Waters of the University of Florida

A Plan for Achieving Sustainable Water Management in the Lake Alice Watershed

Prepared by
Conservation Clinic
University of Florida Levin College of Law

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Executive Summary

This report provides a multi-disciplinary approach to sustainable water management on the University of Florida campus by using scientific data to inform policy and management.

In 1972, the United States Congress enacted the Clean Water Act. This act set forth groundbreaking standards for water quality including the reduction and elimination of point source pollutants. As a result, the nation's waters have, on the whole, improved in water quality.

Today, as a result, non-point source pollution, such as stormwater, is one of the leading causes of impairment. Identifying, managing and preventing non-point source pollution is one of the challenges facing municipalities and communities nationwide. The Clean Water Act addresses stormwater discharge through Phase II of the National Pollutant Discharge Elimination System (NPDES) program. The University of Florida (UF) obtained an NPDES Phase II permit in the fall of 2003. This permit renewed interest in and commitment to water quality, and in particular stormwater management, on the UF campus.

Hydrologic history of the main watershed on campus reveals that Lake Alice has had high nitrogen and phosphorus levels for more than thirty years. Lake Alice has also received numerous designations with potentially conflicting management goals including a Class III water body, a stormwater management system, and a university-designated conservation area. Water quality data for 15 sites throughout campus collected between November 2003 and December 2004 revealed high phosphorus levels throughout the campus and nitrate levels as high as 11.5 mg/L in two creeks, Hume Creek and Fraternity Row Creek. While there are no Class III numeric standards for nitrate levels, research has shown toxicity levels to freshwater species at concentrations below 10 mg/L. A characterization of the Hume Creek watershed during storm events and dry weather periods indicates three stormwater drainage culverts contribute high concentrations of nitrate to the sub-watershed. These culverts receive water from athletic field drainage areas indicating that fertilizers may be the primary source of nitrates.

The scientific data from both the Campus Water Quality monitoring program and the Hume Creek characterization enable the university to potentially address a long-standing water quality concern in Lake Alice through comprehensive basin management, targeted BMP implementation and a Community-Based Social Marketing Strategy. It is through this multi-disciplinary approach to management that the University of Florida may attain sustainable surface waters.

Conclusions and Recommendations

Hydrologic History of Lake Alice

- The Lake Alice watershed is a fully enclosed basin and the watershed is completely within UF campus.
- 1925 – UF purchased the lake and the area around Lake Alice.
- Prior to 1948 – Lake Alice received sewage input and stormwater runoff.
- 1948 – Lake Alice stopped receiving sewage inputs and an earthen dam was constructed which increased the surface area of the lake.
- 1960's – UF began discharging secondarily treated sewage effluent into Lake Alice.
- 1994 – Sewage effluent was diverted to Water Reclamation Plant.
- Today – Lake Alice receives stormwater and irrigation water runoff.
- Historic data reveals high phosphorus and nitrogen values for the past thirty years.

Regulatory Overview of Lake Alice

Lake Alice is:

- A water of the United States that is regulated by Clean Water Act and NPDES permits;
- A water of the State which requires water quality monitoring and adherence to Class III water quality standards;
- A UF conservation area; and
- A permitted stormwater system which is assumed to meet water quality standards if the permit criteria are met and does not require water quality monitoring.

The proposed UF Comprehensive Campus Master Plan 2005-2015 states that UF shall monitor internally "in order to meet Class III water quality standards" (Conservation Committee, September 2005).

Scientific Findings

- A Campus Water Quality monitoring program (CWQ) was launched in the fall of 2003 to evaluate fifteen sites throughout campus for twelve parameters including nitrogen and phosphorus.
- The first year of data indicated sites have dissolved oxygen levels of concern (below Class III standards).
- Nitrogen and phosphorus levels in Lake Alice are typically higher than comparable water bodies (such as Bivens Arm), but there are no numeric criteria which limit the levels of nitrogen and phosphorus.
- Most nitrogen found on campus is in form of nitrate which is found in fertilizers, wastewater, and agricultural runoff.
- Nitrate can run off the surface or leach through the soils. Direct links between surface water nitrates and groundwater nitrates have been made.
- Nitrate concentrations are commonly below 1 mg/L in surface waters (EPA, 1997).
- Recent scientific research recommends that nitrate levels not exceed 2 mg/L in order to prevent toxicity to freshwater organisms (Camargo, 2005).
- Two creeks on campus consistently have nitrate levels above 2 mg/L, Hume Creek and Fraternity Row Creek.
- The watersheds for Hume Creek and Fraternity Row Creek both have athletic fields with underdrain systems.

Conclusions

- The UF Comprehensive Master Plan has committed internally to meet Class III standards, but UF does not have a comprehensive plan to achieve this.
- At a minimum, a comprehensive management plan for maintaining university waters should be created and implemented.
- Since Class III nutrient standards are narrative, they are susceptible to varied interpretations.

- Recent scientific research suggests some criteria for nutrients, such as nitrate, should be more specific than existing narrative standards.
- To achieve UF conservation goals for campus waters, UF should develop internal numeric limits to nutrient concentrations such as nitrate.
- This voluntary adoption of internal limits would define UF as a leader in water quality management.
- UF could apply the structure of the Total Maximum Daily Load program to define internal nutrient goals and develop a Basin Management Action Plan.

Recommendations

Adopt an internal Total Maximum Daily Load (TMDL) for all campus waterways that are considered conservation areas.

- Establish a target maximum nitrate concentration of 2 mg/L.
- Establish a no net increase in volume, rate and pollutant load for nutrients.

Develop a Basin Management Action Plan to implement the TMDL.

<u>Expand the Campus Water Quality Monitoring Program</u>

- Consider adding additional sites to the current monitoring program.
- Begin collecting flow data in order to establish models for volume, rate and pollutant loads of nutrients.

<u>Develop a Management Structure for the Basin Management Action Plan</u>

- Establish a Water Task Force under the Office of Sustainability.

<u>Support Continued Stormwater Research</u>

- Develop a centralized mechanism to support, fund, recognize and record research activities, particularly related to Best Management Practices.

<u>Implement Appropriate Best Management Practices</u>

- Identify BMPs to address specific water quality concerns such as high nitrate concentrations. Potential BMPs to address high nitrate concentrations in the Hume Creek watershed:
  - Nutrient Management (soil moisture, establishing turf)
  - Re-use of water
  - Pretreatment (bioretention area)
  - Wetland Retention area in woods
  - Vegetated buffers (increasing to City of Gainesville or Alachua County recommendations and increasing plant species efficient at denitrification)
  - Denitrification in floodplain soils (spray application)
- Flexible implementation of each BMP should be prioritized to those locations and practices where the greatest benefit in water quality can be achieved for the most reasonable cost.

<u>Establish a Social Marketing Plan for Behavioral Change</u>

- Launch a community-based social marketing strategy using six different behavioral change tools to achieve target behaviors: commitment, prompts, establishing social norms, communication, incentives, and removal of external barriers.

<u>Consider Establishment of a Stormwater Utility Fee</u>

- Develop an “equitable unit cost approach” based on the campus activities which have the greatest impact on water quality: driving, parking and fertilizing of athletic fields.
- Establish a stormwater fee based on one of three mechanisms:
  - Fee on cost of parking decal;
  - Fee on admission price of an event; and/or
  - Fee added to visitor parking.

SECTION 1
SURFACE WATER MANAGEMENT AT THE UNIVERSITY OF FLORIDA:
HISTORICAL AND REGULATORY OVERVIEW

Introduction

The goal of this report is to provide a technical overview of the Lake Alice watershed on the UF campus and propose recommendations for addressing pollutants identified within the watershed. Section 1 provides a regulatory and hydrologic history of the watershed showing how the waters have been utilized and managed in the past. This historical review shows that most water quality analyses on campus have been conducted within Lake Alice, excluding any analysis of contributing tributaries. Since nonpoint source pollution is one of the leading causes of impairment, isolating possible sources of pollutants to Lake Alice is a critical step. To identify potential nonpoint source pollutants within the watershed, a Campus Water Quality monitoring program (CWQ) was initiated in October 2003 to characterize water quality of all the tributaries on campus. Section 2 presents the data for the first year of the monitoring program, revealing that campus creeks had high phosphorus levels throughout campus and that two creeks had elevated nitrate levels. Section 3 provides a more in-depth characterization of one of the two creeks with elevated nitrate levels during storm events and dry weather periods. This characterization indicated three culverts were contributing high concentrations of nitrate. Section 4 discusses policy and management recommendations that would enable UF to meet its regulatory obligations while also improving the water quality on campus. Included within the recommendations are best management practices that could directly address the high nitrate concentrations.

Legal Status of the Lake Alice Watershed

The legal status of Lake Alice has been the subject of much debate since the inception of statutes that protect water quality. The US Environmental Protection Agency (EPA), the Florida Department of Environmental Protection (DEP), the St. Johns River Water Management District (SJRWMD), and the University of Florida (UF) have all debated whether Lake Alice is a "water of the United States," part of a stormwater management system or part of a wastewater treatment system. The legal determination of Lake Alice is important because it dictates how the waters are regulated and what, if any, water quality standards they must meet.

Federal Regulation

The Federal Water Pollution Control Act Amendments, now known as the Clean Water Act, were enacted in 1972 in order to protect the chemical, physical and biological integrity of the country's natural waterways. The initial act protected surface waters by setting water quality standards for contaminants, prohibiting point source discharges into navigable waters without a permit, and supporting the construction of sewage treatment facilities (US Code 1). In 1979, the EPA asserted regulatory jurisdiction over Lake Alice as a water of the United States on the grounds that it was a natural water body that affected interstate commerce (McGhee Appendix A-1). Lake Alice has been regulated under the Clean Water Act both through the impaired water listing process and the NPDES permitting process.

Under the impaired water 303(d) list process, the EPA requires each state to set Total Maximum Daily Load (TMDL) for areas that do not meet water quality standards. These areas are identified on the 303(d) list compiled by the state every two years for submission to the EPA (US Code 2). In 1998, Lake Alice was listed by the state of Florida as an impaired water on the 303(d) list due to high nutrient levels. By 2002, Lake Alice was de-listed because it met the water quality standards for its classification (Florida DEP 2002). Since Lake Alice is no longer on the 303(d) list, there are currently no TMDLs set for the water body.

The Clean Water Act has also required a National Pollutant Discharge Elimination System (NPDES) Phase I permit for any pollutant discharge to a water of the United States. Since the 1979 EPA decision to treat Lake Alice as a water of the United States, UF was requested by the EPA to obtain an NPDES permit for the discharge of sewage effluent into Lake Alice under Federal regulation 40 CFR 122.3 (1980) (McGarry Appendix A-11). According to UF Physical Plant Division, an NPDES Phase I permit for effluent discharge was never obtained (Hogan Appendix A-18).

In 1999, the EPA implemented the NPDES Phase II plan to regulate stormwater discharge in municipal separate storm sewer systems (MS4s) not covered in Phase I (Florida DEP 2005a). Under NPDES Phase II, those managing an MS4 must comprehensively deal with stormwater by reducing pollutant discharge, protecting water quality, meeting water quality standards, and implementing best management practices (BMPs). These efforts must include public education, participation and involvement, detection and elimination of illicit discharges, construction site runoff control, post-construction site runoff control, and pollution prevention (Florida DEP 2005b). The goal is to protect water quality, including meeting any applicable requirements of the Clean Water Act, and to reduce pollutant discharges to the “maximum extent practicable” (MEP), a standard which has neither a specific regulatory definition nor numeric effluent limitations. To achieve the MEP, the permit holder must implement approved BMPs, but is not required to conduct water quality monitoring (US EPA 2000). If a TMDL is established for the receiving water body, the permit holder must ensure that the discharge will not adversely affect the ability to meet the TMDL (US EPA 2004). UF received an NPDES Phase II permit for stormwater discharge in the fall of 2003.

State Regulation

Waters of the state, as defined by the state of Florida, “include, but are not limited to, rivers, lakes, streams, springs, impoundments, wetlands, and all other waters or bodies of water, including fresh, brackish, saline, tidal, surface, or underground waters” (Florida Statute 1). The water quality standards of these waters are subject to state regulation (FAC 2).

Bodies of water owned entirely by one person other than the state are only regulated for possible discharge onto another person’s property (Florida Statute 1). Lake Alice is currently owned by the Board of Trustees of the Internal Improvement Trust Fund, which holds all submerged and tidal land for use by the citizens of Florida (Florida Statute 2). As a body of water held in trust by the state, Lake Alice would therefore be subject to state-regulated water quality standards. In communications in 1994 and 1998, the DEP confirmed that Lake Alice was a water of the state according to Florida Statutes 403.031(13) and FAC 62-312.030 (formerly 17-312.030) (Tyler Appendix A-13).

In addition, under the Federal NPDES program, each state is responsible for designating a state agency to implement and enforce the NPDES permitting process. In Florida, the Department of Environmental Protection (Florida DEP) is " responsible for promulgating rules and issuing permits, managing and reviewing permit applications, and performing compliance and enforcement activities." (Florida DEP 2005a and US Code 1). Each state is required to designate an official use for each water body in its jurisdiction. In Florida, there are five classes: Class I (potable water); Class II (shellfish propagation or harvesting); Class III (recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife); Class IV (agricultural water supplies); and Class V (navigation, utility and industrial use) (FAC 8). As a legally designated Class III water body, Lake Alice is subject to an extensive list of water quality standards.

Florida also regulates stormwater through Environmental Resource Permits issued through each of five regional water management districts. The district that includes the UF campus is the St. Johns River Water Management District (SJRWMD). These permits have general criteria that all stormwater management systems must meet, along with special criteria that apply to individual stormwater management systems. A stormwater management system is a “system which is designed and constructed or implemented to control discharges which are necessitated by rainfall events, incorporating methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water to prevent or reduce flooding, overdrainage, environmental degradation, and water pollution or otherwise affect the quantity and quality of discharges from the system.” (Florida Statute 3)

In 1987, UF obtained a permit from the SJRWMD for stormwater management, including Lake Alice as a wet retention system for stormwater treatment. The rain that falls in this system and flows through it is considered the stormwater of the system (FAC 3). The series of creeks and ponds leading to Lake Alice provide treatment for UF's stormwater through natural filtration and sedimentation. The 1987 permit was renewed in 2000. The current permit attempts to curb stormwater pollution by preventing violations of state water quality standards through construction best management practices, calculating the amount of impervious surface in each basin, and regularly reporting to the St. Johns River Water Management District. The UF Physical Plant Division is responsible for maintenance of this stormwater system (SJRWMD 2000).

While the waters of the Lake Alice watershed are waters of the state, the permit issued in 1987 which allowed the watershed to be used as part of a stormwater management system does not require the university to monitor water quality. According to Florida statute,

> State surface water quality standards applicable to waters of the state, as defined in s. 403.031(13), shall not apply within a stormwater management system which is designed, constructed, operated, and maintained for stormwater treatment in accordance with a valid permit or noticed exemption issued pursuant to chapter 17-25, Florida Administrative Code; a valid permit issued on or subsequent to April 1, 1986, within the Suwannee River Water Management District or the St. Johns River Water Management District pursuant to this part. (Florida Statute 4)

Florida statute requires that one must have a permit to discharge any waste that lowers the quality of water that it is being discharged into (Florida Statute 5). Discharges to groundwater, unless under a specific exemption, should not violate water quality standards for the receiving water body (FAC 4) and monitoring of the discharge must occur (FAC 5). However, section (9)(a) exempts stormwater facilities from monitoring requirements if the discharge does not pose a "potential hazard to human health or the environment…and as long as the facilities do not discharge directly to ground water." (FAC 5) The UF Master Plan states that UF will abide by the conditions of the permits including "reporting water levels in monitoring wells quarterly and submission of groundwater and surface water monitoring tests to the Water Management District." (UF 2000)

At the western end of Lake Alice there are two wells, designated R-1 and R-2. R-1 is located near the bridge by the Baughman Center and R-2 is located near the Bat House. R-2 has been elevated to restrict the flow of Lake Alice water into the well except during high water conditions. R-1, however, has a lower weir enabling it to receive water from Lake Alice on a more regular basis. Currently, neither well is metered for water flows nor is water quality measured. The UF Physical Plant Division indicated that they are in the process of placing a meter on R-1 to fulfill the DEP permit requirements (J. Blair Appendix A-20). Because the Lake Alice water is permitted as stormwater, UF is not required to monitor the quality of water entering either well. Therefore, pollutant levels within the Lake Alice watershed, if left undetected and untreated, could pose contamination threats to groundwater.

Local Regulations

While UF acts as its own regulating entity, its actions inevitably have a major influence on the City of Gainesville and Alachua County. To maintain a high level of water quality, the three entities would ideally coordinate their regulation and management of surface waters, including the implementation of BMPs. State law requires educational facilities coordinate their master plans "with the local comprehensive plan and land development regulations of local governments" (Florida Statute 6).

The Alachua County Comprehensive Plan declares that environmental conservation will be a priority in all decision-making. With regard to stormwater, the Plan says it will "ensure the protection of natural drainage features, including surface water quality and groundwater aquifer quality and quantity recharge functions, from stormwater runoff." Where appropriate, the Plan advocates for "the use of system upgrades, the use of drainageways…as habitat corridors which allow the passage of wildlife between natural areas and throughout the County, as well as providing wildlife habitat". The Plan also calls for the creation of a surface water monitoring program that will develop baselines for water quality as well as biological health (Alachua 2005).

The UF Master Plan includes an Intergovernmental Coordination Element which "establishes a development review process, to be implemented in conjunction with host and affected local governments, to assess the impacts of proposed development on significant local, regional, and state resources and facilities." The Master Plan also states that "level of service standards for … stormwater management (quantity and quality)…shall not be in conflict with those established by the City or County." (UF 2005b) In September 2005, the Conservation Area Study Committee of the Campus Master Planning 2005-2015 process, adopted the following policy:

> Policy 3.7: The University shall continue to monitor Lake Alice and other surface water bodies for compliance with existing standards for water quality in order to meet Class III water quality standards and report findings to the Lakes, Vegetation and Land Use committee annually (UF Conservation 2005b).

The UF Master Plan does not recommend the creation of performance indicators or baselines to measure ecosystem health.

Many local regulations include minimum standards for vegetative buffers around waterways as a mechanism for improving water quality. Buffers can filter silt and pollutants from the water entering the waterway (US EPA 2005a). They also aid in slowing the entry of water into the waterway thereby reducing erosion. Alachua County's Comprehensive Plan requires an average 50 foot buffer (35 foot minimum) for surface waters and wetlands less than or equal to 0.5 acres and 75 foot buffer on average (50 foot minimum) for waters and wetlands greater than 0.5 acre (Alachua 2005). The City of Gainesville Comprehensive Plan establishes a buffer along waterways of at least 35 feet (Gainesville 2001). The Conservation Area Study Committee has established a 25-foot buffer next to creeks, ponds and sinkholes on campus (UF Conservation 2005a).

