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Field Development and Performance Evaluation of a Constructed Wetland System in the Tropics

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FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

FIELD DEVELOPMENT AND PERFORMANCE EVALUATION OF A
CONSTRUCTED WETLAND SYSTEM IN THE TROPICS

A dissertation submitted in partial fulfillment of

the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

CIVIL ENGINEERING

by

Adelaide Pereira Hummel

2014

To: Dean Amir Mirmiran
College of Engineering and Computing

This dissertation, written by Adelaide Pereira Hummel, and entitled Field Development and Performance Evaluation of a Constructed Wetland in the Tropics, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Date of Defense: November 8, 2013

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Florida International University, 2014

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DEDICATION

I dedicate this dissertation to my husband, Andre, and my children, Nicolas and Sophia, with my deepest expression of love and appreciation for their sacrifices made during this long journey and I am very thankful for having you in my life. I also dedicate this dissertation to my parents and my aunt Yolanda for their words of encouragement and for their example of perseverance; and to my nephews Lucas, Alexandre Junior, Felipe and Eduardo, and my nieces Laura and Juliana; I hope to be inspirational to your lives.

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DISCLAIMER

This dissertation proposal was prepared as a part of FIU academic curricula, with data collected under a project sponsored by an agency of the United States Government. Neither the United States of America nor any agency thereof, nor any of their employees, nor any of its contractors, subcontractors, nor their employees make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that's its use would not infringe upon privately owned rights. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or nay agency thereof.

ABSTRACT OF THE DISSERTATION
FIELD DEVELOPMENT AND PERFORMANCE EVALUATION OF A
CONSTRUCTED WETLAND IN THE TROPICS

By

Adelaide Pereira Hummel

Florida International University, 2014

Miami, Florida

Professor Hector R. Fuentes, Major Professor

This study is part of a project that was conducted by Florida International University (FIU), which designed, built, and characterized a constructed wetland (CW) wastewater treatment system in El Salvador, Central America. This study focuses on the detailed performance of a field-scale CW in the tropics, consisting of a subsurface flow wetland (SSF) and a surface flow wetland (SF). The SSF had a total area of 151.2 sq. m., filled with gravel and planted with *Phragmites*, *Thalia*, and *Brachiaria*, along three independent cells operating with a flow in parallel and receiving the influent domestic wastewater from a facultative lagoon and preceded the SF. The SF was a shallow open basin containing alternating regions of open water (195 sq. m. total) with submerged aquatic plants (*Elodea*) and regions of shallower water (605 sq. m. total) filled with emergent wetland vegetation (*Typha*, *Thalia*, and *Cyperus*).

The design, construction, startup and operation phases of the field scale CW in that tropical setting are thus described with detail, including both SSF and SF

characterization of influent and effluents. The SSF average hydraulic detention times during the wet and dry season were 2 days $\pm$ 0.9 days and 4 days $\pm$ 0.4 days, respectively; and the SF average hydraulic detention times during the wet and dry season were 20 days $\pm$ 11.1 days and 77 days $\pm$ 19.5 days, respectively. *Brachiaria/Cyperus* presented better results during the wet season with average BOD₅ residuals of 36% $\pm$ 25%, and *Thalia/Thalia* during the dry season with average BOD₅ residuals of 33% $\pm$ 22%. *Phragmites/Typha* presented better results during both seasons with average TSS residuals of 2% $\pm$ 3% (wet season), and 2% $\pm$ 2% (dry season). Residuals are also presented for COD, Oil & Grease, Total Fecal Coliform, Total Phosphorus, and Total Nitrogen. In addition, an assessment of the empirical models used in the design of the system is completed, having the EPA methodology as the preferred for BOD₅ removal and three methodologies for TSS removal under tropical climate conditions. A comparison of the differences in treatment associated with each one of the selected plants and their combinations is also discussed. In summary, results strongly suggest that the CW system can effectively reduce contaminants in wastewater to levels that are comparable with the objective levels (i.e., secondary treatment levels).

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LIST OF ACRONYMS

AVE	Average
BOD	Biological Oxygen Demand
CENTA	Centro Nacional de Tecnología Agropecuaria y Forestal - El Salvador Agricultural Agency
CO ₂	Carbon Dioxide
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
ET	Evapotranspiration
FC	Fecal Coliform
FIU	Florida International University
HDPE	High-density polyethylene
k	Reaction Rate
n.d.	no date
N.D.	Not detected
NH ₄ as N	Ammonia Nitrogen

NO ₂ - as N	Nitrite Nitrogen
NO ₃ - as N	Nitrate Nitrogen
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
O&G	Oil & Grease
O&M	Operation & Maintenance
Org N	Organic Nitrogen
ORP	Oxidation Reduction Potential
P	Phosphorus
PR	Pump Runtime
PVC	Polyvinyl chloride
SACR	Salvadoran Army Cavalry Regiment
SD	Standard Deviation
SF	Surface Flow
SSF	Subsurface Flow
TDS	Total Dissolved Solids

TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
U.S.	United States
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

1.1 Background

Everyone generates wastewater. When people use water, it becomes wastewater that must be cleaned up before it is safely reused or returned to the environment. Water use should be done in ways that ensure sustainable supplies and quality for future generations.

Wastewater contains organic and inorganic substances, nutrients, such as nitrogen and phosphorus, and solids. Therefore, it is important to treat wastewater not only to ensure its beneficial reuse but also to protect human and environmental health.

Constructed wetlands are one type of wastewater treatment that imitates the natural environment. Constructed wetlands are typically easy to operate and maintain, low in operational and maintenance costs, and capable of effective treatment (Kadlec & Knight, 1996); (Kadlec, et al., 2000); (Halverson, 2004) (Tsihrintzis, et al., 2007). Additional benefits are the provision of habitat for fish and wildlife and their intrinsic aesthetic appeal.

Constructed wetlands (CW) are a competitive technology to treat a variety of wastewater. Their simpler operation and maintenance than more energy-intensive technology, such as the conventional activated sludge, makes them ideal options for the treatment of domestic wastewaters in developing countries, especially when land is available and not costly.

Constructed wetland systems are commonly classified in three types: a) subsurface flow; b) surface flow, and c) hybrid designs that combine both (Zhi & Ji, 2012) (Vymazal, 2011).

Subsurface flow constructed wetland (SSF CW) consists of a basin or channel with a seepage barrier, but the bed is filled with porous media, such as rock and gravel, as shown in Figure 1-1. The media supports the vegetation root structure. SSF CWs are designed to keep the water level below the top of the rock or gravel media. Bed depth for subsurface flow wetlands is generally less than 2ft (0.6 m). Typical flow depths vary from 1.6 to 2.6 ft (0.49 to 0.79 m). Typical hydraulic loading rates are between 0.8-8 in/day (2 to 20 cm/day), which corresponds to a wetland of 4.7 to 47 acres per mgd of flow (0.5 to 5 ha per 1000 m³/day of flow) (Halverson, 2004). SSF CWs tend to be more effective at filtering out solids and removing biological oxygen demand (BOD) per unit land area. Because the wastewater remains below the surface in these systems, there is less possibility for human or wildlife contact with wastewaters and less potential for insect infestation.

Figure 1-1: Subsurface Flow Wetland

Surface flow constructed wetland (SF CW), also called free surface flow wetland, consists of a basin or channels with a barrier layer to prevent seepage, soil to support rooted vegetation, and relatively shallow water flowing through the system, as shown

Figure 1-2. The water flows primarily horizontally and above ground. Water movement in SF CW is complex. It varies in space and time because of the wetland vegetation and waste and it changes the inflow characteristics, and the stochastic nature of hydrologic events. SF CWs are densely vegetated and typically have water depths less than 1.3ft (0.4m). Typical hydraulic loading rates are between 0.3 and 2 in/day (0.7 and 5.0 cm/day), which corresponds to a wetland of 18.7 to 13.1 acres per mgd of flow (2 to 14 ha per 1000m³/day of flow). Typical flow depths for SF CWs are 0.3 to 2.0ft (0.09 to 0.06m) (Halverson, 2004). SF CWs are cheaper and easy to construct, operate and maintain, have higher wildlife habitat values and they offer a greater flow control than subsurface flow wetland. The main disadvantage is that they generally require more land than SSF CW systems.

Figure 1-2: Surface Flow Wetland

CW studies shows that total suspended solids (TSS) loadings of less than 30 kg/d-ha or lower were able to consistently produce an effluent with less than 20 mg/L of TSS. Loadings less than 50 kg/d-ha produced an effluent with less than 30 mg/L TSS (U.S. EPA, 1999). Systems with open water zones were able to produce effluent with lower amounts of TSS than the ones that were fully vegetated. Wetland systems can

significantly reduce constituents with removal efficiencies in the range of 70 to 90 percent for TSS (U.S. Army Corps of Engineers, 2003).

A study of 20 operating wetlands in U.S. that contained significant open-water zones indicated that SF CWs could be expected to yield effluent with less than 20 mg/L BOD at mass loadings below 45 kg/d-ha (U.S. EPA, 1999). Fully vegetated systems will normally produce 50% more effluent BOD and TSS (30 mg/L) than wetlands with open-water areas at comparable loading rates.

The removal of nitrogen and phosphorous takes a limited place on CWs (U.S. EPA, 1999) (Mburu, et al., 2013). Nitrogen removal in the SSF CW system is relatively small since such system is usually anoxic and oxidation does not occur. Nitrogen removals in the literature range between 0.01 and 2.15 g N/m²-day, with an average value of 0.048 g N/m²-day (Vymazal, 2007).

The removal of phosphorous from the wastewater is limited to adsorption onto sediment and plant material, entrainment of phosphorous-containing solids into sediment and uptake into plant tissue (much of which is subsequently released as that tissue decomposes in the wetland) (Stefanakis & Tsihrintzis, 2009). Large wetlands with long hydraulic retention times are needed to achieve significant phosphorous removal. A phosphorous loading of less than 1.5 kg/d-ha and retention time of at least 15 days is needed to achieve only a 1.5 mg/L reduction in total phosphorous (U.S. EPA, 1999). Phosphorus removal in the literature averages in 0.12 g P/m²-day, considered a low removal rate (Vymazal, 2005).

System maturity, climate, maintenance, flow fluctuation, type of plants, and system configuration affect constructed wetlands performance. The average level of function in mature constructed wetlands is generally less than that for natural wetlands. Rate and time of maturation and functional level at maturity will differ from project to project, depending on the type of wetland being restored/constructed. Changes in the characteristics of constructed wetlands can be expected in response to the maturation process, but also in response to changes in the environment. Over time, successful constructed wetlands can be expected to become similar to comparable natural wetlands. Suspended solids are removed primarily by settling in the flow management basin; however, filtering within the constructed wetlands system increases as the plant density increases with system maturity. Vegetation density at full maturity will influence the wetlands' ability to promote sedimentation of TSS and associated BOD (Rodgers, et al., 2002).

CWs are similar to “natural” systems. As a result, operation is mostly passive and requires little operator intervention. Operation involves simple procedures similar to the requirements for operation of a facultative lagoon. The operator must be attentive, take appropriate actions when problems develop, and conduct required monitoring and operational monitoring as necessary. Clogging is considered one of the worst problems during CW's operations as it involves chemical, physical and biological processes (Knowles, et al., 2011) (Wallace & Knight, 2006) (Cooper, et al., 2005). Clogging reduces the life of the CW system and may reduce the system efficiency as well (Caselles-Osorio, et al., 2007) (Rousseau, et al., 2005).

The most critical monitoring issue during the CW startup period is vegetation growth and coverage. The planting strategy, combined with hydro period control as the plants grow, determines the effectiveness of vegetation growth during the startup period. Once the wetland vegetation has been established, the system can be brought online and the wastewater introduced. Most important in the operation of a SF constructed wetland is monitoring hydraulic and organic loadings to, and discharge(s) from, the wetland system (including the monitoring of individual wetland cells). Such tasks require measuring influent and effluent flow rates, and recording water depths in each wetland cell (U.S. Army Corps of Engineers, 2003).

Constructed wetlands require very low maintenance. The maintenance plan depends on the complexity of the constructed wetland design. Simple structures may only require mowing, banks and inlet inspection, outlet structures for signs of clogging, replacing damaged plants, pulling out undesirable plant species and sediment removal routines. More complex structures with mechanical devices such as valves or pumps may require much more detail, including maintenance recommendations from the manufacturer. Establishing preventive and corrective maintenance plan is recommended (Schueler, 1992). If a maintenance plan is not followed, constructed wetlands lifetime may be shortened due to several aspects, such as, spread of undesired plant species, clogging pipes, a broken pump and so forth. Weed invasion can dramatically reduce the ability of wetlands to meet its design objectives. They can form dense mats, exclude light and reduce dissolved oxygen in the water column, and increase the movement of nutrients through the system. Water level management is crucial to control weed growth.

1.1.1 Constructed Wetland Design

Determining the wastewater flow is the most important feature for the design of any wastewater treatment plant. The U.S. EPA gives a range of 47-52 gallons per person per day (U.S. EPA, 1980). These values may vary according to the location and country. Average flows per home can be developed, which may range from 115 to 222 gallons per home per day. Infiltration and precipitation should also be considered in the wastewater flow. Infiltration and inflow (I/I) can be both seasonal and unpredictable. Annual records of seasonal flows are essential to determine the ultimate hydraulic capacity of the wastewater treatment facility.

The designer needs to know the expected BOD, TSS, total nitrogen, and total phosphorus when designing a constructed wetland. Table 1-1 lists the typical domestic raw wastewater concentration values.

Table 1-1: Typical domestic raw wastewater concentration, mg/L

Parameter	Raw Wastewater Concentration, range (typical) (Burks & Minnis, 1994)	Facultative Lagoon Effluent Concentration, range (Reed, et al., 1995)
BOD, mg/L	100-400 (250)	30-40
TSS, mg/L	100-400 (220)	40-100
Total Nitrogen, mg/L	15-90 (40)	-
Total Phosphorus, mg/L	5-20 (12)	-
Fecal Coliform, colonies/100 mL	10^6 - 10^8 (10^7)	-
Oil & Grease, mg/L	50-150 (100)	-

All wastewater treatment facilities are ultimately affected by the water temperature.

Constructed wetlands are very temperature dependent as well. It is important to obtain

information such as, monthly average temperatures, precipitation, evapotranspiration, soil temperatures at 30 inches and solar radiation. In absence of climatic records, examination of local vegetation can be correlated to plant hardiness zones and subsequently to probable minimum temperatures.

Evapotranspiration (ET) can be a major factor in the effectiveness of a constructed wetland. Increasing ET will result in higher hydraulic retention times since the outflow rate decreases. This could result in lower effluent BOD and TSS values. However the evaporation will also concentrate conservative, non-degradable contaminants such as phosphorous, increasing their concentrations in the effluent. Under extremely high temperature and low humidity levels, the amount of ET could approach or exceed the inflow rate into the system resulting in reduced water depth, which could damage some of the vegetation in the system. The use of a submerged bed system minimizes the effects of ET.

1.1.1.1 Common Constructed Wetland Design Models

Models are commonly found for the design of constructed wetlands in temperate climate areas (mainly the U.S.) to determine the size of a constructed wetland system. Among others, the most known are those by Campbell & Ogden (1999), Reed *et al.* (1995), Environmental Protection Agency (U.S. EPA, 1999) and Kadlec and Knight (1995). The Campbell & Ogden model has equations to calculate the area necessary for removal of Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), Ammonia and Nitrate. The model accounts for temperature effect via an Arrhenius-type relationship for the rate constant. The model by Reed *et al.* (1995) estimates the area necessary for

removal of BOD and phosphorus. The authors state that the performance of constructed wetland systems can be described by first-order kinetics in a plug flow regime. EPA has also equations to calculate the area necessary for removal of BOD and TSS. Those equations are conservative, which results in larger wetland areas; the equations are only based on loading rates, and temperature is not accounted for. Kadlec and Knight (1996) model presents other equations to calculate the area necessary for removal of BOD, TSS, phosphorus and nitrogen. Kadlec's equation also follows a first-order kinetic rate expression in a plug-flow setting; this expression is a function of background concentration. First-order models are commonly used and known to be inadequate, but still the most appropriate model available to date (Vymazal & Kropfelova, 2009). These common models are further described below:

a) Campbell & Ogden

Campbell & Ogden (1999) method has equations to calculate the area necessary for removal of BOD, TSS, Ammonia and Nitrate through SSF CW and SF CW.

Temperature is a very important factor in this method. Design equations for temperature dependent rate constant, area, hydraulic detention time are presented as follows.

Design Equation for SSF CW:

The BOD removal is estimated using the following equation:

$$As = \frac{Q * (\ln Co - \ln Ce)}{K_t * d * n} \quad (1)$$

Where: Q = flow, in m³/day

C_o = influent BOD (mg/L)

C_e = effluent BOD (mg/L)

K_t = temperature-dependent rate constant

d = depth of gravel bed

n = porosity of gravel

The temperature-dependent rate constant for SSF CWs, K_t , requires the following adjustment, considering T as the water temperature in °C:

$$K_t = 1.104 * (1.06)^{(T-20)} \quad (2)$$

The main factor considered on TSS removal is the wastewater velocity, because this process consists of filtration and hydraulic detention time. The equation for TSS removal is:

$$TSS_{eff} = TSS_{inf} * (0.1058 + 0.0011 * HLR) \quad (3)$$

Where: HLR = hydraulic loading rate (cm/day)

TSS_{eff} = effluent TSS in mg/L

TSS_{inf} = influent TSS in mg/L

Nitrogen removal is a temperature-dependent process as the BOD removal process is, and the nitrogen in the form of nitrates is easier to be removed by wetlands than in the form

of ammonia. The following formula calculates nitrogen removal, in the form of nitrates (NO_3):

$$\ln(\text{NO}_{3\text{inf}} / \text{NO}_{3\text{eff}}) = K_t * \text{HRT} \quad \text{or} \quad \text{HRT} = [\ln(\text{NO}_{3\text{inf}} / \text{NO}_{3\text{eff}})] / K_t \quad (4)$$

Where: $K_t = 1.15^{(T-20)}$

$\text{NO}_{3\text{inf}}$ = influent nitrate in mg/L

$\text{NO}_{3\text{eff}}$ = effluent nitrate in mg/L

Design Equation for SF CW:

The same formula used for SSF CW to calculate the area for BOD removal can be used for SF CWs, using a different reaction rate constant.

$$A_s = \frac{Q * (\ln Co - \ln Ce)}{K_t * d * n} \quad (5)$$

Where: Q = flow, in m^3/day

Co = influent BOD (mg/L)

Ce = effluent BOD (mg/L)

K_t = temperature-dependent rate constant

d = water depth

n = Porosity (density of the plant stems)

The temperature-dependent rate constant for SF CWs, K_t , requires the following adjustment, considering T as the water temperature in °C:

$$K_t = .278 * (1.06)^{(T-20)} \quad (6)$$

TSS removal equation for a SF CW is presented below:

$$TSS_{eff} = TSS_{inf} * [.1139 + .002(HLR)] \quad (7)$$

The nitrogen removal equations are similar to the SSF CW, with different reaction rate constant for Ammonia removal. The reaction rate constants for nitrogen removal in a SSF CW are:

$$AmmoniaK_t = .2187 * (1.048)^{(T-20)} \quad (8)$$

$$NitrateK_t = 1.15^{(T-20)} \quad (9)$$

b) Reed et al.

Reed et al. method has equations to calculate the area necessary for removal of BOD and phosphorus through SSF CW and removal of BOD through SF CW. Reeds et al. states that all CW systems have their performances described with first-order plug-flow kinetics as shown below.

BOD Removal in SF CW:

The design surface area of the wetland is given by:

$$A = \frac{Q(\ln C_0 - \ln C_e) - 0.6539}{65K_T d} \quad (\text{For slope smaller than 1 percent}) \quad (10)$$

Where: t = hydraulic residence time in the system, days

C_0 = influent BOD concentration, mg/L

C_e = effluent BOD concentration, mg/L

K_T = reaction rate constant, days⁻¹ = $K_T = K_{20}(1.1)^{(T-20)}$

K_{20} = rate constant at 20°C = 0.0057 days⁻¹

d = design water depth in the system

T = temperature, °C

Hydraulic residence time is given by:

$$t = \frac{(\ln C_0 - \ln C_e) - 0.6539}{65K_T} \quad (\text{For slope smaller than 1 percent}) \quad (11)$$

Other values recommended:

Organic loading < 112 kg BOD/(ha · day) [100 lb/(acre·day)]

Specific surface area for attached microbial growth = 15.7 m²/m³

Porosity (n value) of wetland flow path = 0.75

Aspect ratio (L/W) > 10:1

Water depth, warm months < 10 cm, cool months < 45 cm.

BOD Removal in SSF CW:

$$\frac{C_e}{C_o} = \exp\left(-\frac{K_T A_S dn}{Q}\right) \quad (12)$$

Where: C_e = effluent BOD, mg/L

C_o = influent BOD, mg/L

K_T = first-order temperature-dependent rate constant, days⁻¹

A_S = surface area of the system, m² (ft²)

n = bed porosity (as a decimal fraction)

d = depth of submergence, m (ft)

Q = average flow through system, m³/day (ft³/day)

$$K_T = K_{20} (1.1)^{(T-20)} \quad (13)$$

Where: K_{20} = rate constant at 20°C

T = operational temperature of system, °C

K_T = first-order, temperature-dependent rate constant, days⁻¹

It is possible to determine the surface area required for a SSF CW by taking the natural logarithm of both sides of the equation above and rearranging it.

$$A = \frac{Q(\ln C_o - \ln C_e)}{K_T dn} \quad (14)$$

Where:

A_S = required surface area of SSF CW, m^2 (ft^2)

Q = average daily flow through the system, m^3/day (ft^3/day)

C_e = influent BOD, mg/L

C_0 = required effluent BOD, mg/L

K_T = temperature- and porosity-dependent rate constant, $days^{-1} = K_T = K_{20}(1.1)^{(T-20)}$

d = submerged depth of the system, m (ft)

n = porosity of the bed system, as a decimal fraction.

c) EPA

EPA method has equations to calculate the area necessary for removal of BOD and TSS through SSF CW and removal of BOD, TSS, Kjeldahl and ammonia through SF CW.

EPA suggests a very conservative method of calculation which yielded very large wetland areas. EPA equations are based on loading rates only, and temperature is not a differential factor.

$$ALR = QC_o / A_w \quad (15)$$

Where: ALR = areal loading rates: BOD = 40 $kg/ha-d$; TSS = 30 $kg/ha-d$

Q_0 = incoming flow rate, in m^3/d

C_o = influent concentration, in mg/L

A_w = total area of SF CW, in ha

d) Kadlec

Kadlec method has equations to calculate the area necessary for removal of BOD, TSS, phosphorus and nitrogen through SSF CW and SF CW. Kadlec calculates area based on background concentration and reaction rate constant derived from multiple operational wetlands. Background concentration (C^*) is defined as the concentration that cannot be removed from the wastewater, with equations to estimate their C^* for TSS and BOD_5 , as presented below. The general equation for Kadlec's method is shown below.

$$\ln\left(\frac{C_e - C^*}{C_i - C^*}\right) = -\frac{k}{q} \quad (16)$$

Where: C_e = outlet target concentration, mg/L

C_i = inlet concentration, mg/L

C^* = background concentration, mg/L

$$C^*_{BOD} = 3.5 + 0.053 C_i \text{ (For SSF and SF)}$$

$$C^*_{TSS} = 7.8 + 0.063 C_i \text{ (For SSF)}$$

$$C^*_{TSS} = 5.1 + 0.16 C_i \text{ (For SF)}$$

k = first-order areal rate constant, m/yr

q = hydraulic loading rate, m/yr

The area required for a particular pollutant is given by the following equation:

$$A = \left(\frac{0.0365 * Q}{k} \right) * \ln \left(\frac{C_i - C^*}{C_e - C^*} \right) \quad (17)$$

Where: A = required wetland area, ha

Q = water flow rate, m³/d

The concentration of all pollutants is computed with the following equation, using the largest area:

$$C_o = C^* + (C_i - C^*) \exp \left(- \frac{kA}{0.0365Q} \right) \quad (18)$$

Where: C_o = outlet concentration, mg/L

e) Other Models

There are other models to calculate the size of the CW area that require many parameters that are usually hard to measure (Sklarz, et al., 2010) (Marsili-Libelli & Checchi, 2005) (Rousseau, et al., 2004) (Mashauri & Kayombo, 2002), including:

- Monod kinetics: interrelation on substrate availability and growth of biomass for predicting nitrogen and organics dynamics in wetland systems with continuous-stirred tank reactor or plug flow pattern to predict effluent concentrations (Saeed & Sun, 2011);

- Multi-flow dispersion model: the total flow is divided into a number of different flow fractions that follows several pathways each with unique hydraulic features, applied to the plug-flow with dispersion model to obtain different dispersion modules and average hydraulic residence time values (Maloszewski, et al., 2006).

These other models were not further reviewed in this study.

1.1.2 Role of Plants in Constructed Wetlands

The role of plants in CWs is debatable (Mara, 2004), with most studies indicating the selection of plants to use in constructed wetlands as an important aspect of the design (Vymazal & Kropfelova, 2009); and depending on the type of plant selected, pollutant removal may be improved (Akratos & Tsihrintzis, 2007) (Brisson & Chazarenc, 2009) (Kadlec, et al., 2000) (Stefanakis & Tsihrintzis, 2012). Other studies indicate that similar treatment efficiencies through CWs can be achieved independently of the presence or absence of plants, especially for ammonium removal (Sklarz, et al., 2009) (Gross, et al., 2007) (Lahav, et al., 2001) (Green, et al., 1998).

The presence of wetland plants has many benefits to the surface flow wetland. They provide surface area for attached bacterial growth, they provide shade that reduces the growth of algae which can cause suspended solids problems in the effluent, reduce wind turbulence which could cause resuspension of settled solids, transfer limited amounts of oxygen into subsurface soils of rock media in a submerged bed system. On the other hand, dense planted areas interfere with oxygen transfer into the waste and prevent

sunlight penetration, which can stimulate photo destruction of certain contaminants and oxygen production by algae. Open water parts of the wetland or parts containing mostly submerged growth may exhibit aerobic conditions, at least throughout the day. Heavily vegetated parts probably exhibit anoxic or anaerobic conditions throughout. Plants in a subsurface flow wetland have been not found to be as beneficial as in a surface flow wetland. Their major contribution is to limit the access of people and animals to the top of the gravel bed, which may be wet with partially treated wastewater. They also provide aesthetic appeal and ecological benefits since many of the plants that can thrive in such an environment are attractive and provide habitat to wildlife. Some plants have the potential to transfer oxygen down into the gravel bed and transport waste product gases, such as methane, CO₂ and nitrogen out of the bed. However, studies indicate that the rate of gas transfer is small compared to the oxygen demand of the wastewater and thus has little impact on the biodegradation reactions occurring within.

The type of vegetation depends on the goals and objectives of the wetland. Ideally, vegetation should include a variety of species; however, constructed wetlands for treating wastewater need to be as versatile and easily maintained as possible. Practicality might dictate limiting plant species to the hardiest, commonly found, and easily managed. Plant species' performance and removal efficiency is tied to the biota's ability to tolerate the extremely variable conditions. Emergent and floating aquatic plants provide a shade over the water column, limiting phytoplankton production, increasing the potential for accumulation of free-floating aquatic plants that restrict atmospheric re-aeration and the reducing suspended solids within the constructed wetland (U.S. EPA, 1999). Some commonly used plants are shown on the Table 1-2.

There is literature available about characteristics and requirements of various wetland plants. Demonstrational research has found that cattails (*Typha* spp.) and reed canary grass (*Phalaris arundinacea*) have proven to be low cost, easy to establish, low maintenance, and tolerant of a wide range of climatic and contamination conditions. Cattails and reed canary grass can both tolerate drought conditions for several weeks. Broadleaf cattails (*Typha latifolia*) can withstand water depths up to 18 inches and narrowleaf cattails (*Typha angustifolia*) up to 12 inches. The next most versatile and easily managed plants would be common reed (*Phragmites australis*) and various species of bulrush (*Scirpus* spp.).

