

Suwannee River Basin and Estuary: An Integrated Watershed Science Program

White Paper

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1.0 Executive Summary

The Suwannee River Basin (SRB) of southern Georgia and north-central Florida is one of the largest (28,600 km²) and most ecologically unique blackwater river systems of the southeastern United States. The SRB is the only major drainage basin entirely within the Coastal Plain and contains an unrivaled mixture of subtropical forests, wetlands, springs, blackwater rivers, and estuarine habitats. The variety of habitats in the basin supports a range of species from temperate to subtropical, including several Federally or State endangered and protected species. The SRB and Estuary also support a burgeoning economy based on agriculture, commercial and recreational fisheries, clam farming, and ecotourism.

Originating in the Okefenokee Swamp and the headwaters of the Alapaha, Withlacoochee and Little Rivers, the Suwannee River meanders for over 400 km through southern Georgia and northern Florida before emptying into the Gulf of Mexico. Its chemical character changes dramatically as it progresses downstream, reflecting differences in hydrogeology, physiography, and land cover. In drainage area and total discharge, it is the second largest river in Florida and is designated an Outstanding Florida Water by the Florida Department of Environmental Protection (FDEP). The Suwannee River is unimpounded and undiverted and has been referred to as one of the most pristine and undeveloped river systems in the United States.

However, the natural resources of the SRB ecosystem are vulnerable to a growing number of environmental threats. Increased use of pesticides and fertilizers, runoff from dairy and poultry farms, and additional point and non-point sources of contamination threaten the quality of groundwater and surface water in the basin. Increases in nitrate concentrations from human activities are causing human health concerns and adverse ecological effects. Issues related to water supply are also a major concern in the basin. Consumptive use of water resources is increasing in the SRB due to farm irrigation requirements and to increasing demands of a rapidly growing human population. Proposals for diverting water from the Suwannee River to help satisfy the domestic water needs of the greater Tampa metropolitan area have been considered over the last

decade. However, the effects of such withdrawals on riverine or estuarine habitats and fauna are inadequately known and cannot be predicted without further study of the ecosystem. The establishment of minimum flows and levels (MFL) for surface and groundwater has been mandated by the State of Florida in an effort to provide protection to aquatic habitats, wetlands, and water supply (FL STAT 373, 1995). Currently existing data are inadequate to establish informed decisions on MFLs.

More effective management of water resources in the SRB would greatly benefit from increased knowledge about the interactions among hydrologic processes, climate variability, ecosystem and human health, and economic development. As a model of relatively undisturbed large rivers in the southeastern United States, the Suwannee River provides an unparalleled opportunity for assessing its natural resources and for demonstrating how to manage them proactively. The vital interplay among agriculture, socio-economic pressures, underlying geology, changing river hydrology, and unique biological resources from the headwaters to the estuary is now recognized. This inclusive perspective presents an opportunity for the U.S. Geological Survey (USGS) to work closely with other agencies, both local and federal, in addressing issues of the SRB. As part of an action plan to address important resource-management issues in the basin and estuary, the USGS Florida Integrated Science Center (FISC) has initiated talks, workshops, and an interagency science plan.

The USGS is tasked with providing reliable scientific information to describe and understand the Earth, to manage its natural resources, and to enhance the quality of life. The USGS is well situated to address the larger concerns of the SRB by facilitating an integrated interagency research effort that links water availability and quality to ecosystem function and health across county and state boundaries. The USGS, along with Florida's Suwannee River Water Management District (SRWMD), and other Federal and State agencies have been conducting monitoring and research studies in the basin and estuary for several decades. However, a more holistic approach is needed to address the myriad of information needs and to provide supportive data for

meeting management objectives for the entire ecosystem. It is to this end that the combined forces of the USGS FISC have embarked on the Suwannee River Basin and Estuary Initiative to provide timely and appropriate scientific information prior to additional impairment of the basin and its various components. Efforts will include sustained interagency cooperation, development of an integrated watershed-resource information tool, annual workshops, an interagency science plan, and the development of watershed-level models for economic, hydrologic, and ecosystem resources.

2.0 Background

The States of Florida and Georgia, the Federal government, and other local organizations identified the Suwannee River Basin (SRB) and the Suwannee River Estuary System (SRES) as an ecosystem in need of protection because of its unique biota and important water resources. A growing number of environmental threats to the basin and estuary include nitrate contamination of spring waters, elevated mercury levels in fish, habitat loss for ecologically important and threatened species, microbiological contamination of shellfish, excessive withdrawal of groundwater for agricultural activities, and loss of floodplain habitat. Organizations with vested interests in the region formed a coalition, the Suwannee Basin Interagency Alliance (SBIA), to promote interagency management of water and natural resources throughout the basin.

The hydrogeology and ecological diversity of the watershed and estuary along with the wealth of background information provide a unique opportunity for the USGS to integrate process studies of surface water, groundwater, spring flow, estuarine hydrology, and ecosystem health into a holistic science program that is relevant to stakeholder concerns and consistent with integrated science priorities. An integrated approach is needed to address a myriad of scientific questions and to provide a supportive data framework for meeting management objectives for the entire ecosystem.

2.1 USGS Workshop and Initiative

The USGS has taken the lead in addressing basin priorities by holding a successful workshop on integrated science issues at Cedar Key, Florida, September 22-24,

2004 (Katz and Raabe, 2004). Four main goals of the workshop were to (1) bring together research scientists within and outside the USGS who are conducting studies in the basin and estuary, (2) provide an update on current scientific studies in the basin and estuary, (3) develop research priorities and needs, and (4) develop an action plan for future coordinated research activities.

The Cedar Key workshop built upon the first basin-wide conference in April 2001 sponsored by the SBIA (SBIA, 2001). A clear message that emerged from both the 2004 Cedar Key Workshop and the 2001 SBIA Conference is the importance of partnerships between public and private agencies and other stakeholders. These partnerships have been instrumental in identifying and solving problems that affect water quality and ecosystem integrity.

Current research activities were presented in 2004 by more than 40 Federal, State, industry, and university scientists on four topics: hydrogeology, water quality, ecosystem dynamics, and information management. There were more than 120 attendees from over 30 different agencies. Workshop participants identified science and management priorities and data gaps during breakout-session discussions in each topical area. Attendees also discussed developing an interagency science plan as the next step in coordinating science activities in the basin. The workshop closed with a discussion of an interagency science plan and the identification of three priorities for an interagency effort: (1) an integrated-data clearing house, (2) an interstate watershed study, and (3) integrated basin-wide models.

The USGS was identified at the Cedar Key workshop as the agency best suited to develop a program that links water availability and quality to ecosystem function and health across jurisdictional boundaries and to provide a framework for an integrated knowledge base. Future USGS activities will include the coordination of SRB science activities through the development and implementation of an interagency science plan, annual workshops, integrated information management and modeling, and other integrated science products. Efforts to date on the Suwannee Initiative, including workshop results, are available at the USGS Gulf of Mexico website (<http://gulfsci.usgs.gov/index.html>).

