

CURRENT RESEARCH WITH ON-SITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS (OSTDS)

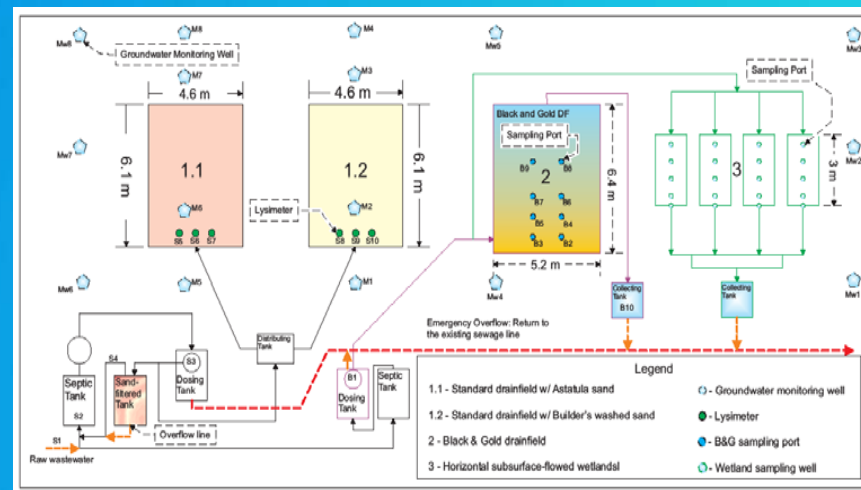
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Stormwater Management Academy

University of Central Florida

Nov 5, 2010



GOALS

- ❑ Conduct tests and provide data that can be used to help develop passive, cost-effective Onsite Sewage Treatment and Disposal Systems (OSTDS).
- ❑ Appreciate the support of FDEP and FDOH



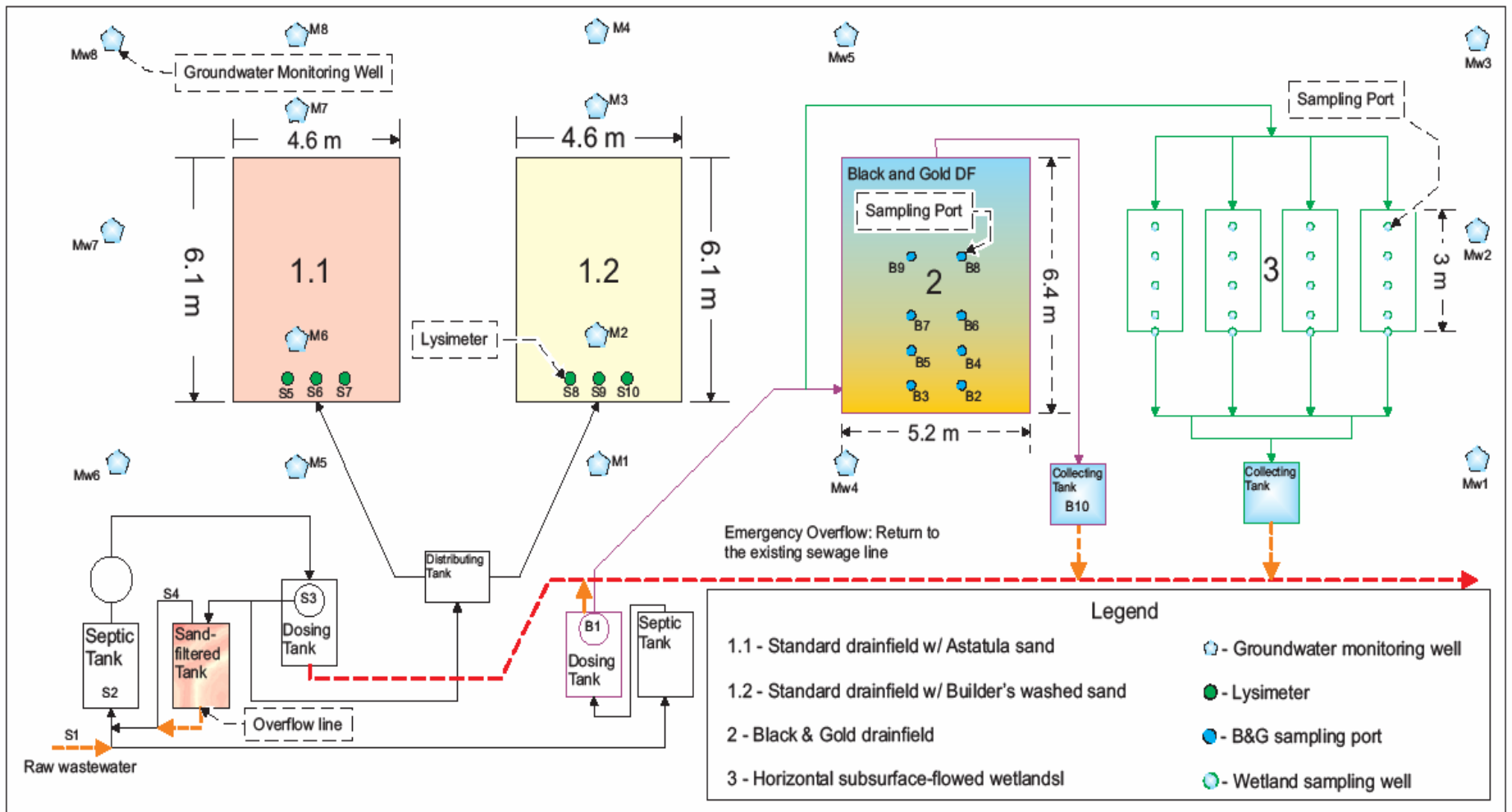
OSTDS Alternatives

- ▣ Conventional drainfields
 - Two different soils in drainfield
 - ▣ Astatula sand
 - ▣ Washed building sand
- ▣ Standard septic tank with recirculation
- ▣ Sorption media filter (Bold & Gold)
- ▣ Sub-surface Upflow Wetland (SUW)
 - With sorption media
 - With different plant species
 - New flow pattern

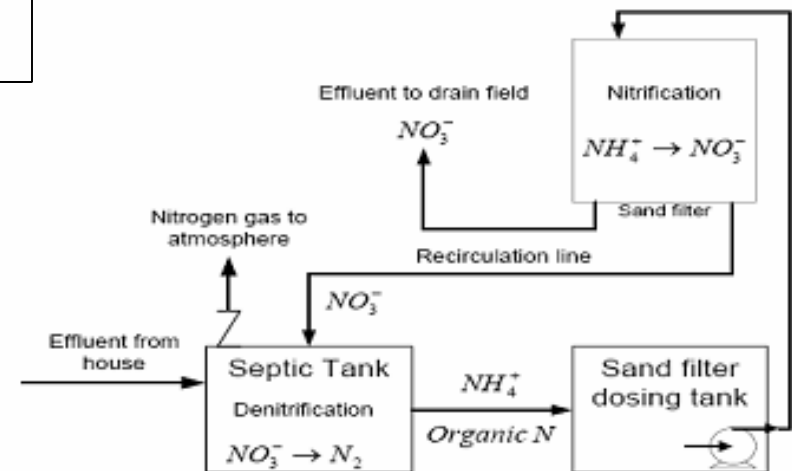
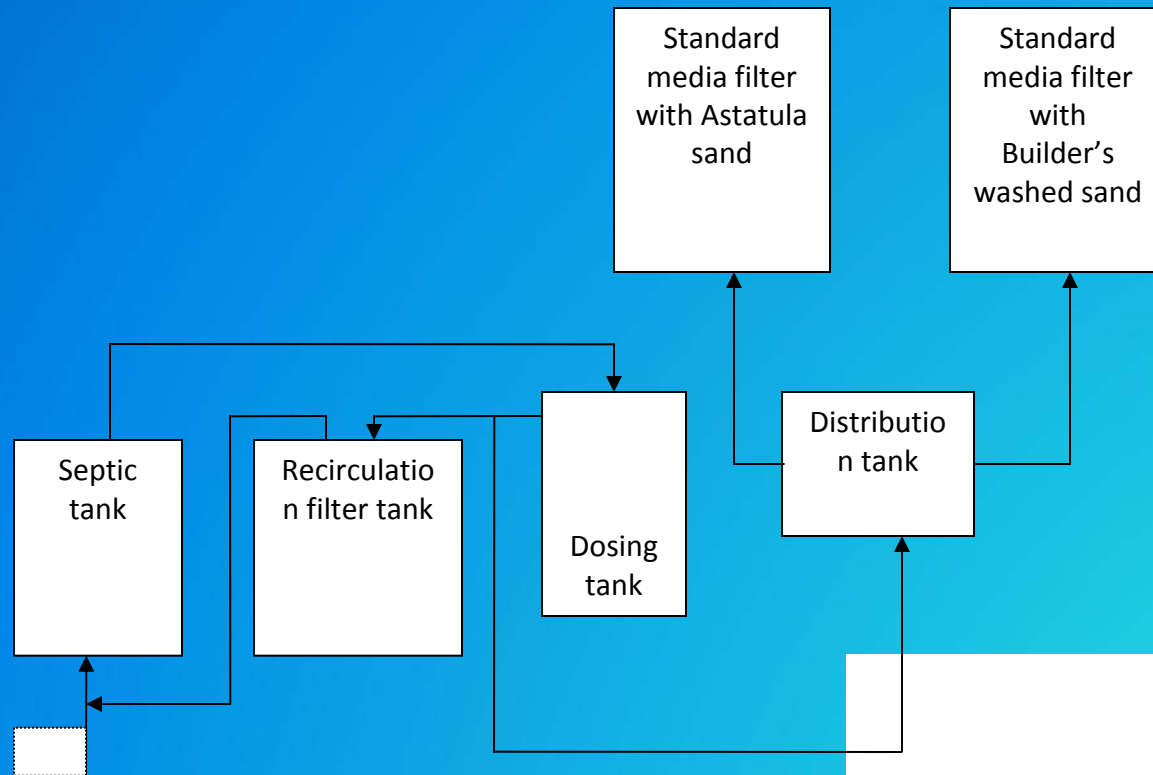
OWTS Center at UCF, Orlando



