VALUING PREFERENCES FOR WATER QUALITY IMPROVEMENT IN THE ICHETUCKNEE SPRINGS SYSTEM: A CASE STUDY FROM COLUMBIA COUNTY, FL

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my grandmother, Donna Foster, for all of her encouragement and support

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This study estimates Columbia County residents' willingness to pay for water quality improvements (specifically nitrate-N reductions) in the Ichetucknee Springs and River using the contingent valuation method, a stated-preference valuation technique. After developing a nutrient budget for the springshed to determine potential sources of nitrate we identified atmospheric deposition, Lake City's wastewater sprayfield, on-site treatment discharge systems (septic tanks ~ 20% of anthropogenic nitrate load), and land uses (improved pasture, row crops, and urban) as the contributing sources. This study focuses on improvements in water quality arising from changes in septic tank technology due to the location of numerous septic tanks in the Icehtucknee Trace and the fact that they are more easily identifiable than the larger non-point sources in the basin.

A contingent valuation survey, a mail-out questionnaire was sent to approximately 1,000 Columbia County residents to achieve the objective. Specifically, residents were asked whether they would support an increase in their monthly utility bill by a certain dollar amount in order to pay for a program that would update septic tanks in the springshed in order to improve wastewater treatment. Information was included in the questionnaire explaining links between

septic tanks in the springshed and resulting nitrate levels in the Ichetucknee. Further, information on prior knowledge, socio-economic data, and demographic data were obtained to assist in interpretation of the results.

The results of the survey reveal that majority of Columbia County residents have visited the Ichetucknee and believe that protecting water quality in the River is an important concern. The variables that affected the amount an individual was willing to pay included their political affiliation, the frequency with which they visited the site, and how important they ranked protecting water quality in the River. The mean willingness to pay was estimated to be $16.2 per household per month over the course of ten years. Extrapolated out for the entire county this amounts to a total willingness to pay of $40.7 million over the course of 10 years. This exceeds the estimated cost ($25-30 million) of implementing the program to receive the increased level of water quality.

The results imply that Columbia County residents place a substantial value on water quality in the Ichetucknee River and are willing to pay for and participate in a program to improve it. Using CVM is one of the few ways to place a value on a good that is otherwise completely unknown. The results of this study help inform the debate over the allocation of funds for groundwater protection, and should provide useful information for policymakers considering stormwater planning, land-use changes in the county, and approval for increased septic tanks permits. While this study provides an estimate of citizen's values for water quality in the Ichetucknee, it is ultimately up to policymakers at the State and County levels to implement any changes.

CHAPTER 1
INTRODUCTION

The Ichetucknee River, in north-central Florida, begins at Ichetucknee Springs and runs 6.2 miles to the Santa Fe River, a tributary of the Suwannee River. The river is a pristine, crystal clear spring run and is one of the largest tourist attractions in Columbia County, attracting around 200,000 visitors per year (FFWCC, 2006) and directly contributing an estimated $23 million per year to the local economy (Bonn and Bell, 2003). The Ichetucknee is a unique environmental, economic, and cultural resource for Columbia County. While immensely popular for tubing, it provides many other recreational opportunities such as swimming, birding, kayaking, and scuba diving.

Over the past two decades, nitrate levels in the springs and river have been increasing. The amount of nitrate-N in the River has reached levels between .6 and .8 milligrams per liter (mg/L) (SRWMD, 2006). This excessive nitrate-N has also occurred in association with dense growth of algae that has occurred in some areas of the river, smothering vegetation and creating floating mats on the surface. Certain varieties of algae (specifically *Lyngbia wollei*, a filamentous mat-forming cyanobacterium) pose a health risk for swimmers and tubers that are allergic to it. While it is hard to draw a mechanistic relationship between nitrate levels and toxic algae in the Ichetucknee, there has been evidence of a correlation between the two (WSI, 2003). The nitrate in the Ichetucknee also eventually ends up discharged into the Santa Fe and Suwannee rivers, larger rivers of regional importance.

Nitrate (NO3) is an inorganic form of Nitrogen (N) that under certain circumstances stimulates plant growth, while ammonium (NH_4) is the preferred form of nitrogen for most plants, plants can readily assimilate nitrate for the formation for amino acids. Nitrite (NO2) can be formed from nitrate by a chemical process called N reduction and can be very toxic however

it is unstable and does not generally occur in significant levels (Phelps, 2004). Nitrate in drinking water is typically measured in terms of the amount of nitrogen (not including oxygen); the federal standard for nitrate in drinking water is 10 mg/L nitrate-N.

Nitrate in groundwater not only causes ecological problems but can be a serious threat to public health. Short-term exposure to drinking water with a nitrate level at or above the health standard of 10 mg/L nitrate-N is a potential health problem primarily for infants and the elderly, leading to a disease called methemoglobinemia. Methemoglobin is formed when nitrite oxidizes the ferrous iron in hemoglobin to the ferric form which means that it cannot bind oxygen (Fan et al. 1987). Infants consume large quantities of water relative to their body weight and their immature digestive systems are more likely than adults' to allow the reduction of nitrate to nitrite (Pierzynski et al, 1994).

Identifying and quantifying the sources of nitrate pollution within the springshed is the first step in developing proper management practices and legal framework to protect the water quality of Florida's springs (Katz, 1999). The definition of a springshed was developed by Hydrogeology Consortium in 2002 and is stated as "those areas within groundwater and surface-water basins that contribute to the discharge of the spring" (Upchurch and Champion, 2002). This definition is important because it includes surface-water drainage basins, such as Rose Creek and Alligator Lake that discharge into the Ichetucknee's groundwater basin via sinkholes, swallets, and sinking streams. Contaminants in surface water run-off ultimately end up in the Ichetucknee and could be significant sources of pollution in the springs. Therefore to gain an understanding of the level of nutrient pollution in a spring one must account for all of the sources in the entire springshed, a process referred to as nutrient budgeting.

Columbia County is mostly rural, and the majority of households are not connected to any type of municipal sewage treatment system. This has led to the proliferation of thousands of on-site sewage treatment discharge systems (OSTDS), more commonly known as septic tanks, in the Ichetucknee springshed. A large percentage of the soils in Florida are unsuitable for conventional septic tanks, mainly due to high water tables and shallow depth to bedrock. Owners of septic tanks face the options of leaving their current systems alone and maintaining the status quo, or paying for the installation of advanced on-site treatment systems which significantly reduce nitrate load by an estimated 80 % (WCDOH).

Other sources include Lake City's wastewater treatment facility, which discharges its effluent, which discharges its effluent on a spray-field in the Ichetucknee springshed. Various land uses also contribute nitrate to the landscape in the springshed as well. Urban areas in the springshed generally located in and around Lake City contribute nitrate mostly via fertilizer runoff from residential lawns. Agricultural lands such as improved pasture and row-crops are applied fertilizers to enhance their productivity and to increase benefits for their owners.

All of these sources of nitrates can be considered the negative consequences of human actions, whether growing crops, fertilizing a yard, or simply flushing the toilet. Most of the people who contribute to the loading of nitrates in the basin only see the benefits of their actions such as a healthier crop or higher beef profits, and are not aware of, or affected by, the negative results of their actions. These negative consequences, referred to as externalities, occur when a person undertakes an action that costs or negative impacts to external stakeholders which need not be paid or accounted for according to existing laws. These users have little incentive to stop impacting the resource because all of the benefits accrue privately while the costs are spread across the public, often from the use of a public good. A public good is a good whereby the

consumption of the good by one individual does not reduce the amount of the good available for consumption by others; and no one can be effectively excluded from using that good (Mitchell and Carson, 1989).

The nature of public goods prevents them from being publicly traded in any type of market structure; however people still value these resources. Groundwater quality is a typical example of a public good, one which is vitally important to humans and often impacted by human actions. Estimating the values of these goods, and the public's preference for them, provides valuable information to public decision-makers and natural resource managers. This information gives them the ability to make better decisions regarding the use of public goods, and could provide reasoning for creating incentives to discourage the affect of externalities. There are a number of methods that provide ways of estimating the value of public goods (Carson, 2000). In order to estimate the citizens of Columbia County's values for the Ichetucknee this study will utilize the contingent valuation method.

The aim of the contingent valuation method (CVM) is to elicit preferences for the provision of a good using a carefully designed survey or questionnaire. The survey asks respondents to state their preferences by directly asking them their willingness to pay (WTP) for a change in the quality or quantity of a public good. In the survey the respondent is presented with a hypothetical market situation where the good can be purchased. The WTP response is contingent on this hypothetical market, which is where the name of the methodology is derived (Mitchell and Carson, 1989). In this study the difference in the level of water quality in the Ichetucknee system is the good that is being purchased. This will allow us to estimate the value of water quality in the Ichetucknee for residents of Columbia County.

There are several reasons why estimates for economic values of environmental resources are required. The main reason is to just to justify and decide how to allocate public tax dollars on conservation initiatives and to consider the public's support for environmental initiatives. Natural resource valuation is also useful in order to compare the benefits of different projects, to prioritize conservation or restoration projects, and to maximize the efficiency of benefits per dollar spent. Ecosystem valuation also appeals to a wide array of groups, from environmentalists who feel that natural ecosystems are severely undervalued and free-market economists who believe valuation can enhance efficiency and allocation of environmental benefits (Carpenter and Turner, 2000).

The purpose of this study is to provide the Columbia County Government, Suwannee River Water Management District, and all other interested parties an inventory of the sources of nitrate pollution in the Ichetucknee springshed. The nutrient budget is needed due to a lack of information and misconceptions of nutrient sources in the basin among decision makers and constituents in the Basin. By identifying the sources and loads of N in the basin, if there is a policy that needs to be implemented concerning the Ichetucknee, this data should inform it.

The other objective of this study is to estimate the public's willingness to pay to improve and protect water quality in the Ichetucknee using the contingent valuation method. The results of this study help inform the debate over the allocation of funds for groundwater protection, and should provide useful information for policymakers in the region. This information can only be provided by surveying the public and asking them directly to state their values and preferences.

CHAPTER 2
BACKGROUND AND AREA OF STUDY

Related Studies

The Ichetucknee is not the only spring system in Florida that is facing threats from nitrate contamination. In fact over the past 40 years many springs in Florida, including those that contribute to the Suwannee River watershed, have shown increasing trends in regard to levels of nitrate-N (Katz 1992, Hornsby and Ceryak 1999).

