NITROGEN AREAL REMOVAL RATES FOR ALGAL TURF SCRUBBER® (ATS™) SYSTEMS IN NON-POINT SOURCE APPLICATIONS

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Plant based biological treatment systems have been shown to offer lower treatment costs then competing technologies for large scale regional treatment systems when applied to non-point source pollution.

In the Lake Okeechobee Watershed (LOW), the LOW Project Delivery Team completed an exhaustive review of over 105 phosphorus control technologies. Of the 54 phosphorus control technologies determined to offer "stand-alone" regional capabilities, Managed Aquatic Plant Systems (MAPS) such as the Algal Turf Scrubber® and constructed treatment wetlands [Emergent Stormwater Treatment Areas, Submerged Aquatic Vegetation based STAs (SAV), Periphyton STAs (PSTA) and Reservoirs] made up the top five technologies.

The Algal Turf Scrubber® (ATS™) is a periphyton based treatment technology in which impaired waters are introduced in wave pulses or surge to a treatment unit in which nitrogen, phosphorus and other contaminants are removed from the water matrix through the routine recovery of cultured algal biomass.

One significant advantage of the ATS™ for non-point source applications is its high nitrogen and phosphorus areal removal rates. These high areal removal rates apply even to the relatively low nitrogen and phosphorus concentrations typical of stormwater runoff and impaired surface waters. High areal removal rates in the context of plant based biological treatment systems correlate to (i) lower treatment costs and (ii) reduced land requirements. Much of the focus to date in South Florida has been on the phosphorus treatment capabilities of biological treatment technologies. Based on performance of systems operated in South Florida, treatment wetland systems routinely achieve phosphorus areal removal rates in the range of 1.0-2.0 g/m2/yr (8.9-17.8 lbs/acre/yr), while the ATS™ technology (300' floway) has produced phosphorus areal removal rates up to 92 g/m2/yr (821 lbs/acre/yr).

With rapidly escalating land prices, and reduced land availability, the benefit associated with the high areal removal rates of the ATS™ technology are rapidly increasing.

Algal Turf Scrubber® Nitrogen Treatment

As with phosphorus control, the Algal Turf Scrubber® has the ability to cost-effectively reduce nitrogen levels to background or below background water levels. This is extremely important in watersheds throughout the United States where land practices (i.e. fertilizer and manure application) produce nitrogen impaired surface and ground water. Many of these impaired waters (e.g. St. Johns River, Suwannee River, Mississippi River, etc.) are large volume flows with relatively low nitrogen and phosphorus concentrations when compared to wastewater discharges. For these applications, due to the dilute nature of the pollutants, nitrogen control using conventional wastewater treatment technologies is very costly.

The Algal Turf Scrubber® however produces high nitrogen areal removal rates, which result in lower treatment costs. The elevated areal removal rates are a result of (i) rapid growth of the algal turf cultured within the ATS™ unit, (ii) frequent recovery of biomass (typical 7-14 day harvest cycle) which maintains an exponential phase of growth, (iii) high hydraulic loadings and (iv) short detention times (6-12 minutes dependent on flow length).

To enhance pollutant recovery rates and reduce treatment costs, ATS™ system designs can be modified (e.g. linear hydraulic loading rates, floway length, etc.) to optimize for site specific conditions and treatment objectives. In the Lake Okeechobee Watershed, three different hydraulic loading rates were evaluated in order to establish optimal treatment system design for full-scale regional systems. Shown in Figure 1 are nitrogen areal removal rate data plotted against nitrogen loading rate for three ATS™ units operated at hydraulic loading rates of 92, 157 and 368 cm/day.

