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Green Residential Stormwater Management Demonstration: An Integrated Stormwater Management and Graywater System to Reduce the Quantity and Improve the Quality of Residential Water Discharges, Post CO Data Analysis

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POST CERTIFICATE OF OCCUPANCY ANALYSIS

Green Residential Stormwater Management Demonstration: An Integrated Stormwater Management and Graywater System to Reduce the Quantity and Improve the Quality of Residential Water Discharges

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By

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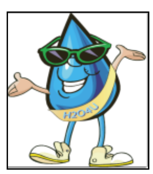

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EXECUTIVE SUMMARY

This is the third of three reports on integrated stormwater, graywater and wastewater treatment for the residential environment. The data and evaluations in this report address the operation of a water cistern for harvesting stormwater and graywater; and the on-site sewage treatment and disposal from a residential home after it received the certificate of occupancy (CO). The home has been continuously occupied by residents since September 4, 2010 and the data collected are over a one year period of time. The first report in this series concentrates on the stormwater, graywater, and wastewater operating data during construction or pre-CO (Wanielista, et al., July 2011). The second report presents the methods and results of education outreach activities (McDaniel and Wanielista, August 2011).

The scarcity and increasing cost of water have prompted investigations to identify alternative water sources and treatment methods. Within this report, information is presented for the use of innovative water harvesting and an on-site sewage treatment and disposal system (OSTDS) at Florida's Showcase Green Envirohome (FSGE.net), while also addressing low impact development (LID) practices. There are two OSTDS at FSGE, namely a conventional septic tank and drainfield and the other a sorption media filter between the septic tank and the drainfield. By OSTDS regulations, FSGE is not required to provide any additional treatment of their sewage, thus the sorption media filter is a bonus in terms of additional treatment. FSGE is a residential home that demonstrates methods that use less water and reduce pollution, among other environmental, energy savings, and wind protection methods.

Population increases have more than just an effect on the volume of water demanded. Adverse impacts on surface and groundwater quality are partially attributed to current design and operation of OSTDS and uncontrolled stormwater discharges. Nutrient mass loadings from stormwater and wastewater treatment systems may be a concern in environments that are impaired by nutrients. Groundwater nitrate concentrations have been shown to exceed drinking water standards by a factor of at least two in soils surrounding conventional OSTDS (Postma et al, 1992, Katz, 2010, Chang et al, 2011). As a contribution to efforts that reduce potable water use and improve water quality, investigated in this study is the effectiveness of a residential integrated stormwater, graywater, and wastewater treatment system installed and operating for over a year at FSGE.

There are two scientific reasons for the report. The first is to quantify the performance of the passive treatment Bold & Gold™ bio-sorption activated media (BAM) filter (Florida Department of Health, FDOH classified “innovative system”) for nutrient removal. Thus, this report presents performance data for the OSTDS at FSGE in Indialantic, Florida during post-CO. These post-CO data are compared to previously published data for pre-CO conditions (Rivera, 2010, Wanielista et al, 2011). This report contains 12 months of post-CO data, along with data from bench scale models of the OSTDS.

The second reason is to evaluate water quality data for non-potable uses of the graywater/stormwater cistern at FSGE. The cistern is also used to prevent stormwater runoff from leaving the property as it collects runoff from the impervious roof surfaces as well as gray water. It was shown in the first report during pre CO conditions that there was no surface

discharge from a 25.5 inch tropical storm over about two days using the cistern with bio-swale and pervious pavements.

The performance of the passive innovative FSGE OSTDS system is compared to past studies using statistical measures. Also bench scale models using Bold & Gold BAM for wastewater nutrient removal are constructed at the University of Central Florida (UCF) Stormwater Management Academy Research and Testing Lab (SMART Lab). The bench scale models are operated to provide data for different residence times. From the OSTDS full scale operation and the bench scale model BAM filter, hydraulic residence times are recommended to achieve total nitrogen less than 10 mg/L. For a typical influent total nitrogen concentration of 50 mg/L, a residence time in the BAM filter of 7.5 days is recommended, and if graywater is used as the source of water for wastewater transport and is similar to the bench scale testing with FSGE wastewater (Total Nitrogen = 105 mg/L), an 11 day residence time in the BAM filter is recommended. A comparison of the pre and post-CO data demonstrates that with longer residence time (similar to that achieved in the pre-CO operation), the removal of nitrogen is greater. For comparison purposes, the typical residence time in a septic tank is in the order of 2 days.

The operating results of the OSTDS are compared to State of Florida minimum treatment standards referenced as “Secondary Treatment Standards” and “Advanced Secondary Treatment Standards. The operating water quality data shows promising results for the sorption media OSTDS and for the use of graywater as the source of wastewater transport. The bench scale data verify that both nitrogen and phosphorus removal occur within the sorption media OSTDS.

The post-CO sampling documents that flow into FSGE OSTDS is reduced with the use of a graywater system to 29 gallons per person per day (gpcd), which is the approximate number reported in the literature for homes using graywater. After the FSGE certificate of occupancy and for one year using Bold & Gold (B&G) BAM, the average drainfield TSS, BOD_5, and $CBOD_5$ are below 10 mg/L which meets those parameters to be classified as a FDOH *Advanced Secondary Treatment System*. For the FSGE conventional OSTDS, measurements of TSS, BOD_5, and $CBOD_5$ from the drainfield are above 10 mg/L (29.6, 35.7, and 29.0 mg/L respectively). The yearly average standard for secondary treatment for $CBOD_5$ and TSS is 20 mg/L. The average drainfield total nitrogen and total phosphorus following the Bold & Gold BAM filter are 29.7 mg/L and 4.1 mg/L respectively. The FDOH *Advanced Secondary Treatment* standard for nitrogen is 20 mg/L and 10 mg/L for phosphorus. The conventional treatment drainfield has an average effluent total nitrogen concentration of 70.1 mg/L and an effluent total phosphorus concentration of 10.6 mg/L, which both fail to meet FDOH *Advanced Secondary Treatment* requirements. The high nitrogen in the effluent of both FSGE treatment systems can be attributed to high influent concentrations (about 2.5 times the normal or an average of 128.5 mg/L). However, longer residence times in the BAM filter are shown to produce a nitrogen removal greater than 90% using BAM in the bench scale units. Also, average nitrate concentrations measured in the effluent of the B&G BAM drainfield and in the effluent of the conventional drainfield were below the 10 mg/L standard.

Based on discharge pollution mass, graywater plumbing as used at FSGE produces less mass discharged than an OSTDS that is designed to meet advanced secondary standards without

graywater use. The average flow without graywater is assumed at 69.3 gpcd compared to 29 gpcd with graywater. Also, the sorption filter without a drainfield and with graywater also discharges less mass than an advanced secondary OSTDS without graywater. A mass loading such as a total mass daily load in addition to a concentration standard should be considered in many locations. Graywater as a source water should be encouraged.

The water quality of the combined stormwater/graywater cistern is compared to irrigation standards. The graywater is filtered and disinfected with ozone to provide water for reuse within FSGE. Nutrient concentrations are measured to compare with irrigation standards, and salinity in the form of sodium, calcium, and magnesium are measured. Although some slightly higher than recommended sodium adsorption ratio (SAR) values and electrical conductivity (EC) values were recorded, any adverse impact from the micro-drip irrigation on the vegetation has not been observed. Make-up water for the cistern comes from an artesian well and as such the well water has high levels of salinity. The only observed effect within the home to date is scale formation in the toilet bowl.

The use of potable water in FSGE is reduced to 41 gpcd using the integrated stormwater and graywater system. Less than 200 gallons of artesian well water was added to the cistern during the year of post-CO sampling. Based on less use of potable water and current potable water cost rates, the integrated stormwater and graywater system at FSGE will save the homeowner about $215 per year. For landscapes requiring more irrigation from the cistern, the cost savings in reduced potable water used for irrigation would increase the savings in using graywater and stormwater.

The treatment cost for B&G BAM over a 40 year period of time based on a flow of 29 gpcd (as measured at FSGE) and for 4 persons is $2.07 per thousand gallons treated. The yearly cost of treatment is about $87.65. There is a reduction in potable water use estimated at 64% of the sewage flow (or 0.64x29=18.5 gpcd) which equates to about 27 thousand gallons in one year (0.64x29x4x365). Using a current average cost of potable water of $4.40 per thousand gallons, and based on reduced potable water usage, the savings per year are about $118.84 (18.5x4x365x 4.40/1000). Thus the yearly savings in potable water cost ($118.84) offsets the cost of OSTDS treatment at FSGE for nutrient control ($87.65) using the data collected at FSGE. This comparison does not include the inflation cost of potable water over time. There is also an environmental preservation intangible cost (not quantifiable from this study) from reduced surface runoff and reduced pollutant discharges. There was no visible surface water discharge recorded from the home site during 25.5 inches of rain from tropical storm Fay. That reduced discharge alone would account for a cost savings.

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CHAPTER 1 INTRODUCTION

The demand for potable water in Florida is steadily rising while the available sources for economically available potable water are diminishing. As a result, there is an increased recognition of the need to utilize nontraditional sources, such as stormwater harvesting, for non-potable applications and thus reducing demand on traditional potable resources. However, water recycling is not yet widely practiced in many locations. This is largely due to the lack of public education and the paucity of technologies for reliable and affordable onsite treatment options, including the use of stormwater runoff.

When analyzing domestic wastewater, it can be categorized into either “graywater”, or “blackwater”. According to Section 381.0065 of Florida Statutes, blackwater consists of the domestic sewage transported from toilets, urinals, and kitchen drains. Graywater is the part of domestic sewage that is not blackwater, which includes waste from the bath, lavatory, laundry, and sink, except kitchen sink waste. Domestic graywater is another alternative non-potable water source. Shower, sink, and laundry water components contribute 50-80% of residential wastewater (Metcalf & Eddy, 2003). Promoting the preservation of high-quality fresh water as well as environmental considerations such as reducing pollutants in the environment and reducing overall supply costs are important needs for public welfare and health. Graywater reuse shows potential for significantly reducing residential potable water demand by eliminating demand for toilet flushing and summer irrigation. This will leave more capacity in water treatment plants for additional development and less demand on traditional supply sources.

Recent developments in technology and public awareness and acceptance towards the applications of water harvesting suggest that there is potential for graywater use to become a viable option to the world's water crisis. Graywater reuse represents the largest potential source of water savings in domestic residence. For example, the use of domestic graywater for landscape irrigation can make a significant contribution towards the reduction in the use of potable water. In the U.S., for example, an average household can generate upwards of 60,000 gallons of graywater per year.

Stormwater runoff not only creates issues with the volume generated, but also with pollution transport that can result in water quality issues as well. Once rainfall impacts an impervious surface, it picks up and transports sediment and pollutants as it travels to nearby collection systems or water bodies. On-site stormwater management is an option to reduce runoff volume and mass of pollutants, including nutrients. When stormwater can be collected and used on-site, the amount of contaminated materials added by off-site ground and other pollutant sources are eliminated, and thus on-site stormwater is a better source for non-potable use. Along with stormwater, graywater can safely be stored and used for non-potable applications with proper handling and minimal treatment required.

Blackwater is often not practical to treat to re-useable levels from an economic perspective, since it consists of the domestic sewage carried from toilets and urinals, as well as organics from kitchen drains. To safely discharge blackwater, it must be treated to the level of regulatory requirements. With traditional septic systems, a drainfield that can consume a relatively large amount of property space is required. Residential blackwater contains a high

level of organics, nutrients, and pathogens, and must be treated with an on-site sewage treatment and disposal system (OSTDS) to meet effluent standards. For high nutrient removal needed for some areas, alternative "sorption" treatment systems or other types are available. Once the wastewater is treated with the OSTDS, it can be discharged. The introduction of these systems will greatly benefit and reduce the nutrient impact of future residential design and development.

The integrated use of graywater with stormwater and sorption based OSTDS used at FSGE result in significantly decreased pollutant discharges and reduced potable water usage. In addition, the options considered and demonstrated require no additional land for treatment and as such, the term Low Impact Development (LID) is used.

In Table 1 is shown the indoor water use per capita in the United States. It is reported that the average household water use in the United States annually is 127,400 gallons. Also, the

Table 1 Indoor Water Use Statistics

Water Use	Gallons per Capita	Percentage of Total Daily Use	Reuse?
Showers	11.6	16.8%	***Yes***
Clothes Washers	15	21.7%	***Yes***
Dishwashers	1	1.4%	*No*
Toilets	18.5	26.7%	*No*
Baths	1.2	1.7%	***Yes***
Leaks	9.5	13.7%	-
Faucets	10.9	15.7%	*Maybe*
Other Domestic Uses	1.6	2.2%	*Maybe*
Total (gpcd)	**69.3**	100%	**40.3**

* *www.drinktap.org/consumerdnn/Home/WaterInformation/Conservation/WaterUseStatistics/tabid/85/Default.aspx*

average daily household water use is 350 gallons. To break it down even further, the average daily indoor per capita use is 69.3 gallons, and indoor water usage with a graywater reuse system is down to 29.0 gallons per capita per day.

1.1 Florida's Showcase Green Envirohome

Florida's Showcase Green Envirohome (FSGE) is a residential site built with stormwater, graywater and wastewater treatment without additional land being used. The site is located in Indialantic, Florida (Figure 1). FSGE began construction in June 2007 and incorporates many green technologies, and is built to meet or exceed 12 green building guidelines. The official website for FSGE can be found at www.FSGE.net or see the stormwater academy site, http://stormwater.ucf.edu/sealofapproval.asp

According to the department of health (DOH), approximately 90,000 of Florida's 2.68 million septic tanks are located in Brevard County, the site of FSGE, and over 20,000 of the septic tanks were installed prior to 1970. An OSTDS has been installed (July 17,2009) at the site and is currently (September 2010 to present) used by the home occupants. The OSTDS consists of a conventional OSTDS and an innovative septic tank, sorption media filter, and drainfield. This treatment system is designed to produce high nutrient and pathogen removals, as well as to meet other regulatory requirements. The sorption media in the OSTDS is a tested and proven Bold and Gold ™ (B&G) filtration bio-sorption activated media (BAM). The B&G™ BAM is a mixture of tire crumb and expanded clay along with a top layer of sand and limestone. The limestone is used to add alkalinity to the water. This media has been previously analyzed in an

experimental set up on the campus of UCF for nutrient removal. The report with others on stormwater and wastewater treatment can be found at: http://www.stormwater.ucf.edu/research/UCF_OSTDSFinalReport04192011.pdf

An emphasis at FSGE is to limit the environmental footprint generated by typical residential activities in a practical and economical fashion. Therefore, the objective of the innovative OSTDS is to achieve the highest nutrient removal possible before the wastewater effluent is discharged into the ground. The innovative OSTDS capital cost is estimated to be 34% greater than the conventional system but the operations and maintenance (O&M) requirements are similar to conventional systems. At the FSGE OSTDS, sampling ports throughout the innovative OSTDS have been installed to monitor the changes in wastewater quality. Also, the effluent wastewater quality is compared to that of the conventional system that is installed parallel to the OSTDS.

At FSGE, stormwater runoff is harvested from green roofs, metal roof and wood decking areas and routed to a water cistern. Graywater from the home, after being disinfected using ozone, is also routed to the same water cistern. Ozonation destroys or inactivates Cryptosporidium, Giardia, bacteria and other organisms. It is also known that disinfection with ozone cannot create the formation of trihalomethanes (THMs), which result from the interaction of chlorine and naturally-occurring organic material in the source water. The combined water supplies are stored in the cistern and used for green roof irrigation, ground level landscape, laundry, and toilet flushing water. Water from an artesian well is added into the cistern through a float valve that opens when water levels fall below a desired amount.

1.2 Objectives

The objectives of this study are to:

(1) Measure the change in water quality parameters throughout the innovative OSTDS, focusing on nitrogen, phosphorus, and bacteria removal.

(2) Quantify the performance of the Bold & Gold^{TM} filter bed media for nutrient removal, and compare with performance of the adjacent conventional OSTDS.

(3) Monitor water quality of a combined graywater/stormwater cistern, focusing on Sodium Adsorption Ratio (SAR) to determine if water is acceptable for irrigation and other home uses.

(4) Monitor water demand in FSGE and calculate cost savings from stormwater harvesting and graywater reuse.

(5) Establish economic and environmental measures of implementing an integrated stormwater, graywater, and wastewater treatment system for residential developments.

1.3 Limitations

The research is conducted in Indialantic on the East coast of Florida. The project is based in a humid, subtropical climate near the Atlantic Ocean. The results of the study are limited to the specific process, materials, and location that are described in this report. Furthermore, the authors are not responsible for the actual effectiveness of these control options or drainage problems that might occur due to their improper use.

Figure 1 Florida's Showcase Green Envirohome Location Map

CHAPTER 2 BACKGROUND

To perform a thorough and accurate analysis of the performance of any system, a detailed understanding of the typical water quality parameters, treatment objectives, and regulatory requirements is valuable. Since the integrated design incorporates three sources of water, it requires an understanding of each of their characteristics and treatment requirements.

2.1 FSGE On-Site Treatment and Disposal System (OSTDS)

An understanding of the physiochemical and biological treatment of the wastewater is helpful for OSTDS. Table 2 provides a list of wastewater constituents and parameters of interest (Metcalf & Eddy, 2003).

2.1.1 Principle Constituents Found in Wastewater and Their Impacts

Total Suspended Solids

Total Suspended solids (TSS) can lead to the development of sludge deposits and anaerobic conditions when water is discharged into aquatic environments. TSS also causes turbidity issues in water bodies and wetlands. High turbidity means low clarity, which blocks out sunlight from the water and inhibits photosynthetic activity and will eventually destabilize the ecosystem.

Table 2 Common Constituents Measured in Wastewater (Metcalf & Eddy, 2003)

Physical Characteristics

Parameter	Abbreviation	Use or Significance of Test Results
Total Suspended Solids	TSS	High levels signal poor treatment
Turbidity	NTU	Assess clarity of treated water
Temperature	^{o}C	Effects biological process during treatment
Conductivity	EC	Assess suitability of treated effluent for agricultural applications

Inorganic Chemical Characteristics

Parameter	Abbreviation	Use or Significance of Test Results
Free Ammonia	NH_4^+	Used as a measure of the nutrients present and the degree of decomposition in wastewater. The oxidized forms can be taken as a measure of the degree of oxidation
Organic Nitrogen	Org N	
Total Kjeldahl Nitrogen	TKN (Org N + NH_4^+-N)	
Nitrites	NO_2^-	
Nitrates	NO_3^-	
Total Nitrogen	TN	
Inorganic Phosphorus	Inorg P	
Organic Phosphorus	Org P	
Total Phosphorus	TP	
pH	-log[H+]	Measure of acid or basic state of wastewater
Alkalinity	$\Sigma\ HCO_3^- + CO_3^{-2}$	Measure of the buffering capacity of the wastewater

Organic Chemical Characteristics

Parameter	Abbreviation	Use or Significance of Test Results
Five-day carbonaceous biochemical oxygen demand	$CBOD_5$	Measure of the amount of oxygen required to stabilize a waste biologically

Biological Characteristics

Parameter	Abbreviation	Use or Significance of Test Results
Coliform Organisms	MPN (Most Probable Number)	Assess the presence of pathogenic bacteria

Biodegradable Organics

Biodegradable organics are composed principally of proteins, carbohydrates, and fats. This group is measured most commonly in terms of BOD (biochemical oxygen demand) and COD (chemical oxygen demand). If discharged untreated to the environment, their biological stabilization can lead to the depletion of natural oxygen resources and to the development of septic conditions.

Pathogens

Communicable diseases can be transmitted by the pathogenic organisms that may be present in wastewater. Pathogenic organisms found in wastewater may be excreted by humans and animals who are infected with disease or who are carriers of an infectious disease. Pathogens found in wastewater can be classified into four broad categories: bacteria, protozoa, helminthes, and viruses. Pathogens, as measured by bacteria, are a priority constituent of concern in the FSGE project.

Bacteria

Domestic wastewater contains a wide variety and concentration range of nonpathogenic and pathogenic bacteria. The most common bacterial pathogen in wastewater is *Salmonella*. This genus contains a wide variety of species that can cause disease in humans and animals. Typhoid fever is the most severe and serious, which is caused by *Salmonella typhi*. Another less common bacterium, *Shigella*, is responsible for the intestinal disease referred to as bacillary dysentery or shigellosis. *Vibrio cholera* is the disease agent for cholera, which is prevalent in

other parts of the world. Humans are the only known hosts, and the most frequent mode of transmission is water. *Mycobacterium tuberculosis* has been found in municipal wastewater, and outbreaks have been reported among persons swimming in water contaminated with wastewater. The measurement of each is outside the scope of this work.

Waterborne gastroenteritis is suspected to be caused by a bacterial agent. A potential source is certain gram-negative bacteria normally considered nonpathogenic. These include *Escherichia coli* and certain strains of *Pseudomonas*, which have been implicated in gastrointestinal disease outbreaks.

Protozoa

The protozoans *Cryptosporidium parvum*, *Cyclospora*, and *Giardia lamblia* are of concern because of their significant impact on individuals with compromised immune systems. Infection is caused by ingestion. *Cryptosporidium* and *Giardia* are the most resistant forms. These organisms in particular are found in almost all wastewaters and conventional disinfection techniques with chlorine having been shown to be ineffective for inactivation. Recent studies show disinfection with Ozone to be effective for inactivation (Metcalf & Eddy, 2003). Ozone is used at FSGE.

Viruses

There are more than 100 different types of enteric viruses excreted by humans that are capable of producing infection or disease. Enteric viruses multiply in the intestinal tract and are released in the fecal matter of infected persons.

Bacterial Indicator

During this study, there was a difference of opinion uncovered in the technical literature on the use of the detection methods for total and fecal coliforms. Metcalf and Eddy (2003) concluded that coliform bacteria are adequate indicators for the potential presence of pathogenic bacteria and viruses, but are inadequate as an indicator of the presence of waterborne protozoa. It was decided to do both Most Probable Number (MPN) as well as the Colilert methods. The Colilert-18 method used in this study is the staining and fluorescent method for total coliforms (TC), *E. coli,* and fecal coliform (FC). In subtropical freshwaters, both MPN and the Colilert methods were used by Choa, et al, (2004) to identify the origin of coliforms and supports the use of both in this study. However, the Colilert method produced more reasonable results.

Total Coliform Bacteria

Total coliforms (TC) are a species of gram-negative rods that may ferment lactose with gas production at 35±0.5 ^{o}C for 24 h. Gram-negative refers to a staining procedure used to differentiate groups of organisms (which is used in Colilert-18 to verify the presence of TC in wastewater). However, there are no longer water quality standards in the State for this measure.

Fecal Coliform Bacteria

The fecal coliform (FC) bacteria group was established based on the ability to produce gas (or colonies) at an elevated incubation temperature (44.5±0.2 ^{o}C for 24 h).

Escherichia coli

E. coli is one form of coliform bacteria population and is more representative of fecal sources than coliform genera.

Nutrients

Both nitrogen and phosphorus are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater. Nutrients are the other priority constituent in the OSTDS study and the focal point for current and future regulations for the area where FSGE is located, and includes numeric nutrient criteria (NNC).

Nitrogen

Since nitrogen is a vital building block in the synthesis of protein, nitrogen data will be required to evaluate the treatability of wastewater by biological process. In wastewater, the principal source of nitrogen is from human waste products of protein metabolism, mostly in the form of organic nitrogen and urea. The average person excretes about 86 mg/L per person per day of nitrogen. In onsite systems, the organic nitrogen is transformed into other forms of nitrogen. Nitrogen has two environmental concerns. First, nitrogen is the limiting nutrient in many water bodies for the growth of aquatic plants. Second, some forms of nitrogen are identified as a public health hazard. The health hazards include methemoglobinemia in infants from nitrate converting to nitrite and entering the bloodstream. The other health hazard is cancer in the elderly from nitrate reacting with amines to form nitrosamines, many of which are suspected carcinogens.

Ammonia nitrogen exists in an aqueous solution as either the ammonium ion (NH_4^+) or ammonia gas (NH_3), depending on the pH of the solution. Any pH below 9.25 results in ammonium being the dominant species (Figure 2). Ammonia is an important compound in freshwater ecosystems. It can stimulate phytoplankton growth, exhibit toxicity to aquatic biota, and exert an oxygen demand in surface waters (Beutel, 2006).

