

Water Resources Research Center

Annual Technical Report

FY 1999

Introduction

PROGRAM REPORT
FLORIDA WATER RESOURCES RESEARCH CENTER
FEDERAL GRANT NO. 1434-HQ-96-GRO2663
PERIOD: March 1, 1999 - February 29, 2000

The Water Resources Research Center (WRRC) was re-established as a separate entity from the combined Center for Wetlands and Water Resources Research in 1995. Historically, since 1964, the WRRC as a separate or combined center has been a university-wide focus for water-resources research and has served as the Water Resources Center for the state of Florida. The mission of the WRRC is to serve as a center of expertise in the water resources field, assist public and private interests in the conservation, development, and use of water resources, provide opportunities for professional training, assist local, state, regional, and federal agencies in planning and regulation, and communicate research findings to interested users. The WRRC administers funding received from the federal Water Resources Research Act 1964 and coordinates water-resources research and technology transfer as authorized by the funding, acts as a liaison for Florida agencies and water management districts, promotes water-resources research by seeking external support, and seeks to enhance the state and national image of the University of Florida (UF) as a focal point for water resources research. The WRRC is funded in part by Section 104 of Public Law 98-242 and Public Law 104-99, which are administered by the U.S. Geological Survey, Department of the Interior. Additional funding and support are provided by UF and research sponsors that include state agencies such as the water management districts.

Research Program

Project Number: FL01
Start Date: 09/98
End Date: 08/00

Title: Well-Field Pumping Effects on Isolated Wetlands

Investigators: William R. Wise and Michael D. Annable, Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida

Focus Categories: WL, HYDROL, ECL

Congressional District: Fifth

Descriptors: Drainage, Ecosystems, Hydrological Models, Land Use, Plant Stress, Soil-Water Relationships, Surface-Groundwater Relationships, Water Levels, Wetlands

Problem and Research Objective:

Increasing demographic pressures in the southeastern United States, particularly in Florida, are stressing the water balances in many areas of urbanization and potential urbanization. Problems arise relating both to water-supply and stormwater-quantity/quality issues. The proposed work addresses the former. Specifically, delicate ecological balances in isolated wetlands may be disturbed as well fields in proximate (underlying) aquifers are developed to provide for the increased demands associated with development of population centers. Destruction of ever-decreasing wildlife habitat and diminishment of the quality of human life in affected regions is possible.

At the present, there is a dearth of understanding of how such isolated wetlands respond to increased pumping in underlying aquifers. In many near-coastal areas, deeper, confined aquifers are not able to supply water for consumption due to enhanced salinity. As a result, pumping from unconfined or semi-confined aquifers is required to satisfy demand. As well fields in such areas are developed, regional water tables fall. A key issue to the ecological health of isolated wetland systems is how well wetland sediments may resist or retard wetland drainage over times sufficient for replenishment of the wetland by rainfall (perhaps including water table rebound effects). Regulators are currently forced to make decisions regarding land and water use based upon inadequate information. Sub-optimal or possibly even irresponsible management of resources may result without proper understanding of the nature of responses of isolated wetland systems (for a variety of wetland types, such as marshes and cypress domes, to name two) to increased pumping.

The primary objective of the proposed research is to further the understanding of how isolated wetland systems are connected to underlying aquifers, and specifically, how pumping in such aquifers affects these wetlands. Because this field is relatively immature, a significant focus will be the development of investigatory procedures. The proposed work involves field, laboratory, and modeling efforts. In order to establish the databases required from which to analyze seasonal trends, a multi-year project was originally proposed.

