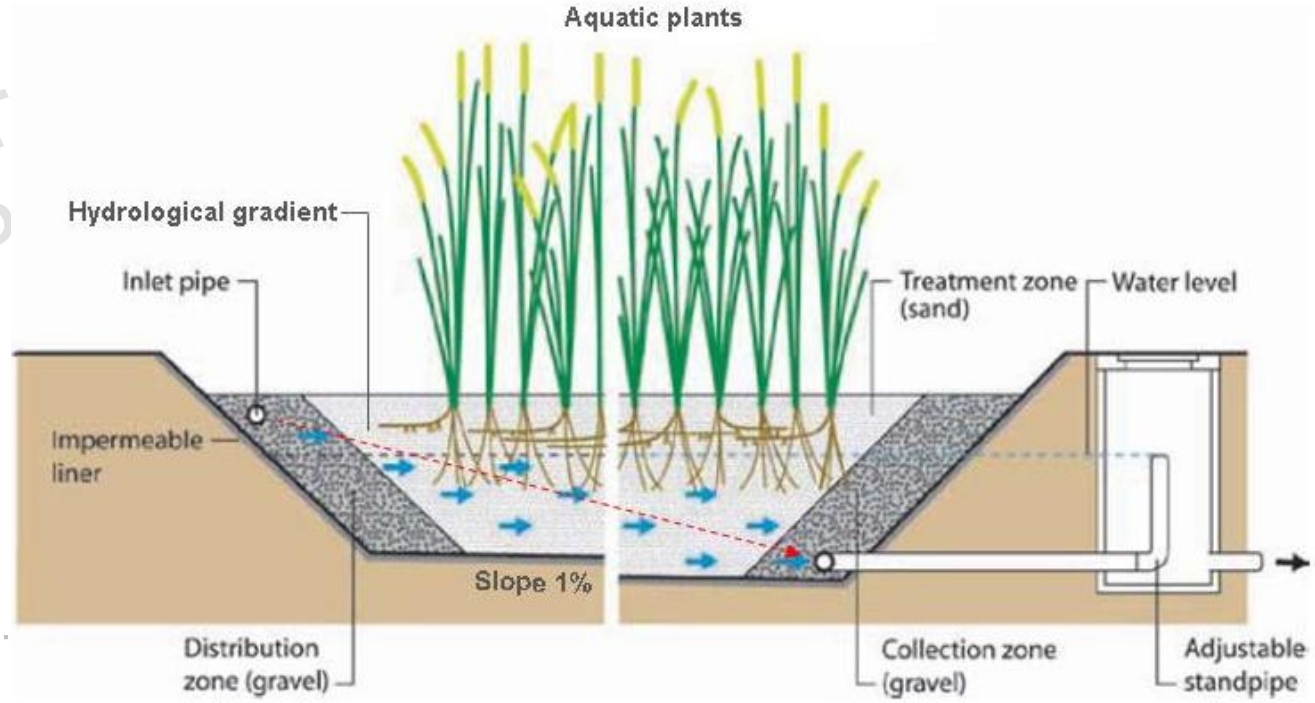


PhD student, Samantha Roberts

Constructed Wetlands

Subsurface Flow: Horizontal

- Gravel and sand-filled channel
- Wastewater flows **horizontally** across system
- Modest treatment, both microbial and vegetative

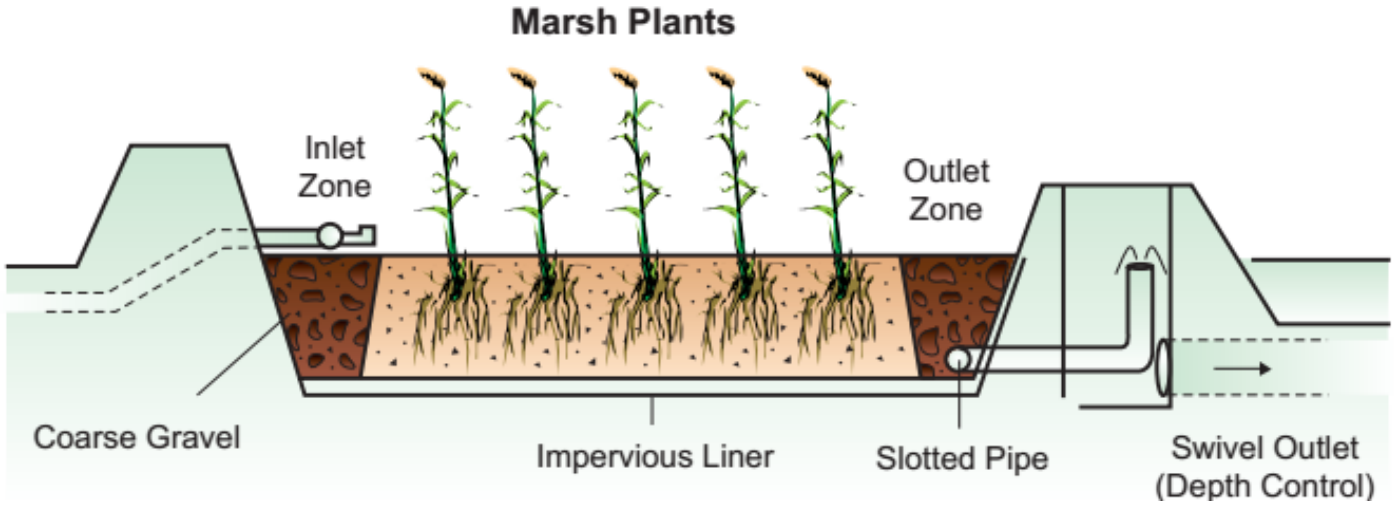


From Tilley et al (2008)

Constructed Wetland

Subsurface Flow: Vertical

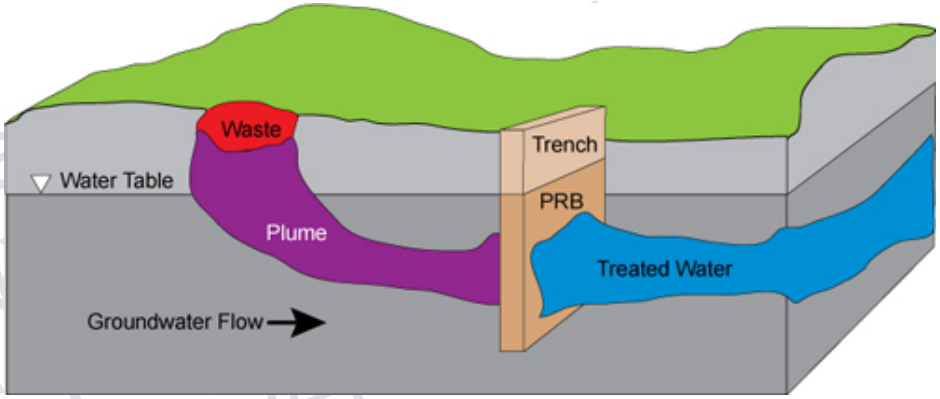
- Wastewater drains **vertically** through the filter layers towards a drainage system at the bottom.
- Enhanced microbial and vegetative treatment.
- Optimized via **recirculation** and additions of **denitrifying** tanks, layers (e.g. wood chips).



From Nivala et al (2013)

Permeable reactive barriers (PRB) to remove nitrogen and other contaminants

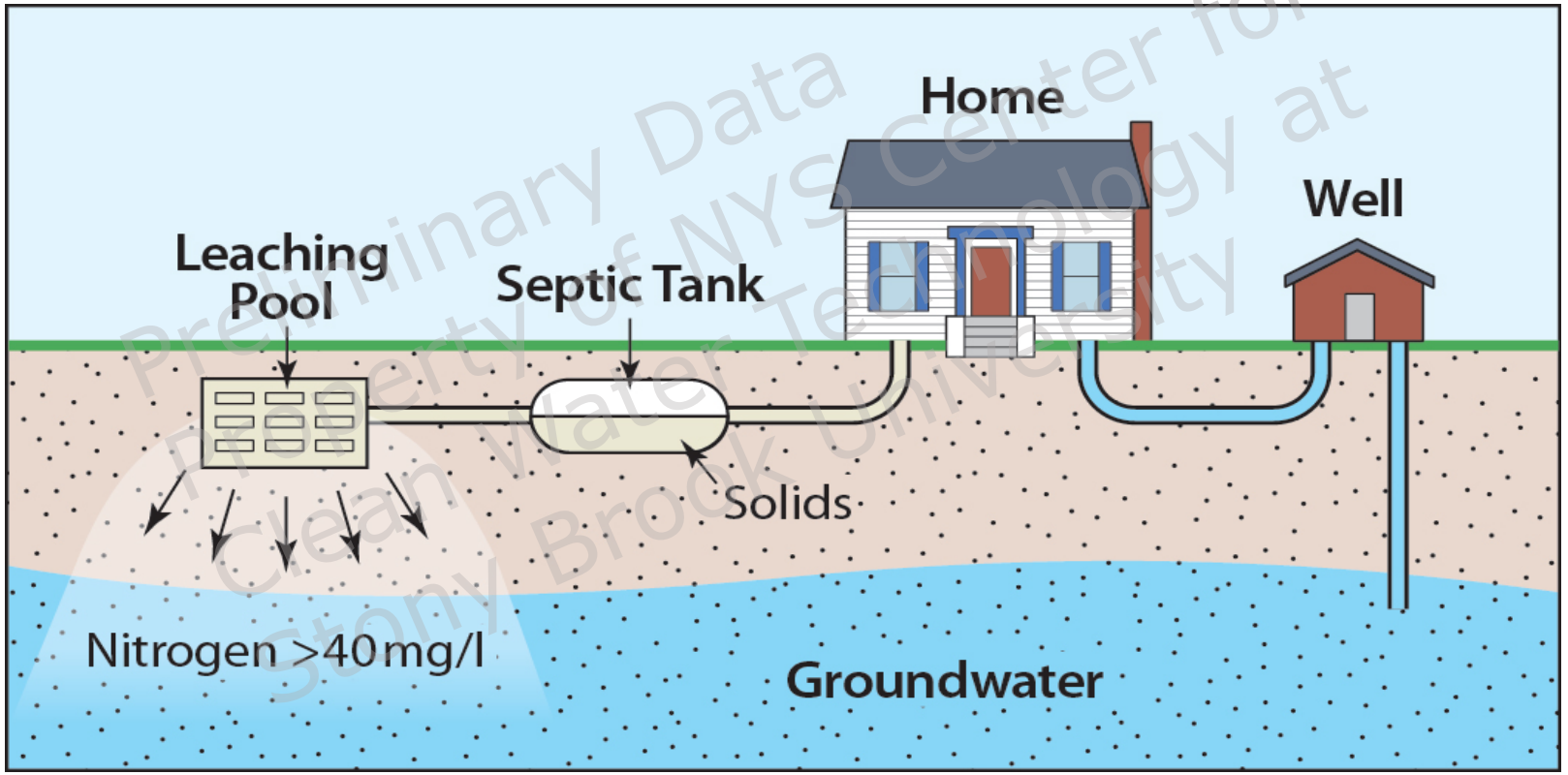
- PRBs contain a carbon source (wood, vegetable oil) in a permeable media to bring in groundwater and promote nitrogen removal via **denitrification** containing high nitrate before it enters surface waters.



- Most effective at the headwaters of streams and/or coves where groundwater discharge is concentrated.

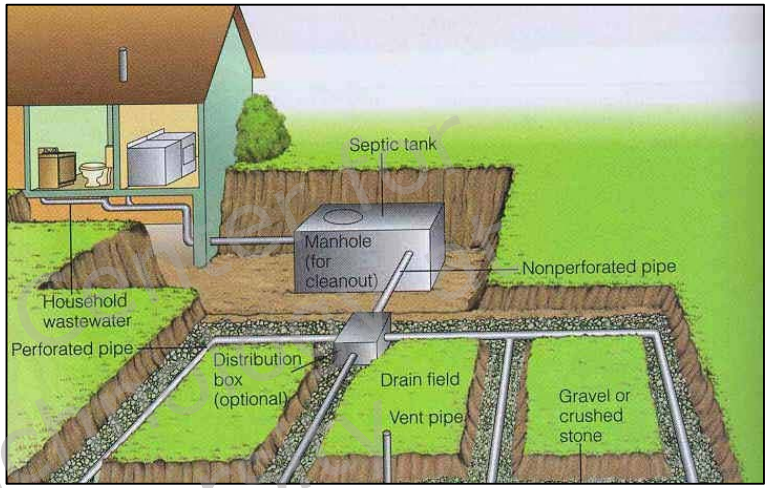
- CCWT is collaboratively studying PRB's in Southampton and East Hampton Towns; CCWT measurements will unlock the black box, expanding understanding.

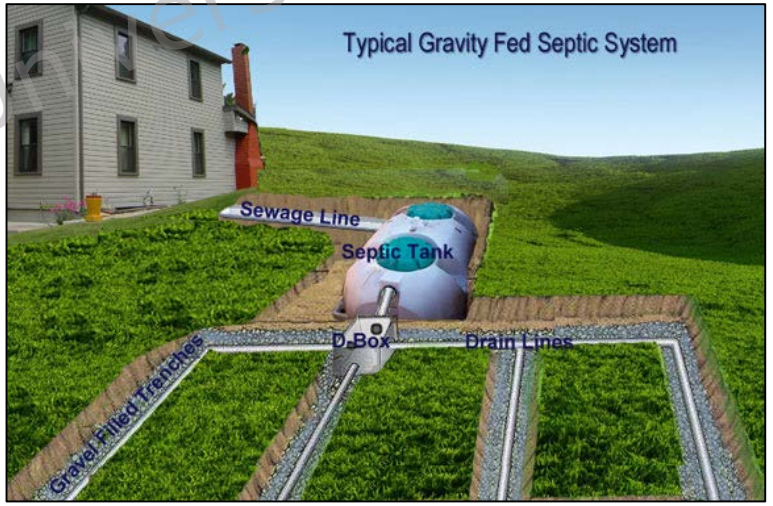
Passive systems to replace current onsite wastewater systems



