Gary Goforth, P.E., Ph.D.[1]

EXECUTIVE SUMMARY

In a recent report to the Martin County Board of County Commissioners and the Martin County Utilities Department, Harbor Branch Oceanographic Institute (HBOI) estimated 397,958 pounds per year of nitrogen reach the St. Lucie River and Estuary (SLE) from septic systems in the Martin County portion of the SLE watershed (LaPointe and Herron 2016). The HBOI study did not measure the movement of nitrogen from individual septic systems, but instead, relied on a set of assumptions, some explicit and some implicit, in estimating the annual loading:

1. 2.5 people per septic system;
2. an annual per capita total nitrogen (TN) loading of 18 pounds per year from each septic tank; and
3. 50 percent load reduction between the septic tank and the SLE.

Compared to documented nitrogen reductions within and downstream of septic systems located within basins of the Indian River Lagoon, the assumptions utilized by HBOI appear overly conservative, and likely resulted in an overestimate of nitrogen loading to the SLE. The HBOI assumptions yielded loading estimates that were more than three times the estimates of nitrogen loading from local septic systems prepared for the Florida Department of Environmental Protection (FDEP). An estimate of nitrogen loading that take into account spatial variability may be closer to 105,000 - 121,000 pounds per year. While still an important source of nitrogen to the SLE, this lower estimated range of total nitrogen loading from septic systems is relatively minor compared to Lake Okeechobee discharges (averaging 1.2 million pounds/yr[2]) and stormwater runoff from agricultural lands (averaging 1.66 million pounds/yr) and stormwater runoff from non-agricultural lands (averaging 0.92 million pounds/yr) (UF Water Institute 2015, FDEP 2013). Comparing biologically reactive nitrogen[3], the lower estimated range of loading from septic systems constitutes approximately 14 percent of the total loading to the SLE, is approximately one-half of the average annual loading from Lake Okeechobee discharges (250,000 lbs/yr), and is less than the runoff from agricultural lands (300,000 lbs/yr) and runoff from non-agricultural lands (170,000 lbs/yr).

It is hoped that a common understanding of nitrogen loading from septic systems to the SLE will be helpful as stakeholders continue to implement measures to protect the SLE.

[1] Gary Goforth, LLC. Stuart, Florida.

[2] Lake Okeechobee discharges exhibit high annual variability; the average annual value reported is for the period analyzed by the University of Florida Water Institute: May 1996 to April 2014.

[3] Biologically reactive nitrogen consists of nitrate, nitrite and ammonium forms of nitrogen

ASSESSMENT OF HBOI ASSUMPTIONS FOR REASONABLENESS

The assumptions utilized by HBOI in developing the estimate of nitrogen loading to the SLE were examined by comparing them to values published by other investigators.

Assumption 1: 2.5 people per septic system

Nitrogen loads from septic systems to the SLE were estimated by Ye and Sun (2013) to assist the FDEP in assigning load reduction credits for the septic-to-sewer conversion projects associated with the St. Lucie Basin Management Action Plan (BMAP). In that study, the authors indicated that their estimate of 2.5 people per house was based on recent census records that identified the average of 2.4 and 2.6 people per house in Martin and St. Lucie counties, respectively. *Summary: the HBOI assumption of 2.5 people per septic system is reasonable.*

Assumption 2: Nitrogen loading from septic tanks

The typical household wastewater consists of about 73 percent organic nitrogen and about 24 percent ammonium nitrogen (IFAS 2011). The transformation and associated reduction of nitrogen within a septic tank is highly variable and depends on the condition of the septic tank. The chemical form of nitrogen in septic tank effluent is typically 70 – 90 percent ammonium-N and 10 – 30 percent organic-N (IFAS 2011). The HBOI loading estimate assumed 18 pounds of total nitrogen per person per year from each septic tank, as cited in Bicki et al. (1984) (LaPointe 2016). Review of Bicki et al. revealed two studies conducted in Wisconsin that documented a range of 44 to 73 lbs of TN per year for a family of four, equivalent to a per capita range of 11 to 18.25 pounds per year. HBOI utilized the upper end of this range (LaPointe 2016). This established an average loading rate for 2.5 people per system of 45.6 pounds per year from each septic tank. In a study of the Wekiva River watershed, the Florida Department of Health (FDOH) reviewed published loading rates in Florida and based on a documented range of 5-15 pounds per year per capita, estimated the per capita nitrogen loading at 11 pounds per year; using 2.5 people per system yields 27.5 pounds per year (Roeder 2007). Similarly, in work conducted for the FDEP Ye and Sun (2013) utilized an average loading from individual septic tanks of 10.6 pounds per year per capita, or approximately 26.5 pounds per year from an individual septic tank serving 2.5 people. In their 2011 work, IFAS cited USEPA in adopting a per capita loading from septic systems as 9 pounds per year; using 2.5 people per system yields 22.5 pounds per year (IFAS 2011). *Summary: the HBOI assumption appears to be well above recent ranges of loading from septic tanks used by multiple State of Florida agencies, including specific studies designed to establish load reduction credits for septic-to-sewer conversion projects.*

