Stony Brook University

NYS Center for Clean Water Technology

Developing robust and cost-effective non-proprietary solutions for onsite residential wastewater disposal on Long Island:

Nitrogen Removing Biofilters

Stuart Waugh, Ph.D. & CFA
Research Scientist
NYS CCWT
June 17 2022

FAR BEYOND

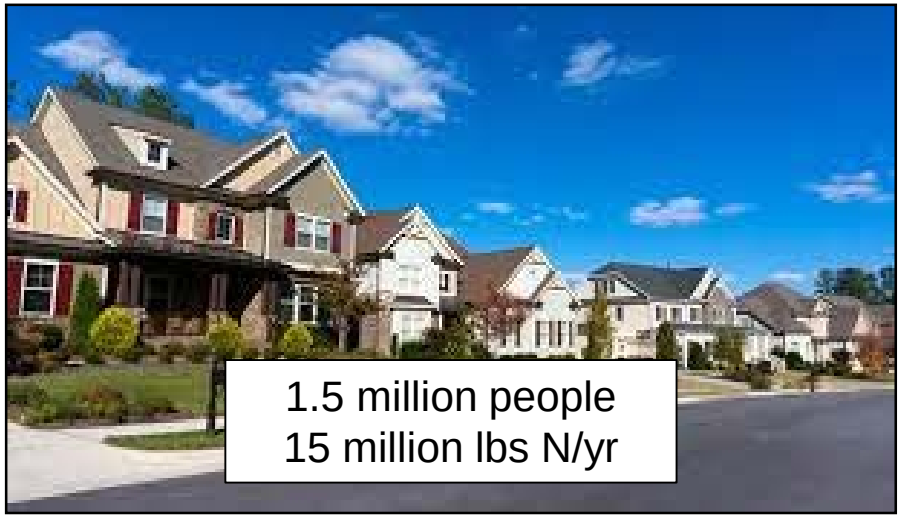
Groundwater Nitrogen on Long Island

1950

200,000 people
1.5 million lbs N/yr

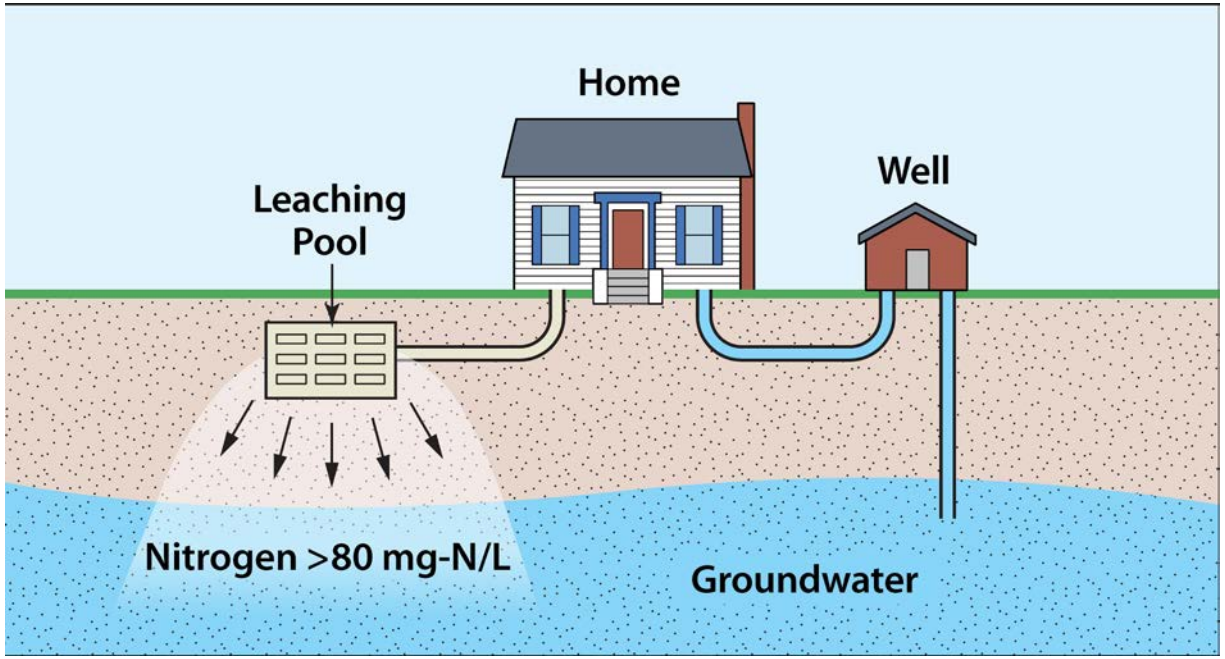
6 million ducks
1.8 million lbs N/yr

2022



1.5 million people
15 million lbs N/yr

One duck farm



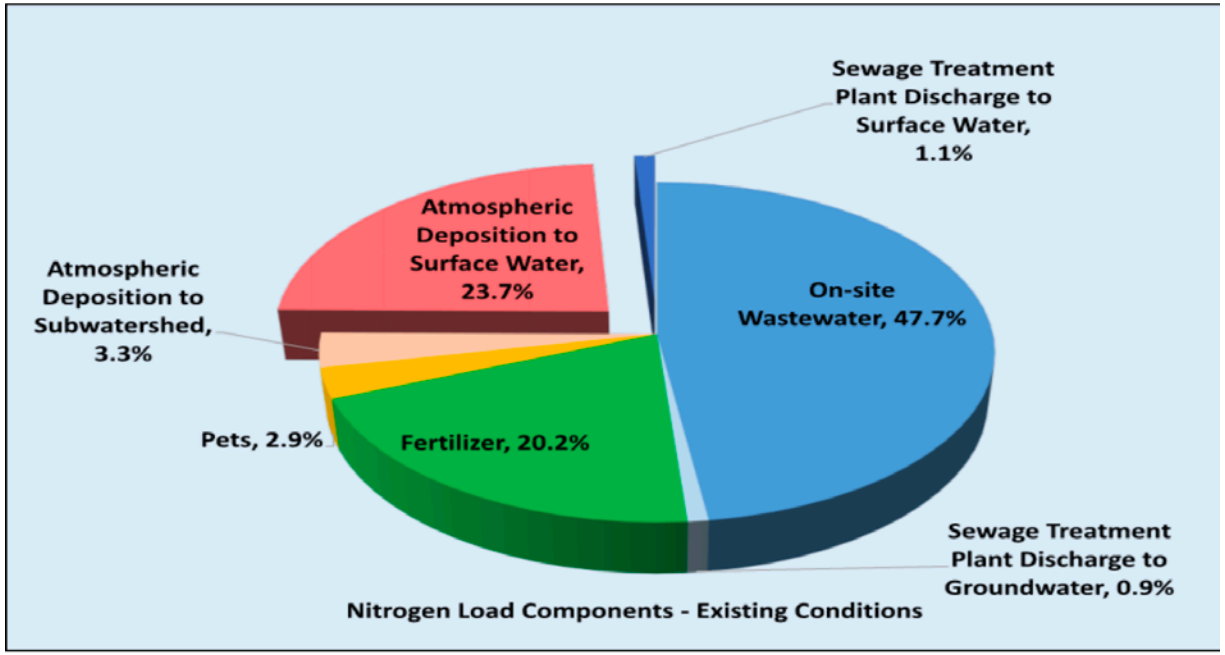
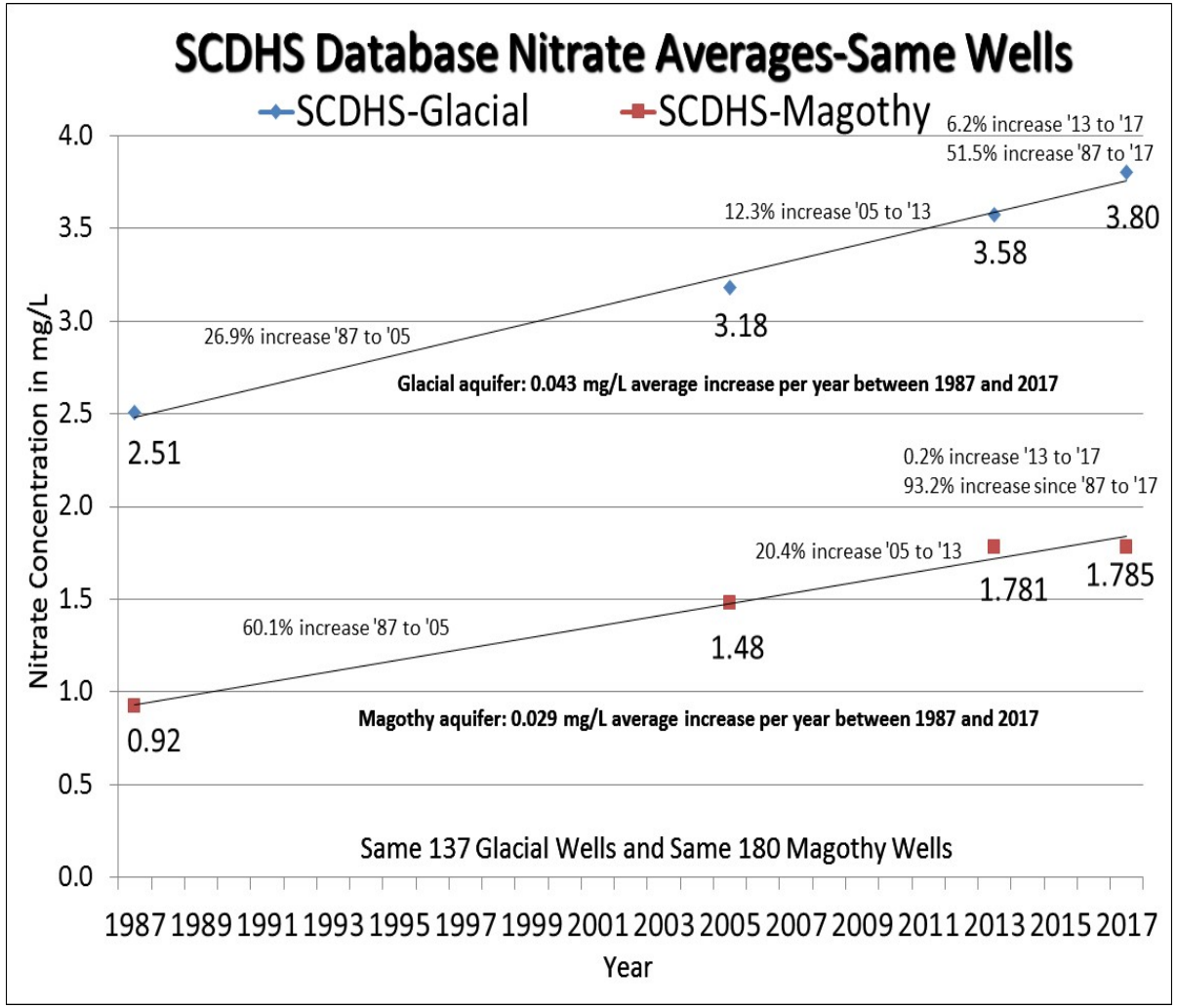


Figure 2-25 Nitrogen Load Components to the 191 Subwatersheds

Suffolk County: 380,000 septic systems leaching into the aquifer



Substantial number of epidemiological studies on impact of drinking water nitrogen on human health in last two decades

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Exposure-based assessment and economic valuation of adverse birth outcomes and cancer risk due to nitrate in United States drinking water.