Note: isolated the B&G and SUW from the groundwater



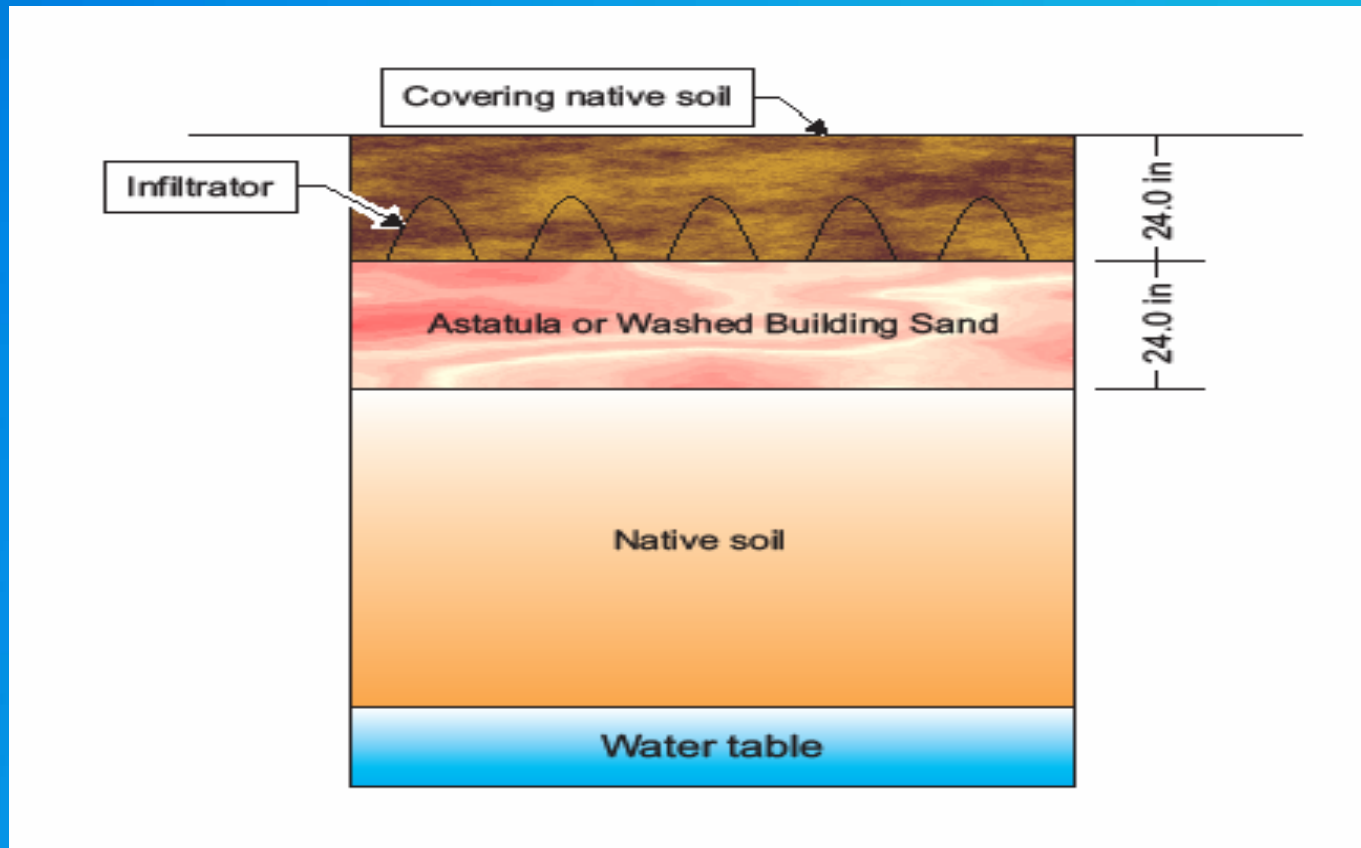
Recirculation with Drainfield



Experimental settings of recirculation OSTDS

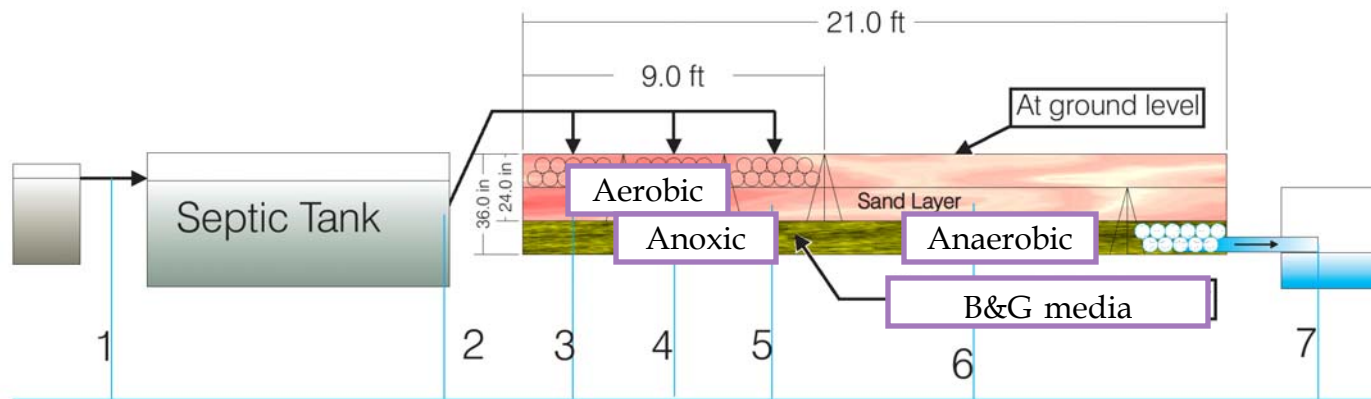
ID	Date	Number of Dataset	Experimental Settings with septic tank recirculation and drain field
Recirculation Design I	Oct – Nov 2008	3	<ul style="list-style-type: none">• 3:1 Return-To-Forward (RTF) ratio• Astatula sand used as the filtrating media in the recirculation tank
Recirculation Design II	Mar – Apr 2009	4	<ul style="list-style-type: none">• 3:1 RTF ratio• Very coarse sand media in the recirculation tank
Recirculation Design III	Sep – Oct 2009	3	<ul style="list-style-type: none">• 3:1 RTF ratio• Coarse Sand over Green Sorption Media

Drainfield Design



Astatula sand and Washed Building sand are used in each of two conventional drainfields for performance comparison

Bold & Gold Media Filter



Bold & Gold (B&G) Media Mixture:

- Astatula Sand
- Saw Dust
- Tire Crumb

Three day detention
Limestone in aerobic
zone

REVISIONS		University of Central Florida 4300 Central Florida Blvd Orlando, FL 32816	
TITLE	B&G Drain Field	DATE	December 25, 2008
DESIGNED BY	Ammarin Daranpob	SCALE	1" = 100'
CHECKED BY		SHEET	1
DATE		OF	SHEETS

Sub-Surface Upflow Wetland Design

Wetland ID	Phase I	Phase II
Wetland 1	Softrush	Canna
Wetland 2	Halifax maidencane	Blue flag
Wetland 3	Giant Cutgrass	Bulrush
Wetland 4	No plant	No plant



Seven day detention

- Expanded Clay Growth Media Mixture:
- Expanded Clay
 - Vermiculite
 - Peat Moss

- Pollution Control Media Mixture:
- Tire Crumb
 - Saw Dust
 - Astatula Sand
 - Lime Stone

Laboratory Analysis

- ▣ Real-Time PCR is used to detect and measure microorganism in the media and soil.
- ▣ Certified Lab for other parameter measures.

Note: NSF 245 Standards are used as the target for the influent and effluent water quality.

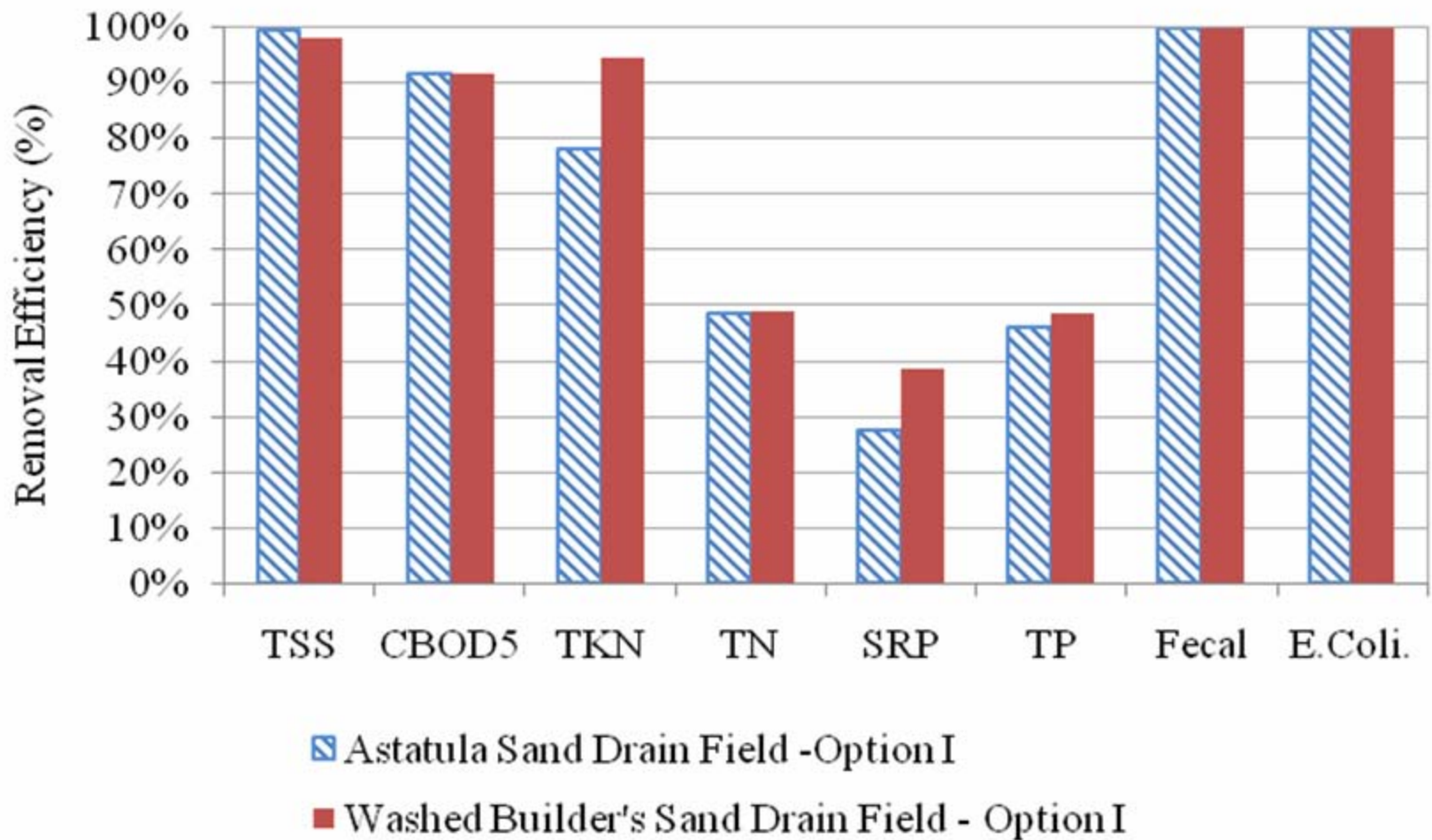


NSF 245 and UCF Wastewater Raw waste or influent numbers

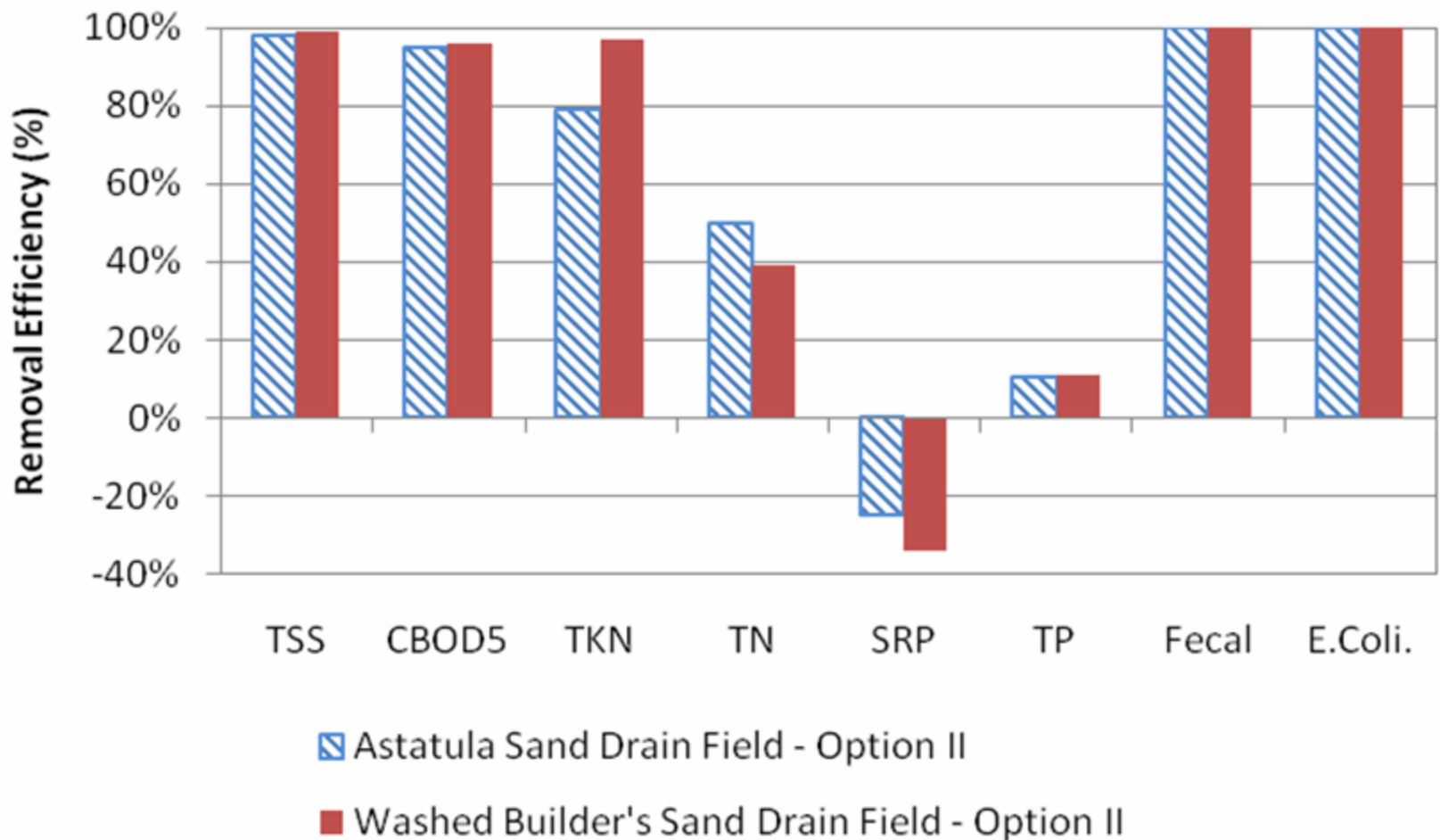
	TSS (mg/L)	CBOD5 (mg/L)	TKN (mg/L)	ALK (mg/L as CaCO ₃)	Temperature (Celsius)	pH (S.U.)
UCF Average Influent	301	119.2	47.1	297.2	23.6	7.6
NSF/ ANSI 245	100 - 350	100 - 300	35 - 70	> 120	10 - 30	6.0 - 9.0
Status	OK	OK	OK	OK	OK	OK