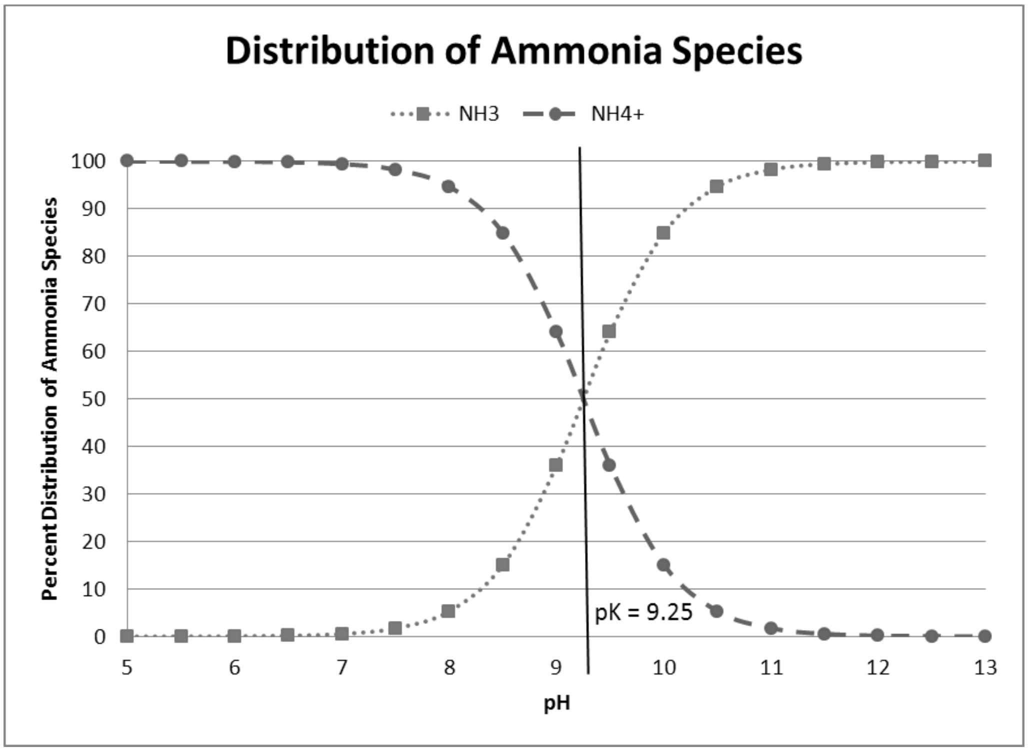

Figure 2 Distribution of Ammonia Species between Ammonium and Ammonia Gas

Nitrite (NO_2^-) is relatively unstable and is easily oxidized to the nitrate form. It is an indicator of polluted water that is in the process of stabilization. Nitrite seldom exceeds 1 mg/L in wastewater. Nitrite is very important in water pollution studies because it is extremely toxic

in aquatic ecosystems. Additionally, nitrite can react with amines chemically or enzymatically to form nitrosamines that are very strong carcinogens (Sawyer et al., 2003).

Nitrate (NO_3^-) is the most oxidized form of nitrogen found in wastewaters. The concentration of nitrate is important when wastewater effluent is utilized for groundwater recharge. Low technology wastewater treated effluents range from 15 to 20 mg/L as N, whereas newer plants can often achieve nitrate effluents below 1 mg/L. Since the nitrate is not easily bound to the soil, OSTDS can represent a large fraction of nutrient loads to ground water aquifers and surface waters. Nitrate can cause human health problems such as liver damage and even cancers (Gabel et al, 1982; Huang et al., 1998). Nitrate can also bind with hemoglobin and create a situation of oxygen deficiency in an infant's body called methemoglobinemia, or Blue-baby syndrome (Kim-Shapiro et al., 2005).

The nitrogen present in influent wastewater is primarily combined in proteinaceous matter and urea. Decomposition bacteria readily change the organic form to ammonia. The age of the wastewater can be determined by the relative amount of ammonia present. In aerobic environments, bacteria oxidize the ammonia nitrogen into nitrites and nitrates. The predominance of nitrate in wastewater indicates the waste is stabilized with respect to oxygen demand.

Phosphorus

Much interest has been focused on controlling the amount of phosphorus compounds that enter surface waters from waste discharges and natural runoff. This is highly attributed to the fact that phosphorus is the limiting nutrient for algal growth in freshwater lakes and rivers. Typical municipal wastewater influent may contain 4 to 16 mg/L of phosphorus as P.

The forms of phosphorus found in aqueous solution include orthophosphate, polyphosphate, and organic phosphate. The orthophosphates are available for biological metabolism without further breakdown. Polyphosphates undergo hydrolysis and revert back to orthophosphates, but quite slowly. The organically bound phosphorous usually ends up in the wastewater sludge.

2.1.2 Septic System Components and Essentials

As explained by Chang, 2010, a conventional septic tank system consists of three (3) main components. The first component is indoor plumbing, which is a system of drains and pipes that is used to transport the wastewater away from the facility and discharges it outside into a septic tank. The conventional septic tank is the second component. A septic tank is a watertight container made of concrete, fiberglass, or other durable material that is typically buried underground operating as both a primary wastewater treatment (settling of solids) and an anaerobic digester that breaks down complex organic compounds.

The third component is the standard drainfield that is constructed by a series of parallel, underground, perforated pipes that allow septic tank effluent to percolate into the surrounding soil in the vadose (unsaturated) zone where it is assumed that most of the residual nutrients may

be assimilated biologically. Several types of effluent distribution are applicable in standard drainfield systems. These include gravity systems, low pressure dosed systems, drip irrigation systems, etc. and some of them require having an additional pump. Through various physical, chemical, and biological processes, most bacteria, viruses and nutrients in wastewater are expected to be consumed or filtered as the wastewater passes through the soil.

After treatment, the effluent enters the vadose zone and ultimately a ground water aquifer acts as a receiving water body. When properly constructed and maintained, the conventional septic system can provide years of safe, reliable, cost-effective service (Etnier et al., 2000). However there is very little nitrogen removal that can be expected in the conventional system which can contribute to higher nitrate concentrations in groundwater, springs and estuaries.

2.1.3 Passive On-Site Wastewater Treatment Alternative

Passive on-site wastewater treatment is defined by the Florida Department of Health (2008) as "a type of OSTDS that excludes the use of aerator pumps, includes no more than one effluent dosing pump with mechanical and moving parts, and uses a reactive media to assist in nitrogen removal". Reactive media are materials that effluent from a septic tank or pretreatment device passes through prior to reaching the ground water. This may include but is not limited to soil, sawdust, zeolites, tire crumb, vegetation, sulfur, spodosols, or other media. Hence, innovative, passive, and performance-based (as opposed to conventional) on-site wastewater treatment technologies to effectively remove nutrients and better protect public health and our ground and surface waters in a cost-effective manner can be passive by FDOH definition. This project implements a newly designed bio-sorption activated media (BAM) called (Bold &

Gold™) to perform passive on-site water treatment for FSGE utilizing both aerobic and anaerobic treatment that promotes the formation of nitrogen as a gas. The goal of this project is to demonstrate the feasibility and effectiveness of the installation of a sorption media into a residential OSTDS. The FSGE OSTDS filter media configuration is shown in Figure 3. The reactive volume is based on a porosity of 0.30 and is 202.5 gallons.

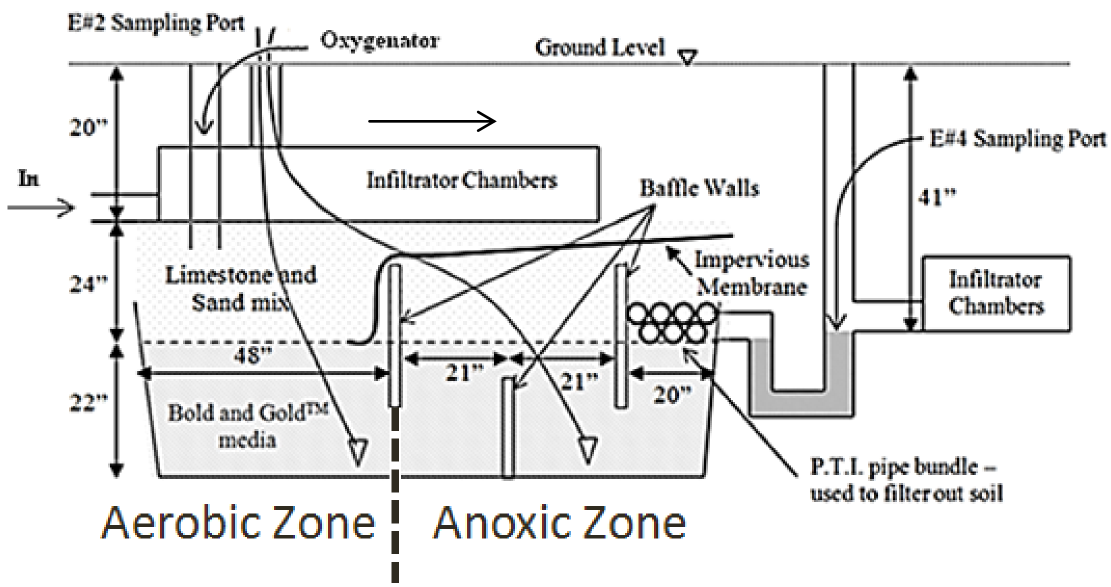

Figure 3 Bold and Gold™ Filter Media Bed Schematic (Rivera, 2010)

2.1.4 Current Regulation of Water Quality and OSTDS Standards

For $CBOD_5$ and TSS, the secondary treatment standards based on arithmetic mean values are each 20 mg/L or 90% removal of the influent, whichever is more stringent (from FAC 62-600.420). There are no secondary standards for Nitrogen and Phosphorus.

DOH Standards for Onsite Sewage Treatment and Disposal Systems (from FAC 64E-6.025)

(1) *Advanced Secondary Treatment* Standards shall meet following requirements

(a) The $CBOD_5$ and TSS values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 10 mg/L
- Quarterly arithmetic mean: 12.5 mg/L
- Seven day arithmetic mean (4 sample min.): 15 mg/L
- Maximum concentration: 20 mg/L

(b) The TN values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 20 mg/L
- Quarterly arithmetic mean: 25 mg/L
- Seven day arithmetic mean (4 sample min.): 30 mg/L
- Maximum concentration: 40 mg/L

(c) The TP values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 10 mg/L
- Quarterly arithmetic mean: 12.5 mg/L
- Seven day arithmetic mean (4 sample min.): 15 mg/L
- Maximum concentration: 20 mg/L

(d) The fecal coliform colonies collected in the effluent shall not exceed

- Annual arithmetic mean: 200 per 100 ml
- Monthly median value (10 sample min.): 200 per 100 ml
- 10% of monthly samples shall not exceed: 400 per 100 ml

- Maximum colony count: 800 per 100 ml

(2) *Advanced Wastewater Treatment* Standards shall meet following requirements

(a) The $CBOD_5$ or TSS values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 5 mg/L
- Quarterly arithmetic mean: 6.25 mg/L
- Seven day arithmetic mean (4 sample min.): 7.5 mg/L
- Maximum concentration: 10 mg/L

(b) The TN values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 3 mg/L
- Quarterly arithmetic mean: 3.75 mg/L
- Seven day arithmetic mean (4 sample min.): 4.5 mg/L
- Maximum concentration: 6 mg/L

(c) The TP values for the effluent samples collected shall not exceed:

- Annual arithmetic mean: 1 mg/L
- Quarterly arithmetic mean: 1.25 mg/L
- Seven day arithmetic mean (4 sample min.): 1.5 mg/L
- Maximum concentration: 2.0 mg/L

(d) The fecal coliform colonies collected in the effluent shall not exceed

- 75% of 30 day samples: Below Detection Limit (BDL)
- Maximum colony count: 25 per 100 ml

(3) *Baseline system standards*

(a) Effluent concentrations from the treatment tank:

1. $CBOD_5$ – <240 mg/L.
2. TSS – <176 mg/L.
3. TN – <45 mg/L.
4. TP – <10 mg/L.

(b) Percolate concentrations from the baseline system prior to discharge to groundwater:

1. $CBOD_5$ – <5 mg/L.
2. TSS – <5 mg/L.
3. TN – <25 mg/L.
4. TP – <5 mg/L.

Regulatory Criteria and Standards

The Florida Department of Environmental Protection (FDEP) is charged with implementing the requirements of the Federal Clean Water Act and the Florida Water Pollution Control Act set forth in Chapter 403, Florida Statutes. FDEP has established by rule a water body classification system and the supporting surface water quality standards, which are designed to protect the beneficial uses set forth in the water body classes. With respect to nutrients, there are both narrative and recently adopted numeric nutrient criterion. These criterions are designed to maintain a healthy human environment as well a balance of flora and fauna. Numeric nutrient criteria (NNC) are being established by FDEP for a water body specific basis when Total Maximum Daily Loads (TMDLs) are adopted for water bodies impaired by nutrients. For example, the TMDL for Wekiwa Springs is a monthly average of 286 µg/L nitrate. In addition, FDEP has adopted the Safe Drinking Water Act

standards which establish nitrate and nitrite maximum contamination levels (MCL) in ground water aquifers and potable water. These should not be above 10.0 mg/L nitrate-nitrogen (NO_3-N) and 1.0 mg/L nitrite-nitrogen (NO_2-N), respectively. The Florida Department of Health (FDOH) is charged with regulating OSTDS through their authority in Chapter 381, F.S., and their implementing regulations in Chapter 10D-6, F.A.C. FDOH's mission is the protection of public health, not water quality, and they use the drinking water standard of 10 mg/L nitrate as their goal.

Tables 3 and 4 are to be used as baseline values for comparison of influent wastewater parameters from FSGE. Table 3 is a list of parameter ranges recommended by the National Sanitation Foundation (NSF) and the American National Standards Institute (ANSI). The NSF/ANSI Standard 245 has been developed for residential wastewater treatment systems designed to provide for nitrogen reduction. The evaluation involves six months of performance

Table 3 NSF 245/ANSI-40 Influent Concentration Standards

Parameter	Range	Unit
BOD_5	100 – 300	mg/L
TSS	100 – 350	mg/L
TKN	35 – 70	mg/L as N
Alkalinity	> 175	mg/L as $CaCO_3$
Temperature	10 – 30	^oC
pH	6.5 – 9	NA

Table 4 Environmental Technology Verification (ETV) Suggested Influent Requirements

Parameter	Range	Unit
$CBOD_5$	100 – 450	mg/L
TSS	100 – 500	mg/L
TKN	25 – 70	mg/L
Total P	3 – 20	mg/L
Alkalinity	> 60	mg/L as $CaCO_3$
Temperature	10 – 30	^oC

testing, incorporating stress tests to simulate wash day, working parent, power outage, and vacation conditions. The standard is set up to evaluate systems having rated capacities between 400 gallons and 1500 gallons per day. Technologies testing against Standard 245 must either be Standard 40 certified or be evaluated against Standard 40 at the same time an evaluation is being carried out for Standard 245, as both tests can be run concurrently.

Throughout the testing, samples are collected during operating periods and evaluated against the pass/fail requirements. A treatment system must meet the influent concentration values during the testing period in order to meet Standard 245.

When comparing FSGE influent to the NSF/ANSI 245 standard it must be realized that FSGE splits the wastewater in the house into graywater and blackwater. Since the graywater is not routed to the septic system, the BOD, nutrient, and TSS concentration values are primarily from human waste and are most likely higher than the NSF/ANSI 245 standard. The mass loading into the septic tank should be in the same range as a normal residential home, but the volume is reduced due to graywater utilization.

2.1.5 Anaerobic Digestion

With on-site wastewater treatment, septic tanks are utilized as passive low-rate anaerobic digesters. The pre-treatment provided by the septic tank is equally important in ensuring the success of other secondary treatment alternatives such as constructed wetlands, ponds, intermittent and recirculating sand filters, peat filters, mound systems, synthetic filters or

membrane systems, up-flow filters, pressure distribution systems, and nitrogen reduction systems (Bounds, 1997). After installation, septic tanks quickly develop their own ecosystem in which facultative and anaerobic organisms perform complex biochemical processes. Within anaerobic digestion there are four key biological and chemical stages; hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

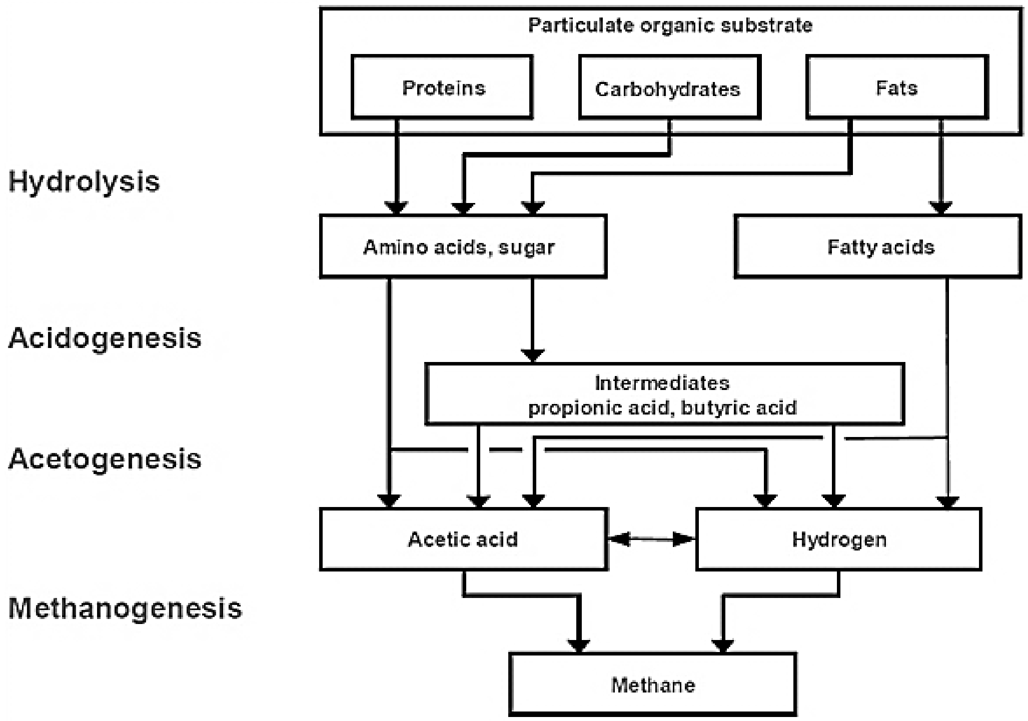

Figure 4 Four Degradation Stages of Anaerobic Digestion

Hydrolysis

The first step in anaerobic digestion is hydrolysis. Hydrolysis is the process of breaking down complex organic molecules into simple sugars, amino acids, and fatty acids (monomers).

The hydrolysis stage is necessary to make the monomers readily available for bacteria to access their energy potential (Ostrem, 2004).

Acidogenesis

The second biological process is acidogenesis. In acidogenesis, the products of hydrolysis are further broken down by fermentative bacteria. Here, volatile fatty acids (VFAs) are created along with ammonia, carbon dioxide, and hydrogen sulfide, as well as other by-products. The principal acidogenesis stage products are propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$), acetic acid (CH_3COOH), formic acid (HCOOH), lactic acid ($C_3H_6O_3$), ethanol (C_2H_5OH) and methanol (CH_3OH), among other.

Acetogenesis

In the third stage, known as acetogenesis, the rest of the acidogenesis products are transformed by acetogenic bacteria into hydrogen, carbon dioxide and acetic acid. Hydrogen plays an important intermediary role in this process, as the reaction will only occur if the hydrogen partial pressure is low enough to thermodynamically allow the conversion of all the acids. Such lowering of the partial pressure is carried out by hydrogen scavenging bacteria, thus the hydrogen concentration of a digester is an indicator of its health (Mata-Alvarez, 2003).

Methanogenesis

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here, methanogens utilize the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. It is these components that make up the majority of the

biogas emitted from the system. Methanogenesis does not typically occur in septic tank systems and therefore will not be expanded upon in this report.

2.1.6 Nutrient Removal Mechanisms

The removal of nutrients from the wastewater occurs in the filter media, which incorporates adsorption, absorption, ion exchange, and precipitation processes. This overall physicochemical process has been tested and verified through a UCF field study. Since it is difficult to differentiate between chemical and physical adsorption, the term “sorption” is used to describe the attachment of adsorbate to adsorbent. Some nutrients, such as phosphorus removed by inorganic media, are likely a sorption/precipitation complex. The distinction between adsorption and precipitation is the nature of the chemical bond forming between the pollutant and sorption media. Yet the attraction of sorption surface between the pollutant and the sorption media causes the pollutants to leave the aqueous solution and simply adhere to the sorption media. This approach to wastewater treatment has “green” implications because of the inclusion of recycled material as part of the material mixture promoting treatment efficiency and effectiveness (Chang, 2010).

Biological Nutrient Removal

The nitrogen cycle in engineered systems or built environments is well understood. Within the microbiological process, if there are organic sources in the wastewater streams, hydrolysis converts particulate organic nitrogen (org. N) to dissolved organic N (DON), and ammonification in turn converts DON to ammonia (NH_3). In addition to ammonification,

important biochemical transformation processes include nitrification and denitrification (Chang, 2010).

Nitrification and denitrification transform nitrogen species between ammonia, nitrite, and nitrate forms via oxidation and reduction reactions in microbiological processes. In the presence of ammonia-oxidizing bacteria (AOB) and oxygen in the aerobic environment, ammonium is converted to nitrite (NO_2^-) and nitrite-oxidizing bacteria (NOB) convert nitrite to nitrate (NO_3^-) constantly and almost simultaneously. Collectively these two reactions are called nitrification. Conversely, denitrification is an anaerobic respiration process using nitrate as a final electron acceptor with the presence of appropriate electron donors, resulting in the stepwise reduction of NO_3^- to NO_2^-, nitric oxide (NO), nitrous oxide (N_2O), and nitrogen gas (N_2). Denitrification also requires the presence of an electron donor, which may commonly include organic carbon, iron, manganese, or sulfur, to make the reduction happen (Chang, 2010). As long as the hydraulic residence time (HRT) is sufficiently long to promote removal, microbe-mineral or sorption media interface can be initiated for either or both nitrification and denitrification process. Detailed literature review of the effects of nitrification and denitrification within the nitrogen cycle are abundant in the literature US EPA (2005), Chang et al 2008, and FDOH, 2009. The steps of ammonia oxidation can be summarized in equations form (Metcalf and Eddy, 2003)

Conversion of ammonia to nitrite (as typified by *Nitrosomonas*)

Equation 1 $$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$$

Conversion of nitrite to nitrate (as typified by *Nitrobacter*)

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

The denitrification of wastewater (as typified by *Pseudomonas)*

Equation 3 $C_{10}H_{19}O_3N + 10NO_3^- \rightarrow 5N_2 + 10CO_2 + 3H_2O + NH_3 + 10OH^-$

All of these three types of reactions occur in the B&G drainfield to result in a high biological removal of nitrogen from the wastewater.

Phosphorus Removal

Phosphorous removal is an emerging concern with regard to wastewater treatment because phosphorous is often the limiting nutrient in the accelerated eutrophication of freshwater lakes in Florida. The environmental concern of phosphorous is less of an issue than nitrogen because most soils serve as a sink for phosphorous. This sink can be almost considered infinite because the concentrations of phosphorous in wastewater tend to be low, about 8 mg/L, and adsorption from soil tends to be high. Orthophosphates can cause eutrophication in surface waters. Thus, preventing phosphates from entering water bodies is essential.

Microbes utilize phosphorus during cell synthesis and energy transport. As a result, 10 to 30 percent of the influent phosphorus is removed during traditional mechanical/biological treatment due to bacterial assimilation for biomass growth (Wenzel and Ekama, 1997). Biological removal of phosphorous occurs through a process called Enhanced Biological Phosphorus Removal (luxury uptake). In this process, phosphorous removing bacteria are stressed under anaerobic conditions. The stressed bacteria are then exposed to the wastewater and aerobic conditions. In response to the stress and exposure, the bacteria ingest phosphorous to meet their nutrient requirements. Through chemical precipitation and biological activity, phosphorous removal can exceed 95 percent (Burke, 1994).

2.1.7 Results from Previous UCF OSTDS Study

A completed study at UCF compared performance of a conventional OSTDS to the B&G BAM systems. A list of effluent water quality values are shown in Table 5.