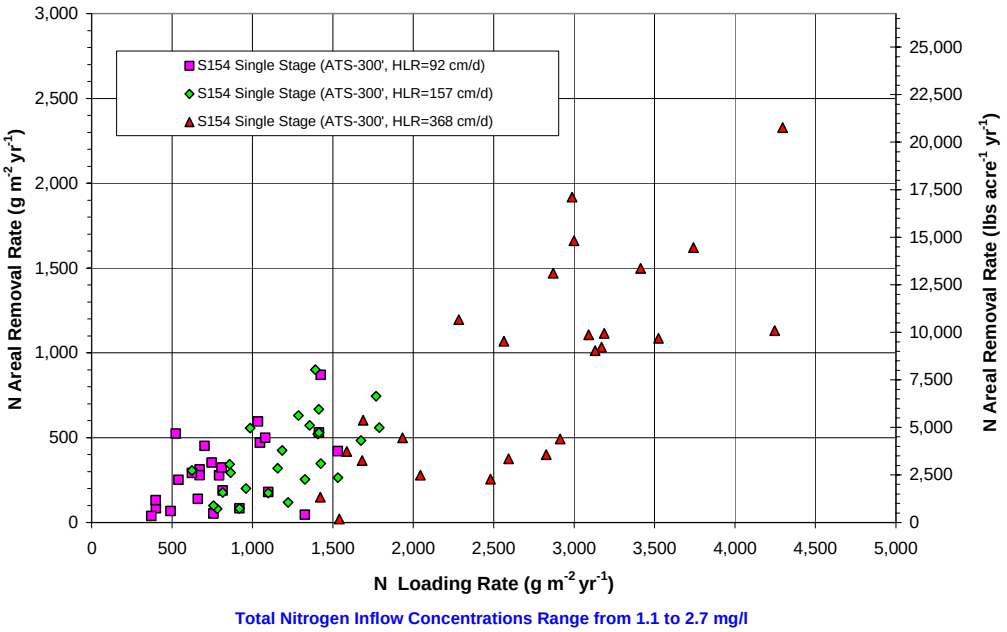


Figure 1. *Nitrogen areal removal rates plotted against nitrogen loading rates for three Algal Turf Scrubber® units operated at differing hydraulic loading rates in Okeechobee, Florida.*

Critical to cost effective non-point source nitrogen control is the ability to remove nitrogen from stormwater runoff, which typically contains nitrogen at levels lower then wastewater treated to AWT standards. ATS™ nitrogen areal removal performance in relationship to inflow total nitrogen concentrations is shown in Figure 2. Inflow total nitrogen concentrations were from 1.1 to 2.7 mg/l – which is typical of stormwater runoff in urban and agricultural regions. Peak nitrogen removal rates were achieved within the ATS™ unit operated at a hydraulic loading rate of 368 cm/day. For this treatment unit, even when total nitrogen concentrations were at the relatively low range of 1.2 to 1.5 mg/l, the ATS™ unit achieved nitrogen areal removal rates in the range of 2,500 – 5,000 lbs/acre/year.

A comparison of treatment efficiency, reported as percent removal of total nitrogen, for the three different 300' ATS™ units shows that efficiency remained at 29-30%, even as hydraulic loadings were significantly increased. ATS™-South (92 cm/day), ATS™-North (157 cm/day) and ATS-Central (368 cm/day) removed total nitrogen at the mean rates of 181 g/m^2-yr (28.96 % removal), 332 g/m^2-yr (29.66% removal) and 722 g/m^2-yr (29.73% removal), respectively (Figure 3). To increase percent removal the ATS™ floway length would be extended.