Wastewater is from a scholarship dorm with 15 beds, kitchen and laundry and when students not there, flow is from the University Reception Home Which has at least two residence year round plus kitchen and laundry.

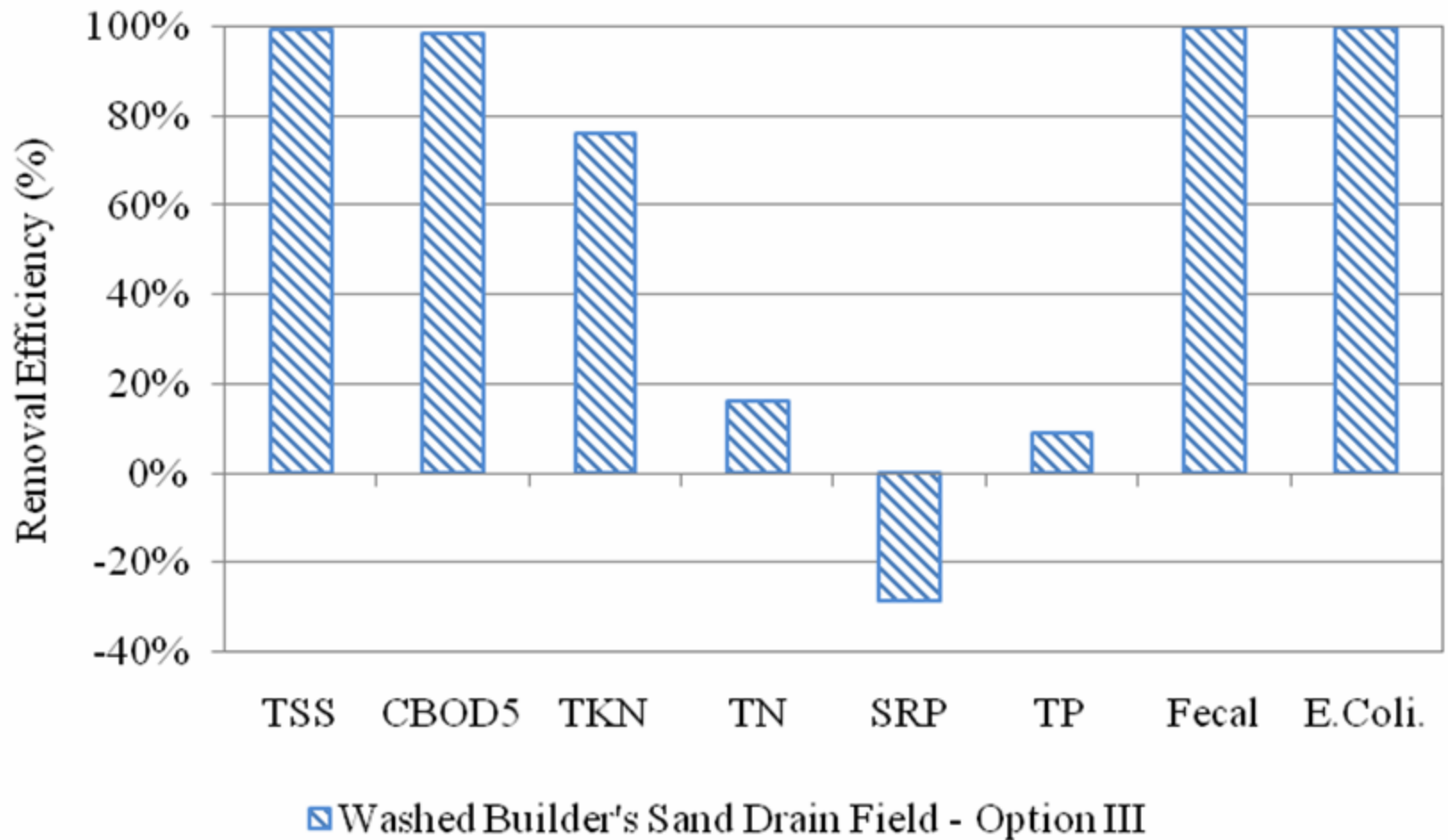
Removal efficiency of the OSTDS Recirculation Design I



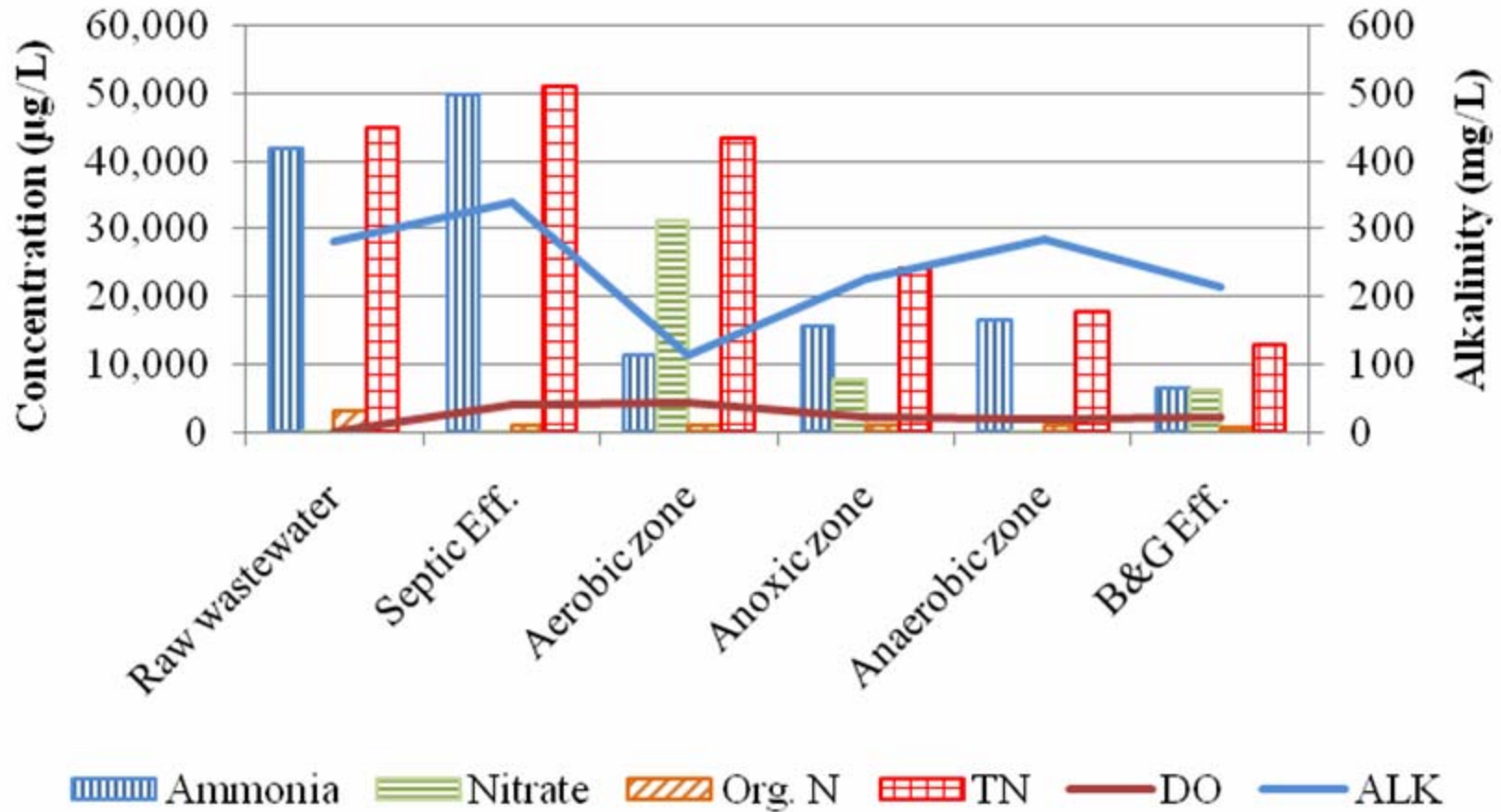
Removal efficiency of the OSTDS Recirculation Design II



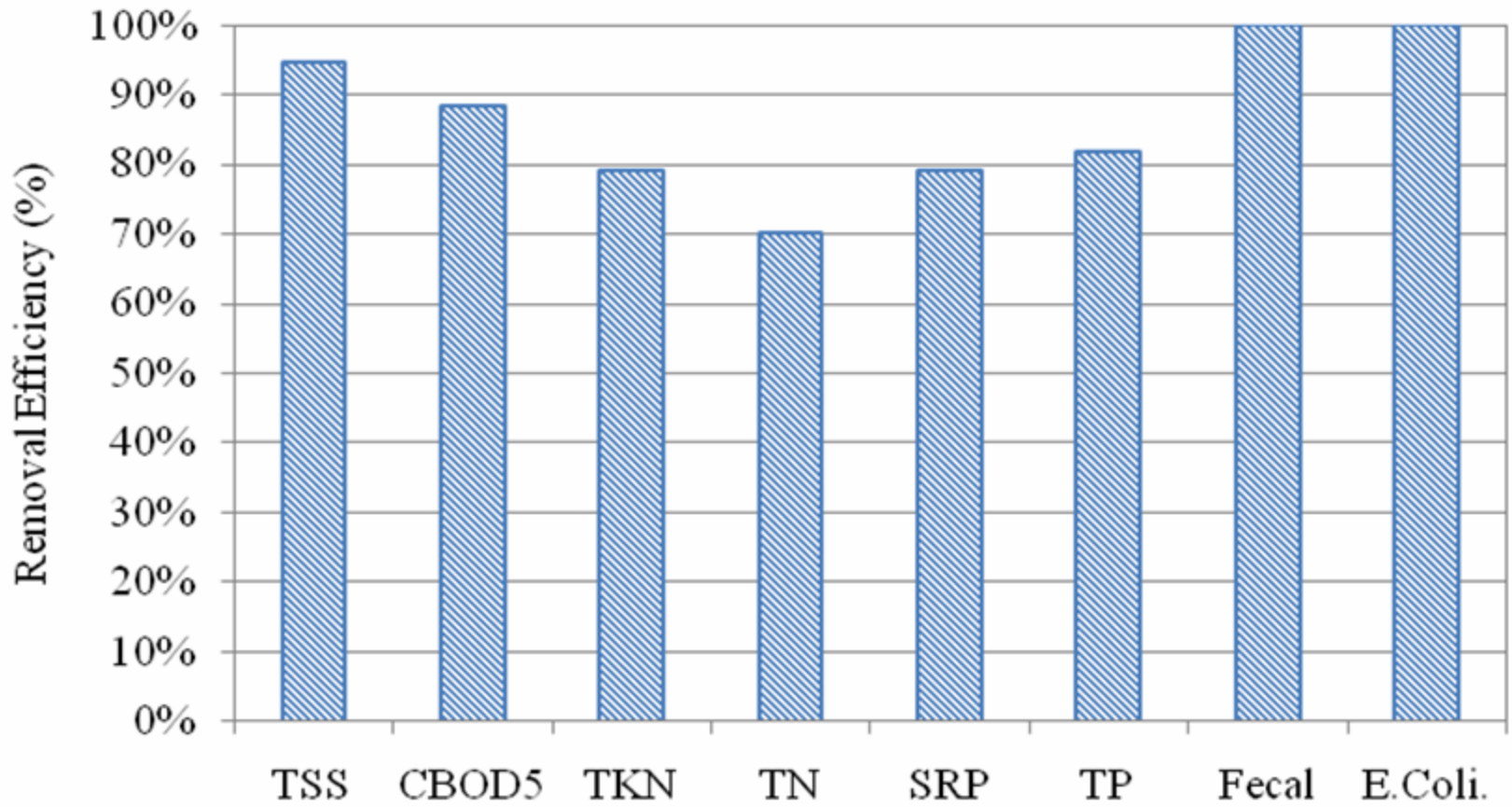
Removal efficiency of the OSTDS Recirculation Design III



