IFAS Nutrient Removal Enhancement Retrofit of an Existing Contact / Stabilization Treatment Process at Neptune Beach, FL

John E. Olson, P.E.[1*]; Todd A. Schwingle, P.E.[1*]; Mark F. Greenwood[2*]; Amy S. Coleman[2*]

[1] Siemens Industry, Inc; 2607 N. Grandview Blvd; Waukesha, WI 53188 USA
*Email: john.e.olson@siemens.com.

[2] City of Neptune Beach; 2010 Forest Ave.; Neptune Beach, FL 32266 USA
*Email: markgreenwood@neptune-beach.com

Background

Bio-diversity in Florida's St. John's River estuaries is dependent on clean water. Run-off from Florida's usually abundant rain naturally scours and replenishes the River's water component of this system. But this fresh water river is increasingly being affected by human populations that are attracted to the Florida coastline. Nutrients in wastewaters from communities located along these shorelines cause rapid eutrification that stagnates biological growth, limiting biodiversity. USEPA has mandated that we protect the biodiversity of these areas by limiting the mass amount of nutrient allowed to be discharged by municipal wastewater treatment plants. Total Mass Discharge Limits (TMDL's) have been promulgated for Nitrogen and Phosphorus discharges into these environments.

Florida's Department of Environmental Protection began implementation of TMDL's on estuary discharges in 2005. The City of Neptune Beach's existing wastewater treatment plant was asked to lower their TN by 80%. Neptune Beach had a total average design flow of 1.5 MGD and the TMDL for Nitrogen discharge from the City of Neptune Beach to the St. John's River was to be less than 70,000 lbs / year. Neptune Beach has always been conscientious about its environmental stewardship. They needed to know how best to comply with the new regulations. Their existing wastewater treatment plant consisted of two units. The original plant on this site was a primary treatment process built in the 1950's. This plant was converted to a contact / stabilization plant in 1974. It was designed to handle an average of 0.9 MGD of municipal wastewater. In 1990, a second packaged activated sludge treatment plant was constructed on the site. It was designed to handle an additional 0.6 MGD of flow. The influent control structure was modified to properly split flow between the two plants. Both plants were efficient in standard wastewater treatment functions of removing BOD, TSS and nitrifying ammonia. However, biological nutrient removal was not part of either design.

Design of New System

The City hired the engineering firm of Applied Technologies and Management to review the situation and provide alternatives. The City of Neptune Beach is a landlocked community surrounded by other communities. AT&M found that abandoning the existing system and moving to a new treatment process built on a new site within the City of Neptune Beach was not practical or financially possible. The option of transferring wastewater to a neighboring community for treatment was researched and found to be a poor option. The City had no problem with converting the existing plant to a pump station even though the cost of building the transport infrastructure was expensive. However, limits on the amount of wastewater that would be allowed to be transferred made the City of Neptune Beach uneasy, as peak flows actually had been recorded higher than what was proposed to be allowed. As negotiations went on it became clear that this problem plus the increased user charges that would result from the project would not be acceptable.

When AT&M asked Siemens to review the existing plant and provide their opinion, Siemens technical experts conducted a cost effective NPV analysis. The result was intriguing. The existing treatment system could be modified to increase its Nitrogen removal capability by incorporating an Integrated Fixed Film Activated Sludge process within the existing structures of both treatment systems. However, substantial changes to either system would have to be implemented. Anoxic zones are required to promote both denitrification for Nitrogen removal and Phosphorus release which then promotes luxury phosphorus up-take. It was easy to see how the smaller package plant system could be sub-divided to incorporate these structures but doing this would not result in the 80% reduction in Nitrogen discharges required. The only option would be to modify the existing contact / stabilization process. Converting this process into an IFAS Nutrient removal process would allow the City to meet the New Total Nitrogen TMDL but it would prove to be difficult for both the AT&M engineers and the Siemens design team.

