# Protecting Wakulla Springs by Reducing Wastewater Nitrate Leaching:
## A Comparison of Two Biological Effluent Treatment Methods for the Tallahassee Wastewater Reuse Facility

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## ABSTRACT

The purpose of this study is to determine which biological effluent treatment method, wetland construction or cropland sprayfield irrigation, best reduces nitrate leaching and helps to preserve Wakulla Springs, one of Florida's most treasured tourist destinations and natural ecosystems. The 2,200 acre cropland sprayfield irrigation alternative is the current tertiary treatment method for municipal effluent in Tallahassee. This land treatment uses a combination of soil filtration and plant nutrient assimilation to reduce high concentrations of nutrients and other potentially harmful components leftover from secondary treatment. Surface flow constructed wetlands have proven to be effective tertiary treatment methods for municipal effluent. This aquatic treatment relies on a combination of plant nutrient assimilation and microbial denitrification to remove excess levels of nutrients in wastewater. An analysis of each alternative using a utilitarian and ecocentric value framework indicates that changing treatment strategies to employ a wetland system would more effectively protect Wakulla Springs from excess nitrate contamination and best serve the regional community.

## INTRODUCTION

### *Wakulla Springs*

("Wakulla Springs," 2005)

**Figure 1.** Aerial view of Edward Ball Wakulla Springs State Park

Edward Ball Wakulla Springs State Park (Fig. 1), located just south of Tallahassee, Florida in the Woodville Karst Plain, is home to "one of the largest and deepest freshwater springs in the world" (Cao, Cowart, & Osmond, 1999, p. 51). This first magnitude spring is the source for the Wakulla River and has one of the largest underwater cave networks in the United States (Hartnett, 2000). As a state park, it holds significant recreational, employment and tourism value for Wakulla County and Florida as a whole (Hartnett, 2000). Furthermore, the spring is known as one of the state's leading wildlife observation areas, bringing in approximately 200,000 visitors a year (Hartnett, 2000). Many of these tourists come to view the spring's unique ecosystem, which is comprised of beautiful aquatic flora and a few rare benthic marcoinvertebrates (Hartnett, 2000).

It is for all of these reasons and more that Wakulla Springs deserves the attention of the environmental planning and natural resource management community. Presently, severe water quality degradation threatens to destroy this one of a kind and treasured aquatic ecosystem. Nonpoint source contamination from chemical disposal, underground septic and storage tank leaks, agricultural chemical leaching, stormwater runoff, and wastewater treatment seepage are just some of the potential pollutants of the spring's water sources (Cao et al., 1999). Among these various pollution problems, the one that environmentalists and researchers have largely focused their attention on is the overabundance of nitrate in the spring (Challete, Pratt, & Katz, 2002).

Reilly, Horne, and Miller (2000) note that increased levels of nitrate can lead to excessive growth of unwanted aquatic plants and algae that can harm an aquatic ecosystem through toxicity or oxygen depletion. In the case of Wakulla Springs, elevated nitrate-nitrogen ($NO_3$-N) concentrations of 1.0 mg/L have led to explosive growth of *Hydrilla verticillata*, an exotic aquatic weed, and *Spirogyra sp.*, a native species of algae (Hartnett, 2000). As first observed in 1997, the *Hydrilla* has overtaken the native eelgrass (*Zostera japonica*), covering previously open areas of the spring; similarly, the *Spirogyra sp.* has responded to the excess $NO_3$-N levels by developing into large, filamentous mats that repress the natural vegetation along the spring floor (Challete et al., 2002; Hartnett, 2000). Consequently, popular glass bottom boat tours are only operational during certain parts of the year when the *Hydrilla* and *Spirogyra* are marginally kept at bay by seasonal growth patterns; regular boat excursions are also less frequent as of late because the abundance of *Hydrilla* is said to clog propellers and make navigation difficult (Bonn & Bell, 2003).

### *Tallahassee Wastewater Treatment*

The City of Tallahassee has received several awards for its efforts in wastewater treatment, including the 1995 U.S. Environmental Protection Agency (EPA) Award for the most effective and innovative reclamation and reuse program. The program is well-received for its computer operated center-pivot sprinkler systems (Fig. 2), profitable crop rotation and farm-like appearance due to the presence of grazing cattle ("*The Southeast Farm,*" 2001). Like many progressive initiatives, this program emerged from humble beginnings.


("Wakulla Springs," 2005)

**Figure 2.** Southeast Farm Manager, Randy Bond, checks the computer operated center-pivot sprinkler system

The cropland sprayfield irrigation project was initiated on the southwest side of Tallahassee in 1966 as an experiment to treat small amounts of post-secondary treatment municipal effluent in upland areas (Yurewicz, 1983). The operation was chosen as an alternative treatment method to mitigate the contamination problems—specifically nutrient enrichment—associated with the direct surface water discharge of secondary-treated municipal effluent to Lake Munson (Hartnett, 2000). Beginning in 1972, after the enactment of the Water Pollution Control Act (precursor to the Clean Water Act of 1977), the US Geological Survey (USGS) took an interest in Tallahassee's southwest sprayfield operation, because the organization wanted to research the potential benefits and/or problems associated with spray application (Challete et al., 2002; Yurewicz, 1983). Specifically, the USGS wanted to determine the efficacy of upland soil filtration and plant nutrient assimilation in reducing high concentrations of nutrients (e.g., Phosphorous, Nitrogen) and trace amounts of metals, bacteria and viruses leftover from secondary treatment (Elder, Hunn, & Calhoun, 1985).