Tracking of nitrogen species in the B&G OSTDS (from April 1, 2009 sample date)



Overall septic and B&G media filter removal efficiency (5 data sets)

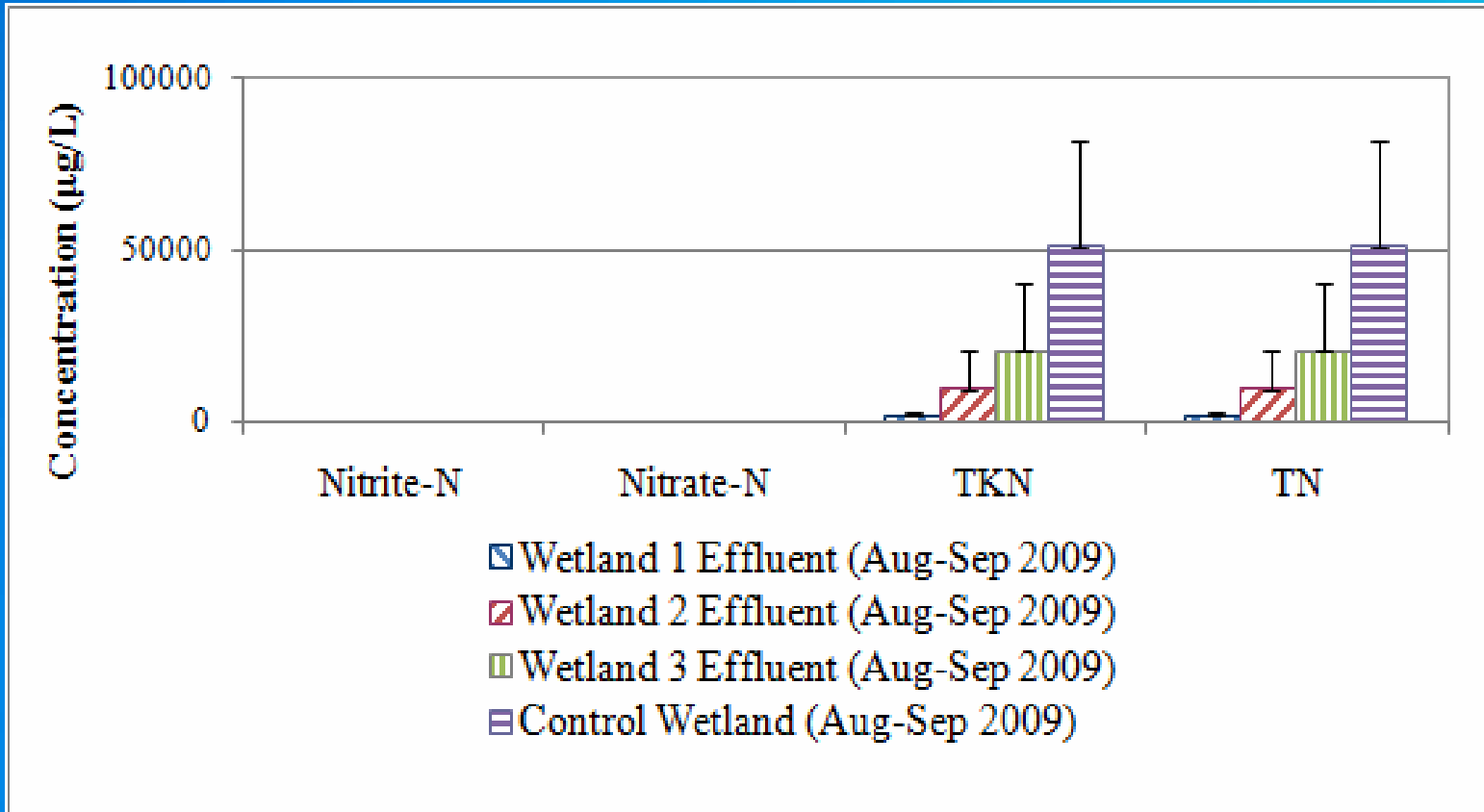


Performance of SUW

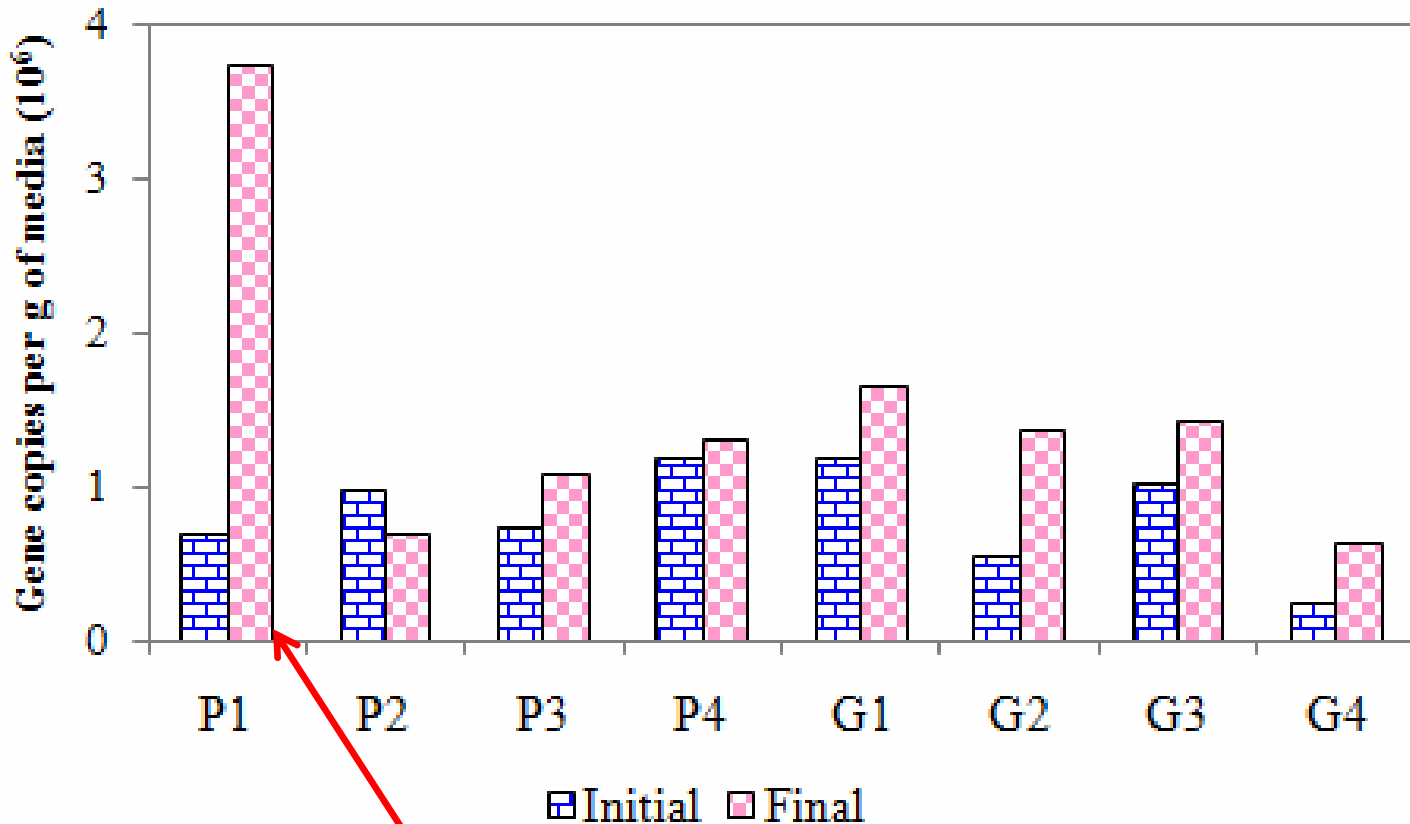
Parameter	Removal efficiency [(in-out)/in]*100 (%)			
	Wetland 1 (Canna)	Wetland 2 (Blue Flag)	Wetland 3 (Bulrush)	Wetland 4 (Control)
Fecal Coliform	99.98	97.06	99.76	99.74
E. Coli	100.00	99.94	99.80	100.00
BOD ₅	89.4	89.6	85.2	75.2
CBOD ₅	87.6	86.5	81.1	79.5
NH ₃	98.6	97.9	62.0	27.6
Total N	97.1	93.0	62.5	10.5
SRP	99.5	99.0	99.6	99.3
Total P	98.3	95.7	98.0	85.7

Nitrogen Species in effluent from 4 SUWs

SUW 1 (Canna) [best performance]