Assumption 3: Fifty percent load reduction between the septic tank and the St. Lucie River and Estuary

Nitrogen loading can be a significant problem from septic systems located in areas underlain by fossilized coral such as the Florida Keys and karst geology such as the springs region of north and central Florida (LaPointe et al. 1990). These areas have been documented to have little to no reduction in groundwater nitrogen loads due to the relatively fast flow velocities and lack of

organic carbon to aid in denitrification. By contrast, Martin County is not underlain by fossilized coral or karst formations, but rather, underlain by shallow warm surficial aquifers.

The transformation and associated reduction of nitrogen between the septic tank and the downstream surface water is generally described to occur in two phases.

1. **Within the drainfield and in the underlying unsaturated zone prior to entering the surficial aquifer (i.e., prior to entering the groundwater).** The chemical form of nitrogen below the drainfield is highly variable and consists primarily of ammonium-N and nitrate-N (IFAS 2011). Site-specific nitrogen load reduction in this phase is highly variable and depends on the condition of the drainfield, the soil type and the depth to groundwater.

2. **During the movement within the groundwater to the downstream surface water.** Prior to 1988, it was typically assumed that nitrate-N exhibited minimal to no reduction in groundwater, however, beginning in 1988, studies began to document denitrification occurring in shallow surficial aquifers, particularly in warmer climates such as Florida (Anderson 2006).

The HBOI loading estimate assumed a fifty percent reduction during these two phases, i.e., between the septic tank and the St. Lucie River and Estuary (LaPointe 2016). This assumed reduction is lower than load reductions recently reported for Florida systems.

1. **Prior to entering the groundwater.** Studies in the Wekiva River basin suggested a range of 10 percent to 50 percent of the nitrogen in effluent may be adsorbed or otherwise removed before the effluent reaches ground water (MACTEC 2007, Roeder 2008). IFAS (2014) indicates that "Research shows that approximately 10% – 50% percent of septic tank effluent total N may be adsorbed or otherwise removed during flow through water-unsaturated soil before the effluent reaches groundwater (Hazen and Sawyer 2009)." In their analysis for FDEP, Ye and Sun (2013) assumed a 30 percent load reduction within the septic system and prior to entering the underlying groundwater.

2. **Movement within the groundwater to the downstream surface water.** Anderson (2006) reports that several studies of denitrification in shallow aquifers specific to septic systems have shown significant reduction or elimination of nitrogen within a short distance downstream of septic system drainfields under certain soil and groundwater conditions. From their study to determine the potential impact from onsite sewage disposal systems on water quality in the Turkey Creek Sub-Basin of the Indian River Lagoon, Ayres (1993) reported: "Analysis of groundwater and surface water samples from wells located at different distances from the OSDS[4] drainfields indicated that the concentration of nitrate, nitrite-nitrogen ($N0_3$, $N0_2$-N), total kjeldahl nitrogen (TKN), total phosphorus (TP), and conductivity were generally significantly higher in the vicinity of the drainfield when compared to the background wells. However, contaminant

[4] OSDS = on-site sewage disposal systems

concentrations were at or below background concentrations in wells located twenty (20) to forty (40) feet from the drainfield." IFAS (2014) referenced a 1998 study within the Indian River Lagoon Basin (Anderson 1998) which found that nitrate levels under septic systems were significantly elevated over background levels, but that by 15 meters down gradient of the septic system, nitrate levels were at or near background levels. Anderson (1998) attributed nitrate reductions to natural denitrification in the groundwater and added that this level of denitrification can be expected in typical Florida soils with a high groundwater table.

In their analysis conducted for the FDEP, Ye and Sun (2013) evaluated the movement of nitrogen from septic systems to area waterbodies, and concluded that nitrogen reduction (denitrification) depends primarily on three factors:

1. distance to the surface water;
2. flow velocity within the shallow aquifer; and
3. soil drainage conditions.