From 1966 to 1977, the southwest sprayfield was expanded from 16 to 119 acres; the hydraulic input rate was also adjusted upward from 0.5 million gallons per day (Mgal/d) to approximately 1.5 Mgal/d (Yurewicz, 1983). Based on the success of its newly established tertiary treatment program, in 1981 the city expanded the sprayfield irrigation operation once more, this time to a new 1,000 acre location on the southeastern edge of the city. Today the "southeast" reuse facility (Fig. 3) encompasses more than 2,100 acres and receives up to 17 Mgal/d from the Thomas

P. Smith facility (Fig. 4), Tallahassee's municipal wastewater treatment plant ("*The Southeast Farm,*" 2001).

("*Wakulla Springs,*" 2005)

**Figure 3.** Aerial view of Southeast Sprayfield

Despite all the accolades and general support of sprayfield irrigation for being an aesthetically pleasing, cost-effective, water conserving treatment for the City of Tallahassee, there is still a history of fundamental human health and ecosystem degradation issues that has emerged from this program (Elder et al., 1985). From 1980 to 1982, as part of its ongoing water quality assessment of spray irrigation, the USGS investigated $NO_3$-N concentrations in the groundwater directly below and within the vicinity of the new southeast sprayfield. Testing several wells inside and outside of the sprayfield area in the Floridan Aquifer and nine surficial aquifers, the researchers concluded that the average $NO_3$-N levels had risen from 0.5 mg/L to more than 4 mg/L in some of the wells (Elder et al., 1985). USGS water quality studies of the Tallahassee sprayfields conducted after 1985 have revealed that the nitrite/nitrate-nitrogen ($NO_2$+$NO_3$-N)[1] concentrations in some wells peaked in excess of 10 mg/L by the early 1990's. Further sampling indicated that this range fell to 4-8 mg/L by the mid-1990's, and remained steady as of 2002 (Challette et al., 2002). Although a precise measure of only the nitrogenous fertilizer ($NO_3$-N) cannot be extracted from these combined nitrite+nitrate-nitrogen ($NO_2$+$NO_3$-N) averages, the Challette et al. report indicates that the varying analyses used in its study (i.e., $NO_3$-N, total; $NO_2$-$NO_3$-N, total; and $NO_2$-$NO_3$-N, dissolved) "yield[ed]

[1] After the mid 1980s, USGS changed its reporting method in certain wells from nitrate-nitrogen, total ($NO_3$-N) to nitrite+nitrate-nitrogen, total ($NO_2$+$NO_3$-N) and nitrite+nitrate-nitrogen, dissolved ($NO_2$+$NO_3$-N).

relatively equivalent results”[2] (Challete et al., 2002, p. 82). This finding reveals that—for the purposes of this study—all nitrate values reported using any of the analyses above can be interpreted in the same way (e.g., 4 mg/L $NO_3$-N ≈ 4 mg/L $NO_2$+$NO_3$-N).

(“Wakulla Springs,” 2005)

**Figure 4.** Aerial view of the Thomas P. Smith Water Reclamation Facility

To put these figures into context, in 1986 the EPA promulgated a public water supply[3] maximum contaminant level (MCL) for $NO_3$-N of 10 mg/L[4] to protect against incidents of methemoglobinemia[5] or “blue-baby syndrome” (Smith, Alexander & Lanfear, 1991). On the opposite end of the spectrum, $NO_3$-N enrichment that does not exceed the EPA standard for water quality but that still affects ecosystem functions, has largely been ignored by the federal government as well as a majority of the states (Richardson & Davis, 1987). In fact, only a handful of states—most notably California—have created regional water quality control boards that enforce water nutrient enrichment standards below the EPA standard. For example, in Tahoe, CA, in order to prevent stream and lake eutrophication, the control board has adopted a range of MCL $NO_3$-N values of 0.05-2.00 mg/L (Reilly et al., 2000). This range is indicative of the fact that no official threshold can be established due to the varying impacts that $NO_3$-N concentrations have on different environments (Smith et al., 1991).

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[2] The reasons why the various nitrogenous compound measurements yield similar results: “Historically there has been no measurable $NO_2$ in the ground water of the study area and, presumptively, all detectable $NO_3$ in ground water is dissolved” (Challete et al., 2002, p. 82).

[3] Private well water is not regulated (USEPA, 2000)

[4] The EPA maximum contaminant level goal for nitrite ($NO_2$-N) in drinking water is 1 mg/L, which indicates a greater risk to human health as compared to the allowable 10 mg/L $NO_3$-N concentration in drinking water (USEPA, 2005).

[5] Although there are other human-health concerns (i.e., cancer) thought to be associated with elevated levels of $NO_3$-N in water, methemoglobinemia was the most clearly established hazard in 1986. Blue-baby syndrome is a potentially fatal condition (mainly for nursing infants) where nitrate interferes with the blood’s ability to carry oxygen, leaving babies “bluish” in appearance (Smith et al., 1991).

In 2002, the Northwest Florida Water Management District released a report stating that over half (55%) of the nitrogen loading in the Wakulla Springs contributory area could be traced back to domestic and industrial wastewater treatment facilities in Leon and Wakulla counties (40% effluent; 15% residuals or biosolids) (Challete et al., 2002). Specifically, the report claimed that of the 40% that was attributable to effluent, a significant portion (≈80%) was generated by Tallahassee municipal facilities (Challete et al., 2002). In essence, the report indicated that approximately 32% of all the nitrogen loading affecting Wakulla Springs water sources—the largest single proportion—was being generated by the City of Tallahassee wastewater treatment facilities. Because the city has elected to process all secondary-treated wastewater through its massive, state-of-the-art sprayfield irrigation system, it is apparent that this treatment method must now be called into question.

As mentioned above, Wakulla Springs is experiencing unnatural concentrations of $NO_3$-N (1.0 mg/L) that are causing extreme ecosystem degradation. It is clear from the literature that the current tertiary effluent treatment system in Tallahassee—while maintaining $NO_3$-N concentrations within EPA guidelines—is likely to be the biggest contributor of nitrogen to Wakulla Springs. It is because of these findings that an in-depth evaluation of current and alternative wastewater treatment disposal methods is warranted.

*The Alternative*

Recently, the use of natural or constructed wetlands for municipal wastewater treatment has become a popular practice in Florida and other states (Spieles & Mitsch, 2000). In fact, Florida was the first state to establish a set of regulations to support wetland treatment for municipal effluent (Richardson & Davis, 1987). The ability of wetlands to act as nutrient sinks or transformers to reduce eutrophication of nearby aquatic systems has been well documented (Blahnik & Day, 2000; Spieles & Mitsch, 2000). Many studies about the nutrient removal capabilities of these treatment systems are optimistic of their success; however, researchers argue that the overall efficacy and long-term durability of these systems have not yet been determined (Spieles & Mitsch, 2000).