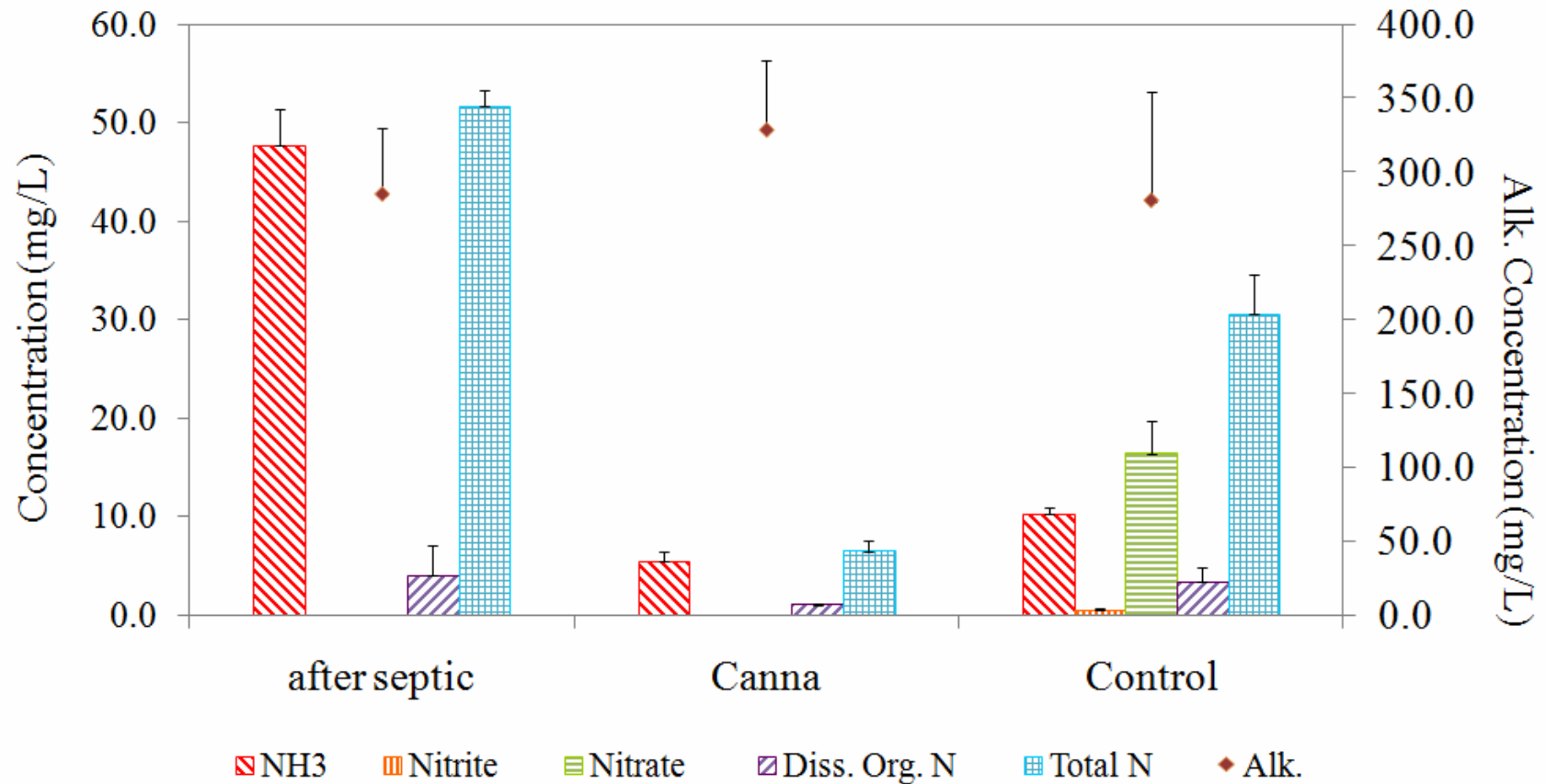
Quantity of denitrifying bacteria



Denitrifying bacteria in pollution control media of SUW cell 1 increased by about five times

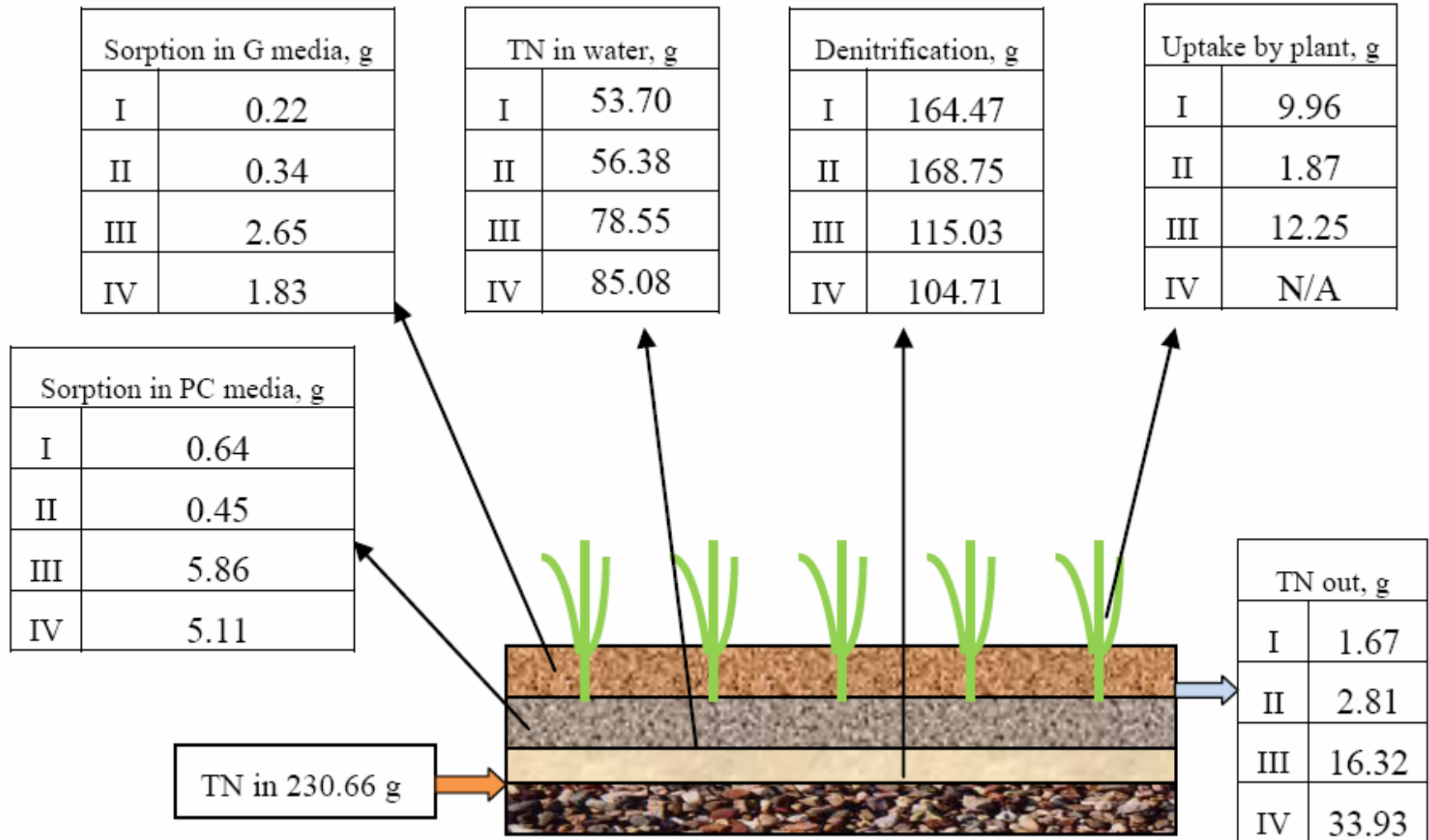
(P1= PC medium in wetland 1, G1= G medium in wetland 1, and so on)