2.2 Partnerships

The importance of interstate cooperation in managing the water and related land resources of the SRB has been recognized for more than a decade. In 1995, after a year of informal discussions among interested agencies, the SBIA was organized to promote ecosystem management throughout the basin. The SBIA is co-chaired by Florida and Georgia and has an executive committee made up of the Suwannee River Water Management District (SRWMD), the Georgia Environmental Protection Division (EPD), Florida Department of Environmental Protection (FDEP), and the U.S. Fish and Wildlife Service (USFWS). Several other Federal, State, and local agencies, as well as private organizations participate in SBIA activities. Unfortunately, the SBIA does not have an operating budget and the agencies are participating on a voluntary basis. However, resources provided by participating agencies have resulted in several notable accomplishments: the production of a LANDSAT satellite composite image of the entire Suwannee Basin in poster format, a 1998 SRWMD report on surface-water quality, the 2001 SBIA Conference (Four Rivers, Two States, One Basin), and a cost-share agreement between the Georgia Soil and Water Conservation Commission (GASWCC) and the SRWMD for a person to promote and coordinate interstate management issues.

Two other partnerships in the basin include the Suwannee River Partnership and the Upper Suwannee River Watershed Initiative (USRWI). The Suwannee River Partnership is a 53-member farm-based group that uses a non-regulatory approach to address nutrient impacts to water quality in the Lower Suwannee and Santa Fe River basins in north-central Florida. The emphasis is on voluntary incentive-based programs to reduce nutrient loading that will help protect the environment and public health. As of 2004, plans for reducing loading using best-management practices have been adopted by 92 percent of the 40 dairies, 97 percent of the 140 poultry farms, and 28 percent of row-crop farms. The proportion of nutrient loading from each source is unknown at this time. This issue needs to be addressed and is a worthy topic for future research studies. Over \$20 million in cost-share funds have been provided by the U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), SRWMD, Florida Department of Agriculture

and Consumer Services (FDACS), FDEP, and from individual farmers. Studies are being conducted by several agencies to evaluate the effectiveness of best-management operations and maintenance in several parts of the basin.

Similar efforts are being developed in the State of Georgia. The USRWI is a multi-agency effort designed to protect water quality in the Upper SRB. They have been holding summits for the past five years to educate citizens to be more aware of the problems and ways to protect and clean up the waters of the basin. Agencies and groups involved in the USRWI include the Pollution Prevention Assistance Division of the Georgia Department of Natural Resources (GDNR), University of Georgia Biological and Agricultural Engineering, South Georgia Regional Development Council, Alapaha Soil and Water Conservation District, Middle South Georgia Soil and Water Conservation District, Seven Rivers Resource Conservation and Development, University Georgia College Agricultural and Environmental Sciences, USDA Agricultural Research Service (USDA-ARS), Southeast Watershed Lab, Georgia Chapter Soil and Water Conservation Society, USDA-NRCS, Georgia EPD, and Mid-South Resource Conservation and Development.

2.3 Reason for effort

The USGS has been conducting research in the basin and estuary for nearly 100 years. Research and monitoring have addressed water quality, surface-water discharge, groundwater/surface-water exchange, floodplain forests, the Gulf sturgeon, benthic macrofauna, and estuarine habitat. Additional research is being conducted in the basin by agencies and university researchers. The missing element in the past has been integration, both basin-wide and inter-disciplinary. A more holistic approach is needed to address myriad scientific questions and to provide a supportive data framework for meeting resource-management objectives for the entire ecosystem in the basin and estuary.

The USGS has a vested interest in the basin and estuary and is committed to continue working with State and local agencies and other interested groups to provide

unbiased scientific information about key resource-management issues. The framework established by SBIA for interagency cooperation serves as a starting point for a new USGS research initiative in the Suwannee River Basin and Estuary to actively address an integrated assessment of the basin's physical, biological, and water resources, and to serve as a model for future integrated watershed programs.

This white paper provides relevant background material to science and resource managers about key issues in the Suwannee River Basin and Estuary that will help in developing a comprehensive and integrated science program. This paper addresses basin and estuary threats, science priorities, interagency coordination, and integrated science goals. Long-term goals of the Suwannee Initiative are to establish a basin-wide knowledge base, strong interagency collaboration for monitoring and research, and integrated basin-wide models that can be applied to more impacted river basins in other parts of the United States. The white paper also serves as a foundation for strengthening partnerships in a basin-wide, interstate effort. A clear message that emerged from both the 2004 Cedar Key Workshop and the 2001 SBIA Conference is the importance of partnerships between public and private agencies and other stakeholders. These partnerships have been instrumental in identifying and solving problems that affect water quality and ecosystem integrity. Several notable examples of these fruitful partnerships are the Suwannee River Partnership, the USRWI, and the SBIA.

2.4 Acknowledgments

Thanks are extended to FISC scientists and managers who have contributed to this effort. Also, contributions from personnel from Federal, State, and local partnering agencies are gratefully acknowledged and have significantly improved this document.

3. The Suwannee River Basin and Estuary

3.1 Suwannee Region

The SRB is located entirely within the Coastal Plain physiographic region of the southeastern U.S., extending from Cordele, Georgia, to Cedar Key, Florida, at the Gulf of Mexico (Figure 1). From the eastern headwaters

in the Okefenokee Swamp to the Gulf of Mexico, the SRB has been referred to as one of the most pristine and undeveloped river systems in the United States. It contains a unique combination of subtropical and temperate forests, swamps, fresh and tidal wetlands, and habitat for aquatic and terrestrial wildlife. The expansive and grassy estuary provides one of the most significant nearshore habitats in the northeastern Gulf of Mexico. The Suwannee River is one of only a few rivers within the U.S. that has suffered negligible damage from human activities, including damming, channeling, redirection, or the introduction of large quantities of contaminants.

The entire watershed connecting DOI trust lands from the Okefenokee National Wildlife Refuge (NWR) to the Lower Suwannee NWR (LSNWR) harbors a rich assemblage of exceptional biological, geological, and hydrological resources, and supports an assortment of ecologically important species. Significant tracts of land within the SRB are protected and managed by local, State, and Federal natural resource agencies, non-government organizations, and private landowners. There are over 50 recreation sites along the river and its tributaries, including many state and county parks. Organizations with important land-management activities within the watershed include: USFWS (Okefenokee and LSNWR), U.S. Forest Service (USFS), Florida SRWMD, Florida Department of Parks and Recreation, Florida Fish and Wildlife Conservation Commission (FFWCC), FDEP, GDNR, The Nature Conservancy, and several silviculture and mining corporations. Selected sites along the Suwannee River and tributaries are currently monitored for water quality and limited benthic sampling by the USGS Water Resources Discipline and National Water Quality Assessment Program (NAWQA), Florida SRWMD, and the FFWCC.