History of Hydrology and Water Quality

Lake Alice, originally called Jonas Pond, was surrounded by farmland and owned by Mr. Witt in the late 1800s. The pond (at that time only two to three acres) was renamed "Alice" after his daughter. UF purchased the Lake Alice area in 1925 as part of an agricultural experiment station.

The lake has undergone a number of changes in terms of size as well as hydrologic and nutrient inputs. Prior to 1948, the lake received infiltrating and runoff waters from the surrounding land as well as sewage inputs. In 1948, an earthen dam was constructed for flood control and irrigation purposes and the sewage was retained in a nearby treatment plant (Karraker 1953). This dam raised the level and surface area of the lake. Much of the prior vegetation including *Cephalanthus occidentalis* (buttonbush), *Quercus virginiana* (live oak), *Pinus taeda* (loblolly pine) and *Liquidambar styraciflua* (sweetgum) was replaced by *Myrica cerifera* (wax myrtle), *Ludwigia peruviana* (willow), *Acer rubrum* (red maple), *Hydrocotyle* (water pennywort), *Eichhornia crassipes* (water-hyacinth), *Pontederia cordata* (pickerel weed), and *Typha* (cattail) (Jenni 1961).

In the 1960's the lake started receiving secondarily treated effluent from the sewage plant and the university medical center's cooling plant. By 1971, Lake Alice was estimated to receive 1 to 2 million gallons per day of effluent and 10 to 12 million gallons per day of cooling water. At this time, Lake Alice exhibited high phosphorus levels (0.9 mg/L) when compared to other Florida lakes, which had typically below 0.1 mg/L of phosphorus. Sewage inputs were thought to be the reason for this high phosphorus level. The annual nitrogen load to Lake Alice was calculated to be more than double any other lake surveyed in Florida (Brezonik and Shannon 1971).

Eichhornia crassipes (water hyacinth) flourished in the lake, possibly as a result of the increased nutrient load. In order to control the water hyacinth, a number of measures were taken including a drag-line, hand removal, and herbicide application (Brezonik and Shannon 1971). The construction of a boardwalk and wire fence encouraged the development of a water hyacinth marsh on the eastside of the lake, where there was once a prairie, while maintaining open water to the west creating conditions similar to current ones with approximately 12 hectares (29.6 acres) of open water and 21 hectares (51.9 acres) of marsh (Gottgens 1981).

In 1975, sampling along the perimeter of Lake Alice revealed that temperature, turbidity, conductivity and nitrogen decreased as water flowed through the marsh whereas dissolved oxygen increased indicating that the marsh provided an important transitional treatment zone for the incoming water (Mitsch 1975).

In 1976, cooling plant effluent was diverted from the lake but sewage effluent continued to provide a high nutrient level to the lake (Vega 1978). In 1977, the waste water treatment plant averaged approximately 1.85 million gallons a day of output (Gottgens 1981). By 1981, concentrations of phosphorus had increased to between 0.98 mg/L and 2.57 mg/L. The lake's water-hyacinth-dominated marsh system was successfully reducing the amount of phosphorus by an average of 25% a year. However, much of this reduction was probably the conversion of inorganic phosphorus to organic forms. Therefore, when the hyacinth died, the phosphorus was re-mineralized in the decomposition process, thereby contributing the phosphorus back to the system (Velga and Ewel 1981).

In 1982, Florida regulations stipulated that discharges into potable aquifers must meet drinking water standards (FAC 7). A high coliform concentration was identified in surface waters on campus that exceeded these standards. Since some of these surface waters had potentially direct connections to aquifers through wells and porous soils, a new sewage treatment plant on campus was constructed that would provide tertiary treatment (Korhnak 1996). When the Water Reclamation Plant opened in 1994, sewage was once again diverted from Lake Alice and phosphorus concentrations in the lake dropped from 1.141 mg/L to 0.59 mg/L. Further investigation suggested that stormwater probably also contributed to high phosphorus levels due to particulates from the Hawthorne Formation that eroded the tributary streambanks. Nitrogen concentrations also dropped from 2.430 mg/L to 0.93 mg/L. The data suggested that nitrogen was being lost and possibly denitrified in the anoxic marsh system (Korhnak 1996).

Florida LAKEWATCH data from 1997 – 2003 showed phosphorus ranges in Lake Alice to be between 0.3 and 0.7 mg/L and nitrogen levels between 0.4 and 1.3 mg/L, indicating a continued eutrophic state, but a lower range of values than those found in 1994 (US EPA 2005c). Data collected between 1998 and 2002 both in Lake Alice and Hume Pond found similar total phosphorus concentrations ranging from 0.2 mg/L to 0.9 mg/L. Additionally, nitrogen levels in Hume Pond were higher than levels found in the lake confirming again that denitrification may be occurring in the marsh system (Canfield 1998 – 2002).

Table 1-1. Summary of historical phosphorus and nitrogen concentrations for Lake Alice.

Author, Date	**Phosphorus**	**Nitrogen**
Brezonik and Shannon 1971	0.9 mg/L	0.5 mg/L
Velga and Ewel 1981	0.98 – 2.57 mg/L	
Korhnak 1994 (with sewage)	1.141 mg/L	2.430 mg/L
Korhnak 1995 (no sewage)	0.59 mg/L	0.93 mg/L
US EPA 2005c and Canfield 1998-2002	0.2-0.9 mg/L	0.4-1.3 mg/L

Current Hydrology

Since 1994, the primary inputs into Lake Alice have been stormwater runoff; irrigation water; inter-storm discharges; and direct inputs from rainwater. Any pollutants that existed in a water body in the Lake Alice watershed would come from one of these sources.

Stormwater runoff is probably the greatest source of water to Lake Alice, draining all of the impervious surfaces in the watershed including pavement, roofs, and sidewalks. As impervious surfaces increase, so does the hydraulic load to the lake. This runoff can pick up pollutants such as oil, grease, and sediment and carry them to the creeks and the lake.

Irrigation water landing on a sidewalk or street can travel into the storm drain system. Additionally, athletic fields with under-drains could drain excess irrigation water into the storm system. According to the Physical Plant Division of the University of Florida, 90% of the irrigation water used on campus is reclaimed water which is treated to Class I water quality standards (potable water) (UF Physical Plant 2005). Irrigation water, regardless of its source, can also pick-up fertilizers and other chemicals applied to the vegetation.

Illicit discharges may contribute to unaccounted nutrient loads but are difficult to detect. During a visit to the Stormwater Ecological Enhancement Project (SEEP) in 2004, water flow entered the SEEP at two different culverts even though there had not been any recent rainfall (M.D. Annable, personal communication, April 1, 2004). Similarly, visits in 2005 revealed inter-storm water inputs into the Hume Creek watershed from four different storm culverts. In one case, a strong smell of bleach emanated from the water leaving the culvert. In another case, a culvert discharge was traced back to a storm drain that was receiving water from a parking lot stormdrain where vehicle washing was occurring (O. Wells, personal visit, July 13 and July 14, 2005). At other times, creeks on campus have had a milky white coloration indicating an unusual substance in the water (O.Wells, personal visit, March 15, 2004).

Further investigation would be needed to characterize whether the nature of potentially illicit discharges. Similarly, there is a need for water quality data on upstream tributaries to assess the sources of nitrogen and phosphorus to the Lake Alice watershed. Section 2 addresses this need by providing a scientific investigation of water quality throughout the University of Florida main campus.

SECTION 2
WATER QUALITY ON THE UNIVERSITY OF FLORIDA MAIN CAMPUS

Introduction

As discussed in section one, each state is required to designate an official use for each water body in its jurisdiction, based upon the relative water quality required for that water body. The five water quality designations, from Class I to Class V, are based upon whether that water is intended to be potable, safe for human contact, or able to maintain a healthy ecosystem. All of the waters on the UF campus are designated by the state of Florida as Class III waters which requires water quality that is both safe for human recreation and capable of maintaining a healthy fish and wildlife population.

There are seventy-one water quality criteria for Class III waters, some of which have specific numeric limits and some of which have narrative criteria with no specific numeric limits. If met, these criteria should ensure that the water body can provide a healthy habitat and resource for both aquatic and terrestrial organisms. If not met, an imbalance can occur in the ecosystem such as eutrophication, a process of high productivity which can result in algae blooms, decreased oxygen availability, and even the death of organisms.

The Campus Water Quality monitoring program tested twelve parameters, some of which have Class III criteria and some which do not. Three of the twelve have numeric Class III standards (pH, conductivity, and dissolved oxygen), two have narrative standards (phosphorus and nitrogen), and the remaining eight do not have Class III standards. This report will only include results for those parameters listed in the Class III standards.

Methods

Characterization of the Lake Alice Watershed

Land use

The 1,827 acre UF main campus is part of four different watersheds: Lake Alice, Hogtown Creek, Bivens Arm and Depressional Basins (Figure 2-1). More than 60% of the campus lies in the Lake Alice watershed (1,140 acres). This watershed is a closed basin system, meaning that all of the water that enters into the watershed terminates at Lake Alice making UF solely responsible for the management of the system (UF 2000).

The Lake Alice watershed was predominately agricultural in the late 1800s, but by 1971 the land use was over 60% urban, with the remainder being fertilized crop (27%) and forested areas (12%) (Brezonik and Shannon 1971). Within the Lake Alice watershed, approximately 40% (425.7 acres) of the area is comprised of impervious surfaces that inhibit downward infiltration of water (McElhoe 1998). These include parking spaces, roads, buildings, and other hard surfaces. All of these surfaces drain stormwater into the stormwater sewer system which conveys through culverts, creeks and ponds that all terminate in Lake Alice, thus increasing the amount of water that would naturally drain to Lake Alice.

Table 2-1. Reported UF Campus Land Uses, 2000 (UF 2000)

Land Use Type	Acres	Percent of Total
Academic	581.4	31.8%
Support	125.15	6.8%
Housing	106	5.8%
Utility	21.11	1.2%
Cultural	12.72	0.7%
Parking	164.61	9%
Active Recreational†	269.69	14.8%
Passive Recreational‡	201.77	11%

Conservation	344.86	18.9%
Total acreage	1827	100%

† Active Recreational includes gyms, pools athletic fields
‡ Passive Recreational includes open spaces but not conservation areas

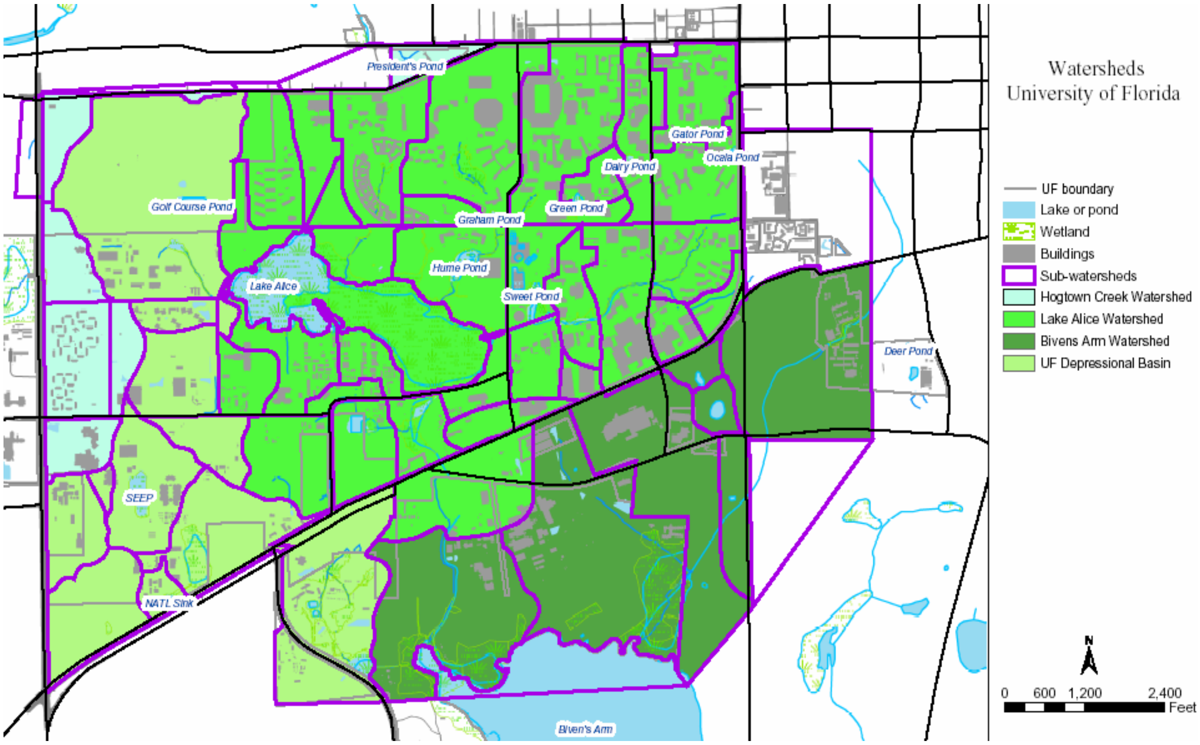


Figure 2-1. Watersheds, University of Florida (UF Office of Planning 2005).

Wildlife

Lake Alice, is considered an Audubon Society sanctuary implying that the lake is a valuable habitat for fish and wildlife (Mitsch 1975). In fact, the lake is known for its prime alligator and wading bird viewing. Vertebrate Zoology at UF lists ospreys, great blue herons and double-breasted cormorants as some of the water birds using Lake Alice (UF Zoology 2005). In the UF's management plan for the Lake Alice South Wetland, many species that may visit the area are listed:

> American Crow, American Goldfinch, American Robin, Bald Eagle, Baltimore Oriole, Black and White Warbler, Belted Kingfisher, Blue-Gray gnatcatcher, Brown-headed cowbird, Blue-headed Vireo, Blue Jay, Brown Thrasher, Boat-tailed Grackle, Carolina Chickadee, Carolina Wren, Downy Woodpecker, Eastern Bluebird, Eastern Phoebe, Eastern Tufted Titmouse, Great Crested Flycatcher, Gray Catbird, Hermit Thrush, House Finch, House Wren, Killdeer, Mourning Dove, Northern Cardinal, Northern Flicker, Northern Mockingbird, Northern Parula, Osprey, Palm Warbler, Pine Warbler, Pileated Woodpecker, Red-bellied Woodpecker, Ruby-crowned Kinglet, Red Headed Woodpecker, Red-Sanhill Crane, Shouldered Hawk, Red-winged Blackbird, Sharp-shinned Hawk, Yellow-bellied Sapsucker, Yellow-rumped Warbler, Anolis carolinesis, Brown anole, Gray Squirrel, Black rat (1), Raccoon, and Feral Cat. (UF Office of Planning 2005)

Site descriptions

Fifteen water sampling sites were selected throughout the main University of Florida campus along each tributary on campus (Figure 2-2). In some cases, multiple sites were placed along a single tributary to provide greater detail on the influence of smaller subwatersheds as well as potential treatment occurring through the stream. The majority of sites are within creeks which have natural, vegetative banks (as opposed to concrete or other impervious surface). Exceptions include site 8 which is within

Lake Alice, site 12 which is the UF Bostick Golf Course pond, and site 13 which is at a drainage culvert on the 7th fairway of the golf course.

Campus Water Quality Monitoring Sites

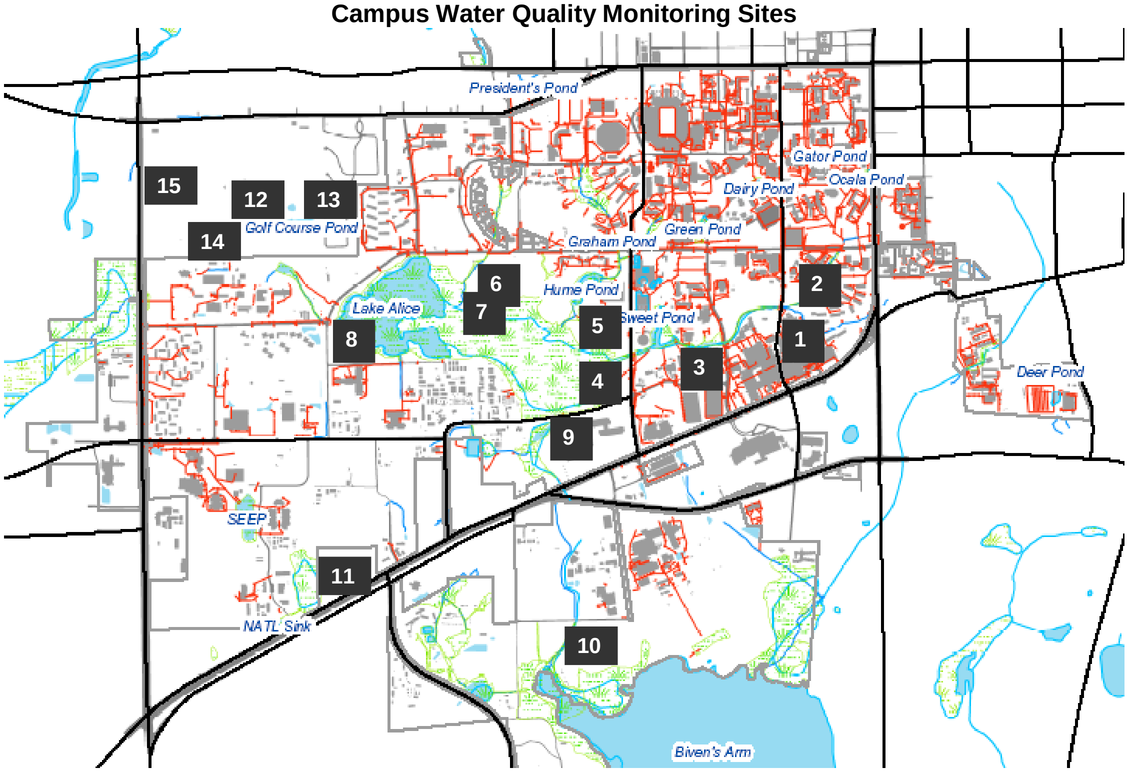


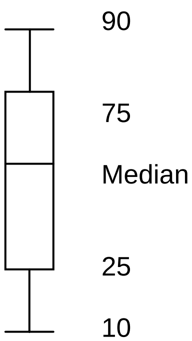
Figure 2-2. Campus water quality sampling locations on the UF campus

Sample Collection

Monthly water samples at each site were analyzed for temperature, dissolved oxygen, pH, conductivity, total dissolved solids, and redox potential were measured with a YSI 556 Multi-Probe Sensor (YSI Environmental, Yellow Springs OH). Thirteen sampling events took place between October 2003 and December 2004, with the exception of sites 12-15 where twelve sampling events occurred. Some sites experienced seasonal dry periods where there was little to no flow and sampling was not possible. Measurements were taken at the midpoint in the water column between 12:00 and 17:00 hours. A 500-mL water sample was collected from the mid-point in the water column. Samples were transported to the laboratory and processed according to standard operating procedures certified by the National Environmental Laboratory Accreditation Conference (NELAC). Samples were analyzed for total suspended solids, total nitrogen, nitrates, total Kjeldahl nitrogen, ammonium, total phosphorus, and soluble reactive phosphorus.