Nitrogen concentration cold weather stress test

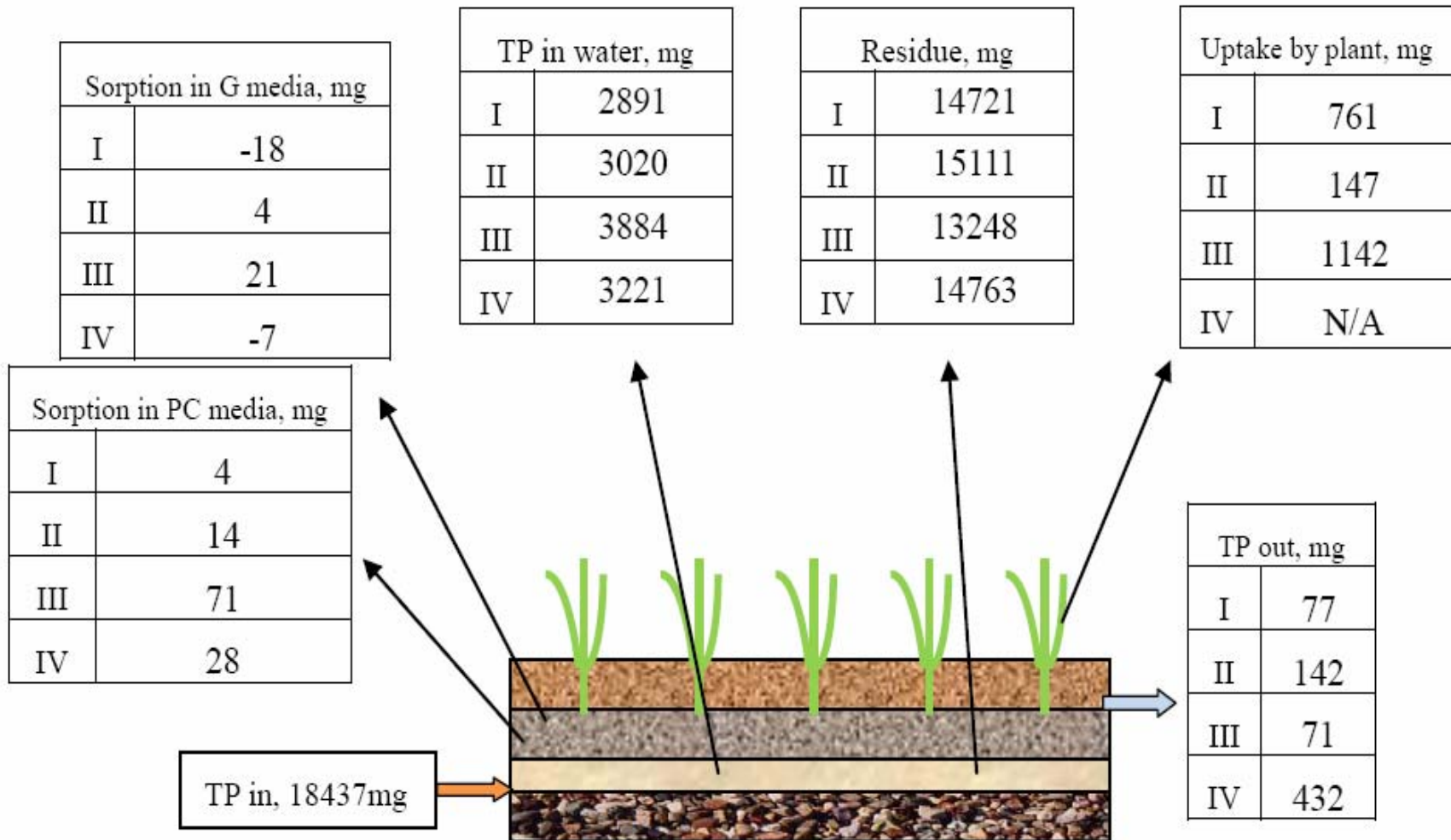


Mass balance of N in SUW

note also a significant (>75%) flow reduction



Mass balance of Phosphorous in SUW



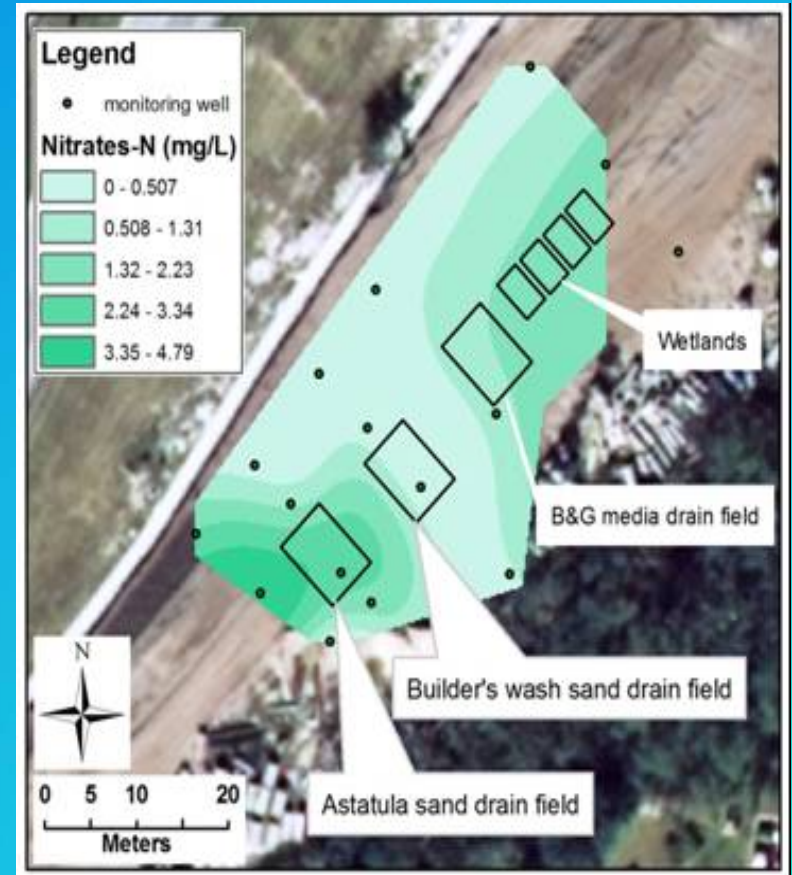
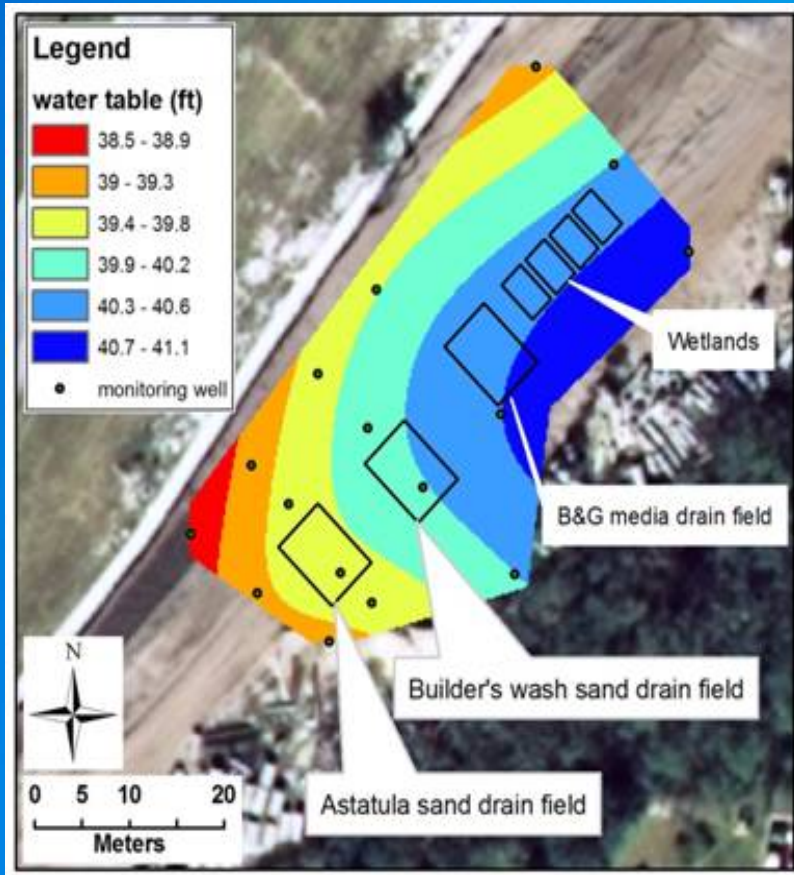
Removal efficiencies of each process unit compared to septic tank effluent

Parameter	RSF Design I	RSF Design II	RSF Design III	B&G Media filter	Wetland 1	Wetland 2	Wetland 3	Control wetland
Alkalinity	15.2%	24.1%	-15.5%	34.6%	-11.4%	8.1%	-7.3%	35.9%
TSS	66.9%	62.1%	53.0%	81.2%	-116.3%	-10.0%	-100.0%	-46.6%
BOD5	51.5%	58.5%	65.0%	90.9%	88.8%	83.2%	84.5%	75.3%
CBOD5	20.3%	62.7%	72.0%	93.9%	87.7%	88.3%	85.4%	83.3%
Ammonia-N	68.4%	37.3%	1.1%	82.3%	98.4%	88.2%	68.3%	22.6%
Org. N	-47.1%	39.3%	-22.2%	43.6%	91.1%	75.2%	71.8%	27.9%
TKN	48.2%	37.6%	-8.0%	79.7%	97.1%	85.8%	69.0%	23.5%
TN	32.2%	18.2%	-7.9%	66.1%	97.1%	85.8%	69.0%	23.5%
SRP	43.5%	-3.1%	-0.6%	84.7%	99.6%	95.7%	99.6%	99.4%
Diss. Org. P	92.7%	-60.0%	-18.6%	5.5%	95.3%	81.0%	94.7%	61.8%
TP	47.8%	-1.9%	-5.0%	77.6%	98.3%	91.3%	98.2%	88.4%
Fecal	99.3%	87.1%	98.9%	100.0%	99.9%	98.5%	98.3%	98.4%
E.Coli.	99.8%	70.5%	98.3%	100.0%	100.0%	99.0%	98.0%	98.3%

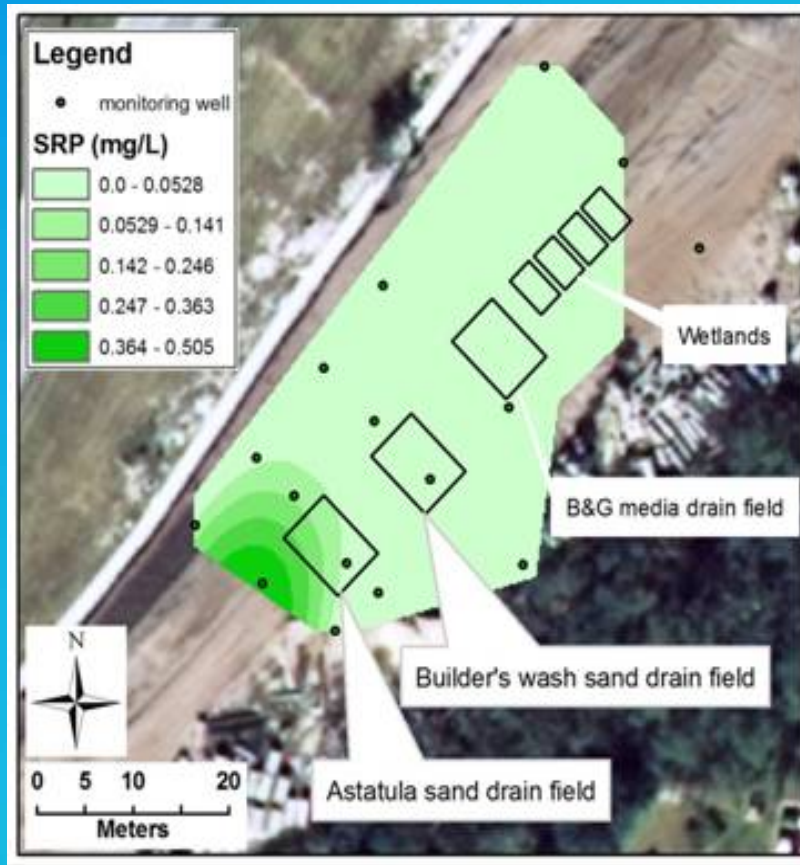
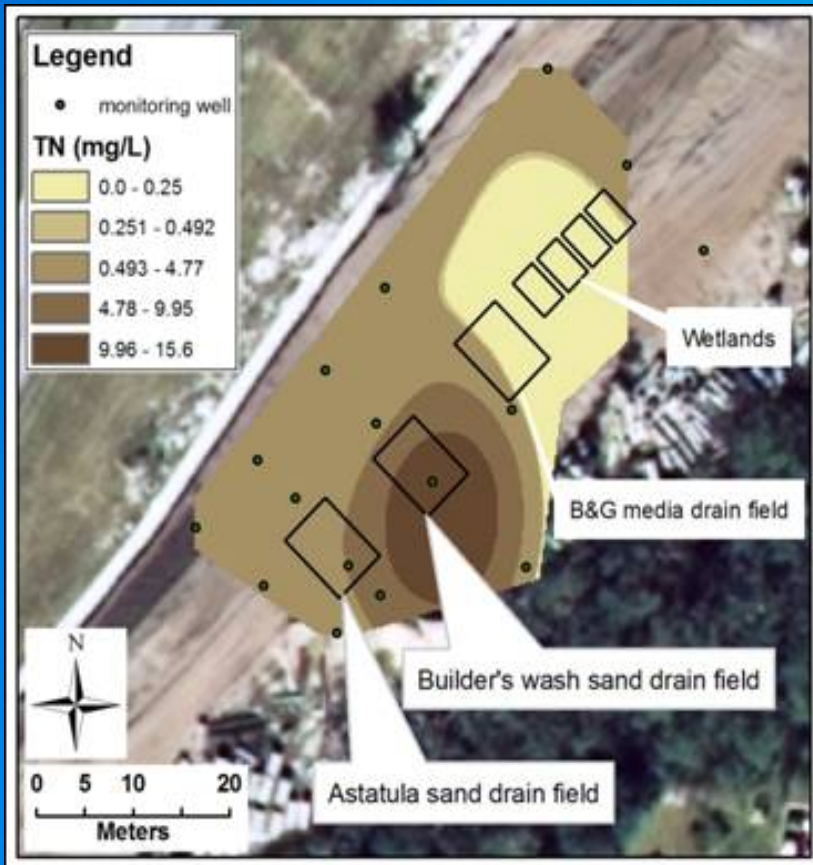
Comparison of average effluent concentrations using four OSTDS designs

	Conventional OSTDS Control case	Recirculation Design I	B&G Media filter	SUW Sorption with Canna Plants
CBOD5 (mg/L)	1	2	5	3
Nitrate-N (mg/L)	41.97	14.86	3.00	0.004
TN (mg/L)	48.09	18.21	13.58	1.73
SRP (mg/L)	4.58	3.07	0.82	0.018
TP (mg/L)	4.92	3.88	1.38	0.096
Fecal (cfu/100mL)	1	2	5	20
E.Coli. (cfu/100mL)	1	1	4.5	1

GW Well Locations and NO3-N



GW TN AND SRP

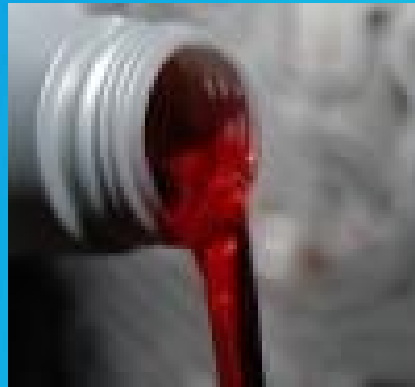
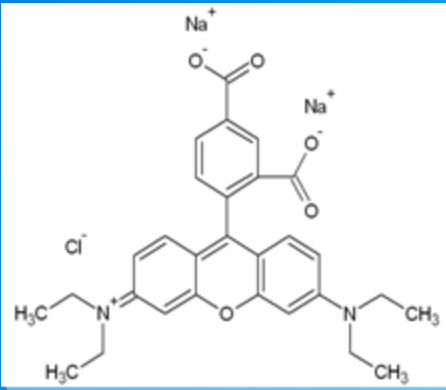


Groundwater Measurements

Parameter/Location	Background concentration	Highest beneath the conventional drain fields
TN (mg/L)	.426	46.4
Nitrate-N (mg/L)	BDL*	29.9
Ammonia-N (mg/L)	.034	42.6
TP (mg/L)	.032	6.53
SRP (mg/L)	.004	2.89

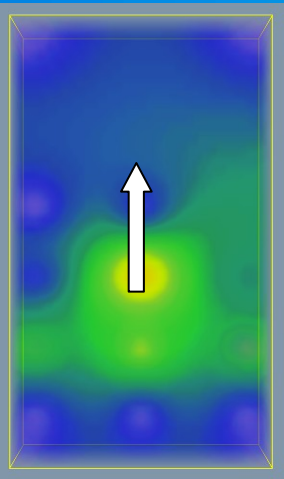
Tracer study

- ▣ Rhodamine WT was used as a tracer within wastewater to determine the direction of flow and HRT.

