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Environmental Engineers & Scientists

Florida HEALTH

FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATEGIES (FOSNRS) STUDY

PNRS II Draft Report

RRAC Meeting Presentation
September 11, 2013

UF UNIVERSITY of FLORIDA Gulf Coast Research and Education Center

SCHOOL OF MINES 1874 COLORADO

AET Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS

Presentation overview

- PNRS II Background
- PNRS II Results
- Next Steps
- Questions and Answers

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TASK A
Passive Nitrogen Removal Study (PNRS) II
Background

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PNRS II test facility was developed

- Follow up to PNRS I with larger, pilot scale units and various media combinations
- Established test facility at Gulf Coast Education and Research Center (University of Florida IFAS)
- Test program for in-vessel and in-situ pilot systems
- Various nitrification and denitrification biofilters tested
- Operated on septic tank effluent for 12+ months
- Produce scalable design criteria from pilot scale biofilters for subsequent full-scale testing

Test facility included numerous treatment trains

- All used two-stage biofilters:
  - Stage 1 Nitrification
  - Stage 2 Denitrification
- Stage 1 unsaturated filters included 2 media layers and evaluated 15” and 30” media depths
- We also evaluated single pass vs recirculating stage 1 biofilters
- For denitrification, we evaluated both lignocellulosic and sulphur denitrification biofilters
- We also tested reactive media in a more in-situ/in-ground system approach

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Various nitrification media were studied

Examples of Stage 1 Media

Zeo-Pure clinoptilolite

Expanded polystyrene

Filter sand

Expanded clay

Various denitrification media were studied

Examples of Stage 2 Media

Lignocellulosics

Elemental Sulphur

Expanded Clay

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PNRS II test facility construction

Setting up tanks

Mixing Media Batches

Underdrain

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Placing media in tanks

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Four process groups established for study

- Group A Systems (5): Single pass Stage 1 Biofilters directly connected to Stage 2 Upflow Biofilters
- Group B Systems (4): Recirculating Stage 1 Biofilters
- Group C Systems (4): Horizontal Stage 2 Biofilters
- Group D Systems (4): Stacked Unsaturated/Saturated (*in situ*) Biofilters

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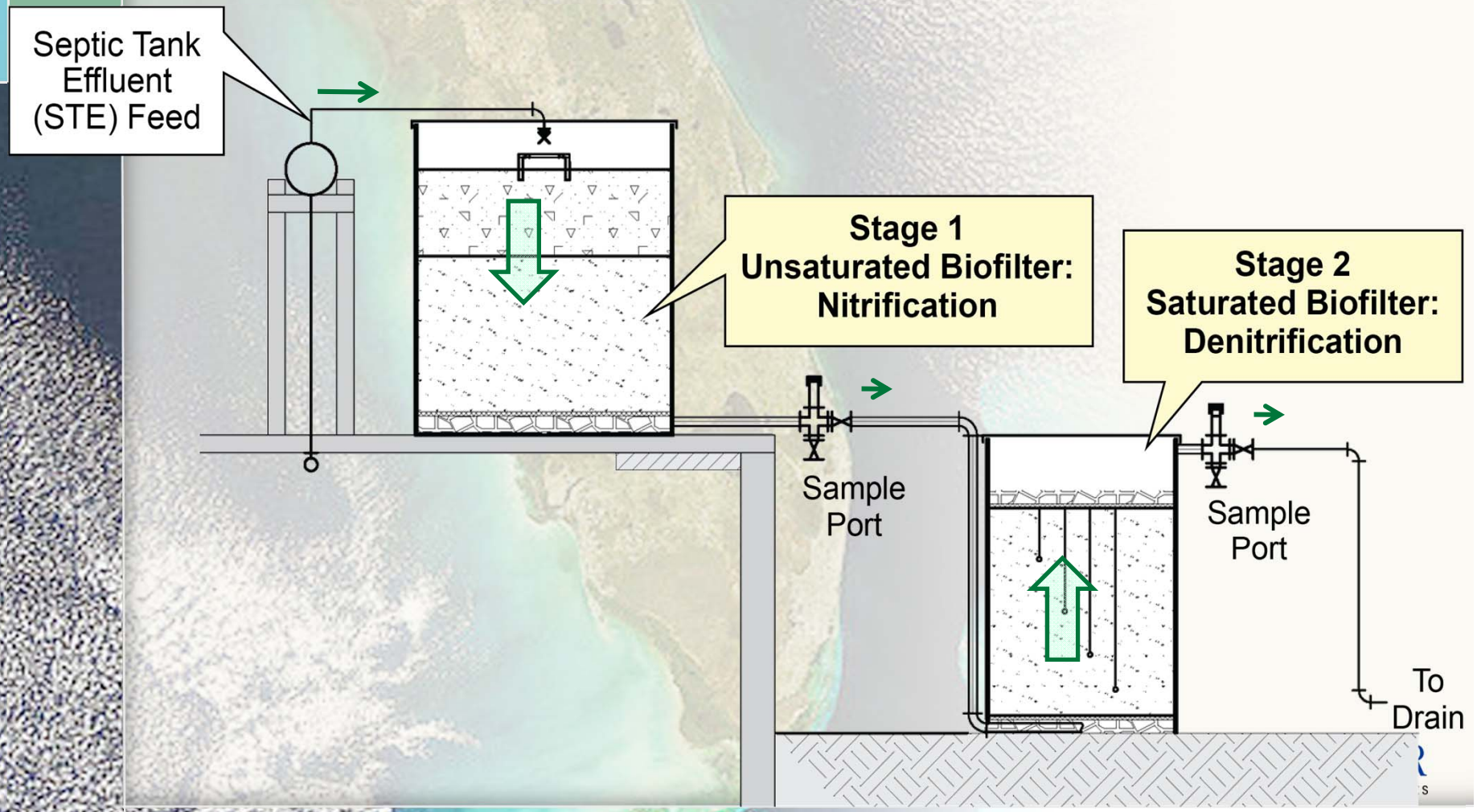
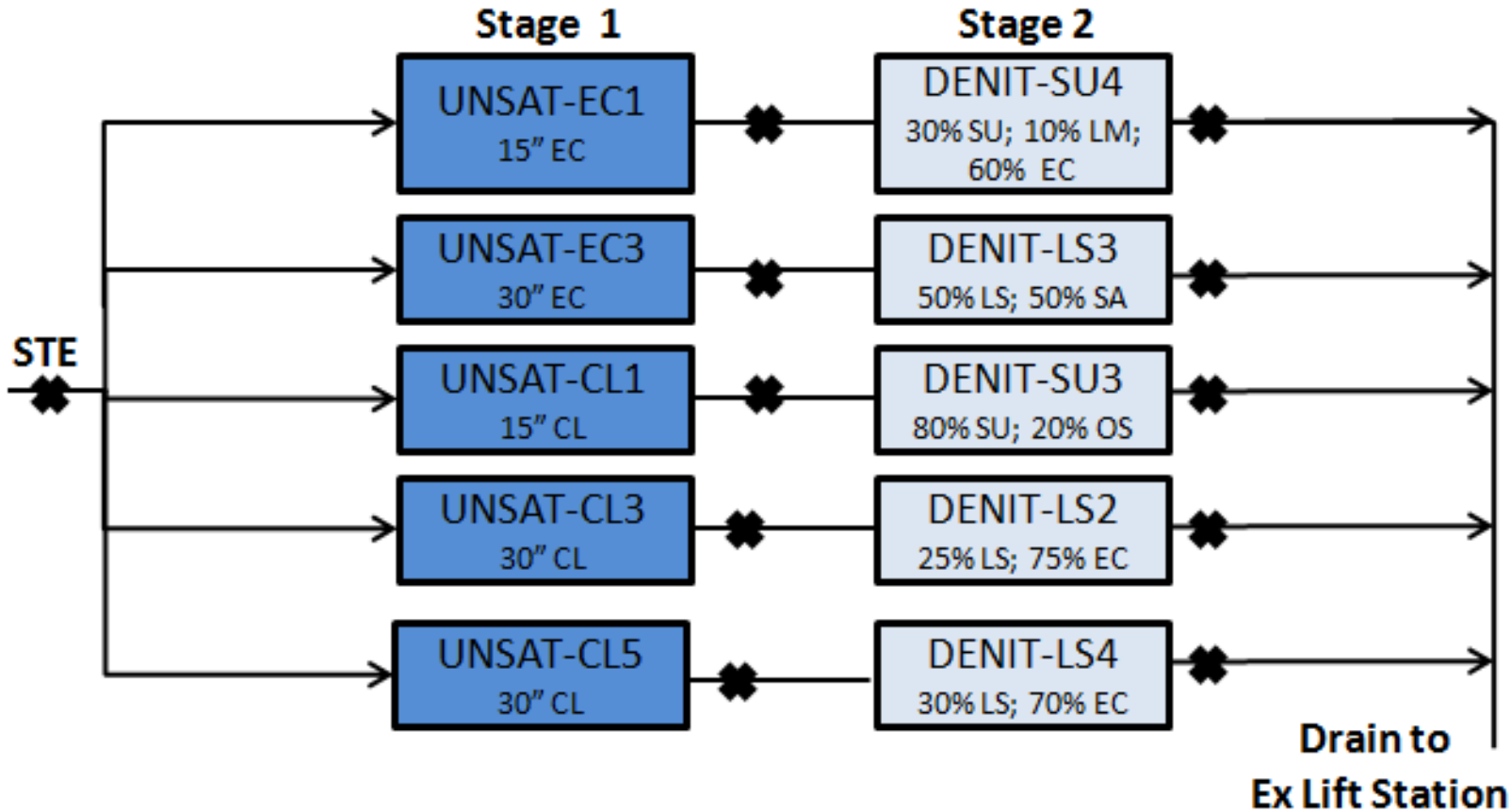
Group A
Two stage single pass biofilter schematic



Group A
Two-stage single pass treatment trains



Stage 1 media: CL = clinoptilolite, EC = expanded clay
Stage 2 media: EC = expanded clay, LM = limerock, LS = lignocellulosic, OS = oyster shell, SA = sand, SU = sulphur

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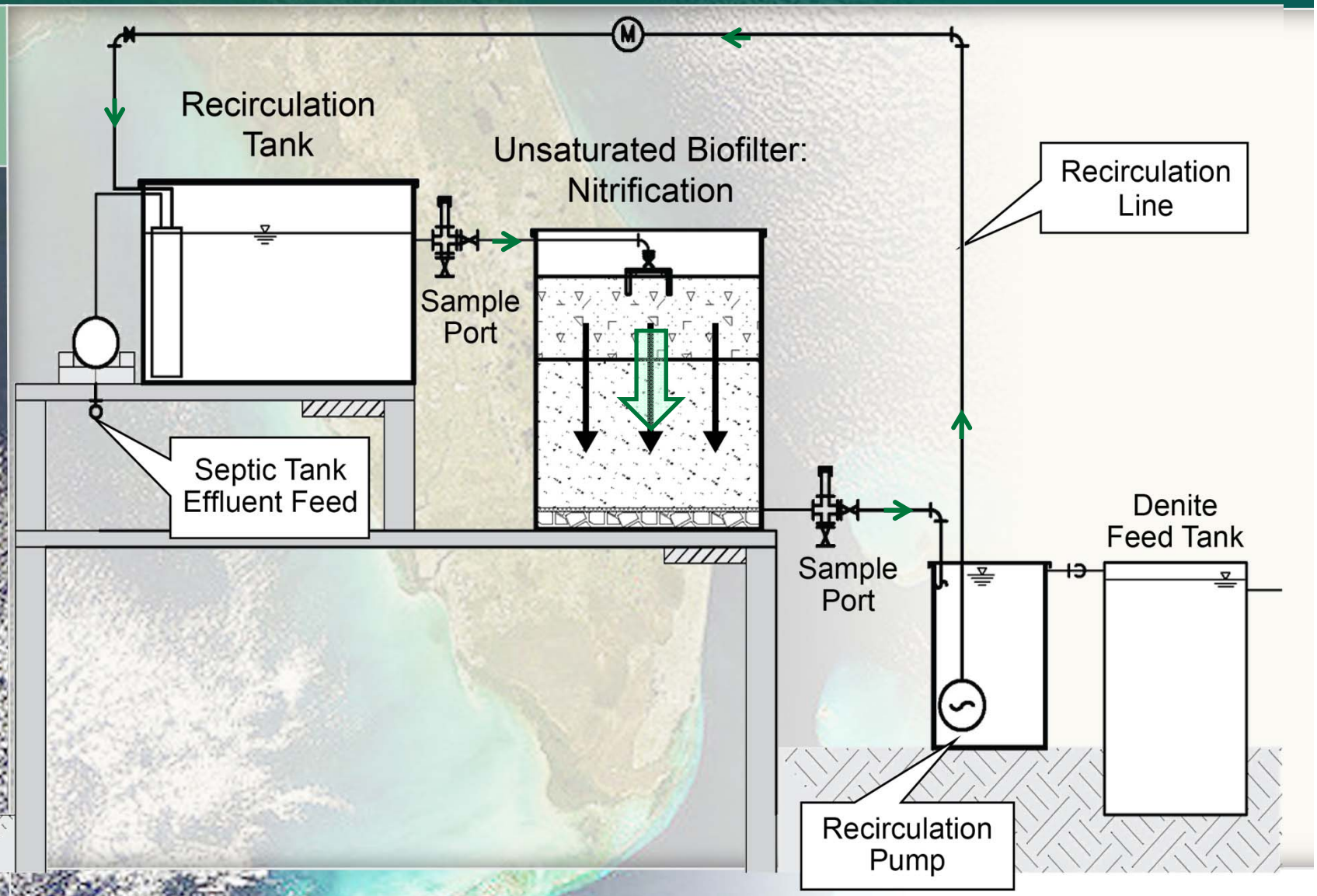
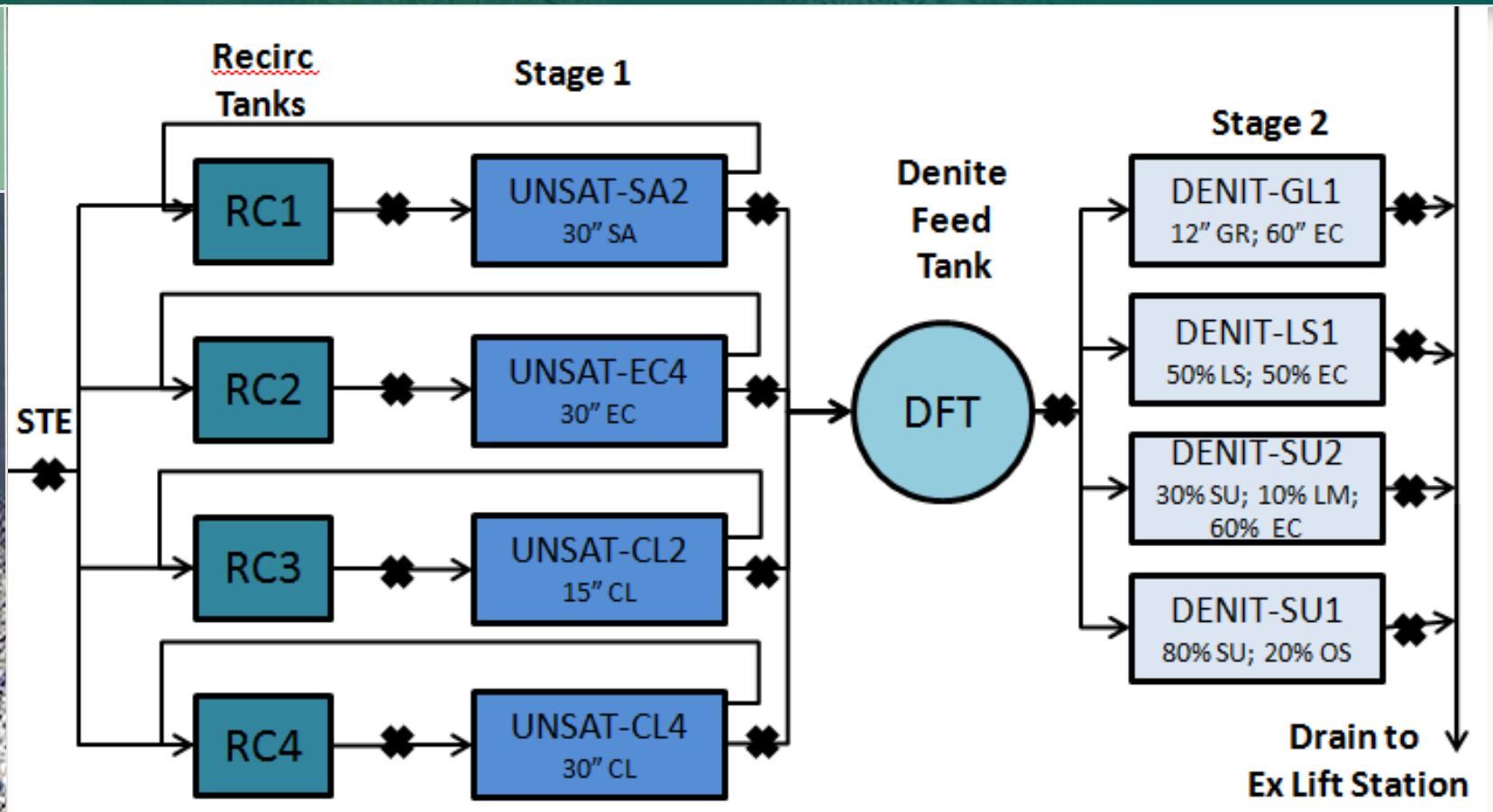
Group A
Two-stage single pass biofilters

