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Wastewater Treatment Improvement for Rush Strong School

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April 26th, 2017

Dear Dr. Cantin,

Please find attached a copy of my Civil Engineering Senior Design report, which serves as my Honors Thesis. The attached report reflects a group effort, and I would like to take this opportunity in this letter and the page immediately following it to highlight my contributions to the project and report.

My senior design team was tasked with improving the wastewater treatment at Rush Strong Elementary school, a rural school located in Strawberry Plains, TN. The school uses a septic tank and recirculating sand filter (RSF) to treat its wastewater, which it ultimately discharges into Crowder Brach Creek. The effluent that enters Crowder Branch is monitored by TDEC and must meet a set of water quality requirements. However, for the past several years, continuing until the current day, the discharge has consistently exceeded TDEC limits for the level of ammonia, which has potential legal ramifications for the school if it is unable to eliminate the problem. Following recommendations from an engineering firm, the school has been dosing the system with sodium bicarbonate daily since 2015. While this has helped reduce the amount of excess ammonia, it did not bring the system fully into compliance, and the school would like to eliminate or at least greatly reduce the cost of chemical treatment. Our job, therefore, was to design a low-cost solution to bring the school's effluent into compliance with TDEC standards, and lower or eliminate the sodium bicarbonate dosing.

The engineering services provided by the team consisted of several field visits to investigate the site, hydraulic analysis of the system, and analysis of water chemistry. When conducting field visits, we worked with the facilities people who maintain the system to understand what the existing conditions at the site are. For the hydraulic analysis, we used a design guide for RSFs to design an "ideal" RSF for the flow for the system and compared that to the current conditions. For the water chemistry analysis, we determined the current rate of removal of ammonia, and calculated how that would change as we improved the system hydraulics, and analyzed how best to keep the system's microbes alive during dry periods. Unfortunately, due to limited data, we were unable to calculate the effect of ceasing sodium bicarbonate dosage.

After analyzing 14 options for the system, the following suggestions were selected. First, we developed guidelines for appropriate maintenance of the system. Next, we suggested changes to the rate that wastewater is applied to the filter and improving the recirculation ratio, including 100% recirculation in the summer. Additionally, we recommended adding access risers to the septic tanks to allow for easy

My contributions to the project are as follows:

- Analyze water consumption data
- Coordinating and participating in site visits
- Researching, understanding and performing water chemistry analysis

My individual calculations for analyzing water consumption and chemistry may be found in Appendix E , which are attached to this report. Other student work is found in other appendices and is available upon request.

Thank you for your time.

Christina Sanford

Christina Sanford

Senior, Civil and Environmental Engineering

This project was a team effort, and all group members had distinct aspects of the project which they contributed. My contributions were particularly related to site visits, water consumption data, analysis of options and water chemistry, and are detailed in the following paragraphs.

One of the first tasks I worked on was coordinating site visits. I worked with the school system to ensure that they knew when we were coming, and that the facility person I worked with was available to meet with us at that time. Additionally, I coordinated sample collection when we took a sample for a test we performed. On site visits, all team members shared equally in asking questions and investigating the site.

Another task I worked on early in the semester was analyzing the school's water consumption data. I worked with KUB and the school to obtain the data and then used statistical calculations to determine the average flow, taking outliers into account.

I was responsible for understanding and analyzing the water chemistry of the system. This was my main job on the team and consisted of much research and work with professors of Environmental Engineering. For this task, I first had to learn about and understand the biochemical processes that drive RSFs. I then had to determine how to use the data that we had to analyze how to what extent those processes are occurring in the current system. I then applied that knowledge to two main areas. First, I determined how much ammonia removal could be increased by the hydraulic improvements such as increasing recirculation. Next, I evaluated the best way to ensure that the microbes are still alive at the end of extended low-flow periods such as summer break.

Wastewater Treatment Improvements

RUSH STRONG ELEMENTARY SCHOOL

KELLI GRISSOM, SHARON COUNTS, KATIE GIPSON, CHRISTINA SANFORD

Rocky Top Water Solutions

SENIOR DESIGN COURSE CE 400 | UNIVERSITY OF TENNESSEE – KNOXVILLE | 4/28/17

WASTEWATER TREATMENT IMPROVEMENTS

for

RUSH STRONG ELEMENTARY SCHOOL

April 28, 2017

Prepared by:

ROCKY TOP WATER SOLUTIONS

University of Tennessee, Knoxville
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Senior Design Project Course (CE400)

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Disclaimer:

This report reflects student work only, and is intended for academic purposes only. Construction is not to be implemented based on the conclusions of this report without approval by a licensed engineer.

Acknowledgements

This design would not have been feasible without the support of a number of individuals who assisted throughout the project deliverables. First and foremost, Rocky Top Water Solutions would like to thank Dr. Retherford for all her hard work putting this course together and supporting our efforts. We would also like to thank Stephanie Farrell for giving her time and expertise to help us succeed and George Garden for his valuable time and support. Rocky Top Water Solutions would also like to acknowledge the efforts of Sharon Hale, CEE's environmental laboratory coordinator for her assistance. Last, but certainly not least, we would like to thank everyone at Rush Strong School and Jefferson County, especially Derald Longmire, for their support and cooperation.

