Protecting Critical Ecosystems: Current EPA Regional Activities and Future Agency Opportunities

Tom Hoctor, Ph.D.
Ginevra Lewis
Matt Marsik
GeoPlan Center
Department of Landscape Architecture
University of Florida

Cooperators:
Office of Policy and Economic Innovation
Region 2
Region 4
Region 5
Region 6
Region 7
Region 8
Region 10

December 15, 2004

Appendices

The following three appendices contain additional resources relevant regional critical ecosystem assessments. Appendix A is an inventory of additional projects and other information that is organized by project/resource. These project, research, and tool descriptions can be used to identify data, analytical techniques, and tools that can be used to enhance future assessments of critical ecosystems by improving data, techniques, and closing gaps. Appendix B includes websites, citations, and data lists that are organized by the SAB Framework Essential Ecological Attributes to serve as sources of information for conducting analyses relevant to identifying critical ecosystems for each category of analysis. Appendix C is a condensed version of thesis project conducted by Ginevra Lewis, part of the University of Florida research team. Her research reviews methods for assessing wetlands for suitability/significance for mitigation and develops indices for prioritizing wetlands based on landscape, habitat, and other characteristics. Many of these indices could be relevant to critical ecosystem identification in other regions.

Appendix C

A Regional Wetland Mitigation Framework for the Protection of Biodiversity: The Northeast Florida Region as a Case Study

Ginevra Lewis

Graduate Candidate

April 2004

Master of Landscape Architecture
Department of Landscape Architecture
Spring Semester 2004

Margaret H. Carr, Department of Landscape Architecture
Robert Grist, Department of Landscape Architecture
Paul D. Zwick, Department of Urban and Regional Planning

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ACI	Areas of Conservation Interest
AHP	Analytic Hierarchy Process
AMNEW	Automated Assessment Method for Northeastern Wetlands
CERCLA	Comprehensive Environmental Response, Compensation, and Liability
CLAN99	Conservation and Recreation Lands 1999
COE	U.S. Army Corps of Engineers
CWA	1972 Clean Water Act
DEM	Digital Elevation Model
DEP	Florida Department of Environmental Protection
DOT	Florida Department of Transportation
EPA	U.S. Environmental Protection Agency
EPATRI	U.S. EPA Toxic Release Inventory
ERP	Environmental Resource Permitting
FFBOT	Florida Forever Board of Trustees Environmental Land Acquisition Projects
FFWCC	Florida Fish and Wildlife Conservation Commission
FGDL	Florida Geographic Data Library
FNAIMA	Florida Natural Areas Inventory Managed Areas
FWC	Florida Fish and Wildlife Conservation Commission
FWCMAS	Fish and Wildlife Conservation Commission Management Areas
FWS	U.S. Fish and Wildlife Service
GFCHOT	Biodiversity Hot Spots
GFCWET	Priority Wetlands Habitat
GIS	Geographic Information Systems
GWECOP	Greenways Project Ecological Model Results Modified by Public
GWPEAX	Greenways Project Priority Ecological Areas (After Exclusion)
LDR	Land Development Regulation
LULC	Land Use/Land Cover
MOA	Memorandum of Agreement
MUA	Multiple Utility Assignment
MUM	Multiple-Use Module
NERPC	Northeast Florida Regional Planning Council
NLCD	National Land Cover Dataset
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWFWMD	Northwest Florida Water Management District
NWI	National Wetlands Inventory
OPPAGA	Office of Program Policy Analysis and Government Accountability
PEA	Priority Ecological Areas
PNA	Potential Natural Areas
RSH	Regionally Significant Habitat
SFWMD	South Florida Water Management District

SHCA	Strategic Habitat Conservation Area
SJRWMD	St. Johns River Water Management District
SJWMDL	St. Johns River Water Management District Lands
SRWMD	Suwannee River Water Management District
SSURGO	Soil Survey Geographic Database
SUA	Single Utility Assignment
SWANCC	Solid Waste Agency of Northern Cook County
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement and Management
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WMD	Water Management District
WRP	Wetland Resource Permitting

Abstract

Wetland mitigation is required, pursuant to federal, state, and local policy, as compensation for impacts to wetlands incurred through dredging and filling activities. Wetland mitigation may occur on-site or off-site from where wetland impacts occur and may be accomplished through wetland restoration, wetland creation, wetland enhancement, wetland preservation, and upland preservation. This project proposes a framework for off-site regional wetland mitigation planning that protects biodiversity. Scientific foundations for the framework include wildlife ecology, conservation biology, landscape ecology, and reserve design principles. Patch size, significant habitat, connectivity, spatial context, water quality, and acquisition feasibility were prime considerations for the framework. The framework was applied as a case study to northeast Florida within the St. Johns River Water Management District. Geographic information systems (GIS) were used to determine suitability of wetlands within the study area for wetland preservation, wetland enhancement, and wetland restoration. Analysis was completed separately for small (0.2 to 5 ha), medium (5 ha to 100 ha), and large (greater than 100 ha) wetlands. The total wetland area included in the study was 440,161 ha. Of the total wetland area, 66.99% of the area was identified as being potentially suitable for preservation, 18.42% was identified as being potentially suitable for enhancement, and 14.59% was identified as being potentially suitable for restoration. The author concludes that the regional framework for wetland mitigation is a flexible process that could potentially be applied to any region where comparable data is available. The study highlights the ecological importance of wetlands of even the smallest size and includes small wetlands within the framework. The framework has potential applications within the St. Johns River Water Management District for both mitigation and land acquisition planning purposes. The study also portrays the importance of protecting integrated landscapes of uplands, wetlands, and open water.

1.0 Background
1.1 Introduction

In accordance with federal, state, regional, and local laws protecting wetlands, wetland mitigation is frequently carried out in the United States to compensate for impacts to wetlands due to human development. On-site mitigation refers to mitigation that takes place on the same site on which wetland impacts occur. This type of mitigation often results in wetlands that are too small and isolated to provide wildlife habitat of value. Additionally, wetland hydrology is often hard to achieve without an influx of water from adjacent wetlands. Without wetland hydrology, a self-sustaining wetland plant community cannot be achieved. Surrounding land use changes may also be detrimental to the mitigation wetland. Additionally, uplands in close proximity to the mitigation wetlands are often under-protected and services that the uplands would have provided for the wetland habitat types are lost. The result is, all too often, an ecologically unsuccessful venture, which pursuant to regulations, requires many years of expensive monitoring and re-design. According to Russell et al. (1997), less than 5% of mitigated wetlands in the United States were in full compliance with stated permit goals in 1992. The authors state, "This apparent failure of mitigation efforts undoubtedly is due to many factors, given the infancy of the science and technology, as well as the diversity and complexity of wetland environments. An inadequate site selection process is one factor that may be contributing to the limited success of these efforts." Although federal, state, and most regional and local policies give preference to on-site mitigation, off-site wetland mitigation is a system that has arisen in response to the problems of on-site mitigation and includes the use of mitigation banks.

The purpose of this study is to evaluate how off-site wetland mitigation options in Florida can be integrated into a regional framework that will most effectively protect biodiversity throughout a watershed. With proper siting in a regional context, off-site mitigation and protection for adjacent uplands, presents an opportunity for the establishment of ecologically functional wetlands, wildlife habitat of value, connectivity within an ecological network, and economic savings. Proper siting is contingent upon the evaluation of connectivity to adjacent wetlands and existing and proposed surrounding land uses and structures. Within a regional context and with proper planning, off-site mitigation may promote protection of biodiversity throughout the watershed.

1.2 Wetland Mitigation Function and Biodiversity Issues at a Regional Scale
1.2.1 Site Selection

A primary goal of mitigation should include the selection of ecologically optimal sites, which will maximize wetland function and biodiversity. According to the Institute for Water Resources (1994), there are several criteria for mitigation site selection. Sites should be judged according to their potential to create, restore, enhance, and maintain adequate wetlands hydrology. They should also be examined for the presence or availability of wetland soils, vegetation, and wildlife species, and the ability to protect the site from harmful adjacent land uses should be determined (Institute for Water Resources, 1994). The most important criteria, many argue, may be the achievement and maintenance of hydrology that will support a wetland ecosystem, because with that in place, the self-organizing ability of wetland ecosystems contributes to the establishment of vegetation and wildlife habitat (Mitsch and Wang, 1998). Additionally, where wetland hydrology already exists, hydric soils are likely as well (Institute for Water Resources, 1994). Hydroperiod has also been suggested as a criterion for assessing wetland function (Snodgrass et al., 2000). Ephemeral wetlands are particularly important for herpetofauna adapted to seasonal hydroperiods and the absence of predatory fish (Russell, Guynn, Jr., and Hanlin, 2002). At a regional scale, patch size, connectivity, and context should also be primary criteria for wetland mitigation site selection and planning.

1.2.2 Patch Size

Many wetland ecologists argue that to maximize protection of wetland function and biodiversity, mitigation sites should be as large as possible to avoid habitat fragmentation (Institute for Water Resources, 1994). Additionally, larger wetlands can provide more habitat for a greater number of species. The California Department of Fish and Game require that mitigation banks should contain at least 50 acres of new or restored habitat (Institute for Water Resources, 1994). According to Cedfeldt et al. (2000), 100 ha is an appropriate threshold for identifying effectiveness of wetlands in providing wildlife habitat based on the needs of interior species. Minimum patch size requirements vary by species, however. A minimum patch size of 5 ha has been reported for marsh birds (Environmental Law Institute, 2003). Some ecologists, such as Florida wetland ecologists, Robin Lewis and Kevin Erwin argue that the historical wetland patterns of the region and threatened species should be the criteria for patch size (Institute for Water Resources, 1994). Another consideration is that losses of small wetland areas are more common in many parts of the country than losses of larger tracts and many species that depend on small wetlands habitats may not be supported by large wetland sites.

Many small wetlands are isolated in wetland-upland mosaics (Institute for Water Resources, 1994). These wetlands often have a seasonal hydroperiod and isolated wetlands serve as habitat for several rare and endemic species of herpetofauna. The loss of these species would significantly alter regional biodiversity (Russell et al., 2002). In a study conducted by Russell et al. (2002), small wetlands (0.1-2.5 ha) within intensively managed pine plantations of the southeastern Coastal Plain were shown to have a disproportionate contribution to herpetofaunal diversity to their size or ephemeral hydrology. There is even some indication that large wetlands in Florida may be less diverse than small wetlands (Semlitsch and Bodie, 1998). Semlitsch and Bodie (1998) argue that small wetlands are of general importance, because they act as essential habitat for amphibians that would otherwise be devoured by fish in large wetlands, and amphibians are of global diversity significance because of their worldwide decline. Furthermore, they harbor many species that are less mobile than birds and mammals such as plants, microcrustaceans, and insects and are, therefore, strongly affected by their loss (Semlitsch and Bodie, 1998). Until more data is available on diversity across wetland sizes, Semlitsch and Bodie (1998) suggest that regulations should protect wetlands as small as 0.2 ha.

1.2.3 Connectivity

Some authors suggest that connectivity may be a more important criterion than size for assessing wetland function due to the importance of both small and large wetlands. Snodgrass et al. (2000) suggest that regulatory agencies should focus on the protection of diverse hydroperiods and connectedness of wetlands to maintain a diversity of wetlands across regional landscapes. Connectedness is described as a measure of the remnant patch size that surrounds individual wetlands (Whited et al., 2000). Whited et al. (2000) demonstrate that wetland connectedness is an optimal landscape measure for predicting bird species assemblages in wetland communities and seems to be an effective surrogate for other landscape measures. Connectedness is also a better predictor of bird assemblages than wetland size (Whited et al., 2000). Increased wetland isolation and reduced wetland density can also cause potential changes in amphibian metapopulation dynamics (Semlitsch and Bodie, 1998). As distance increases between wetlands, the number or density of individuals dispersing decreases as does the probability that a population can be rescued from extinction by dispersers. Semlitsch and Bodie (1998) illustrate that the direct line distance between wetlands affects the dispersal of pond-breeding salamanders and anurans on the upper coastal plain of South Carolina where most of these individuals emigrate less than 200 m.

Roads are a stressor that play a large part in severing connectivity of wetlands. Findlay and Houlahan (1997) demonstrate that increases in paved road density within 2 km of a wetland significantly decreased plant, bird, and herptile species richness in southeastern Ontario. In a subsequent study, Findlay and Bourdages (2000) find that more significant impacts to species richness occur due to road construction if a population is studied over time. In fact, considerable time may elapse between road construction and local extinction of wetland populations, which leads to declines in species richness. This demonstrates that species richness may continue to decline due to road construction even after a significant amount of time has elapsed.

1.2.4 Context

The flat topography and high water table in Florida allow water and nutrients to flow freely between certain wetland types, like swamps, and uplands. For example, in Osceola National Forest in northeast Florida, uplands, hydric hammocks, poorly drained pine flatwoods, bay swamps, shrub bogs, and cypress swamps hydrologically interact to create a complex integrated landscape (Ewel, 1990). This demonstrates that wetlands exist within an integrated landscape and that context is another important criterion for wetland function and biodiversity. According to Whited et al. (2000), wetlands surrounded by a natural landscape are 1) less likely to be affected by land use stresses such as pesticide drift and invasive species, 2) more likely to contain adequate patch diversity to sustain populations, and 3) more likely to provide unrestricted movement for species traveling from uplands to wetlands. Additionally, many semi-aquatic organisms such as insects, frogs, salamanders, snakes, and turtles depend on both aquatic and terrestrial habitats to complete parts of their life cycles (Semlitsch, 1998). Therefore, the preservation of buffer zones around wetlands is integral to protecting biodiversity. For pond-breeding salamanders, Semlitsch (1998) suggests that a buffer zone around wetlands of 164.3 m (534 ft) is needed to protect 95% of a population and that this buffer zone is also applicable to a wide range of species. Burke and Gibbons (1995), demonstrate that a 275 m buffer zone is needed to protect 100% of upland nest and hibernation sites of freshwater turtles around wetlands in Carolina bays. Taylor et al. (1990) contends that upland areas utilized by wetland species can extend as much as 2 km. Joyal et al. (2001) further reiterate the importance of the condition of the upland matrix by demonstrating that Blanding's turtles travel as far as 6760 m over land in southern Maine.

A series of studies have shown that land use in the surrounding matrix has a significant impact on wetland species richness. Amphibian richness in wetlands has been shown to decline when more than 40% of the watershed was urbanized (Whited et al., 2000). Fish species richness and diversity in riparian wetlands decreases as the percentage of cultivated lands surrounding the wetlands increases, and bird species diversity decreases as the percentage of cultivated lands within a 1000 m radius of riparian wetlands increases (Whited et al., 2000).

1.3 Assessment Methodologies for the Prioritization of Wetlands for Preservation, Restoration, and Enhancement

GIS is a useful tool for overlaying information related to various types of data to answer spatially explicit questions about landscapes and regions. As such, it has been used by several researchers to prioritize wetlands for preservation, restoration, or enhancement on landscape and regional scales, and several assessment methodologies have been developed.

1.3.1 Mapping Wetland Habitats of High Priority to Endangered and Threatened Species in Florida

The Florida Fish and Wildlife Conservation Commission (FFWCC) used GIS to map wetland habitats of high priority to endangered and threatened species and species of special concern in Florida (Kautz et al., 1994). The primary objectives of the project included the development of maps that identify Florida wetlands important to the long-term survival of listed wetland-dependent vertebrates and the distribution of those maps to regulatory and review agencies such as the Florida Department of Environmental Protection, Florida's five Water Management Districts, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and U. S. Environmental Protection Agency. Three primary work tasks were accomplished to complete the GIS components of the project.

Task 1 was to develop a statewide map of existing Florida wetlands, which was created from a statewide land cover map completed by FFWCC in December 1990. The land cover map was created using Landsat Thematic Mapper data collected from 1987 to 1989. The following wetland vegetation types were mapped: freshwater marsh and wet prairie, mixed hardwood swamp, cypress swamp, shrub swamp, mangrove swamp, coastal salt marsh, bottomland hardwood forest, and bay swamp. Task 2 was to create statewide distribution maps for the 35 wetland-dependent listed vertebrate species in Florida. The vegetation maps of Florida wetlands created in the first task, models of the habitat requirements of each species, and databases containing known occurrence records were used to create the maps. Task 3 involved overlaying the distribution maps created in the second task to identify the number of species that use wetlands in the state. This approach suggests the relative importance of wetlands based on species richness of wetland-dependent listed species.

There are some important points to note about this assessment methodology and its relevance for developing a methodology for the prioritization of wetlands for mitigation. First, the statewide map of existing Florida wetlands may be used as a base map. Second, the final map produced, which identifies the relative importance of wetlands based on species richness, will be useful for prioritizing wetlands for mitigation based on the presence of listed wildlife species. This map represents the relative importance of wetlands for the protection of biodiversity. It is also useful, because the map displays adjacent uplands required by some species. Additional assessment beyond the scope of this project is needed for the prioritization of wetlands for mitigation, because the current local condition of the wetlands is unclear. Although, information is provided on listed species presence, the restoration or enhancement needs of the wetlands is not. Connectivity, adjacent land uses, and the threat of urban disturbance were also not factored into the analysis.

1.3.2 Synoptic Assessment of Wetland Function in the Midwest

The US EPA Region 7 has developed a synoptic assessment of wetland function using GIS, which is intended to maximize benefits to wetland species biodiversity in the Midwest states, Missouri, Iowa, Nebraska, and Kansas. The method allows the prioritization of sub-basins (delineated by US Geological Survey eight-digit Hydrologic Unit Codes) within the region for conservation and management. The method applies rankings to the sub-basins (Schweiger et al., 2002). Five indicators of habitat quality, two indicators of species sensitivity, and an endemism score were combined in different ways to derive three indices (Diamond and Gordon, 2003).