Table 1-2: Common plants for constructed wetlands

Type of plants	Common Species
Free Floating Aquatic	Common duckweed (<i>Lemna</i>), Big duckweed (<i>Spirodela</i>).
Rooted Floating Aquatic	Water lily (<i>Nymphaea</i>), Pennywort (<i>Hydrocotyle</i>)
Submerged Aquatic	Pondweed (<i>Potamogeton</i>), Water weed (<i>Elodea</i>)
Emergent Aquatic	Cattail (<i>Typha</i>), Bulrush (<i>Scirpus</i>), Common Reed (<i>Phragmites</i>)
Shrubs	Dogwood (<i>Cornus</i>), Holly (<i>Ilex</i>)
Trees	Maple (<i>Acer</i>), Willow (<i>Salix</i>)
Source: (U.S. EPA, 1999)	

1.2 Research Gaps

There are studies and experiences of constructed wetlands in the temperate climate (mostly in the U.S. and Europe); in contrast, information is limited in the tropics (Caselles-Osorio, et al., 2011) (Mburu, et al., 2013). The effectiveness of wetland

systems is affected by climate; important factors include temperature, precipitation and evapotranspiration, which vary from place to place. As a result, experiences and models from temperate climate may not transfer well to the tropics due to the difference in climate. It is generally assumed that constructed wetland systems are more efficient in tropical climates than in temperate climates because higher temperatures encourage plant growth and enhances the kinetics of microbial activity (Bojcevska & Tonderski, 2007); (Kaseva, 2004); (Trang, et al., 2010).

However, there is very limited number of CW studies that use commonly found tropical plants, such as *Thalia*, *Cyperus*, and *Brachiaria*.

Additionally, most studies investigate the CW performance for BOD, and nutrients (total nitrogen and phosphorus); however, not many studies present CW performance results for fecal coliforms, TSS, and Oil & Grease. Fecal coliforms is a parameter of interest under tropical climate conditions as higher temperatures, precipitation and humidity are prone to their proliferation.

1.3 Central Hypothesis and Research Objectives

The central hypothesis is that the constructed wetland system of the study is capable to provide competitive secondary treatment levels, removing significant amounts of biological oxygen demand (BOD₅), total suspended solids (TSS) and pathogens among other water quality indicators, under tropical climatic conditions.

The research objectives are as follows:

- 1) Design, construction, startup, and operation phases of the field scale CW System.

- 2) Characterize SSF and SF influent and effluents for BOD, TSS, Total Nitrogen, Phosphorus, Fecal Coliform, and Oil & Grease.
- 3) Evaluate the design performance using empirical models and observed data.
- 4) Compare the differences in treatment associated with wetland plants commonly used in CW and plants that are typical to the tropics, not traditionally used in CWs.

1.4 Justification and Contribution

The U.S. Department of Defense, in conjunction with Florida International University (FIU), conducted a demonstration and validation of innovative technologies in order to allow an efficient management of military installations, protect the environment, ensure safety and occupational health, and develop renewable clean energy resources.

Constructed wastewater treatment wetland systems in a tropical climate were one of these innovative technologies selected to reduce the discharge of untreated or partially treated wastewater into surface water streams. Such discharges are a risk to human health and cause environmental degradation.

The constructed wetlands demonstration and validation evaluated in this dissertation took place in El Salvador, Central America and focused on determining the effectiveness of treatment wetlands as compared to conventional wastewater treatment methods. The overall purpose of this project was to plan, construct and evaluate a constructed treatment wetland to gain mutually beneficial experience with such system in tropical climate. This

study monitored and evaluated the complexity of the design process, evaluated the suitability of this technology in tropical climate, and assessed the use of typical tropical plants in constructed wetland performance efficiency. Moreover, the predicted values used during design were compared with actual results from the constructed system to evaluate the design methodology appropriateness.

1.5 Dissertation Outline

This dissertation is organized in four chapters. The first chapter is an introduction including background information on constructed wetland systems, research objectives, current research gaps, and a brief description on how this project was initiated by the U.S. Department of Defense and FIU.

Chapter two consists of the experimental setting, including the study location, system description, an overview of the constructed wetland system design and construction, and presents the data collected in this study, such as water balance, quality indicators, and field parameters.

Chapter three includes the results and discussion addressing the objectives of this dissertation. The CW System of this study performance results are presented for BOD₅, TSS, COD, Fecal Coliform, Oil & Grease, Total Nitrogen, Phosphorus, Plant Growth and Health) and evaluated in comparison with the available literature information. An assessment of the models used during design typically used in temperate climate is compared with the actual performance results from this study CW system which is in a

tropical climate. Sensitivity analysis of the methodology used during design was performed for BOD₅ and TSS to determine the variables that have an important role in the CW system process.

Chapter four presents the conclusions, limitations and recommendations as reference for future investigations and applications.

2 METHODOLOGY

2.1 Experimental Setting

2.1.1 Study Location

The field-scale constructed wetland system of this investigation was part of a demonstration project that was conducted by Florida International University (FIU), in conjunction with the United States and the El Salvadoran Armies. The project treated domestic wastewater generated from approximately 600 soldiers and was located at the Salvadoran Army Cavalry Regiment (SACR), near San Juan Opico, La Libertad Province, in El Salvador, as shown in Figure 2-1.

Figure 2-1: Location Map

The site is at an altitude of 460 m above sea level and is of coordinates 13° 48.5' N and 89° 24.4' W. The region is characterized by a hot tropical climate and a savanna-like woodland ecosystem. Two seasons, alternating with two 30-day transitional periods occur during the year: the dry season falls between November and April, and the wet season lasts from May to October. Every year the area receives an average of 1644 mm of rainfall, with monthly maximums approaching 317 mm during the rainy season. Daytime temperatures vary little, ranging from January lows of 22.7°C (72.9°F) to highs of 26.0°C (78.8°F) during April-May (Katsenovich, et al., 2009).

2.1.2 System Description

Prior to the construction of the constructed wetland system in 2005, wastewater at the SACR received only partial treatment in the facultative lagoon (FL) system, followed by the addition of chlorine solution for disinfection, and then the partially treated effluent was discharged into an outfall ditch, as illustrated in Figure 2-2.

Figure 2-2: Facultative Lagoon System Schematic (Prior to CW System Construction)

Figure 2-3 shows a schematic of the complete new treatment system that includes the constructed wetland system (CW system) of this study. The new CW system is in between the three existing facultative lagoons that are now called Basins 1 to 3. Figure 2-4 shows the site layout for the complete treatment system. As mentioned above, this dissertation focuses on the CW system, consisting of three SSF CWs and three SF CWs. An aerial view of the complete system is included in Appendix A.

Figure 2-3: Complete Treatment System Schematic (new)

Figure 2-4: Site Plan with Constructed Wetland System

The CW system was placed near an existing facultative lagoon system at the Cavalry Base (now called Basins 1, 2 and 3). Basin 1, which became an equalization basin, providing some partial primary treatment, has a capacity of 9,800 m³ and it is followed by the SSF CW and the latter followed by a SF CW; the SF CW effluent was then discharged in a new lagoon, then into Basins 2 and 3, depending on operational and possible reuse needs in irrigation.

A 150 m³/day (40,000 gallon per day) pump was installed in the existing flow control structure connecting Basin 1 to the SSF CW. The pump was initially controlled by a simple float switch system and operated based on water level to pump the entire wastewater flow coming out of the first basin to the new wetland system. Since the float switch did not work properly for the entire duration of this study, a timer was installed to start and stop the pump on a regular basis. Water treated by the constructed wetland

system flowed by gravity from the SSF CW to the SF CW and to the new lagoon and then to Basin 2 where it was further cleaned and stored for possible use in irrigation. If not used, the water passed through Basins 2 and 3 and exited through the existing wastewater discharge point.

The SSF CW unit consisted of a 0.6-meter thick bed of 20-30 mm diameter gravel (medium gravel). At the entrance and exit ends of each bed a zone of 40-80 mm diameter coarse gravel allowed for a uniform distribution of flow across the wetland gravel bed. A 0.15-meter thick layer of 5-10 mm diameter fine gravel was over both gravel zones to serve as rooting zone for the wetland plants. The gravel beds were separated into three parallel flow paths to improve the distribution of wastewater and reduce short-circuiting.

The SF CW unit consisted of a shallow open basin containing alternating regions of open water (OW) with submerged aquatic plants and regions of shallower water filled with emergent wetland vegetation. The OW portion of these basins was approximately 1.2 meters deep where atmospheric oxygen, and oxygen generated by submerged plants and algae, interacts with bacteria to change the nature of contaminants in the water, particularly nutrients such as ammonia. The flow then passed into the vegetated sections where interactions between the plants and bacteria growing on the plants, removed these contaminants. In these areas wastewater flowed in an open channel approximately 0.45 meters deep. Like the SSF CW, this wetland bed was divided into three parallel flow paths. Flow from each of the SSF flow paths passed directly into one of the SF CW flow paths through a submerged inlet distribution header. Water flowed into the first open water section, a vegetated section, a second open water section, and then the final

vegetated section. Treated water passed through a narrow gravel bed to remove floating solid matter released from the vegetated sections. Treated water then passed into an effluent collection header identical to the inlet distribution header. The water passed through a level control structure fitted with a swiveling overflow pipe that could be tilted to allow the water level to be adjusted as needed.

Plans and sections of both SSF and SF CW systems, including dimensions, are presented in Appendix A.

2.1.3 Design and Construction

2.1.3.1 Area Calculation

The design of the above mentioned CW System was completed in a step-wise iterative manner following the steps discussed in this Chapter, by former FIU engineer L. Moos, and myself. The basic process design was selected after reviewing a number of current design approaches in common use in the USA for this type of system. The design methodologies described in Chapter 1.1.1.1 and listed below were examined and compared for BOD and TSS removals:

- Campbell, C.S. and Michael H. Ogden. Constructed Wetlands in the Sustainable Landscape. John Wiley & Sons, Inc. 1999.
- EPA. “Constructed Wetlands Treatment of Municipal Wastewaters.” Office of Research and Development. EPA/625/R-99/010. September 2000.

- Kadlec, R.H. and Robert L. Knight. Treatment Wetlands. CRC Lewis Publishers. 1995.
- Reed, S. C., E. Joe Middlebrooks and Ronald W. Crites. Natural Systems for Waste Management & Treatment. McGraw-Hill Book Company. 1988.

The various design calculations were done in a series of Microsoft Excel worksheet, validated by hand calculations of each major calculation. The main input parameters for the various models were wastewater flow, influent characteristics and temperature. Several of the models introduced other parameters unique to their methodology. This analysis revealed a wide range in design approaches and in the resulting calculation of required wetland areas.

Flows, wastewater analysis, nearby water river analysis, well water analysis and precipitation, evapotranspiration and temperature information were the main parameters used on this design. These data were collected from two trips to the Army Bases in El Salvador in July and August 2005. Wastewater and water samples were collected by FIU personnel (L. Moos and myself), and sent to FUSADES Laboratory (a local laboratory) for necessary analysis. Precipitation, evapotranspiration and temperature were provided by CENTA (“Centro Nacional de Tecnología Agropecuaria y Forestal”).

The base flow for approximately 600 soldiers was measured as 22,400 gal/day, resulting in a daily wastewater flow of approximately 37 gal/capita-day (140 L/capita-day).

September was the peak flow month because of the large amount of precipitation with the estimated design flow rates as shown in Table 2-1, and therefore, it was used as the

design month for comparison of required areas. Figure 2-5 illustrates the annual precipitation, evaporation and temperature used in the design process.

Table 2-1: Design Flow Rates Used in Method Comparison

Location	Flow (gal/day) (September)
Base Flow (wastewater only)*	22,400
Basin 1 outlet flow	30,496
SSF CW outlet	31,909
SF CW outlet	38,974
* 600 soldiers, approximately 37 gal/capita-day (140 L/capita-day)	

The design comparison was based on wastewater characteristics estimated for the month of September 2005 as explained above. BOD removal was the controlling process for the SSF CW sizing. A comparison of the areas calculated showed that the Kadlec method yields an area for the SSF CW comparable though somewhat smaller than the other models, and much smaller than the EPA method. The CW area was calculated for the projected influent flow rates and contaminant characteristics for each month of the year, based on the following assumptions:

- Temperature = 20.4 degree C
- SSF CW: Depth of gravel bed = 0.60 m (2 feet)

Porosity of gravel = 0.40

- SF CW: Depth of SF cell = 0.45 m (18 inches)

Porosity (density of plant stems) = 0.65

Depth of OW cell = 1.20 m (4 feet)

Porosity (density of plant stems) = 0.80

Figure 2-5: Precipitation, Evaporation, Temperature

Based on the calculation results of area and hydraulic detention time for each method mentioned above listed in Table 2-2, Kadlec methodology was chosen for final design. Kadlec is the only method that provides calculation tools for all the parameters of interest in this study. As mentioned above, BOD removal was the decision parameter for the SSF CW dimensions, and Total Nitrogen removal was the decision parameter for the SF CW

dimensions. The area was then calculated for each month and the area of the final design was chosen to be the biggest area calculated.

Table 2-2: Different Design Method Results Summary

CW Type	Param.	Design Concentration (mg/L)		Campbell		Reed et al.		EPA		Kadlec	
		In	Out	Area (m ²)	HDT (days)	Area (m ²)	HDT (days)	Area (m ²)	DT (days)	Area (m ²)	HDT (days)
SSF	BOD	74	40	349	0.7	309	0.7	5,549	16.8	173	0.4
	TSS	147	40	76	0.2	-	-	888	2.7	56	0.1
	Total N	40	40	-	-	-	-	-	-	2,467	5.2
	Total P	5	5	-	-	243	0.5	-	-	106	0.2
SF	BOD	40	20	1,356	3.3	45	0.1	537	1.6	1,130	2.8
	TSS	40	20	6.3	0.2	-	-	2,416	7.3	53	0.1
	Total N	40	10	-	-	-	-	5,086	15.4	3,122	7.7
	Total P	5	3	-	-	-	-	-	-	1,902	4.7
Note: HDT = hydraulic detention time											

Table 2-3 lists the calculation results per month using the Kadlec equations for BOD removal from the SSF CW. The area chosen for the final design was the largest monthly area calculated. The design size of 388 square meters was controlled by wet weather conditions in late summer. There are differences in the area size of the SSF CW compared to the initial design area size of 173 m² because during the initial design, the BOD effluent objective of the SSF CW was 40 mg/L, as opposed as the final design of the SSF that had a BOD effluent objective of 20 mg/L. This new BOD effluent at the outlet of the SSF CW raised the area significantly.

Table 2-3: Results of Design Calculations for BOD Removal in SSF CW

Month	BOD_{in} (mg/L)	BOD_{out} (mg/L)	Flow (gal/d)	Area (m²)	Hydraulic Detention time (days)
January	135	20	16,246	322	1.26
February	142	20	15,371	316	1.30
March	147	20	14,831	312	1.34
April	134	20	16,343	323	1.25
May	100	20	22,195	357	1.02
June	76	20	29,294	384	0.83
July	74	20	30,437	387	0.81
August	74	20	30,437	387	0.81
September	73	20	30,755	388	0.80
October	95	20	23,365	362	0.98
November	121	20	18,157	334	1.17
December	131	20	16,733	325	1.23

Table 2-4 lists the calculation results per month using the Kadlec equations for Total N removal from the SF CW. The controlling conditions for nitrogen removal were in January resulting in a design area of 2,316 m², due to the lower temperature encountered in the winter.

Table 2-4: Results of Design Calculations for Total N Removal in SF CW

Month	Nin (mg/L)	Nout (mg/L)	Flow (gal/d)	Area (m2)	Hydraulic Detention time (days)
January	49	10	16,021	2,316	13.75
February	51	10	15,116	2,073	13.04
March	52	10	14,557	2,020	13.20
April	46	10	16,122	1,810	10.68
May	35	10	22,178	1,873	8.03
June	28	10	29,525	2,203	7.10
July	27	10	30,708	2,237	6.93
August	27	10	30,708	2,198	6.81
September	27	10	31,037	2,190	6.71
October	34	10	23,389	2,019	8.21
November	43	10	17,999	2,150	11.36
December	47	10	16,525	2,097	12.07

A safety factor of additional 17 % and 4% was added to the SSF CW and SF CW design areas, respectively should any of the assumptions of values used in the calculations turn out to be incorrect or should conditions other than those anticipated develop. The total SSF CW area was approximately 454 m² (151.2 m² each cell), and the total SF CW area was approximately 2,400 m² (799.6 m² each cell).

2.1.3.2 Plant Selection

The ideal plants would be hardy, fast growing native wetland plants adapted to the climate near the base. El Salvador did not have any plant nurseries that grow or sell

commercial quantities of wetland plants, thus natural sources of these plants were located and the plants harvested for transplanting in the treatment wetlands. Preliminary assessments of wetland plants in the vicinity of the site were made during the two site visits above mentioned and several potential sources were found. In addition, the topic of wetland plants was discussed with several contractors, universities and governmental agencies. It was determined that the most effective means of finding and collecting these plants was to work with a local contractor or agency that knows the local situation and can work with land owners to arrange for removal of these plants. After the plants were selected with assistance of CENTA, CENTA was hired to start a nursery to grow the plants in a more controlled environment until they reached the minimum size required for constructed wetlands.

Three types of plants were used in the CW system: (a) grass-type herbaceous plants such as *Brachiaria mutica* and *Phragmites* sp.; (b) emergent herbaceous plants such as *Thalia*, *Typha*, and *Cyperus* species; and (c) submerged aquatic plant such as *Elodea* spp.

The CW system was divided into three cells, each of which was home to a combination of different species: *Phragmites australis* – *Typha angustifolia* (Cell 1-2-5), *Thalia geniculata* – *Thalia geniculata* (Cell 1-3-6) and *Brachiaria mutica* – *Cyperus alternifolius* (Cell 1-4-7). *Phragmites* is the most used plant around the world in CW systems, and *Typha* is another commonly used species (Vymazal, 2011). *Brachiaria mutica* grows rapidly, achieve and maintain high plant and biomass densities below the water surface, which supports desirable microbial growth. *Thalia* is a widespread tropical plant with the high potential for nitrogen and phosphorus removal (Polomski et. al, 2008)

not typically used in constructed wetland applications. *Thalia* and *Brachiaria* species were used to compare their pollutants removal efficiencies with a traditional wetland-type plant used in constructed wetlands, such as, *Phragmites*. Towards the end of the study, *Lemna* spp. was observed to take over the OW, effectively eliminating the growth of *Elodea* spp.

Cell 1-2-5 was the control CW cell as it had typical wetland plants. The plants in the other two cells were chosen because they were easily found in wetlands near the study area. The plant arrangement was similar on Cell 1-2-5 (control cell), and Cell 1-4-7, where grass type plant was followed by emergent herbaceous plant. The arrangement on Cell 1-3-6 was different than the other two, having emergent herbaceous plant in both SSF and SF CWs. *Thalia* sp. was very abundant in the wetlands near the study area, and it was placed in both CWs in order to evaluate its treatment capacity for both types (SSF and SF CW).

Table 2-5 below summarizes the CW System plants combinations. The flow passed through each of the SSF CW in parallel, then each SSF CW cell was connected in series to one individual SF CW cell that were in parallel. Figure 2-6 illustrates the plants distribution throughout the CW system.

Table 2-5: CW Cells Plant Identification

Monitoring Point ID	Description
SSF 1	Basin 1 Outlet (SSF Inlet)
SSF 1-2	SSF Outlet 2 (Phragmites) from Basin 1
SSF 1-3	SSF Outlet 3 (Thalia) from Basin 1
SSF 1-4	SSF Outlet 4 (Brachiaria) from Basin 1
SF 2-5	SF Outlet 5 (Typha) from SSF Outlet 2 (Phragmites)
SF 3-6	SF Outlet 6 (Thalia) from SSF Outlet 3 (Thalia)
SF 4-7	SF Outlet 7 (Cyperus) from SSF Outlet 4 (Brachiaria)

Figure 2-6: SSF and SF CW Layout, Plants Distribution, and Monitoring Points

2.1.3.3 Construction

The wetland system construction work was undertaken from April to September 2006 by a local contractor, and construction administration also by a local company on a daily basis, with FIU personnel performing monthly site inspections. CENTA was hired to identify and test the required soil materials, and to obtain, collect and transplant the wetland plants required.

2.2 Data Collection

The system was monitored for eleven (11) months, from November 2006 to September 2007, with a total of seventeen (17) monitoring events. Each monitoring event consisted of visual observation, water sample collection, field parameter measurement, water quality analyses, water levels recording, monitoring for plant condition and growth rates. Grab samples were collected by scientists from CENTA (“Centro Nacional de Tecnología Agropecuaria y Forestal”) from level control boxes at the inlet and outlet of each CW cell, and were taken to a local laboratory (FUSADES) for physical/chemical analysis. Table 2-6 presents the actual monitoring event dates. Five (5) out of seventeen (17) monitoring events did not include visual observation, nor field parameter measurements.

Table 2-6: Monitoring Event Dates

Monitoring Event No.	Monitoring Event Date	Monitoring Event No.	Monitoring Event Date
1*	November 29, 2006	10	May 09, 2007
2	December 19, 2006	11	June 27, 2007
3	January 08, 2007	12	July 04, 2007
4	January 17, 2007	13*	July 11, 2007
5	January 24, 2007	14	July 18, 2007
6	January 30, 2007	15*	July 25, 2007
7	February 07, 2007	16	August 15, 2007
8*	March 13, 2007	17	September 19, 2007
9*	April 24, 2007		
* Physical/chemical analysis only Other dates were complete monitoring events.			

Table 2-5 and Figure 2-6 show seven (7) level control structures along SSF and SF cells, with their monitoring points properly identified.

Analytical parameters for monitoring were chosen for adequately characterizing the quality of effluent domestic wastewater from the Cavalry base. Table 2-7 presents the list of the water quality parameters analyzed by FUSADES (a local laboratory) according to the standard methods, using EPA protocols:

Table 2-7: Water Quality Analytical Parameters (by FUSADES)

Physical-Chemical		Microbiological
Biological Oxygen Demand (BOD ₅ soluble)	Total Dissolved Solids (TDS)	Fecal coliforms, (MPN/100ml & membrane filter)
Chemical Oxygen Demand (COD soluble)	Total Nitrogen	Specific
Total Suspended Solids (TSS)	Total phosphorus as P	Oil and Grease

2.2.1 Water Balance

The SSF inlet flow rate (Q_{in}) was calculated based on field measured instantaneous flow rates (Q_{inst}) and recorded pump runtime (PR):

$$Q_{inSSF} = Q_{inst.} * PR \quad (19)$$

Where: Q_{inSSF} = SSF inlet flow rate, m³/d

Q_{inst} = SSF inlet instantaneous flow rate, m³/d

PR = Pump Runtime, h/d

The SSF outlet flow rate (Q_{out}) was calculated as the SSF inlet flow rate plus recorded Precipitation (Pr_{SSF}) minus estimated evaporation (ET_{SSF}). Pr_{SSF} and ET_{SSF} were calculated based on the area (A_{SSF}) of the SSF CW.

$$Q_{outSSF} = Q_{in} + Pr_{SSF} - ET_{SSF} \quad (20)$$

Where: Q_{outSSF} = SSF outlet flow rate, m³/d

Q_{inSSF} = SSF inlet flow rate, m³/d

$$Pr_{SSF} = \text{Precipitation rate (m/d)} * A_{SSF} (m^2), m^3/d$$

$$ET_{SSF} = \text{Evaporation rate (m/d)} * A_{SSF} (m^2), m^3/d$$

$$A_{SSF} = \text{SSF CW Area, } m^2$$

Hydraulic detention time (HDT) was calculated based on SSF outlet flow rate, area, depth, and media porosity.

$$HDT_{cellSSF} = \frac{(A_{SSFcell} * D_{SSF} * n)}{Q_{outcell}} \quad (21)$$

Where: $HDT_{cellSSF}$ = Hydraulic Detention Time per SSF cell, days

$A_{SSFcell}$ = SSF Area per Cell

D_{SSF} = SSF Average Water Depth

n = Gravel Porosity

$Q_{outcellSSF} = Q_{outSSF} / 3$ = SSF outlet flow rate per cell, m^3/d

Table 2-8 and Table 2-9 present the values used in the water balance calculations. The calculated SSF outlet flow rate (Q_{outSSF}) was considered to be the same for the three (3) SSF Cells, without taking into consideration different transpiration rates through the plants.

Table 2-8: Water Balance Values per SSF Cell

Sampling Date	Q_{inst}, m³/d	PR, h/d	Q_{in}^{SSF} (Q_{inst}*PR), m³/d	Pr^{SSF} (Pr*A_{SSF}), m³/d	ET^{SSF} (ET*A_{SSF}), m³/d	Q_{out}^{SSF} (Q_{in}+Pr^{SSF}-ET^{SSF}), m³/d	HDT^{SSF} ((A*D*n)/Q_{out}), days
11/29/06	72.09	6	18.02	0.26	0.69	17.60	2.06
12/19/06	72.09	4	12.02	0.17	0.69	11.50	3.16
01/08/07	72.09	3	9.01	0.00	0.71	8.30	4.37
01/17/07	72.09	3	9.01	0.00	0.71	8.30	4.37
01/24/07	72.09	3	9.01	0.00	0.71	8.30	4.37
01/30/07	72.09	3	9.01	0.00	0.71	8.30	4.37
02/07/07	72.09	3	9.01	0.00	0.83	8.18	4.44
03/13/07	72.09	3	9.01	0.03	0.93	8.12	4.47
04/24/07	72.09	3	9.01	0.43	0.88	8.56	4.24
05/09/07	72.09	3	9.01	0.73	0.75	8.99	4.04
06/27/07	72.09	4	12.02	0.37	0.63	11.75	3.09
07/04/07	72.09	5	15.02	1.70	0.70	16.02	2.27
07/11/07	72.09	6	18.02	1.70	0.70	19.02	1.91
07/18/07	72.09	6	18.02	1.70	0.70	19.02	1.91
07/25/07	72.09	8	24.03	1.70	0.70	25.03	1.45
08/15/07	72.09	8	24.03	1.44	0.75	24.72	1.47
09/19/07	72.09	12	36.05	1.52	0.67	36.90	0.98
Average	72.09	4.88	14.67	0.69	0.73	14.63	3.11
Standard Deviation	0.00	2.47	7.42	0.72	0.07	7.99	1.25
<i>Notes: Q_{inst} = Instantaneous Flow; PR = Pump Runtime; Pr = Precipitation; ET = Evapotranspiration; HDT_{SSF} = Hydraulic Detention Time. A_{SSF} = 151.2 m²; Water Depth = 0.6 m; Gravel Porosity = 0.4 m³/m³</i>							

The SF inlet flow rate (Q_{in}^{SSF}) was the SSF calculated outlet flow rate. The SF outlet flow rate (Q_{out}^{SSF}) was calculated as the SF inlet flow rate plus recorded Precipitation

(Pr_{SF}) minus estimated evaporation (ET_{SF}). Pr_{SF} and ET_{SF} were calculated based on the area (A_{SF}) of the SF CW.

Table 2-9: Water Balance Values per SF Cell

Sampling Date	Q_{inSF} ($Q_{outSSF} + Pr_{SSF} - ET_{SSF}$) ($m^3/d$)	Pr_{SF} ($Pr * A_{SF}$), m^3/d	ET_{SF} ($ET * A_{SF}$), m^3/d	Q_{outSF} ($Q_{inSF} + Pr_{SF} - ET_{SF}$) ($m^3/d$)	HDT_{SF} (($A * D * n$)/Q_{out}), days
11/29/06	17.60	1.39	3.63	15.36	23.70
12/19/06	11.50	0.90	3.64	8.76	41.54
01/08/07	8.30	0.00	3.74	4.56	79.77
01/17/07	8.30	0.00	3.74	4.56	79.77
01/24/07	8.30	0.00	3.74	4.56	79.77
01/30/07	8.30	0.00	3.74	4.56	79.77
02/07/07	8.18	0.00	4.40	3.78	96.27
03/13/07	8.12	0.18	4.90	3.40	107.13
04/24/07	8.56	2.28	4.66	6.17	58.99
05/09/07	8.99	3.87	3.97	8.89	40.96
06/27/07	11.75	1.95	3.33	10.37	35.11
07/04/07	16.02	9.00	3.71	21.31	17.09
07/11/07	19.02	9.00	3.71	24.31	14.98
07/18/07	19.02	9.00	3.71	24.31	14.98
07/25/07	25.03	9.00	3.71	30.32	12.01
08/15/07	24.72	7.64	3.97	28.39	12.83
09/19/07	36.90	8.05	3.52	41.43	8.79
Average	14.63	3.66	3.86	14.43	46.84
Standard Deviation	7.99	3.80	0.38	11.34	31.97
<i>Notes: Pr = Precipitation; ET = Evapotranspiration; HDT = Hydraulic Detention Time.</i> $A_{SF} = 605 \text{ m}^2$; Water Depth = 0.45 m; Root Porosity = $0.65 \text{ m}^3/\text{m}^3$ $A_{OW} = 195 \text{ m}^2$; Water Depth = 1.2 m; Root Porosity = $0.8 \text{ m}^3/\text{m}^3$					

As there was a great variation in flow and hydraulic detention time during the wet and dry season, the water balance data presented above was re-organized by wet and dry season in Table 2-10 and Table 2-11. Wet season includes the months of May to November, and dry season includes the months of December to April.