The authors noted that "the load estimation should not be based on the number of septic systems but needs to consider spatial variability of flow and transport conditions". By contrast, the HBOI estimate of nitrogen load does not consider spatial variability of flow and transport conditions. Ye and Sun (2013) referenced three studies documenting load reductions once the nitrogen enters the groundwater ranging from 57 – 85 percent. The spatial modeling of Ye and Sun (2013) established a load reduction, referred to as "Nitrogen Reduction Ratio," which ranged from 11 to 79 percent for each of seven communities in Martin and St. Lucie Counties (see Table ES-2 from Ye and Sun (2013), reproduced below).

Estimation of Nitrogen Loading from Removed Septic Systems

Table ES-2. ArcNLET estimated total load, number of removed septic systems, load per septic system, and nitrogen reduction ratio per septic system at the City of Port St. Lucie, City of Stuart, and five sites of Martin County.

	City of Port St. Lucie	City of Stuart	Martin County				
			North River Shores	Seagate Harbor	Banner Lake	Rio	Hobe Sound
Total Load (kg/d)	42.48	1.665	8.346	9.255	0.856	0.317	0.346
Number of Septic Systems	5592	146	411	451	105	66	51
Load per Septic System (g/d)	7.60	11.40	20.31	20.52	8.15	4.80	6.78
Nitrogen Reduction Ratio (%)	67.0	50.4	11.7	10.8	64.6	79.1	70.5

Cumulative load reductions between the septic tank and the SLE as estimated by Ye and Sun (2013) ranged from 38 to 85 percent with an average of 72 percent. *Summary: The HBOI assumption of fifty percent load reduction from the septic tanks to the SLE appears to be on the low end of recently reported load reduction ranges, and likely contributed to an overestimate of nitrogen loading to the SLRE.*

CUMULATIVE EFFECT OF HBOI ASSUMPTIONS ON NITROGEN LOAD ESTIMATES

The cumulative effect of the HBOI assumptions on the estimated nitrogen loading to the SLE was assessed by comparing load estimates against a spatial modeling approach conducted for the FDEP and used to assign load reduction credits for the BMAP. Ye and Sun (2013) completed a GIS-based study for FDEP that estimated the nitrogen load reduction credits for septic-to-sewer conversion projects containing over 6,800 septic tanks at approximately 51,000 pounds per year (**Table 1**). Using the HBOI assumptions for these same areas yields a nitrogen loading estimate of approximately 153,000 pounds per year, more than three times the estimate by Ye and Sun. For a larger region containing 35,439 septic systems, Ye and Sun estimated a total nitrogen loading of 230,936 pounds/yr (**Table 2**). Using the HBOI assumptions for these same areas yields a nitrogen loading estimate of more than 797,000 pounds per year, or almost 3.5 times the estimate by Ye and Sun.

The HBOI report estimated the nitrogen loading from 17,687 septic systems in Martin County was 397,958 pounds per year. HBOI utilized the Florida Department of Health (FDOH) estimate of known septic systems (17,687), however, the current FDOH estimate of known tanks in Martin County is 16,172, or 9 percent lower than the number used by HBOI, reflecting the conversion of approximately 1,500 systems to central sewers (**Figure 2;** FDOH 2015). Applying the HBOI assumptions to the current FDOH estimate yields a revised estimate of 363,870 pounds per year for known septic systems in Martin County.

A potential range of the nitrogen loading from the known septic systems in Martin County that incorporates the load reduction assumptions of the FDEP consultants (Ye and Sun) can be estimated by using the comparisons presented above. The Ye and Sun estimates ranged from 29 to 33 percent of the estimates using the HBOI assumptions. Applying this range to the estimate of loading from known septic systems in Martin County using HBOI assumptions (363,870 pounds per year) yields a range of 105,000 to 121,000 pounds per year. While still an important source of total nitrogen to the SLE, this loading is relatively minor compared to Lake Okeechobee discharges (1.2 million lbs/yr[5]) and stormwater runoff from agricultural lands (1.66 million lbs/yr) and stormwater runoff from non-agricultural lands (0.92 million lbs/yr) (**Figure 2**). The nitrogen load from septic systems exists almost entirely as biologically reactive nitrogen, i.e., nitrate-N and ammonium-N. Comparing biologically reactive nitrogen, loading from septic systems constitute approximately 14 percent of the total loading to the SLE, and is approximately one-half of the average annual loading from Lake Okeechobee (**Figure 3**).