Group B
Stage 1 recirculating biofilters schematic



Group B (recirculating Stage 1 biofilters) and Group C (saturated Stage 2 biofilters)



Stage 1 media: CL = clinoptilolite, EC = expanded clay, SA = sand
Stage 2 media: EC = expanded clay, GR = gravel, LM = limerock, LS = lignocellulosic, OS = oyster shell, SU = sulphur

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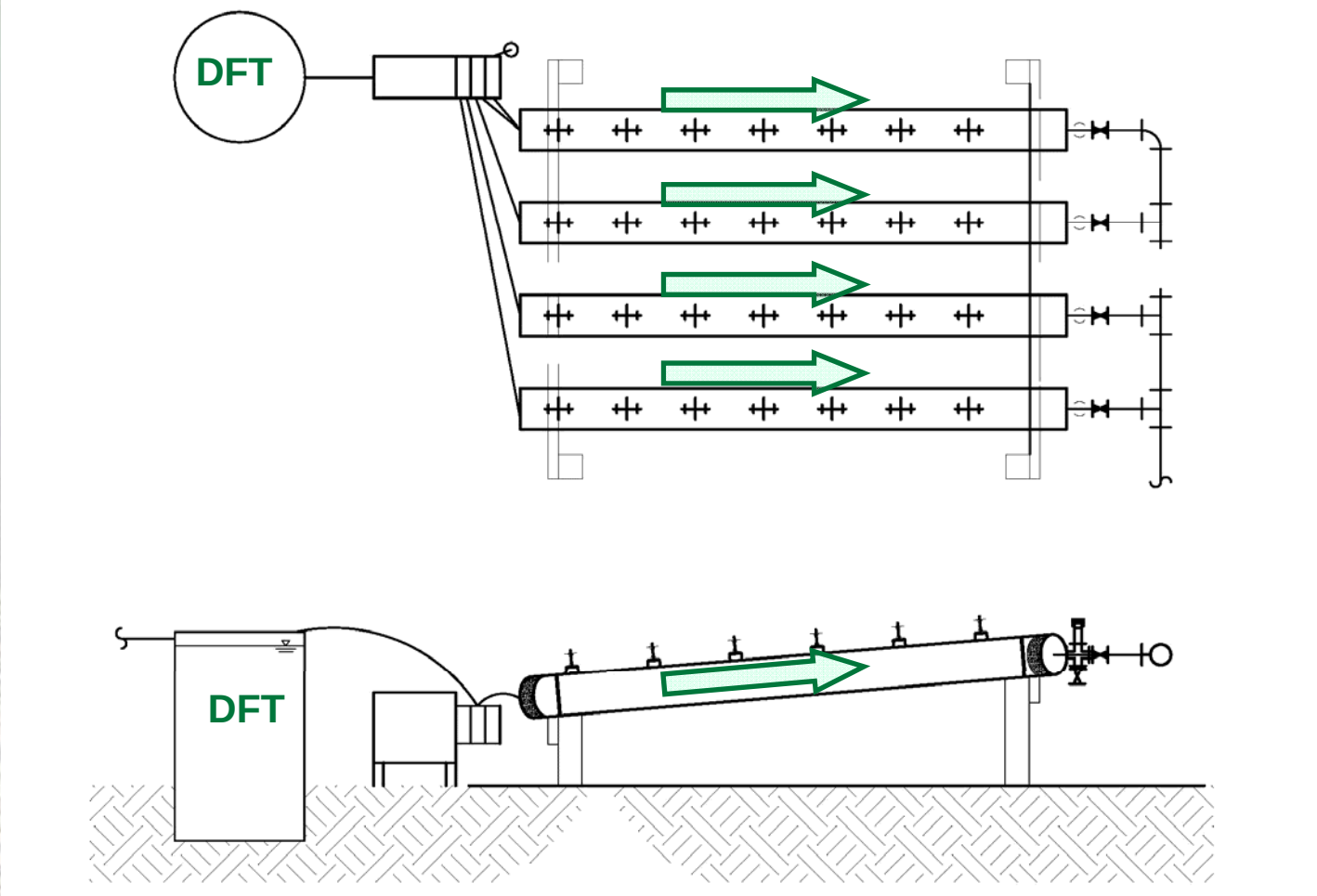
Group C
Horizontal Stage 2 biofilters schematic



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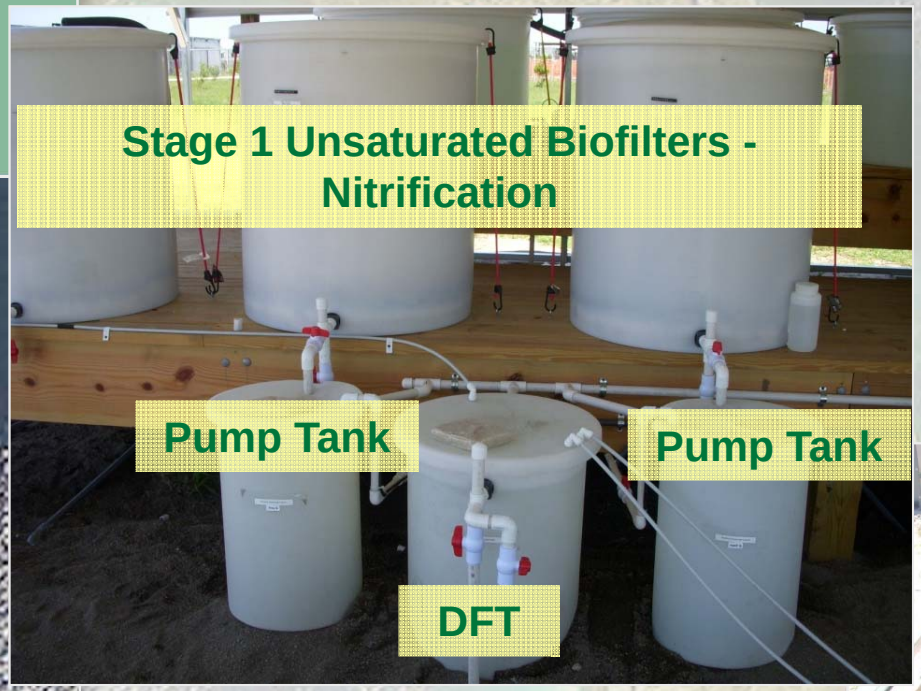
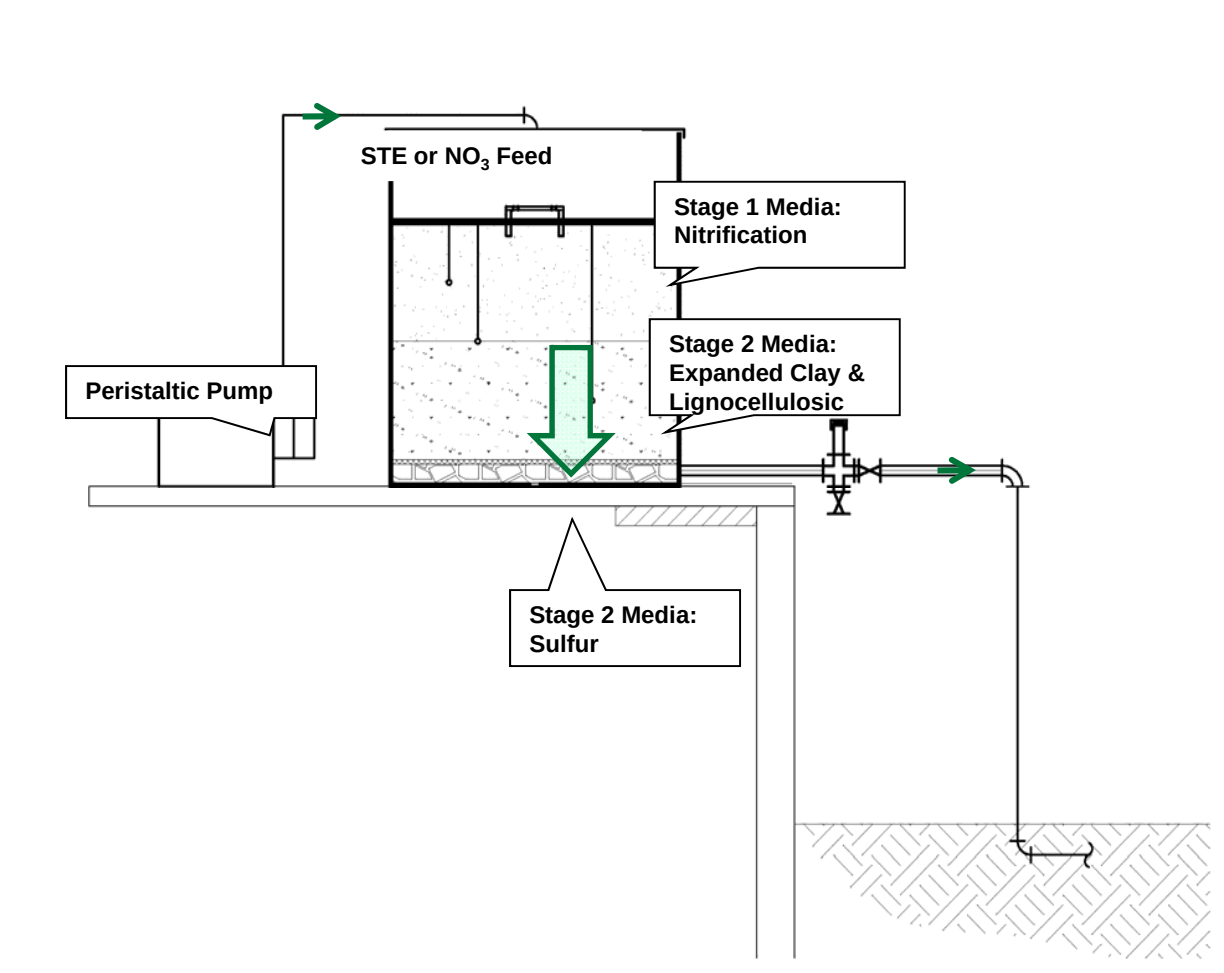
Group B (Stage 1 recirculating biofilters) & Group C (Stage 2 saturated biofilters)