Many of the elements of the nutrient budget portion of this study were designed using similar methods to studies based on other water- and springshed nutrient studies in Florida (Pittman et al 1997, Katz 1999, Chellette 2002, Phelps 2004). All of these studies analyzed nitrate loading from various anthropogenic sources as the main parameter of concern.

Katz (1999) conducted a nutrient inventory of the Suwannee River basin in order to account for sources of nitrate pollution in the many springs discharging into the Santa Fe and Suwannee River. Each source is accounted for on a county by county basis as opposed to hydrologic boundaries, such as a springshed. The study also accounts for fertilizer sales and animal wastes individually, as opposed to estimating the output from agricultural land-uses that account for their combined load. Isotope analysis was used to help determine whether the sources of nitrates were primarily from organic such as human or animal wastes or mineral sources, such as fertilizers.

Approximately 50 years worth of Nitrogen data was analyzed to show the influences and changes of different sources over time. The investigators found that in Columbia County, the largest sources of nitrates in recent years were fertilizers, atmospheric deposition, and wastes from beef cattle. As the Ichetucknee is a sub-component of the Santa Fe and Suwannee River

systems, the sources presented in the Katz (1999) study were closely scrutinized for their applicability to our study.

In order to account for elevated nitrate levels in the Wakulla Springs system Chellette et al (2002) quantify the various inputs of nitrogen to the landscape of Wakulla and Leon counties. One of the major sources of nitrates in these regions is waste-water sprayfields, which are also present in the Ichetucknee system, although to a much lesser extent.

CVM provides a way to estimate values for goods where no markets existed and revealed preference methods could not be used (Brown et al, 2003). The contingent valuation is well suited for estimating the value of a public good such as groundwater quality (Brown et al, 2003). The method has been used successfully to estimate public willingness to pay for water quality improvements in numerous other studies, (Ahtian 2007, d'Arge and Shogren 1989, Loomis et al 2000, Shrestha and Alavalapati, 2004).

Loomis, et al. (2000) used CVM to estimate household's WTP for five ecosystem services associated with restoration of a section of the Platte River in Colorado. The services that were examined included dilution of wastewater, natural water purification, recreation, erosion control, and wildlife habitat. The investigators used a dichotomous-choice WTP question to determine if residents' would pay for increases in these ecosystems services by an increase in their water bill. The funds generated from this increase were to be used for a variety of habitat restoration projects, conservation easements and implementation of best management practices.

The study found that participants were willing to pay an average of $21 per month for the services for a total value of $19-70 million for the population along the river (Loomis et al. 2000). The results indicate that citizens are willing to pay a monthly fee $20 per month to protect water quality in rivers. This study went to great lengths to ensure that participants correctly

interpreted and understood the information presented in the interviews and questionnaires, which enhances its validity.

The rivers of New Mexico's Four Corners Region provide miles of critical habitat for nine threatened or endangered species of fish. Protection of these species required habitat improvements, fish passageways, and releases of water from dams to imitate natural water flows required by the fish (Barrens et al 1996). A CV survey was sent to a sample of 800 households in the Four Corners states of Arizona, Colorado, New Mexico, and Utah. They were told that some State and Federal officials thought the combined costs of the habitat improvements and the restrictions on hydropower were too costly, and were asked if they would contribute to the Four Corners Region Threatened and Endangered Fish Trust Fund (Barrens et al 1996). The annual mean WTP was estimated to be $195 per household, which is a comparable figure from the results of the Loomis (2000) study.

In order to determine WTP for protection from a higher level of environmental threat than increased nutrients runoff, Ahtian (2007) conducted a CV study to determine the value of increased protection from oil spills in the Gulf of Finland. The respondents were asked a dichotomous choice question, whether they would vote for an increase in federal taxes of a certain Bid amount, and the oil spill response and prevention services were described to be provided by the Finnish government. The results reveal a mean WTP from 22.6-83.7 euros ($34-$125.6 US) and a conservative aggregate WTP of 109 million euros for the entire nation.

This estimate is considered very conservative because it uses the lower estimate for mean WTP and assumes that non-respondents values for oil spill protection are zero. The study also does not take into account the values from citizens from other countries surrounding the Gulf, such as Russia and Estonia. While the mean WTP is smaller than in several other studies of river

ecosystems (Loomis 2000, Bishop 1989) the respondents represent a much broader geographic range and are therefore not as closely tied to the resource as the participants in many other CVM studies of water quality. The aggregate WTP is also much larger than in other CVM studies due to the large population size. The Ichetucknee is a much smaller river than those valued in the previous studies and our study will encompass a much smaller geographic area, Columbia County, FL.

Many early CVM studies met with a great deal of criticism and many researchers were skeptical of the "hypothetical market". Many of the criticisms were addressed by several validity studies that took place in subsequent years, the most crucial being Bishop and Heberlein's (1979) validity study. Their study compared CV to two more widely accepted valuation methods, travel-cost method (TCM) and cash transactions showed that CVM generated values that were quite comparable to TCM estimates and slightly conservative compared to cash transactions.

Mitchell and Carson's (1989) book on contingent valuation made a large impact on the practice of CVM, and provided recommendations for designing a CV study, a broad overview of the method for novices, and prescriptive recommendations that led to a new standard for research on the validity of the method (Brown, 2003). While there continued to be doubts pertaining to the reliability of CVM, the 1993 NOAA Blue Ribbon Panel to evaluate the credibility of utilizing CVM to estimate non-use values for environmental goods helped to increase the reliability of the method (NOAA, 1993). The panel provided guidelines and procedures for CVM study design and implementation that develop "reliable" estimates of non-use values (Arrow et al. 1993). Most of the guidelines suggested by the NOAA Panel (Arrow et al. 1993) and Boyle (2003) were taken into account in this study in order to ensure validity and reliable estimates for the value of water quality improvements in the Ichetucknee.

While this study uses a very common version of CVM, it is unique in that (as far as the knowledge of the author) it is one of the only studies to combine this with a complete nutrient inventory of the sample region in which the study is conducted. This combination allows for a more direct relationship between the sources of pollution that are detrimental to the resource and the estimated amount individuals will pay to reduce those sources.

Study Area

Ecological and Physical Characteristics of the Study Area

The Ichetucknee Springs Basin is approximately 300 square miles located mostly in Columbia County. Eight named springs create the Ichetucknee River that joins the Santa Fe River four miles south of the headspring. The springs that collectively comprise the Ichetucknee complex are first magnitude, with an average flow of 222 million gallons per day (SRWMD, 2007). The creeks and lakes in the basin drain through sinkholes into conduits in the limestone. The conduits are gaps in the limestone where the rock has been dissolved away and through which groundwater flows down gradient to Ichetucknee Springs. Large portions of groundwater recharge occur in the un-confined areas of the springshed. Separate dye trace studies have confirmed the connection of Rose Sink to the springs, and Black and Dyal Sinks, located in Clayhole Creek, with Rose Sink and the springs (Upchurch and Champion, 2003).

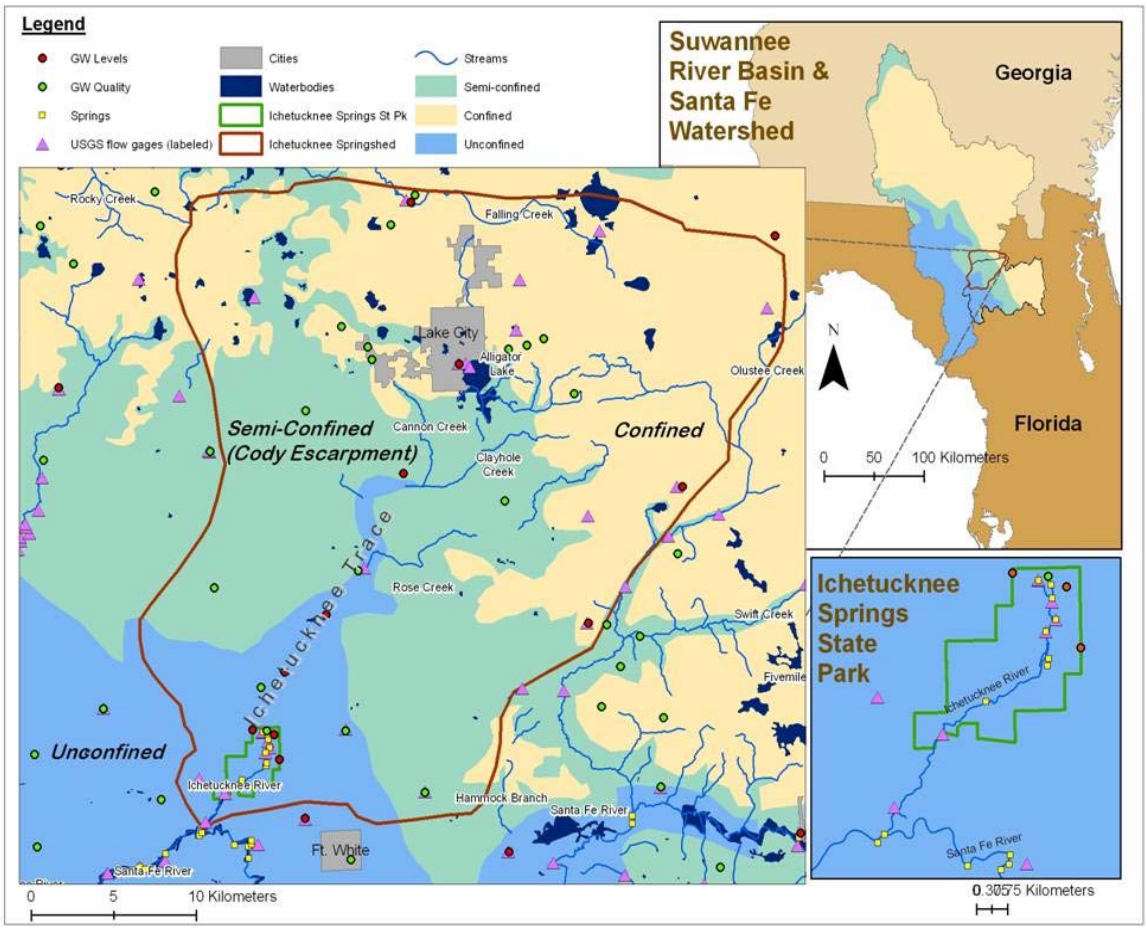


Figure 2-1. Hydrologic Map of the Ichetucknee Springshed

The Cody Scarp is a geological divide that separates lands to the north that are part of the confined region of the aquifer and lands to the south that are considered unconfined. The clay layer in the confined areas north of the scarp helps decrease groundwater intrusion and thus protects groundwater somewhat from pollution. The unconfined areas south of the scarp are more susceptible to groundwater pollution due to this lack of protection.

