

2018 Annual Report to
The Massachusetts Department of Environmental Protection

***The performance monitoring of the non-proprietary layered systems
presently under Site-Specific Pilot Approvals***

REPORT BY

Barnstable County Department of Health and Environment

Massachusetts Alternative Septic System Test Center



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Contact person:

George Heufelder, M.S.,R.S – Cell 508-737-8848

WWTPO Registration Number 7591 4-M Full

System Inspector # SI 4859

Introduction

The following serves as an annual report on four systems allowed under the site-specific Pilot Approval allowance. The systems involve a modification of a standard soil absorption system by placing a layer of organic matrix within the profile of fill installed in accordance with 310 CMR 15.255: Construction in Fill. Specifically, a layer of sand mixed with sawdust at an approximate ratio of 1:1 by volume is placed beneath an 18-inch layer of sand fill which fully meets the above-referenced requirement specification. In each case, the bottom of “the system” for purpose of determining compliance with 310 CMR 15.212: Depth to Groundwater is the bottom-most extent of the sand/sawdust layer or an underlying layer of peastone beneath that layer.

The technology reported on herein has been variously named “layered system”, “layer cake”, “sawdust system” and others. Is a non-proprietary strategy for attenuating nitrogen by facilitating the denitrification of nitrified percolate beneath a soil adsorption system. The soil(fill) profile sequence is illustrated below.

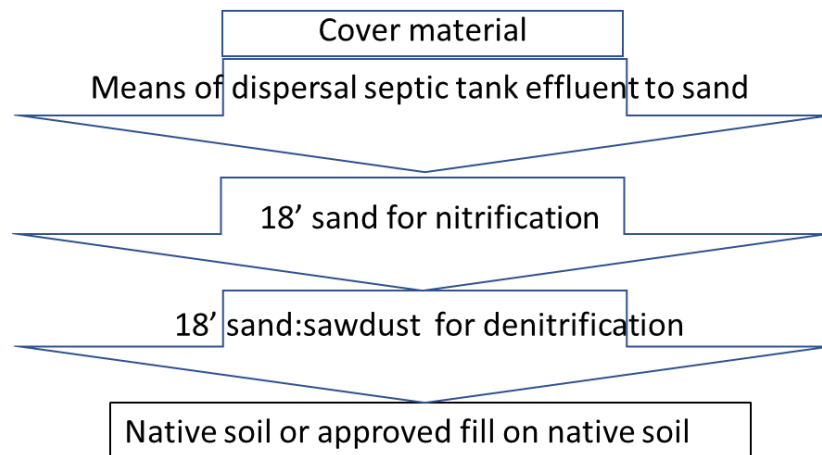


Figure 1 Conceptual representation of layered system for denitrifying percolate beneath onsite septic system soil absorption systems.

Simply described, the layered system is a soil absorption system installed in compliance with 310 CMR 15.000 with the exception that a portion of the fill material used contains organic material which is not allowed by 310 CMR 15.255 (3) which states “The fill shall be comprised of clean granular sand, be free from organic matter...”. The sawdust by nature is classed as organic matter.

Use of this layered strategy derives from work by Robertson (2010; 2005; 2000) and others. Systems reported here were piloted under various demonstration grants and were supported partially by federal or state funds for the purpose of researching this strategy as a simple, sustainable means of attenuating nitrogen from onsite septic systems. The goal is to attenuate the impacts of wastewater-derived nitrogen on sensitive marine embayments in the Commonwealth and elsewhere. Although some commercially-available products are used in the systems reported on herein, the use of any particular products (notably the means of effluent dispersal to the sand layers) is not exclusive and substitutions will likely achieve similar results if properly adapted for pressure distribution.

Sampling

Sampling at all systems was from pan lysimeters placed below the soil absorption system. These sampling ports, by their nature, may not always yield sufficient volume for all assays. *The emphasis and priority for assays was placed on the nitrogen species since in each case of the installations, no relief from SAS sizing requirements was requested.* In all but one of the systems reported a portion of the soil absorption system (SAS) was constructed that complied with 310 CMR 15.00 and acted as a controlled comparison. That is a portion of the soil absorption system did not contain any sawdust in the lower portion (18 inches) of the ~38-inch profile of required fill. Two pan lysimeters were placed in both the treated and control portion of the system and the collection from each was composited to use as a representation of system or control performance. Pan lysimeters are described and illustrated in Appendix A.

All samples were taken by staff of Barnstable County Department of Health and Environment and all analyses were performed at Commonwealth Certified laboratories including the Barnstable County Department of Health and Environment Laboratory. All data collected are reported in Appendices B-E. The following summaries focus on the nitrogen component of the wastewater since this was the primary reason for their installation.

