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HABITAT DISTURBANCE WITHIN AN URBAN FOREST FRAGMENT, TAMPA, FLORIDA

John Forest Turbiville Jr.
University of South Florida

Graduate School
University of South Florida
Tampa, Florida

CERTIFICATE OF APPROVAL

Master's Thesis

This is to certify that the Master's Thesis of

JOHN FOREST TURBIVILLE, JR.

with a major in Geography has been approved by
the Examining Committee on May 31, 1996
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for the Master of Arts degree

Examining Committee:

Major Professor: Joseph Garcia, Ph.D.

Member: Robert Brinkmann, Ph.D.

Member: Kevin Archer, Ph.D.

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by

JOHN FOREST TURBIVILLE, JR.

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts
Department of Geography
University of South Florida

August 1996

Major Professor: Joseph Garcia, Ph.D.

Dedication

To Mom and Dad, who have always given me strong support and encouragement in all my endeavors.

Acknowledgements

Extended thanks goes to the following people and/or organizations: the Hillsborough County Environmental Lands and Acquisition Protection Program for allowing me access to the South MacDill 48 property; Dr. Robert Brinkmann, Professor-USF Geography Dept., for his help on several soil excavations; Dr. Joseph Garcia, Professor-USF Geography Dept., for his guidance and advice during the writing of this thesis; Jason Winnoker, graduate student-USF Geography, for his help on several soil excavations; and Moises Vargas, for his help with graphics. Special thanks goes to Pauline Stamm of Tampa, Florida, for her support throughout the years -- thanks for everything!

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HABITAT DISTURBANCE WITHIN AN URBAN FOREST FRAGMENT,
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An Abstract

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The purpose of this study is to determine the effects of forest fragmentation on a forest fragment in south Tampa, Florida. To determine these effects, several research objectives are defined, which include: (1) an historical analysis of the development and fragmentation of the study area; (2) documentation of the effects of fragmentation on the site; and (3) development of a management policy relating to site-specific fragmentation effects.

Forest fragmentation and its attendant human impacts have altered many of the natural physical and biological processes associated with the three ecosystem types present within this forest fragment. These ecosystems include pine flatwoods, mesic hammock, and hydric hammock. Three major conclusions can be drawn from this study regarding the effects on these ecosystems: (1) although drainage structures are present, a soil and vegetation analysis within the hydric hammock shows no widespread drying or flooding of the hammock soil. The presence of a layer of limestone topped by a 2Bg horizon suggests that the Floridan Aquifer is very near the soil surface within the hydric hammock; (2) due to this forest fragment's urban location and close proximity to exotic plant seed sources, several invasive exotic plant species have become established on the site. These exotic plants can be removed manually or through the use of herbicide; and (3) fire exclusion has led to hardwood invasion within the pine flatwoods. Prescribed burning within the flatwoods will help

control future hardwood invasion.

Abstract Approved: ______________________
Major Professor: Joseph Garcia, Ph.D.
Professor, Department of Geography

DateApproved: 6/20/96

CHAPTER ONE

INTRODUCTION

Forest fragmentation results from development and/or agricultural activities which tend to divide or separate a forest into smaller patches or fragments. These fragments are, in turn, influenced by the surrounding urban, agricultural, or other land use patterns. The effects of isolation on these fragments have been debated by scientists for almost thirty years. Island biogeography theory has been at the center of this debate and its applicability to conservation issues has recently come into question (Saunders et al. 1991; Simberloff and Abele 1976, 1982; Diamond 1975). Island biogeography theory will not be examined in this paper.

Several critical issues relating to the impacts of fragmentation have historically been ignored. Three of these issues include: the physical effects of fragmentation, the biological consequences of these effects on the fragment in question, and management issues related to these effects (Noss and Harris 1986; Saunders et al. 1987; Saunders et al. 1991). Also, little study has been afforded to the historical aspect of the fragmentation process itself (along with associated land use changes). Harris and Silva-Lopez (1992), however,

developed a method of categorizing different types of fragmentation (Figure 1). This method is based upon the various types of development pressures that create forest fragments.