Summary: Utilizing the HBOI assumptions results in estimates of nitrogen loading to the SLE from septic systems range from 3.02 to 3.45 times the spatially-variable estimates by Ye and Sun (2013). Using updated estimates of the number of known septic systems in Martin County, the estimated range of nitrogen loading from septic systems based on the approached used by FDEP to allocate BMAP reduction credits is 105,000 to 121,000 pounds per year.

[5] Lake Okeechobee discharges exhibit high annual variability; the average annual value reported is for the period analyzed by the University of Florida Water Institute: May 1996 to April 2014.

Table 1. Comparison of Estimates of Nitrogen Loading to the SLE From Septic Systems

Area	Number of septic systems	Load to septic system	Reduction in system and to groundwater	Load to groundwater	Nitrogen Reduction Ratio	Ye and Sun Estimate of Load to SLE	HBOI Method: Load to SLE	Potential HBOI Overestimate
	#	lbs/yr	%	lbs/yr	%	lbs/yr	lbs/yr	%
City of PSL	5,592	148,042	30%	103,630	67.0%	34,183	125,820	268%
City of Stuart	146	3,865	30%	2,706	50.5%	1,340	3,285	145%
North River Shores	411	10,881	30%	7,617	11.8%	6,716	9,248	38%
Seagate Harbor	451	11,940	30%	8,358	10.9%	7,447	10,148	36%
Banner Lake	105	2,780	30%	1,946	64.6%	689	2,363	243%
Rio	66	1,747	30%	1,223	79.1%	255	1,485	482%
Hobe Sound	51	1,350	30%	945	70.5%	278	1,148	312%
Total	***6,822***	***180,605***	***30%***	***126,424***	***59.7%***	***50,908***	***153,495***	***202%***

Table 2.

Area	Number of removed septic systems	Number of functioning septic systems	Total number of septic systems	Ye and Sun estimate of load from all septic systems (lbs/yr)	Load estimate using HBOI assumptions (lbs/yr)	Potential HBOI Overestimate
Basin 4-5-6	453	1,240	1,693	15,031	38,093	153%
C-23	1	276	277	1,806	6,233	245%
C-24	173	878	1,051	11,351	23,648	108%
C-44 / S-153	0	234	234	1,431	5,265	268%
North Fork	5,905	23,579	29,484	184,357	663,390	260%
South Fork	146	2,554	2,700	16,960	60,750	258%
Total	***6,678***	***28,761***	***35,439***	***230,936***	***797,378***	***245%***

Figure 2. Department of Health Estimate of Septic Systems in Martin County (FDOH 2016)