System Installations and Results

System #1 – Chapaquoit Rd, West Falmouth

This home is seasonal and includes a guest cottage in the rear of the property that is also connected to the system. The system was installed in spring of 2017 and was sampled four times in 2017 and four times in 2018. A comparison of the nitrogen levels indicates that the sawdust portion of the system removed significantly more nitrogen than the control or standard Title 5 portion of the leachfield (figure 2)

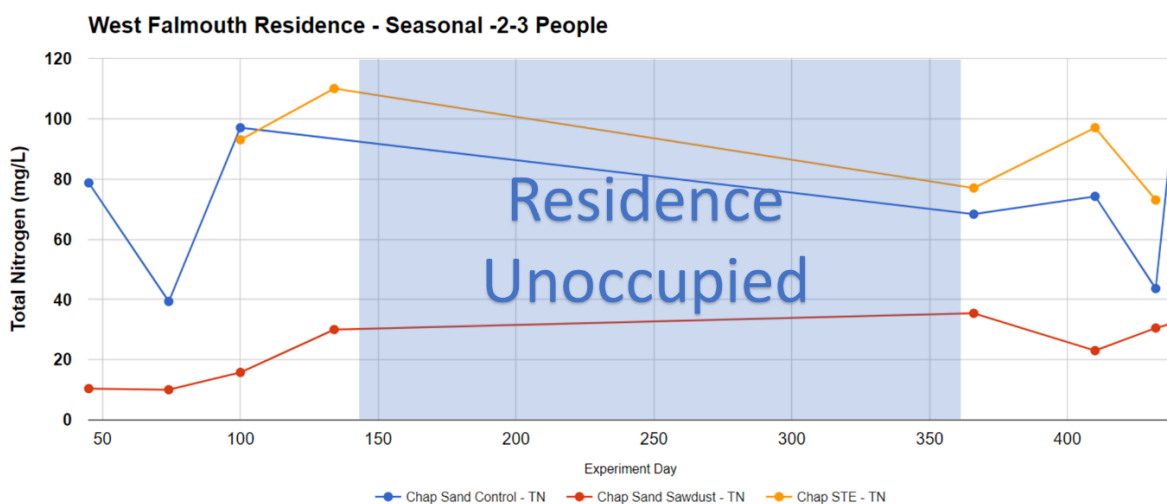


Figure 2 Total nitrogen in percolate beneath a layered and unlayered portion of the soil absorption system at Chapaquoit Rd. in Falmouth during seasonal use in 2017 and 2018.

When occupied, the home used an average of 102 gallons (386 liters) per day. All data collected at the home is included in Appendix B. Of particular note is the fact that the mean Total Nitrogen (TN) from the septic tank was 90 mg/L (80 – 100 mg/L, p=.05), which is higher than levels generally assumed. The standard portion of the system mean TN = 76 mg/L (61 – 90 mg/L, p= .05) represents a 15.6 % reduction in TN. The treated sand/sawdust portion of the system shows a mean TN concentration of 23 mg/L (17 – 30 mg/L, p=.05) which represents a 74.4% reduction in TN. Using this statistic, the layered system offered a 58.5% improved removal of TN compared to the standard system in compliance with Title 5.

System #2 Sippewissett Rd., Falmouth

This residence has some sporadic occupancy but is generally year-round with at least one occupant. Months with no samples represent months where the occupancy was questionable. Seven samples were taken from May 2018 – September 2018 (figure 3) and the average water usage of the home was 121 gallons (4587 liters) per day. The mean Total Nitrogen (TN) from the septic tank was 74 mg/L (50 – 98 mg/L, p=.05). The standard portion of the system mean TN = 48 mg/L (40 – 57 mg/L, p= .05) represents a 35.1 % reduction in TN. The treated sand/sawdust portion of the system show a mean TN concentration of 26 mg/L (21 – 32 mg/L, p=.05) which represents a 64.9% reduction in TN. All data collected are presented in Appendix C. Using this statistic, the layered system offered a 29.8% improved removal of TN compared to the standard system in compliance with Title 5.