Harris and Silva-Lopez (1992) list five types of forest fragmentation: (1) regressive fragmentation, (2) enveloping fragmentation, (3) divisive fragmentation, (4) intrusive fragmentation, and (5) encroaching fragmentation (Figure 1). Regressive fragmentation occurs when the forest is pushed back from one side in a single direction. This usually occurs in coastal areas where urban development spreads from the coast inland. Enveloping fragmentation occurs when development and/or agricultural activities surround the forest and gradually creep inward. This type of fragmentation greatly limits the amount of immigration and/or emigration into and out of the forest. It also helps exclude the fragment from various landscape processes, such as fire. Divisive fragmentation occurs when a forest is bisected by an intrusive force. Examples are highways, power lines, and railroads. These structures can alter the hydrology of adjacent areas, stop the spread of fires, and affect the movement of plant and animal species. Also, roads and highways usually introduce development and/or other intrusive activities to adjacent areas. Intrusive fragmentation occurs when forest-interior habitat is removed. In this case, development begins from within and expands outward. This often happens when interior

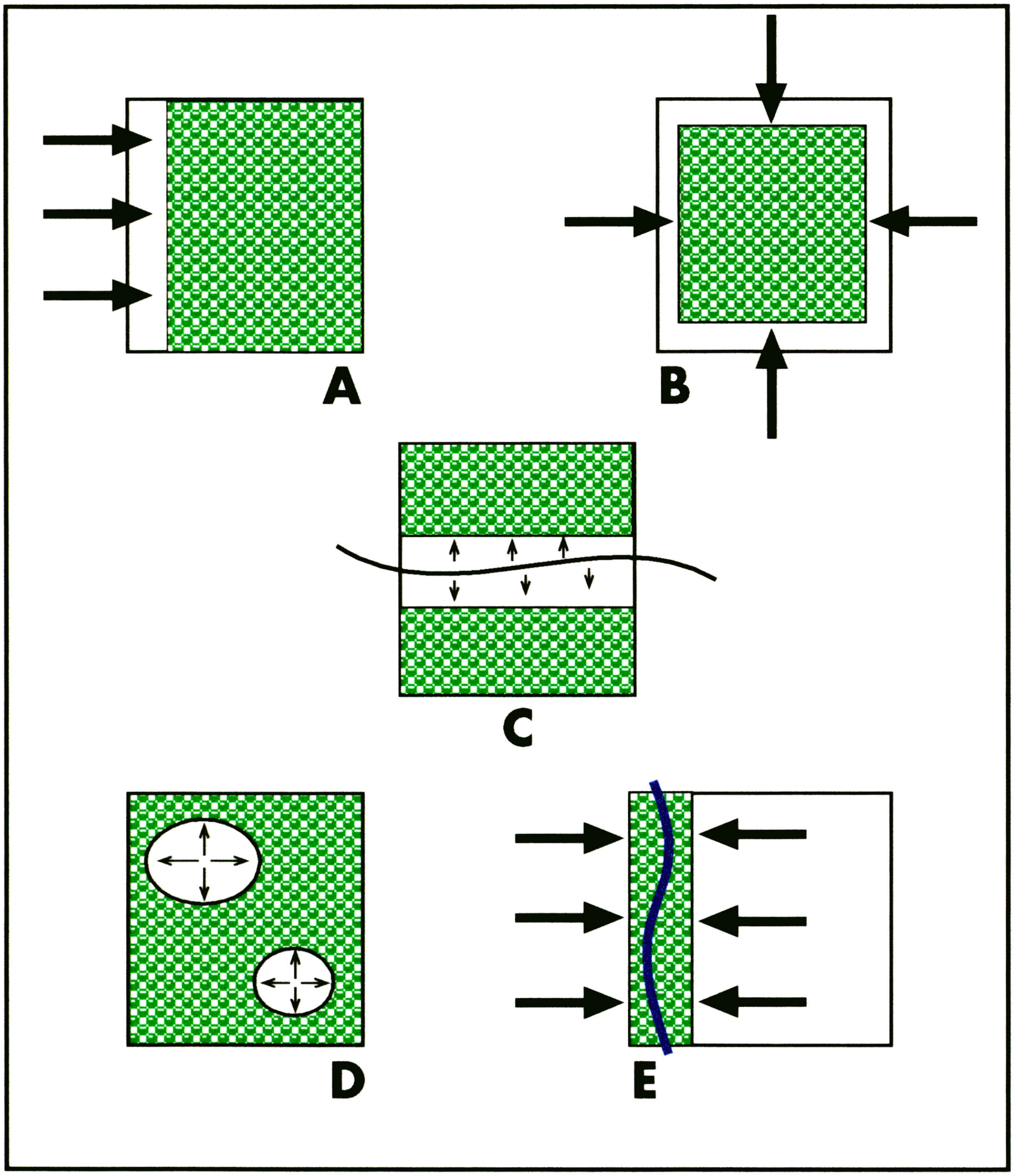

Figure 1. The above diagram depicts several different types of habitat fragmentation. "A" depicts regressive fragmentation; "B" depicts enveloping fragmentation; "C" depicts divisive fragmentation;"D" depicts intrusive fragmentation; and "E" depicts encroaching fragmentation (after Harris and Silva-Lopez 1992).

tracts of forest are clear-cut or some type of development (e.g. industrial) is approved by the county, state, or federal government. Encroaching fragmentation occurs when a river corridor that connects two larger areas of forest becomes surrounded by development on both sides of its banks, thereby becoming isolated from the rest of the forest.

In order to better understand the physical effects of fragmentation and their impact on ecosystems within the fragments, it is not only important to know what type of fragmentation has occurred, but also when it occurred. The process of fragmentation can be determined from aerial photographs, maps, and personal interviews. Documentation of the fragmentation process is necessary to understanding the extent of human impacts within and adjacent to a forest fragment. For example, an urban forest fragment may be affected by a completely different set of physical and biological factors than a rural forest fragment surrounded by agricultural fields. Many fragments (especially those