Group D
Stacked saturated/unsaturated (*in situ*) biofilter schematic



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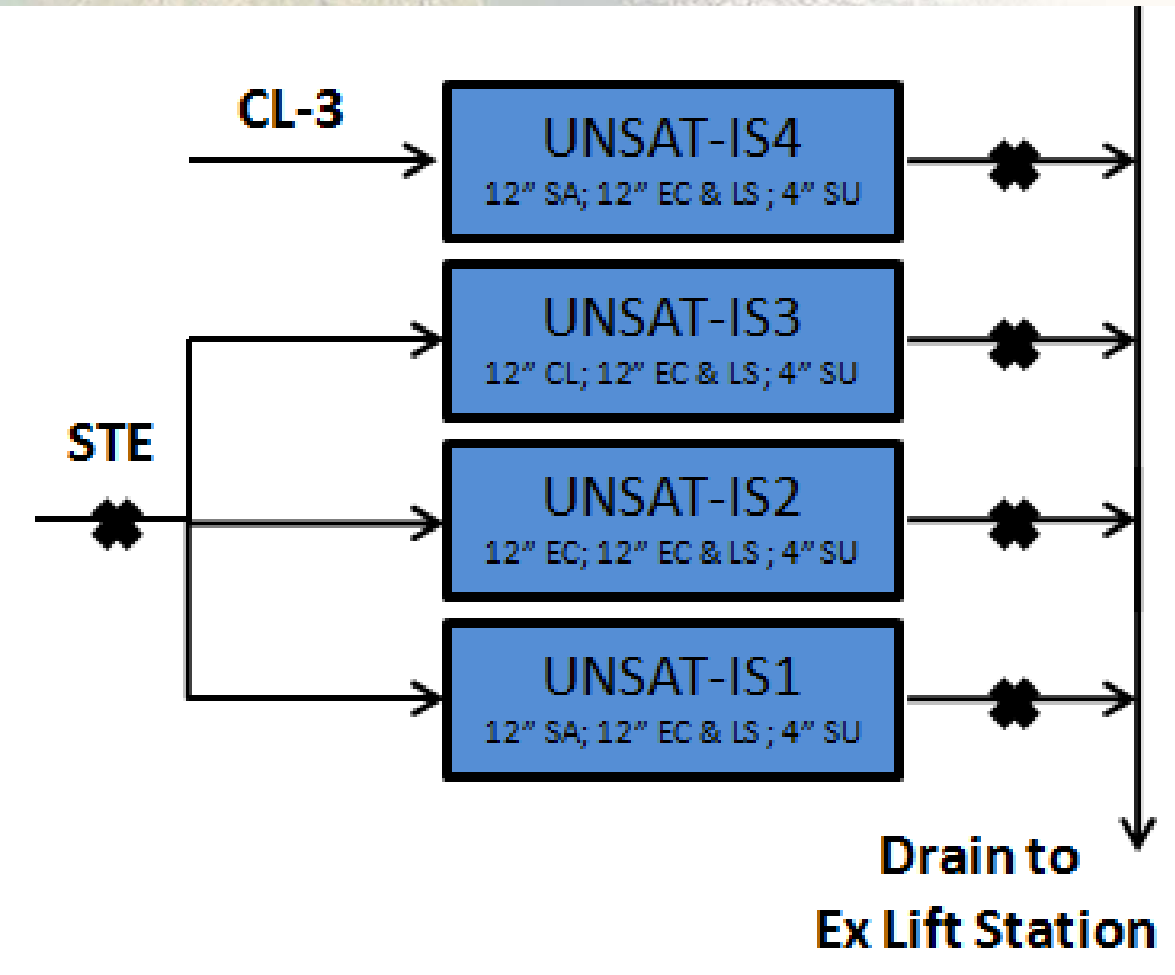
Group D
Stacked saturated/unsaturated (*in situ*) biofilters



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PNRS II monitoring

Sample Event	Date	Experimental Day
Start-up	May 17, 2010	0
Sample Event 1	July 1, 2010	45
Sample Event 2	August 31, 2010	106
Sample Event 3	November 10, 2010	177
Sample Event 4	January 13, 2011	241
Sample Event 5	March 17, 2011	304
Sample Event 6	May 19, 2011	367
Sample Event 7	June 23, 2011	402
Sample Event 8	June 28, 2011	407
Sample Event 9	September 15, 2011	486
Sample Event 10	March 20, 2013	1,038

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PNRS II Results

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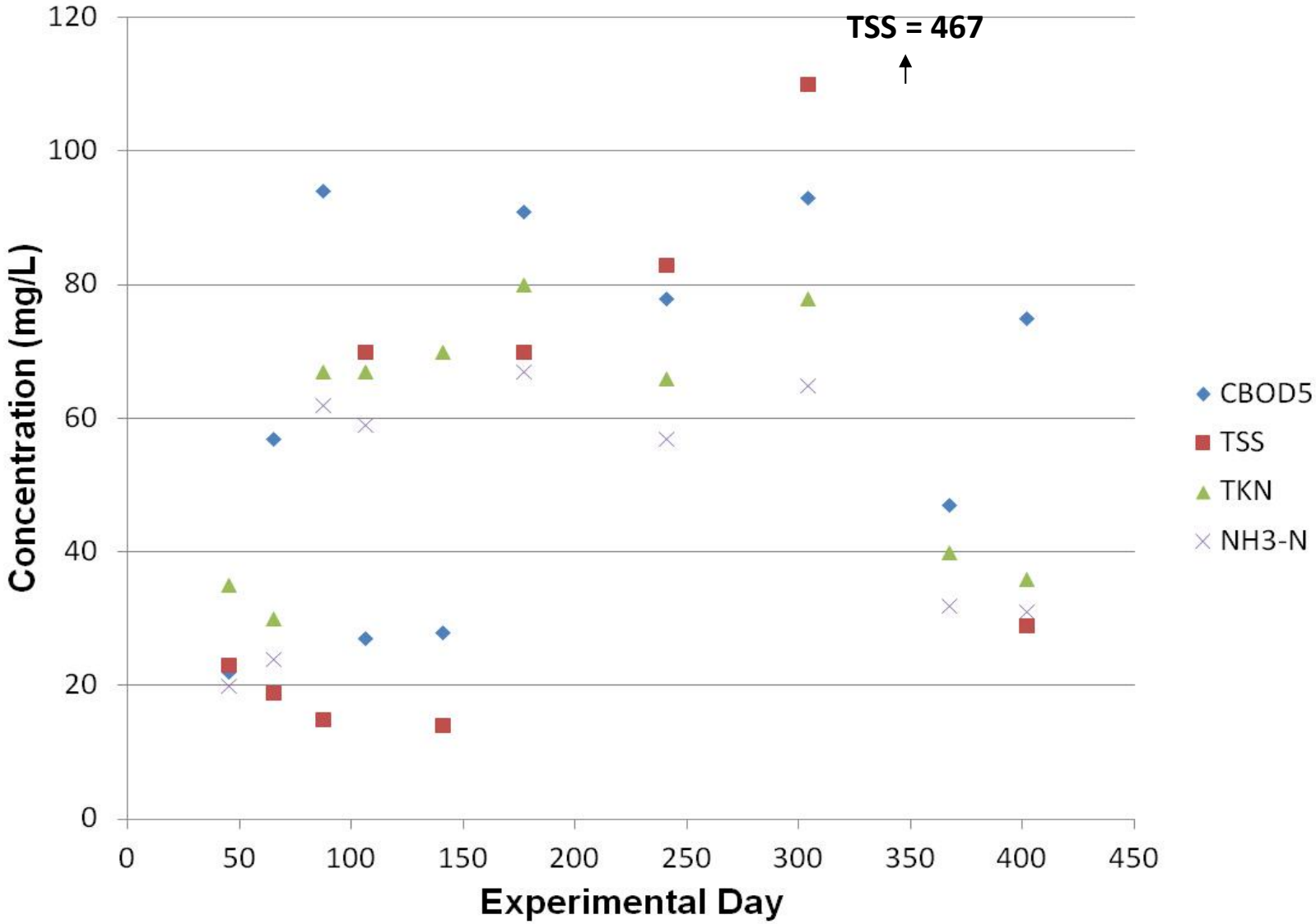
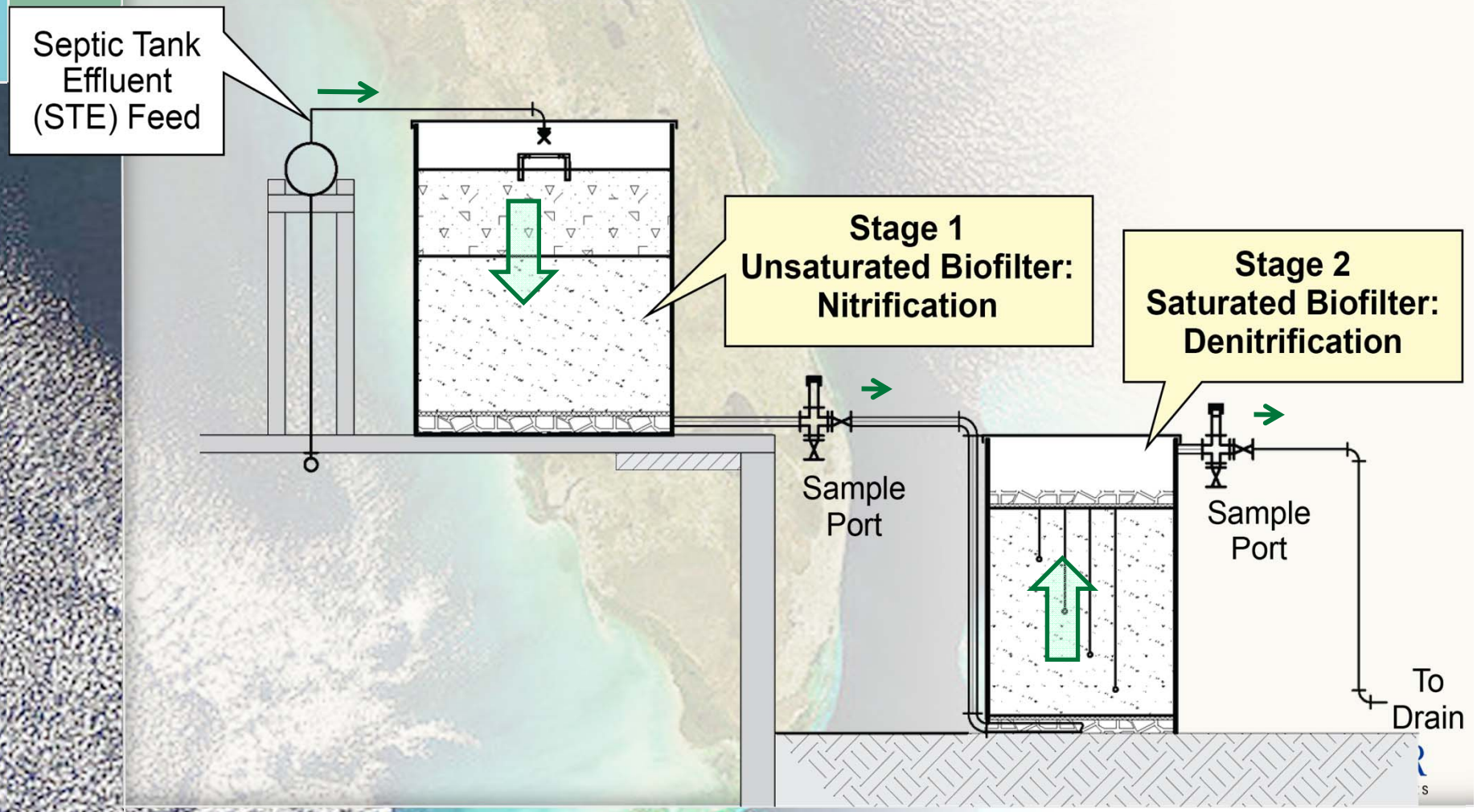
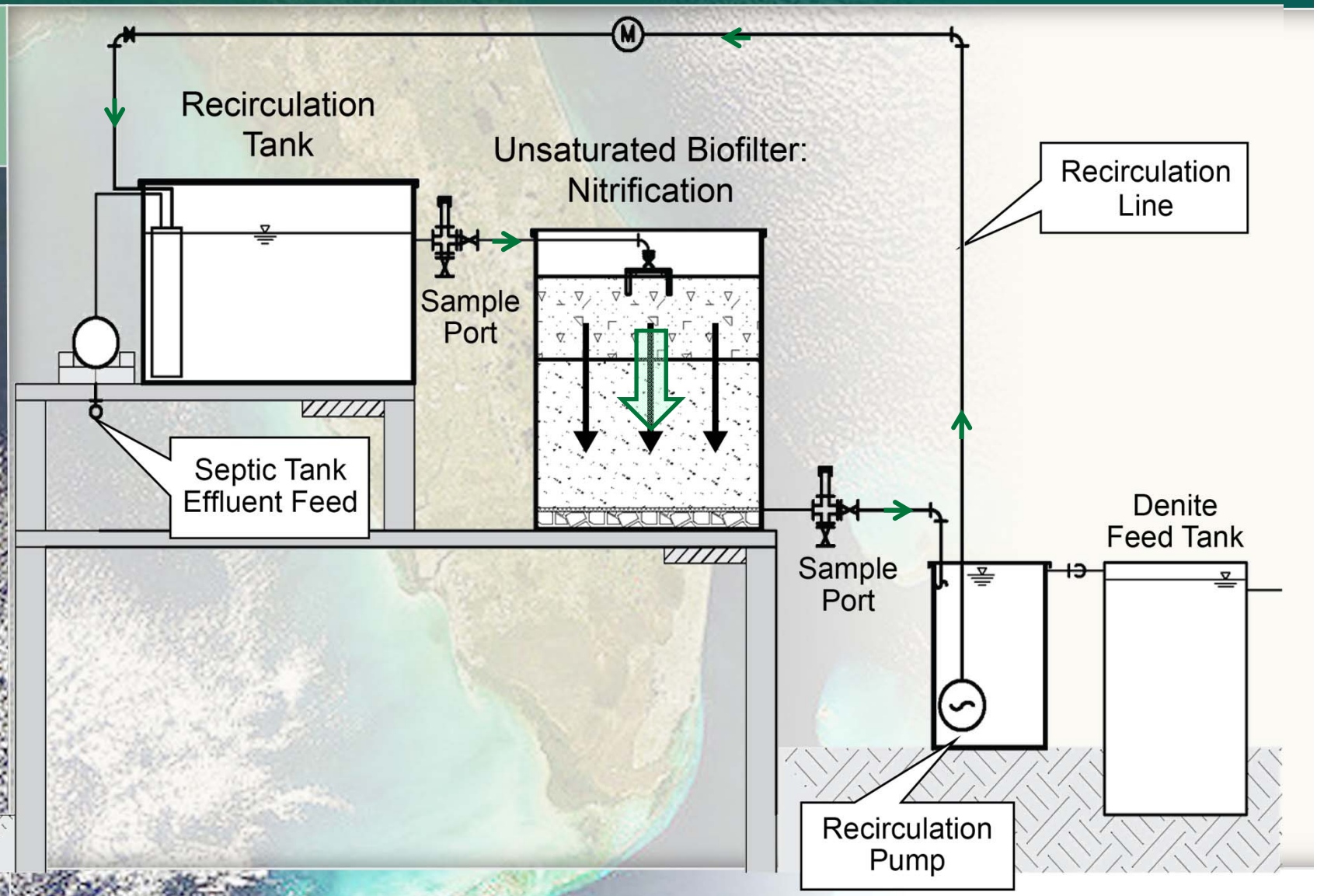
PNRS II primary effluent quality