Alexis Temkin[a,*], Sydney Evans[a], Tatiana Manidis[b], Chris Campbell[a], Olga V. Naidenko[a]

[a] Environmental Working Group, 1436 U Street NW Suite 100, Washington, DC, 20009, USA
[b] Duke University, Nicholas School of the Environment, 9 Circuit Dr, Durham, NC, 27710, USA

Nitrate from Drinking Water and Diet and Bladder Cancer Among Postmenopausal Women in Iowa

Rena R. Jones,[1] Peter J. Weyer,[2] Curt T. DellaValle,[1] Maki Inoue-Choi,[1,3] Kristin E. Anderson,[4,5] Kenneth P. Cantor,[1] Stuart Krasner,[6] Kim Robien,[7] Laura E. Beane Freeman,[1] Debra T. Silverman,[1] and Mary H. Ward[1]

IJC
International Journal of Cancer

Colorectal cancer risk and nitrate exposure through drinking water and diet

Nadia Espejo-Herrera[1,2,3], Esther Gràcia-Lavedan[1,2,3], Elena Boldo[3,4,5], Nuria Aragonés[3,4,5], Beatriz Pérez-Gómez[3,4,5],

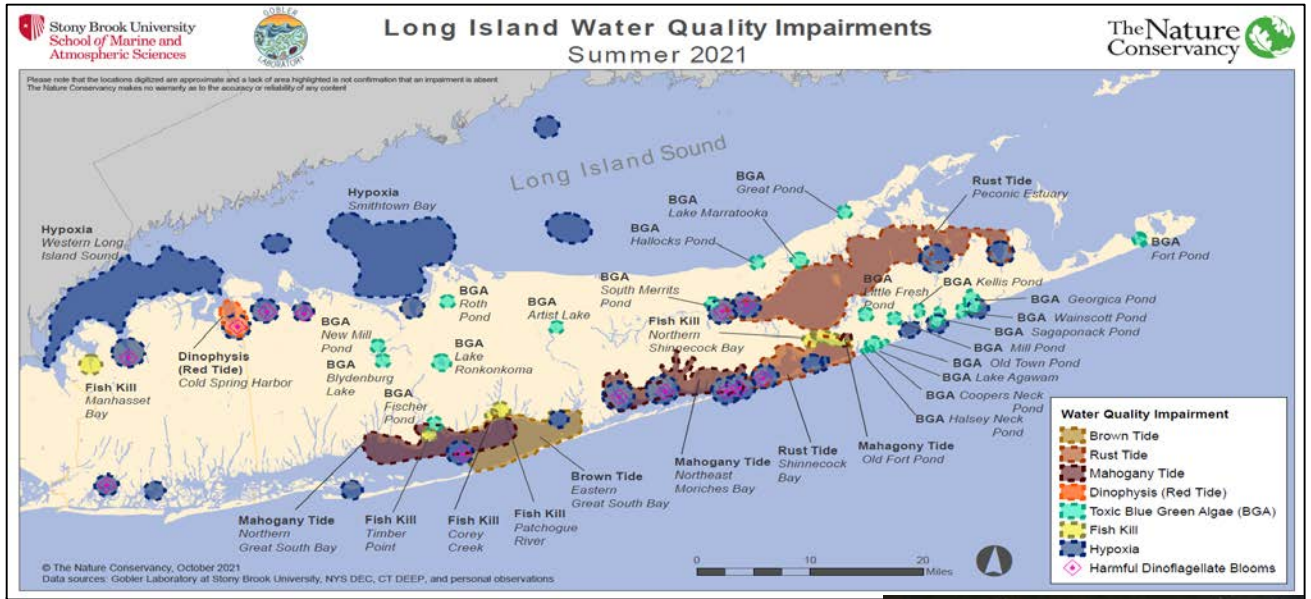
Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study

IJC
International Journal of Cancer

Jörg Schullehner[1,2,3,4], Birgitte Hansen[2], Malene Thygesen[3,4], Carsten B. Pedersen[3,4] and Torben Sigsgaard[1]

Impacts of excess nitrogen on marine and lacustrine ecosystems

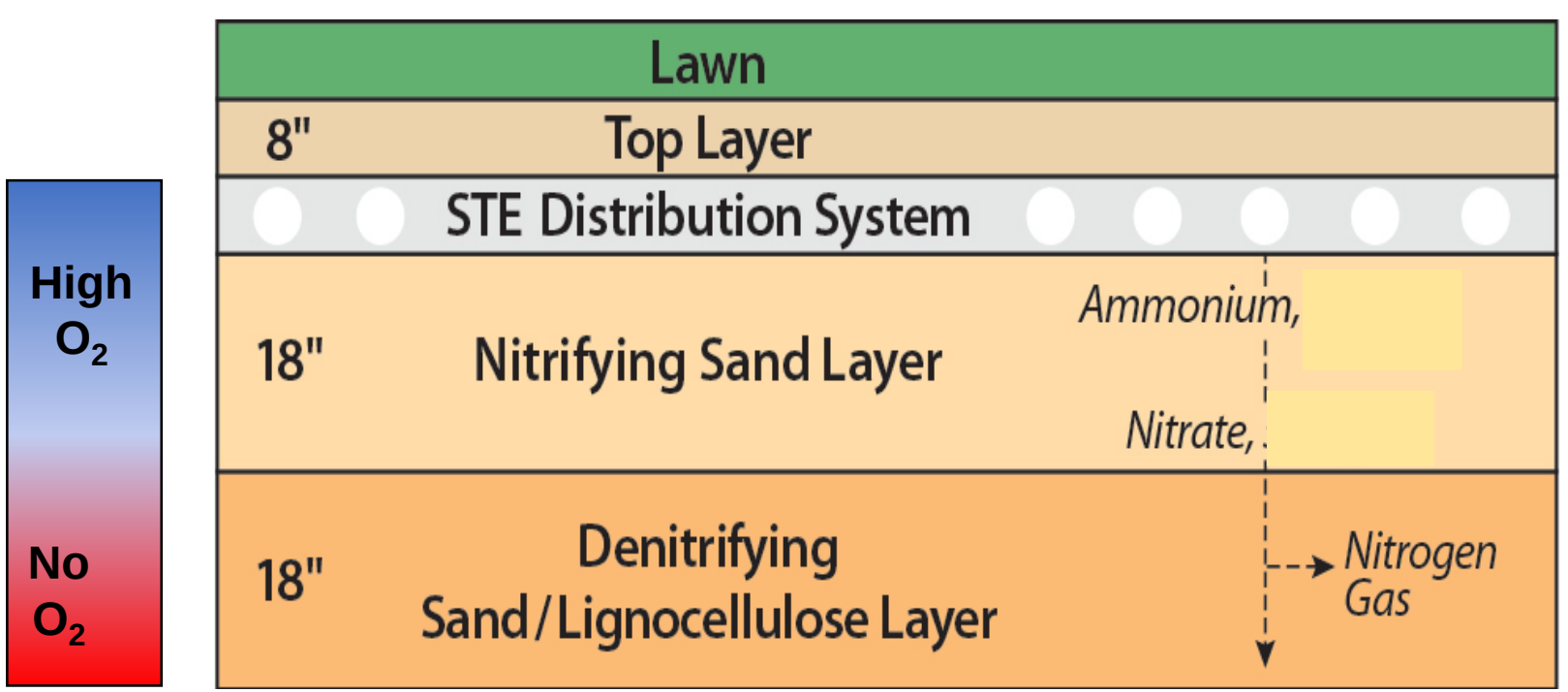
- Turbidity
- Loss of benthic plants
- Loss of aquatic nurseries and ecosystem biodiversity
- Algal blooms and oxygen stripping leading to fish kills
- Harmful algal blooms



Cesspools do not remove nitrogen.