As surface waters, wetlands fall under the jurisdiction of the federal Clean Water Act and therefore cannot be degraded by substances like municipal effluent. Instead, natural wetlands must be used as receiving bodies, and not as official treatment systems (Richardson & Davis, 1987). While some argue that natural wetlands are best suited for nutrient removal from effluent, other researchers contend that artificial or constructed wetlands are more advantageous due to their flexibility in site selection, sizing, control over hydraulic inputs, and effluent retention time (Kadlec & Knight, 1996; Richardson & Davis, 1987). Given the nature of existing conditions at the current Tallahassee reuse facility site, only constructed wetlands are addressed as an alternative to cropland sprayfield irrigation. As such, the purpose of this study is to determine which biological effluent treatment method, wetland construction or cropland sprayfield irrigation, can best reduce nitrate leaching and help to preserve Wakulla Springs, one of Florida's most treasured tourist destinations and natural ecosystems.

## *Evaluation Method*

The value framework adopted for this comparison includes both utilitarian and ecocentrist approaches; as such, the evaluation criteria address the net social benefits and ecosystem preservation qualities of each alternative. Because utilitarianism is centered on the notion that the preferred course of action is the one that achieves the greatest net benefit for society, each alternative is first assessed by performing a categorical benefit-cost analysis for the two-county region[6] made up of Leon and Wakulla (Fig. 5).

**Figure 5.** The two-county region, featuring the sprayfield and spring locations

[6] The two-county region was selected as the unit of analysis in this study because the impact of the wastewater treatment system in Leon County affects Wakulla County, thereby making the issue an inter-jurisdictional or "regional" affair. It is recognized that monetary costs and benefits associated with each alternative will differ based on circumstances within each county.

Based on the results of this first analysis, each alternative is then scored within the context of a Weighted Ordinal Goals Achievement Matrix (WOGAM), where the category "Maximize net benefits" (derived from the first analysis) is one of five total evaluation categories. The alternative with the highest score from the utilitarian evaluation receives the maximum five points; the other alternative is scored based upon how it achieves (or does not achieve) this criterion, comparatively. The possible scores for the lesser alternative are medium (3), low (1) or not met (0).

To evaluate each approach from an ecocentric standpoint, the four remaining categories of the WOGAM are based on the following components of Timothy Beatley's Ecocentric Hierarchical System of Land Duties: Maintain hierarchy of environmental land obligations[7], minimize the human footprint, restore the natural environment wherever possible, and keep options open to future generations (Beatley, 1994). Each category is scored based on the system described above for the "Maximize net benefits" category. The weights of the achievement matrix favor the categories pertaining to environmental restoration and sustainability, because success in these categories is thought to be more reflective of the desired ecological outcome, namely the protection of Wakulla Springs. Ultimately, the foundation of this evaluation is based on the notion that the highest score within the WOGAM should indicate the alternative most suited to protect Wakulla Springs, while also giving ample consideration to the greater good of the regional population and beyond.

### *Research Methods*

In order to make determinations about the successes and failures of each alternative with regard to the evaluation categories listed above, the most pertinent literature has been reviewed. This information base includes peer-reviewed journal articles, government agency and private organization reports, conference proceedings, edited volumes comprised of chapters written by expert scientists, government (federal and local) and private organization websites, and newspaper articles.

## DESCRIPTION OF ALTERNATIVES

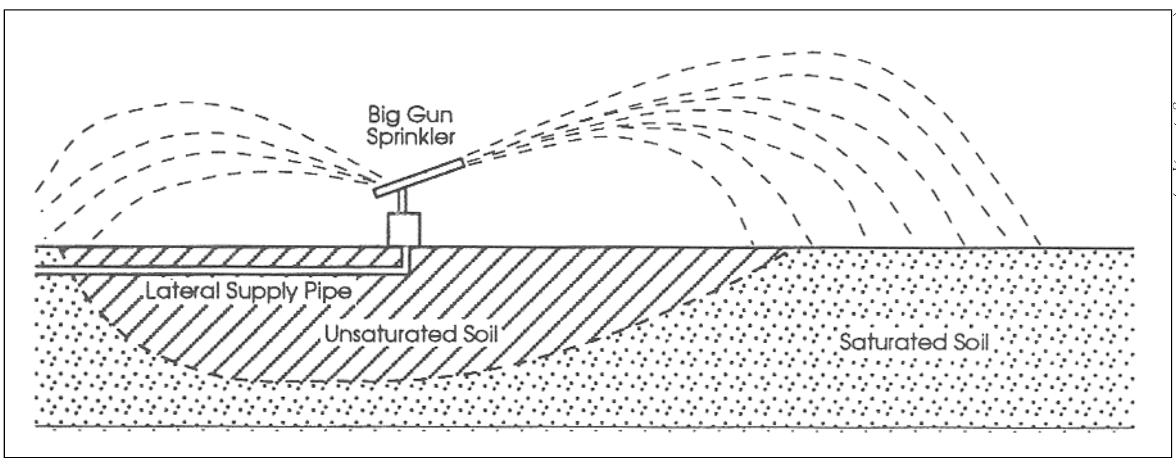
In 2000, the EPA produced its National Water Quality Inventory Report (USEPA, 2000). In its discussion of programs to restore water quality in Florida, the report mentioned two distinct

[7] The hierarchy of Beatley's environmental land obligations is as follows: ecosystems > species > sentient individuals > non-sentient individuals, such that conservation decisions are based on this system.

alternatives for wastewater reuse that are currently being encouraged within the state: irrigation (drip or spray) and constructed or natural wetlands—the two alternatives of interest for this study. As mentioned above, the first of these two alternatives is already established in the area.

### *Sprayfield Irrigation*

Sprayfield irrigation (Fig. 6) is a slow-rate land application of secondary-treated effluent. This method is designed for wastewater "polishing" and disposal via nutrient uptake and filtration by vegetated systems and permeable soils, respectively (Kadlec & Knight, 1996). In this system, irrigation rates are low and infrequent so as to allow for the restoration of aerobic soil conditions, which are vital to the efficacy of the plant and soil components (Kadlec & Knight, 1996). Spray irrigation systems generally fail when frequent use leads to perpetually saturated soil conditions, whereby wastewater percolation and plant nutrient assimilation are significantly hampered by standing water (Kadlec & Knight, 1996).