3.2 Hydrogeology

Geology, climate, and hydrology are intimately linked in the Suwannee River Basin. Variations in the underlying geology, precipitation, hydrologic cycle, and general climate provide the backdrop for a diverse and complex watershed. The hydrogeology in the SRB is highly varied in terms of its underlying geologic framework and consists of three distinct, but dynamically linked



Figure 1. Location map showing the Suwannee River Basin and Estuary system.

hydrologic regimes. The basin covers nearly 28,600 km² drained by the Suwannee, Alapaha, Withlacoochee, and Santa Fe Rivers. The SRB includes the 1,500 km² Okefenokee Swamp, the Nation's second largest wetland complex, small streams, blackwater rivers, tidal salt marshes, and hundreds of springs. Headwaters for the Suwannee River originate in two distinct areas of the Atlantic Coastal Plain of Georgia. The eastern headwaters are predominantly in the Okefenokee Swamp, and the western headwaters include the Alapaha, Little, and Withlacoochee Rivers (Figure 1).

The hydrologic and chemical characteristics of the Suwannee River change dramatically as the river flows toward the Gulf of Mexico, reflecting differences in the underlying geology and physiography of each region it drains. Surface-drainage characteristics, including streams, lakes and wetlands, are more abundant in the upper two-thirds of the SRB and the Upper Santa Fe River basin. Surface drainage exists where soils contain more clays and fine sediments that are resistant to infiltration. These up-gradient waters are acidic and tea-colored as a result of residence-time and flow through

forested swamps with decaying vegetation. Down gradient, in the southern third of the SRB, a relatively thin layer of highly porous sands overlies limestone karst and the Floridan Aquifer system. The water quality of the Lower Suwannee River exhibits strong groundwater characteristics. Downstream of White Springs, FL, the Suwannee River receives inflow from over 200 known springs. The influx of clear, mineral-rich groundwater from the Floridan Aquifer buffers the acidity and darker color of predominantly surface water from upstream. The relative absence of surface-water features such as streams, lakes, and wetlands indicates areas of direct recharge of rainfall to the aquifer in the karst-dominated region.

The transition between the karst region and up-gradient region includes many stream-to-sink subbasins, where stream flow is abruptly captured by sinkholes and routed to the aquifer. This transition zone lies along a feature in Florida known as the Cody Escarpment. The Suwannee River is the only stream in the SRB flowing across the escarpment that is not fully captured by sinkholes. This area and the numerous springs along the reaches of the Lower Suwannee River act as points of interaction between surface water and groundwater.

The SRES consists of the tidal portion of the Suwannee River, nearshore intertidal and subtidal zones, a small delta, and the Gulf of Mexico from Horseshoe Beach to Cedar Key. A series of oyster reefs and a shallow offshore shelf provide a measure of protection for this otherwise everted and open-estuarine system. The coastal area is characterized by low topographic and bathymetric gradients, sedimentary deposits over karst limestone, and the Floridan Aquifer is at or near the land surface throughout this coastal region (Montague and Odum, 1997). The tidal river is bordered by wetland and upland forests, freshwater marsh, and brackish marsh habitat. The lower and nearshore estuary is characterized by a mixture of fresh and saltwater marsh, tidal creeks, mudflats, submerged aquatic vegetation (SAV), and submerged sand and shell features. The estuary, its creeks, rivers, and emergent zones provide wildlife habitat for many ecologically important and valued species. The SRES is a productive estuary. An area of elevated phytoplankton seaward of the Suwannee River outflow was attributed to light and nutrient availability (Bledsoe and Philips, 2000). The coastal

waters are influenced not only by surface freshwater inputs and tidal exchange, but also by submarine groundwater discharge. Evidence for submarine springs and seeps is apparent from the relatively high radium concentrations in estuary and offshore waters (Burnett and others, 1990). Submarine groundwater discharge may also contain elevated concentrations of nutrients and carbon. The estuary system is thought to be mostly pristine, but the shellfish industry has been negatively impacted in the past by contamination.

3.3. Water Resources

Effective management of water resources in the basin and estuary is essential for water sustainability, human health and the viability of the ecosystem, agricultural needs, and economic development. To address these issues, it is critical that historical and current information are available regarding amounts and fluctuations in rainfall, discharge, recharge, and the interaction between surface water and groundwater. In 1995, the State of Florida mandated that all water management districts establish minimum flows and levels (MFLs) for basins and subbasins. MFLs are defined as the flow or level of surface water or groundwater at which further withdrawals of water would be significantly harmful to the water resources or ecology of the area (Florida Water Resources Act, 1995, Statute, Ch. 373.042). Also, detailed hydrologic information is needed for accurate calculations of total maximum daily loads (TMDLs), the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, which have been established by the U.S. Environmental Protection Agency (EPA) Clean Water Act (Section 303).

Historical and current hydrologic information are available for many sites throughout the basin and provide a useful framework to build on. Stream flow has been continuously monitored in the SRB since the establishment of one of the first gauges in Florida, Suwannee River at White Springs, in 1906. This gage is still in operation and currently the USGS and SRWMD monitor river levels or flow at over 60 gauges in the basin through cooperative programs with the States of Florida and Georgia. Ten of these gauges are in Georgia in the upper reaches of the Suwannee and two tributaries, the Alapaha and Withlacoochee Rivers. The remaining gauges are in Florida and include sites on the

Withlacoochee, Alapaha, and Santa Fe Rivers as well as the main stem of the Suwannee. Stream flow also has been measured for several decades in small watersheds within the Upper Suwannee River Basin. The Little River watershed near Tifton, Georgia, was instrumented in 1967 for rainfall and stream flow measurements by the Southeast Watershed Research Laboratory (SEWRL) of the USDA-ARS. The 334 km² Little River watershed includes seven gaged sub-watersheds ranging in size from 2.6 to 115 km². The original hydrologic network consisted of 55 rainfall gauges, eight flow-measurement sites, and three floodplain alluvial groundwater-stage recorders. In 1981 this network was reduced to the current design of 29 rainfall gauges and five flow-measurement sites (<http://sacs.cpes.peachnet.edu/sewrl/>).

A regional surface-water network was begun in 1989 by the Suwannee River Water Management District to assess water quality in priority water bodies as identified in the Surface Water Improvement and Management (SWIM) Program. Currently, SRWMD maintains the Water Assessment Regional Network (WARN) to monitor river, lake, and groundwater levels, river discharge, rainfall, and surface- and groundwater quality conditions (Hornsby and others, 2003). Water levels in 21 lakes are monitored daily, weekly, or monthly, depending on the specific water body. Streams and river levels are measured at varying frequencies at 51 sites, 19 of which are maintained by USGS. A flood-monitoring network consists of 23 river gauges, of which 19 are automated. In addition, rainfall data are collected from 55 monthly stations, of which 31 contain tipping-bucket rain gauges that provide near real-time data.