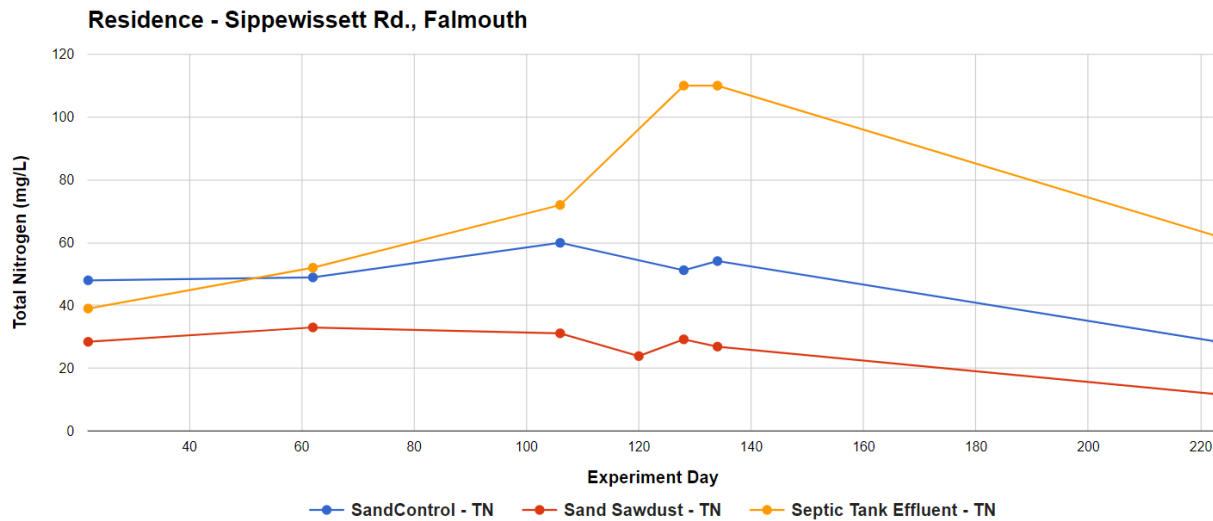


Figure 3 Total nitrogen in percolate beneath a layered and unlayered portion of the soil absorption system at Sippewissett Rd. in Falmouth during 2018.

System #3 South Main St., Acushnet

This year-round residence had two occupants until July 2018 when an additional one person (infant) came to reside. The average daily flow from May – October was 222 gallons (840 liters). Nine samples were taken from May – October 2018 (figure 4).

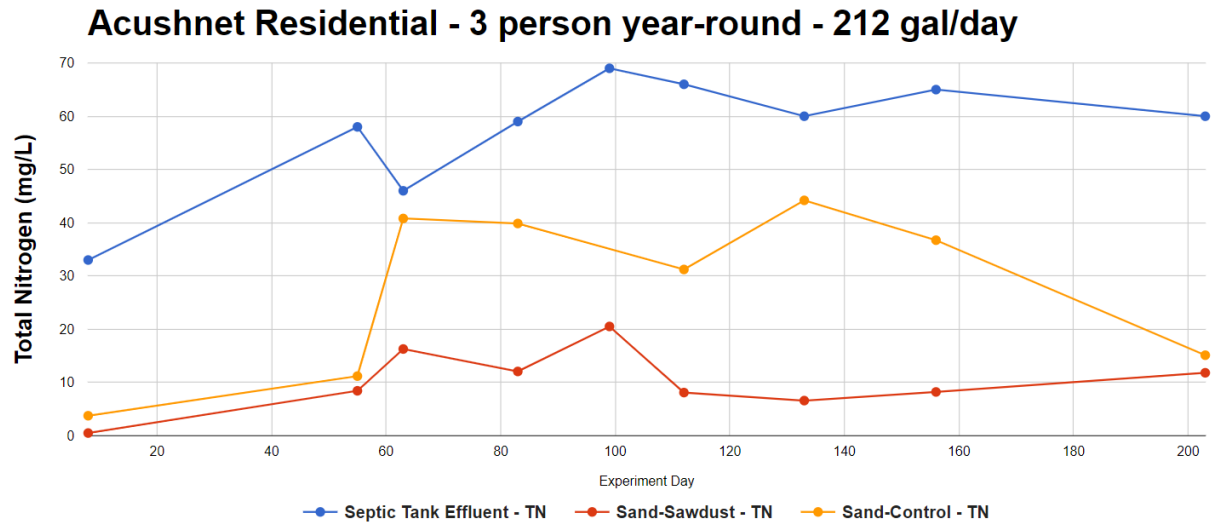


Figure 4 Total nitrogen in percolate beneath a layered and unlayered portion of the soil absorption system at South Main Street, Acushnet during 2018.

All data collected are presented in Appendix D. The mean Total Nitrogen (TN) from the septic tank was 57 mg/L (50 – 65 mg/L, $p=.05$). The standard portion of the system mean TN = 28 mg/L (17 – 39 mg/L, $p= .05$) represents a 50.1 % reduction in TN. The treated sand/sawdust portion of the system show a mean TN concentration of 11 mg/L (7 – 15 mg/L, $p=.05$) which represents an 80.1 % reduction in TN. Using this statistic, the layered system offered a 30.0% improved removal of TN compared to the standard system in compliance with Title 5.