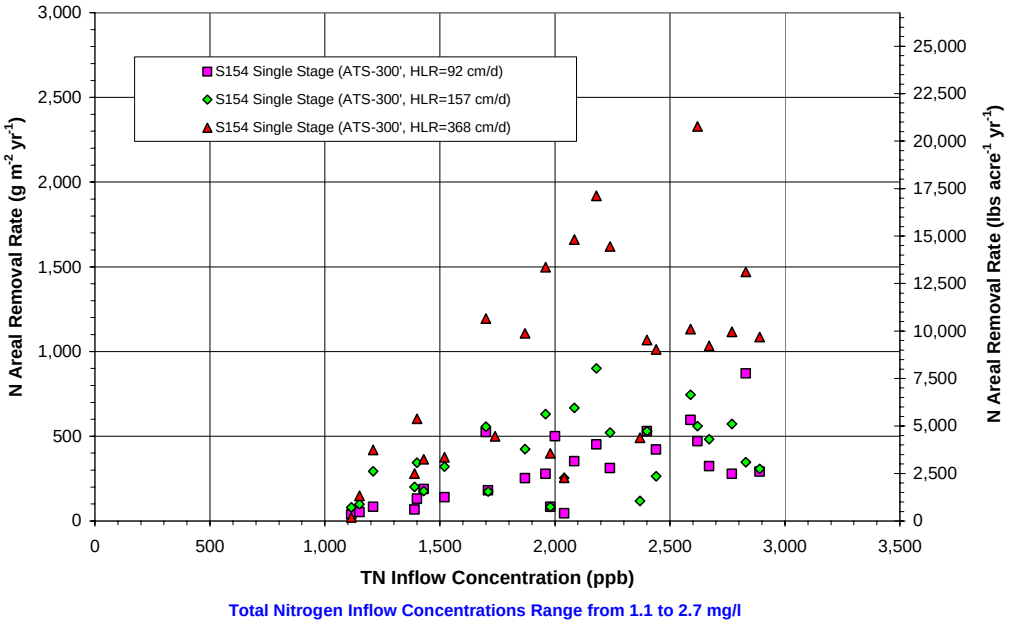


Figure 2. *Nitrogen areal removal rates plotted against inflow total nitrogen concentrations for three Algal Turf Scrubber® units operated at varying hydraulic loading rates in Okeechobee, Florida.*

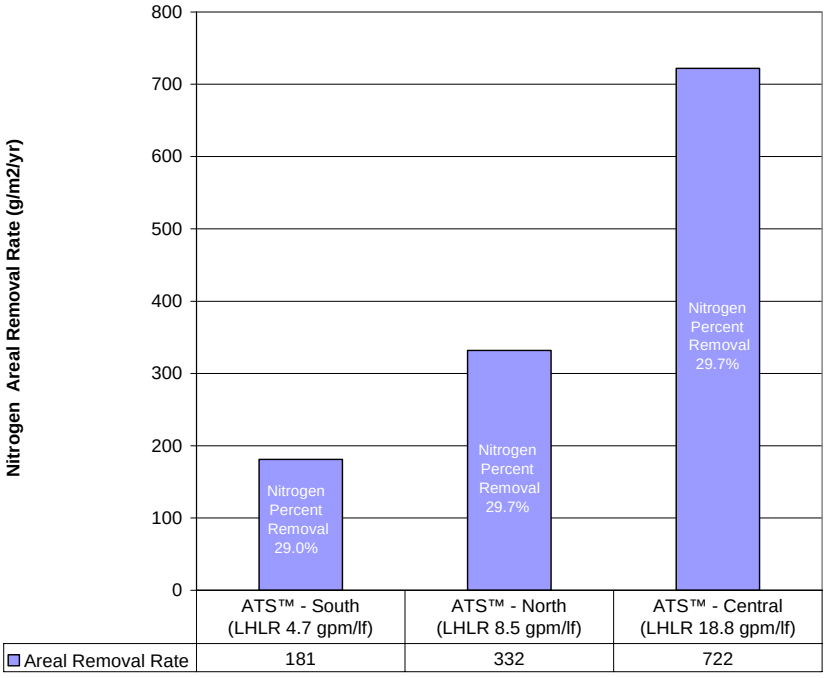


Figure 3. *Nitrogen areal removal rates for three Algal Turf Scrubber® units operated at varying hydraulic loading rates in Okeechobee, Florida.*

The stability of Algal Turf Scrubber® systems and their ability to provide nitrogen control even under harsh conditions is illustrated in treatment performance associated with Hurricanes Jeanne and Frances which directly impacted operations in 2004 and resulted in sustained power outages (See Figure 4).