Project Implementation

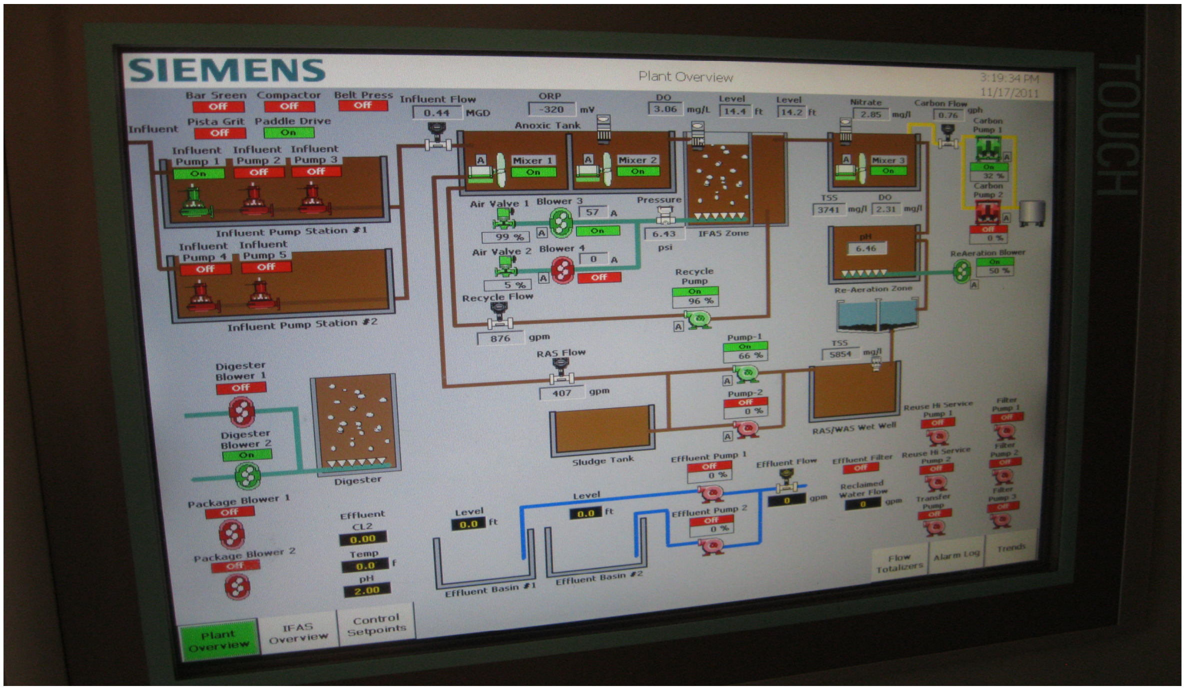
What do you have to do to convert a Contact / Stabilization process into an IFAS nutrient removal process? Figure 1 below is a site plan of the existing system with required modifications shown in bold. As you can see in this plan, the Contact tank is physically separated from the stabilization tank by a considerable distance. In the original C/S process influent flow met returned MLSS from the Stabilization tank in the contact zone. MLSS flow was then split to two clarifiers, the effluent was discharged, and the RAS underflow was sent to the stabilization tank where it was aerated and stabilized. The actual contact time was short. The soluble BOD in the wastewater was absorbed but little nutrient removal took place. Stabilization of the RAS after removal allowed the absorbed BOD to be assimilated but did nothing for nutrient removal.

AT&M, Siemens, and the City began collaborating on the new design. The design of the new IFAS system had two goals: 1). Create a system that had the capability of denitrifying and 2). Add capacity to the system by increasing the design flow to 0.9 MGD and be able to handle the peak daily flow events within the existing plant footprint. Goal No. 1 was achieved by changing the process flow scheme from the contact tank to the stabilization tank and then to the clarifiers. RAS from the clarifiers would be returned to the 94,000 gallon contact tank which then would be physically converted to an anoxic zone. To prevent short-circuiting, a baffle wall with gate was installed in the contact zone, dividing this tank into two anoxic zones. A mixer was installed in each zone to maintain MLSS in suspension.