Robust treatment systems that achieve low nitrogen concentrations at reasonable cost and with low maintenance requirements are needed

Basic principle of coupled nitrification denitrification in a Nitrogen Removing Biofilter (NRB)

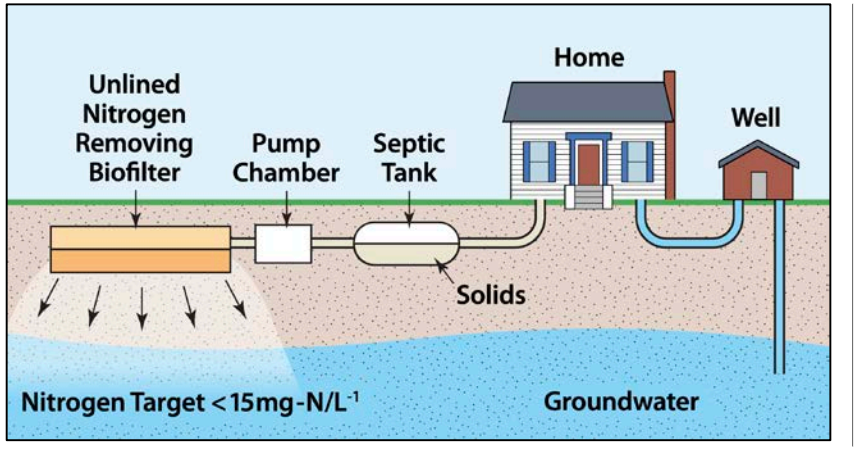


Nitrification: $NH_3 + 2\ O_2 \Rightarrow NO_3^- + H^+ + H_2O$

Denitrification: $5C_6H_{12}O_6 + 24NO_3^- \rightleftharpoons 12N_2 + 24HCO_3^- + 6CO_2 + 18\ H_2O$

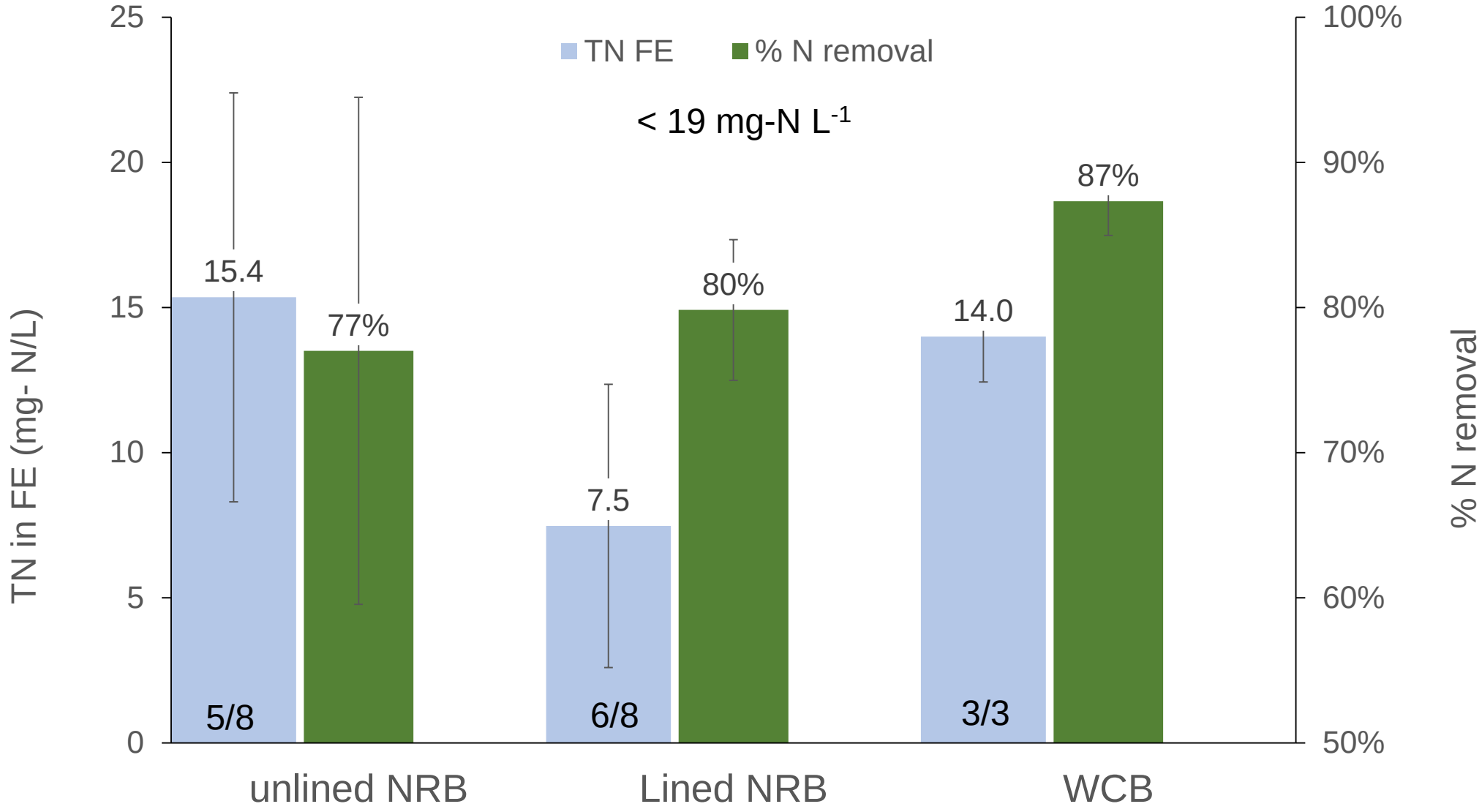
Three NRB designs

Unlined NRB

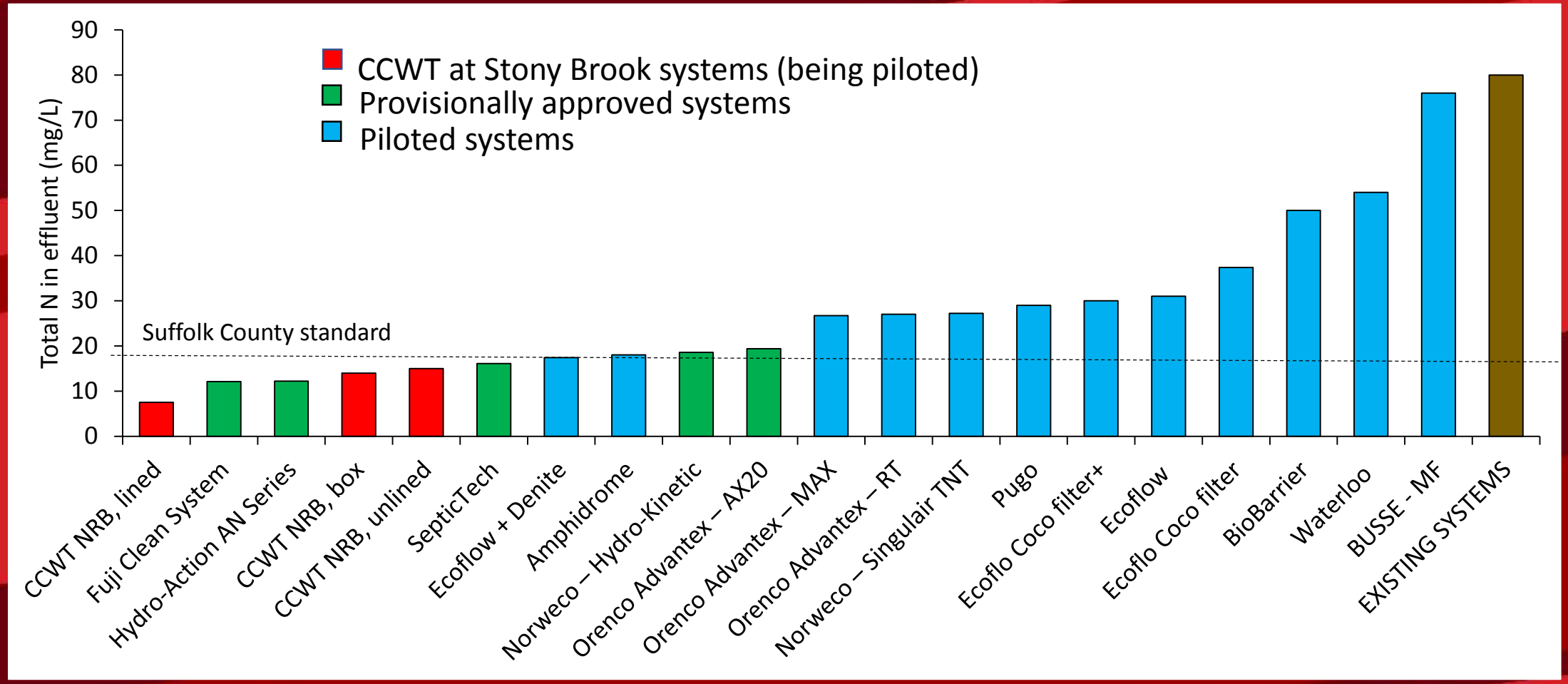


- Final effluent disposal to groundwater
- Woodchip biofilter subject to flow: no flow cycles where denitrification may be less efficient

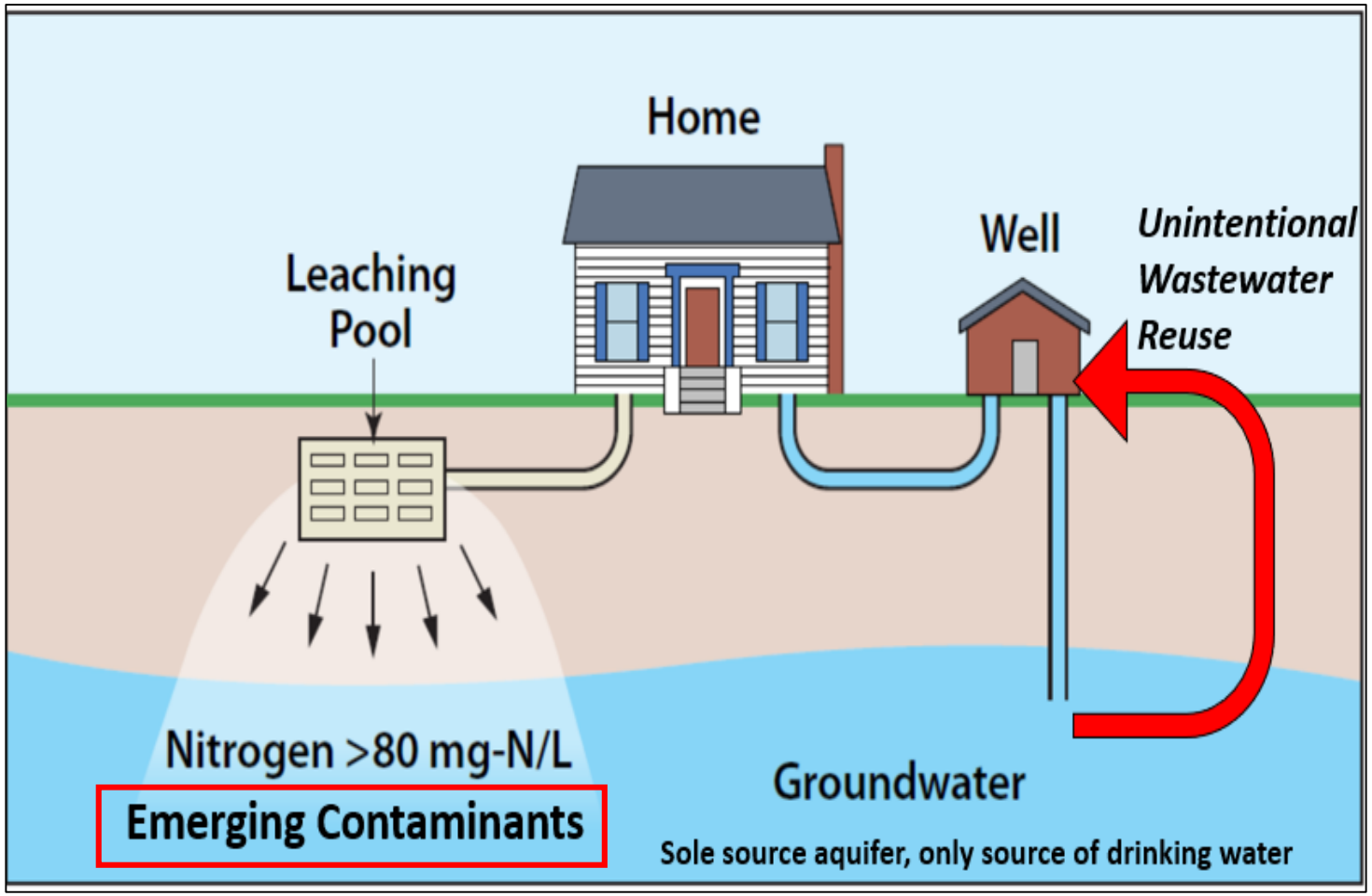
Total Nitrogen in Final Effluent
Article 19 means and %N removal