Group A
Two stage single pass biofilter schematic



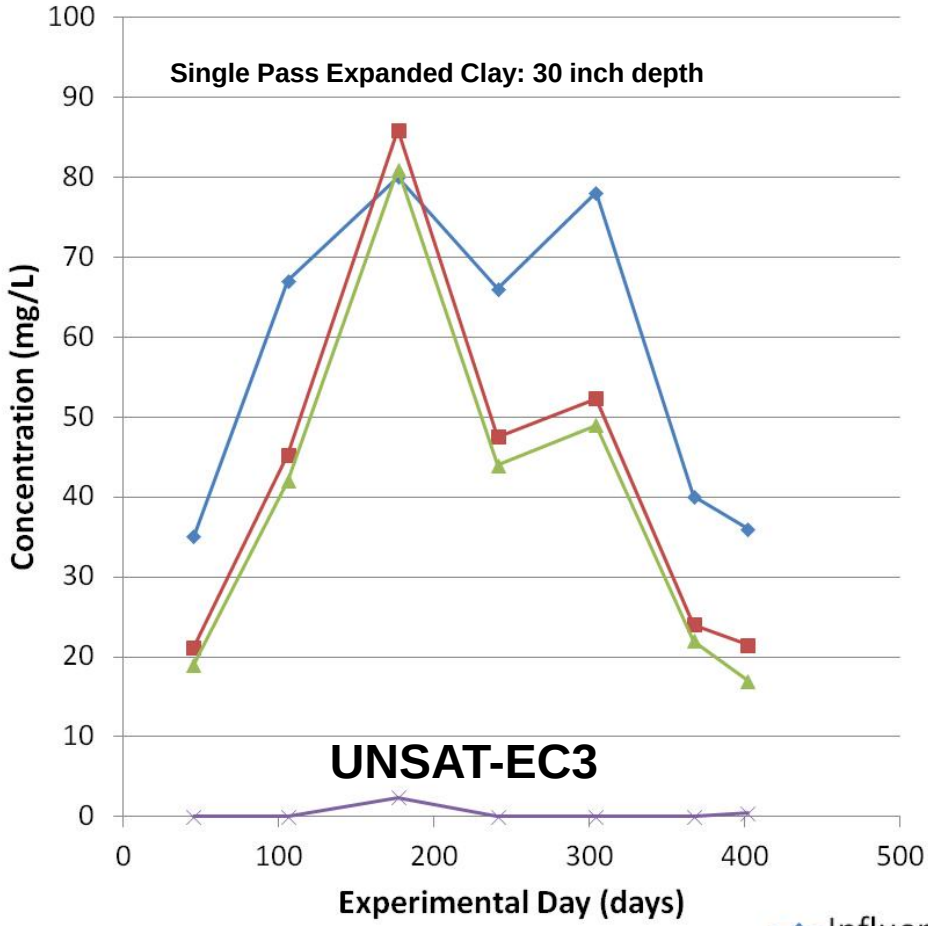
Group B
Stage 1 recirculating biofilters schematic

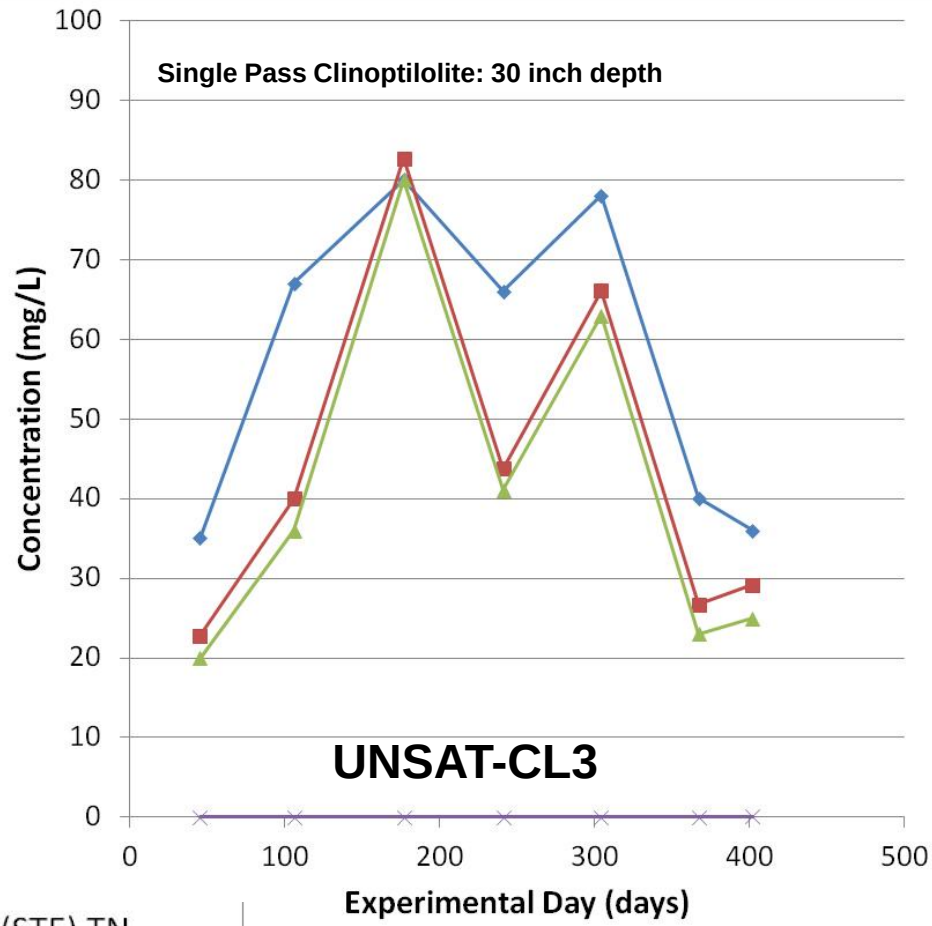


Stage 1 (unsaturated) biofilters
Mean effluent values

	Biofilter	C-BOD_5	COD	TSS	TN	TKN	Organic N	NH_3-N	(NO_3+NO_2) -N	Dissolved Oxygen	pH	Total Alkalinity	Fecal coliform, cfu/100 ml
Group A Single Pass	UNSAT-EC1 (15")	2.0	10.0	1.2	44.7	3.5	3.0	0.510	41.2	6.6	7.0	152	1,307
	UNSAT-EC3 (30")	2.0	13.3	1.5	42.5	3.4	3.0	0.417	39.1	6.9	6.8	177	2
	UNSAT-CL1 (15")	2.0	17.0	2.2	41.0	3.1	3.1	0.012	37.9	6.3	7.4	207	44
	UNSAT-CL3 (30")	2.0	20.0	1.3	44.5	3.3	3.3	0.020	41.2	7.6	7.7	282	38
	UNSAT-CL5 (30")	2.0	-	1.0	15.2	2.9	2.7	0.228	12.3	6.8	7.8	280	24
Group B Recirculating	UNSAT-SA2 (30")	2.2	17.3	4.0	30.8	2.9	2.6	0.255	28.0	6.9	6.8	128	21
	UNSAT-EC4 (30")	2.0	14.3	2.2	34.5	2.4	2.4	0.015	32.1	7.9	7.1	137	8
	UNSAT-CL2 (15")	2.2	21.0	2.3	35.3	2.6	2.6	0.010	32.7	6.0	7.3	163	251
	UNSAT-CL4 (30")	2.0	13.3	2.5	33.0	4.0	4.0	0.010	29.0	8.1	7.4	192	7

Group A
Stage 1 (unsaturated) single pass biofilters
Nitrogen time series





- Influent (STE) TN
- Effluent TN
- Effluent (NO3+NO2)-N
- Effluent NH3-N

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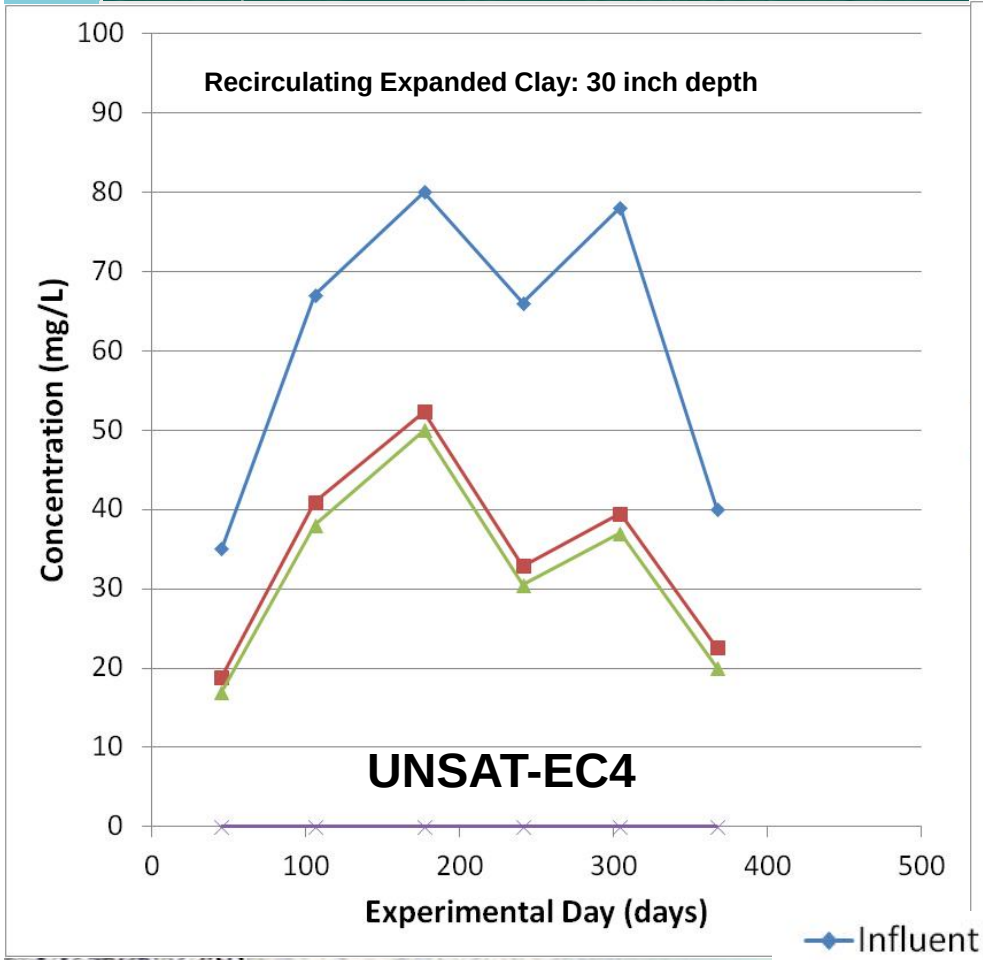
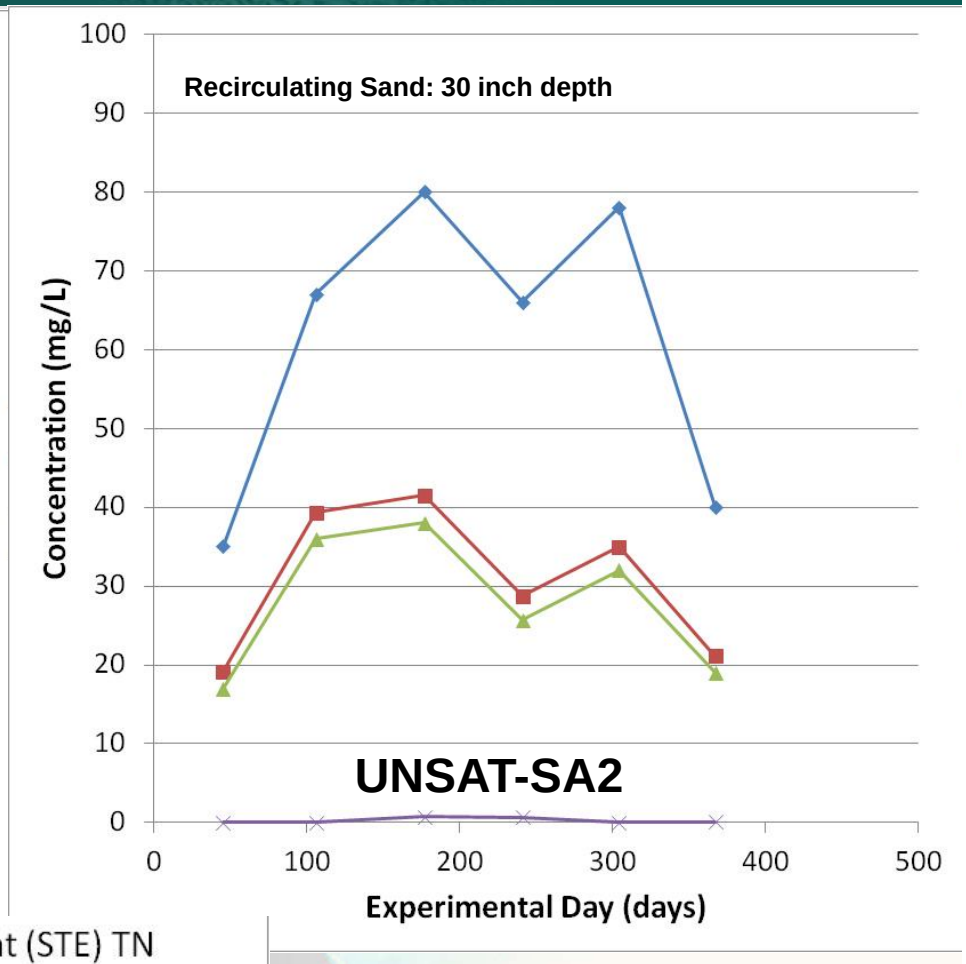
Group B
Stage 1 (Unsaturated) recirculating biofilters
Nitrogen time series