located in urban areas) are affected by hydrologic changes (e.g. lowering of the surface water table), disturbance of the natural fire regime (e.g. fire exclusion), invasion of exotic plant species, and other human impacts (e.g. dumping, recreational usages, etc.) which can affect the natural physical and biological processes associated with a particular ecosystem (Abrahamson 1984; Abrahamson and Hartnett 1990; Brothers and Spingarn 1992; Ewel 1990; Simberloff 1993; Vince

et al. 1989; Wolfe and Drew 1990). Once the extent of human impacts have been discerned, an appropriate management plan can be developed for the fragment which might include prescribed burning, exotic plant control, re-establishment of the original hydrologic regime, cleanup of waste, and habitat restoration.

The purpose of this study is to determine the effects of forest fragmentation (and its attendant human impacts) on a forest fragment in south Tampa, Florida. In order to determine these effects, several research objectives are defined.

1. An historical analysis of the study area, including: (a) an evaluation of the fragmentation process (including land use changes surrounding the site) through interpretation of aerial photographs from 1938 to 1994, (b) an evaluation of physical impacts to the site, including the construction of drainage structures and creation of improved pasture, and (c) discussion of habitat types present on site and typical structure and function of each.

2. Documentation of the effects of fragmentation on the site, including: (a) edge effects and exotic plant invasion, (b) fire exclusion and its effects on vegetation, (c) historical forest clearing on the site (and resulting secondary succession vegetation), (d) construction of drainage structures and their effect on hydrology, vegetation, and

soils, and (e) illegal dumping and trespassing from surrounding housing developments.

3. Development of a management policy that directly relates to site-specific fragmentation effects, including: (a) establishment of a "semi-natural" fire regime, (b) exotic plant control through herbicide or other uses, and (c) security issues, including control of illegal dumping and trespassing.

Study Area

The area of study is located in the Interbay area of south Tampa (Figures 2 and 3). This 48-acre forest fragment (the South MacDill "SMD" 48 property, according to the Environmental Lands Acquisition and Protection Program (ELAPP) of Hillsborough County) was purchased in February 1992 by Hillsborough County through ELAPP (Knight 2/5/92). ELAPP is a taxpayer-supported program initiated in 1987 to purchase and protect environmentally sensitive lands within the county.