Methodology:

Among the principal benefits expected is the closing of the above-mentioned knowledge gap. An enhanced understanding of surface-groundwater interactions as they pertain to isolated wetland systems will be developed and refined. Comprehensive databases (for at least two isolated wetland types) from which accurate water balances may be performed will be collected and analyzed. In particular, a methodology will be developed from which wetland vulnerability to well-field pumping may be assessed through the use of easily managed field procedures, such as soil/sediment sampling and pumping tests, coupled with modeling exercises. Guidance to water managers as to how best to predict well-field influences will be enhanced. Ultimately, conservation of wildlife habitat and preservation of the quality of human life should result from better management of water resources in vulnerable systems. Several students will be trained on the project, including at least one from this request, two from the matching funds, and potentially two independently funded students.

The investigators are not only dedicated to the advancement of knowledge through research, but also through the dissemination of knowledge through teaching and innovative publication of results. The former tact will naturally be realized as research results are incorporated into the courses in which they will be pertinent, such as Environmental Hydrology, Field Methods in Hydrogeology, and Wetlands Ecology. In addition, the principal investigators are currently developing short courses in which the results would be shared with a variety of professionals in both the public and private sectors. Furthermore, the principal investigators are committed to

publishing work as appropriate on the world wide web. In addition, the investigators will submit the results of their research to refereed journals, as well as preparing the final project report.

Principal Findings & Significance:

At the time of writing, two wetland-aquifer interaction tests (WAITs) have been performed, one at a marsh in Martin County, Florida and one in a cypress dome in Lee County, Florida. The Martin County test has been fully analyzed and is summarized in a masters thesis [Walser, 1998]. During that test, the wetland water level was drawn down 0.31 m over the course of a nine-hour pumping period. It took approximately one week for the wetland to recover, indicating that the wetland-aquifer connection is hydrologically significant and quantifiable. It was possible to estimate the in-situ permeability of the underlying peat layer through the WAIT test. To the investigators' knowledge, this is a novel finding. The WAIT was simulated by the team using a three-dimensional, variably-saturated, finite element model. At the present time, the team is not satisfied that such modeling holds promise for isolated wetland systems due to a general lack of knowledge on how to model such hydraulically important features such as peat layers. This modeling exercise has led the team to add some novel experiments to the research. In these experiments, columns of peat overlying sand are being used to mimic systems in which the groundwater level is being lowered. Such experiments are replicating the problem of interest, i.e., water table lowering resulting from groundwater pumping. In addition, experiments will be considered to help develop better ways of quantifying the transmission and retention of water through peat under drainage conditions. To date, four peat/sand capillary behavior-testing apparatuses have been built. Results indicate that a disconnect between the peat and the water table forms when the capillary fringe in the sand falls below the level of the bottom of the peat.

Data from the second WAIT, performed in Lee County, have been processed. In addition, several field trips are scheduled for the summer. Many will meet the long-term monitoring needs (through water level surveys). Some will also expand our cooperative work with the South Florida Water Management District (SFWMD), who is a cosponsor of the research. They are providing the team access to more sites to study. At these sites, the SFWMD is currently recording wetland and groundwater levels on a continuous basis. The idea for this additional work arose during the first year of the current project. Support from this project and the SFWMD is facilitating the development of a solid program in wetland hydrology at the University of Florida. As a direct result of this project, the SFWMD is currently gearing to fund the research group for a study relating the hydrological and biological aspects of wetlands, including the relationship between soil moisture, crayfish and benthic invertebrate populations.

Currently, a manuscript is being prepared that will compare four different methods of determining the connectivity between wetlands and the underlying groundwater. These include the WAIT (an active test performed at the system level), long term water budget analysis (a passive method performed at the system level), in-situ falling head permeameters (an active method performed at various points throughout the system), and seepage meters (a passive method performed at various points throughout the system). The objective is to compare active versus passive tests and system-level versus point-based-level tests. To date all of the analyses are complete for the first three methods at the wetland in Martin County, and the seepage meter tests and analyses have been completed. The material covered in this manuscript will be presented at the INTECOL conference in Quebec City in August 2000.