PROJECT ABSTRACT FORM
WEFTEC® 2017 STUDENT DESIGN COMPETITION

SUBMIT ABSTRACT FORM BY June 1, 2017

Project Title: Wastewater Treatment Improvements for Rush Strong Elementary School

University: University of Tennessee

Faculty Advisor: Dr. Jennifer Retherford

Team Members: Kelli Grissom, Katie Gipson, Christina Sanford, and Sharon Counts

Abstract (not to exceed 200 words):

In 2000, Rush Strong Elementary School upgraded their wastewater package plant to a recirculating sand filter to treat their low-flow wastewater effluent. The existing recirculating sand filter is producing effluent that does not consistently meet the permit requirements of TDEC. While temporary efforts are working to maintain compliance, the rural school district is not financially capable of supporting the operations efforts currently ongoing. Jefferson County School System requested that this student team (Rocky Top Water Solutions) prepare a design that achieves the permit requirements in a cost-effective manner. The team identified multiple alternative design options. These design solutions consider the client's preferences and a multi-criteria decision matrix was employed to provide an objective measure for identifying the most suitable solution to meet the client's needs and preferences. There were no engineered as-built drawings for the system, so this analysis was supported heavily through water chemistry and system performance calculations to ensure an accurate design. The recommended solutions included two categories: operation and maintenance, and design improvements. In addition to the calculations, programming was developed for the optimization of dosing times. With the proposed system improvements, it is believed that the school's effluent will align with the permitted standards.

1 Summary

Rush Strong Elementary is located in Strawberry Plains, TN, and is a part of the Jefferson County School District. The school currently has a wastewater treatment system producing effluent that does not consistently meet the permit requirements of the Tennessee Department of Environment and Conservation (TDEC). The system was designed to function as a recirculating sand filter; however, there was no recirculation valve installed during construction. Rocky Top Water Solutions plans to improve the current system so that the school can comply with State Regulations.

The following engineering report contains a full description of engineering services provided, including site visits, research, and computation. Sections 1-5 provide a thorough background of the project. The scope of work and regulatory requirements may be found in Sections 6 and 7 respectively. Section 8 contains the analysis of options and Sections 9 and 10 present the final recommendations. A series of appendices present detailed engineering services, consisting of the computational work that supports the conclusions drawn in sections 9 and 10.

2 Background Information

Strawberry Plains is a rural area in East Tennessee. In 2015, the average household income was about $45,890, which was about $1,300 below the Tennessee state average, and $7,900 beneath the national average [1,2]. Among students at Rush Strong Elementary School, 54% are on Free or Reduced lunch, which is higher than both the state average of 49% and the national average of 48% [3,4]. Rush Strong Elementary School serves around 650 students from Kindergarten through Eighth grade and has about 50 faculty members. The school consists of two main classroom buildings and a separate gymnasium, located on a 10.32-acre lot. Figure 2.1 shows the grounds of Rush Strong and some of the surrounding areas.

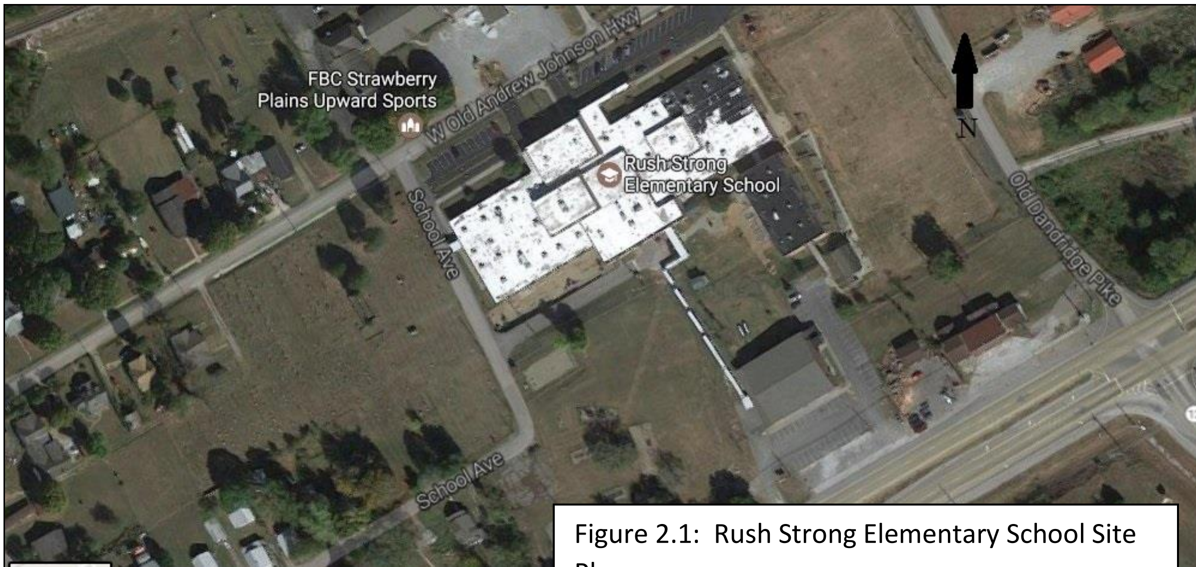


Figure 2.1: Rush Strong Elementary School Site Plan

In 2000, Rush Strong Elementary School received a new wastewater treatment system that treats an average of 2400 gpd and discharges into Crowder Branch Stream, which ultimately flows into the Holston River as a part of the Holston Watershed. The system, designed by Site Inc., was categorized as a recirculating sand filter treatment system and was designed for a 20,000 gpd flow. Initially, there was no mechanism for recirculation. However, in January 2017, a pipe was added that brings some effluent from the filter back to the septic tanks. Prior to the summer of 2015, the wastewater from the gymnasium flowed directly into the filter without going through the septic tanks. Due to this high loading, the system exceeded limits for ammonia nitrogen, E. coli and had unacceptably low pH levels, and the school received several warnings from TDEC about violating water quality standards. In addition to re-routing wastewater from the gymnasium to flow through the septic tanks, the school began dosing the system with 23 pounds of sodium bicarbonate daily. While the effluent is much cleaner than it was before the gymnasium pipe was rerouted, the effluent is still consistently testing above allowable ammonia limits according to TDEC, and the new recirculating pipe is likely not recirculating the correct ratio of water, meaning that the system is not yet performing at its maximum potential.