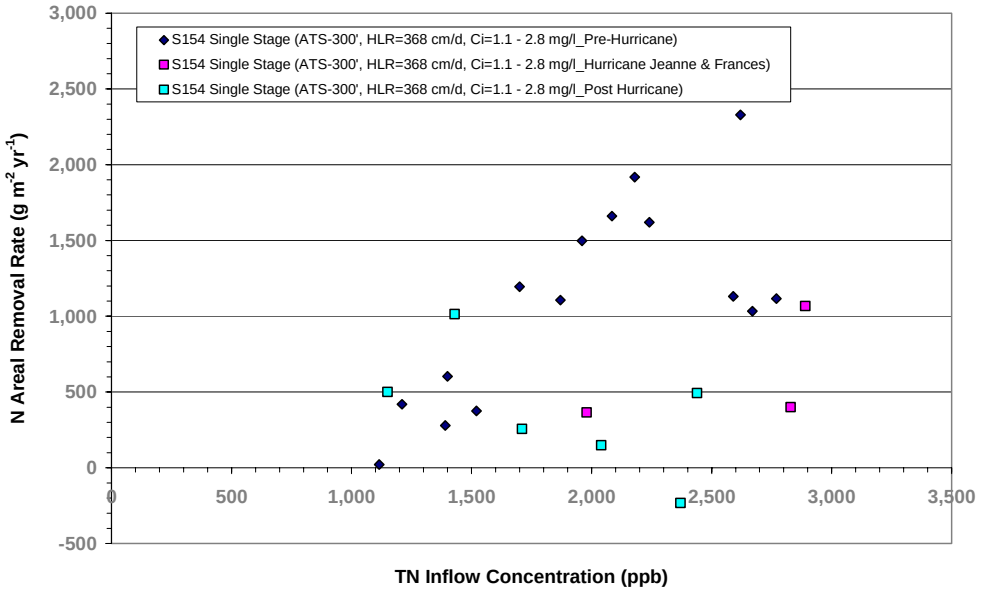


***Figure 4**. Algal Turf Scrubber® nitrogen areal removal rates plotted against nitrogen inflow concentration with pre-hurricane, hurricane impact and post-hurricane periods identified for Hurricane Jeanne and Hurricane Frances.*

Comparative Non-Point Source Nitrogen Treatment Performance of Algal Turf Scrubber® and Constructed Treatment Wetland Systems.

Due to the immense scope and challenge of reducing nitrogen loads to meet TMDL regulations, implementation of Best Management Practices (BMPs) and regional treatment systems must be employed which (i) are capable of producing quantifiable treatment performance and (ii) offer reliable, sustainable, and low cost nitrogen removal for both point source and non-point source applications.

While biological systems including constructed treatment wetlands and managed aquatic plant systems such as the Algal Turf Scrubber® have been shown to offer low cost treatment alternatives for non-point source phosphorus control in South Florida, limited publications have addressed non-point source nitrogen control within these regions.