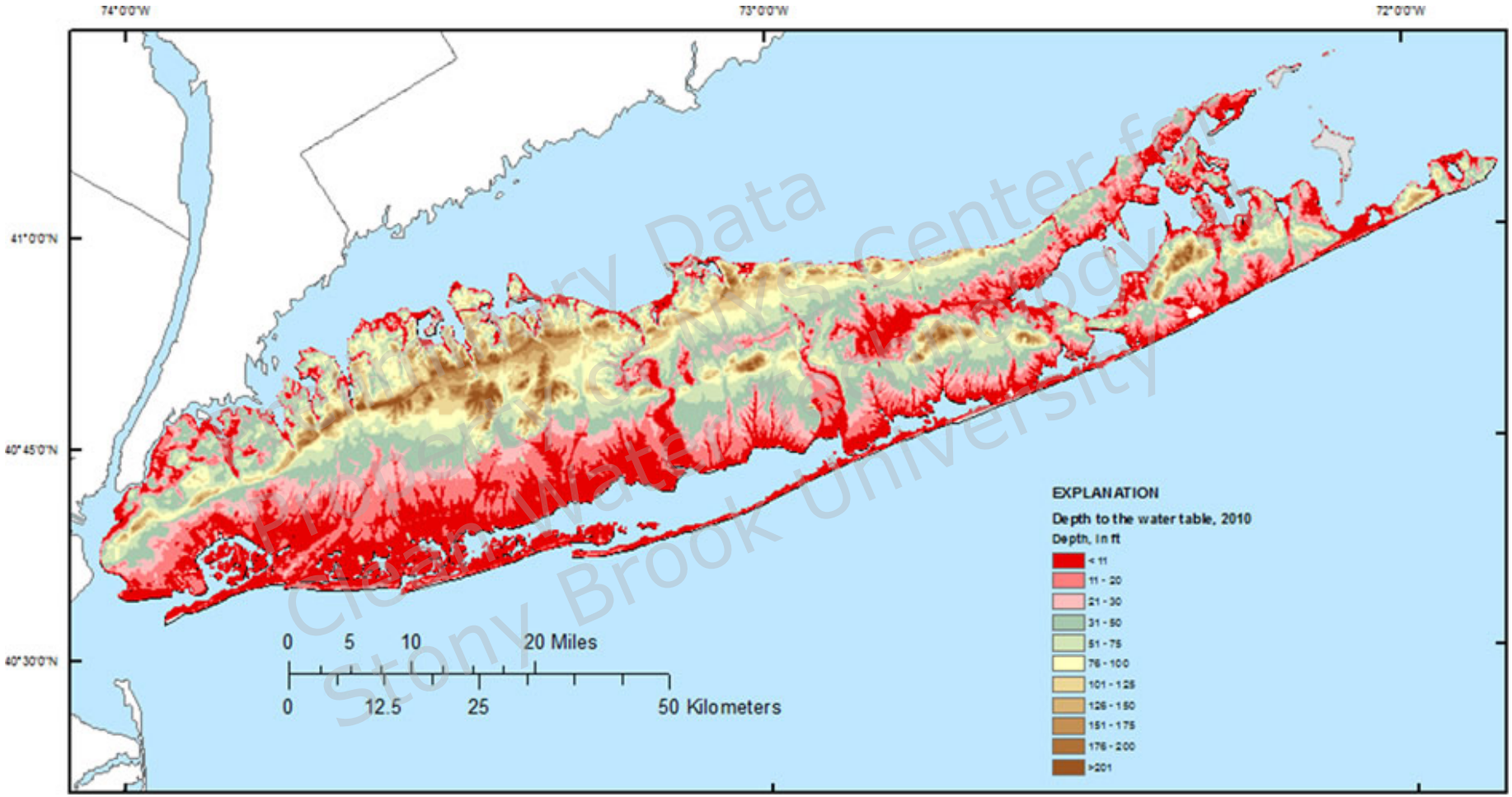
Standard drain field system

- Most common on-site wastewater disposal approach in US.
- Very rarely used on Long Island.
- More nitrogen removal than Long Island leach-pit systems due to proximity to surface.
- Shallow depth (< 2 ft) well-suited for coastal regions experiencing sea-level rise.



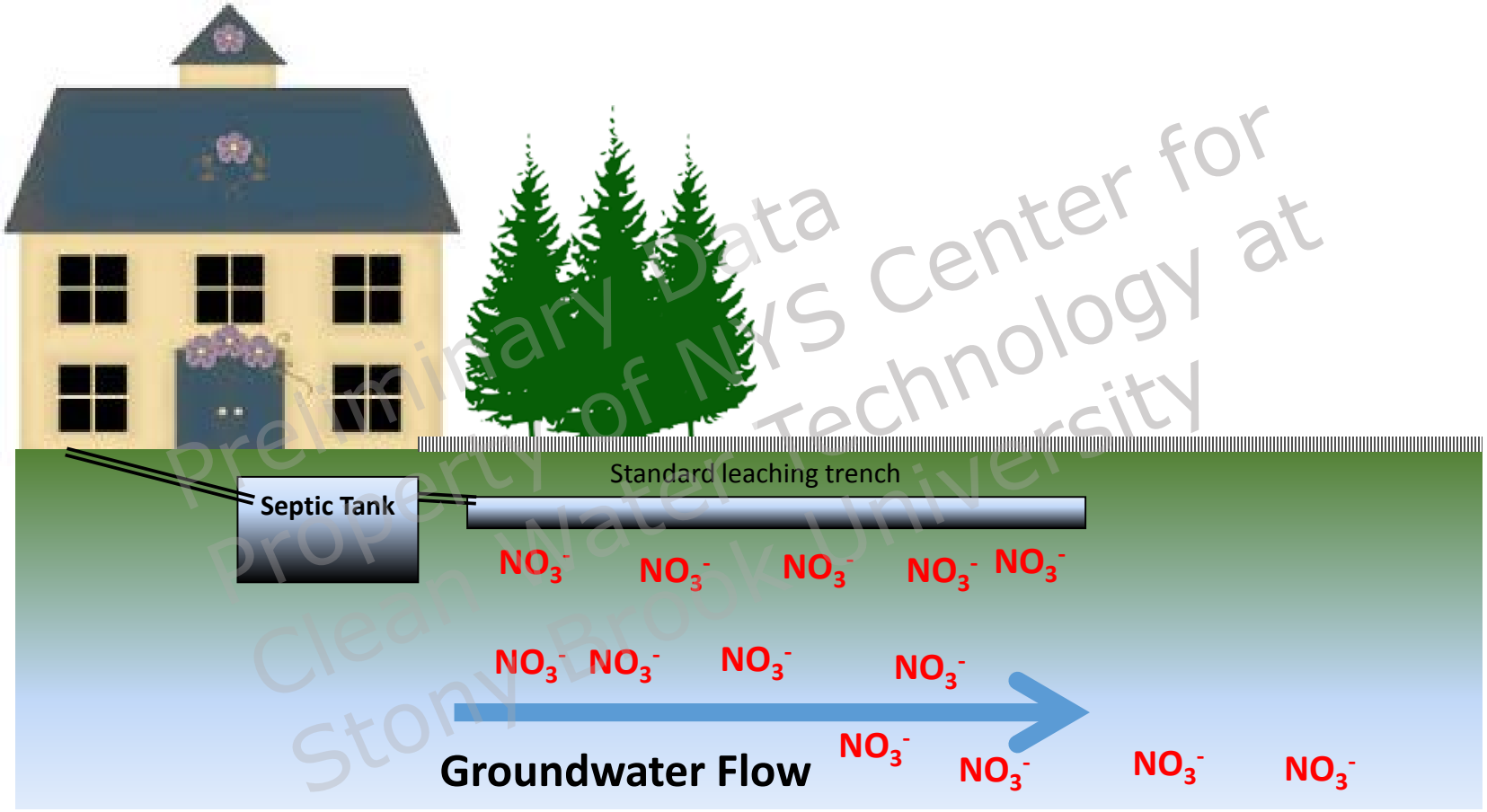


Depth to groundwater on Long Island



- **SoMAS estimates 7 ft of sea level rise this century.**

Standard drain fields still leach nitrogen



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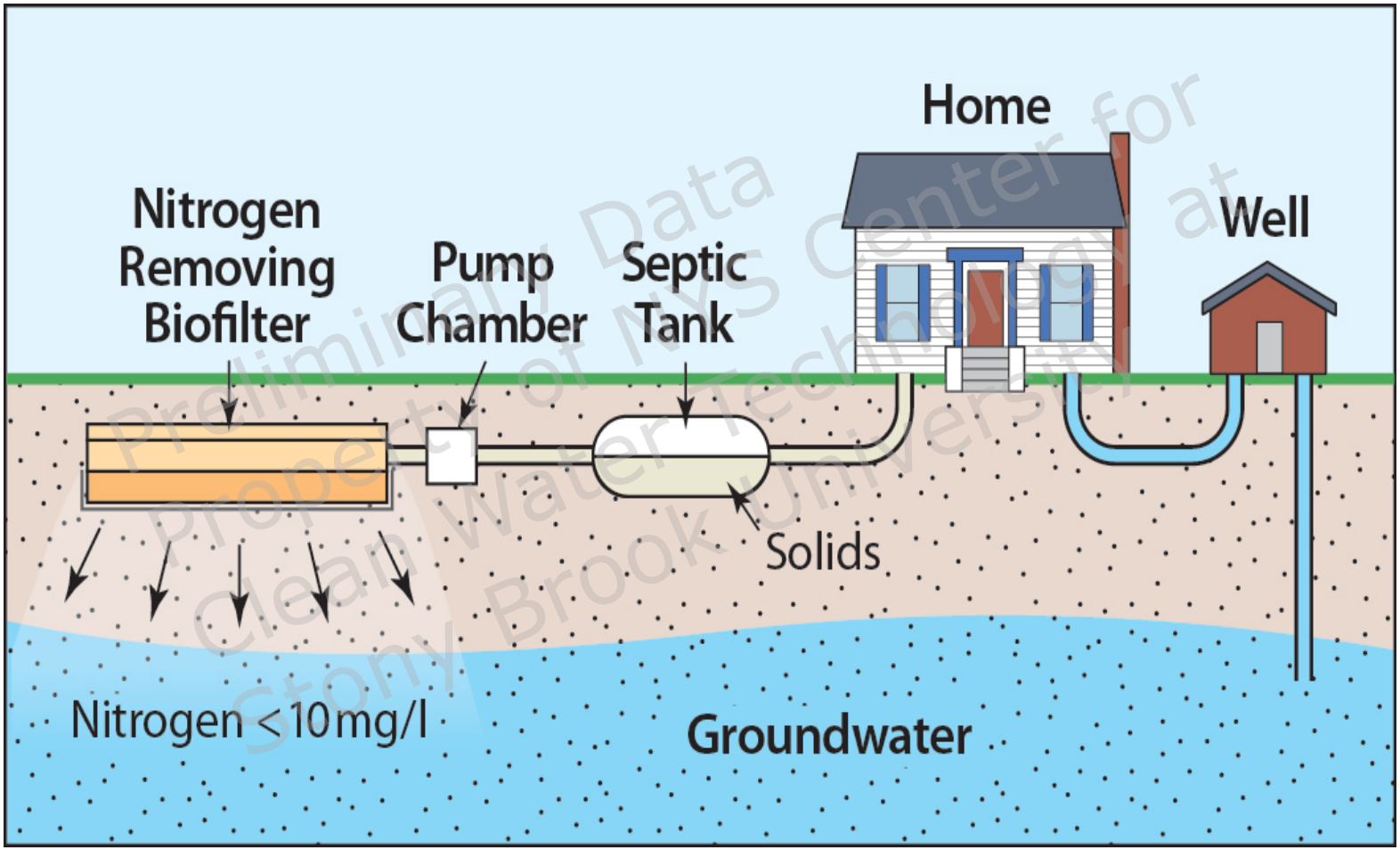
NITROGEN REMOVING BIOFILTERS FOR ONSITE WASTEWATER TREATMENT ON LONG ISLAND: CURRENT AND FUTURE PROSPECTS

JUNE 2016

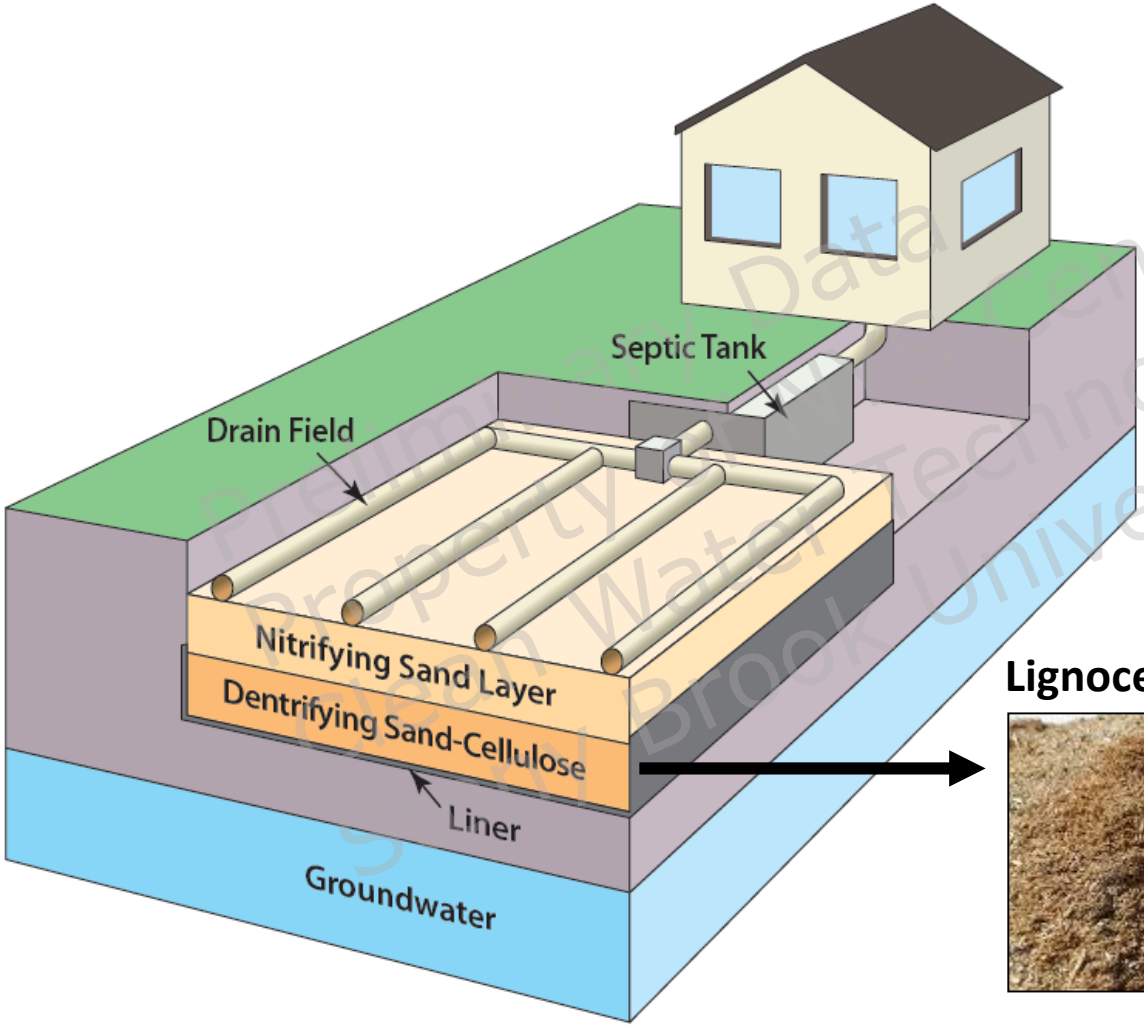
The New York State Center for Clean Water Technology

www.stonybrook.edu/cleanwater

Nitrogen Removing Biofilters (NRB)



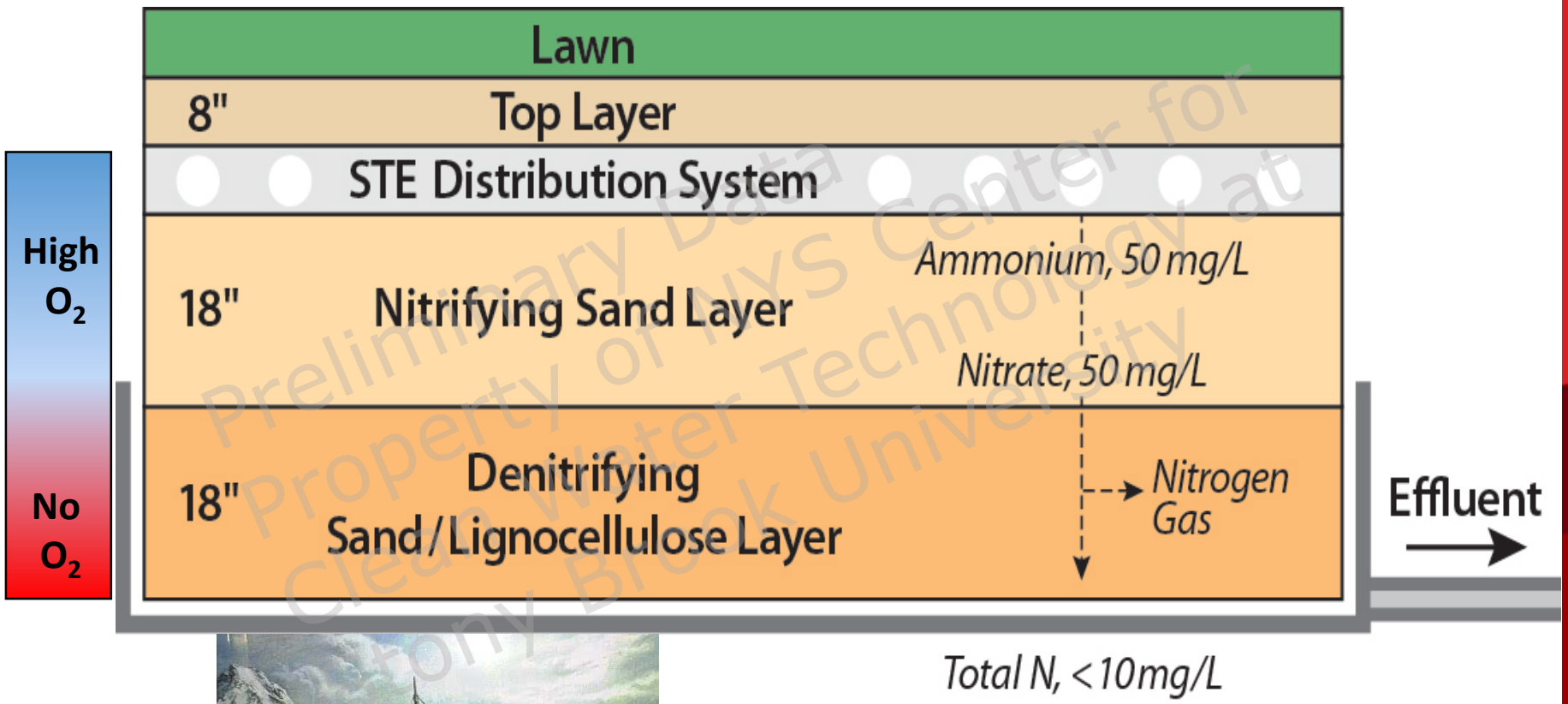
Nitrogen Removing Biofilters (NRB)



Lignocellulose = wood, chips, dust, etc

Carbon source to promote denitrification

Nitrogen Removing Biofilters (NRB)



Viking ship analogy!