Table 2-10: Seasonal Water Balance Values per SSF Cell

Seasonal Water Balance Values per SSF Cell								
Season	Date	Q _{inst} , m ³ /d	PR, h/d	Q _{in} _{SSF} (Q _{inst} *PR), m ³ /d	Pr _{SSF} (Pr*A _{SSF}), m ³ /d	ET _{SSF} (ET*A _{SSF}), m ³ /d	Q _{out} _{SSF} (Q _{in} +Pr _{SSF} -ET _{SSF}), m ³ /d	HDT _{SSF} ((A*D*n) /Q _{out}), days
Wet (May to Nov)	11/29/06	72.09	6	18.02	0.26	0.69	17.60	2.06
	5/9/07	72.09	3	9.01	0.73	0.75	8.99	4.04
	6/27/07	72.09	4	12.02	0.37	0.63	11.75	3.09
	7/4/07	72.09	5	15.02	1.70	0.70	16.02	2.27
	7/11/07	72.09	6	18.02	1.70	0.70	19.02	1.91
	7/18/07	72.09	6	18.02	1.70	0.70	19.02	1.91
	7/25/07	72.09	8	24.03	1.70	0.70	25.03	1.45
	8/15/07	72.09	8	24.03	1.44	0.75	24.72	1.47
	9/19/07	72.09	12	36.05	1.52	0.67	36.90	0.98
	AVE	72.09	6.44	19.36	1.24	0.70	19.90	2.13
	SD	0.00	2.65	7.96	0.61	0.04	8.26	0.93
Dry (Dec to April)	12/19/06	72.09	4	12.02	0.17	0.69	11.50	3.16
	1/8/07	72.09	3	9.01	0.00	0.71	8.30	4.37
	1/17/07	72.09	3	9.01	0.00	0.71	8.30	4.37
	1/24/07	72.09	3	9.01	0.00	0.71	8.30	4.37
	1/30/07	72.09	3	9.01	0.00	0.71	8.30	4.37
	2/7/07	72.09	3	9.01	0.00	0.78	8.23	4.41
	3/13/07	72.09	3	9.01	0.03	0.93	8.12	4.47
	4/24/07	72.09	3	9.01	0.43	0.88	8.56	4.24
	AVE	72.09	3.13	9.39	0.08	0.76	8.70	4.22
	SD	0.00	0.35	1.06	0.15	0.09	1.14	0.43
Notes: Q _{inst} = Instantaneous Flow; PR = Pump Runtime; Pr = Precipitation; ET = Evapotranspiration; DT = Hydraulic Detention Time; AVE = Average; SD = Standard Deviation A _{SSF} = 151.2 m ² ; Water Depth = 0.6 m; Gravel Porosity = 0.4 m ³ /m ³								

As it can be seen in Table 2-10, the calculated SSF CW average influent flows during the wet and dry season were $19.36 \text{ m}^3/\text{day} \pm 7.96 \text{ m}^3/\text{day}$ and $9.39 \text{ m}^3/\text{day} \pm 1.06 \text{ m}^3/\text{day}$, respectively. The calculated SSF CW average effluent flows during the wet and dry season were $19.90 \text{ m}^3/\text{day} \pm 8.26 \text{ m}^3/\text{day}$ and $8.70 \text{ m}^3/\text{day} \pm 1.14 \text{ m}^3/\text{day}$, respectively. The calculated SSF CW average hydraulic detention times during the wet and dry season were $2.13 \text{ days} \pm 0.93 \text{ days}$ and $4.22 \text{ days} \pm 0.43 \text{ days}$, respectively.

Table 2-11: Seasonal Water Balance Values per SF Cell

Season	Date	Q_{inSF} ($Q_{inSSF} + Pr_{SSF} - ET_{SSF}$) (m^3/d)	Pr_{SF} ($Pr * A_{SF}$), m^3/d	ET_{SF} ($ET * A_{SF}$), m^3/d	Q_{outSF} ($Q_{in} + Pr_{SF} - ET_{SF}$) (m^3/d)	HDT_{SF} ($((A * D * n)/Q_{out})$, days
Wet (May to Nov)	11/29/06	17.60	1.39	3.63	15.36	23.70
	5/9/07	8.99	3.87	3.97	8.89	40.96
	6/27/07	11.75	1.95	3.33	10.37	35.11
	7/4/07	16.02	9.00	3.71	21.31	17.09
	7/11/07	19.02	9.00	3.71	24.31	14.98
	7/18/07	19.02	9.00	3.71	24.31	14.98
	7/25/07	25.03	9.00	3.71	30.32	12.01
	8/15/07	24.72	7.64	3.97	28.39	12.83
	9/19/07	36.90	8.05	3.52	41.43	8.79
	AVE	19.90	6.54	3.70	22.74	20.05
	SD	8.26	3.21	0.20	10.28	11.07
Dry (Dec to April)	12/19/06	11.50	0.90	3.64	8.76	41.54
	1/8/07	8.30	0.00	3.74	4.56	79.77
	1/17/07	8.30	0.00	3.74	4.56	79.77
	1/24/07	8.30	0.00	3.74	4.56	79.77
	1/30/07	8.30	0.00	3.74	4.56	79.77
	2/7/07	8.23	0.00	4.14	4.09	89.07
	3/13/07	8.12	0.18	4.90	3.40	107.13
	4/24/07	8.56	2.28	4.66	6.17	58.99
	AVE	8.70	0.42	4.04	5.08	76.98
	SD	1.14	0.81	0.49	1.68	19.52

Notes: Pr = Precipitation; ET = Evapotranspiration; HDT = Hydraulic Detention Time; AVE = Average; SD = Standard Deviation

$A_{SF} = 605 \text{ m}^2$; Water Depth = 0.45 m; Root Porosity = $0.65 \text{ m}^3/\text{m}^3$

$A_{OW} = 195 \text{ m}^2$; Water Depth = 1.2 m; Root Porosity = $0.8 \text{ m}^3/\text{m}^3$

As it can be seen in Table 2-11, the calculated SF CW average influent flows during the wet and dry season were $19.90 \text{ m}^3/\text{day} \pm 8.26 \text{ m}^3/\text{day}$ and $8.70 \text{ m}^3/\text{day} \pm 1.14 \text{ m}^3/\text{day}$, respectively (same as the SSF CW average effluent flow). The calculated SF CW average effluent flows during the wet and dry season were $22.74 \text{ m}^3/\text{day} \pm 10.28 \text{ m}^3/\text{day}$ and $5.08 \text{ m}^3/\text{day} \pm 1.68 \text{ m}^3/\text{day}$, respectively. The calculated SF CW average hydraulic detention times during the wet and dry season were $20.05 \text{ days} \pm 11.07 \text{ days}$ and $76.98 \text{ days} \pm 19.52 \text{ days}$, respectively.

The actual flows in comparison with the flows estimated during design were significant lower, as shown in Figure 2-7. This difference in flow is attributed to soldiers that were assigned to overseas duties during the duration of this study.

Figure 2-7: Design Flow vs. Actual Flow

2.2.2 Quality Indicators

The available data from the SSF CW influent (Sampling Point 1), from the SSF CW cells effluent (Sampling Points 1-2, 1-3, and 1-4), and from the SF CW cells effluent (Sampling Points 2-5, 3-6, and 4-7) are included in Appendix B Tables B-1 to B-7. The average and standard deviation for the available SSF CW, SF CW, and overall CW system data are also included in Appendix B Tables B-8 to B-10, organized by parameter.

As there was a great variation in the data between the seasons, the influent and effluent data were organized by dry and wet season, and are presented in Appendix B – Tables B-11 to B-24 in terms of percent (%) residual. Percent (%) residual was calculated using the following equation:

$$\%Residual = \frac{Effluent\ Concentration}{Influent\ Concentration} \quad (22)$$

As mentioned above, wet season includes the months of May to November, and dry season includes the months of December to April.

2.2.3 Field Parameters

The following field parameters were measured during all the monitoring events:

- Wastewater Temperature;
- pH;
- Oxidation Reduction Potential (ORP);
- Dissolved Oxygen (DO); and

- Conductivity

Field parameters were measured at the following locations:

- SSF Inlet,
- SSF Outlets/SF Inlets;
- Open Water Section located in the SF Inlet (OW-A) at three different depths (surface, 0.6 m below the surface, and bottom);
- Open Water Section located in the middle of the SF CW (OW-B) at three different depths (surface, 0.6 m below the surface, and bottom);
- SF Outlets.

Figure 2-8 to Figure 2-12 present the field data average per location. The temperature dropped approximately 2 degrees Celsius in the open water sections, as shown in Figure 2-8, which can be attributed to the floating vegetation shade in those cells. The pH dropped through the SSF wetland and had a slight increase through the SF wetland (Figure 2-9). The oxidation reduction potential (ORP) went up as the flow was moving through the CW system (Figure 2-10), indicating less reducing conditions (Lazareva & Pichler, 2010). The dissolved oxygen (DO) level reduced through the SSF wetland and it increased by 1 mg/L through the SF wetland (Figure 2-11). Conductivity went down as the flow went through the CW system, with higher conductivity levels at the bottom of the OW sections which could be attributed to limited water mixing and stagnant

conditions at the bottom of the OW sections (Figure 2-12). Field parameters data is included in Appendix B Tables B-25 to B-30.

Figure 2-8: Field Parameter - Average Temperature

Figure 2-9: Field Parameter - Average pH

Figure 2-10: Field Parameter - Average ORP

Figure 2-11: Field Parameter - Average DO

Figure 2-12: Field Parameter - Average Conductivity

2.3 Statistical Analysis.

Basic statistics, such as average and standard deviation results, are presented for comparison of the selected quality indicators in the influent to and effluent from the SSF and SF, including percent removals.

All the statistical calculations were performed using Excel's data analysis tool, with random hand calculation to validate the excel results.

3 RESULTS AND DISCUSSION

This Chapter presents the statistical analysis results as described above for the following:

- SSF, SF, and CW System Influent and Effluent Characterization; and
- Comparative Assessment of Models Used During Design

3.1 Influent and Effluent Characterization

A summary of the SSF CW, SF CW, and overall CW System performances per season and per wetland plant are presented in Appendix B, and discussed further in this Chapter for the following parameters:

- BOD;
- TSS.
- COD;
- Fecal Coliform;
- Oil & Grease;
- Total Nitrogen; and
- Phosphorus

Three approaches are commonly encountered to assess a CW system removal performance: effluent concentrations, areal removed load, and performance mass removal

(Hijosa-Valsero, et al., 2010). Since the design was performed based on effluent concentrations in order to achieve the target effluent objectives, the CW system of this study is assessed based on effluent concentrations, with residual percentage presented herein. The 95% confidence levels for all the above parameters are included in Appendix B (Table B-22 to B-24).

3.1.1 BOD₅

BOD₅ concentrations were reduced by the CW System, with the exception of one (1) monitoring event, as shown in **Figure 3-1**. Seasonal results are summarized below.

Figure 3-1: BOD₅ Influent vs. Effluent Concentrations

The BOD₅ average effluent concentrations ranged from 18.5 to 21.7 mg/L during the wet season (May to November). Table 3-1 summarizes the BOD₅ results during the wet season. SSF Point 1-3 (Inlet/Thalia) and SF Point 4-7 (Brachiaria/Cyperus) presented

better results for wet season BOD₅ removal, with an average residual of 64% ± 17% and 53% ± 26%, respectively. However, when looking at the complete CW System, Point 1-4-7 (Inlet/Brachiaria/Cyperus) presented better overall results with an average residual of 36% ± 25%.

Table 3-1: BOD₅ Wet Season Summary

Location Description	Monitoring Point Location	Wet Season BOD ₅ Minimum Concentration (mg/L)	Wet Season BOD ₅ Maximum Concentration (mg/L)	Wet Season BOD ₅ Average Concentration ± Standard Deviation (mg/L)	Wet Season BOD ₅ Average % Residual ± Standard Deviation
Inlet	1	32.8	80.0	54.8 ± 16.3	-
SSF	1-2	13.7	78.1	39.6 ± 20.9	80% ± 62%
	1-3	21.3	55.1	33.3 ± 10.0	64% ± 17%
	1-4	21.2	49.3	33.5 ± 8.2	65% ± 19%
SF	2-5	10.8	37.3	20.2 ± 8.1	60% ± 23%
	3-6	8.7	45.4	21.7 ± 10.7	64% ± 19%
	4-7	5.5	37.2	18.5 ± 11.6	53% ± 26%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	39% ± 13%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	42% ± 20%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	36% ± 25%

The BOD₅ average effluent concentrations ranged from 23.9 to 79.2 mg/L during the dry season (December to April), which is considered a much larger range compared to the wet season average range. Table 3-2 summarizes the BOD₅ results during the dry season. SSF Point 1-4 (Inlet/Brachiaria) and SF Point 3-6 (Thalia/Thalia) presented better results for dry season BOD₅ removal, with an average residual of 64% ± 21% and 36% ± 23%, respectively. However, when looking at the complete CW System, Point 1-3-6 (Inlet/Thalia/Thalia) presented better overall results with an average residual of 33% ±

22%. Consistent with the achieved results, other studies results show that BOD₅ residual can vary from 18% to 35%, depending on the type of plant and climate conditions (Stefanakis & Tsihrintzis, 2009).

Table 3-2: BOD₅ Dry Season Summary

Location Description	Monitoring Point Location	Dry Season BOD ₅ Minimum Concentration (mg/L)	Dry Season BOD ₅ Maximum Concentration (mg/L)	Dry Season BOD ₅ Average Concentration ± Standard Deviation (mg/L)	Dry Season BOD ₅ Average % Residual ± Standard Deviation
Inlet	1	48.2	152.3	81.3 ± 30.8	-
SSF	1-2	46.8	92.3	62.8 ± 14.6	82% ± 22%
	1-3	39.2	167.4	76.0 ± 40.2	94% ± 31%
	1-4	36.4	80.7	48.9 ± 14.2	64% ± 21%
SF	2-5	7.7	520.0	79.2 ± 178.2	146% ± 339%
	3-6	11.0	44.4	23.4 ± 13.6	36% ± 23%
	4-7	9.9	73.0	28.9 ± 22.4	66% ± 55%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	98% ± 213%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	33% ± 22% %
	1-4-7	same as 4-7	same as 4-7	same as 4-7	39% ± 29%

3.1.2 TSS

TSS concentrations were consistently reduced by the CW System, as shown in **Figure 3-2**. **Figure 3-2** shows TSS spikes during dry period that can be attributed to algae growth in the facultative lagoon. Algae growth was suppressed during the wet season. Seasonal results are summarized below.

Figure 3-2: TSS Influent vs. Effluent Concentrations

Table 3-3 summarizes the TSS results during the wet season (May to November). SSF Point 1-2 (Inlet/Phragmites) and SF Point 2-5 (Phragmites/Typha) presented better results for wet season TSS removal, with an average residual of $11\% \pm 12\%$ and $8\% \pm 14\%$, respectively. Consistently with the individual cell results, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of $2\% \pm 3\%$.

Table 3-3: TSS Wet Season Summary

Location Description	Monitoring Point Location	Wet Season TSS Minimum Concentration (mg/L)	Wet Season TSS Maximum Concentration (mg/L)	Wet Season TSS Average Concentration $\pm$ Standard Deviation (mg/L)	Wet Season TSS Average % Residual $\pm$ Standard Deviation
Inlet	1	25.0	152.0	80.4 $\pm$ 44.5	-
SSF	1-2	0.0	30.0	8.5 $\pm$ 10.5	11% $\pm$ 12%
	1-3	0.0	42.0	10.0 $\pm$ 14.9	12% $\pm$ 15%
	1-4	0.0	40.0	15.5 $\pm$ 15.1	20% $\pm$ 14%
SF	2-5	0.0	6.0	1.4 $\pm$ 2.3	8% $\pm$ 14%
	3-6	0.0	16.0	8.8 $\pm$ 7.6	5,519% $\pm$ 7,675%
	4-7	0.0	40.0	2.8 $\pm$ 3.2	1,013% $\pm$ 2,823%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	2% $\pm$ 3%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	12% $\pm$ 14%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	4% $\pm$ 5%

Table 3-4 summarizes the TSS results during the dry season (December to April). SSF Point 1-4 (Inlet/Brachiaria) and SF Point 2-5 (Phragmites/Typha) presented better results for dry season TSS removal, with an average residual of 12% $\pm$ 11% and 46% $\pm$ 49%, respectively. However, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of 2% $\pm$ 2%. Consistent with the achieved results, other studies results show that TSS residual can vary from 0% to 40%, depending on the type of flow pattern, plant and climate conditions (Pedescoll, et al., 2011).

Table 3-4: TSS Dry Season Summary

Location Description	Monitoring Point Location	Dry Season TSS Minimum Concentration (mg/L)	Dry Season TSS Maximum Concentration (mg/L)	Dry Season TSS Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season TSS Average % Residual $\pm$ Standard Deviation
Inlet	1	136.0	630.0	243.8 $\pm$ 168.5	-
SSF	1-2	4.0	88.0	32.1 $\pm$ 33.8	17% $\pm$ 19%
	1-3	4.0	104.0	39.6 $\pm$ 39.1	21% $\pm$ 22%
	1-4	0.0	44.0	22.8 $\pm$ 17.9	12% $\pm$ 11%
SF	2-5	0.0	10.0	4.6 $\pm$ 4.3	46% $\pm$ 49%
	3-6	0.0	82.0	23.3 $\pm$ 35.8	128% $\pm$ 161%
	4-7	0.0	20.0	5.8 $\pm$ 6.4	536% $\pm$ 1400%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	2% $\pm$ 2%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	7% $\pm$ 8%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	4% $\pm$ 5%

3.1.3 COD

COD concentrations were mostly reduced by the CW System as shown in **Figure 3-3**.

Seasonal results are summarized below.

Figure 3-3: COD Influent vs. Effluent Concentrations

Table 3-5 summarizes the COD results during the wet season (May to November). SSF Point 1-4 (Inlet/Brachiaria) and SF Point 4-7 (Brachiaria/Cyperus) presented better results for wet season COD removal, with an average residual of $47\% \pm 28\%$ and $105\% \pm 115\%$, respectively. Consistently with the individual cell results, when looking at the complete CW System, Point 1-4-7 (Inlet/Brachiaria/Cyperus) presented better overall results with an average residual of $38\% \pm 24\%$.

Table 3-5: COD Wet Season Summary

Location Description	Monitoring Point Location	Wet Season COD Minimum Concentration (mg/L)	Wet Season COD Maximum Concentration (mg/L)	Wet Season COD Average Concentration $\pm$ Standard Deviation (mg/L)	Wet Season COD Average % Residual $\pm$ Standard Deviation
Inlet	1	51.6	316.0	185.3 $\pm$ 81.2	-
SSF	1-2	20.0	184.9	86.2 $\pm$ 53.1	53% $\pm$ 31%
	1-3	45.6	193.3	106.3 $\pm$ 55.4	62% $\pm$ 27%
	1-4	36.0	148.8	73.5 $\pm$ 37.0	47% $\pm$ 28%
SF	2-5	25.2	176.0	74.3 $\pm$ 46.2	124% $\pm$ 101%
	3-6	24.0	413.5	115.4 $\pm$ 124.4	176% $\pm$ 278%
	4-7	33.6	140.0	59.5 $\pm$ 34.7	105% $\pm$ 115%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	54% $\pm$ 56%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	73% $\pm$ 76%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	38% $\pm$ 24%

Table 3-6 summarizes the COD results during the dry season (December to April). SSF Point 1-4 (Inlet/Brachiaria) and SF Point 2-5 (Phragmites/Typha) presented better results for dry season COD removal, with an average residual of 44% $\pm$ 26% and 55% $\pm$ 48%, respectively. However, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of 25% $\pm$ 22%. Consistent with the achieved results, other studies results show that COD residual can vary from 22% to 39%, depending on the type of plant and climate conditions (Stefanakis & Tsihrintzis, 2009).

Even though Point 1-2-5 (Inlet/Phragmites/Typha) and Point 1-4-7 (Inlet/Brachiaria/Cyperus) produced better results for the dry and wet seasons, respectively; both cells achieved acceptable effluent concentrations in accordance with local regulations requirements.

Table 3-6: COD Dry Season Summary

Location Description	Monitoring Point Location	Dry Season COD Minimum Concentration (mg/L)	Dry Season COD Maximum Concentration (mg/L)	Dry Season COD Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season COD Average % Residual $\pm$ Standard Deviation
Inlet	1	142.3	922.1	354.2 $\pm$ 241.4	-
SSF	1-2	106.5	206.7	147.1 $\pm$ 34.5	53% $\pm$ 26%
	1-3	113.8	241.9	176.8 $\pm$ 47.4	62% $\pm$ 26%
	1-4	60.5	180.6	121.8 $\pm$ 45.4	44% $\pm$ 26%
SF	2-5	22.4	171.3	71.7 $\pm$ 48.6	55% $\pm$ 48%
	3-6	24.4	459.0	143.3 $\pm$ 149.3	84% $\pm$ 79%
	4-7	28.5	194.4	90.2 $\pm$ 56.1	80% $\pm$ 49%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	25% $\pm$ 22%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	38% $\pm$ 28%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	31% $\pm$ 25%

3.1.4 Fecal Coliform

Fecal coliform concentrations were reduced by the CW System as expected from other studies results, with residuals in the upper 10% (Lazareva & Pichler, 2010). Seasonal results are summarized below and illustrated in **Figure 3-4**.

Figure 3-4: Fecal Coliform Influent vs. Effluent Concentrations

Table 3-7 summarizes the Fecal Coliform results during the wet season (May to November). SSF Point 1-2 (Inlet/Phragmites) and SF Point 2-5 (Phragmites/Typha) presented better results for wet season Fecal Coliforms removal, with an average residual of $18\% \pm 19\%$ and $21\% \pm 27\%$, respectively. Consistently with the individual cell results, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of $2\% \pm 2\%$. Higher residuals values during the wet season can be attributed to increased disturbance of soil particles during heavy rains and greater summer humidity conducive to Fecal Coliforms survival (Katsenovich, et al., 2009).

Table 3-7: Fecal Coliform Wet Season Summary

Location Description	Monitoring Point Location	Wet Season FC Minimum Concentration (NMP/100mL)	Wet Season FC Maximum Concentration (NMP/100mL)	Wet Season FC Average Concentration $\pm$ Standard Deviation (NMP/100mL)	Wet Season FC Average % Residual $\pm$ Standard Deviation
Inlet	1	2,400	300,000	112,489 $\pm$ 113,039	-
SSF	1-2	240	50,000	12,764 $\pm$ 16,701	18% $\pm$ 19%
	1-3	5,000	80,000	32,333 $\pm$ 23,796	80% $\pm$ 95%
	1-4	240	90,000	17,204 $\pm$ 28,561	20% $\pm$ 25%
SF	2-5	130	1,100	448 $\pm$ 353	21% $\pm$ 27%
	3-6	0	16,000	4,597 $\pm$ 5,529	44% $\pm$ 104%
	4-7	0	5,000	1,646 $\pm$ 2,042	269% $\pm$ 684%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	2% $\pm$ 2%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	77% $\pm$ 221%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	25% $\pm$ 69%

Table 3-8 summarizes the Fecal Coliform results during the dry season (December to April). SSF Point 1-2 (Inlet/Phragmites) and SF Point 2-5 (Phragmites/Typha) presented better results for dry season Fecal Coliforms removal, with an average residual of 12% $\pm$ 12% and 6% $\pm$ 4%, respectively. Consistently with the individual cell results, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of 0% $\pm$ 1%.

Table 3-8: Fecal Coliform Dry Season Summary

Location Description	Monitoring Point Location	Dry Season FC Minimum Concentration (mg/L)	Dry Season FC Maximum Concentration (mg/L)	Dry Season FC Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season FC Average % Residual $\pm$ Standard Deviation
Inlet	1	24,000	1,600,000	274,857 $\pm$ 584,829	-
SSF	1-2	110	17,000	9,749 $\pm$ 8,173	12% $\pm$ 12%
	1-3	70	50,000	20,724 $\pm$ 15,025	40% $\pm$ 43%
	1-4	50	50,000	15,407 $\pm$ 18,430	15% $\pm$ 20%
SF	2-5	13	900	338 $\pm$ 322	6% $\pm$ 4%
	3-6	8	5,000	1,833 $\pm$ 2,214	58% $\pm$ 126%
	4-7	220	8,000	2,260 $\pm$ 2,738	335% $\pm$ 823%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	0% $\pm$ 1%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	2% $\pm$ 3%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	3% $\pm$ 3%

3.1.5 Oil & Grease

Oil and Grease concentrations were reduced by the CW System, with some exceptions, as shown in **Figure 3-5**. Seasonal results are summarized below.

Figure 3-5: Oil & Grease Influent vs. Effluent Concentrations

Table 3-9 summarizes the Oil & Grease results during the wet season (May to November). The SSF CW did not successfully remove Oil & Grease, with its best performance at the Point 1-3 (Inlet/Thalia) still having higher concentration than the inlet concentration ($152\% \pm 225\%$ residual). Point 4-7 (Brachiaria/Cyperus) presented better results for wet season Oil & Grease removal, with an average residual of $56\% \pm 53\%$. Consistently with the individual cell results, when looking at the complete CW System, Point 1-4-7 (Inlet/Brachiaria/Cyperus) presented better overall results with an average residual of $41\% \pm 65\%$.

Table 3-9: Oil & Grease Wet Season Summary

Location Description	Monitoring Point Location	Wet Season O&G Minimum Concentration (mg/L)	Wet Season O&G Maximum Concentration (mg/L)	Wet Season O&G Average Concentration $\pm$ Standard Deviation (mg/L)	Wet Season O&G Average % Residual $\pm$ Standard Deviation
Inlet	1	0.8	16.0	5.5 $\pm$ 4.7	-
SSF	1-2	0.3	9.5	4.0 $\pm$ 3.2	189% $\pm$ 250%
	1-3	0.2	8.6	3.7 $\pm$ 3.4	152% $\pm$ 225%
	1-4	0.0	15.2	5.2 $\pm$ 5.9	220% $\pm$ 412%
SF	2-5	0.0	6.9	1.8 $\pm$ 2.0	97% $\pm$ 179%
	3-6	0.4	8.6	3.4 $\pm$ 3.1	237% $\pm$ 294%
	4-7	0.2	6.7	2.1 $\pm$ 2.5	56% $\pm$ 53%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	62% $\pm$ 76%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	132% $\pm$ 160%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	41% $\pm$ 65%

Table 3-10 summarizes the Oil & Grease results during the dry season (December to April). SSF Point 1-3 (Inlet/Thalia) and SF Point 3-6 (Thalia/Thalia) presented better results for dry season Oil & Grease removal, with an average residual of 64% $\pm$ 56% and 76% $\pm$ 30%, respectively. Consistently with the individual cell results, when looking at the complete CW System, Point 1-3-6 (Inlet/Thalia/Thalia) presented better overall results with an average residual of 41% $\pm$ 25%.

Table 3-10: Oil & Grease Dry Season Summary

Location Description	Monitoring Point Location	Dry Season O&G Minimum Concentration (mg/L)	Dry Season O&G Maximum Concentration (mg/L)	Dry Season O&G Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season O&G Average % Residual $\pm$ Standard Deviation
Inlet	1	0.5	20.2	6.2 $\pm$ 6.6	-
SSF	1-2	0.4	7.4	3.5 $\pm$ 2.9	68% $\pm$ 25%
	1-3	0.6	8.6	2.6 $\pm$ 3.0	64% $\pm$ 56%
	1-4	0.4	4.8	1.7 $\pm$ 1.5	76% $\pm$ 85%
SF	2-5	0.2	55.4	7.9 $\pm$ 19.2	1192% $\pm$ 3252%
	3-6	0.4	5.4	1.8 $\pm$ 1.9	76% $\pm$ 30%

Location Description	Monitoring Point Location	Dry Season O&G Minimum Concentration (mg/L)	Dry Season O&G Maximum Concentration (mg/L)	Dry Season O&G Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season O&G Average % Residual $\pm$ Standard Deviation
	4-7	0.2	9.8	2.3 ± 3.3	$373\% \pm 843\%$
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	$524\% \pm 1388\%$
	1-3-6	same as 3-6	same as 3-6	same as 3-6	$41\% \pm 25\%$
	1-4-7	same as 4-7	same as 4-7	same as 4-7	$43\% \pm 30\%$

3.1.6 Total Nitrogen

Total Nitrogen concentrations were reduced by the CW System, with a few exceptions, as shown in **Figure 3-5**. Seasonal results are summarized below.

