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A GIS-Based Approach to Evaluating Changes in Wetland Areal Extent and Structure Between 1926 and 1999 for Selected Hydrological Sub-Basins in Pinellas County, Florida

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A GIS-Based Approach to Evaluating Changes in Wetland Areal Extent and Structure Between 1926 and 1999 for Selected Hydrological Sub-Basins in Pinellas County, Florida

by

Pamela J. Fetterman

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
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Dedication

This thesis is dedicated to my mother, and to the mystery of the indefatigable process.

True happiness is in love, which is the stream that springs from one's soul. He who will allow this stream to run continually in all conditions of life, in all situations, however difficult, will have a happiness which truly belongs to him(er).

---Hazrat Inayat Kahn
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A GIS-Based Approach to Evaluating Changes in Wetland Areal Extent and Structure for Selected Hydrological Sub-basins between 1926 and 1999 in Pinellas County, Florida

Pamela J. Fetterman

ABSTRACT

A GIS-based study was undertaken comparing wetland coverages in 1926 and 1999 in selected sub-basins within Pinellas County, Florida, one of the most highly urbanized counties in south-central Florida with almost 50% of the existing land area developed into industrial, commercial or residential land uses (Pinellas County Planning Department, 2002). Wetlands were digitized from rectified 1926 aerials and classified according to the FLUCCS classification system. Wetland coverage for the 1999 data set was extracted from FLUCCS 1999 land use coverage provided by the SWFWMD, and topology for both the 1926 and 1999 wetland and surface waters were created. Statistical and spatial analysis was then performed on the vector feature class layers to determine net wetland loss and gain, by watershed, within the sub-basin study area.

Results indicate that substantial and statistically significant net losses in areal extent occurred between the 1926 and 1999 study time frames in most sub-basins for freshwater forested, freshwater herbaceous, saltwater herbaceous, non-vegetated wetlands and in total wetland areal extent. Both open water and upland exhibited statistically significant net increases in areal extent over the same time period. Losses are directly attributable to human-activity such as excavation, ditching, draining, and filling.
Chapter One: Research Objectives and Development History of Pinellas County

Introduction

Wetlands are perhaps one of the most regulated habitats throughout the United States, with layers of Federal, state and local regulations limiting human use of these environments. Likewise, they are one of the most threatened habitats in the United States and throughout the world from human development activities. Human development dates back to at least the dawn of civilization, with increasing evidence of prehistoric use and development (Mitsch and Gooselink, 2000). Use and alteration of these environments throughout human history have been fundamental to our survival as a species. As a landscape component, wetlands provide a number of important ecological and hydrological functions that support and maintain life on this planet. Their protection and regulation has, in large part, resulted from an increased understanding of how their ecosystem function supports human society. Thus, wetland ecological and hydrological functions provide significant services and commodities (for example, food resources or flood water attenuation), termed “wetland values” in the literature, that serve as life-support for human society.

Wetlands are also some of the most ubiquitously altered ecosystems found on the face of the earth. Few wetland systems remain that have not experienced some form of human-induced impact, with hydrologic impacts producing the most profound changes in wetland structure and function, and wetland loss overall. Direct hydrologic impacts
include filling and dredging, both of which result in conversion of wetlands to some other landform types—as either uplands or open surface water bodies. Other direct hydrologic impacts include ditching and draining, and diversion of watershed area or changes in water quantity (volume) entering a system. Other types of impacts that can substantially affect hydrology are levee building, highway construction through wetlands, subsurface mining and ground water withdrawals. Most remaining wetland systems in the world today experience a combination of direct and secondary impacts, such as wetland alteration for and by cattle. Using cattle grazing as an example, typical alterations include excavation of the deeper portion of wetland systems for cattle watering, spoil disposal in the shallower portions from excavation, and vegetative structural changes in both species composition and dominance from grazing impacts.

As a result of these types of activities and uses of wetlands worldwide, Dugan (1993) has estimated as high as a 50% loss of original wetlands. Although wetlands have been ditched, drained, impounded and filled throughout the history of humanity, the speed and effectiveness of wetland conversion starting circa 1850 in the United States, one of the most well documented areas of the world, is unprecedented (Mitsch and Gooselink, 2000). The United States Fish and Wildlife Service (USFWS), by legislative mandate, has created the National Wetlands Inventory (NWI), which documents, through mapping of aerial and satellite imagery, changes in wetland and deepwater habitat areal extent, structure and status since 1982, with 10 year updates (NWI, 2003). By the first NWI estimates in 1986, an estimated 53% loss of wetlands had already occurred within the United States between 1780 and 1980 (Dahl, 1990 and 1991). In the latest NWI report from the U.S. Fish and Wildlife Service, a net loss of an
additional 644,000 acres of wetlands occurred between 1986 and 1997 (Dahl, 2000). For the southeastern United States, containing almost half (43%) of the wetlands within the United States, the NWI estimated an annual net loss rate of 259,000 acres between 1970 and 1980 (Heffner et al, 1984). Documentation of wetland loss and conversion throughout the 20th century for regulatory, development planning and ecological restoration/management purposes is becoming increasingly more important at finer temporal and spatial scales than the analyses provided by the NWI. Finer spatial and temporal scale wetlands trends estimates are particularly important in high-development regions such as the southeastern United States, where the speed and intensity of development activities are outpacing the NWI mapping time frames.

Thus, one of the primary purposes of this thesis is to develop a flexible GIS model for estimating wetland loss at finer spatial scales between any given time periods using commonly available land use data and classification schemes, thus making the model easily applied and exportable to other locations. The model thus developed is primarily intended for application when the years of comparison are already mapped with the same land-use classification system. However, due to the fact that 1926 was not previously mapped, an intensive digitization process applying the FLUCCS land-use classification system was required in order to apply the GIS model developed, and determine net wetland and surface water losses and gains between 1926 and 1999 for this study. The digitization process required for the 1926 data set is not an exportable process, and requires use of personnel with basic knowledge of wetland science as well as localized knowledge and experience with the area being digitized.

Despite having to digitize the 1926 data set, Pinellas County in south central
Florida is nonetheless an excellent area to conduct a finer spatial scale study of wetland loss throughout the 19th century and to develop such a model. Since the 1950's, Pinellas County has seen a tremendous loss of wetland and green space, mostly resulting from rapid urban development. As of 2002, Pinellas County has almost 50% of the land area developed into industrial, commercial or residential land uses (Pinellas County Planning Department, 2002). Throughout this period of development there also exists a library of finer scale aerial photography from which changes in land use and land-cover can be assessed. Thus, Pinellas County presents an excellent case study for application of a GIS model to determine wetland loss over time, and for examining changes in wetland structure and consequently, changes in ecological function, resulting from land conversion. Through the use of a GIS-based analysis comparing changes in wetland and surface water land-cover between 1926 and 1999 for selected sub-basins in Pinellas County, Florida, this study proposes to:

1) Develop a finer spatial scale model to estimate the amount of wetland loss, and conversion of wetland types by watershed using commonly available land-use classification data. The model that will be developed to determine wetland net loss and gain will be applicable to any other geographic setting in the United States, and can utilize either complete landuse/landcover data or just wetland and surface water cover data sets.

2) Evaluate changes in wetland structure for any remaining wetlands in Pinellas County by analyzing changes in wetland classification for 6 subclasses: Open Water, Freshwater Forested, Freshwater Herbaceous, Saltwater Forested, Saltwater Herbaceous and Non-vegetated;
3) Identify those watersheds in Pinellas County experiencing the greatest amount of wetland loss and/or conversion between wetland subclass types, and between three generalized land cover categories of wetland, open water and upland (all non-wetland/non-water classified area). In the identification of the sub-basins experiencing the greatest net losses, the sub-basin differences will also be tested for statistical significance for each of the subclass and generalized land cover categories.

4) Conduct a cluster analysis of the sub-basin net loss and gain data to determine if the data exhibit any groupings or patterns of clustering. Should the analysis determine that groupings exist; probable causes for these groupings will be analyzed and discussed.

5) Determine probable causes contributing to overall wetland loss as well as any identified changes in wetland structure between 1926 and 1999 for remaining wetlands in Pinellas County.

6) Discuss the ways in which the results can be used by Pinellas County to target restoration activities.

The GIS mode developed and the objectives presented above are intended to address and answer three primary research questions: 1) Are there statistically significant differences in wetland areal extent between 1926 and 1999 by hydrological sub-basin within the study area? 2) Which generalized wetland and surface water types (freshwater forested, freshwater herbaceous, saltwater forested, saltwater herbaceous, non-vegetated and open water) exhibit the greatest differences by sub-basin, and how do these differences group within the study area? And finally, 3) Is there a clear link between differences in wetland
areal extent between the selected study periods (1926 and 1999) and development trends within that same time frame?

**Geographic Setting**

Pinellas County, located in west-central Florida in the Gulf coastal lowlands physiographic district, is a peninsula which separates the Gulf of Mexico and Tampa Bay (White, 1970). Figure 1 presents the location of Pinellas County within the greater Florida Peninsula. The Pinellas peninsula began as a large island in the mouth of Tampa Bay, gradually connecting to the mainland peninsular Florida through littoral processes occurring from the Pleistocene to Recent times (Gregory, 1984; Tedrick, 1972). The Pinellas Peninsula, like the greater Florida peninsula, is underlain by a series of sedimentary carbonate units deposited in shallow ancient seas. Present day Florida represents the exposed portion of the greater Floridan platform, and the formation of the present-day peninsula is largely a history of siliclastic sediments deposited and reworked during sea-level rise and fall from the Miocene through the Holocene and superimposed on karst landforms resulting from carbonate dissolution processes (Scott, 1997).

Pinellas County topography is characterized by several Pleistocene marine terraces (mantles of sand ranging between 2 to 35 feet in thickness) representing shorelines of ancient sea-level stands (SCS, 1972). The scarps of these terraces are often represented by abrupt elevations changes, and of the seven marine terraces identified in Florida, four are present in Pinellas County. These are (1) The Pamlico terrace ranging from 1 to 15 feet thick, occurring at elevations of 0 to 25 feet above mean sea level, and
characterized by Oldsmar and Wabasso series soils with acid sand upper horizons and loamy subsoils; (2) The Talbot terrace consisting of fine sands 16 feet thick or less, occurring at elevations of 25 to 42 feet above mean sea level, and characterized by acid
Astatula, Immokalee, Myakka and Pomello series soils; (3) The Penholoway terrace consisting of fine sands up to 25 feet thick, occurring at elevation of 42 to 70 feet above mean sea level and characterized by Astatula, Immokalee, Myakka, Paola, Pomello and St. Lucie series soils; and finally, (4) The Wicomico terrace consisting of fine sands up to 27 feet thick, occurring at elevations of 70 to 97 feet above mean sea level, and consisting of Astatula, Immokalee, Paola, Pomello and St. Lucie series soils (SCS, 1972). These stands resulted from sea level oscillations that occurred throughout the last one million years due to advances and retreats of four great ice sheets. Figure 2 presents the geology of Pinellas County mapped by time series.

Thus, major relief features of the Pinellas peninsula were formed by the same geologic processes that created the physiography of the greater Florida peninsula. Like Florida, the Pinellas peninsula relief is characterized by a sand ridge and hilly uplands running from the northern to the central western part of the county. The southeastern part of the county also contains a large, flat upland plateau. The central, southeastern and barrier islands of the County are characterized as flat lowland (Heath and Smith, 1954; Pinellas County Planning Department, 1968; and, Causseaux, 1985). Surface erosion by small streams, continued modification of the barrier coastline by wave action, and carbonate dissolution of the underlying limestone are the major geologic processes that created and are still creating the current surface topography of Pinellas County since the last sea-level regressive event.

In perusing the 1972 Pinellas County soil survey aerials, despite the relatively high degree of alteration at this point in Pinellas’ history; one can still see that wetlands
Figure 2: Pinellas County geology and marine terraces.
were historically found on all the major relief features described above. Their formation results from the same geologic processes currently sculpting the peninsula. Wetlands were historically present as depressional features in the lowlands, flat uplands and within the hilly uplands; as floodplain features associated with streams and rivers, as linear trough features associated with the Pinellas ridge and with sand dunes on the barrier islands; as seepage areas and depressional karst landforms associated with escarpment edges of the Pinellas ridge as well as hilly uplands and flat upland areas, and as tidal marshes and swamps along the Gulf, Tampa Bay and barrier island coastlines. Thus, at one time, most wetland types typical of the greater Florida peninsula were found in Pinellas County.

Key to understanding wetland loss between 1926 and 1999 are identifying those agents of loss at play within the analysis timeframe. One of the hypotheses of this thesis is that human activity, particularly urban and suburban development, are the primary agents contributing to wetland loss in Pinellas County. Thus, it is extremely pertinent to this analysis to review the development history of Pinellas County, and the major development events and time frames when wetland loss most likely occurred. A review of the development history will also give an historical context for the two timeframes under consideration: 1926 and 1999, and verify to what extent the 1926 data set represents an appropriate background data set of little to no wetland loss or disturbance. A brief development history is summarized below. This history is adapted from the Pinellas Planning Council’s published history and highlights the major events that served as significant forces encouraging development. Figure 3 presents the current municipalities and unincorporated areas of the County. Review of Figure 3 on the
Figure 3: Incorporated and unincorporated areas of Pinellas County (Pinellas County Planning Department, 2002).

Note: The unlabeled, light yellow areas represent unincorporated areas of the County.

The following page will orient and familiarize the reader to the areas of the County discussed.
in the development history presented below.

Development History

As early as 1528 the area now known as Pinellas County was visited by the Spanish explorer Ponfilo de Narvarez, with later excursions by DeSoto in 1539. The landscape that greeted the Spanish explorers was a primeval forest dominated mostly by pine flatwoods (“Pinellas” being derived from “punta pinal”, which translates to point of pines). Also prevalent were open beaches with wide dune areas, extensive mangrove swamps on the fringing barrier islands and along the bays surrounding the peninsula, and lush hardwood forests from Indian Rocks to Dunedin, and in the southern upland area that is now St. Petersburg. Wildlife was abundant, with huge wading bird rookeries and bald eagle nests common throughout the peninsula (Pinellas Planning Council, 1979 and 1986).

In 1832 the first permanent white settlement was established at Safety Harbor, on the northern bay side of the peninsula by Odet Philippe. Two years later, in 1834, Hillsborough County was formed, which included the Pinellas peninsula within the County’s jurisdiction. However, the real impetus for the first wave of settlement did not come until 1842 when the Armed Occupation Act became effective. Under this law, any head of family or single man over 18 years of age that would bear arms, build a fit habitation for five years and cultivate at least 5 acres was provided with 160 acres of land. Even with this attractive offer, the peninsula was slow to settle, with only 50 families occupying the area at the start of the Civil War (Pinellas Planning Council, 1986).
The first areas settled (Clearwater, Ozona, Indian Rocks and St. Petersburg) were conducive to agriculture or within sheltered coastal areas convenient to boat travel to other points in Florida, resulting in isolated areas of development. The interior of the peninsula remained unsettled, and travel over land between settlements was fraught with difficulty. As described by Straub: “When it is said ‘far apart’ on a peninsula only four to fifteen miles wide, it should be remembered that, in addition to the forests, the land was generally covered with densely growing bushes, shrubs and small trees jammed with tall grass that made a jungle difficult to penetrate, with streams of water everywhere” (Straub, 1929).

Despite its relatively unoccupied status, the first major environmental stresses from settlement and farming activities occurred during the late 1800s and early 1900s. These environmental stresses included the deforestation of the St. Petersburg upland and nearby cypress wetlands for lumber, conversion of large areas around settlements for citrus agriculture, the elimination of major predators through organized bear and panther hunts (considered a threat to cattle), and depletion of wading bird populations and destruction of rookeries from plume hunting (Pinellas County Planning Council, 1979 and 1986).

During the late 1880s, an infant tourism industry emerged, later to become a significant economic base and impetus for further development of the peninsula. Dr. W.C. Van Bibber presented a report to the American Medical Society convention in New Orleans, prescribing the healthy climate of the peninsula for many ills, and laying claim to the peninsula as “the healthiest spot on earth.” However, significant development of this industry and the budding agricultural industry did not take place until major
transportation advances made the peninsula more easily accessible. In fact, advances in transportation serve as one of the most important factors contributing to early development on the peninsula.

The first of these major transportation milestones occurred in 1887 with the coming of the Orange Belt Railroad, terminating in St. Petersburg. This brought the first major wave of growth to the peninsula, and ended the pioneering phase. During this period as well, Tarpon Springs became the first incorporated city, originally speculated by Hamilton Disston, who erected one of the first hotels on the peninsula, the Tropical. Disston also became one of the first major tourist developers of the peninsula, and established Disston City, now Gulfport, which included the Hotel Waldorf. The railroad also spurred development of St. Petersburg as the peninsula’s first major metropolis. Other towns along the railroad also rapidly developed, and included the previously mentioned Tarpon Springs, as well as Sutherland (Palm Harbor), Ozona, Dunedin, Clearwater and Largo.

With the railroad came the first real tourist industry, and construction of the largest, occupied wood-frame structure in the world—the Biltmore Hotel in Belleair. The construction of the hotel is credited by historians as one of the major factors that promoted the resort industry and increased the economic status of visitors to the peninsula. The citrus industry also benefited greatly by the railroad, which provided greater and speedier marketing opportunities and delivery of crop. The community of Tarpon Springs and its natural resource based sponge industry was also beginning to flourish, attracting great numbers of Greek immigrants.

The years following the railroad saw the incorporation of more beachfront
communities and the secession of the peninsula from Hillsborough and the establishment of Pinellas County. The creation of Pinellas as a separate county created the political structure needed to mobilize capital and begin developing infrastructure, including badly needed roads connecting communities lying off the main railroad corridor. Development spurred by the railroad also fueled dramatic population increases in settled areas along the railroad line. Population in the major settlement areas of St. Petersburg grew by 804% (1,575 residents to 14,237 residents), in Clearwater by 608% (343 residents to 2,427 residents), in Dunedin by 468% (113 resident to 642 residents) and in Tarpon Springs by 289% (541 residents to 2,105 residents) (Pinellas County Planning Council, 1986, p. 11). The 1900 to 1920s population growth spurt, in part, was also fueled by the 1920s Florida real estate boom which actually began in 1918 in Pinellas County with a large influx of tourists following the end of World War I that same year.

The coming of the Florida real estate boom (1921-1925) saw a significant building boom in Florida in general and Pinellas County in particular. The County’s population growth rate during the 1920s was estimated at approximately 120%, exceeding both the nation (16%) and the state (52%) (Pinellas County Planning Council, 1986, p. 38). During this period as well, most of the big beach and bay front hotels were built, including the world famous Don CeSar, and a large number of small hotels to accommodate the emerging trend of automobile tourism. Further igniting the automobile tourist trend was the opening of the Gandy bridge in 1924 (the world’s longest automobile toll bridge at that time) between Tampa and St. Petersburg. Also in the early 1920s, “plans were begun in 1922 for the first modern system of standard type highways to serve each section of Pinellas County”, which resulted in a 2000% increase in traffic
on county roadways between 1923 and 1928 (Straub, 1929, p. 70). This system not only included direct links between population centers, but also scenic routes for the automobile tourist, such as the scenic roadways built around Boca Ciega Bay (from Pass-a-Grille bridge to the Madeira Beach causeway), the causeway to Clearwater Beach, and shoreline routes connecting Dunedin to Ozona, and another route connecting Bayview to Safety Harbor and the Safety Harbor Bridge. However, other than Clearwater Beach, significant development of the barrier island gulf beaches did not occur during this time period mostly due to “limited access from the mainland, inadequate utilities and services (especially water supply), and numerous mosquitoes.” (Pinellas County Planning Council, 1986, p. 65).

The automobile tourist trend began a cycle of tourist-based expansion and development at play even today. The automobile made vacationing in Florida accessible to all income levels:

...Henry Ford’s inexpensive Model T’s enabled even persons of moderate income to make the trip to Florida. In describing these less affluent tourists, one writer has noted that, “Although their expenditures may not have pumped a lot into the economy, they were great at talking up the virtues and attractions of Florida when they got home, luring others in their wake” (Nolan, 1984, p. 187). Soon, a cycle was well underway, whereby more visitors of all income levels came, invariably investing in real estate, drawn by the lure of easy money and quick profits. This was the start of a period in Florida that came to be known as the Boom, a fast-paced time of multi-million dollar developments, magnificent hotels, and the frenzied buying and selling of real estate (Pinellas County Planning Council, 1986, p.30).

The real estate boom as well fueled the first significant wave of wetland dredging and filling on the peninsula and within the surrounding bays for roadways, beach and bay front commercial development in already established areas, and a few early waterfront canal-style residential developments.
In the early nineteenth century, the type of machinery needed for dredging and filling operations was still relatively primitive and costly to operate. Despite this, by 1926 fresh fill along Tampa, Boca Ciega and Clearwater Bay are evident on the 1926 aerials. An earlier aerial-based fill study conducted by the Pinellas County Planning Department found evidence indicating that no significant fill occurred prior to 1900 in the County (Pinellas County Board of County Commissioners, 1970). However, this short-lived boom of land speculation and development ended abruptly in early 1926, resulting in a steep decline in land prices and shortages of capital. With the onset of the Great Depression in 1929, the local economy was devastated, to the point that immigration into the County ceased, and in some cases such as St. Petersburg, immigrants were outright rejected due to lack of employment.