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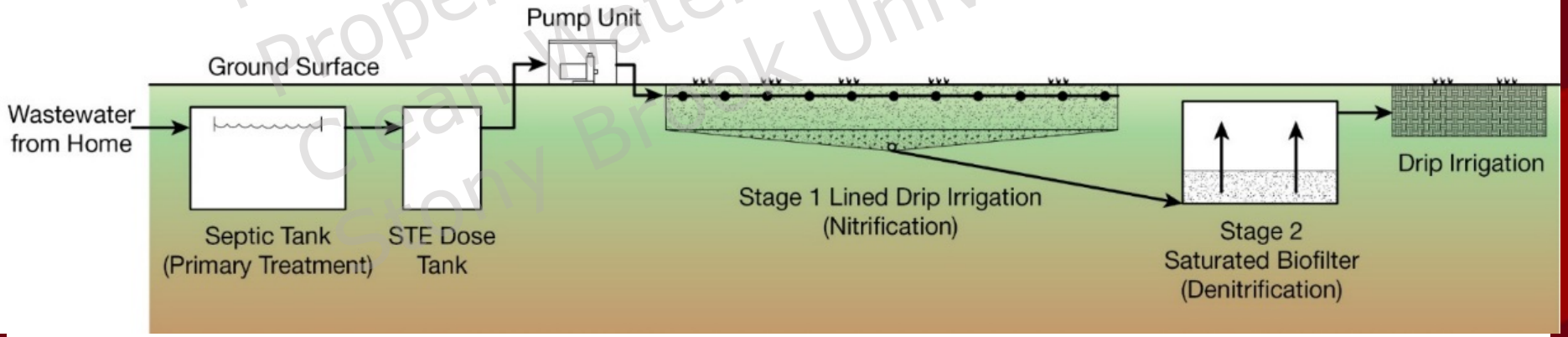
Nitrogen Removing Biofilters in Seminole County, FL by Hazen and Sawyer, Damann Anderson, P.E.

Full-scale, vertically stacked biofilter

	Stage 1 and 2a (sand above sand/ligno mix)	Stage 2 Elemental Sulfur in tank	Drip irrigation Final effluent dispersal
Surface Area	**728 ft²**	**32.3 ft²**	**615 ft²**
Media	**18" Fine Sand above 9" lignocellulosic and fine sand mix, at 50/50 ratio**	**12" elemental sulfur & oyster shell mix, 90/10 ratio**	**N/A**



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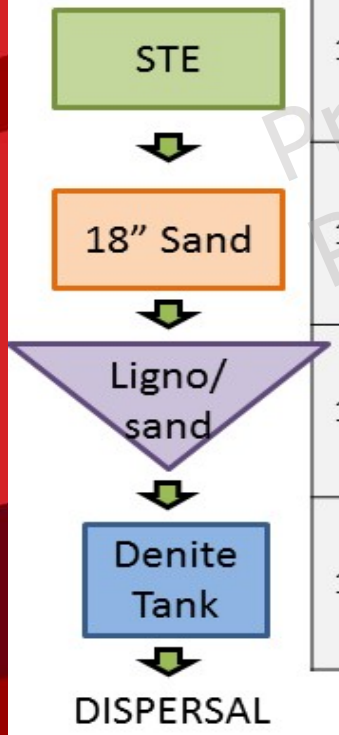
Full-scale system results over 500+ days operation



	n	TKN mg N/L		NH_3 mg N/L		NO_x mg N/L		TN mg N/L		Fecal Coliform (Ct/100 mL)		% TN Reduction
		mean	range	mean	range	mean	range	mean	range	mean	range	mean
STE	13	50.5	30-64	43.5	27-54	0.07	0.02-0.4	50.5	30-64	65,033	20,000-420,000	
18" Sand	13	2.1	1.0-4.9	0.1	0.01-1.6	23.3	1.3-47	25.4	2.5-51.6	1,000 (n=1)	1,000 (n=1)	50%
Ligno/ sand	13	2.1	0.9-4.2	0.2	0.04-0.7	5.8	0.02-14	7.9	1.0-16	32	Non-detect-6,800	84%
Denite Tank	13	1.3	0.8-1.8	0.3	0.02-0.9	0.6	0.02-5.3	1.9	0.84-7.1	5	Non-detect-300	96%

BCDHE
Barnstable County Department of Health and Environment
Promote - Protect - Support
90 YEARS OF SERVICE
1926 - 2016

Investigating Non-proprietary Means of Nitrogen Removal

Massachusetts Alternative Septic System Test Center
Director, George Heufelder

MASSTC

Nitrogen Removing Biofilters at MASSTC

- Column, small-, and full-scale systems tested.
- Systems have examined differing depths of layers, differing amounts of lignocellulose (wood chips), and saturated v. unsaturated.
- MASSTC has been monitoring systems for several years; CCWT has data since January.

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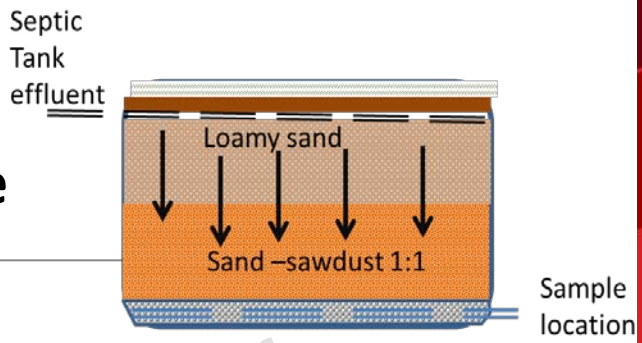
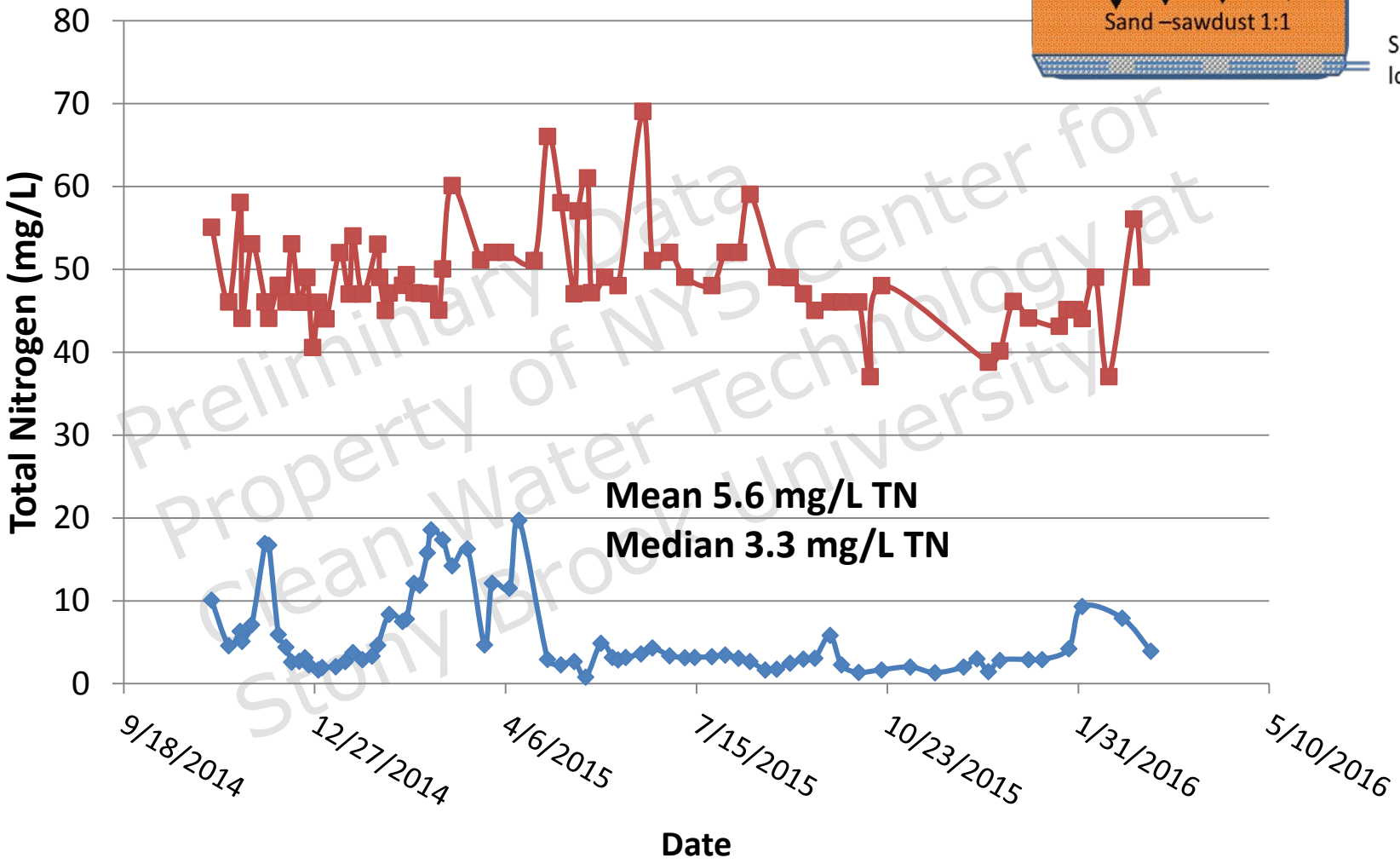
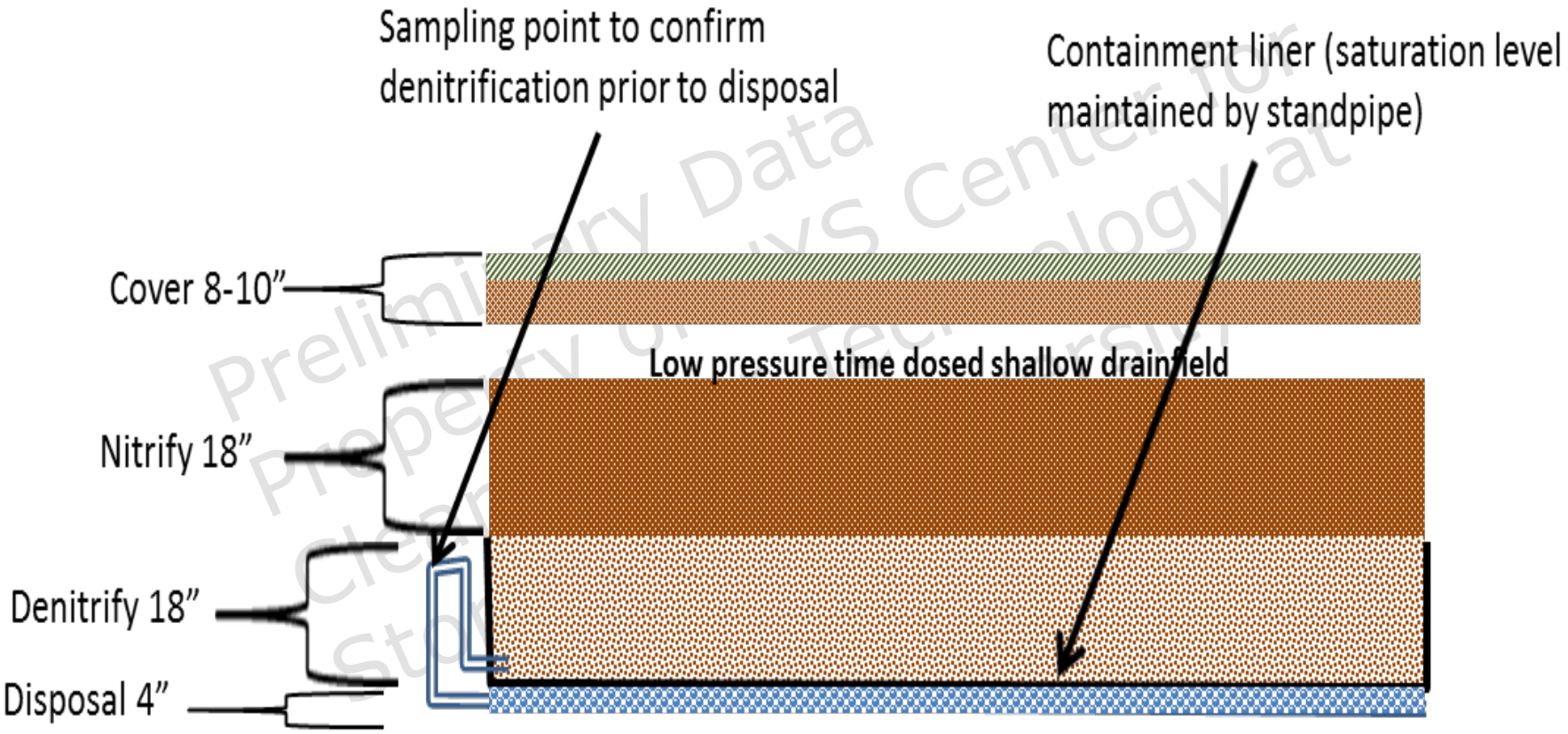
Small-scale (10 x 10), unsaturated system hydraulically loaded at code-prescribed rate