Project No: FL02

Start Date: 5/99

End Date: 5/00

Title: Web Based Integration of Multiporosity Groundwater Modeling with Field Verification in a Virtual Workshop Environment

Investigator: David E. Loper, Geophysical Fluid Dynamics Institute, Florida State University, Tallahassee, Florida

Congressional District: 2nd

Focus Categories: GW, WQ

Descriptors: Groundwater Modeling, Collaborative Technologies, Field Verification, Information Dissemination

Problem and Research Objectives:

The principal goal of this project is to establish and implement a web-based forum, within which more rapid and coherent progress can be made toward understanding underground flow of water and transport of pollutants, particularly in karstic aquifers, and toward the application of this knowledge to the management and protection of water and water-related resources. This effort is being coordinated by the Hydrogeology Consortium (HC), with most, if not all, of the participants in the forum being members of the HC.

Methodology:

Two meetings of the HC have been held. A preliminary planning meeting was held on May 14, 1999 at the offices of the Northwest Florida Water Management District in Midway, FL. At this meeting the concept of a web-based forum was introduced and discussed. Next, a general meeting of the members of the Hydrogeology Consortium was held in Orlando on November 16-17, 1999. This meeting focused on the scientific and technical issues related to a better understanding of karst dynamics.

Findings and Significance:

A web board that was established following the meeting in May 1999 was used to facilitate planning for the November meeting. This was in effect a pilot test of this new format. Since the November meeting, we have attempted to use the web board to facilitate further coordinated action. These efforts have been somewhat disappointing on the whole. There appear to be two main reasons for this lack of success. First, the web board is new and not integrated into the habits of people, in contrast to email, which has quickly become habitual. The web board requires a person to go to the board to access information, in contrast to email, which figuratively sticks it under your nose. (The web board software is supposed to have an email alert when a posting of interest is made, but there have been bugs in the software which have not allowed this.) A second reason for the lack of success is a lack of focus on a specific topic and a lack of urgency needed to get a task accomplished. This reason is not the fault of the web-board concept or the software being used. Rather it is due to the current lack of funding devoted to the completion of specific tasks.

The Steering Committee of the HC intends to continue to seek ways to integrate the web board concept into its administrative and scientific operations.

Project Number: FL 03

Start Date: 03/99

End Date: 02/00

Title: Effect of Toxic Algae on Alligators and Alligator Egg Development.

Investigator: James Perran Ross, Florida Museum of Natural History, University of Florida, Gainesville.

Congressional District: 5th and 6th

Focus Categories: TS, COV, ECL

Descriptors: Algae, Toxic Substances, Wildlife Management, Bioindicators, Alligators.

Problem and Research Objectives:

Unknown factors are affecting alligators (*Alligator mississippiensis*) and other wildlife in Lake Griffin, Florida. Between 1994 and 1997, the hatch rate of alligator eggs collected on Lake Griffin dropped to less than 10%. Since November 1997, more than 230 dead adult alligators have been recorded in Lake Griffin with 101 recorded in 1999. Postulated causes include contaminants, disease, nutrition and toxins produced by blooms of blue green algae. This study examined the effect of algal toxins produced in blooms of *Cylindrospermopsis raciborskii* on alligators and their eggs to determine if this factor requires more extensive examination.

A general pattern of eutrophication in the shallow lakes of subtropical and temperate Florida has been recognized. Increased dissolved nutrient levels, warm temperatures and a year round growing season promote extensive micro-algal blooms. This results in a transition from clear water lakes supporting extensive floating and emergent macrophyte communities to turbid lakes where the predominant flora is Phytoplankton. Concomitant with this transition is the development of extensive layers of flocculent organic sediments, the disappearance of the macrophyte flora and changes in the biota of the lakes, including the loss of valuable sport fisheries. Some algae produce toxins that can affect wildlife. Harmful algal blooms have become the focus of a statewide task force to assess the impacts of this problem. While a major emphasis has been marine algae such as *Gymnodinium breve* (Red tide), *Pfiesteria* sp. and *Gambierdiscus toxicus* (Ciguatera), the potential effects of algal blooms in fresh water on wildlife mortality, water supply quality and human health is widely recognized. A blue green alga (Cyanobacteria) *Cylindrospermopsis raciborskii* is a newly described component of the algal blooms in several Florida lakes (Chapman and Schelske 1997). *C. raciborskii* is known to produce toxins (Carmichael 1997) and has been implicated in wildlife mortality in many areas of the world. Preliminary investigations of unusual numbers of dead and moribund alligators during 1997-1998 in Lake Griffin, central Florida, suggest a temporal association with heavy blooms of *C. raciborskii*, which has become the dominant blooming algae in Lake Griffin.