Table 5 Comparison of Bold and Gold ™ Filter Media and UCF Control Conventional System Effluent (Chang, 2011)

Parameter	Bold and Gold™ Effluent (Dec. 2009-May 2010) Average	Std. Dev.	B&G Concentration Percent Change	Conventional System (UCF Control System) Average	Std. Dev.	Conventional System Concentration % Change
Alkalinity (mg/L)	292	± 165	26.33%	54	± 44	77.10%
TSS (mg/L)	26.4	± 18.6	94.73%	1.96	± 1.05	98.91%
BOD_5 (mg/L)	30.1	± 19.7	85.15%	1.23	± 0.68	99.04%
$CBOD_5$ (mg/L)	24.2	± 15.0	88.35%	0.9	± 0.4	99.23%
Ammonia-N (mg/L)	2.72	± 2.03	81.78%	0.04	± 0.02	99.93%
NO_X-N (mg/L)	0.13	± 0.304	NA	41.973	± 0.089	NA
Nitrite-N (mg/L)	0.02	± 0.044	NA	0.003	± 0.004	NA
Nitrate-N (mg/L)	0.11	± 0.260	NA	41.97	± 6.076	NA
Org. N (mg/L)	4.62	± 2.08	85.83%	6.08	± 3.71	-115.13%
TKN (mg/L)	7.34	± 3.17	82.71%	6.11	± 1.22	63.57%
TN (mg/L)	6.26	± 3.08	70.21%	48.09	± 3.77	-16.47%
SRP (mg/L)	0.01	± 0.004	79.11%	4.577	± 0.571	-193.53%
Org. P (mg/L)	0.046	± 0.042	83.56%	0.347	± 0.237	32.28%
TP (mg/L)	0.09	± 0.035	81.79%	4.924	± 0.804	-1.76%

The study included an economic analysis that provided cost estimates for conventional OSTDS and higher performance treatment systems. The cost estimates are based on a 500 gpd flow and can be found in Table 6.

Table 6 Cost comparison (mid-year 2009 basis) of a conventional OSTDS with B&G and SUW based on a 500 gpd flow (Chang, 2011)

	Construction Cost with 20% contingency ($)	Annualized Construction Cost at 6% interest rate and 20 years ($)	Annual Operating cost ($)	Unit Cost $/1000 gallons
Conventional OSTDS	$ 6.920	$ 600	$ 200	$ 4.38
B&G with sorption media	$ 9.320	$ 810	$ 200	$ 5.53
SUW with sorption media and plants	$ 10.200	$ 890	$ 400	$ 7.07
Continuous Feed Cyclic Reactor & Drip Irrigation	$ 18.200	$ 1.590	$ 1.800	$ 18.58
Recirculation Tank & Drip Irrigation	$ 27.800	$ 2.420	$ 1.850	$ 23.40

2.1.8 OSTDS at the Florida Showcase Green Envirohome

Florida's Showcase Green Envirohome (FSGE) received their Certificate of Occupancy (CO) on August 31st and became permanently occupied on September 4th, 2010. There has been an average of three occupants in the home continuously since starting the second week of September 2010. Visitors to the home average about 3 per week and some use the sanitary facilities during their visit. The monthly sampling of the on-site sewage treatment and disposal system (OSTDS) is for the wastewater from the sanitary facilities, kitchen sinks and one shower area on the first floor. The water systems on the first floor including the toilets are all fully functional for this post-CO sampling. September 2010 was the start of sampling and monthly sampling continued for one year.

In Figure 5, the locations of the sampling sites are provided for FSGE OSTDS. E1 is for the influent to the septic tank. The E2 location is for the discharge of the septic tank water into the dipper tray. The dipper tray is used to evenly divide the flow to a sorption filter media bed/conventional drainfield in series (innovative system), and then also to just a conventional drainfield. The E3 location is the influent side near the bottom of the Bold & Gold^{TM} sorption media filter. Location E4 is the discharge from the sorption media before it enters the conventional drainfield. Two other sample locations are located in the conventional drainfields. E5 is at the bottom of the drainfield following the Bold & Gold filter and E6 is at the bottom of the drainfield without the sorption media filter. Due to low wastewater flow, measured at an average of 45 gallons per day per system, limited sample volume was collected at E5 and E6. All data from the OSTDS is analyzed by an NELAC approved laboratory, namely ERD, Inc, (Certification No. E1031026), in Orlando Florida.

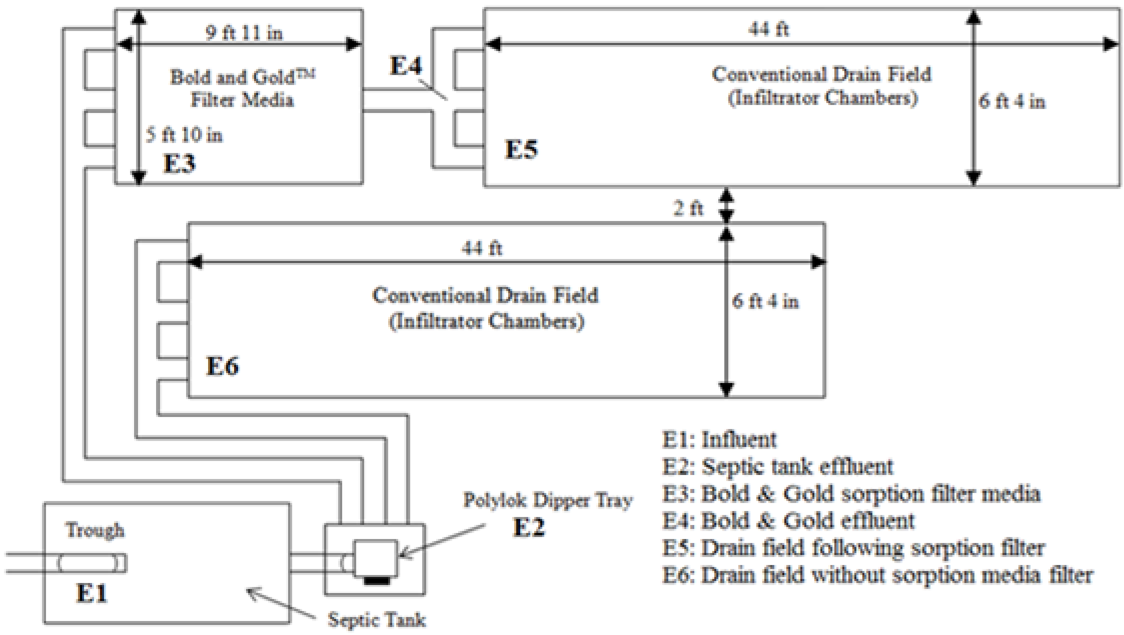

Figure 5 FSGE OSTDS Schematic and Sampling Locations

Aerobic Zone in OSTDS

When analyzing the design of the Bold and Gold^{TM} Filter Media within the OSTDS, significant consideration must be given to the aerobic and anoxic zones. To see the locations of the aerobic and anoxic zones, refer to Figure 3. The role of the aerobic zone is to provide an environment that is ideal for nitrifying organisms to survive. As discussed in the previous sections, nitrifying organisms (*Nitrosomonas* and *Nitrobacter*) convert ammonia to nitrite and nitrate by utilizing oxygen. The aerobic zone does not have anything separating it from the parent soil and an oxygenator assists in bring air down to the B&G layer. An oxygenator is a PVC pipe that is slotted at the bottom to allow air to come in and release at the bottom layer. It also has a sock at the bottom to prevent sediment from entering the pipe.

Anoxic Zone in OSTDS

The anoxic zone follows the aerobic zone in the B&G^{TM} filter media bed. The anoxic zone can also be found in Figure 3. The anoxic zone is designed with an effort to promote conditions that are optimal for denitrifying organisms to exist. Also discussed in previous sections, the denitrifying organisms convert the nitrate to nitrogen gas that is able to leave the system. The anoxic conditions are developed through an impermeable membrane that envelopes the entire anoxic zone. The only way to enter the anoxic zone is to first pass through the aerobic zone. After leaving the anoxic zone, the water is reintroduced to aerobic conditions to raise the DO concentration for safe disposal.

2.2 Bench Scale Model of Bold & Gold Filter Media

The reason for the bench scale models is to simulate and quantify the correlation between residence time and nutrient removal in the Bold & Gold^{TM} BAM filter beds. Two separate filter bed Plexiglas reaction chambers of different volumes are constructed and are under continuous monitoring to compare removal rates to the residence time. Filter Bed #1 (FB1; Figure 6) is scaled down exactly 100 times smaller than the size of FSGE filter bed, and Filter Bed #2 (FB2; Figure 7) is twice the volume of FB1.

2.2.1 Construction of the Bold and Gold™ Filter Media Bed Bench Scale Models

The construction of the filter bed boxes started with determining the dimensions of the sides and baffles. The next step involved purchasing three, 48" by 48" acrylic sheets of ½ inch thickness. The sheets were taken to a specialized machine shop (NCAD Products Inc.). The shop cut the sheets to exact size and smoothed them out with a programmable CNC Router. Once completed, the sheets were taken to the machine shop on campus and were welded together using acrylic cement. The edges were then lined with silicone caulk to assure the boxes were water tight. The baffles are designed to be temporary, in case the box is used for other projects in the future.

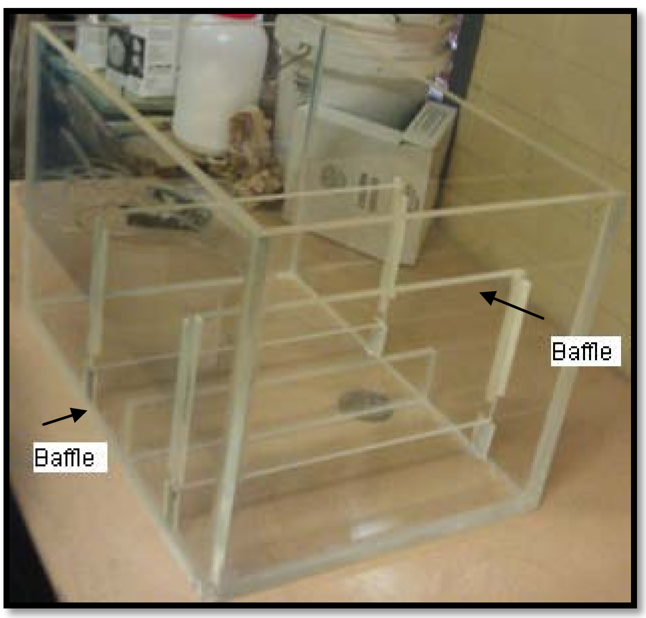

Figure 6 Filter Bed #1 (FB1) Box

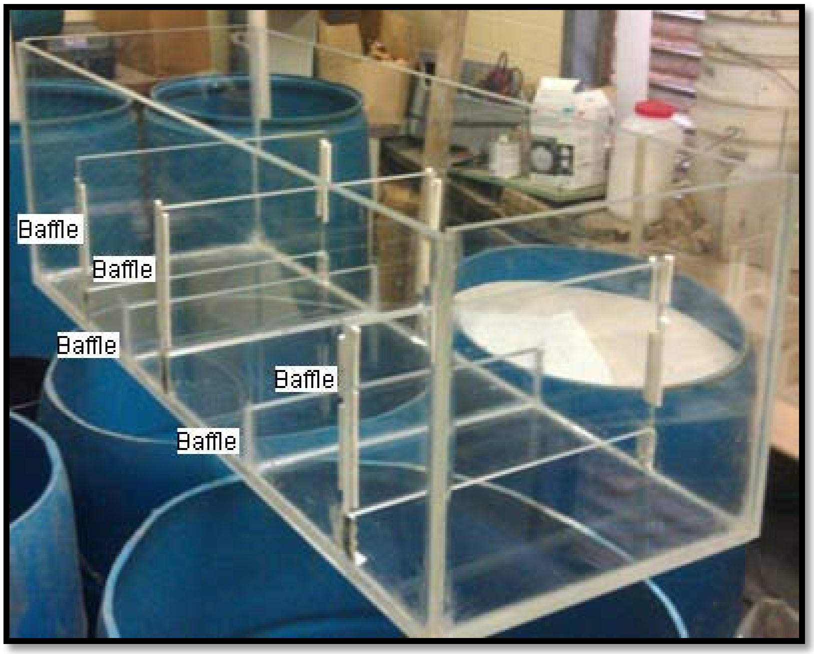

Figure 7 Filter Bed #2 (FB2) Box

2.2.2. Soil Component of the Baffle Boxes

The soil layers of the baffle box system are made to replicate filter bed components at FSGE. The bottom filter layer is a Bold & Gold^{TM} mix at 75% sand 25% tire crumb with a depth of 4.75 inches, which results in a volume of approximately 8 gallons. The next layer is a limestone and sand mix of 20% limestone and 80% sand with a depth of 5 inches. The final layer is native A3 sandy soil with a depth of 4.5 inches (Figure 8).

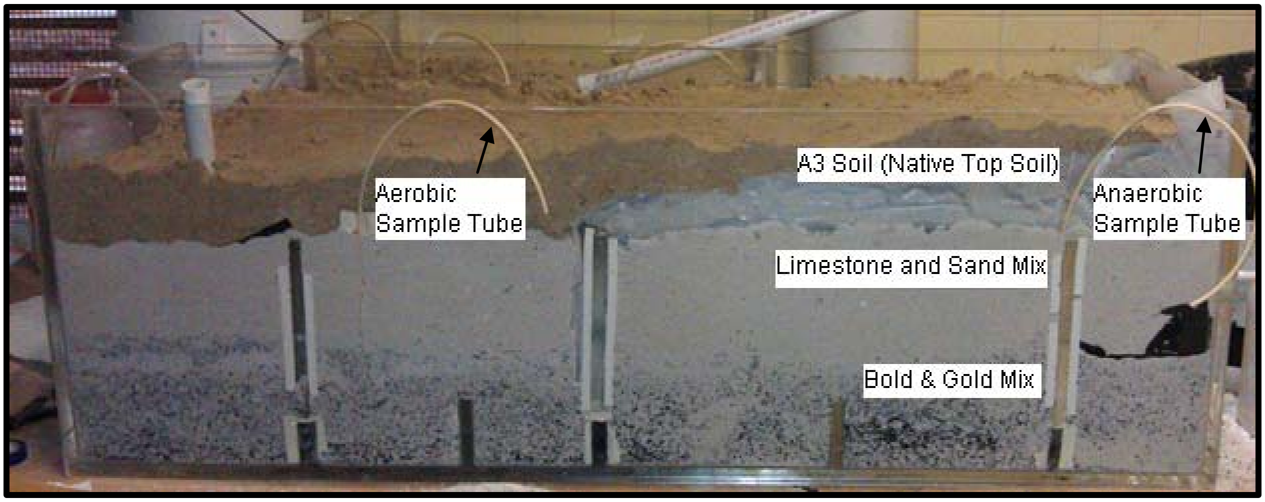

Figure 8 Cross Section of Layers in Filter Bed

2.2.3 Controlling Aerobic and Anaerobic Zones

To generate biological nutrient removal (BNR), appropriate conditions for aerobic and anaerobic zones to occur must accommodated. The aerobic zone has a ½ inch oxygenator pipe installed, while the anaerobic zone has an impermeable membrane liner covered and sealed over it.

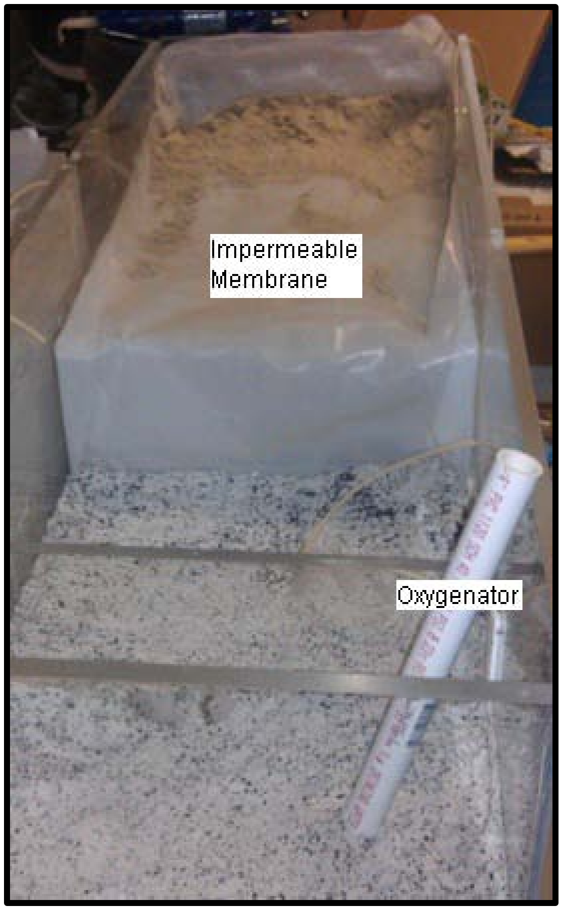

Figure 9 Oxygenator and Impermeable Membrane Installation

Sample ports have been installed in both zones to monitor dissolved oxygen levels and other water chemistry parameters; such as pH, conductivity, and temperature.

2.2.4 Influent and Effluent Methods

The influent flow rate is controlled via peristaltic pump, is water pumped into a simulated infiltrator chamber, made from a ½ gallon plastic sample container cut in half long ways. The influent is introduced at the sand and limestone layer as shown in Figure 10. The effluent

location is at the top of the Bold & Gold™ layer and consists of a plug and tube as shown in Figure 11.

Figure 10 Infiltration Chamber and Impermeable Membrane

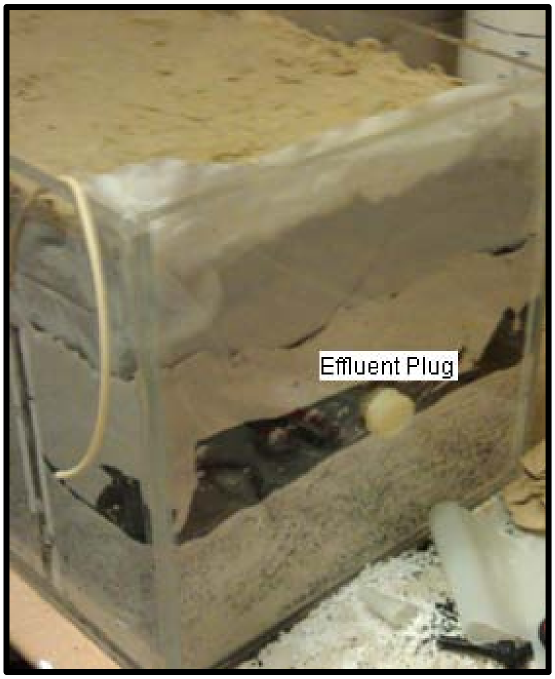

Figure 11 Effluent Location for Filter Bed

2.3 Combined Stormwater-Graywater Cistern

FSGE stormwater methods capture the stormwater runoff from the decking, metal and green roof areas and routes it to the water cistern. The water cistern also receives the graywater from the home. With these different water sources being mixed in the water cistern, the water quality changes over time. Water quality from the sources of water discharging into the cistern (stormwater, graywater, greenroof, air conditioning condensate, and groundwater) are compared to each other and to recommended irrigation water quality as presented in Table 7.

Table 7 Suggested Irrigation Water Quality Compared to Various Sources

Parameter	Irrigation Water	Graywater*	Stormwater*	Green Roof Runoff*	Groundwater*
pH	6.5-8.4	7.2	7.5	7.45	6.5
TDS (mg/L)	175-525	66.5	80	161	300
EC (µS/cm)	250-800	100	120	250	450
Ca (mg/L)	20-60	NA	NA	NA	43
Mg (mg/L)	10-25	NA	NA	NA	3.2
Total P (µg/L)	100-400	2255	270	76	110
PO_4^- (µg/L-P)	100-400	1338	130	46	60
Total N (µg/L)	1100-11300	6125	NA	329	NA
NO_3^- (µg/L-N)	1100-11300	293	600	185	<100

* Average values

References: (Duncan, Carrow and Huck 2000); (Jefferson, et al. 2004); (Lazarova, Hills and Birks 2003); (Pitt and Maestre 2004); (Kelly, Hardin and Wanielista 2007); and (United States Geological Survey 1992)

2.3.1 Graywater Reuse Studies

As communities throughout the United States are becoming interested in innovated approaches to water resource sustainability, household graywater reuse for irrigation is gaining in popularity. According to Criswell et al. (2005), California, Arizona, and New Mexico, and several counties have legalized the practice of graywater reuse. However, there are some concerns with household graywater irrigation that need further scientific study. One concern is the possibility of household graywater irrigation adversely impacting the soil environment and/or irrigated horticultural plants over the long term. Another concern is the possibility of irrigated graywater being a pathway for the spread of human diseases.

2.3.2 Graywater Regulation in Florida

State regulations for graywater are defined in Florida Plumbing Codes, Section 301.3 Appendix C (Florida Building Codes 2010) and require all plumbing fixtures that receive liquid wastes and sewage should be connected properly according to plumbing code. The exceptions are bathtubs, showers, lavatories, clothes washers and laundry trays that may have the effluent directed to an approved graywater recycling system.

In 2009 the Florida Administrative Code for OSTDS was updated and specifies graywater design and operation specifics especially related to flushing of toilets and urinals (Florida Administrative Code, 2007 and 2009). Residence time for graywater used for flushing water closets and urinals is a maximum of 72 hours. Graywater shall pass through an approved filter and be disinfected by an acceptable method using one or more disinfectants such as chlorine, iodine or ozone (Florida Building Code Plumbing, 2010). The holding capacity of the

reservoir shall be a minimum of twice the volume of water required to meet the daily flushing requirements of the fixtures supplied with graywater, but not less than 50 gallons (189 L). Potable water is to be used as a source of makeup water for the graywater system, with the potable water supply protected against backflow (Florida Building Codes 2010).

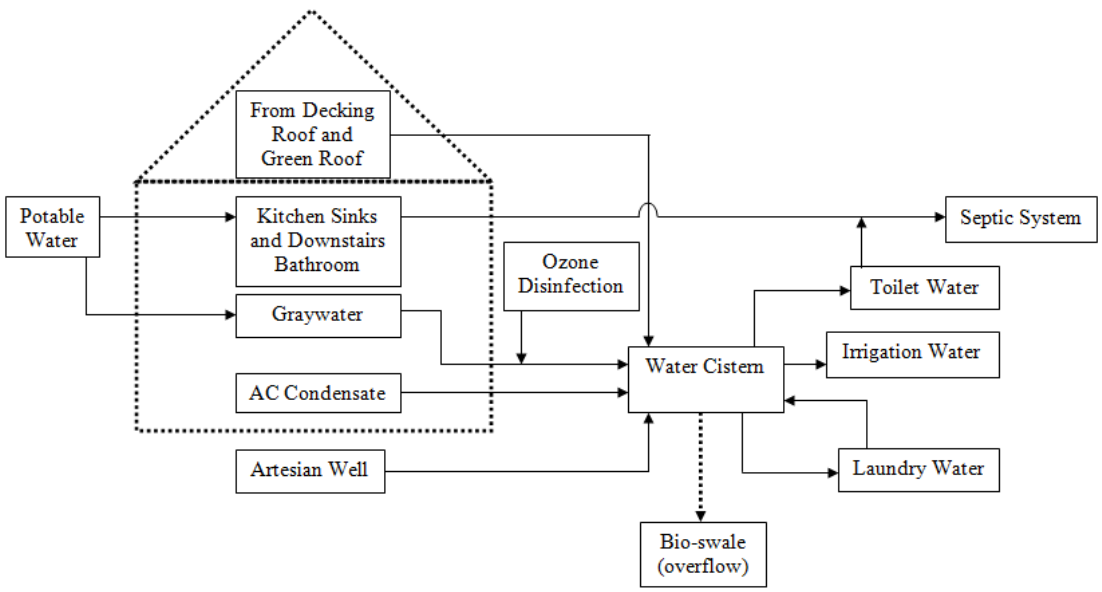

Figure 12 Water Flow Diagram for Florida's Showcase Green Envirohome (Rivera, 2010)

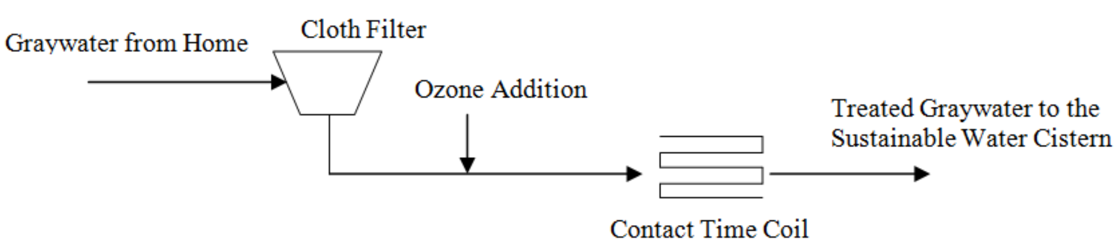

Figure 13 Graywater Ozone Cistern System Schematic (Rivera, 2010)

2.3.4 Irrigation Water Quality

There are many parameters to consider when determining the acceptability of a water (including graywater) for irrigation. Two of the more important considerations are the total dissolved solids (TDS) and the amount of sodium (Na) in water compared to calcium (Ca) plus magnesium (Mg), or the Sodium Absorption Ratio (SAR). Some other parameters that should be monitored include Alkalinity, pH, and hardness. These parameters will be discussed in more detail below. Table 8 has classification system for conductivity ranges between 250- 3000 µS/cm.