Of particular note is the fact that in November, the standard configuration showed a percolate concentration of 15.1 mg/L TN, which was unusually low. This collection followed a heavy rain the previous two days. Excessive water accumulation in the lysimeters for that date suggest saturated conditions existed and may account for the increased nitrogen removal compared with other dates sampled. Saturated conditions following nitrification are conducive to denitrification when adequate carbon is available.

System #4 Little Island Rd., Falmouth

This system was installed in 2017, but due to unfortunate circumstances having to do with the owners' health and intermittent occupation of the property only eight samples have been taken (Appendix E). Considering all eight samples taken to date, the average TN of the influent was 72 mg/L TN (57 – 87 mg/L, $p=.05$). Since there is no control trench installed at this location treatment of the sand/sawdust can only be compared with the septic tank effluent. The percolate collected beneath the system show an average TN of 15 mg/L (7 – 24 mg/L, $p=.05$). This represents a 79.2% removal of TN.

Since the occupancy of the house was sporadic in 2018, effort for sampling was skewed toward times of known high occupancy (July – August 2018) by family members. During this period, the average TN was 8 mg/L (3 – 13 mg/L, $p=.05$) concurrent with influent septic tank TN concentration averaging 90 mg/L. This represents > 90% TN removal.

Special Note

It should be noted the percolate beneath both the standard SAS and the SAS supplemented with sand/sawdust matrix occasionally exhibit values less than 6.0. This is likely due to the low alkalinity of our wastewater and the geologic setting. The authors question the use of this parameter as a regulatory benchmark when being applied to soils-based systems.

Calculation of nitrogen load reduction

In three of the above referenced cases an actual nitrogen load reduction can be estimated based on the wastewater volume discharged. The volume discharged is calculated by measuring the volume per dose to the SAS (performed at each site) and recording the total number of doses over the sampling period. From this is derived a load/day estimate based on the average total nitrogen concentration in the percolate. The formula used is:

$$\text{N Load Per year} = U \frac{\text{Gallons}}{\text{Day}} \times \frac{3.789 \text{ Liters}}{\text{Gallon}} \times C \frac{\text{mg}}{\text{Liters}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

Where:

U = water usage per day and C = Average concentration of nitrogen in element examined (septic tank, standard system, sand/sawdust system). The following are the load estimates from each of the systems above on an annualized basis (assuming year-round use):

System #1 – Chapaquoit Rd, West Falmouth

Load Reductions									
	Gal/day	Liters/day	mg/L	days/year	kg/mg	kg/year	lbs/year	% load reduction	
ST	90.1	341.2	90	356	0.000001	10.9	24.1	-	
Sand	90.1	341.2	76	356	0.000001	9.2	20.3	16%	
Sand/Sawdust	90.1	341.2	23	356	0.000001	2.8	6.1	74%	

System #2 – Sippewissett Rd., Falmouth

Load Reductions									
	Gal/day	Liters/day	mg/L	days/year	kg/mg	kg/year	lbs/year	% load reduction	
ST	121.0	458.5	74	356	0.000001	12.1	26.6	-	
Sand	121.0	458.5	28	356	0.000001	4.6	10.1	62%	
Sand/Sawdust	121.0	458.5	12	356	0.000001	2.0	4.3	84%	

System #3 – South Main Street, Acushnet

Load Reductions									
	Gal/day	Liters/day	mg/L	days/year	kg/mg	kg/year	lbs/year	% load reduction	
ST	222.2	841.8	57	356	0.000001	17.1	37.6	-	
Sand	222.2	841.8	28	356	0.000001	8.4	18.5	51%	
Sand/Sawdust	222.2	841.8	11	356	0.000001	3.3	7.3	81%	

Operation and Maintenance

All systems installed under the Site-Specific Pilot Approval have low pressure distribution components as part of their treatment. Each time in the case of Systems # 1-3, the electrical panel was opened, checked for problems such as leaks and electrical problems, and the meter reading (dose counts) was recorded for the purpose of calculating the above-referenced nitrogen loads. In addition, the pressure-dosed field was walked and inspected. During each sampling event, pump chambers were inspected on all systems. No problems were observed.

The Little Island Road system has an electrical panel using programmable logic controllers which were not inspected (located just inside a barn and visible from the pump chamber), however the system field was walked, inspected and all functions appear to be normal. Field operation at the Test Center suggests that the pressure filters installed after the discharge pump in Systems# 1 – 3 should be removed and cleaned every two years. The low BOD and TSS values in the pump chambers suggest that this guideline remains appropriate for residential operation. During the next year, filters will be removed and cleaned.