Figure 3-6: Total Nitrogen Influent vs. Effluent Concentrations

Table 3-11 summarizes the Total Nitrogen results during the wet season (May to November). SSF Point 1-4 (Inlet/Brachiaria) and SF Point 2-5 (Phragmites/Typha) presented better results for wet season Total Nitrogen removal, with an average residual of $61\% \pm 15\%$ and $28\% \pm 24\%$, respectively. However, when looking at the complete CW System, Point 1-2-5 (Inlet/Phragmites/Typha) presented better overall results with an average residual of $19\% \pm 16\%$.

Table 3-11: Total Nitrogen Wet Season Summary

Location Description	Monitoring Point Location	Wet Season TN Minimum Concentration (mg/L)	Wet Season TN Maximum Concentration (mg/L)	Wet Season TN Average Concentration $\pm$ Standard Deviation (mg/L)	Wet Season TN Average % Residual $\pm$ Standard Deviation
Inlet	1	17.1	26.8	21.1 ± 3.8	-
SSF	1-2	8.1	23.8	14.0 ± 4.7	$68\% \pm 26\%$
	1-3	8.7	18.2	13.2 ± 2.9	$64\% \pm 20\%$
	1-4	9.0	16.3	12.7 ± 2.5	$61\% \pm 15\%$
SF	2-5	1.0	13.6	4.1 ± 4.1	$28\% \pm 24\%$
	3-6	1.6	10.9	4.3 ± 3.1	$33\% \pm 22\%$
	4-7	1.8	10.9	5.2 ± 2.9	$40\% \pm 17\%$
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	$19\% \pm 16\%$
	1-3-6	same as 3-6	same as 3-6	same as 3-6	$20\% \pm 12\%$
	1-4-7	same as 4-7	same as 4-7	same as 4-7	$25\% \pm 12\%$

Table 3-12 summarizes the Total Nitrogen results during the dry season (December to April). The SSF CW did not successfully remove Total Nitrogen, with its best performance at the Point 1-4 (Inlet/Brachiaria) still having a high residual ($96\% \pm 100\%$ residual). Point 2-5 (Phragmites/Typha) presented better results for dry season Total Nitrogen removal, with an average residual of $50\% \pm 24\%$. However, when looking at

the complete CW System, Point 1-4-7 (Inlet/Thalia/Thalia) presented better overall results with an average residual of $46\% \pm 34\%$.

The dry season had higher Total Nitrogen concentrations than the wet season, which could be associated to longer retention time and vegetation decay to during the dry season. A review of other studies indicates that Total Nitrogen residuals through SSF CWs typically range between 45% and 60% (Vymazal, 2007) (Tuncsiper, 2009), which is considered similar results to the achieved in this study. Other studies results for Total Nitrogen residual through a combination of SSF and SF CWs have not been reported.

Table 3-12: Total Nitrogen Dry Season Summary

Location Description	Monitoring Point Location	Dry Season TN Minimum Concentration (mg/L)	Dry Season TN Maximum Concentration (mg/L)	Dry Season TN Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season TN Average % Residual $\pm$ Standard Deviation
Inlet	1	2.8	41.6	18.3 ± 12.5	-
SSF	1-2	5.5	19.7	12.0 ± 4.9	$121\% \pm 133\%$
	1-3	3.4	19.9	12.6 ± 5.2	$111\% \pm 112\%$
	1-4	2.8	17.9	9.7 ± 5.0	$96\% \pm 100\%$
SF	2-5	2.8	7.7	5.3 ± 1.4	$50\% \pm 24\%$
	3-6	2.8	14.3	7.9 ± 4.0	$69\% \pm 40\%$
	4-7	2.8	11.3	5.9 ± 3.0	$79\% \pm 80\%$
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	$56\% \pm 64\%$
	1-3-6	same as 3-6	same as 3-6	same as 3-6	$63\% \pm 56\%$
	1-4-7	same as 4-7	same as 4-7	same as 4-7	$46\% \pm 34\%$

3.1.7 Phosphorus

Phosphorus concentrations were not consistently reduced by the CW System, as shown in **Figure 3-5**. No trend was shown in the SSF CW results, with much more constant results within the SF CW. These closer results in the SF CW can be attributed to the increased oxygen content in the superficial layer of the SF CW cells, which would enable phosphorus uptake by aerobic microorganisms. Seasonal results are summarized below.

Figure 3-7: Phosphorus Influent vs. Effluent Concentrations

Table 3-13 summarizes the Phosphorus results during the wet season (May to November). The SSF CW did not successfully remove Phosphorus, with its best performance at the Point 1-3 (Inlet/Thalia) still having higher concentration than the inlet concentration ($214\% \pm 207\%$ residual). Point 2-5 (Phragmites/Typha) presented better results for wet season Phosphorus removal, with an average residual of $43\% \pm 34\%$.

However, when looking at the complete CW System, none of results were satisfactory for Phosphorus removal with its best performance at the Point 1-4-7 (Inlet/Brachiaria/Cyperus) still having higher concentration than the inlet concentration ($127\% \pm 137\%$ residual). The achieved results were not consistent with other studies for phosphorus removal, typically phosphorus residual vary from 70% to 80% (Brix & Arias, 2005).

Table 3-13: Phosphorus Wet Season Summary

Location Description	Monitoring Point Location	Wet Season Phosphorus Minimum Concentration (mg/L)	Wet Season Phosphorus Maximum Concentration (mg/L)	Wet Season Phosphorus Average Concentration $\pm$ Standard Deviation (mg/L)	Wet Season Phosphorus Average % Residual $\pm$ Standard Deviation
Inlet	1	0.5	4.7	2.1 ± 1.6	-
SSF	1-2	2.0	4.7	3.2 ± 0.9	$288\% \pm 265\%$
	1-3	0.5	4.3	2.9 ± 1.3	$214\% \pm 207\%$
	1-4	1.4	4.6	2.9 ± 1.0	$264\% \pm 266\%$
SF	2-5	0.0	2.7	1.4 ± 1.0	$43\% \pm 34\%$
	3-6	0.4	2.6	1.4 ± 0.9	$95\% \pm 156\%$
	4-7	0.0	2.4	1.2 ± 0.8	$45\% \pm 40\%$
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	$156\% \pm 172\%$
	1-3-6	same as 3-6	same as 3-6	same as 3-6	$162\% \pm 194\%$
	1-4-7	same as 4-7	same as 4-7	same as 4-7	$127\% \pm 137\%$

Table 3-14 summarizes the Phosphorus results during the dry season (December to April). The SSF CW did not successfully remove Phosphorus, with its best performance at the Point 1-3 (Inlet/Thalia) still having higher concentration than the inlet concentration ($178\% \pm 94\%$ residual). Point 3-6 (Thalia/Thalia) presented better results for dry season Phosphorus removal, with an average residual of $79\% \pm 35\%$. However,

when looking at the complete CW System, none of results were satisfactory for Phosphorus removal with its best performance at the Point 1-3-6 (Inlet/Thalia/Thalia) still having higher concentration than the inlet concentration (124% $\pm$ 73% residual).

Table 3-14: Phosphorus Dry Season Summary

Location Description	Monitoring Point Location	Dry Season Phosphorus Minimum Concentration (mg/L)	Dry Season Phosphorus Maximum Concentration (mg/L)	Dry Season Phosphorus Average Concentration $\pm$ Standard Deviation (mg/L)	Dry Season Phosphorus Average % Residual $\pm$ Standard Deviation
Inlet	1	0.8	3.3	1.5 $\pm$ 0.8	-
SSF	1-2	0.4	4.0	2.6 $\pm$ 1.1	198% $\pm$ 112%
	1-3	0.3	3.9	2.4 $\pm$ 1.1	178% $\pm$ 94%
	1-4	0.3	3.9	2.4 $\pm$ 1.1	179% $\pm$ 96%
SF	2-5	0.1	6.0	2.4 $\pm$ 1.7	89% $\pm$ 65%
	3-6	0.2	2.9	1.8 $\pm$ 1.0	79% $\pm$ 35%
	4-7	0.2	3.5	2.7 $\pm$ 1.0	114% $\pm$ 43%
Overall CW (SSF + SF)	1-2-5	same as 2-5	same as 2-5	same as 2-5	180% $\pm$ 142%
	1-3-6	same as 3-6	same as 3-6	same as 3-6	124% $\pm$ 73%
	1-4-7	same as 4-7	same as 4-7	same as 4-7	203% $\pm$ 107%

3.1.8 Plant growth and health

Plant appearance and health were evaluated over the course of the monitoring period.

Care was taken such that all plants used for assessment purposes appeared healthy, with no indication of any sort of pathology. All plants had developed strong root systems within the wetland soil and SSF gravel and were uniform in growth.

Biomass samples were analyzed for nitrogen and phosphorus mineral content. Fast-growing *Brachiaria* proved especially proficient, with N and P content of 1.5-3.14% and 0.17-0.25% per dry plants' biomass, respectively. This plant was harvested three times

during the observational period for use as a fodder for horses and cows. Following transplantation, *Thalia* growth and nutrient content closely matched that of *Brachiaria* (N: 1.7-2.4%, P: 0.2-0.37%). *Thalia* high P content coincides with year-round enhanced Total Phosphorus mass removal efficiency through Points 1-3-6 (Inlet/*Thalia*/*Thalia*). However, *Thalia* requires frequent trimming and after an initial prolific stage it tends to undergo senescence, reducing its capacity to effect contaminant removal. While *Cyperus* had a robust, healthy appearance with respective N and P content of 1.1-1.15% and 0.14-0.17%, it proved particularly difficult to maintain. It was more sensitive than either *Typha* or *Thalia* to changes in water availability, not tolerating water levels greater than 15-20 cm during the growth period. When the water was maintained at 30 cm, growth was inhibited and the vegetation faltered, becoming so overtaken by weeds that it became necessary to replant the entire cell. *Phragmites* boasts a well-developed root system and grows vigorously under wetland conditions with relatively little maintenance. It did not require many trimmings, facilitated respective nitrogen and phosphorus content of 1.3-2.1% and 0.13-0.24% and was unaffected by any plagues and/or diseases. *Typha*, a plant endemic to most natural wetlands, is characterized by well-developed roots, rapid growth and significant nutrient content (N: 0.8-2.2%, P: 0.12-0.3%) (Katsenovich, et al., 2009). The dry plant composition for nitrogen and phosphorus are summarized in Table 3-15.

Table 3-15: Nitrogen and Phosphorus Dry Plant Composition

Plant Species	Nitrogen Content in dry plant %	Phosphorus Content in dry plant %
Brachiaria	1.5 – 3.1%	0.17 – 0.25%
Thalia*	1.7 – 2.4%	0.20 – 0.37%
Cyperus	1.1 – 1.2%	0.14 – 0.17%
Phragmites	1.3 – 2.1%	0.13 – 0.24%
Typha	0.8 – 2.2%	0.12 – 0.30%
* after transplantation		

For comparison purposes, some studies estimated that only 5 to 10% of the nitrogen load is absorbed by the plants (WEF, 2000), with nitrogen plant content as 4% of nitrogen input depending on the plant species (Kantawanichkul, et al., 2003). *Phragmites* had a 7% nitrogen content by plants in another study (Tuncsiper, 2009). All the previous studies nitrogen content results were significantly higher than the ones obtained in study.

The nitrogen and phosphorus plant biomass per season are presented in Table 3-16. It is noted that both nitrogen and phosphorus were higher during the dry season for the SSF plants. The SSF nitrogen biomass ranged from 19 – 46 g/m² and 2.6 – 14.8 g/m² during the dry and wet seasons, respectively. The SSF phosphorus biomass ranged from 1.8 – 5.0 g/m² and 0.4 – 2.0 g/m² during the dry and wet seasons, respectively. It is noted that both nitrogen and phosphorus were higher during the wet season for the SF plants. The SF nitrogen biomass ranged from 3.4 – 8.2 g/m² and 12.5 – 15.4 g/m² during the dry and wet seasons, respectively. The SF phosphorus biomass ranged from 0.4 – 1.2 g/m² and

1.6 – 2.5 g/m² during the dry and wet seasons, respectively. The accumulated nutrients (nitrogen and phosphorus) can be released back to the water during plant senescence, which affects the effluent concentrations in the CW system.

Table 3-16: Plant Biomass Characteristics

CW	Plant Species	Nitrogen, g/m ²		Phosphorus, g/m ²	
		Dry Season*	Wet Season**	Dry Season*	Wet Season**
SSF	Phragmites	19.03	14.79	1.76	1.95
	SSF Thalia	45.84	7.81	4.96	1.02
	Brachiaria	40.21	2.61	4.14	0.44
SF	Typha	8.15	13.94	1.18	1.59
	SF Thalia	4.21	15.44	0.67	2.52
	Cyperus	3.42	12.51	0.40	1.87
* Sample date: 14/Feb/2007; ** Sample date: 15/June/2007					

Other studies reported nitrogen biomass between 0.6 and 72 g/m², with an average of 20.7 g/m² (Johnston, 1991), and also ranging between 5.3 and 58.7 g/m² for various types of constructed wetlands and plants (Vymazal & Kropfelova, 2008). Phosphorus biomass has been reported ranging from 0.2 to 10.5 g/m² for various types of wetlands as well (Vymazal, 2004).

3.2 Comparative Assessment of Models Used During Design

The models used to determine the SSF and SF CW areas during design, presented in Chapter 2.1.3, were re-evaluated using the actual constructed SSF and SF areas, water balance and quality data obtained during the monitoring period. The actual data results were then compared with the design results to evaluate the existing constructed wetland models effectiveness for BOD₅ and TSS removals. Total Nitrogen models were evaluated for SF CW only. Phosphorus, Fecal coliform, COD, and Oil & Grease were not used to size the SSF and the SF CW cells.

3.2.1 SSF CW

As described in Chapter 2.1.3, each SSF cell has an area of 151.20 m², water depth of 0.8 m, and gravel porosity of 0.4 m³/m³. Chapter 2.1.3.1 (Table 2-2, Table 2-3 and Table 2-4) presents the target parameters and treatment objectives used on the design of this study CW system.

3.2.1.1 BOD₅

Kadlec & Knight design calculation used a first-order areal rate constant (k) of 180 m/yr, but the actual average k for all the three cells was 20 m/yr ± 18 m/yr, considered significantly lower than the k used in the design. The BOD₅ background concentration used in the design calculation was 7.4 mg/L, and the actual average background concentration was 7.0 mg/L ± 1.4 mg/L. As shown in **Figure 3-8**, the design BOD target outlet (effluent) concentration based on the Kadlec & Knight design values and actual

SSF dimensions, is much lower than the BOD₅ actual outlet (effluent) concentrations. Had a much lower k value been used for the area calculation, a much larger SSF CW would be required.

Campbell & Ogden and Reed et.al design calculation used a temperature of 20.4 degree Celsius (°C), but the actual average inlet (influent) temperature was 25.8°C ±1.4°C, considered significantly higher than the influent temperature used in the design. As shown in Figure 3-8, the design BOD₅ target outlet (effluent) concentration based on the Campbell & Ogden and Reed et. al design values and actual SSF dimensions, is much lower than the BOD₅ actual outlet (effluent) concentrations. Had a higher influent temperature been used for the area calculation, a smaller SSF CW would be required (25 to 30% smaller).

The EPA design calculation used an areal loading rate (ALR) of 1.6 g/m²-d to attain 20 mg/L effluent concentration (which required a much larger SSF CW area than the actual constructed area). The actual ALR ranged from 2.0 to 11.6 g/m²-d , with an average of 6.0 g/m²-d ± 3.0 g/m²-d. According to the EPA Methodology, an areal loading rate of 6.0 g/m²-d would attain 30 mg/L effluent, which was higher effluent concentration than the treated effluent objective of 20 mg/L. As shown in Figure 3-9, even though the treated effluent objective was 20 mg/L, some of the sampling events achieved the result expected from the EPA Methodology for 30 mg/L with lower areal loading rates.

Based on the current model results presented in this Chapter, and had the treated effluent objective been 30 mg/L (not 20 mg/L as per design), the EPA Methodology seems to have achieved more realistic results than the other methodologies.

It is generally assumed that constructed wetland systems are more efficient in tropical climates than in temperate climates because higher temperatures encourage plant growth and microbial activities, but it is not always the case since higher temperatures are also conducive for secondary contamination. Figure 3-8 and Figure 3-9 clearly show that longer retention times at low BOD areal loading rates during the dry season doesn't improve the water quality; it is actually the opposite and at high tropical temperatures, the BOD₅ parameter actually gets worse. It might be attributed to the secondary contamination coming from decaying falling leaves and accumulation of metabolites produced by bacteria and soil biota.

Figure 3-8: BOD₅ Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden, and Reed et.al (SSF CW)

Figure 3-9: BOD₅ Design Target vs. Actual Effluent Concentrations – EPA (SSF CW)

3.2.1.2 TSS

Kadlec & Knight design calculation used a first-order areal rate constant (k) of 3,000 m/yr, but the actual average k for all the three cells was 92 m/yr $\pm$ 46 m/yr, considered significantly lower than the k used in the design. The TSS background concentration used in the design calculation was 16.5 mg/L, and the actual average background concentration was 18 mg/L $\pm$ 9 mg/L. As shown in Figure 3-10, the design TSS target outlet (effluent) concentration based on the Kadlec & Knight design values and actual SSF dimensions, is different than the TSS actual outlet (effluent) concentrations, but

within an acceptable range. Had a much lower k value been used for the area calculation, a much larger SF CW would be required.

Campbell & Ogden design calculation used a hydraulic loading rate (HLR) of 35.3 cm/d, but the actual HLR was $8.7 \text{ cm/d} \pm 4.1 \text{ cm/d}$, considered significantly lower than the HLR used in the design. As shown in Figure 3-10 and Figure 3-11, the design TSS target outlet (effluent) concentration based on the Campbell & Ogden design values and actual SSF dimensions, is different than the TSS actual outlet (effluent) concentrations, but within an acceptable range. Had a lower HLR been used for the area calculation, a much larger SSF CW would be required (four times larger).

The EPA Methodology calculation recommends an areal loading rate (ALR) of $20 \text{ g/m}^2\text{-d}$ to attain 30 mg/L effluent concentration. The actual ALR ranged from 3.1 to $35.7 \text{ g/m}^2\text{-d}$, with an average of $11.4 \text{ g/m}^2\text{-d} \pm 7.8 \text{ g/m}^2\text{-d}$, considered lower than the areal loading rate used in the design. However, as shown in Figure 3-12, some of the sampling events achieved the result expected from the EPA Methodology (close to 30 mg/L) but with lower areal loading rates.

Based on the current model results presented in this Chapter, all three (3) methodologies seem to have achieved results somewhat closer to the actual results.

Figure 3-10: TSS Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden (SSF CW)

Figure 3-11: TSS Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden (Closer View) (SSF CW)

Figure 3-12: TSS Design Target vs. Actual Effluent Concentrations – EPA (SSF CW)

3.2.2 SF CW

As described in **Chapter 2.1.3**, each SF cell has an area of approximately 800 m² (604 m² SF plus 195 m² OW), water depths of 0.6 m and 1.2 m, and gravel porosity of 0.65 m³/m³ and 0.8 m³/m³, respectively for the SF and OW cells.

3.2.2.1 BOD₅

Kadlec & Knight design calculation used a first-order areal rate constant (k) of 34 m/yr, but the actual average k for all the three cells was 7 m/yr ±10 m/yr, considered

significantly lower than the k used in the design. The BOD_5 background concentration used in the design calculation was 5.1 mg/L, and the actual average background concentration was $6.1 \text{ mg/L} \pm 1.3 \text{ mg/L}$. As shown in Figure 3-13, the design BOD_5 target outlet (effluent) concentration based on the Kadlec & Knight design values and actual SSF dimensions, is much lower than the BOD_5 actual outlet (effluent) concentrations. Had a much lower k value been used for the area calculation, a much larger SSF CW would be required.

Campbell & Ogden and Reed et.al design calculation used a temperature of 20.4 degree Celsius ($^{\circ}\text{C}$), but the actual average inlet (influent) temperature was $25.8^{\circ}\text{C} \pm 1.4^{\circ}\text{C}$, considered significantly higher than the influent temperature used in the design. As shown in Figure 3-13, the design BOD_5 target outlet (effluent) concentration based on the Campbell & Ogden and Reed et. al design values and actual SF dimensions, is much lower than the BOD_5 actual outlet (effluent) concentrations.

The EPA design calculation used an areal loading rate (ALR) of $4.5 \text{ g/m}^2\text{-d}$ to attain 20 mg/L effluent concentration. The actual ALR ranged from 0.2 to $2.0 \text{ g/m}^2\text{-d}$, with an average of $0.69 \text{ g/m}^2\text{-d} \pm 0.45 \text{ g/m}^2\text{-d}$, considered much lower than the areal loading recommended by EPA to attain 20 mg/L BOD_5 effluent. However, as shown in Figure 3-14, most of the sampling events achieved the results below 20 mg/L with lower areal loading rates than the EPA number.

Based on the current model results presented in this Chapter, the EPA Methodology seems to have achieved better results than the other methodologies.

As mentioned in the Section 3.2.1.1, constructed wetland systems are expected to be more efficient in tropical climates than in temperate climates because higher temperatures encourage plant growth and microbial activities; however, higher temperatures are conducive for secondary contamination which may worsen the BOD₅ effluent concentration due to decaying falling leaves and accumulation of metabolites produced by bacteria and soil biota.

Figure 3-13: BOD₅ Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden, and Reed et.al (SF CW)

Figure 3-14: BOD₅ Design Target vs. Actual Effluent Concentrations – EPA (SF CW)

3.2.2.2 TSS

Kadlec & Knight design calculation used a first-order areal rate constant (k) of 1,000 m/yr, but the actual average k for all the three cells was $4.2 \text{ m/yr} \pm 10.3 \text{ m/yr}$, considered significantly lower than the k used in the design. The TSS background concentration used in the design calculation was 14.7 mg/L , and the actual average background concentration was $4.6 \text{ mg/L} \pm 1.3 \text{ mg/L}$. As shown in Figure 3-15, the design TSS target outlet (effluent) concentration based on the Kadlec & Knight design values and actual SSF dimensions, is different than the TSS actual outlet (effluent) concentrations, but within an acceptable range. Had a much lower k value been used for the area calculation, a much larger SSF CW would be required.

Campbell & Ogden design calculation used a hydraulic loading rate (HLR) of 68.1 cm/d, but the actual HLR was $1.8 \text{ cm/d} \pm 1.5 \text{ cm/d}$, considered significantly lower than the HLR used in the design. As shown in Figure 3-15 and Figure 3-16, the design TSS target outlet (effluent) concentration based on the Campbell & Ogden design values and actual SSF dimensions, is different than the TSS actual outlet (effluent) concentrations, but within an acceptable range. Had a lower HLR been used for the area calculation, a much larger SSF CW would be required.

The EPA design calculation used an areal loading rate (ALR) of $3 \text{ g/m}^2\text{-d}$ to attain 20 mg/L effluent concentration. The actual ALR ranged from 0.0 to $1.6 \text{ g/m}^2\text{-d}$, with an average of $0.24 \text{ g/m}^2\text{-d} \pm 0.32 \text{ g/m}^2\text{-d}$, considered lower than the areal loading rate recommended by EPA to attain 20 mg/L. However, as shown in Figure 3-17, most of the sampling events achieved result better than the expected from the EPA Methodology (close to 20 mg/L) but with lower areal loading rates.

Based on the current model results presented in this Chapter, all three (3) methodologies seem to have achieved results somewhat closer to the actual results.

Figure 3-15: TSS Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden

Figure 3-16: TSS Design Target vs. Actual Effluent Concentrations – Kadlec & Knight, Campbell & Ogden (Closer View)

Figure 3-17: TSS Design Target vs. Actual Effluent Concentrations - EPA

3.2.2.3 Total Nitrogen

Kadlec & Knight design calculation used a first-order areal rate constant (k) of 22 m/yr, but the actual average k for all the three cells was 8.5 m/yr $\pm$ 14.8 m/yr, considered not significantly different than the k used in the design. The Total Nitrogen background concentration used in the design calculation was 2 mg/L, and the actual average background concentration was 4.1 mg/L $\pm$ 0.3 mg/L. As shown in Figure 3-18, the design Total Nitrogen target outlet (effluent) concentration based on the Kadlec & Knight design values and actual SF dimensions, is somewhat different than the Total Nitrogen actual outlet (effluent) concentrations, but within an acceptable range.

Based on the current model results presented in this Chapter, the Kadlec & Knight methodology seems to have achieved results somewhat closer to the actual results.

Figure 3-18: Total Nitrogen Design Target vs. Actual Effluent Concentrations – Kadlec & Knight

3.3 Sensitivity Analysis

Sensitivity Analysis was performed for BOD and TSS removals using the Kadlec model (as the Kadlec model was the model used for sizing the CW system of this study) to identify the parameters that have the greatest effect on the predicted results. The following parameters were analyzed for SSF and SF:

- First order areal rate constant;
- Background concentration; and
- Net flow.

The same methodology was used for both SSF and SF wetlands sensitivity analysis, as well as for both BOD and TSS, as described in the following chapters.

3.3.1 Sensitivity Analysis for BOD

First order areal rate constant, background concentration, and net flow values ranging from minimum and maximum were used in a set-interval for BOD, as presented in Table 3-17. The sensitivity analysis values were selected as the closest round numbers to the minimum and maximum values and the value used during design.

Table 3-17: Sensitivity Analysis Minimum and Maximum Values Used for BOD

First-order areal rate constant (k in m/yr)								
	Point 1-2	Point 1-3	Point 1-4	Point 1-2 Point 1-3 Point 1-4	Point 2-5	Point 3-6	Point 4-7	Point 2-5 Point 3-6 Point 4-7
Minimum	2.5	0.6	12.0	0.6	0.3	0.6	-1.2	-1.2
Average	13.3	22.1	23.3	19.7	5.5	5.4	9.9	7.0
Maximum	39.6	77.5	78.0	78.0	12.7	26.6	55.7	55.7
Sensitivity Analysis Values	1, 5, 10, 15, 20, 180				-1, 2.5, 5, 10, 15, 20, 25, 50			
Background Concentration (c* in mg/L)						Net Flow (Qnet in m³/day)		
	Point 1	Point 1-2	Point 1-3	Point 1-4	Average Point 1-2 Point 1-3 Point 1-4	Point 1-2 Point 1-3 Point 1-4	Point 2-5 Point 3-6 Point 4-7	
Minimum	5.2	4.2	4.6	4.6	4.5	8.1	3.4	
Average	7.0	6.2	6.3	5.7	6.1	14.6	14.4	
Maximum	11.6	8.4	12.4	7.8	9.5	36.9	41.4	
Sensitivity Analysis Values	0, 1, 5, 7.5, 10, 15, 20					5, 10, 15, 20, 25, 30, 35, 40		

The first order areal rate has the most potential to influence the BOD predicted values, as shown in Figure 3-19. The net flow was the second parameter with potential to influence the BOD predicted values (Figure 3-20). As their values changed, they moved away from the actual values. On the other hand, background concentration showed no

substantial differences from the actual versus predicted values (Figure 3-21), with the BOD predicted values within the actual values.

Figure 3-19: SSF Sensitivity Analysis for Areal Rate Constant (BOD)

Figure 3-20: SSF Sensitivity Analysis for Net Flow (BOD)

Figure 3-21: SSF Sensitivity Analysis for Background Concentration (BOD)

Similar results were obtained for SF models for BOD, having the first areal rate constant as the most sensitive parameter. Sensitivity analysis results for BOD model predictions using SF wetland are presented in Appendix C.

3.3.2 Sensitivity Analysis for TSS

First order areal rate constant, background concentration, and net flow values ranging from minimum and maximum were used in a set-interval for TSS, as presented in Table 3-18. The sensitivity analysis values were selected as the closest round numbers to the minimum and maximum values and the value used during design.

TSS background concentration (c^*) had the most potential to influence the TSS predicted values, because when the c^* value is greater than the effluent TSS concentration, the areal rate constant (k) for TSS could not be calculated, and the TSS effluent concentration could not be predicted (Figure 3-24). When the areal rate constant could be calculated, the net flow showed also potential to influence the TSS predicted values (Figure 3-23). As the background concentration and net flow values changed, the predicted values moved away from the actual values. The areal rate constant showed some potential to influence the TSS predicted values (Figure 3-22); however, it is important to note that the areal rate constant was not calculated using the actual background concentration; therefore, all the predicted values were calculated.