Statistical Analysis

The data for each parameter was presented in a graphic with site 10%, 25% 50% (median), 75% and 90% quartiles expressed as a box and whiskers plot.



Each graph also has a dotted horizontal line indicating the average for all points. Statistical outliers were retained on the graphic to show the full range in values of samples collected. Tables with the minimum, maximum, and mean for each site can be found in the Appendix C. Additionally, monitoring data from Bivens Arm collected by Lakewatch, a statewide volunteer lake monitoring program, was provided as a comparison when presenting total nitrogen and total phosphorus data.

Results and Discussion

pH

Class III standards require that pH not fall below 6 units or rise above 8.5 units in fresh waters (FAC 6). Extreme pH levels can limit the biological diversity and lower pH levels can mobilize some toxic elements. Geology, wastewater discharges and acid rain influence pH levels (US EPA 1997).

The pH ranged from 4.72 to 8.85 (Figure 2-5). This range exceeded the range set forth by Class III water quality standards. The majority of measurements, however, were within this range. Samples that fell below pH of 6 were taken on 5 different sampling dates and could be a result of discharges into the creek.

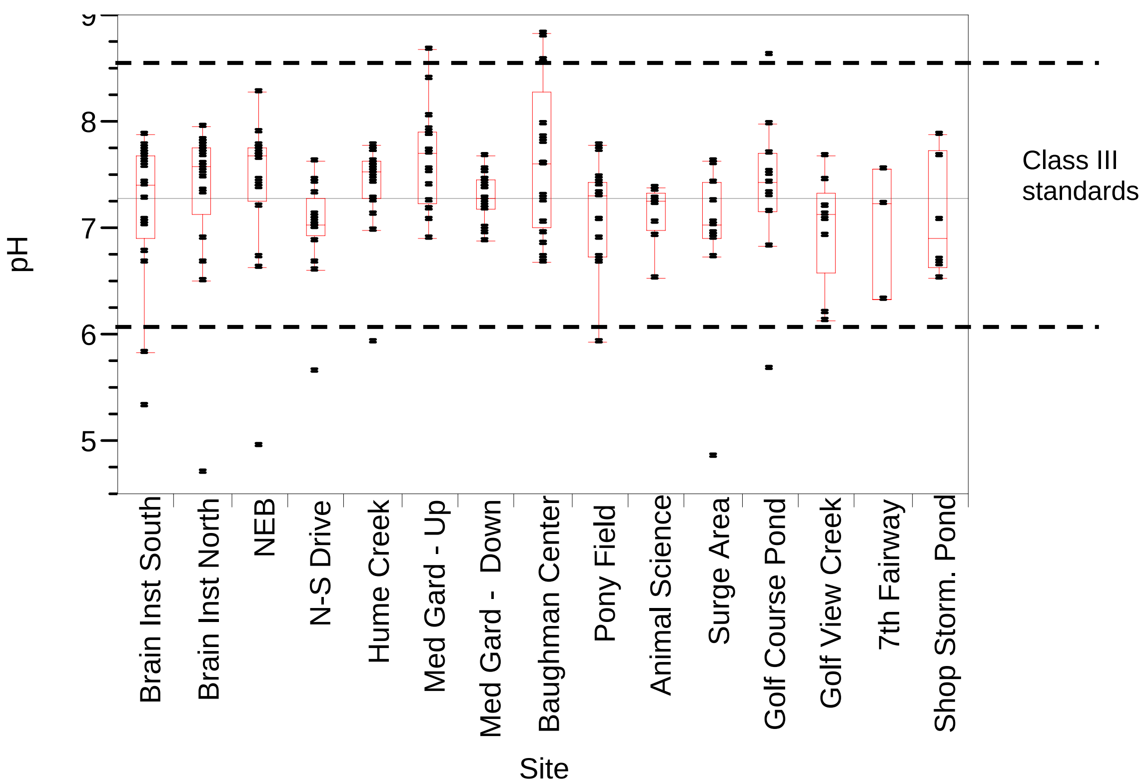


Figure 2-5. Levels of pH by site.

Conductivity

Specific conductivity should not exceed the greater of 50% more than background levels or 1275 according to Class III standards (FAC 6). Conductivity levels between 150 and 500 µhos/cm are optimal for maintaining fisheries. Geology and discharges are the primary influences on conductivity.

Conductivity ranged from 6 to 999 µS (Figure 2-6). The majority of data points, however were between 100 and 500 µS (area between dashed lines), the range acceptable for aquatic wildlife in freshwater ecosystems (US EPA 1997). Two sites, the Hume Creek and the Golf Course Pond, showed higher ranges for conductivity than those found in the other sites on campus. High conductivity levels for Hume Creek could have been due to high nitrate levels that were identified (described later in the chapter). However, high nitrates were also found at the Medicinal Garden sites (both up and downstream) and these sites did not appear to have elevated conductivity levels. High levels at the Golf Course Pond, on the other hand, may have been due to increased ion concentrations in the reuse water being supplied by the campus water reclamation facility for the pond. Both Hume Creek and the Golf Course pond had greater fluctuations of conductivity than other sites.

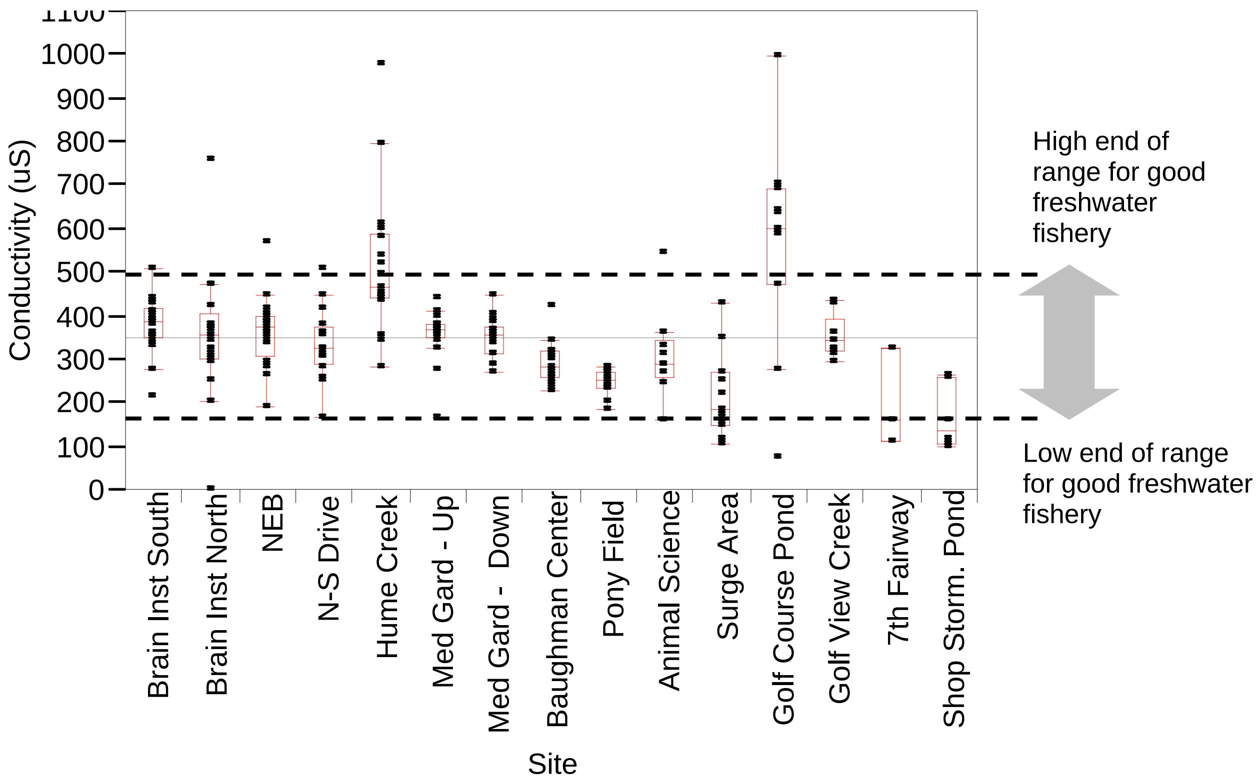


Figure 2-6. Conductivity by site.

Dissolved Oxygen

Dissolved oxygen should be maintained at or above 5 mg/L both on a daily and seasonal basis according to Class III standards (FAC 6). Dissolved oxygen levels fluctuate as a result of temperature, flow, rates of photosynthesis, decomposition, aquatic animal respiration and discharges to the water body (US EPA 1997).

Dissolved oxygen, in mg/L, ranged from 0 mg/L to 14.38 mg/L (Figure 2-8). Class III standards require that dissolved oxygen levels remain at 5 mg/L or higher.

While dissolved oxygen levels may fluctuate over a 24-hour period, most samples were collected at approximately the same time of the day between 12:00 and 17:00. The variation of dissolved oxygen levels between sites could have been due to a number of different factors. The Pony Field was one site which shows consistently low oxygen, possibly due to a high level of organic matter found in the water, whereas, the Golf Course Pond had higher daytime levels of oxygen which may have been due a high algal population. N-S Drive site, which had consistently low dissolved oxygen levels, was downstream from the Brain Institute and NEB sites, which all had acceptable levels. Reasons for this change in dissolved oxygen within the tributary were unknown but could have been a result of discharges between the NEB and N-S Drive sites or due to the flow of the creek through a wetland area which may have reduced the oxygen levels. The Shop Stormwater Pond samples water exiting a wetland system which naturally has lower dissolved oxygen levels than a stream system.

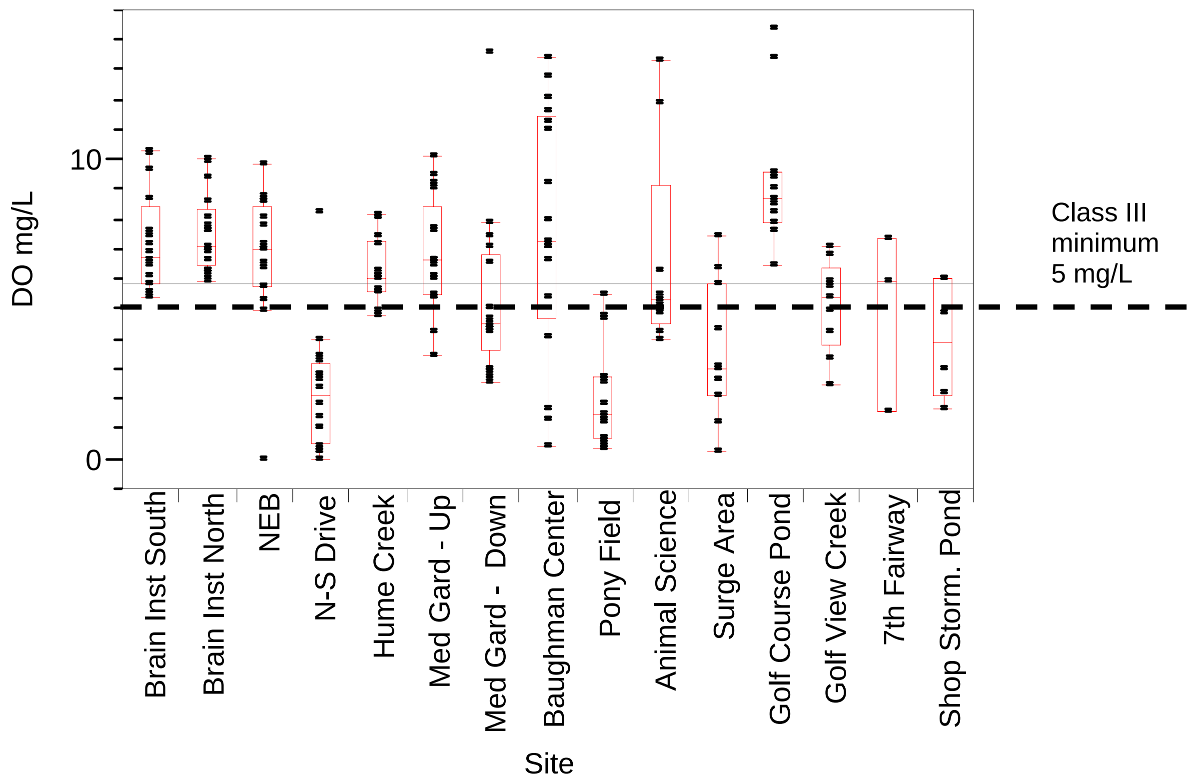


Figure 2-8: Dissolved oxygen in mg/L by site.

Total Nitrogen

Nitrogen levels do not have a numeric limitation in Class III water bodies. They are to be limited, however, “to prevent violations of other standards” and “in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna” (FAC 6). Higher levels of nitrogen can increase eutrophication rates. Nitrogen sources include blue-green algae, fertilizer, and waste products (Tippecanoe 2004).

The range of values for Total Nitrogen (TN) was 0.07 mg/L to 14.53 mg/L (Figure 2-11). There were no numeric Class III water quality standards for nitrogen. Three sampling sites consistently showed elevated TN values relative to the rest of campus. When compared to LAKEWATCH data for Bivens Arm, all sites had comparable values with the exception of the Hume Creek and Medicinal Garden sites which had ranges above the highest concentrations found at Bivens Arm (Figure 2-12). The Baughman Center site, located within Lake Alice, shows consistently low levels of total nitrogen indicating a potential loss of nitrogen in the system, most probably within the Lake Alice marsh.

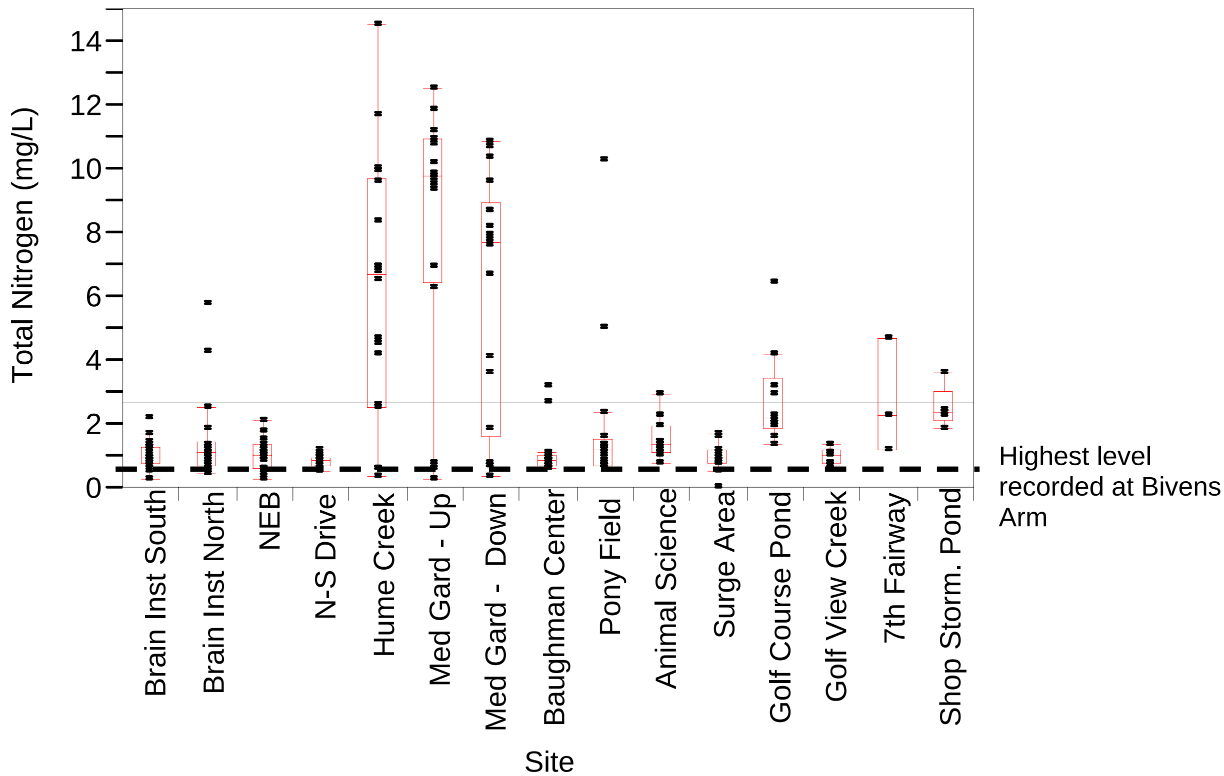


Figure 2-11. Total nitrogen concentration by site.

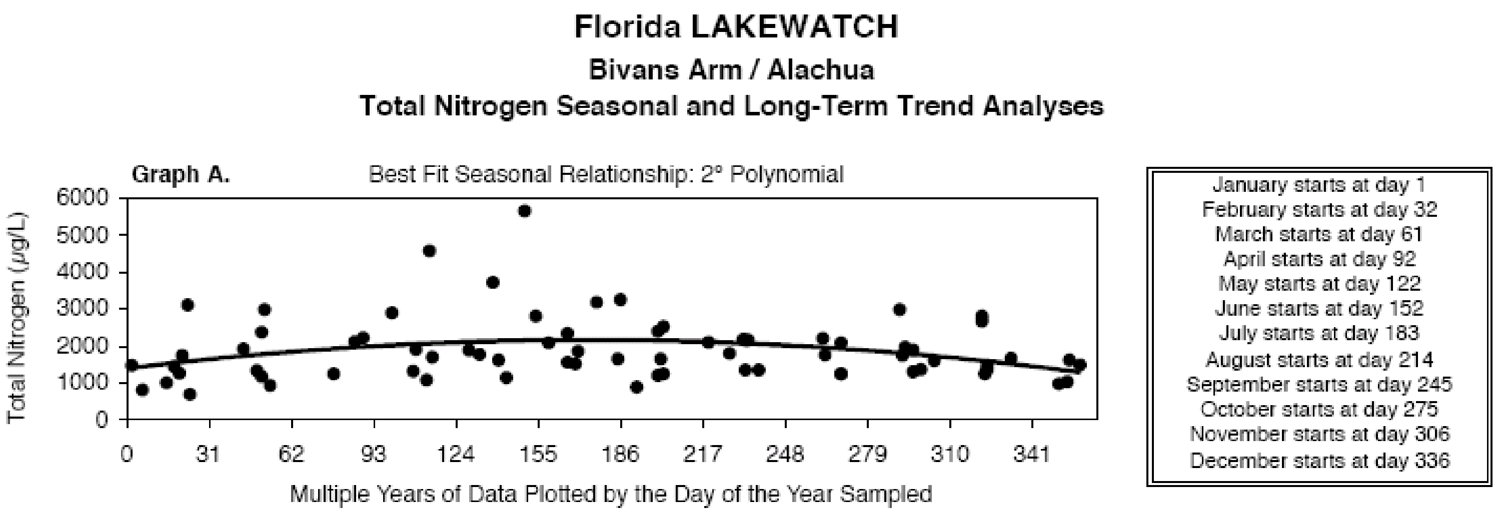


Figure 2-12. Florida LAKEWATCH data for total nitrogen concentrations of Bivens Arm (Florida LAKEWATCH 2003).