Spring flow in the Lower SRB is being measured at 14 gauges installed in 2001-2002, including the Ichetucknee springs system, Troy, Fanning, and Manatee Springs, which provide a substantial amount of the base flow to the Suwannee River. The SRWMD maintains groundwater-monitoring networks that include records of groundwater level for 1,028 wells. Most of these wells are only measured during record high or low flow conditions, and 362 wells are inactive. Monthly water levels are being measured at 181 wells, of which 73 have continuous recorders. SRWMD maintains two groundwater quality networks, which began in October 2000: (1) a trends network consisting of 97 wells tapping the Floridan Aquifer system that are sampled

quarterly, and (2) a status network consisting of 146 randomly selected wells that are sampled once per year. Groundwater quality data exist for over 1,700 wells that have been sampled from 1975 to present.

Effective management of water resources in the basin would benefit from linked hydrologic and water-quality models and integrated monitoring that crosses all jurisdictional boundaries. A well-developed hydrologic model of the watershed and estuary system that addresses surface and groundwater interactions, seasonal and inter-annual variability in rainfall and recharge, and long-term climate forecasts would facilitate assessment of water supply and demand and greatly assist resource managers.

3.4 Ecosystem Function

A series of multi-disciplinary studies of physical, chemical, and biological processes in the basin is needed to understand complex interactions among system components. The Suwannee River is one of only a few rivers within the U.S. with relatively intact historic hydrologic form and function. The SRB and Estuary are known for high-quality wildlife habitats, including pine flatwoods, freshwater swamps, salt marshes, and seagrass beds. The SRB habitats support terrestrial and aquatic communities and several Federally or State protected species including the threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*), the endangered West Indian manatee (*Trichechus manatus latirostris*), and rare freshwater mussel species. Tree species richness in wetland forests of the Lower Suwannee River floodplain is among the highest of North American river floodplains. The spring systems in the Lower SRB contain the greatest diversity of obligate, subterranean decapod crustaceans in the world. Yet, little is known about this fauna regarding their distribution, abundance, ecological requirements, and sensitivity to changes in water quality and other abiotic stressors. The basin ecosystem, in addition to intrinsic natural values, supports commercial and recreational fisheries, ecotourism, and recreational opportunities for basin residents and visitors. Existing management of the basin is focused on individual tracts of land or individual resources within the watershed. A comprehensive research plan is needed to identify how watershed habitats are linked not only to each other, but to wildlife,

water quality, surface water and groundwater supply, underlying geology, and human activities.

The SRB includes two USFWS NWR. The Okefenokee NWR encompasses approximately 396,000 acres in Georgia and contains most of the 438,000 acre Okefenokee Swamp. This refuge provides sanctuary and breeding grounds for migratory birds, endangered and threatened species, and other wildlife. The LSNWR was established to protect 20 miles of the Suwannee River upstream from its mouth in Florida with approximately 52,000 acres including river floodplain, wetlands, and uplands.

Research on individual species includes life history and habitat use by manatees (Langtimm and Beck, 2003), and Gulf sturgeon (Sulak and others, 2002). Historical data are being used to build a comprehensive model of Gulf sturgeon life history, ecology, habitat use, population biology, and behavior (Sulak and Randall, 2002). Other studies are assessing habitats for freshwater species such as rare freshwater mussel species endemic to the SRB and a faunal inventory to provide baseline information on freshwater fishes and mussels at springs within the Florida State Park system (Lydeard and others, 1999). The USGS Southeast Amphibian Research and Monitoring Initiative (SEARMI) is responsible for monitoring the status of 144 species of amphibians from the southeast, Puerto Rico, and the Virgin Islands (Dodd and Smith, 2003). Research has been conducted in the Okefenokee NWR and LSNWR, where little or no historical amphibian data currently exist. SEARMI has documented 19 species of frogs and four species of salamanders from LSNWR. A comprehensive quantitative assessment is being made of the diversity, biomass, abundance, and species dominance of the benthic invertebrate macrofaunal populations inhabiting the Suwannee River and adjacent river-mouth estuary (Brooks and Sulak, 2004).

The SRES is a productive and relatively unaltered natural system where the Suwannee River enters the Gulf of Mexico. The SRES harbors shallow habitat, seagrass, saltmarsh, and low-salinity conditions along the coast from Horseshoe Beach to Cedar Key. The estuary is a State Aquatic Preserve, a part of the LSNWR, and has been designated an Outstanding Florida Water. This grassy stretch of coast, with few

natural sandy beaches, is best known for its fishing and shellfish industry. The SRES contains expansive oyster reefs, sand bars, tidal creeks, salt marsh, submerged aquatic vegetation, and productive clam leases. These estuarine habitats support ecologically important and valued fish species, many during breeding, nursery, and juvenile phases. SRES contains large areas of estuarine habitat for many ecologically important and valued fish and mammal species, such as the Gulf sturgeon and the West Indian manatee. The Florida Fish and Wildlife Research Institute (FFWRI) at the Kirkpatrick Marine Lab in Cedar Key, Florida, maintains an active monitoring program of fish communities and aquatic habitats in the estuary.

Previous USGS coastal research utilized a time series of remotely sensed imagery, historic charts, and aerial photography to identify short-term fluctuation and long-term changes along the Big Bend marsh coast (Raabe and Stumpf, 1997; Raabe and others, 2004). This earlier effort included the SRES in an evaluation of regional coastal-vegetation change, marine transgression, and adaptation of the ecosystem to fluctuations in sea level, drought, and catastrophic events such as storm surge. A similar approach to biomass change in the basin, landcover alteration, flooding regimes, detailed topography, water quality, and habitat can be mapped and modeled using various remotely sensing and mapping tools and linked to ground-based data such as discharge, drought index, precipitation, fire, logging, and biological resources.

Interrelated ecological and hydrodynamic issues are being investigated in the SRES by USGS in cooperation with the USFWS and the FDEP. Hyperspectral remotely sensed imagery is being used to link structural habitat with hydrologic conditions, and relate fish usage to habitats in the estuary (Raabe and others, in press; Dennis and others, 2001). This study linked expertise from several disciplines to understand this ecologically complex and dynamic system better. The mapping effort highlights the links in the estuary between underlying geology, surface water and groundwater hydrology and marine conditions. The estuary is coupled to floodplain and watershed dynamics, as well as to sea level and marine conditions in the Gulf of Mexico. The SRES and portions of the Gulf of Mexico are now being evaluated through remote sensing, empirical data, and

the development of a three-dimensional hydrodynamic and transport model to understand the relation between salinity characteristics, groundwater, and freshwater flow in the estuary.

Similar efforts to map habitat, link species to habitat, and model hydrology are needed throughout the SRB. Effective research and informed management of the basin's ecological resources would benefit from integrated efforts and a basin-wide resource information tool. By incorporating state-of-the-art imagery and mapping techniques with biologic and hydrologic investigations, this integrated effort would provide the needed links between hydrology and ecology of the SRB from Georgia's swamplands and wetlands to the Florida estuary at the Gulf of Mexico.

3.5 Socio-economic Conditions

Historically, the SRB has been largely rural, sparsely populated, and undeveloped. Agriculture accounts for most of the developed land uses within the SRB in both Georgia and Florida, including silviculture, row crops, and pasture. The forest industry, primarily pine plantations, is active in large areas of the SRB and provides timber and fiber for mills. Trends over the last decade indicate a general shift toward more intensive production of food and forage crops as well as animals. In recent years, ecotourism has boomed, attracting visitors to the clear springs, scenic waterways, abundant wildlife, and rural landscapes.