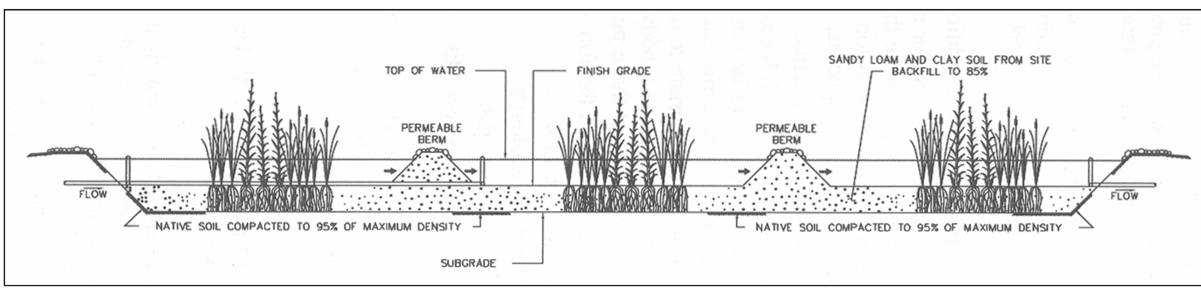

(Kadlec & Knight, 1996, p.35)

**Figure 6.** Cross-section schematic of the sprayfield irrigation technique (note: this figure illustrates the big gun sprinkler system as opposed to the computer operated center-pivot sprinkler system used in this study)

Wastewater reuse within the Tallahassee Water and Sewer Department system is largely performed at the southeast farm where the spray irrigation technique is being applied to a crop rotation consisting of corn, sorghum, canola and soy beans (*"Wastewater management,"* 2001). Like most sprayfield irrigation systems, the Tallahassee facility uses a combination of soil filtration and plant nutrient assimilation to reduce high concentrations of nutrients (e.g., P, N) and other potentially harmful components leftover from secondary treatment (Elder et al., 1985). The "for profit" nature of this farm is evidenced by the fact that crops are sold for animal consumption, fields are rented to farmers for cattle grazing and crop growing, and additional inputs of inorganic nitrogen fertilizer are applied to crops (Challete et al., 2002; Stevenson, J., personal communication, February 8, 2005). Currently, this 2,159 acre facility disperses more than 17 million gallons of municipal effluent per day with a capacity of more than 26 Mgal/d *("The Southeast Farm,"* 2001). It is important to note that the original southwest farm—now only 89 acres—is still a part of this tertiary treatment system and is included within the scope of this study (Challete, 2002).

### *Constructed Wetland*

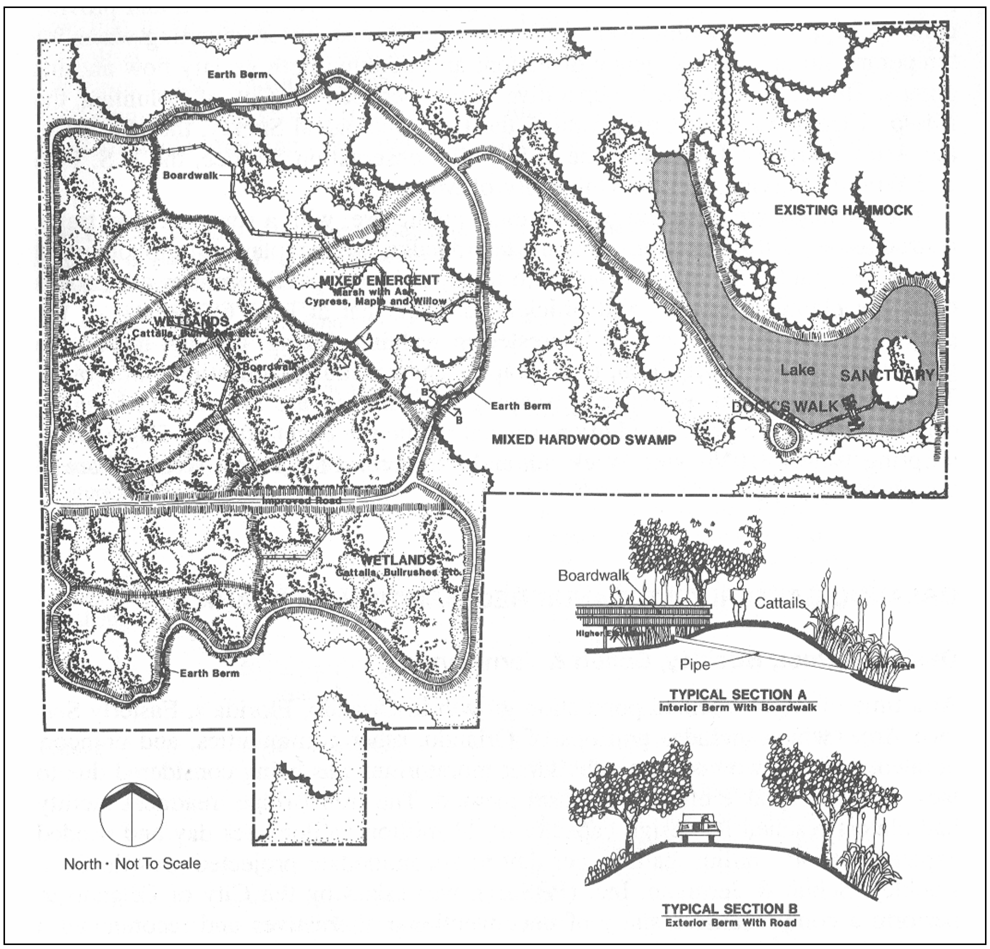
The second alternative in this study is to have the City of Tallahassee replace the existing cropland sprayfield irrigation system with a constructed surface flow (SF) wetland, which is modeled on the 1,200 acre Iron Bridge constructed wetland in Orlando, FL. Surface flow wetlands (Fig. 7) consist of emergent aquatic plants situated in shallow beds or channels (Brown & Reed, 1994). Subsurface flow (SSF) wetlands are similar to SF wetlands in vegetation and design except that they are housed within a permeable medium (e.g., gravel), which places the water level and all system functions below the top of the medium (Brown & Reed, 1994). This allows for a deeper system than SF wetlands, and in turn reduces the amount of area needed for nutrient removal processes (Brown & Reed, 1994). According to Curtis Richardson, Director of the Wetlands Center at Duke University, SSF wetlands are generally more expensive, have difficulties providing carbon sources for microbial denitrifying agents and are easily clogged (personal communication, March 15, 2005).