Table 3-18: Sensitivity Analysis Minimum and Maximum Values Used for TSS

First-order areal rate constant (k in m/yr)								
	Point 1-2	Point 1-3	Point 1-4	Point 1-2 Point 1-3 Point 1-4	Point 2-5	Point 3-6	Point 4-7	Point 2-5 Point 3-6 Point 4-7
Minimum	39.3	31.7	30.2	30.2	-1.1	-4.9	0.0	-4.9
Average	82.5	103.0	83.0	89.6	2.5	0.9	10.5	4.2
Maximum	128.1	194.5	164.4	194.5	21.7	10.2	38.7	38.7
Sensitivity Analysis Values	30, 60, 90, 120, 150, 180, 210, 500, 1000, 1500				-5, -1, 5, 10, 15, 20, 25, 50			
Background Concentration (c* in mg/L)						Net Flow (Qnet in m³/day)		
	Point 1	Point 1-2	Point 1-3	Point 1-4	Average Point 1-2 Point 1-3 Point 1-4	Point 1-2 Point 1-3 Point 1-4	Point 2-5 Point 3-6 Point 4-7	
Minimum	9.4	3.5	3.5	3.5	3.5	8.1	3.4	
Average	18.0	4.5	4.7	4.5	4.6	13.2	14.4	
Maximum	47.5	8.2	9.0	5.8	7.6	25.0	41.4	
Sensitivity Analysis Values	0, 10, 20, 30, 40, 50, 100 (for Point 1) 0, 1, 5, 7.5, 10, 15, 20 (for Point 1-2, Point 1-3, 1-4)					5, 10, 15, 20, 25, 30, 35, 40

Figure 3-22: SSF Sensitivity Analysis for Areal Rate Constant (TSS)

Figure 3-23: SSF Sensitivity Analysis for Net Flow (TSS)

Figure 3-24: SSF Sensitivity Analysis for Background Concentration (TSS)

Similar results were obtained for SF models for TSS, having the TSS background concentration as the most sensitive parameter. Sensitivity analysis results for TSS model predictions using SF wetland are presented in Appendix C.

4 CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

4.1 Conclusions

The central hypothesis of this research was “that the constructed wetland system of the study is capable to provide competitive secondary treatment levels, removing significant amounts of biological oxygen demand (BOD₅), total suspended solids (TSS) and pathogens among other water quality indicators, under tropical climatic conditions.”

Consequently to the detailed discussion of the measured water quality parameters (Chapters 2 and 3), the results strongly suggest that this CW system can effectively reduce contaminants in wastewater to levels that are comparable with the objective levels (i.e., secondary treatment levels). The CW system performance also proved to be reliable under the extremes of tropical conditions, such as those occurring during the peaks of the wet and dry seasons in El Salvador. Conclusively, the central hypothesis of the research was proven to be correct.

Based on the results of organic and nutrients removal analyses, *Phragmites* and *Brachiaria* were the most effective SSF plants; *Brachiaria* provided the added benefit of serving as a source of fodder. *Typha* produced the best dry season results within the SF component. Monitoring Point 1-2-5 (Inlet/Phragmites/Typha) performed better year-round than either Monitoring Points 1-3-6 or 1-4-7 (Inlet/Thalia/Thalia or Inlet/Brachiaria/Cyperus, respectively). Similarly, Monitoring Point 1-4-7 reduced contaminant concentrations more than did Monitoring Point 1-3-6 over both seasons. Conditions were only slightly more conducive to reduction over the wet season, although this effect becomes much more exaggerated when the effects of evapotranspiration and

dilution are considered. Amongst all measured parameters, the greatest reductions were observed with Total Nitrogen, TSS and Fecal coliform, perhaps due to such efficient reduction in ammonium and physical processes as sedimentation and filtration (Songa, et al., 2006).

All the research objectives were also achieved, as follows:

- 1) The design approach of the field scale SSF CW was described in Chapter 2.1.3.
- 2) The SSF characterization of influent and effluents for BOD₅, COD, TSS, Oil & Grease, Fecal Coliform, Total Nitrogen, and Phosphorus was presented in Chapter 3.1.
- 3) Comparative assessment of empirical models and selection of most appropriate models used during design for BOD₅, TSS, and Total Nitrogen were presented in Chapter 3.2, and it was concluded that:
 - a) The EPA Methodology seems to have achieved more realistic results than the other methodologies for BOD₅ removal;
 - b) All evaluated methodologies seem to have achieved results somewhat closer to the actual TSS results; and
 - c) Kadlec & Knight methodology for Total Nitrogen removal seems to have achieved results somewhat closer to the actual results.
- 4) Comparison of the differences in treatment associated with each one of the selected plants was described in Chapter 3.1.

4.2 Limitations and Recommendations

Based on the constructed wetland system performance, the following is recommended:

- The flow in this study was poorly operated and lacked in a trustful flow. In order to improve the flow condition, one of the cells could have been closed down during the dry season to increase the flow and have a more constant flow throughout the year, which would result in a more constant performance. However, the only drawback of closing down one of the cells is that the plants in that cell would require an irrigation system to keep the plants alive until the wet season.
- For future studies, building a small reactor prior to the actual pilot study in order to simulate the tropical climate conditions is recommended to minimize the difference between the actual and the predicted results.
- More monitoring would allow for better results, and the seasonal variation would be even more obvious. Daily monitoring would be ideal; but for budget limitations, once a week would be the least frequency recommended.
- The relationships between inflow and outflow loadings, instead of concentrations, may be a better approach for comparison of results during different seasons, as the flow greatly varied from dry and wet seasons due to the difference in precipitation.
- Future designs should consider a reduction in the facultative lagoon total area and incorporate measures that optimize resilience and responsiveness to dynamic

water flow patterns over the course of the year. SSF CW should be used cautiously to treat facultative lagoon effluents due to algae bloom, the leading cause of SSF CW clogging. Care should be taken to prevent the discharge of military-specific pollutants during the dry season when system equalization abilities are limited.

- The depth of OW Sections should be further evaluated in order to minimize limited water mixing and stagnant conditions at the bottom of OW sections,.
- Even though *Cyperus* showed a slightly better performance for BOD₅ removal in the SF CW than *Typha* and *Thalia*; *Cyperus* required high maintenance which deviates from the purpose of CW systems of minimal maintenance requirements. Therefore, *Cyperus* would not be recommended for SF CWs.
- The measured plant biomass N and P content is comparable to other studies of constructed wetlands (Kadlec & Wallace, 2008); however, further research is needed to examine trends in vegetation nutrients content in dry and wet seasons.

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APPENDICES

APPENDIX A

PLANS AND SECTIONS

CW System Aerial View

Source: Google Maps, Accessed April 17, 2014

CONSTRUCTED TREATMENT WETLAND SYSTEM

SALVADOREAN ARMY CAVALRY REGIMENT

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Cavalry and Engineering Base Base Map	
CHECKED BY: ADELAIDE HUMMEL	SH REF NO S1	CADD FILE NAME S1_Base Map.dwg
SUPERVISED BY: LAWRENCE MOOS	SCALE: NTS	DATE: 01/23/2008 SHEET: 1/15

SEE DRAWINGS D2-D4
FOR CROSS SECTIONS
AND ELEVATIONS

SEE DRAWINGS D1-D5
FOR DETAILS

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA		
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Subsurface Wetland Site Plan		
CHECKED BY: ADELAIDE HUMMEL			
SUPERVISED BY: LAWRENCE MOOS	SH REF NO C1	CADD FILE NAME C1 SSF.dwg	
	SCALE: 1:250	DATE: 01/28/08	SHEET: 4/15

**Cross Section A-A Details
CAVALRY REGIMENT**

**Cross Section C-C Details
CAVALRY REGIMENT**

Note 1:
E: Engineering Base
C: Cavalry Base

Note 2:
Surplus soil, if any, shall be placed on outer berm of basins and graded to blend new berms into existing site contours and reduce slope.

Note 3:
All elevations shown are based on the elevation of the top of the existing Basin 3 outlet structure of 463.99 m for the Cavalry Base. Contractor shall verify these elevations and adjust the elevations shown, if necessary.

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA		
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Subsurface Wetland Cross Sections (SSF) Cavalry Base		
CHECKED BY: ADELAIDE HUMMEL	SH REF NO C2-A	CADD FILE NAME C2-A SSF Cavalry Cross Section.dwg	
SUPERVISED BY: LAWRENCE MOOS	SCALE: 1:100	DATE: 01/24/2006	SHEET: 5/15

DISEÑADO POR: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA
DIBUJADO POR: LAWRENCE MOOS	
REVISADO POR: ADELAIDE HUMMEL	
SUPERVISADO POR: LAWRENCE MOOS	
REF NO C3	CADD FILE NAME C3 SF Plan.dwg
ESCALA: 1:400	FECHA: 01/25/2006
	HOJA: 7/15

Cross Section D-D Details

Section F-F Details

Note 1:

Surplus soil, if any, shall be placed on outer berm of basins and graded to blend new berms into existing site contours and reduce slope.

Note 2:

All elevations shown are based on the elevation of the top of the existing Basin 3 outlet structure of 463.99 m for the Cavalry Base. Contractor shall verify these elevations and adjust the elevations shown, if necessary.

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Surface Flow Wetland Cross Sections (SF) Cavalry Base	
CHECKED BY: ADELAIDE HUMMEL	SH REF NO C4	CADD FILE NAME C4 SF Cross Section.dwg
SUPERVISED BY: LAWRENCE MOOS	SCALE: 1:100	DATE: 01/31/2006 SHEET: 8/15

Vista en Planta

Seccion de corte Vista paralela al caudal

Caja Divisoria del caudal de entrada (Típica en dos lugares)

Tubería de distribución del Afluente (Cabezal) y Tubería de recolección del Efluente (Cabezal) para Humedal SF y de Cama Vegetal (VB)

Escala 1:100

Tubería de distribución del Afluente (Cabezal) y Tubería de recolección del Efluente (Cabezal) para Humedales de Flujo Subsuperficial

Escala: 1:100

Caja de control para el Efluente Humedal SF y de Cama Vegetal (VB)

Scale: 1:100

Detalle de la Tubería de Descarga Ajustable Proveniente del Humedal SF

Escala 1:5

Detalle del tapon de limpieza (Sin escala)

DISEÑADO POR: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DIBUJADO POR: LAWRENCE MOOS	Regimiento de Caballería del Ejército Salvadoreño	
REVISADO POR: ADELAIDE HUMMEL	Detalles Generales 01	
SUPERVISADO POR: LAWRENCE MOOS	REF NO D1	CADD FILE NAME D1 Details.dwg
ESCALA: COMO INDICADO FECHA: 01/26/2006 HOJA: -1/15

Weir in SSF Basin Flow Distribution Boxes
Scale 1:25

Weir in SSF Basin Outlet Level Control Boxes
Scale 1:25

Influent Flow Splitter Box

Effluent Level Control Box

Scale 1:100

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment General Details 2	
CHECKED BY: ADELAIDE HUMMEL	8H REF NO D2	CADD FILE NAME D2 Details.dwg
SUPERVISED BY: LAWRENCE MOOS	SCALE: As Indicated	DATE: 01/28/2008 SHEET: 12/15

POWER AND CONTROL CIRCUIT

NOT TO SCALE

NOTES:

1.- THE EXISTING LAGOONS HAS AVAILABILITY OF ENERGY FROM AN EXISTING PANEL TO THE CHLORINATION STATION, WHICH IS FED BY A 15 KVA TRANSFORMER. THE ELECTRIC SYSTEM SPECIFICATIONS AVAILABLE ARE 120V-240V, MONOPHASE THREE WIRE.

2. - THE POWER CIRCUIT WILL BE FED WITH 240V, MONOPHASE WITH THE RESPECTIVE PROTECTIONS AGAINST SHORT CIRCUIT AND OVERLOAD. THE PUMP SHALL RUN AUTOMATICALLY BY A FLOATING SWITCH AND IN MANUAL FORM BY A STOP-START BUTTON

3.- THE TYPE OF PUMP RECOMENDED FOR THIS APPLICATION IS OF SELF PRIMING PEDESTAL TYPE

SYMBOLS:

- TWO POLES THERMIC SWITCH
- OPEN NORMAL CONTACTS
- CLOSED NORMAL CONTACTS
- COIL
- OVERLOAD PROTECTION
- FLOAT SWITCHES
- PILOT LIGHT

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Bases de Caballeria y Ingenieria Electrical Circuit Detail for Pump	
CHECKED BY: ADELAIDE HUMMEL	SH REF NO D3	CADD FILE NAME D3_Detail Electrical Plan.dwg
SUPERVISED BY: LAWRENCE MOOS	SCALE: As Indicated	DATE: 01/23/2006 SHEET: 13/15

INFLUENT FLOW SPLITTER BOX (SAME IN TWO PLACES)

SCALE 1:40

DETAIL IN COOKED CLAY WALLS IN SPLITTER BOX

SCALE 1:40

SECTION 1-1
SCALE 1:20

JOINT DETAIL IN THE CONCRETE WALLS

SCALE 1:15

CONCRETE TOP BEAM DETA

SCALE 1:10

**CROSS SECTION
BLOCK WALL**

SCALE 1:40

2\", 3\"/>

SCALE 1:15

PLAN

CROSS SECTION

EFFLUENT LEVEL CONTROL BOX (SF AND VB)

SCALE 1:40

PLAN

SECTION 2-2

STEEL PLATE COVER

SCALE 1:20

**ADDITIONAL REINFORCEMENT
DETAIL IN THE PIPE HOLE**

SCALE 1:15

DESIGNED BY:
JOSE BENDANA
DRAWN BY:
JOSE BENDANA
CHECKED BY:
ADELAIDE HUMMEL
SUPERVISED BY:
LAWRENCE MOOS

FLORIDA INTERNATIONAL UNIVERSITY
MIAMI, FLORIDA, USA

Salvadoran Army Cavalry Regiment
Structural Details 01

SH REF NO

D4

CADD FILE NAME

D4 Structural Details.dwg

SCALE: As Indicated

DATE: 01/31/2006

SHEET: 14/15

Cross Section B-B Details
Scale 1:200

Cross Section C-C Details
Scale 1:200

DESIGNED BY: MOOS / HUMMEL	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA	
DRAWN BY: ADELAIDE HUMMEL	Salvadoran Army Cavalry Regiment Cross Sections BB Cavalry Base	
CHECKED BY: ADELAIDE HUMMEL	SH REF NO C1B	CADD FILE NAME C1B Cross Section BB.dwg
SUPERVISED BY: DR ALFREDO RAVINET	SCALE:	DATE: 05/18/2006 SHEET: 3/3

Cross Section C-C Details

DESIGNED BY: LAWRENCE MOOS	FLORIDA INTERNATIONAL UNIVERSITY MIAMI, FLORIDA, USA		
DRAWN BY: LAWRENCE MOOS	Salvadoran Army Cavalry Regiment Cross Sections CC Cavalry Base		
CHECKED BY: ADELAIDE HUMMEL	SH REF NO	CADD FILE NAME	
SUPERVISED BY: LAWRENCE MOOS	C1C	C1C Cross Section CC.dwg	
	SCALE: 1:150	DATE: 04/18/2006	SHEET:

APPENDIX B

DATA SET

Table B-1 SSF Influent Data (SSF 1)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	300,000	2.40	2.23	0.0	320.0	72.43	223.21	4.0	114	24.46	1.08
12/19/06	50,000	0.91	3.82	0.0	420.0	152.27	304.88	9.4	205	24.83	5.16
01/08/07	24,000	1.30	11.31	0.0	450.0	80.04	142.28	0.5	140	16.56	0.16
01/17/07	-	1.42	3.08	0.0	489.5	65.43	267.58	7.0	176	5.52	0.17
01/24/07	90,000	1.17	3.01	0.0	522.0	80.55	222.22	0.6	136	2.76	0.19
01/30/07	30,000	1.35	2.94	0.0	524.5	83.18	252.02	1.4	168	11.04	0.67
02/07/07	50,000	1.36	3.46	0.0	645.5	67.90	324.80	3.5	160	17.94	2.71
03/13/07	80,000	3.31	9.12	0.0	808.5	72.48	922.11	7.1	335	41.59	-
04/24/07	1,600,000	0.83	5.59	0.0	229.5	48.20	397.29	20.2	630	25.74	6.56
05/09/07	300,000	1.15	5.66	0.0	484.5	32.81	184.87	3.4	152	20.13	2.25
06/27/07	50,000	3.58	15.43	0.0	617.5	63.27	216.00	16.0	100	21.01	7.40
07/04/07	2,400	3.41	3.48	0.8	606.0	43.59	51.59	0.8	30	17.51	14.67
07/11/07	50,000	2.41	4.57	0.0	606.5	43.16	96.00	9.4	25	17.14	9.51
07/18/07	140,000	0.48	1.35	0.0	474.5	79.99	316.00	5.4	72	17.67	12.69
07/25/07	30,000	0.53	2.59	0.0	510.5	42.64	180.00	1.2	102	25.16	21.85
08/15/07	90,000	0.57	8.47	0.0	563.0	63.44	214.29	4.1	48	26.84	15.80
09/19/07	50,000	4.69	0.57	-	-	42.92	-	5.6	-	-	15.84
Average	183,525	1.82	5.10	0.1	517.0	66.72	269.70	5.9	162	19.74	7.29
Standard Deviation	388,002	1.26	3.90	0.2	133.9	27.34	194.64	5.5	146	9.09	6.99
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-2 SSF Effluent (SSF 1-2 Phragmites)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	50,000	2.22	2.09	0.00	330.0	44.76	128.97	4.0	30	16.30	2.85
12/19/06	16,000	0.42	2.76	0.00	430.0	92.33	172.76	7.4	80	15.18	4.60
01/08/07	3,000	4.02	10.71	0.00	535.0	66.31	130.08	0.4	34	11.04	5.56
01/17/07	-	2.37	2.16	0.00	536.0	46.76	175.78	3.6	88	13.80	1.75
01/24/07	16,000	2.09	10.28	0.00	528.0	62.16	106.48	0.6	4	11.04	3.24
01/30/07	110	2.46	6.11	0.00	524.5	52.77	206.65	0.6	4	5.52	6.42
02/07/07	130	2.57	3.65	0.00	598.0	56.36	114.17	2.5	6	5.52	11.51
03/13/07	17,000	3.54	8.00	0.00	753.5	61.90	139.34	6.6	25	14.51	-
04/24/07	16,000	3.36	1.20	0.00	686.5	63.83	131.78	5.9	16	19.70	13.69
05/09/07	240	3.59	19.56	0.00	518.5	78.10	184.87	9.5	4	23.76	18.69
06/27/07	30,000	2.81	2.71	0.00	516.0	32.60	80.00	4.3	0	13.18	8.66
07/04/07	240	2.97	19.68	0.02	554.5	41.18	47.62	3.8	0	14.20	12.52
07/11/07	9,000	3.63	3.19	0.03	578.5	28.45	56.00	0.3	6	13.94	3.42
07/18/07	2,400	2.73	0.66	0.00	411.0	64.32	112.00	3.1	16	8.07	5.35
07/25/07	9,000	2.02	0.97	0.34	439.0	16.93	20.00	8.5	12	12.02	11.16
08/15/07	3,000	4.73	0.25	0.00	459.5	35.98	60.15	1.4	0	10.56	10.39
09/19/07	11,000	4.28	0.78	-	-	13.67	-	1.0	-	-	7.89
Average	11,445	2.93	5.57	0.02	524.9	50.49	116.67	3.7	20	13.02	7.98
Standard Deviation	13,337	1.02	6.20	0.08	103.1	21.02	53.50	3.0	27	4.71	4.70
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-3 SSF Effluent (SSF 1-3 Thalia)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	50,000	2.16	2.55	0	330	41.29	158.73	3.4	16	13.59	3.21
12/19/06	50,000	0.29	1.89	0	460	167.4	238.82	8.6	95	16.56	8.14
01/08/07	24,000	3.92	8.29	0	522	48.24	113.82	0.9	42	13.8	7.06
01/17/07	-	2.08	2.06	0	512	39.16	171.88	1	104	8.28	1.22
01/24/07	16,000	2.00	4.21	0	528.5	66.78	175.93	0.6	20	10.35	4.47
01/30/07	70	2.23	4.02	0	514.5	65.56	241.94	0.6	4	3.45	7.59
02/07/07	17,000	2.57	3.63	0	645.5	93.65	127.95	0.9	4	12.42	13.86
03/13/07	22,000	3.53	11.25	0	746.5	61.03	196.72	2.3	30	16.29	-
04/24/07	16,000	2.62	0.27	0	615.5	66.03	147.29	5.9	18	19.87	13.69
05/09/07	17,000	2.97	14.62	0	520	32.06	193.28	7.9	0	18.24	14.16
06/27/07	13,000	3.56	5.47	0	507.5	31.02	144	2.2	0	12.66	9.13
07/04/07	5,000	3.47	19.68	4	551.5	36.05	45.63	1	0	15.63	11.88
07/11/07	30,000	3.71	5.54	0.03	547.5	25.74	56	1.3	4	14.11	9.22
07/18/07	30,000	1.60	2.67	0	422.5	55.12	112	7.9	18	8.65	7.37
07/25/07	80,000	0.47	1.57	0.61	478	27.06	92	8.6	42	11.49	10.14
08/15/07	16,000	4.06	0.59	0	471	30.23	48.87	1.2	0	11.01	8.73
09/19/07	50,000	4.25	0.72	-	-	21.33	-	0.2	-	-	7.34
Average	27,254	2.68	5.24	0.29	523.3	53.40	141.55	3.2	25	12.90	8.58
Standard Deviation	20,680	1.18	5.38	1.00	93.6	35.20	61.69	3.2	32	4.11	3.70
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-4 SSF Effluent (SSF 1-4 Brachiaria)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	90,000	2.15	2.71	0	320	39.23	148.81	2.6	34	16.3	2.85
12/19/06	11,000	0.28	3.43	0	420	80.67	96.54	4.8	30	2.76	5.56
01/08/07	800	3.87	7.19	0	542.5	45.11	109.76	1.1	44	8.28	5.79
01/17/07	-	2.89	2.67	0	537	38.44	175.78	0.8	40	11.04	4.04
01/24/07	50,000	1.76	6.72	0	502	44.33	180.56	1.2	4	8.28	4.12
01/30/07	50	2.04	6.2	0	489	47.95	60.48	0.5	0	4.83	5.9
02/07/07	3,000	2.31	3.1	0	590.5	36.36	102.36	1.9	16	9.66	12.4
03/13/07	13,000	3.58	11.98	0	697.5	42.57	163.93	2.5	40	15.21	-
04/24/07	30,000	2.70	3.68	0	615	55.99	85.27	0.4	8	17.86	12.39
05/09/07	3,000	2.68	15.61	0	489.5	35.6	42.02	12.9	0	16	12.39
06/27/07	1,400	2.20	11.91	0	476.5	30.35	74	2	40	12.96	9.13
07/04/07	240	2.64	17.32	0.02	477	32.14	51.59	0	8	12.82	11.27
07/11/07	2,200	3.49	2.44	0.13	479	32.62	64	0.9	6	12.89	0.84
07/18/07	5,000	2.87	1.92	0	544.5	49.33	104	10.5	16	9.03	8.64
07/25/07	22,000	1.43	3.07	0.41	431	24.73	36	15.2	20	11.47	11.16
08/15/07	9,000	4.62	0.59	0	450	35.86	67.67	1.5	0	10.42	8.73
09/19/07	22,000	4.06	0.63	-	-	21.25	-	0.9	-	-	7.89
Average	16,418	2.68	5.95	0.04	503.8	40.74	97.67	3.5	19	11.24	7.69
Standard Deviation	23,912	1.06	5.19	0.11	86.9	13.58	47.15	4.7	16	4.12	3.68
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-5 SF Effluent (SF 2-5 Phragmites/Typha)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	800	0.02	1.25	0.00	270.00	15.39	79.37	1.00	4.00	13.59	0.15
12/19/06	140	0.14	1.25	0.00	300.00	11.93	22.36	2.00	0.00	5.52	0.13
01/08/07	300	2.08	2.01	0.00	438.50	9.64	32.52	0.20	4.00	2.76	0.14
01/17/07	-	1.37	1.99	0.00	490.00	13.85	54.69	0.80	0.00	5.52	0.17
01/24/07	900	2.01	2.65	0.00	528.50	25.06	171.30	0.50	4.00	5.52	0.17
01/30/07	13	5.97	1.95	2.44	0.00	520.00	46.78	55.44	0.80	4.00	2.76
02/07/07	13	1.85	2.08	0.00	554.00	7.70	55.56	1.90	8.00	5.52	2.71
03/13/07	500	2.64	5.09	0.00	846.50	24.52	81.97	1.40	10.00	5.93	-
04/24/07	500	2.85	2.44	0.00	750.00	21.13	108.53	1.00	10.00	7.70	0.29
05/09/07	130	2.72	5.17	0.00	480.00	13.45	25.21	6.90	0.00	5.43	1.04
06/27/07	240	0.50	6.05	0.00	425.00	20.01	88.00	1.80	0.00	2.01	0.12
07/04/07	170	0.66	3.13	0.00	294.50	27.07	41.67	1.40	0.00	1.77	0.00
07/11/07	1100	0.70	2.67	0.00	178.50	22.09	176.00	1.70	1.00	2.03	0.19
07/18/07	140	1.10	0.00	0.00	291.00	37.29	76.00	0.70	6.00	2.10	0.16
07/25/07	500	2.22	1.03	0.60	356.00	15.35	48.00	1.00	0.00	4.61	3.76
08/15/07	500	2.33	0.47	0.00	311.00	20.52	60.15	1.30	0.00	1.02	0.35
09/19/07	2200	2.26	0.55	-	-	10.77	-	0.00	-	-	0.00
Average	509	1.85	2.34	0.19	407.1	47.99	73.01	4.6	3	4.69	0.76
Standard Deviation	553	1.41	1.71	0.62	207.6	121.87	45.81	13.2	4	3.06	1.19
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-6 SSF Effluent (SF 3-6 Thalia/Thalia)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	11000	0.47	1.63	0.00	330.00	18.05	101.19	0.40	10.00	10.87	0.09
12/19/06	280	0.30	2.24	0.23	350.00	11.27	24.39	3.80	0.00	8.28	0.09
01/08/07	1400	2.86	2.68	0.00	469.50	13.14	48.78	0.40	6.00	8.28	0.07
01/17/07	-	2.60	1.67	0.00	519.00	10.95	46.88	0.90	0.00	2.76	0.47
01/24/07	900	1.82	2.53	0.00	540.00	25.29	212.96	0.40	8.00	5.52	0.30
01/30/07	240	2.16	2.51	0.00	518.50	39.71	50.40	0.80	6.00	5.52	0.34
02/07/07	8	2.02	2.56	0.00	574.50	12.15	79.37	0.50	4.00	5.52	1.50
03/13/07	5000	2.07	5.64	0.00	766.00	44.45	459.02	1.90	80.00	13.31	-
04/24/07	5000	0.23	4.62	0.00	621.00	30.09	224.81	5.40	82.00	14.27	1.97
05/09/07	2400	0.38	6.38	0.34	374.50	25.51	33.61	8.60	16.00	6.34	0.19
06/27/07	500	0.95	3.12	0.00	377.50	13.58	92.00	0.90	16.00	2.73	0.13
07/04/07	16000	1.07	1.92	0.00	325.50	25.31	103.17	3.90	12.00	1.89	0.45
07/11/07	170	0.84	1.75	1.09	250.00	21.56	24.00	1.10	0.00	2.50	0.67
07/18/07	5000	1.84	1.58	0.00	373.00	45.36	96.00	4.40	16.00	3.55	1.64
07/25/07	5000	2.36	1.75	0.00	361.50	13.31	60.00	1.30	0.00	4.72	428.00
08/15/07	1300	2.44	0.78	0.00	353.50	23.79	413.53	8.10	0.00	1.63	0.90
09/19/07	0	2.57	1.56	-	-	8.73	-	1.50	-	-	0.00
Average	3,387	1.59	2.64	0.10	444.0	22.49	129.38	2.6	16	6.11	27.30
Standard Deviation	4,502	0.91	1.52	0.28	135.6	11.76	133.58	2.7	26	3.95	106.85
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-7 SSF Effluent (SF 4-7 Brachiaria/Cyperus)											
Sampling Date	Fecal Coliform (NMP/100 mL)	Phosphorus (mg/L)	Nitrates (mg/L)	Nitrites (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Oil & Grease (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Ammonium (mg/L)
11/29/06	800	0.00	0.95	0.00	270.00	12.82	71.43	0.20	0.00	10.87	0.11
12/19/06	220	0.21	1.15	0.00	330.00	9.93	28.46	3.40	0.00	7.59	0.57
01/08/07	300	2.64	2.54	0.00	453.00	11.14	36.59	0.20	6.00	2.76	0.04
01/17/07	-	3.03	1.73	0.00	553.00	10.49	50.78	0.40	0.00	5.52	0.67
01/24/07	2400	3.49	2.82	0.00	533.50	72.99	194.44	0.50	4.00	2.76	0.28
01/30/07	1100	2.98	2.65	0.00	515.00	36.48	70.56	1.20	4.00	2.76	0.23
02/07/07	800	2.90	2.15	0.00	605.00	48.25	119.05	0.20	4.00	6.90	0.40
03/13/07	8000	3.06	5.03	0.00	740.50	21.62	90.16	2.50	20.00	7.19	-
04/24/07	3000	3.02	4.47	0.00	702.50	20.39	131.78	9.80	8.00	11.29	0.35
05/09/07	2400	2.43	11.98	0.25	506.00	27.28	33.61	6.70	8.00	6.64	0.07
06/27/07	80	0.68	2.76	0.00	374.50	10.32	52.00	0.60	0.00	2.26	0.16
07/04/07	5000	0.60	12.21	0.00	360.50	27.31	37.70	5.90	4.00	5.48	0.56
07/11/07	5000	0.60	5.08	1.06	312.00	5.73	40.00	0.70	0.00	4.20	0.14
07/18/07	1100	1.55	0.00	0.00	314.50	37.16	56.00	1.50	4.00	3.92	0.14
07/25/07	300	1.80	6.61	0.35	309.50	12.15	140.00	0.20	6.00	6.67	5.70
08/15/07	130	0.94	0.53	0.06	270.00	28.25	45.11	2.10	0.00	1.80	1.19
09/19/07	0	1.92	0.70	-	-	5.50	-	1.10	-	-	0.00
Average	1,914	1.87	3.73	0.11	446.8	23.40	74.85	2.2	4	5.54	0.66
Standard Deviation	2,307	1.17	3.63	0.27	152.1	17.76	47.79	2.8	5	2.89	1.38
Note: Shaded cell indicates N.D. (non-detectable); - = data not available											

Table B-8 Summary of SSF Effluent Concentration and % Residual – Average and Standard Deviation

Parameter	SSF 1		SSF 1-2				SSF 1-3				SSF 1-4			
	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD (mg/L)	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD
Fecal Coliform	183,525	388,002	11,445	13,337	15%	16%	27,254	20,680	63%	77%	16,418	23,912	18%	22%
Phosphorus	1.8	1.3	2.9	1.0	246%	207%	2.7	1.3	197%	160%	2.7	1.1	224%	203%
Nitrates	5.1	3.9	5.6	6.2	136%	149%	5.2	5.4	129%	130%	6.0	5.2	139%	114%
Nitrites**	0.1	0.2	0.0	0.1	0%	1%	0.3	1.0	36%	134%	0.0	0.1	0%	1%
TDS	517.0	133.9	524.9	103.1	109%	52%	523.3	93.6	108%	44%	503.8	86.9	105%	45%
BOD	66.7	27.3	50.5	21.0	81%	46%	53.4	35.2	78%	28%	40.7	13.6	64%	19%
COD	269.7	194.6	116.7	53.5	53%	28%	141.6	61.7	62%	26%	97.7	47.1	45%	26%
Oil & Grease	5.9	5.5	3.7	3.0	132%	188%	3.2	3.2	111%	170%	3.5	4.7	152%	306%
TSS	162.1	145.9	20.3	27.1	14%	16%	24.8	32.4	16%	19%	19.1	16.4	12%	12%
Total Nitrogen	19.7	9.1	13.0	4.7	95%	96%	12.9	4.1	88%	82%	11.2	4.1	79%	72%
Ammonium	7.3	1.4	8.0	4.7	590%	910%	8.6	3.7	683%	1160%	7.7	3.7	690%	1073%

Notes: Conc. = Concentration; AVE = average; SD = standard deviation; Res.=Residual; SSF 1 = SSF Influent, SSF 1-2 = Phragmites, SSF 1-3 = Thalia; SSF 1-4 = Brachiaria.