Yet, even during the 1930s and 40s, mostly as a result of the influx of federal monies and programs designed to lift the nation out of the Great Depression, several significant transportation and development advances did occur, specifically paving the way for the post-World War II development of the Gulf Coast barrier islands and beaches. During this time period, Pinellas County also developed its water system (1934), and constructed the Treasure Island causeway (1939) connecting St. Petersburg with the infant city of Treasure Island. Throughout the 1930s, the County’s population growth rate continued to exceed both the nation and the state, growing by approximately 48% (Pinellas County Planning Council, 1986, p. 38). Yet, even with this significant growth rate, by 1943, the County only urbanized less than 10% of the total land area. According to statistics compiled by the Pinellas County Planning Council, from 1930 on the percent of the population residing in urban areas far outpaced the percent residing in
rural areas, which steadily declined from 1920 through 1980 (Table 1). This is a significant trend that poignantly illustrates the history of urbanization in Pinellas County, revealing the early orientation of the County’s economics towards tourism.

Table 1: Population growth and percentage of population residing in rural versus urban areas in Pinellas County from 1920-1980 (adapted from Pinellas Planning Council, p. 35, 1986).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Population</th>
<th>Urban Population (% of Total)</th>
<th>Rural Population (% of Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>28,265</td>
<td>50.4</td>
<td>49.6</td>
</tr>
<tr>
<td>1930</td>
<td>62,149</td>
<td>82.8</td>
<td>17.2</td>
</tr>
<tr>
<td>1940</td>
<td>91,852</td>
<td>80.9</td>
<td>19.1</td>
</tr>
<tr>
<td>1950</td>
<td>159,249</td>
<td>86.5</td>
<td>13.5</td>
</tr>
<tr>
<td>1960</td>
<td>374,665</td>
<td>91.1</td>
<td>8.9</td>
</tr>
<tr>
<td>1970</td>
<td>522,329</td>
<td>96.2</td>
<td>3.8</td>
</tr>
<tr>
<td>1980</td>
<td>728,531</td>
<td>99.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

With the onset of World War II, the County’s growth rate slowed, as the war effort demanded labor in the major industrial centers in the north and Midwest. The tourist industry was likewise impacted, but was soon boosted by an Army Air Corpstraining center, established in St. Petersburg. Hotels in the area were rented by the Federal government and converted to dormitories for the fresh recruits, and the St. Petersburg-Clearwater International Airport was constructed to train fighter pilots. The end of the war, in 1945, heralded one of the largest growth periods experienced thus far by the southwest Florida region and Pinellas County, continuing into the 1970s.

This post-war boom was fueled by several factors, including housing shortages resulting from the cessation of war-time civilian building, an increased demand for
waterfront property exceeding supply, spurred by the rebirth of the tourism industry, and
the completion of the final phase of US 19 terminating in St. Petersburg. The completion
of US 19 provided a direct automobile connection from Tallahassee and regions north,
thus spurring rapid commercial development along this major transportation corridor.
The net result was large-scale wetland losses from large, planned residential
developments and fill operations on the barrier islands to create beaches and new
developable upland.

Throughout the 1950’s, dredges were operated 24 hours a day. These filling
operations drastically increased the amount of upland for development, and significantly
modified the County’s bay fronts. Treasure Island, for example, doubled in size and an
entire new island (Terra Verde) was created during this time period. By 1970, 4,790
acres in Tampa, Boca Ciega and Clearwater Bays were filled for development, resulting
in significant losses of estuarine and marine wetland systems within and along bay front
shorelines. By 1963, approximately 39% of the County’s land area was urbanized.

Adding to the amount of fill upland created in Tampa Bay was construction of two of the
areas largest and longest bridges---the first span of the Sunshine Skyway Bridge in 1954
(providing a major connection between the Tampa Bay area to more southern Manatee
and Sarasota County coastal areas) and the Howard Franklin Bridge in 1960 (providing a
faster and more direct automobile connection between the region’s two largest cities—
Tampa and St. Petersburg).

As early as 1955, adverse environmental effects resulting from fill development
were recognized, and the Pinellas County Water and Navigation Control Authority was
created to regulate and control development of navigable surface waters within the
County. Prior to any national or state wetland’s regulation, Pinellas County representatives in the state legislature in 1969 and 1972, respectively, proposed two Special Acts to create the first Aquatic Preserves: Boca Ciega Bay and the Pinellas County Aquatic Preserve, which effectively stopped the sale of state-owned submerged lands by Florida to private developments thus stopping the massive dredge and fill bay front and barrier island developments.

What these local rules did not halt, however, were filling of isolated wetlands for development purposes, or the continued spread of urban sprawl development throughout the interior of the peninsula. Beginning in the post-war period and into the 1980’s, a second major form of commercial development began to take significant hold---the shopping centers, and later in the 1970’s, the shopping malls. The post-war boom of suburban residential development outside of the traditional downtown business centers created a demand for services more proximate to these new developments, which in turn created more of a demand for infrastructure and roadways. This cycle of development continued throughout the post-war period and beyond, and can still be witnessed throughout southwestern Florida today. Mobile home developments, as well, gained popularity during this time period because of their affordability to moderate income folks and retirees, giving them an opportunity for second residences, and the ability to escape to the mild climate of southwestern Florida from severe northern winters (Pinellas Planning Council, 1986).

The 1970’s heralded another major boom period in building with the advent of condominium development. By 1973, development had sorely outpaced infrastructure resulting in potable water and sewage treatment shortages, resulting in a short-term
building moratorium in the mid seventies and potable water rationing. The infrastructure crises also led to the re-establishment of the Pinellas Planning Council in 1974 (created 10 years earlier) in its present form and capacity under a Special Act of the Florida Legislature, mandating the development of a comprehensive plan for growth management and regulation of ad hoc development.

The comprehensive plan as a means of development regulation was further strengthened by the 1975 passage of the state-wide Local Government Comprehensive Planning Act. Part of the function of the plan was to identify priority natural areas for conservation and preservation purposes, and in 1979 many of the large, remaining, undeveloped wetlands in the Brooker Creek watershed were preserved through creation of a County park. A substantial portion of Sand Key was also preserved during this time period, thus preserving a portion of the quickly disappearing sand dunes and interdunal wetlands from the condominium development relentlessly marching down the barrier islands’ beaches and shorelines.

Wetlands regulation in the form of the Clean Water Act, Section 404, also made its advent in the 1970s, and the Army Corps of Engineers became the delegated Federal agency to regulate, through permitting, dredging and filling operations in waters of the United States. However, isolated depressional wetlands were not included within their regulatory purview. State regulation of wetlands and surface waters emerged in 1984 with the passage of the Warren Henderson Act, later evolving into the Environmental Resource Permitting program in 1994. Both the Federal and Florida state regulatory programs require mitigation (replacement) for permanent dredging and filling impacts to wetlands and surface waters. However, by the time federal and state wetlands regulation
became effective, Pinellas County had lost 79% of its total forested acreage to development, with Cypress and other forested wetlands and mangrove wetlands likely a significant portion of the 79%.

The 1980’s brought additional commercial and residential development, most noteworthy of which is the proliferation of shopping centers, and expansive growth into the northern regions. This growth trend, which continues into the current day, is transforming the remaining undeveloped regions such as Palm Harbor, East Lake Tarpon and the historic cities of Oldsmar and Safety Harbor. The Oldsmar and Safety Harbor regions saw a relative decline in development early on after the coming of the railroad to St. Petersburg shifted development to the central, southern and western County (Pinellas Planning Council, 1984). The other major area to see an increase in development is Gateway/Highpoint in mid-county. This development trend to the north is particularly noteworthy, as the majority of the remaining wetlands and undeveloped karst depressions are located in this part of the County.

An effect of federal and state wetlands and storm water regulation on development in the County has been to effectively restrict further development into wetlands and floodplains located within the hotspot development areas that emerged in the 1980s. The North County and Gateway/Highpoint areas continue to experience the highest rates of growth through the 1990s and into the millennium. Floodplain areas and wetlands are now generally taken out of the “developable land” determination, as these areas are extremely difficult and cost prohibitive to mitigate with so little remaining open land available within the County. Additionally, the County comprehensive plan has also adopted local regulations restricting and limiting development in these areas. Throughout
the 1990s and into the new millennium, County government has also increased its efforts by purchasing and protecting environmentally sensitive areas, such as undeveloped beachfront, scrub habitats, wetlands and other locally rare upland habitats in unincorporated areas of the County. As a result, land designated as preservation/conservation has increased from 13.25% in 1989 to 23.43% in 2002 (Pinellas Planning Department, 2004).

Thus, the 1924 and 1999 wetland’s loss analysis encompasses the majority of the development events except for initial settlement and the first major wave of commercial and residential building that occurred in the early part of the 1920s real estate boom. The development history thus presented, with the major real-estate/building booms overlain on population growth since settlement (see Figure 4 below), is an excellent context within which to interpret the analysis results.
Figure 4: Permanent population growth in Pinellas County from 1890 to present, with major real-estate and building booms identified. (Pinellas County, 2005).
Chapter Two: Literature Review

Using GIS platforms as a basis for estimating wetland loss is well established in both academic and government literature. The advent of wetlands regulation in 1972 created a need for both localized and national level inventories both to document the rate of loss as well as determine the effectiveness of regulatory programs to stem the tide of wetland loss and conversion. In this chapter, the NWI program previously referred to in Chapter 1 is reviewed in depth, as well as several juried studies examining wetlands loss and conversion. Through this literature review, several specific agents of loss and conversion consistently emerge. Also discussed are common land-use classification schemes used for wetlands loss studies. Land-use classification mapping is an integral part of wetlands loss analysis, and the classification scheme used can have significant effects on the estimates derived, as well as on the comparability between estimates.

**National Wetlands Inventory (NWI) estimates of Wetland Loss and Conversion**

The USFWS through the NWI program maintains the most comprehensive GIS database of wetland coverage and changes in wetland coverage since 1982 for the United States. The NWI is charged with conducting wetland status and trends studies by the Emergency Wetlands Resource Act of 1986. The methodology employed for all the wetland status and trends reports is consistent, and is accomplished through a stratified sampling design consisting of 4,375 randomly selected sample plots throughout the United States (Dahl, 2000). The NWI relies heavily on aerial and other remotely sensed
imagery and GIS-based technologies in combination with field ground-truthing for determining changes in wetland and deepwater habitat areal extent, structure and status (gains and losses) since 1982, with 10 year updates (NWI, 2003).

While the NWI wetlands data set and status and wetland trends reports are by far the most comprehensive studies of wetlands loss in the United States, producing a relatively high level of accuracy (estimated at over 90% by Kudray and Gale, 2000), the status and trends time frames and mapping methodology limits application of NWI data sets to regional level studies. For example, the NWI wetland status and trends reports generally consider 10 year time frames, and a single 10 year status and trends report uses imagery from a mosaic of different years (Dahl, 2000). Additionally, the target mapping population is wetlands 3 acres and larger (Dahl, 2000). Although the NWI results show that for all wetland categories the minimum sized mapped was less than an acre, Dahl (2000) states outright that not all wetlands less than 3 acres were mapped. For regional scale studies, particularly in the coastal southeastern United States where the landscape is dotted with numerous depressional wetlands less than 3 acres, the NWI mapping methods can potentially grossly underestimate the amount of wetland loss or conversion. Likewise, the 1986-1997 report also found that land use changes in Florida were some of the most numerous and extensive for the study period (Dahl, 2000), again making a 10 year study period impracticable for many regional and local management purposes and needs in rapidly developing areas.

The NWI, however, has conducted large-scale regional studies in areas of unusually fast wetlands loss, as determined by the national status and trends reports. Heffner et al (1994) published a status and trends report analyzing wetlands loss from the
mid 1970s to the mid 1980s in the Southeastern United States. This study highlighted the importance of wetlands as a landscape component in the southeast. As previously mentioned, Heffner et al (1994) estimated that almost half (47%) of the wetlands within the conterminous United States occur in the southeast, and three-quarters of southeast wetlands (74%) occur within the Gulf-Atlantic coastal zone, with more than 62% of the southeast region’s total wetland loss occurring within the Gulf-Atlantic coastal zone. As determined by Heffner et al (1994), Figure 5 compares wetlands loss with the Gulf-Atlantic coastal zone to the remainder of the southeast and the conterminous United States.

Of all of the states encompassing the southeast region, Florida was found to have the highest total wetland acreage and density, approximately 30 percent of the state or more than 11 million acres (Heffner et al, 1994). A net annual loss of 260,000 acres between the mid 70s and 80s for Florida was determined (Figure 6), mostly as a result of loss or conversion to open water bodies of forested freshwater wetlands, which accounted for approximately 5.5 million acres, or nearly half of the wetland acreage within the state (Heffner et al, 1994). Heffner et al (1994) also determined that approximately two-thirds of the loss of forested freshwater (palustrine) wetlands and all 110,00 acres of herbaceous freshwater (palustrine) wetland loss was attributable to agricultural development, with the remaining one-third of forested freshwater wetland loss split evenly between urban development and “other” land uses. Estuarine wetlands within Florida were estimated at approximately 1.4 million acres, with urban development being identified as the land-use with the greatest impact on estuarine systems (Heffner et al, 1994). Florida, along with Louisiana, were two to the states experiencing the most
Figure 5: Comparison of wetland loss between the Gulf-Atlantic coastal flats and the remainder of the conterminous United States (from Heffner et al, 1994).

notable overall wetland losses in the southeast region for the time period (Figure 6).

Regional and Local estimates of Wetland Loss and Conversion

As a result of the intensive study efforts and findings of the NWI both nationally and in the southeast, several independent initiatives and some in-depth NWI studies examining regional and local wetland loss across different time scales and at finer resolution have emerged, often incorporating or comparing to NWI estimates. Changes in wetland coverage between 1937 and 1978 within the Hunting Creek watershed of Fairfax County, Virginia were examined by Newbury (1981). Kuzila et al (1991) quantified and compared GIS methods (with and without digital overlay procedures) for
Figure 6: Wetland acreages and net losses by state from the mid-1970’s to the mid 1980’s, as a percentage of total landscapes (from Heffner et al, 1994).

<table>
<thead>
<tr>
<th>State</th>
<th>Wetlands % of State Landscape</th>
<th>Millions of Acres</th>
<th>Total State Study Area</th>
<th>Standard Deviations Exceed Estimated Net Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>8%</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arkansas</td>
<td>10%</td>
<td>20</td>
<td>42,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>30%</td>
<td>30</td>
<td>240,000 acres net change</td>
<td>Includes marine and estuarine offshore habitats</td>
</tr>
<tr>
<td>Georgia</td>
<td>20%</td>
<td>30</td>
<td>78,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>Kentucky</td>
<td>1%</td>
<td>30</td>
<td>518,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td>28%</td>
<td>30</td>
<td>209,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>Mississippi</td>
<td>14%</td>
<td>30</td>
<td>1,199,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>North Carolina</td>
<td>15%</td>
<td>30</td>
<td>61,000 acres net change</td>
<td></td>
</tr>
<tr>
<td>South Carolina</td>
<td>24%</td>
<td>30</td>
<td>25,000 acres net change</td>
<td></td>
</tr>
</tbody>
</table>

estimating wetland loss in the Rainbasin region of Nebraska between 1927 and 1981.

Bernert et al (1990) used a two-stage, stratified sampling design to determine amount and

More recently, Nelson et al (2000) quantified land cover change and transition rates in the upper, freshwater part of the Barataria Basin Estuary, Louisiana over a 20 year period using 80 m Landsat MSS data. Syphard and Garcia (2001) also did a raster, GIS-based comparison between 1953 and 1994 wetland acreages in the Chickahominy River watershed to determine wetland loss and conversion due to both anthropogenic causes and beaver activity. Most commonly, however, regional and local GIS-based studies inventorying or identifying wetland areal extent and loss have been undertaken for identifying and prioritizing wetland restoration efforts (Llewellyn et al, 1995; O’Neill et al, 1997; Russell et al, 1997; Brown et al, 1998; Richardson and Gatti, 2000).

Besides the Southeastern wetlands status and trends report previously mentioned, the NWI has also undertaken statewide, regional or local mapping and status and trends studies for South Carolina (Dahl, 1999), Texas coastal wetlands (Moulton et al, 1997), for select national parks and recreation areas such as Boston Harbor Island National Recreation Area (Tiner et al, 2003) and Yellowstone Park (Elliot and Heckner, 2000), and specialized studies for the Hackensack Meadowlands wetlands located in New York and New Jersey (Tiner et al, 2002), and Maryland’s Nanticoke River and Coastal Bays
watersheds (Tiner et al, 2000).

**Agents of Wetland Loss and Conversion**

Agricultural development has been one of the primary causes cited for wetland loss, both in the southeast (Heffner et al, 1994) and throughout the United States (Kuzila et al, 1991; Imhoff, 1981; Bernet et al, 1999; Dahl et al, 1991). The latest NWI report however, documents that currently the highest wetland losses nationally (30%) are due to dredging and filling for urban development (Dahl, 1997). The remaining losses are attributed to agricultural conversion at 26%, silviculture, at 23%, and rural development, at 21% (Dahl, 1997).

Most of the referenced regional and local studies were also undertaken in areas that experienced high rates of wetland loss or alteration primarily due to some type of anthropogenic land development or conversion activity (agricultural, urban/suburban development, water resource development). The Nelson et al (2000) and Syphard and Garcia (2001) studies are some of the few published research that also examines significant natural causes such as land subsidence and beaver activity, respectively. However, Syphard and Garcia (2001) still concluded that the major agent for wetland loss within the Chickahominy watershed was the construction of two large potable water supply reservoirs, and secondly, urbanization. Beavers, in contrast were found to be a significant agent of conversion between wetland types, but not for wetland loss (Syphard and Garcia, 2000). The author’s estimated that beaver activity accounted for 23% of the 90% shift in wetland type for the 1953 to 1994 study period. Likewise, Nelson et al (2002), although concluding increases in total wetland area within the Upper Barataria
Basin were a result of land subsidence, also point to agriculture and urbanization as significant environmental stressors to the survival of any remaining bottomland hardwood forests. The authors specifically found an increase in the conversion of surrounding upland areas from native to agricultural and urban land covers, which may result in water quality and quantity impacts and thus potentially accelerating the conversion of bottomland hardwood forest [dominated by American elm (*Ulmus americana*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraceflua*) and sugarberry (*Celtis laevigata*)] into swamp forest [dominated by bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*)].

**Wetland and Land Use/Cover Classification and Mapping**

To arrive at loss and conversion estimates, all of these studies must employ some type of wetland and land cover classification scheme to lesser or greater degrees. Cowardin’s (1979) system of wetland classification is the standard for all of the NWI mapping and status and trends reports, and as a result is also one of the most widely used classification systems in many GIS-based wetlands studies.

Another national land use and land cover classification often used in GIS-based studies is the USGS Land-Use and Land-Cover Classification System for Use with Remote Sensor Data (Anderson et al, 1976). This is one of the first national classification schemes, and was specifically developed for satellite imagery data. This classification scheme employs 2 levels (Figure 8). There are several disadvantages in using this scheme for wetland loss and conversion studies: (1) the classification levels are broad, general categories; (2) only two wetland categories are defined—forested and
non-forested, thus unsuitable for any studies comparing conversions between estuarine and freshwater systems, and (3) several wetland habitat types, such as beaches and salt flats, are categorized into other Level 1 categories such as Barren Land, Tundra, and Water (Table 2).

Table 2: The USGS land cover classification scheme (from Anderson et al, 1976).

<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Urban or Built-up Land</td>
<td>11 Residential.</td>
</tr>
<tr>
<td></td>
<td>12 Commercial and Services.</td>
</tr>
<tr>
<td></td>
<td>13 Industrial.</td>
</tr>
<tr>
<td></td>
<td>14 Transportation, Communications, and Utilities.</td>
</tr>
<tr>
<td></td>
<td>15 Industrial and Commercial Complexes.</td>
</tr>
<tr>
<td></td>
<td>16 Mixed Urban or Built-up Land.</td>
</tr>
<tr>
<td></td>
<td>17 Other Urban or Built-up Land.</td>
</tr>
<tr>
<td>2 Agricultural Land</td>
<td>21 Cropland and Pasture.</td>
</tr>
<tr>
<td></td>
<td>22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas.</td>
</tr>
<tr>
<td></td>
<td>23 Confined Feeding Operations.</td>
</tr>
<tr>
<td></td>
<td>24 Other Agricultural Land.</td>
</tr>
<tr>
<td>3 Rangeland</td>
<td>31 Herbaceous Rangeland.</td>
</tr>
<tr>
<td></td>
<td>32 Shrub and Brush Rangeland.</td>
</tr>
<tr>
<td></td>
<td>33 Mixed Rangeland.</td>
</tr>
<tr>
<td>4 Forest Land</td>
<td>41 Deciduous Forest Land.</td>
</tr>
<tr>
<td></td>
<td>42 Evergreen Forest Land.</td>
</tr>
<tr>
<td></td>
<td>43 Mixed Forest Land.</td>
</tr>
<tr>
<td>5 Water</td>
<td>51 Streams and Canals.</td>
</tr>
<tr>
<td></td>
<td>52 Lakes.</td>
</tr>
<tr>
<td></td>
<td>53 Reservoirs</td>
</tr>
<tr>
<td></td>
<td>54 Bays and Estuaries.</td>
</tr>
<tr>
<td>6 Wetland</td>
<td>61 Forested Wetland.</td>
</tr>
<tr>
<td></td>
<td>62 Nonforested Wetland.</td>
</tr>
<tr>
<td>7 Barren Land</td>
<td>71 Dry Salt Flats.</td>
</tr>
<tr>
<td></td>
<td>72 Beaches.</td>
</tr>
<tr>
<td></td>
<td>73 Sandy Areas other than Beaches.</td>
</tr>
<tr>
<td></td>
<td>74 Bare Exposed Rock.</td>
</tr>
<tr>
<td></td>
<td>75 Strip Mines, Quarries, and Grave Pits.</td>
</tr>
<tr>
<td></td>
<td>76 Transitional Areas.</td>
</tr>
<tr>
<td></td>
<td>77 Mixed Barren Land.</td>
</tr>
<tr>
<td>8 Tundra</td>
<td>81 Shrub and Brush Tundra.</td>
</tr>
<tr>
<td></td>
<td>82 Herbaceous Tundra.</td>
</tr>
<tr>
<td></td>
<td>83 Bare Ground Tundra.</td>
</tr>
<tr>
<td></td>
<td>84 Wet Tundra.</td>
</tr>
<tr>
<td></td>
<td>85 Mixed Tundra.</td>
</tr>
</tbody>
</table>
Most states within the continental United States also have natural areas or heritage inventories, sponsored or in partnership with the Nature Conservancy, that map natural habitats and land covers in order to track changes in status of protected and threatened habitat types and biological diversity such as rare species occurrences. The Florida Natural Areas Inventory (FNAI) is one pertinent example, and is administered by Florida State University (FNAI, 2005). The inventory uses the Florida Land Use Landcover Classification System (FLUCCS) as the basis for many of its mapping efforts.