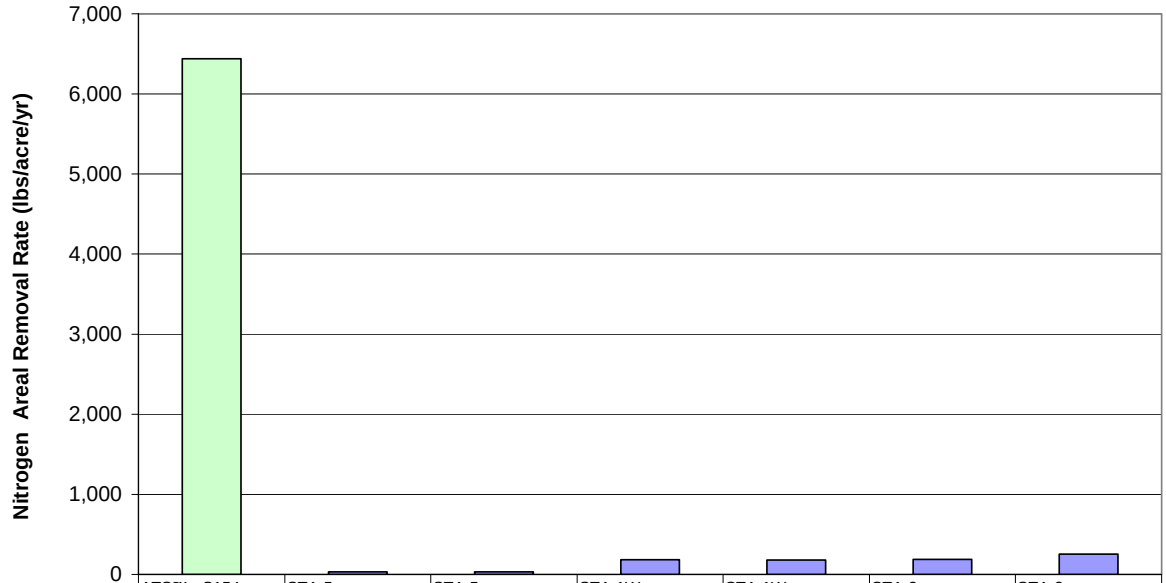
Kelly (2006) in the report titled *Stormwater Treatment Areas: Experience with Nitrate Removal* investigated the use and performance of STAs for nitrate control. Nitrate control was reported for constructed wetlands in Illinois, Ohio, California and Florida; however, the majority of the systems cited represented performance associated with treatment of wastewater with relatively high nitrate inflows (3.5 – 10.3 mg/l). Conditions more consistent with non-point source runoff (Inflow NO_3 = 0.38-0.55 mg/l) were reflected in data cited for Water Conservation Areas 1, 2 and 3. These wetlands were reported to have nitrate areal removal rates of 78 to 155 lbs/acre/year.

While Kelly (2006) did not include nitrate performance date for the Everglades STAs, total nitrogen removal rates can be calculated based on information included for

STAs 1W, 2 and 6 reported in the South Florida Environmental Report (SFWMD, 2005 and 2006). For water years 2004 and 2005, total nitrogen areal removal rates ranged from 29-252 lbs/acre/year for STAs 1W, 2 and 6. (Figure 5).

Treatment costs for biological systems such as the constructed treatment wetlands and ATS™ systems will be significantly impacted by system nitrogen areal removal rates due to (i) rapidly escalating land costs and construction costs and (ii) land availability in Florida. Therefore relative areal removal rate performance serves somewhat as indices of treatment costs.

A comparison of nitrogen areal removal rates for these systems is provided in Figure 5. From the performance data investigated, when comparing treatment system with relatively similar inflow nitrogen concentrations (STA-5 and ATS™), the algal turf scrubber provided over 200 times greater nitrogen areal removal rate then the constructed treatment wetland.



	ATS™ - S154	STA-5	STA-5	STA-1W	STA-1W	STA-2	STA-2
	LHLR 18.8 gpm/lf	WY2004	WY2005	WY2004	WY2005	WY2004	WY2005
	TNin=1.85 mg/l	TNin=1.61 mg/l	TNin=1.63 mg/l	TNin=4.11 mg/l	TNin=3.92 mg/l	TNin=4.14 mg/l	TNin=4.34 mg/l
	TNout=1.32 mg/l	TNout=1.33 mg/l	TNout=1.32 mg/l	TNout=2.56 mg/l	TNout=2.78 mg/l	TNout=2.34 mg/l	TNout=2.38 mg/l
Areal Removal Rate	6,441	30	29	184	178	188	252

Figure 5. *Comparative nitrogen areal removal rates for Algal Turf Scrubber® and constructed treatment wetlands (aka Stormwater Treatment Areas) in South Florida.*

The Algal Turf Scrubber® technology was specifically developed for the purpose of nitrogen and phosphorus control in low nutrient applications. Over nearly three decades of research and commercial application, the technology has been refined and optimized to increase pollutant uptake and operational efficiencies.

From these efforts, one of the primary benefits of the ATS™ is its ability to treat large volumes of water, and remove large quantities of nitrogen and phosphorus from relatively dilute stormwater runoff. This unique feature of the ATS™ allows for reduced land requirements and lower treatment costs.