Table 8 Permissible Limits for Classes of Irrigation Water (Fipps, 2004)

Classes of water	Concentration, total dissolved solids	
	Electrical conductivity µS/cm	Gravimetric ppm
Class 1, Excellent	250	175
Class 2, Good	250-750	175-525
Class 3, Permissible[1]	750-2000	525-1400
Class 4, Doubtful[2]	2000-3000	1400-2100
Class 5, Unsuitable[2]	>3000	>2100

* Micro-Siemens/cm at 25 degrees C.
[1] Leaching needed if used
[2] Good drainage needed and sensitive plants will have difficulty obtaining stands

Nearly all waters contain dissolved salts and trace elements, many of which result from the natural weathering of the earth's surface. Sodium introduced into soils can radically affect the infiltration of a soil system. For instance, clay soils that come into contact water that has high concentrations of sodium ions compared to calcium and magnesium become virtually

impermeable to rain or applied water. This can cause dramatic problems leading to ponding and empirical water storage calculations in the design process for different soil media. The soil degradation processes under sodic conditions also has a large impact on permeability. These conditions basically alter the geometry of soil pores, thereby affecting permeability of soil to water and air, which depends on the SAR of the soil and electrolyte concentration of the applied water solution.

Infiltration refers to the process of water from the ground surface entering the soil (Liu & Evett, 2000). It is the rate at which the soil is able to absorb rainwater or irrigation water. The custom rate for infiltration measurements within the United States is measured in inches per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur, unless there is some physical barrier.

2.3.5 Groundwater Quality

Groundwater quality at the house, particularly artesian well water, is of concern because it is one of the sources of the cistern at FSGE. When there is low rainfall and low graywater inputs, the resulting low water level triggers a float valve that will pump in water from an artesian well to provide an adequate supply for toilet and irrigation use.

Groundwater contains salt concentrations that range from less than 25 mg/L in a quartzite spring to more than 300,000 mg/L in brines. The species and concentration of salts depend on the environment, movement, and source of the groundwater (Todd & Mays, 2005). Customarily, higher concentrations of dissolved constituents are found in groundwater than in surface water because of the greater exposure to soluble materials in geological strata. The groundwater from

the artesian well is found to have well above average salinity, which can be attributed to saltwater intrusion, which will be discussed later in this paper.

Salts are added to groundwater passing through soils by soluble products of soil weathering and of erosion by rainfall and flowing water. Also, excess irrigation water percolating to the water table may contribute substantial quantities of salt. In addition, soluble soil materials, fertilizers, and selective absorption of salts by plants will alter salinity values (Todd & Mays, 2005).

2.3.6 Sodium Impacts

Sodium can have significant effects on soil properties and plant growth and these have been well comprehended for at least half a century by soil scientists, agriculturalists, and irrigation experts. For these reasons, the sodium content of soils and irrigation waters, as well as the modes of occurrence and action of sodium in the soil, have been routinely measured to characterize the quality of soil and irrigation water for cropping and to predict the risk of toxic impacts (Graaff & Patterson, 2001). This study also will investigate sodium content in FSGE's home irrigation water. Past experiences, current evaluations, and future projections suggest that the need to provide more crop growth to an expanding human population will result in an increase in the use of poor-quality waters and soils for crop production. Consequently, the problems of sodic soils can be expected to increase in the future, particularly in the case of improper water management (Qadir & Schubert, 2002).

2.3.7 Sodium Adsorption Ratio (SAR)

Measuring factors have been standardized to analyze the sodium accumulation of soils and various other materials affected. These mechanisms can more elaborately explain sodic behavior and can provide framework to refine practices used to manage these scenarios. Therefore, an understanding of the structural degradation processes and nutrient constraints limiting plant growth in sodic soils is important for long-term sustainable agriculture (Qadir & Schubert, 2002). Two of these factors are the sodium adsorption ratio (SAR) and the exchangeable sodium percentage (ESP).

Equation 4 (All concentrations in meq/L)

Table 9 Typical Classifications of Water Hazard Based on SAR Value (Fipps, 2004)

SAR Value	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned
10-17	Medium	Amendments (such as Gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
>26	Very High	Generally unsuitable for use.

Exchangeable sodium percentage (ESP) is the amount of sodium held in exchangeable form on the soil's cation exchange complex expressed as a percentage of the total cation exchange capacity (CEC) (Graaff & Patterson, 2001).

Equation 5

It is important to note that while ESP and sodicity are properties of soil, SAR is a property of water. Clay particles in a soil in contact with the water in the soil will strive to be in chemical equilibrium with that particular source water. If the clay surfaces are densely populated with adsorbed cations, there will also be more cations in the film of water surrounding the particles themselves. If, amongst the adsorbed cations the majority consists of sodium, then there will also be a greater proportion of sodium ions in the surrounding slurry solution (Graaff & Patterson, 2001). Conversely, if the water percolating through a soil has a high relative concentration of sodium, the properties of adsorbed cations will adjust themselves to that. This is where the concept of sodium adsorption ratio (SAR) has been developed (Graaff & Patterson, 2001).

The strength of the bond between clay particles is reduced if the salinity of the solution between the soil aggregates is too low. When low salinity water is present in the soil solution, such as just after heavy rain, water tends to move by the process of osmosis from the soil solution into the space between clay particles, causing excessive swelling and dispersion. Conversely, the application of saline water will improve soil structure, even if sodium ions lie between the clay particles, but vegetation usually is unable to take advantage of this situation because of a chemical drought effect.

Gypsum improves soil structural stability by providing a mildly saline soil solution that is not strong enough to adversely affect water uptake by most vegetation, but which restricts the movement of water molecules into the space between clay particles. Gypsum also contains calcium, which displaces sodium and magnesium from the exchange sites between clay particles.

Where soil pH is below about 6.5 (measured in calcium chloride solution) the use of lime or a gypsum/lime blend may be the most effective and profitable way of dealing with a sodicity problem.

There are several categories of constituents that affect groundwater quality just as sodium does. Prior to urbanization, natural groundwater recharge resulted from infiltration of precipitation through pervious surfaces, including grasslands and woods. This infiltrating water was relatively uncontaminated (Pitt et al., 1999). With urbanization, the permeable soil surface area through which recharge by infiltration could occur was reduced. This resulted in less groundwater recharge and increased surface runoff. In addition, the waters available for recharge generally carried increased quantities of pollutants such as sodium (Pitt et al., 1999). In Arizona, stormwater infiltration in dry wells dissolves natural salts in the vadose zone which are then carried to the groundwater (Pitt et al., 1999).

The hydraulic implications placed onto the environment caused by excess sodium leads to additional issues such as a surplus of runoff waters and ponding. Studies have shown the clear adverse impacts on infiltration in soil (Suarez et al., 2006). Elevated values of SAR result in decreased hydraulic conductivity, decreased aggregate stability, clay dispersion, swelling of expandable clays, surface crusting and reduced tilth. Tilth is a term referring to soil that has the proper structure and nutrients to grow healthy vegetation.

The permeability performance of a soil heavily depends on conditions at the soil surface. Sodicity influences the soil at the scale of clay microstructure, more commonly referring to the surface where fine particles migrate resulting from wetting. Soil degradation mechanisms under

sodic conditions proceed through a number of different stages. Initially, the dry aggregates are strong with high attractive forces between clay particles, rendering the swollen wet aggregate weak. Generally, initial hydration of sodic soils clays leads to slaking and swelling while continuous (extensive) hydration results in the liberation and spontaneous dispersion of clay particles from the aggregates (Qadir & Schubert, 2002). Aggregates at the soil surface are stated to be more vulnerable to the degradation processes because of the stresses set up by rapid water uptake, release of entrapped air and mechanical impact and stirring action caused by flowing water commonly applied through irrigation or added as rainfall.

A primary observation with sodic soils and water mixtures is crusting. Crusting is a major mechanism affecting the steady-state infiltration rate in soils of arid and semiarid regions where organic matter is usually low and soil structure is unstable. Past research conducted has shown that soils that have been irrigated with sewage effluents for many years were, in most cases, more susceptible to seal formation and low infiltration rate than adjacent soils irrigated with fresh water (Qadir & Schubert, 2002). Another type of soil degradation is called hardsetting. The effect is similar to a sealing of the surface soil. The major difference between the two is that hard-setting leads to complete aggregate breakdown and clay movement within the entire Soil horizon, whereas in crusting soils, clay mobility is restricted to the top few millimeters (Qadir & Schubert, 2002).

For a given SAR value, the opposing impacts on soil physical properties are reduced with increasing salinity. Salinity is commonly reported as electrical conductivity (EC) in µS/cm (Suarez et al., 2006). Past literature states the reduction in hydraulic conductivities for soil types

and infiltration rates, but not much has been completed using rain events or at least simulated rain events. More specifically, there are a limited number of studies where rain or dilute waters were applied after saline waters and infiltration or hydraulic conductivities was measured (Suarez et al., 2006).

Shainberg et al. (1981) reported decreases in relative hydraulic conductivity to, respectively, 20% and 10% of the initial value when soil-sand mixtures of a soil, previously leached with saline solutions of, respectively, SAR 5 and 10, were subsequently leached with deionized water. The adverse effect was said to likely be accentuated by the mixing of soil and sand and subsequent high flow rates of the solutions through the columns. High flow rates increase particle detachment from aggregates and clay movement (Suarez et al., 2006).

As for infiltration rates, Agassi et al. (1981) determined that the infiltration rate was more sensitive to the effects of sodicity when applying the water via rainfall simulator as compared to changes in hydraulic conductivity in saturated column studies. These differences were stated to be attributed to particle disturbance on the soil surface. One prominent study on infiltration that focused on longer term wetting on the soil was conducted by Oster and Schroder in 1979. The study was reported on undisturbed cropped soil columns in a greenhouse. Eighteen waters of varying composition were applied, one container for each treatment. They concluded that even for the set of waters around SAR 2-4.6 there was increased infiltration as the irrigation water increased from EC 0.5-2.8.

The soil degradation processes under sodic conditions also has a large impact on permeability. These conditions basically alter the geometry of soil pores, thereby affecting permeability of soil to water and air, which depends on ESP or SAR of the soil and electrolyte concentration of the applied water solution (Qadir & Schubert, 2002). The infiltration rate and the hydraulic conductivity tend to decrease with decreasing levels of soil salinity and increasing levels of soil sodicity (sodium levels) (Qadir & Schubert, 2002).

Clay dispersion can be a problem across a range of ESP values provided the TEC is below the critical flocculation concentration. Under these conditions the thickness of the diffuse double layer increases and the attractive forces between clay particles decrease, resulting in dispersion. The reduction in permeability in sodic soils is a result from a decrease in surface infiltration caused by surface crusting. This can also result from pore blockage. Laboratory studies using disturbed soil samples have shown that both saturated and unsaturated soil hydraulic conductivity can decrease as a result of sodium accumulation (Menneer et al., 2001).

With proper amounts of calcium and magnesium in the irrigation water, the soil will be granular in texture, easily worked, and permeable. With increasing proportions of sodium, the soil will tend to become less permeable and saturated conditions may occur.

Clays in soils with an excess of sodium ions, compared to calcium and magnesium ions, remain in a dispersed condition, and are almost impermeable to rain or applied water. A "dispersed" clayey soil is extremely sticky when wet, tends to crust, and becomes very hard and cloddy when dry. Dispersion caused by sodium may result in poor physical soil conditions and water and air do not readily move through the soil. An SAR value of 15 or greater indicates that

an excess of sodium will be adsorbed by the soil clay particles and should be severely restricted. SAR near 5 also has the ability to cause serious problems, depending on the type of clay present.

2.4 FSGE LID, Stormwater Harvesting Design, and Vegetation

On-site stormwater management is an option to reduce runoff volume and mass of pollutants generated from a residential location. If no additional land is needed for the stormwater treatment, the management methods are labeled as Low Impact Development (LID). To implement LID practices, the home consists of three greenroofs on the decking and one small greenroof on the utility building. The greenroof system collects runoff from the roofing and channels it to the combined stormwater/graywater cistern. The vegetation that is planted in the greenroofs is carefully selected native species that can survive in the very unique conditions (Figures 14-15). The gutter system around the decking is designed to collect the stormwater runoff that had not been captured by the greenroof systems. A pervious pavement system consists of KBI's "Flexi-Pave" technology in the driveway and the pool deck and "Hanson Aquaflow Pervious Pavers" for the sidewalks around the home collect any stormwater that would otherwise be generated by those impervious areas (Figure 16). There are over 2500 square feet of Flexi-Pave installed and approximately 1500 square feet of Hanson pavers installed. The Flexi-Pave system requires 0.3 tires per square foot; therefore, FSGE prevented 750 tires from being land filled. Studies on the strength and infiltration performance of both pervious pavement systems can be found on the Stormwater Management Academy Website (www.stormwater.ucf.edu). A 100 square foot bioswale (Figure 17) is installed along the back of the property to safely drain any of the combined stormwater/graywater cistern overflow.

Figure 14 Plant Species on FSGE Greenroofs (Rivera, 2010)

Figure 15 Plant Species on FSGE Greenroofs and property

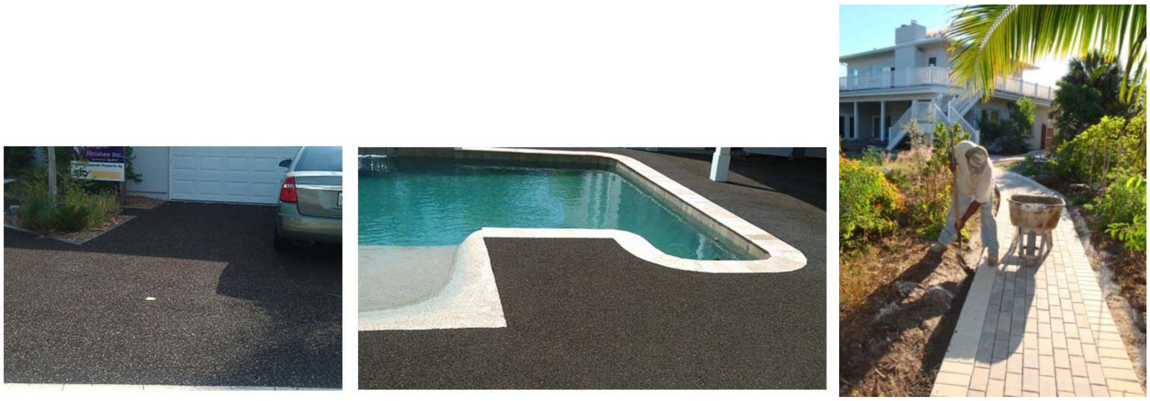

Figure 16 Flexi-Pave and Hanson Pervious Pavement Systems in Driveway and Pool Deck

Figure 17 Bioswale Installation

The selection of vegetation for FSGE is based on the residential location and climate for the selection of native species, defined as existing in Florida before Ponce de Leon's landing in 1513. The plants are able to handle the characteristics of a coastal environment, such as an excess of salt that prevents them from absorbing water properly. The sandy soils found near beach areas retain less water and nutrients than do less porous soils, so plants growing in the coastal soils are especially susceptible to salt damage.

For example, muhly grass is a tough native grass useful in many different landscape sites. It has extreme tolerance to drought and flooding; while also being moderately salt tolerant. These characteristics make it strongly suited for wetland sites as well as beachfront landscapes. Muhly grass is one of the most adaptable plants and is virtually maintenance free. The growth is best in sandy or rocky soil (Gilman, 2007). Table 10 (below) provides a list of plant species and quantities that are located on the greenroofs of FSGE.

2.5 FSGE Existing Soil Conditions

FSGE existing soils were review through the US Department of Agriculture (USDA) Web Soil Survey (WSS). The WSS provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. The soil map unit name is Canaveral-Palm Beach-Urban land complex. From the report, the maximum SAR the soils can handle is 6.0. This value will be the level used for analysis whether on suitable or unsuitable SAR values.

Table 10 List of Plant Species and Quantities

Location	Plant Species	Quantity	Location	Plant Species	Quantity
Pump House	Purple Lovegrass	12	**Small Roof East Side**	Sunshine Mimosa	19
	Muhly Grass	11		Coral Honeysuckle	15
	Moon Vine	10		Elliotts Lovegrass	6
	Railroad Vine	10		Blanket Flower	19
	NA			Lemon Bacopa	19
				Pineland Helietrope	15
Crow's Nest 200 sq ft	Blue Porterweed	15	**East Side roof area**	Red Sage	24
	Verbena	15		Coral Honeysuckle	33
	Horsemint	15		Coastal Verbena	23
	Muhly Grass	15		Black-eyed Susan	11
	Dotted Horsemint	15		FL Elephant's Foot	10
	Goldenrod	15		Railroad Vine	11
	Seaside Helietrope	15		FL Gamma Grass	19
	NA			Muhly Grass	21
				Porterweed (addition)	11
				Lemon Bacopa	12
				Pineland Helietrope	13
				Peperomia	15

CHAPTER 3 RESULTS & DISCUSSION

The sampling schedule for FSGE is once per month, occurring at the beginning of each month. The OSTDS is sampled for all the constituents listed in Table 2 located in Chapter 2. The cistern and artesian well are sampled for field parameters, SAR, and nutrients. The cistern was sampled in a previous study to verify the absence of bacteria and other pathogens. The results are provided with analysis observations of the site performance. These results are vital in the future progression and application of this integrated water design. For the bench scale testing, the project began in the middle of May 2011 and biweekly sampling events occurred through the summer until September 2011. The parameters for the bench scale analysis were focused on nutrient removal (Nitrogen and Phosphorus).

3.1 FSGE On-Site Treatment and Disposal System

3.1.1 Results

The first set of results for the FSGE OSTDS are the field measurements. The water quality measurements that are taken on site are pH, conductivity, dissolved oxygen (DO), and temperature. Each sample location has these measurements recorded in an effort to monitor trends and specific changes in water chemistry as the water passes through the system. In Tables 11-16, the values and statistical analysis are provided for the OSTDS field parameters. The flow rate counter data through the OSTDS is shown in Table 17. The laboratory water quality data for FSGE OSTDS are shown in Tables 18-22.

The sampling results are divided into two categories, one is the pre-certificate of occupancy (CO) and the other is post-CO. While there were no permanent residents in the home before CO, there were workers who would frequent the home during construction phase and used the toilets after the drainfield had been completed. After the CO had been obtained, two and then three people lived in the home and used the facilities, and family and visitors would occasionally stay at the home. There was a maximum of 4 people in the home at any one time. The average occupancy was calculated as 3.1 persons per day during the year of Post-CO sampling

Figures 18-20 are presented to illustrate that an average value for nutrients and BOD_5 were obtained from the number of samples over a one year period of time. An average value to reflect the wastewater conditions has been calculated based on the data used for these Figures. If another sample were added, it is highly unlikely that the averages would change significantly. These Figures also indicate the stability of the data over time. The complete data sets are found in the appendices and were reported by a NELAC - certified laboratory.

Table 11 Sampling Statistics for Sampling Point E1 Field Measurements for Water Quality Parameters at FSGE OSTDS

Sampling Point: E1 Post-CO Sampling Statistics (Influent)

Summary Stats	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.86	3.05	2.43	26.09
Median	7.82	3.08	2.05	25.45
Std. Dev	0.39	1.13	1.36	4.6

E1 Pre-CO Sampling Statistics (8 Months)

Summary Stats	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.15	4.72	3.02	25.43
Median	7.17	4.36	3.21	25.75
Std. Dev	0.69	1.12	2.52	3.99

Table 12 E2 Field Measurements for Water Quality Parameters at FSGE OSTDS

Sampling Point: E2 Post-CO Sampling Statistics (Septic Effluent)

Summary Stats	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.51	2.78	0.15	25.46
Median	7.52	2.75	0.14	25.9
Std. Dev	0.23	0.3	0.07	4.66

E2 Pre-CO Sampling Statistics (1 Sample)

Summary Stats	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Value	7.25	2.71	0.47	30.4

Table 13 E3 Field Measurements for Water Quality Parameters at FSGE OSTDS

Sampling Point: E3 Post-CO Sampling Statistics (B&G Filter Bed)

Sampling Statistics	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.07	2.6	2.42	25.69
Median	7.11	2.63	2.46	26.1
Std. Dev	0.15	0.14	0.32	4.71

E3 Pre-CO Sampling Statistics (8 Months)

Date	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.16	2.46	2.24	24.34
Median	7.1	2.4	2.69	23.95
Std. Dev	0.11	0.13	0.42	2.39

Table 14 E4 Field Measurements for Water Quality Parameters at FSGE OSTDS

Sampling Point: E4 Post-CO Sampling Statistics (B&G Effluent)

Sampling Statistics	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.18	2.62	2.67	25.48
Median	7.2	2.59	2.47	26
Std. Dev	0.18	0.28	0.67	4.45

E4 Pre-CO Sampling Statistics (8 Months)

Date	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.1	2.45	2.32	25.43
Median	7.06	2.48	2.42	25.45
Std. Dev	0.12	0.18	0.3	3.5

Table 15 E5 Field Measurements for Water Quality Post-CO at FSGE OSTDS

Sampling Point: E5 Post-CO Sampling Statistics (B&G + Drainfield Effluent)

Sampling Statistics	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.34	2.6	5.04	25.66
Median	7.52	2.51	4.84	24.5
Std. Dev.	0.35	0.23	1.09	4.6

Table 16 E6 Field Measurements for Water Quality Post-CO at FSGE OSTDS

Sampling Point: E6 Post-CO Sampling Statistics (Drainfield Effluent)

Sampling Statistics	pH	Conductivity (mS/cm)	DO (mg/L)	Temperature (°C)
Averages	7.64	2.24	0.79	28.9
Median	7.76	2.43	0.73	28.8
Std. Dev.	0.28	0.62	0.26	2.89

Table 17 Counter Data Average and Peak Flow Estimate Over 4 Month Period

Average Daily Flow Rate

Date	Day	Time	Count	Volume (gallons)	Volume Change (gallons)	Flow rate (gpd)	GPCD
4/4/2011	Mon.	12:00	0	0	NA	NA	NA
8/3/2011	Wed.	9:30	7151	10726.5	10727	**88**	**29.3**

Peak Hourly Flow

Date	Day	Time	Count	Volume (gallons)	Volume Change (gallons)	Flow rate (gpd)	GPCD
4/15/2011	Fri	9:30	555	832.5	NA	NA	NA
		10:05	559	838.5	6	**246.9**	**82.29**
		10:30	561	841.5	9	**216.0**	**72**