- Influent (STE) TN
- Effluent TN
- Effluent (NO3+NO2)-N
- Effluent NH3-N

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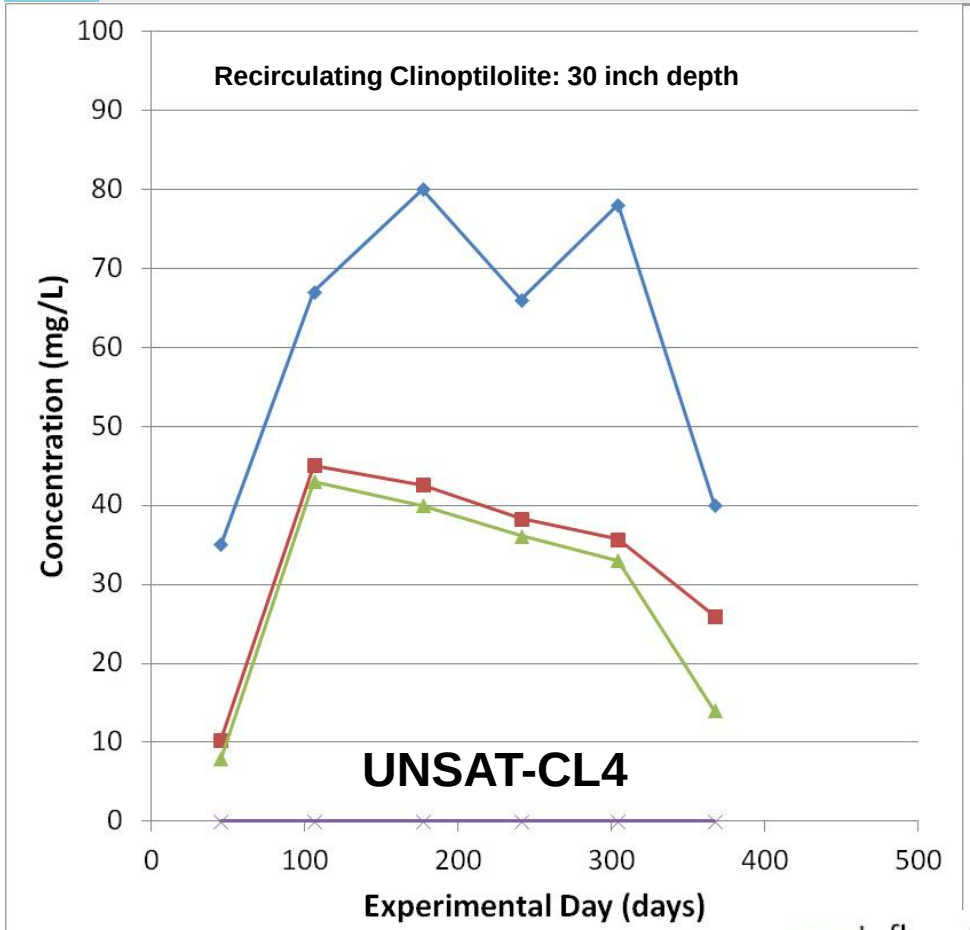
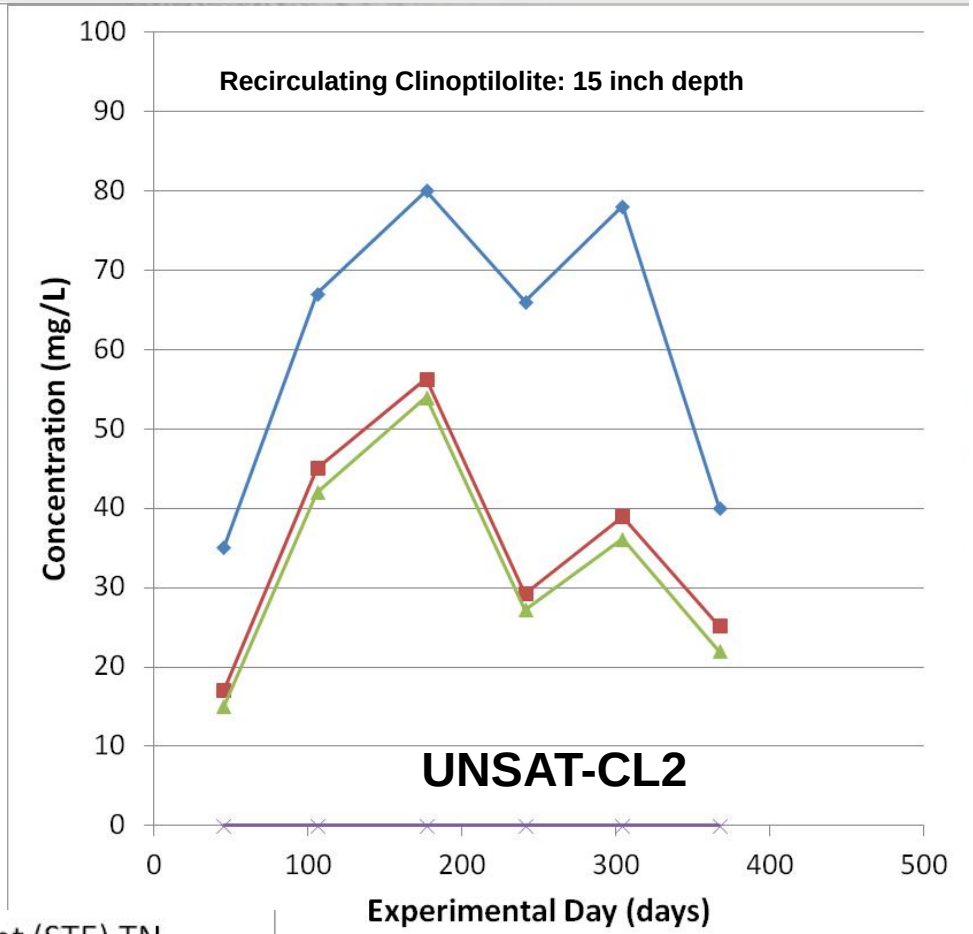
Group B
Stage 1 (unsaturated) recirculating biofilters
Nitrogen time series





- Influent (STE) TN
- Effluent TN
- Effluent (NO3+NO2)-N
- Effluent NH3-N

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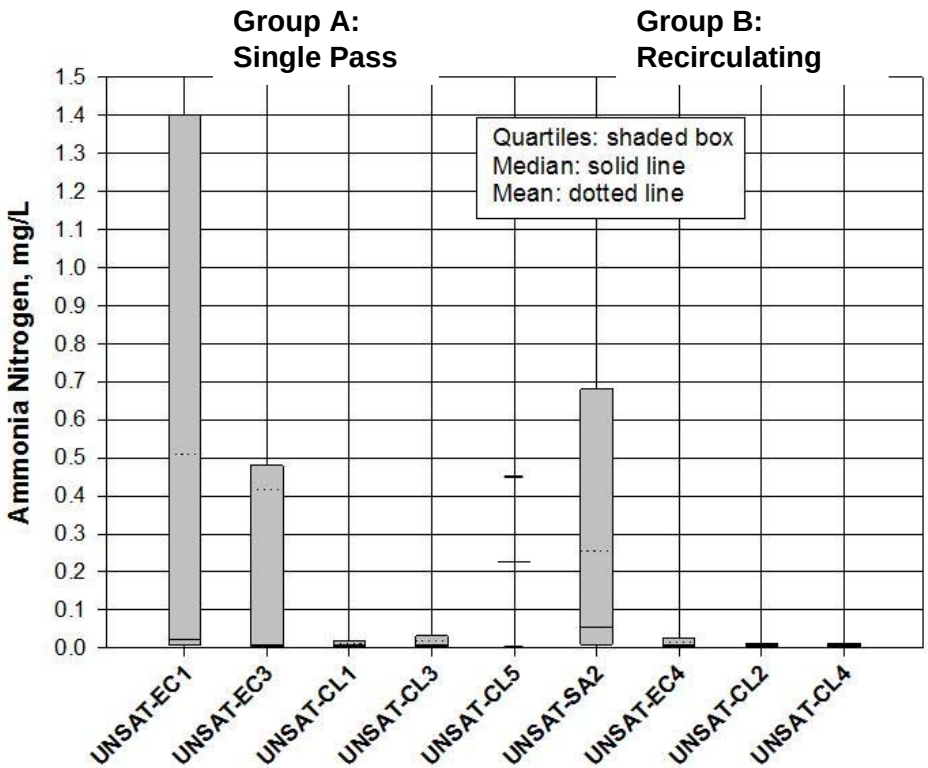
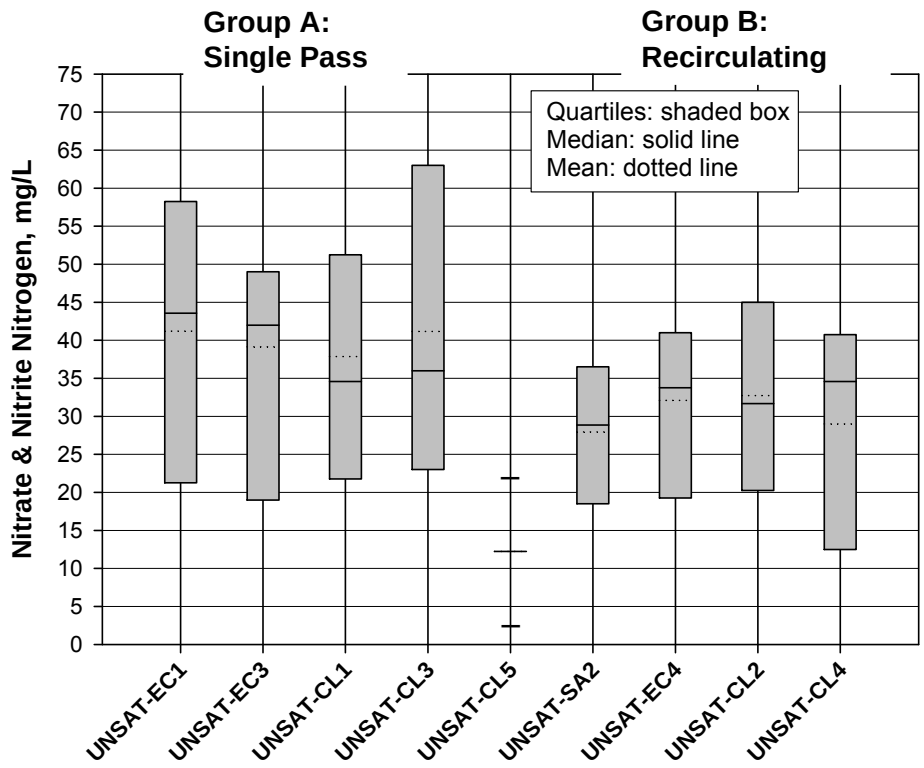
Groups A and B
Stage 1 (unsaturated) biofilters
Effluent nitrogen: box and whisker plots





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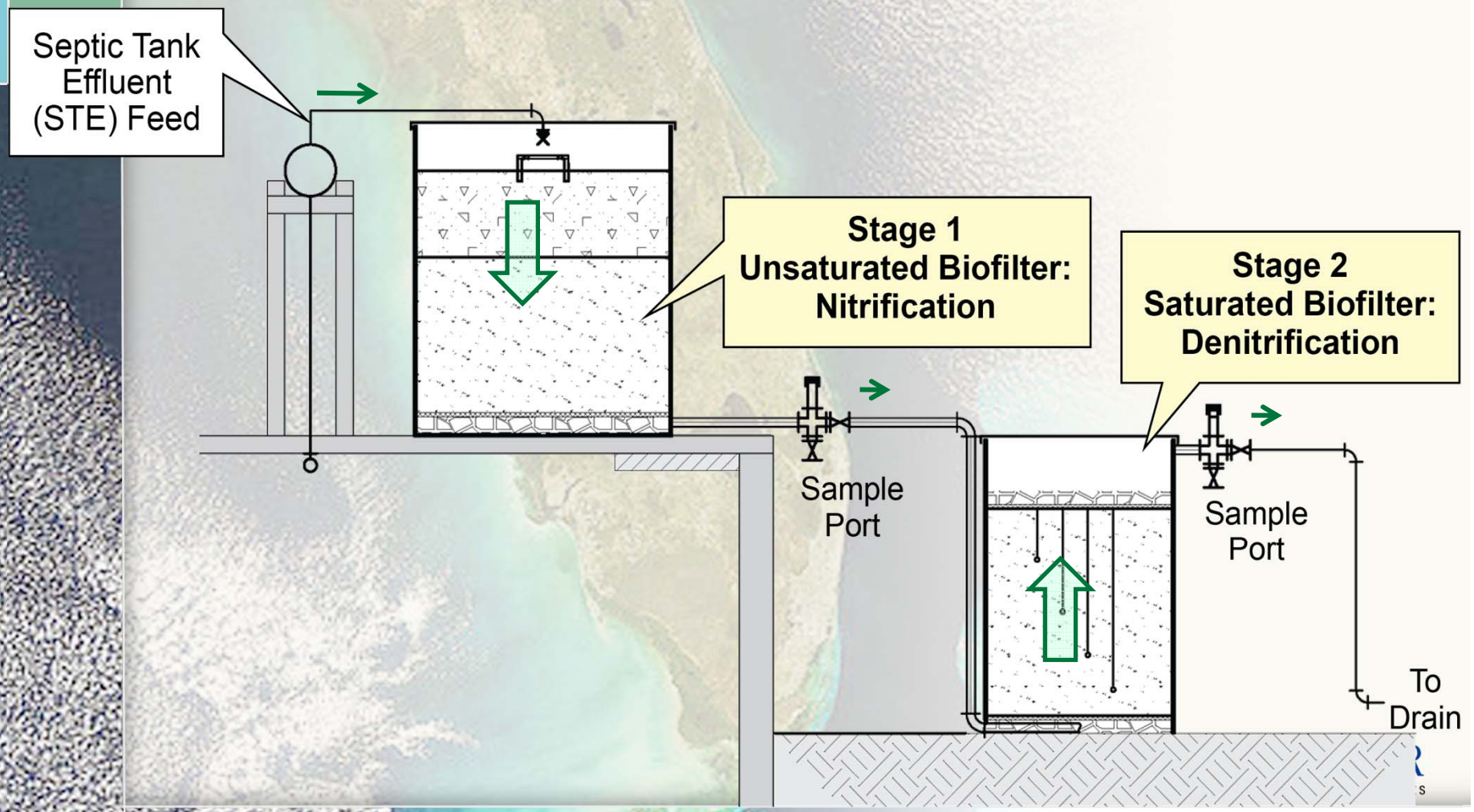
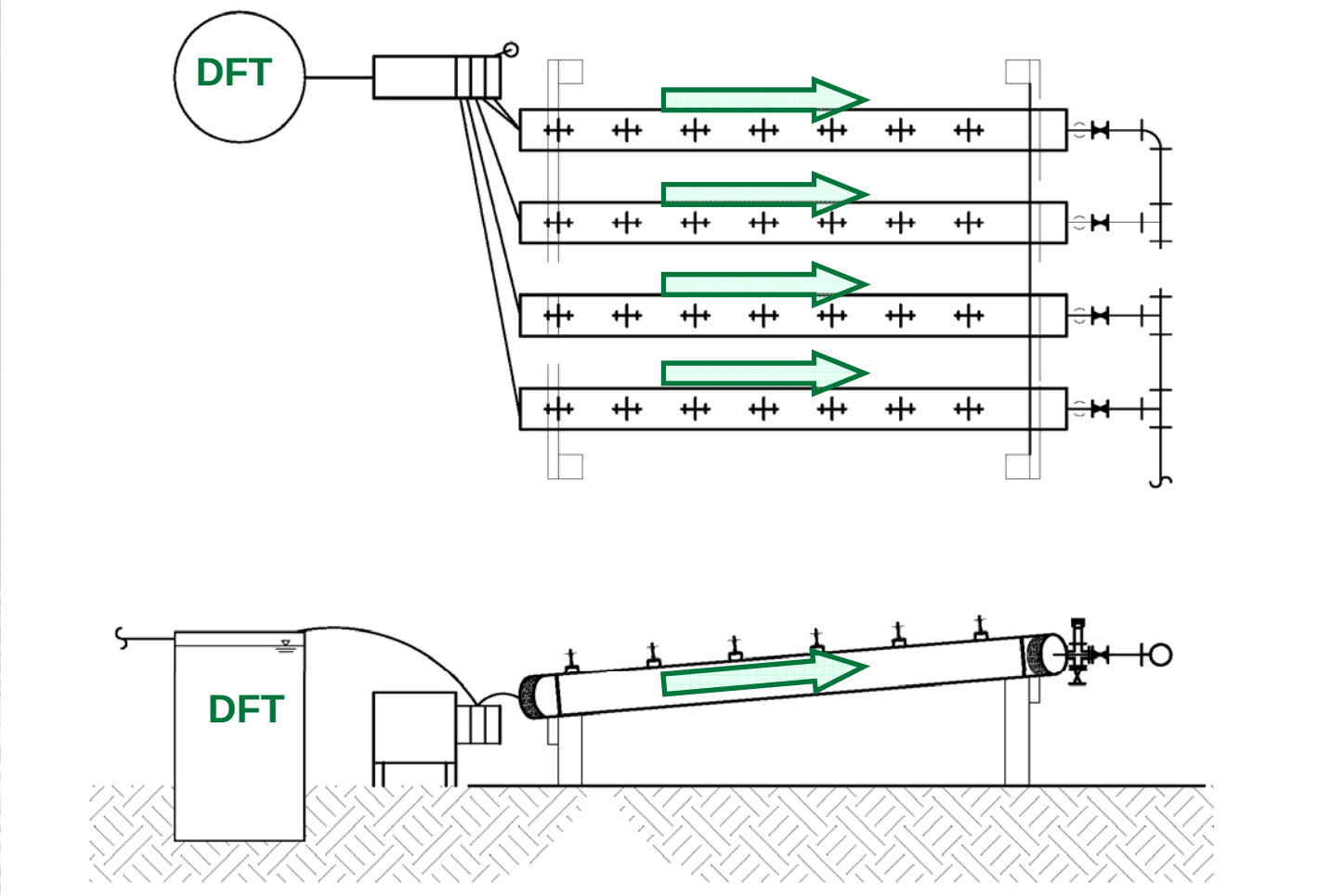
Group A
Two stage single pass biofilter schematic