Table B-9 Summary of SF Effluent Concentration and % Residual – Average and Standard Deviation

Parameter	SF 2-5				SF 3-6				SF 4-7			
	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD (mg/L)	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD
Fecal Coliform	509.1	552.9	14%	20%	3,387.4	4,502.2	50%	110%	1,914.4	2,307.0	298%	722%
Phosphorus	1.8	1.4	65%	55%	1.6	0.9	88%	113%	1.9	1.2	78%	54%
Nitrates	2.3	1.7	82%	67%	2.6	1.5	171%	400%	3.7	3.6	75%	60%
Nitrites**	0.2	0.6	12%	46%	0.1	0.3	260%	971%	0.1	0.3	64%	217%
TDS	407.1	207.6	81%	21%	444.0	135.6	85%	17%	446.8	152.1	87%	19%
BOD	48.0	121.9	101%	229%	22.5	11.8	51%	24%	23.4	17.8	59%	42%
COD	73.0	45.8	90%	84%	129.4	133.6	130%	203%	74.9	47.8	93%	86%
Oil & Grease	4.6	13.2	612%	2227%	2.6	2.7	161%	224%	2.2	2.8	214%	599%
TSS	3.0	3.7	27%	40%	16.0	26.1	2824%	5937%	4.3	5.1	28%	35%
Total Nitrogen	4.7	3.1	39%	26%	6.1	3.9	51%	36%	5.5	2.9	59%	60%
Ammonium	0.8	1.2	9%	13%	27.3	106.9	272%	1053%	0.7	1.4	9%	13%

Notes: Conc. = Concentration; AVE = average; SD = standard deviation; Res.=Residual; SF 2-5 = Phragmites/Typha, SF 3-6 = Thalia/Thalia; SF 4-7 = Brachiaria/Cyperus.

Table B-10 Summary of CW System Effluent Concentration and % Residual – Average and Standard Deviation														
Parameter	SSF 1		SSF 1-2-5				SSF 1-3-6				SSF 1-4-7			
	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD (mg/L)	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD	AVE Conc. (mg/L)	Conc. SD (mg/L)	AVE % Res.	% Res. SD
Fecal Coliform	183,525	388,002	509.1	552.9	1%	2%	3,387.4	4,502.2	44%	166%	1,914.4	2,307.0	15%	52%
Phosphorus	1.8	1.3	1.8	1.4	168%	154%	1.6	0.9	144%	147%	1.9	1.2	163%	126%
Nitrates	5.1	3.9	2.3	1.7	57%	26%	2.6	1.5	76%	59%	3.7	3.6	95%	95%
Nitrites**	0.1	0.2	0.2	0.6	0%	0%	0.1	0.3	0%	0%	0.1	0.3	0%	0%
TDS	517.0	133.9	407.1	207.6	94%	68%	444.0	135.6	94%	51%	446.8	152.1	95%	60%
BOD	66.7	27.3	48.0	121.9	67%	145%	22.5	11.8	38%	21%	23.4	17.8	38%	26%
COD	269.7	194.6	73.0	45.8	40%	44%	129.4	133.6	56%	59%	74.9	47.8	35%	24%
Oil & Grease	5.9	5.5	4.6	13.2	280%	950%	2.6	2.7	89%	124%	2.2	2.8	42%	49%
TSS	162.1	145.9	3.0	3.7	2%	2%	16.0	26.1	9%	11%	4.3	5.1	3%	4%
Total Nitrogen	19.7	9.1	4.7	3.1	37%	49%	6.1	3.9	41%	45%	5.5	2.9	36%	27%
Ammonium	7.3	1.4	0.8	1.2	55%	103%	27.3	106.9	164%	484%	0.7	1.4	43%	100%
<i>Notes:</i> Conc. = Concentration; AVE = average; SD = standard deviation; Res.=Residual; SSF 1 = SSF Influent, SSF 1-2-5 = Influent/Phragmites/Typha, SSF 1-3-6 = Influent/Thalia/Thalia; SSF 1-4-7 = Influent/Brachiaria/Cyperus.														

Table B-11 Fecal Coliform (FC) Seasonal Percent Residual

Season	Date	FC Point 1 Conc. (NMP/100 mL)	FC Point 1-2		FC Point 1-3		FC Point 1-4		FC Point 2-5		FC Point 3-6		FC Point 4-7	
			Conc. (NMP/100 mL)	% Res.	Conc. (NMP/100 mL)	% Res.	Conc. (NMP/100 mL)	% Res.	Conc. (NMP/100 mL)	% Res.	Conc. (NMP/100 mL)	% Res.	Conc. (NMP/100 mL)	% Res.
Wet (May to Nov)	11/29/06	300,000	50,000	17%	50,000	17%	90,000	30%	800	2%	11,000	22%	800	1%
	5/9/07	300,000	240	0.1%	17,000	5.7%	3,000	1.0%	130	54%	2,400	14%	2,400	80%
	6/27/07	50,000	30,000	60%	13,000	26%	1,400	3%	240	1%	500	4%	80	6%
	7/4/07	2,400	240	10%	5,000	208%	240	10%	170	71%	16,000	320%	5,000	2083%
	7/11/07	50,000	9,000	18%	30,000	60%	2,200	4%	1,100	12%	170	1%	5,000	227%
	7/18/07	140,000	2,400	2%	30,000	21%	5,000	4%	140	6%	5,000	17%	1,100	22%
	7/25/07	30,000	9,000	30%	80,000	267%	22,000	73%	500	6%	5,000	6%	300	1%
	8/15/07	90,000	3,000	3%	16,000	18%	9,000	10%	500	17%	1,300	8%	130	1%
	9/19/07	50,000	11,000	22%	50,000	100%	22,000	44%	-	-	0	0%	0	0%
	AVE	112,489	12,764	18%	32,333	80%	17,204	20%	448	21%	4,597	44%	1,646	269%
	SD	113,039	16,701	19%	23,796	95%	28,561	25%	353	27%	5,529	104%	2,042	684%
Dry (Dec to April)	12/19/06	50,000	16,000	32%	50,000	100%	11,000	22%	140	1%	280	1%	220	2%
	1/8/07	24,000	3,000	13%	24,000	100%	800	3%	300	10%	1,400	6%	300	38%
	1/17/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	1/24/07	90,000	16,000	18%	16,000	18%	50,000	56%	900	6%	900	6%	2,400	5%
	1/30/07	30,000	110	0.4%	70	0.2%	50	0.2%	13	12%	240	343%	1,100	2200%
	2/7/07	50,000	130	0.3%	17,000	34.0%	3,000	6.0%	13	10%	8	0%	800	27%
	3/13/07	80,000	17,000	21%	22,000	28%	13,000	16%	500	3%	5,000	23%	8,000	62%
	4/24/07	1,600,000	16,000	1%	16,000	1%	30,000	2%	500	3%	5,000	31%	3,000	10%
	AVE	274,857	9,749	12%	20,724	40.1%	15,407	15%	338	6%	1,833	58%	2,260	335%
	SD	584,829	8,173	12%	15,025	42.8%	18,430	20%	322	4%	2,214	126%	2,738	823%

Notes

- AVE = average; SD = standard deviation; Res.=Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-12 Total Phosphorus (TP) Seasonal Percent Residual

Season	Date	TP Point 1 Conc. (mg/L)	TP Point 1-2		TP Point 1-3		TP Point 1-4		TP Point 2-5		TP Point 3-6		TP Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	2.40	2.22	93%	2.16	90%	2.15	90%	0.02	1%	0.47	22%	0.00	0%
	5/9/07	1.15	3.59	314%	2.97	259%	2.68	234%	2.72	76%	0.38	13%	2.43	91%
	6/27/07	3.58	2.81	78%	3.56	99%	2.20	61%	0.50	18%	0.95	27%	0.68	31%
	7/4/07	3.41	2.97	87%	3.47	102%	2.64	78%	0.66	22%	1.07	31%	0.60	23%
	7/11/07	2.41	3.63	151%	3.71	154%	3.49	145%	0.70	19%	0.84	23%	0.60	17%
	7/18/07	0.48	2.73	569%	1.60	333%	2.87	598%	1.10	40%	1.84	115%	1.55	54%
	7/25/07	0.53	2.02	381%	0.47	89%	1.43	270%	2.22	110%	2.36	502%	1.80	126%
	8/15/07	0.57	4.73	831%	4.06	714%	4.62	812%	2.33	49%	2.44	60%	0.94	20%
	9/19/07	4.69	4.28	91%	4.25	91%	4.06	87%	2.26	53%	2.57	61%	1.92	47%
	AVE	2.13	3.22	288%	2.92	214%	2.90	264%	1.39	43%	1.44	95%	1.17	45%
	SD	1.55	0.91	265%	1.26	207%	1.00	266%	0.99	34%	0.87	156%	0.79	40%
Dry (Dec to April)	12/19/06	0.91	0.42	46%	0.29	32%	0.28	31%	0.14	33%	0.30	103%	0.21	72%
	1/8/07	1.30	4.02	309%	3.92	301%	3.87	297%	2.08	52%	2.86	73%	2.64	68%
	1/17/07	1.42	2.37	167%	2.08	147%	2.89	204%	1.37	58%	2.60	125%	3.03	105%
	1/24/07	1.17	2.09	178%	2.00	170%	1.76	150%	2.01	96%	1.82	91%	3.49	198%
	1/30/07	1.35	2.46	182%	2.23	165%	2.04	151%	5.97	243%	2.16	97%	2.98	146%
	2/7/07	1.36	2.57	189%	2.57	189%	2.31	170%	1.85	72%	2.02	78%	2.90	125%
	3/13/07	3.31	3.54	107%	3.53	107%	3.58	108%	2.64	75%	2.07	58%	3.06	86%
	4/24/07	0.83	3.36	404%	2.62	315%	2.70	325%	2.85	85%	0.23	9%	3.02	112%
	AVE	1.46	2.60	198%	2.41	178%	2.43	179%	2.36	89%	1.76	79%	2.67	114%
	SD	0.78	1.11	112%	1.10	94%	1.13	96%	1.68	65%	0.98	35%	1.02	43%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-13 Nitrates Seasonal Percent Residual

Season	Date	Nitrates Point 1 Conc. (mg/L)	Nitrates Point 1-2		Nitrates Point 1-3		Nitrates Point 1-4		Nitrates Point 2-5		Nitrates Point 3-6		Nitrates Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	2.23	2.09	94%	2.55	114%	2.71	122%	1.25	60%	1.63	64%	0.95	35%
	5/9/07	5.66	19.56	346%	14.62	258%	15.61	276%	5.17	26%	6.38	44%	11.98	77%
	6/27/07	15.43	2.71	18%	5.47	35%	11.91	77%	6.05	223%	3.12	57%	2.76	23%
	7/4/07	3.48	19.68	566%	19.68	566%	17.32	498%	3.13	16%	1.92	10%	12.21	70%
	7/11/07	4.57	3.19	70%	5.54	121%	2.44	53%	2.67	84%	1.75	32%	5.08	208%
	7/18/07	1.35	0.66	49%	2.67	198%	1.92	142%	0.00	0%	1.58	59%	0.00	0%
	7/25/07	2.59	0.97	37%	1.57	61%	3.07	119%	1.03	106%	1.75	111%	6.61	215%
	8/15/07	8.47	0.25	3%	0.59	7%	0.59	7%	0.47	188%	0.78	132%	0.53	90%
	9/19/07	0.57	0.78	137%	0.72	126%	0.63	111%	0.55	71%	1.56	217%	0.70	111%
	AVE	4.93	5.54	146%	5.93	165%	6.24	156%	2.54	97%	2.27	81%	4.54	92%
	SD	4.61	8.04	188%	6.72	169%	6.72	148%	2.13	74%	1.65	63%	4.83	76%
Dry (Dec to April)	12/19/06	3.82	2.76	72%	1.89	49%	3.43	90%	1.25	45%	2.24	119%	1.15	34%
	1/8/07	11.31	10.71	95%	8.29	73%	7.19	64%	2.01	19%	2.68	32%	2.54	35%
	1/17/07	3.08	2.16	70%	2.06	67%	2.67	87%	1.99	92%	1.67	81%	1.73	65%
	1/24/07	3.01	10.28	342%	4.21	140%	6.72	223%	2.65	26%	2.53	60%	2.82	42%
	1/30/07	2.94	6.11	208%	4.02	137%	6.20	211%	1.95	32%	2.51	62%	2.65	43%
	2/7/07	3.46	3.65	105%	3.63	105%	3.10	90%	2.08	57%	2.56	71%	2.15	69%
	3/13/07	9.12	8.00	88%	11.25	123%	11.98	131%	5.09	64%	5.64	50%	5.03	42%
	4/24/07	5.59	1.20	21%	0.27	5%	3.68	66%	2.44	203%	4.62	1711%	4.47	121%
	AVE	5.29	5.61	125%	4.45	87%	5.62	120%	2.43	67%	3.06	273%	2.82	56%
	SD	3.21	3.72	102%	3.62	47%	3.12	63%	1.15	60%	1.35	582%	1.32	29%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-14 Nitrites Seasonal Percent Residual

Season	Date	Nitrites Point 1 Conc. (mg/L)	Nitrites Point 1-2		Nitrites Point 1-3		Nitrites Point 1-4		Nitrites Point 2-5		Nitrites Point 3-6		Nitrites Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	5/9/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.34	>1000%	0.25	>1000%
	6/27/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	7/4/07	0.80	0.02	2.5%	4.00	500.0%	0.02	2.5%	0.00	0%	0.00	0%	0.00	0%
	7/11/07	0.00	0.03	0.0%	0.03	>1000%	0.13	>1000%	0.00	0%	1.09	3633%	1.06	815%
	7/18/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	7/25/07	0.00	0.34	>100%	0.61	>1000%	0.41	>1000%	0.60	176%	0.00	0%	0.35	85%
	8/15/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.06	>1000%
	9/19/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVE	0.10	0.05	0.4%	0.58	83.3%	0.07	0.4%	0.08	22%	0.18	519%	0.22	150%
	SD	0.28	0.12	0.9%	1.40	204.1%	0.14	1.0%	0.21	62%	0.39	1373%	0.37	328%
Dry (Dec to April)	12/19/06	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.23	>1000%	0.00	0%
	1/8/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	1/17/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	1/24/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	1/30/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	2.44	>1000%	0.00	0%	0.00	0%
	2/7/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	3/13/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	4/24/07	0.00	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0%	0.00	0%	0.00	0%
	AVE	0.00	0.00	0%	0.00	0%	0.00	0%	0.31	0%	0.03	0%	0.00	0%
	SD	0.00	0.00	0%	0.00	0%	0.00	0%	0.86	0%	0.08	0%	0.00	0%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-15 Total Dissolved Solids (TDS) Seasonal Percent Residual

Season	Date	TDS Point 1 Conc. (mg/L)	TDS Point 1-2		TDS Point 1-3		TDS Point 1-4		TDS Point 2-5		TDS Point 3-6		TDS Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	320.0	330.0	103%	330.0	103%	320.0	100%	270.00	82%	330.00	100%	270.00	84%
	5/9/07	484.5	518.5	107%	520.0	107%	489.5	101%	480.00	93%	374.50	72%	506.00	103%
	6/27/07	617.5	516.0	84%	507.5	82%	476.5	77%	425.00	82%	377.50	74%	374.50	79%
	7/4/07	606.0	554.5	92%	551.5	91%	477.0	79%	294.50	53%	325.50	59%	360.50	76%
	7/11/07	606.5	578.5	95%	547.5	90%	479.0	79%	178.50	31%	250.00	46%	312.00	65%
	7/18/07	474.5	411.0	87%	422.5	89%	544.5	115%	291.00	71%	373.00	88%	314.50	58%
	7/25/07	510.5	439.0	86%	478.0	94%	431.0	84%	356.00	81%	361.50	76%	309.50	72%
	8/15/07	563.0	459.5	82%	471.0	84%	450.0	80%	311.00	68%	353.50	75%	270.00	60%
	9/19/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVE	522.8	475.9	92%	478.5	93%	458.4	89%	325.8	70%	343.2	74%	339.6	75%
	SD	99.7	82.2	9%	73.6	9%	64.9	14%	93.9	20%	42.5	17%	76.8	15%
Dry (Dec to April)	12/19/06	420.0	430.0	102%	460.0	110%	420.0	100%	300.00	70%	350.00	76%	330.00	79%
	1/8/07	450.0	535.0	119%	522.0	116%	542.5	121%	438.50	82%	469.50	90%	453.00	84%
	1/17/07	489.5	536.0	109%	512.0	105%	537.0	110%	490.00	91%	519.00	101%	553.00	103%
	1/24/07	522.0	528.0	101%	528.5	101%	502.0	96%	528.50	100%	540.00	102%	533.50	106%
	1/30/07	524.5	524.5	100%	514.5	98%	489.0	93%	0.00	0%	518.50	101%	515.00	105%
	2/7/07	645.5	598.0	93%	645.5	100%	590.5	91%	554.00	93%	574.50	89%	605.00	102%
	3/13/07	808.5	753.5	93%	746.5	92%	697.5	86%	846.50	112%	766.00	103%	740.50	106%
	4/24/07	229.5	686.5	299%	615.5	268%	615.0	268%	750.00	109%	621.00	101%	702.50	114%
	AVE	511.2	573.9	127%	568.1	124%	549.2	121%	558.2	94%	544.8	95%	554.1	100%
	SD	168.4	102.6	70%	93.7	59%	85.2	61%	185.5	15%	119.9	10%	131.9	12%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-16 5-day Biological Oxygen Demand (BOD₅) Seasonal Percent Residual

Season	Date	BOD ₅ Point 1 Conc. (mg/L)	BOD ₅ Point 1-2		BOD ₅ Point 1-3		BOD ₅ Point 1-4		BOD ₅ Point 2-5		BOD ₅ Point 3-6		BOD ₅ Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	72.43	44.76	62%	41.29	57%	39.23	54%	15.39	34%	18.05	44%	12.82	33%
	5/9/07	32.81	78.10	238%	32.06	98%	35.60	109%	13.45	17%	25.51	80%	27.28	77%
	6/27/07	63.27	32.60	52%	31.02	49%	30.35	48%	20.01	61%	13.58	44%	10.32	34%
	7/4/07	43.59	41.18	94%	36.05	83%	32.14	74%	27.07	66%	25.31	70%	27.31	85%
	7/11/07	43.16	28.45	66%	25.74	60%	32.62	76%	22.09	78%	21.56	84%	5.73	18%
	7/18/07	79.99	64.32	80%	55.12	69%	49.33	62%	37.29	58%	45.36	82%	37.16	75%
	7/25/07	42.64	16.93	40%	27.06	63%	24.73	58%	15.35	91%	13.31	49%	12.15	49%
	8/15/07	63.44	35.98	57%	30.23	48%	35.86	57%	20.52	57%	23.79	79%	28.25	79%
	9/19/07	42.92	13.67	32%	21.33	50%	21.25	50%	10.77	79%	8.73	41%	5.50	26%
	AVE	53.81	39.55	80%	33.32	64%	33.46	65%	20.22	60%	21.69	64%	18.50	53%
	SD	16.27	20.90	62%	10.02	17%	8.16	19%	8.09	23%	10.66	19%	11.56	26%
Dry (Dec to April)	12/19/06	152.27	92.33	61%	167.40	110%	80.67	53%	11.93	13%	11.27	7%	9.93	12%
	1/8/07	80.04	66.31	83%	48.24	60%	45.11	56%	9.64	15%	13.14	27%	11.14	25%
	1/17/07	65.43	46.76	71%	39.16	60%	38.44	59%	13.85	30%	10.95	28%	10.49	27%
	1/24/07	80.55	62.16	77%	66.78	83%	44.33	55%	25.06	40%	25.29	38%	72.99	165%
	1/30/07	83.18	52.77	63%	65.56	79%	47.95	58%	520.00	985%	39.71	61%	36.48	76%
	2/7/07	67.90	56.36	83%	93.65	138%	36.36	54%	7.70	14%	12.15	13%	48.25	133%
	3/13/07	72.48	61.90	85%	61.03	84%	42.57	59%	24.52	40%	44.45	73%	21.62	51%
	4/24/07	48.20	63.83	132%	66.03	137%	55.99	116%	21.13	33%	30.09	46%	20.39	36%
	AVE	81.26	62.80	82%	75.98	94%	48.93	64%	79.23	146%	23.38	36%	28.91	66%
	SD	30.82	13.55	22%	40.20	31%	14.15	21%	178.22	339%	13.58	23%	22.41	55%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-17 Chemical Oxygen Demand (COD) Seasonal Percent Residual														
Season	Date	COD Point 1 Conc. (mg/L)	COD Point 1-2		COD Point 1-3		COD Point 1-4		COD Point 2-5		COD Point 3-6		COD Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	223.21	128.97	58%	158.73	71%	148.81	67%	79.37	62%	101.19	64%	71.43	48%
	5/9/07	184.87	184.87	100%	193.28	105%	42.02	23%	25.21	14%	33.61	17%	33.61	80%
	6/27/07	216.00	80.00	37%	144.00	67%	74.00	34%	88.00	110%	92.00	64%	52.00	70%
	7/4/07	51.59	47.62	92%	45.63	88%	51.59	100%	41.67	88%	103.17	226%	37.70	73%
	7/11/07	96.00	56.00	58%	56.00	58%	64.00	67%	176.00	314%	24.00	43%	40.00	63%
	7/18/07	316.00	112.00	35%	112.00	35%	104.00	33%	76.00	68%	96.00	86%	56.00	54%
	7/25/07	180.00	20.00	11%	92.00	51%	36.00	20%	48.00	240%	60.00	65%	140.00	389%
	8/15/07	214.29	60.15	28%	48.87	23%	67.67	32%	60.15	100%	413.53	846%	45.11	67%
	9/19/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVE	185.25	86.20	53%	106.31	62%	73.51	47%	74.30	124%	115.44	176%	59.48	105%
	SD	81.23	53.09	31%	55.40	27%	37.04	28%	46.18	101%	124.37	278%	34.69	115%
Dry (Dec to April)	12/19/06	304.88	172.76	57%	238.82	78%	96.54	32%	22.36	13%	24.39	10%	28.46	29%
	1/8/07	142.28	130.08	91%	113.82	80%	109.76	77%	32.52	25%	48.78	43%	36.59	33%
	1/17/07	267.58	175.78	66%	171.88	64%	175.78	66%	54.69	31%	46.88	27%	50.78	29%
	1/24/07	222.22	106.48	48%	175.93	79%	180.56	81%	171.30	161%	212.96	121%	194.44	108%
	1/30/07	252.02	206.65	82%	241.94	96%	60.48	24%	46.78	23%	50.40	21%	70.56	117%
	2/7/07	324.80	114.17	35%	127.95	39%	102.36	32%	55.56	49%	79.37	62%	119.05	116%
	3/13/07	922.11	139.34	15%	196.72	21%	163.93	18%	81.97	59%	459.02	233%	90.16	55%
	4/24/07	397.29	131.78	33%	147.29	37%	85.27	21%	108.53	82%	224.81	153%	131.78	155%
	AVE	354.15	147.13	53%	176.79	62%	121.84	44%	71.71	55%	143.33	84%	90.23	80%
	SD	241.41	34.53	26%	47.41	26%	45.35	26%	48.58	48%	149.41	79%	56.13	49%
Notes		<ul style="list-style-type: none"> - AVE = average; SD = standard deviation; Res. = Residual - Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus - Shaded cells indicates N.D. (non-detectable); - = data not available - Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed. 												