Table 18a TSS BOD_5 and $CBOD_5$ data for Post-CO FSGE OSTDS

Sampling Point	Statistic	Alkalinity (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	$CBOD_5$ (mg/L)
E1 (Influent)	**Average**	381	260	311	291
	Median	375	206	304	266
	Std. Deviation	131	181	225	216
E2 (Septic Effluent)	**Average**	418	41	52	47
	Median	445	31	47	43
	Std. Deviation	122	35	27	26
E3 (B&G Filter Bed)	**Average**	326	7.6	2.1	1.6
	Median	361	3.7	1.7	1.4
	Std. Deviation	97	9.2	1.0	0.7
E4 (B&G Effluent)	**Average**	360	21.6	8.0	6.4
	Median	370	13.0	6.8	6.1
	Std. Deviation	143	22.9	4.7	3.1
E5 (B&G + Drainfield)	**Average**	365.7	7.2	4.1	3.5
	Median	386.0	9.0	4.1	3.5
	Std. Deviation	202.0	4.9	2.0	1.8
E6 (Conventional Drainfield)	**Average**	433	29.6	35.7	29.0
	Median	486	37.3	29.8	22.0
	Std. Deviation	141	16.4	15.1	14.3
E1 to E2	**Removal Efficiency between Sampling Points**	NA	**84.40%**	**83.40%**	**84.00%**
E1 to E4	**Removal Efficiency between Sampling Points**	NA	**91.70%**	**97.40%**	**97.80%**
E1 to E5	**Removal Efficiency between Sampling Points**	NA	**97.20%**	**98.70%**	**98.80%**
E1 to E6	**Removal Efficiency between Sampling Points**	NA	**88.60%**	**88.50%**	**90.00%**

Table 19a Nitrogen Data for Post-CO FSGE OSTDS

Sampling Site	Statistic	NH_3 (mg/L)	NO_x-N (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Org. N (mg/L)	TKN (mg/L)	Total N (mg/L)
E1 (Influent)	**Average**	51.5	8.1	7.0	1.1	71.2	120.5	128.5
	Median	53.4	0.3	0.0	0.1	31.4	96.5	96.8
	Std. Deviation	31.2	22.0	19.2	2.8	91.2	89.2	98.4
E2 (Septic Effluent)	**Average**	78.9	7.1	4.0	3.2	23.8	85.9	93.1
	Median	83.1	0.5	0.0	0.5	4.3	95.4	95.5
	Std. Deviation	33.6	13.8	10.0	5.7	37.4	27.9	28.2
E3 (B&G Filter Bed)	**Average**	30.9	20.3	2.0	18.3	11.1	40.0	60.4
	Median	33.0	19.2	0.0	15.2	3.7	40.5	61.2
	Std. Deviation	13.4	12.1	4.0	12.8	22.0	17.0	14.3
E4 (B&G Effluent)	**Average**	24.5	2.6	0.7	2.0	9.7	34.4	37.0
	Median	18.5	0.5	0.0	0.5	2.9	32.3	34.0
	Std. Deviation	17.5	3.7	1.2	3.1	20.7	21.5	21.6
E5 (B&G + Drainfield)	**Average**	14.6	4.6	1.3	3.3	5.8	25.1	29.7
	Median	12.6	1.7	0.0	1.7	1.1	24.5	28.9
	Std. Deviation	9.5	5.4	3.9	4.0	9.7	15.9	15.2
E6 (Conventional Drainfield)	**Average**	51.1	0.5	0.1	0.4	14.0	59.7	70.1
	Median	59.7	0.7	0.0	0.6	4.5	69.9	75.1
	Std. Deviation	33.8	0.4	0.1	0.3	16.6	39.4	32.2
E1 to E4	**Removal Efficiency between Sampling Points**	**71.6%**	NA	NA	NA	**86.4%**	**71.5%**	**71.2%**
E1 to E5	**Removal Efficiency between Sampling Points**	**71.6%**	NA	NA	NA	**91.9%**	**79.1%**	**76.9%**
E1 to E6	**Removal Efficiency between Sampling Points**	**0.70%**	NA	NA	NA	**80.3%**	**50.4%**	**45.5%**

Table 20 Phosphorus Data for Post-CO FSGE OSTDS

Sampling Site	Statistic	SRP (mg/L)	Org. P (mg/L)	Total P (mg/L)
E1 (Influent)	Average	8.1	3.5	15.7
	Median	7.0	0.6	13.6
	Std. Deviation	5.0	7.2	9.9
E2 (Septic Effluent)	Average	10.2	1.9	12.9
	Median	10.4	0.5	12.8
	Std. Deviation	2.3	2.5	2.0
E3 (B&G Filter Bed)	Average	8.6	0.9	9.5
	Median	7.6	0.5	8.8
	Std. Deviation	3.0	0.9	4.4
E4 (B&G Effluent)	Average	3.9	0.5	5.1
	Median	3.5	0.1	4.6
	Std. Deviation	3.6	1.0	3.7
E5 (B&G + Drainfield)	Average	3.4	0.2	4.1
	Median	3.5	0.2	4.2
	Std. Deviation	2.7	0.1	3.0
E6 (Conventional Drainfield)	Average	11.4	0.3	10.6
	Median	12.4	0.4	11.9
	Std. Deviation	1.8	0.2	4.0
E1 to E4	**Removal Efficiency between Sampling Points**	NA	**85.8%**	**67.7%**
E1 to E5	**Removal Efficiency between Sampling Points**	NA	**94.5%**	**73.6%**
E1 to E6	**Removal Efficiency between Sampling Points**	NA	**91.7%**	**32.1%**

Table 21 Pre-CO Biological and Phosphorus Data

Pre CO Statistical Analysis (monthly sampling)

Sampling Site	Statistic	Alkalinity (mg/l)	TSS (mg/l)	BOD_5 (mg/l)	$CBOD_5$ (mg/l)	SRP (mg/l)	Org. P (mg/l)	Total P (mg/l)
E1 (9 samples)	Average	266	305.3	461.2	399.1	11.2	2.4	18.7
	Median	220	88	372	279	9.1	1.2	16.5
	Std. Deviation	122	360.8	323.6	328.5	7.9	2.4	12.7
E2 (3 samples)	Average	243	23.1	43.3	36	8.3	1.1	9.7
	Median	242	26	34.6	23	7.686	0.405	10.664
	Std. Deviation	81	7.8	38.6	41.9	5.173	1.568	5.196
E3 (9 samples)	Average	285	39.35	46.65	30.26	2.24	0.09	2.46
	Median	217	15	39.2	28.4	0.02	0.05	0.08
	Std. Deviation	145	48.48	20.25	17.99	3.74	0.08	5.58
E4 (9 samples)	Average	293	30.838	26.83	21.913	0.009	0.036	0.081
	Median	288	33.9	19.32	16.9	0.012	0.035	0.082
	Std. Deviation	152	20.621	17.851	13.441	0.004	0.04	0.037
E1 to E4	**Removal Efficiencies**	**NA**	**89.00%**	**94.20%**	**94.50%**	**99.90%**	**98.50%**	**99.60%**

Table 22 Pre-CO Nitrogen Data

Pre CO Statistical Analysis (monthly sampling)

Sampling Site	Statistic	NH_3 (mg/l)	NO_x-N (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)	Org. N (mg/l)	TKN (mg/l)	Total N (mg/l)
E1 (9 samples)	Average	109	0.866	0.321	0.643	287.4	389.1	389.9
	Median	47.7	0.98	0.091	0.222	257.5	348.2	348.2
	Std. Deviation	143	0.735	0.383	0.747	222.6	382.2	381.9
E2 (3 samples)	Average	28.2	9.9	1	8.9	25.6	51.1	61
	Median	29.021	6.553	1.047	5.136	22.798	0.684	56.985
	Std. Deviation	20.638	12.159	0.713	11.909	23.306	37.582	33.928
E3 (9 samples)	Average	5.29	7.91	0.45	7.46	17.21	22.5	36.11
	Median	2.01	0.01	0	0.01	4.05	8.17	4.62
	Std. Deviation	2.6	6.18	5.82	0.42	34.27	36.13	48.42
E4 (9 samples)	Average	2.629	0.107	0.019	0.088	5.373	8.002	7.889
	Median	1.959	0.015	0.006	0.01	6.373	7.671	8.848
	Std. Deviation	2.699	0.261	0.038	0.224	2.478	4.366	4.489
E1 - E4	**Removal Efficientcy**	**92.20%**	**NA**	**NA**	**NA**	**98.10%**	**97.50%**	**98.00%**

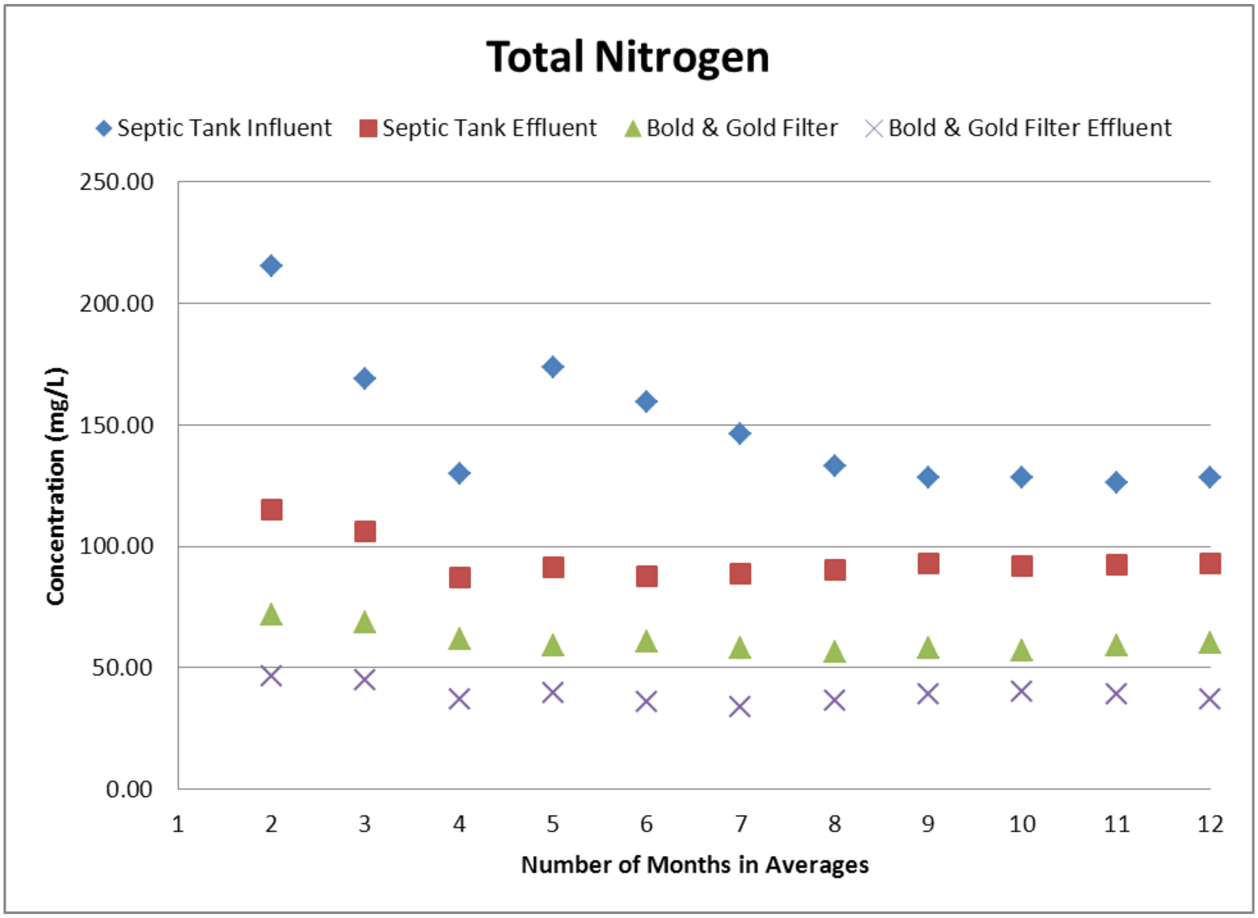

Figure 18 TN Averages Trend During Post-CO 12 Month Sampling (E1-E4)

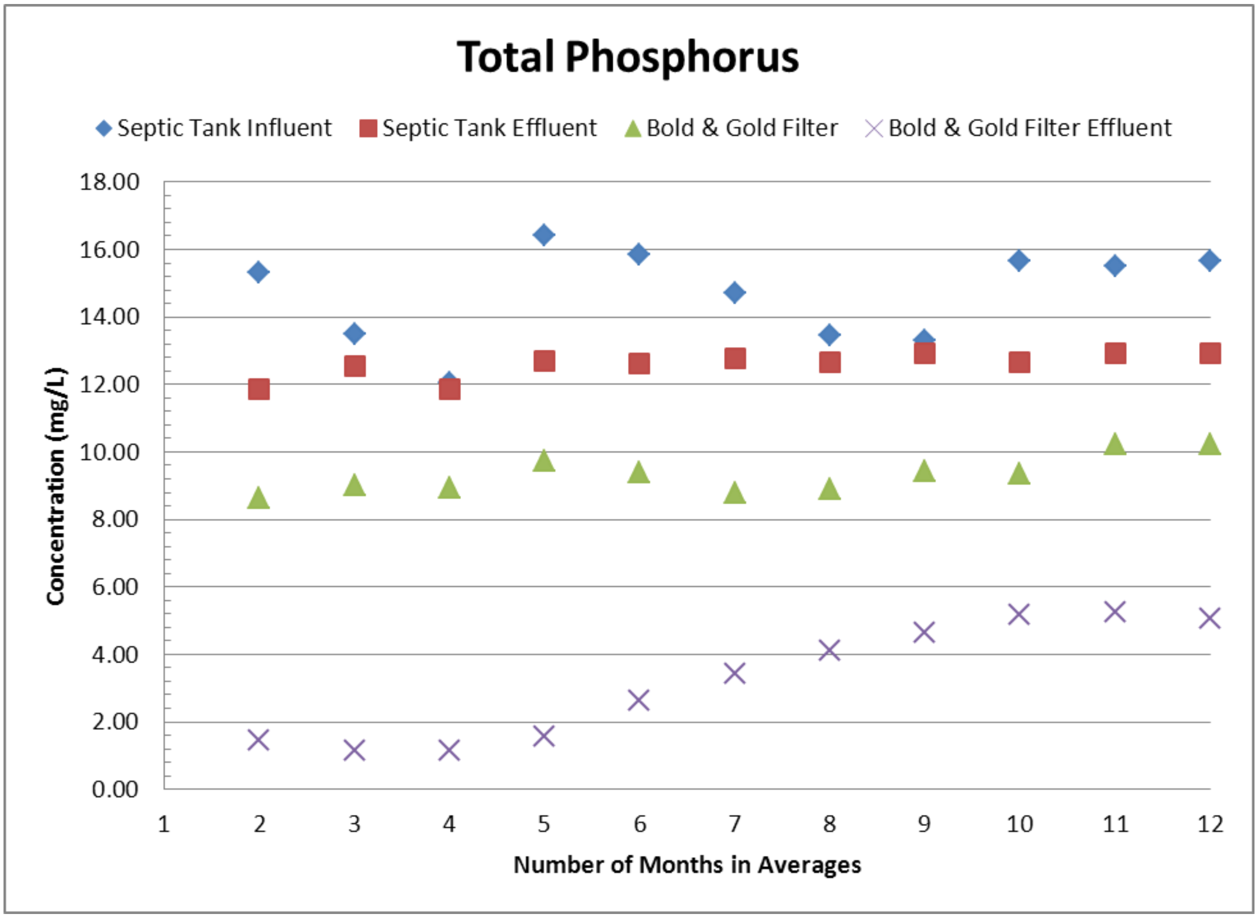

Figure 19 TP Averages Trend During Post-CO 12 Month Sampling (E1-E4)

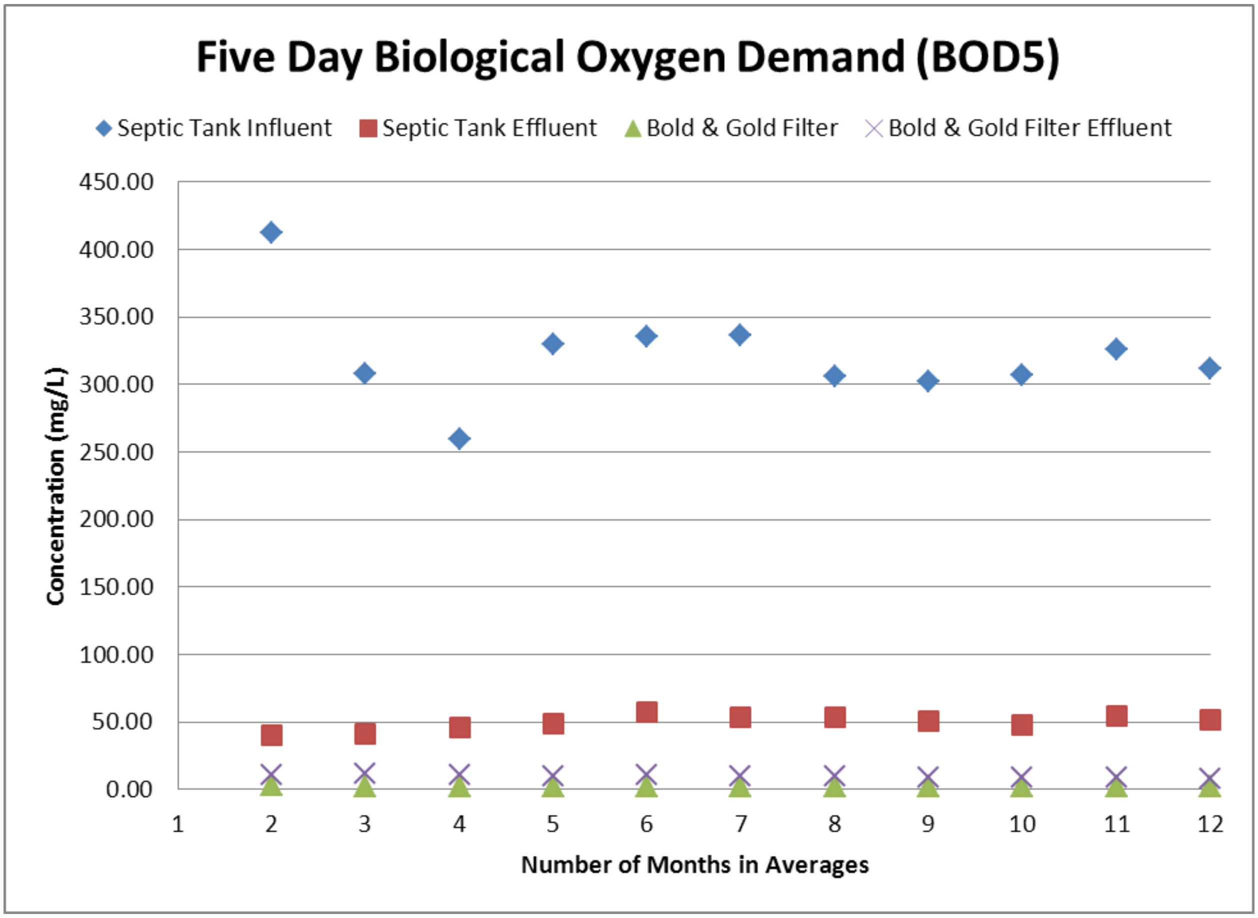

Figure 20 BOD_5 Averages Trend During Post-CO 12 Months Sampling (E1-E4)

Table 23 Average Bacteria Values from Colilert-18 Method Post-CO

Sample Location	Total Coliform (MPN per 100 mL)	Fecal Coliform (MPN per 100 mL)	E. Coli (MPN per 100 mL)
E1	8,163,620	554,180	352,400
E2	476,833	45,635	53,800
E3	5,240	273.7	367
E4	5,660	620.5	567
E5	2,180	30	40.8

Note: Values averages are for 8/08/2010 – 8/03/2011

Table 24 Bacteria Values Using Pour and Spread Plate Counts Post-CO

Note: Values averages are for 10/08/2010 – 5/05/2011

Sample Location	Fecal Coliform (CFU per 100 mL)	E. Coli (CFU per 100 mL)
E1	1,861,190	1,145,567
E2	41,738	18,332
E3	566	65.5
E4	53	30
E5	8.67	5.33
E6	33,600	17,183

Table 25 Average Bacteria Values Pre-CO

Sample Location Number of Samples	Statistic	Fecal Coliform (cfu per 100 mL)	E. Coli (cfu per 100 mL)
E1 N=8	Average	13,781,110	10,840,939
	Std Deviation	19,483,367	14,539,401
E2 N=1	Value	1,523	985
E3 N=8	Average	1,637	42.5
	Std Deviation	1,851	30.4
E4 N=8	Average	19.5	<1
	Std Deviation	13.2	0.00

3.1.2 Discussion

The OSTDS sampling cycles are for a year prior to and one year after obtaining the certificate of occupancy (CO). All data collected during both cycles are shown in the Appendices. The composition of the wastewater reflects higher ratios of fecal and urine waste during both pre- and post-CO, as compared to typical non graywater wastewater influent to OSTDS. This is because of the use of graywater in the post-CO sampling. The only source of dilution is from one shower out of four bathing areas that discharge to the OSTDS, and it is only occasionally used. Kitchen fixture use is considered average and can be another source of dilution when food organics and other wastes are not being disposed.

The influent prior to CO contained a higher composition of urine and fecal matter than post-CO, which is attributed to construction workers who worked on the home and lack of kitchen sink and shower waste inputs. Human urine composition has a high percentage of the organic compound urea [$(NH_2)_2CO$], with a concentration of 9,300 mg/L to upwards of 23,300 mg/L (Putnam, 1971). Since urea is derived from ammonia, urine has a significant impact on the concentration of nitrogen entering the OSTDS. Total phosphorus concentrations in urine range from 470 mg/L to 1,070 mg/L. The TP concentration is about eight (8) times less than the TN concentration. The post-CO raw wastewater concentrations are more stable due to the fact that the use of fixtures are more routine and the home has a diurnal flow schedule typical of a residential home site. Inputs from the one shower and the kitchen sinks dilute the urine and fecal concentrations and therefore result in lower BOD, TSS, and nutrient concentrations than in the pre-CO conditions.

After the certificate of occupancy, typically three people have been using the toilet facilities and the fixtures in the kitchens, starting on September 4, 2010. Four bathing areas and other fixtures are included in the graywater discharge. Thus, it is expected that the sampling of the influent wastewater to the septic tank reflects primarily the human waste from the home and from the kitchen sinks. This is verified from samples of the septic tank influent, which most likely has an accumulation of urine and fecal matter. The average influent or raw wastewater BOD_5 is 461.2 mg/L (Table 21) and 311 mg/L (Table 18) before and after the CO, respectively. TSS is representative of strength common to household waste but is on the high side. Total Kjedahl Nitrogen (TKN) and Total Nitrogen (TN) are higher (see Tables 19 and 22) than typical home wastewater (see Table 3) without graywater, but that is expected because the waste stream is primarily human in origin. The comparison of FSGE OSTDS raw wastewater concentrations to those typical OSTDS without graywater, and as used by the National Sanitation Foundation is shown in Table 26. FSGE waste stream is of a higher strength, or more concentrated, in nitrogen and BOD, which can be attributed to a lesser amount of potable water in the wastewater.

Table 25 FSGE OSTDS Influent Concentrations Compared to NSF Standard 245

Influent Parameters	Pre-CO Averages	Post-CO Averages	NSF 245 Standard	
			Low Value	High Value
BOD_5 (mg/L)	461	311	100	300
TSS (mg/L)	305	260	100	350
TKN (mg/L as N)	389	120.5	35	70
Alkalinity (mg/L as $CaCO_3$)	266	381	>175	NA
Temperature (^oC)	25.4	26.1	10	30
pH	7.15	7.86	6.5	9

The statistical values and percent concentration removal for the OSTDS septic tank and sorption media are provided in Tables 18-22. Based on averages for the septic tank, B&G BAM and drainfield treatment train, the post-CO reduction of $CBOD_5$ is 98.8% and TSS removal is at 97.2% (Table 18).

The reduction of total phosphorus is 73.6% during post-CO operation using the B&G BAM and drainfield, and the SRP is near zero in the effluent from the sorption media filter. The average percent removal of total nitrogen after the B&G BAM and drainfield is 98.0% (Table 22) and 71.2% (Table 19) before and after the CO was obtained, in spite of the high influent nitrogen concentrations. There was a longer residence time of 13.5 days before CO compared to 4.5 days after CO. An increased residence time increases the contact time with the sorption media for biological removal of nitrogen. The average concentration of Nitrate-Nitrogen after the sorption filter was 0.088 mg/L and 2.0 mg/L before and after the CO, respectively. Nitrate-Nitrogen as Nitrogen concentrationc did not exceed 10.0 mg/L for all testing with the range of effluent nitrate-nitrogen values between 0.002 to 3.10 mg/L.