Ichetucknee Springs State Park (ISSP) was established in 1970 and today it is the premier tubing river in the country. Trampling of the river bottom by tubers during the 1970's caused severe damage to the native aquatic plant communities of the springs and river. A carrying

capacity was initiated in the 1980's to maintain a balance between recreational use and preservation of the river (ISBWG, 2006). A survey of submerged aquatic vegetation was conducted in 2003 and found that approximately 78% of the Ichetucknee river-bottom is covered with submerged aquatic vegetation (SAV). By comparing this to an older study conducted before the formation of ISSP, they found that SAV had increased by 350% since 1979 (Kurtz et al 2004)

In 2006 FDEP conducted a water quality study of the Ichetucknee, comparing data between 1995-2006, with the purpose of determining whether sites of contamination in the basin were affecting water quality and to see if algal growth in areas of the river were having a negative affect. Several sampling sites were established in the recharge basin and compared to sites along the river. The study found that pesticide, herbicide, and metals were not an issue along the river. Total phosphorous was found to be relatively low in the river and showed no significant change from 1995-2006. Nitrate-nitrite levels in the springs however were elevated, and many exceeded the 85-90th percentile concentration for Florida rivers (FDEP, 2006a). The 2006 nitrate concentrations also tended to be slightly higher than those in 1995 indicating an increasing trend over time. However, this study could not provide conclusive links between the presence of nitrates and overgrowth of algae that has occurred in parts of the river.

Another FDEP ecological study was conducted in 2006 that measured water quality data, as well as conducting a habitat assessment and benthic macro-invertebrate stream condition index (SCI). This study also found levels of nitrates to be elevated in the Ichetucknee. The habitat assessment score was 134 and which is considered in the "optimal" range. The results of the SCI, a complex method of comparing taxa of macro-invertebrates, revealed a score of 56 which is comparable to other relatively undisturbed streams in the state (FDEP, 2006b). Both of

these studies conclude that the main issue of concern in the Ichetucknee system is the level of nitrate-N, however cannot conclude that Nitrate is necessarily causing the problems of algae growth, based on their evidence.

Socio-Economic Characteristics of the Study Area

Columbia County located in North-central Florida has a population of approximately 67,000 and a relatively low population density of 71 people per square mile. The area has seen fast population growth, almost 19% between the years 2000-2006, higher than even Florida's average of 13% during that period (USCB, 2007). There are around 21,000 households in the county, with approximately 2.6 people per household. The county seat is the City of Lake City, its largest population center with approximately 14,000 residents.

Median household income was $32,455 which is lower than the State average of $40,900 and the poverty level is around 14%. In 2000, the home-ownership rate was 77% which is higher than the state average. Healthcare is the largest employment sector with over 3,000 paid employees; other large employers in the county include Retail and Accommodation and Food Services (USCB, 2007).

CHAPTER 3
METHODOLOGY TO DEVELOP A NUTRIENT INVENTORY AND PUBLIC WILLINGNESS TO PAY FOR WATER QUALITY IN THE ICHETUCKNEE SPRINGS SYSTEM

Nutrient Inventory of the Ichetucknee Springshed

Ichetucknee River

To quantify the N mass-balance equation of the Ichetucknee springshed system, the total mass of Nitrate leaving the system via the River was needed. This was calculated by multiplying the mean concentration, by mass, of nitrate in the river water by the total flow in Liters-per-day

Atmospheric Deposition

Atmospheric deposition of nitrogen and other elements is a naturally occurring phenomenon that has been altered by human activities, specifically the burning of fossil fuels and the release of nitrogen- and sulphur-oxides into the atmosphere. It is then deposited on the land surface by rainfall and dry deposition. The National Atmospheric Deposition Program (NADP) is a cooperative effort between the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities which monitors atmospheric deposition of nitrogen and other substances. The estimate for nitrate loading contributed by atmospheric deposition were obtained using data collected by the NADP/NTN station located in Bradford Forest (Bradford County, Florida; ca. 50km from Ichetucknee) (NADP, 2006) and multiplying by the area of the springshed.

Lake City's Waste Water Treatment Facility (WWTF) Sprayfield

Lake City is a town of roughly 14,000, located in Columbia County. The city's effluent irrigation spray-field system was completed in 1987, sending secondary effluent from the St. Margaret Road Water Reclamation Facility through 4 miles of pipeline to the effluent irrigation site. Effluent is applied to the treatment fields through an irrigation system consisting of 70

fixed-gun type sprinklers (CLC, 2006). The Lake City Waste-Water Treatment Facility (WWTF) is located south of the Cody Scarp in the springshed. To calculate the nitrate load from the Lake City WWTF, the average annual concentration of nitrate was multiplied by the average annual loading rate of the system.

OSTDS

On-site Sewage Treatment Discharge Systems (OSTDS) are the most common form of domestic wastewater treatment in rural and unincorporated areas outside of cities. Due to the rural nature of the Ichetucknee Springs Basin, the majority of households located in the area are not connected to any type of municipal sewage treatment facility. Therefore most use OSTDS, more commonly referred to as septic tanks. For most properly sited and installed septic tanks nitrification is the most prominent mechanism in aerobic soils, and leads to a conversion of organic and ammonium nitrogen to nitrate nitrogen. The majority of soils are incapable of absorbing these nitrates, which eventually penetrate the groundwater (Bicki, 1984).

Septic tank effluent typically contains levels of total N between 40 and 80 mg/l and mean levels around 55mg/l (Otis, 1975). Many studies have demonstrated high levels of nitrates, those exceeding the safe drinking-water level of 10 mg/l, great distances from OSTDS sites. Nitrate is very soluble and travels easily through aerobic soils into groundwater.

A large percentage of the soils in Florida are unsuitable for conventional septic tanks, mainly due to high water tables and shallow depth to bedrock. However, these conventional systems can be modified to improve the treatment of effluent and reduce nitrates in the groundwater. Some advanced modifications include mechanical aeration, separated chambers, nutrient removal systems, pressurized application systems, and electro-osmosis systems (Bicki, 1984)

Due to unreliable records it is difficult to determine the actual number of active septic tanks in the basin. This study instead attempts to simply determine the approximate population of people in the basin using septic tanks. The amount of N input from septic tanks was determined by estimating the total number of people within the basin that were not on municipal water supply (therefore assumed to be on septic systems). This was done by multiplying the area of the basin by the population density of Columbia County to obtain a total population for the basin (25,123 people), and subtracting the number of citizens served by Lake City's municipal water supply (approximately 13,500 people) for a total of 11,623. This figure was multiplied by the per capita load of 4.2kg N/yr (Otis, 1993) for the total annual load from septic tanks. This per capita figure was used by Katz, et al in a nutrient study of the Suwannee River watershed (Katz, 1999) as well as Chellette in a study of the Wakulla Springs system (Chellette, 2002).

Land-Uses

Land-use within a drainage basin is on of the most important factors in determining the characteristics of runoff and groundwater quality in the basin. Several different types of land-uses are associated with elevated levels of nitrogen, most obviously agricultural land-uses. Several studies have used fertilizer sales as a proxy for the amount of nitrogen applied to agricultural lands (Chelette 2002, Phelps, 2004) though there are several drawbacks to this technique. There is no guarantee that fertilizer sold in a county is used only in that county, or that fertilizer is not imported from outside the county and subsequently applied to agricultural land in the study area.

This study examines the specific types of land-uses in the Ichetucknee Springshed and the nutrient loads associated with these lands. This was accomplished using GIS mapping and data. By overlapping the SRWMD 1995 Land-Use Map with the delineated boundaries of the Ichetucknee Springshed we were able to determine the area of hectares of every type of land-use

in the Ichetucknee Springshed (Appendix A). While there are a variety of land-use designations in the area, improved pasture land, row crops, and urban land-uses were examined closely due to their associated levels of nitrogen input.

For the urban and improved pasture land-use categories, per hectare values of nitrate-N loading were obtained from Harper's (1994) study of stormwater run-off from various types of land-uses in Central and South Florida.

Urban. The Urban land-use designation used in this study is very general and is defined as "urban and built-up lands consisting of areas of intensive use with much of the land occupied by man-made structures" (FDOT, 1999). This includes strip malls, residential areas, shopping centers, commercial and industrial complexes, government buildings, etc. The Urban category takes precedent over other categories if the area meets the criteria for more than one designation. For example, a Residential area with sufficient tree canopy cover to be considered an Upland Forest designation will still be classified as Urban.

Urban land-uses are often associated with large percentages of impermeable surfaces such as buildings and parking lots, and therefore have a significant affect on stormwater run-off. Other sources of nitrates associate with the urban land-use designation include fertilizer run-off from residential lawns. To calculate the amount of nitrate loading associated with urban land-use the area of urban land was multiplied by the per-area amount from the Harper (1994) study.

Improved Pasture. The Improved Pasture land-use designation used in this study was defined as "land which has been cleared, tilled, reseeded with specific grass and periodically improved with brush control and fertilizer applications" (FDOT, 1999). This was one of the largest land-uses in the basin and therefore played a significant role in the overall nutrient

budget. To determine the nitrate load from Improved Pasture lands the area of coverage was multiplied by the loading rate from the Harper study.

Row Crops. The Row Crops land-use designation is defined as fields where "rows remain well-defined even after crops have been harvested" (FDOT, 1999) and typically include potatoes, beans, corn and tomatoes. These types of land-uses are often associated with heavy levels of nutrient input, mainly in the form of fertilizers.

To determine the amount of nitrate loading per hectare from Row Crops, a value was obtained from a watershed assessment study by Soil and Water Engineering Technology for SRWMD (SWET, 1998). The study used computer modeling to simulate N loading to groundwater from various types of land-uses. Their figure for Row Crops was multiplied by the amount of hectares of Row Crops in the basin to obtain a total load. This value is much higher on a per-hectare basis than the other land-uses, as would be expected from a higher-intensity agricultural designation.