Table B-18 Oil & Grease (O&G) Seasonal Percent Residual

Season	Date	O&G Point 1 Conc. (mg/L)	O&G Point 1-2		O&G Point 1-3		O&G Point 1-4		O&G Point 2-5		O&G Point 3-6		O&G Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	4.0	4.0	100%	3.4	85%	2.6	65%	1.00	25%	0.40	12%	0.20	8%
	5/9/07	3.4	9.5	279%	7.9	232%	12.9	379%	6.90	73%	8.60	109%	6.70	52%
	6/27/07	16.0	4.3	27%	2.2	14%	2.0	13%	1.80	42%	0.90	41%	0.60	30%
	7/4/07	0.8	3.8	475%	1.0	125%	0.0	0%	1.40	37%	3.90	390%	5.90	>1000%
	7/11/07	9.4	0.3	3%	1.3	14%	0.9	10%	1.70	567%	1.10	85%	0.70	78%
	7/18/07	5.4	3.1	57%	7.9	146%	10.5	194%	0.70	23%	4.40	56%	1.50	14%
	7/25/07	1.2	8.5	708%	8.6	717%	15.2	1267%	1.00	12%	1.30	15%	0.20	1%
	8/15/07	4.1	1.4	35%	1.2	30%	1.5	37%	1.30	93%	8.10	675%	2.10	140%
	9/19/07	5.6	1.0	18%	0.2	4%	0.9	16%	0.00	0%	1.50	750%	1.10	122%
	AVE	5.5	4.0	189%	3.7	152%	5.2	220%	1.8	97%	3.4	237%	2.1	56%
	SD	4.7	3.2	250%	3.4	225%	5.9	412%	2.0	179%	3.1	294%	2.5	53%
Dry (Dec to April)	12/19/06	9.4	7.4	79%	8.6	91%	4.8	51%	2.00	27%	3.80	44%	3.40	71%
	1/8/07	0.5	0.4	80%	0.9	180%	1.1	220%	0.20	50%	0.40	44%	0.20	18%
	1/17/07	7.0	3.6	51%	1.0	14%	0.8	11%	0.80	22%	0.90	90%	0.40	50%
	1/24/07	0.6	0.6	100%	0.6	100%	1.2	200%	0.50	83%	0.40	67%	0.50	42%
	1/30/07	1.4	0.6	43%	0.6	43%	0.5	36%	55.44	9240%	0.80	133%	1.20	240%
	2/7/07	3.5	2.5	71%	0.9	26%	1.9	54%	1.90	76%	0.50	56%	0.20	11%
	3/13/07	7.1	6.6	93%	2.3	32%	2.5	35%	1.40	21%	1.90	83%	2.50	100%
	4/24/07	20.2	5.9	29%	5.9	29%	0.4	2%	1.00	17%	5.40	92%	9.80	2450%
	AVE	6.2	3.5	68%	2.6	64%	1.7	76%	7.9	1192%	1.8	76%	2.3	373%
	SD	6.6	2.9	25%	3.0	56%	1.5	85%	19.2	3252%	1.9	30%	3.3	843%

Notes

- AVE = average; SD = standard deviation; Res.=Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-19 Total Suspended Solids (TSS) Seasonal Percent Residual

Season	Date	TSS Point 1 Conc. (mg/L)	TSS Point 1-2		TSS Point 1-3		TSS Point 1-4		TSS Point 2-5		TSS Point 3-6		TSS Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	114	30	26%	16	14%	34	30%	4.00	13%	10.00	63%	0.00	0%
	5/9/07	152	4	3%	0	0%	0	0%	0.00	0%	16.00	16000%	8.00	>1000%
	6/27/07	100	0	0%	0	0%	40	0%	0.00	0%	16.00	16000%	0.00	0%
	7/4/07	30	0	0%	0	0%	8	0%	0.00	0%	12.00	12000%	4.00	50%
	7/11/07	25	6	24%	4	16%	6	24%	1.00	17%	0.00	0%	0.00	0%
	7/18/07	72	16	22%	18	25%	16	22%	6.00	38%	16.00	89%	4.00	25%
	7/25/07	102	12	12%	42	41%	20	20%	0.00	0%	0.00	0%	6.00	30%
	8/15/07	48	0	0%	0	0%	0	0%	0.00	0%	0.00	0%	0.00	0%
	9/19/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVE	80	9	11%	10	12%	16	12%	1	8%	9	5519%	3	15%
	SD	44	11	12%	15	15%	15	13%	2	14%	8	7675%	3	20%
Dry (Dec to April)	12/19/06	205	80	39%	95	46%	30	15%	0.00	0%	0.00	0%	0.00	0%
	1/8/07	140	34	24%	42	30%	44	31%	4.00	12%	6.00	14%	6.00	14%
	1/17/07	176	88	50%	104	59%	40	23%	0.00	0%	0.00	0%	0.00	0%
	1/24/07	136	4	3%	20	15%	4	3%	4.00	100%	8.00	40%	4.00	100%
	1/30/07	168	4	2%	4	2%	0	0%	0.80	20%	6.00	150%	4.00	>1000%
	2/7/07	160	6	4%	4	3%	16	10%	8.00	133%	4.00	100%	4.00	25%
	3/13/07	335	25	7%	30	9%	40	12%	10.00	40%	80.00	267%	20.00	50%
	4/24/07	630	16	3%	18	3%	8	1%	10.00	63%	82.00	456%	8.00	100%
	AVE	244	32	17%	40	21%	23	12%	5	46%	23	128%	6	41%
	SD	168	34	19%	39	22%	18	11%	4	49%	36	161%	6	44%

Notes

- AVE = average; SD = standard deviation; Res.=Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-20 Total Nitrogen (TN) Seasonal Percent Residual

Season	Date	TN Point 1 Conc. (mg/L)	TN Point 1-2		TN Point 1-3		TN Point 1-4		TN Point 2-5		TN Point 3-6		TN Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	24.46	16.30	67%	13.59	56%	16.30	67%	13.59	83%	10.87	80%	10.87	67%
	5/9/07	20.13	23.76	118%	18.24	91%	16.00	79%	5.43	23%	6.34	35%	6.64	42%
	6/27/07	21.01	13.18	63%	12.66	60%	12.96	62%	2.01	15%	2.73	22%	2.26	17%
	7/4/07	17.51	14.20	81%	15.63	89%	12.82	73%	1.77	12%	1.89	12%	5.48	43%
	7/11/07	17.14	13.94	81%	14.11	82%	12.89	75%	2.03	15%	2.50	18%	4.20	33%
	7/18/07	17.67	8.07	46%	8.65	49%	9.03	51%	2.10	26%	3.55	41%	3.92	43%
	7/25/07	25.16	12.02	48%	11.49	46%	11.47	46%	4.61	38%	4.72	41%	6.67	58%
	8/15/07	26.84	10.56	39%	11.01	41%	10.42	39%	1.02	10%	1.63	15%	1.80	17%
	9/19/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	AVE	21.24	14.00	68%	13.17	64%	12.74	61%	4.07	28%	4.28	33%	5.23	40%
	SD	3.81	4.66	26%	2.95	20%	2.51	15%	4.13	24%	3.09	22%	2.91	17%
Dry (Dec to April)	12/19/06	24.83	15.18	61%	16.56	67%	2.76	11%	5.52	36%	8.28	50%	7.59	275%
	1/8/07	16.56	11.04	67%	13.80	83%	8.28	50%	2.76	25%	8.28	60%	2.76	33%
	1/17/07	5.52	13.80	250%	8.28	150%	11.04	200%	5.52	40%	2.76	33%	5.52	50%
	1/24/07	2.76	11.04	400%	10.35	375%	8.28	300%	5.52	50%	5.52	53%	2.76	33%
	1/30/07	11.04	5.52	50%	3.45	31%	4.83	44%	4.00	72%	5.52	160%	2.76	57%
	2/7/07	17.94	5.52	31%	12.42	69%	9.66	54%	5.52	100%	5.52	44%	6.90	71%
	3/13/07	41.59	14.51	35%	16.29	39%	15.21	37%	5.93	41%	13.31	82%	7.19	47%
	4/24/07	25.74	19.70	77%	19.87	77%	17.86	69%	7.70	39%	14.27	72%	11.29	63%
	AVE	18.25	12.04	121%	12.63	111%	9.74	96%	5.31	50%	7.93	69%	5.85	79%
	SD	12.54	4.85	133%	5.22	112%	4.99	100%	1.44	24%	4.03	40%	3.03	80%

Notes

- AVE = average; SD = standard deviation; Res. = Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.; Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-21 Ammonium Seasonal Percent Residual

Season	Date	Ammonium Point 1 Conc. (mg/L)	Ammonium Point 1-2		Ammonium Point 1-3		Ammonium Point 1-4		Ammonium Point 2-5		Ammonium Point 3-6		Ammonium Point 4-7	
			Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.	Conc. (mg/L)	% Res.
Wet (May to Nov)	11/29/06	1.08	2.85	264%	3.21	297%	2.85	264%	0.15	5%	0.09	3%	0.11	4%
	5/9/07	2.25	18.69	831%	14.16	629%	12.39	551%	1.04	6%	0.19	1%	0.07	1%
	6/27/07	7.40	8.66	117%	9.13	123%	9.13	123%	0.12	1%	0.13	1%	0.16	2%
	7/4/07	14.67	12.52	85%	11.88	81%	11.27	77%	0.00	0%	0.45	4%	0.56	5%
	7/11/07	9.51	3.42	36%	9.22	97%	0.84	9%	0.19	6%	0.67	7%	0.14	17%
	7/18/07	12.69	5.35	42%	7.37	58%	8.64	68%	0.16	3%	1.64	22%	0.14	2%
	7/25/07	21.85	11.16	51%	10.14	46%	11.16	51%	3.76	34%	428.00	4221%	5.70	51%
	8/15/07	15.80	10.39	66%	8.73	55%	8.73	55%	0.35	3%	0.90	10%	1.19	14%
	9/19/07	15.84	7.89	50%	7.34	46%	7.89	50%	0.00	0%	0.00	0%	0.00	0%
	AVE	11.23	8.99	171%	9.02	159%	8.10	139%	0.64	6%	48.01	474%	0.90	10%
	SD	6.80	4.96	257%	3.07	193%	3.87	171%	1.21	10%	142.50	1405%	1.84	16%
Dry (Dec to April)	12/19/06	5.16	4.60	89%	8.14	158%	5.56	108%	0.13	3%	0.09	1%	0.57	10%
	1/8/07	0.16	5.56	3475%	7.06	4413%	5.79	3619%	0.14	3%	0.07	1%	0.04	1%
	1/17/07	0.17	1.75	1029%	1.22	718%	4.04	2376%	0.17	10%	0.47	39%	0.67	17%
	1/24/07	0.19	3.24	1705%	4.47	2353%	4.12	2168%	0.17	5%	0.30	7%	0.28	7%
	1/30/07	0.67	6.42	958%	7.59	1133%	5.90	881%	2.76	43%	0.34	4%	0.23	4%
	2/7/07	2.71	11.51	425%	13.86	511%	12.40	458%	2.71	24%	1.50	11%	0.40	3%
	3/13/07	-	-	-	-	-	-	-	-	-	-	-	-	-
	4/24/07	6.56	13.69	209%	13.69	209%	12.39	189%	0.29	2%	1.97	14%	0.35	3%
	AVE	2.23	6.68	1127%	8.00	1356%	7.17	1400%	0.91	13%	0.68	11%	0.36	6%
	SD	2.67	4.36	1176%	4.59	1542%	3.65	1339%	1.25	15%	0.75	13%	0.21	5%

Notes

- AVE = average; SD = standard deviation; Res.=Residual
- Point 1 = SSF Influent, Point 1-2 = Phragmites, Point 1-3 = Thalia; Point 1-4 = Brachiaria.;
Point 2-5 = Phragmites/Typha; Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus
- Shaded cells indicates N.D. (non-detectable); - = data not available
- Average % residual marked with a square around is greater than 90%; therefore, no further analysis was performed.

Table B-22 Summary of Seasonal Average Performance – SSF CW																													
Season	Parameter	Point 1				Point 1-2								Point 1-3								Point 1-4							
		Concentration				Concentration				% Residual				Concentration				% Residual				Concentration				% Residual			
		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD			AVE	SD	95% C.I.	
				Min	Max			Min	Max			Min	Max			Min	Max			Min	Max			Min	Max			Min	Max
Wet (May to Nov)	FC. (NMP/100 mL)	112,489	113,039	25,600	199,378	12,764	16,701	-73	25,602	18%	19%	4%	32%	32,333	23,796	14,042	50,625	80%	95%	7%	153%	17,204	28,561	-4,750	39,158	20%	25%	1%	39%
	BOD (mg/L)	53.8	16.3	41.3	66.3	39.6	20.9	23.5	55.6	80%	62%	32%	128%	33.3	10.0	25.6	41.0	64%	17%	51%	77%	33.5	8.2	27.2	39.7	65%	19%	51%	80%
	COD (mg/L)	185.2	81.2	117.3	253.2	86.2	53.1	41.8	130.6	53%	31%	27%	78%	106.3	55.4	60.0	152.6	62%	27%	40%	85%	73.5	37.0	42.5	104.5	47%	28%	23%	70%
	O&G (mg/L)	5.5	4.7	1.9	9.1	4.0	3.2	1.5	6.4	189%	250%	-3%	381%	3.7	3.4	1.1	6.4	152%	225%	-21%	325%	5.2	5.9	0.6	9.7	220%	412%	-96%	537%
	TSS (mg/L)	80.4	44.5	43.2	117.5	8.5	10.5	-0.3	17.3	11%	12%	1%	21%	10.0	14.9	-2.5	22.5	12%	15%	-1%	25%	15.5	15.1	2.9	28.1	20%	14%	9%	32%
	TN (mg/L)	21.2	3.8	18.1	24.4	14.0	4.7	10.1	17.9	68%	26%	46%	89%	13.2	3.0	10.7	15.6	64%	20%	47%	81%	12.7	2.5	10.6	14.8	61%	15%	49%	74%
	TP (mg/L)	2.1	1.5	0.9	3.3	3.2	0.9	2.5	3.9	288%	265%	84%	492%	2.9	1.3	1.9	3.9	214%	207%	56%	373%	2.9	1.0	2.1	3.7	264%	266%	60%	468%
Dry (Dec to April)	FC (NMP/100 mL)	274,857	584,829	-266,020	815,734	9,749	8,173	2,190	17,307	12%	12%	1%	24%	20,724	15,025	6,828	34,620	40%	43%	0%	80%	15,407	18,430	-1,638	32,452	15%	20%	-3%	33%
	BOD (mg/L)	81.3	30.8	55.5	107.0	62.8	13.6	51.5	74.1	82%	22%	63%	101%	76.0	40.2	42.4	109.6	94%	31%	68%	120%	48.9	14.2	37.1	60.8	64%	21%	46%	81%
	COD (mg/L)	354.1	241.4	152.3	556.0	147.1	34.5	118.3	176.0	53%	26%	32%	75%	176.8	47.4	137.2	216.4	62%	26%	40%	84%	121.8	45.4	83.9	159.7	44%	26%	22%	66%
	O&G (mg/L)	6.2	6.6	0.7	11.7	3.5	2.9	1.0	5.9	68%	25%	48%	89%	2.6	3.0	0.1	5.1	64%	56%	18%	111%	1.7	1.5	0.4	2.9	76%	85%	5%	147%
	TSS (mg/L)	243.8	168.5	102.9	384.6	32.1	33.8	3.9	60.4	17%	19%	1%	32%	39.6	39.1	6.9	72.3	21%	22%	2%	39%	22.8	17.9	7.8	37.7	12%	11%	3%	21%
	TN (mg/L)	18.2	12.5	7.8	28.7	12.0	4.9	8.0	16.1	121%	133%	10%	232%	12.6	5.2	8.3	17.0	111%	112%	18%	205%	9.7	5.0	5.6	13.9	96%	100%	12%	179%
	TP (mg/L)	1.5	0.8	0.8	2.1	2.6	1.1	1.7	3.5	198%	112%	104%	291%	2.4	1.1	1.5	3.3	178%	94%	100%	257%	2.4	1.1	1.5	3.4	179%	96%	99%	260%
Notes: AVE = average; SD = standard deviation; Point 1 = SSF Influent, Point 1-2 = Inlet/Phragmites, Point 1-3 = Inlet/Thalia; Point 1-4 = Inlet/Brachiaria; Conc. = Concentration; Res. = Residual; C.I. = Confidence Interval																													

Table B-23 Summary of Seasonal Average Performance – SF CW																									
Season	Parameter	Point 2-5								Point 3-6								Point 4-7							
		Concentration				% Residual				Concentration				% Residual				Concentration			% Residual				
		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.	
				Min	Max			Min	Max			Min	Max			Min	Max			Min	Max			Min	Max
Wet (May to Nov)	Fecal Colif. (NMP/100 mL)	448	353	176	719	21%	27%	1%	41%	4,597	5,529	347	8,847	44%	104%	-36%	123%	1,646	2,042	76	3,215	269%	684%	-257%	795%
	BOD (mg/L)	20.2	8.1	14.0	26.4	60%	23%	43%	78%	21.7	10.7	13.5	29.9	64%	19%	49%	78%	18.5	11.6	9.6	27.4	53%	26%	33%	73%
	COD (mg/L)	74.3	46.2	35.7	112.9	124%	101%	40%	209%	115.4	124.4	11.5	219.4	176%	278%	-56%	409%	59.5	34.7	30.5	88.5	105%	115%	9%	202%
	Oil & Grease (mg/L)	1.8	2.0	0.2	3.3	97%	179%	-41%	234%	3.4	3.1	0.9	5.8	237%	294%	11%	463%	2.1	2.5	0.2	4.0	56%	53%	15%	96%
	TSS (mg/L)	1.4	2.3	-0.6	3.3	8%	14%	-3%	20%	8.8	7.6	2.4	15.1	5519%	7675%	-898%	11935%	2.8	3.2	0.1	5.4	1013%	2823%	-1347%	3373%
	TN (mg/L)	4.1	4.1	0.6	7.5	28%	24%	8%	48%	4.3	3.1	1.7	6.9	33%	22%	14%	52%	5.2	2.9	2.8	7.7	40%	17%	25%	55%
	TP (mg/L)	1.4	1.0	0.6	2.2	43%	34%	17%	69%	1.4	0.9	0.8	2.1	95%	156%	-25%	215%	1.2	0.8	0.6	1.8	45%	40%	15%	76%
Dry (Dec to April)	Fecal Colif., (NMP/100 mL)	338	322	41	635	6%	4%	2%	10%	1,833	2,214	-215	3,880	58%	126%	-58%	175%	2,260	2,738	-273	4,793	335%	823%	-426%	1096%
	BOD (mg/L)	79.2	178.2	-69.8	228.2	146%	339%	-138%	430%	23.4	13.6	12.0	34.7	36%	23%	18%	55%	28.9	22.4	10.2	47.6	66%	55%	19%	112%
	COD (mg/L)	71.7	48.6	31.1	112.3	55%	48%	15%	96%	143.3	149.4	18.4	268.2	84%	79%	18%	149%	90.2	56.1	43.3	137.2	80%	49%	39%	121%
	Oil & Grease (mg/L)	7.9	19.2	-8.2	24.0	1192%	3252%	-1527%	3911%	1.8	1.9	0.2	3.3	76%	30%	51%	101%	2.3	3.3	-0.5	5.0	373%	843%	-332%	1077%
	TSS (mg/L)	4.6	4.3	1.0	8.2	46%	49%	5%	87%	23.3	35.8	-6.6	53.1	128%	161%	-6%	263%	5.8	6.4	0.4	11.1	536%	1400%	-635%	1707%
	TN (mg/L)	5.3	1.4	4.1	6.5	50%	24%	30%	71%	7.9	4.0	4.6	11.3	69%	40%	36%	102%	5.8	3.0	3.3	8.4	79%	80%	12%	146%
	TP (mg/L)	2.4	1.7	1.0	3.8	89%	65%	34%	144%	1.8	1.0	0.9	2.6	79%	35%	50%	109%	2.7	1.0	1.8	3.5	114%	43%	78%	150%
Notes: AVE = average; SD = standard deviation; Point 2-5 = Phragmites/Typha, Point 3-6 = Thalia/Thalia; Point 4-7 = Brachiaria/Cyperus; Conc. = Concentration; Res. = Residual; C.I. = Confidence Interval																									

Table B-24 Summary of Seasonal Average Performance – CW System (SF +SSF)																									
Season	Parameter	Point 1-2-5								Point 1-3-6								Point 1-4-7							
		Concentration				% Residual				Concentration				% Residual				Concentration			% Residual				
		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.		AVE	SD	95% C.I.	
				Min	Max			Min	Max			Min	Max			Min	Max			Min	Max			Min	Max
Wet (May to Nov)	Fecal Colif. (NMP/100 mL)	448	353	176	719	2%	2%	0%	3%	4,597	5,529	347	8,847	77%	221%	-93%	247%	1,646	2,042	76	3,215	25%	69%	-28%	78%
	BOD (mg/L)	20.2	8.1	14.0	26.4	39%	13%	29%	49%	21.7	10.7	13.5	29.9	42%	20%	27%	57%	18.5	11.6	9.6	27.4	36%	25%	17%	55%
	COD (mg/L)	74.3	46.2	35.7	112.9	54%	56%	7%	101%	115.4	124.4	11.5	219.4	73%	76%	10%	137%	59.5	34.7	30.5	88.5	38%	24%	18%	59%
	Oil & Grease (mg/L)	1.8	2.0	0.2	3.3	62%	76%	4%	121%	3.4	3.1	0.9	5.8	132%	160%	9%	255%	2.1	2.5	0.2	4.0	41%	65%	-9%	91%
	TSS (mg/L)	1.4	2.3	-0.6	3.3	2%	3%	-1%	5%	8.8	7.6	2.4	15.1	12%	14%	1%	24%	2.8	3.2	0.1	5.4	4%	5%	0%	8%
	TN (mg/L)	4.1	4.1	0.6	7.5	19%	16%	5%	32%	4.3	3.1	1.7	6.9	20%	12%	9%	30%	5.2	2.9	2.8	7.7	25%	12%	15%	35%
	TP (mg/L)	1.4	1.0	0.6	2.2	156%	172%	24%	289%	1.4	0.9	0.8	2.1	162%	194%	13%	311%	1.2	0.8	0.6	1.8	127%	137%	22%	232%
Dry (Dec to April)	Fecal Colif., (NMP/100 mL)	338	322	41	635	0%	1%	0%	1%	1,833	2,214	-215	3,880	2%	3%	0%	5%	2,260	2,738	-273	4,793	3%	3%	0%	6%
	BOD (mg/L)	79.2	178.2	-69.8	228.2	98%	213%	-80%	277%	23.4	13.6	12.0	34.7	33%	22%	14%	51%	28.9	22.4	10.2	47.6	39%	29%	15%	64%
	COD (mg/L)	71.7	48.6	31.1	112.3	25%	22%	6%	43%	143.3	149.4	18.4	268.2	38%	28%	15%	62%	90.2	56.1	43.3	137.2	31%	25%	10%	52%
	Oil & Grease (mg/L)	7.9	19.2	-8.2	24.0	524%	1388%	-636%	1685%	1.8	1.9	0.2	3.3	41%	25%	20%	61%	2.3	3.3	-0.5	5.0	43%	30%	17%	68%
	TSS (mg/L)	4.6	4.3	1.0	8.2	2%	2%	0%	3%	23.3	35.8	-6.6	53.1	7%	8%	0%	13%	5.8	6.4	0.4	11.1	2%	2%	1%	4%
	TN (mg/L)	5.3	1.4	4.1	6.5	56%	64%	3%	110%	7.9	4.0	4.6	11.3	63%	56%	16%	110%	5.8	3.0	3.3	8.4	46%	34%	18%	75%
	TP (mg/L)	2.4	1.7	1.0	3.8	180%	142%	61%	299%	1.8	1.0	0.9	2.6	124%	73%	63%	184%	2.7	1.0	1.8	3.5	203%	107%	114%	292%
Notes: AVE = average; SD = standard deviation; Point 1-2-5 = Inlet/Phragmites/Typha, Point 1-3-6 = Inlet/Thalia/Thalia; Point 1-4-7 = Inlet/Brachiaria/Cyperus; Conc. = Concentration; Res. = Residual; C.I. = Confidence Interval																									

Table B-25 Field Parameter: Temperature (degree Celsius)									
Date	Point 1	Point 1-2	OW1-2-5a _B	OW1-2-5a _M	OW1-2-5a _S	OW1-2-5b _B	OW1-2-5b _M	OW1-2-5b _S	Point 2-5
10/19/2006	0.6	0.7	0.6	0.6	0.6	0.3	0.3	0.3	0.3
11/6/2006	0.7	0.6	0.4	0.5	0.4	0.4	0.3	0.4	0.3
12/19/2006	0.8	0.8	0.3	0.6	0.5	0.7	0.6	0.5	0.5
1/8/2007	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.8
1/17/2007	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7
1/24/2007	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8
1/30/2007	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8
2/7/2007	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.9
3/28/2007	1.9	2.9	2.3	2.2	2.3	2.2	2.1	2.1	2.6
4/24/2007	1.7	2.2	2.7	2.3	2.3	2.5	2.3	2.3	2.2
5/9/2007	1.4	1.7	2.3	1.7	1.7	2.1	1.9	1.8	1.4
5/23/2007	1.5	1.8	2.2	1.5	1.8	1.8	1.7	1.7	1.7
6/27/2007	1.7	1.7	2.0	1.6	1.7	1.5	1.4	1.4	1.2
7/4/2007	1.8	1.8	2.0	1.6	1.5				0.6
7/18/2007	1.5	1.3	1.4	1.1	1.0	1.1	1.0	0.9	0.6
8/15/2007	1.8	1.7	2.3	1.4	1.4	1.3	1.1	1.1	0.7
9/19/2007	1.2	1.1	1.4	1.0	1.0				0.5
Average	1.2	1.3	1.4	1.2	1.2	1.2	1.1	1.1	1.0
Standard Deviation	0.5	0.6	0.8	0.6	0.6	0.7	0.7	0.6	0.6
Sampling Date	Point 1	Point 1-3	OW1-3-6a _B	OW1-3-6a _M	OW1-3-6a _S	OW1-3-6b _B	OW1-3-6b _M	OW1-3-6b _S	Point 3-6
10/19/2006	26.7	27.4	27.5	27.4	29.3	28.0	27.8	29.4	27.5
11/6/2006	26.2	27.3	25.9	26.4	26.7	26.9	27.3	27.9	26.8
12/19/2006	24.8	24.5	22.5	22.4	22.3	22.8	22.5	22.8	25.8
1/8/2007	24.4	23.4	21.9	21.7	21.7	22.0	22.8	21.9	24.8
1/17/2007	23.8	22.6	21.4	21.3	21.4	21.5	21.1	21.1	25.6
1/24/2007	24.0	22.7	21.2	21.2	21.2	21.3	21.3	21.3	22.6
1/30/2007	23.9	23.1	20.8	20.6	20.6	20.7	20.7	20.7	24.2
2/7/2007	24.2	23.1	20.8	20.8	20.8	21.4	21.2	21.3	26.3
3/28/2007	25.2	26.2	21.1	21.1	22.0	21.5	21.9	21.9	27.1
4/24/2007	26.4	27.0	23.8	24.1	24.3	24.3	24.4	24.4	24.3
5/9/2007	26.1	26.5	24.3	24.3	24.4	25.6	25.0	25.6	24.4
5/23/2007	26.6	26.1	23.5	23.5	23.5	25.7	25.1	22.3	25.4
6/27/2007	27.2	27.7	24.3	24.3	24.4	24.6	24.6	24.6	25.4
7/4/2007	28.2	28.4	24.4	24.2	24.3				26.4
7/18/2007	26.4	26.1	24.2	24.2	24.3	24.3	24.0	24.1	24.3
8/15/2007	27.1	25.7	24.6	24.5	24.5	25.5	25.7	25.9	24.4
9/19/2007	26.1	25.0	24.3	24.3	24.3				23.5

Average	25.7	25.5	23.3	23.3	23.5	23.7	23.7	23.7	25.2
Standard Deviation	1.3	1.9	1.9	2.0	2.2	2.3	2.3	2.6	1.3
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	26.7	28.0	27.6	27.6	29.7	27.2	27.4	29.6	27.8
11/6/2006	26.2	27.7	25.8	26.1	26.2	25.9	26.5	27.0	26.5
12/19/2006	24.8	24.9	23.4	23.5	23.5	23.8	23.8	23.8	25.3
1/8/2007	24.4	24.0	22.1	22.1	22.0	22.3	22.1	22.0	24.4
1/17/2007	23.8	23.2	20.9	21.4	21.3	21.3	20.5	21.6	25.3
1/24/2007	24.0	22.9	21.7	21.4	21.4	20.8	20.9	20.9	23.4
1/30/2007	23.9	23.5	20.7	20.5	20.6	20.5	20.3	20.4	22.8
2/7/2007	24.2	23.6	21.1	21.1	21.1	20.9	20.8	20.8	24.2
3/28/2007	25.2	27.4	21.2	21.1	22.3	21.7	21.3	21.5	27.6
4/24/2007	26.4	26.3	23.8	23.9	23.9	23.9	23.8	23.8	25.2
5/9/2007	26.1	25.8	23.8	23.6	23.9	24.2	24.1	24.2	25.4
5/23/2007	26.6	26.7	23.6	23.6	23.7	24.5	24.1	24.2	25.2
6/27/2007	27.2	27.4	24.7	24.6	24.7	24.3	23.9	24.0	25.9
7/4/2007	28.2	24.9	24.7	24.5	24.5				26.0
7/18/2007	26.4	26.1	24.4	24.3	24.5	23.8	23.7	23.8	23.8
8/15/2007	27.1	27.6	24.6	24.0	24.6	24.5	26.1	26.1	24.5
9/19/2007	26.1	25.9	24.4	24.4	24.3				23.7
Average	25.7	25.6	23.4	23.4	23.6	23.3	23.3	23.6	25.1
Standard Deviation	1.3	1.7	1.9	1.9	2.2	2.0	2.3	2.5	1.4
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