Nitrate

Nitrate, a form of nitrogen, does not have a Class III standard, but cannot exceed 10 mg/L in Class I Drinking Waters. Nitrate levels are commonly below 1 mg/L in surface waters (US EPA 1997). As nitrate levels increase, so does the rate of eutrophication. Some research has suggested that to prevent nitrate toxicity in sensitive freshwater organisms, levels should not exceed 2 mg/L (Camargo 2005). Nitrates come from fertilizers, wastewater, animal manure and other discharges (US EPA 1997).

The range for nitrate was 0 mg/L to 11.5 mg/L (Figure 2-13). There were no numeric criteria for nitrate levels in Class III waters. Nitrates comprised the majority of total nitrogen identified on campus. The Hume Creek and Medicinal Garden sites had consistently elevated nitrate values, corresponding to their high total nitrogen values. In a few samples, the levels exceeded 10 mg/L (the legal limit for Class I potable waters) which could result in toxic conditions for aquatic organisms (see dashed line on graph).

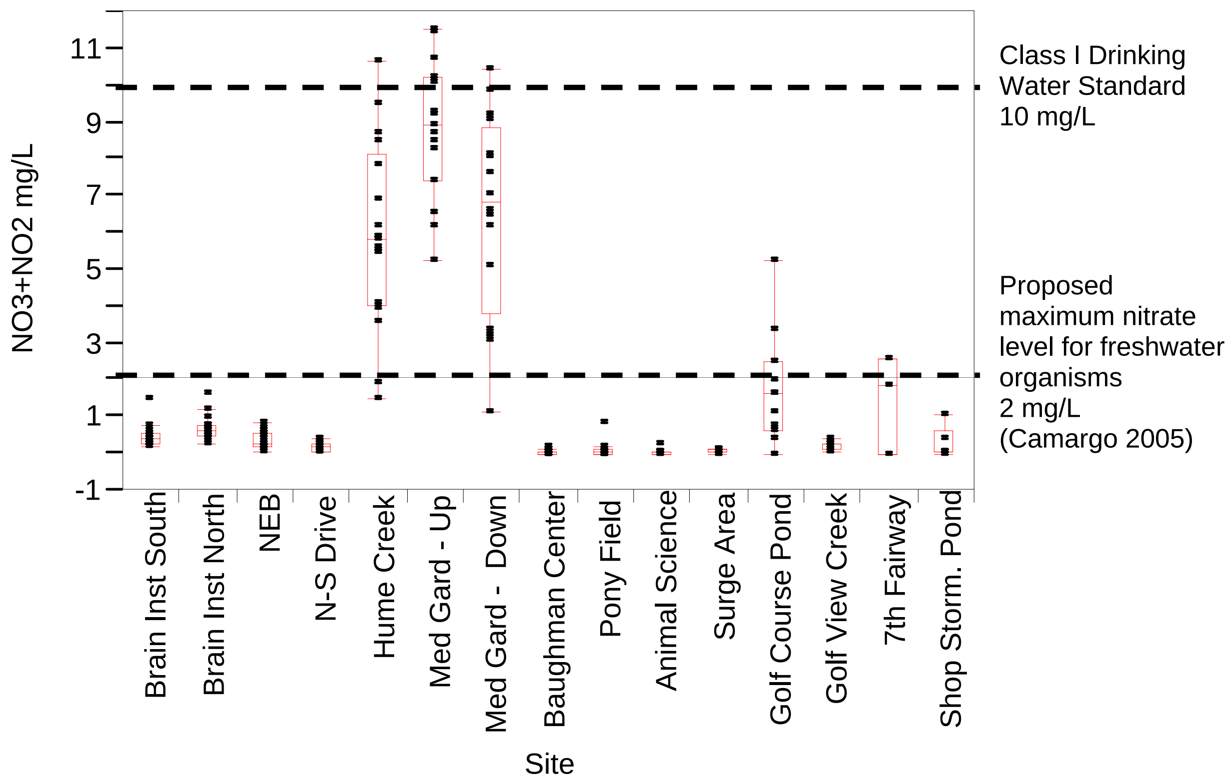


Figure 2-13. Nitrate concentration by site.

However, research has shown nitrate toxicity can occur at levels at or below 10 mg/L. A proposed nitrate level for a healthy freshwater ecosystem is 2 mg/L (Camargo 2005). The majority of sites on campus were below this level.

Phosphorus

Phosphorus, an essential nutrient, does not have a Class III standard, but in high concentrations can accelerate eutrophication. Phosphorus sources include geology, wastewater, fertilizers, animal waste, and other discharges (US EPA 1997).

The range of data for Total Phosphorus (TP) was 0.11 to 5.75 mg/L (Figure 2-16). There were no Class III standards for phosphorus. When comparing these values to LAKEWATCH data from Bivens Arm (Figure 2-17) the majority of samples on campus were higher (see dashed line at 0.5 mg/L on Figure 2-16). Phosphorus sources could have been natural or anthropogenic. A natural source of phosphorus may be from clay soils which are prevalent in the area. On the other hand, the Pony Field and Animal Science sites received runoff from animal pastures with animal waste, a likely contributing factor of phosphorus. The Golf Course Pond, 7th Fairway and Shop Stormwater Pond sites

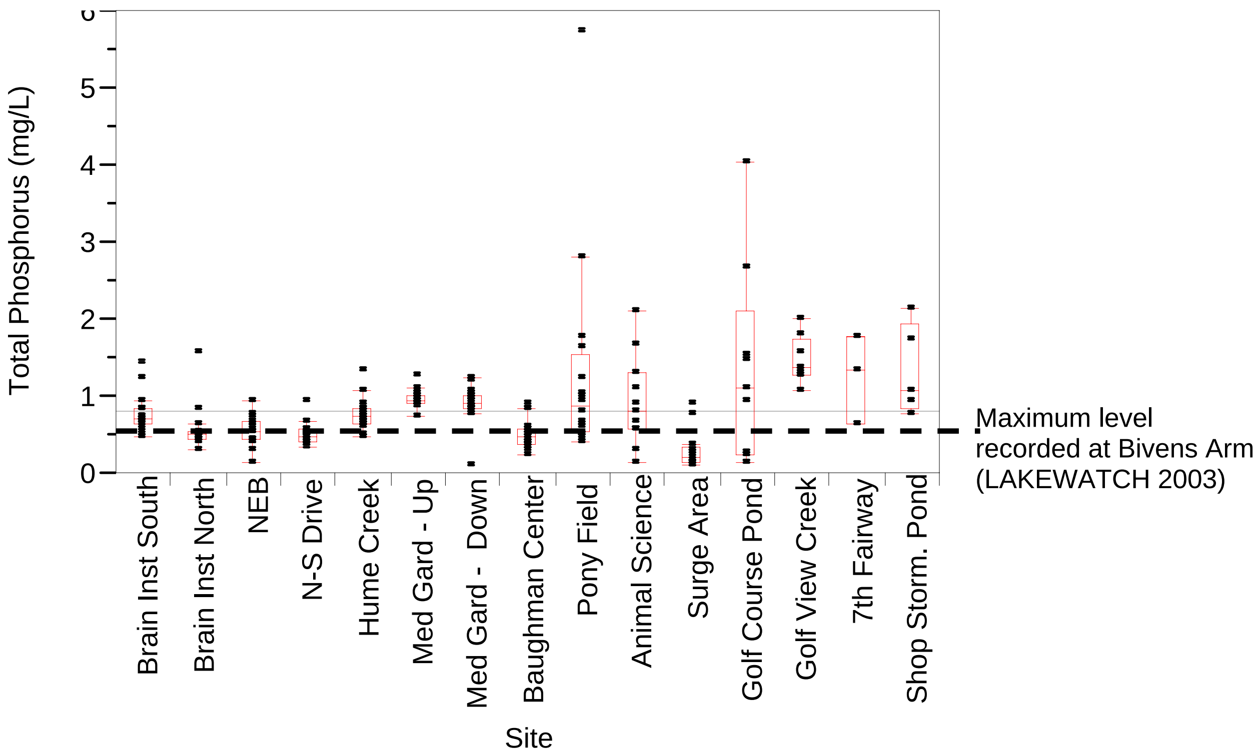


Figure 2-16. Total phosphorus concentration by site.

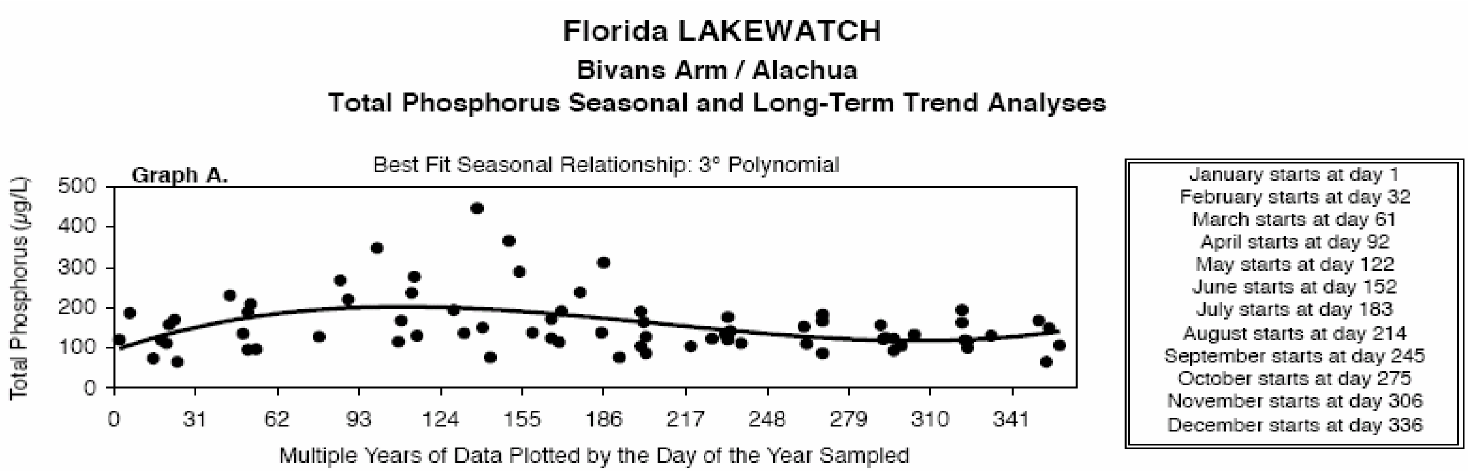


Figure 2-17. LAKEWATCH data for Bivens Arm (Florida LAKEWATCH 2003)

This first set of campus-wide water quality data provided a valuable characterization by which to identify potential pollutant problems. Many of the parameters did not have Class III water quality standards by which to measure the data. In these cases, ranges that were most habitable to freshwater aquatic organisms were identified and used as a benchmark by which to compare the data.

Of all the parameters studied, the nitrate data revealed ranges of most critical concern to aquatic organisms. This source of nitrogen may be a contributing factor to eutrophic levels within Lake Alice. It may also, however, pose dangers to the creek ecosystems if not kept in check. Section 3 will investigate the Hume Creek watershed in an effort to identify the sources of nitrate and enable appropriate best management practices to be implemented.

SECTION 3
NITRATE SOURCES IN HUME CREEK

Introduction

Nitrogen is necessary to maintaining life, however it can be toxic in excess amounts. Nitrate (NO_3), a form of nitrogen found in fertilizers, wastewater, and agricultural runoff, can be washed off of surfaces with irrigation or rain or it can leach through the soil. Once it enters a waterway it can remain there for extended periods until taken up by plants or wildlife or be reduced to nitrogen gas under anoxic conditions. In karst sensitive areas, higher nitrate concentrations have been found in groundwater which is near agricultural areas (Neill 2004). This direct linkage between the surface and groundwaters is particularly prevalent in North Central Florida.

In Florida, nitrate levels have increased in natural springs (waterways that emerge to the surface from underground aquifers) which were once thought to be safe from surface water pollution. A U.S. Geological Survey study in the Silver Springs Basin, Florida showed a more than 100% increase in nitrate since the 1960's with current concentrations at or above 1 mg/L. The maximum concentration measured was 12 mg/L, a level which exceeds the drinking water standard of 10 mg/L (Phelps 2004).

Although no specific threshold of concern for nitrate levels exist on campus, enriched nutrient levels in a water body can lead to excessive algal growth and an overall imbalance in the ecology of an ecosystem. Nitrate exposure has also been shown to cause abnormalities in amphibians at concentrations as low as 3 mg/L (Rouse 1999). One paper which reviewed published scientific literature on the impacts of nitrates on freshwater and marine animals found that long term exposure to nitrate concentrations of 10 mg NO3- N/L could have toxic effects on freshwater invertebrates. Researchers concluded that to prevent nitrate toxicity in freshwater levels should not exceed 2.0 mg/L (Camargo 2005).

The University of Florida has declared that all surface water bodies on campus are conservation areas. Keeping the nitrate level low is essential to maintaining a balanced ecosystem within Hume Creek. Campus-wide water quality testing found two creeks have elevated total nitrogen levels (Hume Creek and Fraternity Row Creek). An investigation of the Hume Creek sub-watershed was completed to locate possible sources of nitrate. The goals of this investigation were to

1. Determine nitrate concentrations for all culverts draining into Hume Creek during storm events;
2. Identify culverts which have flow during dry periods and determine nitrate concentrations for these flows;
3. Identify culverts with nitrate concentrations of concern; and
4. Examine the sub-watersheds of culverts with high nitrate concentrations to establish potential links with land-use.

If the nitrate source can be identified, preventative and treatment measures can be taken that will reduce the nitrate loading to the ecosystem, thereby meeting the goals of the conservation areas.

Methods

Site Description of Hume Creek

Hume Creek, unofficially named after Hume Pond through which it flows, begins with two forks and terminates at Lake Alice (Figure 3-1). The eastern fork originates in a ravine to the west of Reitz Union in the Reitz Ravine Woods. Seven culverts convey water to the creek in this wooded area (Figure 3-3). The creek is deeply incised in areas where heavy flows exit the culverts. The creek flow is slowed down through pooling, widening and meandering before it exits the ravine woods through a culvert under Museum and North-South Drives. When the creek exits the culvert, its banks have a few trees and some minimal vegetation with areas of mowed grass coming up to the edge of the creek in some areas before joining the western fork. The drainage basin for the eastern fork includes academic buildings, Reitz Union, the Ben Hill Griffin Stadium, and the Union Lawn.

The western fork begins in Graham Woods to the south of Perry Field and Stadium Drive. Fifteen culverts convey water into the western creek in these woods (Figure 3-2). Some areas of the creek have deeply incised streambanks near the culverts. Like the eastern fork, periodic pooling and widening assist in slowing the flow of water. The creek exits the woods through an underground culvert and empties into Graham Pond which often has maintained landscape edges with mowed grass and minimal vegetated buffers. The water leaving Graham Pond flows under Museum Drive and through a minimally buffered area where it joins the eastern creek. Once the two forks meet, the creek continues to the north of Parking Garage 5 (south of the Honors Residential College at Hume Hall), flows through Hume Pond, and terminates at Lake Alice. The drainage basin for the western fork includes the O’Connell Center, residential halls, the football practice field, Perry Field and a parking lot and garage. The combined sub-watersheds of the two forks comprise the majority of the total Hume Creek watershed.

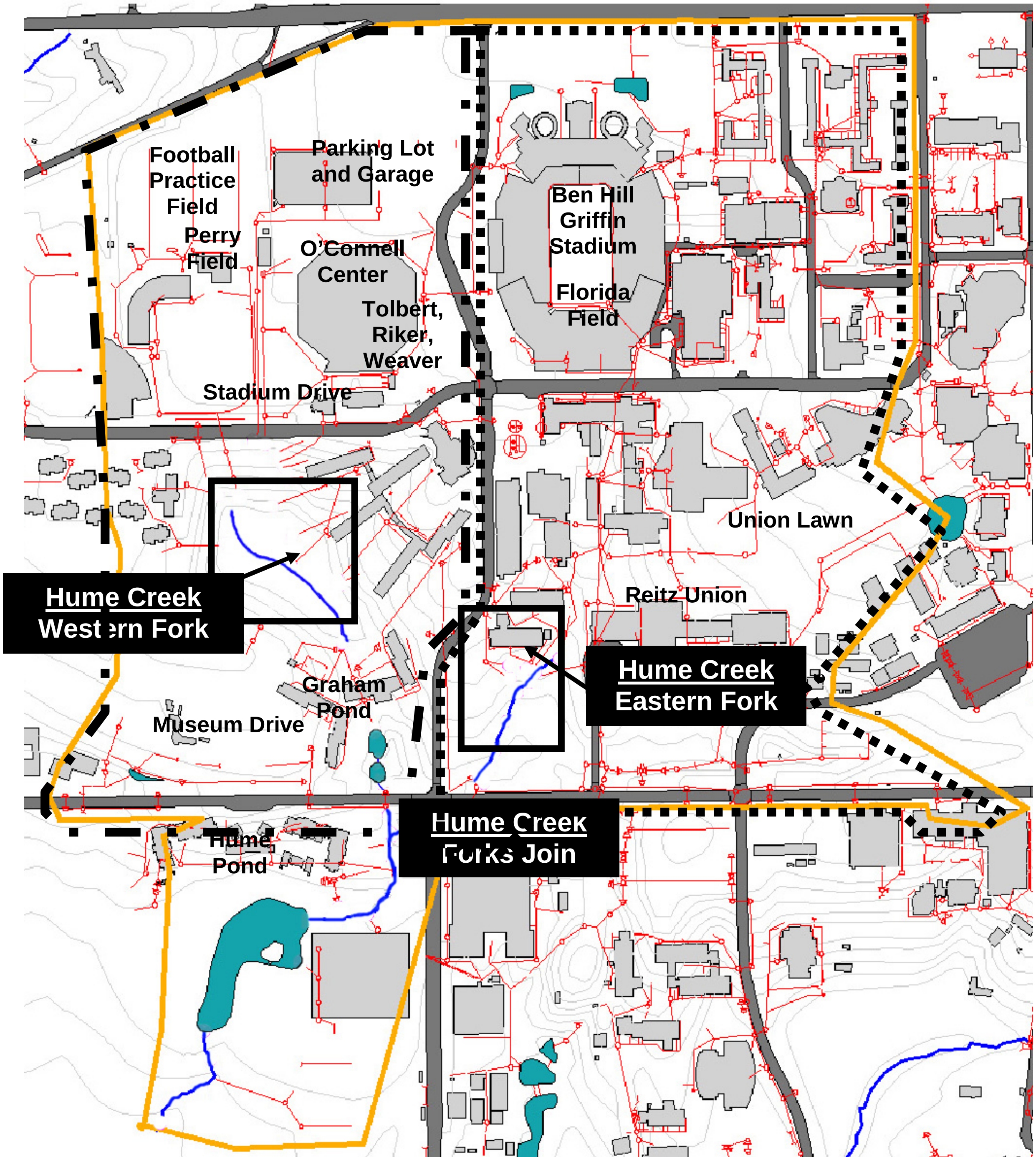


Figure 3-1. Hume Creek and the eastern and western forks. The sub-watersheds of each fork are outlined in dotted and dashed lines. The storm storm sewer system is shows underground drainage culverts, manholes and storm drains. Inset boxes indicate the two wooded areas where culverts drain into the two forks of Hume Creek. Each boxed area is enlarged below with site numbers for each culvert (Figures 3-2 and 3-3).