Contingent Valuation Survey

Theoretical Framework

The model for contingent valuation method is based in random utility theory (McFadden, 1973). Utility is defined as a function of a household's income, *y,* given price of goods which are constant, a vector of environmental quality, *q*, and a vector of individual characteristics, C:

$$u = u(y, q, C) \quad (1)$$

Indirect utility, *v*, is composed of two parts, one that can be estimated by the researcher and one that is random:

$$v = u + \varepsilon \quad (2)$$

The utility for maintaining the status quo for environmental quality, q^0 is:

$$v_0 = u_0(y, q^0, C) + \varepsilon_0 \quad (3)$$

while the utility for a change in environmental quality, q^1, where p is the price paid, is:

$$v_1 = u_1(y\text{-}p, q^1, C) + \varepsilon_1 \quad (4)$$

where ε_i ($i = 0, 1$) are the random, unobserved components of utility that are independently and identically distributed.

$$u_{i1} = \sigma C_i + B(y_i - p) + \varepsilon_1 \quad (5)$$

$$u_{i0} = \sigma C_i + B y_i + \varepsilon_0 \quad (6)$$

For an individual that must answer a question: "Would you vote for a program that permanently increased water quality from q^0 to q^1 if it would increase your monthly utility bill by $\$p$ for this year?" the individual would respond yes if

$$u_1 (y\text{-}p, q^1, C) + \varepsilon_1 - u_0 (y, q^0, C) + \varepsilon_0 \geq 0 \quad (7)$$

The probability of a yes response is given by the probability that utility received with the program is greater than the utility received without the program:

$$\Pr(Y) = \Pr[v_1 (y\text{-}p, q^1, C) + \varepsilon_1 > v(y, q^0, C) + \varepsilon_0] = \Pr[\Delta u > 0] \quad (8)$$

Survey Design

The design of the survey instrument is the most important part of the contingent valuation method, because the results of contingent valuation surveys are extremely sensitive to what respondents believe they are being asked to value, as well as the context that is described in the survey (Holmes and Boyle, 2005). It is important to clearly define the good that is being valued and the method of its provision, and to demonstrate that respondents are actually stating their values for the good when they answer the WTP question.

The contingent valuation portion of this study focused on the nitrate load from septic tanks. This source was chosen for several reasons, first, they are point source in the sense that the majority of the tanks in the basin can be located and identified. Second, information on the method to reduce this load, installing advanced treatment tanks, is available and the cost of such a program can be estimated readily. Third, while septic tanks may be a relatively small fraction of the total load of nitrate to the landscape, many tanks are located in areas of the Springshed (Ichetucknee Trace) that are particularly vulnerable to N loading and transport. The sample population for this study was chosen to be all the residents of Columbia County due mainly to their proximity to the Ichetucknee.

While citizens from other counties and most likely other states visit the River and value the health of the ecosystem, it was not feasible to account for these non-residents due to time and cost restraints. It was also not considered feasible to target only residents of the Ichetucknee Springshed due to the difficulty of obtaining addresses for that limited area as well as the fact that any implementation of a tax or utility fee increase across a non-standard political boundary is unrealistic.

A sample size of approximately 1,000 residents was chosen to ensure significant numbers for statistical analysis for the population of Columbia County, which is approximately 64,000 people. Addresses were obtained from the Columbia County Property Appraisers Office, which resulted in a sample of households who are home-owners as opposed to renters. This is significant in that renters would have very little incentive to pay increased fees for a septic system they do not own.

A mail survey was selected as the form of data collection mode for several reasons. First, mail surveys are the most commonly used method for contingent valuation studies (Brown,

2003) and Columbia County has reliable records for mailing addresses. Second, because the information to be collected was easily presented in such a format, it was unnecessary to communicate directly with participants via phone or in person. Third, this collection mode was consistent with the budget and time restraints of the investigators.

An important component of the survey design process was development of the information and questions to be included in the survey (Mitchell and Carson 1989, Boyle 2003). The survey was designed based on input from experts, policymakers in the area, and residents of the area. The booklet first gave a description of Ichetucknee and asked questions concerning the participants' interaction with the River. The next section described generally the role of nitrates in the environmental change and common man-made sources of nitrates. It then described the problem of nitrates in the Ichetucknee, a brief description of septic tanks, and the role septic tanks play in the problem.

Following each information treatment, questions were asked to determine the participants' prior knowledge of each subject, and understanding of the issue. These questions were included in order to help ensure that respondents would carefully read the material in the questionnaire, so they could make an informed choice when responding to the WTP question. The WTP question proposes a creating a program that would replace standard septic tanks in the Ichetucknee Springshed with advanced models that greatly reduce nitrate pollution. The program would result in an increase in the respondents' monthly utility bill.

For the response format of the contingent valuation question this study used a dichotomous choice or For/Against question format. This essentially allows the participant to vote for or against a set monetary amount (Bid Amount), which was varied evenly across the sample population. The dichotomous choice format forces respondents to choose between the utility

associated with paying the stated amount or maintaining the status quo. If the participant perceives the increased utility is greater than the $ amount, he will vote "For" the program (Hanemann, 1984). The dichotomous choice format was chosen for its applicability to the subject and simplicity of analysis. The actual wording for the CV question was:

> **Q-8** Suppose that Columbia County is considering implementing a program to update, modify, and maintain septic tanks in the county in order to improve water quality in the Ichetucknee River. The program would use tax dollars to create incentives to compensate home-owners who currently have septic tanks to update to new treatment technologies. Based on scientific evidence this program is expected to reduce nitrate loading to the Ichetucknee River by approximately 20% over the next 10 years.
>
> The ecological benefits in the Ichetucknee would include improved water clarity, reduction of excessive algae growth, and protection of natural wildlife habitat. The funding for this program would come from an increase in Columbia County households' utility bills of $_____ per month for the next 10 years. If this initiative were on the next election ballot would you vote:
>
> ☐ ***For*** ☐ ***Against***

The time frame for payment was described as monthly payments over the period of 10 years, which was selected in order to be realistic about the amount of time it would take to get a program such as the one described in the survey operating. The bid amounts were set as $5, $10, $15, $20, and $25 per month and were evenly dispersed through the sample. The estimated cost of this program was estimated to be approximately $25 million based on the estimated number of septic tanks in the basin (5,000) and the approximate cost of installation for advanced treatment systems ($5,000 per unit -WCDOH, 2007). Ancillary questions were asked in order to obtain socio-economic data on the participants.

Pre-Testing

Pre-testing helps to ensure that survey questions are stated clearly, easily understandable to respondents, and are eliciting the information they are intended to (Brown et al, 2003). Pre-testing of the survey was limited due to budgetary constraints. After designing the survey and reviewing it with several experts and colleagues on campus at the University of Florida the survey was sent via email too several local contacts in Columbia County. The draft survey was sent electronically to several knowledgeable local experts on the area including the Columbia County Manager at the time Dale Williams and the head of the Ichetucknee Springs Basin Working Group, Jim Stevenson, for review.

The pre-testing was conducted on a one-on-one basis with the investigator and pre-test subjects from Alachua and Columbia Counties. Three pre-test subjects were interviewed at Ichetucknee Springs, while two were interviewed at local area establishments. Participants were asked to read through and complete the entire survey as if they had just received it in the mail, while recording any comments or concerns they had. After completing they survey, they were asked to share their comments and were questions to determine how well they understood the content of the survey.

Results of the pre-tests varied but most of the participants had little problem interpreting the problems associated with nitrates or the WTP question. Two participants were not very familiar with the Ichetucknee but felt the survey conveyed the issues quite well. Most of the concerns from pre-testing involved the fairness of taxing the entire county when only a small portion of county residents septic tanks are located in the springshed. Several participants reasoned that only those residents with septic tanks near the springs should be responsible for paying for water quality improvements. Some participants were also concerned about the equitability of the tax and its impact on low-income residents. The comments received during

pre-testing were incorporated into the survey as best as possible, and after a final review the surveys were deemed ready for mass printing and mailing.

Implementation

Following a modified version of Dillman's method (2000), a technique designed to improve response rates from surveys, a pre-notification was sent to every participant several days before they received the surveys. The notification was in the form of a postcard which explained that the respondent had been randomly selected for a study by the University of Florida concerning water quality in the Ichetucknee River. It informed them that they would be receiving a questionnaire in the next few days and that their opinions were greatly needed. It also explained that their answers were strictly confidential. The actual wording of the notification postcard was:

> The University of Florida is conducting a study to explore the possibility of improving and protecting water quality in the Ichetucknee River. In a few days you will receive a questionnaire in the mail. In this study we will ask you a series of questions regarding your interactions with the Ichetucknee and your preference towards improving water quality in the river and springs.
>
> The information we are collecting will help us better manage the River and protect its waters. The questionnaire takes approximately 10 minutes and is completely confidential. Please take the time to answer the questions, as we greatly value your opinions and need your assistance.

In total, 948 surveys were sent out via first class mail from the University of Florida Mail Room on July 9, 2007. Due to budget constraints neither a follow-up reminder letter nor a second wave of surveys could be sent. The mailing addresses were selected randomly from a list of approximately 20,000 that was composed by the Columbia County Property Appraisers Office. Of the 1,000 surveys that were planned to be sent out approximately 52 were no included due to bad addresses, deceased residents, or where it was indicated the property was held in a trust. The total amount of surveys mailed out was 948, of which only two were returned to sender, for a

total of 946. The number of valid returned surveys was 169, for a response rate of **17.8%**. The first surveys to be returned were received on July 23rd and the majority were received by the 20th of August.

Analysis

Since the respondents to the survey were asked to give a "Yes/No" response to a specific dollar amount to implement the program, as represented by Equation 8 of the theoretical model, the probability of them answering "Yes" to a certain amount is statistically calculated using the logit model (Hanemann, 1984). The relationship is presented as:

$$\text{Probability Yes} = 1 - \{1+\exp[B_0 - B_1(\$X)]\}^{-1} \quad (9)$$

Where B's are coefficients estimated using logit analysis, $X is a monetary amount the household is asked to pay. The coefficients must include the bid amount, and may also include socio-economic information and responses to attitude questions (Loomis, 2000).

Different specifications of the logit model are possible. The model present here includes several theoretically important socio-economic variables as well questions concerning opinions and interactions with the Ichetucknee. The logistic regression was performed using STATA statistical program, the results of which will be discussed in Chapter 4.