3 Existing Conditions

There are no engineered as-built drawings for the system; however, after numerous visual inspections the system's configuration has been determined. The existing conditions can be split into two separate categories: the physical system and the treatment system. The physical system begins where influent passes through a system of three septic tanks. The influent then flows into a dosage tank where the wastewater is pumped to a 1680 ft^2 sand filtration bed. The influent flow enters the recirculating sand filter system through a series of 10 PVC access risers, presented in Figure 3.1 to the right. The flow is equally distributed through each riser and is settled down into the recirculation chamber at the bottom of the filter system. From here, the influent flows to the pump tanks, and is then pumped to a six-way hydrotek valve that distributes the influent to each lateral; this flow process can be seen in Figure 3.2 below.

Figure 3.1: Access Risers

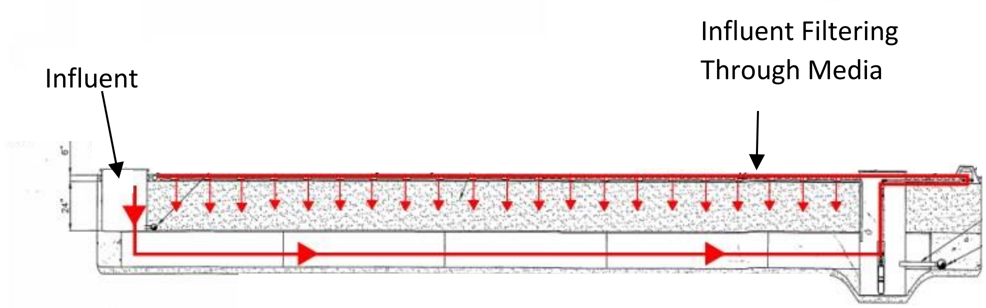


Figure 3.2: RSF Flow

This physical system is made up of 12 zones and two hydrotek valves, where each valve serves 6 zones and each zone has 2 laterals (Figure 3.3). Once filtered through the bed, the treated flow collects in the underdrains to eventually discharge to the disinfection shed. The hydrotek valve that doses zones 6-12 is connected to both the primary and the final filter bed. The primary filter bed is made up of zones 1-9, while the final filter bed is the portion of the bed that discharges the treated wastewater and is made up of zones 10-12. One pipe from the hydrotek valve that doses zones 6-12 carries filtered water back to the septic tanks, as water is divided into a 1:12 ratio for which the smaller quantity is sent back to the septic tanks. This recirculation line was installed recently to provide an amount of recirculation that was not being provided before. Before this installation, there was no recirculation occurring, which defeats the purpose of a RSF. Although this improvement has helped the system, a higher recirculation rate would be more effective in helping the effluent come into compliance. When the hydrotek valve distributes flow to the final filter bed, the treated flow is collected and sent to a tank under the UV disinfection shed. After disinfection, the effluent is discharged into Crowder Branch Stream.

The treatment process begins with the influent being treated with 23 lb per day of sodium bicarbonate. Primary treatment occurs in the septic tanks as BOD and TSS are removed through screening and settling processes. Most of the solids in the septic tanks are retained in the first tank. Secondary treatment occurs in the sand filtration bed as the influent is filtered through the system from the laterals. The current system produces effluent with the following average characteristics as shown in Table 3.1 below:

Figure 3.3: Zone

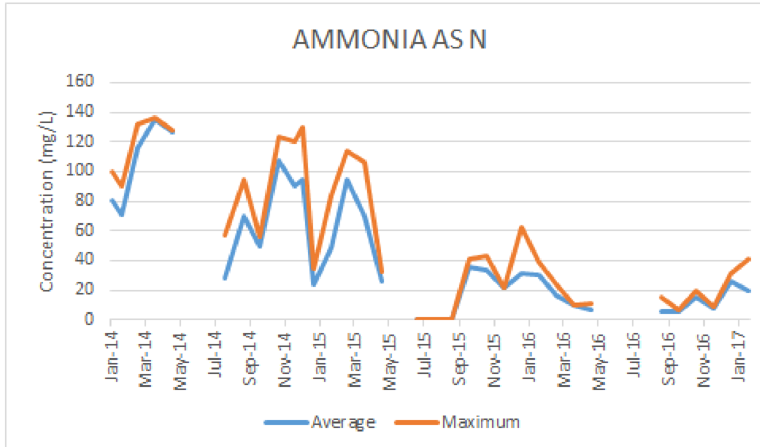


Table 3.1: Effluent Properties and Limitations								
	BOD (max)	Suspended Solids (max)	DO (min)	Ammonia as N in summer (max)	Ammonia as N in winter (max)	pH (max)	pH (min)	E. coli (max)
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(SU)	(SU)	(CFU/100mL)
Rush Strong Output	15.12	6.10	4.42	62.66	55.44	7.70	6.77	674.65
Permit Discharge Criteria	≤ 25.00	≤ 45.00	≥ 6.00	≤ 4.00	≤ 10.00	≤ 9.00	≥ 6.00	≤ 941.00

This table presents that this system is out of compliance in ammonia as nitrogen concentrations as well as dissolved oxygen concentrations. As can be seen in Figure 3.4 below, the ammonia levels have been out of compliance since January of 2014. These recorded ammonia levels are much higher than the required output, as it should be less than 4 mg/L in the summer and less than 10 mg/L in the winter. This system receives very drastic changes in flow due to the dynamics of use by the school. There is little to no influent coming into the system during the summer months; therefore, the ammonia levels will start to decrease. Figure 3.4 displays a trend of having higher ammonia levels during the winter months, with the exception of December. Just like the summer period, December is a school break and the system will receive little to no influent. Therefore, the ammoni

Figure 3.4: Ammonia as Nitrogen

ber, which is represented by the dip in Figure 3.4. With the help of the operator's influence on the system, the ammonia levels have been generally decreasing

with time. Prior to July of 2015, the gymnasium was connected directly into the head of the filter bed, with no screening or settling of the influent. During July of 2015, this issue was resolved by connecting the gymnasiums influent into the head of the septic tanks. This improvement helped lower the ammonia levels as the solids were no longer causing major clogging. The school also started to treat the system with sodium bicarbonate during this

Figure 3.4: Ammonia as Nitrogen Levels

period, which also drastically improved the ammonia levels. However, these improvements are not enough to bring the system into compliance as the dynamics of use from the school is not good for the system. The high and low periods are not healthy for the microorganisms as they will either die off or go dormant in the low periods, which helps contribute to them becoming over-saturated in the high periods. Sufficient oxygen is not being maintained in the system as the dissolved oxygen levels are too low. In order to improve the DO levels, sufficient alkalinity needs to be present in the influent along with optimized dosing levels. Having sufficient alkalinity and oxygen levels are vital in oxidizing ammonia as nitrogen.