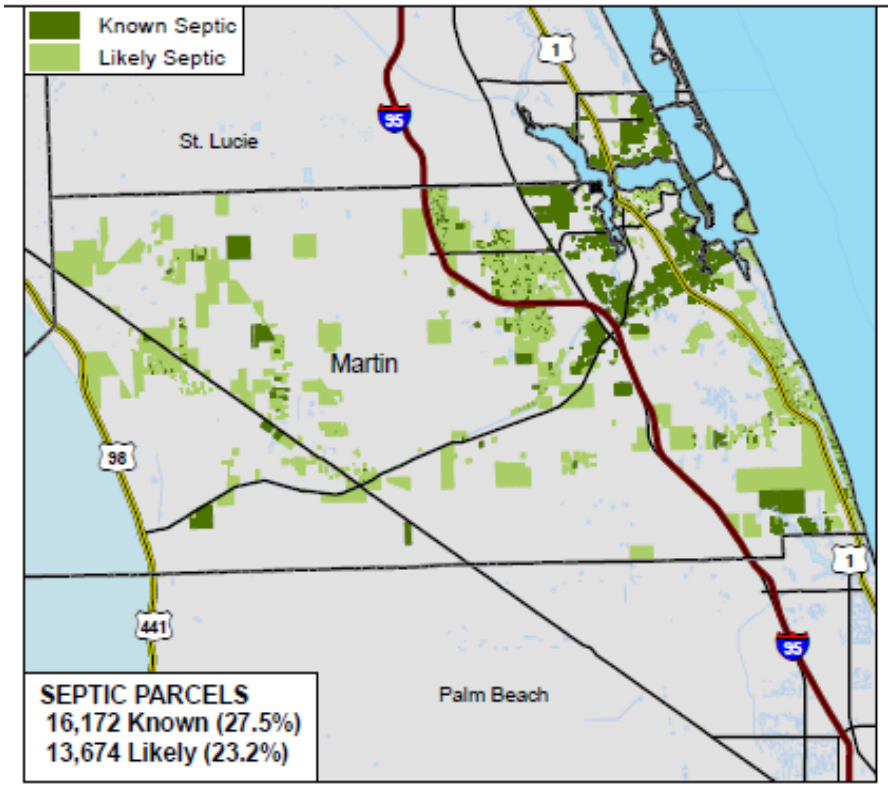


Figure 3.

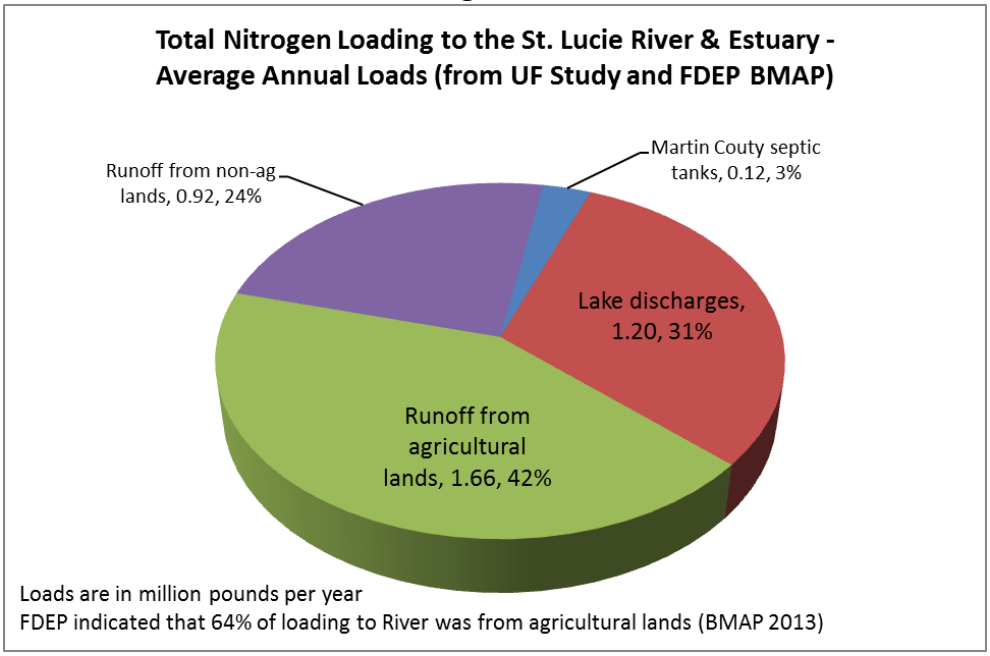
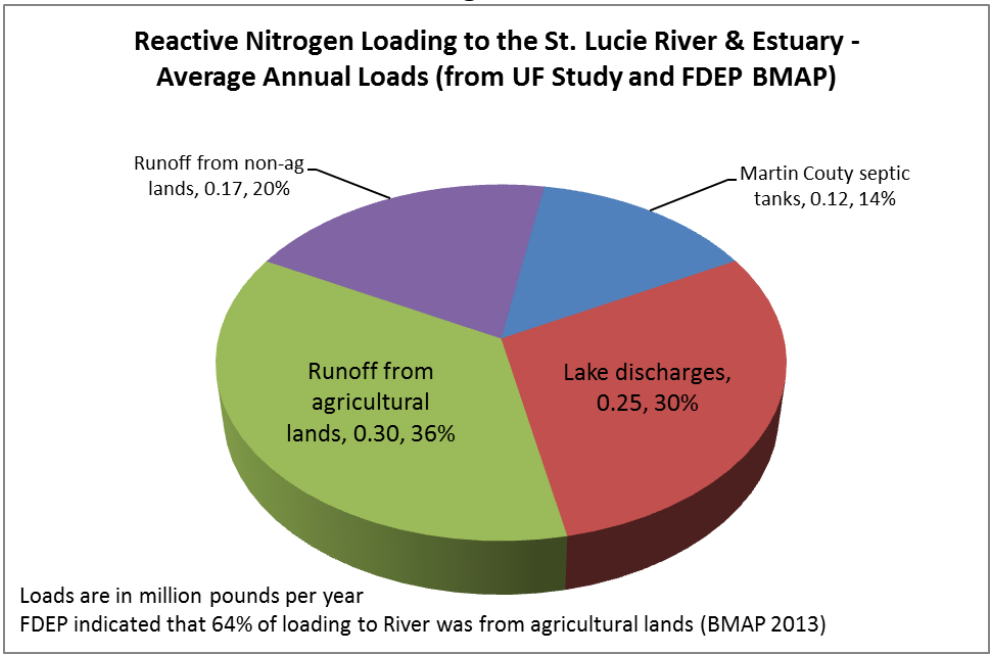


Figure 4.