Index 1 included indicators related to wetland habitat quality (agricultural density and wetland density), which were combined (Diamond and Gordon, 2003). Index 2 combined the five wetland habitat quality indicators agricultural density, wetland density, wetland habitat diversity, mean distance between wetland patches, and mean wetland patch size. All habitat indicators were calculated using data from the National Land Cover Dataset (NLCD) 1992-93 30-meter satellite thematic mapper imagery (Diamond and Gordon, 2003). Index 3 combined indicators related to wetland species sensitivity: the heritage species global rarity score and a modifier to the global rarity score based on the habitat quality indicators of Index 2. Endemism scores for each species were also used in Index 3. The species sensitivity indicators were evaluated from the 1995 Natural Heritage Program database. All index values were attached to the sub-basins, which were ranked in terms of wetland importance (Diamond and Gordon, 2003).

The synoptic assessment is relevant to developing a methodology for the prioritization of wetlands for mitigation for several reasons. The landscape condition of wetlands and species rarity are considered and are both useful for prioritizing wetlands for the protection of biodiversity. The landscape condition indicators of patch size (mean wetland patch size), isolation (mean distance between wetland patches), and landscape composition (agricultural density, wetland density, and wetland habitat diversity) are included in the habitat indicators of Index 1 and 2. Sub-basins with rare species presence are also assigned higher rankings, which afford endangered and threatened species higher priority. The assessment’s direct applicability to prioritizing wetlands for mitigation is somewhat diminished, because the methodology is designed to prioritize sub-basins and not individual wetlands. However, some variants of the indicators may still be successfully applied for the prioritization of individual wetlands. Existing and proposed conservation lands are not identified, which would be useful for siting wetlands for preservation in close proximity to these lands. Additionally, indicators for water resource protection and local site conditions are not included but would be helpful in identifying restoration and enhancement needs of individual wetlands.

1.3.3 Integrated Wildlife Habitat Ranking System

The FFWCC developed an additional habitat assessment method using GIS to identify and rank landscape level habitat areas, which are important to rare or focal species in Florida (FFWCC, 2001). The project was intended to assist the Florida Department of Transportation (DOT) in 1) determining ways to avoid or minimize impacts to wildlife by choosing alternate road alignments, 2) assessing direct, secondary, and cumulative impacts to wildlife, and 3) identifying suitable areas for public land acquisition for wetland and upland mitigation purposes. The model was originally created for DOT district 5.

The three steps included in the Integrated Wildlife Habitat Ranking System are 1) identification of variables to include in the model, 2) scoring and standardization of all variables, and 3) the addition of all variables to produce a final image. All data layers were derived from existing data layers including land cover (created by FFWCC in 1990), public lands (compiled by Florida Natural Areas Inventory), Strategic Habitat Conservation Areas, wildlife potential habitat models (created by FFWCC in 1994 and updated in 2000), Florida Ecological Network, Conservation and Recreation Lands, and Save Our Rivers Lands (lands acquired by the water management districts), and the Florida Geographic Data Library's major roads coverage. A landscape diversity data layer was created from the existing land cover data layer. The land cover data layer was added to major roads to identify roadless habitat patch sizes. A listed species presence layer was created from the wildlife potential habitat models, which were also used to create a species richness layer. By combining derivations of the public lands, roadless areas, landscape diversity, and land cover data layers, a black bear potential habitat model was created. A distance query was also performed on the public lands data set and lands closest to public lands were given higher rankings. The final image was created by simply adding all standardized coverages together.

Although this methodology was not solely intended for the identification of priority wetlands, one of its purposes was to aid in the identification of suitable areas for wetland and upland mitigation purposes. It is very useful for developing a methodology for prioritizing wetlands for preservation, but it was not intended to identify wetlands suitable for restoration or enhancement.

1.3.4 Prioritizing Sites for Riparian Wetland Restoration Based on Hydrology and Land Use

A study by Russell et al. (1997) developed an approach for prioritizing sites for riparian wetland restoration based on hydrology and land use. Flood attenuation and species habitat were chosen as the primary functions of interest in the study, because they were considered to best represent the study area's ability to support riparian wetland function. The methodology uses GIS to rank sites for their potential for restoration or preservation based on their relative wetness, patch size, and proximity to existing riparian vegetation. Wetland site selection was made at a watershed scale in the San Luis Rey River Basin in San Diego County, California.

Two primary stages included in the methodology developed by Russell et al. (1997) were an identification stage and a prioritization stage. The identification stage involved the combination of two data layers derived from two existing data layers: USGS 7.5-minute digital elevation models (DEMs) were used to derive a "wetness potential" index data layer and Landsat Thematic Mapper data collected in 1992 was used to derive a land use/land cover map. Index values for the wetness potential data layers were generalized into the categories of low, medium, and high wetness potential. Potential restoration or preservation sites were identified by overlaying these two data layers. Land use/land cover classes with medium and high wetness indices were selected for preservation or restoration. Agriculture, bare/herbaceous, or scrub land use/land cover classes were identified as potential restoration sites. Scrub, forested, and riparian land use/land cover classes were identified as potential preservation sites. The second stage, prioritization of restoration and preservation sites included the use of proximal constraints and spatial constraints. A decision tree was used for guiding prioritization. The sites identified in the first stage were evaluated for their proximity to extant riparian and water land cover (within 90 m), size (at least 1 ha), and adjacency to high priority sites.

The methodology created by Russell et al. (1997) provides a means for identifying potential riparian wetland preservation and restoration sites and for prioritizing restoration sites, and is therefore, useful for selecting and prioritizing wetland mitigation sites for preservation and restoration. All data sets were derived from existing and nationally available data layers; therefore, the methodology may be applied nation-wide. However, the approach was designed for riparian wetland preservation and restoration, and its applicability for selecting other major wetland types for preservation or restoration, such as marine, estuarine, and lacustrine wetlands, is unclear.

1.3.5 Using GIS to Identify Functionally Significant Wetlands in the Northeastern United States

Cedfeldt et al. (2000) developed a GIS methodology for identifying functionally significant wetlands in the Northeastern United States. Predictors for three wetland functions were included in the approach: flood flow alteration (the process by which peak flows from precipitation, runoff, surface flow, and groundwater interflow and discharge are stored in a wetland), surface water quality improvement, and wildlife habitat provision. These three wetland functions were chosen because they are generally regarded as the primary functions that wetlands perform. All predictors of the three wetland functions had to be applicable in the Northeast, supported in the literature, spatially defined, and measurable by a GIS using widely available data layers. The Automated Assessment Method for Northeastern Wetlands (AMNEW) program that runs in the ARC/INFO GRID module was used in the approach. Existing data layers used as input included Landsat Thematic Mapper land cover, DEMs, watershed boundaries, surface water, soils, roads, landfills, and dams (Cedfeldt et al., 2000).

The flood flow alteration and surface water quality improvement predictors were divided into the two categories of opportunity predictors and effectiveness predictors. The opportunity predictors assess the potential of a wetland to perform a given function. The effectiveness predictors assess the capability of a wetland to perform a given function. For the wildlife habitat support function, all wetlands were considered to have the opportunity to provide wildlife habitat, so all predictors were considered effectiveness predictors.

The opportunity predictors for flood flow alteration included: 1) upslope wetlands comprise less than 5% of the wetland's watershed, 2) wetland area is less than 20% of the watershed area, 3) the majority (>50%) of the wetland's watershed is made up of impervious surfaces, and 4) most of the soil (>80%) of the wetland's watershed have a very slow infiltration rate (<1.5 mm/hour). The effectiveness predictors for flood flow alteration included: 1) wetland is located near an intermittent or first-order stream, 2) wetland area is larger than 81 ha, and 3) wetland has no connection to the surface water network.

The opportunity predictors for surface water quality improvement function included: 1) wetland's watershed contains potential sources of pollutants; 2) a majority of the watershed is not forested or scrub shrub, wetland is less than 5% of watershed acreage, and upslope wetlands comprise less than 5% of the watershed; 3) average slope of the wetland's watershed is greater than 10%; 4) and wetland type is riparian. The effectiveness predictors for surface water quality improvement function included: 1) the soil type underlying a wetland is either histosol or frequently flooded mineral soil with both high clay and high organic matter content and 2) the wetland is located near an intermittent or first-order stream.

The effectiveness predictors for wildlife habitat function included: 1) wetland size is larger than 100 ha, 2) there is at least one wetland of a different type bordering the wetland being considered, 3) wetland type is the least common in relation to the surface water network, 4) wetland is connected to the surface water network, 5) wetland is completely surrounded by a minimum of 100 m of natural vegetation, 6) wetland is hydrologically connected to another wetland within 400 m, and 7) presence of a natural vegetation corridor to another within 400 m.

Cedfeldt et al. (2000) concluded that this approach is a successful methodology for identifying wetlands that perform both water quality improvement and wildlife habitat functions. This methodology seems to have applicability for selecting sites for preservation for wetland mitigation based on water quality improvement function and wildlife habitat function.

1.3.6 A GIS-Based Model for the Selection of Potential Wetlands Restoration Sites, Southeastern Virginia

The Center for Coastal Resources Management, Virginia Institute of Marine Science of the College of William and Mary developed a protocol that uses GIS to select future wetlands restoration sites across the landscape in southeastern Virginia (Berman et al., 2002). The protocol was driven by the requirements that it had to be GIS-based and use existing GIS coverages or themes, and site selection would be governed by the opportunity to convert existing land uses to wetlands. A ranking system was employed, which ranks sites based on the number of conditions met and appraises sites as 1) potential, 2) good, 3) high, and 4) excellent for restoration opportunity. A hierarchical approach was used for the protocol with land use as the foundation of the hierarchy. Only sites with land use types considered to offer opportunity for conversion to wetlands were further evaluated. The land use data set used was the National Land Cover Dataset representing conditions between 1989 and 1992. Only land cover types classified as forested (including deciduous, conifer, and mixed forest) and agriculture (row crops, probable row crops, and hay/pasture/grass) were evaluated in the protocol hierarchy, because they were considered to have a high degree of probability that the land could be converted to a wetland if other physical requirements were present (Berman et al., 2002). Four protocol levels were used to evaluate lands classified as having forested or agriculture land use/land covers. Level 1 identified forested or agricultural lands with hydric soils that were greater than 0.25 acres. These sites were classified as "potential" restoration sites in the final analysis. Level 2 added a hydrography data set to identify areas of hydric soils that intersect with streams. This level evaluates lands for hydrologic connectivity. The sites identified in this level were classified as "moderate" choices for wetland restoration. Level 3 uses National Wetlands Inventory (NWI) data to identify lands with hydric soils and hydrologic connectivity that are adjacent to existing wetlands. At this level, lands identified that are forested are ranked as "good" choices for restoration and lands identified that have agricultural land uses are ranked as having "high" potential for restoration. Lands with forest cover are given lower suitability for restoration, because forest cover itself has ecological value and may be preserved as forest buffers. Lands with agricultural land uses are given higher suitability, because the model assumes that agricultural lands meeting wetland soil and hydrology conditions may have been wetlands filled to create farmland. Level 4 is the last criteria of the protocol and introduces existing conservation areas into the hierarchy. Adjacency to existing conservation areas is used as a modifier to Level 3 rankings. At this level, lands ranked as "good" choices for restoration are elevated to "high" if they are adjacent to existing conservation lands. Lands ranked as having "high" potential for restoration are elevated to "excellent" if they are adjacent to existing conservation lands (Berman et al., 2002).

After validation of the protocol, it was determined that the land use/land cover data set was too outdated to yield accurate results, and the protocol was rerun with a newer data set. Thirty-five-meter buffers were also included around transportation networks to eliminate the selection of medians and right of ways as potential restoration sites. Two-meter buffers were placed around wetland polygons of the NWI coverage to generate connectivity between wetlands and hydrology. Sites of less than one acre were eliminated as potential restoration sites as were very long thin wetlands under the assumption that they were drainage ditches (Berman et al., 2002).

This protocol has valuable characteristics that could effectively be applied towards developing a methodology for the prioritization of wetlands for restoration mitigation in Florida. First, the protocol uses only five basic data sets that are widely available: soils, hydrology, wetlands, land use, and existing conservation areas. The study illustrates the importance of using the most current data available. The study is also valuable in that it illustrates the potential for false positives and corrects for them by eliminating the inclusion of transportation medians and right of ways and drainage ditches. According to authors such as Semlitsch (1998), Burke and Gibbons (1995), Taylor et al. (1990), and Joyal et al. (2001), however, upland buffers larger than 2 m are needed around wetlands to accommodate a wide range of wetland species. Additionally, although the protocol considers adjacency of sites to existing wetlands and conservation areas as positive indicators for restoration potential, the protocol does not include the adjacency of potentially negative adjacent land uses such as roads, urban, and industrial areas as negative indicators for restoration potential.

1.3.7 Potential Wetland Restoration and Enhancement Site Identification Procedure, North Carolina Coastal Area

The Division of Coastal Management of the North Carolina Department of Environment and Natural Resources has developed a procedure for identifying potential wetland restoration and enhancement sites in the North Carolina coastal area using GIS (Williams, 2002). The procedure is intended to identify historic and degraded wetlands. The procedure begins with the identification of hydric soils where 1) wetland characteristics formerly existed (identified as restoration sites) and where 2) wetlands currently exist but have been degraded or converted to a different type of wetland than formerly existed (usually identified as enhancement sites). The procedure uses the following data sets: Division of Coastal Management wetland type data, Natural Resources Conservation Service soil data, land use/land cover, and hydrography. The procedure identifies wetland disturbance type (classified into 9 classes), management goal (restoration or enhancement), and restoration type (including 7 classes based on soil type that represent the natural wetland type to be achieved through enhancement or restoration).

Once all areas with hydric soils or water are identified, the first step of the procedure includes the classification of wetland disturbance types (Williams, 2002). Disturbance type classifications are separated into two groups: 1) greater than 100 ft. from a channelized stream/ditch and 2) less than100 ft. from a channelized stream/ditch. The disturbance type classifications in the grouping greater than 100 ft. from a channelized stream/ditch include: 1) three classifications for drained and cleared, 2) ditched, not cleared, 3) managed pine, 4) impounded, and 5) excavated or filled. The disturbance type classifications in the grouping less than 100 ft. from a channelized stream/ditch include: 1) drained, not cleared and 2) ditched, not cleared. Once the disturbance classification is complete, areas can be identified as potential enhancement or restoration sites. Areas identified as enhancement sites have the disturbance classifications: ditched, not cleared; managed pine; or impounded. Areas identified as restoration sites have the disturbance classifications: drained and cleared; excavated or filled; or drained, not cleared. Restoration types are then classified according to soil taxonomy, a frequency analysis of the Division of Coastal Management's wetland type mapping results (wetland type vs. soil mapping unit), landscape position, and input from wetland scientists and soil scientists. The restoration types include: marsh; estuarine shrub/scrub or forest, maritime swamp forest; swamp forests/bottomland hardwood; bottomland hardwood/headwater forest; wet flatwoods; and pocosins.

The procedure developed by the Division of Coastal Management has direct relevance to developing a methodology for the prioritization of wetlands for restoration and enhancement mitigation in Florida. The procedure is beneficial, because it allows a distinction between potential restoration sites and potential enhancement sites. It also classifies sites according to restoration type, which would be valuable for selecting mitigation sites while considering type-for-type compensatory mitigation.

1.4 Land Ownership and Land Values

Land ownership and land values are important factors in siting wetland mitigation sites because of their effects on feasibility of land acquisition. Wetland mitigation may take place on either public or private lands. Public lands do not have to be acquired for mitigation and are more likely to be secure in perpetuity. Additionally, the acceptance of funds for compensatory mitigation may allow the restoration of public lands where insufficient funds are available. They are also less likely to meet local or adjacent landowner opposition. However, there are some significant disadvantages to siting mitigation on public lands. EPA Region IV (which has jurisdiction in Florida) objects to the use of federal lands for mitigation, because they are less likely to be threatened by development and may be restored under existing wetland restoration programs without mitigation funding. Furthermore, restoring privately owned wetlands more directly compensates for wetland losses on private lands (Institute for Water Resources, 1994).

Consequently, if mitigation sites are to be located on private lands, land values also become an important factor in acquisition feasibility.

A GIS data set available to assist in determining the acquisition feasibility for mitigation sites in Florida is Florida Department of Revenue Property Tax Data Records Summarized To Section, available through the Florida Geographic Data Library. Land values are included in the data set as a sum of land values for all records at the Township, Range, Section (TRS) level (Florida Geographic Data Library Documentation, 2003). The land value sums may be used to determine the average dollar value per acre.

2.0 Methodology
2.1 General Overview of Methodology

The purpose of the study is to evaluate how off-site wetland mitigation options in Florida can be integrated into a regional framework that will most effectively protect biodiversity throughout a watershed. Principles of conservation biology, reserve design, and landscape ecology (concepts of patch, corridor, and matrix) are utilized in the process. Site selection criteria such as significant wildlife habitat, existing wetland hydrology, hydric soils, patch size, connectivity, and context are integral components of the process. Spatial analysis is used in developing a regional wetland mitigation framework.

The study area of this project consists of the thirteen mitigation basins of the St. Johns River Water Management District that fully or partially contain the seven counties of the Northeast Florida Regional Planning Council (NERPC) jurisdiction: Baker, Clay, Duval, Flagler, Nassau, Putnam, and St. Johns Counties. The study area was extended beyond the limits of the NERPC jurisdiction to include the complete boundaries of mitigation basins that contain those counties. Therefore, seven counties beyond the NERPC jurisdiction are also partially contained within the study area and include Alachua, Bradford, Columbia, Lake, Marion, Union, and Volusia Counties. Analysis for this study took place during the months of February and March 2004.

General methodology of the study includes 1) the formulation of goals, objectives, and sub-objectives 2) selection of existing datasets to use for GIS analysis to satisfy goals, objectives, and sub-objectives 3) derivation and reclassification of datasets to produce single utility assignments (SUAs), and 4) combination of SUAs to produce multiple utility assignments (MUAs).