(Campbell & Ogden, 1999, p.74)

**Figure 7.** Cross-section schematic of surface flow constructed wetland

The general layout of the SF wetland would consist of a series of contiguous wetland cells located above a polypropylene liner to manage flow patterns and water depth and prevent seepage; the cell walls would be made up of interlocking berms, the soil for which would be taken from a single location on the property resulting in the creation of a pond for recreational use (Fig. 8). As in all wetlands, a combination of denitrifying agents, namely plants and microorganisms, would be at work in the system (Blahnik & Day, 2000; Reilly et al., 2000; Spieles et al., 2000). The vegetation within the wetland would include a combination of species taken from the Tallahassee area, including cattail (*Typha spp.),* bulrush (*Scirpus spp.*), common reeds[8] (*Phragmites australis*), duckweed[9] (*Lemna spp.*), grasses (along edges and berms), and wetland forest species (Campbell & Ogden, 1999). The site would consist of three main treatment stages: 1) a deep marsh consisting of cattail, bulrush and common reed for initial nutrient removal; 2) a mixed marsh made up of the aforementioned vegetation as well as grass and hardwood species for additional nutrient treatment; and 3) a hardwood swamp providing the final nutrient sink area (Campbell & Ogden, 1999). Mosquito fish (*Gambusia affinis*) would be used to control mosquito populations (Knight, 1993). Lastly, the design for the new wetland would include a series of boardwalks and paths along berms for scenic and recreation opportunities.




(Campbell & Ogden, 1999, p.244)

**Figure 8.** Schematic of the Iron Bridge constructed wetland in Orlando, FL by Post Buckley, Schuh & Jernigan

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[8] Cattail, bulrush, and common reed are the three most widely used aquatic plants in constructed wetlands; their universal application is due to the "vigorous growth and rooting habits" exhibited by each (Campbell & Ogden, 1999, p. 24).

[9] Duckweed is a flowering wetland plant also known for creating surface mats which help minimize light penetration, a common cause of excessive algal blooms (Campbell & Ogden, 1999)

Because the Iron Bridge wetland was designed for secondary-treated effluent at a hydraulic input rate of 16 Mgal/d and because it has been shown that an average *total* nitrogen outflow of less than 1 mg/L is consistently released by that system, it is assumed that the acreage required for a new constructed wetland in Tallahassee of similar function would be only slightly more than the 1,200 acre system in Orlando (Campbell & Ogden, 1999; Kadlec & Knight, 1996).

### *Transition Assessment*

Overcoming the costs associated with the implementation of the constructed wetland and the transition between the two systems would be the greatest hurdle to this alternative. The most obvious and perhaps most dependable source of long-term funding would likely be the city's capital improvement plan budget. Another potential source of support—with a history of funding wastewater treatment projects—is the Clean Water State Revolving Fund (CWSRF). This loan program is run by states and receives partial funding from the EPA and other organizations (Campbell & Ogden, 1999). A crude cost formula based on wetland size and type suggests that such a project could cost the city approximately 26 million dollars for the wetland alone (Kadlec & Knight, 1996). Projected costs for a transitional stage are beyond the scope of this study.

Because the constructed wetland is expected to occupy only slightly more than half of the current sprayfield area, a fairly expeditious transition could be made between the two alternatives. This could be accomplished by establishing a short-term spray irrigation system within any nearby forested areas leftover from the city's 1964 land exchange with the US Forest service (Challete et al., 2002). Use of such a biological treatment method would be cheaper than developing other temporary advanced wastewater treatment facilities and would only have to accommodate approximately 1,275[10] acres worth of treatment area at any one time. This would be made possible because ≈900 acres of sprayfields on the southeast farm as well as the 89 acres on the southwest farm could be retained until the constructed wetland was in place. If the aforementioned forest land[11] were deemed insufficient in size or unavailable, other public or privately owned forest lands could be temporarily used, and rent payments or tax incentives could be provided as appropriate.

[10] Because Iron Bridge is 1,200 acres and supports 16 Mgal/d, a crude computation for proportionality indicates that only 1,275 acres would be needed to accommodate 17 Mgal/d of Tallahassee municipal effluent.

[11] It should be noted that while some believe that a third alternative—drip or spray application to forest lands—is a viable option, Sopper (1976) showed that these treatment systems are sensitive to the daily irrigation requirements necessary for most mid-sized cities, such that long-term $NO_3$-N removal is ineffective under such hydraulic loading demands. This finding indicates that forest land treatment requires larger areas than cropland irrigation systems.

## EVALUATION OF ALTERNATIVES

### *Utilitarian Evaluation*

Addressing each alternative within a utilitarian value framework, it is evident that the surface flow constructed wetland would generate a greater net benefit to the region with regard to the following human interest categories: climate change, human health, economic prosperity and public amenities (Table 1).

**Table 1.** Tabulation of benefits and costs of each alternative to people (Benefits in **blue**, those who benefit in **green**; Costs in **plum**, people affected in **red**; supporting text in black)