IMPLICATIONS FOR THE ST. LUCIE RIVER WATERSHED BASIN MANAGEMENT ACTION PLAN

Martin County has achieved significant nutrient load reductions by removing 70 package wastewater treatment plants and 1,762 septic tanks since 1990 (Polley 2014, Fielding 2015). Estimated annual nitrogen load reductions from these two measures were estimated to be more than 580,000 pounds/year (Polley 2014, FDEP 2015). Concurrently, nitrate-nitrite

levels adjacent to the River and Estuary have significantly decreased (**Figure 5**). As a result of the conversion of 928 septic tanks since 2000, FDEP allocated nitrogen load reduction credits of 15,369 pounds per year towards the BMAP goal (**Figure 6;** FDEP 2015). Therefore, Martin County does not need additional septic-to-sewer conversion projects in order to achieve the nitrogen load reduction Target required by the BMAP and TMDL: the County presently has more than enough nitrogen reduction credits. If the County receives phosphorus reduction credits attributable to previous septic conversion projects, there may possibly be no need for additional phosphorus reduction projects. If the County desires to achieve additional nitrogen load reductions, and absent State or Federal appropriations for this purpose, in addition to septic-to-sewer conversions, more cost-effective regional alternatives should be considered, such as hybrid wetland treatment, with a nominal unit removal cost of $528 per pound of nitrogen removed per year (FDEP (2015); **Table 3**).

Human health and safety. Septic-to-sewer conversion projects may be needed for human health and safety reasons, and these should be pursued expeditiously. Data analyzed by FDEP (2016) and HBOI (2016) identified that remediation is likely needed in two communities: Old Palm City and Golden Gate Estates. As more studies document evidence of site-specific human biological markers adjacent to communities with septic systems, additional remediation projects should be pursued.

Figure 5.