Large-scale saturated system, 26 x 26 ft



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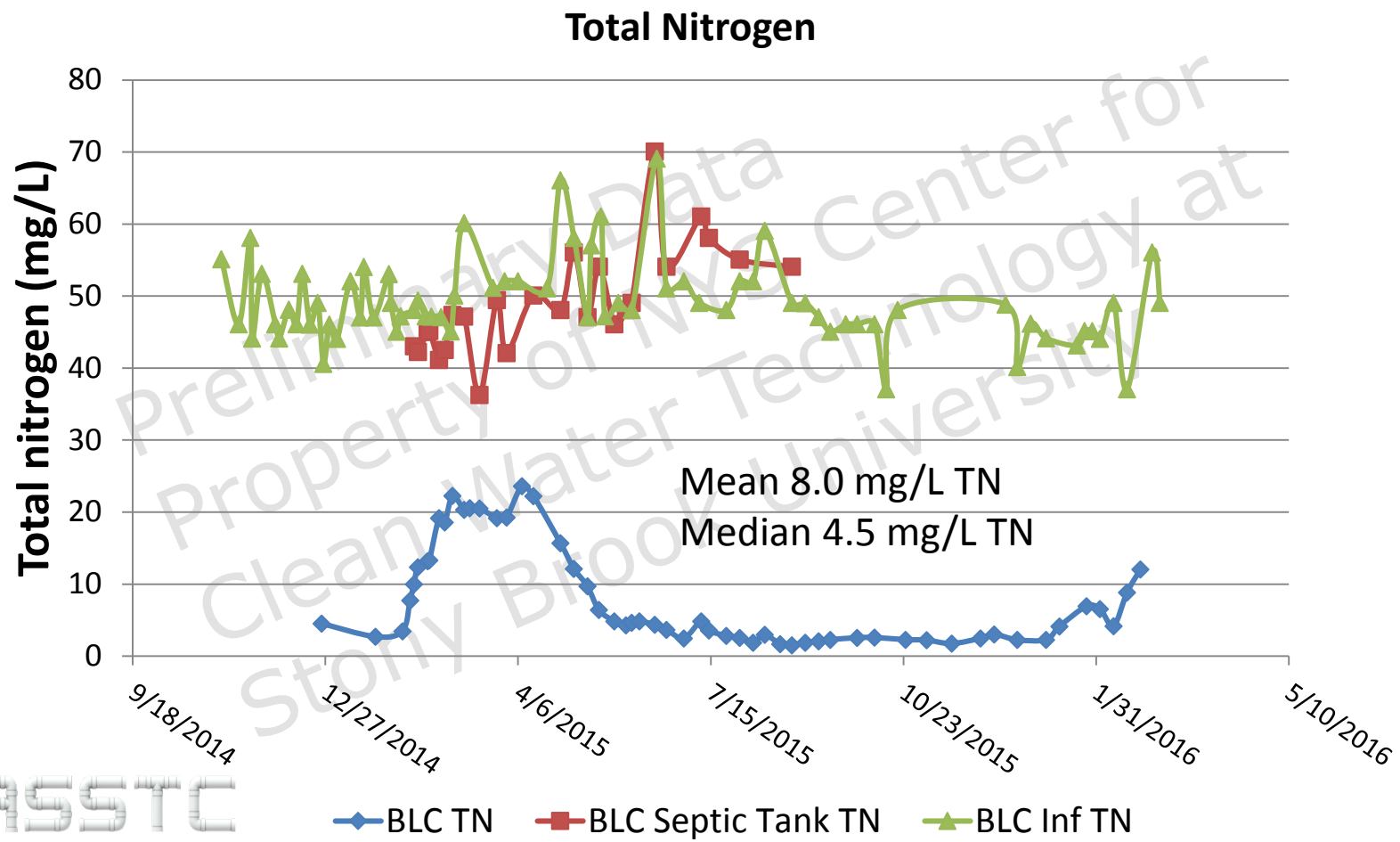
Large-scale saturated system

Hydraulic Loading 0.6 gal/day/ sq. ft, (**220 gallons/day**), Alternately dosed distribution laterals

Large-scale saturated system



MASSTC

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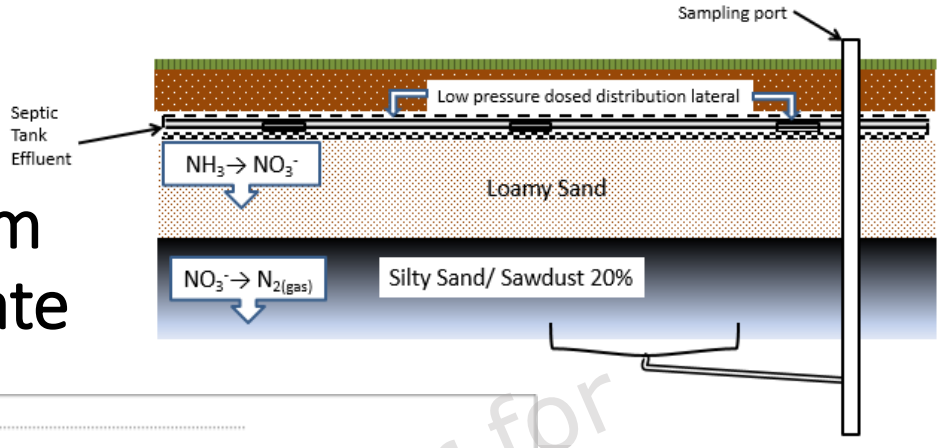
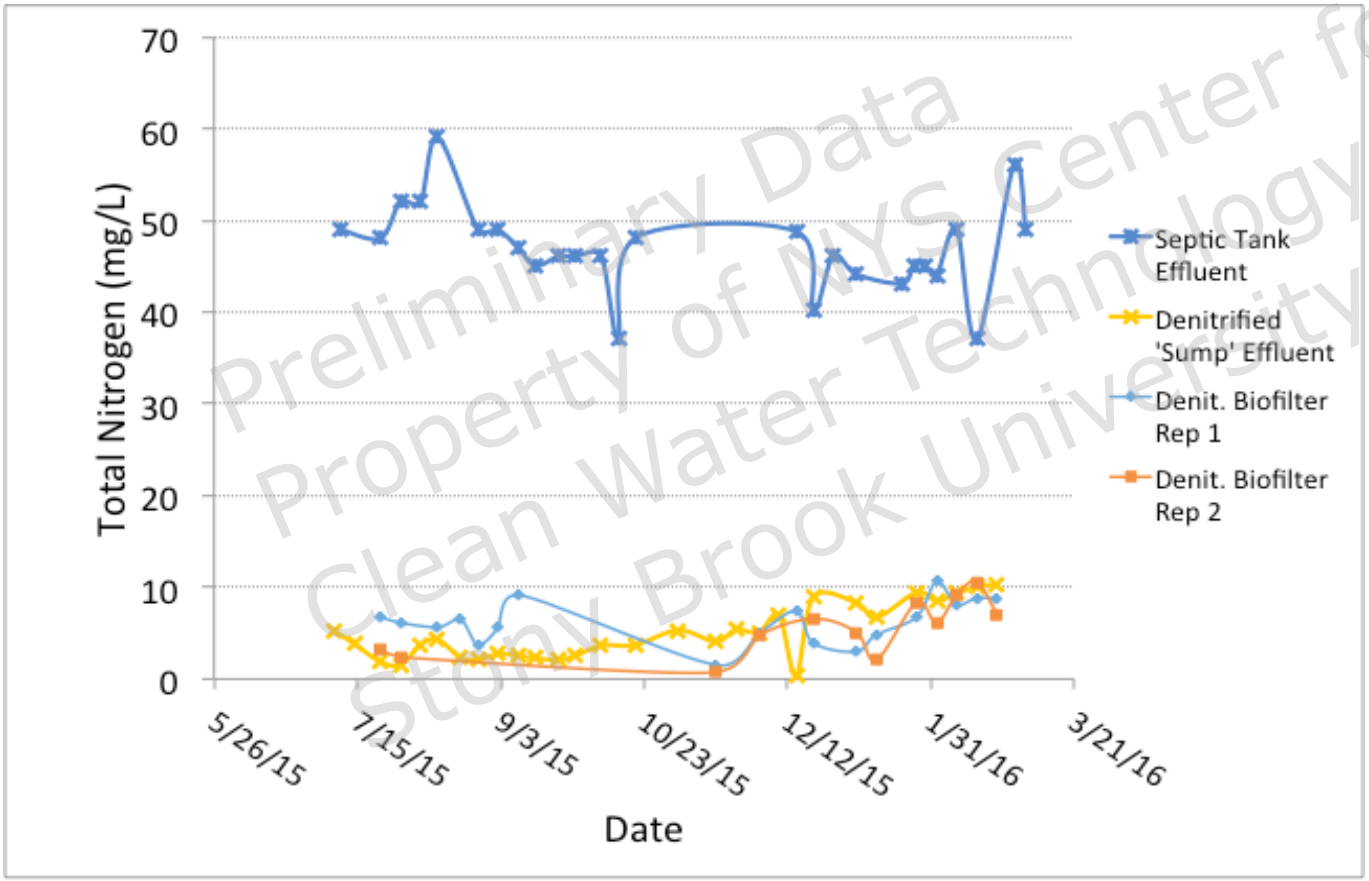
Full scale, unsaturated system loaded at code-prescribed rate

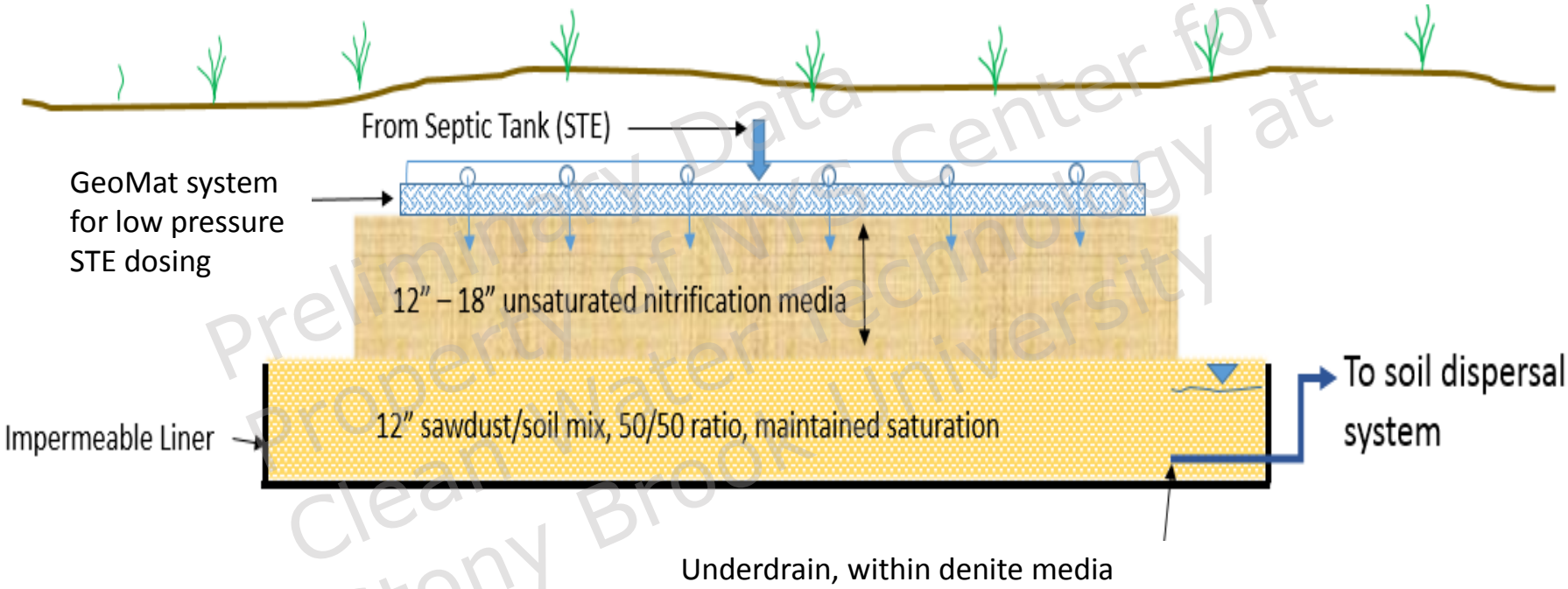




CCWT Design Charrette, March 2016

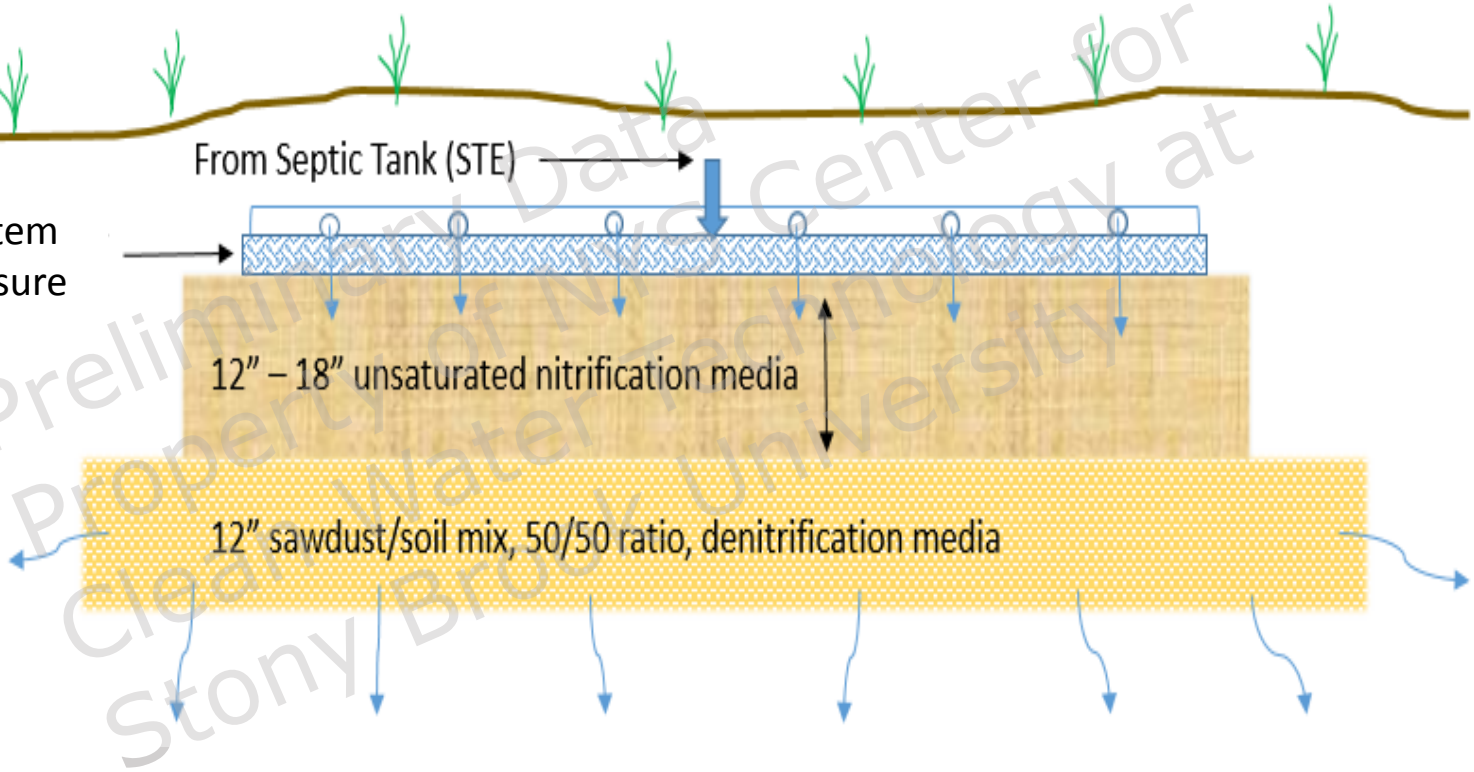
- Two-day gathering of regional and national experts on NRBs.
- Consensus on testing Long Island native materials.
- Consensus building on function and optimal, next generation design.