| Alternative | Benefits | People Affected | Costs | People Affected |
|---|---|---|---|---|
| **Cropland Sprayfield Irrigation** | | | | |
| | A combination of plant assimilation & percolation **remove nitrates to acceptable EPA drinking water standards** (highest avg. 4-6 mg/L $NO_2$+$NO_3$-N = <10 mg/L $NO_3$-N ) (Challete, 2002) | **All well users in the sprayfield contributory area.** | Crop assimilation of nitrates can have low thresholds during certain parts of the year which can lead to **greenhouse gas emissions** ($N_2O$) **and leaching** (Krupa, 2002; Schoonover & Willard, 2003) | Greenhouse gas emissions will affect the **global community** and leaching will affect **people who depend on water from the sprayfield catchment area** |
| | **Easy for small cities** with available open land to maintain and expand upon (Sopper, 1976) | **City of Tallahassee residents** | **High maintenance and operations costs**, including future expansion, as compared to wetland systems (Kadlec & Knight, 1996) | **City of Tallahassee residents** |
| | There are **clear economic payoffs present in the system** such as crop sales and rent for cattle use (Stevenson, 2005) | **City of Tallahassee residents** | Slow hydraulic loading rates (0.15-1.60 cm/d) as compared to wetland systems requires **larger treatment areas and future expansion** (Kadlec & Knight, 1996) | **Tallahassee-Leon County residents living near treatment area** that may be impacted by future expansion |
| | **The system is in place** and will not incur any capital costs | **City of Tallahassee residents** | Leading contributor of $NO_3$-N loading to Wakulla Springs, **generating ecosystem degradation** (Chalette et al., 2002) | **People who enjoy the aesthetic value of Wakulla Springs** |
| | The system is **cheaper than industrial advanced wastewater treatment** (Elder et al., 1985) | **City of Tallahassee residents** | Leading contributor of $NO_3$-N loading to Wakulla Springs, reducing **current and future park and county revenue generated by tourism –** avg. employee wages of ≈$4.3 M/yr and tourist spending within Wakulla County of ≈$22.17 M/yr (Bonn & Bell, 2003) | **≈350 employees** (8% of the Wakulla County workforce) and **≈200,000 tourists** who visit the area every year |
| | **Aesthetic quality of farmland** | **Some Tallahassee-Leon County residents** | **Additional inorganic nitrogen is applied to crops** (Stevenson, 2005) | **Well users in the catchment area and Wakulla Springs enthusiasts** |
| | **City employment opportunities** | **Some Tallahassee-Leon County residents** | | |

| Alternative | Benefits | People Affected | Costs | People Affected |
|---|---|---|---|---|
| **Surface Flow (SF) Constructed Wetland** | | | | |
| | A combination of plant assimilation and microbial denitrification can **remove nitrates to acceptable EPA drinking water standards** (<10 mg/L $NO_3$-N ) and can **remove total nitrogen below the highest current cropland sprayfield irrigation system averages** (4-6 mg/L $NO_2$+$NO_3$-N in some wells) (Campbell & Ogden, 1999; Challete, 2002; and Moshiri, 1993) | **All well users in the sprayfield contributory area and people who are concerned with Wakulla Springs restoration (including park employees and tourists)** | Wetlands process nitrites and nitrates ($NO_2$ and $NO_3$), sulfates ($SO_4$) and carbon (C) and **release a range of gases** like nitrous oxide ($N_20$), sulfur ($SO_2$), methane ($CH_4$) and carbon dioxide ($CO_2$) into the atmosphere; these gases **play a role in global climate change** (Richardson, 1994). | These gases will affect the **regional population** (acid rain) and the **global population** (greenhouse gas emissions) |
| | Beyond capital costs and transition costs, this system **incurs less maintenance and operations costs** than the alternative (Kadlec & Knight, 1996) | **City of Tallahassee residents** | Using a crude cost formula from Kadlec & Knight (1996), the capital costs for a new surface flow constructed wetland could be **≈$26 million + unknown transition costs** | **City of Tallahassee residents** |

| Alternative | Benefits | People Affected | Costs | People Affected |
|---|---|---|---|---|
| | Will enhance local area by contributing **aesthetic qualities, recreation, research and educational opportunities** (Campbell & Ogden, 1999; Knight, 1993) | **Some Tallahassee-Leon County residents and visitors to the area** | The lower estimate for the **lifespan of this kind of constructed wetland is 33 years** (although the upper estimate is 150) (Campbell & Ogden, 1999) | **City of Tallahassee residents** |
| | More efficient nutrient removal capabilities per unit acre **requires less total acreage** (Kadlec & Knight, 1996) | **Tallahassee-Leon County residents living near treatment area or those concerned with the current size of the cropland sprayfield facility** | Wetland environments commonly support populations of **venomous snakes, alligators and mosquitoes** that act as pathogen vectors (Knight, 1993) Despite a design constructed to minimize human contact with these hazards, their presence is ultimately unavoidable. | **Some Tallahassee-Leon County residents and visitors to the area** |
| | Wetlands provide a **refuge for several species of migratory birds** (Richardson, 1994) | **Local and visiting bird enthusiasts** | | |

Global climate change concerns associated with each system are evident. Studies indicate that each alternative produces greenhouse gas emissions that contribute to global warming (Krupa, 2002; Richardson, 1994). Dr. Curtis Richardson of the Duke University Wetlands Center states that greater amounts of greenhouse gas emissions are derived from wetlands due to higher rates of nutrient transformation in these systems (personal communication, March 15, 2005). However, Dr. Richardson also contends that there is more nutrient fixation in wetland systems, which may act to counter-balance the release of methane ($CH_4$) and carbon dioxide ($CO_2$) in the system. Furthermore, Dr. Richardson suggests that ultimately there is a tradeoff between the wetland system that is better at removing nutrients and the cropland system that gives off fewer greenhouse gases.

Results from years of USGS water quality data in Tallahassee suggest that the current sprayfield system is producing groundwater recharge that might be of some concern to locals (Challete et al., 2002). Based on the assumption that there are no significant reductions in nitrate concentration for water extracted south of sprayfield wells, it is possible that well users within the sprayfield catchment area are currently being exposed to $NO_2$+$NO_3$-N concentrations as high as 6-8 mg/L. Furthermore, some areas—in combination with nitrogen from other groundwater loading sources—could be experiencing levels that exceed the EPA municipal public drinking standard of 10 mg/L. Alternatively, the Iron Bridge wetland—the model for this alternative—generates total nitrogen outflow concentrations that average less than 1 mg/L (Campbell & Ogden, 1999). Although it is unclear as to whether such nitrogen removal rates could be achieved in a Tallahassee wetland system, it is assumed that with the city's current nutrient loading rate being similar to the Iron Bridge system, such goals could be met if design standards were comparable. As mentioned above, the current acreage of the sprayfield system is more than enough land to construct the desired wetland facility, and because nitrate is a fraction of the Iron Bridge total nitrogen outflow figure, it is likely that a newly constructed system could generate lower output levels than are currently achieved.