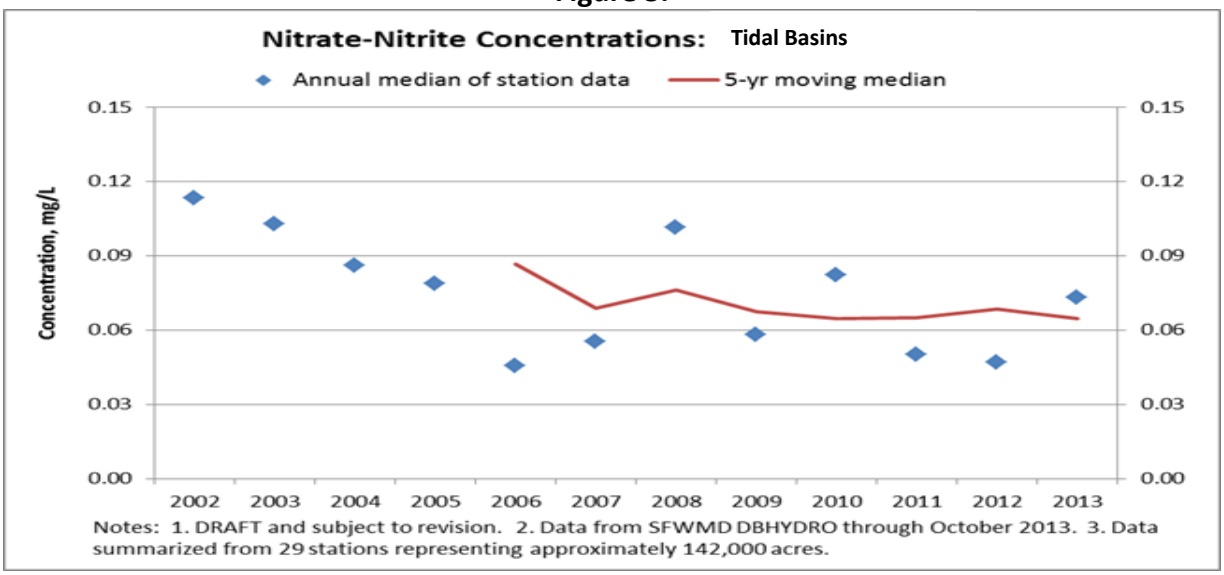
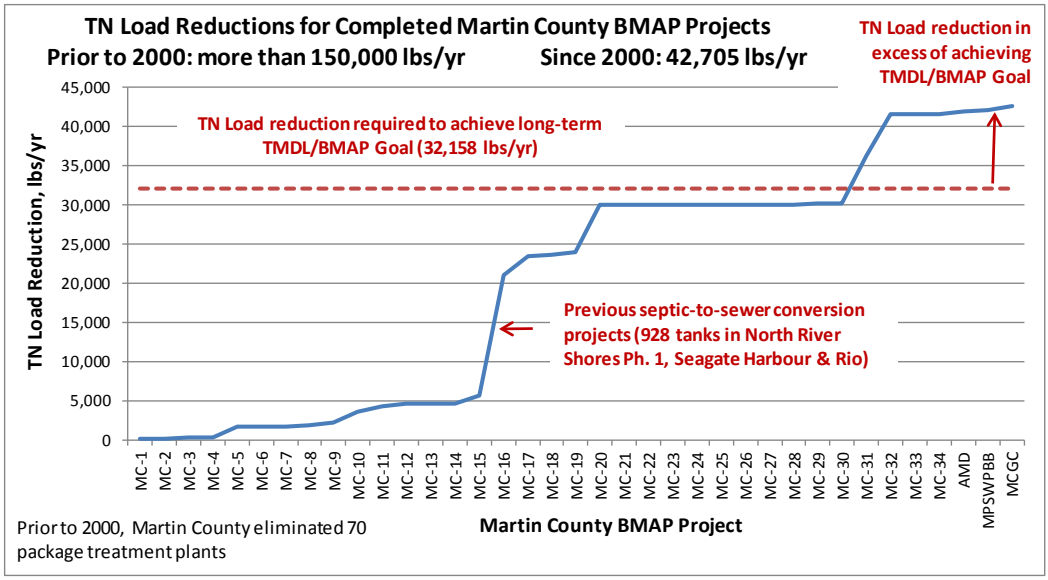


Figure 6.



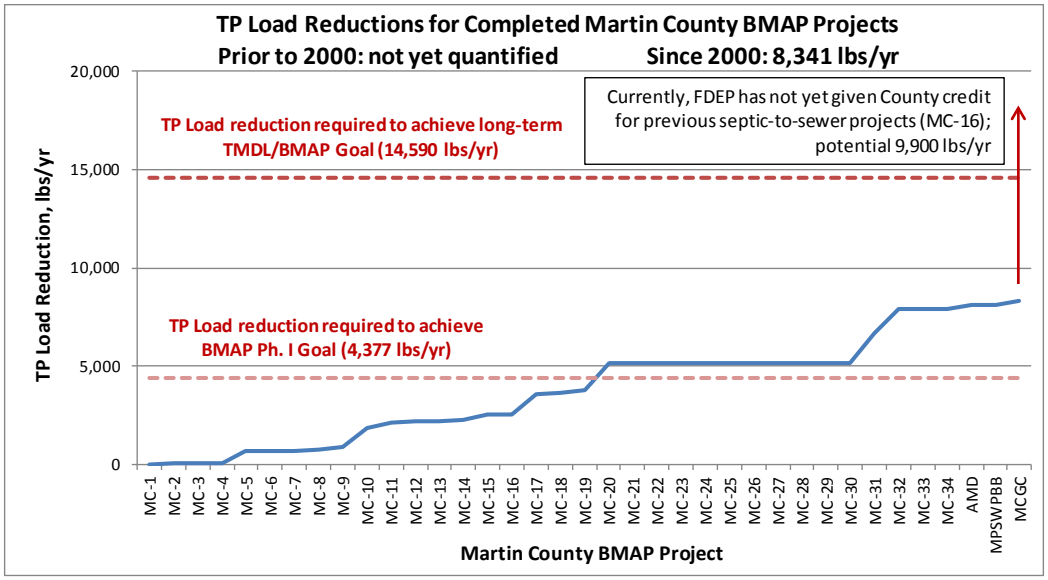


Table 3. Estimated Nutrient Removal Costs of Completed Martin County BMAP Projects (FDEP 2015)