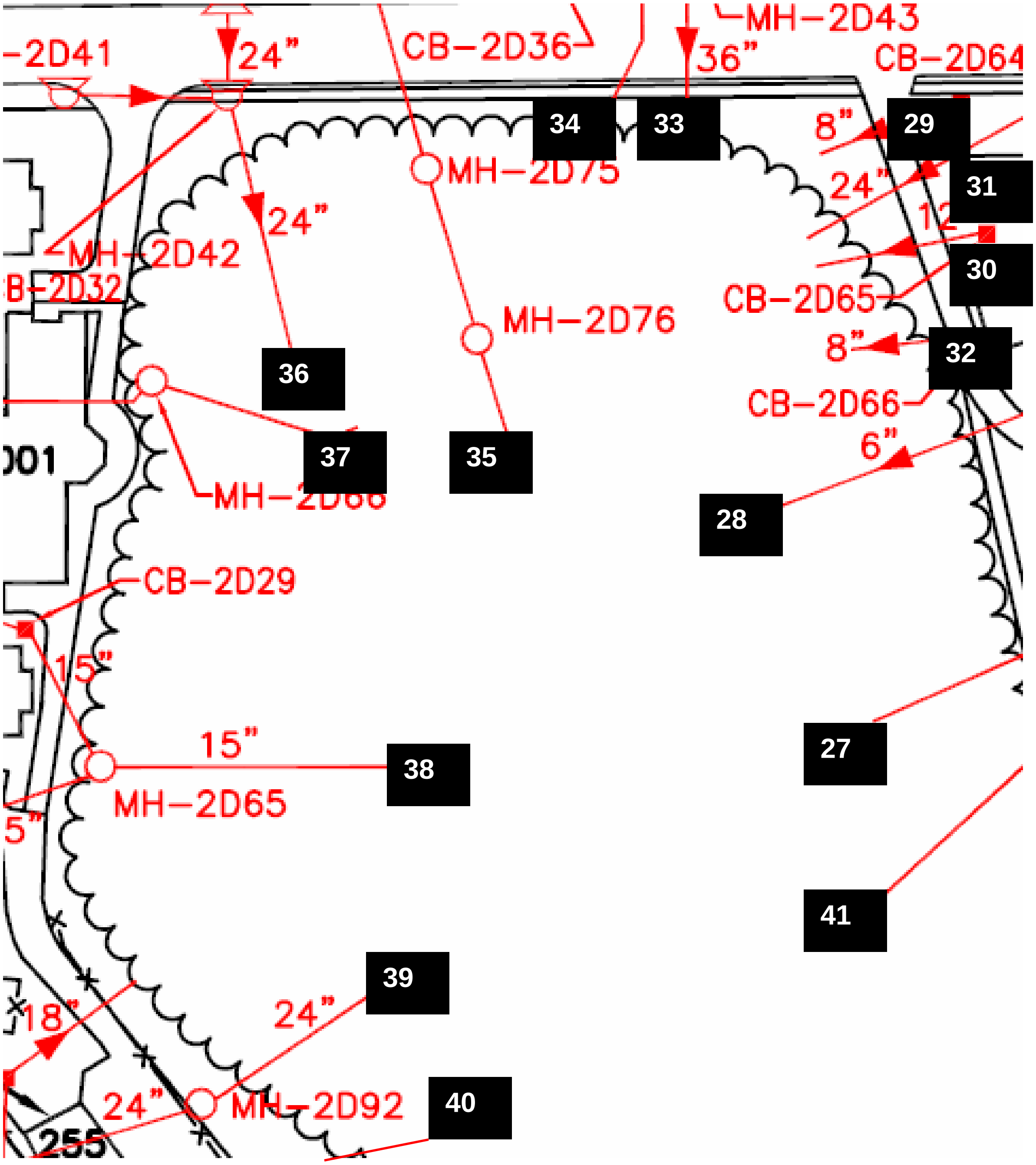


Figure 3-2. Graham Woods sites.

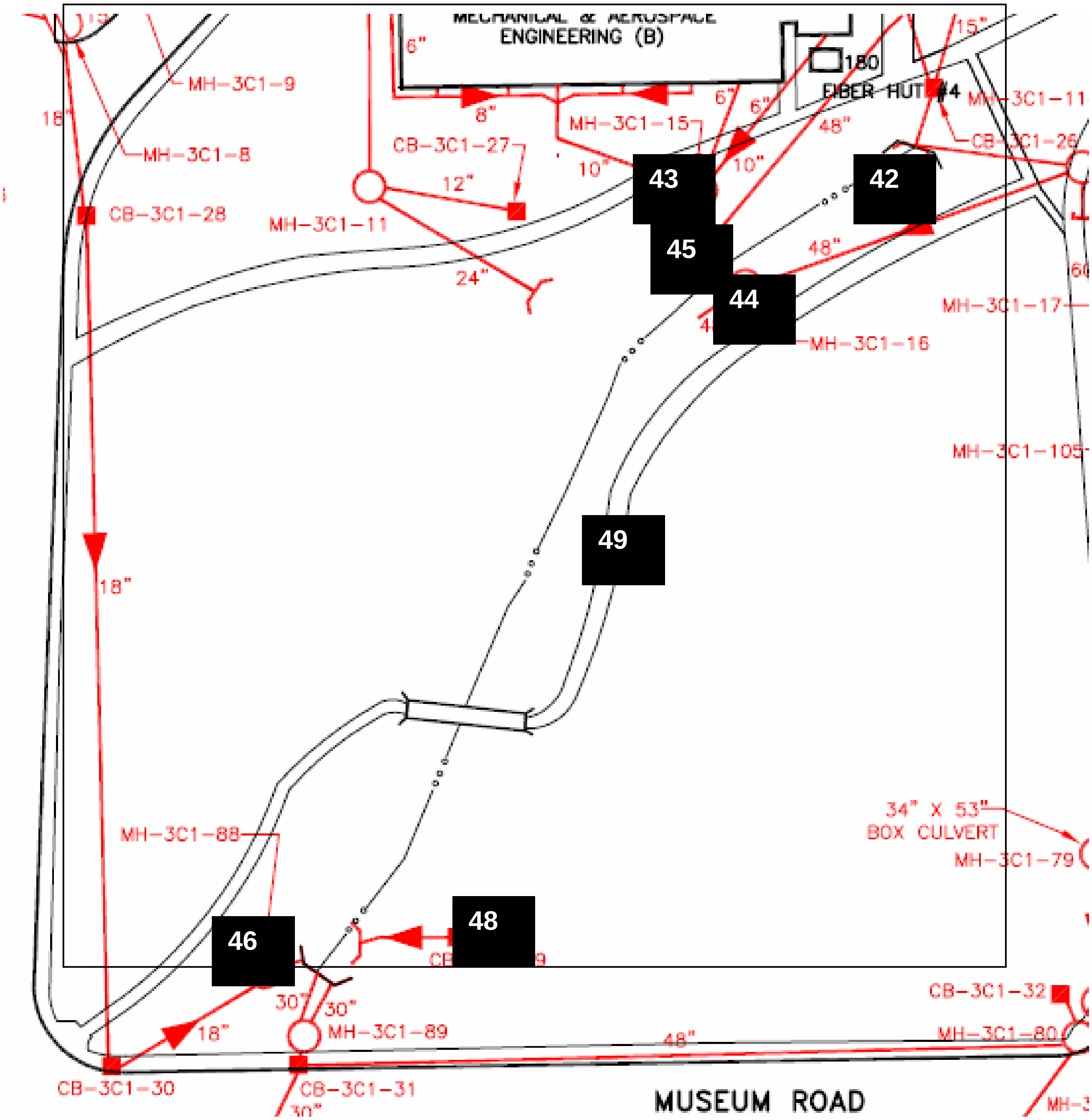


Figure 3-3. Reitz Ravine Woods sites.

Water Sampling

Two sampling experiments were conducted: a culvert storm sampling and a culvert dry weather sampling. Samples were measured for nitrate concentration. Flow data was not collected due to financial constraints of the project.

Culvert storm sampling

To establish stormwater nitrate concentrations for all culverts draining into Hume Creek, a culvert storm sampling device was designed to capture a random grab sample of water exiting each culvert during a storm event. All culverts were visited and diameter and material were documented (Table 3-1 and Figure 3-4). Two metal rods and a turnbuckle were inserted vertically into the culvert and tightened to maintain rigidity during a storm event (Figure 3-5). An acid washed 125-mL plastic bottle was attached to the bottom of the rod using zip ties. A small inflated balloon was inserted into the bottle to serve as a plug when the bottle filled up. The devices were tested during several storm events to ensure their stability and effectiveness. Samples were collected within 24 hours following the storm and, in most cases within 2 hours following the storm. Three storm events were sampled. Water which settled on top of the balloon during the storm (and after the bottle had filled up) was suctioned off before the sample was processed. All of the devices were set up no more than 24 hours before a storm to prevent contamination of the containers. Rainfall depth was recorded by a weather station located on the roof of the University of Florida Physics Building at the intersection of North-South and Museum Drives. In some cases the rainfall did not reach an intensity level to produce enough flow within a culvert to collect a sample.

Figure 3-4. Example of a culvert (site 35) with deeply incised creek walls.

Figure 3-5. Example of stormwater sampling device installed in a culvert.

Culvert dry weather sampling

The dry weather sampling experiment was designed to identify the concentrations of nitrate exiting culverts during dry, or non-storm event, conditions. Samples were collected from all culverts which had a flow after at least 4 days without rain. Additional samples were collected at the eastern and western forks and after the two forks joined. Samples were collected by hand in acid washed 50-mL plastic bottles, processed within two hours, and stored at 4 ^{o}C until analysis.

Results and Discussion

Culvert Storm Sampling

Storm events were sampled on 6/3/05, 6/22/05 and 7/14/05 with rainfall of 0.31 inches, 0.11 inches and 0.18 inches respectively. Most of the samples (69.3%) had negligible (< 1 mg/L) concentrations of nitrate and 83.6% of the samples had concentrations below 1.5 mg/L (Figure 3-6). Site 35, however, exhibited consistently high nitrate concentrations through all three storms with concentrations ranging from 7.58 mg/L to 38.6 mg/L. Site 36 had one sampling event with a higher nitrate concentration of 7.02 mg/L. Sites 44 and 45 showed slightly elevated nitrate levels as compared to other culverts in the watershed.

Since the sampling device collected a random grab sample during the storm event, it was impossible to tell when exactly during the storm the bottle filled up. Therefore, it was difficult to know how the nitrate concentrations varied at each site during the storm. An automated sampling device would provide more detailed information in future studies.

Site 26 was located in the creek (not a culvert) at the location where the western fork exited Graham Woods and enters an underground culvert before reaching Graham Pond. Nitrate concentrations at the location where the western fork exited Graham Woods (site 26) appeared to be elevated above the majority of the culverts in the western fork. The concentrations, however, were lower than that of site 35 which could indicate dilution of concentrations from site 35 or denitrification occurring in the ravine.

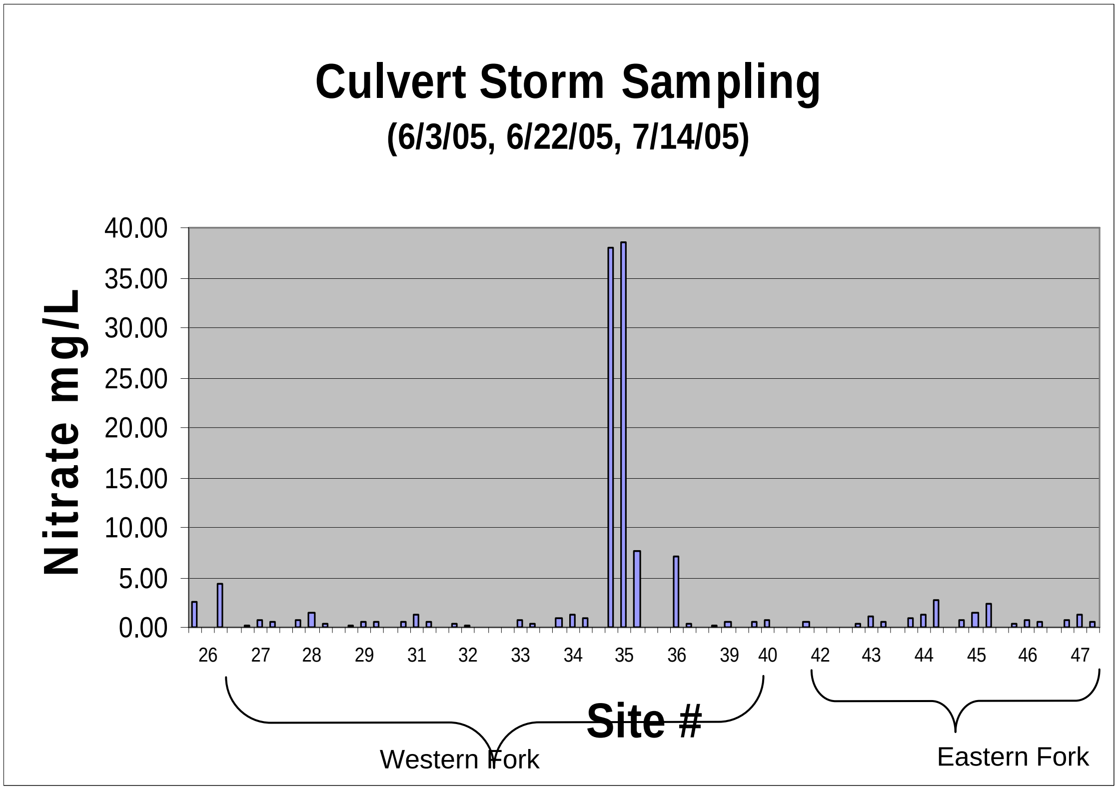


Figure 3-6. Cumulative Nitrate concentrations in culverts during three storm events. Site 26 samples the creek where it exited Graham Woods. Site 47 sampled the creek where it exited Reitz Ravine Woods.

Culvert Dry Weather Sampling

During each of the three dry flow sampling events, water discharged from four sites (33, 35, 44, and 45). Additionally, discharge was also found from site 27 during two sampling events. The remainder of the sites had no flow during any of the sampling events. Culvert concentrations were highest at site 35 (ranging from 4.63 mg/L to 9.62 mg/L) (Figure 3-7). This was the same culvert that had the highest nitrate concentrations during storm events, however the concentrations found during dry events were generally lower than the concentrations found during storm events (Figure 3-8). Higher storm event concentrations could be a result of fertilizer runoff from the athletic fields during the storm.

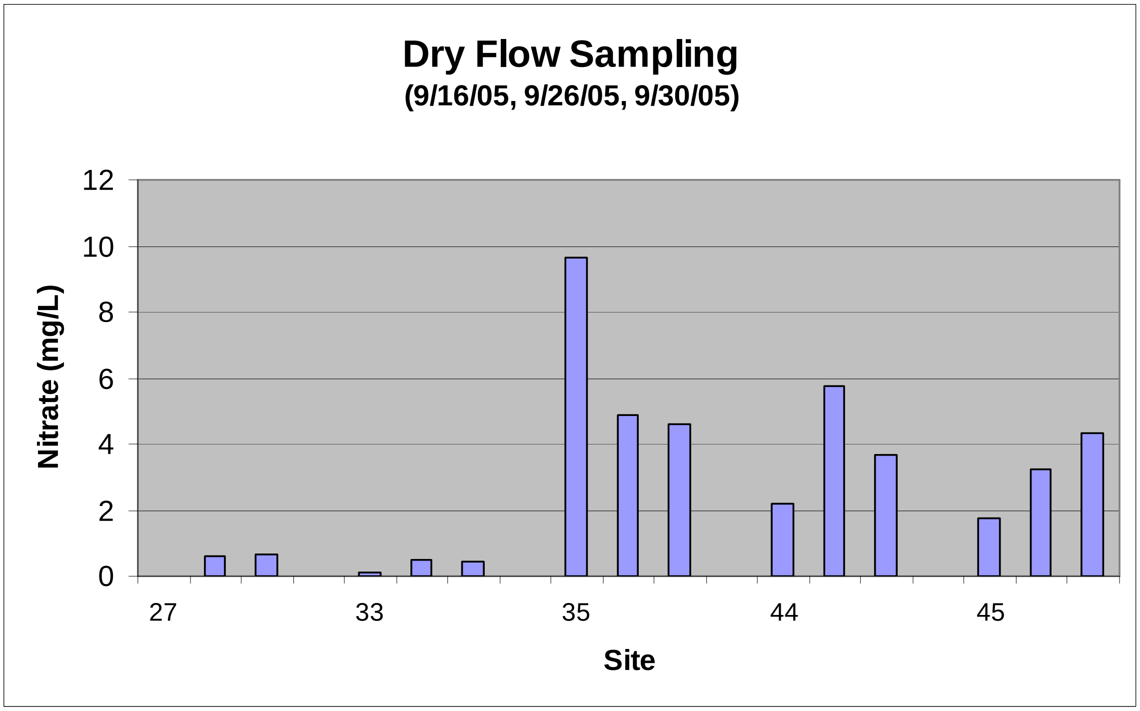


Figure 3-7. Nitrate concentration for culverts with dry weather flows.