The FLUCCS classification system was originally created by the Florida Department of Transportation, and is now updated by Florida’s five Water Management Districts to track land use changes statewide on five year mapping intervals. The mapping is based on 1:40,000 scale color-infrared photography, and represent one of the most comprehensive and detailed coverages available. The classification system employs four levels of classification encompassing all land classes (urban, rural and natural). Levels three and four were specifically developed to map ecological and wetland communities (FDOT, 1999).

Most commonly, however, the regional and local studies previously cited have developed study or site specific classification schemes, or have relied on secondary references, such as soil survey maps, to develop land cover maps for historic time periods without mapped NWI coverages. NRCS soils data, which identifies hydric soils that typically correspond to wetland habitat types, were specifically used by Kuzila et al
(1991) to estimate 1927 wetland’s coverage, and by Bernert et al (1999) to develop a stratified sampling design for the Willamette Valley. Use of soil surveys has several advantages for historic studies in that they are mapped at relatively fine scales (1:20,000 or 24,000), are widely available, are field-mapped, and were often conducted and mapped prior to the emergence of more advanced remote sensing techniques. Additionally, the identification of hydric soil series in the surveys also results in higher probabilities of detecting wetland areas that may not be readily identified by an aerial signature on older, black and white aerial photography.

Development of a site-specific classification scheme was employed by much of the independent research previously cited. For example, the Nelson et al (2002) study of the Upper Baratara Basin relied on a land cover classification scheme previously developed by earlier research in the basin (Conner et al, 1987). The restoration studies previously cited also developed study-specific schemes, as the classification of wetland types is more critical due to the need to determine degree of alteration for identifying and prioritizing candidate sites for restoration efforts.

One of the best examples of a system specific classification scheme can be found in a series of studies mapping and classifying the vegetation of the Everglades ecosystem in southern Florida (Welch et al, 1999; Doren et al, 1999; McCormick, 1999; and Madden et al, 1999). The occurrence of unique floristic communities was one of the primary reasons that an independent initiative was developed by the National Park Service and its partners, instead of using the more widely available USGS, NWI or FLUCCS classification schemes (Madden, 1999).
Chapter Three: Research Methods

Analysis Overview

A GIS-based approach, utilizing the ESRI ARC GIS 9.2 software package was used to digitize and estimate both the degree of wetland loss and amount of conversion between generalized wetland types, to upland, and to open water for the land area comprising Pinellas County north of St. Petersburg, Florida, including the offshore barrier islands. Throughout the methods and analysis section, terms used to refer to the 1926 and 1999 hydrographic feature data sets, commonly thought of as “layers” in GIS terms, are described specifically according to definitions used by ESRI ARC GIS version 9.2, and familiarity with these terms will aid in the reading and comprehension of the results. Definitions of these terms can be found in the ESRI ARC GIS Help. Due to the intensive digitizing effort required for the 1926 mapping, the scope of analysis was changed from the entire County, as originally proposed, to exclude from the northern boundary of St. Petersburg south (roughly the southern 1/3 of the County) since almost this entire area has subsequently been converted into developed upland, and was significantly ditched and developed compared to other areas of the County prior to 1926.

Figure 7 depicts the study area sub-basins in relation to all the sub-basins comprising the County.

The analysis was conducted between two time-frames--1926 and 1999. Comparisons between these two years were based on the FLUCCS or FLUCCFS (Florida...
Figure 7: Study area sub-basins within Pinellas County.
Land Use and Cover Classification System) for land-cover types. The 1926 data represents the baseline data set, as this is effectively the earliest, most complete aerial photographic record prior to the greatest amount of development beginning in 1945 (Pinellas County Planning Department, 1986). A period of development did occur previous to the 1926 baseline data set beginning in 1918 with the 1920’s real estate boom. A gross estimate of wetland loss was not performed, although a 1915 soil survey of Pinellas County does exist which theoretically could provide an earlier baseline from which to derive an estimate of pre-1926 wetland acreage loss, particularly from St. Petersburg south.

The 1926 aerials were supplied in digital format (TIFF) by Pinellas County as scanned 1 inch = 600 foot scaled black and white aerials. Rectification and development of a project grid for the 1926 aerials was previously performed as part of a 2004 USF Master’s thesis mapping sinkholes throughout the County (Wilson, 2004). However, because of the lack of features that were consistent between the 1926 and 1999 sets, several areas are offset or do not completely overlay, and thus mapped features will sometimes appear to diverge as mapped across sheet boundaries. As part of this analysis, wetland and surface water features were photo-interpreted and digitized to create a 1926 wetlands and surface waters (hydrographic features) feature class with associated topology. These feature classes are digitally stored as part of an ArcMap geodatabase created for this analysis.

A FLUCCS classified land-use layer for the 1999 data exists and was supplied by the Southwest Florida Water Management District (SWFWMD). Classified wetland and open water features, as other land use classes encompassing non-vegetated wetland
features were selected from this layer and converted into a feature class, with associated
topology. The 1999 data set originally supplied did not contain topology, and this had to
be created and verified as part of the analysis. As with the 1926 data, the feature classes
and topology are digitally stored as part of ArcMap geodatabases created for this
analysis.

In order to determine wetland loss and conversion to other wetland types or open
water, a vector analysis approach was used for both the 1926 wetlands and surface water
and the 1999 land-use data set. A vector based analysis approach was chosen because
upland for 1926 was not mapped, therefore these areas would be classified as “no data” in
a raster-based approach. For both datasets, the FLUCCS level three tiers were
generalized into the hydrographic feature subclasses of open water, non-vegetated
wetlands, freshwater herbaceous wetland, saltwater herbaceous wetland, freshwater
forested wetland, and saltwater forested wetland. Upland acreages for the 1926 data set
were estimated as the difference between the total hydrographic features acreage and sub-
basin acreage for each sub-basin. Acreages of each hydrographic feature by sub-basin
were determined by utilizing the calculate geometry table procedure after intersecting the
sub-basin and hydrographic features feature classes for both data sets. The watershed
sub-basin layer used to create the sub-basin feature classes for 1926 and 1999 currently
exists as vector data and was supplied by the Southwest Florida Water Management
District (SWFWMD).

The hydrographic features by sub-basin feature class tables for both 1926 and
1999 were then exported to Excel spreadsheets, and final net/gain loss calculations were
performed for the entire study area and each sub-basin between 1926 and 1999. For
each sub-basin, net conversion between hydrographic feature subclasses and upland (expressed as a percentage), and between the three generalized feature type categories of wetland, open water and upland were calculated in the same manner as net hydrographic feature subclass area loss and gain. Final net/gain maps for the generalized hydrographic feature types were then created by exporting an excel spreadsheet to ARC GIS to create the data table for the generalized net/gain loss by sub-basin maps.

**Mapping Methods**

The first step in the analysis consisted of digitizing and classifying hydrographic features on the 1926 black and white aerials. The features were digitized using the editor function in Arc Map/Arc Info to create a vector land-use feature class classified by the FLUCCS, or FLUCFCS (Florida Land Use, Cover and Forms Classification System). Upland land use features were not mapped for the 1926 data set. Table 3 presents the 4-tiered classification system, which forms the organizational foundation for this analysis. Table 3 also designates the categories that were consolidated to create the categories used in the wetland acreage by sub-basin and wetlands loss analysis discussed under the Analysis Methods subsection of this chapter. The 1926 hydrographic features were only classified to the 3rd tier classification as a data attribute. A general description from the 1999 Florida Department of Transportation (FDOT) FLUCCS Manual is included in Table 3 for the level categories, as well as specific criteria for each classification level. Also included was the 7100 (beaches other than swimming beaches) and 1810 (swimming beach) subcategories within the 700 (barren land) and 180 (recreational) series, as the areas mapped in 1999 as 7100 and 1800 are essentially non-vegetated.
wetlands. Specific notes regarding application of the classification system for the 1926 data set are also included in the comments section of Table 3, especially where application may result in an interpretation different from the strict narrative description in the FLUCCS manual.

To generate the 1999 land-use feature class for Pinellas County, the 1999 land use data for the entire SWFWMD, which is also classified by FLUCCS, was clipped by the Pinellas County boundary feature class (generated from County Boundary feature class data also provided by the SWFWMD) to create a separate polygon feature class only containing land-use data within the Pinellas County boundary. The 1999 land-use data thus generated, however, excluded any open water features connected to Tampa Bay or the Gulf of Mexico, since the County boundary polygon followed the shoreline of the land mass and offshore barrier islands. As a result, several open water features occurring internal to the land mass (such as the Anclote River, for example), as well as emergent and forested off shore estuarine vegetation and non-vegetated wetland areas intermittently exposed (i.e. mangrove islands and some areas of tidal flats) had to be redigitized or copied and pasted from the original 1999 land use data set. Clearwater Harbor was also redigitized, since this is a separately named marine water body that is partially enclosed by the peninsular land mass and off-shore barrier islands.

A subset data feature class only displaying hydrographic polygon features (as identified by the FLUCCS classifications, see Table 3) was generated from the 1999 land-use layer using geoprocessing tools contained in ArcMap/Arc Info version 9.2. While a complete 1999 hydrographic features feature class was created, the open water features and offshore vegetation within offshore estuarine water bodies were excluded.
Table 3: FDOT FLUCCS code tiers and descriptions used in the classification of hydrographic features in the 1926 and 1999 data sets.

<table>
<thead>
<tr>
<th>FLUCCS CODE TIERS</th>
<th>FLUCCS MANUAL DESCRIPTION</th>
<th>HYDROGRAPHIC FEATURE</th>
<th>COMMENTS REGARDING MAPPING APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Level 2</td>
<td>Level 3</td>
<td>Level 4</td>
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<tr>
<td>Level 5</td>
<td>Level 50</td>
<td>Level 500</td>
<td>Level 5000</td>
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<tr>
<td>Level 51</td>
<td>Level 510</td>
<td>Level 5100</td>
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Table 3 Continued.

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<th>FLUCCS CODE TIERS</th>
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<td>52</td>
<td>520</td>
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<td>524</td>
<td>5240</td>
</tr>
<tr>
<td>53</td>
<td>530</td>
<td>5300</td>
<td>Reservoirs—artificial impoundments of water used for irrigation, flood control, water supply, recreation and hydro-electric power generation.</td>
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<td></td>
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<td>531</td>
<td>5310</td>
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<td>533</td>
<td>5330</td>
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<tr>
<td>53</td>
<td>534</td>
<td>5340</td>
<td>&lt;10 acres and that are dominant features</td>
</tr>
<tr>
<td>54</td>
<td>540</td>
<td>5400</td>
<td>Bays and Estuaries—inlets or arms of the sea that extend inland and included within the greater land mass of Florida.</td>
</tr>
<tr>
<td></td>
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<td>541</td>
<td>5410</td>
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<td></td>
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<td>5</td>
<td>56</td>
<td>560</td>
<td>5600</td>
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<tr>
<td>Slough Waters--Channels of slow moving water in the coastal marshland, also refers to &quot;backwater sloughs&quot; associated with inland rivers.</td>
<td></td>
<td></td>
<td>These features were rarely mapped separately from streams and waterways, except in cases of wide, poorly defined open water channels.</td>
</tr>
<tr>
<td>Level 6</td>
<td>Level 60</td>
<td>Level 600</td>
<td>Level 6000</td>
</tr>
<tr>
<td>WETLANDS--Water table at, near or above the land surface for a significant portion of the year, creating a hydrologic regime such that aquatic or hydrophytic vegetation is dominant. This code also includes unvegetated areas subject to periodic flooding. Definition in the FLUCCS manual is tailored to aerial image analysis, not to the regulatory definition of a wetland.</td>
<td></td>
<td></td>
<td>Wetland features were recognized in the low resolution 1926 data set as generally circular or polymorphic, lobed features that had a significantly darker signature than the surrounding upland. However, there were numerous exceptions to this rule for the 1926 data set, especially in areas of thick, closed upland forest canopy, some types of herbaceous wetlands, wetland areas associated with streams or lakes, coastal wetlands, and unvegetated wetland features, which often exhibited a lighter signature than the surrounding upland or open water. Prior to any signature being mapped as wetland, the signature was corroborated by soils, elevation, NWI data, in some areas mapped 1950s land use data, and in most cases either 1940's or 1970's black and white, higher resolution aerial imagery.</td>
</tr>
<tr>
<td>61</td>
<td>610</td>
<td>6100</td>
<td></td>
</tr>
<tr>
<td>Wetland Hardwood Forests--Meet a minimum 10% crown closure requirements; 60% or more dominated by hardwood species (salt or freshwater)</td>
<td></td>
<td></td>
<td>Areas with textured signatures typical of a canopy were mapped in this category if corroborated by soils, elevation, later land-use and/or 1942 and 1970s aerial signature.</td>
</tr>
<tr>
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<td>Level 1</td>
<td>Level 2</td>
<td>Level 3</td>
<td>Level 4</td>
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<tr>
<td>6 61 611 6110</td>
<td>Bay Swamps-- Loblolly bay, sweet bay magnolia, swamp bay is pure or predominant. Associated components include slash pine and loblolly pine, under story includes gallberry, fetterbush, wax myrtle and titi.</td>
<td>Freshwater Forested</td>
<td>These signatures were sometimes very difficult to interpret from salt marsh due to the low resolution of the 1926 data set. Several factors, including estimated elevation of the signature relative to MHWL, and degree of texture or darkness in the signature was used to distinguish between this community type and salt marsh, which can often include seedling mangrove. Due to mosquito ditching, the prevalence of this community type at higher elevations in later years was not used exclusively to determine presence in 1926 if no ditching was evident.</td>
</tr>
<tr>
<td>612 6120</td>
<td>Mangrove Swamps-- Coastal hardwood community composed of red and/or black mangrove that is pure or predominant, includes major associates white mangrove, buttonwood, cabbage palm and sea grape.</td>
<td>Saltwater Forested</td>
<td></td>
</tr>
<tr>
<td>613 6130</td>
<td>Gum Swamps-- Swamp tupelo (aka black gum) or water tupelo (aka tupelo gum) is pure or predominant, major associates include bald cypress and other freshwater wetland hardwood species.</td>
<td>Freshwater Forested</td>
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Table 3 Continued.

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<tr>
<td>Level 1 Level 2 Level 3 Level 4</td>
<td>Stream and Lake Swamps <em>(Bottomland)</em>: Hardwood community usually found on, but not restricted to river, creek and lake flood plains or overflow areas. Variety of hardwoods are pure or predominant, and may include red maple, river birch, water oak, sweet gum, willows, tupelos, water hickory, bays, water ash, and buttonbush. Associated species include cypress, slash pine, loblolly pine and/or spruce pine.</td>
<td>Additional mapping information.</td>
<td>This community type was most often mapped in both the 1926 and 1999 data sets for large wetland areas associated with streams, rivers and lakes.</td>
</tr>
<tr>
<td>6 61 615 6150</td>
<td>Wetland Coniferous Forests: A crown closure requirement of 10% or more and are the result of natural regeneration.</td>
<td>Additional mapping information.</td>
<td></td>
</tr>
<tr>
<td>62 620 6200</td>
<td>Cypress: Pond or bald cypress is pure or predominant. Pond cypress associates include swamp tupelo, slash pine and black titi, while bald cypress associates include a variety of hardwood species, and sweet gum and sweet bay on less moist sites.</td>
<td>Additional mapping information.</td>
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Table 3 Continued.

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<td>623</td>
<td>6230</td>
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<tr>
<td>624</td>
<td>6240</td>
<td>Cypress - Pine - Cabbage Palm—A mixed forested community type that occurs in a combination in which no species achieves dominance. Not strictly a wetlands community type, often a transitional community type between hydric and moist upland community types.</td>
<td>This community type was only mapped as hydric, or wetland, if other indicators were present to suggest sufficient hydrology (low elevations, hydric soils, signature on 1942 and/or 1970s aerials).</td>
</tr>
<tr>
<td>625</td>
<td>6250</td>
<td>Hydric Pine Flatwoods—A forest with a sparse to moderate (open) canopy of Slash pine with an herbaceous understory. Palmetto is sparse.</td>
<td>These community types were mapped as wetland if other indicators were present to suggest sufficient hydrology (low elevations, signature on 1942 and/or 1970s aerials), even though they most often occurred in flatwoods B/D soils.</td>
</tr>
<tr>
<td>626</td>
<td>6260</td>
<td>Hydric Pine Savanna—A forest with a sparse to moderate (open) canopy of slash or longleaf pine with a ground cover of grasses, forbs, and wetland shrubs.</td>
<td></td>
</tr>
</tbody>
</table>

Atlantic White Cedar is the indicator species, but may not be the most abundant. Associates include slash pine, cypress, swamp tupelo, sweet bay, red bay, loblolly bay, black titi and red maple.

Freshwater Forested

This community type was only mapped as hydric, or wetland, if other indicators were present to suggest sufficient hydrology (low elevations, hydric soils, signature on 1942 and/or 1970s aerials).

These community types were mapped as wetland if other indicators were present to suggest sufficient hydrology (low elevations, signature on 1942 and/or 1970s aerials), even though they most often occurred in flatwoods B/D soils.
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Freshwater forested
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</thead>
<tbody>
<tr>
<td>6 64 641 6410</td>
<td><em>Freshwater Marshes</em>--one or more of the following herbaceous species dominate: sawgrass, cat-tail, arrowhead, maidencane grass, buttonbush, cordgrass, giant cutgrass, switch grass, bulrush, needlerush, common reed, arrow root.</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6411</td>
<td>areal cover ≥ 66% dominated by Sawgrass</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6412</td>
<td>areal cover ≥ 66% dominated by cat-tail</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6413</td>
<td>areal cover ≥ 66% dominated by spike rush</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6414</td>
<td>areal cover ≥ 66% dominated by maidencane</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6415</td>
<td>areal cover ≥ 66% dominated by dog fennel and low marsh grasses</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6416</td>
<td>areal cover ≥ 66% dominated by arrowroot</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6417</td>
<td>areal cover ≥ 66% marsh with shrubs, brush, and vines</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6418</td>
<td>areal cover ≥ 66% giant cutgrass</td>
<td>Freshwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>642 6420</td>
<td><em>Saltwater Marshes</em>--One or more of the following salt-tolerant herbaceous species dominate: cordgrasses, needlerush, seashore saltgrass, saltwort, glassworts, fringerush, salt dropseed grass, seaside daisy, salt jointgrass.</td>
<td>Saltwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6421</td>
<td>areal coverage ≥ 66% cordgrass</td>
<td>Saltwater Herbaceous</td>
<td></td>
</tr>
<tr>
<td>6422</td>
<td>areal coverage ≥ 66% needlerush</td>
<td>Saltwater Herbaceous</td>
<td></td>
</tr>
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<td>FLUCCS CODE TIERS</td>
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<tr>
<td>6</td>
<td>64</td>
<td>643</td>
<td>6430</td>
</tr>
</tbody>
</table>

644 | 6440 | Emergent Aquatic Vegetation--floating vegetation and emergent vegetation found with or partially or completely above the surface of the water. |

6441 | Water lettuce (floating aquatic) |
6442 | Spatterdock (floating emergent) |
6443 | Water hyacinth (floating aquatic) |
6444 | Duck weed (floating aquatic) |
6445 | Water Lily (floating emergent) |

645 | 6450 | Submergent Aquatic Vegetation--Significant area of dense coverage of aquatic species and communities found growing completely below the surface of the water. |

6451 | Hydrilla |

Freshwater Herbaceous | Freshwater Herbaceous |
Not mapped in the 1926 data set, but if mapped in 1999, included in the freshwater herbaceous category. |
Not mapped in the 1926 data set, but if mapped in 1999, included in the freshwater herbaceous category.
Table 3 Continued.