CHAPTER 4
RESULTS AND DISCUSSION

Ichetucknee Springshed Nutrient Budget Results: Total and Relative Nitrate Loads from Inventoried Sources

Ichetucknee River

The mean concentration of nitrate in the Ichetucknee River in 2006 was 0.6 mg/L (FDEP, 2006a) and the total flow of the river was 222.26 million GPD. This amounts to a total of 184,235 kg N per year flowing from the Ichetucknee River.

Table 4-1. Estimated amount of nitrate-N leaving the Ichetucknee River

Flow(L per day)	mg/L N	Kg N/yr
222,260,000	0.6	184,235

Atmospheric Deposition

The estimate for nitrate loading contributed by atmospheric deposition was obtained using data collected by the NADP/NTN station which was then multiplied by the area of the springshed (approximately 92,000 ha), to give an estimate of the total amount of nitrate-N contributed to the Ichetucknee Springshed by atmospheric deposition. The estimated nitrate-N Load From atmospheric deposition was **199,603 KgN/yr.**

Lake City's Waste-Water Sprayfield

To calculate the nitrate load from the Lake City WWTF, the average annual concentration of nitrate (approximately 10mg/L) was multiplied by the average annual loading rate of the system (2.5 million GPD) for a total of 34,538 kgN/year. The potential nitrate load was also calculated using the total permitted loading rate of 3.0 million GPD for a total of 41,446 kgN/yr.

Table 4-2. Estimated nitrate-N load from Lake City's WWTF Sprayfield

WWTF MGD	L/Gallon	mg/L N	Kg/day	kgN/yr
Actual 2,500,000	3.785	10	94.625	34,538
Permit 3,000,000	3.785	10	113.55	41,446

OSTDS

The amount of N input from septic tanks was determined by estimating the total number of people within the basin that were not on municipal water supply multiplied by the per capita load of 4.2kg N/yr. The total annual load from septic tanks was estimated to be 48,817 kgN/yr.

Table 4-3. Estimated nitrate-N load from On-Site Sewage Treatment Discharge Systems (Septic Tanks)

OSTDS Population	kg-N/yr per capita	kg-N/yr
11,623	4.2	48,817

Land Uses

Urban. To calculate the amount of nitrate loading associated with urban land-use the area of urban land (8,400 ha) was multiplied by the per-area load (7.4 kgN/ha-yr) for a total of 62,160 kgN/yr.

Improved Pasture. To determine the nitrate load from improved pasture lands the area of coverage (20,500 ha) was multiplied by the loading rate (11kgN/ha-yr) for a total of 225,500 kg-N/yr.

Row Crops. The estimated load from row crops was determined by multiplying the loading rate of 38 lbs/ac-yr (42.6 kgN/ha-yr) by the amount of hectares of row crops in the basin (1,300), for a total of 55,380 kg-N/yr.

Table 4-4. Estimated nitrate-N load from land lses in the Ichetucknee Springshed

Land Use Type	Kg-N/ha yr	Ha	Kg-N/yr
Urban	7.4	8400	62160
Improved Pasture	11	20500	225500
Row Crops	42.6	1300	55380
Total N L-Use			343040

Summary of Total and Relative Loads

The estimates in Table 6 represent total loads to the landscape within the Ichetucknee Springshed in 2006, not necessarily total loads to the aquifer, which has been standard practice for other nutrient budget studies (Chellette 2002, Katz, 1999). This fact accounts for the large difference between the total nitrate load (approximately 626,000 kgN/yr) compared to the yield from the River (184,235 kgN/yr). The difference between the load and yield must be assumed to be the result of a variety of uptakes, sinks, and transformations that occur between the point that the nitrate is release to the landscape and the time that it emerges in the River. Attempting to accurately account for the affect of these dissimilarity processes was considered beyond the scope of this project, due mainly to time constraints, but would be a very useful exercise for future studies.

Table 4-5. Complete Inventory of nitrate-N Loads in the Ichetucknee Springshed

Source	Load (kg-N/yr)
WWTF	34,538
OSTDS	48,817
Atm Dep	199,603
Urban	62,160
Crop	55,380
Pasture	225,500
Total	625,998

Another factor that most likely contributed to the large difference between the load of nitrates and the yield is the affect of geology on the amounts and rates of nitrate intrusion in the different areas of the springshed. While certain sources of nitrates might occur mainly in the relatively protected, confined areas of the springshed, other sources might have more immediate impacts in the unconfined areas of the Ichetucknee Trace. The application of nitrate from sources such as the Lake City WWTF and septic tanks are typically constant and concentrated in a small area, while the application of nitrates in the form of fertilizers are most likely seasonal and relatively diffuse.

There is also a significant time-lag that is not accounted for in this study, which only considers the nitrate loads from 2006. While the loading occurred in 2006, the amount of time it will take for that water to emerge in the springs is not really known, and could likely vary from weeks in the Ichetucknee Trace to years in the confined areas in the northern regions of the springshed. Water that was discharged years before this study was conducted could be having an affect on the current level of nitrate in the springs and river. One of the largest assumptions this study makes is the assertion that reducing loads from current sources will have a more or less immediate impact on the water quality of the springs, which may simply not be the case.

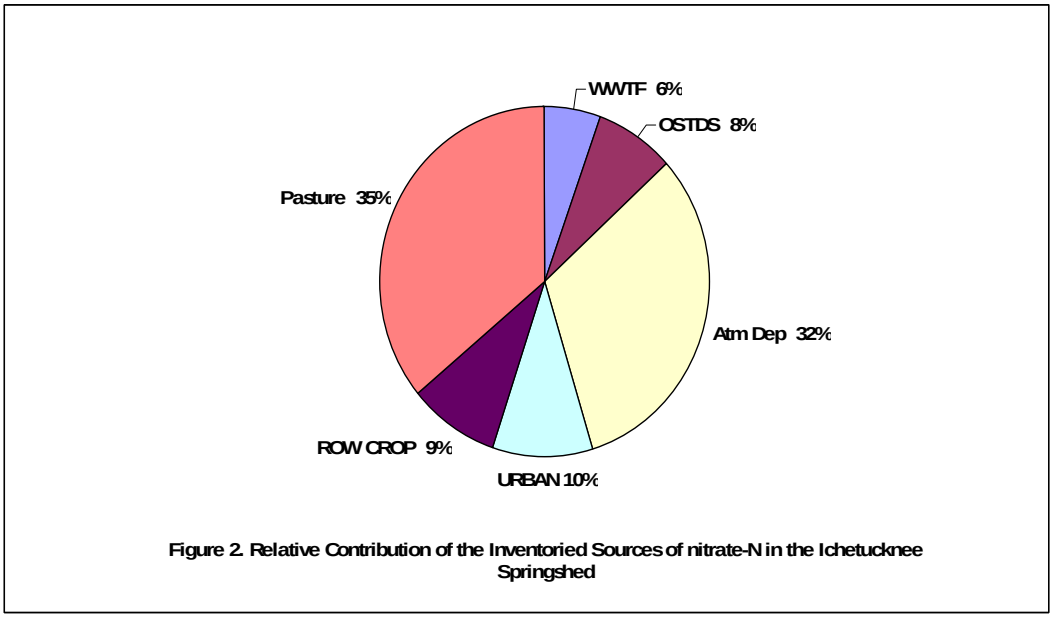


Figure 2. Relative Contribution of the Inventoried Sources of nitrate-N in the Ichetucknee Springshed

Figure4-1. Relative Contribution of Inventoried Sources to nitrate-N to the Ichetucknee Springshed

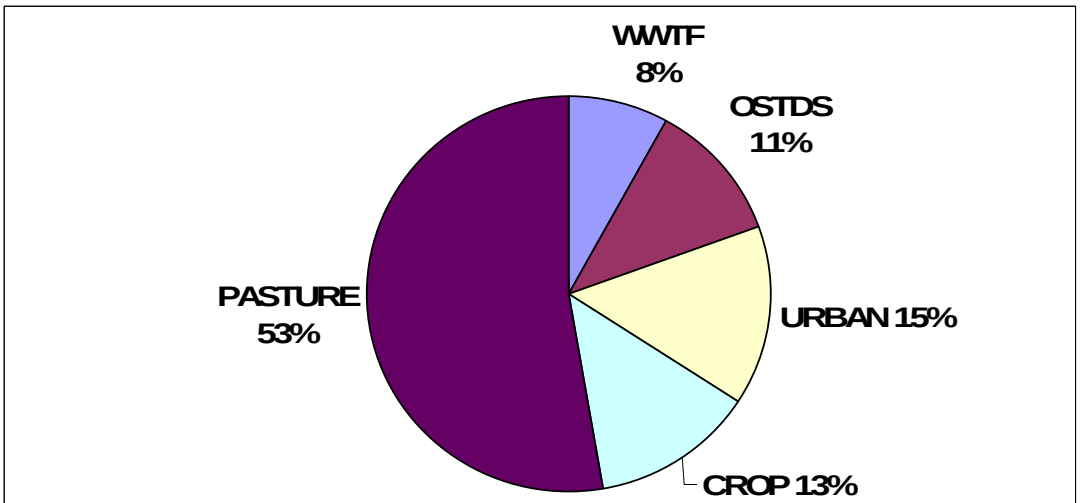


Figure 3. Relative Contribution from Anthropogenic nitrate-N Sources in Ichetucknee Springshed

Figure 4-2. Relative Contribution of Anthropogenic Sources of nitrate-N to the Ichetucknee Springshed

Figure 3 summarizes the relative contribution of each inventoried source of nitrate in the Springshed in 2006, while Figure 4 summarizes the relative contribution of the anthropogenic

sources of nitrate, therefore it does include atmospheric deposition. While the levels of nitrate contributed from Atmospheric Deposition have been influenced by human actions, particularly emissions of Nitrous oxides into the atmosphere, this issue could not be addressed in this study.

The results of the nutrient budget reveal that at the scale of the Ichetucknee Springshed it is clear that runoff from Land Uses comprises around 80% of the anthropogenic load, with over half derived from Improved Pasture land-uses. Septic Tanks and Lake City's WWTF comprise the remainder of the load. Fertilizer runoff from agricultural land uses (improved pasture and row crops) is the greatest contributor of nitrate to the landscape, and should be a major focus in managing the Springshed. Lake City's WWTF does not appear to be a major contributor of nitrates to the Springshed. While septic tanks were utilized in the CVM portion of this study, they do not represent a major relative load to the landscape.