Since flow measurements were estimated during pre-CO using number of toilet flushes and sink use, it would be beneficial to obtain additional residence time data to verify operating HRT in the pre-CO flows. For this reason, bench scale models are constructed at the Stormwater Management Academy Research and Testing Lab (SMART Lab). During post-CO, direct volumetric measures of flow were collected. These data are used to estimate average and peak flows. The peak flow factor for the FSGE OSTDS is around 2.8 times the average daily flow.

Comparisons of OSTDS Concentrations (Pre- and Post-CO)

When comparing the pollutant removal rates between pre- and post-CO, it should be noted that the residence time pre-CO is significantly greater than the post-CO residence time. The difference in water quality values between pre-CO and post-CO can be largely attributed to this difference in hydraulic residence time (HRT). An increased residence time increases the contact time with the sorption media for phosphorus removal, while also increasing the time in the aerobic and anaerobic zones for biological removal of nitrogen.

Although there is no direct measurement of the flow rate pre-CO, from construction records and conversations, the flow through the Sorption OSTDS is estimated at 15 gpd. There were no permanent residents and the only water use was toilet and sink wastewater during construction of the home, which resulted in flow only during the daytime. With the 15 gpd estimation, the pre-CO sorption filter bed residence time is 13.5 days (reactive volume of 202.5 gallons/15gpd) compared to a post-CO residence time of 4.5 days (based on 45 gpd). This implies that the sewage flow had three times the amount of residence for biological and chemical treatment before CO.

Septic Tank Effluent (E2)

The first values that suggest high residence time during pre-CO are the TSS, BOD_5, and $CBOD_5$ at location E2 (septic tank effluent). The longer the blackwater resides in the septic tank, the more time the microbes (enteric bacteria) have time to solubilize complex organic materials to volatile organic acids. These organisms are primarily heterotrophic bacteria, and some are facultative microbes (organisms that can function in either aerobic or anaerobic

conditions). The strict anaerobes in a septic tank can ferment the volatile organic acids to gases (methane, carbon dioxide, hydrogen sulfide, etc.). The microbes use the solubilized nutrients in the wastewater for cell growth and energy. The pre-CO percent removal of BOD_5 leaving the septic tank (E2) is 89.6%, while the post-CO removal is 83.4%. This can be attributed to the HRT. TSS removal is almost identical, with an 89.9% pre-CO removal and a post-CO value of 83.6%. It should be noted that the E2 values for pre-CO only had four sample dates, as that location was not an original location for the sample set.

The nitrogen species in the effluent pre-CO are also of interest. When referring to Table 22, the pre-CO nitrogen concentration dramatically changes from E1 to E2. This can possibly be attributed to two events. The first reason could be the result of "grab" sampling, which means that the influent is sampled at an instantaneous moment. The selected times that the influent samples were collected may not be representative of the average influent concentrations that enters the OSTDS over an entire day. The pre-CO samples were often sampled in the morning while people were working on site or immediately after the fixture use, which would likely result in higher than average concentrations. The second contributing factor is, again, the HRT of the septic tank. The long residence time in the septic tank results in more time for anaerobic digestion. Hydrolysis, the first process of anaerobic digestion, involves the breakdown of the complex organic compounds, which results in the conversion of organic nitrogen (Org-N) to ammonia (NH_3). Pre-CO data suggest that a 91.1% reduction in Org-N occurred from the blackwater entering and exiting the septic tank, as opposed to 70.5% conversion during post-CO sampling.

The septic effluent location (E2), which is also the polylok dipper tray, has a 74% reduction in ammonia during pre-CO conditions. The post-CO data had an increase in ammonia of 53.2% and an increase is what should be expected. There are also two explanations for this difference. The first reason for the drastic difference is again the question of variability of the "grab sample" method. The peak concentration that occurs during the grab sample has not been diluted by the diurnal fluctuation of concentration and flow. The second explanation for the reduction in NH_3 rather than increase is again attributed to the low flow rate pre-CO. The low flow into the system results in a long residence time on the dipper tray, which is partially open to the atmosphere. The amount of time that the septic effluent stays on the dipper tray, the more time the water has to convert to nitrate (NO_3^-) and then nitrogen gas (N_2), if there are appropriate bacteria in the wastewater. The septic effluent increase in nitrate concentration to 8.9 mg/L suggests that some aeration and conversion from ammonia was occurring in the dipper tray.

The total phosphorus concentration change from E1 to E2 pre- and post-CO suggests that the difference in values is attributed to the previously discussed lack of representativeness in the grab samples. Anaerobic digester (septic tank) conditions are not ideal for biological nutrient removal (BNR) and enhanced biological phosphorus removal (EBPR) to occur. Therefore, any variance between E1 and E2 must be due to the difference between the grab sample influent concentration and the average daily influent concentration. In the post-CO sampling, a composite for raw wastewater (influent to the septic tank) is used.

Bold & Gold Filter Effluent (E4)

The pre-CO percent removal for nitrogen is based on grab samples of the raw wastewater, but the effluent concentrations in the pre- and post-CO sampling are collected as a composite. The effluent concentration from the B&G filter pre-CO averaged 7.9 mg/L, with a percent removal of 98.0% (Table 22). The B&G effluent concentration post-CO averaged 37.0 mg/L, for a percent removal of 71.2% (Table 19). A reason for the concentration difference can be the HRT in the B&G filter. A conservative pre-CO HRT estimate of 13.5 days, compared to a verified post-CO HRT of 4.5 days means that the sewage had three times as long residence time in the aerobic and anaerobic zones for nitrification and denitrification.

The post-CO total phosphorus effluent annual average for location E4 is 5.1 mg/L, which is much higher than the pre-CO TP concentration of 0.08 mg/L. An explanation for this could be that the sorption capacity of the media is declining or the HRT is longer for pre CO data.

Since flow measurements were not collected until post-CO, it is decided to operate bench scale models at different residence times and to record nutrient removal. For this reason, bench scale models were constructed at the Stormwater Management Academy Research and Testing Lab (SMART Lab).

Bold & Gold Filter Effluent + Drainfield (E5)

In the post-CO time period, the effluent nitrogen data from the B&G sorption filter (E4) can be compared to that from the drainfield (E5) to determine if the drainfield is adding additional nitrogen removal after the sorption filter bed. According to the results in Table 19, the concentration leaving E5 is 7.3 mg/L less than E4, increasing the removal of TN up to 76.9%. This increase in removal is considered significant and the drainfield following the sorption media

filter would have value in providing additional nitrogen removal. Also if the sorption media filter becomes clogged, then the standard conventional system remains in operation until the sorption media filter can be made functional again.

The TP measured at E4 in Table 20 is 5.1 mg/L with a percent removal of 67.7%. This is different from the 4.1 mg/L recorded for the drainfield (73.6% removal) at E5 location. SRP is known to adhere to soils naturally and could just as easily be sorbed to the natural sandy soil condition as it does in the filter sand existing in the drainfield.

Conventional Drainfield (E6) compared to the sorption media plus drainfield (E5)

Again, the conventional drainfield had not been sampled during pre-CO conditions due to the low flow, but the post-CO conditions E4, E5 and E6 data can be used. The average concentration of total nitrogen (TN) leaving the conventional drainfield is 70.1 mg/L. The average concentration from the septic tank is 93.1 mg/L. This is significantly higher than the 29.7 mg/L leaving the sorption filter bed and its drainfield. The total phosphorus (TP) effluent concentration from the conventional drainfield (E6) had a concentration of 10.6 mg/L and a reduction of 32.1%. The concentration from the sorption media and drainfield (E5) is about 60% less or 4.1 mg/L.

Nitrification and Denitrification in Sorption Media

The sorption media is specifically designed to have conditions that will promote both nitrification and denitrification in the system. After reviewing the results, the DO concentration in the aerobic zone of the sorption media (E3) shows significant conversion of ammonia to nitrate. From E2 to E3, ammonia decreases from 78.9 mg/L to 30.9 mg/L and nitrate increases from 3.2 mg/L to 18.3 mg/L. This suggests that it is possible that nitrification-denitrification is occurring simultaneous. The DO concentration in the aerobic zone is 2.42 mg/L, which is adequate for microbial growth of *Nitrosomonas* and *Nitrobacter*.

The conditions in E4 are measured at the discharge location of the sorption media following the anaerobic zone. At this location the nitrate concentration is reduced from 18.3 mg/L to 2.0 mg/L, which implies denitrification has occurred. The DO concentration at E4 is 2.67 mg/L, which does not fall into the range of anoxic/ anaerobic conditions. A possible explanation for this increase in DO concentration is that the riser pipe used for sample collection allows oxygen from the atmosphere to contact the water surface. Pre-CO sampling of the anaerobic zone suggests a DO of about 1.0 mg/L, which is still not reasonably accommodating for anaerobic bacteria at that particular location. A recent study by Hayatsu et al (2008) suggests that that a wide variety of bacteria are able to carry out aerobic denitrification and that aerobic denitrifying bacteria are distributed across diverse environments. In addition, the influence of O_2 concentration on the denitrifying activity differed from one denitrifying bacterium to another. Thus, aerobic denitrification is now considered as a variant represented by several denitrifying

bacteria rather than a rare exception. *Paracoccus denitrificans* (*pantotropha*), a representative aerobic denitrifying bacterium, has been characterized extensively (Hayatsu et al, 2008).

Final Effluent Concentrations

The final effluents from location E5 (B&G BAM + Drainfield) and E6 (Conventional Drainfield) are significantly different. The sorption media plus drainfield provide TSS and $CBOD_5$ below the required 10 mg/L (7.2 mg/L and 3.5 mg/L) for the FDOH classified *Advanced Secondary Treatment Systems*. The effluent for the conventional drainfield had TSS and $CBOD_5$ above 10 mg/L (29.6 and 29.0 mg/L). The effluent total nitrogen and total phosphorus for the innovative system are 29.7 mg/L and 4.1 mg/L, which are not low enough for the 20 mg/L nitrogen requirements, but are below the 10 mg/L phosphorus requirements. The conventional drainfield has an effluent total nitrogen concentration of 70.1 mg/L and an effluent total phosphorus concentration of 10.6 mg/L, which both fail to meet FDOH *Advanced Secondary Treatment* requirements. The estimates of daily and yearly mass loadings for the sorption filter system (B&G + drainfield) compared to the conventional system at FSGE are shown in Tables 23 and 24. The sorption filter system has lower mass loadings. This is because of concentration differences in the effluent in the bottom of the drainfields. The average flow for each system is 45 gallons per day from direct measurements of flow.

Final Effluent Loadings

In terms of mass loadings, the sorption filter OSDTS is compared to a conventional OSTDS, both with gray water use (Tables 27 and 28). Also, OSTDS with and without the use of graywater are compared in terms of mass loadings (Table 29). For OSTDS not using gray water and for calculation purposes, a flow rate of 69.3 gpcd (Table 1) is used with an average occupancy of 3.1 persons for a total flow into an OSTDS of 215 gallons per day. The flow when using gray water is 90 gallons per day as measured at FSGE OSTDS. Assuming an OSTDS can be operated to meet advanced secondary standards of 10 mg/L for TSS, $CBOD_5$, and Phosphorus; and 20 mg/L for Nitrogen, the daily discharge mass loadings based on 10 mg/L are calculated for the non graywater advanced secondary OSTDS as 0.018 pounds/day [10 mg/L x 215 gallons/day x $8.35(10^{-6})$ conversion factor]. The conversion factor is [3.79 (Liters/gallon) /(1000 (millgrams/gram) x 454 (grams/pound))]. Thus advanced secondary treatment effluent mass loadings at 10 mg/L can be calculated based on a given flow rate

There are approximately 2.68 million OSTDS in the State of Florida. The average daily load based on the effluent concentration data from the OSTDS FSGE systems using graywater at a flow rate of 90 gpd are compared to the advanced secondary treatment standards using 215gpd (or no use of graywater). The results shown in Table 29 illustrate that the graywater system with sorption media produce less pollutant mass than the advanced secondary OSTDS without graywater. Also, the sorption filter without a drainfield and with graywater also discharges less mass than an advanced secondary one without graywater. The differences in Table 29 on a daily basis appear significant.

Table 26 Daily Pollutant Mass Loadings from FSGE OSTDS

Using Average Flow Rate at FSGE in study period of 45 gallons/day

Sampling Site	TSS (lbs/day)	$CBOD_5$ (lbs/day)	Total Nitrogen (lbs/day)	Total Phosphorus (lbs/day)
E4 : B&G	0.0086	0.0024	0.0140	0.0019
E5 : B&G & Drainfield	0.0034	0.0013	0.0112	0.0015
E6 : Conventional	0.0113	0.0111	0.0261	0.0038

Table 27 Yearly Mass Loadings from FSGE OSTDS with Graywater

Using Average Flow Rate at FSGE in study period of 45 gallons/day

Sampling Site	TSS (lbs/year)	$CBOD_5$ (lbs/year)	Total Nitrogen (lbs/year)	Total Phosphorus (lbs/year)
E4 : B&G	3.14	0.89	5.11	0.71
E5 : B&G & Drainfield	1.23	0.49	4.09	0.55
E6 : Conventional	4.13	4.05	9.54	1.37

Table 28 Daily Mass Loadings for FSGE OSTDS with Graywater Compared to Advanced Secondary Treatment without Graywater for OSTDSs in the State of Florida

For graywater, average flow rate of 90 gallons/day/system. A septic tank population of 2.68 million

Sampling Site	TSS (lbs/day)	$CBOD_5$ (lbs/day)	Total Nitrogen (lbs/day)	Total Phosphorus (lbs/day)
E4 : B&G	46,166	12,864	75,040	10,426
E5 : B&G & Drainfield	18,104	6,968	60,032	8,058
E6 : Conventional	60,684	59,496	139,896	20,166
AS : Advanced Secondary Std & no Graywater (Q=215gpd)	at 10 mg/L 48,100	at 10 mg/L 48,100	at 20 mg/L 96,200	at 10 mg/L 48,200
Difference (E6-E5)	**42,580**	**52,528**	**79,864**	**12,108**
Difference (AS-E5)	**29,996**	**41,132**	**36,168**	**40,142**
Difference (AS-E4)	**1,934**	**35,236**	**21,160**	**37,774**

3.2 Bench Scale Model of Bold & Gold Filter Media

The sorption bench scale B&G filter model is operated at 3 HRTs (1, 2.25 and 4.50 days), from May to August, 2011. The influent water used is directly collected from the E2 location at FSGE. The samples are analyzed by a NELAC certified laboratory for nitrogen and phosphorus species. The field parameters (pH, DO, conductivity, and temperature) are monitored at the bench scale operation. The nutrient results are shown in Table 30 along with alkalinity. The percent removal for nutrients is summarized in Table 31.

3.2.1 Results

Table 29 Nutrient Data for Bench Scale Filter Beds

Overall Statistics	Alkalinity (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	TKN (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Average	413	93.2	0.1	0.0	0.1	104.8	104.8	12.2	12.6
Median	410	98.0	0.1	0.0	0.1	110.0	110.0	12.0	13.0
Std. Dev	52.4	14.0	0.0	0.0	0.0	19.1	19.1	1.7	2.6

HRT = 2.25 days

Overall Statistics	Alkalinity (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	TKN (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Average	365	38.20	0.06	0.01	0.07	46.60	46.60	0.08	0.37
Median	382	39.00	0.06	0.01	0.05	48.00	48.00	0.02	0.26
Std. Dev	38.6	6.98	0.03	0.00	0.03	8.44	8.44	0.12	0.27
Removal	**NA**	**59.0%**	**NA**	**NA**	**NA**	**55.5%**	**55.5%**	**99.4%**	**97.0%**

HRT = 4.50 days

Overall Statistics	Alkalinity (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	TKN (mg/L)	TN (mg/L)	SRP (mg/L)	TP (mg/L)
Average	370	30.50	0.09	0.01	0.10	34.50	34.50	0.02	0.11
Median	375	33.00	0.06	0.01	0.09	37.50	37.50	0.02	0.12
Std. Dev	29.4	8.81	0.08	0.00	0.07	10.85	10.85	0.01	0.02
Removal	**NA**	**67.3%**	**NA**	**NA**	**NA**	**67.1%**	**67.1%**	**99.8%**	**99.2%**

Table 30 Table of HRT and Percent TN Removal

HRT (Days)	**Percent TN Removal (%)**	%TP Removal
1.00	37.1	91.0
2.25	55.5	97.0
4.50	69.2	99.2
13.5	98.0	99.6

The removal data for nitrogen associated with HRT values of 1.00 and 2.25 are derived from the bench scale model. The 4.50 days HRT is averaged between bench scale model (67.1%) and FSGE percent removal (71.2%) during post-CO sampling. The 13.5 day HRT data are from the pre-CO operation (Rivera, 2010). The removal data for phosphorus removal are associated with the HRT values for 1.00, 2.25, and 4.50 as determined from bench scale model values. The 13.5 day HRT percent phosphorus removal value is taken from pre-CO operation (Rivera, 2010).

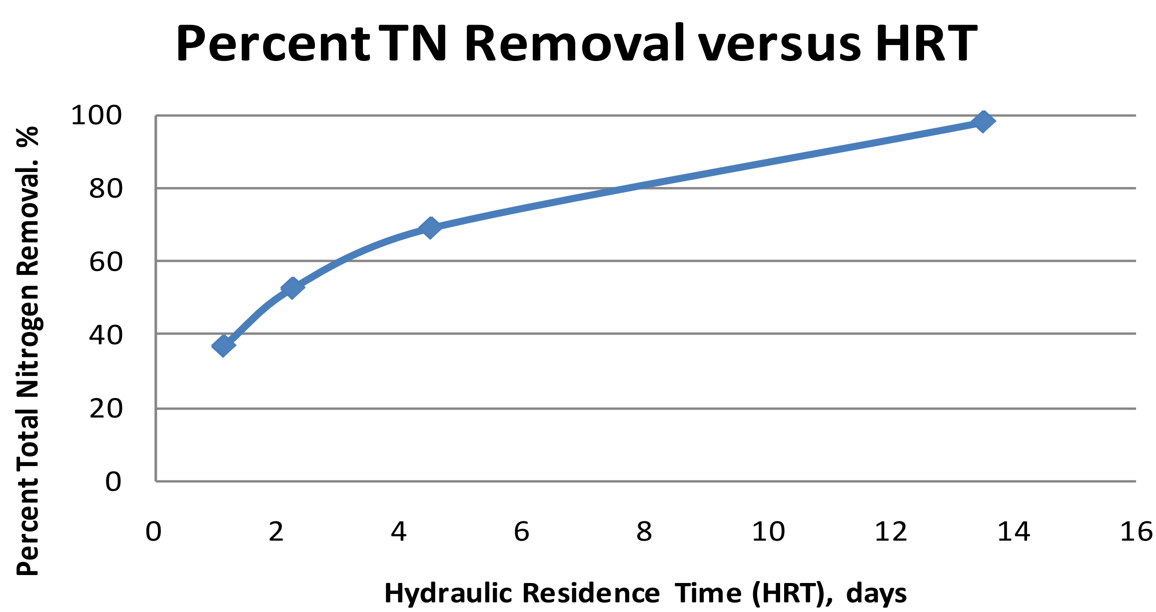

Figure 21 Total Nitrogen Percent Removal versus HRT

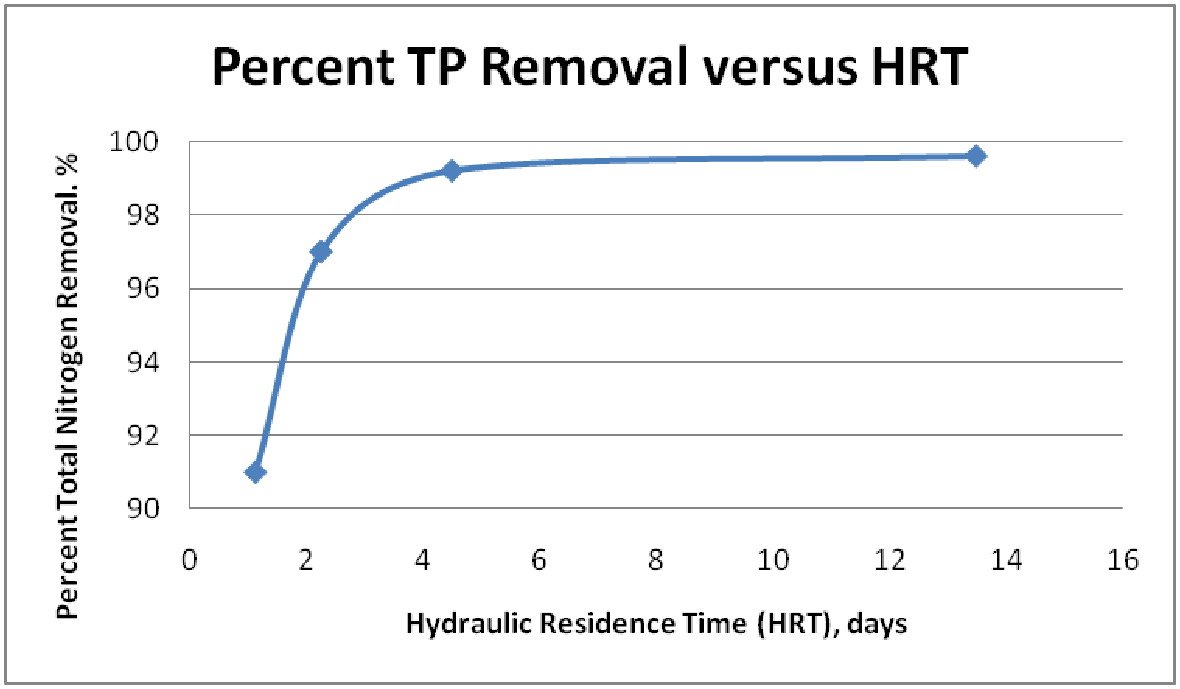

Figure 22 Total Phosphorus Percent Removal versus HRT

3.2.2 Discussion

The results from the bench scale model are compared for verification, to those of the full scale operation of FSGE OSTDS results. At a 4.50 days HRT for both the full scale and the bench scale the average removal was 67.1 % and 71.2 % during post-CO operation. Although the bench scale TN removal rates are consistent with FSGE removal rates, the phosphorus removal rates are higher in the bench scale testing. The plausible explanation for this difference in TP percent removal is that the capacity of the sorption media has steadily decreased over the two years of operation. A number of previous Bold & Gold filter studies support the removal value of 90% for long term operation however.

The curves of Figures 21 and 22 follow a logarithmic trend, having a correlation coefficient (r) value close to 1.0. A longer HRT produces a greater removal.

To achieve an average nitrogen effluent of 10 mg/L with an average influent of 104.8 mg/l (average during the bench scale treatment), a removal of about 90.5% is needed which is a HRT of about 11 days (Figure 21). However, if the influent nitrogen concentration were around 50 mg/L, then 80% removal is necessary which from Figure 21 a HRT of about 7.5 days.

The plot of total phosphorus (TP) versus HRT is shown in Figure 22. The trend line for TP removal versus HRT indicates removal is approaching 100% with increasing HRT. It appears that there is limited additional phosphorus removal past a HRT of about 5-6 days.

3.3 Combined Stormwater-Graywater Cistern

3.3.1 Results

Table 31 Post-CO Field Measurements for Cistern Water

Statistic	pH	Turbidity (NTU)	Conductivity (µS/cm)	Temperature (°C)	Alkalinity (mg/L $CaCO_3$)	DO (mg/L)
Averages	7.56	4.35	2828	24.48	92.08	6.33
Median	7.58	2.69	2840	24.10	101.50	5.87
Std. Dev	0.22	3.12	1091	3.68	32.10	2.42

Table 32 Post-CO Laboratory Metals Data for Cistern Water

Statistic	Sodium, Na (mg/L)	Magnesium, Mg (mg/L)	Calcium, Ca (mg/L)	SAR	Hardness (mg/L as CaCO3)
Averages	345	66.7	97.9	6.59	518.5
Median	369	77.7	120.6	6.44	620.7
Std. Dev	153	34.7	50.6	1.60	83.6

Table 33 Post-CO Laboratory Nutrient Data for Cistern Water

Statistic	Ortho-Phosphate (mg/L P)	TP (mg/L)	Ammonia (mg/L)	NO_x-N (mg/L)	TN (mg/L)
Averages	0.05	0.09	0.60	0.11	0.69
Median	0.03	0.05	0.58	0.10	0.61
Std. Dev	0.04	0.09	0.47	0.08	0.32

Table 34 Ten Month Nutrient Statistics for Cistern Water (Pre-CO)

Statistic	Ortho-Phosphate (mg/L P)	TP (mg/L)	Ammonia (mg/L)	NO_x-N (mg/L)	TN (mg/L)
Averages	0.10	0.31	0.09	0.16	0.73
Median	0.09	0.29	0.06	0.11	0.54
Std. Dev	0.08	0.22	0.07	0.11	0.36

Table 35 Ten Month Bacterial Sample Statistics for Cistern Water (Pre-CO)

Statistic	Total Coliform (cfu per 100 mL)	E. Coli (cfu per 100 mL)	Enterococci (cfu per 100 mL)
Average	194.2	5.6	138.5
Median	241.6	0.0	141.36
Std. Dev.	76.5	15.0	95.81

3.3.2 Discussion

From the cistern water data in the previous section (Tables 32-36), it can be concluded that the cistern water is acceptable for its intended applications at FSGE. The pH, alkalinity, turbidity, DO, and temperature are consistent and acceptable values for typical non-potable use. The nutrient concentrations are well below discharge standards, but at the same time the presence of nitrogen and phosphorus will be beneficial for vegetative uptake and synthesis

during irrigation events. The high sodium concentration is acceptable for the salt tolerant plants that are native to the subtropical climate of Florida, and more specifically the coastal regions.