Project Type	Number of Projects	Total Cost of Projects, $	TN Reduction Credit, lbs/yr	TP Reduction Credit, lbs/yr	Unit Removal Cost TN Reduced, $/lb/yr	Unit Removal Cost TP Reduced, $/lb/yr
Wet detention	13	35,842,232	8,734	3,867	4,104	9,268
Dry detention	2	2,107,988	47	12	44,472	169,999
2nd generation baffle boxes	3	1,760,343	403	80	4,367	22,059
Hybrid Wetland Treatment Technology	2	6,000,000	11,359	2,755	528	2,178
Exfiltration trenches and swales	1	497,430	230	49	2,164	10,090
Previous septic to sewer conversion	1	28,678,946	15,369	TBD	1,866	TBD

Note: Martin County staff is evaluating costs and credits associated with previous septic conversions.

REFERENCES

Anderson, D. 2006. A Review of Nitrogen Loading and Treatment Performance Recommendations for Onsite Wastewater Treatment Systems (OWTS) in the Wekiva Study Area. February 2006.

Ayres Associates 1993. An Investigation Of The Surface Water Contamination Potential From On-Site Sewage Disposal Systems (OSDS) In The Turkey Creek Sub-Basin Of The Indian River Lagoon. Project Funded by: St. Johns River Water Management District SWIM Project 1R-1-110.1-D. February 1993.

Bicki, T. J., Randall S. Brewn, Mary E. Collins, Robert S. Mansell, and Donald F. Rothwell 1984. Impact of On-site Sewage Disposal Systems on Surface and Ground Water Quality. Report to Florida Department of Health and Rehabilitative Services. November 1984.

FDEP 2013. St. Lucie River and Estuary Basin Management Action Plan. June 2013.

FDEP 2015. 2015 Progress Report for the St. Lucie River and Estuary Basin Management Action Plan. December 2015.

FDEP 2016. South Fork St. Lucie Estuary and River Microbial Source Tracking Study. Division of Environmental Assessment and Restoration Florida Department of Environmental Protection. February 12, 2016.

FDOH 2015. Florida Water Management Inventory Martin County 2015. December 4, 2015.

Fielding, E. 2015. Op-ed in Stuart News. Pollution solutions in our own backyard: Septic-to-sewer conversions. October 13, 2015

IFAS 2011. Gurpal S. Toor, Mary Lusk, and Tom Obreza. Onsite Sewage Treatment and Disposal Systems: Nitrogen. This document is SL348, one of a series of the Soil and Water Science, UF/IFAS Extension. Original publication date June 2011. Reviewed: February 2014.

LaPointe, B.E., J.D. O'Connell, and G.S. Garrett 1990. "Nutrient Couplings between On-site Sewage Disposal Systems, Groundwaters, and Nearshore Surface Waters of the Florida Keys." Biodegradation 10 (1990):289-307.

LaPointe, B. 2016. Personal correspondence dated March 29, 2016.

LaPointe, B. and L. Herren 2016. 2015 Martin County Watershed To Reef Septic Study Draft Final Report. Marine Ecosystem Health program, Harbor Branch Oceanographic Institute, Florida Atlantic University. February 29, 2016.

MACTEC 2007. Phase I Report Wekiva River Basin Nitrate Sourcing Study. Prepared for the St. Johns River Water Management District and Florida Department of Environmental Protection. March 2007.

Roeder, E. 2007. A Range of Cost-Effective Strategies For Reducing Nitrogen Contributions from Onsite Sewage Treatment and Disposal Systems (Draft). Bureau of Onsite Sewage Programs Florida Department of Health. June 7, 2007.

Roeder, E. 2008. Revised Estimates of Nitrogen Inputs and Nitrogen Loads in the Wekiva Study Area. Bureau of Onsite Sewage Programs Florida Department of Health. May 19, 2008.

University of Florida Water Institute 2015. Options to Reduce High Volume Freshwater Flows to the St. Lucie and Caloosahatchee Estuaries and Move More Water from Lake Okeechobee to the Southern Everglades. An Independent Technical Review by the University of Florida Water Institute. March 2015.

Ye, Ming and Huaiwei Sun 2013. Estimation of Nitrogen Load from Removed Septic Systems to Surface Water Bodies in the City of Port St. Lucie, the City of Stuart, and Martin County. Prepared for the Florida Department of Environmental Protection. September 2013.