Population growth and development within the SRB have been steady since the 1960s. The population in the basin increased from 384,000 in 1990 to about 430,000 in 2000. Growth projections in and around the SRB indicate a similar increase in population over the coming decade. Irrigated acreage has increased considerably in the SRB over the last several decades as technologies have improved and market conditions have changed. Crops and products from the SRB include dairy and poultry, fruits and vegetables, grains, pasture, and forestry products. Basin-wide precipitation and runoff is the primary water source for agriculture, industry, and urban development. Small surface-water reservoirs supplement water supply in Georgia, and groundwater from the Floridan Aquifer supplements the water supply in the Florida karst region.

Finding the balance between economic growth, human health, and protection of natural resources is a challenge across the United States. Partnerships in the SRB and Estuary system continue to demonstrate the importance of collaboration among State, local, and Federal agencies in addressing watershed issues at the local scale with a national perspective. Over the past 20 years, the USDA-ARS and the University of Georgia have established fundamental knowledge on the functions of riparian ecosystems for stream-corridor restoration in the Upper SRB. Best management practices (BMP) in stream corridor and riparian management efforts incorporate an integrated approach that accounts for different types of pollutant sources, including livestock enterprise. Several agricultural management efforts in the western headwaters of the SRB are voluntary, incentive-based projects. In Florida, the SRWMD has taken a proactive approach for resource management by land acquisition, cooperative studies with other agencies, and extensive monitoring networks. The Suwannee River Partnership, a farm-based cooperative effort, has obtained over \$20 million in cost-share funding from USDA-NRCS, SRWMD, FDACS, FDEP, and from individual farmers to create voluntary incentive-based programs that reduce nutrient loading to groundwater. Recent cooperative studies between the USGS and SRWMD have addressed issues such as timescales and sources of nitrate contamination of groundwater, hydrodynamics of flow to the estuary system, and potential impacts of flow reductions on tidal floodplain forests.

Apart from intrinsic natural values, the riverine, estuarine, and spring systems support commercial and recreational fisheries, ecotourism, and recreational opportunities for basin residents and visitors. Issues related to water quantity are a major concern for these activities in the basin. The SRB contains an abundance of water that is sought by more developed parts of the State in addition to water supply demands within the basin itself. Effective management of water resources in the SRB would benefit from improved knowledge about the interactions among human activities, economic development, climate variability, hydrologic processes, and ecological function.

4. Suwannee River Basin Issues and Research Needs

4.1 Threats to Water Resources

Competing demands on the natural resources of the SRB require a better understanding of the sources and effects of contamination, water withdrawals, and climate change and the interactions among these stressors. Climate variation alone can result in significant changes in rainfall, with subsequent impacts on surface-water and groundwater supply. Natural fluctuation in water supply, coupled with water consumption, can place added stress on biological communities. Intermittent droughts in Florida over the last two decades have heightened concerns about management of water resources within the watershed. In the future, it will be desirable to improve interagency communication and coordination of groundwater and surface water monitoring, as well as developing predictive capabilities.

Improvements to Basin-Wide Water Resources Information and Management

- Develop and apply consistent and comparable data-collection methods
- Establish improved technique and coordination among agencies and across jurisdictions
- Ensure spatial distribution and environmental coverage
- Develop integrated land-use and land-cover database: past, present, and planned
- Develop improved groundwater/surface water interaction models
- Improve predictive capabilities

4.1.1 Water Supply

Consumptive use of water resources is increasing in the SRB due to farm irrigation requirements and to increasing demands of a rapidly growing human population. Although the Suwannee is undiverted, groundwater is already being mined for bottling at

several spring sources (about one million gallons/day near Ginnie Springs and Madison Blue Spring). Changes in the groundwater-flow regime can have impacts on stream ecosystems by changing in-stream flow characteristics, and water temperature and quality. Feedback loops can start from a single event or source, resulting in degradation or loss of resource quality or capacity. For instance, a change in flow regime through hydrologic alterations can have important impacts on stream ecosystems by changing in-stream flow characteristics and water temperature. Higher water temperatures reduce oxygen solubility and thus tend to reduce dissolved-oxygen concentrations. Further, increased water temperatures increase the rate of metabolic activity in natural waters, which in turn can increase oxygen consumption by aquatic organisms.

Adequate groundwater is especially important in the Lower Suwannee River where spring systems are abundant. Demands for groundwater from intensifying urban development and extensive agricultural activities in this part of the basin have resulted in increased withdrawals of water from the Upper Floridan Aquifer. As an example of water-quantity-related problems, some springs in the SRB have essentially stopped flowing at certain times of the year due to lowering of the water table that results from pumping and lower recharge to the aquifer. A growing population, changing land use, and increased demands on natural resources are altering the rural nature of the SRB.

Proposals for diverting water from the Suwannee River to help satisfy the domestic water needs of the greater Tampa metropolitan area have been considered over the last decade. The effects of such withdrawals on riverine or estuarine habitats and fauna are inadequately known and cannot be predicted without an integrated study and model of the ecosystem.

Water Supply/Water Budget Research Needs and Opportunities

- Extend hydrologic models to include climate-change scenarios:
 - *Evaluate past and potential interannual and seasonal variations*

- Tie MFLs to regional changes in climate, precipitation, and sea level
- Basin-wide hydrologic model
 - Extend and integrate surface and groundwater models across Florida and Georgia
 - Identify and map existing land use and projected changes in water consumption
 - Model impact of changes in water use on springs, biological resources, and water quality
- Extend water budget models to estuary
 - Improve and standardize data-collection techniques in Lower Suwannee and Estuary
 - Evaluate seasonal and interannual variations in estuarine mixing zones
 - Assess coastal groundwater discharge and role of submarine springs
 - Model tidal and freshwater interactions

4.1.2 Water Quality

Although studies in the basin indicate generally good overall water quality, large nitrogen inputs to the land surface from fertilizers, animal wastes, sewage effluent (septic tanks and land application of treated sewage effluent), and atmospheric deposition, are raising concerns regarding human and ecosystem health. This problem occurs along most of the entire course of the Suwannee River, as evidenced by massive mats of benthic filamentous algal turf from Big Shoals to the lower parts of the basin. Nitrate concentrations in groundwater and spring waters have increased substantially from near background concentrations of less than 0.1 mg/L in the 1960s and 1970s (Rosenau and others, 1977) to more than 5 mg/L in the late 1990s at some first-magnitude springs (Hornsby and Ceryak, 1999; Katz and others, 1999). In some areas of the basin, nitrate-N concentrations in the Upper Floridan Aquifer (the source of water supply) exceed the maximum contaminant level of 10 mg/L for drinking water. Also of concern are the effects of high nitrate concentrations in the SRES, such as contamination of the local shellfish industry and impacts to coastal fisheries.