Lined, saturated NRB

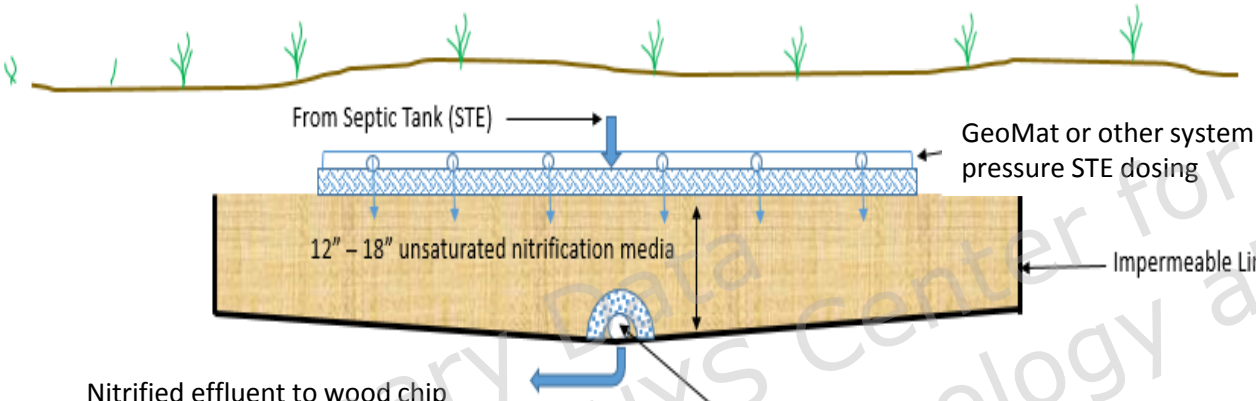


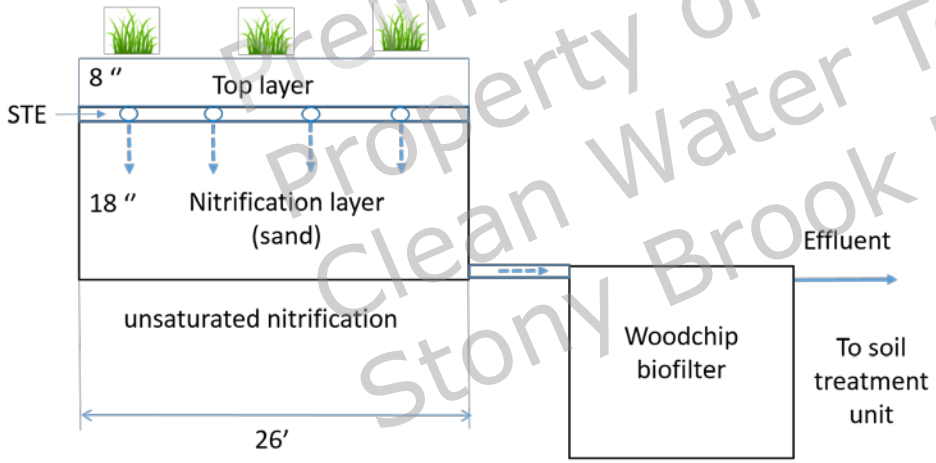
Unlined, unsaturated NRB

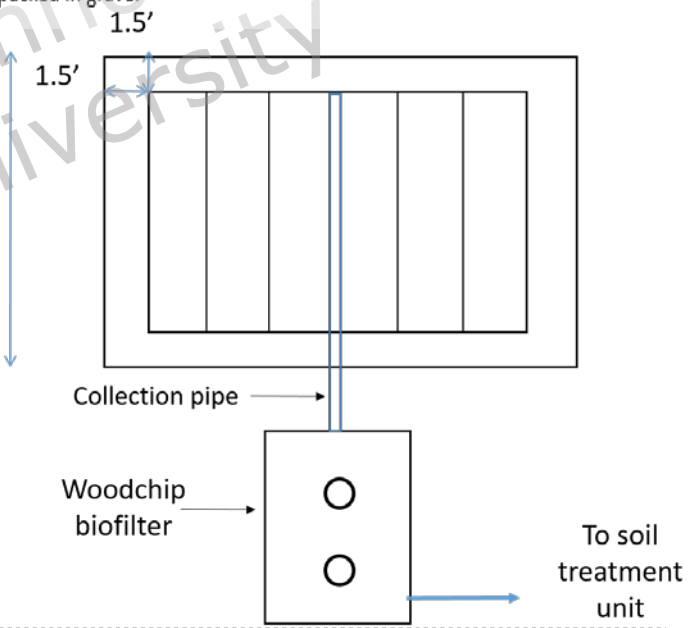
GeoMat system for low pressure STE dosing



Replaceable woodchip biofilter





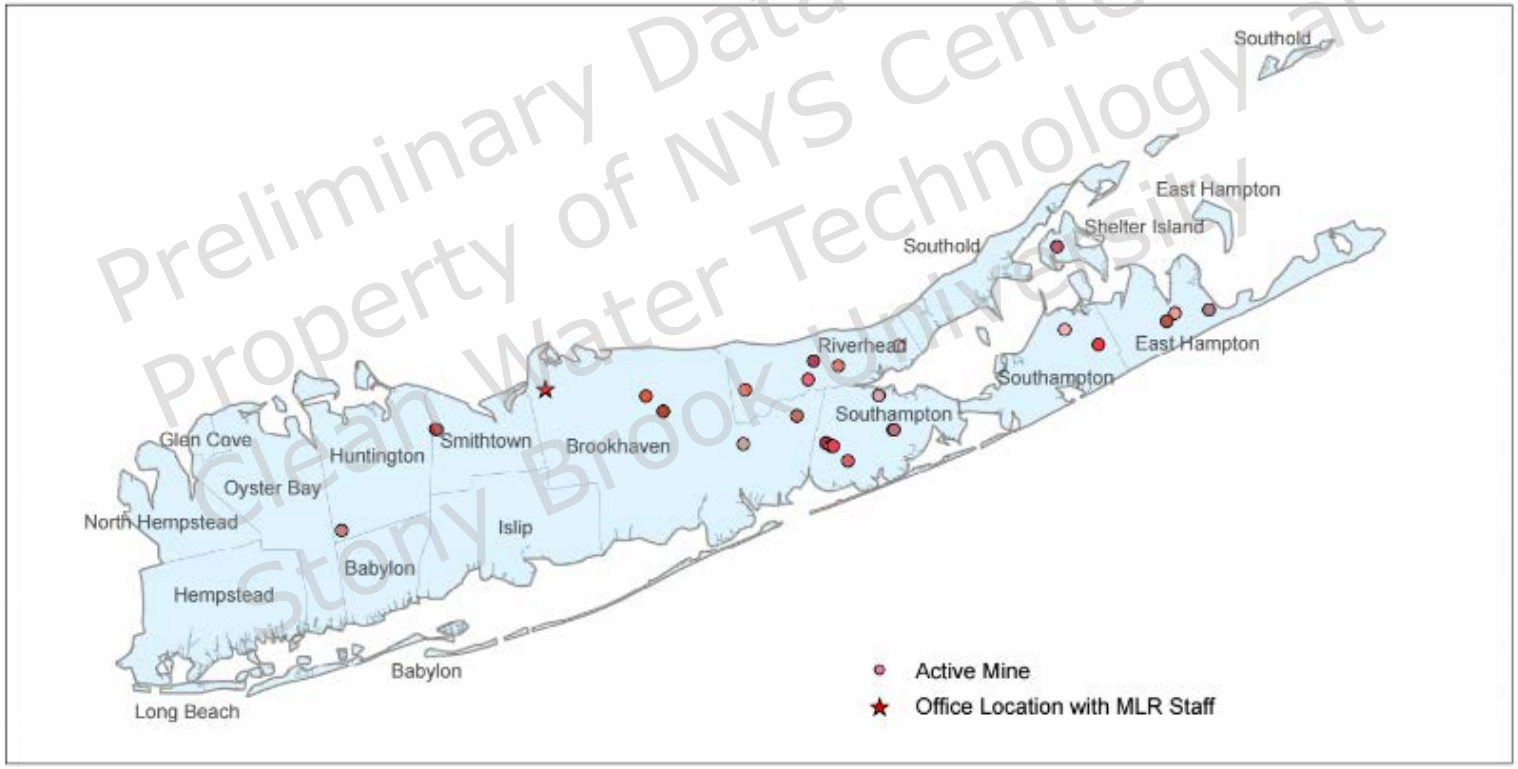


Denitrification

Sourcing native sands and wood products

NYS Department of Environmental Conservation
Division of Mineral Resources

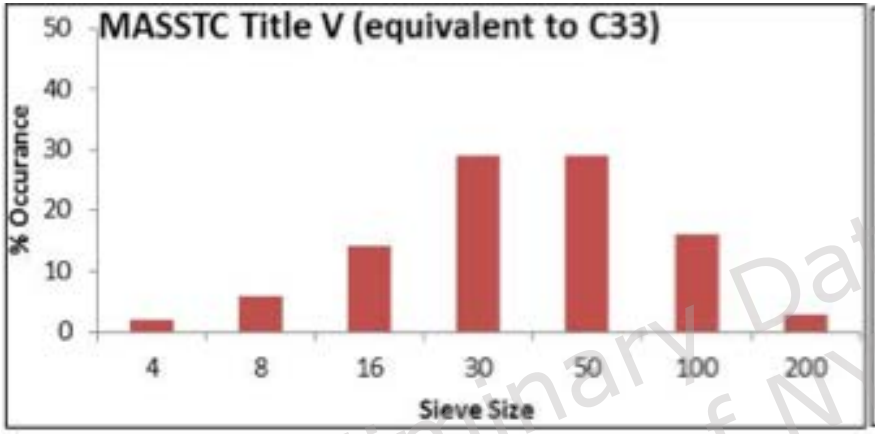
Region 1 Mine Locations

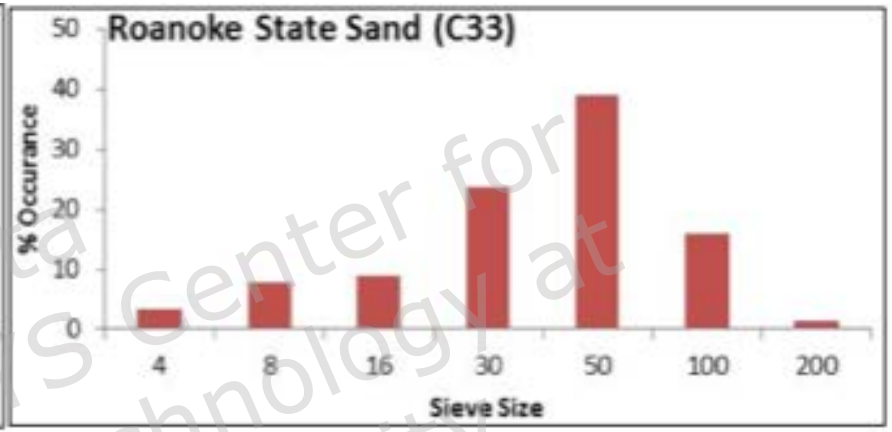


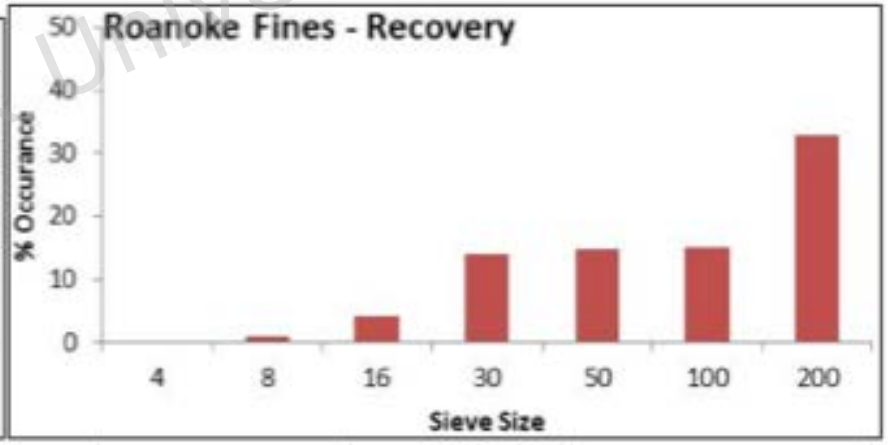
Survey of sand from Suffolk mines

Sample	% Organic	porosity	ALK mg CaCO3/L
MASSTC Silt	**9.08**	**0.25**	**28.45**
MASSTC Loam	**11.89**	**0.30**	**31.84**
East Coast Coarse.Fine	3.32	0.42	8.69
East Coast Bank	3.57	0.32	28.50
East Coast Concrete	3.26	0.52	8.13
East Coast Fine.Fine	3.84	0.25	9.18
Ranko Fls	4.01	0.42	10.41
Ranko Scs	1.94	0.36	10.59
Ranko Pitt	0.88	0.43	8.67
Roanoke Fine Sand	3.86	0.38	3.45
Roanoke State Sand	1.64	0.35	10.63
Roanoke Fine.Recovery	3.06	0.31	3.52

We have a winner…







Long Island native sands and wood chips have arrived in Massachusetts…

System installation in the coming weeks!

Suffolk County Reclaim Our Waters, demonstration of innovative/alternative onsite wastewater treatment systems, phase II

- CCWT applied to the County's phase II, Request for Expressions of Interest ("RFEI") using the NRB.
- Summer/Fall 2016 - Phase II Design and Installations of NRB Begin
- Fall 2016, 2017 - Monitoring of NRB
- 2017 - Provisional approval of NRB?

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Performance of Saturated and Unsaturated Nitrogen Removing Biofilters (NRB) at MASTCC

Xinwei Mao, Stuart Waugh, Molly Graffam, Samantha Roberts, Kylie Langlois, Patricia Clyde, Jeanette Lee, Megan Ladds, Benjamin Karmar

NYS Center for Clean Water Technology

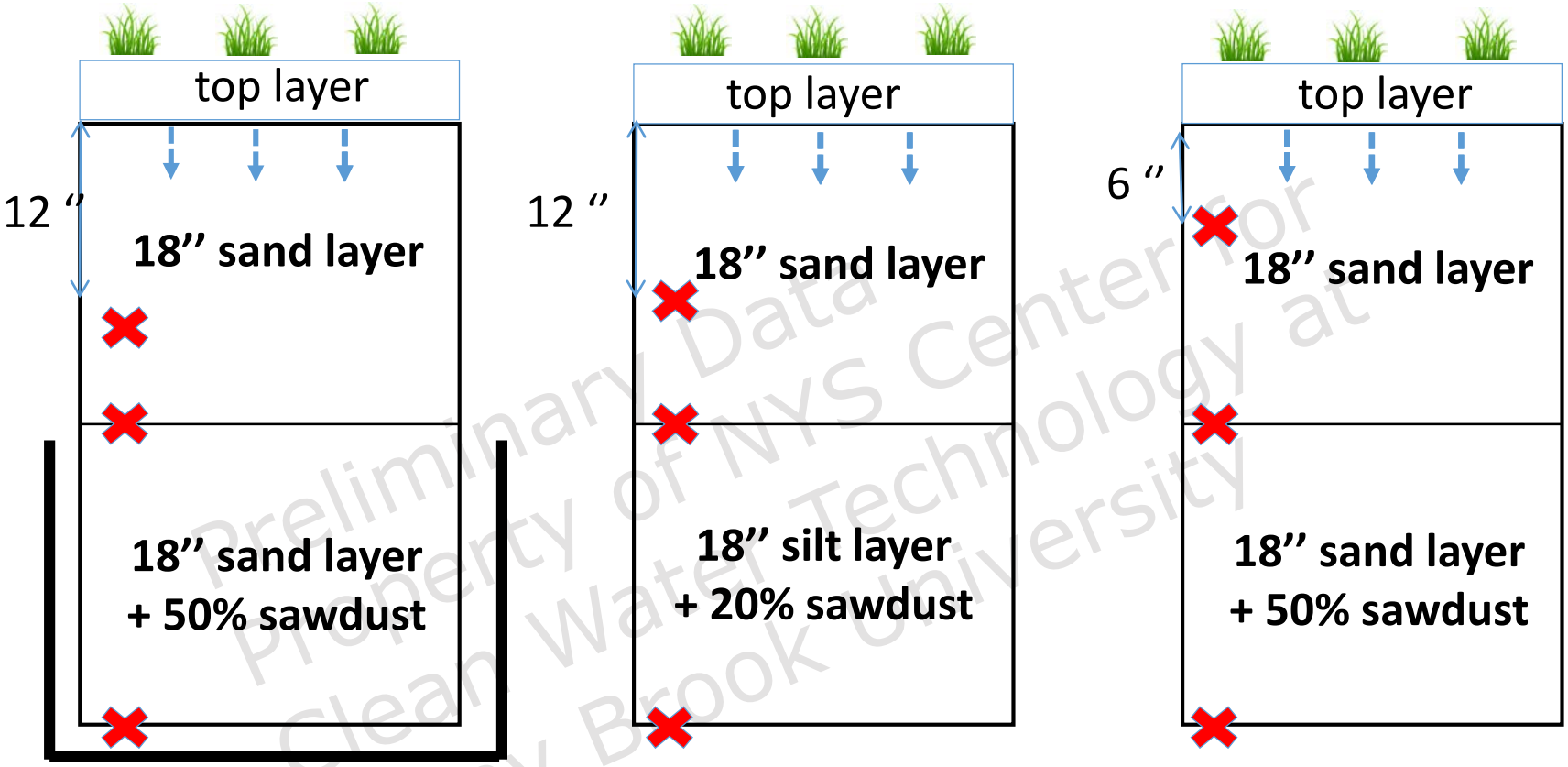
FAR BEYOND

Sampling systems description

The Massachutess Alternative Septic System Test Center was constructed on a site adjacent to the Massachusetts Military Reservation Wastewater Treatment Plant. The Center intercepts wastewater on its way to the treatment plant and distributes it to the test cells. Wastewater is from residential households and a county jail.