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>6</td>
<td>64</td>
<td>646</td>
<td>6460</td>
<td>Treeless Hydric Savanna--A wire grass or cutthroat grass dominated system along with wetland plant associates. A treeless variant of 626. Freshwater Herbaceous</td>
</tr>
<tr>
<td>65</td>
<td>650</td>
<td>6500</td>
<td></td>
<td>Non-Vegetated-- Those hydric surfaces on which vegetation is lacking due to the erosional effects of wind and water that prohibit or hinder the establishment of plant communities, or the fluctuation of the water surface level prohibits the establishment of vegetation. Includes areas of extreme soil toxicity and acidity due to submergence and saturation that prohibit the establishment of vegetation. Non - Vegetated Wetlands</td>
</tr>
<tr>
<td>651</td>
<td>6510</td>
<td></td>
<td></td>
<td>Tidal Flats--That portion of the shore environment protected from wave action, often found within estuaries, composed primarily of muds transported by tidal channels. Characterized by an alternating tidal cycle of submergence and exposure to the atmosphere. Tidal Flats</td>
</tr>
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from the analysis after intersection with the Pinellas sub-basin data layer, as the original HUC sub-basin layer was also clipped with the County boundary layer.

Photo interpretation of wetland types and land use was corroborated and aided by GIS layers for soils (digitized from the 1972 Pinellas County soil survey, NRCS 1972), 1950 and 1999 land-use (classified by FLUCCS or FLUCFCWS), 1983 National Wetland Inventory (NWI) layer, 1970 historical black and white aerials, 1942 black and white aerials available on the Pinellas County Web site, and USGS mapped 5-foot contours supplied by the SWFWMD. Metadata for these layers can be found at http://www.swfwmd.state.fl.us/data/gis/layer_library/. The 1999 aerial photography was supplied by both the SWFWMD and Pinellas County. Since 1999 land-use was previously mapped and available from SWFWMD, this data layer was used to estimate the 1999 wetland and open water coverage. Prior to utilizing feature class or data layers provided by SWFWMD, the 1999 and 1950 land-use, soils, NWI, County boundary, 5-foot elevation data and USGS hydrologic sub basins were all converted to the same projection and coordinate system as the 1926 data set (Albers, GCS HARN 1983) so that the greatest amount of alignment could be achieved during the digitizing process.

The 1970’s black and white aerials used as an underlay during the mapping process were projected on the fly by the ArcView program. While these were used to generally corroborate the presence of wetland signatures on the 1926 aerials and determine level 3 wetland type, they were not used for digitizing the boundaries of these features. Boundaries of the 1926 wetlands were solely digitized on the basis of the signature present on the 1926 aerials.

Aerial interpretation of vegetative community type to the third tier classification
is both an art and a science. Previous general field knowledge and prior experience by the researcher (17+ years) factored heavily into the categorization of the 1926 wetlands. Figure 8 presents generalized decision matrices used to aerially interpret and assign wetland type, which identifies some of the assumptions made during the interpretation process, as well as the rational used in applying the supporting data layers to photo-interpret wetland type to the level 3 tier. At this point, it should also be noted that, although presented for informational purposes in Table 3, photo-interpretation to the level 4 tier from black and white aerials is virtually impossible at the resolution of the 1926 aerials. The poor resolution of the aerials made level 3 interpretation difficult in some areas, and more often than not interpretation to level 3 was heavily dependent on vegetative signatures appearing on later 1942 and 1970s black and white aerials (barring the presence of other factors indicating alteration), 1950s and 1990s mapped land-use in the areas of the County where it occurred, and the researcher’s breadth of experience with wetland habitat types in Florida. Figure 9 presents a range of examples of map resolution qualities encountered during the digitizing process.

Concurrent with the digitizing, topology was also created for both the 1926 hydrographic features class and 1999 land-use feature class using topology creation geoprocessing tools contained in ArcMap/ArcInfo version 9.2. The created topologies were verified throughout the digitizing process and at the conclusion of the mapping for each feature class. All applicable topology errors during the verification process were corrected using topology editing tools in Arc Map/Arc Info, and re-verified. Creation of topology for these hydrographic feature classes is crucial to the analysis in order for the features to have a spatial correspondence with other feature classes (layers, and to create
Figure 8. A generalized decision tree for mapping a signature as wetland or surface water, and for determining FLUCCS third level classification (1926 data set only).
Figure 9. Examples of ranges of aerial raster image quality and resolution used for identifying and mapping wetlands that existed in 1926 in Pinellas County, Florida.

1) Clearwater is 1:10,000 scale, (2) Indian Rocks is 1:10,000 scale, (3) Northeast corner near Hillsborough County is 1:3,265 scale, and represents the 1926 aerial photo mapping resolution.
a relational database structure for any future spatial analysis the County may wish to pursue. Refer to Appendix A to view the metadata for the hydrofeature layers.

Analysis Methods

The second part of the process was to determine general hydrographic feature coverage for the 1926 and 1999 data sets, and then compare the data sets for wetland and surface water areal extents, and areal extent for the generalized hydrographic feature types by sub-basin. Determination of areal extent both for the entire project area and by sub-basin is the foundation upon which any further analysis and comparison to determine conversion between hydrographic feature types or to upland is based, and forms the foundation of any easily exportable GIS model for determining net wetland loss and gain between any two time periods. Additionally, because both data sets are mapped to the level 3 FLUCCS tier, the potential exists for more specific analysis and use of the data. For example, if the County is interested in determining the possibility of the occurrence of a rare, wetland orchid occurring primarily in wet-prairie habitats, using the 1926 and 1999 hydrographic features layers they could determine the occurrence of wet-prairie (FLUCCS code 643), or other similar wetland habitat types (i.e. hydric pine, FLUCCS code 625), and then determine the historic versus the current occurrence of these habitat types, and thus current and historic potential for occurrence or range of the rare orchid within Pinellas County.

Only a vector analysis approach was utilized to determine wetlands and open water (hydrographic feature type) by sub-basin. Because upland was not actually mapped for the 1926 data set, this data set could not be converted to a raster grid, as all of
Figure 10: GIS vector cartographic model for the determination of 1926 and 1999 wetland and surface water subclass acreages by USGS Hydrographic Catalog Units (HUC) sub-basins in Pinellas County, Florida.
the unmapped area would show as “no data” and would not be able to be reclassified. Instead, a vector approach (see Figure 10 for the vector cartographic model) utilizing geoprocessing tools and table operations was the method by which areas of hydrographic feature type by sub-basin were calculated.

Since digitized data layers for the entire land area and sub-basins of the County that existed in 1926 are not available, the sub-basins were clipped by the current County boundary layer to create the sub-basin study area layer. This layer reflects the modern land areal extent. For the coastal barrier islands specifically, the actual land that existed in 1926 is considerably less than what exists today. Since the County boundary excludes most of the estuarine water bodies (for example Clearwater Harbor, Boca Ciega Bay, and
the Anclote River), areas that exist as upland today were actually open water in 1926. Thus, the net upland gain is underestimated between 1926 and 1999 for the Direct Runoff to Gulf sub-basin.

The same vector-based analysis used for the 1926 data set was also performed on the 1999 data set to ensure comparability and consistency between calculated acreages. Final differences in total areas between 1926 and 1999, and percent net gain and loss for each hydrographic feature type subclass and upland by sub-basin were calculated utilizing an Excel spreadsheet after exporting the 1926 and 1999 hydrographic feature subclass area by sub-basin data into an Excel spreadsheet. The pivot tables feature in Excel was utilized to summarize hydrographic feature acreage by sub-basin, and create percent distribution bar graphs for 1926 and 1999.

The final percent net gain/loss by sub-basin maps for each hydrographic feature subclass and generalized type (open water, wetlands, upland) were created by importing a modified net loss/gain excel spreadsheet into ArcView 9.2 and joining this table to the sub-basin layer attribute table. Figure 1 presents a cartographic model for production of the final percent net gains/losses by sub-basin for each hydrographic feature sub-class and the three generalized wetland, open water and upland categories. Wetland, upland and open water area net loss/gain data are then used to identify those sub-basins experiencing the greatest amount of wetland loss.

The net loss/gain, 1926 and 1999 hydrographic feature subclass acreage data is also analyzed using hierarchical cluster analysis techniques to determine natural groupings of sub-basins. Quantitative cluster analysis techniques are particularly useful when trying to both verify the existence of suspected groups within data, and as an
exploratory data analysis tool (StatSoft, 2004). Numerous options for both linkage rules and distance measures are available in hierarchical cluster analysis, and different methods and distance measures often produce different clustering solutions. Often, the determination of the appropriate method and distance measure can only result from experimental runs with the data. Amalgamation methods chosen for the analysis were single linkage (nearest neighbor), between groups, complete linkage (furthest neighbor), unweighted pair group centroid and weighted pair-group centroid (median). The single, between groups and complete linkages were all calculated using Euclidean distance, while the centroid method utilized the squared Euclidean distance, which is the more appropriate distance measure for these methods (SPSS Statistics Coach, 2006). These methods were chosen because the sub-basins (categories) were analyzed separately for each scaled hydrographic feature subclass variable.
Results of the net loss/gain analysis and cluster analysis are used to infer effects of development and drainage activities on wetland and surface water structure and function over time, as well as identify agents of wetland loss. Lastly, statistical testing of differences between years for each hydrographic feature subclass was performed to determine if significant differences in areal extent of feature coverage was present. An appropriate statistical method was chosen after running descriptive and exploratory statistics on both 1926 and 1999 data sets to test for normality and determine if the 1926 and 1999 populations, as well as their differences, met all test assumptions. All statistical testing and analysis was performed using subroutine procedures found in SPSS Graduate Pack 15,0 for Windows.

Although the convention in most academic literature is to use metric units, English units are used throughout the presentation and discussion of analysis results. English units were chosen because the primary recipient of this research work, Pinellas County, uses English units as the standardized measure in technical literature produced by the County. Additionally, the intended audience for this work is local and regional governments and municipalities within the United States, where English units are largely the convention used in most technical reporting and writing. It is also one of the primary objectives of this thesis to develop a finer-scale spatial model for estimating wetland loss that is easily exportable and adaptable to the types of data available for most local and regional governments, thus English units are the more appropriate measure.
Overview

Discussion of the analysis results featured below first focuses on total wetland and surface water loss and conversion between 1926 and 1999. The discussion then turns to examining the degree, trends and patterns of hydrographic feature conversion and loss within the study area sub-basins. Changes in relative wetland and surface water distribution and structure between the two time periods are discussed using relevant sub-basin examples. Sub-basin trends in net gain and loss of the two generalized hydrographic feature types (wetland and water) and upland are also summarized and discussed with examples of relevant sub-basins used to demonstrate agents of wetland loss and conversion typically at play. Following this discussion, net gain/loss maps for the hydrographic feature subclasses, generalized types and upland are presented and discussed in terms of the trends observed previously. Sub-basin hydrographic feature classes and upland sub-basin differences in acreage are tested for statistical significance between the two study time periods of 1926 and 1999. The results of hierarchical cluster analysis are then used to verify patterns of grouping between sub-basins. How these patterns relate to the trends and patterns of wetland loss and conversion is discussed. Patterns of grouping and the major trends identified by the analysis are then summarized in terms of probable agents of wetland loss and
Total Hydrographic Features 1926 vs. 1999

In 1926, an estimated 49,871 acres of wetlands and surface waters existed within the study area. By 1999, this same area contained 24,921 acres of wetlands and surface waters. This difference in area represents a 59 percent loss of wetlands and surface waters from what previously existed in 1926. The actual percent loss for the entire County may be even higher, considering that the southern portion of the landmass is almost completely developed. Since surface waters other than estuarine water bodies were included as part of this estimate, the 50% loss within the study area represents those areas that were converted to upland (non-wetland) by 1999, either through direct filling or drainage. This rate of loss over the 73 year study period is comparable to the rates of loss previously presented for Florida (30%) and for the Gulf Atlantic Coastal Flats (55%) eco region over a 10 year period from the mid-1970s to the mid-1980s.

Table 4 presents total acres of hydrographic features within the study area for 1926 and 1999, and total net gain/loss for each hydrographic feature class. Total net/gain loss of uplands were determined by subtracting the total hydrographic features acreage for the sub-basin from the total sub-basin acreage. Since the spatial comparison was based on sub-basin boundaries drawn well after 1926, and more indicative of 1999, the 1926 uplands calculated in this manner are actually greater than what actually existed, since offshore water bodies and most embayments were excluded from the analysis as a result of clipping the sub-basin layer file with the County boundary. Thus, many areas that were calculated as upland in 1926 were most likely open water (i.e. Clearwater
Harbor, Boca Ciega Bay, Tampa Bay, etc.). The difference between the 59% loss calculated between the total hydrographic feature acreage and the 27% in Table 4, which is 23%, thus represents the amount of previously open marine and estuarine water bodies lost through filling to create upland from 1926 to 1999.

The net gain/loss trends presented in Table 4 also follow trends discussed earlier in Chapter 2, with saltwater and freshwater herbaceous wetlands showing the greatest net loss, followed by freshwater forested wetlands. Surprisingly, saltwater forested wetlands actually gained by 23 percent. This may be partially due to mosquito ditching, allowing for greater penetration of tidal waters, and subsequent colonization of historic salt marsh and salt tern areas by mangroves. By 1970, most, if not all, tidal wetlands within the study area were mosquito ditched, and very little salt tern signature remained on the 1970s aerials.

Table 4. Total areas of hydrographic features and upland (estimated) within the study area between 1926 and 1999, and percent net gain and loss between these time periods.
Salt tern, an unvegetated wetland, is easy to distinguish on the historic aerials by its white to very light gray signature, generally occurring at the mean high high tide elevations and slightly above.

As expected, both the open water and upland categories also display net gains, with open water comprising the greatest net gain of any hydrographic feature subclass. While an estimated 27% of estuarine and bay bottoms within the study area may have been lost to filling, additional open water features were created inland through dredging of both uplands and wetlands for storm water ponds and canals, and along the coast through the dredging of tidal creeks, shallow embayments and bayous. One specific basin that experienced massive dredging was Long Bayou, which will be discussed in more specifically as part of the sub-basin analysis.

Figures 12 and 13 present hydrographic feature class coverage for 1926 and 1999 overlain on the sub-basin map. Visual comparison clearly corroborates the summary net loss and gain results in Table 4. Freshwater forested and saltwater herbaceous wetlands are the more dominant signatures in 1926, while in 1999 the dominant signatures are open water, mangroves along the Tampa Bay coast, and remnant freshwater forested wetland in the northeastern portion of the County. Freshwater herbaceous signatures are hardly discernible in the 1999 coverage, while in 1926 they comprise a large portion of the landscape within the inland sub-basins. Further investigation at the sub-basin level will reveal that these larger trends continue to hold true at the sub-basin scale.
Figure 12. Distribution of 1926 wetlands and surface waters (hydrographic features) within the Pinellas County sub-basin study area.
Figure 13. Distribution of 1999 wetlands and surface waters (hydrographic features) within the Pinellas County sub-basin study area.
Wetland and Surface Water Coverages by Sub-basin: 1926 vs. 1999

Figures 14 and 15 present sub-basin graphs showing percent of hydrographic features for 1926 and 1999, respectively. The larger trends previously discussed are clearly visualized by comparison of Figures 14 and 15, as well as trends within individual sub-basins. Allen Creek (Figure 16) serves as an excellent example of freshwater forested wetland loss and conversion to open water. In 1926, freshwater forested wetlands comprised 60% of the hydrographic features present, while open water comprised less than 10% of the hydrographic features within that sub-basin. By 1999, a complete inversion had resulted, with open water comprising 60% and the previously dominant freshwater forested features comprising less than 10% of the hydrographic features within the sub-basin.

Likewise, even sub-basins with historically large open water areas, such as Lake Tarpon (Figure 17) still exhibited substantial declines of herbaceous wetlands. While the percentage of freshwater forested wetlands remained relatively consistent between 1926 and 1999, herbaceous wetlands were almost eliminated. In 1926, open water, largely from Lake Tarpon, comprised 50% of the hydrographic feature area, and 20% of the basin’s wetland features consisted of freshwater herbaceous wetlands. By 1999, the Lake Tarpon sub-basin had lost nearly all of its freshwater herbaceous wetlands. By 1999, freshwater marshes comprised less than 5% of the total hydrographic features. In conjunction with increases in open water area, loss of freshwater forested and herbaceous wetlands is the other most noticeable trend graphed. Several sub-basins display complete losses of either freshwater forested or herbaceous wetlands as a significant feature component within the study period, and some sub-basins experienced
Figure 14. Percent of 1926 hydrographic feature types within study area sub-basins.

Figure 15. Percent of 1999 hydrographic feature types within study area sub-basins.
a complete loss of all freshwater wetlands. Examples of sub-basins exhibiting complete or near complete losses of freshwater wetlands (less than < 5% of the areal extent of hydrographic features present) are: Bellair Golf Club Run (Figure 18), Cedar Creek (Figure 19), Church Creek (Figure 20), Jerry Branch (Figure 21), Long Bayou (Figure 22), Long Branch (Figure 23), McCay Creek (Figure 24), Papys Bayou (Figure 25), Pinellas Park Ditch (Figure 26), Stevenson Creek (Figure 27), Sutherland Bayou (Figure 28), and Walsingham Reservoir (Figure 29). The dredging of Long Bayou serves as one of the most dramatic examples. In 1926, Long Bayou contained only 10% open water relative to the other hydrographic feature subclasses. By 1999, open water accounted for 75% of the features present. An equally dramatic decline in freshwater wetlands also occurred, from 90% of the features in 1926 to 18% of the features in 1999.
Figure 16: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Allen Creek Sub-basin.
Figure 17: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Lake Tarpon Sub-basin.
Figure 18: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Bellair Golf Club Run Sub-basin.

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<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
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<td>Upland</td>
<td>765.33</td>
<td>1044.97</td>
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Figure 19: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Cedar Creek Sub-basin.
Figure 20: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Church Creek Sub-basin.

Legend

HYDROGRAPHIC_FEATURE_CLASS
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries

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<td>Upland</td>
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Figure 21: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Jerry Branch Sub-basin.
Figure 22: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Long Bayou Sub-basin.
Figure 23: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Long Branch Sub-basin.
Figure 24: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the McCay Creek Sub-basin.

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Figure 25: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Papys Bayou Sub-basin.
Figure 26: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Pinellas Park Ditch Sub-basin.

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HYDROGRAPHIC_FEATURE_CLASS
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries
Figure 27: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Stevenson Creek Sub-basin.
Figure 28: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Sutherland Bayou Sub-basin.
Figure 29: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Walsingham Reservoir Sub-basin.

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<th>Hydrographic Feature Class</th>
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<td>Freshwater Forested</td>
<td>311.12</td>
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<td>Saltwater Herbaceous</td>
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<td>0.00</td>
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<tr>
<td>Non-vegetated</td>
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<td>0.00</td>
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<tr>
<td>Open Water</td>
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<td>Upland</td>
<td>1017.94</td>
<td>1483.55</td>
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- **HYDROGRAPHIC_FEATURE_CLASS**
  - Freshwater Forested
  - Freshwater Herbaceous
  - Open Water
  - Saltwater Forested
  - Saltwater Herbaceous
  - Non-vegetated
  - Upland and Sub-Basin Boundaries
Another significant large scale trend that bears out at the sub-basin level is the loss of unvegetated wetlands and salt marsh relative to total hydrographic feature coverage, and the relative increase in saltwater forested wetlands. This is most noticeable within the Tampa Bay and Direct Runoff to Bay sub-basins (Figures 30 and 31, respectively). Historically, unvegetated wetlands comprised 20% and 10% of the hydrographic features in these sub-basins, whereas mangroves accounted for approximately 55% of the features present. By 1999, less than 2 acres of unvegetated wetland were mapped as occurring within the Tampa Bay sub-basin, and 80% or greater of the hydrographic features present consisted of mangrove areas. Likewise, mangroves within the Direct Runoff to Bay Sub-basin comprised 20% of the hydrographic features in 1926, but increased to 60% of the total hydrographic features present by 1999.

Masters and Mobbly Bayous (Figures 32 and 33, respectively) as well as Cross Canal North (Figure 35) exhibit similar trends. Historically, saltwater herbaceous wetlands were significant components (~25%) of Mater’s and Mobbly Bayous. By 1999, virtually no saltwater herbaceous wetlands remained, while mangrove comprised 78% and 50% of hydrographic features present, respectively, compared to approximately 45% and 20% in 1926. In the case of Cross Canal North (Figure 34), mangrove comprised less than 5% of the wetland and surface water features in this sub-basin in 1926, while salt marsh and unvegetated wetlands comprised approximately 12%. By 1999, the salt marsh and unvegetated wetlands were completely converted to mangroves, now at 10% of all wetland and surface water features present. As with other basins with dredged features, Cross Canal North also exhibits a dramatic increase in open water from 5% in 1926 to 25% of the hydrographic feature types by 1999.
Figure 30: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Tampa Bay Sub-basin.