Group C
Horizontal Stage 2 biofilters schematic



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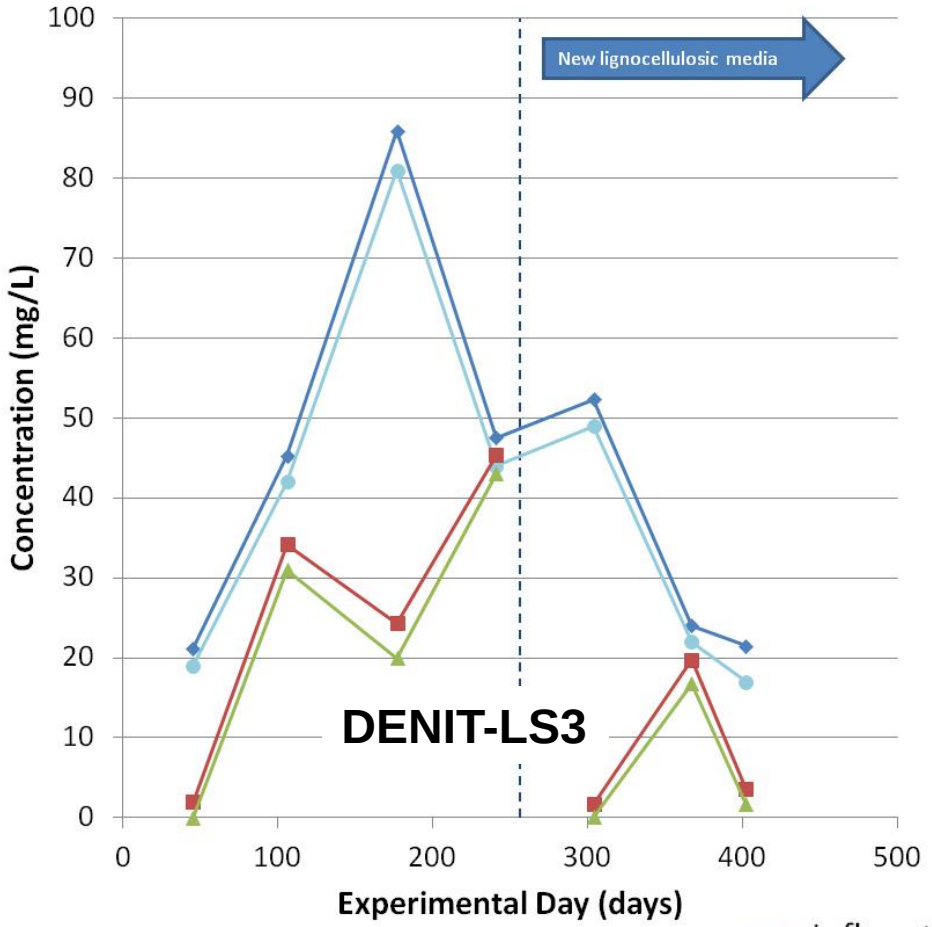
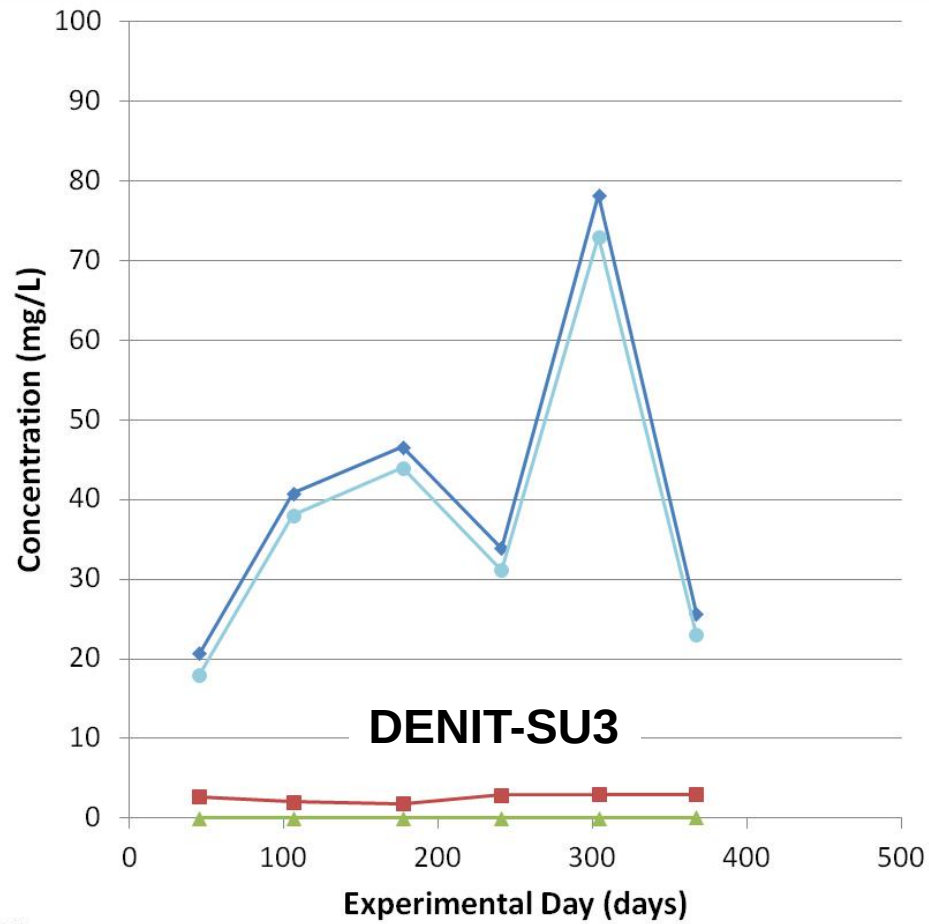
Groups A and C
Stage 2 (saturated) biofilters
Mean effluent values

	Biofilter	C-BOD_5	COD	TSS	TN	TKN	Organic N	NH_3-N	(NO_3+NO_2) - N	Dissolved Oxygen	pH	Total Alkalinity	Fecal coliform, cfu/100 ml
Group A	DENIT-SU4	2.0	21.7	2.8	1.3	1.2	0.9	0.32	0.075	2.3	7.1	220	89
	DENIT-LS3	61.0	320	1.5	8.3	2.2	1.3	0.87	6.18	2.2	7.1	355	1
	DENIT-SU3	6.0	38.5	6.2	2.6	2.6	1.4	1.14	0.047	1.4	7.1	235	3
	DENIT-LS2	2.0	39.0	3.0	17.3	3.1	2.4	0.62	14.2	3.6	7.9	197	0
	DENIT-LS4	4.5	90.0	7.5	5.9	5.6	0.9	4.71	0.22	1.3	7.8	315	1
Group C	DENIT-SU1	13.3	45.0	1.5	2.5	2.4	1.1	1.35	0.11	0.6	7.0	223	3
	DENIT-SU2	8.5	29.7	3.5	1.6	1.6	1.0	0.58	0.035	0.6	7.0	215	2
	DENIT-LS1	89.5	320	13.0	10.0	10.0	9.7	0.27	0.020	0.1	7.2	270	1
	DENIT-GL1	148	257	18.5	3.8	3.8	0.63	3.12	0.07	0.59	6.94	402	600

Group A
Stage 2 (saturated) upflow single pass biofilters
Nitrogen time series





- Influent TN
- Influent (NO3+NO2)-N
- Effluent TN
- Effluent (NO3+NO2)-N

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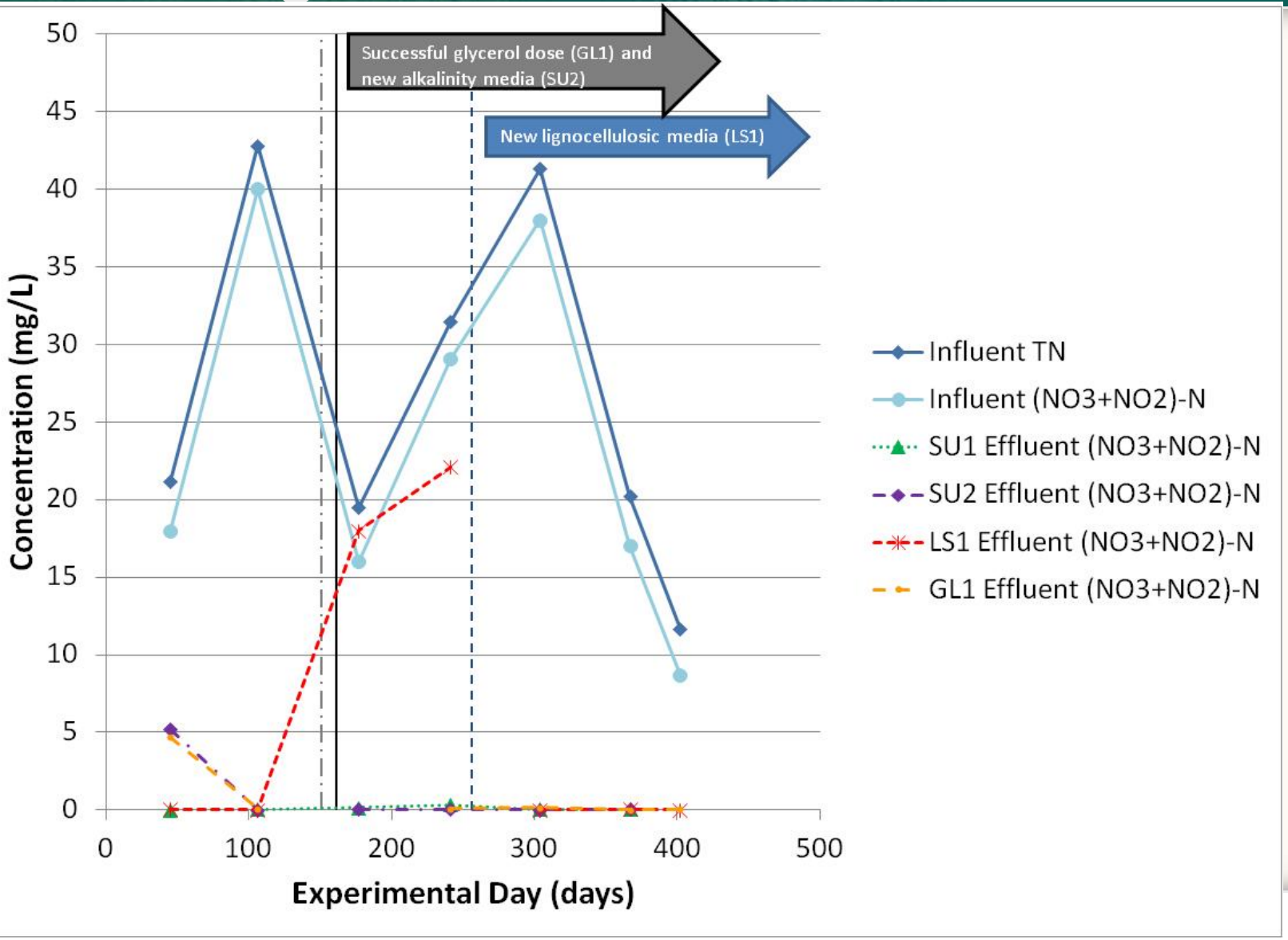
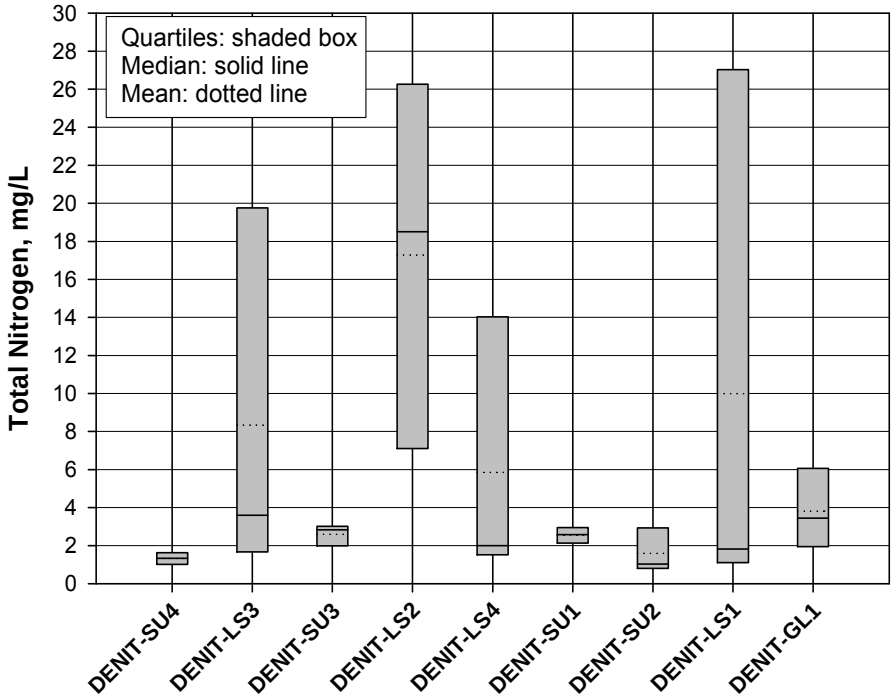
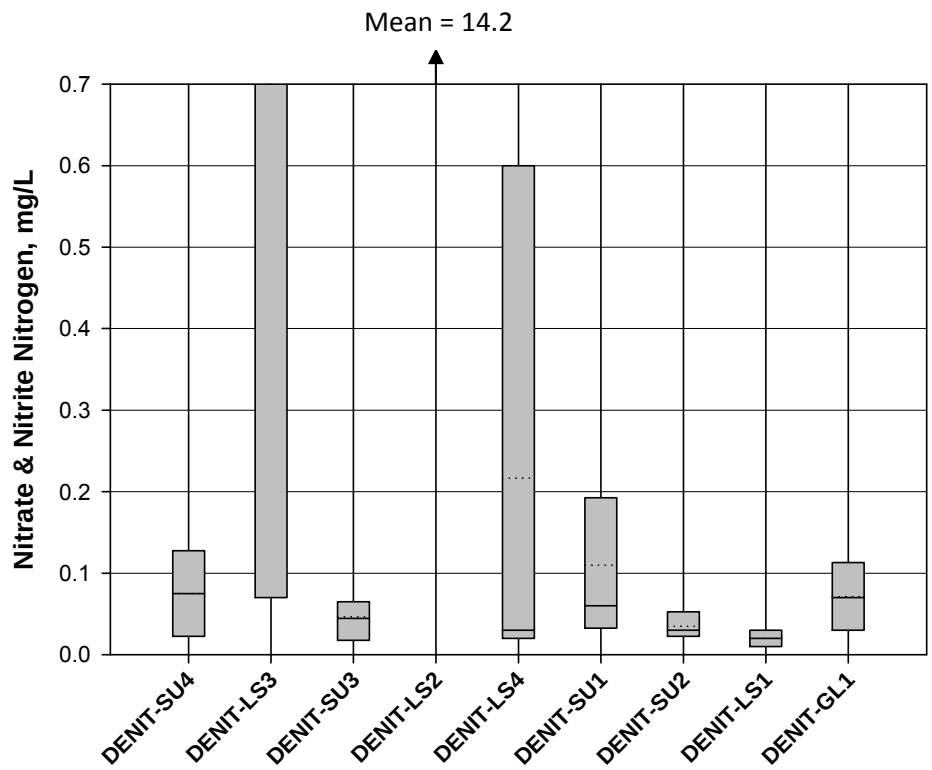
Group C
Stage 2 (saturated) horizontal biofilters
Nitrate-nitrogen time series