Alligators provide a valuable bio-indicator or sentinel species for ecosystem perturbations. They are large, long-lived predators and feed at the top of food chains. They accumulate contaminants and can carry large body loads in their fat, but their robust physiology reduces lethal effects on adults. However, their developing eggs are particularly prone to embryological disruption by exogenous compounds of either maternal or environmental origin. The presence of contaminants in run-off waters, as well as the direct introduction of herbicides and pesticides into lakes, has introduced anthropogenic compounds capable of exerting profound disruptive effects on the embryonic development of organisms at very low doses by endocrine disruption. The effects of hormone disrupting contaminants in alligators has become a model for examining this process and its physiological and ecological effects (Crews and Ross 1998, Gross et al. 1994). The presumptive association of algal blooms and alligator mortality and impaired reproduction opens the possibility that phytotoxins may have similar effects. The effects of algal toxins in alligators need to be evaluated both by the direct effect on alligator physiology (including

sublethal and reproductive effects) and by examining pathways of toxin transfer through the ecosystem to these top predators. Elucidating these effects in the Oklawaha system will provide valuable information for the control and mitigation of algal toxicity at the State and regional level.

The primary objective of this study was to conduct preliminary analyses of the presence of algal toxins in alligator tissues and eggs in conjunction with existing studies of alligator populations and reproduction to establish if there is sufficient cause to examine algal toxin effects in more detail. Alligators found dead or moribund in Lake Griffin were examined to establish if they showed chemical residues and hepatological and neurological indications of algal toxicity and whether alligator eggs which fail to hatch under controlled incubation have algal toxins.

Methodology:

This project was conducted with cooperation and logistic support from researchers at the University of Florida (UF), Fish and Wildlife Conservation Commission (FWC), St. Johns River Water Management District (SJRWMD), and U.S. Fish and Wildlife Service. Parameters on Lake Griffin were compared with Lake Woodruff, a reference lake of presumed low eutrophication and anthropogenic inputs. Biweekly inspection of Lake Griffin was conducted by airboat, and an intense search for dead and dying alligators made. Dead alligators were marked to prevent double counting. Water samples of approximately 1 liter were collected using an integrated water column tube sample, decanted to clean bottles, and held on ice until transfer to the SJRWMD algal task force personnel who identified and quantified the micro algal flora. Routine water quality data were also collected during the course of our study by SJRWMD personnel.

In the course of these inspections, alligators showing abnormal behavior including inattention, paralysis, and reluctance to submerge or avoid close approach were identified. Five sick alligators were captured in 1999, augmenting a sample of five sick alligators previously captured on Lake Griffin in 1998 and 1997. Following capture of a sick alligator on Lake Griffin, healthy alligators of similar size and sex were captured on Lake Woodruff. All alligators were captured using a wire snare, restrained by taping the eyes and mouth and transported to the UF animal facilities. Alligators were held for clinical examination in outdoor dog runs modified to allow partial flooding with continuously flowing tap water to a depth of 40 cm. Water temperatures were measured daily and remained at 24°C. The animals were not fed. This work was conducted under permit from FWC and approval by the UF Institutional Animal Care and Use Committee.