Results from the Contingent Valuation Survey of Columbia County

Descriptive Statistics

This section is a brief summary of some of the descriptive statistics obtained from the contingent valuation survey. The attitudinal and behavioral questions that were included in the survey allow the researcher to gain an understanding of how the population feels and how often they interact with the resource that is being valued. These questions are useful to gauge how well the participants understand the information described in the survey and their prior knowledge. A complete version of the results from the survey can be found in Appendix: C. The descriptive statistics were performed using Microsoft Excel and STATA statistical package.

Visitation: Approximately 84% of those surveyed indicated they have visited Ichetucknee Springs at least once, while 60% of respondents visit the springs 1-2 times per year, 15% visit 3-5 times per year, 3% visit 6-10 times per year, and 5% visit over 11 times per year. The fact that such a large proportion of the sample population has visited the Ichetucknee indicates how

popular the site is among residents of Columbia County. There is a possibility that this high rate of visitation (84%) could be an effect of sample bias, however, the researchers feel that this is unlikely. Ichetucknee Springs is the largest tourist attraction in Columbia County and it stands to reason that a large percentage of local residents would have visited the site. Almost 20,000 local residents visited in 2002 alone (Bonn and Bell, 2003), therefore it seems that 84% is not an unrealistic figure and would most likely be reflected in the total population.

Importance: When asked "How important is it to you to protect Ichetucknee Springs from nitrate pollution?" 57% responded 'Very Important', 33% responded 'Important', 8% responded 'Somewhat Important', and only 2% responded 'Not Important'. These results indicate that a high percentage of Columbia County residents are concerned about the health of the Ichetucknee. This could also be affected by response bias, as individuals who have little regard of the Ichetucknee would not be likely to participate in a study on it.

Participation: When septic tank owners were asked "How likely are you to participate in an incentive program such as the one described, if such a program was implemented?" 20.9% responded 'Unlikely', 11.2% responded 'Somewhat Unlikely', 39.4% responded 'Somewhat Likely', and 28.4% responded 'Very Likely'. The fact that almost 70% of septic tank owners in the sample indicated they would be likely to participate in this type of program is encouraging. It can be inferred that a septic tank replacement and improvement program could stand a chance of being successfully implemented in Columbia County and have a high level of voluntary participation.

Demographic Data: The participants' average household income in 2006 was between $55,000-65,000 which is higher than the county and state average. The average level of education was an associate degree; however there were an unusually high percentage of

participants that claimed to have a graduate or other advanced degree. All of the participants were homeowners, which is due to fact that the addresses for the sample population were obtained from the Columbia County Property Appraisers office and therefore only included property owners (while Columbia County's home ownership rate is 77%). This might explain the higher level of income in the sample, since property owners are likely to have high income versus renters.

Logit Analysis

The final statistical model was:

$$\Delta u = B_0 - B_1(\text{Bid}) + B_2(\text{Income}) + B(\text{Education}) + B(\text{Politic}) - B(\text{Importance}) + B(\text{Visitation}) + error$$

Where 'yes' is the dependent variable and records if a person was or wasn't willing to pay the amount asked in the survey. (1 = Yes, 0 = No),

Bid: The Bid variable refers to the dollar amount that the participant was asked to pay. This variable is always included in a logit model and sign on the coefficient is expected to be negative. This indicates that as the dollar amount participants were asked to pay increases, the less likely they would be to vote for the program. The amounts varied from $5, $10, $15, $20, and $25.

Income: Income level was included because it usually has a positive relation to willingness to pay. The higher a persons income, the larger the amount they are usually willing to pay for environmental services, therefore we would expect a positive sign on the coefficient. (0 = less than $45,000 household annual income, 1 = greater than $45,000 household annual income)

Education: A person's level of education is another socio-economic variable that can have an affect on one's values for environmental goods and services. A positive sign would be

expected on the Education coefficient, indicating that as education level increases, so does the tendency to answer positively to the WTP question. (0 = Less than college education, 1 = College Education)

Politic: Political affiliation was included because it is has been shown to have an impact on WTP estimates. Politically conservative individuals tend to have more anti-environmental leanings when compared to more liberal individuals (Dietz et al 19998). A positive sign on the coefficient is expected, meaning respondents who consider themselves more liberal are more likely to vote for the program. (0= Conservative, 1= Liberal)

Importance: The Importance variable was added because how individuals answer attitudinal questions have shown to have an impact on WTP for environmental goods (Loomis, 2000a). A negative sign is expected, meaning the less important the respondent believes the issue of "protecting Ichetucknee Springs from nitrate pollution" is, the less likely they will vote for the program. (0= Important, 1= Not Important)

Visitation: The Visitation variable was included because there is a positive relationship between frequency with which the participant uses or interacts with the resource that is being valued and their WTP. A positive sign is expected in this case, which would indicate that the more often a participant visits Ichetucknee Springs the more likely they are to vote for the program. (0 = None, 1-2 visits per year, 1 = 3 or more visits per year)

The results of the logistic regression are summarized in Table 7.

Table 4-6. Logistic regression model of probability to pay vote for increased utility bill

WTP	Coef.
Bid	-0.0926***
Income	-.1014
Education	.4654
Politic	1.0298*
Importance	-2.1103***
Visitation	1.1802**
Constant	2.0281
Number of obs	131

*** indicates the variable was significant at the .01 level
** indicates the variable was significant at the .05 level
* indicates the variable was significant at the .1 level
Log likelihood = -73.5355

Interpretation of Regression Results

Bid: Bid has a statistically significant affect on the probability of a 'Yes' response at the .01 level. The negative sign on the coefficient indicates that as the higher the dollar amount participants were asked to pay, the less likely they would be to vote for the program. This result was expected and conforms to economic theory.

Politic: Politic has a significant affect on the probability of a 'Yes' response, at the .1 level. The positive sign indicates that respondents who consider themselves more liberal are more likely to vote for the program, as was predicted. This result could have interesting implications in Columbia County as it is a mostly conservative area, and only about 20% of the sample population identified themselves as liberal.

Importance: The Importance variable has statistically significant affect at the .01 level. The negative sign indicates that the less important the respondent believes the issue of "protecting Ichetucknee Springs from nitrate pollution" is, the less likely they will vote for the program. This affect was expected and conforms with other results in the literature (Loomis, 2000a). This result implies that if policy makers or educators were to enact programs that increase awareness and concern for the ecological health of the Ichetucknee, it would increase the value that individuals place on the river.

Visitation: Visitation has a significant affect at the .05 level. The positive sign indicates that the more often a participant visits Ichetucknee Springs the more likely they are to vote for the program. This sign was expected and conforms to theory as well. The result is interesting in that it might provide managers of Ichetucknee incentive to implement programs to increase visitation at the park by local residents. However the river already has an enforced capacity in summer, and can only withstand a certain increase in activity during those months. One possible solution could be to attempt to increase visitation by local residents during other times of the year, with an emphasis on more passive uses of the resource.

Mean WTP

Hanemann's (1984) formula to calculate the value of mean willingness to pay is:

$$\text{Mean WTP} = (1/B_1)*\ln(1 + e^{B_0}) \quad (8)$$

where B_1 is the coefficient on the Bid amount and B_0 is either the estimated constant (if there are no other independent variables in the model) or the sum of the constant plus the product of the other independent variables times their respective means.

Using this formula mean WTP was calculated and found to be $18.7 per household per month, without incorporating the independent variables. After incorporating the effects of the independent variables, mean WTP was estimated to be $16.9 per household per month for the

increase in water quality in the Ichetucknee River. This amounts to an average annual value of $202 per household. Expanded across all households in Columbia County this comes to total WTP of $42.4 million dollars over ten years. This figure is within the range of other river studies such as Loomis et al (2000) study of the South Platte River ($252 annually) or Hanemann et al (1991) study of salmon restoration in the San Joaquin River ($452 annually). However, the Ichetucknee is a fraction of the size of those larger rivers, yet still commands a similar value from local residents. This again emphasizes the point that citizens of Columbia County are genuinely concerned for the health of the Ichetucknee Springs system.

CHAPTER 5
CONCLUSIONS AND LIMITATIONS

Summary of Study

The purpose of this study was identify the sources of nitrate pollution in the Ichetucknee Springshed and to gain a greater understanding of the value's that citizens of Columbia County place water quality in the Ichetucknee. The results of the nutrient budget reveal that at the scale of the Ichetucknee Springshed it is clear that runoff from Land Uses comprises around 80% of the anthropogenic load, with over half derived from Improved Pasture land-uses. Septic Tanks and Lake City's WWTF comprise the remainder of the load. Fertilizer runoff from agricultural land uses (Improved Pasture and Row Crops) is the greatest contributor of nitrate to the landscape, and should be a major focus in managing the Springshed. Lake City's WWTF does not appear to be a major contributor of nitrates to the Springshed.

The Contingent Valuation survey reveals a good deal of information about Columbia County residents' attitudes and preferences towards the Ichetucknee. A large percentage of participants (84%) have visited the springs and a majority feels that protecting water quality in the river is "Very Important". The general level of knowledge towards the problems associated with nitrates in the Ichetucknee was moderate. These results should be motivation for decision-makers and environmental managers in the area to implement education efforts in the County and springshed, aimed at increasing the knowledge and concern that residents have for the Ichetucknee.

The logit model shows the affects a variety of factors have on participants' willingness to pay responses. As the bid amount increases, the probability of a positive response decreases. These effects of the variables are statistically significant and conform to theoretical and empirical expectations. The probability of accepting the bid amount increases with the

participants' level of visitation to the Ichetucknee and how important they believe water quality in the river to be. The probability of accepting the bid is also higher the more liberal the participants' identify themselves politically, which could have interesting implications due to the generally conservative nature of Columbia County

The mean willingness to pay for the increase in water quality in the Ichetucknee River was calculated to be $16.9 per household, per month over the course of 10 years. This amounts to a total WTP of $42.4 million for Columbia County. This value may be considered a high estimate, due to the fact that it assumes non-respondents have the same WTP as respondents. The aggregate WTP value exceeds the estimated cost of implementing the program of $25 million. While this study uses septic tanks as the method for a 20% improvement water quality, the value that is estimated is not necessarily restricted to improvement from septic tanks, it is for any general 20% improvement in water quality. This is valuable information that can only be provided by surveying the public and asking them directly to state their values and preferences. It also allows for a greater representation of populace's interests in public decision-making.