Conclusion:

These results appear promising that the simple layering of organic matter that serves as a source of carbon, can reduce nitrogen in percolate from soil absorption systems. However, there still remain questions regarding the longevity of the media and degree to which the sawdust will settle over time.

Literature Cited

- Robertson, W. et al., 2000. Long-term performance of in situ reactive barriers for nitrate remediation. *Ground Water*, 38(5), pp.689–695.
- Robertson, W., 2010. Nitrate removal rates in woodchip media of varying age. *Ecological Engineering*, 36(11), pp.1581–1587.
- Robertson, W. & Cherry, J., 2005. In situ denitrification of septic-system nitrate using reactive porous media barriers: field trials. *Ground Water*, 33(1), pp.99–111.

APPENDIX 1 – ILLUSTRATIONS OF PAN LYSIMETER SAMPLING PORTS

Crude pics and sketches of pan
lysimeter construction

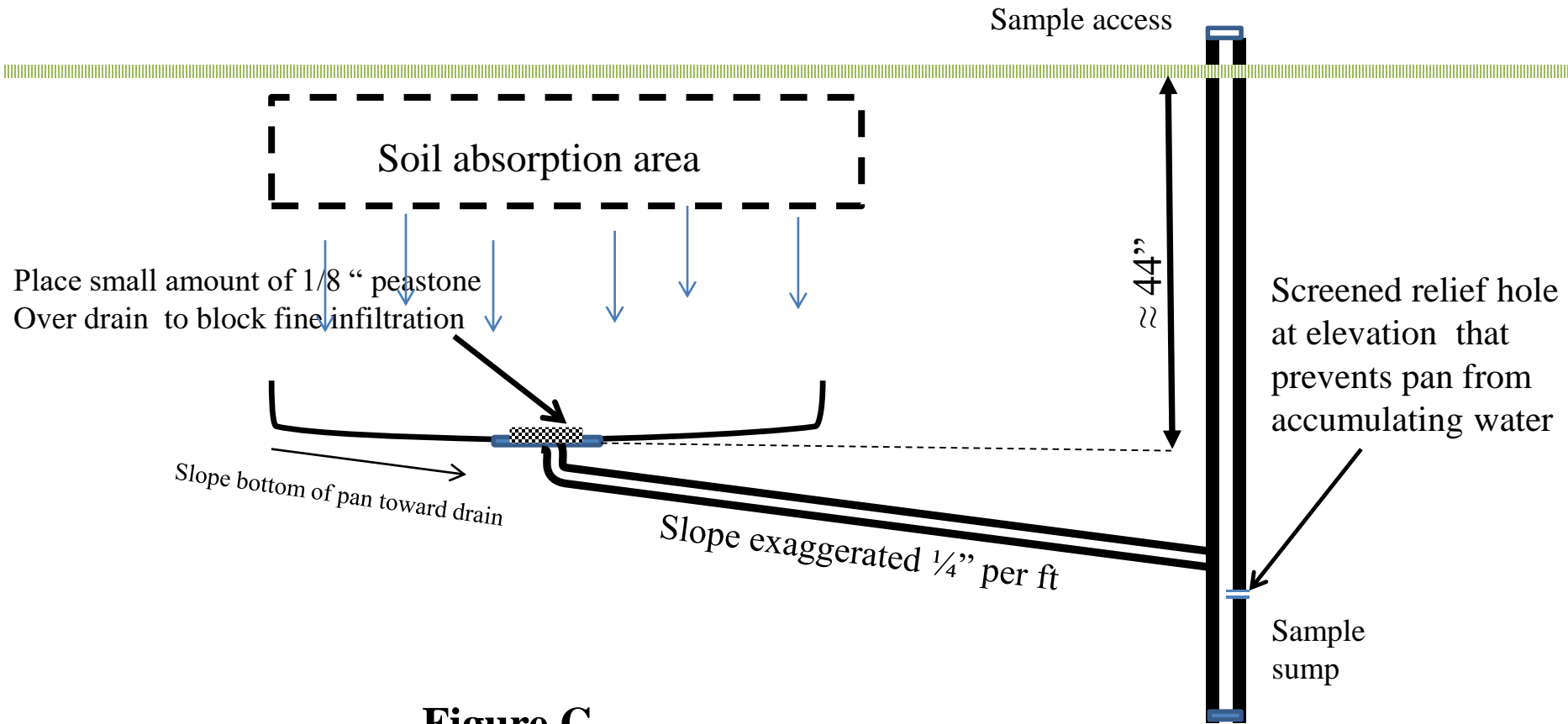
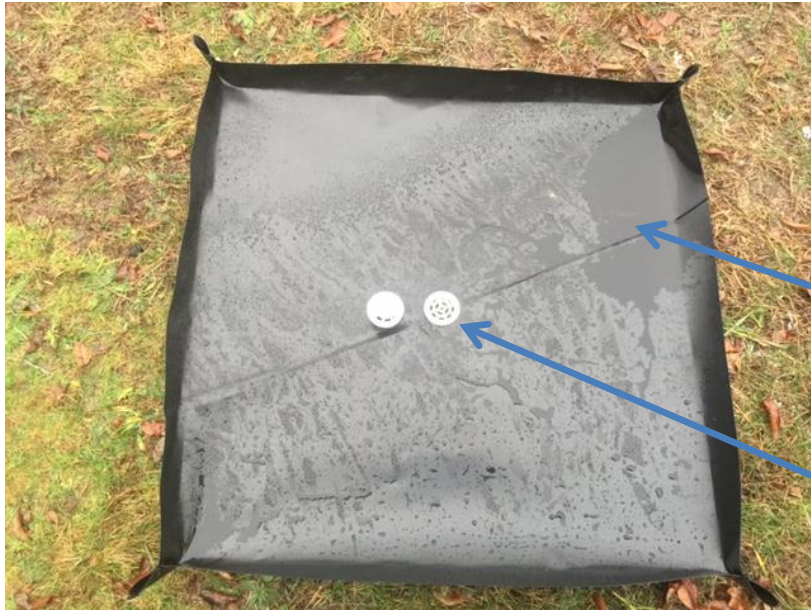