Alligators were subjected to an intense veterinary clinical screening by Dr. T. R. Schoeb and colleagues. Blood samples were collected from the occipital sinus and a broad range of physical and chemical blood parameters measured using standard clinical techniques. Microbiological cultures were incubated for bacterial and mycoplasma growth. Neurological evaluation was done using a modified veterinary clinical examination testing avoidance response, toe pinch withdrawal reflex, righting and corneal blink. Electromyography, nerve conduction velocity, repetitive stimulus responses, spinal cord and brainstem evoked potentials were tested. Finally, animals were euthanized and subject to veterinary necropsy including gross and histological examination of all major organs and tissues. The brains and sciatic nerve of a sample of alligators from Lake Griffin demonstrating advanced neurological impairment were prepared and examined by electron microscopy. Tissue samples (muscle, fat, gonad, and liver) were excised, wrapped in foil and frozen at -80°C until shipped for analysis.

Egg Viability. In June 1999, alligator nests were located during helicopter surveys by FWC personnel, and eggs from 34 nests on Lake Griffin (and 211 clutches from other Florida lakes, approximately 4000 eggs total) were collected and removed to the FWC facility in Gainesville. Each clutch was incubated in a plastic pan with natural nest material in a controlled environment at 32°C and 92%-94% RH. These conditions are optimal for embryonic survival. Eggs that failed to hatch were removed, opened and examined to determine the stage of

development. Samples of viable and failed eggs and partially developed embryos were set aside and frozen for analysis of toxins.

Algal Toxin Analysis. Eight water samples, thirteen alligator liver samples (seven from Lake Griffin and six from Lake Woodruff) and five whole alligator eggs were sent to the laboratory of Dr. W. Carmichael at Wright State University, Ohio for analysis of algal toxins. The sample was stored at -20°C prior to use, and a subsample was used for the analysis. The different analyses done were a.) Mouse bioassay (LD 50 resulting from inter peritoneal injection of extracted algae), b.) enzyme linked immunosorbent assay (ELISA) for microcystins, c.) protein phosphatase (PP2A) inhibition assay to detect PP inhibitors such as microcystin, and d) high pressure liquid chromatography (HPLC) for cylindrospermopsin. Additional testing by liquid chromatography/mass spectrometry (LC/MS) is planned for 2000.

Principal Findings and Significance:

Alligator mortality has continued to occur at levels far above normal background mortality through the study. The seasonal pattern of alligator mortality is consistent in 1997-1999 with a large peak occurring in April - June and a smaller peak occurring in November - January. These peaks correspond approximately to periods of lower rainfall and also to periods of higher stress for alligators (the onset of cool weather in the fall and the spring breeding season). However, no causal relationship is obvious.

In the same period, intense algal blooms have continued to occur in Lake Griffin and these are dominated by *Cylindrospermopsis raceborskii*. However, numerous other species, including at least four other toxic algae have been identified as components of these blooms. Alligator mortality and peak algae blooms are not directly correlated. The earlier temporal association noted in 1998 appears to be fortuitous and was not repeated. The water samples tested for toxins indicate that algae in Lake Griffin produce toxins in concentrations sufficient to kill mice in a laboratory test. This is first confirmation of toxicity from fresh-water blue green algae in north America and will be submitted for publication. The algae in Lake Griffin produce microcystin and cylindrospermopsin, which affect the liver, but it is not proved that these toxins are responsible for the observed toxic effects. (i.e. it could be another toxin or another toxic algae). All samples were positive for microcystins by ELISA and PPIA. The levels found are not high enough to explain acute toxicity based upon tests with mammals (no data are available for alligators or reptiles). Since this included Lake Woodruff samples, we conclude that while microcystins were present they would not have been responsible for the acute toxicities observed in the Lake Griffin alligators. It does suggest that microcystins are in the food chain to alligators. Further tests by LC/MS for microcystins and cylindrospermopsins will allow a more complete picture of cyanotoxin exposure to be done.