The property is comprised of three different habitat types: mesic pine flatwoods, mesic hammock, and hydric hammock (Figure 4). The flatwoods occupy the western and southern one-third of the site. Vegetation here is characterized by slash and longleaf pine with an understory of saw palmetto, wiregrass, and gallberry. The mesic hammock occupies the fringes of the hydric hammock and is dominated by live oak and cabbage palm. The hydric hammock occupies the

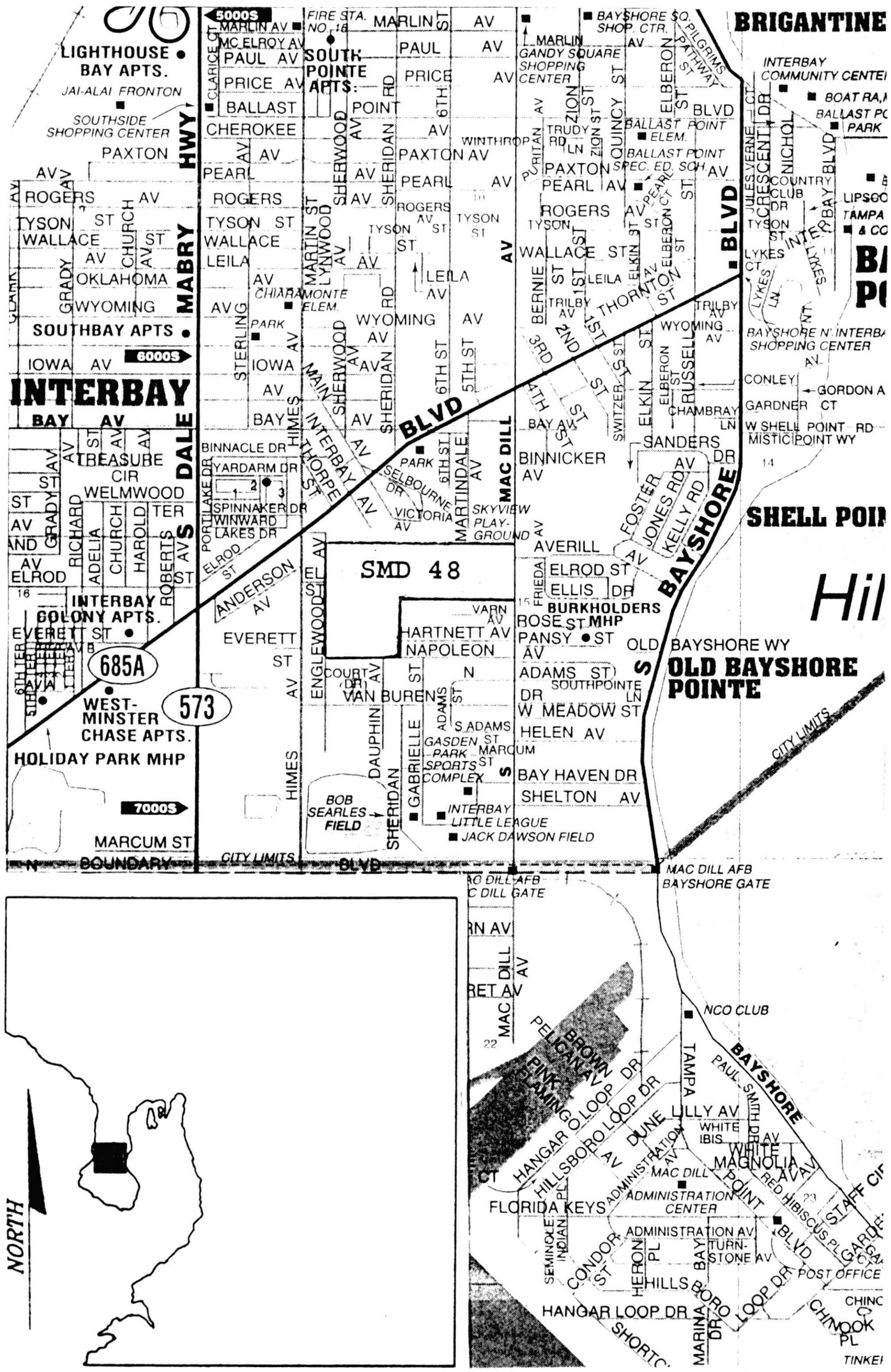

Figure 2. The "South MacDill 48" property is located on the Interbay peninsula in south Tampa (scale: 1" = 1/2 mile - map courtesy of Hillsborough County ELAPP).