Figure C

TOP VIEW



PVC impervious liner 30mil
Dimensions variable – this pan approx 2'x2'

2" drain sold by Home Depot and inserted into a hole cut in liner little tolerance (extra drain shown also)



2" PVC horizontal drain

2" elbow

2" PVC Tee with sweep

Sample sump

2" PVC cap

2" vertical stand pipe

Pan shown with parts to be installed below pan



Stainless
screen over
relief hole

Corner of pan close up
(you could also use a
manufactured shower pan or
any other pan like structure



Bottom view with drain connected and sump assembled





Pan lysimeter assembled

Standpipe (to surface)

SUMP



Standpipe and access to
sampling sump

Peastone (some removed
just prior to backfill)



Access pipes for Lysimeters

APPENDIX B
Chapoquoit Street

Sample Date	Sample Location	Alkalinity (mg/L)	NH ₄ (mg/L)	BOD ₅ -day (mg/L)	CBOD ₅ -day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO ₃ (mg/L)	NO ₂ (mg/L)	TKN (mg/L)	pH (units)	Temp (deg C)	TN (mg/L)
2017-09-19	Chap STE	470	92	440			15000			93			93
2017-10-23	Chap STE	540	92	160		2.4	6200			110	7.1	16.6	110
2018-06-12	Chap STE	340		160		2.3				77	6.7	13.9	77
2018-07-26	Chap STE	350								97			97
2018-08-17	Chap STE	290				1.4				73	6.7	23.5	73
Mean		398		253									90
Std Dev.													14
Count													7
95% Conf. Int.													10
Upper limit													100
Lower limit													80
2017-07-26	Control	300	1.1				10	76	0.1	2.6			79
2017-08-24	Control	200	2.2		21	5.5	30	33	0.35	6	6.9	22.1	39
2017-09-19	Control	260	2.7				2400	92	0.00	5			97
2018-06-12	Control	180	0.32	1		5.5		66	0.03	2.3	6.2	16.0	68
2018-07-26	Control	160	0.125			6.7		72	0.03	2.2	6.7	22.2	74
2018-08-17	Control	100	0.125					42	0.03	1.6			44
2018-08-23	Control	140	0.125					94	0.03	1.1	6.4	22.5	95
Mean		191											76
Std Dev.													20
Count													7
95% Conf. Int.													15
Upper limit													90
Lower limit													61