Assuming such results are possible, the wetland system would greatly reduce people's exposure to moderate/unhealthy concentrations of $NO_3$-N, thereby reducing the risk of blue-baby syndrome and other potential health concerns such as cancer. Furthermore, because the Challete et al. report indicates that the sprayfield system accounts for approximately a third of all nitrogen loading in Wakulla Springs, it can also be assumed that a wetland system which functions at or just below the Iron Bridge system could yield lower $NO_3$-N concentrations in the spring. This result would have major implications for Wakulla Springs enthusiasts and the economy of the Wakulla Springs area. This potential impact is explored below.

From an economic standpoint, although the estimated capital costs and undefined but anticipated transition/minimal operating costs appear overwhelming for the wetland, a 2003 economic analysis of Wakulla Springs and its impact on the Wakulla County economic base indicates that continued environmental degradation—largely attributable to the current sprayfield system—could lead to significant losses in both tourist dollars and employment in Wakulla County (Bonn & Bell, 2003). If park attendance continues to decline as it has over the last few years—with the possibility of one day closing its doors—Wakulla County could eventually lose up to $22.17 million in annual tourist spending in the area (Bonn & Bell, 2003). Thus, even if the capital and transition costs associated with the wetland amounted to $70 million, the regional revenue losses incurred from the destruction of Wakulla Springs could be significantly more costly over time.

Furthermore, despite the fact that the sprayfield alternative is a "for profit" treatment system, it has been reported that the system only generates approximately $25,000 annually (personal communication, April 19, 2005). Lastly, although a transition to a wetland system would eliminate some jobs at the current sprayfield facility, these losses would pale in comparison to the impact that the loss of Wakulla Springs would have in Wakulla County. According to Bonn & Bell (2003), the park currently employs close to 400 people and makes up an impressive 8% of the county's workforce.

Implementation of the wetland also appears to be a more favorable alternative with regard to public amenities and aesthetic quality. Several researchers have noted a number of societal values associated with wetlands (Campbell & Ogden, 1999; Knight, 1993; Richardson, 1994). In the case of this constructed wetland modeled on the Iron Bridge system, amenities such as recreation and research/education opportunities would be possible (Campbell & Ogden, 1999). Furthermore, walking trails, boardwalks and a lake—not to mention a variety of plant and animal species—would provide excellent scenic opportunities in the wetland area. Conversely, aside from the aesthetic quality of farm fields, very few public amenities are present in the current system.

("Wakulla Springs," 2005)

**Figure 9.** Many of the 2,000 annual tourists jump from this platform to enjoy the cool spring water below

As mentioned above, this rudimentary benefit-cost analysis clearly points to the wetland alternative as being the obvious choice for the region. The analysis shows that this alternative is more beneficial across nearly all of the human interest categories in this analysis. Consequently, this system received a score of five in the WOGAM, whereas the sprayfield system was scored a one for its *attempt* to be both a profitable and environmentally friendly biological effluent treatment facility.

### *Ecocentric Evaluation*

Analyzing each alternative under the selected components of Beatley's Ecocentric Hierarchical System of Land Duties, the surface flow constructed wetland scored higher within the other four categories of the WOGAM (Table 2).

**Table 2.** Weighted Ordinal Goals Achievement Matrix

| | Achievement of Evaluation Criteria | | | | | |
|---|---|---|---|---|---|---|
| Alternatives | Maximize net benefits | Maintain hierarchy of ecosystems, species, sentient individuals, and non-sentient individuals | Minimize the human footprint | Restore the natural environment wherever possible | Keep options open for future generations | Total Score |
| Weight: | 2 | 1 | 1 | 3 | 3 | |
| Cropland Sprayfield Irrigation | 1 | 0 | 0 | 0 | 0 | **2** |
| Surface Flow (SF) Constructed Wetland | 5 | 3 | 3 | 5 | 5 | **46** |

Where High = 5
Medium = 3
Low = 1
Not met = 0

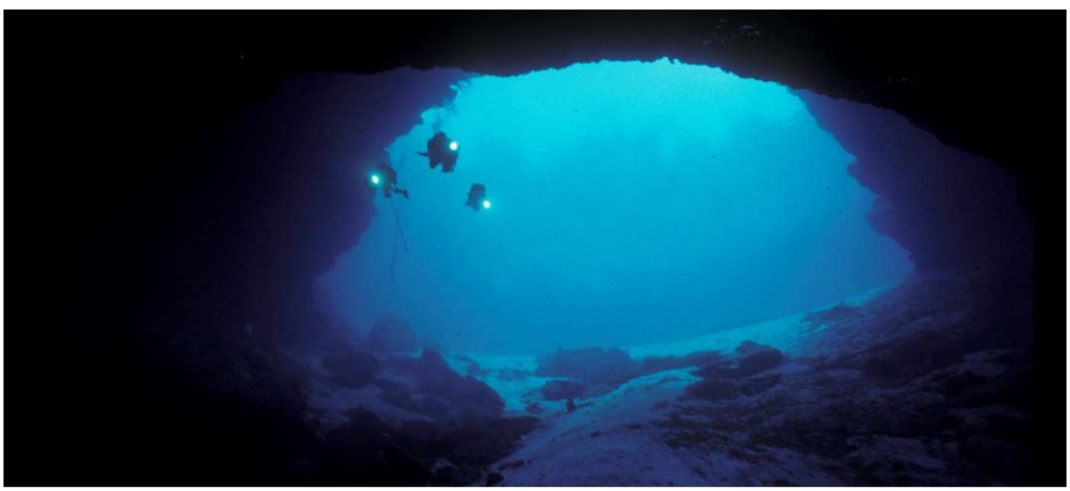
### *Maintain Hierarchy of Environmental Land Obligations*

With regard to maintaining obligations to Beatley's hierarchy of ecosystems, species, sentient individuals, and non-sentient individuals, it is clear that the present sprayfield system does quite the opposite. In an effort to expand the wastewater treatment program during the mid 1960s, the city of Tallahassee made a land exchange with the US Forest Service to obtain several acres of forest land for its southwest facility (Challete et al., 2002). Since that time, the city has purchased over 2,000 acres of land in its dual commitment to cropland sprayfield treatment and profitable farming. Thus, over the 39 year history of this system, it is clear that the active farming element of this treatment approach has done more to degrade natural ecosystems than maintain them. For this reason, the sprayfield system was scored a zero. After all, it is not difficult for even the layperson to recognize that the practice of monocropping does less to maintain Beatley's ecocentric hierarchy than the preservation of an existing forest or field.