<table>
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<th>Hydrographic Feature Class</th>
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<td>Freshwater Herbaceous</td>
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Legend

- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries
Figure 31: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Direct Runoff to Bay Sub-basin.
Figure 32: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Masters Bayou Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>0.46</td>
<td>62.19</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>6.49</td>
<td>0.75</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>123.39</td>
<td>202.33</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>85.81</td>
<td>0.75</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>42.89</td>
<td>0.01</td>
</tr>
<tr>
<td>Open Water</td>
<td>43.15</td>
<td>0.43</td>
</tr>
<tr>
<td>Upland</td>
<td>226.43</td>
<td>262.14</td>
</tr>
</tbody>
</table>

Legend

HYDROGRAPHIC_FEATURE_CLASS

- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Non-vegetated
- Upland and Sub-Basin Boundaries
Figure 33: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Mobbly Bayou Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>95.90</td>
<td>21.37</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>56.39</td>
<td>24.22</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>113.19</td>
<td>185.94</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>169.71</td>
<td>38.14</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>83.21</td>
<td>9.40</td>
</tr>
<tr>
<td>Open Water</td>
<td>16.22</td>
<td>92.16</td>
</tr>
<tr>
<td>Upland</td>
<td>1193.73</td>
<td>1357.13</td>
</tr>
</tbody>
</table>

Legend

HYDROGRAPHIC_FEATURE_CLASS

- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries
Figure 34: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Cross Canal North Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>181.65</td>
<td>71.28</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>517.06</td>
<td>63.43</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>26.14</td>
<td>28.66</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>82.22</td>
<td>0.00</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>13.42</td>
<td>0.71</td>
</tr>
<tr>
<td>Open Water</td>
<td>19.61</td>
<td>127.49</td>
</tr>
<tr>
<td>Upland</td>
<td>3495.76</td>
<td>4044.29</td>
</tr>
</tbody>
</table>

Legend

HYDROGRAPHIC_FEATURE_CLASS
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries

Legend
- Cross Canal North Sub-basin
- Pinellas County Study Area

Miles

Feet
This trend, however, appears to be reversed for the Direct Runoff to Gulf (Figure 35) sub-basin. This sub-basin exhibits a considerable increase in unvegetated wetland coverage as a percent of the total hydrographic feature types present between 1926 and 1999. In 1926, unvegetated wetlands (tidal flats and salt terns) accounted for a little over 10% of the hydrographic features present. By 1999, this number had jumped to almost 45% of the hydrographic features present. Concurrent with this increase in unvegetated wetlands; however, saltwater herbaceous wetlands were almost entirely eliminated within the sub-basin. Comprising 30% of total hydrographic features in 1926, by 1999 salt marsh comprised less than 5% of the hydrographic feature types remaining. Only one basin actually exhibited an increase in the percentage of salt marsh relative to other hydrographic features, and that was Bishop Creek (Figure 36). Approximately 10% of wetlands within Bishop Creek were salt marsh in 1926. By 1999, this percentage had tripled, mostly as a result of the loss of freshwater wetlands as opposed to an actual increase in areal extent of salt marsh.

While some coastal sub-basins such as Cross Canal South (Figure 37) and the sub-basins associated with Tampa Bay appear to experience increases in saltwater forested (mangrove) wetland coverage, other coastal sub-basins experienced significant losses of saltwater wetlands in conjunction with significant increases in open water area. Prime examples of sub-basins displaying saltwater wetland loss are Klosterman Bayou Run (Figure 38), Lake Tarpon Canal (Figure 39), and Curlew Creek (Figure 40).
Figure 35: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Direct Runoff to Gulf Sub-basin.
Figure 36: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Bishop Creek Sub-basin

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>117.42</td>
<td>15.84</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>54.67</td>
<td>1.65</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>0.00</td>
<td>1.62</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>16.90</td>
<td>11.45</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Open Water</td>
<td>0.66</td>
<td>8.86</td>
</tr>
<tr>
<td>Upland</td>
<td>731.96</td>
<td>883.09</td>
</tr>
</tbody>
</table>
Figure 37: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Cross Canal South Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>505.10</td>
<td>21.86</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>483.02</td>
<td>12.36</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>79.61</td>
<td>113.93</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>149.56</td>
<td>30.59</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>19.39</td>
<td>9.45</td>
</tr>
<tr>
<td>Open Water</td>
<td>56.70</td>
<td>167.37</td>
</tr>
<tr>
<td>Upland</td>
<td>3612.64</td>
<td>4550.47</td>
</tr>
</tbody>
</table>

Legend

- **HYDROGRAPHIC_FEATURE_CLASS**
  - Freshwater Forested
  - Freshwater Herbaceous
  - Open Water
  - Saltwater Forested
  - Saltwater Herbaceous
  - Unvegetated
  - Upland and Sub-Basin Boundaries
Figure 38: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Klosterman Bayou Run Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>101.21</td>
<td>65.54</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>345.86</td>
<td>14.85</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>0.00</td>
<td>0.90</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>60.63</td>
<td>1.59</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Open Water</td>
<td>2.23</td>
<td>65.63</td>
</tr>
<tr>
<td>Upland</td>
<td>1155.44</td>
<td>1496.92</td>
</tr>
</tbody>
</table>

Legend

- **HYDROGRAPHIC_FEATURE_CLASS**
  - Freshwater Forested
  - Freshwater Herbaceous
  - Open Water
  - Saltwater Forested
  - Saltwater Herbaceous
  - Unvegetated
  - Upland and Sub-Basin Boundaries
Figure 39: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Lake Tarpon Canal Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>119.44</td>
<td>26.29</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>148.98</td>
<td>15.58</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>24.52</td>
<td>0.00</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>65.44</td>
<td>7.58</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>15.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Open Water</td>
<td>3.50</td>
<td>89.34</td>
</tr>
<tr>
<td>Upland</td>
<td>1395.49</td>
<td>1634.08</td>
</tr>
</tbody>
</table>

Legend

HYDROGRAPHIC_FEATURE_CLASS
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Non-vegetated
- Upland and Sub-Basin Boundaries
Figure 40: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Curlew Creek Sub-basin.
Although all sub-basins experienced some wetland loss, only four sub-basins exhibit less alteration in the relative distribution of hydrographic features from 1926 to 1999. Brooker Creek (Figure 41) maintained its baseline distribution of 80% forested freshwater wetlands between 1926 and 1999, and the Anclote River (Figure 42) sub-basin also maintained similar relative distributions of hydrographic feature types. Double Branch (Figure 43) retained most of its historic distribution of wetlands into 1999, as did Hollin Creek (Figure 44). This is not to say, however, that these sub-basins did not experience wetland loss or conversion. Brooker Creek saw an 8 to 9% decrease in herbaceous wetlands compared to other hydrographic features, and a concurrent 8% increase in open water from 1926 to 1999. Double Branch also experienced a 5% increase in open water area relative to other hydrographic features in between 1926 and 1999. In 1926, no open water was mapped as occurring within either of these sub-basins. The Anclote River still exhibits a slight 3% increase in open water area in 1999 relative to other hydrographic features, as well as a 10% increase in forested freshwater wetlands compared to the 1926 relative distributions of hydrographic features. And lastly, Hollin Creek did not register any open water in 1926, but by 1999 open water accounted for 10% of the hydrographic features present.

The foregoing discussion and comparison of relative percent distribution of hydrographic feature subclass types between 1926 and 1999 revealed significant trends in wetland loss and conversion throughout the sub-basins within the study area. While these relative comparisons may seem significant, they really only reveal trends in hydrographic feature distribution amongst the features, and not necessarily in relation to overall land use and development patterns or conversion to upland. The Bishops Creek example
Figure 41: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Brooker Creek Sub-basin.
Figure 42: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Anclote River Sub-basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>691.55</td>
<td>471.23</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>494.88</td>
<td>103.86</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>15.04</td>
<td>39.43</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>564.55</td>
<td>270.58</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>1.18</td>
<td>0.00</td>
</tr>
<tr>
<td>Open Water</td>
<td>241.04</td>
<td>133.03</td>
</tr>
<tr>
<td>Upland</td>
<td>3742.25</td>
<td>4752.36</td>
</tr>
</tbody>
</table>

Legend

**HYDROGRAPHIC FEATURE CLASS**
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-Basin Boundaries
Figure 43: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Double Branch Basin.
Figure 44: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Hollin Creek Basin.
illustrates this nicely. Although the saltwater marsh on the graphs appeared to substantially increase, this increase was solely due to the loss of other hydrographic feature types, and not to an actual increase in areal extent of salt marsh.

**Percent Net Loss/Gain Analysis**

In order to determine the actual areal extent of wetland loss within each sub-basin, calculation and comparison of actual percent net increases and decreases in hydrographic feature and upland acreage between the two study periods were performed. Table 5 summarizes percent net gain and loss of wetlands, open water and upland for each sub-basin. The same trends identified for the entire study area and within the sub-basin relative percent hydrographic feature analysis previously discussed are evident, with almost all basins showing overall percent net losses in wetlands, and net gains in open water and upland. Two sub-basins show an exception to this trend: Tampa Bay and Masters Bayou. Both of these sub-basins also exhibit overall net losses in Open Water; however they also exhibit overall net increase of wetlands. In the case of Tampa Bay (see Figure 30), the inclusion of causeway fill within the footprint of the sub-basin partially explains some of this increase, as the edges of these areas have become established with mangroves. Although the causeways are depicted as part of the sub-basin in 1926, in actuality these causeways did not exist, and were open water areas most likely too deep for mangrove colonization.

The increase in wetlands within Master’s Bayou (see Figure 32), seems to be due to a mapping discrepancy between the two time periods, specifically, the presence of mapped freshwater forested wetlands in 1999 that was not mapped in 1926. This actual
increase could be a mapping oversight or miss-classification. Alternatively, it could also be a result of alterations of land elevations or changes in drainage patterns, which can only be verified by ground-truthing and additional historical aerial research.

Table 5. Net gain and loss of wetlands, open water and uplands by sub-basin within the Pinellas County study area.

<table>
<thead>
<tr>
<th>Basin</th>
<th>1926 Wetland Acres</th>
<th>1926 Water Acres</th>
<th>1999 Wetland Acres</th>
<th>1999 Water Acres</th>
<th>%Net Wetland</th>
<th>%Net Water</th>
<th>%Net Upland</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALLEN CREEK</td>
<td>1703.52</td>
<td>49.67</td>
<td>3559.07</td>
<td>118.30</td>
<td>-93%</td>
<td>303%</td>
<td>40%</td>
</tr>
<tr>
<td>ALLIGATOR CREEK</td>
<td>1599.13</td>
<td>166.63</td>
<td>3843.69</td>
<td>254.25</td>
<td>-84%</td>
<td>26%</td>
<td>34%</td>
</tr>
<tr>
<td>ANCLOTE RIVER</td>
<td>1767.20</td>
<td>241.04</td>
<td>3742.25</td>
<td>865.10</td>
<td>-51%</td>
<td>-45%</td>
<td>27%</td>
</tr>
<tr>
<td>BELLEAIR GOLFCLUB RUN</td>
<td>307.70</td>
<td>0.94</td>
<td>765.33</td>
<td>0.42</td>
<td>-100%</td>
<td>2941%</td>
<td>37%</td>
</tr>
<tr>
<td>BISHOP CREEK</td>
<td>188.40</td>
<td>0.66</td>
<td>731.46</td>
<td>28.56</td>
<td>-85%</td>
<td>1235%</td>
<td>21%</td>
</tr>
<tr>
<td>BROOKER CREEK</td>
<td>4552.60</td>
<td>1.88</td>
<td>4599.23</td>
<td>3358.77</td>
<td>-26%</td>
<td>16426%</td>
<td>19%</td>
</tr>
<tr>
<td>CEDAR CREEK</td>
<td>312.20</td>
<td>4.67</td>
<td>682.87</td>
<td>67.89</td>
<td>-78%</td>
<td>70%</td>
<td>35%</td>
</tr>
<tr>
<td>CHURCH CREEK</td>
<td>280.00</td>
<td>1.92</td>
<td>779.75</td>
<td>3.58</td>
<td>-99%</td>
<td>1595%</td>
<td>32%</td>
</tr>
<tr>
<td>COW BRANCH</td>
<td>359.68</td>
<td>79.09</td>
<td>1203.07</td>
<td>109.62</td>
<td>-70%</td>
<td>38%</td>
<td>18%</td>
</tr>
<tr>
<td>CROSS CANAL (NORTH)</td>
<td>820.49</td>
<td>19.61</td>
<td>3495.76</td>
<td>164.08</td>
<td>-80%</td>
<td>550%</td>
<td>16%</td>
</tr>
<tr>
<td>CROSS CANAL (SOUTH)</td>
<td>1236.69</td>
<td>56.70</td>
<td>3612.64</td>
<td>188.19</td>
<td>-85%</td>
<td>195%</td>
<td>26%</td>
</tr>
<tr>
<td>CURLEW CREEK</td>
<td>948.12</td>
<td>50.92</td>
<td>3137.81</td>
<td>104.05</td>
<td>-89%</td>
<td>119%</td>
<td>25%</td>
</tr>
<tr>
<td>DIRECT RUNOFF TO BAY</td>
<td>5065.91</td>
<td>375.45</td>
<td>7336.37</td>
<td>2612.37</td>
<td>-48%</td>
<td>101%</td>
<td>28%</td>
</tr>
<tr>
<td>DIRECT RUNOFF TO GULF</td>
<td>4612.12</td>
<td>106.06</td>
<td>11390.00</td>
<td>1870.86</td>
<td>-59%</td>
<td>105%</td>
<td>23%</td>
</tr>
<tr>
<td>DOUBLE BRANCH</td>
<td>755.24</td>
<td>0.00</td>
<td>762.07</td>
<td>746.11</td>
<td>-1%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>DUCK SLOUGH</td>
<td>18.65</td>
<td>0.00</td>
<td>41.18</td>
<td>15.12</td>
<td>-19%</td>
<td>0%</td>
<td>9%</td>
</tr>
<tr>
<td>HOLLIN CREEK</td>
<td>2075.51</td>
<td>1.63</td>
<td>2254.18</td>
<td>1342.69</td>
<td>-35%</td>
<td>9158%</td>
<td>26%</td>
</tr>
<tr>
<td>JERRY BRANCH</td>
<td>765.43</td>
<td>43.37</td>
<td>1527.02</td>
<td>102.67</td>
<td>-87%</td>
<td>161%</td>
<td>39%</td>
</tr>
<tr>
<td>KLOSTERMAN BAYOU RUN</td>
<td>507.80</td>
<td>2.23</td>
<td>1155.44</td>
<td>102.92</td>
<td>-80%</td>
<td>2847%</td>
<td>30%</td>
</tr>
<tr>
<td>LAKE TARPON</td>
<td>2864.93</td>
<td>2658.21</td>
<td>4502.35</td>
<td>1401.62</td>
<td>-51%</td>
<td>6%</td>
<td>29%</td>
</tr>
<tr>
<td>LAKE TARPON CANAL</td>
<td>373.87</td>
<td>3.50</td>
<td>1395.49</td>
<td>49.44</td>
<td>-87%</td>
<td>2455%</td>
<td>17%</td>
</tr>
<tr>
<td>LONG BAYOU</td>
<td>3662.41</td>
<td>408.91</td>
<td>9499.35</td>
<td>378.12</td>
<td>-90%</td>
<td>169%</td>
<td>27%</td>
</tr>
<tr>
<td>LONG BRANCH</td>
<td>356.66</td>
<td>8.53</td>
<td>1146.63</td>
<td>22.04</td>
<td>-94%</td>
<td>278%</td>
<td>27%</td>
</tr>
<tr>
<td>MASTERS BAYOU</td>
<td>259.04</td>
<td>43.15</td>
<td>226.43</td>
<td>266.05</td>
<td>-3%</td>
<td>99%</td>
<td>16%</td>
</tr>
<tr>
<td>MCKAY CREEK</td>
<td>709.25</td>
<td>33.84</td>
<td>2233.58</td>
<td>46.26</td>
<td>-93%</td>
<td>176%</td>
<td>27%</td>
</tr>
<tr>
<td>MOBILLY BAYOU</td>
<td>518.40</td>
<td>16.22</td>
<td>1193.73</td>
<td>279.07</td>
<td>-46%</td>
<td>468%</td>
<td>14%</td>
</tr>
<tr>
<td>MOCCASIN CREEK</td>
<td>1243.84</td>
<td>6.47</td>
<td>1548.73</td>
<td>769.27</td>
<td>-38%</td>
<td>1899%</td>
<td>23%</td>
</tr>
<tr>
<td>MULLET CREEK</td>
<td>437.15</td>
<td>2.36</td>
<td>1453.65</td>
<td>80.73</td>
<td>-82%</td>
<td>1828%</td>
<td>22%</td>
</tr>
<tr>
<td>PAPYS BAYOU</td>
<td>3144.57</td>
<td>235.25</td>
<td>5421.22</td>
<td>1127.99</td>
<td>-64%</td>
<td>54%</td>
<td>32%</td>
</tr>
<tr>
<td>PINELLAS PARK DITCH</td>
<td>716.49</td>
<td>34.41</td>
<td>1529.71</td>
<td>44.24</td>
<td>-94%</td>
<td>200%</td>
<td>39%</td>
</tr>
<tr>
<td>SALT LAKE</td>
<td>112.82</td>
<td>71.15</td>
<td>163.83</td>
<td>61.01</td>
<td>-46%</td>
<td>-90%</td>
<td>71%</td>
</tr>
<tr>
<td>STEVENSON CREEK</td>
<td>1560.70</td>
<td>96.10</td>
<td>4331.64</td>
<td>68.30</td>
<td>-96%</td>
<td>18%</td>
<td>34%</td>
</tr>
<tr>
<td>SUTHERLAND BAYOU</td>
<td>325.02</td>
<td>7.47</td>
<td>800.45</td>
<td>41.17</td>
<td>-87%</td>
<td>76%</td>
<td>33%</td>
</tr>
<tr>
<td>TAMPA BAY</td>
<td>133.55</td>
<td>17.05</td>
<td>327.36</td>
<td>224.37</td>
<td>68%</td>
<td>-98%</td>
<td>-23%</td>
</tr>
<tr>
<td>UNNAMED DITCH</td>
<td>135.72</td>
<td>0.00</td>
<td>93.88</td>
<td>99.74</td>
<td>-27%</td>
<td>0%</td>
<td>38%</td>
</tr>
<tr>
<td>WALSINGHAM RESERVOIR</td>
<td>594.20</td>
<td>1.75</td>
<td>1017.94</td>
<td>18.75</td>
<td>-97%</td>
<td>6270%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Only two sub-basins did not exhibit any gains in open water. These sub-basins are Duck Slough and the Unnamed Ditch. For both of these sub-basins, only very small slivers of the watershed occur within Pinellas County. The majority of these sub-basins...
are within Hillsborough County, thus the sample size for these sub-basins is too small to draw any meaningful conclusions indicative of basin wide trends or patterns.

Mapping of the percent net gain and loss for the six hydrographic feature classes (freshwater forested, freshwater herbaceous, saltwater forested, saltwater herbaceous, unvegetated and open water) and two additional generalized features types (wetland and upland) on a continuous scale for the study sub-basins reveals some additional trends. Figures 45 (key map to the study area sub-basins) and 46 (1999 FLUCCS land-use) provide reference figures for the net gain/loss analysis and discussion. Graphical exhibition of the net gain and loss data helps to better visualize sub-basin trends previously discussed, and also identify trends that were not readily apparent by the sub-basin comparison of relative percent distribution amongst hydrographic features.

From study and comparison of these figures, some overall loss patterns begin to emerge. Figure 47 (freshwater forested percent net loss/gain) reveals that the sub-basins with the highest net loss (> 75% net loss of forested wetlands) occur throughout the majority of the study area, particularly along the western and central peninsula, which is also some of the most highly developed portions of the County (see Figure 48). The next highest areas of loss (75% to 50%) are clustered along central and southern Tampa Bay, with the exception of Masters Bayou, the only sub-basin experiencing a net gain in areal extent of freshwater forested wetlands. This anomaly was also previously identified through graphing of the percent distribution of hydrofeatures by sub-basin. The northeastern portion of the County, which is also the least developed, experienced the least loss within the study time period (< 50%), and includes basins previously identified as the least impacted (Brooker Creek, Anclote River and Double Branch sub-basins).
Figure 45: Key map to Pinellas County sub-basins within the study area.
Figure 46: 1999 FLUCCS land use for Pinellas County.
Figure 47: Percent net gain/loss of freshwater forested wetlands within the Pinellas County sub-basin study area.
By far, the hydrographic feature experiencing the greatest extent of areal loss and conversion is freshwater herbaceous wetlands (Figure 48). The majority of the sub-basins within the study area experienced a > 75% net loss. As with freshwater forested wetlands, the areas experiencing less than a 75% loss are clustered in the northeastern portion of the County. Surprisingly, one basin (Double Branch) actually experienced a net gain in freshwater herbaceous wetlands. Hollin Creek in the very north exhibits the least loss of freshwater herbaceous wetlands of any sub-basin.

Conversely, saltwater forested wetlands (Figure 49) actually exhibit some of the highest net gains of any of the hydrographic features with the exception of open water. Several basins, mostly associated with Tampa Bay and Long Bayou, exhibited overall net gains in saltwater forested wetlands, as did the Anclote River. The Direct Runoff to Gulf Basin, as expected, exhibited overall net losses most likely as a result of canal dredging and filling for creation of developable land, as did some basins surrounding Tampa Bay.

Like freshwater herbaceous wetlands, saltwater herbaceous wetlands experienced some of the greatest loss and conversion of any hydrographic feature between 1926 and 1999 (see Figure 50). Only two basins (Cedar Creek and Hollin Creek) exhibited a modest increase in the areal extent of salt marsh. For both saltwater hydrographic feature types, inland basins such as Brooker Creek that are not tidally influenced exhibit no net loss or gain (are classified within the 0% range).