4 Standard Recirculating Sand Filter Design

Recirculating sand filters (RSF) can provide secondary treatment of septic tank effluent. A standard RSF system consists of a septic tank, a recirculation tank, and a sand filter (Figure 4.1). Operation of the system begins with primary treatment in the septic tank. The treated septic tank effluent is then pumped to the recirculating tank. The wastewater is distributed along the top of the sand filter bed through a network of drain lines (Figure 4.2). As the wastewater flows downward through the sand filter, biological treatment occurs on the surface of the sand particles in order to reduce pollutants. The treated wastewater is then collected at the bottom of the filter and the discharge is split at a 5:1 ratio; the majority of the flow returns to the recirculation tank, where it mixes with the fresh influent from the septic tank. The remainder of water is collected and sent to the disinfection facility, from which it is discharged to the receiving body of water.

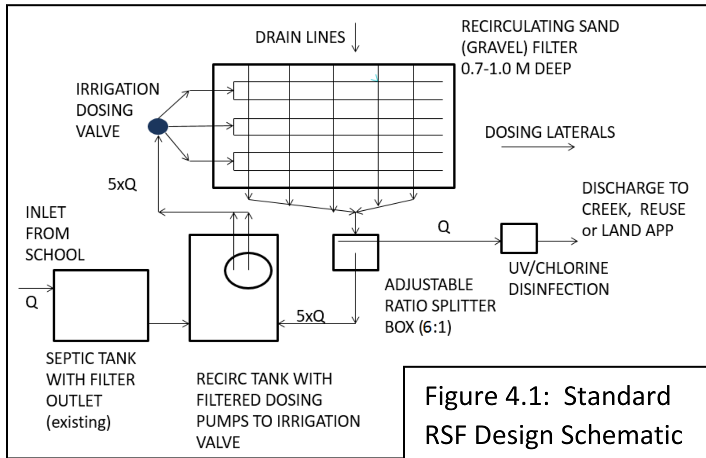


Figure 4.1: Standard RSF Design Schematic

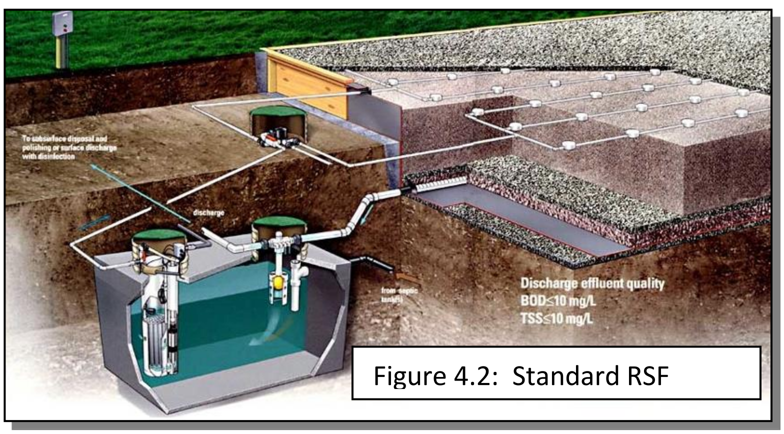


Figure 4.2: Standard RSF

5 Water Chemistry

While the hydraulics, as described above, are an important facet of the overall system, the main way in which RSFs improve water quality is via aerobic biochemical treatment using the microbes, mainly bacteria, which naturally occur in wastewater. The primary biochemical process that occurs in RSFs is nitrification, aided by two types of aerobic autotrophic bacteria. *Nitrosomonas* bacteria perform the oxidation of ammonia to nitrite, which is then oxidized by *nitrobacter* to form nitrate as detailed in Appendix E-2. Using stoichiometric equations, it can be shown that 7.14 g of alkalinity as $CaCO_3$ and 4.57 g of oxygen as O_2 are needed to oxidize 1 g of ammonia as nitrogen. This chemistry shows that the limiting factors in RSF beds are the presence of sufficient oxygen and alkalinity to provide adequate nitrification. Therefore, in RSF design, care should be taken to ensure that sufficient alkalinity is present in the influent and to maintain an appropriate dosage level so that sufficient oxygen can be pulled into the system. If all elements are present, RSFs can achieve greater than 90% ammonia removal.

Currently, the system is not functioning properly due to insufficient recirculation which causes the ammonia levels in the influent to be much higher than the system is designed to treat. Influent to the filter from the septic tank is not monitored as regularly as effluent from the filter, but the 3 known samples, dating between February and April 2017, all showed ammonia levels between 90 and 110 mg/l of ammonia, with an average of 101.6 mg/L. This is an exceptionally high concentration of ammonia compared to typical wastewater, but is easily explained by the long septic tank detention time and the fact that the system is located at a school, making the water particularly high in urine and ammonia based cleaners. However, at this influent concentration, even if the system operates to its maximum capability and removes up to 90% of the ammonia, the effluent will still be out of compliance.

As of April 2017, based on the average influent and the effluent ammonia concentrations that correspond with the influent measurements, the system is removing approximately 80% of the ammonia, which means that while it is operating near maximum efficiency, there is still room for improvement. With an appropriate recirculation ratio, an 80% removal rate will reduce the final effluent level to appropriate level on the second cycle after improving the recirculation rate, as demonstrated in Appendix E-2. However, raising the removal rate a mere one percent eliminates this problem. Therefore, merely improving the recirculation rate will nearly remove the entirety of the excess effluent ammonia.