Limitations and Assumptions

Creating a nutrient budget for a specific springshed within the Floridan Aquifer is complicated and requires a number of simplifying assumptions (Chellette, 2002). Many of the processes that are summarized here are highly variable over time, and certain areas of the Ichetucknee Springshed are highly permeable to groundwater while others are well confined. The contingent valuation method has been proven to provide reliable estimates for non-market values, but still relies on some basic assumptions and faces several limitations. The limitation and assumptions associated with this the study are presented here:

Limitations

- This data only represents the total load to the landscape of the springshed and not to the aquifer.

- The rates of de-nitrification and uptake of nitrate sources in the springshed are not well understood.

- The data presented here only represents the loads that occurred in 2006. Nitrate levels in the Icheutcknee system are highly variable over time and

- The survey only includes Columbia County residents and does not incorporate the values of visitors from nearby counties or from farther distances whom may have also have a value for the Ichetucknee. Considering that 80% of visitors to the Springs are not local residents, it is highly likely that residents of surrounding counties such as Alachua and Suwannee also value the resource.

Assumptions

- The Land-Use Data from 1995 is still accurate in 2006. This is very unlikely; however at the time of the study, this was the most accurate land-use data available.

- Land-use Loading Rates from the Harper and SWET studies are representative of the actual loading rates in the Springshed. Both studies were conducted in Florida so it is not unlikely that these rates are applicable.

- 0.6 mg/L nitrate-N was representative of conditions in the River for the entire year of 2006.

- The flow rate of 222 MGD was representative of conditions in the Ichetucknee River for the entire year of 2006. Water levels and flows change with time, depending on rainfall and other factors.

- Survey respondents answered truthfully to all questions. This is an inherent problem with all stated-preference methods, and must be assumed to be true.

- Respondents would actually pay the amount stated in the survey if it were presented in a real-life situation.

- It is assumed that the payment vehicle did not have an affect on WTP. There is a possibility that respondents to the survey did not agree with the idea of a flat tax on all citizens of the county. Pre-testing revealed some concerns that a flat rate was inequitable to lower income residents and that it was unfair to charge non-septic tank users. This could have an effect on a respondent's WTP.

Conclusions

While the nutrient budget gives a general idea of the major sources of nitrate in the basin, it is still limited in its ability to determine the amounts of pollution that actually enter the groundwater and end up in the springs. Further analysis in this area could include various types of modeling to predict actual nitrate flows to groundwater from all sources in the springshed. Using spatial and hydrological data to predict areas in the springshed that are most vulnerable to groundwater contamination would also be useful to managing nutrients in the springshed. Further study of the karst systems and the movement of groundwater in the springshed could also provide insight into how nutrients are transported from the landscape to the springs.

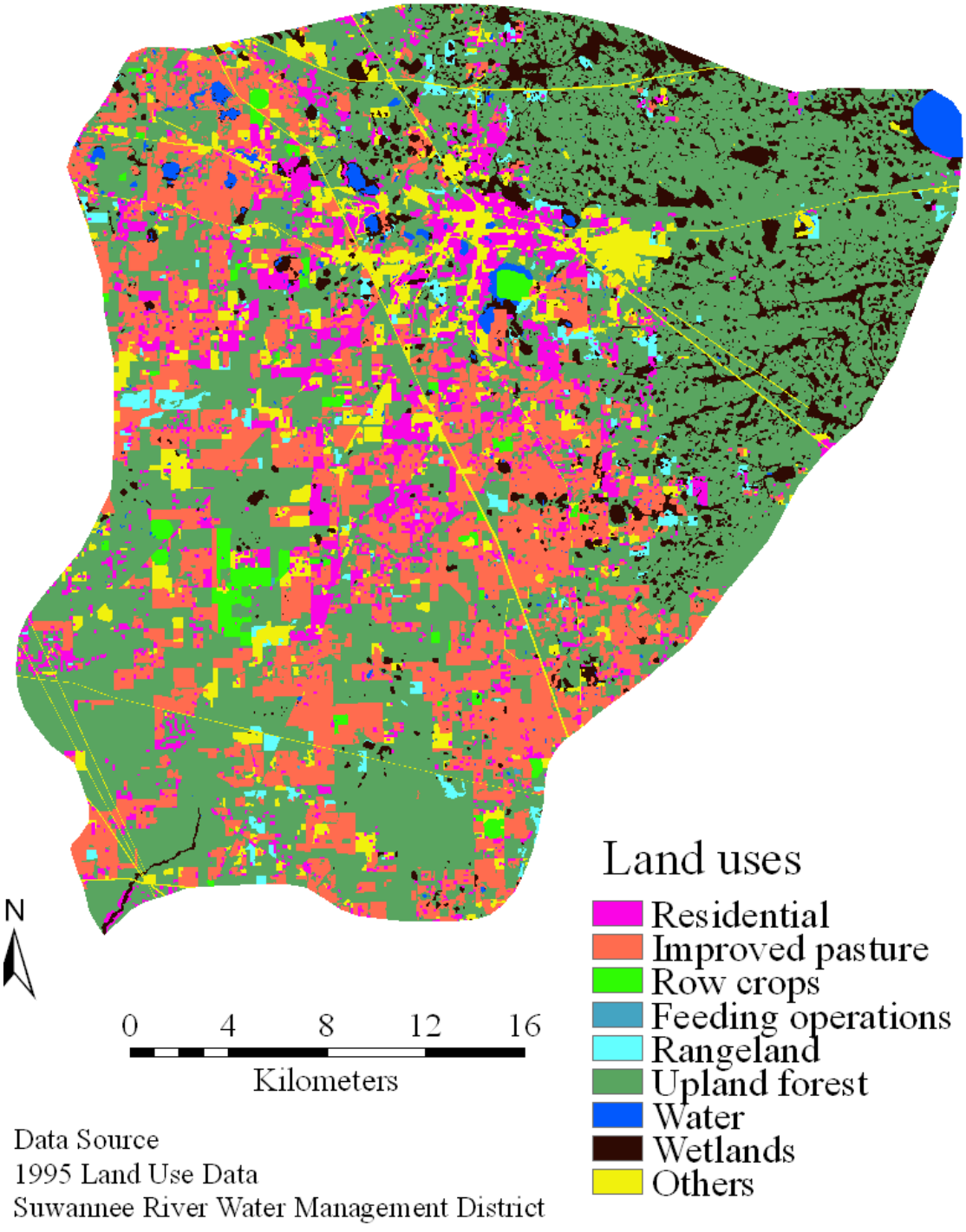
The results of the CVM survey imply that Columbia County residents place a substantial value on water quality in the Ichetucknee River and are willing to pay for and participate in a program to improve it. Using CVM is one of the few ways to place a value on a good that is otherwise completely unknown. This information is important for policymakers to have in order to make informed decisions that affect the water resources that citizen's depend on for drinking water, tourism, and recreation (Loomis, 2000b). The results of this study help inform the debate over the allocation of funds for groundwater protection, and should provide useful information for policymakers considering stormwater planning, land-use changes in the county, and approval for increased septic tanks permits.

The results also imply that if a referendum program of this nature were placed on a ballot in Columbia County, it could face a fair chance of passing. If a flat tax increase for the entire county is unfeasible, one possible action might be to create a special taxing district along hydrologic boundaries, to better ensure that the people who are most drastically impacting the resource are the ones who pay more to improve it. While this study provides an estimate of

citizen's values for water quality in the Ichetucknee, it is ultimately up to policymakers at the State and County levels to implement any changes.

A great amount of research in this area lies ahead. The variety of nutrient sources in the springshed, their relative impacts, and the methods of nutrient transport should all be examined in greater detail. Continued research on the affects of nitrates in the river and other possible causes for the problems of excessive algae growth in the Ichetucknee should also be explored. An interesting area for future socio-economic studies would be to vary the sources of nutrients in the springshed, the level of pollution reduction that would be provided, and the costs of the improvement. This could allow different attributes of the good to be valued as well as provide incremental values for improved water quality in the Ichetucknee. Using another method, such as TCM, to be compared to the results from this study would also be informative.

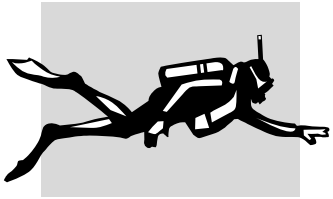
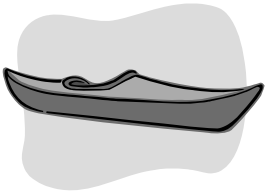
APPENDIX A
LAND-USE MAP OF THE ICHETUCKNEE SPRINGSHED



Data Source
1995 Land Use Data
Suwannee River Water Management District

APPENDIX B
CONTINGENT VALUATION SURVEY: IMPROVING WATER QUALITY IN THE ICHETUCKNEE RIVER

Improving Water Quality in the Ichetucknee River


The University of Florida is conducting a study to explore the possibility of improving water quality in the Ichetucknee. In this survey we will ask you a series of questions regarding your interactions with the Ichetucknee River and your preferences and opinions related to water quality in the river. Please answer all the questions to the best of your ability. We value your opinions greatly and need your help.

Thank you for your time!

School of Natural Resources and Environment
University of Florida

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The Foundation for The Gator Nation

The Ichetucknee River

- The Ichetucknee River is a pristine, crystal clear 5-mile spring run and is the largest tourist attraction in Columbia County, attracting between 3,000-5,000 people a day in busy summer months. While immensely popular for tubing, it has many other recreational opportunities such as swimming, birding, kayaking, and scuba diving.
- The River is also a unique ecological resource and provides habitat for a wide range of fish, reptiles, birds, and aquatic mammals.
- However, over the past decade, the Ichetucknee Springs and River have become threatened by increased groundwater contamination, especially higher levels of nitrates.

Q-1 Have you ever visited Ichetucknee Springs?

Yes
No ⇨ Please go to Q-4

Q-2 How many times a year do you visit Ichetucknee Springs?

☐ 1-2 times per year
☐ 3-5 times per year
☐ 6-10 times per year
☐ 11+ times per year

Q-3 What activities do you participate in when you visit the Ichetucknee (please check all that apply)

☐ Tubing
☐ Canoeing/Kayaking
☐ Wildlife Viewing
☐ Picnicking
☐ Swimming
☐ Hiking
☐ Scuba Diving
☐ Other _____

What are Nitrates?

- Nitrate (NO_3) is a naturally occurring form of nitrogen found in soil and is a nutrient essential to all plant life.
- Nitrates form when microorganisms break down fertilizers, decaying plants, manures or other organic matter. Usually plants take up these nitrates, but sometimes rain or irrigation water can cause them to be released into groundwater.
- Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to result from human activities. Common sources of nitrate generated by human activity include fertilizers and manure, municipal wastewater and sludge, and septic systems.