Sources of water quality degradation:

Atmospheric deposition (Hg)
 Concentrated animal-feeding operations
 Cropland farming
 Waste-disposal systems (human)
 Industrial wastes
 Land-surface/land-cover alterations
 Drought or other hydrologic change

Types of contamination:

Nitrogen and other nutrients
 Pesticides, chemical compounds and their metabolites
 Sediment load and reduced water clarity
 Toxins: mercury and organic chemicals
 Endocrine disruptor compounds
 Pathogens, Bacteria, and Parasites
 Infectious disease: *Cryptosporidium parvum*

Results of water quality degradation:

Potential human health effects
 Loss of economic base (fishery, shellfish industry, recreation, ecotourism)
 Loss of important species or habitats

Elevated nitrate concentrations in rivers can cause eutrophication, which can result in algal blooms and depletion of oxygen that can lead to fish kills (Bledsoe and Philips, 2000). Increases in nitrate concentrations from human activities may cause adverse ecological effects, indicated by an increase in periphyton biomass along the middle and lower reaches of the Suwannee

River (Hornsby and Mattson, 1998). High nitrate concentrations are also a major concern in the SRES.

Bioaccumulation of mercury in certain fish species is an important water-quality issue in the Suwannee River Basin. Mercury levels in crayfish, sunfish, and largemouth bass increased significantly in the Suwannee River with increasing distance upstream of its mouth (Chasar and others, 2004). Fish-consumption advisories for mercury in largemouth bass have been issued for the Santa Fe River, a major tributary to the Suwannee River. Also, fish-consumption advisories for mercury have been issued for stream segments in the Alapaha, Withlacoochee, and Upper Suwannee subbasins in Georgia. Additional work needs to be done to evaluate how mercury sources and transport and local biogeochemical processes affect mercury concentrations in water and biota.

Water quality within the basin, the river floodplain, river channels, springs, wetlands, and estuary is essential to both human and ecosystem health. Animal production (swine and poultry) with confined feeding operations is expected to increase in the Coastal Plain. Management of water quality in the SRB will require consistent basin-wide monitoring networks, a linked basin-wide database, hydrologic models, and the monitoring of areas where BMPs have been implemented to evaluate their effectiveness in reducing nutrient loading and economic viability.

Water Quality Research Gaps and Opportunities

- Evaluate natural reduction of elevated nitrate via surface water/groundwater interactions:
 - *Role of wetlands in denitrification process*
 - *Effects of mixing of organic-carbon-rich river water with groundwater and reduction of nitrate due to denitrification in the aquifer during high flow conditions*
- Evaluate occurrence of agricultural chemicals in groundwater, springs, river, and estuary
- Assess impact of endocrine-disruptor compounds, pesticides, and their degradates to aquatic system health
- Assess impact of atmospheric transport of mercury and other airborne contaminants on human health and ecology
- Apply sediment-transport algorithm to evaluate sediment-transport process
 - *Investigate use of acoustic-velocity meters as surrogate sediment indicator*
- Link water quality to biogeochemical processes:
 - *Biological interactions from micro to macro scales*
 - *Physical and chemical interactions in water, soil, and rock*
- Link water quality from headwaters to estuary:
 - *What are the minimum flows and levels needed to preserve water quality and protect ecosystem and human health?*
 - *Investigate relations among nutrient-enriched freshwater and the health, productivity, and sustainability of the downstream and estuarine ecosystems*
 - *Address effect of nutrient loads in Upper Suwannee on biota in the estuary*

4.2 Human Health

The occurrence of natural and anthropogenic contaminants in water and their effect on human health has become an increasing environmental concern. Naturally occurring contaminants in the SRB and Estuary include airborne dusts that can be transported from western Africa in trade winds across the Atlantic Ocean to the Caribbean and to the southeastern U.S. These dusts contain a variety of plant, animal, and opportunistic human pathogens from 20 different bacterial genera and fungi that contain both pathogenic and nonpathogenic members (Kellogg and others, 2004). Radionuclides that are present in Hawthorn Group sediments overlying the Upper Floridan Aquifer represent another source of natural contaminants. Gamma rays, alpha particles, and beta particles that are given off during radioactive decay of uranium or

thorium-decay series nuclides (e.g. ^{222}Rn , ^{226}Ra , ^{224}Ra , ^{228}Ra , ^{234}U , and ^{238}U) are all ionizing radiation. Each type of radiation has the potential to damage or destroy living cells. For example, radium in drinking water is known to increase cancer risk, primarily for bone and sinus cancer (Mays and others, 1985). Exposure to radon gas has been recognized by the Surgeon General of the United States as being second only to cigarette smoking as a cause of lung cancer (U.S. Environmental Protection Agency, 1992).

Atmospheric transport and deposition of mercury is an important health issue. Total maximum daily loads (TMDLs) for total mercury were established for the protection of public health associated with the consumption of fish in Georgia. Impaired waters that were listed on the State of Georgia's 2000 Section 303(d) list were located in streams in the Alapaha, Withlacoochee, and the Upper Suwannee subwatersheds in Georgia.

Several human health concerns are associated with elevated nitrate concentrations in groundwater used for drinking. Infants under six months of age who ingest nitrate in drinking water are susceptible to methemoglobinemia, which can lead to reduced blood-oxygen levels and can result in death. For these health concerns, the U.S. EPA established a maximum contaminant level (MCL) for nitrate of 10 mg/L as nitrogen (N) for drinking water. Another study found an increased risk of non-Hodgkins lymphoma associated with nitrate concentrations of 4 mg/L or more in rural drinking-water supplies.

Little is known about the presence of bioactive chemicals in surface and groundwaters in the basin. The presence of these compounds in aquatic systems originates from the waste disposal of human and veterinary pharmaceuticals and from active ingredients in personal care products. Recent studies have shown that pharmaceuticals, endocrine-disrupting chemicals (hormones), and other organic wastewater contaminants are present in streams throughout the U.S. (Kolpin et al., 2002). Although present in generally very low concentrations, little is known about the potential interactive effects on human health and the health of aquatic organisms that may occur from complex

mixtures of organic wastewater contaminants and their metabolites in surface waters.

During prolonged wet periods, when river floodwaters flow into the karstic Aquifer system along the Lower Suwannee River corridor, there is an opportunity for waterborne pathogens (e.g. *Cryptosporidium* and *Giardia* oocysts) to enter the aquifer system. Also, these waters contain very high concentrations of naturally occurring organic matter, which could react with disinfectants such as chlorine and produce harmful trihalomethanes and haloacetic acids.

In the late 1980s, contaminants from human and dairy wastes were transported in river water and closed the oyster industry at the mouth of the Suwannee. Better waste-management systems that replaced failing septic tanks, and management of the upstream dairy farms served to improve water quality in the estuary. A prospering clam industry, designed to bolster failing economy of coastal counties, is now established between the Suwannee River mouth and Cedar Key. Cedar Key clams are highly sought after and are now the largest source of farm-raised clams in the U.S. Water quality monitoring continues in the clam leases as well as renewed interest in upstream land-use and land use change. Future failures to maintain water quality at the mouth of the Suwannee and Estuary is a constant threat to the newly established local economic base. In addition, natural disasters such as the 2004 hurricane season can wreak havoc on the clam leases, effectively destroying the 2004 crop.