Comparison of I/A performance in Suffolk County



Wastewater contains more than nitrogen…



Science of the Total Environment 771 (2021) 144806

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

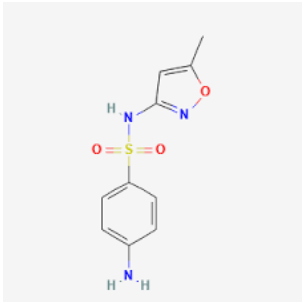
Removal of 1,4-dioxane during on-site wastewater treatment using nitrogen removing biofilters

Cheng-Shiuan Lee [a], Caitlin Asato [a], Mian Wang [a,c], Xinwei Mao [a,c], Christopher J. Gobler [a,b], Arjun K. Venkatesan [a,b,c,*]

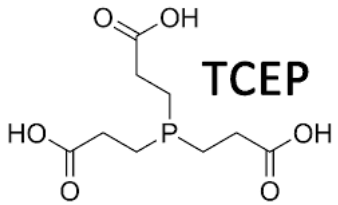
1,4-dioxane is a **probable carcinogen**, according to US EPA

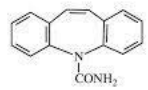
NRBs removed 1,4- dioxane to < the NYS drinking water standard (1 µg L^{-1})

50 – 100% removal of two dozen drugs, pharmaceuticals, personal care products by NRBs in Suffolk County (better removal than sewage treatment plants)



Compound	Use	Removal (%)
Acetaminophen	NSAID	94 – 100
Caffeine	stimulant	99 – 100
Paraxanthine	human metabolite of caffeine	98 – 99
DEET	mosquito repellant	82 – 96
Nicotine	stimulant	92 – 97
Cotinine	human metabolite of nicotine	86 – 98
Sulfamethoxazole	antibiotic	85 – 97
Diphenhydramine	antihistamine	97 – 95
Trimethoprim	antibiotic	87 – 90
Ciprofloxacin	antibiotic	64 – 78
Atenolol	beta blocker	88 – 97
Metoprolol	beta blocker	85 – 90
Diltiazem	calcium channel blocker	76 – 90
Carbamazepine	anticonvulsant	51 -60
Ketoprofen	NSAID	68 – 74
TCEP	flame retardant	60 – 70
Salbutamol	bronchiodialator	50 – 78
Ranitidine	anti-acid	82 – 100
Diclofenac	NSAID	76
Propranolol	beta blocker	98 – 100
Venlafaxine	antibiotic	98
Fluoxetine	antidepressant (SSRI)	64 – 66
Lamotrigine	anticonvulsant	82
Primidone	anticonvulsant	58

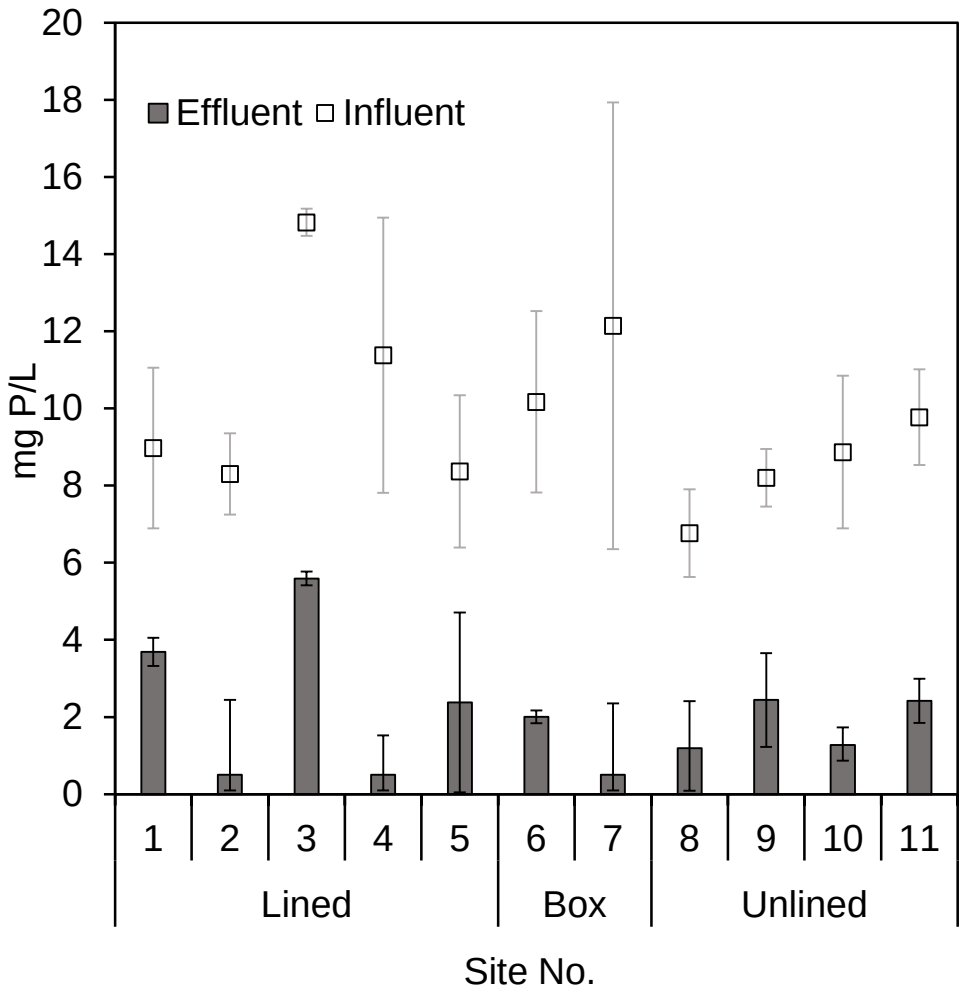




Data courtesy of Dr. Tricia Clyde

Phosphorus removal from NRBs

Site number	Configuration	Operation duration (months)	P Removal Efficiency (%)
1	Lined	5	58.9
2	Lined	6	94.0
3	Lined	27	62.3
4	Lined	30	95.6
5	Lined	43	71.6
6	Box	17	80.2
7	Box	32	95.9
8	Unlined	5	82.4
9	Unlined	6	70.2
10	Unlined	34	85.7
11	Unlined	43	75.2



(Data collected since June 2021)

Advancing NRBs to from pilot testing to provisional acceptance permitting

Experimental → Pilot Required units: 8 → Provisional Required units: 20 → General Use

unlined NRB 

Anticipated decision on Provisional Acceptance: Q1-2023

Lined NRB 

Anticipated decision on Provisional Acceptance: Q1-2023

Woodchip box NRB 

Additional installs Fall 22022; testing and anticipated decision on Provisional Acceptance by year-end 2023

Center initiated grant financing of installations → Commercial transact potential w/ SIP grants

NRB installations on a commercial basis under provisional permitting

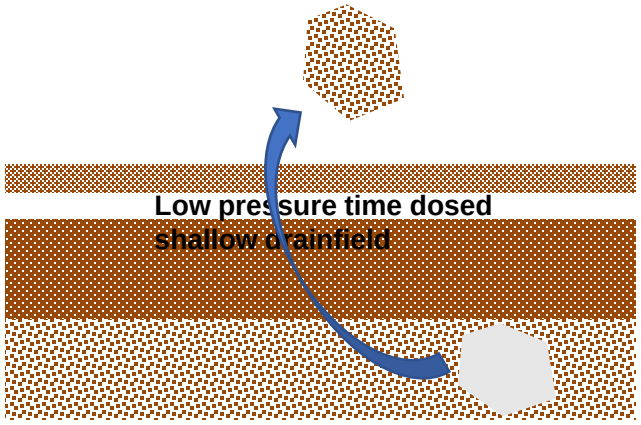
- Carbon longevity
- Footprint & landscaping
- Cost
- Installation time