6 Technical Scope of Work

The scope of work for this project requires a modification to the current treatment system that will bring the school's wastewater system into compliance with TDEC permit requirements in a cost-effective manner. This will be achieved by analyzing current data to determine the needs of the system, and performing engineering calculations, following a design guide published by Orenco Systems, Inc, to improve the consistency with which TDEC water quality standards are met. Current data includes GIS maps, TDEC water quality data, the school's water consumption data and monthly operating reports, as well as the school's National Pollutant Discharge Elimination System (NPDES) report. Alternative solutions will be developed and the most cost-effective solution, which safely meets TDEC requirements, will be recommended to the client for implementation.

7 Regulatory and Other Requirements

Rush Strong School was issued a NPDES Permit, a copy of which is presented in Appendix A, by TDEC which became effective on March 1, 2015. This permit states that Rush Strong School is authorized to discharge treated domestic wastewater from Outfall 001 to the receiving waters of Crowder Branch between mile 0.4 to Holston River and mile 17.7 in accordance with effluent limitations, monitoring requirements and other conditions. Outfall 001 has a design capacity of 0.02 MGD. Crowder Branch has not been assessed for water quality at these mile marker sections. The stream is assumed to be fully supportive of its designated use classification. While there is no knowledge of the stream limits, there is knowledge of the system and its required limits according to this NPDES permit. These criteria referenced in the permit can be seen in Appendix A as well as in Table 3.1.

8 Analysis of Options

Several design alternatives were derived and evaluated through engineering analysis in response to numerous site investigations. These alternative designs were analyzed based on a multi-criteria decision matrix, which can be found later in this section. This matrix is a decision-making tool that provides a qualitative means to identify the best design solution(s) utilizing a multi-faceted sustainability analysis. The consideration of cost, operation and maintenance, efficient technologies, and feasibility were weighed and the best option was chosen based on the overall score. The analysis of options included evaluation of the existing conditions and potential changes to the system based on the design guide set forth by Orenco Systems, Inc [6].

The team developed multiple alternative options using the Orenco design guide as a means of identifying the key parameters of the idealized system performance. This required identifying a number of design input parameters such as the daily flow, for which the average was derived and approximated from data provided from Jefferson County Schools, and pump characteristics. An average flow rate of 2,400 gpd was determined from data provided and pump characteristics were found from Red Jacket Pumps. An idealized system was modeled and the parameters of the design were manipulated to analyze the existing system conditions. During this calibration process, the team was able to identify problem areas within the system and determine modifications to the physical system to achieve performance criteria as stated by TDEC.

The original system was not designed as a common RSF and does not operate in a consistent manner. Common RSFs have a recirculation tank, where influent and recirculated effluent are mixed and run through the system via a pump. These tanks are used to provide 100% recirculation during dry periods to keep microorganisms alive within the filter bed. RSF's are also sized to filter influent at or near standard flow rates for the specific service area. A major issue with the original RSF at Rush Strong was the lack of proper recirculation, without which an RSF cannot properly treat influent. Another area of concern is that the average daily flow is 2,400 gpd, which is approximately 1/8 of the design flow for the original system of 20,000 gpd. Without adequate flow, the filter chemistry can be depleted and therefore will not properly denitrify the influent, which is the cause of high ammonia levels.

A peak flow of 4,000 gpd was used to understand how the system functions under high demands, while the average flow of 2400 gpd was used for all other calculations. The current filter bed was found to be more than two times the needed size for a 4,000 gpd system. However, after thorough discussion with professionals, this was determined not to be a major concern for the integrity of this system.

Additionally, a comparison of the current design ratio of 1:12 to design guides showed that it was less than 60 times the recommended ratio of 5:1. The recirculation ratio is important for the health of the overall system, because it ensures that there is constant flow through the system to prevent the dying-off of key microorganisms within the filter. If there are not enough microorganisms in the filter to remove nutrients, the effluent characteristics will not meet state and federal standards for water quality. Recognizing that the system is not like standard sand filter designs, the analysis of options was developed throughout the project duration as new details about the system were discovered.

Throughout analysis of the system 14 ideas were presented that would improve the system performance and effluent characteristics. The most important factor and design improvement for this system is to provide appropriate recirculation, which could be addressed in several different ways. The system currently has recirculation as discussed in the existing conditions; however, this method does not adequately recirculate throughout the system during low flows. To provide a more standard design for the RSF, the addition of a recirculation tank was considered. This idea, however, was found to be expensive due to the cost of excavation and installing a tank, and unnecessary, as the underdrains acted as a recirculation chamber. The implementation of a splitter box between the filter bed and the disinfection shed was also discussed. Installation of the splitter box would ensure that a recirculation ratio of 5:1 would be maintained throughout the system and that all of the water would recirculate during periods of low flow (Figure 8.1); however, the flows were found to be too low to create a feasible sharp-crested weir splitter box, as seen in Appendix E-3 calculations [7]. This option would require the design of two

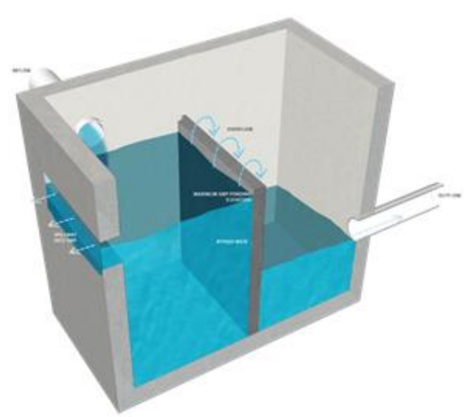


Figure 8.1: Splitter Box with

sharp crested weirs to distribute water through the box at the correct ratio. A splitter box was designed, but it was found that the low flows would require weirs with 6” lengths to function properly.