Non-vegetated wetlands (Figure 51) exhibit predominately near complete net losses in most basins, with the exception of Direct Runoff to Gulf and Allen Creek, and those basins not tidally influenced. The Direct Runoff to Gulf and Allen Creek basins are the only basins that experienced net gains from 1926 to 1999.
Figure 48: Percent net gain/loss of freshwater herbaceous wetlands within the Pinellas County sub-basin study area.
Figure 49: Percent net gain/loss of saltwater forested wetlands within the Pinellas County sub-basin study area.
Figure 50: Percent net gain/loss of saltwater herbaceous wetlands within the Pinellas County sub-basin study area.
Figure 51: Percent net gain/loss of non-vegetated wetlands within the Pinellas County sub-basin study area.
Overall, all sub-basins except two (Masters Bayou and Tampa Bay) experienced overall net losses in wetlands between 1926 and 1999 (see Figure 52). For the majority of sub-basins, these losses are substantial, at greater than 50% of the wetlands originally present in 1926. Sub-basins in the northeastern portion of the County and the Direct Runoff to Bay sub-basins exhibit less wetland loss (< 50% of wetland originally present in 1926), and only Double Branch exhibits no substantial net wetland loss (< 10%). With the exception of the Direct Runoff to Bay sub-basin, sub-basins experiencing the least amount of net loss are also those sub-basins within the least developed portion of the County. The Direct Runoff to Bay sub-basin, although developed, still contains large undeveloped coastal wetland areas.

The two exceptional basins experiencing net gains, Master’s Bayou and Tampa Bay, are both located in coastal basins that have substantial filled bay for roadway causeways, thus providing shoreline area for recruitment of mangroves along these causeway areas. In 1926, mangroves did not exist in these causeway areas, nor did two of the three causeways. They are also basins that have retained much of their original coastal wetlands (although converted from salt marsh or unvegetated into mangrove). It must also be noted that The Tampa Bay basin proper is composed only of a sliver of shoreline along Tampa Bay and the causeway fill that extends into the Bay, thus the relative land area of this basin is much smaller compared to other basins, and contains no real developable land. Gains in Masters Bayou were discussed previously as part of the percent hydrographic feature distribution analysis. Most likely the net gain observed in Masters Bayou is due to net gains in freshwater forested wetland acreage that was not discernable or did not exist in 1926.
Figure 52: Percent net gain/loss of wetlands within the Pinellas County sub-basin study area.
The only hydrographic feature to experience overall net gains from 1926 to 1999 is open water (see Figure 53). Several sub-basins experienced greater than 100% gains in open water features from what existed in 1926. Brooker Creek, although the least developed, experienced one of the highest percent net gains (10,000-20,0000 percent range), largely due to the fact that no significant areas of open water such as ponds or lakes existed in this sub-basin in 1926. By 1999, fully 1/3 of the western portion of this sub-basin’s wetlands were excavated into open water features (see Figure 41). By far, excavation of wetland and surface water features accounts for the majority of these net gains.

Four basins, however, did experience net losses in open water features between 1926 and 1999. These were the Anclote River, Salt Lake, Tampa Bay and Master’s Bayou sub-basins. Net losses within the Anclote River and Salt Lake appear to be associated with spoil disposal within the river channel (See Figure 42) and filling of what appeared to be historically open water areas in 1926 (See Figure 53). In the case of Tampa Bay, loss is most likely associated with recruitment of mangroves, while in Master’s Bayou, loss is again associated with filling of shallow open water features (see Figures 30 and 32, respectively).

Finally, all sub-basins except Tampa Bay experienced a net gain in upland areas (see Figure 55) from 1926 to 1999. This can only be the result of filling of historic wetland or open water areas to create upland. Although Tampa Bay exhibits a net loss, this is most likely a result of how upland area was calculated than an actual net loss in upland area between the study time periods.
Figure 5: Percent net gain/loss of open water within the Pinellas County sub-basin study area.
Figure 54: Comparison of the distribution of hydrographic feature types between 1926 and 1999 in the Salt Lake Basin.

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>1926 Total Acres</th>
<th>1999 Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Forested</td>
<td>27.63</td>
<td>23.01</td>
</tr>
<tr>
<td>Freshwater Herbaceous</td>
<td>60.85</td>
<td>17.35</td>
</tr>
<tr>
<td>Saltwater Forested</td>
<td>1.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Saltwater Herbaceous</td>
<td>23.29</td>
<td>20.66</td>
</tr>
<tr>
<td>Non-vegetated</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Open Water</td>
<td>71.13</td>
<td>7.05</td>
</tr>
<tr>
<td>Upland</td>
<td>163.83</td>
<td>279.74</td>
</tr>
</tbody>
</table>

Legend

HYDROGRAPHIC_FEATURE_CLASS
- Freshwater Forested
- Freshwater Herbaceous
- Open Water
- Saltwater Forested
- Saltwater Herbaceous
- Unvegetated
- Upland and Sub-BasinBoundaries

1926

1999
Figure 55: Percent net gain/loss of upland within the Pinellas County sub-basin study area.
Statistical Significance Testing of Differences

Statistical testing of differences in sub-basin acreages for each hydrographic feature between 1926 and 1999 was performed to quantitatively verify if significant differences exist between the study time periods. The Kolmogorov-Smirnov and Shapiro-Wilk tests where used to test 1926 and 1999 sub-basin means to determine if the data were normally distributed. Results of the normality testing revealed that at the 95% confidence level, both data sets are significant, rejecting the null hypothesis that the data are normally distributed (refer to Table 6 below). Thus, the non-parametric Wilcoxon Signed-Rank test was chosen for paired sample testing. The Wilcoxon Signed rank test is a common non-parametric alternative to the paired student’s t-test, and tests the null hypothesis that the population median of the paired differences of the two samples (1926 and 1999) is zero (PROPHET, 2007).

Table 6: Results of the Komogorov-Smirnov and Shapiro-Wilk test for normality at the 95% confidence level for 1926 and 1999 hydrographic feature class sub-basin means.

1926 Means

<table>
<thead>
<tr>
<th>Hydrographic Feature Class</th>
<th>Kolmogorov-Smirnov(a)</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
</tr>
<tr>
<td>1926 Freshwater Forested Acres</td>
<td>0.206</td>
<td>36</td>
</tr>
<tr>
<td>1926 Freshwater Herbaceous Acres</td>
<td>0.175</td>
<td>36</td>
</tr>
<tr>
<td>1926 Saltwater Forested Acres</td>
<td>0.386</td>
<td>36</td>
</tr>
<tr>
<td>1926 Saltwater Herbaceous Acres</td>
<td>0.335</td>
<td>36</td>
</tr>
<tr>
<td>1926 Non-vegetated Acres</td>
<td>0.384</td>
<td>36</td>
</tr>
<tr>
<td>1926 Open Water Acres</td>
<td>0.381</td>
<td>36</td>
</tr>
<tr>
<td>1926 Upland Acres</td>
<td>0.231</td>
<td>36</td>
</tr>
<tr>
<td>1926 Wetland Acres</td>
<td>0.233</td>
<td>36</td>
</tr>
</tbody>
</table>

(a) Lilliefors Significance Correction
Results of the Wilcoxon Signed-Rank test verify the results of the net gain and loss analysis, and demonstrate that for all hydrographic feature classes and types except saltwater forested wetlands, differences in sub-basin median acreages between 1926 and 1999 are significant at the 95% confidence level (see Table 7). Table 8 displays the ranking results. For all of the parameters except water, uplands, and saltwater forested wetlands, the majority of the basins ranked negatively, which are interpreted as the overall median acres of hydrofeatures occurring in 1999 are less than the median acres of hydrofeatures occurring in 1926, quantitatively demonstrating an overall net loss of freshwater forested, freshwater herbaceous, saltwater herbaceous, non-vegetated and total wetland hydrofeatures for the study area between 1926 and 1999. Open water and upland are the only two variables that ranked positively and were significant, which is interpreted as the overall median acres of water and upland occurring in 1999 are greater than the median acres of open water and upland occurring in 1926, again quantitatively demonstrating an overall net gain of open water and upland within the study area.
Table 7: Test statistic for the Wilcoxon Signed Ranks Test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>99 FFOR acres - 26 FFOR acres</td>
<td>-5.059(a)</td>
<td>0.000</td>
</tr>
<tr>
<td>99 FHER acres - 26 FHER acres</td>
<td>-5.059(a)</td>
<td>0.000</td>
</tr>
<tr>
<td>99 SFOR acres - 26 SFOR acres</td>
<td>-1.435(b)</td>
<td>0.151</td>
</tr>
<tr>
<td>99 SHER acres - 26 SHER acres</td>
<td>-4.440(a)</td>
<td>0.000</td>
</tr>
<tr>
<td>99 UNVEG acres - 26 UNVEG acres</td>
<td>-3.224(a)</td>
<td>0.001</td>
</tr>
<tr>
<td>99 WATER acres - 26 WATER acres</td>
<td>-4.129(b)</td>
<td>0.000</td>
</tr>
<tr>
<td>99 UPLAND acres - 26 UPLAND acres</td>
<td>-5.137(b)</td>
<td>0.000</td>
</tr>
<tr>
<td>99 WETLAND acres - 26 WETLAND acres</td>
<td>-5.106(a)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Based on positive ranks.
* Based on negative ranks.

Table 8: Ranking results from the Wilcoxon Signed Ranks Test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>99 FFOR acres - 26 FFOR acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>33(a)</td>
<td>19.85</td>
<td>655.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>3(b)</td>
<td>3.67</td>
<td>11.00</td>
</tr>
<tr>
<td>Ties</td>
<td>0(c)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99 FHER acres - 26 FHER acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>35(d)</td>
<td>18.71</td>
<td>655.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>1(e)</td>
<td>11.00</td>
<td>11.00</td>
</tr>
<tr>
<td>Ties</td>
<td>0(f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99 SFOR acres - 26 SFOR acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>10(g)</td>
<td>11.90</td>
<td>119.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>16(h)</td>
<td>14.50</td>
<td>232.00</td>
</tr>
<tr>
<td>Ties</td>
<td>10(i)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99 SHER acres - 26 SHER acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative Ranks</td>
<td>26(j)</td>
<td>15.31</td>
<td>398.00</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>2(k)</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Ties</td>
<td>8(l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The exception, saltwater forested wetlands, presents an interesting case study in land development dynamics. Much of the coastal alteration that occurred between the study time period involved the dredging of tidal creeks and water bodies for navigational purposes, and the dredging of mosquito ditches. Several canals, such as Lake Tarpon canal, were also dredged much deeper and further inland than the former natural water courses existed in 1926. These dredged and channelized water bodies allow for saltwater
to penetrate further upstream than under natural conditions. Additionally, mosquito ditching of most coastal areas by the 1970s was evident throughout the study area, again allowing for greater tidal penetration inland, and the establishment of more saline water and soil conditions. Dredging and mosquito ditching thus created the perfect opportunity for colonization of former salt tern and high marsh areas by mangroves, as mangrove seeds are water borne, and under natural conditions may only have reached these areas under extremely high tides or during storm events. Gains through these activities were substantial enough to offset any losses experienced during the time period, and result in a net gain that is not, however, statistically significant.

**Cluster Analysis of Results**

Cluster analysis conducted to group similar drainage sub-basins together based upon the type of gains and losses of particular wetland types. The results of the cluster analysis quantitatively verify many of the sub-basin net gain and loss trends and exceptions previously identified. Since both similarity and dissimilarity linkage rules were used, analysis results were able to identify similar groups as well as exceptions. Following the discussion, Table 9 at the end of this section presents the hierarchical cluster analysis results for the hydrographic feature and upland net gain and loss data utilizing four different methods: nearest neighbor, furthest neighbor, unweighted pair group centroid, and weighted pair group centroid (median).

A two-cluster solution was consistently found between all linkage methods for the freshwater forested net gain/loss variable. Masters Bayou and Tampa Bay clustered together separately from all other sub-basins. Masters Bayou, as previously identified,
represents the only significant net gain, while Tampa Bay represents the only significant zero net change, primarily because freshwater forested wetlands never occurred within this sub-basin, presently or historically.

Cluster analysis results for the freshwater herbaceous net variable exhibited more diversity than results for freshwater forested. In both two and three cluster solutions, Hollin Creek and Double Branch consistently grouped separately from all other sub-basins. Hollin Creek was identified earlier in the discussion as the sub-basin experiencing the least net loss, while Double Branch is the only basin identified as experiencing a net gain in freshwater wetlands, primarily through conversion of forested wetlands from what appears to be a large, linear transmission feature (power lines or pipeline) in the eastern part of the sub-basin (see Figure 43). The furthest neighbor linkage method produced a fourth cluster composed of Moccasin Creek, Salt Lake, Brooker Creek and Mobly Bayou. These sub-basins are also the only sub-basins that are mapped in the 50-75% net loss category (Figure 48), and experiencing the least net loss second to Hollin Creek.

Analysis results for the saltwater forested net loss/gain variable exhibited two, three and four cluster solutions. All linkage methods grouped Long Branch separately from all others, which is the sub-basin experiencing the greatest net gain. Pinellas Park Ditch and Tampa Bay also clustered out separately from Long Branch and all other sub-basins, with Pinellas Park experiencing the second highest net gains, and Tamp Bay the third highest net gains in saltwater forested wetlands.

For saltwater herbaceous net gains/losses, however, the cluster analysis had much less interpretable results. Only two of the five linkage methods (nearest neighbor and
weighted pair group centroid (median) produced distinct solutions with Cedar Creek grouping out separately from all other sub-basins. Cedar Creek is one of only two basins that exhibited net gains in saltwater herbaceous wetlands. The other three linkage methods produced a cluster of sub-basins primarily composed of basins within the range of < 50% net loss to net gains, and includes those inland basins where salt marsh never existed historically or currently.

Solutions produced by the unvegetated net cluster analyses were similar to the salt water herbaceous analysis in clustering. Two, three and four cluster solutions emerged, with Direct Runoff to Gulf (highest net gain) consistently grouping separately in all solutions. Cross Canal South and Moccasin Creek formed a cluster separate from all others in the four cluster solutions as the only two basins exhibiting less than 75% net loss. The three and four cluster solutions produced two predominately large clusters of sub-basins, one largely composed of those sub-basins exhibiting no net loss, and those sub-basins with high net loss (> 75%).

The overall wetland net loss/gain cluster analysis produced primarily two and three cluster solutions, with Tampa Bay consistently falling out as a separate cluster, reiterating the sub-basin net gain/loss analysis results as the only watershed to experience net gains. The furthest neighbor analysis produced a 3 cluster solution, with a cluster composed of all the basins experiencing less than 50% loss except Direct Runoff to Bay. The other linkage methods primarily identified two large groups in the three cluster solutions that could be divided into high net loss sub-basins (roughly > 75%) and lower net loss sub-basins (roughly < 75%). Double Branch and Masters Bayou also clustered out separately in several linkage methods, with Double Branch representing the only
basin to experience no substantial wetland net loss or gain, and Maters Bayou as the only other basin to experience substantial overall net wetland gains.

Solutions for the open water net variable resulted in very distinct two and three cluster solutions. Brooker Creek clustered separately from all others in both the two and three cluster solutions, and represents the highest net gain in open water, although overall experiencing lower net losses in wetlands than many other sub-basins. In the three cluster solution, Hollin Creek and Walsingham Reservoir consistently separated out as a cluster, and represent the second highest net gains, respectively. Like Brooker Creek, Hollin Creek had no substantial open water areas in 1926, but by 1999 almost a third of the wetlands historically present had been converted to open water. In the case of Walsingham Reservoir, the creation of the reservoir is largely responsible for the increase in open water within this sub-basin, as well as conversion of almost all wetland features that existed in 1926 to open water by 1999 (see Figure 29). The remainder of the basins grouped together, and represent overall net gains. Surprisingly, the Anclote River sub-basin, the only basin experiencing a substantial net loss, did not group separately.

Finally, for the upland net variable, the cluster analysis produced two, three and four solutions. Salt Lake consistently clustered separately from all others for all linkage methods and in all solutions. While Salt Lake experienced some of the highest upland net gains of any basin, it did not experience the highest net gain. Tampa Bay (the only sub-basin experiencing net losses) and Double Branch (the sub-basin experiencing the highest net gains of any) clustered together as a single cluster in the between groups and unweighted pair group centroid analyses, and represent the extremes of net loss and gain, respectively. The four cluster solution produced a fourth cluster composed of sub-basins
experiencing net gains roughly in the 30% to 35% range.

Summary of Results in Terms of the Primary Research Questions

Overall, analysis results indicate that indeed, statistically significant freshwater forested, freshwater herbaceous, saltwater herbaceous, non-vegetated and overall wetland losses have occurred between the two study time periods for most sub-basins in Pinellas County. Additionally, statistically significant increases in open water and upland through dredging and filling activities and a compelling historical library of aerial imagery undoubtedly point to human-induced land development and land alterations activities as the primary causal agents behind wetland losses between the two time frames, as opposed to natural forces such as beaver activity, land subsidence, or rising sea level. Net gain/loss mapping and cluster analysis of sub-basins indicate clear groupings, with some of the highest sub-basin net losses occurring generally within the oldest developed portions of the County (incorporated municipalities) that were settled and developed prior to the advent of state and federal wetlands regulations in the mid-1980s, while the lowest losses occurred within sub-basins in the northeastern, least developed portion of the County. Additionally, dredging activities for navigation, filling and creation of storm water retention ponds proved to be the single largest agent of wetland conversion (from native vegetated habitats to open water) within most of the sub-basins experiencing overall net losses. Ironically, the one wetland type to exhibit net gains, saltwater forested wetlands, can be directly attributed to mosquito ditching of historical salt marsh and salt tern habitats.
Table 9: Sub-basin cluster solutions for five hierarchical linkage methods.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Single (Nearset Neighbor)</th>
<th>Between Groups</th>
<th>Complete (Furthest Neighbor)</th>
<th>Centroid</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FFOR Net</strong></td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
</tr>
<tr>
<td></td>
<td>Tampa Bay &amp; Masters Bayou</td>
<td>Tampa Bay &amp; Masters Bayou</td>
<td>Tampa Bay &amp; Masters Bayou</td>
<td>Tampa Bay &amp; Masters Bayou</td>
<td>Tampa Bay &amp; Masters Bayou</td>
</tr>
<tr>
<td><strong>FHER Net</strong></td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
<td>All Others</td>
</tr>
<tr>
<td></td>
<td>Double Branch</td>
<td>Double Branch</td>
<td>Hollin Creek</td>
<td>Double Branch</td>
<td>Double Branch</td>
</tr>
<tr>
<td></td>
<td>All Others</td>
<td>All Others</td>
<td>Double Branch</td>
<td>All Others</td>
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<td>Pinellas Park Ditch &amp; Tampa Bay</td>
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130
Table 9 Continued.

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<td>Unnamed Ditch, Walsingham Reservoir, Bishop Creek, Salt Lake, Sutherland Bayou, Klosterman Bayou Run, Lake Tarpon, Hollin Creek, Jerry Branch, Double Branch, Duck Slough, Brooker Creek, Cow Branch, Allen Creek, Cross Canal N &amp; Moccasin Creek</td>
<td>Unnamed Ditch, Walsingham Reservoir, Bishop Creek, Salt Lake, Sutherland Bayou, Klosterman Bayou Run, Lake Tarpon, Hollin Creek, Jerry Branch, Double Branch, Duck Slough, Brooker Creek, Cow Branch, Allen Creek, Cross Canal N &amp; Moccasin Creek</td>
<td>Unnamed Ditch, Walsingham Reservoir, Bishop Creek, Salt Lake, Sutherland Bayou, Klosterman Bayou Run, Lake Tarpon, Hollin Creek, Jerry Branch, Double Branch, Duck Slough, Brooker Creek, Cow Branch, Allen Creek</td>
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**UNVEG Net**

| Direct To Gulf | Pinellas Park Ditch, Stevenson Creek, Alligator Creek, Long Branch, McKay Creek, Curlew Creek, Lake Tarpon Canal, Cedar Creek, Church Creek, Anclote River, Belleair GC Run, Mullet Creek, Masters Bayou, Direct to Bay, Papsys Bayou, Tampa Bay, Long Bayou, Cr | Pinellas Park Ditch, Stevenson Creek, Alligator Creek, Long Branch, McKay Creek, Curlew Creek, Lake Tarpon Canal, Cedar Creek, Church Creek, Anclote River, Belleair GC Run, Mullet Creek, Masters Bayou, Direct to Bay, Papsys Bayou, Tampa Bay, Long Bayou, Cr | Pinellas Park Ditch, Stevenson Creek, Alligator Creek, Long Branch, McKay Creek, Curlew Creek, Lake Tarpon Canal, Cedar Creek, Church Creek, Anclote River, Belleair GC Run, Mullet Creek, Masters Bayou, Direct to Bay, Papsys Bayou, Tampa Bay, Long Bayou, Cr | Pinellas Park Ditch, Stevenson Creek, Alligator Creek, Long Branch, McKay Creek, Curlew Creek, Lake Tarpon Canal, Cedar Creek, Church Creek, Anclote River, Belleair GC Run, Mullet Creek, Masters Bayou, Direct to Bay, Papsys Bayou, Tampa Bay, Long Bayou, Cr |

Cross Canal S & Moccasin Creek

Cross Canal S & Moccasin Creek
Table 9 Continued.