Carbon Longevity

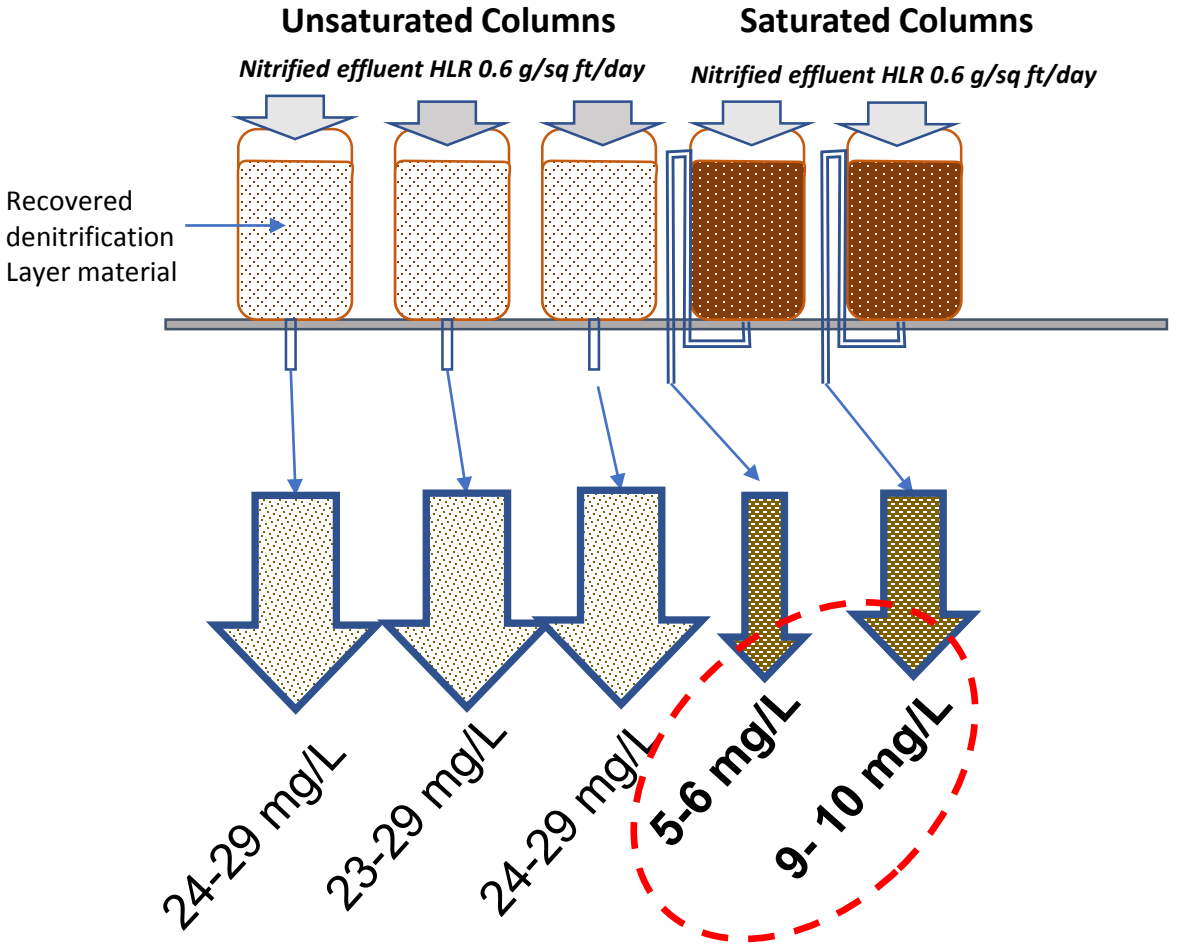
MASSTC
The Massachusetts Alternative Septic System Test Center

STONY BROOK GRADUATE STUDENT ORGANIZATION

6 year in-ground Unlined NRB prototype

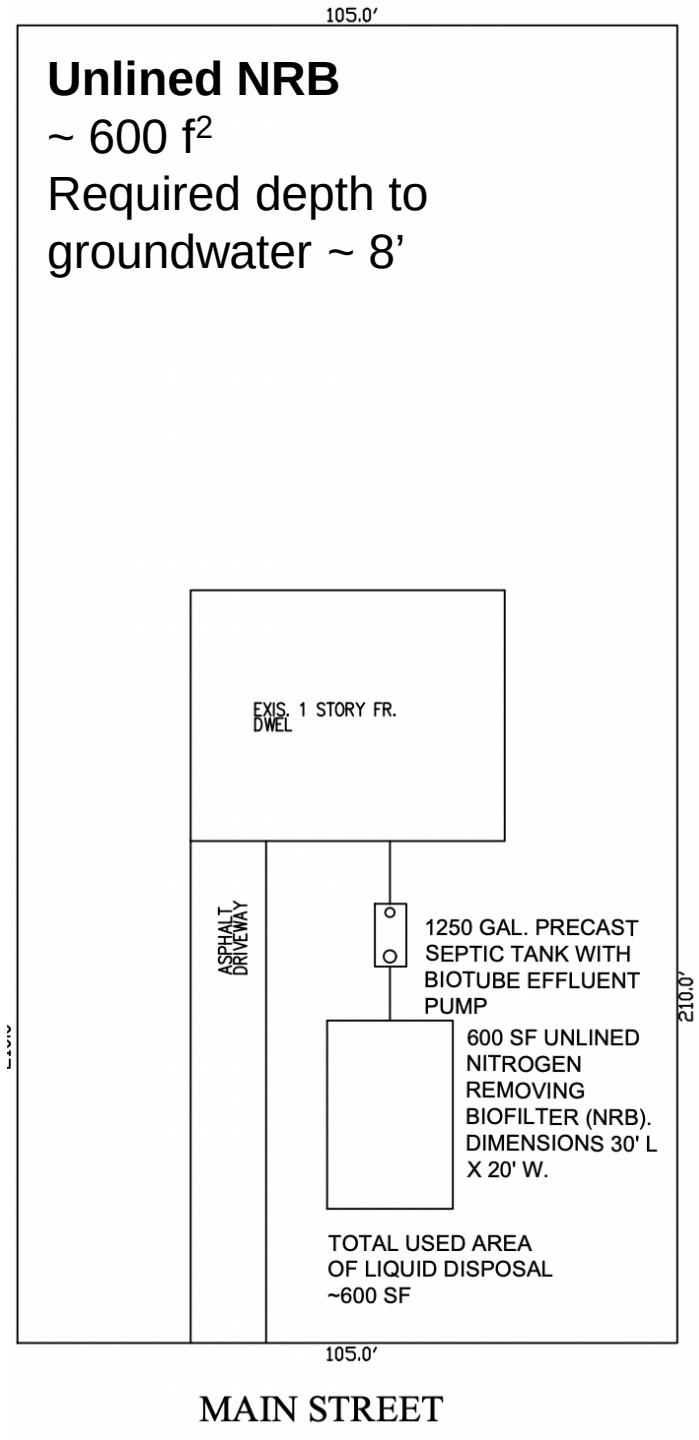


TN influent 25 -29 mg/L



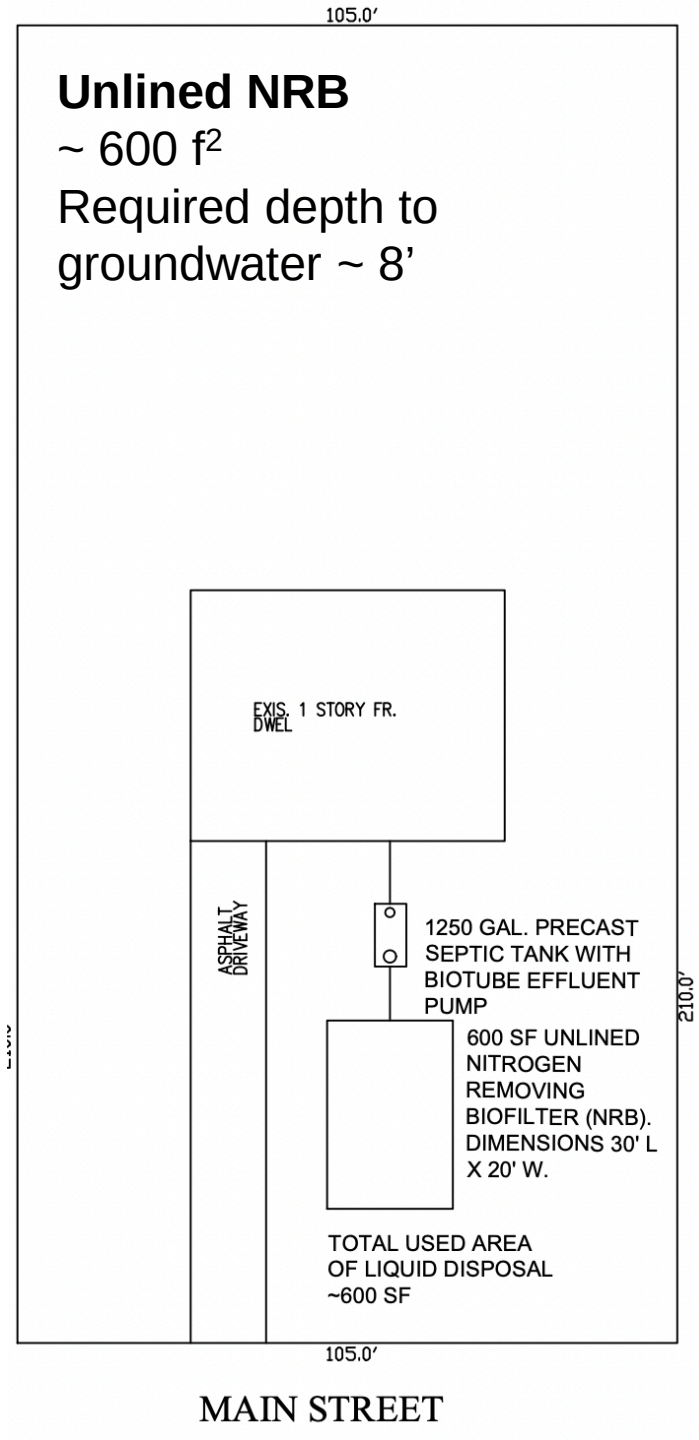
Footprint of unlined NRB, landscaping

Unlined NRB
~ 600 f^2
Required depth to groundwater ~ 8’