Goal No. 2 was achieved by creating an IFAS system in the existing 125,000 gallon stabilization tank. The new IFAS tank would contain four zones – IFAS, wet well, post anoxic and re-aeration. The IFAS zone would be the aerobic zone of the system containing Siemens Biosphere™ media. Hydraulically sized screens would keep the media trapped in place in the IFAS tank and not allow them to flow onto the clarifiers or b3e recycled back to the anoxic zone. IFAS Aeration is supplied by the existing 40 Hp positive displacement blowers of the old C/S plant.. A variable speed recycle pump with the capacity of 1600 GPM located in the wet-well chamber after the screens. This pump is used to return nitrified MLSS from the aerobic IFAS zone back to the anoxic zone for denitrification. The second anoxic zone is used to drive total Nitrogen levels down below 3.0 mg/l.

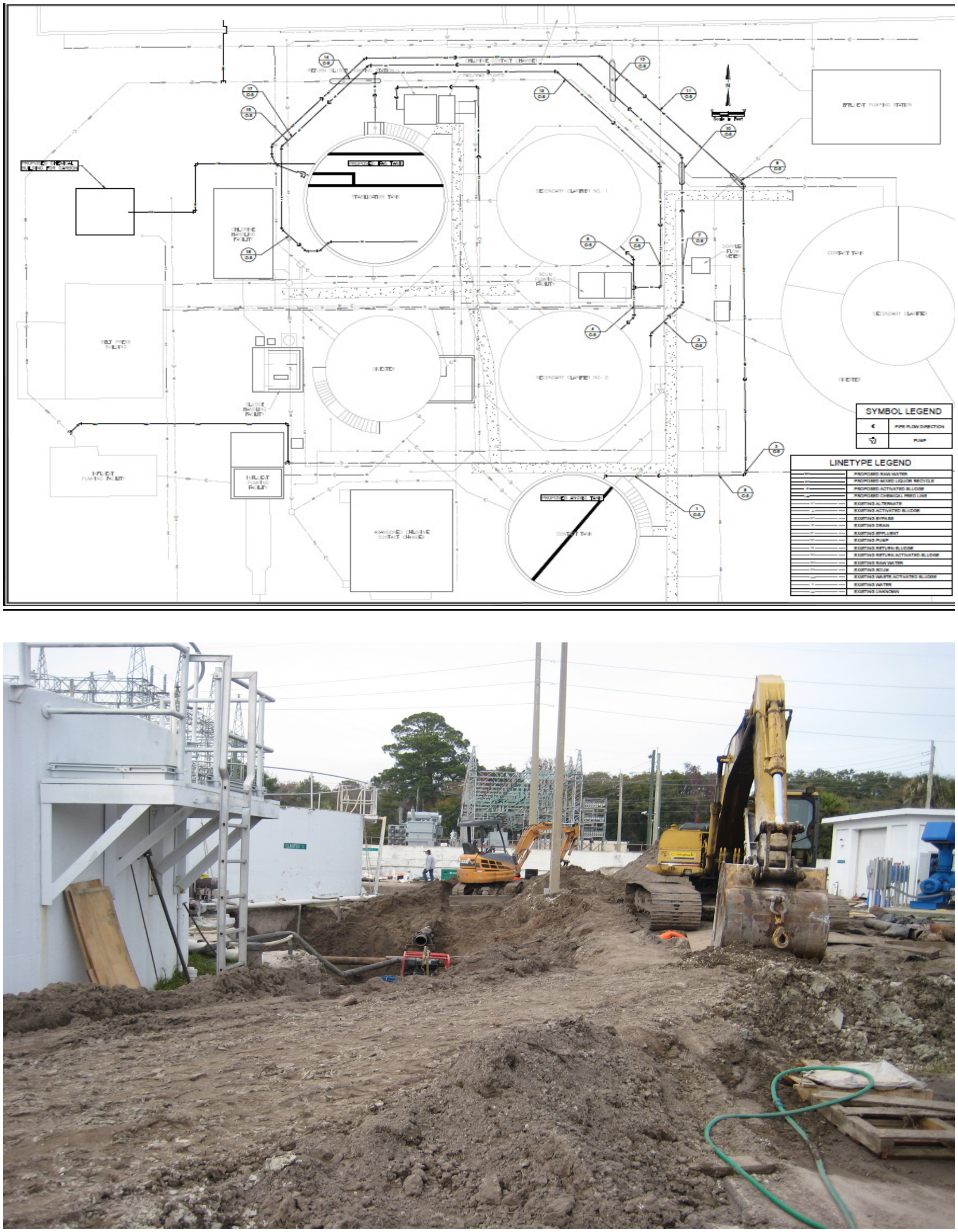
In order to do this, a supplemental Carbon feed system was installed to feed commercially available carbon compounds into the second anoxic zone. Re-aeration is accomplished in the last zone prior to discharge to the clarifiers. Air is supplied to this zone by a dedicated 10-HP PD blower.