Three major goals that relate to wetland mitigation options in Florida were identified for this study: 1) Identify wetlands for preservation that will optimally protect wetland species biodiversity, 2) Identify optimal sites for wetland enhancement, and 3) Identify optimal sites for wetland restoration. For each goal, subsets of three size threshold classes (small, medium, and large) are selected. Each size class is evaluated separately. Goals, objectives, and sub-objectives are described in greater detail in Section 2.2.

Existing datasets were chosen for the derivation and reclassification of SUAs (described in Section 2.3.1) and were provided by the Florida Geographic Data Library (FGDL) housed at the GeoPlan Center, College of Design, Construction, and Planning, University of Florida, Gainesville, Florida; Florida Fish and Wildlife Conservation Commission; St. Johns River Water Management District; City of Jacksonville Preservation Project; Florida Department of Environmental Protection; and Jason Teisinger, M.A.U.R.P.

All GIS analysis during this study was completed using ArcView 3.2 and ArcView 9x. The framework utilizes raster data (grid); therefore, existing vector datasets are converted to raster data to develop SUAs. Cell output size is 30 meters x 30 meters. SUAs are weighted and combined to produce MUAs (more detailed description of MUAs in Section 2.3.2). All SUAs and MUAs have a range of values between 1 and 9 (lowest suitability receives a rank of 1, highest suitability receives a rank of 9). However, for ease of viewing, final suitability grids are reclassified to three classes (1,2, and 3) to represent low, medium, and high suitability, respectively.

Weighting schemes were formulated by using, Expert Choice©, a program that uses the analytic hierarchy process. The analytic hierarchy process (AHP) is a process, which can be used to make decisions about weighting schemes (Forman, 2003). It allows GIS users to derive weights to combine data rather than arbitrarily assigning them. To use the process, a problem must first be broken down into its component parts: goals, objectives, sub-objectives, and alternatives (see Figure 2-1). Pairwise relative

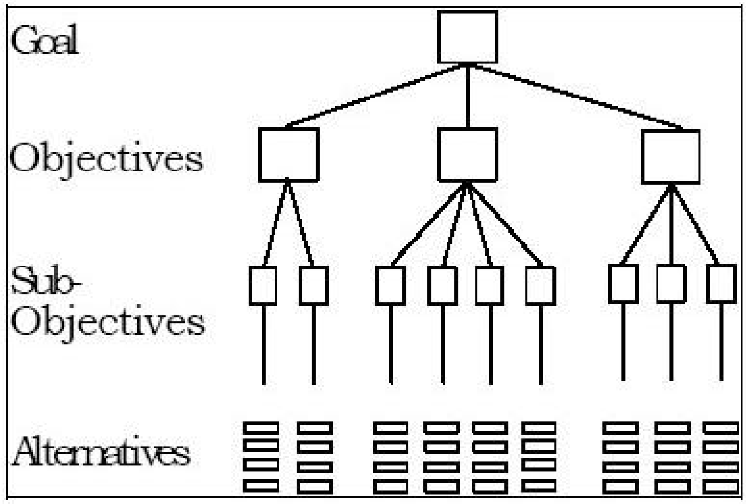


Figure 2-1. Hierarchical structure of the analytic hierarchy process. *Source: Forman, 2003.*

comparisons are used during the AHP to compare components, or factors, and may be executed with numbers, graphical bars, or words (Forman, 2003).

Numbers or graphical bars are often used when comparing economic or measurable factors. Verbal comparisons are often preferable in social, psychological or political contexts, because they are easier to make and easier to justify for qualitative comparisons (Forman, 2003). Refer to Figure 2-2 for a representation of the verbal scale used in the AHP computer program, Expert Choice©, and its relation to numerical value on a nine-point scale. Pairwise comparison allows the user to make relative judgments between items rather than absolute judgments, and weights, or priorities, are derived from the set of judgments. These relative judgments are easier to justify than arbitrarily assigned weights. The process may also be repeated with varying pairwise comparison judgments to evaluate different scenarios (Forman, 2003). Verbal comparisons were used to make decisions regarding the priority of SUAs in this study. A final suitability MUA is produced for each size class for each of the three goals totaling 9 final suitability grids (see Table 2-1).

In addition to the process outlined in this framework, end users may also add their own criteria. Therefore, the methodology is used to provide an example set for adding criteria to the process. Added criteria, for example, may include the identification of optimal wetlands of a specific type (e.g. cypress swamp) for any of the three goals, within a chosen mitigation basin (e.g. St. Johns River (Welaka to Bayard) mitigation basin).

Numerical Value	Verbal Scale	Explanation
1.0	Equal importance of both elements	Two elements contribute equally
3.0	Moderate importance of one element over another	Experience and judgment favor one element over another
5.0	Strong importance of one element over another	An element is strongly favored
7.0	Very strong importance of one element over another	An element is very strongly dominant
9.0	Extreme importance of one element over another	An element is favored by at least an order of magnitude
2.0, 4.0, 6.0, 8.0	Intermediate values	Used to compromise between two judgments

Figure 2-2. Verbal scale used in computer program, Expert Choice©. *Source: Forman, 2003.*

Table 2-1. Nine final suitability grids.

Size Classes		Goals		
		Identification of Optimal Preservation Sites	**Identification of Optimal Enhancement Sites**	**Identification of Optimal Restoration Sites**
	Small	Final Suitability Grid-Small Wetland Preservation Sites	Final Suitability Grid-Small Wetland Enhancement Sites	Final Suitability Grid-Small Wetland Restoration Sites
	Medium	Final Suitability Grid-Medium Wetland Preservation Sites	Final Suitability Grid-Medium Wetland Enhancement Sites	Final Suitability Grid-Medium Wetland Restoration Sites
	Large	Final Suitability Grid-Large Wetland Preservation Sites	Final Suitability Grid-Large Wetland Enhancement Sites	Final Suitability Grid-Large Wetland Restoration Sites

2.2 Goals and Objectives

GIS methodology for the regional wetland mitigation framework included the development of suitabilities to address three goals: identify optimal sites for 1) wetland preservation, 2) wetland enhancement, and 3) wetland restoration. Three size classes (small, medium, and large) were analyzed to address each of the three goals: 1) small: greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres), 2) medium: greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres), and 3) large: greater than or equal to 100 ha (247.1 acres) (see Figure 2-3, Figure 2-4, and Figure 2-5). Three sizes were used for analysis, because of discrepancies of patch size requirements among different wetland species. For example, small wetlands support different species than large wetlands do and the loss of several small wetlands should not be compensated by the mitigation of one large wetland (Semlitsch, 2000). Therefore, for compensatory mitigation purposes, the end user may identify suitable wetlands within small, medium, or large size classes.

Goal 1: Identify wetlands for preservation that will optimally protect wetland species biodiversity

Objective 1: Identify existing wetlands on privately owned lands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) without disturbance conditions

Rationale: Existing wetlands on privately owned lands (as opposed to publicly owned lands) are considered for preservation, because mitigation on privately owned lands more directly compensates for wetland losses on private lands.

Objective 2: Identify wetlands in three patch size thresholds
Sub-Objective 1: Identify small wetlands greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)
Rationale: Small wetlands support populations of many species of herpetofauna that larger wetlands do not, because they provide refugia from predators such as wading birds. Wetlands as small as 0.2 ha have been recommended for regulatory protection based on habitat criteria for a wide range of species including herpetofauna, plants, microcrustaceans, and insects (Semlitsch and Bodie, 1998).

Sub-Objective 2: Identify medium-sized wetlands greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)
Rationale: A minimum patch size of 5 ha has been reported for marsh birds (Environmental Law Institute, 2003).

Sub-Objective 3: Identify large wetlands greater than or equal to 100 ha (247.1 acres)
Rationale: According to Cedfeldt et al. (2000), 100 ha is an appropriate threshold for identifying effectiveness of wetlands in providing wildlife habitat based on the needs of species that require undisturbed interior habitat.

Objective 3: Protect significant wetland wildlife habitat
Sub-Objective 1: Include wetlands of high species richness

Rationale: Wetlands of high species richness provide habitat for a high diversity of wetland species.

Sub-Objective 2: Include wetlands identified as Priority Ecological Areas identified by Statewide Greenways Planning Project
Rationale: Priority ecological areas represent areas of ecological significance for various criteria including, but not limited to, potential black bear habitat; National Estuarine Research Reserves, Shellfish Harvesting Waters, and Wild and Scenic Rivers surrounded by 1000 m buffers; and significant riparian areas.

Sub-Objective 3: Include wetlands identified as Regionally Significant Habitat in the St. Johns River Water Management District (Identified by SJRWMD by combining Strategic Habitat Conservation Areas and biodiversity hot spots and limiting to natural land cover types, not occurring in urban areas and on Class 2 agricultural, silvicultural, or range lands)
Rationale: Strategic Habitat Conservation Areas include lands outside existing protected areas needed to maintain or restore minimally viable populations of 30 focal vertebrate species, rare natural community types, important wetlands for wading birds, and globally rare plant species. Biodiversity hot spots are areas where there is a high degree of overlap in habitat for species of conservation interest.

Objective 4: Identify landscape connectivity
Sub-Objective 1: Include wetlands located within the Florida Greenways ecological network model
Rationale: The Florida Greenways ecological network model identifies opportunities for a network of conservation hubs and corridors to provide large habitat patches and promote the movement of energy, materials, and species in the Florida landscape (Florida Greenways Commission, 1994).

Objective 5: Identify wetlands in positive spatial contexts
Sub-Objective 1: Identify wetlands within large contiguous areas of wetlands, water, and natural or semi-natural upland cover (rangeland, unimproved and woodland pastures, and plantations) that are bounded by paved roads and railroads
Rationale: Various authors have reported on negative effects of adjacent land uses on wetland species richness, composition, and recruitment. Many wetland-dependent species also require surrounding uplands to complete parts of their life cycles and some use terrestrial habitats for much of the year. Additionally, unfragmented wetland-upland mosaics provide unimpeded movement for individuals from wetlands to other nearby wetlands. Zedler (1996) contends that coastal wetlands support greater biodiversity if they have good linkages with adjacent ecosystems such as uplands, riparian corridors, and nearshore waters.

Goal 1: Identify wetlands for preservation that will optimally protect wetland species biodiversity

Existing, privately owned, wetlands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) without disturbance conditions.

Small Wetlands
Greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)

Significant habitat
- High wetland species richness
- Priority Ecological Areas
- Regionally significant habitat

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Medium Wetlands
Greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)

Significant habitat
- High wetland species richness
- Priority Ecological Areas
- Regionally significant habitat

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Large Wetlands
Greater than or equal to 100 ha (247.1 acres)

Significant habitat
- High wetland species richness
- Priority Ecological Areas
- Regionally significant habitat

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

End user to add criteria

Figure 2-3. Goal 1 objectives and sub-objectives. Three patch size classes are analyzed separately for this goal.

Goal 2: Identify optimal sites for wetland enhancement

Existing, privately owned, wetlands (excluding privately-owned conservation lands) that have hydric soils, and silvicultural land uses.

Or

Existing, privately owned, wetlands (excluding privately-owned conservation lands) that have been partially drained/ditched or diked/impounded

Or

Existing, privately owned, wetlands (excluding privately-owned conservation lands) that are less than 100 ft. from a ditch or channelized stream.

Small Wetlands

Greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Medium Wetlands

Greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Large Wetlands

Greater than or equal to 100 ha (247.1 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

End user to add criteria

Figure 2-4. Goal 2 objectives and sub-objectives. Three patch size classes are analyzed separately for this goal.

Goal 3: Identify optimal sites for wetland restoration

Existing, privately owned, wetlands (excluding privately-owned conservation lands) that have hydric soils, and agricultural land uses.

Or

Privately owned uplands (excluding privately-owned conservation lands) that have hydric soils and agricultural or silvicultural land uses.

Or

Existing, privately owned, wetlands (excluding privately-owned conservation lands) that have hydric soils and have been excavated or are classified as spoil.

Small Wetlands

Greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Medium Wetlands

Greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

Large Wetlands

Greater than or equal to 100 ha (247.1 acres)

Landscape Connectivity
- Florida Ecological Network

Spatial Context
- Contiguous areas of wetlands, water, and natural and semi-natural uplands
- Wetlands with high counts of neighboring wetlands and water
- Proximity to existing conservation lands
- Small buffer zone
- Large buffer zone
- Road density
- Low growth pressure

Protection of Water Quality
- Distance to hazardous sites in basins with reported poor water quality

Acquisition Feasibility
- Low growth pressure
- Low average dollar value

End user to add criteria

Figure 2-5. Goal 3 objectives and sub-objectives. Three patch size classes are analyzed separately for this goal.

Sub-Objective 2: Identify wetlands that have high counts of nearby wetlands and water within 1000 m (wetland clusters)
Rationale: Wetlands that are relatively close in proximity (low isolation) to each other and connected by natural and semi-natural upland habitats (rangeland, unimproved and woodland pastures, and plantations) support metapopulation movement between wetlands and are critical in source-sink processes. The average distance to the nearest wetland affects the probability of migration and recolonization by herpetofauna, and according to Semlitsch and Bodie (1998), many pond-breeding salamanders do not emigrate distances farther than 200 m. Interpond movements of 1 km and 1.6 km have been expected for the dark gopher frog (*Rana sevosa*) (Richter et al., 2001) and movements of the Florida gopher frog (*Rana capito aesopus*) have been reported up to 2 km (Greenberg, 2001). Increased avian species richness has also been associated with clusters of small marshes (Whited et al., 2000) and Farmer and Parent (1997) report that complexes of small, closely spaced wetlands act as important migration stopovers for shorebirds.

Sub-Objective 3: Identify wetlands adjacent to existing conservation lands
Rationale: Existing conservation lands have been acquired for conservation in perpetuity and act as conservation hubs and linkages in ecological networks. They are a positive adjacent land use to other natural areas and locating proposed conservation lands near existing conservation lands expands the ecological network of a landscape.

Sub-Objective 4: Identify wetlands with a buffer zone of at least 164.3 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)
Rationale: This buffer zone is based on upland habitat utilization by pond-breeding salamanders in the southeastern coastal plain. Semlitsch (1998) contends that the buffer zone is applicable to a wide-range of species.

Sub-Objective 5: Identify wetlands with a buffer zone of at least 1000 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)
Rationale: Many semi-aquatic organisms such as insects, frogs, salamanders, snakes, and turtles depend on both aquatic and terrestrial habitats to complete parts of their life cycles (Semlitsch, 1998). Burke and Gibbons (1995), demonstrate that a 275 m buffer zone is needed to protect 100% of upland nest and hibernation sites of freshwater turtles around wetlands in Carolina bays. Richter et al. (2001) recommend a 1000 m buffer zone around wetlands to satisfy terrestrial habitat requirements of the dark gopher frog (*Rana sevosa*). Taylor et al. (1990) also contend that upland areas utilized by wetland species can extend as much as 2 km.

Sub-Objective 6: Identify wetlands that are in areas of low paved road density (less than 2 m/ha)
Rationale: Findlay and Houlahan (1997) found that increases in paved road density greater than or equal to 2 m/ha within 2 km of a wetland significantly decrease plant, bird, and herpetofauna species richness.

Sub-Objective 7: Identify wetlands that are under low growth pressure.
Rationale: Areas of low growth potential will incur slower increases in density of negative land uses such as urban, industrial, and roads.

Objective 6: Identify areas with good water quality
Sub-Objective 1: Identify wetlands that are greater than 3000 m from Toxic Release Inventory sites by EPA, Superfund sites by EPA, National Pollution Discharge Elimination System sites by EPA, Ground Water Contamination Areas by FDEP, or animal feeding operations that are also in basins that have reported poor water quality
Rationale: According to Houlahan and Findlay (2003), effects of water quality on wetland amphibian species richness, abundance, and community composition peaks at 2000 to 3000 m.

Objective 7: Identify acquisition feasibility of wetlands
Sub-Objective 1: Identify wetlands that are under low growth pressure
Rationale: Areas of low growth potential are expected to have lower land values.

Sub-Objective 2: Identify wetlands that have a low average dollar value per acre (less than $195,000 based on the highest price per acre of land acquired by the St. Johns River Water Management District through December 2003).
Rationale: Acquisition of lands with low average dollar value per acre is expected to be more economically feasible.

Goal 2: Identify optimal sites for wetland enhancement

Objective 1: Identify existing wetlands that have been degraded or converted to a different type of wetland than formerly existed that may be identified according to any of the following sub-objectives:
Sub-Objective 1: Identify existing, privately owned, wetlands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that have hydric soils, and silvicultural land uses

Sub-Objective 2: Identify existing, privately owned, wetlands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that have been partially drained/ditched or diked/impounded

Sub-Objective 3: Identify existing, privately owned, wetlands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that are less than 100 ft. from a ditch or channelized stream.
Rationale: Wetlands that have the above disturbance conditions are likely to require improvement to support a diversity of species, but may not be in such a degraded state as to require restoration.

Objective 2: Identify wetlands in three patch size thresholds
Sub-Objective 1: Identify small wetlands greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)
Rationale: Small wetlands support populations of many species of herpetofauna that larger wetlands do not, because they provide refugia from predators such as wading birds. Wetlands as small as 0.2 ha have been recommended for regulatory protection based on habitat criteria for a wide range of species including herpetofauna, plants, microcrustaceans, and insects (Semlitsch and Bodie, 1998).

Sub-Objective 2: Identify medium-sized wetlands greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)
Rationale: A minimum patch size of 5 ha has been reported for marsh birds (Environmental Law Institute, 2003).

Sub-Objective 3: Identify large wetlands greater than or equal to 100 ha (247.1 acres)
Rationale: According to Cedfeldt et al. (2000), 100 ha is an appropriate threshold for identifying effectiveness of wetlands in providing wildlife habitat based on the needs of species that require undisturbed interior habitat.