The graph is from G. Heufelder, Barnstable County

Sampling systems description----Schematic

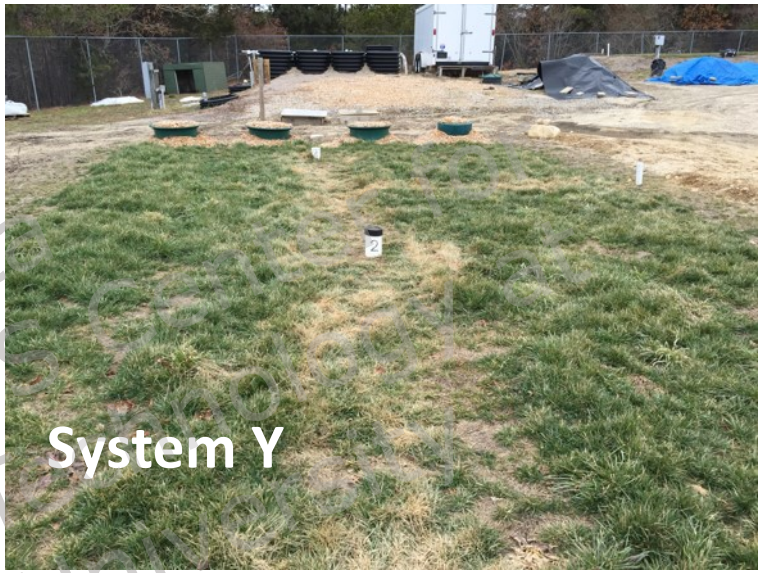


Sand system (Saturated) X

Silt system (un-saturated) Y

Sand system (un-saturated) Z

Sampling systems description----field sites



Effluent port

Pan Lysimeter

Sample frequency: Jan, 2016 and Apr, 2016.

Sampling systems description-cont'd

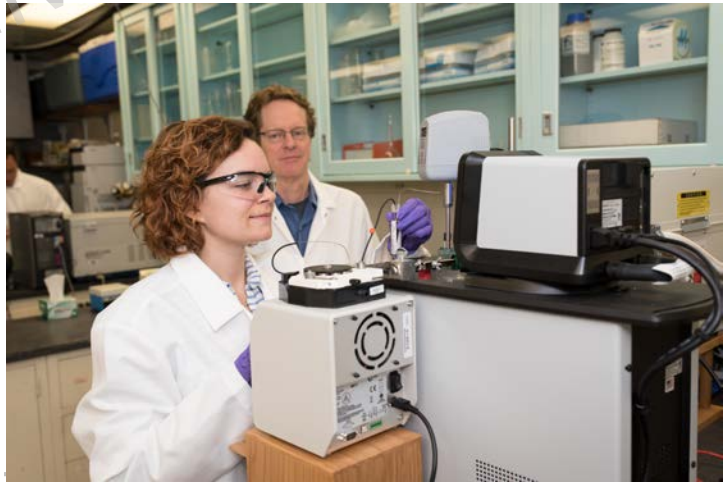
On-ground denitrifying bioreactor

Nitrified percolate

Column system (Saturated) C

Field sample analyses

- BOD_5
- TSS
- Alkalinity
- Nutrients
- Microbiology
- PPCPs



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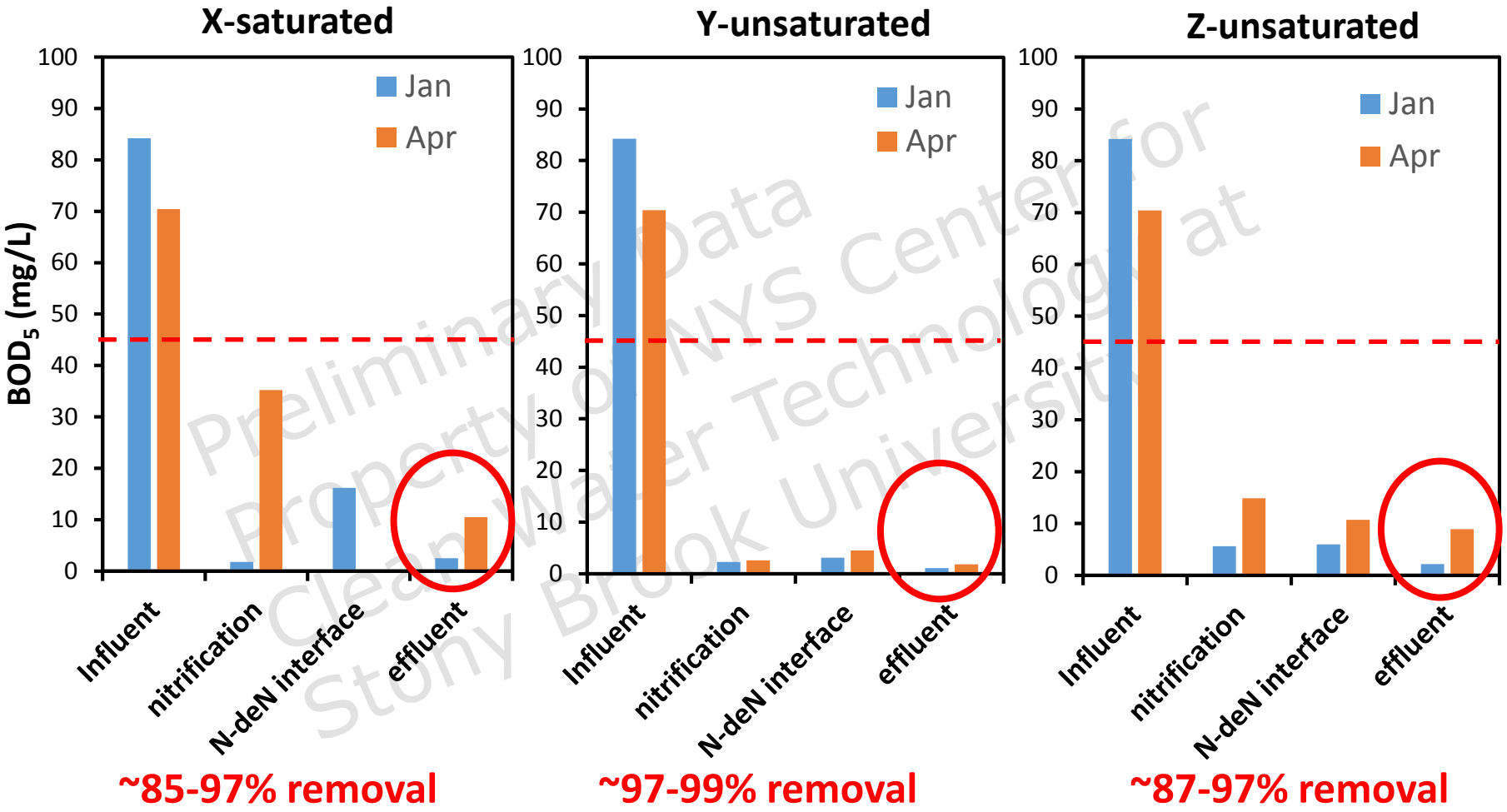
BOD_5 (biochemical oxygen demand)



~85-97% removal

~97-99% removal

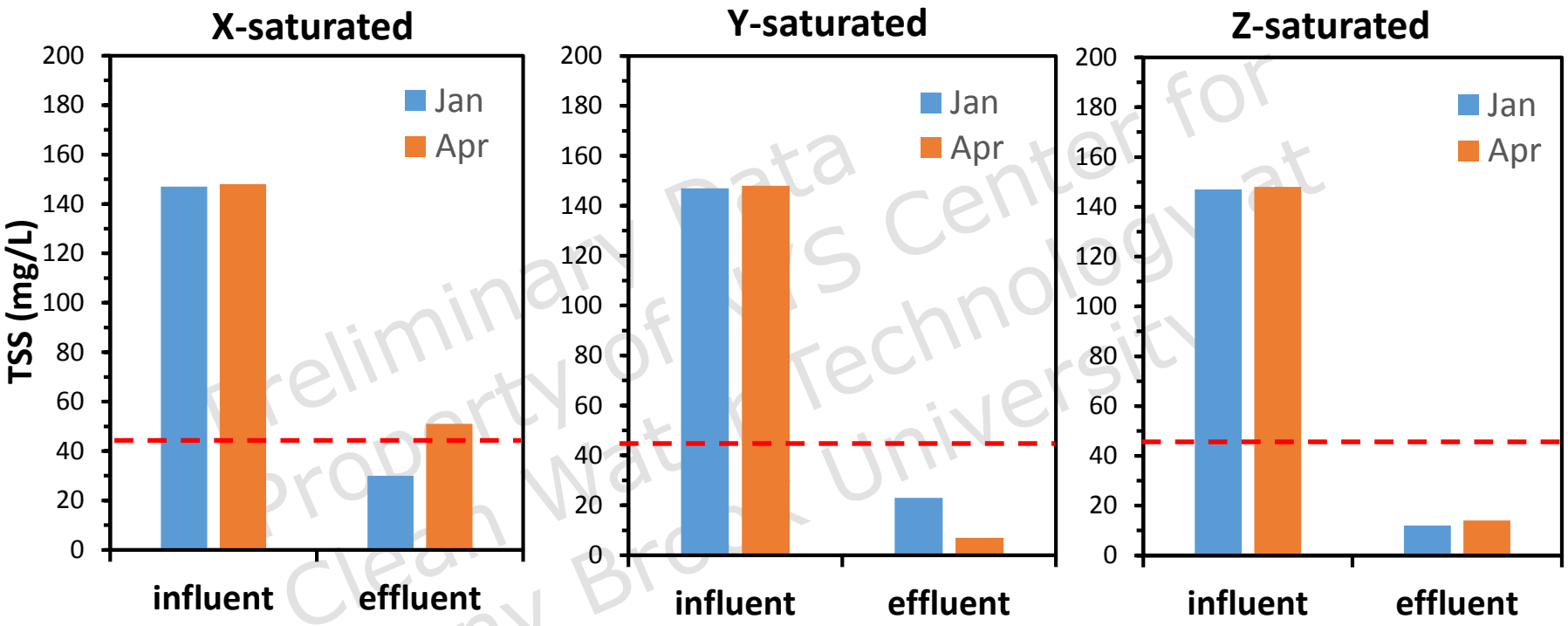
~87-97% removal

FAR BEYOND

7-day effluent BOD requirement for surface water discharge, New York State

40 CFR Part 133.102

TSS (Total Suspended Solids)



~65-80% removal

~84-95% removal

~91-92% removal

FAR BEYOND

7-day average effluent TSS requirement for surface water discharge, New York State

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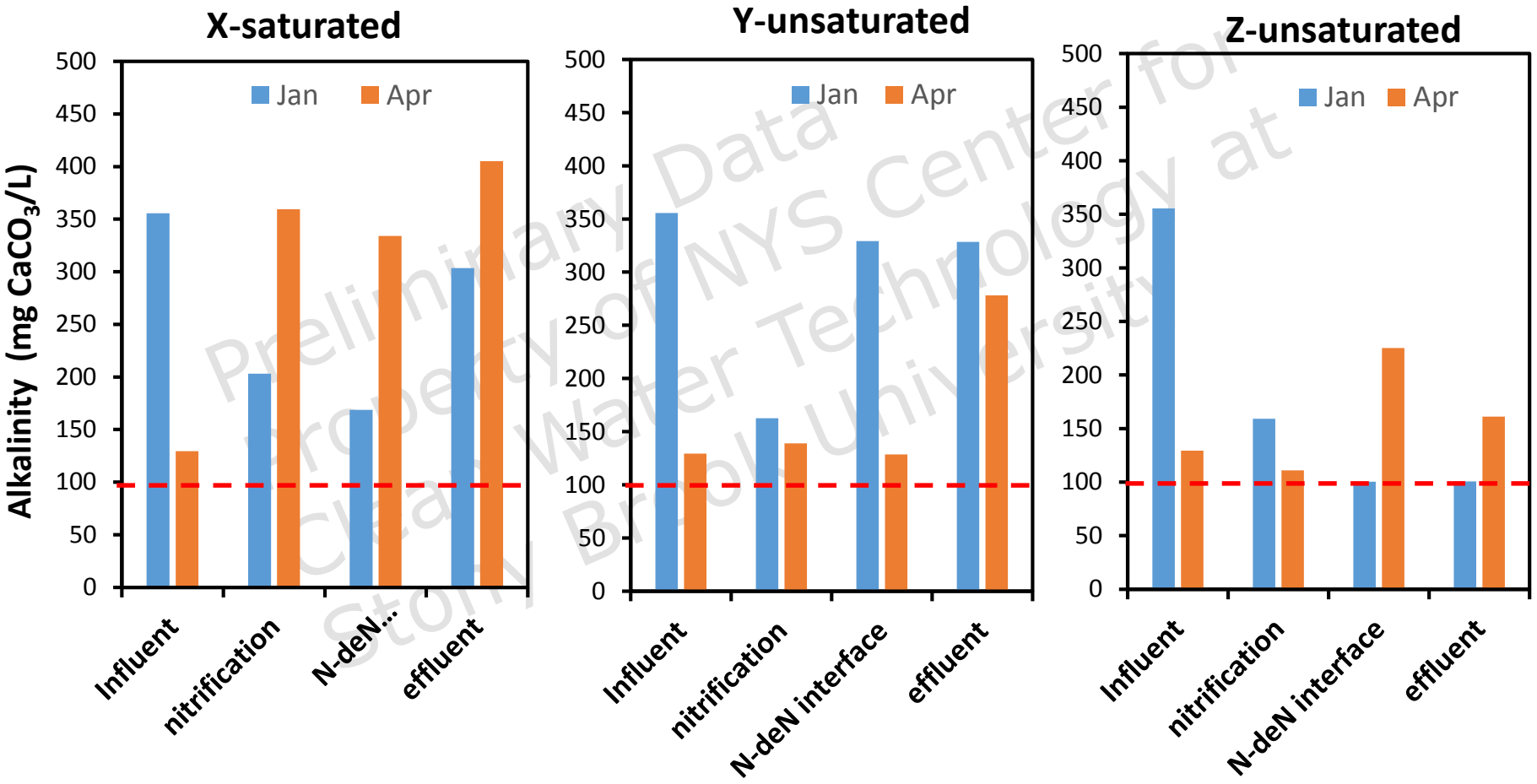
Alkalinity---- important for nitrification