Q-4 How familiar were you with the role of nitrates in the environment before reading this questionnaire?

☐ Very Familiar
☐ Somewhat Familiar
☐ Not Familiar

Q-5 How familiar were you with the sources of nitrates in groundwater resulting from human activities before reading this questionnaire?

☐ Very Familiar
☐ Somewhat Familiar
☐ Not Familiar

Nitrates in the Ichetucknee

- Scientific studies have shown that there are unnaturally high levels of nitrate in the Ichetucknee.
- The excessive nitrate levels in the Ichetucknee can cause dense growth of algae that smothers the native eelgrass and creates floating mats on the surface. The increased amounts of algae reduce water clarity which detracts from the snorkeling and scuba diving experience.
- Certain varieties of noxious algae pose a health risk for swimmers and tubers that are allergic to it.
- Excessive nitrates can have negative effects on habitat for aquatic turtles, crawfish, and other species of wildlife.
- Several of scientific studies have shown that one of the major sources of nitrates in the Ichetucknee is septic tanks in the surrounding area. Septic tanks are used by households that are not connected to a city's municipal sewer system, for waste disposal.

Q-6 How familiar were you with the problem of increased Nitrates in the Ichetucknee before reading this questionnaire?

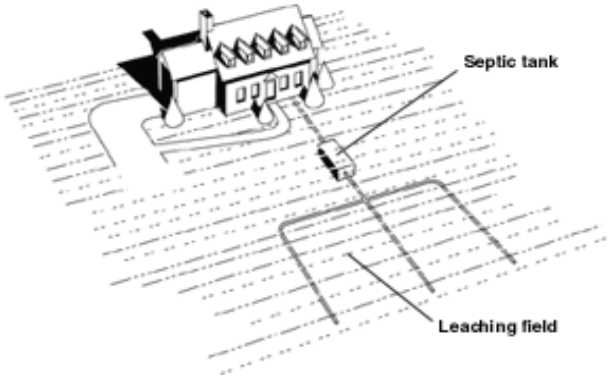
- ☐ Very Familiar
- ☐ Somewhat Familiar
- ☐ Not Familiar

Q-7 How important is it to you to protect Ichetucknee Springs from nitrate pollution?

- ☐ Very Important
- ☐ Important
- ☐ Somewhat Important
- ☐ Not Important

What are Septic Tanks?

- A septic tank generally consists of a 1,500 gallon tank which is connected to an inlet wastewater pipe at one end and to a leaching or drain field at the other.



- Wastewater from the home enters through the inlet pipe, and treatment of the wastewater is accomplished by physical, chemical, and biological processes in the tank system.
- The remaining impurities, including high levels of nitrates, are released through the drain field, which usually consists or a gravel bed and are eventually taken up through the root system of plants or added to the groundwater.

Septic Tanks in Columbia County

- Septic tanks are regulated by Columbia County's Department of Health and it is estimated that there are approximately 5,000 septic tanks in the area that are impacting the Ichetucknee.
- This addition of run-off from thousands of septic tanks in the Ichetucknee River basin has contributed to the increase of nitrates in the spring system and accounts for approximately 20% of the nitrate load to the springs.
- Advanced septic systems have been developed that use improved artificial and natural filtration techniques to reduce the amount of nitrates released into the groundwater.

Q-8 *Suppose that Columbia County is considering implementing a program to update, modify, and maintain septic tanks in the county in order to improve water quality in the Ichetucknee River. The program would use tax dollars to create incentives to compensate home-*

owners who currently have septic tanks to update to new treatment technologies. Based on scientific evidence this program is expected to reduce nitrate loading to the Ichetucknee River by approximately 20% over the next 10 years.

The ecological benefits in the Ichetucknee would include improved water clarity, reduction of excessive algae growth, and protection of natural wildlife habitat. The funding for this program would come from an increase in Columbia County households' utility bills of $_____ per month for the next 10 years. If this initiative were on the next election ballot would you vote:

☐ ***For*** ☐ ***Against***

Q-9 Does your home use a septic system?

☐ Yes ⇨ Q-10

☐ No

☐ Not Sure

Q-10 How likely are you to participate in an incentive program such as described in Question 8, if such a program was implemented?

☐ Unlikely
☐ Somewhat Unlikely
☐ Somewhat Likely
☐ Very Likely

Please provide some information about yourself for analysis purposes:

1) Are you ☐ Male ☐ Female

2) How old are you? _____

3) Please check your highest level of education:

- ☐ **Some High School**
- ☐ **High School Graduate Or Equivalent**
- ☐ **Trade of Vocational School**
- ☐ **Some College**
- ☐ **Associate Degree**
- ☐ **College Graduate**
- ☐ **Graduate or Professional Degree**

4) Are you a member of any environmental organizations?

☐**YES** ☐ **NO**

If YES, please specify: _____

5) How many people live in your household?

_____ Persons

6) Do you own or rent your home?

☐ **OWN** ☐ **RENT**

7) Please indicate the range of your 2006 annual household income (before taxes):

- ☐ **BELOW $15,000**
- ☐ **$16,000 – 25,000**
- ☐ **$25,001 – 35,000**
- ☐ **$35,001 – 45,000**
- ☐ **$45,001 – 55,000**
- ☐ **$55,001 – 65,000**
- ☐ **$65,001 – 75,000**
- ☐ **$75,001 – 100,000**
- ☐ **$100,001 – 125,000**
- ☐ **OVER $125,000**

Please Continue on Back ⇨

8) How many people contribute to your household income?

_____ Persons

9) How would you describe your political views?

☐ **Very Conservative**
☐ **Somewhat Conservative**
☐ **Moderate**
☐ **Somewhat Liberal**
☐ **Very Liberal**

10) What is your ethnicity?

☐ **White**
☐ **African American or Black**
☐ **Hispanic, Latino, or Spanish origin**
☐ **Native American or Alaskan native**
☐ **Asian**
☐ **Hawaiian or Pacific Islander**
☐ **Other _____**

Please fold the survey in half and insert it into the pre-paid envelope included. Feel free to make any additional comments about your answers to these questions or about the survey itself.

Comments:

Thank you for participating in this survey!

For further information, please contact:

Dr. Janaki Alavalapati or Mr. Chad Foster
School of Forest Resources and Conservation
University of Florida
Newins-Ziegler Hall, PO Box 110410
Gainesville, FL 32611
Phone: (352) 846-0899 or (352) 222 - 0911
Email: janaki@ufl.edu or chadrfos@ufl.edu

ID# - 0001

APPENDIX B
COMPLETE STATISTICAL RESULTS

Survey Response Results

Q-1 Have you ever visited Ichetucknee Springs?

Yes	**84%**
No	**16%**

Q-2 How many times a year do you visit Ichetucknee Springs?

1-2 times per year	**60.0%**
3-5 times per year	**15.3%**
6-10 times per year	**2.3%**
11+ times per year	**5.3%**

Q-3 What activities do you participate in when you visit the Ichetucknee (please check all that apply)

Tubing	**61%**
Canoeing/Kayaking	**12.2%**
Wildlife Viewing	**33.5%**
Picnicking	**36%**
Swimming	**56%**
Hiking	**15.2%**
Scuba Diving	**2.4%**

Q-4 How familiar were you with the role of nitrates in the environment before reading this questionnaire?

Very Familiar	**20.9%**
Somewhat Familiar	**54.6%**
Not Familiar	**24.5%**

Q-5 How familiar were you with the sources of nitrates in groundwater resulting from human activities before reading this questionnaire?

Very Familiar	**23.3%**
Somewhat Familiar	**51.5%**
Not Familiar	**25.2%**

Q-6 How familiar were you with the problem of increased Nitrates in the Ichetucknee before reading this questionnaire?

Very Familiar	**17.2%**
Somewhat Familiar	**44.8%**
Not Familiar	**38.0%**

Q-7 How important is it to you to protect Ichetucknee Springs from nitrate pollution?

Very Important	**56.9%**
Important	**33.1%**
Somewhat Important	**7.70%**
Not Important	**2.30%**

Q-9 Does your home use a septic system?

Yes	**83.5%**
No	**16.5%**

Q-10 How likely are you to participate in an incentive program such as described in Question 8, if such a program was implemented?

Unlikely	**20.9%**
Somewhat Unlikely	**11.2%**
Somewhat Likely	**39.6%**
Very Likely	**28.4%**

---

1) Gender

Male	52%
Female	48%

2) How old are you?

Mean =55

3) Please check your highest level of education:

1-Some High School	1.5%
2-High School Graduate	13.8%
3-Trade of Vocational School	4.6%
4-Some College	25.4%
5-Associate Degree	15.4%
6-College Graduate	16.2%
7-Graduate or Professional Degree	23.1%

Mean = 4.8

4) Are you a member of any environmental organizations?

YES	7.3%
NO	92.7%

5) How many people live in your household?

Mean = 2.4 persons

6) Do you own or rent your home?

Own = 100%

7) Please indicate the range of your 2006 annual household income (before taxes):

1-BELOW $15,000	3.8%
2-$16,000 – 25,000	9.2%
3-$25,001 – 35,000	10.8%
4-$35,001 – 45,000	7.7%
5-$45,001 – 55,000	13.1%
6-$55,001 – 65,000	8.5%
7-$65,001 – 75,000	8.5%
8-$75,001 – 100,000	12.3%
9-$100,001 – 125,000	9.2%
10-OVER $125,000	16.9%

Mean = 6.1

8) How many people contribute to your household income?

Mean = 1.58 Persons

9) How would you describe your political views?

Very Conservative	9.2%
Somewhat Conservative	28.5%
Moderate	41.5%
Somewhat Liberal	16.9%
Very Liberal	3.8%

Mean = 2.78

10) What is your ethnicity?

White	94.5%
African American or Black	3.1%
Hispanic, Latino, or Spanish origin	1.2%
Native American or Alaskan native	0.6%
Asian	0.6%
Hawaiian or Pacific Islander	0.0%

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BIOGRAPHICAL SKETCH

Chad Foster graduated Cum Laude from the University of Florida's School of Natural Resources and Environment with a B.A. in environmental science in 2005. He is currently pursuing a Degree of Master of Science in interdisciplinary ecology, in the University of Florida's School of Natural Resources and Environment.