Research Opportunities in Human Health

- Endocrine disruptor chemicals and organic wastewater compounds
- Mercury methylation and accumulation in fish tissue
- Fate of nitrate in drinking water and aquatic systems
- Radionuclide occurrence in drinking water and associated health issues
- Pathogens and bacteria influx to karstic groundwater during flood periods
- Elevated natural organic material and the formation of disinfection by-products

4.3 Ecosystem Threats

Changing land use and a growing human population threaten ecological resources in the basin through pollution, geographic limitation, food web disruption, water supply, and the introduction of invasive species. Alteration in the timing, duration, and frequency of flooding and the concomitant degradation of water quality directly threaten aquatic habitat and species. Natural environmental variability, such as drought or severe storms, may further impair ecosystem resilience. The SRB lies entirely within the Coastal Plain province, yet it straddles the climatic boundary between temperate and subtropical species distributions, where tropical species reach their northern limits, and temperate species reach their southern limits. Adaptations forced by climate change, such as the migration of ‘borderline’ species, places additional stress on biological resources. Threats to ecological resources may be further subdivided into habitat threats and threats to species, each with distinct research needs.

In general, methods that link geographic distribution of hydrologic and physical features with human activities and biological resources will more effectively serve ecosystem management efforts to address basin-wide ecosystem threats.

General Ecosystem Threats

- Natural environmental variation such as precipitation and temperature
- Alteration to water supply
- Pollution and disease
- Geographic constraints through land use or climate change
- Alteration of trophic dynamics (nutrient/energy transfer)
- Invasive species

4.3.1 Habitat Threats

Habitats in the basin are closely linked to topography, hydrology, climate, soils and geology. Each habitat is limited geographically by the co-occurrence of specific environmental characteristics. As pressures increase

from human activities, the total area available for each habitat is decreased and connectivity between habitats may be eliminated. Today there are insufficient data in the basin on the location and condition of habitats or of imminent threats to habitats. A primary research need is a thorough mapping of basin features and the habitats associated with each suite of features. An analysis of land use and projected land use is needed to evaluate existing and potential threats to habitat area, habitat links, and habitat quality. Also needed is an evaluation of the role of water supply to habitat quality and a hydrologic model for evaluating future scenarios. Water quality and water supply play important roles in the value of habitat to particular species. Small alterations to the flooding regime, nutrient loads, and water clarity can have profound impacts on the species present.

The role of water supply in the viability of habitats varies between the Upper and Lower Suwannee Basin, and the estuary system. Surface water storage and flow plays a critical role in the Upper Suwannee, but groundwater plays an equally vital role in habitat quality of the Lower Suwannee. The role of water in the estuary is even more complex and will require monitoring and modeling of surface water, groundwater, and tidal waters. Research needs in the estuary include determination of submarine groundwater discharge to coastal areas, source identification of wastewater contaminants, and models of salinity and nutrient-transport processes.

Threats to habitat are linked to threats to species because individual species requirements for territory, feeding area, migration, and gene pool are directly linked to habitat availability, links between habitats, and access to nutrients, shelter, and suitable reproductive conditions. An emphasis on integrated science efforts between habitat research and species research is necessary. A recently completed USGS study addressed the issue of potential reductions of flow for wetlands protection by relating hydrologic conditions, soils, and vegetation of floodplain forests to river flow in the Lower Suwannee River (Light and others, 2002). Research opportunities include the characterization of wetland habitats in the Upper SRB and relating these to amphibian and mussel research studies.

Habitat Conservation Research Gaps and Opportunities

- Identify and map terrestrial and aquatic habitats
 - *Utilize existing data and state-of-the-art remote sensing capabilities for complete spatial coverage of basin habitats*
 - *Map and model topographic, hydrologic, and structural features such as spring watersheds and submarine groundwater discharge*
 - *Identify patch size, connectivity and landscape mosaic*
 - *Identify community composition*
 - *Evaluate natural variability within habitat*
- Identify and model changing water supply on habitats
 - *Identify and model changing water quality*
 - *Identify changes to habitat structure or function*
- Identify impact of changing land use on habitats
 - *Identify and model alterations to habitat size and connectivity*
 - *Evaluate potential habitat degradation from pollution*
- Link habitat threats to species threats
 - *Link manatee foraging needs to sea grass mapping and monitoring*
- Evaluate invasive species and loss of habitat

4.3.2 Threats to Species

Individual biological species are susceptible to changes in climate, land use, habitat alteration, water quality and supply, and changing food resources. Species conservation requires not only conservation of habitat, but also an understanding of population dynamics, genetics, predator/prey relations, nutrient cycling, and interplay with the human landscape. Competing land-use activities, recreation, economics, and cultural history can impede the process to conserve and protect the biological resources of the basin. Specifically, the balance between human economics, natural resources, and biological communities requires dedicated

management to provide information and incentives to basin population and visitors. Additionally, introduced species can displace native species. One widespread but barely studied invasive, the Asian clam, *Corbicula fluminea*, has probably driven several native mussel species to near extinction in the river. However, the filter-feeding Asian clam may be an important player now in consuming excess phytoplankton production resulting from excess nutrients. Two other non-indigenous species found in the SRB are the Cuban tree frog (*Osteopilus septentrionalis*) and the red-eared slider (*Trachemys scripta elegans*).

Decreased flow and degraded water quality at springs threaten the many faunal species that depend on spring habitat. The Florida manatee is of special concern because of its endangered status and dependence on natural springs as warm water refugia during cold winters. The Gulf sturgeon, a subspecies of Atlantic sturgeon, was listed as threatened under the Endangered Species Act in 1991, when populations declined after a century of fishing for meat and caviar. Gulf sturgeon eat by siphoning tiny invertebrates from the mud deposited on the estuary floor. They migrate up the Suwannee River from the Gulf of Mexico in the springtime to spawn, but do not feed while in the river. Interdisciplinary approaches are critically needed to relate population ecology of the Gulf sturgeon and manatee to habitat and hydrology, and together to assist State and Federal managers in identifying management actions and assessing their efficacy. Adaptive management models would greatly benefit from the integration of hydrodynamic and water-quality models with ecological research focused on species, biological communities, and their habitats.