Objective 3: Identify landscape connectivity
Sub-Objective 1: Include wetlands located within the Florida Greenways ecological network model
Rationale: The Florida Greenways ecological network model identifies opportunities for a network of conservation hubs and corridors to provide large habitat patches and promote the movement of energy, materials, and species in the Florida landscape (Florida Greenways Commission, 1994).

Objective 4: Identify wetlands in positive spatial contexts

Sub-Objective 1: Identify wetlands within large contiguous areas of wetlands, water, and natural or semi-natural upland cover (rangeland, unimproved and woodland pastures, and plantations) that are bounded by paved roads and railroads

Rationale: Various authors have reported on negative effects of adjacent land uses on wetland species richness, composition, and recruitment. Many wetland-dependent species also require surrounding uplands to complete parts of their life cycles and some use terrestrial habitats for much of the year. Additionally, unfragmented wetland-upland mosaics provide unimpeded movement for individuals from wetlands to other nearby wetlands. Zedler (1996) contends that coastal wetlands support greater biodiversity if they have good linkages with adjacent ecosystems such as uplands, riparian corridors, and nearshore waters.

Sub-Objective 2: Identify wetlands that have high counts of nearby wetlands and water within 1000 m (wetland clusters)

Rationale: Wetlands that are relatively close in proximity (low isolation) to each other and connected by natural and semi-natural upland habitats (rangeland, unimproved and woodland pastures, and plantations) support metapopulation movement between wetlands and are critical in source-sink processes. The average distance to the nearest wetland affects the probability of migration and recolonization by herpetofauna, and according to Semlitsch and Bodie (1998), many pond-breeding salamanders do not emigrate distances farther than 200 m. Interpond movements of 1 km and 1.6 km have been expected for the dark gopher frog (*Rana sevosa*) (Richter et al., 2001) and movements of the Florida gopher frog (*Rana capito aesopus*) have been reported up to 2 km (Greenberg, 2001). Increased avian species richness has also been associated with clusters of small marshes (Whited et al., 2000) and Farmer and Parent (1997) report that complexes of small, closely spaced wetlands act as important migration stopovers for shorebirds.

Sub-Objective 3: Identify wetlands adjacent to existing conservation lands

Rationale: Existing conservation lands have been acquired for conservation in perpetuity and act as conservation hubs and linkages in ecological networks. They are a positive adjacent land use to other natural areas and locating proposed conservation lands near existing conservation lands expands the ecological network of a landscape.

Sub-Objective 4: Identify wetlands with a buffer zone of at least 164.3 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)

Rationale: This buffer zone is based on upland habitat utilization by pond-breeding salamanders in the southeastern coastal plain. Semlitsch (1998) contends that the buffer zone is applicable to a wide-range of species.

Sub-Objective 5: Identify wetlands with a buffer zone of at least 1000 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)

Rationale: Many semi-aquatic organisms such as insects, frogs, salamanders, snakes, and turtles depend on both aquatic and terrestrial habitats to complete parts of their life cycles (Semlitsch, 1998). Burke and Gibbons (1995), demonstrate that a 275 m buffer zone is needed to protect 100% of upland nest and hibernation sites of freshwater turtles around wetlands in Carolina bays. Richter et al. (2001) recommend a 1000 m buffer zone around wetlands to satisfy terrestrial habitat requirements of the dark gopher frog (*Rana sevosa*). Taylor et al. (1990) also contend that upland areas utilized by wetland species can extend as much as 2 km.

Sub-Objective 6: Identify wetlands that are in areas of low paved road density (less than 2 m/ha)
Rationale: Findlay and Houlahan (1997) found that increases in paved road density greater than or equal to 2 m/ha within 2 km of a wetland significantly decrease plant, bird, and herpetofauna species richness.

Sub-Objective 7: Identify wetlands that are under low growth pressure
Rationale: Areas of low growth potential will incur slower increases in density of negative land uses such as urban, industrial, and roads.

Objective 5: Identify areas with good water quality
Sub-Objective 1: Identify wetlands that are greater than 3000 m from Toxic Release Inventory sites by EPA, Superfund sites by EPA, National Pollution Discharge Elimination System sites by EPA, Ground Water Contamination Areas by FDEP, or animal feeding operations that are also in basins that have reported poor water quality.
Rationale: According to Houlahan and Findlay (2003), effects of water quality on wetland amphibian species richness, abundance, and community composition peaks at 2000 to 3000 m.

Objective 6: Identify acquisition feasibility of wetlands
Sub-Objective 1: Identify wetlands that are under low growth pressure
Rationale: Areas of low growth potential are expected to have lower land values.

Sub-Objective 2: Identify wetlands that have a low average dollar value per acre (less than $195,000 based on the highest price per acre of land acquired by the St. Johns River Water Management District through December 2003).
Rationale: Acquisition of lands with low average dollar value per acre is expected to be more economically feasible.

<u>Goal 3: Identify optimal sites for wetland restoration</u>

<u>Objective 1:</u> Identify potential historic wetlands that may be identified according to any of the following sub-objectives:
<u>Sub-Objective 1</u>: Identify existing, privately owned, (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that have hydric soils, and agricultural land uses.

<u>Sub-Objective 2:</u> Privately owned uplands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that have hydric soils and agricultural or silvicultural land uses.

<u>Sub-Objective 3:</u> Identify existing, privately owned, wetlands (excluding privately-owned conservation lands such as lands with conservation easements or lands owned by non-governmental organizations) that have hydric soils and have been excavated or are classified as spoil.
<u>Rationale</u>: Historic wetlands that have the above disturbance conditions are likely to require substantial improvement to support a diversity of species.

<u>Objective 2:</u> Identify wetlands in three patch size thresholds
<u>Sub-Objective 1:</u> Identify small wetlands greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres)
<u>Rationale</u>: Small wetlands support populations of many species of herpetofauna that larger wetlands do not, because they provide refugia from predators such as wading birds. Wetlands as small as 0.2 ha have been recommended for regulatory protection based on habitat criteria for a wide range of species including herpetofauna, plants, microcrustaceans, and insects (Semlitsch and Bodie, 1998).

<u>Sub-Objective 2:</u> Identify medium-sized wetlands greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres)
<u>Rationale</u>: A minimum patch size of 5 ha has been reported for marsh birds (Environmental Law Institute, 2003).

<u>Sub-Objective 3</u>: Identify large wetlands greater than or equal to 100 ha (247.1 acres)
<u>Rationale</u>: According to Cedfeldt et al. (2000), 100 ha is an appropriate threshold for identifying effectiveness of wetlands in providing wildlife habitat based on the needs of species that require undisturbed interior habitat.

<u>Objective 3:</u> Identify landscape connectivity
<u>Sub-Objective 1:</u> Include wetlands located within the Florida Greenways ecological network model
<u>Rationale</u>: The Florida Greenways ecological network model identifies opportunities for a network of conservation hubs and corridors to provide large habitat patches and promote the movement of energy, materials, and species in the Florida landscape (Florida Greenways Commission, 1994).

Objective 4: **Identify wetlands in positive spatial contexts**

Sub-Objective 1: Identify wetlands within large contiguous areas of wetlands, water, and natural or semi-natural upland cover (rangeland, unimproved and woodland pastures, and plantations) that are bounded by paved roads and railroads

Rationale: Various authors have reported on negative effects of adjacent land uses on wetland species richness, composition, and recruitment. Many wetland-dependent species also require surrounding uplands to complete parts of their life cycles and some use terrestrial habitats for much of the year. Additionally, unfragmented wetland-upland mosaics provide unimpeded movement for individuals from wetlands to other nearby wetlands. Zedler (1996) contends that coastal wetlands support greater biodiversity if they have good linkages with adjacent ecosystems such as uplands, riparian corridors, and nearshore waters.

Sub-Objective 2: Identify wetlands that have high counts of nearby wetlands and water within 1000 m (wetland clusters)

Rationale: Wetlands that are relatively close in proximity (low isolation) to each other and connected by natural and semi-natural upland habitats (rangeland, unimproved and woodland pastures, and plantations) support metapopulation movement between wetlands and are critical in source-sink processes. The average distance to the nearest wetland affects the probability of migration and recolonization by herpetofauna, and according to Semlitsch and Bodie (1998), many pond-breeding salamanders do not emigrate distances farther than 200 m. Interpond movements of 1 km and 1.6 km have been expected for the dark gopher frog (*Rana sevosa*) (Richter et al., 2001) and movements of the Florida gopher frog (*Rana capito aesopus*) have been reported up to 2 km (Greenberg, 2001). Increased avian species richness has also been associated with clusters of small marshes (Whited et al., 2000) and Farmer and Parent (1997) report that complexes of small, closely spaced wetlands act as important migration stopovers for shorebirds.

Sub-Objective 3: Identify wetlands adjacent to existing conservation lands

Rationale: Existing conservation lands have been acquired for conservation in perpetuity and act as conservation hubs and linkages in ecological networks. They are a positive adjacent land use to other natural areas and locating proposed conservation lands near existing conservation lands expands the ecological network of a landscape.

Sub-Objective 4: Identify wetlands with a buffer zone of at least 164.3 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)

Rationale: This buffer zone is based on upland habitat utilization by pond-breeding salamanders in the southeastern coastal plain. Semlitsch (1998) contends that the buffer zone is applicable to a wide-range of species.

Sub-Objective 5: Identify wetlands with a buffer zone of at least 1000 m of surrounding natural or semi-natural land cover (rangeland, unimproved and woodland pastures, and plantations)

Rationale: Many semi-aquatic organisms such as insects, frogs, salamanders, snakes, and turtles depend on both aquatic and terrestrial habitats to complete parts of their life cycles (Semlitsch, 1998). Burke and Gibbons (1995), demonstrate that a 275 m buffer zone is needed to protect 100% of upland nest and hibernation sites of freshwater turtles around wetlands in Carolina bays. Richter et al. (2001) recommend a 1000 m buffer zone around wetlands to satisfy terrestrial habitat requirements of the dark gopher frog (*Rana sevosa*). Taylor et al. (1990) also contend that upland areas utilized by wetland species can extend as much as 2 km.

Sub-Objective 6: Identify wetlands that are in areas of low paved road density (less than 2 m/ha)
Rationale: Findlay and Houlahan (1997) found that increases in paved road density greater than or equal to 2 m/ha within 2 km of a wetland significantly decrease plant, bird, and herpetofauna species richness.

Sub-Objective 7: Identify wetlands that are under low growth pressure
Rationale: Areas of low growth potential will incur slower increases in density of negative land uses such as urban, industrial, and roads.

Objective 5: Identify areas with good water quality
Sub-Objective 1: Identify wetlands that are greater than 3000 m from Toxic Release Inventory sites by EPA, Superfund sites by EPA, National Pollution Discharge Elimination System sites by EPA, Ground Water Contamination Areas by FDEP, or animal feeding operations that are also in basins that have reported poor water quality.
Rationale: According to Houlahan and Findlay (2003), effects of water quality on wetland amphibian species richness, abundance, and community composition peaks at 2000 to 3000 m.

Objective 6: Identify acquisition feasibility of wetlands
Sub-Objective 1: Identify wetlands that are under low growth pressure
Rationale: Areas of low growth potential are expected to have lower land values.

Sub-Objective 2: Identify wetlands that have a low average dollar value per acre (less than $195,000 based on the highest price per acre of land acquired by the St. Johns River Water Management District through December 2003).
Rationale: Acquisition of lands with low average dollar value per acre is expected to be more economically feasible.

2.3 Specific GIS Methodology
2.3.1 Existing Input Datasets

Several existing datasets are used in the regional wetland mitigation framework to create single utility assignments (SUAs) and to add criteria to final suitability grids. The datasets are available from the following sources: the Florida Geographic Data Library (FGDL) housed at the GeoPlan Center, College of Design, Construction, and Planning, University of Florida, Gainesville, Florida; Florida Fish and Wildlife Conservation Commission; St. Johns River Water Management District; City of Jacksonville Preservation Project; Florida Department of Environmental Protection; and Jason Teisinger, M.A.U.R.P.

St. Johns River Water Management District Land use/Land Cover (LULC) 2000. This dataset is based on 1999 color infrared aerial photography and was developed to support St. Johns River Water Management District (SJRWMD) programs such as pollution load reduction goal development, land acquisition, land management, water supply planning, floodplain management, and surface and ground water quality monitoring (St. Johns River Water Management District, 2004).

National Wetlands Inventory (NWI). The NWI dataset depicts wetland area locations and classifications as defined by the U.S. Fish & Wildlife Service. The dataset was compiled from data sources such as aerial photography, Natural Resources Conservation Service (NRCS) Soil Surveys, and field checking of wetland photo signatures. Dates of data sources range from February 1971 to December 1992 (Florida Geographic Data Library Documentation, 2003).

Florida Natural Areas Inventory Managed Areas (FNAIMA). This dataset contains information about public, and some private, lands that have been identified as having natural resource value by the Florida Natural Areas Inventory (FNAI) (Florida Geographic Data Library Documentation, 2003).

Fish and Wildlife Conservation Commission Management Areas (FWCMAS). Management areas of the Florida Fish and Wildlife Conservation Commission are included in this dataset (Florida Geographic Data Library Documentation, 2003).

Florida Forever / Board of Trustees Environmental Land Acquisition Projects (FFBOT). This dataset contains an inventory of boundaries of all Florida Forever land acquisition projects administered by the Florida Department of Environmental Protection, Division of State Lands, for the State Board of Trustees (Florida Natural Areas Inventory, 2004).

St. Johns Water Management District Lands (SJWMDL). This dataset contains boundaries of SJRWMD public land areas (current and potential acquisitions) as of January 2001 (Florida Geographic Data Library Documentation, 2003).

Conservation And Recreation Lands 1999 (Clan99). This dataset contains Conservation and Recreation Lands spatial extents added up to December 1999 (Florida Geographic Data Library Documentation, 2003).

Preservation Project Jacksonville Acquired Lands. Boundaries of lands acquired through the program, Preservation Project Jacksonville, are contained in this dataset.

Soil Survey Geographic (SSURGO) Database. Digitized county soil surveys for the SJRWMD jurisdiction are included in this dataset, which is generally the most detailed soil geographic data developed by the SJRWMD and National Resources Conservation Service (St. Johns River Water Management District, 2004).

USGS 1:100,000 Hydrography. This dataset contains hydrographic area and line elements from the 1:100,000-scale DLG files. The 1:100,000-scale dataset is recommended for projects that are at the multi-county or regional level (Florida Geographic Data Library Documentation, 2003).

Priority Wetlands Habitats (GFCWET). Wetland species "hot spots" are identified in this dataset, which was created by combining habitat models for 35 listed wetland-dependent taxa. The data was derived from 1985 - 1989 LandSat Thematic Mapper Imagery (Florida Geographic Data Library Documentation, 2003).

Greenways Project Priority Ecological Areas (After Exclusion) (GWPEAX). This dataset was used a component of the Florida Ecological Network model as part of The Florida Greenways Project. It identifies Priority Ecological Areas (PEAs) after the removal (exclusion) of incompatible areas, which were given the highest priority for inclusion and linkage in the Network. Incompatible areas were considered to be developed land uses: residential, commercial, and industrial but not including intensive agriculture. Data layers that were used to create the PEA dataset included Florida Fish and Wildlife Conservation Commission (FWC) Strategic Habitat Conservation Areas (SHCAs); FWC hot spots of biodiversity (GFCHOT); Priority Wetlands Habitats (GFCWET); FNAI Areas of Conservation Interest (ACIs); FNAI Potential Natural Areas (PNAs); Rare and priority natural community types based on FWC habitat data and rankings by FNAI; Existing public conservation lands and private preserves; Proposed public conservation lands and easements; Lands identified as part of the Coastal Barrier Resources Act, Roadless areas; "Roadless" areas without major roads; State aquatic preserves, national estuarine research reserves, outstanding Florida waters, shellfish harvesting waters, wild and scenic rivers; and moderately ranked FWC focal species, FWC wetland species hotspots, lower-ranked FNAI PNAs, and smaller roadless areas that overlap with 100-year floodplains or areas of significant aquifer recharge (Hoctor et al., 2000).

Regionally Significant Habitat (RSH). This dataset contains lands considered by the SJRWMD to be important for sustaining native plants and animals in the District, and is intended to be used as a screening tool for land acquisition and land use planning. It was created by combining FWC hot spots of biodiversity (GFCHOT) and FWC SHCAs and then excluding habitat occurring in urban areas and on Class 2 agricultural, silvicultural, or range lands (St. Johns River Water Management District, 2004).

Greenways Project Ecological Model Results Modified By Public (GWECOP). The Florida Ecological Network results of the Florida Greenways GIS Decision Support Model as modified by public comment are contained in this dataset. It was created by using a concept of ecological hubs and linkages. Priority Ecological Areas were identified as hubs and least-cost path analysis was used to identify landscape linkages. Public comment was used to modify the results by deleting areas from the Network that were developed or by adding other significant ecological features (Florida Geographic Data Library Documentation, 2003).

US Census Bureau (TIGER) 1:100,000 Roads. All statewide roads from the 2000 TIGER/Line Files are contained in this dataset (Florida Geographic Data Library Documentation, 2003).

Florida Statewide Residential Growth Potential Model. This dataset represents the potential for residential growth in Florida. It was developed using five primary analyses: 1) location, 2) historic change, 3) vacant residential, 4) projected census change, and 5) non-developable lands subset. The Central Place Theory and Median Location Theory and their influence on residential growth were used to address location. For example, the theories state that amenities such as roads or waterfront property attract residential growth and the closer the amenity, the greater the attraction. Change in residential development between 1992 and 1999 per square mile section was used to address historic change. Vacant residential properties per section for 1999 addressed vacant residential. Projected change in densities between 1990 and 2010 addressed projected census change. To create the non-developable lands subset, existing urban land uses and non-developable natural areas were combined (Teisinger, 2002).