Another consideration was to tie a recirculation pipe into the septic tank or pump tank. At a site visit, it was found that a pipe was already placed and tied into the head of the septic tanks as a recirculation tool. The system was still not producing the necessary effluent characteristics, because this method does not ensure 100% recirculation and causes the anaerobic processes of the septic tanks to become aerobic due to the introduction of oxygen. The issue of the dosage pump system’s activation also was a concern for this method because as low or no flow enters the system, there may not be enough water to turn the pump on. Recirculation would not occur if the pump is not filled to a certain level and water would remain in the pump tank until influent from the school enters the system. Similarly, another option was to tie the recirculation pipe into the pipe between the pump tank and the sand filter, with the addition of an in-line static mixer to achieve the appropriate mixing (Figure 8.2). While this is a reasonable option, it was determined that the underdrains at the bottom of the filter would provide adequate mixing. The final modification option, ultimately a component of final design, is to tie the recirculation pipe directly into the risers at the head of the sand filter. This option was chosen due to its low cost and the ability to properly mix the return water with the new influent. It also allows for recirculation at low or no flow. While recirculation methods were a large part of the analysis for this system, many other ideas were considered to improve the overall operation of the RSF.

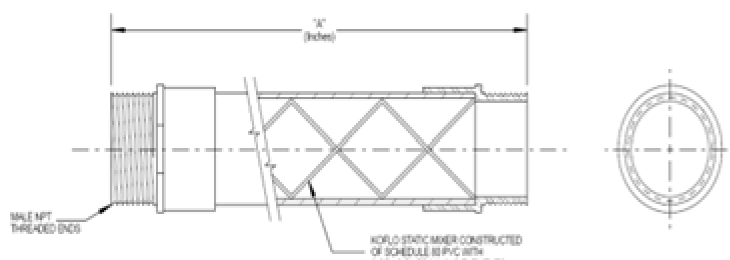


Figure 8.2: In-line Static

A decision matrix was created to compare the effectiveness of each option considered, and the decision criteria were weighted based on relative importance. Cost, and operation and maintenance were considered the most important criteria and were each given a weight of 0.3.

The efficient use of technology and the feasibility of the option were considered to be of secondary importance and were each given a weight of 0.15. Client preference, while considered in the design process, was considered to have the least importance in the decision-making process, and was given a weight of 0.1.

Table 8.1: Multi-Criteria Decision Matrix

Options	Criteria					Weighted score
	Cost 0.3	O&M 0.3	Efficient Technology 0.15	Client Preference 0.1	Feasibility 0.15	
In-line mixer	3	8	4	5	3	4.85
septic or pump tank as recirc tank	6	4	3	10	6	5.35
weirs/splitter box	2	9	5	4	4	5.05
decrease filter area	5	5	2	2	5	4.25
increase recirc ratio	7	10	9	6	7	8.1
new recirc tank	1	3	1	1	2	1.75
Continuous bleed-off of solids	9	2	8	8	8	6.5
total zone separation	10	6	7	9	11	8.4
reroute recirc line to riser	8	7	10	7	10	8.2
alternating sand beds	4	1	6	3	1	2.85
100% recirc	11	11	11	11	9	10.7

1=Unfavorable 11=Favorable

Other improvements to this system were considered throughout site investigations. During one site visit, it was found that the laterals were clogged, which caused inadequate dosing of the filter bed. The addition of a series of ball valves to the ends of each lateral would allow for a continuous release of built-up solids. A variation of the ball valve design was analyzed and used in the final design process. A new check valve would be installed on every other zone to completely connect the existing flushing system. This would ease the maintenance of the monthly lateral cleaning, and eliminate the complications associated with regularly cleaning the laterals.

In lieu of the clogged laterals, it became a concern that the media itself was clogged and might potentially need to be replaced. If media is clogged, then the system does not properly drain and water will not be treated appropriately due to lack of chemical processes (Section 5). In order to mitigate this issue several changes would be made to the sand bed. First, the media would be replaced; being sure that the new media met the criteria of having an effective grain size of approximately 0.25 mm and a uniformity coefficient of 1.5 to be in accordance with EPA recommendations for RSF design. Based on the Orenco design guide analysis, it was additionally recommended that the sand filter be reduced to approximately half its current size to have a surface area of 800 ft^2 to gain the appropriate loading rate for the system. The area currently used for the media bed would be divided into two separate beds. One filter bed would run at a time, until media replacement was required. The system would then need to be switched to the other bed while media replacement and maintenance occurred on the first media bed. After visual inspection of the media, this option was ruled unnecessary and overly expensive for the scope of this project.

Another improvement option was the addition of a sewer blanket to insulate the system during colder months. While this prevents issues related to frozen pipes and microorganism die-off, the system is in an area where this is not a common problem. The average temperature during the winter months of November, December, January, and February regularly stays above 32°F. Matt’s Sewer Blankets is a common brand, and is typically used in Canada and the Upper Midwest where there are harsher temperatures and more snow. Although a low-cost and easily implemented solution, this is not necessarily a major problem for the system at hand.

The team and the professionals involved also determined that risers should be implemented on the septic tanks to avoid excavation each time they need to be accessed. This would ease the maintenance of the septic system and would reduce the overall cost of maintenance.

While many of these options are viable, only a few were chosen as part of the final design. Based on this analysis, 5 key elements to the solution were identified: implementing 100% recirculation, increasing the recirculation ratio, rerouting the recirculation line to the access risers, adding gate valves to completely separate zones, and extending the flushing valve system.