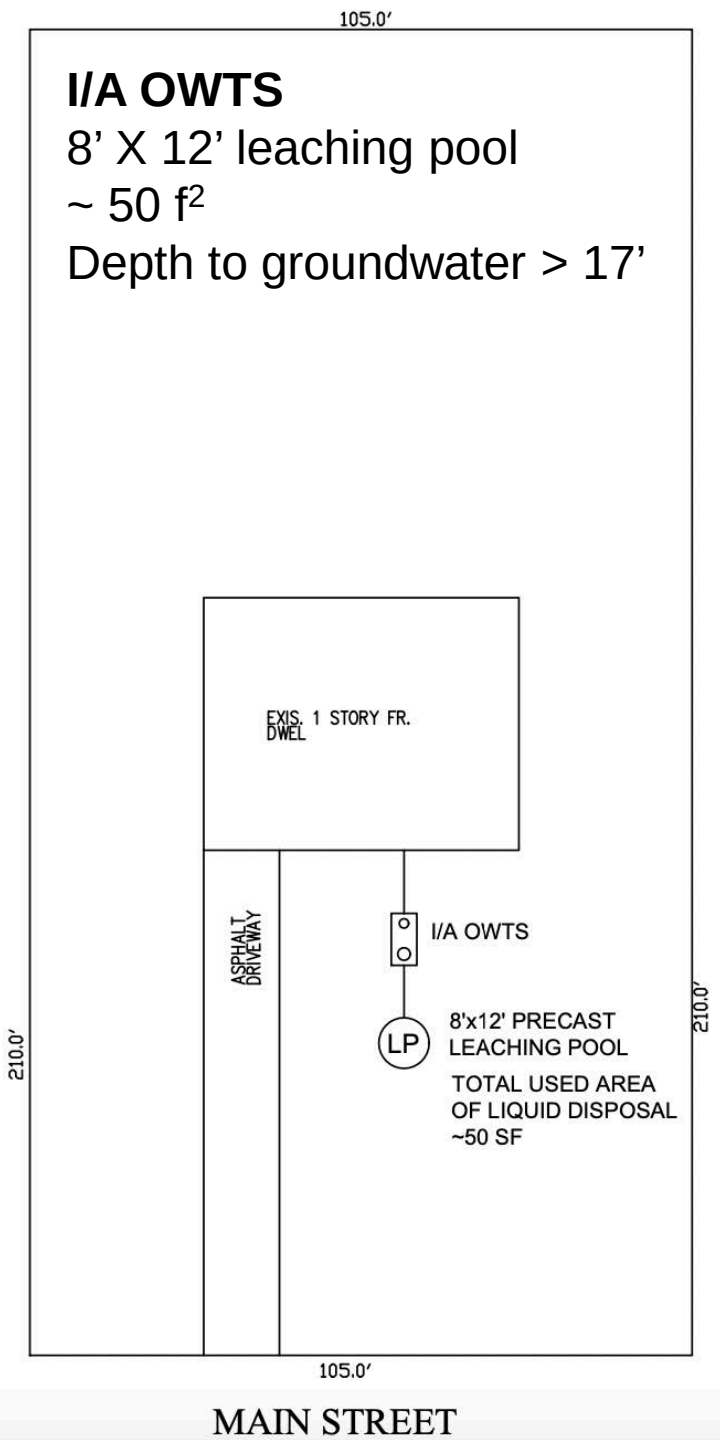


Design alternatives for a Four-bedroom home on ½ acre plot

Unlined NRB
~ 600 f^2
Required depth to groundwater ~ 8’

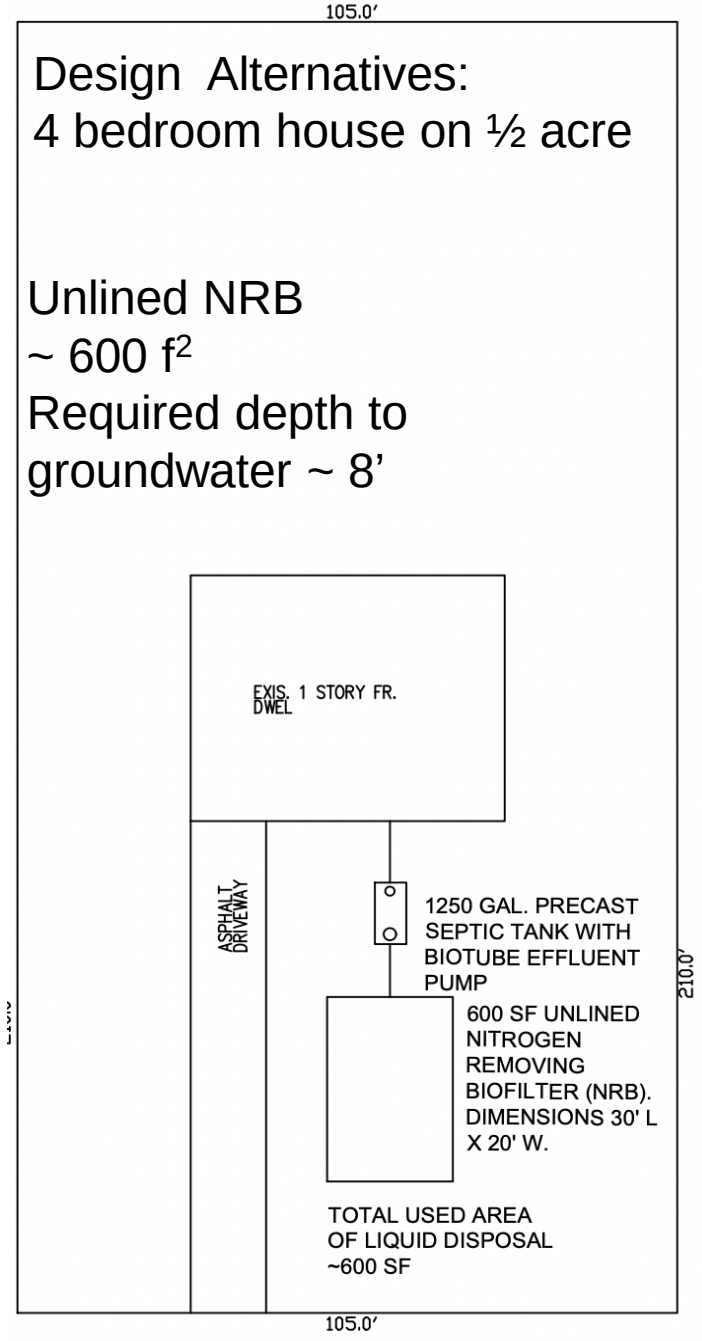


I/A OWTS
8’ X 12’ leaching pool
~ 50 f^2
Depth to groundwater > 17’