US EPA Toxic Release Inventory (EPATRI). Data on annual releases of over 300 toxic chemicals to air, water, and land by the manufacturing industry are contained in this dataset (Florida Geographic Data Library Documentation, 2003).

Superfund Hazardous Waste Sites. Locations for Superfund Hazardous Waste Sites in Florida, according to the EPA's Comprehensive Environmental Response, Compensation, and Liability (CERCLA) Information System, are included in this dataset (Florida Geographic Data Library Documentation, 2003).

National Pollutant Discharge Elimination System Sites In Florida – 1998 (NPDES). Locations of EPA National Pollutant Discharge Elimination System sites within Florida are contained in this dataset (Florida Geographic Data Library Documentation, 2003).

Ground Water Contamination Areas. This dataset contains locations of contaminated ground water sites not meeting primary drinking water standards in regard to any of 42 ground water contaminants as described by DEP rule 17-550 (Florida Department of Environmental Protection, 2003).

DEP Water Quality Data 305(b) 2000. This dataset contains statewide coverage of water quality data created by the Watershed Planning and Coordination Section that was submitted to Congress in 2000 pursuant to Section 305(b) of the Clean Water Act (Florida Department of Environmental Protection, 2003).

Florida Department Of Revenue Property Tax Data Records Summarized To Section – 2002. These tables contain tax data summarized to the Township, Range, and Section (TRS) level and may be joined to the Public Land Survey System dataset to include spatial extents of Sections (Florida Geographic Data Library Documentation, 2003).

2.3.2 Reclassification, Derivation, and Combination of Datasets

Existing datasets are used to create SUAs and to add criteria to final suitability grids. Preliminary subsets for potential preservation sites, enhancement sites, and restoration sites are created. Final subsets are then created by applying patch size criteria to preliminary subsets. Three patch size thresholds are used resulting in three final subsets for each preliminary subset that is created. Therefore, nine final suitability grids are created using nine final subsets. Existing datasets are reclassified and used to derive SUAs, which are clipped using the final subsets. Single utility assignments are then combined to create multiple utility assignments (MUAs), and MUAs are combined to create final suitability grids. End users of the regional wetland mitigation framework may then use existing data to add criteria to final suitability grids.

2.3.2.1 Subsets

Preliminary Subsets. A preliminary subset for potential preservation sites is created by selecting existing wetlands from SJRWMD Land Use/Land Cover 2000 that do not have disturbance conditions according to the National Wetlands Inventory (NWI).

Potential enhancement sites are identified in a preliminary subset by selecting existing wetlands that have been degraded or converted to a different type of wetland than formerly existed. Any one of the following conditions must be met to be considered a potential enhancement site: 1) existing wetlands (according to NWI) that have hydric soils according to the SSURGO Database and silvicultural land uses according to SJRWMD Land Use/Land Cover 2000, 2) existing wetlands according to SJRWMD Land Use/Land Cover 2000 that have been drained/ditched or diked/impounded according to NWI, or 3) existing wetlands according to SJRWMD Land Use/Land Cover 2000 that are less than 100 feet from a ditch or channelized stream identified in the USGS 1:100,000 Hydrography dataset. Wetlands on publicly owned and privately owned conservation lands are excluded.

A preliminary subset for potential restoration sites is created by identifying potential historic wetlands. These sites are selected by meeting any of the following criteria: 1) existing wetlands (according to NWI) that have hydric soils according to the SSURGO Database and agricultural land uses according to SJRWMD Land Use/Land Cover 2000, 2) uplands (according to NWI) that have hydric soils according to the SSURGO Database and agricultural or silvicultural land uses according to SJRWMD Land Use/Land Cover 2000, or 3) existing wetlands according to SJRWMD Land Use/Land Cover 2000 that have been excavated or are classified as spoil according to NWI.

Wetlands on publicly owned and privately owned conservation lands are excluded from all three preliminary subsets. The datasets used to identify conservation lands include FNAIMA, FWCMAS, FFBOT, SJWMDL, CLAN99, and Preservation Project Jacksonville Acquired Lands.

Final Subsets. Once preliminary subsets are created, patch size criteria are applied to create three final subsets for each preliminary subset representing three patch size thresholds. A region group command is performed in order to make patch size selections. The three patch size thresholds include 1) small: wetlands greater than or equal to 0.2 ha (0.4942 acre) and less than 5 ha (12.36 acres), 2) medium: wetlands greater than or equal to 5 ha (12.36 acres) and less than 100 ha (247.1 acres), and 3) large: wetlands greater than or equal to 100 ha (247.1 acres).

2.3.2.2 Single Utility Assignments

The following SUAs are created from existing datasets, which are then clipped using final subsets. The SUAs are combined to create MUAs, which are described in Section 2.3.2.3 (see Figure 2-6, Figure 2-7, and Figure 2-8).

Wetland Species Richness. This data layer is created by reclassifying the existing dataset, GFCWET (9= 10-12 focal species, 8= 7-9 focal species, 7= 4-6 focal species, 6= 1-3 focal species, 1= background and water). The wetlands in areas with more focal species are considered to have higher suitability than wetlands with fewer focal species. This SUA is used only for identifying optimal sites for wetland preservation.

Priority Ecological Areas. This data layer is created by reclassifying the existing dataset, GWPEAX (9= priority ecological area, 1= background). Wetlands within priority ecological areas are considered to have higher suitability than wetlands that are not. This SUA is used only for identifying optimal sites for wetland preservation.

Regionally Significant Habitat. This data layer is created by reclassifying the existing dataset, Regionally Significant Habitat (9= regionally significant habitat, 1= background). Wetlands within areas of regionally significant habitat are considered to have a higher suitability than wetlands that are not. This SUA is used only for identifying optimal sites for wetland preservation.

Florida Ecological Network. This data layer is created by reclassifying the existing dataset, GWECOP (9= within Florida Ecological Network, 1= background). Wetlands within the Florida Ecological Network are considered to have higher suitability than wetlands that are not. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Contiguous Areas. This data layer identifies and gives high suitability to wetlands within large contiguous areas of natural or semi-natural land. It is created first by reclassifying the SJRWMD Land Use/Land Cover 2000 dataset (1= wetlands, water, natural uplands including upland forest and open land, and semi-natural uplands including rangeland, unimproved pasture, woodland pasture, and plantations; 0= other agriculture, disturbed land, urban, industrial, and barren land uses). The TIGER roads dataset is reclassified (1= background, 0= paved road classes). The land use grid and roads are combined, using query methodology, and the resulting data layer is reclassified (1= wetlands, water, natural uplands including upland forest and open land, and semi-natural uplands including rangeland, unimproved pasture, woodland pasture, plantations, and paved roads; 0= background). A region group of values of 1 is performed on the reclassified data layer. The resulting data layer is reclassified on count using natural breaks (9= 296,633-558,156; 8=168,039-296,633; 7= 118,454-168,038; 6= 80,168-118,453; 5=52,342-80,167; 4=32,202-52,341; 3=17,615-32,201; 2=7,302-17,614; 1=1-7,301). After clipping the data layer with the subset, the final SUA represents wetlands within a range of size classes of contiguous natural or semi-natural lands, where wetlands within the larger contiguous areas are considered to have higher suitability, and wetlands within the smaller contiguous areas are considered to have lower suitability. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Wetland Clusters. This data layer identifies and gives high suitability to wetlands that have a clustered spatial relationship with other nearby wetlands. To create this data layer, wetland and water classes are first selected from the SJRWMD Land Use/Land Cover 2000 dataset. Centroids are then generated for each wetland or water polygon and a point distance command is performed. In the resulting table, each point has a record associated with it that lists the count of points that are within 1000 m. The table is joined to the original wetlands/water shapefile. The shapefile is then converted to grid on count and reclassified using natural breaks (9= 62 – 97, 8= 49 – 61, 7= 41 – 48, 6= 34 – 40, 5= 28 – 33, 4= 22 – 27, 3= 15 – 21, 2= 8 – 14, 1= 1 – 7). Once the subset is used to clip the resulting data layer, the final SUA identifies wetlands with a larger count of nearby wetlands (within 1000 m) as having higher suitability than wetlands with a lower count of nearby wetlands). This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

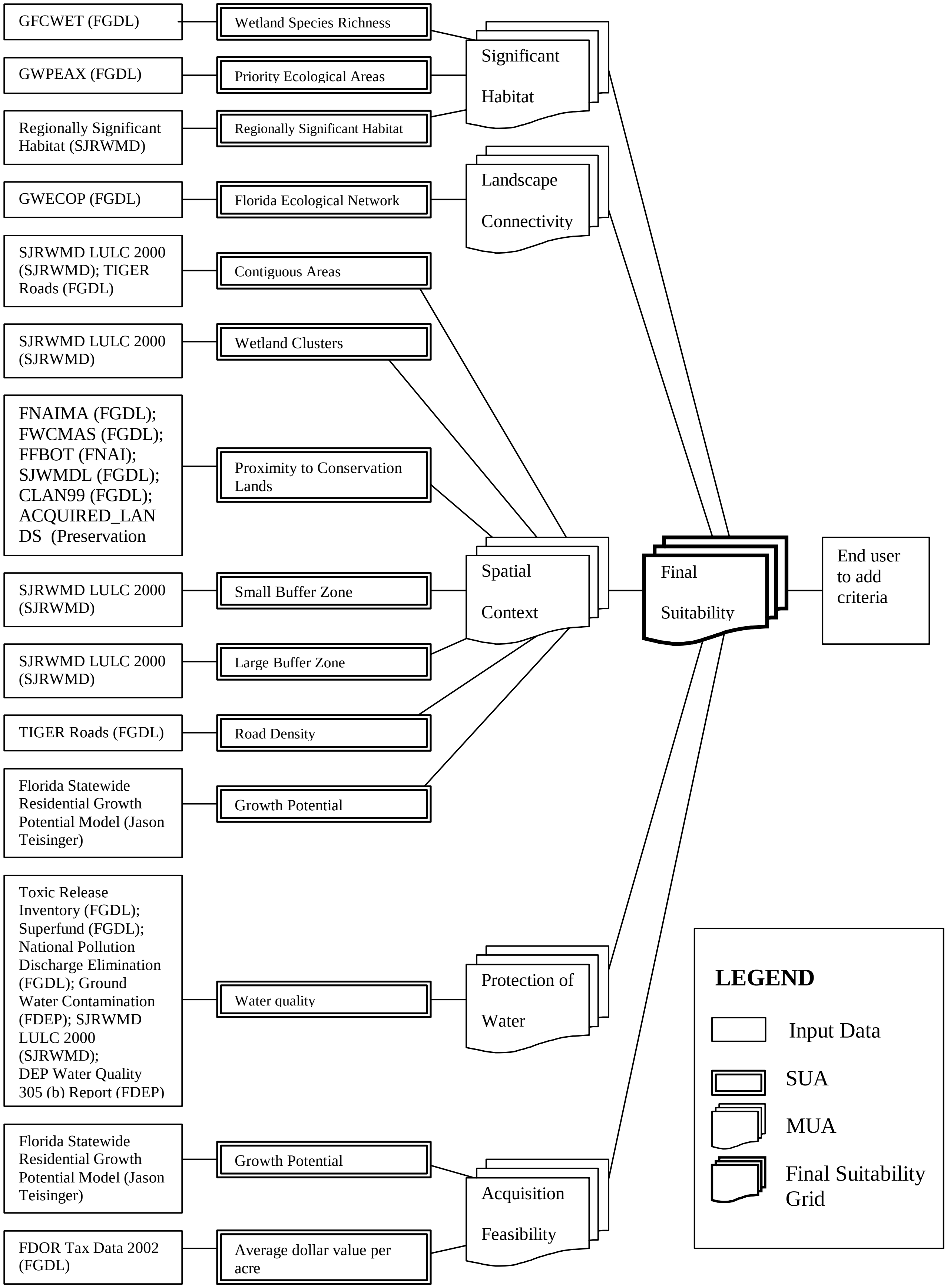


Figure 2-6. Regional wetland mitigation framework process for identifying optimal sites for preservation. Sources of input data are listed in parentheses.

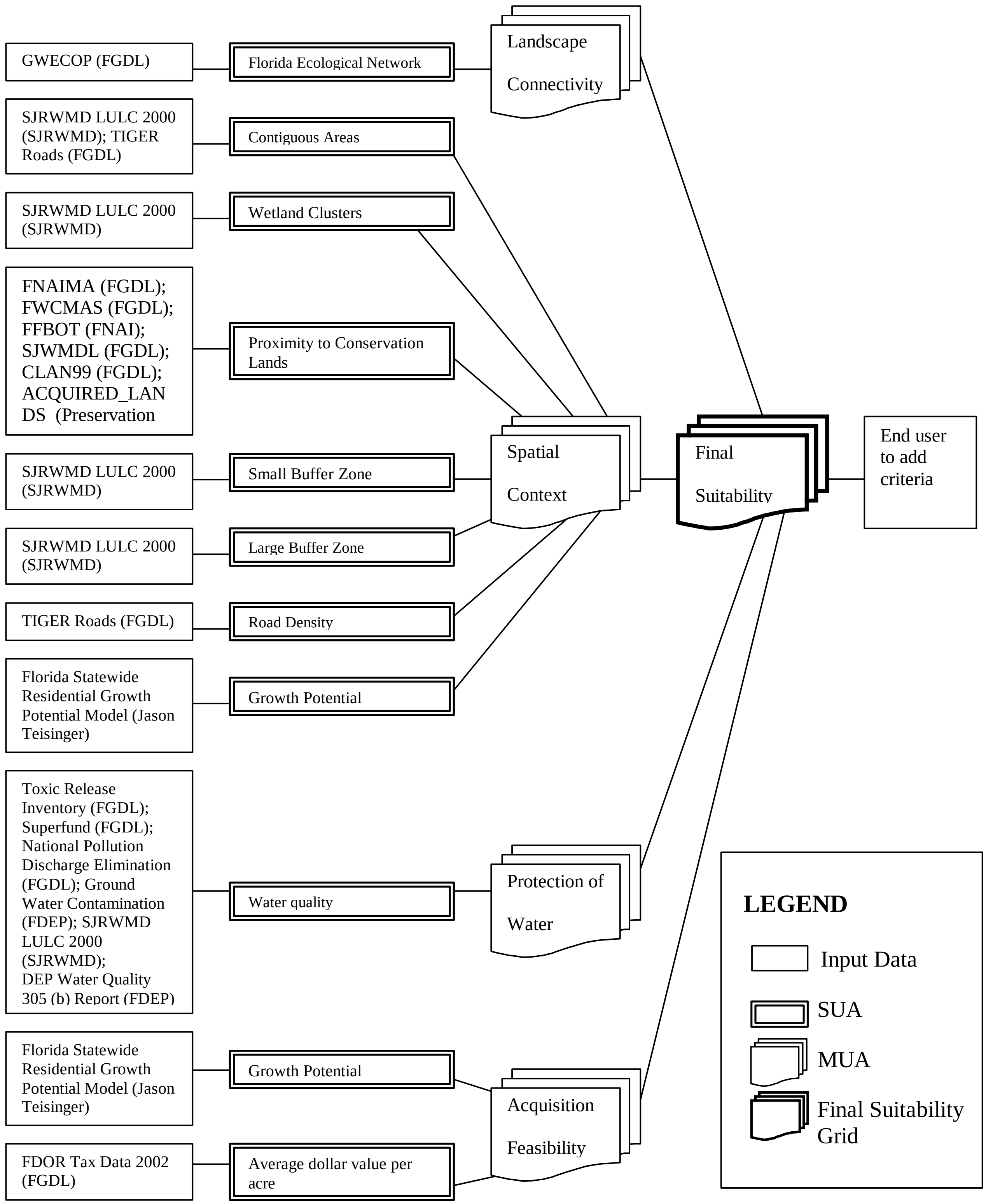


Figure 2-7. Regional wetland mitigation framework process for identifying optimal sites for enhancement. Sources of input data are listed in parentheses.