The sick alligators from Lake Griffin do not demonstrate any visible sign of gross organ or tissue abnormality. All the animals are adult size and in good to excellent physical appearance and condition. Both sexes are represented. No consistent differences in a wide range of hematological, serum chemical and microbiological values were noted between sick alligators from Lake Griffin and healthy alligators from Lake Woodruff. However, all the Lake Griffin alligators demonstrated one or more signs of severe neurological impairment. These include depressed clinical responses, reduced nerve conduction velocities, axonal degeneration and necrosis of specific foci in the mid brain. Therefore, for the first time, we can identify an apparent reason for death in alligators, although its cause remains unclear.

These clinical results do not directly support algal toxins being the proximate cause of mortality in alligators in lake Griffin. *C. raceborskii*, the dominant alga in the system, produces cylindrospermopsin, which normally acts as a hepatotoxic agent in mammals. Microcystin, another epatotoxin, produced by algae genera *Microcystis* and *Anabaena*, was also identified during our study in both water samples and alligator livers, but in quantities

thought to reflect background but not acute toxicity (W. Carmichael pers. comm.). The livers and associated serum parameters of all the alligators were normal and the levels of microcystin were not significantly different in alligators from Lake Griffin and alligators from Lake Woodruff. These all suggest that the algal toxin levels found in alligators reflect normal chronic exposure to blue green algae and their toxins in the environment, but not at levels sufficient to cause toxicity. This is not surprising given the abundance of these algae in Florida fresh waters. A recent State wide survey indicated *Cylindrospermopsis*, *Microcystis* and *Anabaena* as common and dominant components of algae floras throughout the State. (Williams et al. 2000). Some uncertainties remain. *C. raceborskii* is a worldwide species and is reported to sometimes produce saxitoxin, a potent neurotoxin. The action of algal toxins in reptiles is completely unknown. Fish are generally more tolerant of algal toxins than mammals and can bioaccumulate them. It is not beyond the realm of possibility that either a different toxin or a neurotoxin from another algae is involved or that the action of the toxin in alligators is different from that in mammals.

A small sample of sick alligators from Lake Griffin and healthy alligators from Lake Woodruff (two of each) tested during 1999 did not have high or abnormal levels of a number of toxic metals including mercury, lead, and selenium (known neurotoxins) in their fat.

The clutch viability (proportion of all eggs laid that hatch) of alligator eggs from Lake Griffin improved from less than 10% in 1996-97 to 28% in 1998 and 32% in 1999. While these values remain significantly lower than any other Florida lake (normal range 40%-90%), this slow improvement has occurred at the same time as algal blooms and adult alligator mortality have increased in intensity. Technical constraints prevented analysis of algal toxins in alligator eggs in 1999 but the samples are in storage.

In summary, the contention that either the mortality of adult alligators or the low viability of alligator eggs in Lake Griffin is a direct result of exposure to toxins produced by Blue green algal blooms remains, at best, unsupported. We intend to continue these investigations with other funding to examine alternate possible causes such as contaminants and dietary or nutritional factors. Because of the interest of the Florida Harmful Algae Task Force, we will conduct additional analyses of algal toxins on existing water and animal tissue samples. We have also designed an experiment to expose juvenile alligators to large doses of algae in a force feeding trial. However, the current emphasis of our work is to conduct contaminant screening on existing alligator and other animal tissues and continue regular monitoring and sample collection to try to identify other possible causes of the neural impairment we have discovered in alligators in Lake Griffin.

References:

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Crews, D. and J. P. Ross, 1998, Consequences of Hormone Disruption of Sexual Development for Crocodilian Conservation, In: Crocodiles, Proceedings of the 14th Working Meeting of the Crocodile Specialist Group, IUCN, Gland Switzerland, pp. 174-190.

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Lee, E.Y.C, 1992, Expression of the Catalytic Subunit of Phosphorylase Phosphatase (protein phosphatase-1) in *Escherichia coli*, *Journal of Biological Chemistry*, 267(3): pp. 1484-1490.