Groups A and C
Stage 2 (saturated) biofilters
Effluent nitrogen: box and whisker plots



Group A: Upflow **Group C: Horizontal**



Group A: Upflow **Group C: Horizontal**

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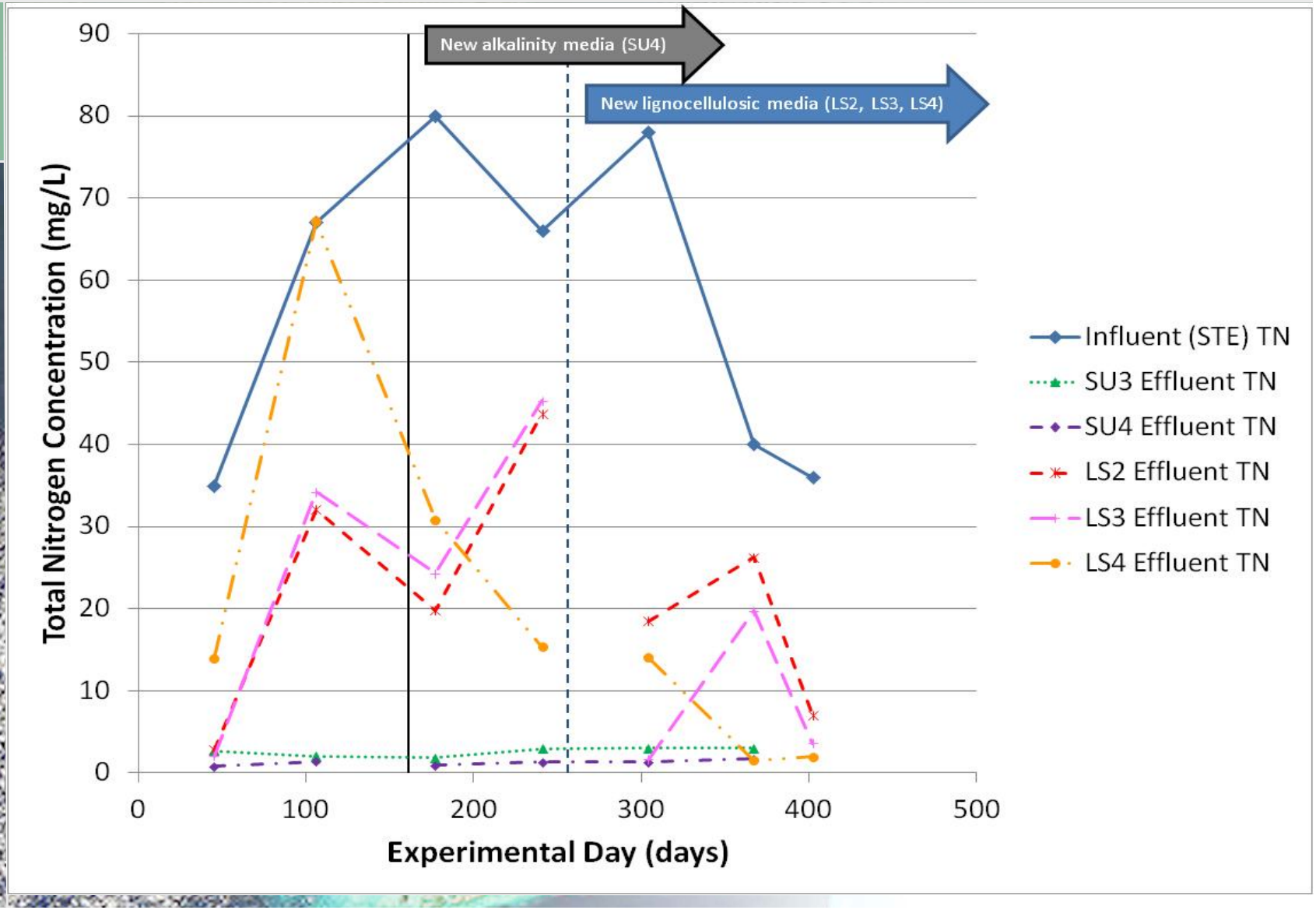
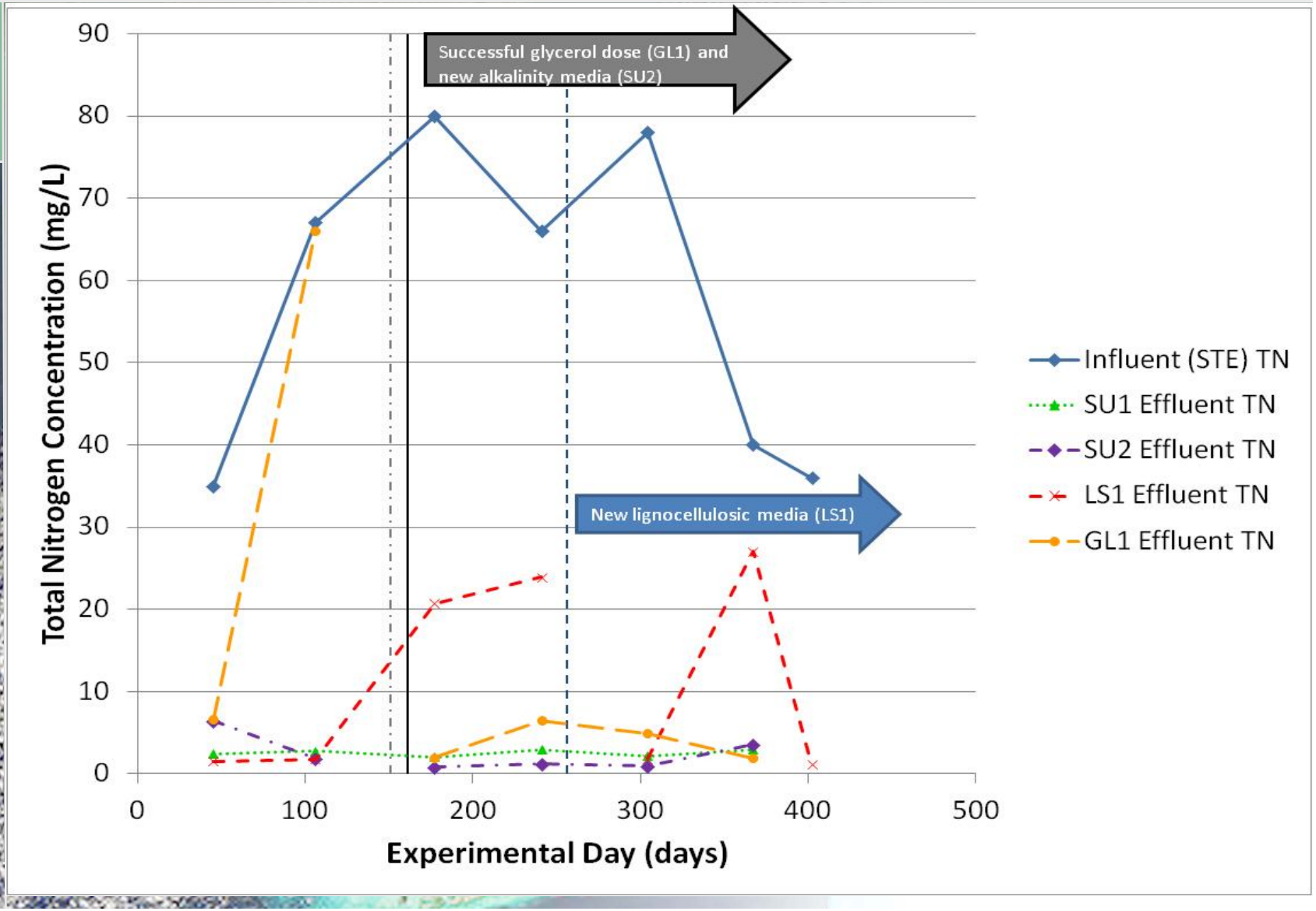
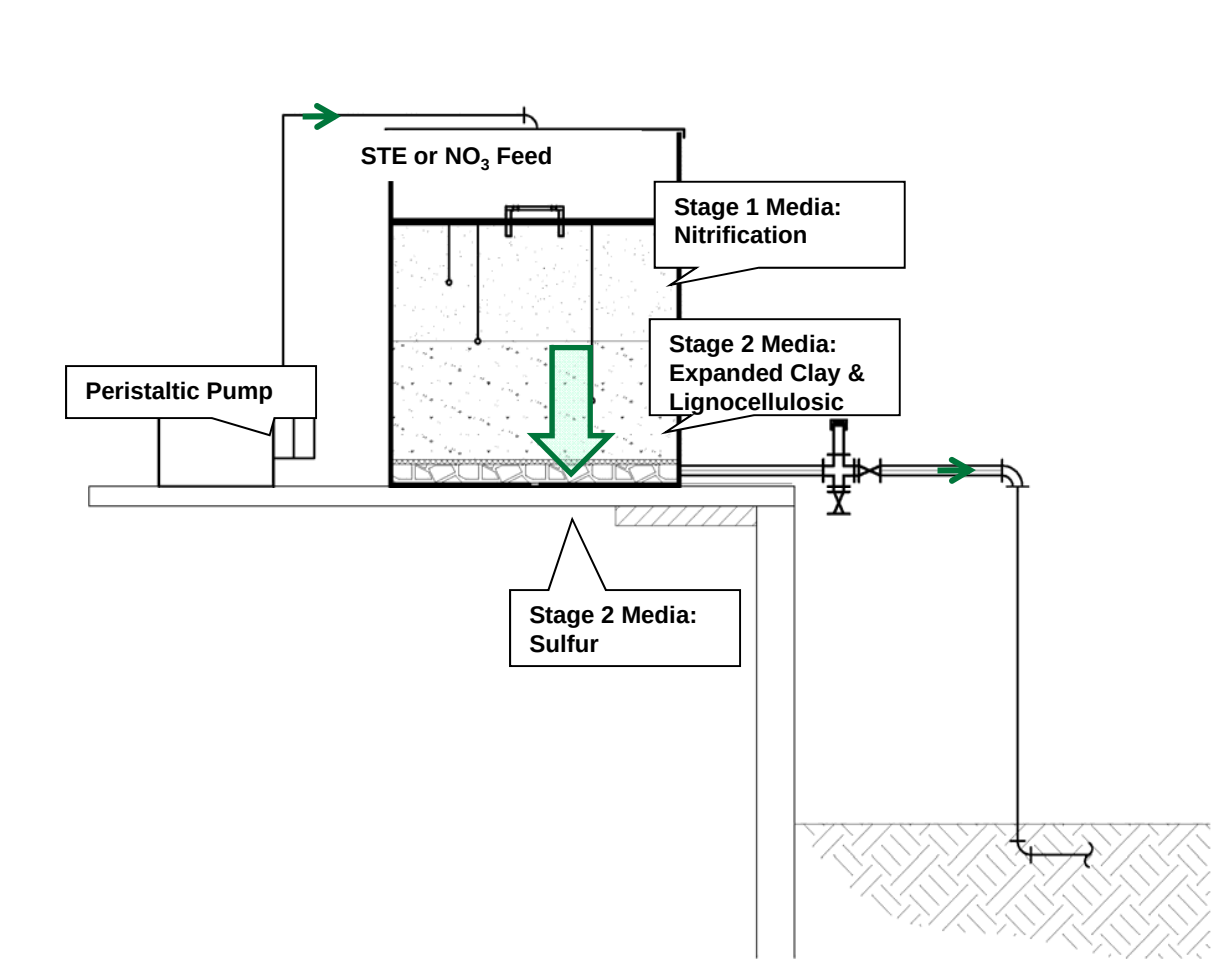
Group A single pass systems
Two-stage system: total nitrogen removal



Groups B (recirculating) and C (horizontal) Two-stage system: total nitrogen removal