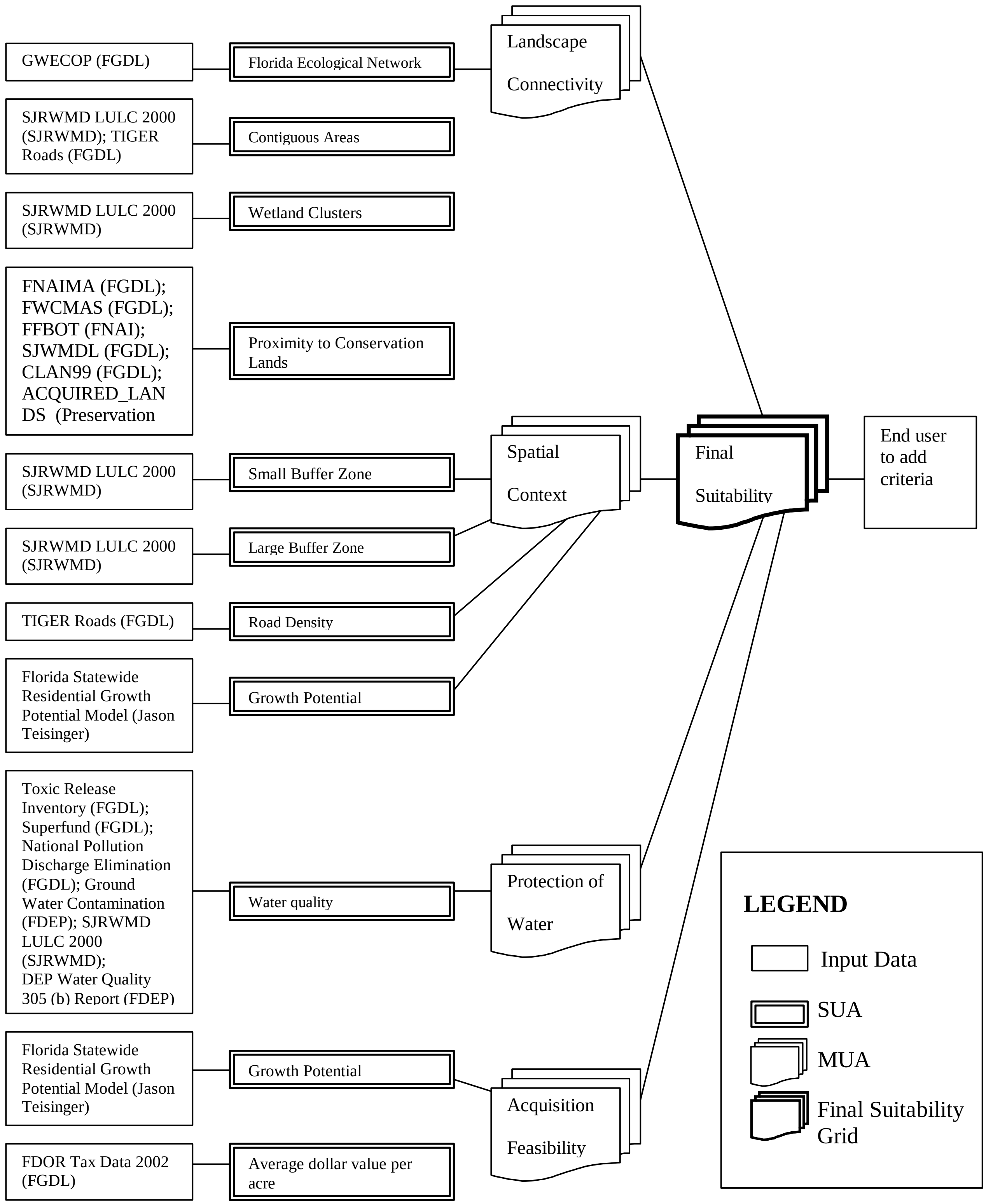


Figure 2-8. Regional wetland mitigation framework process for identifying optimal sites for restoration. Sources of input data are listed in parentheses.

Proximity to Conservation Lands. This data layer identifies and gives high suitability to wetlands that are in close proximity to existing conservation lands. Existing conservation lands are selected from the following datasets, which are then merged: FNAIMA, FWCMAS, FFBOT, SJWMDL, CLAN99, and Preservation Project Jacksonville Acquired Lands. Straight-line distance from conservation lands is calculated in meters and the grid is reclassified (9= 0 m- 1,111 m; 8= 1,111 m – 2,222 m; 7= 2,222 m- 3,333 m; 6= 3,333 m- 4,444 m; 5= 4,444 m- 5,555 m; 4= 5,555 m- 6,666 m; 3=6,666 m- 7,777 m; 2=7,777 m- 8,888 m; 1= 8,888 m+). The final SUA identifies wetlands that are closer to existing conservation lands as having higher suitability than wetlands that are farther away. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Small Buffer Zone. This data layer identifies and gives high suitability to wetlands that have a high percent of natural and semi-natural lands surrounding them within a 164-meter buffer zone. To create this dataset, buffer zones at a distance of 164 meters are established around all wetlands of each of the nine final subsets. The SJRWMD Land Use/Land Cover 2000 dataset is reclassified (1= wetlands, water, natural uplands including upland forest and open land, and semi-natural uplands including rangeland, unimproved pasture, woodland pasture, and plantations; 0= other agriculture, disturbed land, urban, industrial, and barren land uses). Areas within the buffer zones are tabulated for each value of the reclassified land use data layer, and the percent of land use with a value of 1 within the buffers is calculated. The data layer is then reclassified on percent using equal interval (9= 88.88 %-100 %, 8= 77.77 %- 88.88 %, 7= 66.66 %- 77.77 %, 6= 55.55 %- 66.66 %, 5= 44.44 %- 55.55 %, 4= 33.33 %- 44.44 %, 3= 22.22 %- 33.33 %, 2= 11.11 %- 22.22 %, 1= 1 %- 11.11 %). The final SUA identifies wetlands with higher percentages of surrounding positive land uses as having higher suitability than wetlands with lower percentages of positive land uses. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Large Buffer Zone. This data layer identifies and gives high suitability to wetlands that have a high percent of natural and semi-natural lands surrounding them within a 1000-meter buffer zone. To create this dataset, buffer zones at a distance of 1000 meters are established around all wetlands of each of the nine final subsets. The SJRWMD Land Use/Land Cover 2000 dataset is reclassified (1= wetlands, water, natural uplands including upland forest and open land, and semi-natural uplands including rangeland, unimproved pasture, woodland pasture, and plantations; 0= other agriculture, disturbed land, urban, industrial, and barren land uses). Areas within the buffer zones are tabulated for each value of the reclassified land use data layer, and the percent of land use with a value of 1 within the buffers is calculated. The data layer is then reclassified on percent using equal interval (9= 88.88 %-100 %, 8= 77.77 %- 88.88 %, 7= 66.66 %- 77.77 %, 6= 55.55 %- 66.66 %, 5= 44.44 %- 55.55 %, 4= 33.33 %- 44.44 %, 3= 22.22 %- 33.33 %, 2= 11.11 %- 22.22 %, 1= 1 %- 11.11 %). The final SUA identifies wetlands with higher percentages of surrounding positive land uses as having higher suitability than wetlands with lower percentages of positive land uses. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Road Density. This data layer identifies wetlands and gives high suitability to wetlands within areas that have low road density. First, paved road classes are selected from the TIGER roads dataset. Line density is calculated using a 100-meter cell size.

The resulting grid is multiplied by 10,000 using map calculator. A query is used to determine where road density is less than 2 meters/hectare, and the grid is reclassified (9= less than 2 m/ha, 1= greater than or equal to 2 m/ha). The final SUA identifies wetlands within low road density areas (less than 2 m/ha) as higher suitability than wetlands within high road density areas. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Growth Potential. This SUA identifies and gives high suitability to wetlands that are within areas with low growth potential. The Statewide Growth Potential Final grid (which excluded some wetlands) was combined, using a query, with an earlier version of the Statewide Growth Potential Model that did not have wetlands excluded from the analysis to add values into the grid for wetland areas. The resulting grid is reclassified, so that wetlands within areas of low growth potential are considered to have higher suitability than wetlands within areas of high growth potential (9= 1-2, 8= 2-3, 7= 3-4, 6= 4-5, 5= 5-6, 4= 6-7, 3= 7-8, 2= 8-9, 1= 9-10). This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Water Quality. This data layer identifies and gives high suitability to wetlands within areas that have good water quality. The following existing shapefile datasets are merged: EPATRI, Superfund Hazardous Waste Sites, NPDES, and Ground Water Contamination Areas. The straight-line distance in meters from these potential sources of water pollution is calculated, and the resulting grid is reclassified (1= 0-3,000 m; 0= 3,000 m+). This grid is combined with DEP Water Quality Data 305(b) 2000 (which classifies basins as having good, fair, or poor water quality), using a query. The grid is then reclassified (9= good water quality and within 3,000 m of a potential pollutant source; 5= fair water quality and within 3,000 m of a potential pollutant source; 1= poor water quality and within 3,000 m of a potential pollutant source). The final SUA identifies wetlands that are within basins with good water quality and that are within 3,000 m of a potential pollutant source as having higher suitability than wetlands that are within basins with poor water quality and that are within 3,000 m of a potential pollutant source. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Average Dollar Value Per Acre. This data layer identifies and gives high suitability to wetlands that have a low dollar value per acre. The Florida Department Of Revenue Property Tax Data Records Summarized To Section (2002) tables are joined to Public Land Survey System data and the average land value per acre is calculated for each section. The data layer is then converted to grid and reclassified based on average land value per acre using equal interval for values between $0 and $195,000 to create eight classes (9= $0- $24,371.91; 8= $24,371.91- $ 48,743.82; 7= $ 48,743.82- $73,115.73; 6= $73,115.73- $97,487.63; 5= $97,482.63- $121,859; 4= $121,859- $146,231.45; 3= $146,231.45- $170,603.36; 2= $170,603.36- $194,975.27; 1= greater than $194,975.27). The final SUA identifies and gives higher suitability to wetlands that are within areas with lower average dollar value per acre than wetlands within areas with higher average dollar value per acre. This SUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

2.3.2.3 Multiple Utility Assignments

Single utility assignments are weighted and combined to produce MUAs (see Figure 2-6, Figure 2-7, and Figure 2-8). The computer program, Expert Choice©, which uses the analytic hierarchy process, is used to develop weighting schemes. Verbal comparisons are used to make decisions regarding the priority of SUAs. By using a program that utilizes the analytic hierarchy process, users of the regional wetland mitigation framework may create new weighting schemes quite easily, and repeat the process with varying pairwise comparison judgments.

Significant Habitat. This MUA combines the SUAs, Wetland Species Richness, Priority Ecological Areas, and Regionally Significant Habitat. Using AHP, the Priority Ecological Areas SUA is judged to be most important due to the large breadth of information that was considered and included in the construction of the existing dataset GWPEAX (see Figure 2-9). The Wetland Species Richness SUA is judged to be the least important of the three SUAs due to the singular nature of information it contains. The weights given to the three SUAs are as follows: Wetland Species Richness= 8.6%, Priority Ecological Areas= 61.8%, Regionally Significant Habitat= 29.7%. The resulting MUA is used only for identifying optimal sites for wetland preservation.

Landscape Connectivity. The SUA, Florida Ecological Network, is the sole SUA that comprises the Landscape Connectivity MUA. This MUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Spatial Context. This MUA combines the SUAs, Contiguous Areas, Wetland Clusters, Proximity to Conservation Lands, Small Buffer Zone, Large Buffer Zone, Road Density, and Growth Potential. Using AHP, the Proximity to Conservation Lands SUA is judged to be most important due to the concept that adjacent conservation lands provide positive spatial context that is protected in perpetuity (see Figure 2-10). The Growth Potential SUA is judged to be the least important of the SUAs, because the existing dataset used to create the SUA, the Florida Statewide Residential Growth Potential Model**,** predicts a future outcome that may or may not come to pass. The weights given to the SUAs are as follows: Contiguous Areas = 16.0%, Wetland Clusters = 16.0%, Proximity to Conservation Lands = 18.1%, Small Buffer Zone= 16.0%, Large Buffer Zone= 16.0%, Road Density= 14.7%, Growth Potential= 3.2%. The resulting MUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Protection of Water Quality. The SUA, Water Quality, is the sole SUA that comprises Protection of Water Quality MUA. This MUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Acquisition Feasibility. This MUA combines the SUAs, Growth Potential and Average Dollar Value Per Acre. Using AHP, the Average Dollar Value Per Acre SUA is judged to be most important, because it represents current economic conditions rather than predicted growth (see Figure 2-11). The weights given to the SUAs are as follows: Growth Potential = 12.5%, Average Dollar Value Per Acre = 87.5%. The resulting MUA is used for identifying optimal sites for wetland preservation, wetland enhancement, and wetland restoration.

Final Suitability Grids for Wetland Preservation Goal. The final suitability grids for the wetland preservation goal are produced by combining the following MUAs: Significant Habitat, Landscape Connectivity, Spatial Context, Protection of Water Quality, and Acquisition Feasibility. Using AHP, the MUAs, Significant Habitat, Landscape Connectivity, and Spatial Context are judged to be equally the most important, because they represent landscape conditions that favor ecologically functional wetlands and biodiversity (see Figure 2-12). The MUA, Protection of Water Quality, is judged to be less important than the aforementioned MUAs, because water quality in the United States has generally improved since the 1970s, while habitat loss and habitat

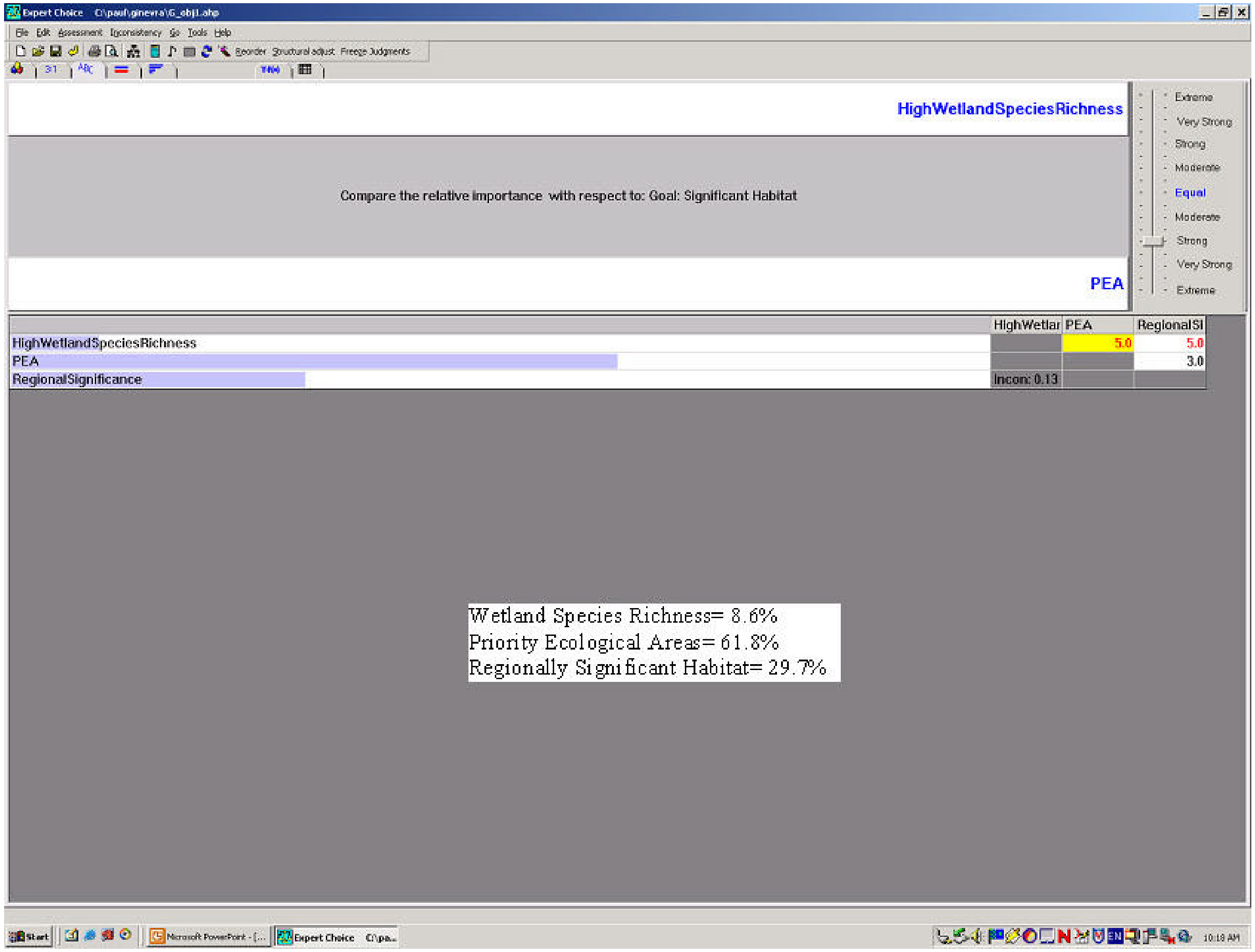
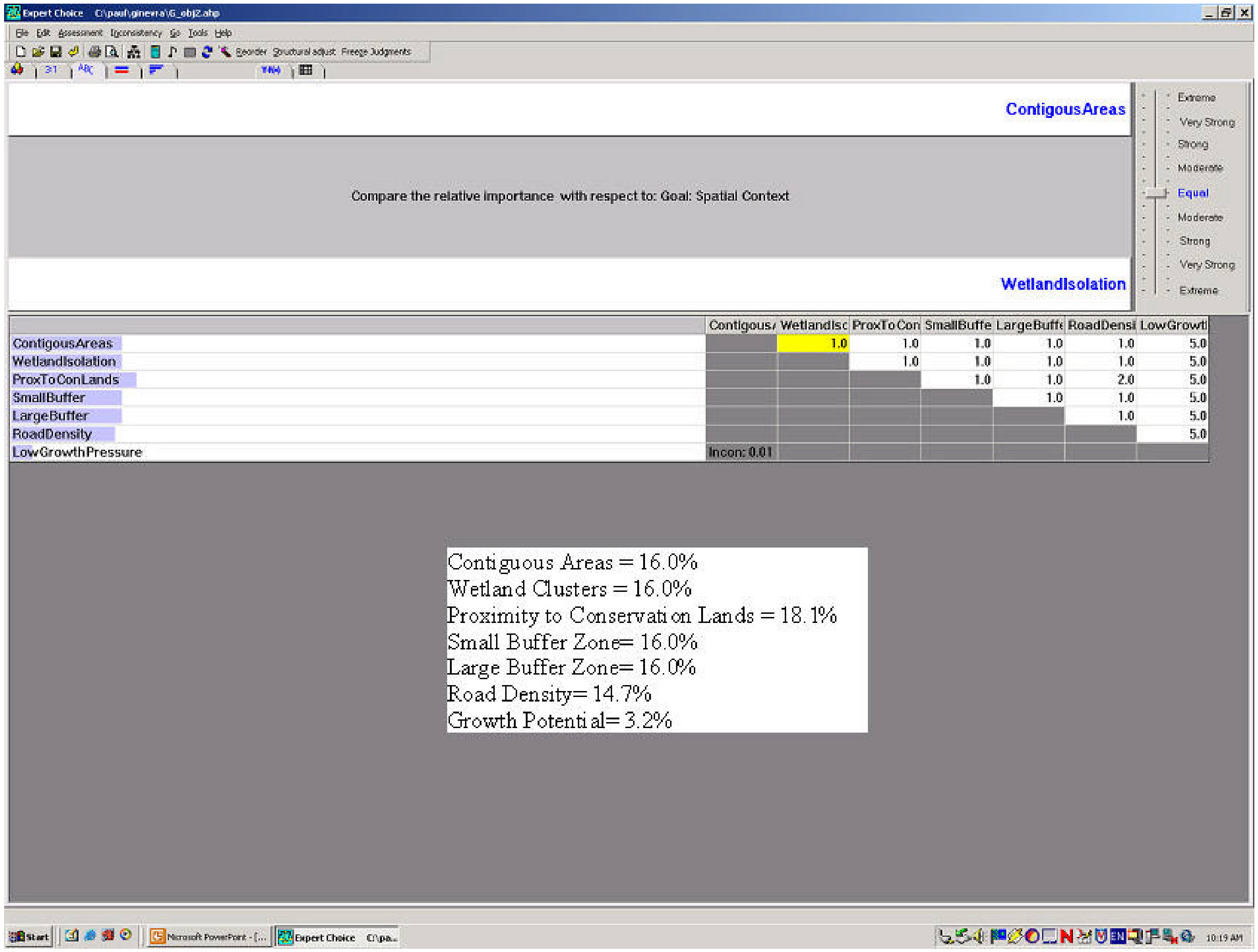


Figure 2-9. Pairwise comparisons used during AHP decision-making for Significant Habitat MUA and outcome of final weights.