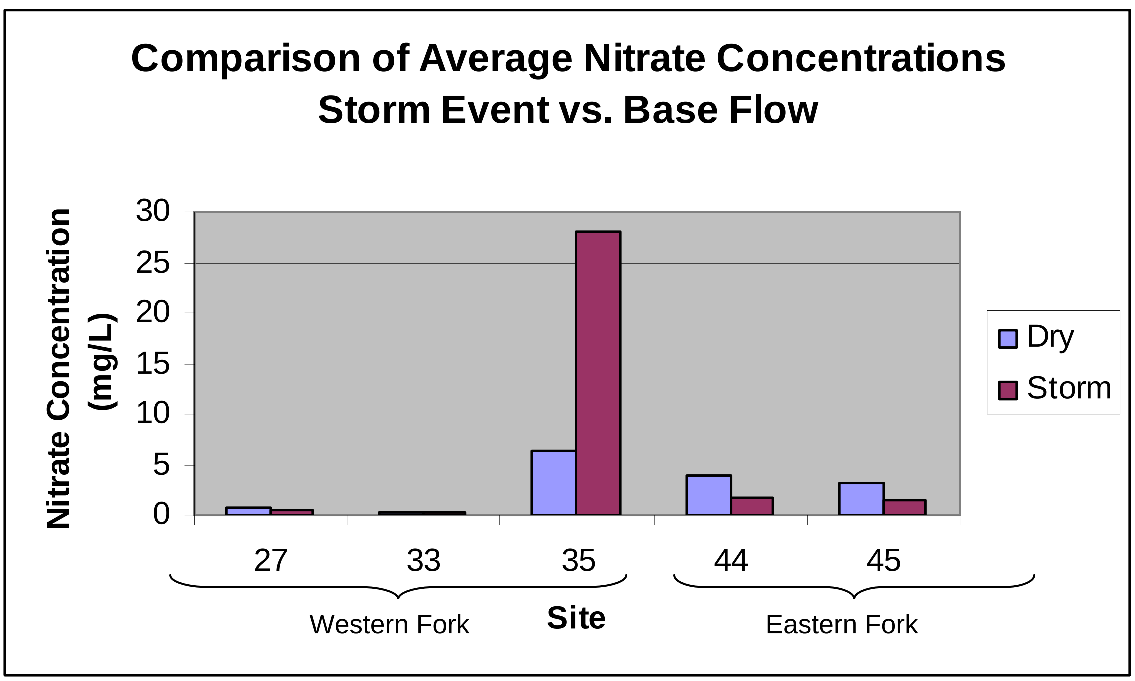


Figure 3-8. Comparison of average nitrate concentrations between dry flow events and storm events.

Sites 44 and 45 both had higher nitrate concentrations during dry flow periods than during storm events, probably due to dilution from additional rainwater in the system (Figure 3-8). While nitrate concentrations at sites 44 and 45 were lower than those found at site 35, they were higher than the 2 mg/L cited by researchers as a recommended level for healthy aquatic systems (Camargo 2005).

Land Use

Stormdrain system maps were obtained from the University of Florida Physical Plant. These maps provided detailed information as to where water entered the storm sewer system before exiting a particular culvert.

Sites 35, 44 and 45 all received a portion of their runoff from fertilized athletic fields. Site 35 appeared to be the primary drainage for Perry Field and Sanders Football Practice Fields which both have an under drain system to drain the fields in times of high rainfall or irrigation (Figure 3-9). Site 35 may have had elevated nitrate concentrations during a storm event (as compared to dry flow events) because of fertilizer runoff from the athletic fields and the absence of non-field runoff to dilute the concentration.

Site 44 drained a large area of campus to the north of the Reitz Ravine Woods including many academic buildings as well as the Ben Hill Griffin Stadium and Florida Field which has an under drain system (Figure 3-10). Site 45 appeared to provide drainage for some buildings, but also seemed to provide additional drainage for Site 44's subwatershed (Figure 3-11).

It appeared that the source of high nitrate concentrations for site 35 was from athletic fields. However, site 44 also received runoff from an athletic field, but the overall sub-watershed was much greater. Therefore, it is possible that site 44 was receiving high nitrate concentrations from the Florida Field, but they were being diluted with additional water sources from throughout the sub-watershed. Further investigation could include sampling runoff directly at Florida Field.

Further Research

The results from this investigation yielded interesting data that supports the implementation of one or more best management practices within the watershed. Further research on the watershed would assist in determining which BMP(s) would be most appropriate. In particular, calculations of loads from all culverts both during dry and wet periods would be valuable. For instance, if the volume of water from the high nitrate site 35 were relatively low compared to other culverts, the diversion of this water may not decrease the overall creek volume appreciably. From observations, it appears that site 44 had a constant and relatively large flow, both during dry and storm events. This was probably due to the large sub-watershed that conveyed water to site 44. It is likely, however, that the nitrates were from a single source within the sub-watershed, namely the Florida Field at Ben Hill Griffin Stadium, and that this source may have discharged much higher nitrate concentrations which were being diluted by the rest of the sub-watershed. Sampling at the culverts which drain directly from the field would yield data to test this hypothesis. Flow sampling directly at the field would also provide an estimate of how much water flowing out of site 44 was from the field verses the rest of the sub-watershed and whether diverting this flow for re-use or treatment would be feasible.

If the university selects a BMP for implementation, it would be important to collect pre-implementation water quality and quantity data as well as post-implementation data. Additionally, Hume Creek with BMPs could be compared to Fraternity Row Creek as a "control" that currently has similarly high nitrate values and no BMPs.

While additional sampling would be helpful in determining loads and seasonality of the nitrate concentrations, this scientific data provided information that will be helpful in addressing the high nitrate concentrations through management decisions that include the implementation of best management practices. The next section proposes policy and management recommendations for improving water quality in the Lake Alice watershed as well as best management practices that could directly address the high nitrate concentrations.

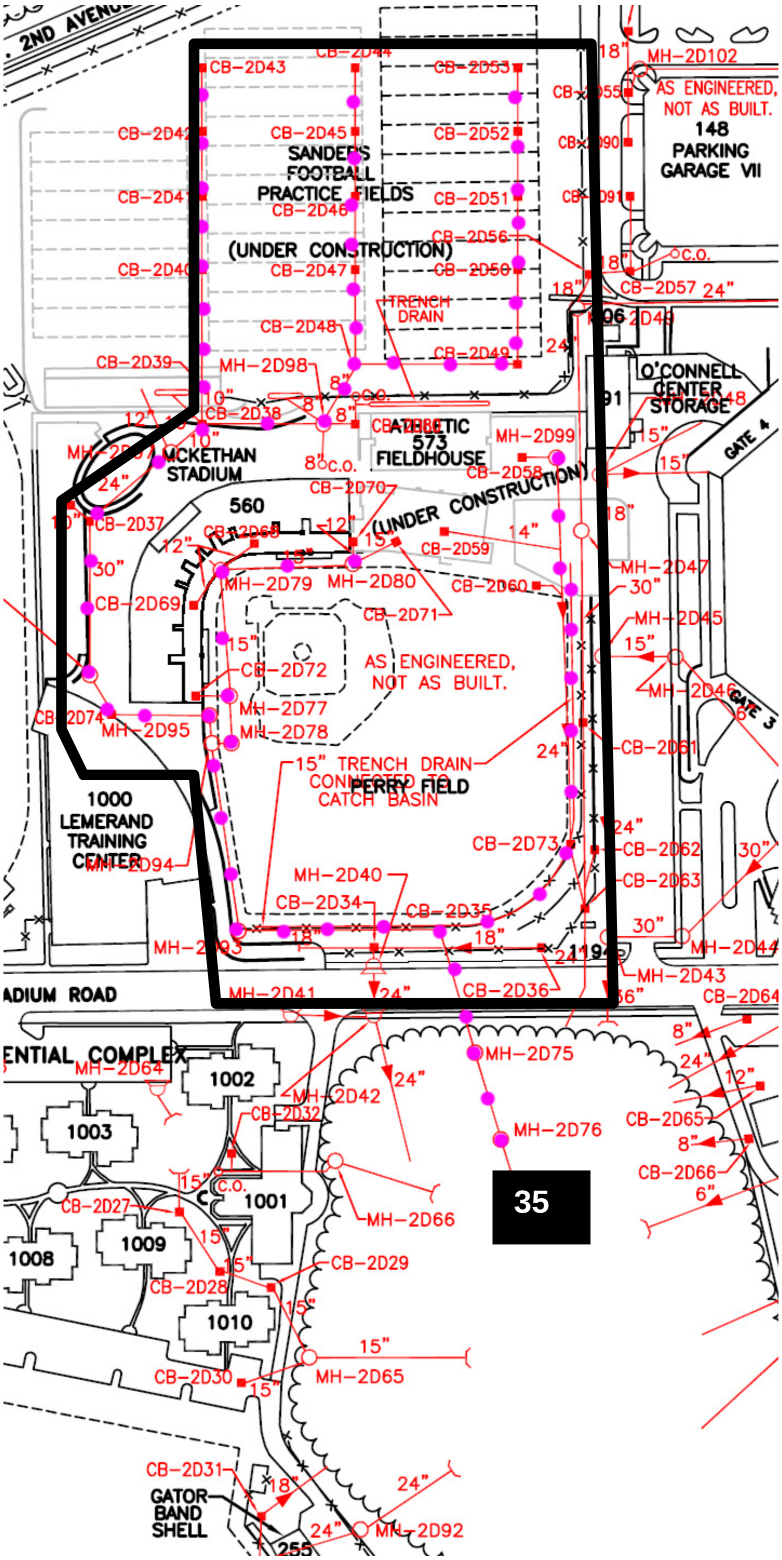


Figure 3-9. Sub-watershed for site 35. Shaded box indicates the area of the sub-watershed. The lines with dots indicate the portion of the storm drainage system that contributes to this watershed.

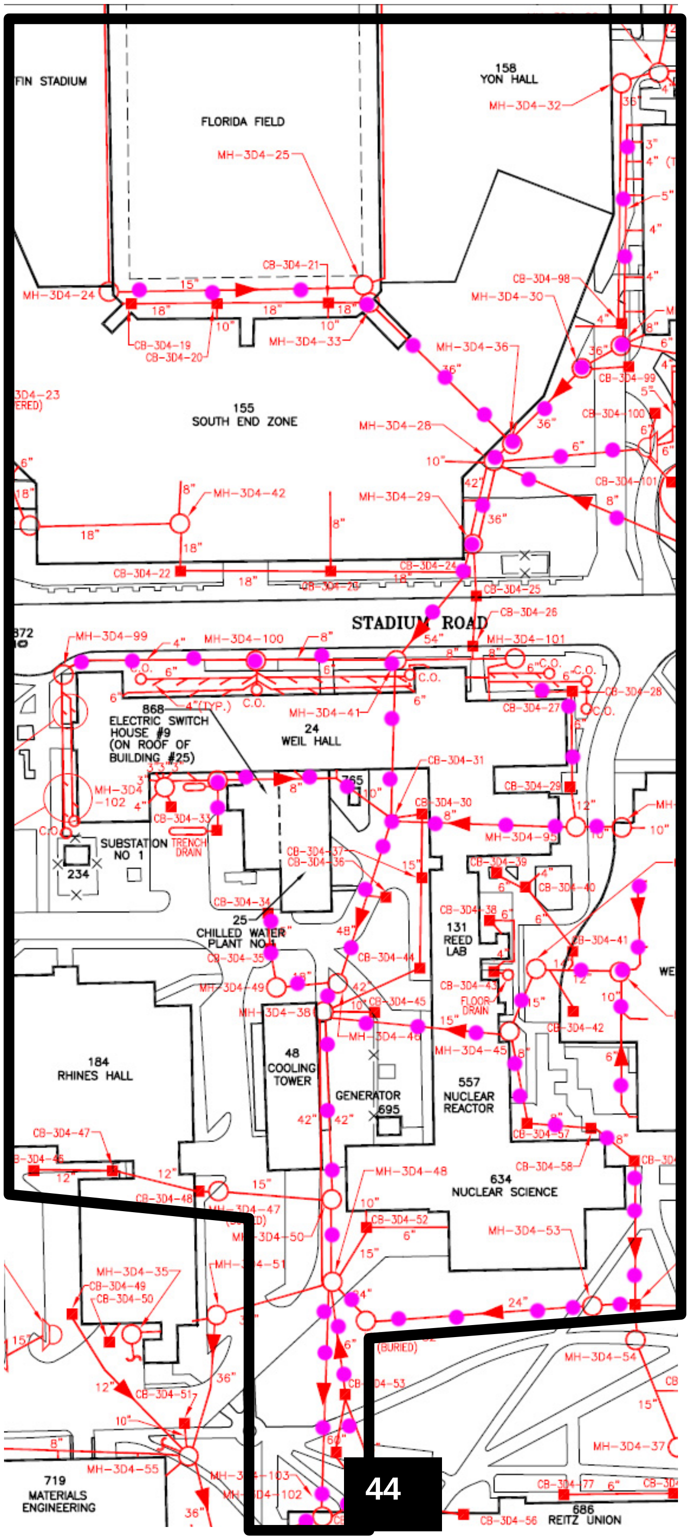


Figure 3-10. Sub-watershed for site 44. Shaded box indicates the area of the sub-watershed. The lines with dots indicate the portion of the storm drainage system that contributes to this watershed.

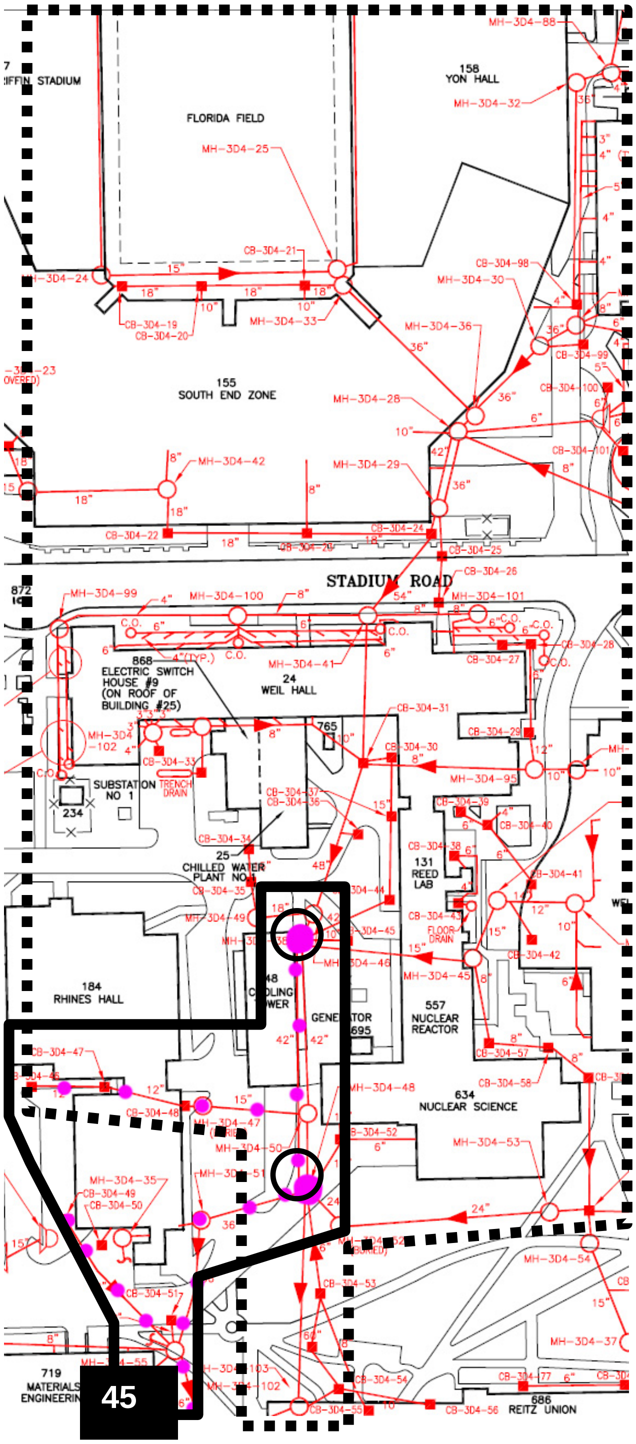


Figure 3-11. Sub-watershed of site 45. Shaded box with solid lines indicates the area of the sub-watershed. The larger shaded box with dashed lines indicates the sub-watershed of site 44 which is also a contributor to site 45. The small circles indicate two areas where water may be directed from site 44's sub-watershed to site 45.

SECTION 4
RECOMMENDATIONS FOR DEVELOPING AN INTERNAL TOTAL MAXIMUM DAILY LOAD PROGRAM

Summary of Current Conditions

The Lake Alice watershed is currently a Class III water body, a stormwater management system, and a university-designated conservation area. Each of these designations has potentially conflicting goals in terms of policy and management. For instance, Class III waters must be monitored, while UF's permit for a stormwater management system (including Lake Alice) specifically exempts the university from conducting regular monitoring.

Current water quality data indicates that some locations in the Lake Alice watershed fail to meet Class III numeric standards such as dissolved oxygen. The greatest issue of concern, however, is nitrate, a nutrient that does not have a numeric standard. Legally, Lake Alice is currently not considered an impaired water body and, therefore, there are not limits on the Total Maximum Daily Load (TMDLs) of nutrients, such as nitrogen and phosphorus. Historical and current water quality data, however, indicate these nutrient concentrations are higher at Lake Alice than in comparable water bodies and they are a major contributing factor to eutrophic conditions.

To improve water quality would require the university to make a clear commitment to sustainable water management. One mechanism for achieving this is to develop an internal goal for nitrate levels on campus using the framework of the federally mandated TMDL program. There are a number of other universities that have developed innovative methods for ensuring a high standard of water quality, and key examples of these programs are discussed below.

TMDL Framework

A Total Maximum Daily Load is “a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources” (US EPA 2005d). The Florida Department of Environmental Protection (DEP) has developed a five-step strategy for implementing TMDLs throughout the state:

> 1. Preliminary basin assessment focusing on existing data; 2. Strategic water quality monitoring to obtain additional detailed scientific evidence of water quality conditions; 3. Data analysis and TMDL development and adoption; 4. Development of a Basin Management Action Plan, in conjunction with local stakeholders, to allocate, among the local sources of pollution, reductions necessary to meet the TMDL; and 5. Implementation of the TMDL. (Florida DEP 2005c)

The first two steps have been achieved largely through this study, and the Campus Water Quality monitoring program. The next steps for UF are to adopt an internal TMDL and develop a Basin Management Action Plan to achieve the TMDL.