In order for this system to achieve continual nitrogen removal efficiency, a Siemens SmartBNR™ system incorporating custom designed PLC-based control programming was provided. One ORP probe were installed in the anoxic zone to monitor and help
maintain controlled homogenous anoxic conditions. The IFAS tank has 2 DO probes to control aerobic conditions. One is located in the IFAS zone and another in the Re-Aeration Zone. The PLC is programmed to control the DO in each zone according to the desired set-point provided by the operators by pacing the variable speed blowers. Two TSS meters located in the re-aeration and RAS/WAS splitter box are used to control the SRT of the suspended MLSS in the plant. Again, the SRT of the plant is set-point controlled by the operator. Two Nitrate probes are used. The Nitrate probe located in the re-aeration zone controls carbon feed to the second anoxic zone. A Nitrate probe located in the clarifier effluent is used as a back-up.



Extensive piping re-routes were required to make this conversion work. Figure 1 shows the highlighted paths of new piping that needed to be designed and constructed. The pipeline from the influent pumping facility was re-routed to carry raw wastewater to the appropriate point in the new anoxic zone. The existing effluent line from the contact tank had to be re-routed to carry MLSS to the new IFAS tank. In reverse direction, a new recycle pipe had to be run from the MLSS wet-well of the IFAS tank back to the new anoxic tank. A new pipe had to be created to carry and evenly split MLSS flow from the effluent of the IFAS tank to the clarifiers. The RAS piping from the clarifiers had to be re-routed to the RAS pump room so that it could be returned to the new anoxic tank. Finally, a new chemical storage building was installed on the site to house the Carbon feed chemicals and a new carbon feed pipe was installed to carry this chemical solution to the second anoxic zone. Installation of these pipe routes proved to be a challenge during construction as many of the existing below-grade pipes and structures were not positioned as shown on the plans. These obstacles were overcome by a great cooperative effort on the part of the contractor and the operators at the City and played a key role in the success of this project.

Figure 1
Contact / Stabilization Plant Modifications



Another great challenge was the fact that project implementation required the Existing C/S facility to be taken out of service and all of the City's wastewater needed to be treated in the existing package treatment system. Planning for construction during the dry season was an important issue. It was also realized that the package system would need to be operated in an overload condition. The operational staff performed this function admirably but it was found that the package plant clarifier could not handle the peak flow experienced. A new siphon and extra piping had to be installed to bring one of the C/S plant clarifiers back on line to bring the plant back into control.

Start-up

Construction was completed during the spring of 2011 and actual start-up of the new IFAS system occurred on May 31' 2011 when the Biosphere™ media was placed into the IFAS zone of the IFAS tank. The primary objectives of start-up were to develop the anoxic/aerobic characteristics within the system, allow the new attached growth to develop on the media and place the control system in operation. Seed for the new IFAS system was obtained by re-routing RAS from the package plant to the new IFAS system. Growth of attached biology on the media would take time so an initial period of acclimation was expected. Treatment efficiency during this period would rely on the suspended growth in the process so longer SRT values were initially set in the control system. As acclimation of the attached growth occurred, The SRT set-point was to be reduced.