Threats to Species: Research Gaps and Opportunities

- Identify keystone species and functions (example is blue crab in estuary)
 - *Productivity and role in ecosystem balance*
 - *Versus flagship species (charismatic)*
 - *Versus indicator species (indicative of a specific parameter)*

- Map species distribution, biodiversity, and link to habitat
 - *Identify populations, isolation, and genetic viability*
 - *Identify susceptibility to changes in water supply and water quality*
 - *Identify species mobility in response to climate and other changes*
 - *Identify vulnerable populations and interrelated populations*
 - *Develop BMP to conserve existing viable populations*
- Assess role of benthic macrofauna and algal flora
 - *Role in mitigating sediment surface oxygen levels*
 - *Impacts from changing water supply, load and quality*
 - *Role in productivity, food web and trophic levels*
 - *Evaluate abundance, biomass, diversity, and turnover rates*
 - *Changes to habitat structure or function*
- Evaluate role of subterranean fauna (planktonic microcrustaceans)
 - *Evaluate populations and locations*
 - *Assess sensitivity to groundwater perturbations*
 - *In trophic cycle and processing of nutrients; role as water quality indicators*
- Evaluate sources and cycling of nutrients in terrestrial, fresh and tidal waters
 - *Conduct trophodynamic forensic studies with stable isotopes*
 - *Define nutrient sources and sinks*
- Evaluate recovery and survival of endangered or threatened species
 - *Relate to health and function of ecosystem*
 - *Assess efficacy of management efforts*

4.4 Economic Base

The economic base in the SRB currently consists of agriculture, silviculture, mining and other industries, and ecotourism. Alteration of the water supply directly threatens agricultural activities, existing populations, and development plans. Unregulated development and degradation of water quality threaten all resource-based industries including fishing, aquaculture, and ecotourism. Water withdrawal or obstruction of recharge zones may pose long-term risks for economic viability. Management in the basin needs an effective plan for water supply and land use that will support sustainable economic growth without risk to water supply and natural resources of the region. Development, evaluation, and application of BMPs, outreach, and education will continue to play an important role in establishing a balance between land use, sustainable economic growth, human health, and a productive ecosystem.

Continued degradation of water quality could have a major impact on the economy of local communities in the basin. A recent study found that about 190,000 people visited Ichetucknee Springs State Park in 2002 and spent about \$22.7 million in the communities surrounding the park (Bonn and Bell, 2004). This area has higher poverty and unemployment rates than State averages and benefits from the growth of the ecotourism industry. It is estimated that nature-based tourism could double in the next 10 years, and this increase could create more than 2,200 new jobs throughout the region.

Research Opportunities in Basin Economics

- Evaluate impact of best management practices on economy and natural resources
- Evaluate cost/benefit of agricultural practices (timing/amount of fertilizer and water)
- Develop models and evaluate scenarios for land use and economic growth
- Evaluate potential for ecotourism, impact, and value of coordinated education
- Evaluate incentives for environmentally sensitive development

- Develop and evaluate educational programs (Master Farmers Curriculum, Florida Yards and Neighborhoods, Natural/Organic Farming Techniques)

5. Strategy

Management of the nation's freshwater resources must address water supply and water quality for urban growth, food production, and industry. Competing needs for adequate water supply have resulted in threats to human and ecosystem health in many watersheds throughout the U.S. The Suwannee River watershed offers a unique opportunity to study effects of excessive nutrient loading, increasing freshwater withdrawals, and habitat degradation in a relatively pristine area that is undergoing extensive changes in land use and water consumption. Attention has been drawn recently to the SRB, following proposals to divert water to fulfill demands in populous counties in the Tampa metropolitan area. The vital interplay among agriculture, socio-economic pressures, underlying geology, changing river hydrology, and unique biologic resources from the headwaters to the estuary is now recognized. The Suwannee River drains 21 counties in Georgia and 13 counties in Florida and plays an important role in estuarine productivity at the Gulf of Mexico. As a model of relatively undisturbed large rivers in the southeastern United States, the SRB provides an unparalleled opportunity for assessing its natural resources and for demonstrating how to coordinate the interstate management of watershed and estuarine resources successfully.

5.1 Partnering for an Integrated Watershed Database

The key to coordinating multi-agency research studies in the Suwannee Basin and Estuary is to leverage partnerships to develop integrated research and resource management tools. The SBIA, which operates in a planning and advisory capacity, promotes the sharing of information and resources by Georgia and Florida. This information sharing allows for leveraging of the limited funds that each State has available for water, natural resources, and economic activities. Constraints

on State agencies limit their jurisdictional authority. Federal agencies (USDA, FWS, EPA) currently involved in the SRB have specific mandates that limit issues or geographic extent of their activities. The USGS mandate and skill set is appropriate to meet this challenge.

The Consortium of Universities for the Advancement of Hydrologic Studies, Inc. (CUAHSI) in conjunction with the National Science Foundation (NSF), is developing a network of hydrologic observatories (HO) across the U.S. that focuses on issues related to the science and management of hydrologic systems. If the proposed HO for the SRB is funded, this effort will coincide with the USGS initiative in a complementary fashion. Valdosta State University (VSU) is also seeking NSF funding for an undergraduate research program in the SRB. This effort is supported by various agencies including the USGS. Combined efforts by universities, and local, State and Federal agencies promise a solid foundation for research and cooperation in the SRB.

The existing partnership framework will serve as the basis for a collaborative effort to develop an Integrated Watershed Resource Information Tool. Primary efforts are being focused on the creation of a data portal to provide links among data bases containing hydrologic, biologic, water quality, and geographic information. This effort can facilitate cooperation among agencies by identifying data gaps and information needs. The USGS is committed to developing a prototype information tool, supported through a web-based environment, which links land use, biology, water, and geology information from various agencies working in the basin and estuary. Links to existing data sets will eliminate the need to have all data in a single location. This arrangement will permit individual agencies to continue to collect and develop mission-specific information while making the final products and datasets available to a wider science and management community. The web-link concept is conducive to a dynamic research environment, in which updates are initiated by the participating agency or research scientists, rather than a third party. An example of an interactive information resource tool is the Invasive Species Information Node, where information regarding invasive species is updated by experts (<http://invasivespecies.nbi.gov/>). The geospatially-linked resource-information tool will serve as a model for developing similar data systems for other watersheds.

Another example of a flexible data server is the USGS Hydrologic Data Web Portal developed by the USGS for the Southwest Florida Water Management District (SWFMD).

A preliminary effort targeted at data integration will be developed this year (FY2005) for presentation at the next workshop. The initial effort will focus on land use and existing hydrologic datasets. Over time it is expected to include links to imagery of the basin, dynamic mapping products, hydrologic models, and biological resources. All parties concerned have also expressed a strong interest in the development of watershed models to address various economic, hydrologic, and biological-resource scenarios. This resource information tool will set the stage for future modeling activities.

5.2 Science Plan, Workshops, and the Future

The next workshop for the Suwannee Initiative is planned for June 2005 in Folkston, Georgia, near the eastern headwaters of the Suwannee River. The workshop will be held at the Okefenokee Educational Research Center (OERC), a new facility dedicated to promote education and research in the Okefenokee Swamp. Topics to be discussed include coordination of research activities described in the Science Plan for the Suwannee River Basin and Estuary system, and the continued development of a web-based resource information tool.

The specific goals of the 2005 workshop are to:

1. initiate interstate dialogue
2. develop a science plan framework
3. identify key issues and agencies/researchers to address issues
4. continue developing the web-based resource information tool.

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