	Contigous/	WetlandIsc	ProxToCon	SmallBuffe	LargeBuffe	RoadDensi	LowGrowtl
ContigousAreas		1.0	1.0	1.0	1.0	1.0	5.0
WetlandIsolation			1.0	1.0	1.0	1.0	5.0
ProxToConLands				1.0	1.0	2.0	5.0
SmallBuffer					1.0	1.0	5.0
LargeBuffer						1.0	5.0
RoadDensity							5.0
LowGrowthPressure	Incon: 0.01						

Figure 2-10. Pairwise comparisons used during AHP decision-making for Spatial Context MUA and outcome of final weights.

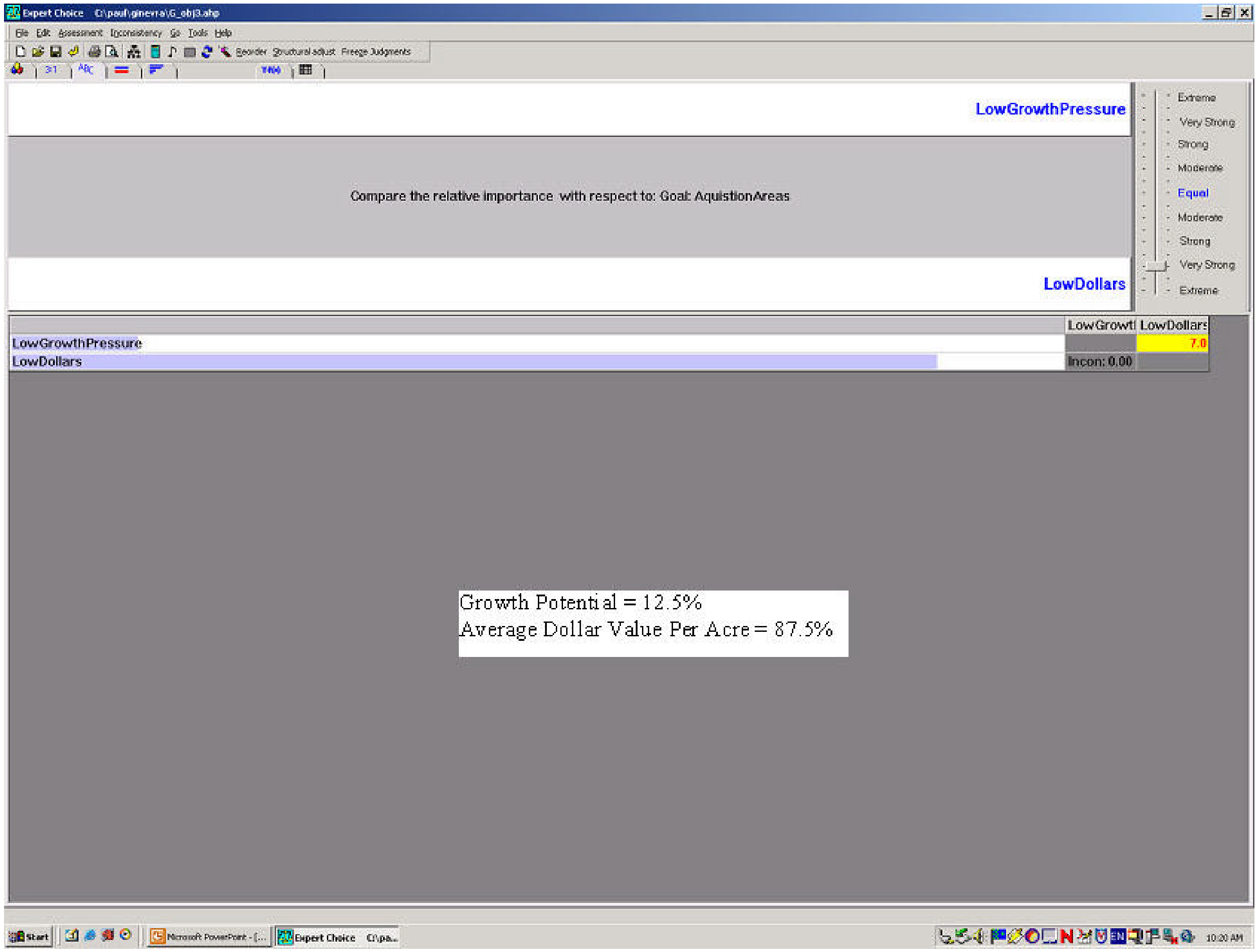


Figure 2-11. Pairwise comparisons used during AHP decision-making for Acquisition Feasibility MUA and outcome of final weights.

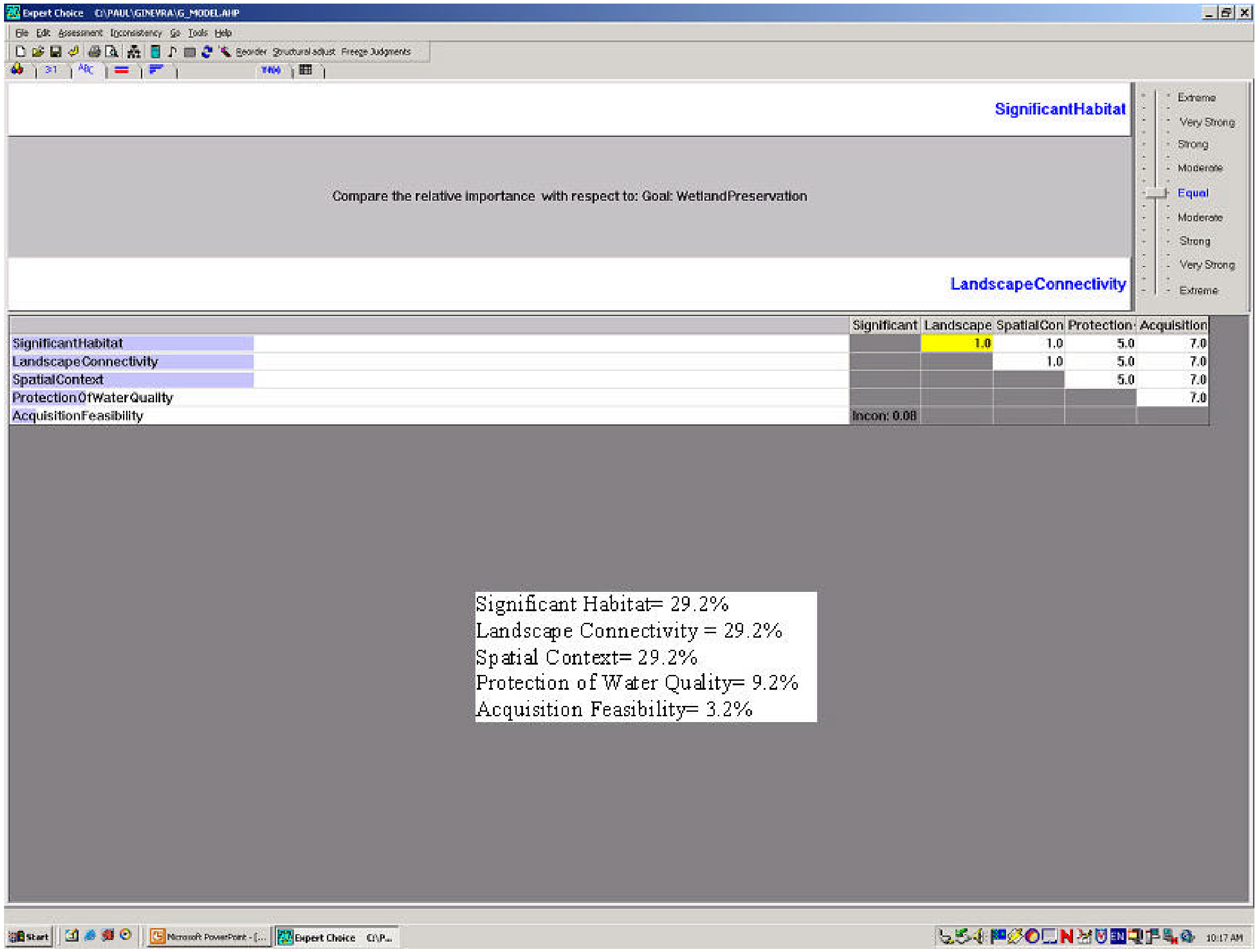


Figure 2-12. Pairwise comparisons used during AHP decision-making for final suitability grids for the wetland preservation goal and outcome of final weights.

fragmentation continue to cause declines in biodiversity. The MUA, Acquisition Feasibility, is judged to be the least important, because it represents economic, rather than ecological objectives. The weights given to the MUAs are as follows: Significant Habitat= 29.2%, Landscape Connectivity = 29.2%, Spatial Context= 29.2%, Protection of Water Quality= 9.2%, Acquisition Feasibility= 3.2%.

Final Suitability Grids for Wetland Enhancement and Restoration Goals. The final suitability grids for the wetland enhancement and restoration goals are produced by combining the following MUAs: Landscape Connectivity, Spatial Context, Protection of Water Quality, and Acquisition Feasibility. Using AHP, the MUAs, Landscape Connectivity, and Spatial Context are judged to be equally the most important, because they represent landscape conditions that favor ecologically functional wetlands and biodiversity (see Figure 2-13). The MUA, Protection of Water Quality, is judged to be less important than the aforementioned MUAs, because water quality in the United States has generally improved since the 1970s, while habitat loss and habitat fragmentation continue to cause declines in biodiversity. The MUA, Acquisition Feasibility, is judged to be the least important, because it represents economic, rather than ecological objectives. The weights given to the MUAs are as follows: Landscape Connectivity = 41.2%, Spatial Context= 41.2%, Protection of Water Quality= 13.5%, Acquisition Feasibility= 4.1%.

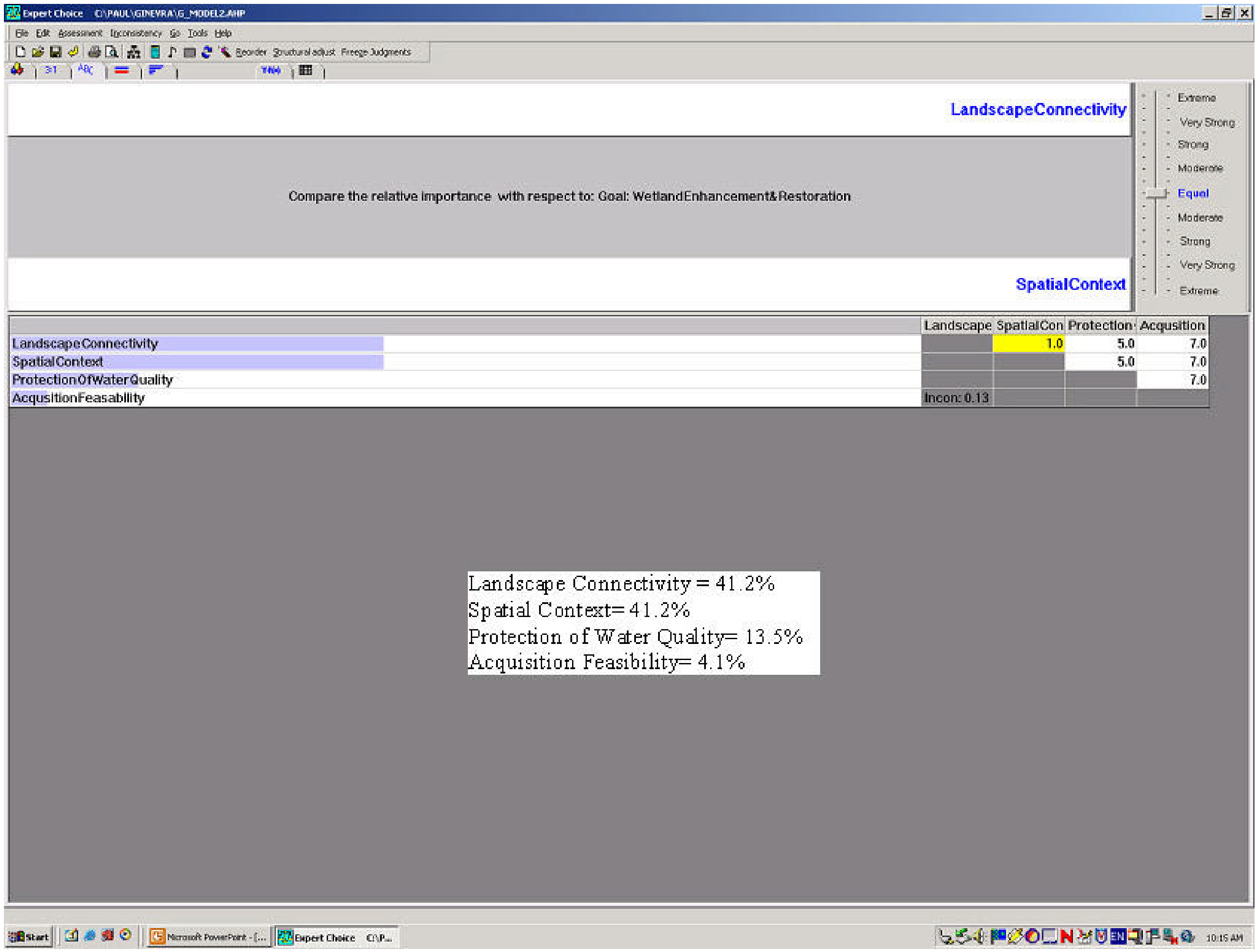


Figure 2-13. Pairwise comparisons used during AHP decision-making for final suitability grids for the wetland enhancement and restoration goals and outcome of final weights.

2.3.2.4 Added Criteria Example Set

End users may add criteria to final suitability grids. As an example set of criteria that may be added, the identification of optimal wetlands of a specific type for one of the three goals, within a chosen mitigation basin is evaluated. The suitability of cypress swamps of the medium patch size, 5 to 100 hectares, for preservation within the St. Johns River (Welaka to Bayard) mitigation basin (regulatory basin 8) is determined. To create the grid, cypress swamps within the St. Johns River mitigation basin are selected from SJRWMD Land Use/Land Cover 2000 data. The final three-class suitability grid for the preservation goal and the patch size, 5 to 100 hectares, is clipped to the extent of the St. Johns River (Welaka to Bayard) mitigation basin. The cypress swamp shapefile is converted to grid, used as a subset, and combined with the final three-class suitability grid using a query. The grid is reclassified into three classes (1,2, and 3) representing low, medium, and high suitability of cypress swamp preservation for compensatory mitigation within the St. Johns River mitigation basin.

3.0 Results

The results of this study show that of the total wetland area of 440,161 hectares (1,087,600 acres) within the study area, 66.99% of the wetland area was identified as being potentially suitable for preservation, 18.42% was identified as being potentially suitable for enhancement, and 14.59% was identified as being potentially suitable for restoration for compensatory mitigation purposes. Using the regional wetland mitigation framework, wetlands are selected for one of these three mitigation options by identifying the intensity of disturbance on the sites. According to the results, the majority of wetlands within the study area may be considered to be in fairly pristine condition and were considered in the study for preservation suitability. Sites identified for wetland enhancement may be considered to be somewhat disturbed, and sites identified for wetland restoration may be considered to be the most disturbed wetlands. Wetlands that fell into the most disturbed category made up the smallest group within the study area.

The percentage of small pristine wetlands that were found to be highly suitable for preservation was 47.13%, while 26.21% were identified as having medium suitability is, and 26.66% were identified as having low suitability (see Table 3-1). The percentage of medium-sized pristine wetlands that were found to be highly suitable for preservation was 49.09%, while the percentage of medium-sized pristine wetlands with medium suitability is 25.13%, and the percentage with low suitability is 25.78%. The majority of large pristine wetlands were identified as having high suitability for preservation (75.05%). The percentage of large pristine wetlands with medium suitability for preservation is 14.87%, and the percentage with low suitability is 10.08%.

Table 3-1. Percentages of total wetland area within each size class that were identified as having high, medium, or low suitability for preservation, enhancement, or restoration.