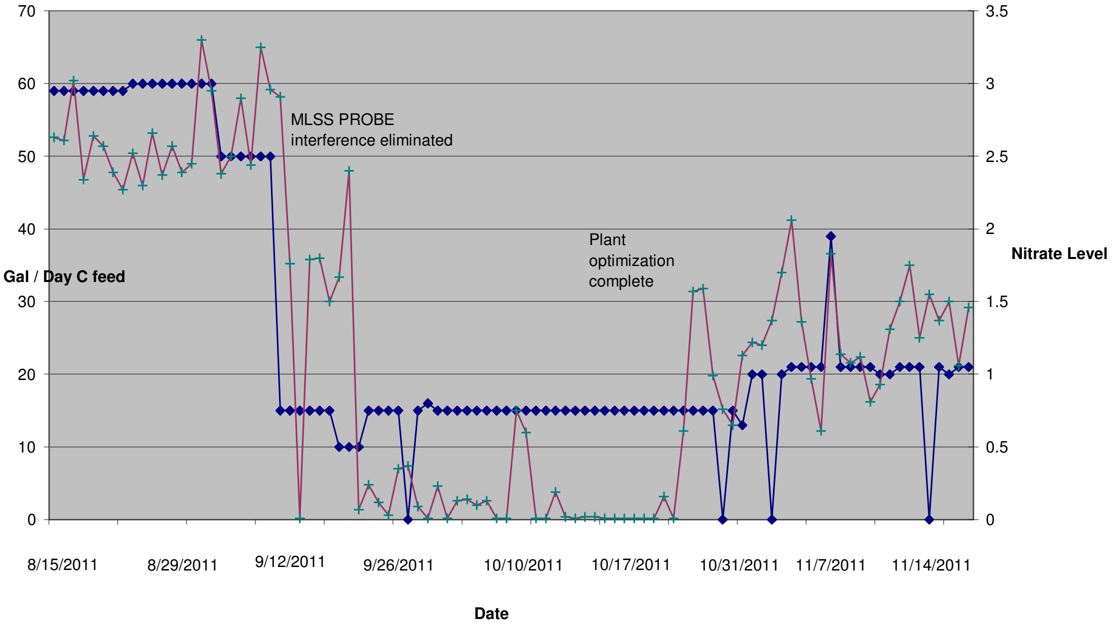
As with any project, plans and reality are often two different things. One of the main obstacles encountered during the start-up phase was the amount of wasting required to maintain the SRT and the MLSS at desired levels. Carbon being fed to enhance nitrogen removal in the biomass growing on the Biosphere™ was also being used by the suspended growth in the system, resulting in higher growth rates and increasing required wasting rates. The operators struggled to process the required waste sludge necessary to maintain targeted MLSS levels at the 3000 range. When MLSS crept higher than the target, excessive foaming occurred. Eventually, the operators adjusted their sludge processing procedures to accommodate the higher wasting requirements. Stable operation without excessive foaming has been achieved with MLSS levels ranging between 1800 – 2000 mg/l.

Another obstacle encountered was that initial carbon dosing rates were much higher than predicted. The problem was originally attributed to the acclimation period but once stable operation was achieved, feed rates continued to be high. Eventually, a wet chemistry investigation of the process identified that the Nitrate probe readings being used for controlling the carbon feed were not accurate and were actually reading too high. The actual NO3 level was 1 to 2 mg/l lower. The cause of this error was due to the interference of the suspended solids in the MLSS matrix where the probe was located. Solids must be removed from the solutions for accurate measurement of nitrates. This was proven by relocating a probe to the clarifier effluent box and measuring the differential between its readings and the Nitrate probe readings in the MLSS. Eventually, an offset was developed that could be programmed into the nitrate probe to compensate for this. While working on this problem, it also became apparent that the aluminum staffs that the probes were mounted on were corroding rapidly due to the chloride content in the wastewater. This problem was solved by changing the material of the staffs to stainless steel.

Figure 2 below shows data from start-up during the process of fine tuning carbon dosage rates in the second anoxic zone. The system is now performing at or better than its design expectation. By incorporating a Siemens SmartBNR™ control system to monitor the condition of each tank, the process can achieve automatic adjustment of the carbon feed and internal recycle pump rates, stabilizing effluent nutrient removal results. ORP is used to monitor the condition of the anoxic denitrification tanks and DO is used to monitor the condition of the oxic IFAS zones. The air flow rate and carbon feed rates are automatically adjusted to control these environments for efficient nutrient removal.