Table B-26 Field Parameter: pH									
Date	Point 1	Point 1-2	OW1-2-5a _B	OW1-2-5a _M	OW1-2-5a _S	OW1-2-5b _B	OW1-2-5b _M	OW1-2-5b _S	Point 2-5
10/19/2006	7.9	7.2	7.8	7.8	7.8	8.1	8.1	8.0	8.0
11/6/2006	8.0	7.4	7.8	7.8	7.8	7.5	7.5	7.5	7.8
12/19/2006	7.9	7.0	7.9	8.4	8.5	7.7	8.4	8.7	7.8
1/8/2007	8.1	6.9	7.3	7.2	7.2	7.2	7.6	7.3	7.5
1/17/2007	9.3	8.1	7.6	7.7	7.8	8.1	8.1	8.1	8.1
1/24/2007	9.5	8.1	8.0	8.3	8.2	8.0	8.4	8.3	7.9
1/30/2007	9.5	7.5	7.1	7.3	7.3	7.9	8.1	8.1	7.8
2/7/2007	9.3	7.4	7.5	7.6	7.6	7.9	8.0	8.0	8.3
3/28/2007	8.7	7.0	6.7	7.1	7.0	6.8	6.9	7.0	7.5
4/24/2007	8.9	7.0	6.7	7.2	7.1	7.0	7.2	7.3	7.4
5/9/2007	8.6	6.6	6.3	6.6	6.7	6.8	6.8	7.0	7.1
5/23/2007	8.8	6.6	6.3	6.7	6.7	6.7	6.8	6.8	7.0
6/27/2007	7.8	6.8	6.5	7.2	7.1	7.0	7.1	7.1	7.0
7/4/2007	7.3	6.8	6.6	7.1	7.4				7.1
7/18/2007	7.7	7.0	6.8	7.1	7.0	7.2	7.2	7.2	6.9
8/15/2007	7.9	7.5	7.1	7.5	7.5	7.5	7.8	7.6	7.6
9/19/2007	8.2	8.1	7.9	8.1	8.1				8.2
Average	8.4	7.2	7.2	7.4	7.5	7.4	7.6	7.6	7.6
Standard Deviation	0.7	0.5	0.6	0.5	0.5	0.5	0.6	0.6	0.5
Sampling Date	Point 1	Point 1-3	OW1-3-6a _B	OW1-3-6a _M	OW1-3-6a _S	OW1-3-6b _B	OW1-3-6b _M	OW1-3-6b _S	Point 3-6
10/19/2006	7.9	7.1	7.6	7.7	7.7	7.7	7.8	7.8	7.9
11/6/2006	8.0	7.2	8.5	8.6	8.5	8.0	8.1	8.1	8.6
12/19/2006	7.9	6.9	7.9	7.8	8.0	8.4	8.4	8.6	8.0
1/8/2007	8.1	6.9	7.0	7.1	7.1	7.4	7.6	7.5	7.5
1/17/2007	9.3	8.4	8.1	8.1	8.1	7.6	7.9	8.1	8.2
1/24/2007	9.5	8.1	7.6	8.1	8.1	7.9	8.4	8.4	7.8
1/30/2007	9.5	7.5	7.1	7.2	7.3	7.4	7.8	7.8	7.8
2/7/2007	9.3	7.5	7.6	7.4	7.6	7.6	7.7	7.8	8.2
3/28/2007	8.7	6.9	6.6	6.9	7.0	6.8	7.0	6.9	7.5
4/24/2007	8.9	6.9	6.7	7.0	7.0	6.6	7.1	7.1	7.0
5/9/2007	8.6	6.6	6.5	6.9	6.9	6.6	7.2	7.2	6.7
5/23/2007	8.8	6.6	6.5	6.5	6.6	6.6	7.1	6.9	6.9
6/27/2007	7.8	6.8	6.5	6.7	6.7	6.7	6.9	6.9	6.8
7/4/2007	7.3	6.9	6.7	6.8	6.9				7.0
7/18/2007	7.7	6.9	6.9	7.1	7.1	6.8	7.1	7.0	6.8
8/15/2007	7.9	7.5	7.5	7.6	7.6	7.7	8.0	8.0	7.7
9/19/2007	8.2	8.1	7.8	8.1	8.1				8.1

Average	8.4	7.2	7.2	7.4	7.4	7.3	7.6	7.6	7.6
Standard Deviation	0.7	0.5	0.6	0.6	0.6	0.6	0.5	0.6	0.6
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	7.9	7.2	7.4	7.7	7.7	7.7	7.7	8.0	7.8
11/6/2006	8.0	7.4	7.7	7.7	7.7	7.6	7.7	7.6	7.5
12/19/2006	7.9	7.2	6.7	7.0	7.1	7.4	7.6	7.6	7.6
1/8/2007	8.1	7.0	7.1	7.1	7.1	7.4	7.4	7.4	7.4
1/17/2007	9.3	7.7	7.6	7.6	7.6	8.0	7.9	7.9	8.2
1/24/2007	9.5	7.9	7.5	7.7	7.8	7.9	7.9	8.0	8.0
1/30/2007	9.5	7.4	6.8	7.1	7.1	7.5	7.8	7.7	7.8
2/7/2007	9.3	7.4	7.4	7.4	7.4	7.6	7.7	7.7	8.0
3/28/2007	8.7	7.0	7.0	7.0	7.2	7.0	7.1	7.1	7.8
4/24/2007	8.9	6.9	6.5	6.9	6.9	6.8	7.0	7.1	7.1
5/9/2007	8.6	6.6	6.5	6.7	6.8	6.3	6.9	7.0	6.8
5/23/2007	8.8	6.5	6.3	6.4	6.5	6.3	6.8	6.8	7.0
6/27/2007	7.8	6.6	6.5	6.77	6.7	6.6	6.8	6.8	7.1
7/4/2007	7.3	6.8	6.2	6.4	6.4				7.1
7/18/2007	7.7	6.9	6.6	6.9	7.0	6.8	6.8	6.8	7.0
8/15/2007	7.9	7.5	7.5	7.5	7.7	7.7	8.2	8.3	7.7
9/19/2007	8.2	8.1	7.8	8.1	8.1				7.9
Average	8.4	7.2	7.0	7.2	7.2	7.2	7.4	7.4	7.5
Standard Deviation	0.7	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.4
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

Table B-27 Field Parameter: ORP (mV)

Date	Point 1	Point 1-2	OW1-2-5a _B	OW1-2-5a _M	OW1-2-5a _S	OW1-2-5b _B	OW1-2-5b _M	OW1-2-5b _S	Point 2-5
10/19/2006	-225.9	-152.8	2.9	35.9	80.9	67.0	60.3	100.0	190.0
11/6/2006	-170.6	-141.5	56.3	36.8	43.2	110.6	47.7	100.8	273.2
12/19/2006	-177.0	-187.9	-132.8	-168.8	-164.7	-107.0	-127.0	-110.3	179.9
1/8/2007	-233.4	-234.1	-183.9	-238.6	-228.9	-150.0	-161.0	-173.4	75.7
1/17/2007	-187.0	-179.0	-177.8	-208.1	-204.9	-127.6	-134.4	-135.1	154.5
1/24/2007	-164.0	-207.0	-158.5	-200.9	-195.8	-98.9	-127.6	-125.5	133.9
1/30/2007	-175.2	-208.5	-152.7	-182.4	-176.5	-54.9	-64.8	-63.2	114.4
2/7/2007	-181.7	-210.0	-182.8	-211.9	-204.3	-115.5	-129.8	-122.8	197.6
3/28/2007	-155.4	-254.9	-209.9	-262.7	-250.6	-229.5	-257.9	-249.8	-181.4
4/24/2007	-279.1	-269.7	-293.3	-305.8	-303.7	-273.8	-299.2	-291.8	-130.0
5/9/2007	-279.2	-273.8	-261.8	-274.3	-273.9	-268.9	-284.7	-282.7	-61.5
5/23/2007	-270.8	-265.5	-175.7	-237.6	-230.0	-232.6	-242.9	-246.0	-97.9
6/27/2007	-197.5	-176.4	-172.8	-163.8	-174.0	-87.8	-123.5	-110.8	45.8
7/4/2007	-166.5	-172.4	-128.7	-147.6	-154.2				-38.4
7/18/2007	-165.7	-174.0	-125.9	-140.7	-134.4	-58.4	-88.3	-80.0	161.2
8/15/2007	-186.1	-161.7	-117.9	-142.4	-140.9	-42.5	-85.2	-69.3	-14.2
9/19/2007	-175.6	-160.5	-113.7	-125.7	-121.0				31.8
Average	-199.4	-201.7	-148.8	-172.9	-166.7	-111.3	-134.6	-124.0	60.8
Standard Deviation	42.0	43.4	83.1	93.8	99.5	111.5	106.3	118.4	130.8
Sampling Date	Point 1	Point 1-3	OW1-3-6a _B	OW1-3-6a _M	OW1-3-6a _S	OW1-3-6b _B	OW1-3-6b _M	OW1-3-6b _S	Point 3-6
10/19/2006	-225.9	-219.6	46.0	32.1	130.0	-70.5	-16.5	61.0	187.3
11/6/2006	-170.6	-174.2	60.8	27.1	38.9	64.0	60.6	60.1	242.1
12/19/2006	-177.0	-166.9	-141.5	-161.7	-175.2	-158.8	-160.6	-142.5	159.3
1/8/2007	-233.4	-230.0	-218.9	-247.6	-236.9	-181.0	-181.2	-193.5	54.4
1/17/2007	-187.0	-176.2	-121.4	-186.4	-173.3	-154.0	-174.4	-184.1	95.2
1/24/2007	-164.0	-199.2	-149.5	-176.7	-178.5	-155.7	-148.7	-163.7	57.8
1/30/2007	-175.2	-199.0	-145.0	-154.7	-160.9	-107.9	-120.1	-121.7	-34.7
2/7/2007	-181.7	-210.8	-151.7	-163.7	-160.9	-121.9	-148.2	-147.7	139.6
3/28/2007	-155.4	-239.9	-217.9	-241.0	-239.2	-232.2	-267.5	-260.5	-189.0
4/24/2007	-279.1	-231.0	280.9	-282.8	-286.0	-278.6	-290.1	-287.6	-62.4
5/9/2007	-279.2	-250.1	-262.3	-267.5	-267.5	-230.0	-261.5	-264.1	-94.1
5/23/2007	-270.8	-266.1	-141.7	-155.5	-156.0	-116.0	-235.0	-242.8	-126.0
6/27/2007	-197.5	-168.0	-160.2	-179.0	-178.3	-138.7	-152.3	-149.1	-64.4
7/4/2007	-166.5	-172.7	-159.2	-171.0	-173.5				-63.7
7/18/2007	-165.7	-162.9	-172.1	-126.9	-189.4	-107.8	-136.6	-132.5	-61.6
8/15/2007	-186.1	-151.8	-124.0	-139.1	-137.4	-81.2	-71.0	-83.2	-43.6
9/19/2007	-175.6	-163.7	-144.7	-154.3	-156.9				-9.0

Average	-199.4	-198.9	-113.1	-161.7	-158.9	-138.0	-153.5	-150.1	11.0
Standard Deviation	42.0	35.3	129.8	85.1	101.8	80.7	94.1	103.6	120.2
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	-225.9	-164.5	-50.0	-17.2	125.2	65.2	63.5	70.1	193.2
11/6/2006	-170.6	-153.6	38.2	32.8	31.9	80.1	76.6	74.6	190.2
12/19/2006	-177.0	-170.3	-150.3	-181.4	-207.6	-121.9	-152.3	-173.9	130.1
1/8/2007	-233.4	-210.8	-201.9	-253.1	-237.5	-160.0	-180.5	-177.1	-79.9
1/17/2007	-187.0	-179.3	-178.2	-204.9	-199.8	-124.5	-159.3	-151.8	7.9
1/24/2007	-164.0	-166.8	-167.5	-195.5	-195.0	-133.9	-166.7	-152.6	-25.9
1/30/2007	-175.2	-182.3	-146.3	-170.4	-170.5	-120.4	-150.9	-142.0	-43.5
2/7/2007	-181.7	-191.7	-171.0	-196.0	-184.7	-164.0	-179.1	-176.5	-53.2
3/28/2007	-155.4	-239.9	-212.7	-237.1	-227.8	-222.9	-260.9	-248.9	-188.2
4/24/2007	-279.1	-193.9	-263.9	-290.7	-288.8	-279.5	-305.7	-304.9	-45.4
5/9/2007	-279.2	-179.6	-260.5	-269.6	-270.3	-262.0	-276.1	-273.4	-61.9
5/23/2007	-270.8	-251.9	-150.4	-153.3	-155.2	-186.9	-214.4	-217.8	-70.9
6/27/2007	-197.5	-121.8	-130.5	-160.6	-153.9	-98.9	-130.3	-122.2	-42.4
7/4/2007	-166.5	-64.5	-109.2	-137.7	-131.3				-62.6
7/18/2007	-165.7	-141.9	-126.4	-170.0	-160.4	-64.5	-79.7	-75.7	-35.8
8/15/2007	-186.1	-115.5	-31.5	-27.2	-23.1	-23.0	-170.8	-180.3	-23.1
9/19/2007	-175.6	-131.6	-142.7	-157.0	-158.5				17.1
Average	-199.4	-168.2	-144.4	-164.1	-153.4	-121.1	-152.4	-150.2	-11.4
Standard Deviation	42.0	45.8	77.0	88.2	106.7	104.1	107.4	107.5	98.2
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

Table B-28 Field Parameter: Dissolved Oxygen (mg/L)									
Date	Point 1	Point 1-2	OW1-2-5a _B	OW1-2-5a _M	OW1-2-5a _S	OW1-2-5b _B	OW1-2-5b _M	OW1-2-5b _S	Point 2-5
10/19/2006	0.2	0.1	6.9	7.1	6.9	7.6	8.1	9.2	3.4
11/6/2006	0.4	0.2	3.8	3.9	4.3	2.8	3.8	4.4	2.9
12/19/2006	0.2	0.2	0.1	0.2	0.3	0.1	1.0	2.8	2.8
1/8/2007	4.5	3.8	1.8	3.2	3.4	3.7	5.3	2.8	1.7
1/17/2007	0.2	0.2	0.2	0.1	0.1	0.3	0.3	0.4	2.5
1/24/2007	0.2	0.1	0.3	0.1	0.2	0.8	0.4	0.6	0.4
1/30/2007	0.4	0.9	0.5	0.1	0.1	0.2	0.3	0.3	1.7
2/7/2007	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.1	2.7
3/28/2007	0.1	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.2
4/24/2007	0.1	0.6	0.3	0.3	0.3	0.3	0.1	0.1	0.2
5/9/2007	0.1	0.5	0.9	0.3	0.4	0.2	0.1	0.1	0.3
5/23/2007	0.1	0.3	0.4	0.3	1.0	0.2	0.1	0.1	0.6
6/27/2007	0.1	0.2	0.7	0.5	1.2	0.2	0.1	0.1	0.3
7/4/2007	0.2	0.2	0.5	0.5	0.7				0.4
7/18/2007	0.2	0.1	0.3	0.1	0.2	0.7	0.1	0.2	0.4
8/15/2007	0.2	0.3	1.3	0.5	0.7	0.4	0.3	0.2	0.3
9/19/2007	0.8	0.5	0.1	0.2	0.4				1.7
Average	0.5	0.5	1.1	1.0	1.2	1.2	1.3	1.4	1.3
Standard Deviation	1.1	0.9	1.8	1.9	1.9	2.1	2.4	2.5	1.2
Sampling Date	Point 1	Point 1-3	OW1-3-6a _B	OW1-3-6a _M	OW1-3-6a _S	OW1-3-6b _B	OW1-3-6b _M	OW1-3-6b _S	Point 3-6
10/19/2006	0.2	0.1	3.5	12.0	5.2	7.3	6.9	6.8	3.9
11/6/2006	0.4	0.1	6.4	6.6	7.6	4.3	5.0	5.8	5.0
12/19/2006	0.2	0.3	0.3	0.2	0.2	0.1	0.1	1.3	2.6
1/8/2007	4.5	2.7	4.3	4.8	4.5	5.2	4.5	5.1	3.1
1/17/2007	0.2	0.2	2.8	1.5	1.5	0.2	0.1	0.1	2.0
1/24/2007	0.2	0.2	0.5	0.4	0.4	0.6	0.7	0.7	1.0
1/30/2007	0.4	0.2	0.2	0.1	0.1	0.3	0.1	0.2	0.2
2/7/2007	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.8
3/28/2007	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2
4/24/2007	0.1	0.8	0.5	0.4	0.6	0.2	0.0	0.1	0.2
5/9/2007	0.1	0.3	0.3	0.7	0.3	0.2	0.1	0.1	0.2
5/23/2007	0.1	0.3	0.6	0.1	0.1	0.2	0.1	0.2	0.2
6/27/2007	0.1	0.2	0.8	0.4	0.5	0.1	0.1	0.1	0.2
7/4/2007	0.2	0.1	0.4	0.4	0.4				0.1
7/18/2007	0.2	0.2	0.1	0.1	0.1	0.4	0.1	0.1	0.3
8/15/2007	0.2	0.3	0.7	0.1	0.1	0.3	0.4	3.4	0.6
9/19/2007	0.8	0.6	0.6	0.2	0.4				0.9

Average	0.5	0.4	1.3	1.7	1.3	1.3	1.2	1.6	1.3
Standard Deviation	1.1	0.6	1.8	3.2	2.2	2.3	2.3	2.4	1.5
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	0.2	0.2	2.2	5.2	5.2	5.8	6.6	9.7	3.1
11/6/2006	0.4	0.1	1.0	1.8	4.2	2.5	4.6	7.0	0.6
12/19/2006	0.2	0.4	0.0	0.0	0.2	0.1	0.0	0.2	1.6
1/8/2007	4.5	1.6	6.0	5.7	5.7	2.5	5.0	3.0	5.6
1/17/2007	0.2	0.2	0.5	0.2	0.3	0.3	0.1	0.1	1.9
1/24/2007	0.2	0.2	0.4	0.1	0.1	0.3	0.1	0.2	0.2
1/30/2007	0.4	0.2	0.7	0.3	0.3	0.5	0.2	0.2	0.4
2/7/2007	0.1	0.2	0.4	0.2	0.2	0.1	0.1	0.1	0.2
3/28/2007	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
4/24/2007	0.1	0.1	0.9	0.5	0.7	0.2	0.1	0.1	0.1
5/9/2007	0.1	0.2	1.1	0.5	0.8	0.3	0.1	0.1	0.3
5/23/2007	0.1	0.2	0.1	0.1	0.1	0.5	0.1	0.2	0.2
6/27/2007	0.1	0.2	0.3	0.4	0.3	0.2	0.1	0.1	0.4
7/4/2007	0.2	0.2	0.3	0.3	0.3				0.4
7/18/2007	0.2	0.2	0.2	0.1	0.1	0.6	0.1	0.2	0.5
8/15/2007	0.2	0.3	0.1	0.2	0.2	0.2	0.8	0.7	0.2
9/19/2007	0.8	1.5	0.1	0.2	0.1				0.9
Average	0.5	0.4	0.8	0.9	1.1	0.9	1.2	1.5	1.0
Standard Deviation	1.1	0.5	1.4	1.7	1.9	1.6	2.2	2.9	1.4
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

Table B-29 Field Parameter: Conductivity (MS/cm)									
Date	Point 1	Point 1-2	OW1-2-5a_B	OW1-2-5a_M	OW1-2-5a_S	OW1-2-5b_B	OW1-2-5b_M	OW1-2-5b_S	Point 2-5
10/19/2006	0.6	0.7	0.6	0.6	0.6	0.3	0.3	0.3	0.3
11/6/2006	0.7	0.6	0.4	0.5	0.4	0.4	0.3	0.4	0.3
12/19/2006	0.8	0.8	0.3	0.6	0.5	0.7	0.6	0.5	0.5
1/8/2007	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.8
1/17/2007	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7
1/24/2007	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8
1/30/2007	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8
2/7/2007	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.9
3/28/2007	1.9	2.9	2.3	2.2	2.3	2.2	2.1	2.1	2.6
4/24/2007	1.7	2.2	2.7	2.3	2.3	2.5	2.3	2.3	2.2
5/9/2007	1.4	1.7	2.3	1.7	1.7	2.1	1.9	1.8	1.4
5/23/2007	1.5	1.8	2.2	1.5	1.8	1.8	1.7	1.7	1.7
6/27/2007	1.7	1.7	2.0	1.6	1.7	1.5	1.4	1.4	1.2
7/4/2007	1.8	1.8	2.0	1.6	1.5				0.6
7/18/2007	1.5	1.3	1.4	1.1	1.0	1.1	1.0	0.9	0.6
8/15/2007	1.8	1.7	2.3	1.4	1.4	1.3	1.1	1.1	0.7
9/19/2007	1.2	1.1	1.4	1.0	1.0				0.5
Average	1.2	1.3	1.4	1.2	1.2	1.2	1.1	1.1	1.0
Standard Deviation	0.5	0.6	0.8	0.6	0.6	0.7	0.7	0.6	0.6
Sampling Date	Point 1	Point 1-3	OW1-3-6a_B	OW1-3-6a_M	OW1-3-6a_S	OW1-3-6b_B	OW1-3-6b_M	OW1-3-6b_S	Point 3-6
10/19/2006	0.6	0.7	0.7	0.6	0.7	0.4	0.4	0.4	0.3
11/6/2006	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.4	0.3
12/19/2006	0.8	0.8	0.7	0.7	0.6	0.7	0.7	0.6	0.7
1/8/2007	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.8
1/17/2007	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8
1/24/2007	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.8
1/30/2007	0.7	0.8	0.7	0.7	0.8	0.8	0.7	0.8	0.8
2/7/2007	0.8	0.9	0.8	0.8	0.7	0.8	0.8	0.7	0.9
3/28/2007	1.9	2.9	2.2	2.1	2.1	2.1	2.1	2.1	2.2
4/24/2007	1.7	2.1	2.3	2.0	2.0	2.3	1.9	1.9	1.7
5/9/2007	1.4	1.7	1.9	1.7	1.6	2.3	1.4	1.4	1.0
5/23/2007	1.5	1.7	1.8	1.6	1.7	2.0	1.6	1.7	1.5
6/27/2007	1.7	1.6	1.6	1.5	1.5	1.3	1.2	1.2	1.1
7/4/2007	1.8	1.7	1.9	1.4	1.5				0.9
7/18/2007	1.5	1.3	1.2	1.3	1.1	1.3	1.2	1.2	0.8
8/15/2007	1.8	1.6	1.4	1.4	1.4	1.3	1.1	1.0	0.8
9/19/2007	1.2	1.1	1.2	1.0	1.0				0.6

Average	1.2	1.3	1.2	1.1	1.1	1.2	1.0	1.0	0.9
Standard Deviation	0.5	0.6	0.6	0.5	0.5	0.7	0.5	0.5	0.5
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	0.6	0.6	0.6	0.6	0.6	0.3	0.3	0.4	0.3
11/6/2006	0.7	0.6	0.5	0.43	0.5	0.3	0.3	0.4	0.4
12/19/2006	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6
1/8/2007	0.8	0.9	0.7	0.8	0.8	0.7	0.7	0.7	0.8
1/17/2007	0.7	0.7	0.8	0.7	0.8	0.7	0.7	0.8	0.8
1/24/2007	0.7	0.7	0.8	0.7	0.7	0.8	0.7	0.8	0.8
1/30/2007	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.8
2/7/2007	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.9
3/28/2007	1.9	3.5	2.2	2.1	2.2	2.1	2.1	2.1	2.4
4/24/2007	1.7	2.1	2.8	2.1	2.2	2.4	2.2	2.2	2.1
5/9/2007	1.4	1.5	1.9	1.5	1.5	2.3	1.6	1.6	1.5
5/23/2007	1.5	1.7	1.6	1.5	1.6	1.8	1.6	1.6	1.7
6/27/2007	1.7	1.6	1.6	1.4	1.5	1.2	1.0	1.0	1.1
7/4/2007	1.8	1.4	1.4	1.3	1.4				0.7
7/18/2007	1.5	1.2	1.5	0.9	0.8	0.8	0.7	0.7	0.7
8/15/2007	1.8	1.6	0.7	0.7	0.7	0.7	1.2	1.2	0.7
9/19/2007	1.2	1.1	1.0	0.9	0.9				0.5
Average	1.2	1.3	1.2	1.1	1.1	1.1	1.0	1.0	1.0
Standard Deviation	0.5	0.7	0.7	0.5	0.5	0.7	0.6	0.6	0.6
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

Table B-30 Field Parameter: Salinity (mg/L)									
Date	Point 1	Point 1-2	OW1-2-5a _B	OW1-2-5a _M	OW1-2-5a _S	OW1-2-5b _B	OW1-2-5b _M	OW1-2-5b _S	Point 2-5
10/19/2006	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.1
11/6/2006	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
12/19/2006	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
1/8/2007	0.4	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.4
1/17/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/24/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/30/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
2/7/2007	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3/28/2007	0.9	1.5	1.3	1.2	1.2	1.2	1.2	1.2	1.3
4/24/2007	0.9	1.1	1.4	1.2	1.2	1.3	1.2	1.2	1.1
5/9/2007	0.7	0.8	1.2	0.9	0.9	1.1	1.0	0.9	0.7
5/23/2007	0.7	0.9	1.2	0.8	0.9	1.0	0.9	0.9	0.8
6/27/2007	0.8	0.8	1.0	0.8	0.8	0.8	0.7	0.7	0.6
7/4/2007	0.9	0.8	1.0	0.8	0.7				0.3
7/18/2007	0.7	0.6	0.7	0.5	0.5	0.6	0.5	0.4	0.3
8/15/2007	0.9	0.8	1.2	0.7	0.7	0.6	0.6	0.6	0.4
9/19/2007	0.6	0.6	0.7	0.5	0.5				0.3
Average	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5
Standard Deviation	0.2	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.3
Sampling Date	Point 1	Point 1-3	OW1-3-6a _B	OW1-3-6a _M	OW1-3-6a _S	OW1-3-6b _B	OW1-3-6b _M	OW1-3-6b _S	Point 3-6
10/19/2006	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
11/6/2006	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
12/19/2006	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
1/8/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/17/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/24/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/30/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
2/7/2007	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3/28/2007	0.9	1.4	1.3	1.2	1.2	1.2	1.1	1.1	1.1
4/24/2007	0.9	1.0	1.2	1.0	1.0	1.2	1.0	1.0	0.8
5/9/2007	0.7	0.8	1.0	0.8	0.8	1.2	0.7	0.7	0.5
5/23/2007	0.7	0.8	0.9	0.9	0.9	1.0	0.8	0.8	0.8
6/27/2007	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.6
7/4/2007	0.9	0.8	0.8	0.7	0.8				0.4
7/18/2007	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.4
8/15/2007	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.5	0.4
9/19/2007	0.6	0.5	0.6	0.5	0.5				0.3

Average	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5
Standard Deviation	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.2
Sampling Date	Point 1	Point 1-4	OW1-4-7a_B	OW1-4-7a_M	OW1-4-7a_S	OW1-4-7b_B	OW1-4-7b_M	OW1-4-7b_S	Point 4-7
10/19/2006	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
11/6/2006	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
12/19/2006	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
1/8/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/17/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/24/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
1/30/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
2/7/2007	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3/28/2007	0.9	1.7	1.2	1.2	1.2	1.2	1.2	1.2	1.1
4/24/2007	0.9	1.0	1.5	1.1	1.1	1.3	1.2	1.1	1.1
5/9/2007	0.7	0.8	1.0	0.8	0.8	1.2	0.8	0.8	0.8
5/23/2007	0.7	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9
6/27/2007	0.8	0.8	0.8	0.7	0.8	0.6	0.6	0.5	0.6
7/4/2007	0.9	0.7	0.7	0.7	0.7				0.4
7/18/2007	0.7	0.6	0.7	0.4	0.4	0.6	0.1	0.2	0.3
8/15/2007	0.9	0.7	0.3	0.3	0.3	0.3	0.6	0.6	0.3
9/19/2007	0.6	0.5	0.5	0.4	0.4				0.3
Average	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5
Standard Deviation	0.2	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.3
<i>Note: S = surface; M = 0.6 m below the surface; B = bottom</i>									

APPENDIX C

SENSITIVITY ANALYSIS RESULTS

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Hummel Batista, Adelaide P., Nathan Morris, Joseph Gemin, Patricia Quackenbush, Alvin Pilobello, and Zirui (Ray) Yu. Evaluation of Ion Exchange and Reverse Osmosis Technologies for Sulphate Removal from Groundwater for the Region of Waterloo. Ontario Water Works Association Annual Conference, May 2012 (Oral Presentation).

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