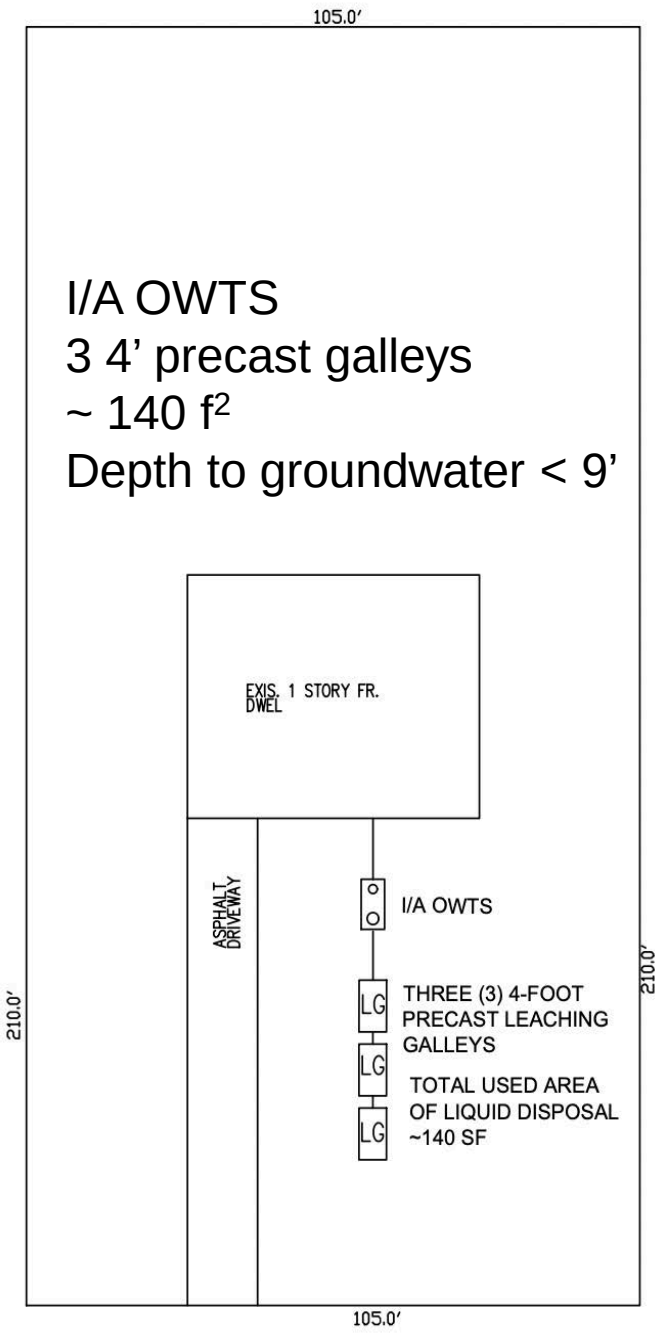


Design Alternatives:
4 bedroom house on ½ acre

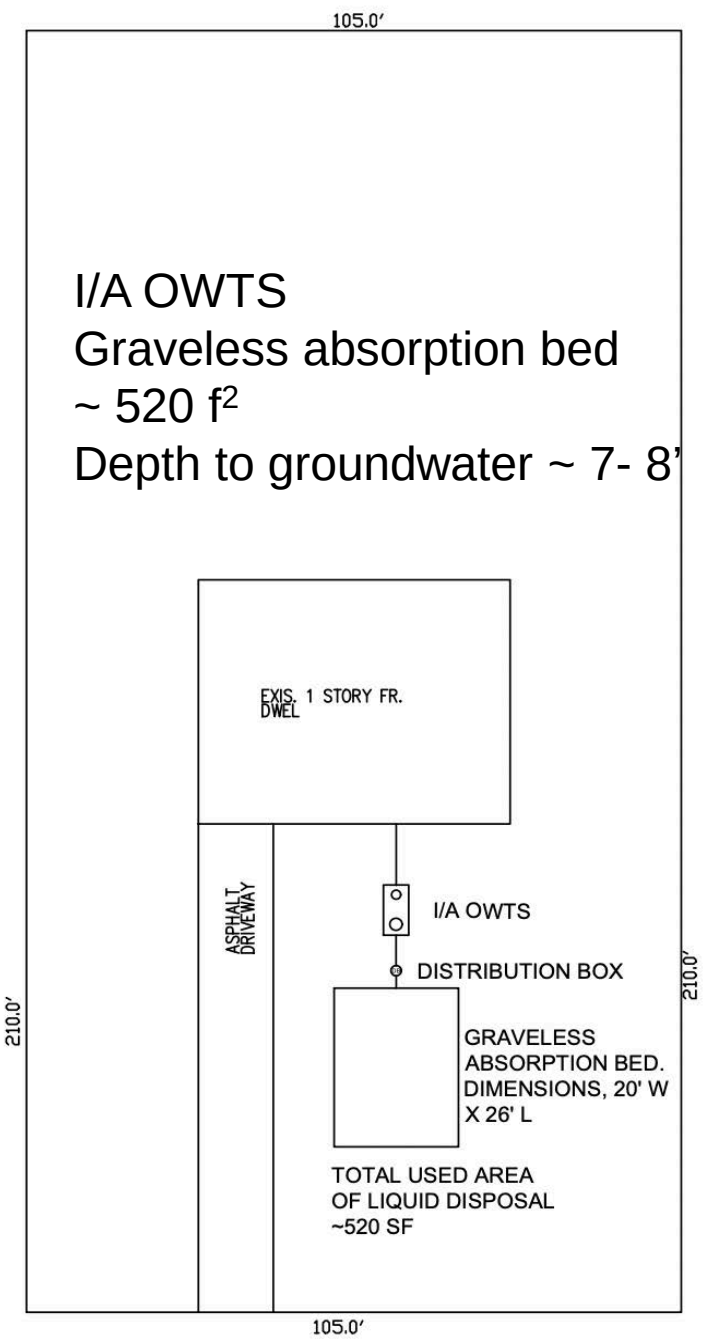
Unlined NRB
~ 600 f^2
Required depth to groundwater ~ 8’



I/A OWTS
3 4’ precast galleys
~ 140 f^2
Depth to groundwater < 9’



I/A OWTS
Graveless absorption bed
~ 520 f^2
Depth to groundwater ~ 7- 8’



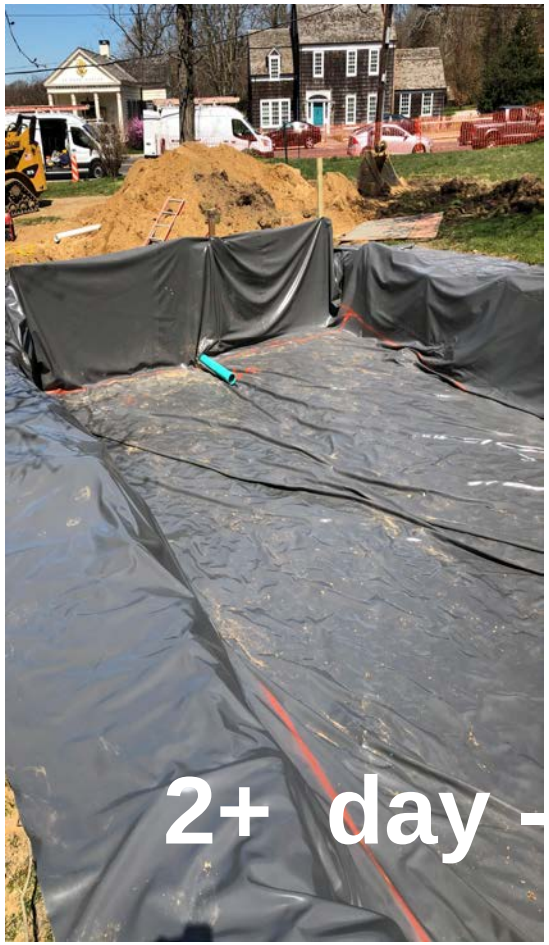
Equipment & materials costs: unlined NRB at four-bedroom site

		Unlined NRB	Proposed model
Septic Tank	1,500 precast	$2,200	$2,200
Pump Tank	1,000 precast	2,200	0
electrical panel	Orenco	900	900
pump/float/inducer	simplex	1,400	1,400
pipes & fittings, liner		750	750
Geomat	100’ roll	1,400	1,400
sand	50 cy $45	2,250	2,250
woodchips	25 cy $60	1,500	750
fill removal		2,300	1,200
Total Cost		**$14,900**	**$10,850**

- Relative to total costs of installation, I/A equipment & available SIP grants, equipment and materials costs are not likely the dominant cost.
- Further cost savings potentially achievable by eliminating pump tank and rationalizing costs for woodchips and fill removal.

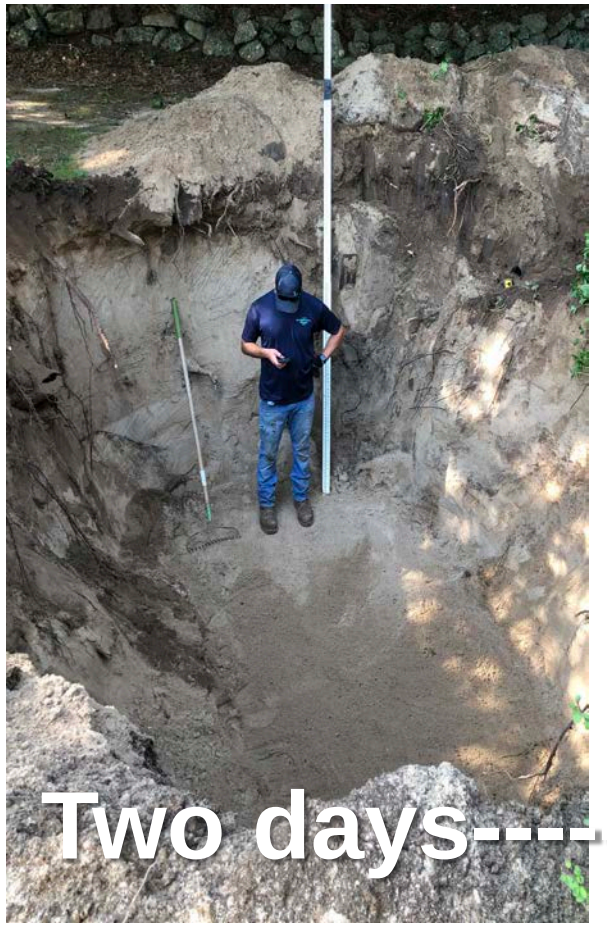
Installation time for different NRB design