Monitoring of the HPC bacterial count of the cistern was performed during post-CO conditions and established that there were low, if any, fecal coliform or *E. Coli* in the cistern water. The graywater is filtered and disinfected with ozone with an oxidation reduction potential (ORP) probe to assure the ORP is above the required 600 mV for water disinfection. The 600 mV should sufficiently destroy the microorganisms, resulting in less than 1 cfu per 100 mL.

Estimated integrated stormwater and graywater for blackwater flow within the home is 90 gpd and is based on an average occupancy of 3.1 persons per day at 29 gallons per person per day over the one year measurement period. The remainder of the demand for integrated stormwater and graywater is for micro-drip irrigation of lawn plants, residual water in laundry, and the five green roofs.

3.4 Economic Feasibility

The economic feasibility of implementing the combined stormwater/graywater cistern is assessed knowing there is a reduction in potable water demand. For a conventional home the average estimated indoor water use in gallons per day per capita (gpcd) is 69.3 (Table 1). The average potable water use at FSGE has been reduced to about 41 gpcd. From Table 1, the toilet usage is 26.7% of typical indoor water use, and based on the typical average consumption

use of Table 1, the indoor water used for the toilets is 18.5 gpcd (69.3x0.267) or as used in the toilets. If this water were replaced with graywater and using a potable charge fee of $4.40 per 1000 gallons (http://www.melbourneflorida.org/utilbill/rates.htm), the estimated annual savings due to reduced potable water use for a home with four occupants is approximately $118.84 (18.5x4x365x4.40/1000). FSGE also uses graywater for cloths washing, thus the additional annual savings in potable water cost is $96.60 (69.3x0.217x4x365x4.40/1000). The savings in potable water cost using FSGE integrated stormwater and graywater cistern design is $215.44 (118.84+96.60) per year. Note that this does not include the irrigation demand, which could be a significant addition to potable water demand and thus could increase the amount of savings per year. The additional construction cost of FSGE graywater system is $8600 (plumbing plus the cisterns). Simply dividing the capital cost by the yearly savings means that the capital cost would be recovered in about 40 years. This does not include the yearly increase in the cost of water or the savings in irrigation water demand. The system life expectancy is about 40 years.

The economic feasibility of implementing the B&G BAM wastewater treatment can be related to the additional cost of the treatment and the cost savings due to less potable water used. Through the combined stormwater/graywater cistern, the sewage flow over a four (4) month period of time is an average of 29 gpcd. This includes flow from the toilets and the kitchen sinks, plus one downstairs shower. The graywater used in the toilets is estimated at 18.5 gpcd (see Table 1) which is 64% (18.5/29) of the sewage flow. Additional cost of the B&G BAM OSTDS is $3500. Based on a home with four occupants, the yearly (365 day) flow

at 29 gpcd is 42,340 gallons (29x4x365). Over forty years (expected lifetime) with no inflation in the cost, the treatment cost would be $2.07 per thousand gallons [($3500)/(40x42.34)]. The yearly cost would be $87.65 (2.07x29x4x365/1000). The cost savings in potable water is based on the volume of potable water not used. The yearly cost of potable water not used at $4.40 per thousand gallons when replaced by graywater for toilet flushing is $118.84 (18.5x4x365x4.40/1000). The yearly potable water saved is 27 thousand gallons (18.5x4x365/1000). Thus there would be an offsetting yearly benefit from additional treatment due to the savings in potable water cost or ($118.84 vs. $87.65). It is worth repeating that this analysis assumes no inflation for potable water rate cost as well as no off setting cost due to environmental improvement from lower nutrient loadings. Also the plumbing cost to deliver the graywater has not been considered. The plumbing costs however were considered in the cistern cost analysis.

CHAPTER 4 CONCLUSIONS

4.1 Onsite Sewage Treatment and Disposal System

After completing the one year sample plan for the OSTDS at FSGE, a number of conclusions have been established. First, for the flow rate and wastewater strength associated with FSGE, a graywater home, a septic tank followed by a sorption media filter and drainfield can be used to meet TSS and $CBOD_5$ secondary treatment standards as well as advanced secondary TSS and $CBOD_5$ treatment standards. The conventional OSTDS (septic tank and drainfield) does not provide adequate conditions for biological and physical removal to meet desired secondary treatment standards, and much less the advanced secondary treatment standards. With regard to nutrient removal, the sorption media OSTDS performed to remove more nitrogen and phosphorus than the conventional system. Also, nitrogen removal can be reduced significantly with longer residence time in the B&G BAM filter.

One outcome from an analysis of the wastewater data is the identification of higher concentrations of raw wastewater pollutants from a home designed for using graywater. Thus additional reduction in the concentration of the pollutants must be accomplished with OSTDS. This is of particular concern with nitrogen as the raw water concentrations were about 2.5 times greater (~ 128.5 vs. 50 mg/L) than with homes using conventional plumbing or those not using graywater.

Passive on-site treatment is currently a practical OSTDS option to the state of Florida's nutrient issue while also considering the triple bottom line (TBL) of social acceptability, low cost and environmental protection. The TBL is a framework for encouraging institutional concern about sustainability in every aspect of future practices. Within the framework of TBL is consideration for the impact on society, the environment, and economic sustainability. The intersection of all three considerations leads to sustainable solutions (see Figure 23).

The innovative system (Bold & Gold™ BAM sorption media filter bed) at FSGE addresses economic sustainability, as the system has a unit cost of only $1.15 more than a conventional drain system per 1000 gallons treated (Table 6). The installation cost of the additional B&G BAM was about $3500. The cost savings considering the reduce cost for using less potable water was shown to be about equal to the additional treatment cost per 1000 gallons ($4.40 for potable water vs. $4.13 additional cost of the B&G BAM over 20 years with no increases in potable cost over time). Also, the passive treatment system means there are no energy costs and the O&M is considered equivalent to a conventional system. The life expectancy of a sorption media filter bed in terms of nutrient removal is as least as long as a drainfield life expectancy. Considering all the OSTDS in the State of Florida, our State's water quality and the environmental sustainability would be well enhanced through the approval of this innovative passive nutrient reducing OSTDS since they have the potential to eliminate tons per day of pollutants (nutrients, TSS, and pathogens) from Florida's water bodies. Since the system is passive there is no energy consumption, the B&G BAM or any passive system reduces the amount of energy consumption that directly or indirectly leads to greenhouse gas emissions and

specifically more nitrogen in the atmosphere that results in increased nitrogen levels in stormwater. Finally, the sorption media contains approximately 200 gallons of shredded recycled tire that could otherwise be burned or disposed of in a landfill. The impact on society can only be viewed as positive. Future installation of these systems in third world countries, or other areas that are in need for practical wastewater treatment, is extremely plausible. The resources required for installation of the Bold & Gold™ Bio-sorption Activated Media are readily available and the installation is not complex. The systems do not have an effect on societal activities, as they are designed as a replacement to the current conventional system.

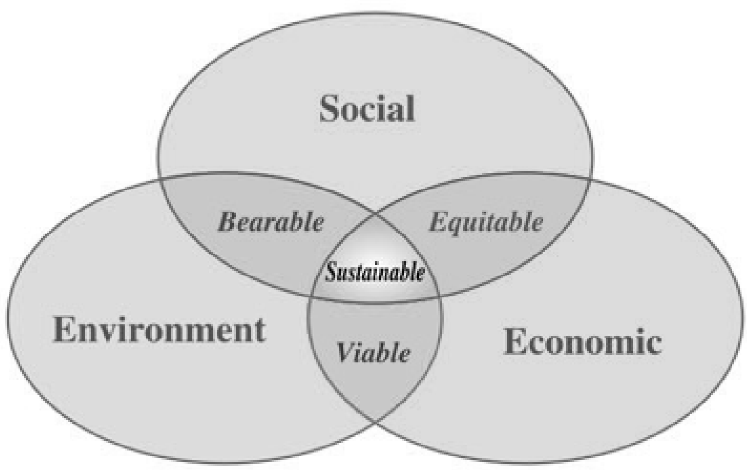

Figure 23 Triple Bottom Line Diagram

The simplicity of the passive system makes them ideal for the general population. It should take no additional maintenance with the B&G BAM system relative to the conventional OSTDS. At the same time, it is recognized that even with passive treatment, septic tanks are still one of the more significant contributors to nutrient pollution. The fact is that there are about

2.68 million septic tanks and the estimated nutrient concentration in the effluent is an order of magnitude higher than the average wastewater treatment plant. A State or local program can be made to bring all contributing sources of nutrient loadings to equally low concentrations. The technology is there to bring OSTDS effluent concentrations below 10 mg/L TN, the design and implementation need to be aligned and a funding program implemented for an integrated stormwater, graywater and wastewater home.

4.2 Graywater/Stormwater Cistern

The water quality in the cistern presents no hazards for non-potable applications. The pre-CO bacterial analysis showed that the stormwater and graywater had no fecal coliform present. The high salinity does not adversely impact the vegetation or soils. The sodium adsorption ratio appears to also not be a concern. The ozonation is reducing the bacteria populations and not causing any of the cancer causing issues when using chlorine. In addition, there was always a significant quantity of water in the cistern because the graywater inputs are independent of rainfall and available on a daily basis. The stormwater also was contained on the site with the LID practices that are in place. The green roofs also are functioning properly in the post-CO as well as the pre-CO analyses periods.

The only issue appears to be based on the observation of scale formations in the toilets. However the scale can be removed by simple cleaning without caustic chemicals.

4.3 Recommendations for Future Work

In some watersheds such as those feeding springs and estuaries, there is an interest in reducing nutrient concentrations and mass loadings. This is especially true where Total Maximum Daily Loads have been adopted for impaired water bodies and pollutant load reductions are required to achieve the TMDL standards. Since central sewers may not be possible in all areas, the innovative nutrient reducing OSTDS is a viable option to reduce nutrient loadings. This study provides an option of using Biosorption Activated Media to reduce nutrient concentrations and an integrated stormwater and graywater system to reduce flows. These systems may be furthered refined in design and operation and then measured.

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APPENDICES

Table 36 List of Bacteria Data for FSGE OSTDS

Date Collected	Sample Description	Fecal Coliform (cfu per 100 mL)	E. Coli (cfu per 100 mL)
11/16/2009	E1	5,000.00	4,200.00
	E3	< 1	< 1
	E7	< 1	< 1
	E4	< 1	< 1
12/30/2009	E1	< 1	< 1
	E3	< 1	< 1
	E7	< 1	< 1
	E4	< 1	< 1
1/26/2010	E1	< 1	< 1
	E3	8.00	4.00
	E7	< 1	< 1
	E4	< 1	< 1
2/10/2010	E1	551.00	496.00
	E3	< 1	< 1
	E7	< 1	< 1
	E4	< 1	< 1
3/11/2010	E1	< 1	< 1
	E3	< 1	< 1
	E7	283	-115.6
	E4	< 1	< 1
4/15/2010	E1	52,000,000.00	38,400,000.00
	E3	4,900.00	81.00
	E7	293	263
	E4	35.00	< 1
5/18/2010	E1	14,000,000.00	13,200,000.00
	E3	4.00	< 1
	E7	8	4
	E4	< 1	< 1
7/20/2010	E1	2,900,000.00	2,600,000.00
	E2	1,523.00	985.00
	E3	30	11
	E4	4.00	<1

Date Collected	Sample Description	Fecal Coliform (cfu per 100 mL)	E. Coli (cfu per 100 mL)
10/08/2010	E1	19200000	14266667.0
	E2	48000	36900.0
	E3	254	148.0
	E4	204	136.0
	E5	22	15.0
11/09/2010	E1	53,000.00	22,000.00
	E2	54,600.00	43,600.00
	E3	81.00	73.00
	E4	106.00	67.00
	E5	-	-
12/09/2010	E1	260,000.00	55,000.00
	E2	13,500.00	8,400.00
	E3	27.00	8.00
	E4	26.00	11.00
	E5	-	-
	E6	-	-
1/13/2011	E1	956,522.00	490,000.00
	E2	29,200.00	4,900.00
	E3	148.00	4.00
	E4	0.00	0.00
	E5	-	-
2/10/2011	E1	2,000,000.00	1,660,870.00
	E2	54,000.00	8,400.00
	E3	96.00	15.00
	E4	0.00	0.00
	E5	-	-
3/08/2011	E1	2,200,000.00	2,020,000.00
	E2	8,200.00	1,460.00
	E3	172.00	64.00
	E4	0.00	0.00
	E5	0.00	0.00

Date Collected	Sample Description	Fecal Coliform (cfu per 100 mL)	E. Coli (cfu per 100 mL)
4/07/2011	E1	3,300,000.00	3,200,000.00
	E2	47,200.00	18,000.00
	E3	46.00	4.00
	E4	4.00	0.00
	E5	-	-
	E6	22,800.00	10,150.00
5/05/2011	E1	4,200,000.00	290,000.00
	E2	79,200.00	25,000.00
	E3	3,700.00	208.00
	E4	88.00	42.00
	E5	-	-
	E6	44,400.00	41,400.00
6/06/2011	E1	3,800,000.00	932,740.00
	E2	63,200.00	39,600.00
	E3	12.00	4.00
	E4	4.00	0.00
	E5	-	-
	E6	59,200.00	39,600.00
7/07/2011	E1	3,400,000	1,382,609
	E2	52,800	50,400
	E3	854	815
	E4	15	4
	E5	35	4
	E6	28,200	26,400
8/03/2011	E1	2,266,667	550,000
	E2	11,333	7,600
	E3	196.00	168.00
	E4	156.00	48.00
	E5	23.00	0.00
	E6	10,800.00	4,000.00

Table 37 List of OSTDS Field Measurements

Date Collected	Sample Description	pH	Conductivity (µS/cm)	DO (mg/L)	Temperature (°C)
12/09/2009	E1	6.62	3.50	5.73	25.6
	E3	7.08	2.45	1.98	25.2
	E7	6.98	2.46	2.22	25.6
	E4	7.09	2.48	2.06	24.9
1/26/2010	E1	6.30	4.08	5.37	20.4
	E3	7.11	2.30	2.89	20.5
	E7	7.07	2.62	5.14	20.8
	E4	6.95	2.48	2.69	22.5
2/23/2010	E1	6.54	3.68	5.46	20.1
	E3	7.05	2.35	3.02	20.1
	E7	7.03	2.56	4.86	19.9
	E4	7.02	2.36	2.56	20.1
3/31/2010	E1	6.42	3.75	5.58	22.8
	E3	7.03	2.25	2.75	22.7
	E7	6.99	2.59	3.54	22.8
	E4	7.02	2.55	2.54	22.6
4/29/2010	E1	8.02	5.31	0.32	25.9
	E3	7.36	2.50	1.96	25.5
	E7	7.34	2.20	2.02	26.4
	E4	7.28	2.58	2.20	26.0
6/02/2010	E1	7.75	4.63	0.54	26.3
	E3	7.21	2.63	2.63	26.0
	E7	7.02	2.14	2.22	26.4
	E4	7.10	2.02	2.50	26.3
7/28/2010	E1	7.71	6.55	1.05	30.8
	E2	7.25	2.71	0.47	30.4
	E3	7.23	2.86	2.78	30.4
	E4	7.29	2.45	2.33	30.4
8/12/2010	E1	7.84	6.29	0.14	31.5
	E2	7.77	3.00	0.70	29.9
	E3	7.15	2.78	3.13	31.4
	E4	7.02	2.66	1.70	30.6
9/19/2010	E1	7.79	4.44	2.00	28.6
	E2	7.62	3.1	0.2	30.3
	E3	7.00	2.64	2.00	30.4
	E4	7.08	2.64	1.86	30.4
10/17/2010	E1	7.22	4.10	1.80	25.9
	E2	7.3	3.1	0.12	27.1
	E3	6.76	2.75	2.57	27.4
	E4	6.96	2.76	2.17	27.2

Date Collected	Sample Description	pH	Conductivity (µS/cm)	DO (mg/L)	Temperature (°C)
11/09/2010	E1	8.10	3.95	5.40	22.8
	E2	7.80	2.99	0.14	23.7
	E3	7.18	2.79	2.51	23.7
	E4	7.11	2.74	3.08	22.4
	E5	6.77	2.90	6.80	24.5
12/09/2010	E1	8.03	2.77	3.70	24.4
	E2	7.73	3.19	0.20	19.6
	E3	7.19	2.65	1.79	19.8
	E4	7.45	3.42	3.08	20.0
1/13/2011	E1	7.48	4.79	3.94	15.9
	E2	7.53	2.57	0.32	15.8
	E3	7.25	2.41	2.40	16.2
	E4	7.40	2.59	4.51	16.3
	E5	7.83	2.51	6.50	15.9
2/10/2011	E1	7.85	3.07	2.07	22.0
	E2	7.51	2.45	0.09	21.6
	E3	7.21	2.62	2.85	21.7
	E4	7.18	2.63	2.42	22.3
	E5	7.54	2.60	5.11	22.1
3/08/2011	E1	7.61	2.13	2.33	24.6
	E2	7.15	2.69	0.19	24.1
	E3	7.13	2.60	2.92	24.3
	E4	7.21	2.25	2.42	24.6
	E5	7.54	2.60	5.11	22.1
4/07/2011	E1	7.89	1.12	0.73	25.0
	E2	7.36	2.30	0.15	25.1
	E3	7.07	2.34	2.10	24.8
	E4	7.13	2.37	2.52	25.0
	E5	7.11	2.38	4.84	24.4
	E6	7.89	1.12	0.73	25
5/05/2011	E1	8.74	1.99	3.23	28.7
	E2	7.64	3.12	0.04	26.7
	E3	7.12	2.70	2.30	27.5
	E4	7.24	2.46	2.03	27.0
	E5	7.68	3.12	5.76	30.0
	E6	7.78	2.09	0.71	26.7
6/06/2011	E1	7.77	3.09	0.30	29.8
	E2	7.43	2.8	0.13	28.6
	E3	7.09	2.72	2.61	29.8
	E4	7.31	2.53	2.6	29.7
	E5	7.55	2.48	3.7	28.8
	E6	7.66	2.87	0.44	28.8
7/7/2011	E1	7.50	1.50	1.67	31.7
	E2	7.14	2.41	0.1	30.1
	E3	6.79	2.44	2.67	29.2

Date Collected	Sample Description	pH	Conductivity (µS/cm)	DO (mg/L)	Temperature (°C)
7/7/2011	E4	6.80	2.58	2.37	28.7
	E5	6.92	2.49	3.41	28.9
	E6	7.1	2.43	0.84	30.9
8/03/2011	E1	8.31	3.59	2.03	33.7
	E2	7.87	2.59	0.08	32.8
	E3	7	2.5	2.32	33.5
	E4	7.34	2.45	2.93	32.2
	E5	7.52	2.57	4.37	31.9
	E6	7.76	2.67	1.23	33.1

Table 38 List of Chemical Data for FSGE OSTDS

Date Collected	Sample Description	Alkalinity (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	$CBOD_5$ (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Org. N (mg/L)	TKN (mg/L)	Total N (mg/L)	SRP (mg/L)	Org. P (mg/L)	Total P (mg/L)
12/9/2009	E1	567	85.5	314	197	6.763	1.716	0.011	1.705	367.246	374.009	375.725	6.355	1.612	7.967
	E3	524	25	102	79.5	0.62	0.013	0.004	0.009	10.858	11.478	11.491	0.017	0.091	0.108
	E7	528	21	55.6	55.2	0.983	0.01	0.004	0.006	10.601	11.584	11.594	0.002	0.062	0.064
	E4	515	54.1	32.7	29.9	0.254	0.006	0.002	0.004	7.379	7.633	7.639	0.011	0.108	0.119
1/20/2010	E1	212	31	1101	1080	64.464	0.55	0.091	0.459	747.275	811.739	1271.161	10.95	5.562	16.533
	E3	346	99	108	20	10.06	5.325	1.038	4.287	8.257	18.317	15.945	0	0.055	0.09
	E7	277	22	106	105	2.783	0.01	0.003	0.007	2.96	5.743	3.097	0.011	0.071	0.09
	E4	348	43	59.9	46	2.609	0.005	0.003	0.002	3.425	6.034	3.612	0.009	0.059	0.08
2/23/2010	E1	220	43	524	420	31.016	1.199	0.912	0.287	170.529	201.545	176.361	7.078	0.416	7.804
	E3	193	64	1.4	1.2	9.349	21.857	0.369	21.488	16.23	25.579	39.15	0.008	0.085	0.099
	E7	148	15	56	42.8	1.23	0.015	0.006	0.009	1.275	2.505	1.556	0.07	0.018	0.098
	E4	92	27	45.9	34.6	2.505	0.009	0.003	0.006	2.723	5.228	3.029	0.002	0.038	0.129
3/31/2010	E1	240	977	538	489	20.19	0.231	0.081	0.15	122.625	142.815	146.165	28.314	2.066	37.322
	E3	166	33	1.1	0	0.068	1.028	0.039	0.989	1.291	1.359	3.136	0.095	0.012	0.29
	E7	156	5	22.8	14	0.088	0.006	0	0.006	1.146	1.234	2.551	0.029	0.06	0.196
	E4	173	12	13.8	9	1.309	0.005	0.003	0.002	3.036	4.345	10.378	0.012	0.07	0.108
4/29/2010	E1	227	140	630	561	4.258	0.127	0.062	0.065	354.535	358.793	356.911	13.876	6.788	24.206
	E3	180	28	52.5	40.5	5.113	0.013	0	0.013	19.949	25.062	39.299	3.51	0.071	4.094
	E7	126	11	56.5	54.5	0.142	0.004	0	0.004	0.872	1.014	0.893	0.034	0.033	0.078
	E4	193	13	17.9	15.8	0.352	0.004	0	0.004	4.065	4.417	4.108	0.014	0.001	0.037
6/2/2010	E1	216	88	71.5	51.5	17.561	1.756	0.264	1.492	21.538	39.099	25.057	1.755	0.545	3.551
	E3	304	24	94	93.5	3.455	26.484	0.982	25.502	0.293	3.748	27.852	0.071	0.011	0.091
	E7	429	15	3.5	2.6	3.761	0.129	0.009	0.12	7.354	11.115	7.527	0.016	0.022	0.062
	E4	430	9	10.5	10	0.614	0.751	0.11	0.641	7.095	7.709	8.793	0.01	0.002	0.068
6/28/2010	E1	237	334	372	279	24.698	0.98	0.823	0.157	331.95	356.648	427.607	9.135	0.953	16.717
	E3	166	11.8	9.9	5.5	3.733	1.636	1.111	0.525	56.537	60.27	74.67	13.795	0.405	14.352
	E7	137	8	16.1	7.2	5.445	0.019	0.001	0.018	5.142	10.587	6.137	2.451	0.135	3.508
	E4	183	63.8	20.7	18	5.892	0.024	0.008	0.016	5.65	11.542	8.902	0.012	0.011	0.083
7/28/2010	E1	212	744	139	115	99.872	12.329	1.746	10.583	183.134	283.006	339.551	12.425	1.249	35.551
	E2	320	28.5	16.7	4.4	20.707	11.47	1.723	9.747	25.647	46.354	102.191	7.686	2.939	10.664
	E3	404	30	4.3	1.9	9.945	6.885	0.034	6.851	24.256	34.201	77.317	0.411	0.028	0.526
	E4	408	24.8	13.2	12	7.496	0.055	0.026	0.029	9.609	17.105	16.649	0.004	0.001	0.027
9/19/2010	E1	245	156	60	59	7.114	17.59	16.488	1.102	101.571	108.685	143.377	10.602	0.237	15.863
	E2	172	22	5.6	4.4	8.85	22.801	20.108	2.693	84.52	93.37	93.617	10.988	0.331	12.84
	E3	127	12	3.9	2.6	3.7	0.072	0.056	0.016	16.11	19.81	60.018	8.626	0.012	8.812
	E4	194	49	8.1	7.6	1.174	0.016	0.014	0.002	15.52	16.694	15.898	0.017	0.025	2.86