Mitigation Goal	**Suitability (percent of total wetland area)**		
Preservation	**High**	**Medium**	**Low**
Small	47.13%	26.21%	26.66%
Medium	49.09%	25.13%	25.78%
Large	75.05%	14.87%	10.08%
Enhancement	**High**	**Medium**	**Low**
Small	70.91%	5.19%	23.90%
Medium	23.31%	65.32%	11.37%
Large	77.18%	9.34%	13.48%
Restoration	**High**	**Medium**	**Low**
Small	71.57%	7.08%	21.36%
Medium	75.94%	4.73%	19.33%
Large	75.75%	3.74%	20.50%

The majority of small, somewhat disturbed, wetlands were identified as having high suitability for enhancement (70.91%). The percentage of small, somewhat disturbed, wetlands with medium suitability for enhancement is 5.19%, and the percentage with low suitability is 23.90%. The percentage of medium-sized, somewhat disturbed, wetlands identified as having high suitability for enhancement is 23.31%. The majority of medium-sized, somewhat disturbed, wetlands were identified as having medium suitability for enhancement (65.32%). The percentage of medium-sized, somewhat disturbed, wetlands with low suitability is 11.37%. The percentage of large, somewhat disturbed, wetlands identified as having high suitability for enhancement is 77.18%. The percentage of large, somewhat disturbed, wetlands with medium suitability for enhancement is 9.34%, and the percentage with low suitability is 13.48%.

Most small, highly disturbed, wetlands within the study area were identified as having high suitability for restoration (71.57%). The percentage of small, highly disturbed, wetlands with medium suitability is 7.08%, and the percentage with low suitability is 21.36%. The percentage of medium-sized, highly disturbed, wetlands identified as having high suitability for restoration is 75.94%. The percentage of medium-sized, highly disturbed, wetlands with medium suitability for restoration is 4.73%, and the percentage with low suitability is 19.33%. The percentage of large, highly disturbed, wetlands identified, as having high suitability for restoration is 75.75%. The percentage of large, highly disturbed, wetlands with medium suitability for restoration is 3.74%, and the percentage with low suitability is 20.50%. Refer to Lewis (2004) for further explanation of results.

4.0 Conclusions

The regional wetland mitigation framework has several key strengths including universal applicability. The fundamental principles that form the foundation of the framework: protection of significant habitat, ecological connectivity and spatial context, consideration of water quality effects on wildlife, and feasibility of land acquisition are pertinent in any region. Therefore, the framework may be attuned to reflect the specific needs of any region (although its utilization is limited by available data). Some criteria as described in this paper are specifically adapted for use in Florida; however, they may be adapted to other sites as well. For example, buffer zones and land value thresholds were chosen based on their application in northeast Florida. However, they may be increased or decreased according to the requirements of any particular region.

The framework also has potential applications beyond wetland mitigation planning for the St. Johns River Water Management District including land acquisition planning and land management. It provides a fairly simple process for identifying suitability of small, medium, and large wetlands for wetland preservation, wetland enhancement, and wetland restoration. It also has the informative potential to answer several suitability questions regarding wetlands even within the same study area. Used in addition to the current methods for wetland mitigation site selection such as aerial photography study and field verification, the framework could be utilized for rapid screening purposes.

The framework utilizes a weighting scheme for the combination of SUAs to produce MUAs and the combination of MUAs to produce final suitability grids. This is a fairly rapid procedure for combining data layers, which is also quite flexible. Users may alter weights from those presented in this paper according to expert consensus. This paper demonstrates that the use of the analytic hierarchy process (AHP) provides a fairly simple way to make judgments on weighting schemes and to evaluate different scenarios by using various pairwise comparisons.

The process may also be replicated and enhanced with new data. The accuracy of any suitability model is dependent upon the accuracy of input datasets. The process may be repeated when updated datasets are available to ensure that the model is as current as possible.

With added funding and time, future improvements to the framework may include the addition of focal species models. Although species richness data was incorporated into the process, focal species models may be added in order to fine tune results according to program objectives. Additionally, the objective of protecting water quality was carried out in this study by identifying those areas that currently have good water quality and by giving high suitability to those areas. With the addition of hydrological modeling, more complex questions related to the protection of water quality may be answered with this process. For example, modeling that predicts surface and ground water flows may allow for more sophisticated planning with regards to water quality.

This study highlights the ecological importance of all wetland sizes including wetlands of the smallest sizes. Small wetlands support rare species of herpetofauna that large wetlands do not and provide refugia for these species from predatory fish. Larger wetlands are also valuable, because they provide more interior habitat. Therefore, wetlands of all sizes were included within the framework.

This framework adds a new dimension to off-site wetland mitigation planning by giving ecological connectivity and spatial context high priority. Wetlands are an intermediary natural system between open water and upland habitat and exist with delicate hydrological regimes. Many wetland-dependent species also require unspoiled upland habitat in order to survive and reproduce, while many wetland systems are also dependent upon the influx of water from open water bodies. The protection of healthy and functioning wetland, upland, and open water matrixes is critical to the health of any singular wetland and to the persistence of ecologically functional landscapes and regions and local and global biodiversity. The establishment of mitigation wetlands without regard to connectivity and context is sure to result in unsuccessful mitigation efforts. This study is an attempt to include these issues in a planning framework and to promote efforts that preserve, enhance and restore wetlands and their contexts as complete and interwoven landscapes.

5.0 Literature Cited

Berman, M.R., T. Rudnicky, H. Berquist, and C. Hershner. 2002. *Protocols for Implementation of a GIS-Based Model for the Selection of Potential Wetlands Restoration Sites, Southeastern Virginia.* Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia. Submitted to the Office of Environmental Programs, U.S. Environmental Protection Agency, Region 3, Philadelphia, PA. Retrieved December 23, 2003 at http://www.vims.edu/ccrm/cci/adv_id/advid.pdf

Burke, V.J. and J.W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina Bay. *Conservation Biology* 9(6): 1365-1369.

Carr, M.H., T.S. Hoctor, C. Goodison, P.D. Zwick, J. Green, P. Hernandez, C. McCain, K. Whitney and J. Teisinger. 2002. *Final Report, Southeastern Ecological Framework*. Submitted to the Planning and Analysis Branch, U.S. Environmental Protection Agency, Region 4, Atlanta, Georgia.

Cavanaugh, P.M. 1995. Environmental reckoning. *Landscape Architecture Magazine* 85(7): 48-53.

Cedfeldt, P.T., M.C. Watzin, and B.D. Richardson. 2000. Using GIS to identify functionally significant wetlands in the Northeastern United States. *Environmental Management* 26(1): 13-24.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. *Closing the Gaps in Florida's Wildlife Habitat Conservation System: Recommendations to Meet Minimum Goals for Declining Wildlife Species and Rare Plant and Animal Communities.* Office of Environmental Services, Florida Game and Fresh Water Fish Commission, Tallahassee, FL. 239 pp.

Diamond, D.D. and T. Gordon. 2003. *Final Report, State-based Ranking of Watersheds Using the Synoptic Assessment of Wetland Function Model*. Submitted to the U.S. Environmental Protection Agency, Region 7, Kansas City, Kansas.

Dramstad, W.E., J.D. Olson, and R.T.T. Forman. 1996. *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning.* Island Press, Washington, D.C. 80 pp.

Environmental Law Institute. 2003. *Conservation Thresholds For Land Use Planners.* Environmental Law Institute, Washington, D.C.

Ewel, K.C. 1990. "Swamps." In *Ecosystems of Florida* (R.L. Myers and J.J. Ewel, eds.). University of Central Florida Press, Orlando, FL. Pp. 281-323.

Farmer, A.H. and A.H. Parent. 1997. Effects of the landscape on shorebird movements at spring migration stopovers. *The Condor* 99: 698-707.

Federal Highway Administration. 1998. *Case Histories of Wetland Restoration.* Publication No. FHWA-EP-00-025- HEPN/9-2000/(300). Washington, D.C.: U.S. Department of Transportation. 121 pp.

Findlay, C.S. and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. *Conservation Biology* 14(1): 86-94.

Findlay, C.S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. *Conservation Biology* 11: 1000-1009.

Florida Department of Community Affairs. 2000. *Growth Management Programs, A Comparison of Selected States.* Retrieved at http://www.floridagrowth.org

Florida Department of Environmental Protection. 2003. *GIS GeoData Directory*. [Online] Retrieved March 20, 2004 at http://www.dep.state.fl.us/gis/datadir.asp

Florida Fish and Wildlife Conservation Commission. 2001. *Integrated Wildlife Habitat Ranking System*. Florida Fish and Wildlife Conservation Commission, Office of Environmental Services, Tallahassee, Florida. [Online] Retrieved November 25, 2003 at http://www.floridaconservation.org/oes/habitat_sec/hab_rank.pdf.

Florida Geographic Data Library Documentation. 2003. [Online] Retrieved December 28, 2003 at http://www.fgdl.org.

Florida Greenways Commission. 1994. *Creating a Statewide Greenways System: For People, for Wildlife, for Florida.* Florida Greenways Commission Report to the Governor. [Online] Retrieved November 6, 2003 at http://www.geoplan.ufl.edu/projects/greenways/whatisagreenway.html#conservingecosystems

Florida Natural Areas Inventory. 2004. *Data.* [Online] Retrieved September, 2003 at http://www.fnai.org/gis_data.cfm.

Forman, E. 2003. *Decision By Objectives (How To Convince Others That You Are Right).* 416 pp. [Online] Retrieved February 26, 2004 at http://www.expertchoice.com/dbo/chapter4.pdf.

Forman, R.T.T. 1995. *Land Mosaics: the Ecology of Landscapes and Regions.* Cambridge University Press, Cambridge, UK. 632 pp.

Forman, R.T.T. and M. Godron. 1986. *Landscape Ecology*. John Wiley & Sons, New York, NY. 619 pp.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes? *Ecological Applications* 3(2): 202-205.

Greenberg, C.H. 2001. Spatio-temporal dynamics of pond use and recruitment in Florida gopher frogs (*Rana capito aesopus*). *Journal of Herpetology* 35(1): 74-85.

Hoctor, T.S., M.H. Carr, and P.D. Zwick. 2000. Identifying a linked reserve system using a regional landscape approach: the Florida Ecological Network. *Conservation Biology* 14(4): 984-1000.

Houlahan, J.E. and C.S. Findlay. 2003. The effects of adjacent land use on wetland amphibian species richness and community composition. *Canadian Journal of Fisheries and Aquatic Sciences* 60(9): 1078-1094.

Institute for Water Resources. 1994. *National Wetland Mitigation Banking Study: Wetland Mitigation Banking.* IWR Report 94-WMB-6. Washington D.C.: Environmental Law Institute. 178 pp.

Interrain Pacific. 1996. *Coquille Subbasin Working Atlas: An Introduction to Available Geographic Information*. Inforrain website. [Online] Retrieved April 10, 2004 at http://www.inforain.org/coqatlas/.

Joyal, L.A., M. McCollough, and M.L. Hunter Jr. 2001. Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. *Conservation Biology* 15(6): 1755-1762.

Kartika A.B. and S. Supriyanto. Date unknown. *GIS Database Design and Presentation.* [Online] Retrieved April 10, 2004 at http://www.indomap.com/geosci/.

Kautz, R., J. Cox, M. MacLaughlin, and J. Stys. 1994. *Final Project Report, Mapping Wetland Habitats Of High Priority To Endangered And Threatened Species In Florida*. Submitted to the U.S. Environmental Protection Agency, Region 4, Atlanta, Georgia.

Krause, M.L. 1996. *Wetland mitigation banking in Florida: issues and concerns.* Audubon of Florida website. [Online] Retrieved February 10, 2003 at http://www.audobonofflorida.org/main/Publications/Policydocs/Mitigation.pdf.

Kushlan, J.A. 1990. "Freshwater Marshes." In *Ecosystems of Florida* (R.L. Myers and J.J. Ewel, eds.). University of Central Florida Press, Orlando, FL. Pp. 324-363.

Lewis, G.L. 2004. *A Regional Wetland Mitigation Framework for the Protection of Biodiversity: The Northeast Florida Region as a Case Study*. Submitted in partial fulfillment of the requirements for the degree of Master of Landscape Architecture to the Graduate School of the University of Florida, Gainesville, Florida.

Meffe, G.K., C.R. Carroll, and Contributors. 1997. *Principles of Conservation Biology*. 2nd Ed. Sinauer Associates, Inc., Sunderland, MA. 729 pp.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. New York: John Wiley & Sons. 722 pp.

Mitsch, W.J. and N. Wang. 1998. A whole-ecosystem experiment in self-design. [Online], American Institute of Biological Sciences. Retrieved October 22, 2002, from http://bess.fcla.edu/~fcliac/cgi-bin/cgi2iac/UF?RI533392385.

Montague, C.L. and R.G. Wiegert. 1990. "Salt Marshes." In *Ecosystems of Florida* (R.L. Myers and J.J. Ewel, eds.). University of Central Florida Press, Orlando, FL. Pp. 481-516.

Noss, R.F. and L.D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. *Environ. Mgmt.* 10: 299-309.

Richter, S.C., J.E. Young, and R.A. Seigel. 2001. Postbreeding movements of the dark gopher frog, *Rana sevosa* goin and netting: implications for conservation and management. *Journal of Herpetology* 35(2): 316-321.

Rowland, A. April 24, 2003. 3 city hopefuls say current wetlands rules enough. *The Gainesville Sun*. [Online] Retrieved September 30, 2003 at http://www.gainesvillesun.com.

Russell, G.D., C.P. Hawkins, and M.P. O'Neill. 1997. The role of GIS in selecting sites for riparian restoration based on hydrology and land use. *Restoration Ecology* 5(4S): 56-68.

Russell, K.R., D.C. Guynn, Jr., and H.G. Hanlin. 2002. Importance of small isolated wetlands for herpetofaunal diversity in managed, young growth forests in the Coastal Plain of South Carolina. *Forest Ecology and Management* 163: 43-59.

Schweiger, E.W., S.G. Leibowitz, J.B. Hyman, W.E. Foster, and M.C. Downing. 2002. Synoptic assessment of wetland function: a planning tool for protection of wetland species biodiversity. *Biodiversity and Conservation* 11: 379–406.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12(5): 1113-1119.

Semlitsch, R.D. 2000. Size does matter: the value of small isolated wetlands. *National Wetlands Newsletter* 22(1): 5-13.

Semlitsch, R.D. and J.R. Bodie. 1998. Are small, isolated wetlands expendable? *Conservation Biology* 12(5): 1129-1133.

Snodgrass, J.W., M.J. Komoroski, A.L. Bryan Jr., and J. Burger. 2000. Relationships among isolated wetland size, hydroperiod, and amphibian species richness: implications for wetland regulations. *Conservation Biology* 14(2): 414-419.

State of Florida. 2003. *Wetlands*. Florida Department of Environmental Protection website. [Online] Retrieved July 20, 2003 at http://www.dep.state.fl.us/water/wetlands.htm.

St. Johns River Water Management District. 2003. *Applicant's Handbook: Management and Storage Of Surface Waters*. 298 pp. [Online] Retrieved on November 11, 2003 at http://sjr.state.fl.us/programs/regulation/handbooks/msswhdbk.html.

St. Johns River Water Management District. 2004. *GIS Export Library*. [Online] Retrieved March 16, 2004 at http://sjr.state.fl.us/programs/data.html

Taylor, A.K., P. Sprott, and F.J. Mazzotti. 1990. The vital link between land and water: the importance of uplands for protecting wetland functions. Report No. WEC-45. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. [Online] Retrieved July 15, 2003 at http:/edis.ifas.ufl.edu.

Teisinger, J.K. 2002. *Where Will We Grow? Using Geographic Information Systems to Determine Florida Statewide Residential Growth Potential.* Submitted in partial fulfillment of the requirements for the degree of Master of Arts in Urban and Regional Planning to the Graduate School of the University of Florida, Gainesville, Florida.

The Florida Senate. 2003. The 2003 Florida Statutes. The Florida Senate Online. [Online] Retrieved November 4, 2003 at http://www.flsenate.gov/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=Ch0373/SEC4135.HTM&Title=->2003->Ch0373->Section%204135

The Nature Conservancy. 1998. *Restoration Procedures Manual for Public Lands in Florida.* 124 pp. [Online] Retrieved on September 12, 2003 at http://www.dep.state.fl.us/water/wetlands/docs/mitigate/mitman.pdf/

U.S. Environmental Protection Agency. 1995. *Federal Guidance for the Establishment, Use, and Operation of Mitigation Banks.* Notice, Federal Register: November 28, 1995 60(228). Pp. 58605-58614 [Online]. Retrieved February 10, 2003 at http://www.epa.gov/OWOW/wetlands/mitbankn.html.

U.S. Environmental Protection Agency. 2001. Supreme court ruling concerning CWA jurisdiction over isolated waters. [Online] Retrieved October 19, 2002, http://www.epa.gov/owow/wetlands/swancc-ogc.pdf.

Voigt, P.C. and L.E. Danielson. 1996. Wetlands mitigation banking systems: a means of compensating for wetlands impacts. *Applied Resource Economics and Policy Group Paper AREP96-2.* [Online] Retrieved November 11, 2002 at http://www.bae.ncsu.edu/bae/programs/extension/publicat/arep/2arep962.html.

Votteler, T.H. and T.A. Muir. 2002. Wetland management and research: wetland protection legislation. *U.S. Geological Survey Water Supply Paper 2425.* [Online] Retrieved July 23, 2003 at http://water.usgs.gov/nwsum/WSP2425/history.html.

Whited, D., S. Galatowitsch, J.R. Tester, K. Schik, R. Lehtinen, and J. Husveth. 2000. The importance of local and regional factors in predicting effective conservation planning strategies for wetland bird communities in agricultural and urban landscapes. *Landscape and Urban Planning* 49: 49-65.

Williams, K.B. 2002. *The Potential Wetland Restoration and Enhancement Site Identification Procedure: A Geographic Information System For Targeting Wetland Restoration and Enhancement*. North Carolina Division of Coastal Management, Department of Environment and Natural Resources, Raleigh, NC.

Zedler, J.B. 1996. Coastal mitigation in southern California: the need for a regional restoration strategy. *Ecological Applications* 6(1): 84-93.