APPENDIX B
Chapoquoit Street

Sample Date	Sample Location	Alkalinity (mg/L)	NH ₄ (mg/L)	BOD _{5-day} (mg/L)	CBOD _{5-day} (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO ₃ (mg/L)	NO ₂ (mg/L)	TKN (mg/L)	pH (units)	Temp (deg C)	TN (mg/L)
2017-07-26	Sand:Sawdust	480	0.51		810	1.4	5	1	1.90	8	6.5	21.4	10
2017-08-24	Sand:Sawdust	470	7.4		200	1.5	5	0	0.00	10	6.8	23.2	10
2017-09-19	Sand:Sawdust	370	7.5				6500	3	2.20	11			16
2017-10-23	Sand:Sawdust	300	0.62		2.8	2.2	4900	29	0.01	1	6.5	17.8	30
2018-06-12	Sand:Sawdust	210	0.78	2.7		1.4		32	0.85	2.6	6.5	14.9	35
2018-07-26	Sand:Sawdust	220	0.125			6.0		20	0.03	3	6.2	21.5	23
2018-08-17	Sand:Sawdust	240	0.125					26	0.03	4.5	6.3	26.2	31
2018-08-23	Sand:Sawdust	250	0.125			2.3		28	0.38	3.7	6.4	23.3	32
Mean		318											23
Std Dev.													9
Count													8
95% Conf. Int.													7
Upper limit													30
Lower limit													17

APPENDIX C
Sippewissett Road

Sample Date	Sample Location	Alkalinity (mg/L)	NH4 (mg/L)	BOD5-day (mg/L)	CBOD5-day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO3 (mg/L)	NO2 (mg/L)	pH (units)	Temp (deg C)	TKN (mg/L)	TN (mg/L)	TSS
2018-11-20	STE	330										62	62	
2018-08-23	STE											110	110	
2018-08-17	STE	400				1.72				6.5	23.6	110	110	
2018-07-26	STE	270				2.92				7.2	24.6	72	72	
2018-06-12	STE	290		41		2.01				6.7	14.7	52	52	33
2018-05-03	STE	240		150								39	39	20
Mean		306		96									74	
Std Dev.													30	
Count													6	
95% Conf. Int.													24	
Upper limit													98	
Lower limit													50	
2018-11-20	SandControl	92	0.125					27	0.025			1.4	28	
2018-08-23	SandControl	41	0.125					52	0.025			2.1	54	
2018-08-17	SandControl	46	0.29			6.35		50	0.025	5.9	28.8	1.2	51	
2018-07-26	SandControl	34	0.125			5.93		58	0.23	6.1	22.2	1.7	60	
2018-06-12	SandControl	63	0.26	6.8				46	0.32	6.6	16.3	2.6	49	
2018-05-03	SandControl	78	2.2	72		7.27		42	1.8	5.9	14.8	4.2	48	
Mean		59											48	
Std Dev.													11	
Count													6	
95% Conf. Int.													9	
Upper limit													57	
Lower limit													40	

APPENDIX C
Sippewissett Road

Sample Date	Sample Location	Alkalinity (mg/L)	NH4 (mg/L)	BOD5-day (mg/L)	CBOD5-day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO3 (mg/L)	NO2 (mg/L)	pH (units)	Temp (deg C)	TKN (mg/L)	TN (mg/L)	TSS
2018-11-20	Sand Sawdust	150	0.125					9.6	0.025			2.1	12	
2018-08-23	Sand Sawdust	120	0.125					24	0.98			1.9	27	
2018-08-17	Sand Sawdust	110	0.125			2.43		26	1.1	6.4	23.5	2.1	29	
2018-08-09	Sand Sawdust	120	0.37			2.65		20	0.76	6.1	21.7	3.1	24	
2018-07-26	Sand Sawdust	140	3.2			2.22		24	0.92	6.3	21.3	6.2	31	
2018-06-12	Sand Sawdust	150	8.6	36		0.4		20	0.99	6.4	14.2	12	33	22
2018-05-03	Sand Sawdust	130	11	150		4.77		14	0.41	6.2	11.2	14	28	21
Mean		131											26	
Std Dev.													7	
Count													7	
95% Conf. Int.													5	
Upper limit													32	
Lower limit													21	