Date Collected	Sample Description	Alkalinity (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	$CBOD_5$ (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Org. N (mg/L)	TKN (mg/L)	Total N (mg/L)	SRP (mg/L)	Org. P (mg/L)	Total P (mg/L)
10/7/2010	E1	262	259	765	717	12.05	76	66	10	236.58	248.63	287.391	9.763	1.756	14.731
	E2	178	38	74.8	55.8	14.1	41	27	14	99.68	113.78	137.081	9.314	0.528	10.897
	E3	120	15	1.5	1.1	4.78	22	3	19	79.45	84.23	83.499	7.342	0.816	8.432
	E4	200	20	12.7	10.6	5.9533	4.8	1.7	3.1	73.955	79.9083	76.752	0	0.023	0.076
11/9/2010	E1	366	136	98.5	80.5	61.198	0.769	0.025	0.74	9.469	70.667	76.055	7.864	0.406	9.887
	E2	468	13.5	43.8	37.3	79.766	3.067	0.319	2.75	3.401	83.167	88.155	7.687	6.127	13.869
	E3	366	1.6	1.4	1.2	32.176	15.832	9.555	6.28	2.078	34.254	62.479	7.733	2.221	0.977
	E4	401	4	13.7	11.3	31.065	0.318	0.064	0.25	2.11	33.175	41.987	0.002	0.351	0.465
	E5	269	9	NA	NA	14.026	15.061	12.411	2.65	3.511	17.537	36.243	0.022	0.086	0.137
12/9/2010	E1	289	114	116	105	12.375	0.145	0.011	0.134	0.333	12.708	13.393	6.013	0.709	7.76
	E2	442	60	60	58.8	14.528	14.573	0.01	14.563	0.262	14.79	29.775	8.133	0.201	9.758
	E3	336	4	1.5	1	11.194	23.175	11.004	12.171	2.53	13.724	40.794	7.562	0.209	8.772
	E4	339	82	9.7	7.2	7.089	5.43	3.906	1.524	0.128	7.217	13.232	0.026	0.049	1.144
	E5	NA	NA	NA	NA	6.148	1.718	0.025	1.693	0.222	6.37	9.628	0.025	0.012	0.265
	E6	NA	NA	NA	NA	9.616	NA	NA	NA	NA	NA	12.116	NA	NA	2.993
1/13/2011	E1	384	558	609	576	61.54	0.054	0.042	0.012	266.2	327.75	349.14	3.981	24.917	33.764
	E2	440	118	58	49	106.1	0.162	0.01	0.152	0.597	106.7	107.15	9.713	5.354	16.112
	E3	373	8.6	3	2.4	33.8	14.487	0.44	14.047	0.82	34.66	48.8	9.64	2.656	12.889
	E4	420	8	2.8	2.4	31.749	11.722	1.514	10.208	0.987	32.74	50.43	3.094	0.098	3.199
	E5	NA	NA	NA	NA	29.121	9.564	0.115	9.449	0.222	29.34	38.91	0.16	0.042	0.502
2/10/2011	E1	366	208	364	359	70.184	0.06	0.05	0.01	17.548	87.732	88.642	6.43	0.581	13.136
	E2	441	90	100	98	66.9	3	0.024	2.976	2.892	69.792	70.733	6.21	4.982	12.19
	E3	391	33	3.8	3	40.755	9	0.073	8.927	1.061	16.061	67.64	6.86	0.195	7.688
	E4	204	13	17.8	9.8	15	6.7	0.602	6.098	0.235	21.688	16.41	7.17	0.07	8.083
	E5	NA	NA	NA	NA	21.453	5.8	0.499	5.301	0.585	22.038	33.849	6.88	0.184	7.194
3/8/2011	E1	424	108	340	280	46.93	0.521	0.401	0.12	10.472	64.317	64.838	7.629	0.025	7.717
	E2	447	37.4	33	19	76.466	0.065	0.001	0.064	13.84	95.807	95.872	11.491	1.361	13.623
	E3	378	1.2	2	1.5	25.498	13.73	0.006	13.724	4.557	30.468	44.198	4.607	0.24	5.101
	E4	200	13	3.2	3.1	15.086	0.198	0.007	0.191	5.779	22.398	22.596	7.962	0.036	8.023
	E5	NA	NA	NA	NA	10.271	0.165	0.005	0.16	31.098	63.585	63.75	5.91	0.339	7.774
4/7/2011	E1	134	56	97	78	21.93	0.663	0.404	0.259	8.018	39.119	39.782	4.133	0.148	4.636
	E2	416	15.5	50.8	49.8	87.116	0.019	0.003	0.016	0.789	100.095	100.114	12.061	0.001	12.064
	E3	345	2	1.4	1.1	17.363	26.825	0.024	26.801	0.797	19.287	46.112	7.072	0.826	9.724
	E4	513	10	6.7	6.2	53.567	0.979	0.024	0.955	0.527	54.698	55.677	7.696	0.497	9.005
	E5	NA	NA	NA	NA	11.183	1.77	0.015	1.755	x	26.125	27.895	3.084	x	4.447
	E6	181	5.5	19.4	15.2	12.625	1.068	0.339	0.729	39.443	69.859	70.927	8.935	0.36	10.638

Date Collected	Sample Description	Alkalinity (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	$CBOD_5$ (mg/L)	NH_3 (mg/L)	NO_x-N (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Org. N (mg/L)	TKN (mg/L)	Total N (mg/L)	SRP (mg/L)	Org. P (mg/L)	Total P (mg/L)
5/5/2011	E1	517	390	267	252	32.672	0.573	0.062	0.511	45.348	89.874	90.447	3.938	1.082	12.253
	E2	494	27.3	25	24	106.114	0.308	0.03	0.278	5.16	111.562	111.87	14.203	0.54	14.826
	E3	377	3.4	1.4	1.2	47.316	16.328	0.02	16.308	3.497	50.971	67.299	12.743	0.196	13.636
	E4	545	11	4	3.6	54.765	0.413	0.037	0.376	5.697	60.874	61.287	4.348	3.722	8.769
	E5	NA	NA	NA	NA	2.747	10.807	0.026	10.781	3.91	7.18	17.987	3.648	0.351	4.03
	E6	514	41	27	19	77.047	0.083	0.017	0.066	22.439	104.568	104.651	13.008	0.096	13.235
6/6/2011	E1	522	307	357	353	76.709	0.048	0.038	0.01	9.864	129.779	129.827	22.368	9.036	36.697
	E2	511	22	28.3	27.8	56.734	0.011	0.011	0	8.678	84.355	84.366	9.411	0.433	10.197
	E3	355	2	1.9	1.8	20	27.055	0.016	27.039	3.919	23.958	51.013	7.199	1.628	8.829
	E4	267	19.5	6.1	5.8	38.73	0.295	0.019	0.276	3.649	48.359	48.654	9.78	0.139	10.204
	E5	NA	NA	NA	NA	26.155	0.267	0.017	0.25	1.142	29.685	29.952	6.929	0.087	7.695
	E6	500	44	46	45.5	47.246	0.737	0.152	0.585	4.548	60.899	61.636	12.652	0.41	13.235
7/7/2011	E1	542	626	507	489	51.067	0.064	0.027	0.037	48.885	103.036	103.1	7.555	2.363	14.136
	E2	480	35	116	116	86.434	0.113	0.026	0.087	2.757	94.953	95.066	11.933	3.048	15.836
	E3	400	7.5	2.6	1.6	45.797	26.473	0.018	26.455	7.983	54.083	80.556	15.759	0.259	18.634
	E4	507	28.8	6.9	6	21.925	0.01	0.004	0.006	1	25.924	25.934	3.991	0.779	5.977
	E5	442	12	4.7	4	21.918	0.118	0.003	0.115	0.345	22.888	23.006	3.451	0.396	5.329
	E6	485	37.3	56.5	43.3	72.112	0.015	0.004	0.011	0.953	79.293	79.308	12.406	0.438	13.229
8/3/2011	E1	519	203	154	146	55.718	0.166	0.014	0.152	99.642	156.276	156.442	6.46	0.225	7.238
	E2	522	8	25.8	20.5	36.932	0.673	0.013	0.66	63.582	102.607	103.28	11.46	0.367	12.838
	E3	344	0.8	1.1	0.8	12.51	48.869	0.005	48.864	10.041	23.046	71.915	8.652	1.777	10.633
	E4	528	0.8	3.7	2.8	7.083	0.616	0.003	0.613	6.388	14.37	14.986	2.621	0.089	2.861
	E5	386	0.7	3.4	3	3.074	0.419	0.002	0.417	10.963	15.341	15.76	3.542	0.224	3.876
	E6	486	20	29.8	22	88.206	0.65	0.003	0.647	2.599	91.4	92.05	10.117	0.136	10.393

Date	Day	Time	Count	Volume (gallons)
4/4/2011	Mon.	12:00	0	0
4/14/2011	Thurs	11:29	427	641
		12:06	445	668
4/15/2011	Fri	9:30	555	833
		10:05	559	839
		10:45	563	845
		12:35	596	894
4/20/2011	Wed	10:07	955	1433
		19:55	984	1476
4/21/2011	Thurs	12:10	1032	1548
4/22/2011	Fri	13:30	1147	1721
		14:00	1148	1722
4/25/2011	Mon	13:44	1343	2015
5/5/2011	Thurs	9:24	2141	3212
		10:37	2150	3225
		10:45	2152	3228
		11:15	2155	3233
5/13/2011	Fri.	16:00	2831	4247
5/25/2011	Wed	9:11	3515	5273
6/2/2011	Tue.	9:30	3910	5865
6/6/2011	Mon.	10:00	4106	6159
		10:30	4110	6165
6/16/2011	Thur.	9:40	4350	6525
6/22/2011	Wed.	9:20	4526	6789
6/28/2011	Thurs.	9:22	4901	7351.5
6/29/2011	Thurs.	10:22	5011	7516.5
7/1/2011	Fri.	5:30	5224	7836
7/7/2011	Thurs.	10:15	5601	8401.5
7/11/211	Mon.	11:43	5852	8778
7/14/2011	Thurs.	9:07	6018	9027
7/19/2011	Tues.	9:31	6287	9430.5
7/26/2011	Tues.	9:40	6531	9796.5
8/1/2011	Mon	6:34	6967	10450.5
8/3/2011	Wed.	9:30	7151	10726.5
AVERAGE	**NA**	**NA**	**88 GPD**	**29.3 GPDC**

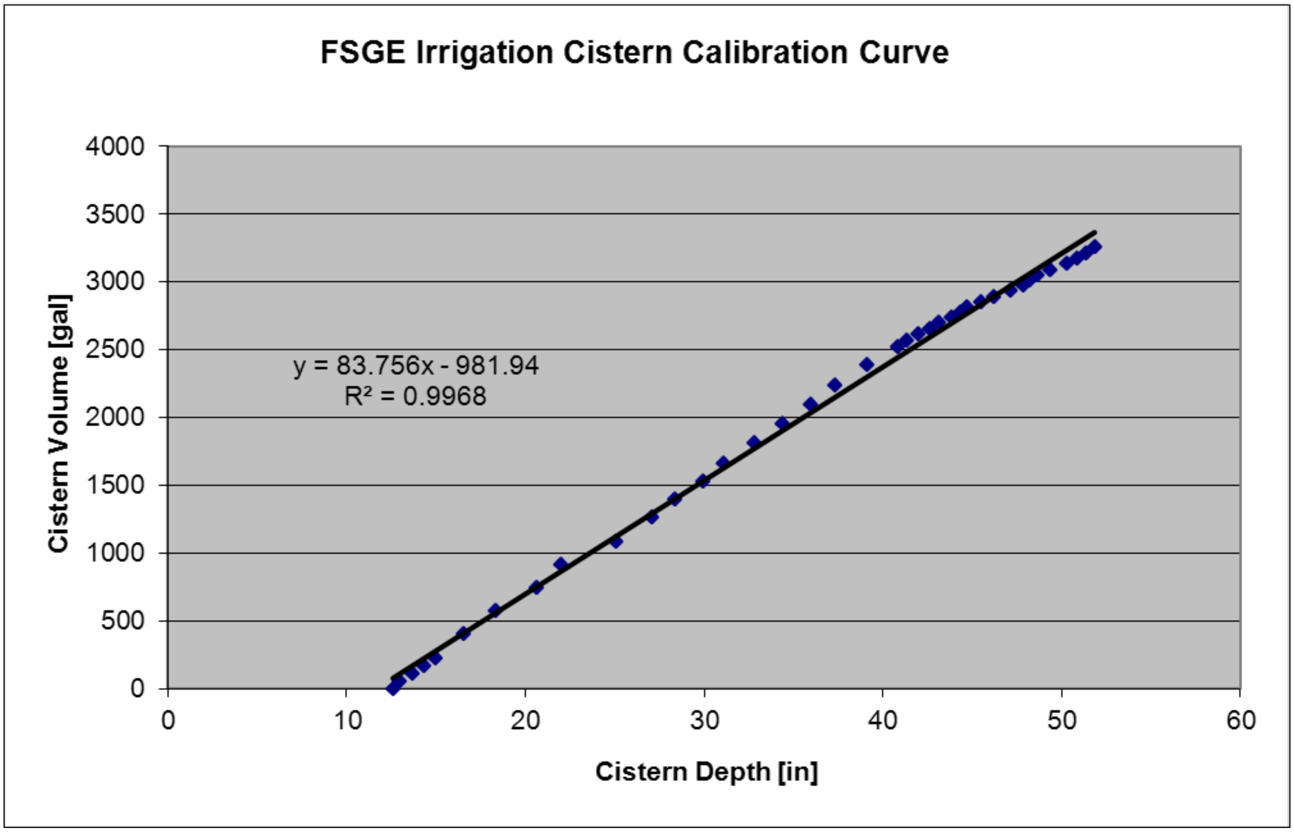

Figure 24 FSGE Irrigation Cistern Calibration Curve

Date	pH (on-site)	Turbidity (NTU)	Conductivity (µS/cm)	Temperature (°C)	Alkalinity (mg/L $CaCO_3$)	Dissolved Oxygen (mg/L)
1/21/2009	7.87	1.98	2490	23.9	76	8.09
1/26/2009	7.76	3.1	3610	20.8	118	11.71
2/12/2009	7.64	8.6	3220	20.0	75	9.75
3/31/2010	7.45	10.6	2450	21.1	22	7.89
4/29/2010	7.18	1.72	1283	23.7	37	6.57
6/2/2010	7.48	2.14	3650	25.1	97	5.87
6/28/2010	7.58	7.8	4290	27.8	116	3.57
7/27/2010	7.48	2.28	1200	31.8	120	3.65
8/12/2010	7.25		2195	29.1		7.09
9/19/2010	7.6	5.06	3710	27.3	122	2.33
10/7/2010	7.14		1465	25.3	82	5.70
11/9/2011	7.84	1.36	4300	24.1	119	5.20
12/9/2011	7.56	1.1	3324	23.4	98	4.4
1/13/2011	7.76	6.4	3580	17.1	105	4.86
2/10/2011	7.52		2840	21.8	100	3.70
3/8/2011	7.58		3488	24.4	90	4.1
4/7/2011	7.7		1010	25.2		6.2
5/5/2011	7.71		3950	27.5	87	9.06
6/6/2011	7.85		2321	27.4	112	5.6
7/7/2011	7.08		2850	28.7		6.7
8/3/2011	7.75		2374	27.5		3.9

Stormwater Management Academy

FSGE – Nutrient Sampling

Standard Operating Procedure (SOP)

1. SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) defines the procedures to be followed for the collection and handling of nutrient samples at the Florida Showcase Green Envirohome (FSGE).

2. EQUIPMENT AND REAGENTS

The following is a list of equipment required to be used during analysis:

- One (1) Masterflex L/S Peristaltic Pump with Easy Load II Pump Head
- Six (10) 1 liter amber jars
- Twelve (12) waterproof labels
- One gallon of D.I. water
- Hach model HQ40d Dual Input pH/ Conductivity/ Temperature/ Dissolved Oxygen meter.
- PHC101 Standard pH Probe
- CDC401 Standard Conductivity Probe
- Coleman Cooler
- Sample tubing
- Dipper pole
- LDO101 Standard Dissolved Oxygen Probe
- One (1) sample container filled with D.I. to record temperature of samples.
- Kim wipes
- D.I. rinse bottle
- Nitrile gloves
- 5-micron filters
- 50 mL LDPE sample container with screw cap
- 50 mL plastic cups for measuring pH, conductivity, temperature, and DO
- 5-micron filter paper
- Suction vacuum for filtering
- Suction glass for sample collection
- 250 mL measuring glass

3. COLLECTION PROCEDURE

The following section describes the collection method to be followed for nutrient sampling:

1. Give a 24 hr notice to ERD lab including the amount and type of samples that need to be tested (407-855-9465). Give Mark Baker notice to put cap on influent trough.
2. Pick up the peristaltic pump, Hach pH/Conductivity/Temperature/ DO meter, and other equipment listed from the UCF CECE Chemical/Biological Process Lab (ENG 2 438).
3. Before arriving at FSGE (220 Coral Way W, Indialantic, FL), pick up a bag of ice to chill samples to 4^{o} C after sampling.
4. Once at FSGE, turn on the Hach meter, plug in the pump with an extension cord, and write labels for samples.
5. The sample labels should contain: Samplers name, the project (Envirohome), the sample location (ex. E1), the date, and the time the sample was collected. There should be Labels for the septic samples (E1-6) and one for each the cistern and well.
6. Begin pumping from the influent for 2 hrs between 7-9 am, then 11-1, and 5-8 pm. Combining samples at the end to make one composite sample.
7. Begin pumping a sample from location E4 using the tubing that is stored at that station
8. After the 1 liter amber bottle is filled, fill the 50 mL plastic cup for pH, conductivity, temperature, and DO measurements.
9. Pump D.I. water through the tubing for 5-10 seconds to rinse out the septic water
10. Place the probes into the 50 mL cup and record the pH, conductivity, temperature, and DO. Record into field data book. Rinse probes with DI water and wipe with Kim wipes.
11. Repeat steps 7 through 10 for station E2 (Collect from dipper tray)
12. Repeat steps 7 - 10 for station E1 (Collect from trough). Rinse tubing for 20-30 seconds
13. Repeat steps 7 through 10 for station E3, making sure to collect from the tubing with the green electrical tape on it.
14. Collect a sample from the cistern using the on-site dipper pole, use the 50 mL sample to measure and record water quality parameters (step 10).
15. Collect a sample from the well faucet. Open the valve and let the water run for a couple

minutes before collecting sample. Collect a 50 mL sample and perform step 10.

16. Place all samples in cooler and chill them with the bag of ice. Return to UCF

4. HANDLING PROCEDURE

This section describes the handling method to be followed for the septic samples (E1-4):

1. Take the samples back to the CECE Chemical/Biological Process Lab (ENG 2 438)
2. Pour 200 mL of each sample into separate 250 mL beakers (properly labeled)
3. Collect twelve 50 mL sample bottles with screw tops (Three for each location)
4. Label each sample bottle with the following: sampler name, project name, sample Location, date, and time. Also include either F (filtered), A (Acidified), or FA (both)
5. Filter 150 mL of the E1 beaker using the lab suction vacuum, and a 5 micron filter paper.
6. Pour the filtered sample into appropriate 50 mL bottles (F and FA).
7. Pour the remaining 50 mL left in the beaker into the “A” sample bottle
8. Add 120 µL of concentrated (98%) Sulfuric Acid (H_2SO_4) into the “A” and “FA” sample
9. Acid wash and rinse all instruments and equipment used and repeat for the remaining samples

   Place all of the sample bottles (including ambers) into the cooler and drop off at Environmental Research and Development (ERD).

   3419 Trentwood Blvd., Suite 102, *Orlando*, FL 32812

Stormwater Management Academy

FSGE – Biological Sampling

Standard Operating Procedure (SOP)

1. SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) defines the procedures to be followed for the collection and handling of biological samples at the Florida Showcase Green Envirohome (FSGE).

2. EQUIPMENT AND REAGENTS

The following is a list of equipment required to be used during analysis:

- One (1) Masterflex L/S peristaltic pump with Easy Load II Pump Head
- Six (6) Corning coliform water test sample containers, sterile with Sodium Thiosulfate tablet (120 mL)
- Two (2) Coliform water test sample containers, sterile without sodium thiosulfate (120 mL)
- Twelve (16) waterproof labels
- One gallon of D.I. water
- Coleman Cooler
- Sample tubing
- Dipper pole
- One (1) sample container filled with D.I. to record temperature of samples.
- Nitrile gloves

3. COLLECTION PROCEDURE

The following section describes the collection method to be followed for nutrient sampling:

1. Give a 24 hr notice to ERD lab including the amount and type of samples that need to be tested. (407-855-9465)
2. Give a 24 hr notice to Mark Baker, so he can place the plug onto the end of the influent trough. This is done to create a composite influent sample.
3. Pick up the cooler, gloves, and other necessary equipment listed in section 2.0 from the UCF CECE Chemical/Biological Process Lab (ENG 2 438).
4. Before arriving at FSGE (220 Coral Way W, Indialantic, FL), pick up a bag of ice to chill samples to 4^{o} C after sampling.
5. Once at FSGE write labels for samples. The sample labels should contain: Samplers name, the project (Envirohome), the sample location (ex. E1), the date, and the time the sample was collected. There should be labels for the septic samples (E1-6) and one for each the cistern and well water.
6. Begin pumping a sample from location E4 using the Masterflex silicone tubing that is stored at that station.
7. After the 120 mL sample container is filled, pump D.I. water through the tubing for 10-15 seconds to rinse out the septic water.
8. Repeat steps 6 and 7 for station E2 (Collect from dipper tray).
9. Repeat steps 6 and 7 for station E1 (Collect from trough). Rinse tubing for 20-30 seconds.
10. Repeat steps 6 and 7 for station E3, but make sure to connect the tubing to the tubing with the green electrical tape on it.
11. Collect a sample from the cistern using the on-site dipper pole.
12. Collect a sample from the well faucet. Open the valve and let the water run for a couple minutes to purge the well before collecting sample.
13. Place all of the sample bottles (including ambers) into the cooler and drop off at Environmental Research and Development (ERD)., Orlando, Fl 32812.

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Brevard County, Florida

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

Custom Soil Resource Report
Soil Map

Brevard County, Florida

25—Canaveral-Palm Beach-Urban land complex

Map Unit Setting

Elevation: 10 to 20 feet
Mean annual precipitation: 49 to 57 inches
Mean annual air temperature: 68 to 75 degrees F
Frost-free period: 350 to 365 days

Map Unit Composition

Canaveral and similar soils: 31 percent
Palm beach and similar soils: 30 percent
Urban land: 29 percent
Minor components: 10 percent

Description of Canaveral

Setting

Landform: Ridges on marine terraces, flats on marine terraces
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Sandy marine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very high (19.98 to 50.02 in/hr)
Depth to water table: About 12 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 6.0
Available water capacity: Very low (about 1.4 inches)

Interpretive groups

Land capability (nonirrigated): 6s

Typical profile

0 to 6 inches: Sand
6 to 12 inches: Sand
12 to 80 inches: Coarse sand

Description of Palm Beach

Setting

Landform: Flats on marine terraces
Landform position (three-dimensional): Talf
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Shells and sandy marine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Very high (19.98 to 50.02 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 4.0
Available water capacity: Very low (about 1.8 inches)

Interpretive groups

Land capability (nonirrigated): 7s

Typical profile

0 to 3 inches: Sand
3 to 80 inches: Sand

Description of Urban Land

Setting

Landform: Marine terraces
Landform position (three-dimensional): Interfluve, talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: No parent material