Figure 2

IFAS TRAIN NITRATE



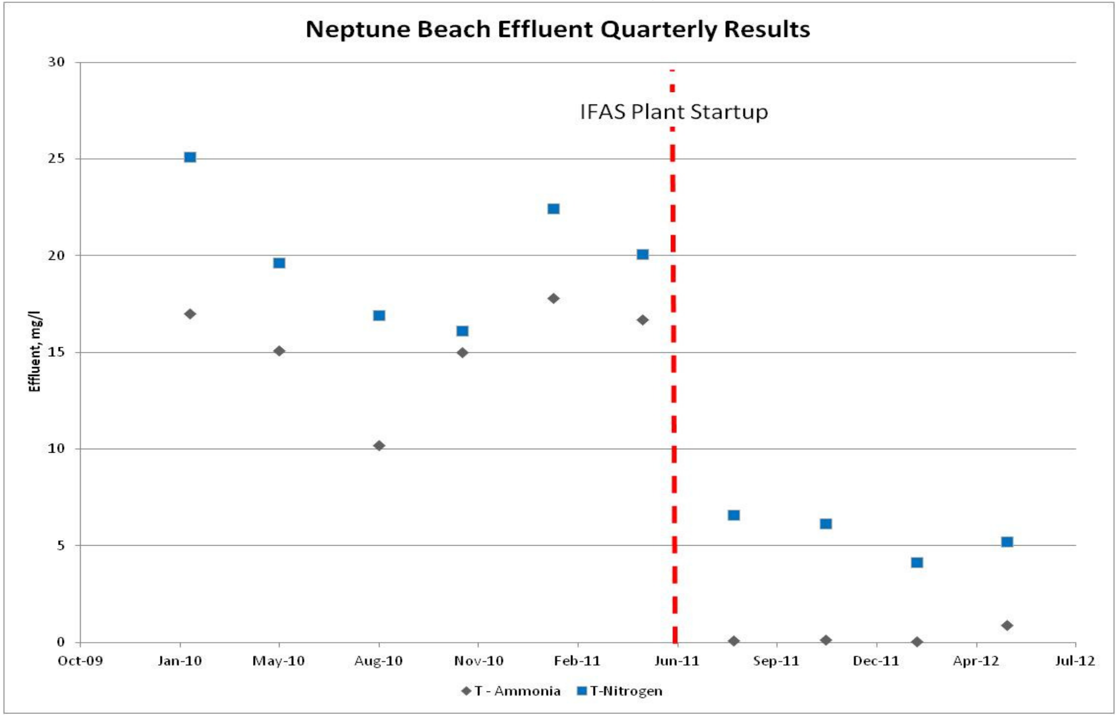
Process Performance

As the process stabilized, the operators made a few changes in the process control that benefitted operation of the plant. In early August of 2011 it was discovered that the plant performed better when the RAS to Influent Pacing was lowered to 130%. The initial Internal Mixed Liquor Recycle pump setting was adjusted to 250%. Finally, the SRT control set-point was slowly lowered from 15 days to 3 - 4 days, which lowered the MLSS to near 2000 mg/l. This then controlled IFAS tank foaming. Acclimation and adjustment of nitrate probe readings allowed the carbon feed rate to be lowered from 80 gallons per day to below 20 gallons per day, providing a considerable savings in operational cost. Moving the Nitrate probe farther away from the point of carbon feed resulted in more stable nitrat3e readings, helping to stabilize Carbon dosing rates.

This plant has and continues to put out an amazing amount of solids. The high sludge yield is the result of operating at lower SRT values and the impact on Carbon feed in the second anoxic zone on both the attached growth and suspended grown biology. The existing NB plant was required to waste approximately 10,000 gallons of solids / day. The new IFAS system needs to waste 40,000 gallons solids / day to maintain stable operation. This can be attributed to the nitrification by the bio-film in the IFAS zone. In retrospect, more digester capacity would have been helpful even though the operators have learned to control the amount of sludge in the system by decanting and running the belt press more often. The plant now averages 1950 mg/l MLSS and the blankets in the clarifiers are being maintained in the system between 6 in. and 1 ft. The plant has run very well with the low blankets.

To further evaluate how the new IFAS process improved the effluent quality, a simple comparison to the effluent before and after implementation provides a clear indication. Figure 3 below compares the quarterly average effluent ammonia and total nitrogen before and after implementation of the IFAS plant. After startup and optimization of the IFAS plant, Neptune Beach was able to dramatically improve their effluent nitrogen and ultimately meet the TMDL goals.