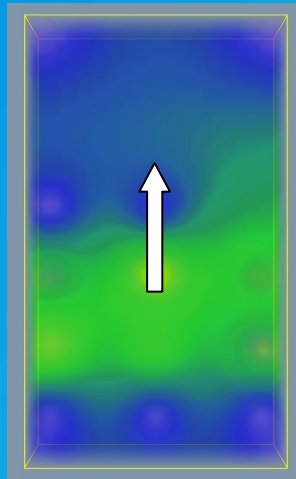


Plan view and 3-dimensional scenarios of the tracer distribution in the B&G media filter; unit: ppb. The arrow shows the flow direction

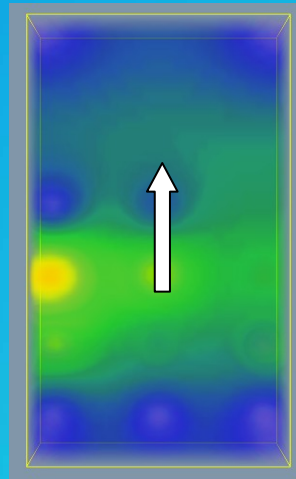
Design HRT = 3.0 days, Measured = 3.3 days



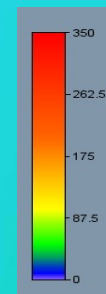
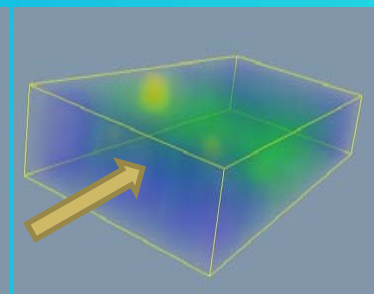
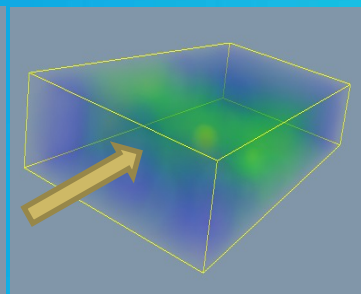
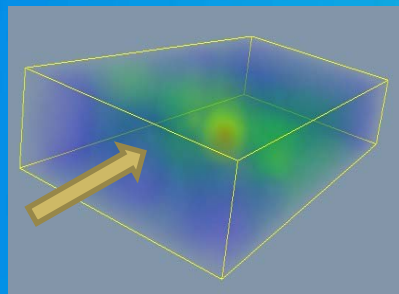
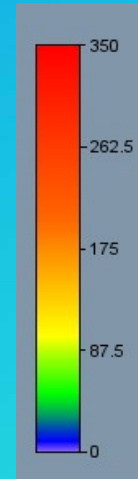
7th day



10th day

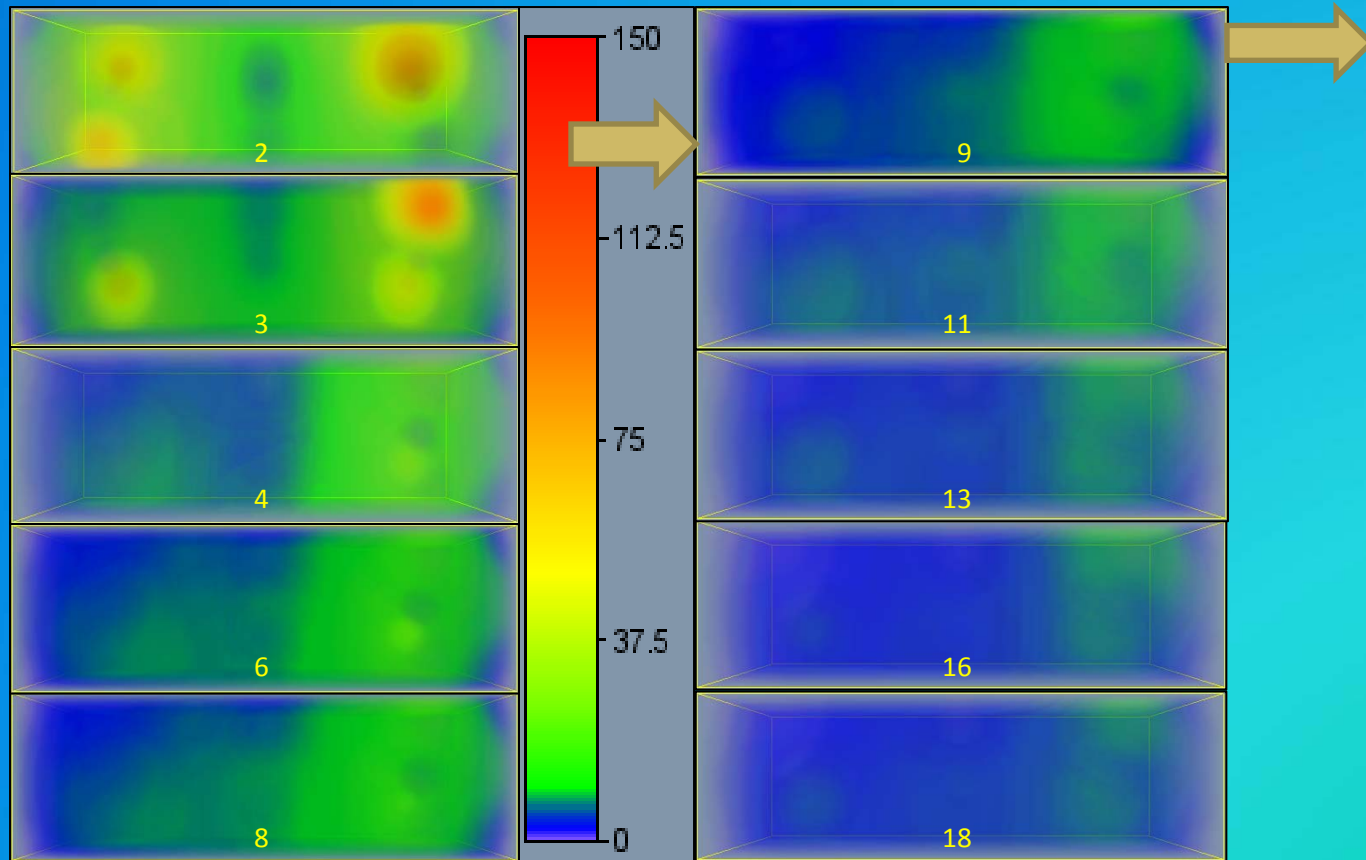


14th day



Section view of the tracer distribution in SUW

Design HRT=6.6 days, Measured = 7.1 days



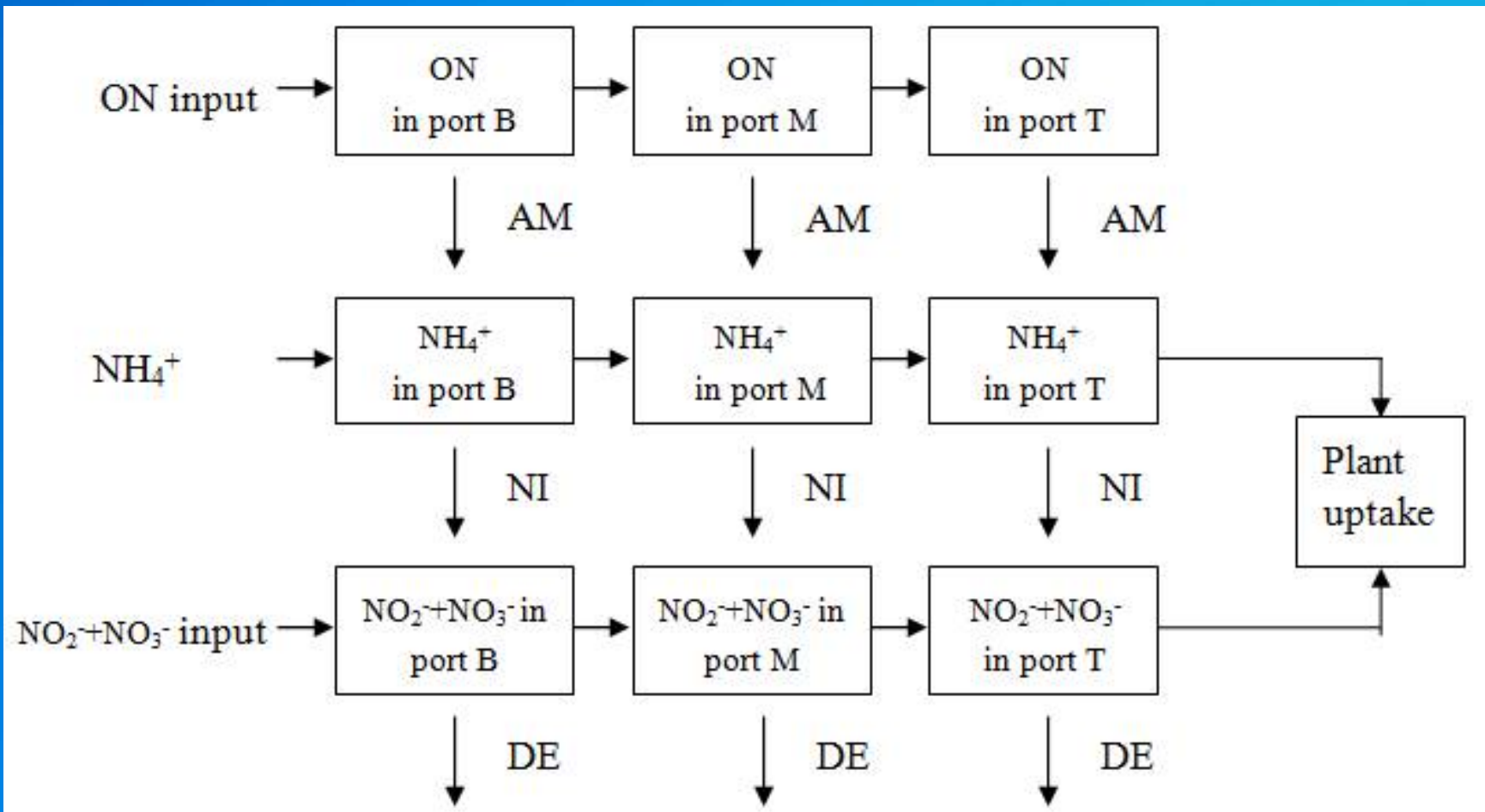
(Left five small images: 2 days, 3 days, 4 days, 6 days, 8 days; Right five: 9 days, 11 days, 13 days, 16 days, 18 days). The vertical scale is showing the concentration (ppb)

Tracer HRT of SUW

t(d)	C(t) (ppb)	C(t) dt	tC(t) dt
0.0	0.0	-	-
2.0	73.1	146.2	292.4
3.0	105.1	105.1	315.3
4.0	39.3	39.3	157.3
6.0	32.4	64.8	388.8
8.0	30.0	60.1	480.5
9.0	30.0	30.0	270.1
11.0	24.2	48.3	531.5
13.0	18.5	37.1	481.8
16.0	20.1	60.4	966.7
18.0	13.7	27.3	491.8
-	-summation-	618.6	4376.1

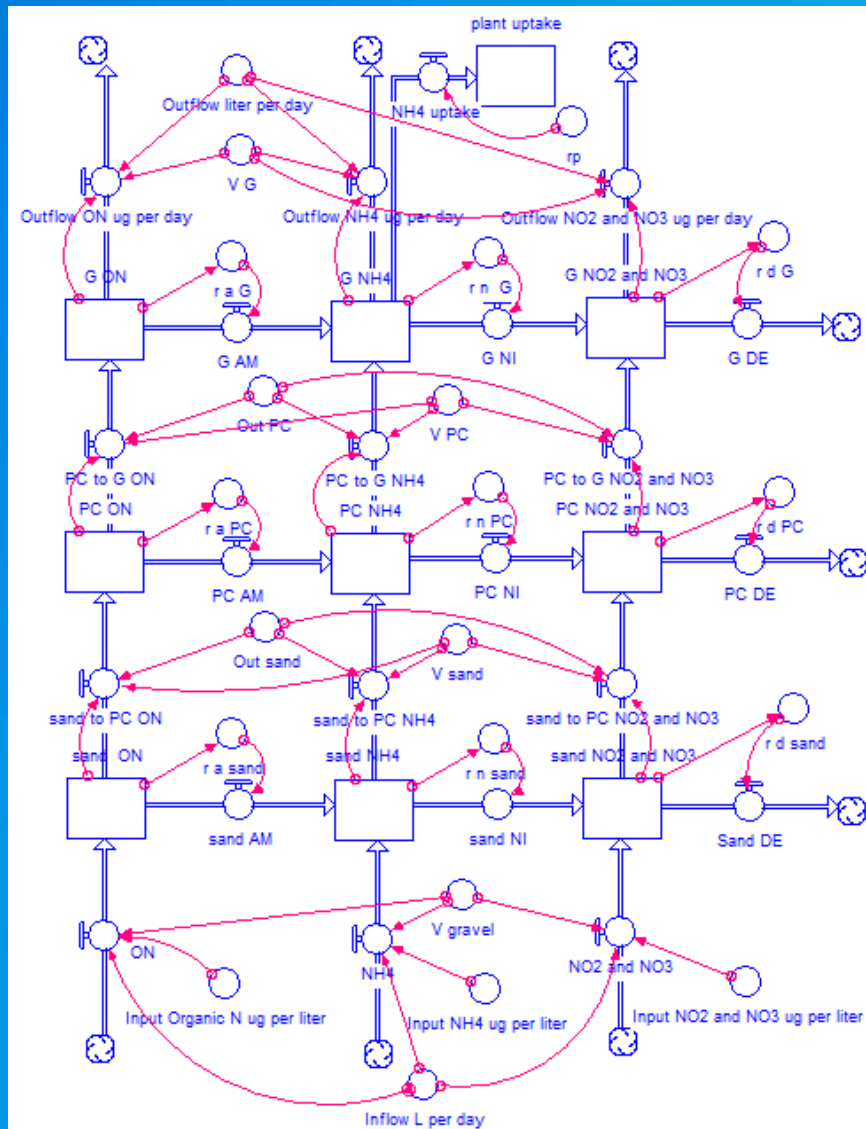
Tracer HRT = 7.1 days (4376.1/618.6)