APPENDIX D
ACUSHNET LAYERED SYSTEM

Sample Date	Sample Location	Alkalinity (mg/L)	NH4 (mg/L)	BOD5-day (mg/L)	CBOD5-day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO3 (mg/L)	NO2 (mg/L)	pH (units)	Temp (deg C)	TKN (mg/L)	TN (mg/L)	TSS
2018-05-09	STE	170		78		2.12				9.6	14.7	33	33	120
2018-06-25	STE	220		260		0.53				8.0	28.4	58	58	22
2018-07-03	STE	210	42			1.57				8.5	23.7	46	46	40
2018-07-23	STE	220	44			1.69				8.1	24.6	59	59	
2018-08-08	STE	290	52			0.11				7.3	26.0	69	69	
2018-08-21	STE	300	51			0.4				7.7	24.0	66	66	150
2018-09-11	STE	250	52			0.57				6.9	22.5	60	60	68
2018-10-04	STE	260	49		54	0.12				7.9	20.2	65	65	56
2018-11-20	STE	240	43		220							60	60	280
Mean		240		169	137	0.89						57	57	105
Std Dev.													11	
Count													9	
95% Conf. Int.													7	
Upper limit													65	
Lower limit													50	
2018-05-09	Sand-Control	18	0.125			6.66		3.4	0.025	5.4	12.3	0.36	3.8	
2018-06-25	Sand-Control	64	2.9					6	0.003			5.2	11.2	
2018-07-03	Sand-Control	15	0.125					38	0.025	6.1	27.3	2.8	40.8	
2018-07-23	Sand-Control	10	0.57					37	0.36	6.1	24.6	2.5	39.9	
2018-08-21	Sand-Control	5	0.125					29	0.025			2.2	31.2	
2018-09-11	Sand-Control	8.6	0.125			5.27		42	0.003	6.2	21.3	2.2	44.2	
2018-10-04	Sand-Control	11	0.125			4.68		35	0.025	5.1	19.9	1.7	36.7	
2018-11-20	Sand-Control	33	0.125					14	0.025			1.1	15.1	
Mean		21											27.9	
Std Dev.													16	
Count													8	
95% Conf. Int.													11	
Upper limit													38.6	
Lower limit													17.1	

APPENDIX D
ACUSHNET LAYERED SYSTEM

Sample Date	Sample Location	Alkalinity (mg/L)	NH4 (mg/L)	BOD5-day (mg/L)	CBOD5-day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO3 (mg/L)	NO2 (mg/L)	pH (units)	Temp (deg C)	TKN (mg/L)	TN (mg/L)	TSS
2018-05-09	Sand-Sawdust	26	0.125			4		0.05	0.025	5.3	12.1	0.51	0.5	
2018-06-25	Sand-Sawdust	47	0.51	500		1.04	5	0	0.24	5.0	19.3	8.2	8.4	83
2018-07-03	Sand-Sawdust	48	0.3			2.06		0.29	0.025	4.4	20.9	16	16.3	
2018-07-23	Sand-Sawdust	80	2.8			2.21		0.05	0.025	5.6	22.8	12	12.1	
2018-08-08	Sand-Sawdust	67	6.4			2.1		5.5	0.025	6.0	23.9	15	20.5	
2018-08-20	Sand-Sawdust	90	1.5			2.57		0.61	0.3	6.8	23.6	7.2	8.1	
2018-09-10	Sand-Sawdust	110	1.3	20		1.16		0.76	0.24	5.9	22.0	5.6	6.6	
2018-10-03	Sand-Sawdust	110	0.5			1.18		5.3	0.025	5.8	20.8	2.9	8.2	
2018-11-20	Sand-Sawdust	81	0.125					9.6	0.025			2.2	11.8	
Mean		73											11.2	
Std Dev.													5	
Count													6	
95% Conf. Int.													4	
Upper limit													15.3	
Lower limit													7.2	

APPENDIX E

Sample Date	Sample Location	Alkalinity (mg/L)	NH4 (mg/L)	BOD5-day (mg/L)	CBOD5-day (mg/L)	DO (mg/L)	Fecal coliform (CFU/100 ml)	NO3 (mg/L)	NO2 (mg/L)	pH (units)	Temp (deg C)	TKN (mg/L)	TN (mg/L)	TSS
6/28/2017	STE	260		32			12000					46	46	34
7/26/2017	STE	270		51			4600					56	56	
8/24/2017	STE	210		50			10000					74	74	52
9/19/2017	STE	400		21			99					76	76	
2018-08-16	STE	370				1.5				6.9	24.2	100	100	
2018-07-26	STE	280										79	79	
Mean		298		39									72	43
Std Dev.													19	
Count													6	
95% Conf. Int.													15	
Upper limit													87	
Lower limit													57	
6/28/2017	Sand-Sawdust	120			0		5	19	0.05			0.91	20	21
7/26/2017	Sand-Sawdust	110	0.01		4		50	9.7	0.05			1.2	11	
8/24/2017	Sand-Sawdust	100			1		320	41				1.7	43	13
9/19/2017	Sand-Sawdust	110	0.01		1		5	13				1.8	15	
2018-08-23	Sand-Sawdust	67	0.125					5.5	0.025			1.4	7	
2018-08-17	Sand-Sawdust	82	0.125			5.01		13	0.025	6.7	21.0	1.7	15	
2018-08-09	Sand-Sawdust	54	0.125					5.7	0.025			2.8	9	
2018-07-26	Sand-Sawdust	68	0.78					0.05	0.025			2.5	3	
Mean		89											15	
Std Dev.													12	
Count													8	
95% Conf. Int.													9	
Upper limit													24	
Lower limit													7	