Figure 3
Ammonia and Total Nitrogen Effluent



Both the IFAS plant effluent and the existing package plant effluent are combined before filtering and disinfection. The package plant effluent ammonia is generally high which in turn increases the effluent TN above 3 mg/L. Approximately 70% of the plant influent is directed to the IFAS plant. Neptune Beach did not want to decommission the package plant as it helps during the rainy season to handle storm flows. Figure 5 shows the difference in the effluent TIN quality between the two plants in operation. The IFAS consistently has an effluent TIN of less than 2 mg/L which helps decrease the overall effluent TN to be able to meet the TMDL limit. Figure 4 below shows the effectiveness of the IFAS modification by comparing influent TIN with the effluent TIN from the unmodified package system and effluent TIN from the new IFAS system. The data presented Table 4 below shows the difference in results obtained from the unmodified package plant system vs. the new IFAS system during and after start-up in 2010. The Table shows conclusively that the IFAS system is consistently meeting its design objectives of less than 3 mg/l TIN.

Figure 4

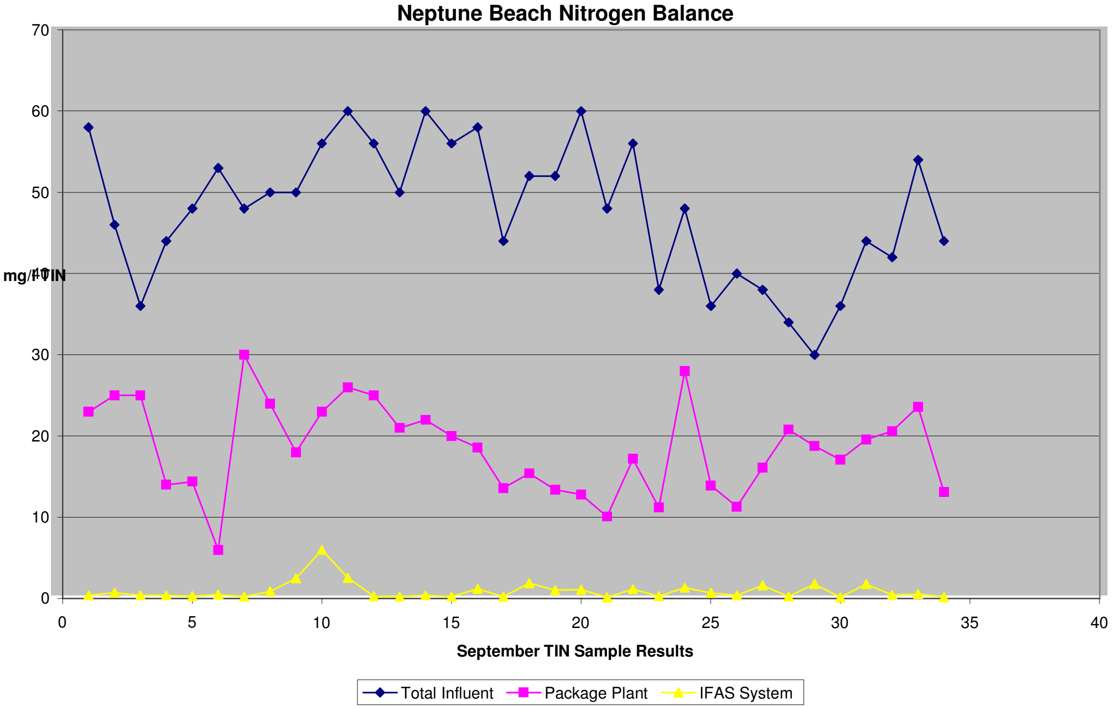
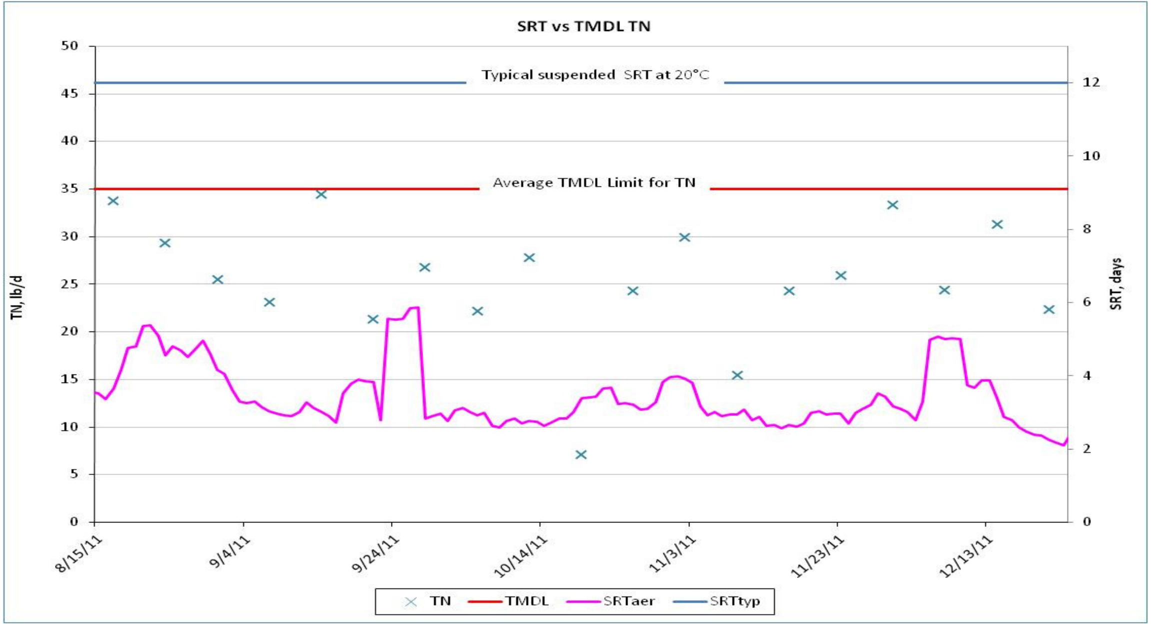