Lined & woodchip box NRBs

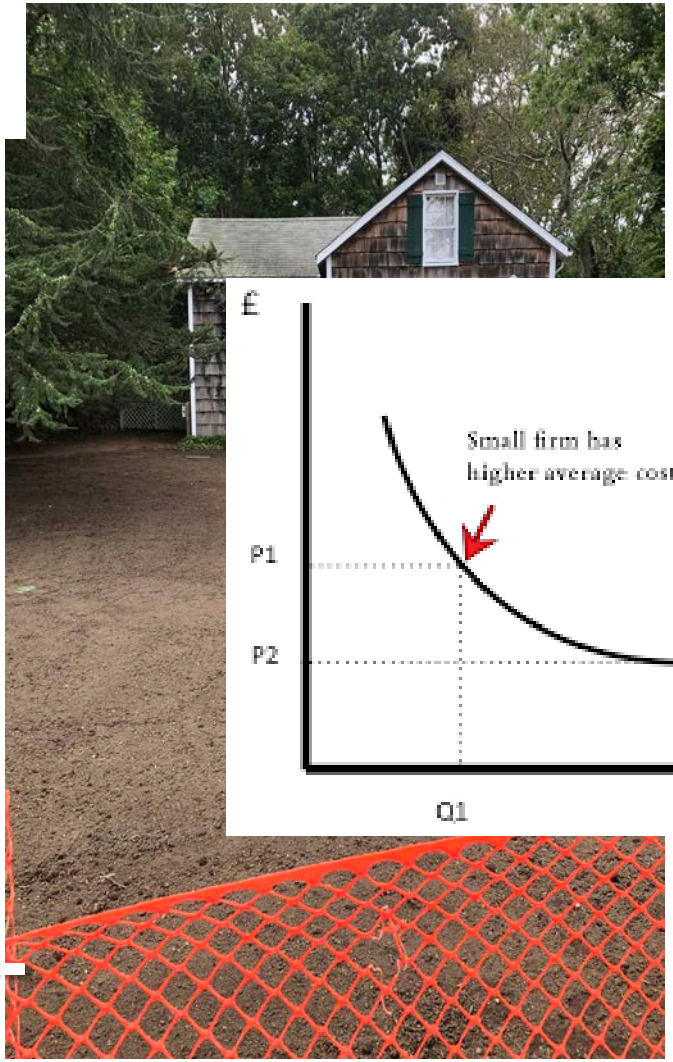


Installation time for different NRB designs

Unlined NRB



Two days-----



Lined & woodchip box NRBs

Two days+

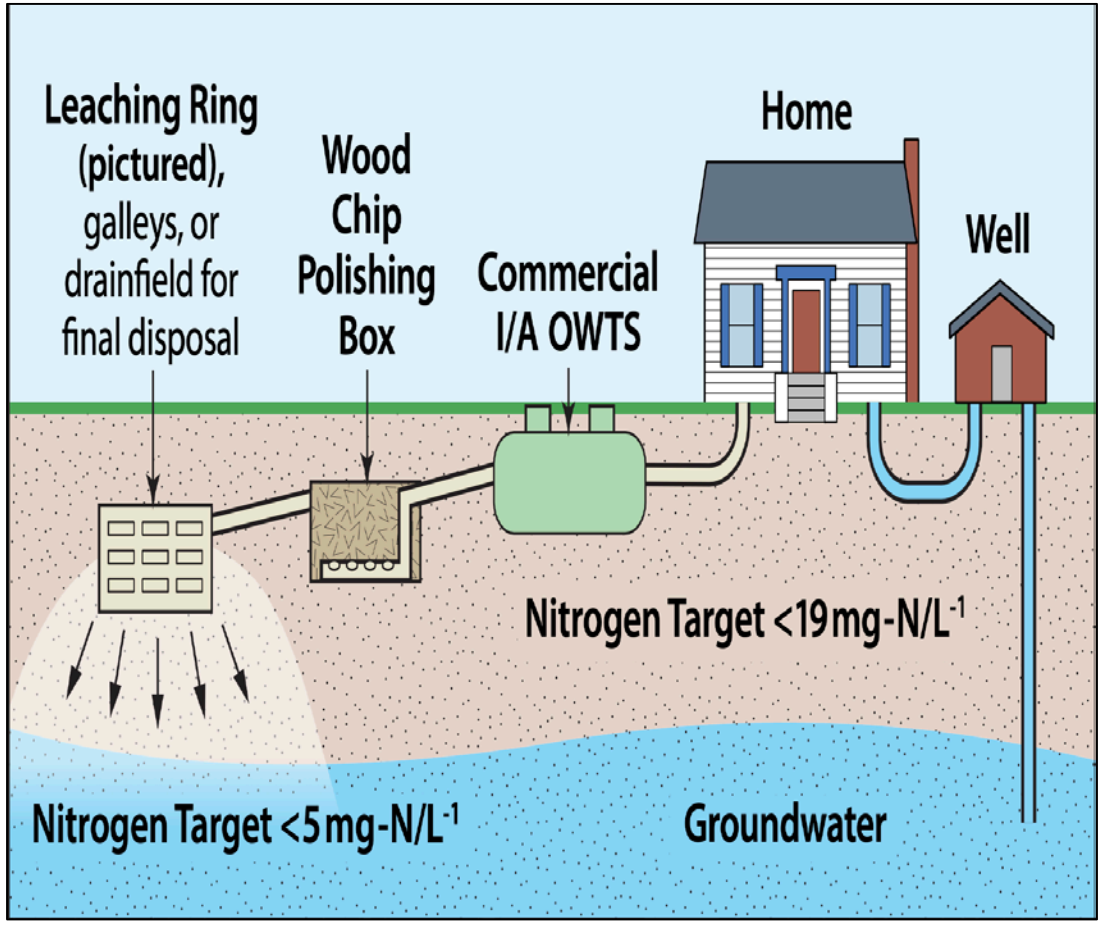
Next steps for non-proprietary NRBs

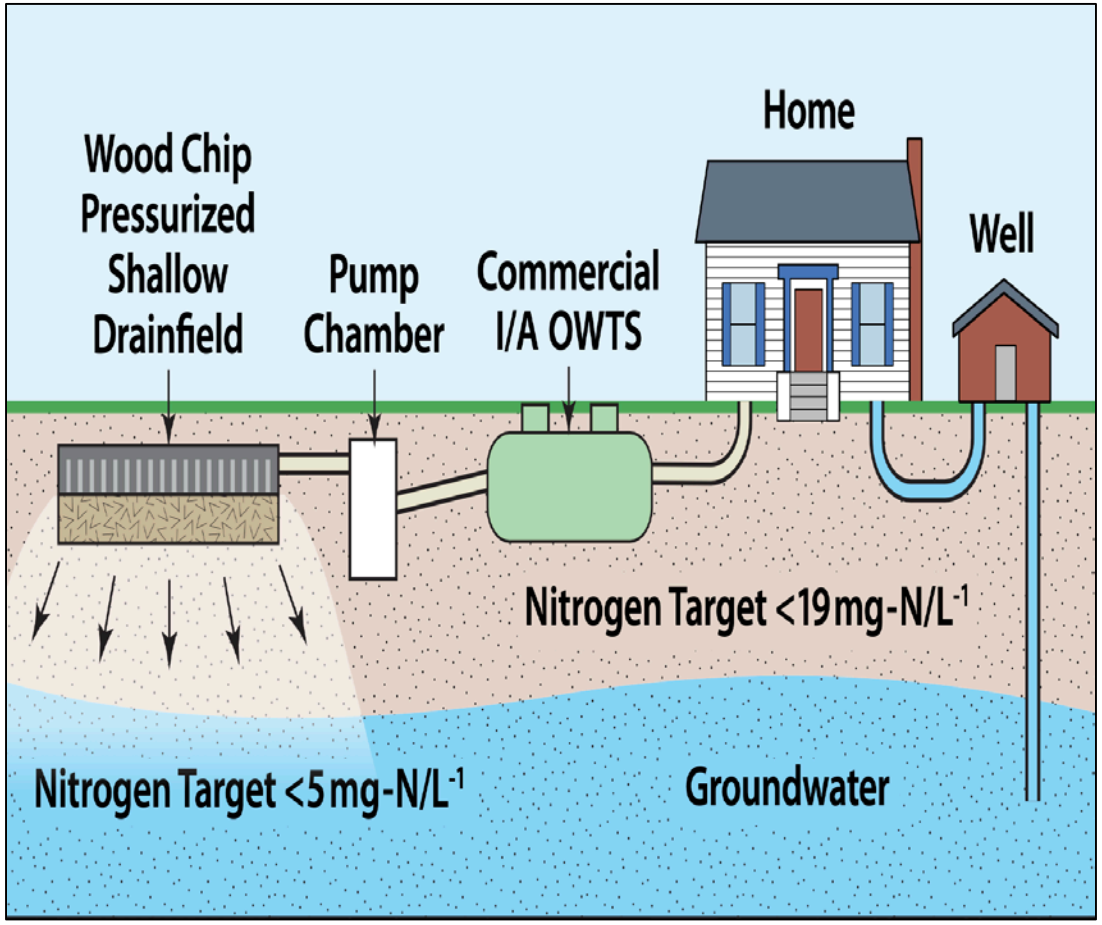
- Continue research on woodchip sources and silt to improve performance of unlined NRBs to accommodate higher influent TKN

- Publish guidance document and design/installation training course
  - Reduce costs of woodchips & fill
  - Reduce time required for NRB installations

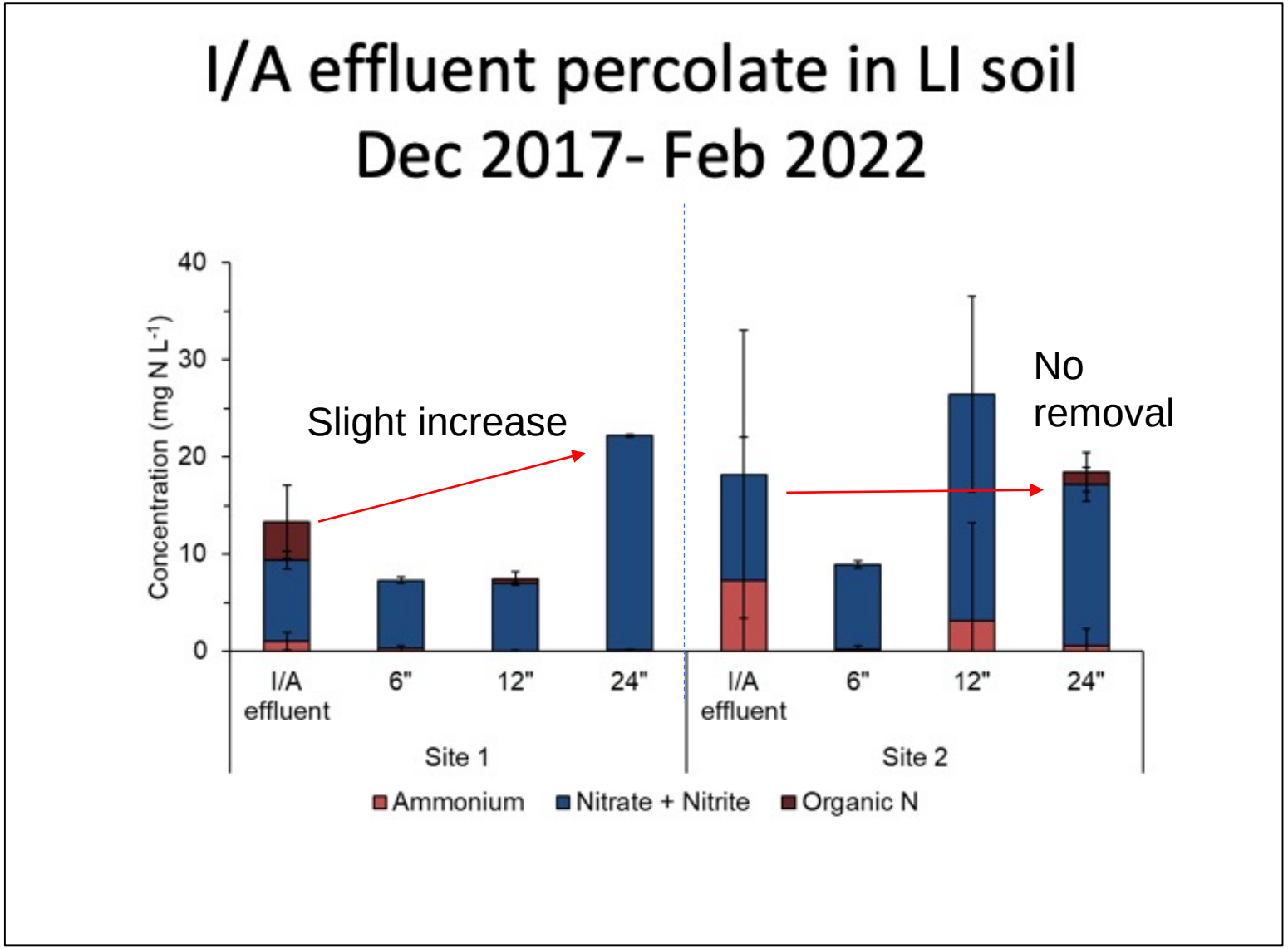
- Work with installers to make NRBs a common I/A septic solution in Suffolk County and beyond

Woodchip biofilters coupled to commercial IA OWTS





Conventional drainfields do not remove N



Coupled commercial IA – CCWT woodchip box systems removal nearly all nitrate