Conceptual model of nitrogen removal in SUW



Note: ON = Organic Nitrogen; AM = ammonification; NI= nitrification; DE= denitrification
B = Bottom Layer; M = Middle Layer; T = Top Layer

SUW flow diagram of nitrogen removal model in STELLA model



Growth Media

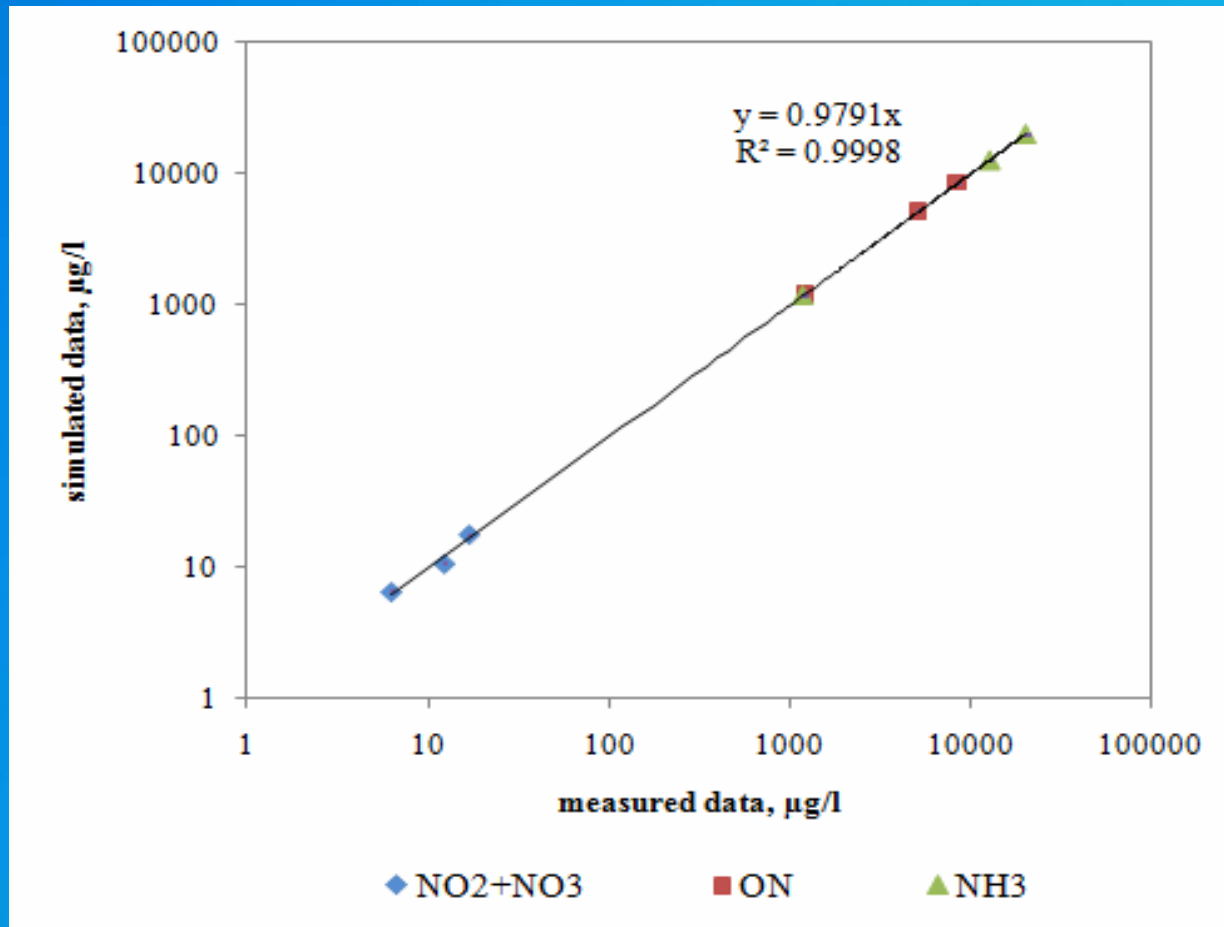
Pollution Control Media

Sand Media

Description of parameters in SUW model

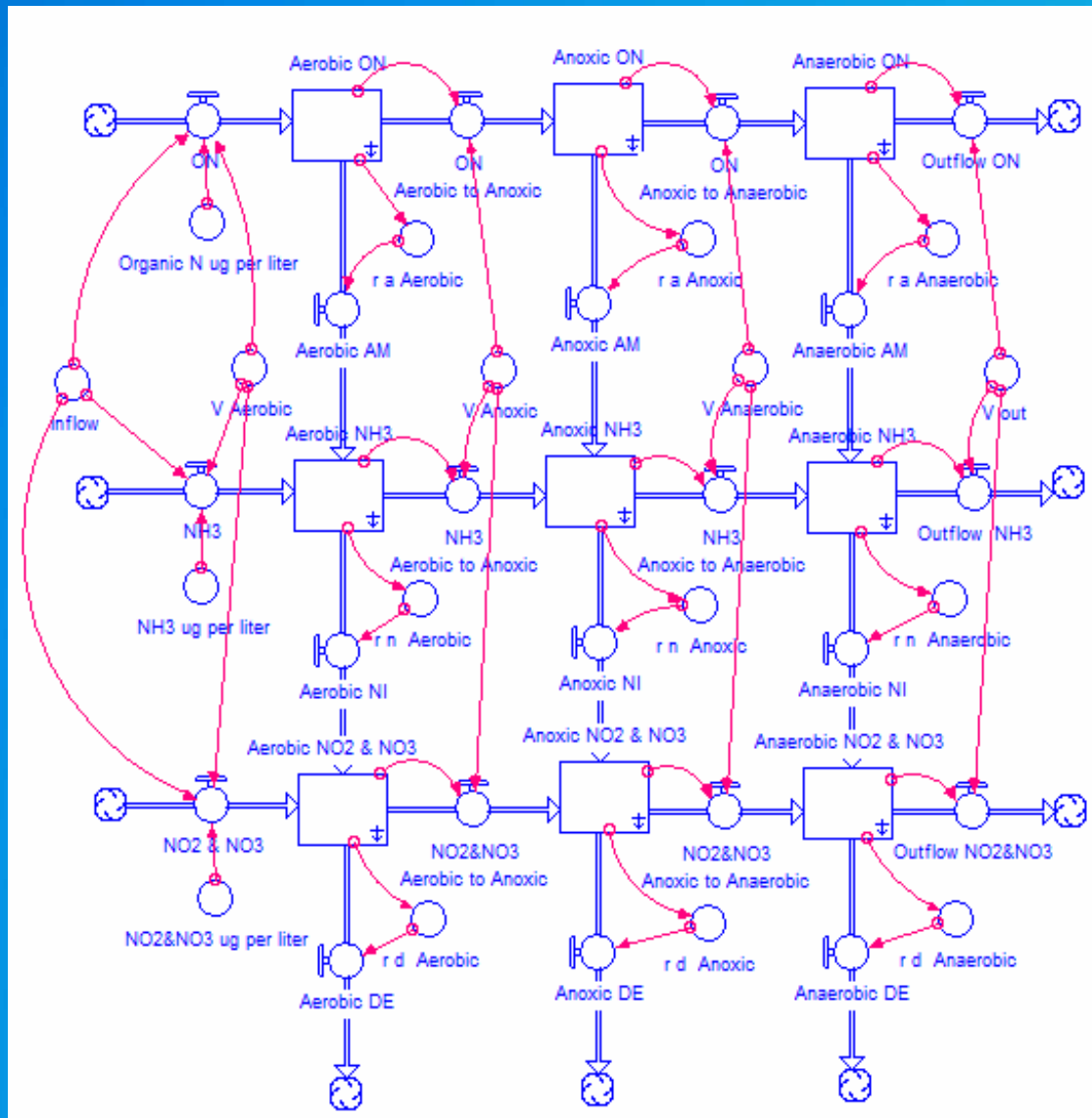
Parameter	Description	Rate equations	Values	Source
Ka	Ammonification constant	$r_a = kaC_{ON}$	Optimised	Beran and Kargi, 2005
Gp	Plant growth rate	$r_p = iNPgp$	0.5	Yi et al, 2009
iNP	Plant N content	$r_p = iNPgp$	Measured	Yi et al, 2009
u_N	Nitrosomonas growth rate	$r_n = \frac{u_N}{Y_N} e^{0.098(T-15)} [1 - 0.833(7.2 - pH)] \left(\frac{C_{AN}}{1 + C_{AN}} \right) \left(\frac{C_{DO}}{1.3 + C_{DO}} \right)$	Optimised	Kadlec and Knight, 1996
Y_N	Nitrosomonas yield coefficient	$r_n = \frac{u_N}{Y_N} e^{0.098(T-15)} [1 - 0.833(7.2 - pH)] \left(\frac{C_{AN}}{1 + C_{AN}} \right) \left(\frac{C_{DO}}{1.3 + C_{DO}} \right)$	Optimised	Kadlec and Knight, 1996
K_{20d}	Denitrification rate	$r_d = K_{20d} \theta_d^{(T-20)}$	Optimised	Mayo and Mutamba, 2005

Simulated vs. Measured Data in model calibration



Note: model validation had an R^2 value of 0.9644

B&G Model



Modeling Summary and Findings

- ▣ The system dynamic model is designed to simulate the SUW and B&G media filter
- ▣ Model reproduces high removal of nutrient and bacteria in the specific filtration beds integrated with plant species.
- ▣ The predicted and measured concentrations of the ON, NH_4 and $\text{NO}_2 + \text{NO}_3$ in SUW and B&G media filter were in good agreement.
- ▣ Model calibration and validation resulted in “strong” R-squared values.

Cost Comparisons

Year 2009 data, 500 gpd basis

	Construction Cost with 20% contingency (\$)	Annualized Construction Cost at 6% interest rate and 20 years (\$)	Annual Operating cost (\$)	Unit Cost \$/1000 gallons design flow
Conventional OSTDS	\$ 5,770	\$ 500	\$ 200	\$ 3.84
Conventional OSTDS with Recycle Filter	\$ 6,920	\$ 600	\$ 390	\$ 5.42
B&G with sorption media and drain field	\$ 8,370	\$ 725	\$ 200	\$ 5.10
SUW with sorption media and plants	\$ 9,070	\$ 785	\$ 400	\$ 6.50
Conventional with Drip Irrigation	\$ 10,500	\$ 920	\$ 1460	\$ 13.04
Continuous Feed Cyclic Reactor & Drip Irrigation	\$ 15,170	\$ 1,325	\$ 1,800	\$17.12
Recirculation Tank & Drip Irrigation	\$ 23,170	\$ 2,015	\$ 1,850	\$ 21.18