9 Proposed Design Recommendation

The final design recommendation considers the client's preferences and employs a multi-criteria decision matrix in order to evaluate the alternatives based on four criteria categories derived from a multi-faceted sustainability analysis: cost, operating and maintenance, efficient technologies, and feasibility. Through this analysis, several design modifications are recommended for the existing system in order to bring the water chemistry of the effluent into compliance with TDEC. A portion of the improvements are intended to be updated through operation and maintenance. The proposed design modifications as well as the operation and maintenance improvements are presented in Table 9.1. This table addresses which elements are representing design modifications and O&M improvements as well as the order of implementation, if not installed all at once, and the benefits that each element offers.

Table 9.1: Final Recommended Elements

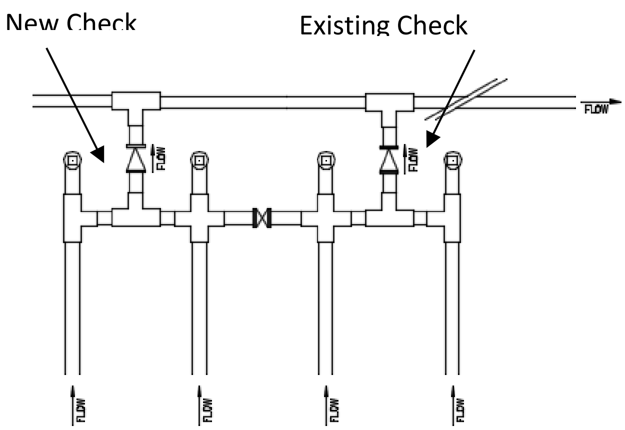
Proposed Element	Design	O&M	Order of Implementation	Benefit
Provide Above Ground Access to Septic Tanks		X	1	Provides easy access to septic tanks and allows more frequent monitoring of solids levels
Increase Recirculation Ratio	X		2	More opportunities for ammonia removal
100% Recirculation During Low Flows	X			Ensures the filter stays wet and bugs have food
Block Zones 10 through12 in Summer		X		Ensures 100% recirculation is maintained
Continuous Bleed-Off of Solids	X		3	Prevent clogging of laterals
Backwash Laterals		X		Returns system to full capacity
Monthly Flushing of Laterals		X		Prevents future clogging of laterals
Total Separation of Zones	X		4	Removes improper zone dosing
Reroute Recirculation Line to Risers	X			Provides adequate recirculation and mixing
Ensure Laterals are Straight and Properly Buried		X	5	Ensures entire filter is being dosed
Remove Vegetation		X		Prevent media clogging

The specifics of the proposed design components are detailed in the following paragraphs. With regards to the recirculation line currently flowing to the septic tanks, it is recommended that the line be diverted to tie into the risers at the head of the filter bed, where thorough mixing will occur with the influent flow from the pump tank. From the access risers, the water will flow through the filter underdrain via gravity. The underdrain functions as a recirculation tank and the new influent will naturally mix with the recirculated effluent. There are two major reasons why the recirculation line should be rerouted to the access risers. First, having the recirculation line tie into the septic tank harms the anaerobic processes that should be occurring in the filter. Instead of the once treated water continuously recirculating and mixing with new influent, the water is stagnating in the septic tank until it is pumped back to the filter. Secondly, during the summer months, the amount of water recirculating to the septic tank will not be adequate to raise the water level in the pump tank enough to pump the recirculated water back to the filter.

Additionally, it is recommended to optimize the pump cycling times to increase runtime and downtime efficiencies. Currently the pump cycling times are 2 minutes on and 4 minutes off, with two pumps pumping at the same time, dosing different zones. For example, pump one will dose zone 1 at the same time that pump two will dose zone 6, and the pumps switch to a new zone each time they come on. A set of pseudo codes composed of "if-then scenarios" was created to help optimize the system, as detailed in Appendix F. This was designed to help increase the dissolved oxygen content, which will in turn oxidize more ammonia. Through thorough calculations and coding, three optimized pump times were designed, one for low, average, and peak flow conditions. During average flows, the pump rate should be set to 18 gpm to maintain the pump run time at 8 minutes on and 10 minutes off. During low flows, the pump rate will need to decrease to 6 gpm in order to maintain a pump on time of 8 minutes and a pump off time of 25 minutes. During peak flows, the pump rate will need to increase to 25 gpm to maintain a pump on time of 8 minutes and pump off time of 3 minutes. According to monthly monitoring reports, the lowest flow for 2016 was 428 gpd and the highest flow was 5514 gpd. These values were used to find low flow and high flow pumping information. The programmable logic control panel (PLC) can be reprogrammed to optimize the dosing rate. The reprogrammed PLC will appropriately update the timer for the pump on and pump off times based on the water use from the school, as in low-flow, average-flow, or peak-flow scenario.

In the summer, when there is little to no new influent flow, it is recommended to implement

100% recirculation by turning off zones 10, 11, and 12. Currently, water exits the system after passing through zones 10-12, but by keeping water from entering these 3 zones, water will be forced to recirculate instead of exiting the system. This will ensure that the filter remains wet, which will help keep the microorganisms alive during the summer, although they will still likely go dormant due to the lack of food. In order to prevent a spike in effluent ammonia levels at the start of the school year when the bacteria are still dormant, it is recommended to feed the system with a cheap nutrient source, such as dog food, 1 to2 weeks before the school year begins. This early influx of nutrients will allow the bacteria to come out of dormancy in time to adequately digest the sudden increase in nutrients in the system.



During a site visit, it was discovered that every two zones were connected at the end of the laterals, turning two separate zones into one larger zone, which can create improper dosing of the zones. As seen in Figure 9.1, it is recommended to install gate valves to completely separate the zones at the end of the laterals where they are currently connected. This will ensure that zones do not discharge into other zones, especially during periods of 100% recirculation when water flowing through zone 9 could accidentally leave the system through zone 10. Originally, there was one check valve per two zones, as the two zones were connected to make one. With the addition of the gate valve, a new check valve should also be added so that each zone would be connected to the flushing system. This new check valve layout will bleed off enough of the solids in the system to allow the laterals to continue functioning until the system is fully flushed each month.