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$



FAR BEYOND

Recommended residual alkalinity to maintain system's pH

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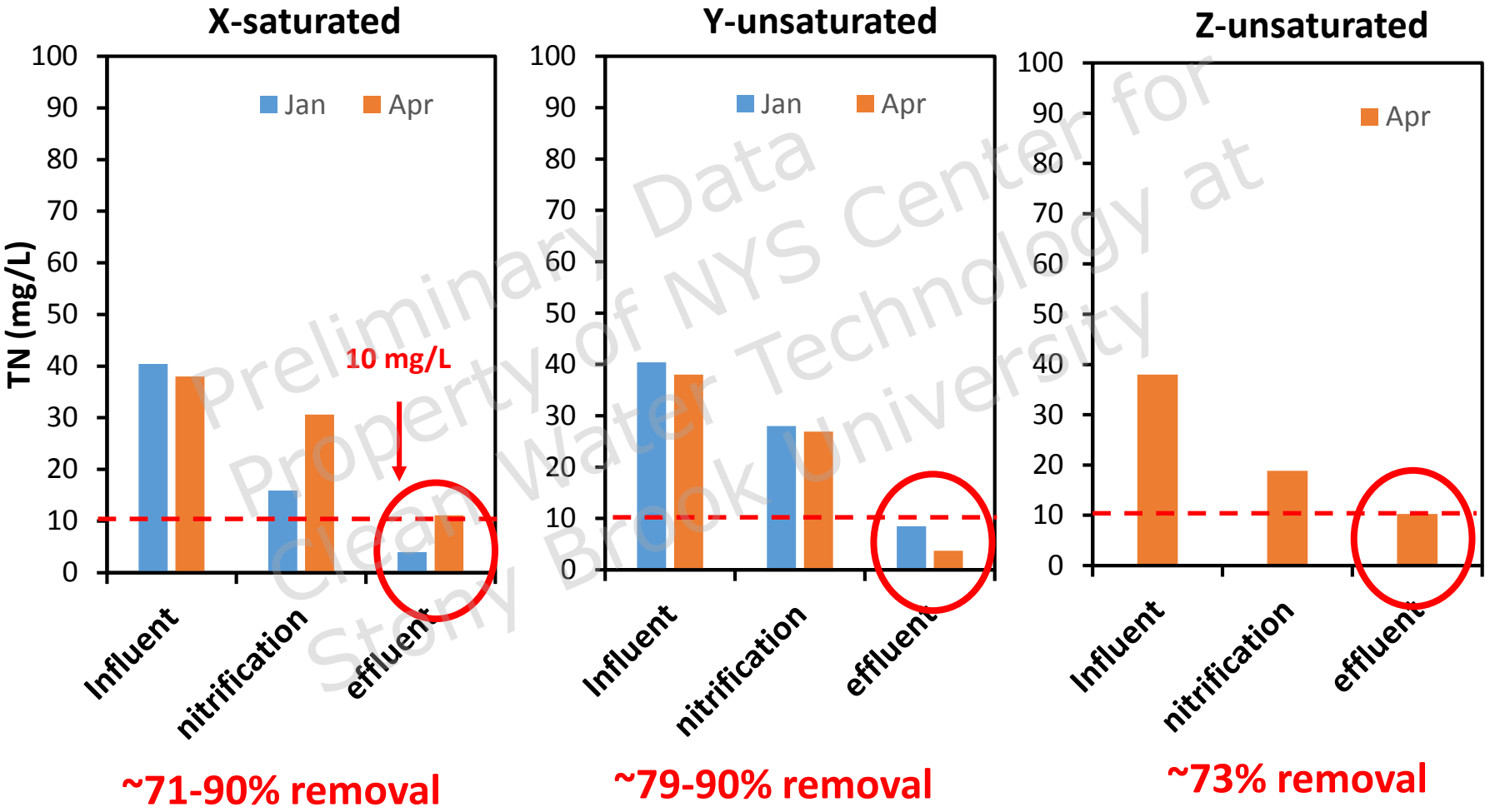
Nutrients (Total Nitrogen removal)



FAR BEYOND

*the influent and effluent data are the average of three biological replicate.

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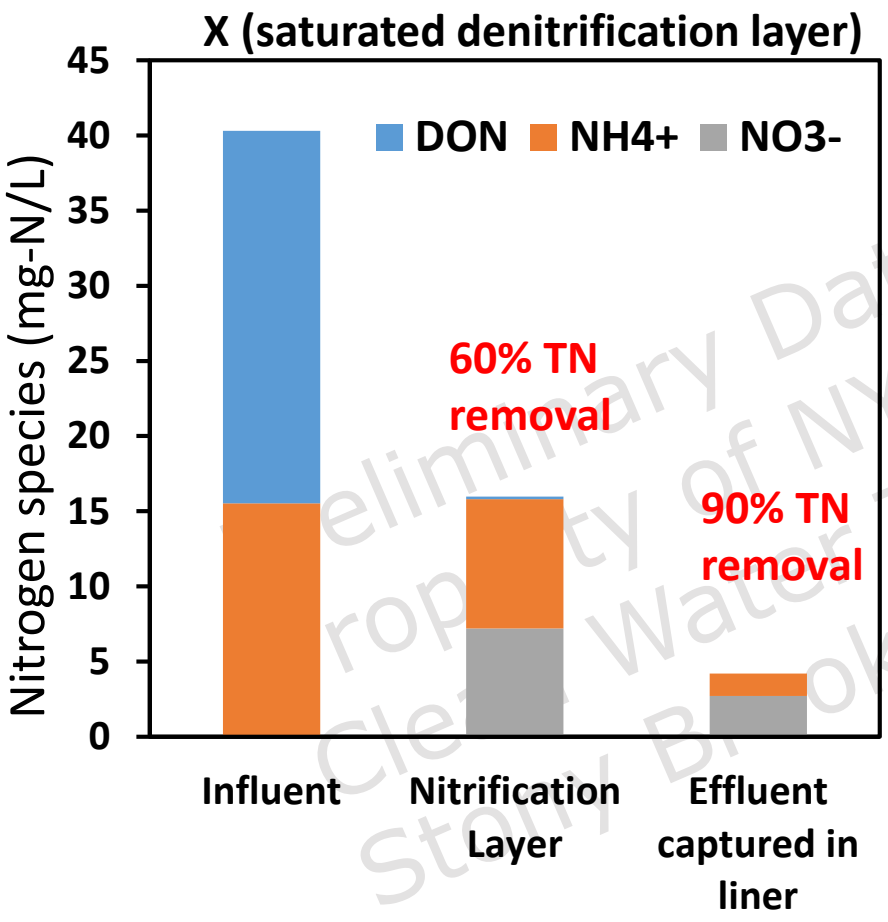
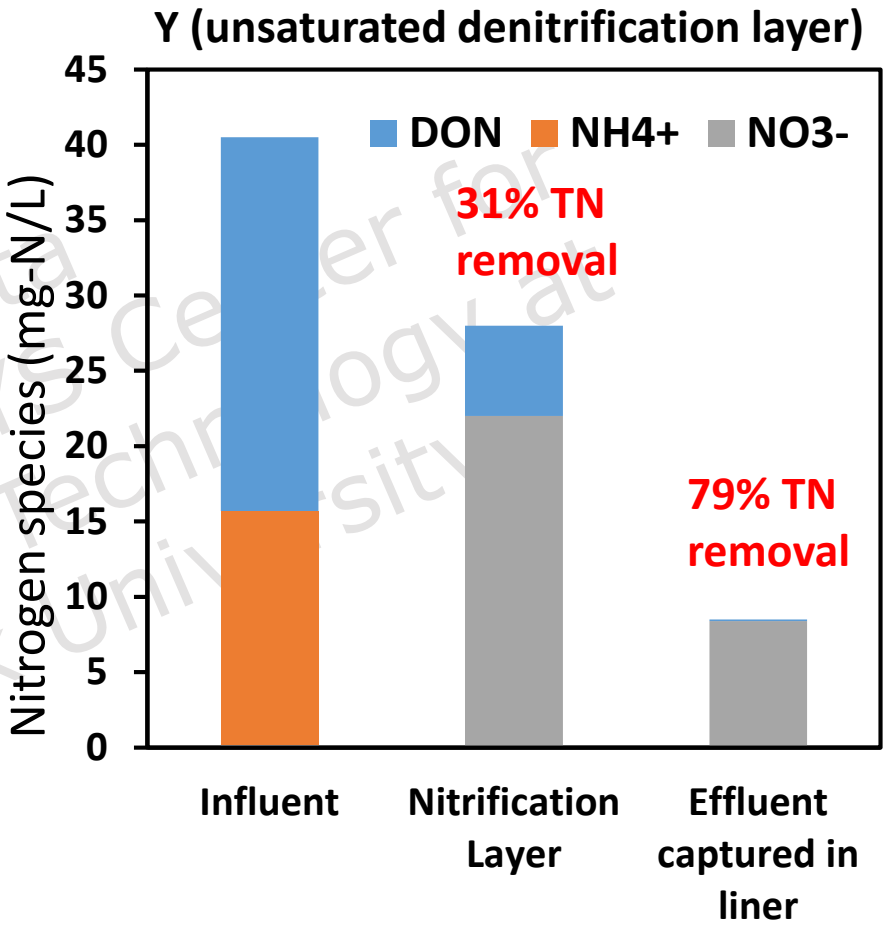
Nutrients (nitrogen balance in the system)





Denitrification may occur at both nitrification and denitrification zones.

* Data is from trip in Jan, 2016.

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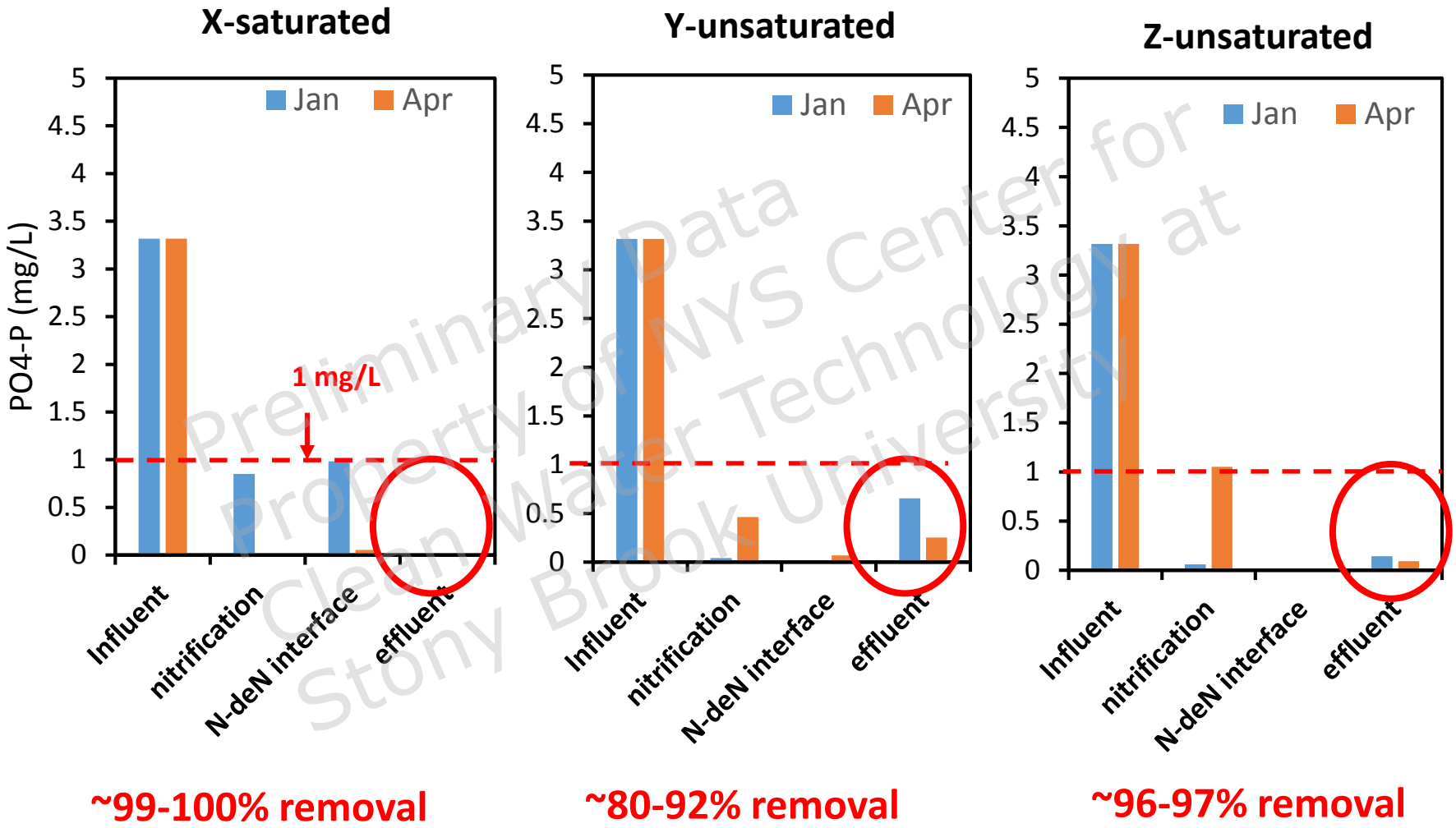
Nutrients (phosphorus removal)