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WETLAND Net
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Chapter Five: Conclusions

Overall Trends and Agents in Wetland Loss and Conversion

Pinellas County is a poignant illustration of the effects of unregulated development and land use alteration on the loss of wetlands as significant components within the landscape. Throughout the study period, 86% of freshwater herbaceous wetlands that occurred in 1926 were either largely eliminated or converted to open water. Likewise, 56% percent of the freshwater forested wetlands present in 1926 were either eliminated, converted to open water or to freshwater herbaceous wetlands. Within the coastal areas, saltwater herbaceous wetlands experienced the overall highest net losses of any coastal wetland type (83%), largely due to elimination through dredging and filling, and conversion to mangrove swamp from mosquito ditching and saltwater intrusion. Non-vegetated wetlands exhibited considerably less wetland loss than all other hydrographic feature classes at 37%. Agents of non-vegetated wetland loss were largely the same as for saltwater herbaceous—dredging of tidal creeks and for creation of artificial waterways, filling for water front development, and saltwater intrusion as a result of mosquito ditching and dredging. The differences in median sub-basin wetland acreages for all these wetland hydrofeature classes were statistically significant at the 95% confidence level, quantitatively verifying substantial and significant losses in these wetland hydrofeatures classes between 1926 and 1999.
Only two wetland categories experienced net gains in areal extent from what occurred in 1926—saltwater forested at 23% and open water at 63%. Mosquito ditching and dredging, as well as the construction of causeway fill into Tampa Bay, are largely the agents responsible for this increase in the aerial extent of mangroves. As mangroves seeds are only dispersed by water, mosquito ditching and dredging of natural tidal creeks and canals has created higher salinity conditions further upstream and inland than what existed in 1926, particularly in historical high marsh and salt tern areas that under undredged conditions would only be inundated during extreme tidal events or storm surges and thus would be much slower to colonize with mangroves. Although not statistically significant at the 95% confidence level, this trend will most likely continue to increase over time, given the combined effects of rising sea level over the last century and global climate change.

Through examination of relative distribution of hydrofeatures between 1926 and 1999, increases in open water are concluded to be undoubtedly associated with excavation of wetland features for storm water drainage, and excavation of natural slough systems and water courses for storm water conveyance. There are virtually no water courses remaining with the study sub-basin area that have not been ditched or dredged. Excavation of inland wetlands for a water supply reservoir, and of shallow coastal wetland features for the creation of canal-style development and navigation (Long Bayou and the Lake Tarpon Canal) are also agents that contributed substantially to net open water gains within the study area sub-basins. Losses of vegetated, native wetlands and conversion to open water also represent a dramatic simplification of wetland ecosystems.
remaining in Pinellas County, and most likely concurrent and significant losses of floral
and faunal diversity within the County.

Likewise, most sub-basins within the study area exhibited increases in upland area
between 1926 and 1999, largely through filling of wetland and shallow open water areas
and ditching and draining of wetlands for agricultural and development purposes. Any
substantial wetland loss due to ditching and draining most likely occurred prior to 1970,
as by this time frame most wetlands were ditched within the study area to create arable
land for citrus, row crop and improved pasture. Even in 1926, substantial ditching of
wetlands was already present in several sub-basins, particularly north of St. Petersburg
and near Dunedin, Pinellas Park and Largo. Although roughly half of the estimated gain
in open water, median differences in sub-basin upland acreages between the study time
periods was statistically significant at the 95% confidence level.

The net/gain loss analysis by sub-basin and cluster analysis of these results
revealed some interesting trends among sub-basins. Generally, sub-basins within the
northeastern portion of the County experienced some of the lowest net losses, and some
of the overall highest net gains in open water features, largely due to the lack of open
water features in 1926. The northeastern portion of the County also contains some of the
lesser developed areas within Pinellas County. As expected, highly urbanized portions of
Pinellas County within the study area grouped together for most hydrofeatures and
generally exhibited higher net gains in open water and upland. Most of these areas also
generally represent developed portions of the County prior to the advent of state and
federal wetlands protection and regulation in the mid 1980s. The southeastern portion of
the study area encompassed by sub-basins bordering Tampa Bay and/or Long Bayou and Cross Canal exhibited overall net gains in saltwater forested wetlands, again largely attributable to salt water intrusion and mosquito ditching.

**Accomplishment of Modeling Goals and Limitations of the Analysis**

The GIS model developed for estimating wetland loss and conversion was able to effectively identify both large scale and sub-basin trends within the Pinellas County study area. The model was developed using commonly available land-use data, and the FLUCCS classification scheme chosen as the basis for comparison is available for every County in the State of Florida. The model accomplishes the desired flexibility by being applicable to any County within the state, and if using a different classification scheme, exportable to any geographic region as long as the classification scheme is consistent between the time periods being compared. The study utilized the USGS HUC sub-basins as the standard unit for comparison between time periods. HUC data is also available for every region in the United States, as well as for some international locations, thus making the model applicable to a wide geographic extent.

While accomplishing flexibility in the applicability of the model, use of the HUC data as the standard watershed unit for comparison can result in several limitations in the use of the model for estimating wetland loss and conversion to upland or open water. The primary limitation is that the model estimates are relative to when the sub-basin units were determined. In many locations, sub-basins that existed in the past may no longer exist, and rapid development in other areas has resulted in the substantial alteration and
redirecting of water flow, resulting in connection or severing of sub-basin areas from the time they were originally drawn. If the goal is to determine a relative estimate over time, then the model can produce reasonably accurate results. However, if the goal in estimating wetland loss and conversion is for restoration purposes for a specific sub-basin or watershed, then the historic watershed boundaries should be determined, or redrawing of sub-basin boundaries may be required.

Another limitation of the model and analysis is in the method used to calculate upland. As pointed out several times, the 1999 sub-basin areas were clipped by a County boundary layer that included a detailed coastline, thus several areas of man-made upland along the barrier islands are included within the analysis “footprint”, and several coastal and inland estuarine water bodies are excluded. As a result, the calculated net gain in upland acreage, although significant at the 95% confidence level, most likely underestimates the net gain in upland area, especially since many of the areas filled to create upland existed as estuarine open water bodies in 1926 and were not included within the sub-basin analysis. Likewise, the net gain in open water may be overestimated since the actual extent of most of the estuarine water bodies were excluded from the analysis.

The third major limitation to use of the model lies in the subjectivity of the GIS analyst. Even when employing consistent classification schemes across time periods, it is unlikely or impossible that the same analyst mapped the same areas for both time periods, thus discrepancies in mapped features are unavoidable. Several factors can affect the mapping accuracy, including the analysts experience in photo interpretation, the analyst’s
knowledge and experience of wetland signatures and ground truthing experience, and even the analyst’s mental or emotional state during digitizing. Masters Bayou, although the only sub-basins that showed a questionable discrepancy in mapped features, is one possible example of this. When using older aerials, as this study did, resolution can also greatly affect the accuracy of mapped features, especially if no other aerial data sources are available to cross-reference during the digitizing. Lastly, how the classification scheme is applied can also greatly affect results. Had the strict definitions of the FLUCCS classification been utilized, then beaches and several other non-vegetated wetland types would be completely excluded from the analysis. Since the 1999 hydrofeature data was selected by applying the same definitions used in the 1926 analysis (see Table 3), errors associated with miss-classification were largely, although doubtedly entirely, eliminated.

The last significant limitation of the study is the degree to which wetland conversion can be estimated. Although mapped to the Level 3 FLUCCS code, determining dominant species of most features at the 1926 mapping resolution was largely impossible, and relied heavily on past experience of the analyst and on reading signatures on an extensive historical aerial database maintained by Pinellas County. Changes between open water, herbaceous and forested were more obvious most of the time, but in several areas were extremely difficult to determine just based on the 1926 aerial resolution alone. Had Pinellas County not been fortunate enough to have an extensive aerial on-line database, determination even to the Level 2 tier would likely been largely guess work in some low resolution areas, particularly just north of St. Petersburg.
Thus, the most efficient and flexible use of the GIS-model thus presented is when comparing time periods that have already been mapped by a standard landuse or habitat classification system.

**Using Analysis Results to Target Restoration**

One pertinent application of the results of this analysis is in targeting sub-basins for restoration. Those sub-basins experiencing complete or near complete conversion of wetlands to open water features also represent some of the most highly urbanized and developed sub-basins. Remaining wetlands could be identified, and targeted for restoration. Additionally, planting of littoral areas of excavated features with native vegetation and maintenance of these areas to reduce nuisance and exotic species can also provide some significant restoration and water quality benefits, and in fact may be the only real restoration opportunity available within some of these sub-basins. The sub-basins adjoining Tampa Bay, however, present numerous opportunities for coastal restoration, both through backfilling of mosquito ditching in those areas with limited mangrove recruitment, or of nuisance and exotic species removal from spoil bank areas, and if feasible, regrading to back plug mosquito ditching. While navigation and storm water conveyance may prohibit restoration of some natural tidal creek features, restoration may be possible in some of the smaller dredged features, within tributaries, or further upstream. Most significantly, the results can be used to effectively target preservation efforts in sub-basins where significant wetland habitats still exist, and to identify these areas for additional protection from the negative environmental impacts of
land development activities, or for acquisition for conservation purposes.
References


*Florida Natural Areas Inventory*. 2005. Florida State University. October 8, 2007 [http://www.fnai.org/about.cfm](http://www.fnai.org/about.cfm)


Pinellas County Board of County Commissioners. 1970. Bay Area Fills. Clearwater, Florida: Pinellas County Planning Department.


Pinellas County Planning Council. 1986. Pinellas County Historical Background. Pinellas County Planning Department. 90pp.

*Pinellas County Planning Department Homepage.* Pinellas County Government. March 1, 2004. [http://www.co.pinellas.fl.us/bcc/Plan/default.htm](http://www.co.pinellas.fl.us/bcc/Plan/default.htm)

Pinellas County Planning Department. 2002. “Existing Land Use Inventory for Pinellas County-Countywide as of April 1, 2002.” http://www.co.pinellas.fl.us/bcc/Plan/pdf_files/exlanduse_tbl.pdf


Appendix A: Metadata for 1926 and 1999 Hydrofeature Layers

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Identification Information:
Citation:
  Originator: Pamela Fetterman, USF
  Publication_Date: Unknown
  Title: Pinella County Wetlands1926
  Geospatial_Data_Presentation_Form: vector digital data
  Online Linkage: None at this time.

Description:
Abstract: Hydrographic features of the land mass of Pinellas County were digitized from 1926 black and white 1:800 foot scaled aerials, and classified according to the 1999 FDOT FLUCCS land-use classification. Upland and non-hydrographic features were not digitized as part of the creation of this feature class.

Purpose: The data set was developed as part of a USF Masters of Science thesis comparing hydrographic feature coverage in 1926 and 1999 to determine net gain/loss of major hydrofeature types and classes by sub-basin within Pinellas County.


Time_Period_of_Content:
  Time_Period_Information:
    Single_Date/Time:
      Calendar_Date: 1926
    Currentness_Reference: ground condition

Status:
  Progress: In work
  Maintenance_and_Update_Frequency: None planned

Spatial Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -82.853897
    East_Bounding_Coordinate: -82.583368
    North_Bounding_Coordinate: 28.177813
    South_Bounding_Coordinate: 27.703745

Keywords:
  Theme:
    Theme.Keyword_Thesaurus: wetlands or land use
    Theme.Keyword: wetlands

Place:
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Place_Keyword: Pinellas County, Florida
Temporal:
Temporal_Keyword: historic
Access_Constraints: As determined by USF Department of Geography or Pinellas County. Please check with these entities for any constraints.
Use_Constraints: As determined by USF Department of Geography or Pinellas County. Please check with these entities for any constraints.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Pamela Fetterman
Contact_Organization: E Sciences, Incorporated
Contact_Position: Senior Scientist
Contact_Address:
Address_Type: mailing and physical address
Address: 1990 Main Street, Suite 750
City: Sarasota
State_or_Province: FL
Postal_Code: 34236
Country: United States of America
Contact_Voice_Telephone: (941) 309-5309
Contact_Facsimile_Telephone: (541) 309-5409
Contact_Electronic_Mail_Address: pfetterman@esciencesinc.com
Hours_of_Service: 8am to 5pm
Data_Set_Credit: Pamela Fetterman, 1926 aerial rectification by K.V. Wilson
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600)
Service Pack 2; ESRI ArcCatalog 9.2.0.1324
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Visual inspection of the 1926 hydrographic features over the aerials and
corroboration with ancillary data sources. Checks for duplicates were performed,
as well as verification of topology. No statistical accuracy verifications have
been done. Based on past projects of a similar nature it is estimated that
classification accuracies of between 80% - 90% can be expected for Level II
categories.
Logical_Consistency_Report: The source product was checked against the aerial
source material, and cross-referenced to ancillary data sources such as black and
white 1942 aerial data accessed on the Pinellas County webstie and 1970s black
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

and white aerial aerials provided by the Southwest Florida Water Management District. In mapping of the features, other ancillary data sources such as 1950s FLUCCS land use, 1980s NWI and soils data, and USGS topography were also used to corroborate features mapped as wetlands.

Completeness_Report: To date, approximately 2/3 of the county is mapped to St. Petersburg. Eight of the southernmost panels still require mapping. Mapping of the entire County is expected to be completed by December, 2007.

Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: Visual inspection of the 1926 linework over the aerials at a scale of 1: 3,265, was conducted after mapping a complete panel set across the County from east to west or west to east. The scale represents the resolution of the aerials as determined by ArcView. Aerials were scanned TIFF images originally flown at a 1 inch = 800 ft scale.

Lineage:

Source_Information:

Source_Citation:

Citation_Information:
Originator: K.V. Wilson
Publication_Date: 2004
Title: 1926possiblesinks
Geospatial_Data_Presentation_Form: vector digital data
Publication_Information:
Publication_Place: University of South Florida
Publisher: USF Geography Department
Other_Citation_Details: Created as part of a 2004 M.S. Thesis evaluating changes in sinkhole areal extent between 1926 and 1999.

Source_Scale_Denominator: 800
Type_of_Source_Media: CD-ROM shapefiles
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 2003
Ending_Date: 2004
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: 1926possiblesinks.shp
Source_Contribution: 1926 Sinkholes mapped by K.V. Wilson was the feature coverage layer that was used to map wetland extent. The source material was
substantially modified in the mapping process, however, to reflect areal wetland extent that existed in 1926.

**Process Step:**

**Process Description:** Dataset copied. The data set was then modified in ArcInfo v. 9.2 using the Editor toolbar to digitize wetland areal coverage in 1926. Topology was created and verified throughout the mapping and digitizing process using topology creation tools and topology verification tools and fix it tools available through the Topology toolbox and toolbar. Existence of wetlands were corroborated with ancillary data previous to mapping as a hydrographic feature and assigning a FLUCCS attribute code. After digitizing a series of aerial panels from east to west across the County, topology would be verified and all null polygons identified and assigned the appropriate FLUCCS attribute and a unique I.D. number. Lastly, a hydrographic_feature_class field was created which grouped the Level III FLUCCS attributes into one of six general categories: freshwater forested, freshwater herbaceous, saltwater forested, saltwater herbaceous, unvegetated and open water. Uplands were not mapped, and the "no gaps" topology was excluded for the data set.

**Source Used Citation Abbreviation:** D:\Kelly's Pinellas\Pinellas karst GIS\1926sinks

**Process Date:** 2005-2007

**Process Contact:**

**Contact Information:**
- **Contact Person Primary:** Pamela Fetterman
- **Contact Organization:** E Sciences, Incorporated
- **Contact Position:** Senior Scientist
- **Contact Address:**
  - **Address Type:** mailing and physical address
  - **Address:** 1990 Main Street, Suite 750
  - **City:** Sarasota
  - **State or Province:** FL
  - **Postal Code:** 34236
  - **Country:** United States of America
- **Contact Voice Telephone:** [941] 309-5309
- **Contact Facsimile Telephone:** [941] 309-5409
- **Contact Electronic Mail Address:** pfetterman@esciencesinc.com
- **Hours of Service:** 8am to 5pm

**Process Step:**
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation: Q:\Workspace\Pinellas Deliverables\1926\1926wetlands

Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation: Cloud_Cover: Unknown

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector

Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 10250

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 24.000000
Standard_Parallel: 31.500000
Longitude_of_Central_Meridian: -84.000000
Latitude_of_Projection_Origin: 24.000000
False_Easting: 400000.000000
False_Northing: 0.000000

Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000128
Ordinate_Resolution: 0.000128
Planar_Distance_Units: meters

Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Altitude_Resolution: 0.000010
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
   Entity_Type_Label: wetlands1926
Attribute:
   Attribute_Label: Id
   Attribute_Definition: Internal feature number
   Attribute_Definition_Source: ESRI
   Attribute_Domain_Values:
      Unrepresentable_Domain: Sequential unique whole numbers that were assigned to each individual polygon during digitizing.
   Attribute_Measurement_Frequency: None planned
Attribute:
   Attribute_Label: Shape
   Attribute_Definition: Feature geometry.
   Attribute_Definition_Source: ESRI
   Attribute_Domain_Values:
      Unrepresentable_Domain: Coordinates defining the features.
Attribute:
   Attribute_Label: OBJECTID
   Attribute_Definition: Internal feature number.
   Attribute_Definition_Source: ESRI
   Attribute_Domain_Values:
      Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
   Attribute_Measurement_Frequency: None planned
Attribute:
   Attribute_Label: Shape_Length
   Attribute_Definition: Length of feature in internal units.
   Attribute_Definition_Source: ESRI
   Attribute_Domain_Values:
      Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
   Attribute_Label: Shape_Area
   Attribute_Definition: Area of feature in internal units squared.
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: FLUCCS_CODE
Attribute_Definition: Numeric classification of the Land Uses/Land Cover classification code as defined in the Florida Department of Transportation (FDOT) Florida Land Use and Land Cover Classification System (FLUCCS).
   This is the Level 3 classification.
Attribute_Definition_Source: FDOT
Attribute_Domain_Values:
Codeset_Domain:
   Codeset_Name: Florida Land Use, Cover and Forms Classification System
   Codeset_Source: Florida Department of Transportation, Surveying and Mapping Office, Geographic Mapping Section
Attribute:
Attribute_Label: HFC_Code
Attribute_Definition: Hydrographic Feature Class Code
Attribute_Definition_Source: User Defined, based on Level II FLUCCS Code
Attribute_Domain_Values:
Codeset_Domain:
   Codeset_Name: Florida Land Use, Cover and Forms Classification System
   Codeset_Source: Florida Department of Transportation, Surveying and Mapping Office, Geographic Mapping Section
Attribute:
Attribute_Label: HYDROGRAPHIC_FEATURE_CLASS
Attribute_Definition: Character description of the HFC_Code
Attribute_Definition_Source: User Defined
Attribute_Domain_Values:
Codeset_Domain:
   Codeset_Name: User Defined Categories of Freshwater Forested, Freshwater Herbaceous, Saltwater Forested, Saltwater Herbaceous, Unvegetated, and Open Water that correspond to major wetland types and surface water.
   Codeset_Source: User Defined
Attribute:
Attribute_Label: Perimeter
Attribute_Definition: polygon perimeter in map units, corresponds to Shape_Length
Attribute_Definition_Source: User Defined
Attribute_Domain_Values:
Appendix A (Continued)

1986 Pinellas County Hydrographic Features and Topology Feature Classes

Unrepresentable_Domain: Positive real numbers that are generated by the calculate geometry table tool.
Attribute_Measurement_Frequency: As needed
Attribute:
  Attribute_Label: Area
  Attribute_Definition: polygon area in map units, corresponds to Shape_Area
  Attribute_Definition_Source: User Defined
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are generated by the calculate geometry table tool.
  Attribute_Measurement_Frequency: As needed
Attribute:
  Attribute_Label: Acres
  Attribute_Definition: Polygon area calculated in acres
  Attribute_Definition_Source: User Defined
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are generated by the calculate geometry table tool.
  Attribute_Measurement_Frequency: As needed
Attribute:
  Attribute_Label: Hectares
  Attribute_Definition: Polygon area in hectares
  Attribute_Definition_Source: User Defined
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are generated by the calculate geometry table tool.
  Attribute_Measurement_Frequency: As needed

Distribution_Information:
Distributor:
  Contact_Information:
    Contact_Organization_Primary:
      Contact_Organization: University of South Florida
      Contact_Person: Dr. Robert Brinkmann
      Contact_Position: Chair, Department of Geography
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 4202 East Fowler Avenue, NES 107
      City: Tampa
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

State_or_Province: FL
Postal_Code: 33630
Country: USA
Contact_Voice_Telephone: [813) 974-2386
Contact_Facsimile_Telephone: [813] 974-4808
Hours_of_Service: 8am to 5pm

Resource_Description: Downloadable data. Translation of files to formats other than those described here is the sole responsibility of individuals downloading the data.

Distribution_Liability: The data are being provided on an ‘as is’ basis. USF specifically disclaims any warranty, expressed or implied, including, but not limited to, the implied warranties or merchantability and fitness for a particular use. The entire risk as to quality and performance is with the user. In no event will USF or its staff be liable for any direct, indirect, incidental, special, consequential, or other damages, including loss of profit, arising out of the use of these data even if USF has been advised of the possibility of such damages. All data are intended for resource management use.