Conversely, the wetland alternative would be an improvement upon the norm in this regard. Outside of rainforests, wetlands produce more biomass than any other environment in the world (Campbell & Ogden, 1999). This fact can be traced back to the overall complexity of a wetland, in that a special combination of microorganisms, plants, amphibians, fishes, mammals and birds are at work in the system (Campbell & Ogden, 1999). Ultimately, these findings demonstrate that the creation of such an ecosystem would contribute more to Beatley's hierarchy of obligations than the sprayfield system. However, because implementation of the wetland alternative would alter an existing ecosystem—as opposed to maintaining one—it was scored a three.

### *Minimize the Human Footprint*

When comparing each alternative within the context of a geographical impact or "footprint," once again the wetland system appears to be the logical choice. Several water quality studies concerning the Tallahassee sprayfield sites indicate a consistent pattern of expansion since the time of the program's inception in 1966 (Challete et al., 2002; Elder et al., 1985; Yurewicz, 1983). While early expansion was due to the city's commitment to this strategy as the official tertiary treatment method for municipal effluent, it is also clear that later expansion was the result of a need to accommodate more wastewater. This finding is supported by Kadlec and Knight (1996) who—through years of research on biological treatment systems—have concluded that spray or drip irrigation systems are limited by low hydraulic loading rates and must therefore employ larger treatment areas.



(Skiles, 2005)

**Figure 10.** Divers enter the mouth of the Wakulla Spring cave network

The current sprayfield system—including both sites—consumes over 2,200 acres of total land (Challete et al., 2002). As mentioned above, a constructed wetland modeled on the Iron Bridge wetland would encompass approximately 1,275 acres. This differential in land consumption between the two alternatives reaffirms an earlier statement that wetland systems are more efficient at nutrient removal per unit area than cropland systems, and therefore require less land. As such, the sprayfield alternative was scored a zero for the expansive nature of the system. Because it is known that high tech industrial advanced wastewater treatment systems—while very costly—are another alternative that would result in the smallest footprint, the wetland alternative was scored a three for its mid-range land requirements among the alternatives discussed.

*Restore the Natural Environment Where Possible*

With regard to the natural restorative qualities associated with each alternative, the wetland system would be noticeably more effective at accomplishing this goal. For the reasons mentioned above, throughout its history, the sprayfield system has not directly contributed to the restoration of any natural systems. Although some may argue that a switch to irrigation saved Lake Munson from direct discharge of secondary-treated effluent, this is viewed as an indirect result, as the consequence was not part of the design or function of the sprayfield system. The wetland system, however, would be expected to achieve this goal two-fold. Not only would the system be designed to create a naturally occurring ecosystem, but its purpose would also be to restore Wakulla Springs. As a result of these findings, the sprayfield system was awarded a zero and the wetland system a five.

*Keep Options Open for Future Generations*

An analysis of the final criterion—consideration of future generations—proved to be quite similar to the one before it. While the sprayfield system's expansive nature and impact on Wakulla Springs are far removed from any level of sustainability, the wetland system would work in the opposite fashion to reduce land consumption for wastewater treatment and protect the contributory areas of Wakulla Springs. In addition, there are two more sides to the issue that demonstrate a consideration to future generations: 1) wetlands help to maintain genetic diversity (Knight, 1993); and 2) the nation's history of undervaluing and destroying wetlands has created a need for more protection and restoration of these systems, as they are now recognized for being essential to the longevity of human civilization (Spieles & Mitsch, 2000). Consequently, the sprayfield system was scored a zero for working against this criterion; the wetland system was awarded a five for the collection of reasons just explained.

As mentioned above, the foundation of this evaluation was based on the premise that the highest score within the WOGAM would indicate the alternative most suited to protect Wakulla Springs, while also giving ample consideration to the greater good of the region. It is evident from the total scores in Table 2 that the surface flow constructed wetland is the obvious choice.

Ultimately, it has been shown that the sprayfield system is less beneficial to people and largely fails to preserve ecosystems.

## CONCLUSIONS

The findings in this study reveal that the current system of tertiary wastewater treatment in Tallahassee could be improved to better protect Wakulla Springs from $NO_3$-N contamination. At the same time, however, it is clear that wastewater treatment is only part of the story – there are still other problems such as septic tanks, stormwater runoff and agricultural chemicals that play a role in all of this. Nevertheless, it seems clear that a surface flow constructed wetland based on the Orlando Iron Bridge system could work to mitigate the effects of nitrate contamination, thereby helping to protect the Wakulla Springs aquatic ecosystem and the profitable tourist industry associated with it.

("*Wakulla Springs*," 2005)

**Figure 11.** A Moorehen and her chicks; one of many birds and other animals found in the park

In researching this environmental planning problem, two other issues of importance came to light. First, there is an obvious human health concern associated with nitrate contamination in drinking water. Although the EPA has outlined a general standard for public water supplies, it is clear that more regulations need to be put in place for other water sources and their effects on people *and* ecosystems. Additionally, further research must be performed to determine the other health risks related to nitrate contamination and the thresholds that apply. Like many environmental protection efforts, any link to a human health concern dramatically enlarges the audience and increases the level of support for the issue. Secondly, this study reveals the importance of a move toward regional planning efforts where appropriate. Had the study simply assessed the value of each alternative from just one county's perspective, the results would have differed. Ultimately, the regional nature of this issue illustrates the importance of extending concern for natural systems beyond arbitrary political boundaries.

During the mid 1960's when Tallahassee was faced with the need to save Lake Munson from total degradation by wastewater pollution, the city responded by researching and eventually investing in what was considered a cost-effective, environmentally friendly, tertiary treatment of municipal effluent – cropland sprayfield irrigation. Today, a similar problem has arisen one county over, and Tallahassee must decide if it will once again rise to the challenge and be progressive in its pursuit of wastewater treatment.

> *There are always better ways to do things, and we have to seek improved technology and methods, and accept new ideas and concepts, in order to move forward.*
>
> -Jim Stevenson, former chairman of the Florida Springs Task Force
>
> (Bruno, 2005)

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