Adoption of a TMDL

To accomplish these next steps in the TMDL process, and as already recommended internally by the Conservation Committee (UF Conservation 2005b), UF should follow Class III water quality standards for all surface water bodies on campus including Lake Alice, ponds and creeks. Regular water quality monitoring and wildlife sampling should be conducted in key locations throughout campus to ensure the maintenance of Class III standards. The frequency of monitoring should be, at minimum, quarterly in order to identify seasonal variations. If Class III standards are not met, the university should develop an internal TMDL to address the issue.

In some cases, Class III standards may not be stringent enough to ensure the water is safe for recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. For example, nutrients, such as nitrogen, do not have a numeric limits but should be limited so as to not “cause an imbalance in natural populations of aquatic flora or fauna” (FAC 7). One potential challenge with narrative criteria is that there is only emerging scientific knowledge about the potential impacts of some chemicals on wildlife and an “imbalance” may be difficult to prove unless it is specifically being studied. For instance, high levels of nutrients like nitrogen can cause algae blooms and eutrophication.

UF should adopt an internal TMDL for all waters not to exceed nitrate concentrations of 2 mg/L, the level recommended in a scientific review of research on the nitrate impacts on wildlife (Camargo 2005). Additionally, the University of Florida can create an internal goal of no net increase for volume, rate and pollutant loads.

The University of North Carolina at Chapel Hill (UNC) made the following commitments in the stormwater component of their development plan:

> “No increase in the volume of runoff leaving main campus for all future development projects. No increase in the rate of runoff or the quantity of non-point source pollutants as a result of new development. An overall decrease in the volume of stormwater runoff, the rate of runoff, and the amount of non-point source pollutants leaving campus as compared to existing conditions” (UNC Development Plan 2005).

The policy of no net increase is a major institutional commitment that requires extensive modeling and vigilance in post development monitoring. To achieve this, UNC used GIS and a USDA Soil Conservation Service “Cover Complex Method” to predict how future development will impact the volume of runoff. UNC will implement the no net increase policy at each individual basin rather than the campus as a whole. Each new development project will include stormwater management technologies when possible or mitigation within the basin itself. Additionally, UNC committed to monitoring outfall locations for flow and water quality as well as a semi-annual benthic invertebrate sampling along a campus creek (UNC Development Plan 2005).

The University of Florida currently does not have a no net increase policy for volume, rate and pollutant load for any of its watersheds. In the case of the Lake Alice and Depressional Basin watersheds, there is no outfall to a water source off the university property. However, there are waters that feed into the Hogtown and Bivens Arm watersheds off campus (UF Master Plan 2000). UF does not conduct modeling to assess pollutant load implications for current or future development.

The University of Florida should adopt a policy of no net increase in volume, rate or pollutant load for all campus watersheds. In order to enforce this policy, the University should develop a monitoring program which monitors flows at outlet points and water quality throughout campus.

The University of Florida should also develop a model for all surface waters on campus to predict how the volume, rate and pollutant loads may change with increased development.

To achieve an internal TMDL, UF should develop a Basin Area Management Plan. This plan would include water quality monitoring and modeling, a management structure, a set of best management practices, a research program and a financing plan.

Monitoring and Modeling

Regular water quality monitoring should be continued throughout campus and at identified “hot spots” for potential pollutants. Modeling of pollutant loads should be conducted throughout campus as well as at key locations where point source pollutants have been identified such as site 35.

Management

The University of North Carolina at Chapel Hill has a Stormwater Committee including representatives from Directors of Real Estate, Facilities Planning and Design, Transportation, Facilities Operations, Water Quality Group, the University Architect, and extension. The committee is given training specific to the design and use of BMPs (UNC Sustainability Coalition 2005).

The University of Florida should develop a Water Task Force under the Office of Sustainability. The Task Force should include representatives from the Physical Plant, the Office of Planning, the University Athletic Association, IFAS, Custodial Staff, Office of the President, Landscaping Division, faculty from the landscape architecture, environmental engineering, soil and water sciences, School of Natural Resources and Environment, and wildlife, and student representatives from the UF Wetlands Club, the American Water Resources Association, and the Environmental Action Group. The Committee would set campus-wide priorities regarding stormwater issues on campus and would provide an annual report to the Lakes, Vegetation and Landscape Committee.

Best Management Practices

There are two types of BMPs: behavioral and structural. Behavioral BMPs require a behavioral change on the part of individuals. For instance, a janitor who empties wastewater into a storm drain can change their behavior and improve water quality. Structural BMPs require a physical structure which can assist in controlling water quantity and/or water quality. In some cases, multiple BMPs can be implemented for maximum effectiveness to create a “treatment train”. Scientific data on the success of BMPs is limited, but growing. Comparing the effectiveness of different BMPs has proven challenging because of the variety of research methods and designs utilized. Nevertheless, BMPs, if designed and maintained correctly, are considered by the federal government to be reliable mechanisms for treating stormwater.

BMP implementation on the campus should, when possible, address water quality concerns that have been identified, such as nitrate in Hume Creek. Mechanisms for removing nitrate from the water can include denitrification in anoxic environments, plant assimilation, leaching to groundwater, and volatilization (Poe 2003). Wetlands and floodplains and riparian forests can act as valuable sinks for nitrate (Tockner 1999).

In the case of Hume Creek, the likely nitrate source is fertilizer being applied to athletic fields. There are a number of best management practices that could be implemented to either reduce the inputs of nitrate or to treat the nitrate once it has entered the stormwater drainage system.

Nutrient management

Currently there are no formal written policies with regard to the rate of fertilizer applications on fields maintained by the University Athletic Association (Scott Roberts, personal communication, September 23, 2005). The University Athletic Association and the Physical Plant (where applicable) can alter its turf management practices to include more sustainable nutrient management practices. For instance, limiting fertilizer applications when soil moisture is high or when rainfall is expected would reduce runoff (Shuman 2002). Research has shown that leaching and runoff of nitrate is higher from newly seeded turfgrass than from established turfgrass (Easton and Petrovic 2004). By reducing fertilizer applications for a period of time after seeding fields, nitrate concentrations may be reduced.

The Conservation Area Study Committee has taken steps to ensure this best management practice is implemented in the future. The following policy and recommendations were adopted on September 1, 2005 for inclusion in the Comprehensive Campus Master Plan 2005-2015:

> **Policy 3.2:** The University shall continue to mitigate University generated stormwater and to minimize stormwater borne pollutants through implementation of Best Management Practices (BMPs) that includes, but is not limited to:
>
> …• Using slow release fertilizers and/or carefully managed fertilizer applications timed to ensure maximum root uptake and minimal surface water runoff or leaching to groundwater…
>
> …• Incorporating features into the design of fertilizer and pesticide storage, mixing and loading areas that are designed to prevent/minimize spillage (UF Conservation 2).

Re-use of the water

Since nitrate is a component of fertilizers, it may be possible to re-use the nitrate laden water that is draining from the athletic fields for subsequent irrigation of those or other fields. This would require a facility that could store the water, possibly transport the water and re-use it when necessary. By re-using the water for irrigation, the amount of additional fertilizer could be potentially reduced.

Pretreatment

The water that discharges through sites 35, 44 and 45 could be diverted and pre-treated prior to entry into Hume Creek. One possible mechanism for pre-treatment would be a bioretention facility such as that found next to the soccer and softball fields near the intersection of Museum and Hull Roads.

Wetland retention area in Graham Woods

Water that enters Graham Woods and Reitz Ravine Woods could be treated partially via a wetland retention area in the woods itself. Small dams or weirs could be installed near the outlets of sites 35, 44 and 45 which would slow water down and provide temporary storage and treatment. One study indicated that denitrification rates increase by 400% following rainfall and increased inorganic nitrogen loading (Poe 2003). It may, therefore, be important to develop mechanisms by which the wooded areas can retain a larger volume of water during periods when nitrogen loading is expected to be highest. This would require coordination with the University Athletic Association and the Physical Plant staff who apply fertilizers.

Vegetated buffers

Vegetative buffers have often been used as a mechanism for nitrate removal in agricultural areas. In the case of Hume Creek, the forested buffer provides some treatment as the culvert waters flow towards the main creek and can also provide treatment for the creek as it rises into the wooded floodplain during heavy rains. The Alachua County Comprehensive Plan 2001-2020 requires a minimum 35 foot buffer (50 foot average) around surface waters that are less than 0.5 acres and a minimum 50 foot buffer (75 foot average) around waters greater than 0.5 acres. Preserving and possibly increasing the buffered area to these recommended widths could assist in nitrate reduction.

While plant assimilation of nitrogen is advantageous to nitrogen removal, the nitrogen may be re-mobilized in the environment when the plant decays. Therefore, denitrification is a preferred mechanism for removing nitrate. Denitrification could be maximized by planting species which are particularly efficient at denitrification (Matheson 2002).

Denitrification in floodplain soils

Research has shown that nitrate concentrations can be reduced by applying the contaminated water to the floodplain soils. The infiltration of water through the sediments results in denitrifcation in the anoxic soil layers with sufficient organic matter (Chung 2004 and Tockner 1999 and Almendinger 1999). Diversion of high nitrate concentration waters from the storm drain culvert system to a spray application on floodplain soils may provide a mechanism by which the waters can be treated as they filter through the soils and, eventually, into the creek system.

Additional BMPs that are not specific to nitrate reduction include monitoring flows into the groundwater wells and revising the UF Development Guidelines.

Groundwater well monitoring

Groundwater well R-1 should be raised such that it receives water only during extreme high water conditions (like R-2). A gauge to monitor flows into the two wells should be installed as soon as possible in order to meet the requirements of the 2000 Master Stormwater Permit. Water entering into either R-1 or R-2 should be monitored for water quality to prevent contamination of groundwater.

The Conservation Area Study Committee acknowledged the need to monitor these wells in September 2005 through the adoption of the following policy:

> **Policy 1.5:** The University shall abide by all requirements and conditions of the current Master Stormwater Permit by the SJRWMD and shall seek renewal of the permit in 2010. Those conditions include reporting water levels in monitoring wells quarterly and submission of groundwater and surface water monitoring tests to the water management district (UF Conservation 2).

Development guidelines

On many university campuses, there are guidelines which dictate the process for designing and approving any new development project, particularly those which increase the percentage of impervious surface. North Carolina State University's (NC State) Stormwater Guidelines for New Development are specific about not only creating adequate opportunities for detention of stormwater, but also about reducing the amount of nitrogen that enters the stormwater system. The guidelines are in direct response to regulations outlined in the Wayne County Stormwater Ordinance, Article 300, Section 301 (E) which limit the amount of nitrogen that can be exported from a new development. NC State addresses this requirement by providing a mechanism for calculating the projected nitrogen loads for a new development and recommending specific BMPs which can reduce nitrogen loading (NC State 2005). Additionally, NC State has made a concerted effort to monitor BMPs they have implemented both on and off campus to assess their effectiveness and appropriateness for various water quality concerns.

Cleveland State University's Campus Master Plan has guidelines for new development which include vegetative roofs, water conservation, the use of native plants and low maintenance plants, reduction of fertilizer usage, permeable paved surfaces for parking, rainwater harvesting, and green spaces which can store and filter stormwater (Cleveland 2005).

The University of Florida's Design and Construction Standards currently includes policies for the minimum stormwater control measures as required under the NPDES permit. These policies do not, however, include limits to the nutrient loading from new developments, nor do they include design guidelines for more innovative stormwater management strategies such as rainwater harvesting, porous pavement, and vegetative roofs (UF Conservation 1).

In September 2005, the Conservation Area Study Area Committee approved the following policies for inclusion in the UF Comprehensive Campus Master Plan 2005-2015:

> Object[sic] 4: The University shall implement sustainable stormwater practices in all campus site development incorporating Low Impact Development techniques where physically, economically, and practically possible.
>
> Policy 4.1: The University shall strive to incorporate stormwater improvements into all new building sites and into modification of existing sites. These improvements include, but are not limited to, rain gardens, roof-top gardens, porous soil amendments, hardscape storage, pervious pavement and other innovative stormwater techniques.
>
> Policy 4.2: The University shall identify opportunities for retrofitting existing open space (i.e. land use classifications of Buffer, Urban Park and Conservation) to incorporate rain gardens and other multi-use detention practices that maintain the primary use, but with the added benefit of slowing water discharges into the stormwater system. Examples include: lowered flower beds (i.e. instead of raised beds), curb openings (i.e. brick and other hardscape removal in edging and seat wall

footings) that allow water to enter vegetated areas, use of lawn areas for incorporating slight depressions that retain rainfall, and elevating storm drains where water detention is acceptable so that they are not at the lowest elevation (UF Conservation 2).

This policy, if approved in the final Campus Master Plan, would set forth more stringent and innovative policies for development on campus. This policy should be expanded into a standard set of best management practices that architects and engineers are required to work from. Whenever possible, the implemented practice should be coordinated with researchers who can monitor the effectiveness of the BMP before, during and after implementation.

Stormwater Research

A number of universities have developed mechanisms to integrate research with stormwater management on their campuses. The Villanova University Stormwater BMP Park is one example of how BMPs are being actively researched by students and faculty. Villanova developed the Urban Stormwater Partnershp to foster public, private and academic partnerships in researching stormwater BMPs. In the last two years, five student research projects or theses have been completed related to BMP effectiveness and numerous faculty tours or presentations have been made related to BMPs (Villanova 2005).

Another example is Ohio State University where a collaborative group called CampUShed, composed of students, faculty and staff, integrates research, education and hands-on environmental solutions. Their goals are to foster the implementation of scientifically-based environmental solutions on campus, encourage faculty to integrate on-campus projects in their courses, and provide an information clearinghouse of events and activities. Many of the projects CampUShed has worked on include stormwater management practices such as a bioretention area and constructed wetlands (Ohio 2005).

In September 2005, the Conservation Area Study Committee approved the following policies for inclusion in the Comprehensive Campus Master Plan 2005-2015:

> Objective 5: The University shall keep faculty, staff, students and visitors informed on stormwater issues through outreach and demonstration projects.
>
> Policy 5.1: The University shall strive where practicable to include interpretive information and educational opportunities that go along with the University's efforts to integrate innovative structural stormwater design and BMP concepts.
>
> Policy 5.2: The University shall maintain financial and personnel support of stormwater related education and awareness programs for the campus community.
>
> Policy 5.3: The University shall pursue grants and other opportunities to fund implementation, outreach and study of stormwater best management practices on campus (UF Conservation 2).

If approved in the final Campus Master Plan, these policies will set forth a firm commitment to stormwater research on the UF campus. In the past, water quality data collected in Lake Alice and student research papers on campus waters was kept in disparate locations (such as professor's offices), often only located through word of mouth. In order to ensure research efforts are synchronized and complementary, UF should develop a centralized mechanism by which to support, recognize and record research activities related to water and stormwater on the campus such as the UF Clean Water Campaign website or the Office of Sustainability.

Behavioral Change: A Community Based Social Marketing Strategy

The National Pollutant Discharge Elimination System Phase II Permit (NPDES) has six minimum control requirements including a mandate to conduct public outreach and education. It is believed that by educating individuals about the sources of stormwater pollution and the solutions to prevent it, improved water quality can be attained. Educational campaigns which seek behavioral change are heavily centered on social psychology observations. However, research has shown that public education and involvement campaigns fail to show a direct correlation between individuals' increased knowledge of storm water issues and an improvement in behavior around storm water pollution. In fact, according to a survey completed in Los Angeles, “knowledge about storm water and runoff are unrelated to behavior affecting runoff volume and composition” (Berk 2000). While many campaigns do report changes in measured variables, many do not have evaluation measurements to show that individual behavior has changed and, even more importantly, to show that the water quality has improved as a result of behavioral change, education and participation activities. Creating this bridge between behavior and environmental improvement is challenging because the environmental problem itself is hard to define – non-point source pollution does not come from one source or one specific behavior; it is a combined effect of many different behaviors from many different sources. A review of literature and other similar campaigns around the country reveals that an “education campaign” alone will not suffice in actually changing behavior. However, a Community-Based Social Marketing Strategy would enhance a traditional public education campaign and focus on strategies which target behavioral change. This strategy combines successful elements of numerous behavioral change theories into a straight-forward format that hones in on how and why people will change their behavior. It is, therefore, recommended that the UF Clean Water Campaign implement a full-scale Community-Based Social Marketing Strategy as outlined in the appendix. Some aspects of this strategy have been implemented and can be enhanced over the next few years.

Financing

The TMDL framework recommends developing a strategy for funding the TMDL process. One example is to assess a fee on items which contribute to pollution such as fertilizer. Many municipalities have implemented stormwater utility fees to help defray the costs of building, operating and maintaining stormwater management systems. "Stormwater utility" is defined as the “funding of a stormwater management program by assessing the cost of the program to the beneficiaries based on their relative contribution to its need. It is operated as a typical utility which bills services regularly, similar to water and wastewater services” (Florida Statute 1). These fees are based upon “an equitable unit cost approach”. In Gainesville, property users are assessed a fee based on the estimated area of their building (impervious surface). The fees are applied to those individuals who are using the property and receive the services of the municipality.

The University operates autonomously from the City of Gainesville and provides services to its users and residents just as a city would. Student enrollment has steadily increased over time and now includes 49,650 students (UF Facts 2005). The more than 1,800 acre campus provides services and amenities to the surrounding Gainesville community such as the Shands medical facility, Ben Griffin Stadium, the Harn Museum, and the Phillips Center for the Performing Arts. In 2002-2003, an estimated 1.8 million people visited UF for an event (UF Economic Impact 2005). In 2003, 37,631 parking decals were sold with revenues of $4.5 million (UF Audit and Compliance 2004).

UF should implement a stormwater utility fee for users of the campus property. The primary mechanism by which users of the campus may contribute to stormwater pollution is by driving and parking on the campus. Therefore, in order to create an equitable cost approach, it is recommended that a stormwater utility fee be assessed according to the usage of roads and parking spaces on campus. A stormwater utility fee may be assessed in one of three ways (or a combination of the following):

- a fee added to the cost of a parking decal;
- a fee added to the admission price of an event on campus in which users are parking and driving on campus; and
- a fee added to visitor parking tokens.

Revenues generated may be used for the management, operation and maintenance of the stormwater management system on campus including the installation of new BMPs.

Conclusion

The Lake Alice watershed currently has multiple designations with potentially conflicting goals in terms of policy and management of UF water bodies. In order to meet the goals of each of the regulatory designations and improve water quality, the university must adopt a comprehensive strategy for sustainable water management.

In September 2005, the Conservation Area Study Committee adopted some bold new policies for inclusion in the Comprehensive Campus Master Plan 2005-2015 including meeting Class III water quality standards for Lake Alice and its contributing waterways, monitoring the groundwater wells in Lake Alice, incorporating best management practices into new development and supporting research and education efforts around stormwater. However, the policies fall short of setting numeric limits to volume, rate and pollutant loads on campus. The policies also do not outline a monitoring plan nor a clear management structure. Lastly, there is no formalized mechanism within the proposed policies to link scientific investigation with the implementation of best management practices (BMPs). The scientific data gathered through this study enables the university to potentially address a long-standing problem of high nitrogen concentrations through targeted BMP implementation.