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Williams, C. A. Chapman, M. Pawlowicz, W. Carmichael and J. Burns. An Assessment of Toxigenic Cyanobacteria in Florida's Surface Water. American Fisheries Society, Florida Chapter 20th Annual Meeting March 2000.

Information Transfer Program

During FY 1999, the Florida WRRC actively promoted the transfer of water resources results in Florida. An updated email list was used to provide timely information about research proposal deadlines and other water-related activities. The WRRC maintains a library of technical reports that have been published by the WRRC, and copies of these reports can be checked out by researchers. Also, copies of these reports are distributed upon request at a nominal charge that covers the cost of reproduction and mailing. Support was provided by the WRRC for presenting research results at technical conferences and for publishing research results in refereed scientific and technical journals. A home page for the WRRC (<http://www.ce.ufl.edu/~wrrc>) was established. This site, which is updated on a continual basis, lists proposal and meeting announcements and publications available from the library maintained by the WRRC and provides links to other water resource organizations and agencies, including the five water management districts in Florida and the USGS.

USGS Internship Program

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	0	2	0	2
Masters	3	6	0	0	9
Ph.D.	1	1	0	0	2
Post-Doc.	1	0	0	0	1
Total	5	7	2	0	14

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

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Carmichael W. W. and J. P. Ross, 2000, First Report of Toxicity in *Cylindrospermopsis raceborskii* Dominated Blooms in North America (in preparation).

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Wise, W.R., M.D. Annable, C.J. Martinez, R.S. Switt, and P.P. Hwu, 2000, A Comparison of Methods for Evaluation of the Hydraulic Communication Between a Wetland and the Underlying Groundwater, (to be submitted to *Water Resources Research*).

Wise, W.R., M.D. Annable, J.A.E. Walser, R.S. Switt, and D.T. Shaw, 2000, A Wetland-Aquifer Interaction Test, *Journal of Hydrology*, 227, 2000, pp. 257-272.

Book Chapters

None

Dissertations

Dogan, A., 1999, Variably Saturated Three-Dimensional Rainfall Driven Groundwater Pumping Model, Ph.D. Dissertation, Department of Civil and Coastal Engineering, University of Florida, Gainesville, 254 pp.

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Temsiripong, Y., 1999, Growth and Survival Rates of Wild and Repatriated Hatchling American Alligators (*Alligator mississippiensis*) in Central Florida Lakes. M.S. Thesis, Department of Wildlife Ecology and Conservation, University of Florida, 55 pp.

Water Resources Research Institute Reports

None

Conference Proceedings

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Engineering Conference, American Society of Civil Engineers, Seattle, Washington, August 8-11.

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Wise, W.R., M.D. Annable, R.S. Switt and J.A. Walser, Wetland-Aquifer Interaction Tests, 1999, Spring Meeting of the American Geophysical Union, Boston, Massachusetts, June 1-4 (a).

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Other Publications

Loper, D.E., 1999, Hydrogeology Consortium WebBoard, [http://www.lampl-herbert.com/webboard/\\$webb.exe/~planning](http://www.lampl-herbert.com/webboard/$webb.exe/~planning).

Loper, D.E., 1999, Minutes of the Meetings of the Hydrogeology Consortium, <http://hc.gfdi.fsu.edu/minutes/htm>.

Ross, J.P., 2000, Florida Legislative Task Force on Water Management in Lake Griffin, Presentations to Rep. D. Kelly, Lakeland, July and September.

Ross, J.P., 2000, Presentation to Lake County Water Authority, Board Meeting, March.

Steidinger, K., J. Landsberg, C. Tomas & J. Burns. Harmful Algal Blooms in Florida, Review presented to the Harmful Algal Blooms Task Force Technical Advisory Group.

Woodward, A. R., D.S. Bermudez and D. A. Carbonneau, 2000, Alligator Clutch Viability in Florida, Preliminary Report, Florida Fish and Wildlife Conservation Commission.