Group D
Stacked saturated/unsaturated (*in situ*) biofilter schematic



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Group D
Stacked saturated/unsaturated (*in situ*) biofilters

Biofilter	Influent	Sample Location	C-BOD_5	COD	TSS	TN	TKN	Organic N	NH_3-N	(NO_3+NO_2) - N	Dissolved Oxygen	pH	Total Alkalinity	Fecal coliform, cfu/100 ml
UNSAT-IS1 (12"SA, 12"EC&LS, 4"SU)	Primary Effluent	Final Effluent	62	240	5.0	22.9	20.6	3.6	17.0	2.2	4.1	7.1	320	1
UNSAT-IS2 (12"SA, 12"EC&LS, 4"SU)	Primary Effluent	Above Sulfur	13	63	2.0	35.4	4.7	1.6	3.10	30.7	1.0	6.4	69	-
		Final Effluent	11	82	8.5	24.5	11.4	4.3	7.05	13.1	5.0	7.2	255	19
UNSAT-IS3 (12"CL, 12"EC&LS, 4"SU)	Primary Effluent	Above Sulfur	2.5	120	3.0	13.3	3.4	3.1	0.23	9.9	3.3	7.1	455	1
		Final Effluent	4.5	96	4.5	2.6	2.4	1.4	0.98	1.1	5.0	7.3	385	9
UNSAT-IS4 (12"SA, 12"EC&LS, 4"SU)	Nitrified Effluent (UNSAT-CL3)	Above Sulfur	6.0	80	12	12.0	2.9	2.5	0.37	9.1	2.1	7.0	325	1
		Final Effluent	24	88	39	2.6	2.4	1.4	0.98	1.1	1.2	6.8	495	7

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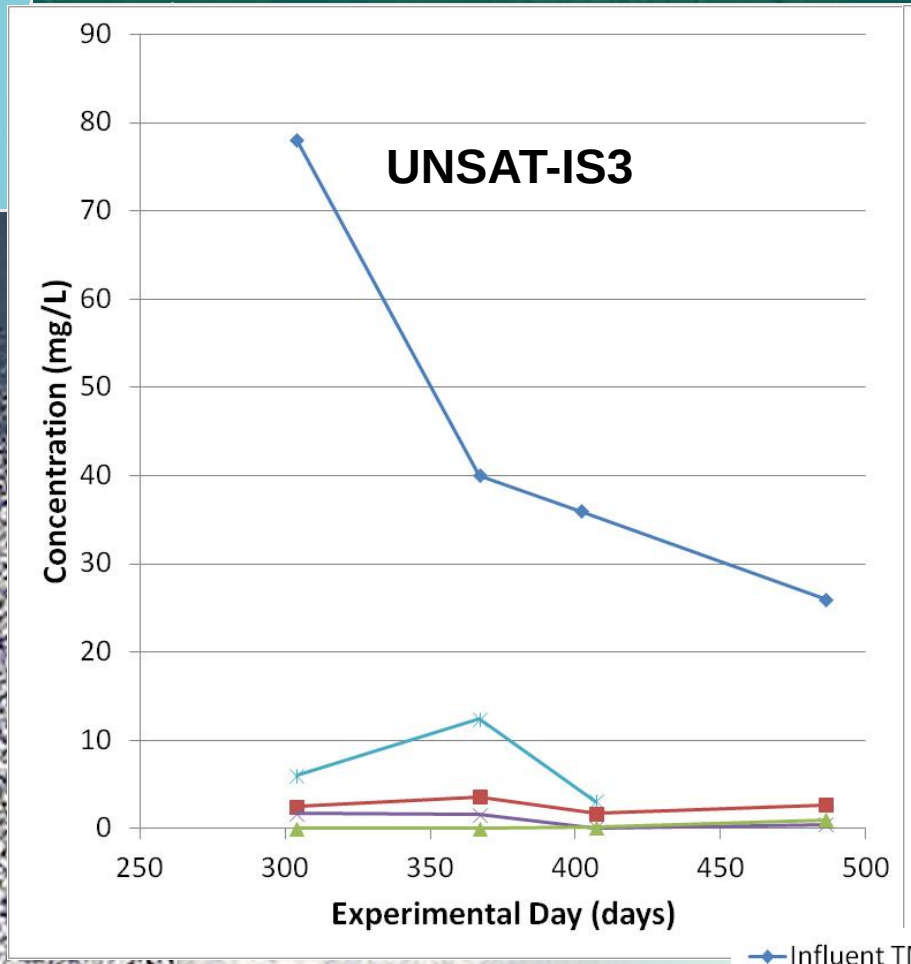
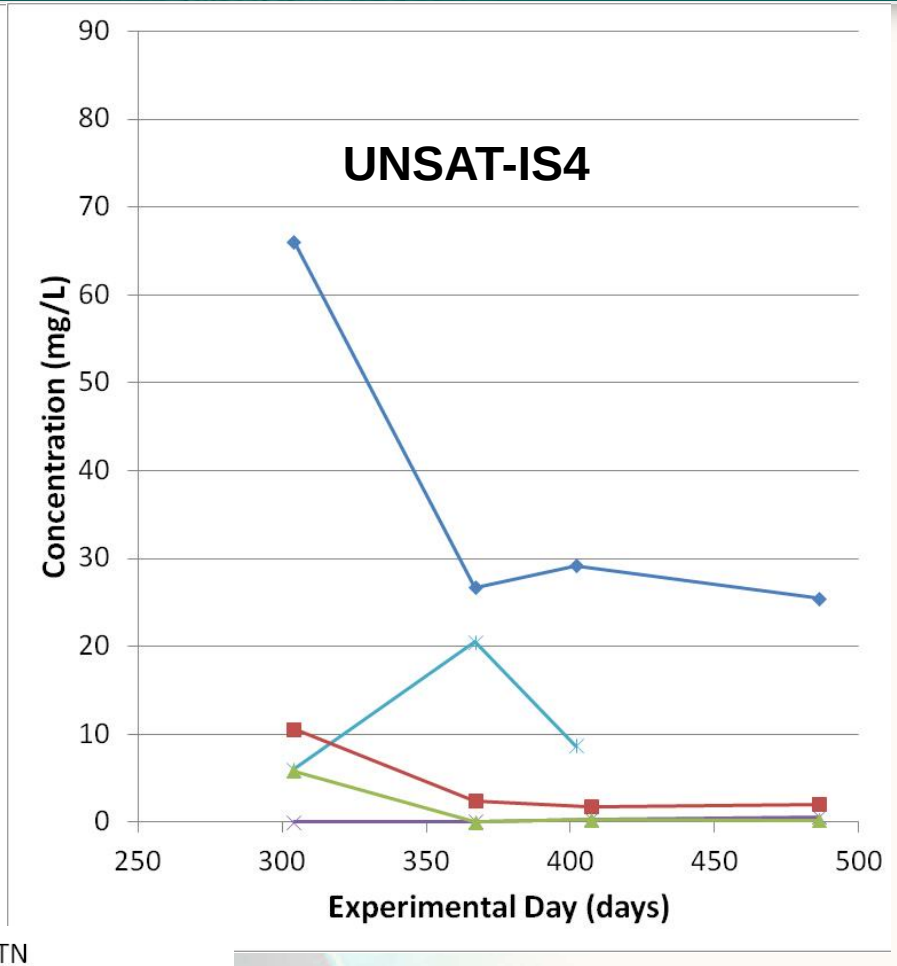
Group D
Stacked saturated/unsaturated biofilters
Nitrogen time series





- Influent TN
- Above Sulfur (NO3+NO2)-N
- Effluent TN
- Effluent NH3-N
- Effluent (NO3+NO2)-N

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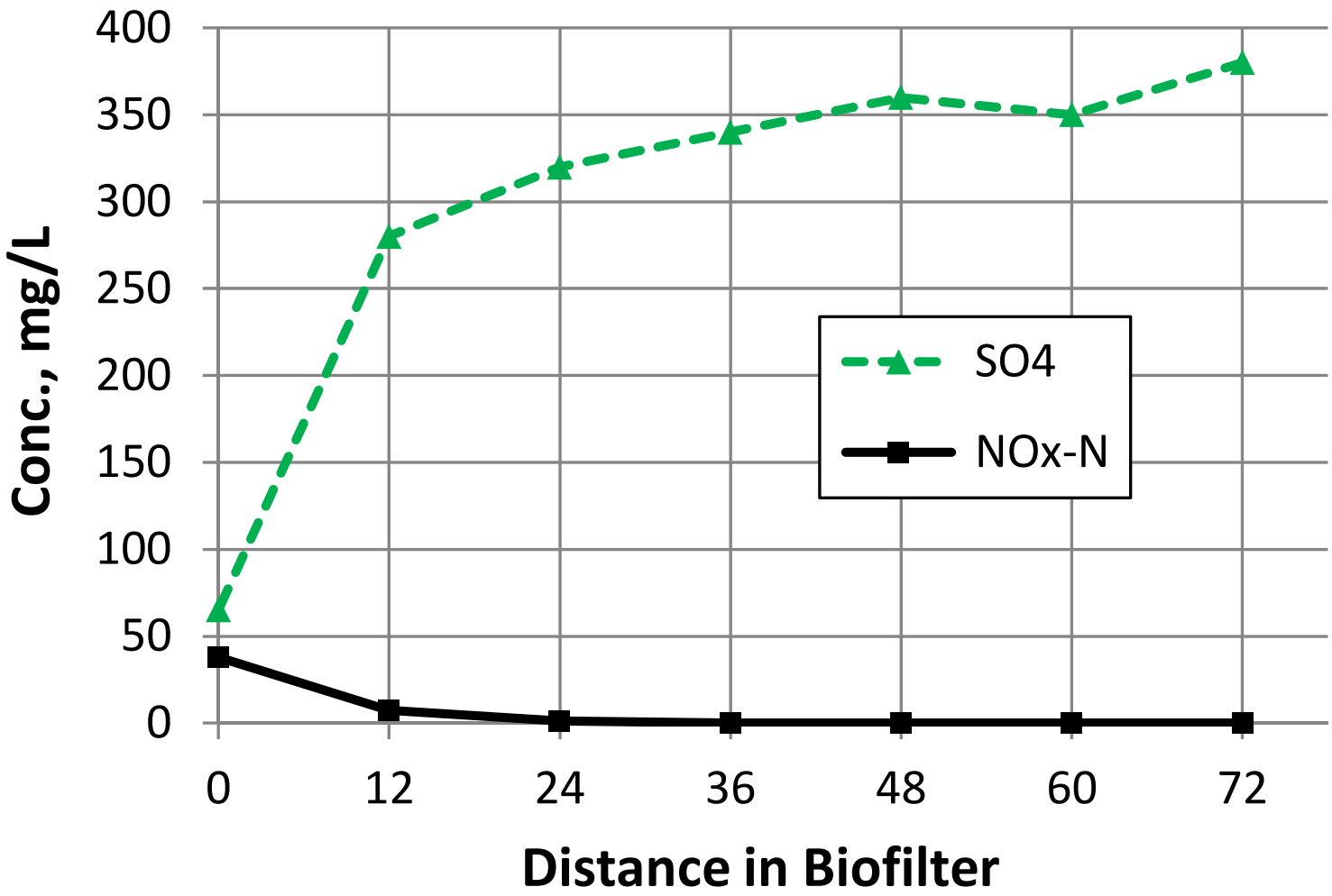
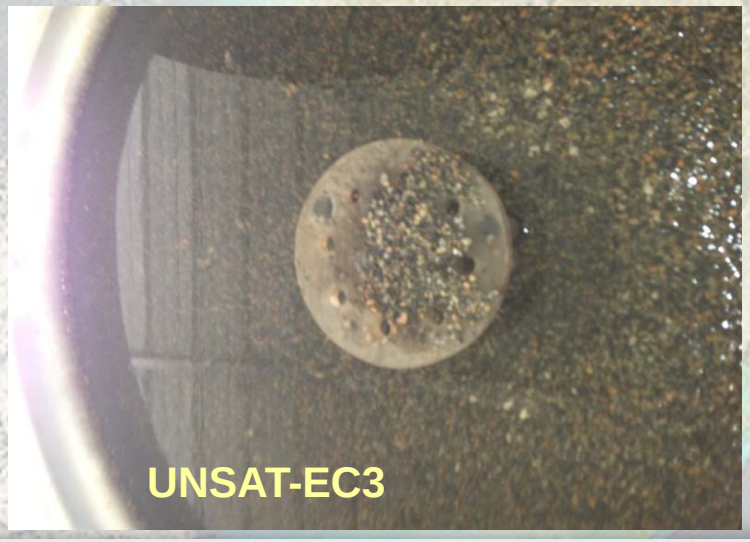
Solute profile in DENIT-SU2 experimental day 305



Group A – Stage 1 single pass biofilters increased hydraulic loading rate



Group B – Stage 1 recirculating biofilters increased hydraulic loading rate

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Next Steps

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Preliminary guidance recommendations for full-scale testing of passive systems

Unsaturated Recycle (Stage 1)

Media	Hydraulic Loading Rate, gal/ft^2-day	Total Media Depth, inch	Media Stratification and Particle Size Distribution		
			Layer	Depth, inch	Particle Size Spec, mm
Expanded Clay	≤ 3.0	≥ 24	Upper	≥ 8	≥1.53
			Lower	≥ 16	<1.53
Clinoptilolite	≤ 3.0	≥ 24	Upper	≥ 8	≥ 1.4 - 2.3
			Lower	≥ 16	0.5 - 1.5
Sand	≤ 3.0	≥ 24	Upper	≥ 8	E.S. ≥ 0.8-1.2 U.C.≤4
			Lower	≥ 16	E.S. 0.45 - 0.55 U.C.≤4

Unsaturated Single Pass (Stage 1)

Media	Forward Flow Hydraulic Loading Rate, gal/ft^2-day	Total Media Depth, inch	Media Stratification and Particle Size Distribution		
			Layer	Depth, inch	Particle Size Spec, mm
Expanded Clay	≤ 3.0	≥ 24	Upper	≥ 8	≥1.53
			Lower	≥ 16	<1.53
Clinoptilolite	≤ 3.0	≥ 24	Upper	≥ 8	≥ 1.4 - 2.3
			Lower	≥ 16	0.5 - 1.5

Saturated (Stage 2)

Media	%	Total Media Depth, inch	Empty Bed Residence Time, hour	Media Particle Size Distribution
				Particle Size Spec, mm
Elemental Sulfur	≥ 50	≥ 24	≥ 30	2.0 - 3.36 <0.5% fines
Limestone or oyster shell	0-20[1]			0.5 - 5
Lignocellulosic media (SYP)	80-100	≥ 24	≥ 120	1 - 30

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B-HS2 construction photos

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Questions?

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