The federal Total Maximum Daily Load (TMDL) program provides a useful framework by which the university can develop internal goals for pollutant loads and a Basin Area Management Plan to achieve these goals. Through the TMDL program framework, the University of Florida can define clear numeric targets for water quality criteria, in particular nitrate. Be linking scientific investigation with policy, the University of Florida can attain a sustainable water management program that achieves a high standard of water quality and meets all of its regulatory designations.

Appendix A
Community-Based Social Marketing Strategy

Appendix A outlines a Community-Based Social Marketing Strategy for promoting behaviors which reduce stormwater pollution on campus through the UF Clean Water Campaign.

Changing individual's detrimental behaviors is a key component to decreasing non-point source pollution. Successful campaigns are heavily centered on social psychology observations. Behavior change research reveals the following:

- An individual's intended behavior is influenced by his/her own positive or negative evaluation of performing the behavior (known as attitude toward the behavior) and the perceived social pressures put on the individual to perform the behavior (known as the subjective norm or social norm). (Ajzen 1985)
- External factors unrelated to attitudes and social norms can affect the outcome of a behavior. (Ajzen 1985)
- There is no apparent link between good intentions and good behavior. (Kaplan 2000)
- Individuals who believe that their actions will make a difference are far more likely to participate in environmentally responsible actions than those who do not feel control over the situation. (Kaplan 2000)
- How an individual processes new information strongly determines if persuasive information will be enduring. "Participants who thoughtfully considered message content demonstrated more enduring attitude change; in contrast, when participants had little motivation and/or ability to think about the message presented, the effects were typically short lived". (Bator 2000).
- Direct experience and engaging activities that arouse emotions produce instrumental behaviors useful for reaching goals beyond the performance of the behavior; indirect experience and factual knowledge lead to consummatory behaviors that are performed only for the behavior itself. (Millar 1996)
- Many approaches toward changing individual's behavior have been tried, including (a) religious and moral approaches that appeal to values, (b) education to change attitudes and provide information, (c) efforts to change the material incentive structure of behavior, and (d) community management involving the establishment of shared rules and expectations. "By far, the most effective behavior change programs involve combinations of intervention types". (Stern 2000).

When applying these theories to environmental education campaigns, the following was found:

- Many public education and involvement campaigns conducted by municipalities in the U.S. fail to show a direct correlation between individuals' increased knowledge of storm water issues and an improvement in behavior around storm water pollution. In fact, according to a survey completed in Los Angeles, "knowledge about storm water and runoff are unrelated to behavior affecting runoff volume and composition" (Berk 2000).
- While many campaigns do report changes in measured variables, many do not have evaluation measurements to show that individual behavior has changed and, even more importantly, to show that the water quality has improved as a result of behavioral change, education and participation activities.
- Creating this bridge between behavior and environmental improvement is challenging because the environmental problem itself is hard to define – non-point source pollution does not come from one source or one specific behavior; it is a combined effect of many different behaviors from many different sources.

A review of literature and other similar campaigns around the country reveals that an "education campaign" alone will not suffice in actually changing behavior. For this reason, a Community-Based Social Marketing Strategy would be preferrable. This strategy combines successful elements of numerous behavioral change theories into a straight-forward format that hones in on how and why people will change their behavior.

The Community-Based Social Marketing Strategy is structured around three guiding questions:
1. What behavior(s) should be promoted?
2. Who should the program address or target? and
3. What conditions will an individual face in deciding to adopt a new behavior?

Each of these questions is addressed below in the context of the goals of the UF Clean Water Campaign.

What behavior(s) should be promoted?

The UF Clean Water Campaign should promote the following behaviors:
1. Keeping storm drains clear of trash and leaves;
2. Checking your vehicle for fluid leaks;
3. Getting regular tune-ups for your vehicle;
4. Washing ones' car on grass, gravel or at a commercial car wash;
5. Picking up after one's pet;
6. Properly disposing of hazardous wastes both in your home and on campus;
7. Reporting questionable dumping; and
8. Reduction of fertilizer and pesticide usage.

Who should the program address or target?

The campaign focuses on two audiences through two implementation phases. Phase I includes the broader UF community (students and faculty), while Phase II focuses on the UF institutional community (Physical Plant staff and administration). The majority of the strategy outlined focuses on Phase I, but can easily be adapted to also address Phase II, the institutional community.

What conditions will an individual face in deciding to adopt a new behavior?

Each behavior has its own matrix of barriers and benefits. To identify the top barriers and benefits, the campaign should rely upon survey responses and focus groups. Barriers to specific behaviors include the following:

Behavior	Possible Barrier
Throwing trash in a trash can or recycling container.	• Not a nearby trash can • Not a nearby recycling bin • Don't know what is recyclable
Reporting questionable dumping into a lake, creek, or storm drain to a hotline or authorities.	• Don't see it happen • Don't have the phone number • Don't know if it is actually pollution • It would not make a difference • Don't have the time • Fear of confrontation
Sweeping or blowing grass clippings and leaves away from the street, curb and storm drain.	• A clean street is more important than a clean storm drain • Grass and leaves are not a pollution problem • Don't have the time • Don't have a rake or blower.

Having routine maintenance on one's car, moped or motorcycle including checking for leaks.	• Don't know what to look for • Don't have the money • Forget to check • Don't know how often to check • Don't know where to go • Don't know why it is important
Washing the car at a commercial car wash or on the grass/gravel (instead of a street or paved driveway).	• Don't want to park on grass • Don't have a yard • Don't want to spend $ on car wash • Believe that commercial car washes are worse for the environment
Disposing of dog or cat pet waste (both in a personal yard and elsewhere) in a trash can or toilet.	• Pet poop isn't a pollution problem • Don't always have bags with me • Throwing it away causes more waste in a landfill • Don't want to carry the waste around until I find a trash can • Pet poops in person's own yard
Taking hazardous materials (paint, antifreeze, oil, batteries) to a recycling or hazardous waste drop-off location.	• Don't have any hazardous waste • Don't have a place to store it • Don't have transportation • Don't know where to take it • Don't know what is hazardous • Don't have time • Hazardous waste drop-off events are not held often enough

In general, benefits or reasons for doing a particular behavior will fall into the following categories:

- To improve the environment / prevent pollution;
- To save money;
- To make the community look better;
- Because other people do it; and
- To avoid getting in trouble (like a fine or ticket).

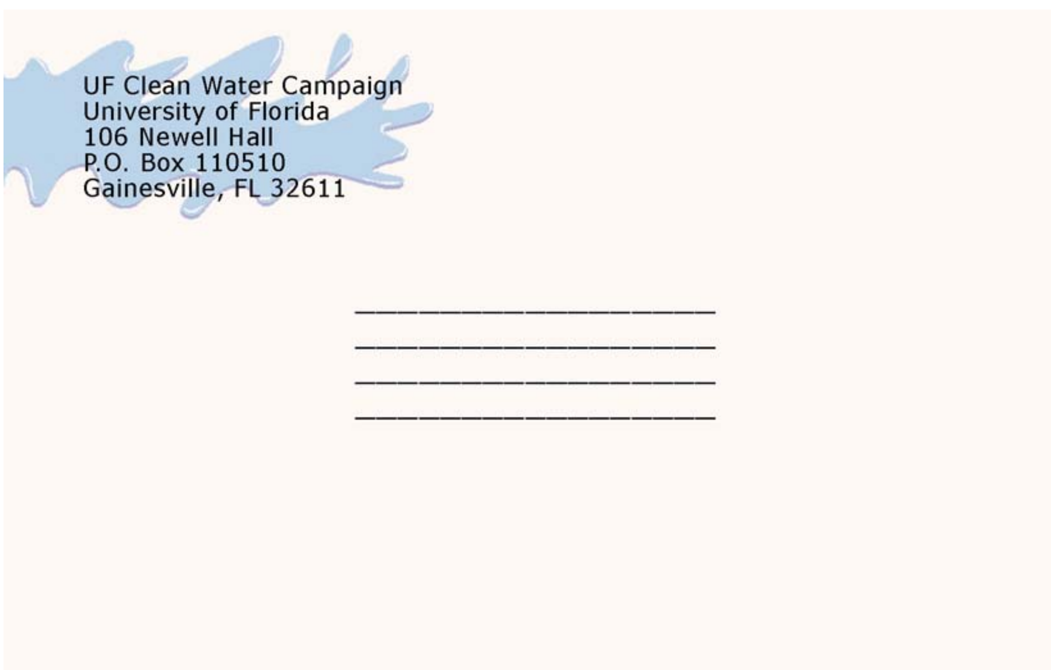
Behavioral Change Tools

A community-based social marketing strategy uses six different behavioral change tools to achieve target behaviors: commitment, prompts, establishing social norms, communication, incentives, and removal of external barriers. Mechanisms for implementing each of these tools within UF Clean Water Campaign are discussed below.

Commitments

Commitments can be obtained from individuals as well as groups. Commitments can be in the form of a written pledge or participation in an event. For instance, individuals may be asked to complete a self-addressed postcard with a checklist of actions that they can pledge to do in the next year. The postcard is then sent back to the individual within the next six months as a reminder of their pledge. Similar commitments may be completed by groups such as a club, residence hall, or division of the Physical Plant that jointly pledge to specific actions. Public recognition of commitments encourages follow-through with the pledge and also encourages others to pledge as well. An example of recognition may in the form of a newspaper ad which lists all who have made a commitment. Commitments from key community leaders will be sought after such as the UF President, administrators, faculty, athletes, and student leaders to lend status to the commitment process.

Commitments can also be in the form of participation in an event. Students who volunteer to help lay storm drain markers on storm drains throughout campus may be asked to make a commitment to keep storm drains both on UF campus and near their home free from trash and leaves. Those who register on-line for their parking decal may be asked to commit to up to 3 actions (such as not washing car on grass, checking for fluid leaks and recycling their oil, radiator fluid and car battery). Another example may be having the Physical Plant staff participate in a training that asks for their commitment to a specific action.



Prompts

Prompts are strategically placed friendly reminders that help reinforce a specific behavior. Some prompts may be installed on campus permanently while others may be "mobile" prompts that are given out to individuals. Permanent prompts should be placed in highly visible locations closest to the point of action. Mobile prompts will be in the form of an item that is easily and regularly carried or seen by an individual. All of the prompts will focus on the seven primary behaviors for the general public. Messages will be clear, to the point, positive and repetitive. When possible, visuals will be incorporated into the prompt. Examples of prompts that may be implemented are detailed below.

Permanent Prompts

- ***Storm Drain Markers***

  Plastic markers that feature the UF Clean Water Campaign logo and say “Keep it Clean” and “Drains to Lake Alice” have been placed on close to 500 storm drains throughout the UF campus. These provide visual reminders to not place trash in storm drains. One of the advantages of this prompt is its repetitive nature where passersby will see the prompt in many different locations.

- ***Water Quality Monitoring Signage***

  Signage at each of the water sampling sites would inform individuals that the water on campus was being monitored for pollutants. The signage would also include a phone number and/or website where they could report questionable dumping or pollution if observed.

- ***Parking Lot Signage & Parking Decal reminder stickers***

  Signs in campus parking lots could remind car owners to check for fluid leaks, conduct routine maintenance on their vehicles and recycle car fluids and batteries. Individuals who receive parking lot decals could be given removable stickers to place on their windshield with information on how often to check for fluid leaks and where to recycle fluids and batteries.

Storm Drain Markers

Mobile Prompts

- ***Wallet Card***

  A business card sized prompt can be distributed to any individual. The card includes information on how to report questionable pollution and lists six actions that help prevent stormwater pollution. These cards are easy to read and can be placed in ones’ wallet for easy reference. Because of their size, individuals will be much more likely to keep them as opposed to a large 8.5 x 11” flyer.

- ***Key Chain***

Small plastic key chains may be distributed to all individuals applying for a parking decal on campus. The key chain would include the logo and simple actions that are specific to car ownership.

- ***Refrigerator Magnet***

A refrigerator magnet provides information regarding hazardous wastes. The magnet would include information on what is considered hazardous, where these materials can be recycled or disposed of and alternative, non-hazardous products to use. A website and phone number would also be included. Having this magnet on the home refrigerator serves as a regular reminder to individuals.

- ***Water Bottles***

Athletic water bottles can be distributed to students that feature the UF Clean Water Campaign logo and include the primary actions individuals can take to prevent stormwater pollution. Students often use water bottles on a regular basis and take them to class. Each water bottle serves as a prompt not only for the user, but for others who see it.

Establishing social norms

Societal norms can greatly influence behaviors. According to the Diffusion of Innovations Theory, when faced with new or irregular situations, individuals often look to those around them to determine appropriate responses. Therefore, if pollution prevention activities such as washing cars on gravel surfaces are perceived as “socially normal,” then individuals are more likely to engage in the this activity than activities that are less socially accepted. In order to establish clear social norms on campus, it is important that the norms are visible to students, faculty and staff. Particularly in a community with such substantial annual turn around, the norms need to be continually brought to light so they can be identified by new community members.

- ***Student and Faculty Senate Resolutions***

One of the most official ways the university can establish social norms is through formal expressions of opinion in the student and faculty senates. In each of these legislative bodies, resolutions can be passed that detail the student body or faculty body position on a specific subject. Passing student and faculty senate resolutions that “thereby resolve” the university is committed to keeping surface waterbodies can help establish a campus-wide norm that is highly accepted and considered by university administrative policies.

- ***Events***

Public events which focus on the UF Clean Water Campaign show broad participation and buy-in. Events may target specific desired behaviors. For instance, a “Leak Check Day” may involve volunteers in UF Clean Water Campaign t-shirts checking cars in a parking lot for vehicle leaks. Every user of the parking lot would receive either an “award” for having no leaks or a “ticket” indicating that their car has an active leak. Participants may be asked to commit to getting their car repaired or given a coupon for a repair service as an incentive.

> # Leak Alert!
>
> **Today we found a fluid leak in your car.**
>
> When your car leaks oil or antifreeze, these fluids can wash down the storm drain and pollute our campus creeks, ponds and lake. Please take your car to a repair professional to have it checked!
>
> Thanks for helping us
> Keep our Water Clean!
>
> UF Clean Water Campaign

- ***Advertising Commitments***

Advertising group and individual commitments to behavior change is another active method to share accepted behaviors. For example, if at an Earth Day presentation 50 students sign a commitment to change their behaviors to reduce non-point source pollution, the UF Clean Water Campaign might publish the names of those who made commitment in an Independent Florida Alligator ad or on the campaign Web site under the heading “These students have committed to help keep campus waters clean. Here’s how you can to… “

- ***Passive Techniques***

Sometimes more passive notices can create a social norm. The UF Clean Water Campaign storm drain markers, for example, set a formal precedent that dumping is not socially acceptable on campus. Similarly, if the campaign designed a tour of water quality best management practices on campus with kiosk and informational brochures, this social norm could be visible if it was sought out and recognized.

Communication

The better a campaign message captures attention, the more likely it is to get noticed and mentally processed. In order to capture attention, a message should be vivid, concrete and personalized. Once a message is noticed, it must be interesting and relevant to the recipient. Message content should be simple, to the point and very specific. According to case studies of successful public service announcements, “messages should explain precisely how a behavior change should occur, and this explanation should be vivid and involving without having vivid and distracting additional information.”

- ***A Simple, Memorable Slogan***

- In accordance with these research suggestions, the Campaign selected “Keep it Clean” as a slogan. This message is simple and clear when tied to the UF Clean Water Campaign name but may not be as effective when used as a stand along slogan that is not visually linked to the Campaign.

- ***Recognizable Logo***

A logo was designed that is consistent with the UF theme and looks like the child of Albert and Alberta, the UF gator mascots. The logo is placed on all of the storm drain markers throughout campus providing regular visual reminders of the campaign. The logo is also placed on all literature and prompts produced by the campaign to provide visual consistency.

- ***Clearly Defined Target Behaviors***

Besides the slogan, there are seven main actions individuals can take that are concrete, specific and solution-oriented. These seven behaviors should be printed on all communication displays and handouts, including business cards, water bottles and posters. The behaviors should always be displayed in conjunction with the slogan and campaign logo.

- ***Credible Sources of Information***

Using trusted sources of information is important in presenting new information to a skeptical audience. By attaching the university name to the campaign title and by making the connection clear in the logo, there is a level of legitimacy given to the campaign. All materials produced through the campaign should rely on credible and respected sources of information.

- ***Establishing Personal Connections***

According to the Diffusion of Innovations Theory, personal connections and peer influences can be the most important factor in adoption of new behaviors by the majority. One way to achieve this is to train students to become spokespersons for the campaign. Students who serve in leadership roles such as residence hall advisors, student government and club presidents and tour guides can all help reinforce the message of the campaign. The campaign can also use peer-oriented media outlets to advertise its activities and to present PSAs. Such outlets include The Independent Florida Alligator, In Scene Magazine, WUFT TV, WUFT FM, WRUF AM, and movie theater advertisements.

Informational Booth at UF's 2004 Earth Day and Logo

UNIVERSITY of FLORIDA
CLEAN WATER CAMPAIGN

Incentives

Behavior psychology shows that "incentives, financial or otherwise (e.g., social approval) can provide the motivation for individuals to perform more effectively an activity they already engage in" (McKenzie-Mohr and Smith 1999). In the most extreme situations, incentives can persuade an individual to engage in a behavior they might have otherwise never considered.

- ***Coupons***

Providing incentives to engage in water pollution prevention behavior, more students may be likely to adopt these behaviors. For instance, discount car wash coupons may encourage the use of approved commercial car wash facilities. Similarly, providing students with coupons for discount oil changes and routine car maintenance can help encourage regular car tune-ups and fixing of leaks.

- ***Volunteer / Community Service hours***

  Volunteer hours are a non-monetary incentive for college students, as many organizations on campus including sororities, fraternities and service organizations encourage students to engage in community service events.

- ***Giveaways***

  Giveaway items such as magnets, key chains, water bottles and t-shirts can provide incentives for individuals to participate in activities or commitments. Some items may be reserved as rewards for individuals who have shown greater commitment than the majority.

Removing External Barriers

A key component of fostering sustainable behaviors is the removal or reduction of external barriers. External barriers are factors that may limit an individual behavior even when the individual is very inclined to do the behavior. For instance, time, convenience and money are typical external barriers. The barriers for each behavior will vary; therefore, identification of the biggest barriers is important to the success of the campaign. The identification of key external barriers should become clearer as surveys and focus groups are conducted.

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