Figure 5 below compares the aerobic SRT to the effluent TN load and a traditional suspended growth SRT. Even though the plant runs a very short aerobic SRT (< 3 days), the effluent TN is easily met. Figure 5 also illustrates the successful implementation of the IFAS process in meeting the Total Nitrogen TMDL to the St. John's River ecosystem. The aerobic SRT of the plant is typically 1/6th that of what would be required for a conventional activated sludge system to meet the same effluent.

Figure 5



Summary and Conclusion

Many issues were encountered during start-up that required the manufacturer, engineer and City personnel to work together as a team to overcome them. Site constraints required a unique yard piping arrangement to accommodate the new process flow scheme. In addition, time constraints due to seasonal flow patterns meant that all parties involved had to work quickly and efficiently to meet the short schedule. Startup of the IFAS plant and integrating all the instruments to work together properly proved to be a challenge successfully met by everyone involved. The plant was successfully started May 31, 2010 and continues to perform efficiently. Some minor items still continue to be a challenge. For example, the small re-aeration blower tends to trip on “high-temp” fault during high flow events that cause the water to rise to near 16 ft SWD. The City is contemplating changing out the motor. The IFAS tank walls were raised approximately 2 feet but the Anoxic tank walls were not raised during this project. The operators have had issues with overflow of this tank during periods of heavy Storm-water flow. The City is currently investigating the possibility of raising the walls on the anoxic tank as well to alleviate this problem.

All things being considered, the City of Neptune Beach considers this project a greatly successful, cost effective solution for meeting their TMDL requirement. The ultimate goal of reducing Neptune Beach’s effluent Total Nitrogen discharges to the St. John’s River has been achieved. The St. John River’s ecosystem is better because of this effort. Other area communities that discharge to this surface water have been much less successful. The plant is stable and operates automatically without continual operator attention. Operational costs have been controlled to only those which are needed to meet the new TMDL and user charges remain low.

The successful implementation of this project is indicative of the City of Neptune Beach’s leadership in environmental compliance and the professionalism of their operational staff.