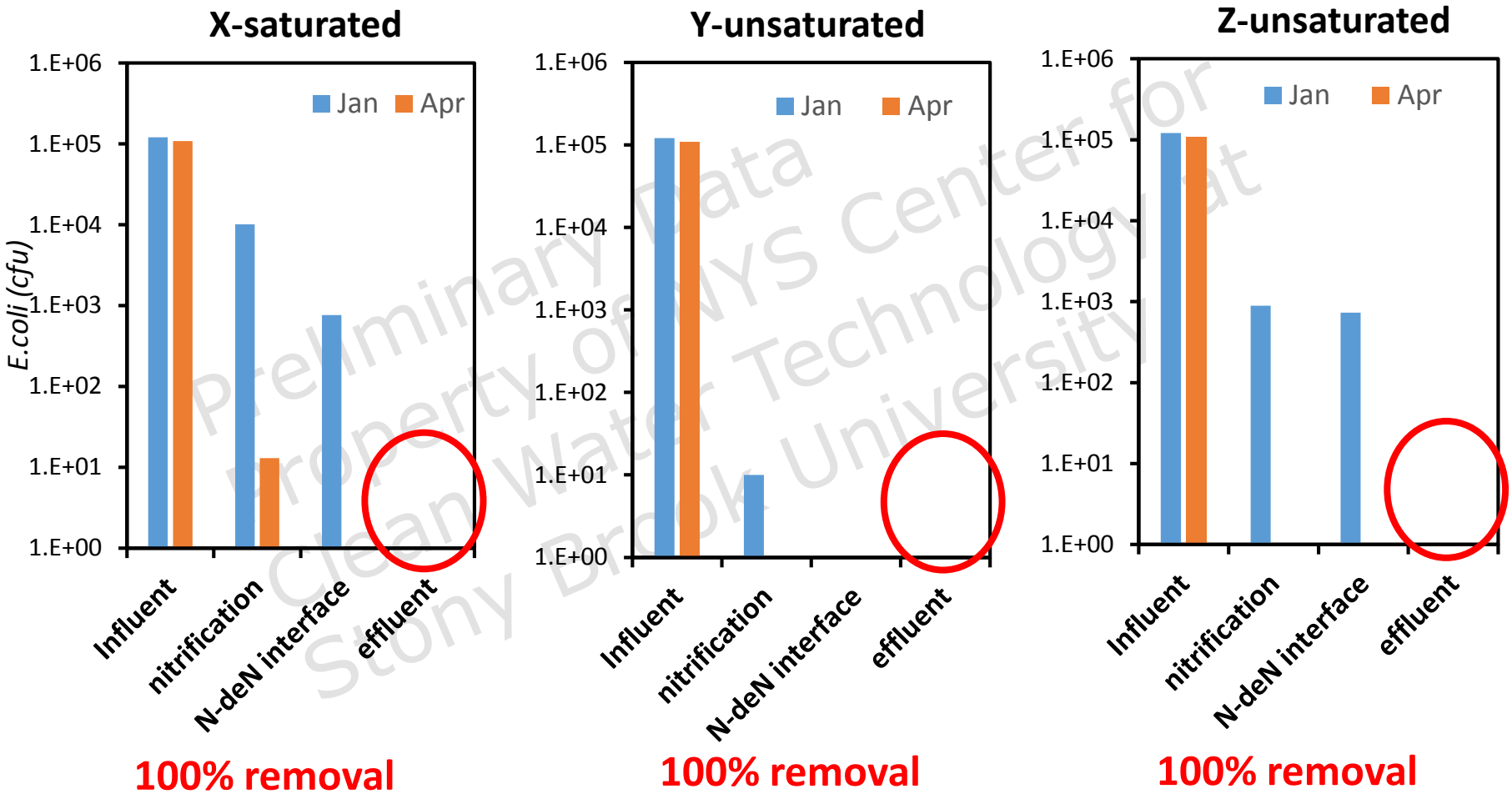
~99-100% removal

~80-92% removal

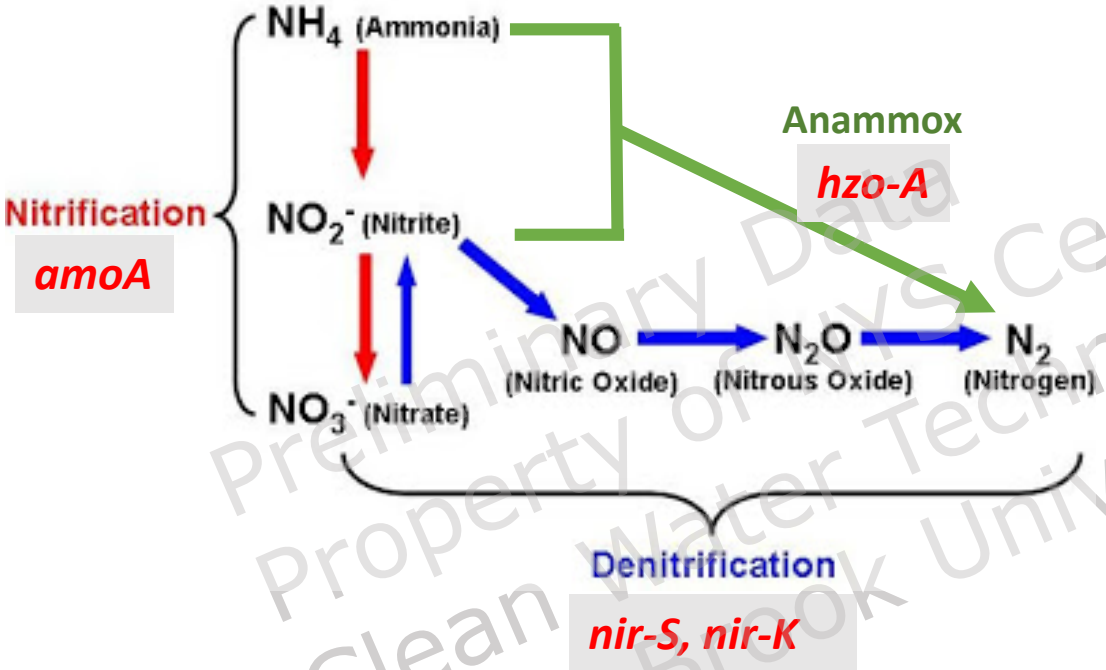
~96-97% removal

FAR BEYOND – – 30-day average effluent TP requirement for surface water discharge, New York State

Microbial analysis----*E.coli* *(indicator of pathogens)*



Microbial analysis----nitrogen cycling pathways



PCR (polymerase chain reaction) for all collected samples (liquid/core)

Microbial analysis----presence of functional genes

Function	Bio-marker (gene)	inf	Saturate system X			Un-saturate system Y			Un-saturate system Z			C
			X-1	X-2	X-3	Y-1	Y-2	Y-3	Z-1	Z-2	Z-3	
nitrification	*amoA (arc)*											
	amoA (bac)											
denitrification	*Nir-S*											
	Nir-K											
anammox	*hzo-A*											

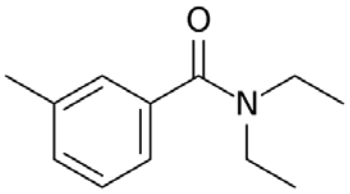
no amplification | Presence (strong band) | Presence (weak band) | N.A.

Microbial analysis----In progress

I-tag 16S sequencing Metagenomics Metatranscriptomics	PCR	quantitative- PCR
what microorganisms are present in different parts of existing systems	presence/absence of each functional guild in different parts of existing systems	abundance and activity of each functional guild in different parts of existing system.

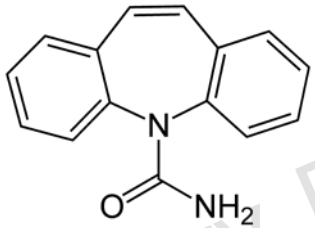
PPCPs (Pharmaceuticals and Personal Care Products)

DEET



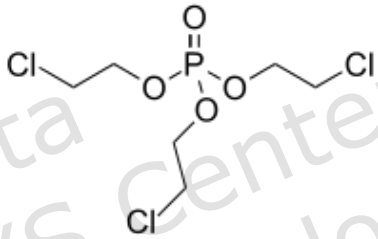
- Pesticide
- Persistent in the environment
- The most frequently detected in US GW

Carbamazepine



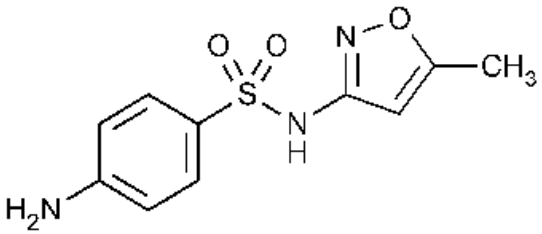
- Anticonvulsant
- Carcinogenic to rats
- Most frequently detected PPCP in two studies of LI GW

TCEP



- Widely used flame retardant
- found at higher levels than other PPCPs in drinking water

Sulfamethoxazole

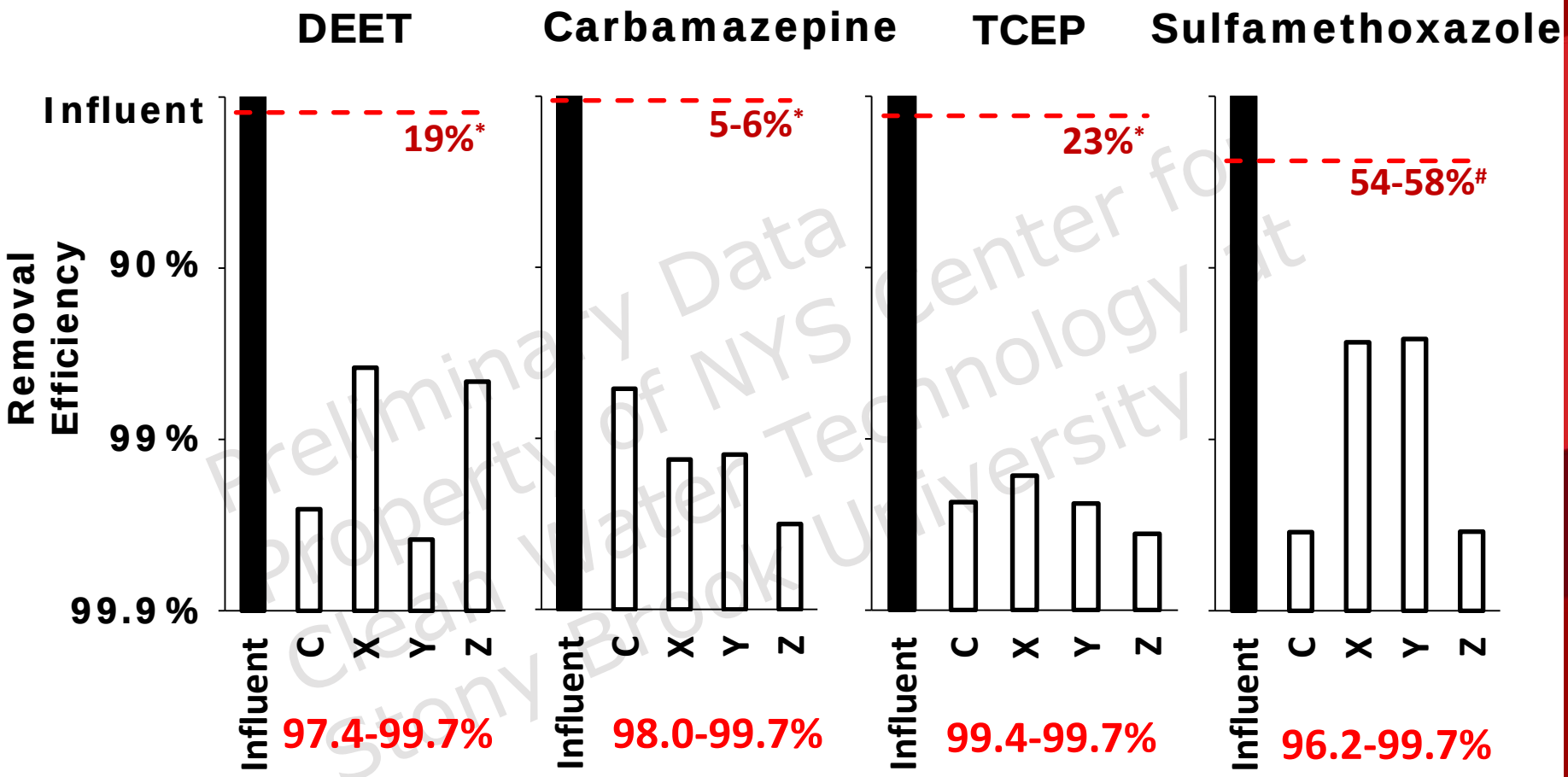


- Commonly prescribed antiobiotic
- Danger of leading to antibiotic-resistant bacteria

- They have **all** been measured in groundwater near OSWTs.
- They are **poorly treated** by full-scale activated sludge treatment systems.

Stony Brook University

PPCPs (Pharmaceuticals and Personal Care Products)



Over 95% removal of all 18 PPCPs detected in influent

FAR BEYOND

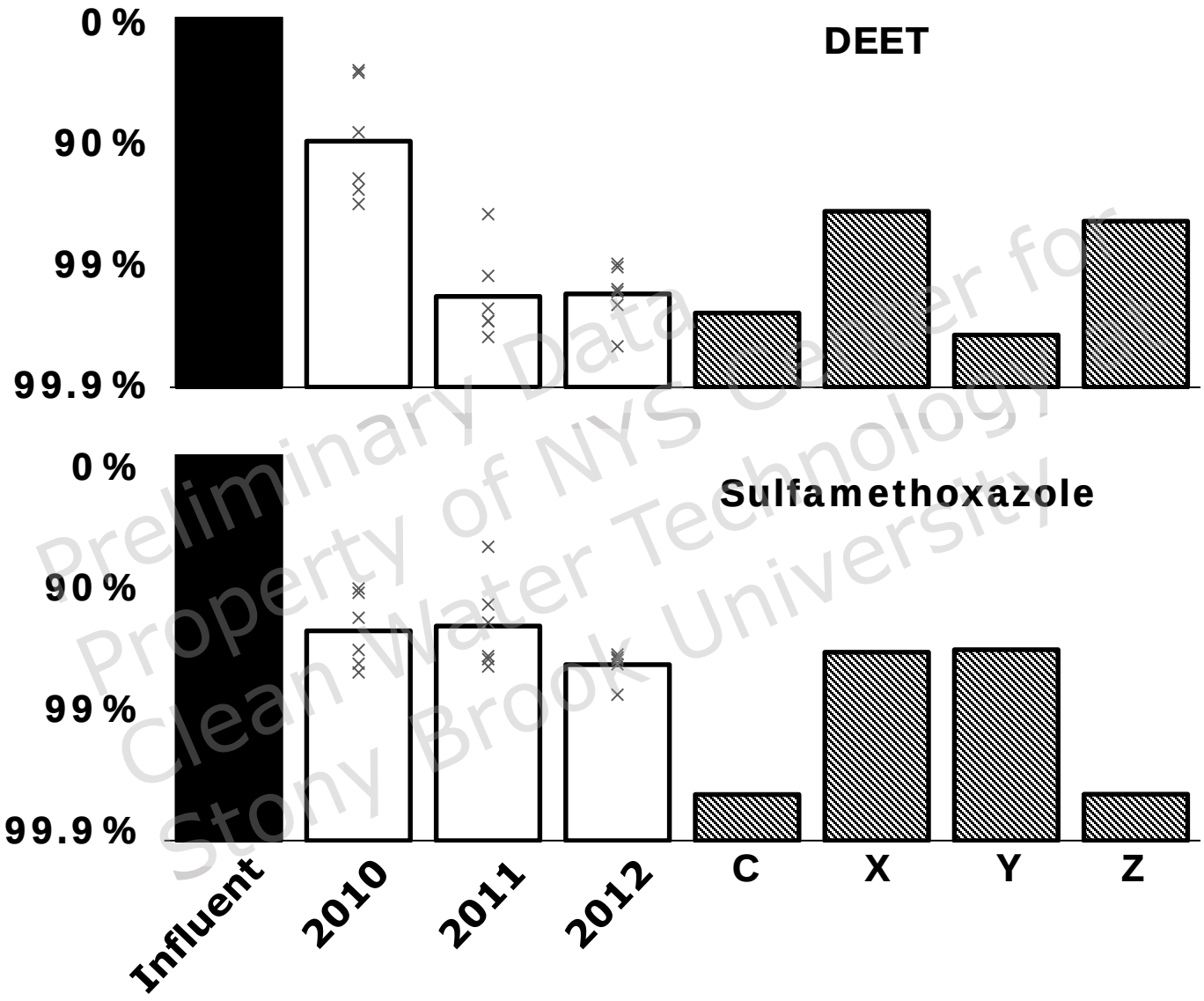
– – Removal efficiency in full scale wastewater treatment plants

*Reemtsma, 2008 #EPA, 2010; Lara-Martin, 2014

Summary

- These results demonstrate MASSTC's passive NRBs are highly efficient at removing nitrogen, even in the winter.
- The results also indicated nitrogen loss at both nitrification and denitrification zones in NRBs.
- The NRBs investigated in this study can efficiently remove BOD, pathogen indicators, and all PPCPs detected.
- Molecular biology tools (e.g. sequencing, qPCR) are extremely useful to study the microbial ecology and could be used to evaluate, predict and improve the performance of existing and novel on-site wastewater treatment systems.

Supporting Materials



TCEP