Standard_Order_Process:

Metadata_Reference_Information:
Metadata_Date: 20071012

Custom_Order_Process: Contact Dr. Brinkmann or Pinellas County GIS Section

Metadata_Contact:
Contact_Information:
Contact_Organization: USF Environmental Science and Policy Department
Contact_Person: Pamela Fetterman
Contact_Position: M.S. Graduate Student
Contact_Address:
Address_Type: mailing and physical address
Address: 1990 Main Street, Suite 750
City: Sarasota
State_or_Province: FL
Postal_Code: 34236
Country: USA
Address_Type: mailing and physical address
Address: 4202 East Fowler Avenue, NES 107
City: Tampa
Appendix A (Continued)

1926 Pinellas County Hydrographic Features and Topology Feature Classes

Contact_Voice_Telephone: [941] 309-5309
Contact_Facsimile_Telephone: [941] 309-5409
Contact_Electronic_Mail_Address: pfetterman@esciencesinc.com
Hours_of_Service: 8am to 5pm
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Time_Convention: local time
Metadata_Security_Information:
  Metadata_Security_Classification: Unclassified
Metadata_Extensions:
  Online_Linkage: http://www.esri.com/metadata/esriprof80.html
  Profile_Name: ESRI Metadata Profile

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Identification_Information:
  Citation:
  Citation_Information:
    Originator: Pamela Fetterman
    Publication_Date: Unpublished Material
    Title: 1999 Pinellas County Hydrofeatures
    Geospatial_Data_Presentation_Form: vector digital data
  Series_Information:
  Publication_Information:
  Other_Citation_Details: Adapted from 1999 FLUCCS Land Use/Cover provided by the SWFWMD.

Description:
  Abstract: 1999 hydrographic features in Pinellas County categorized according to the Florida Land Use and Cover Classification System (FLUCCS). The features were photointerpreted from 1:12,000 UGSG color infrared (CIR) digital orthophoto quarter quadrangles (DOQQs).
  Purpose: This data layer was created to quantify hydrographic features present in Pinellas County as seen in 1999. This may be useful for future management applications regarding land use change and wetland loss detection, as well as inventoring of natural resources.
  Time_Period_of_Content:
  Time_Period_Information:
    Single_Date/Time:
      Calendar_Date: 1999
    Currentness_Reference: ground condition
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -82.854773
East_Bounding_Coordinate: -82.561120
North_Bounding_Coordinate: 28.175187
South_Bounding_Coordinate: 27.609646
Keywords:
Theme:
Theme_Keyword_Thesaurus: none
Theme_Keyword: 1999 hydrofeatures
Theme_Keyword: FLUCCS
Theme:
Theme_Keyword_Thesaurus: ArcIMS Metadata Server Theme Codes
Theme_Keyword: imageryBaseMapsEarthCover
Place:
Place_Keyword_Thesaurus: none
Place_Keyword: Pinellas County
Place_Keyword: SWFWMD
Access_Constraints: None
Use_Constraints: These data were not collected under the supervision of a licensed Professional Surveyor and Mapper. Use of these data requires a general understanding of GIS.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Pamela Fetterman
Contact_Organization: E Sciences, Incorporated
Contact_Position: Senior Scientist
Contact_Address:
Address_Type: mailing and physical address
Address: 2379 Broad Street (U.S. 41 South)
City: Brooksville
State_or_Province: FL
Postal_Code: 34604-6899
Contact_Voice_Telephone: (941) 309-5309
Contact_Facsimile_Telephone: (941) 309-5409
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classses

Contact_Electronic_Mail_Address: pippetman@esciencesinc.com
Hours_of_Service: 8:00 a.m. to 5:00 p.m.
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.2.0.1324
Cross_Reference:
Citation_Information:
Originator: Southwest Florida Water Management District
Publication_Date: 20031205
Title: 1999 FLUCCS Land Use
Series_Information:
Series_Name: FLUCCS Land Use
Issue_Identification: 1999
Publication_Information:
Publication-placeholder: 2379 Broad Street, Brooksville Florida
Publisher: Southwest Florida Water Management District
Online_Linkage: http://www.swfwmd.state.fl.us/data/gis/
Larger_Work_Citation:
Citation_Information:
Originator: Southwest Florida Water Management District
Publication_Date: 1995 through current
Title: FLUCCS Land Use
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage: http://www.swfwmd.state.fl.us/data/gis/

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Visual inspection of the 1999 hydrofeatures to the 1999 land use and land cover data, and to 1999 DOQQs. The 1995 land use and land cover data was used as reference data. Additional checks on the original 1999 land use and land cover data included Arc/INFO's labelerror procedures to verify proper annotation of features. No statistical accuracy verifications have been done. Based on past projects of a similar nature it is estimated that classification accuracies of between 80% - 90% can be expected for Level II categories. In March of 2007, the additional domains of HFC_Code (alias for LEV4) and Hydrographic_Feature_Classification were edited and created, respectively, to classify the hydrofeature data.
Logical_Consistency_Report: The final product was checked against the source material, and any errors found were corrected.
Completeness_Report: There are no significant omissions.
Positional_Accuracy:
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Horizontal Positional Accuracy:
Horizontal Positional Accuracy_Report: Visual inspection of the 1999 linework over
the DOQQs, at a scale of 1:8,000, was used to verify the positional placement of
the linework. Data is estimated to be compliant with the National Map Accuracy
Standards for 1:12,000, estimated +/- 33.3 feet. Dates range between July and

September of 2001. The goal of this project was to update the existing 1995 land
use and land cover data layer using the 1999 DOQQs that meet or exceed
National Map Accuracy Standards for 1:12,000. Land use and land cover
boundaries are not always well defined, however, given the use of ancillary data
sources (e.g. soils data or National Wetlands Inventory) to determine feature
boundaries, it is expected that data acreage should be accurate.

Lineage:
Source Information:
Source Citation:
Citation Information:
Originator: Southwest Florida Water Management District
Publication Date: 19980701
Title: 1995 Land Use and Land Cover Data Layer
Publication Information:
Publication Place: 2379 Broad Street, Brooksville, Florida 34604-6899
Publisher: Southwest Florida Water Management District
Other Citation Details:
See the District's 1995 Land Use and Land Cover metadata regarding source
production.
Additional Information: (352) 796-7211
Online Linkage:
http://www.swfwmd.state.fl.us/data/gis/libraries/metadata/html/l/lu95_metadata.html
Source Scale Denominator: 12,000
Type of Source Media: Digital, ArcInfo Coverages
Source Time Period of Content:
Time Period Information:
Range of Dates/Times:
Beginning Date: 19940101
Ending Date: 19950101
Source Currentness Reference: ground condition
Source Citation Abbreviation: LU95
Source Information:
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Source_Citation:
Citation_Information:
  Originator: United States Geological Survey
  Publication_Date: Unknown
  Title: 1999 USGS Digital Orthophoto Quarter Quadrangles
Publication_Information:
  Publication Place: Sioux Falls, SD 57198
  Publisher: USGS
  Other_Citation_Details: Additional Information: 1-888-ASK-USGS
Online_Linkage:
Source_Scale_Denominator: 12,000
Type_of_Source_Media: Digital imagery
Source_Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date: 19990101
      Ending_Date: 20000101
    Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: 99DOQQ
Source_Information:
Source_Citation:
Citation_Information:
  Originator: United States Geological Survey
  Publication_Date: Unknown
  Title: 1995 USGS Digital Orthophoto Quarter Quadrangles
Publication_Information:
  Publication Place: Sioux Falls, SD 57198
  Publisher: USGS
  Other_Citation_Details: Additional Information: 1-888-ASK-USGS
Source_Scale_Denominator: 12,000
Type_of_Source_Media: Digital imagery
Source_Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date: 19940101
      Ending_Date: 19950101
    Source_Currentness_Reference: ground condition
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Source_Citation_Abbreviation: 95DOQQ
Source_Information:
Source_Citation:
  Citation_Information:
    Originator: Southwest Florida Water Management District
    Publication_Date: 20010901
    Title: 1999 Land Use and Land Cover Draft 1
    Publication_Information:
      Publication_Place: 2379 Broad Street, Brooksville, Florida 34604-6899
      Publisher: Southwest Florida Water Management District
Source_Scale_Denominator: 1:12,000
Type_of_Source_Media: Digital, ArcInfo Coverages
Source_Time_Period_of_Content:
  Time_Period_Information:
    Single_Date/Time:
      Calendar_Date: 1999
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: LU99_1

Process_Step:
Process_Description: Each quarter quadrangle, within the District, was plotted out two times; once with the existing 1995 land use/cover linework, attribute and the 1995 doqq and a second with the 1995 land use/cover, attribute and the 1999 doqq. The plots were plotted out at a scale of 1:8000.

Changes that occurred with the land use or cover between the 1995 and 1999 study were documented on the 1:8000 plot using a green marker. Linework or labels that were to be removed were indicated by placing a series of "x" over the linework to be deleted. New linework and labels were delineated as a solid line. Only areas of change between 1995 and 1999 were delineated. The 1995 land use/cover was assumed to be corrected.

The 1999 land use/cover map standards remained the same as the 1995 land use: must fit feature boundaries at a scale of 1:12,000, minimum mapping unit of .5 acres for wetlands and 5 acres for uplands. The FDOT's Florida Land Use, Cover and Forms Classification System (FLUCCS) was used to classify all features.

Ancillary data sources were used to the fullest extent to ensure proper delineation of land use/cover features. These data sources included: 1984, 1990, 1994/1995 color infrared aerial photography; 1990 and 1995 land use/cover, National
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Wetlands Inventory 1:24,000 maps, NRCS county soil surveys and SWFWMD aerial mapping sheets. Additionally, interpreters had the stereo pairs for 1999/2000 photography to view stereoscopically to verify feature delineations. Any features that could not be reliably interpreted were field reviewed.

Land use and land cover features were delineated, on screen, using the 1999/2000 USGS color infrared (CIR) digital orthophoto quarter quadrangles (doqq) as a back drop. Edits were made, using heads-up digitizing in ArcEdit, with the 1995 land use/cover as the edit coverage. Linework and labels were added, deleted or reshaped according to the corrections delineated on the interpreted image plots. Using the 1995 land use/cover as the edit cover ensured that sliver polygons were not generated with boundaries that remained unchanged.

Topology was generated using the ArcINFO BUILD or CLEAN command. The completed coverage was examined for unlabeled and multiple labeled polygons using the ArcINFO LABELERRORS command. Dangle nodes were checked for using the NODEERRORS command. Any errors found were corrected using ArcEdit.

Upon completion of digitizing, all the individual coverages were visually inspected in ArcView with the 1999/2000 doqq and the 1995 land use/cover as backdrops. Any feature delineation errors or attribute errors were brought to the interpreters attention and corrections made in ArcEdit. The completed coverages were appended together using the MAPJOIN command and common boundaries removed using the DISSOLVE command. Topology was generated for the final coverage using the BUILD command. The final coverage was examined for correct projection, fuzzy tolerance (.001 meters), labelerrors, and attribute items.

Source_Used_Citation_Abbreviation: LU95
Source_Used_Citation_Abbreviation: 99DOQQ
Source_Used_Citation_Abbreviation: 95DOQQ
Process_Date: 20000901 - 20010901
Source_Produced_Citation_Abbreviation: LU99_1
Process_Contact:
Contact_Information:
  Contact_Organization_Primary:
    Contact_Organization: Southwest Florida Water Management District
    Contact_Person: Mapping and GIS Section
  Contact_Address:
    Address_Type: mailing and physical address
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Address: 2379 Broad Street (U.S. 41 South)
City: Brooksville
State_or_Province: FL
Postal_Code: 34604-6899
Contact_Voice_Telephone: (352) 796-7211
Contact_Facsimile_Telephone: (352) 540-6018
Hours_of_Service: 8:00 a.m. to 5:00 p.m.

Process_Step:
Source_Used_Citation_Abbreviation: 99DOQQ
Source_Used_Citation_Abbreviation: LU99_1

Process_Description: In December 2003, an enterprise geodatabase was designed and implemented. Coverages were converted into feature classes using ArcCatalog 8.3. The feature classes were created new in a feature dataset, with column names, shape type, grid size, and projection information defined during creation. An X/Y Domain and Precision were set at MinX: -700,000; MinY: 2,000,000; Precision: 1000. Z-Values were set at MinZ: -20; Precision: 1000. The Grid Tile Size is 4,500. Data was then loaded into the feature classes from the coverages using the 'Load Data' tool in ArcCatalog 8.3. Indexes were created for attributes when there were more than 100 records in the data set. See Attribute Accuracy for attribute domains used for attribute validation.

Process_Date: 20031205

Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Address:
Address_Type: mailing and physical address
Address: 2379 Broad Street (U.S. 41 South)
City: Brooksville
State_or_Province: FL
Postal_Code: 34604-6899
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

City: Brooksville  
State_or_Province: FL  
Postal_Code: 34604-6899  
Contact_Voice_Telephone: (352) 796-7211  
Contact_Facsimile_Telephone: (352) 540-6018  
Hours_of_Service: 8:00 a.m. to 5:00 p.m.

Process_Step:
The dataset was copied, then clipped by the Pinellas County Boundary (detailed coastline) feature class provided by the Southwest Florida Water Management District to create 1999 Land Use for Pinellas County (see metadata for this layer for complete process step). After completion of redigitizing of excluded features, all 500, 600, 700 and 800 series FLUCCS codes were selected and exported to create the hydrographic features layer. FLUCCS Level III features within the 700 and 800 series that are not hydrographic in nature were deleted. The additional domains of HFC_Code and Hydrographic_Feature_Class were created, as well as the addition of perimeter, area, acres and hectares domains. The layer was also reprojected after redigitizing export to the coordinate system cited below in order that the layer would be spatially compatible with other layers used in a geospatial analysis of wetland loss between 1926 and 1999 in Pinellas County, Florida.

Process_Date: Various dates from 2005 to 2007

Process_Contact:
Contact_Information:
Contact_Person_Primary: Pamela Fetterman  
Contact_Organization: E Sciences, Incorporated  
Contact_Position: Senior Scientist  
Contact_Voice_Telephone: [941] 309-5309  
Contact_Facsimile_Telephone: [941] 309-5409  
Contact_Electronic_Mail_Address: pfetterman@esciencesinc.com  
Hours_of_Service: 8am to 5pm

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon  
Point_and_Vector_Object_Count: 5810
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 24.000000
Standard_Parallel: 31.500000
Longitude_of_Central_Meridian: -84.000000
Latitude_of_Projection_Origin: 24.000000
False_Easting: 400000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000031
Ordinate_Resolution: 0.000031
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: D_North_American_1983_HARN
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Resolution: 1.000000
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: hydrofeatures1999
Entity_Type_Definition: SDE Geodatabase feature class
Entity_Type_Definition_Source: ESRI Geodatabase
Attribute:
Attribute_Label: OBJECTID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
1999 Pinellas County Hydrographic Features and Topology Feature Classes

  Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.

  Attribute:
  Attribute_Label: Shape
  Attribute_Definition: Feature geometry.
  Attribute_Definition_Source: ESRI
  Attribute_Domain_Values:
    Unrepresentable_Domain: Coordinates defining the features.

  Attribute:
  Attribute_Label: FLUCCSCODE
  Attribute_Definition: Character description of the Land Use/Land Cover classification code as defined in the Florida Department of Transportations (DOT) Florida Land Use and Land Cover Classification System (FLUCCS). This is also considered Level 4.
  Attribute_Definition_Source: DOT
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Florida Land Use, Cover and Forms Classification System
      Codeset_Source: Department of Transportation, State of Topographic Bureau,

Thematic Mapping Section

  Attribute:
  Attribute_Label: FLUCSDESC
  Attribute_Definition: Character description of the FLUCCSCODE (i.e. fluccscode 2000 = Agriculture)
  Attribute_Definition_Source: DOT

  Attribute:
  Attribute_Label: DATESTAMP
  Attribute_Definition: The date the feature was last edited or entered into the map libraries by SWFWMD staff.
  Attribute_Definition_Source: User Defined

  Attribute:
  Attribute_Label: LEV1
  Attribute_Definition: Very general classification of land use/cover as defined in the Florida DOT's FLUCCS classification system.
  Attribute_Definition_Source: DOT
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Florida Land Use, Cover and Forms Classification System
      Codeset_Source: Department of Transportation, State of Topographic Bureau,
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Thematic Mapping Section

Attribute:
  Attribute_Label: LEV2
  Attribute_Definition: Land use classification more detailed than Lev 1 as defined in
  the Florida DOT's FLUCCS classification system.
  Attribute_Definition_Source: DOT
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Florida Land Use, Cover and Forms Classification System
      Codeset_Source: Department of Transportation, State of Topographic Bureau,

Thematic Mapping Section

Attribute:
  Attribute_Label: LEV3
  Attribute_Definition: Detailed classification of Land use/cover as defined in the
  Florida DOT's FLUCCS classification system.
  Attribute_Definition_Source: DOT
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Florida Land Use, Cover and Forms Classification System
      Codeset_Source: Department of Transportation, State of Topographic Bureau,

Thematic Mapping Section

Attribute:
  Attribute_Label: LEV4
  Attribute_Definition: This attribute was edited to represent both applicable Level 3
  and Level 4 FLUCCS Codes used to define the hydrographic feature class domain
  Attribute_Definition_Source: User defined
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Florida Land Use, Cover and Forms Classification System
      Codeset_Source: Department of Transportation, State of Topographic Bureau,

Thematic Mapping Section

Attribute:
  Attribute_Label: SHAPE
  Attribute_Definition: Feature geometry.
  Attribute_Definition_Source: ESRI
  Attribute_Domain_Values:
    Unrepresentable_Domain: Coordinates defining the features.

Attribute:
  Attribute_Label: SHAPE_Length
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Attribute_Definition: Length of feature in internal units.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
  Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
  Attribute_Label: SHAPE_Area
  Attribute_Definition: Area of feature in internal units squared.
  Attribute_Definition_Source: ESRI
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
  Attribute_Label: Perimeter
  Attribute_Definition: Length of polygon feature in internal map units
  Attribute_Definition_Source: User defined
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are generated using the
calculate geometry command within the attribute table.
Attribute:
  Attribute_Label: HYDROGRAPHIC_FEATURE_CLASS
  Attribute_Definition: Character description of the HFC_Code
  Attribute_Definition_Source: User Defined
  Attribute_Domain_Values:
    Codeset_Domain:
      Codeset_Name: Hydrographic Feature Class
      Codeset_Source: User Defined in one of six categories: Freshwater forested,
freshwater herbaceous, Saltwater forested, saltwater herbaceous, unvegetated and open
water
Attribute:
  Attribute_Label: Shape_Length
  Attribute_Definition: Length of feature in internal units.
  Attribute_Definition_Source: ESRI
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
  Attribute_Label: Shape_Area
  Attribute_Definition: Area of feature in internal units squared.
  Attribute_Definition_Source: ESRI
  Attribute_Domain_Values:
    Unrepresentable_Domain: Positive real numbers that are automatically generated.
Appendix A (Continued)

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Attribute:
Attribute_Label: Area
Attribute_Definition: Area of feature in map units squared.
Attribute_Definition_Source: User Defined
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are generated using the calculate geometry command within the attribute table functions.

Attribute:
Attribute_Label: Acres
Attribute_Definition: Area of polygon feature in units of acres.
Attribute_Definition_Source: User defined
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are generated using the calculate geometry command within the attribute table functions.

Attribute:
Attribute_Label: Hectares
Attribute_Definition: Area of polygon feature in unit of hectares.
Attribute_Definition_Source: User defined
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are generated using the calculate geometry command within the attribute table functions.

Distribution Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: University of South Florida
Contact_Person: Dr. Robert Brinkmann
Contact_Position: Chair, Department of Geography
Contact_Address:
Address_Type: mailing and physical address
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City: Tampa
State_orProvince: FL
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Country: USA
Contact_Voice_Telephone: (813) 974-2386
Contact_Facsimile_Telephone: [813] 974-4808
Hours_of_Service: 8am to 5pm
Resource_Description: Downloadable Data. The data are being provided on an 'as is'
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

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Custom_Order_Process: Contact Dr. Brinkmann or Pinellas County GIS Section

Distribution_Information:

Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Southwest Florida Water Management District
Contact_Person: Mapping and GIS Section
Contact_Address:
Address_Type: mailing and physical address
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City: Brooksville
State_or_Province: FL
Postal_Code: 34604-6899
Contact_Voice_Telephone: (352) 796-7211
Contact_Facsimile_Telephone: (352) 540-6018
Hours_of_Service: 8:00 a.m. to 5:00 p.m.

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Metadata_Reference_Information:
Metadata_Date: 20071012
Metadata_Contact:
Contact_Information:
Appendix A (Continued)

1999 Pinellas County Hydrographic Features and Topology Feature Classes

Contact_Person_Primary:
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   Contact_Organization: E Sciences, Incorporated
   Contact_Position: Senior Scientist
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      City: Brooksville
      State_or_Province: FL
      Postal_Code: 34604-6899
   Contact_Voice_Telephone: (941) 309-5309
   Contact_Facsimile_Telephone: (941) 309-5409
   Contact_Electronic_Mail_Address: pfetterman@esciencesinc.com
   Hours_of_Service: 8:00 a.m. to 5:00 p.m.

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Time_Convention: local time
Metadata_Extensions:
   Online_Linkage: http://www.esri.com/metadata/esriprof80.html
   Profile_Name: ESRI Metadata Profile