From the recommended design, a portion of the improvements are intended to be updated through operation and maintenance. First, installing above-ground access to the septic tanks is recommended so that the operator can monitor the solids level. The operator needs to monitor the solids level in the septic tanks so that the solids can be pumped out once they reach a certain solids buildup amount. If the septic tanks are not properly maintained, then a large volume of solids could be pumped up to the sand filter and cause unwanted clogging. It is also recommended for the operators to ensure that the laterals stay aligned and buried with proper cover, in order to keep water in the media and increase efficiency. Additionally, it is recommended for the laterals to be backwashed to remove all materials clogging the system. During a site visit, all of the orifices in two of the zones were uncovered and water was manually forced through the zones. The orifices were examined at this time, and it was discovered that water was only flowing along approximately half the length of the laterals. Further investigations revealed that the laterals in every zone were completely clogged for the majority of the second half of their lengths. Backwashing the laterals will return the filter to full capacity and ensure the entire filter remains wet. To prevent future clogging, it is recommended that the system be flushed on a monthly basis. The operators will flush the system by opening the flushing valve and manually operating the pumps so that each zone is cleaned for approximately 5 minutes every month. Vegetation has also been discovered to grow on the top of the sand filter. The sand filter should be cleared of vegetation, as the roots of the vegetation could potentially clog the system as well. When 100% recirculation begins, the operator will need to block the entrance to zones 10-12 from the hydrotek valve. Once this period ends, when school begins in the fall, the operators will need to unblock the entrance to the zones for normal operation.

Table 9.2 shows a materials cost estimation based on the proposed design. Initially, RS Means was used to assemble the cost analysis, but was later abandoned since several of the design elements were not listed in the necessary sizes. Instead, only material costs were analyzed and unit prices were obtained based on online market prices.

Table 9.2: Cost Analysis				
Item	Quantity	Unit	Cost/Unit	Cost
1-1/2" Check Valves	6	Ea.	11.58	69.48
1-1/2" Gate Valves	6	Ea.	11.06	66.36
2" PVC Pipe	3	20 LF	16.33	48.99
1-1/2" PVC Pipe	1	20 LF	11.06	11.06
2" PVC 90° Elbow	12	Ea.	2.44	29.28
1-1/2" PVC 90° Elbow	2	Ea.	1.43	2.86
2" PVC Tee	9	Ea.	3.67	33.03
1-1/2" PVC Tee	10	Ea.	2.18	21.8
2" PVC Cap	1	Ea.	0.70	0.70
			Total Cost:	**283.56**
			Price (w/ Tax):	**311.21**

10 Conclusion

Implementing the proposed modifications should ensure that Rush Strong Elementary School has a properly functioning RSF that will allow the school to dispose of its wastewater in a safe manner and meet the permit requirements. The recommended solutions included two categories: design improvements and operation and maintenance. The recommended design modifications to the system are: diversion of the existing recirculation line from the septic tanks to the access risers, increasing the recirculation ratio, complete separation of zones by using gate valves, continuous bleed-off of solids using check valves, and 100% recirculation during the summer period. From the recommended design, a portion of the improvements are intended to be updated and kept through operation and maintenance. The recommended operation and maintenance criteria include: cleaning of the laterals, monthly flushing of the laterals, monitoring of the solids in the septic tank, ensure the laterals are aligned and buried with proper cover, remove growing vegetation from the sand bed, and block the entrance to the discharging zones during low-flow in the summer. Based on the recommendations and calculations presented in this report, the system will recirculate properly, which will reduce the amount of money the school system spends on treatment chemicals each year. However, it is recommended that more testing be conducted in order to confirm that the results are in compliance with TDEC standards. With the proposed system improvements, it is believed that

Rush Strong Elementary School's effluent will align with the permitted standards and continue to operate for many years in a sustainably cost-effective and environmentally friendly manner.

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APPENDIX E

The primary biochemical treatment process utilized by RSFs is nitrification. Nitrification occurs when ammonia is converted to nitrite and then to nitrate via oxidation. In the nitrification process, a type of aerobic autotrophic bacteria called *nitrosomonas* oxidizes ammonia while the resulting nitrite is digested by *nitrobacter.* The oxidation occurs in two steps. First, ammonia is converted to nitrite by the following process:

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$$

Next, the nitrite is converted to nitrate per the following equation:

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

These combine to create the overall oxidation equation:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

Thus, converting 1 g of ammonia to nitrate uses 4.57 g of oxygen. The amount of alkalinity required can be found using

$$NH_4^+HCO_3^- + 2O_2 \rightarrow NO_3^- + CO_2 + 3H_2O$$

This equation yields that 7.14 g of alkalinity as $CaCO_3$ are needed to oxidize 1 g of ammonia as nitrogen. Therefore, increasing the pH of the influent is important for maximizing the system's capabilities.

Average Influent Ammonia Concentrations with Recirculation		
	Winter	Summer
Influent from Septic NH_3 (mg/L)*	101.567	101.567
Current Recirculated Influent NH_3 (mg/L)	60.6	55.4
Mixed Influent NH_3 (mg/L)*	25.34	24.62
Remaining conc. at 80 % Removal	5.07	4.92
Remaining conc. at 90 % Removal	2.53	2.46
Second Cycle Recirculated Influent NH_3 (mg/L)	5.07	4.92
Mixed Influent NH_3 (mg/L)**	17.63	17.61
Remaining conc. at 80 % Removal	3.53	3.52
Remaining conc. at 90 % Removal	1.76	1.76
TDEC limit Recirculated Influent NH_3 (mg/L)	10	4
Mixed Influent NH_3 (mg/L)*	18.32	17.48
Remaining conc. at 80 % Removal	3.66	3.50
Remaining conc. at 90 % Removal	1.83	1.75
*		
**Mixed influent is equal to a weighted average of septic influent (s) and recirculated influent (r) , = (s+(5/6)r)/6		

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