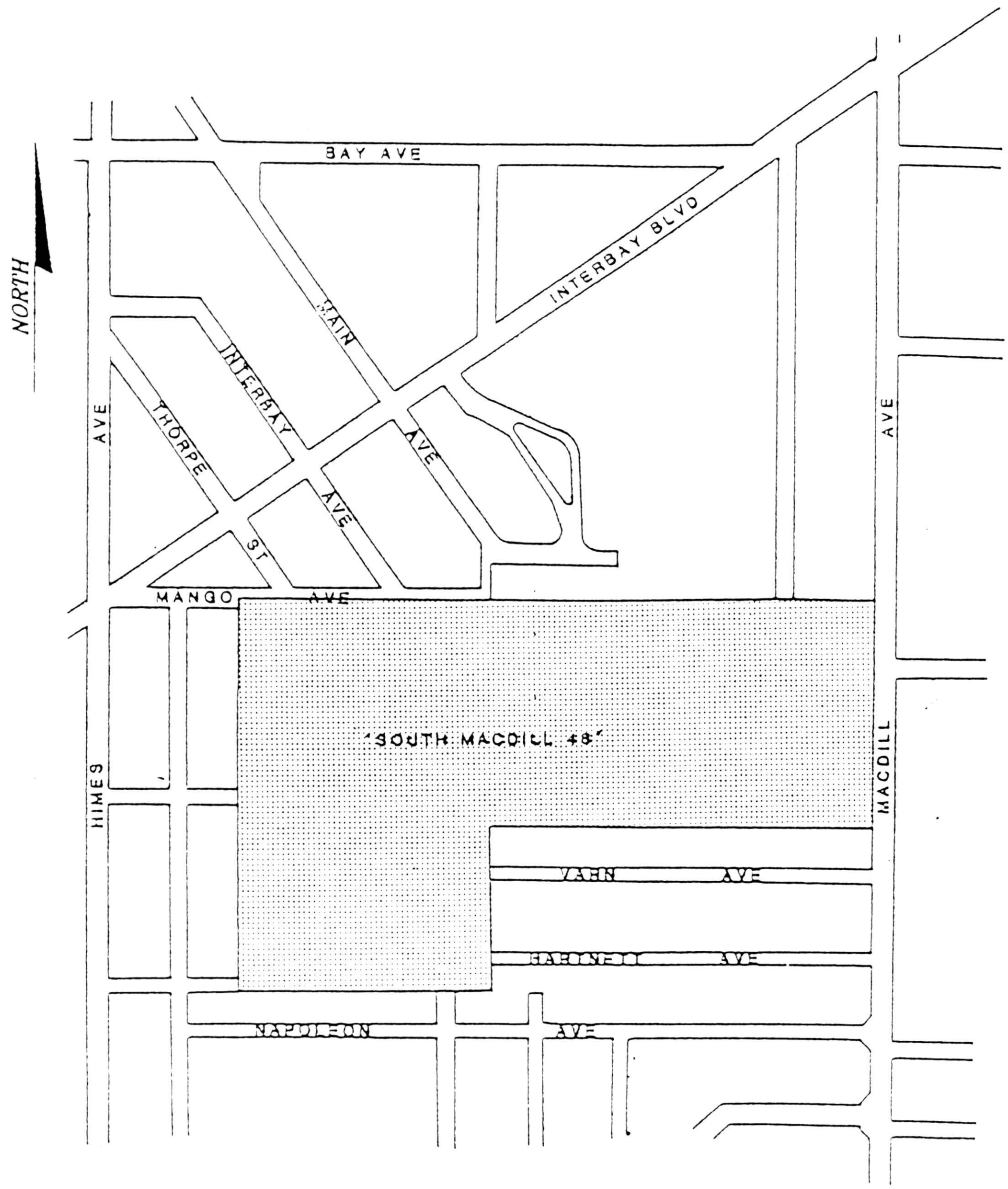

Figure 3. The "South MacDill 48" property is bounded by Himes Avenue to the west, MacDill Avenue to the east, Mango Avenue to the north, and Napolean Avenue to the south (map courtesy of Hillsborough County ELAPP).

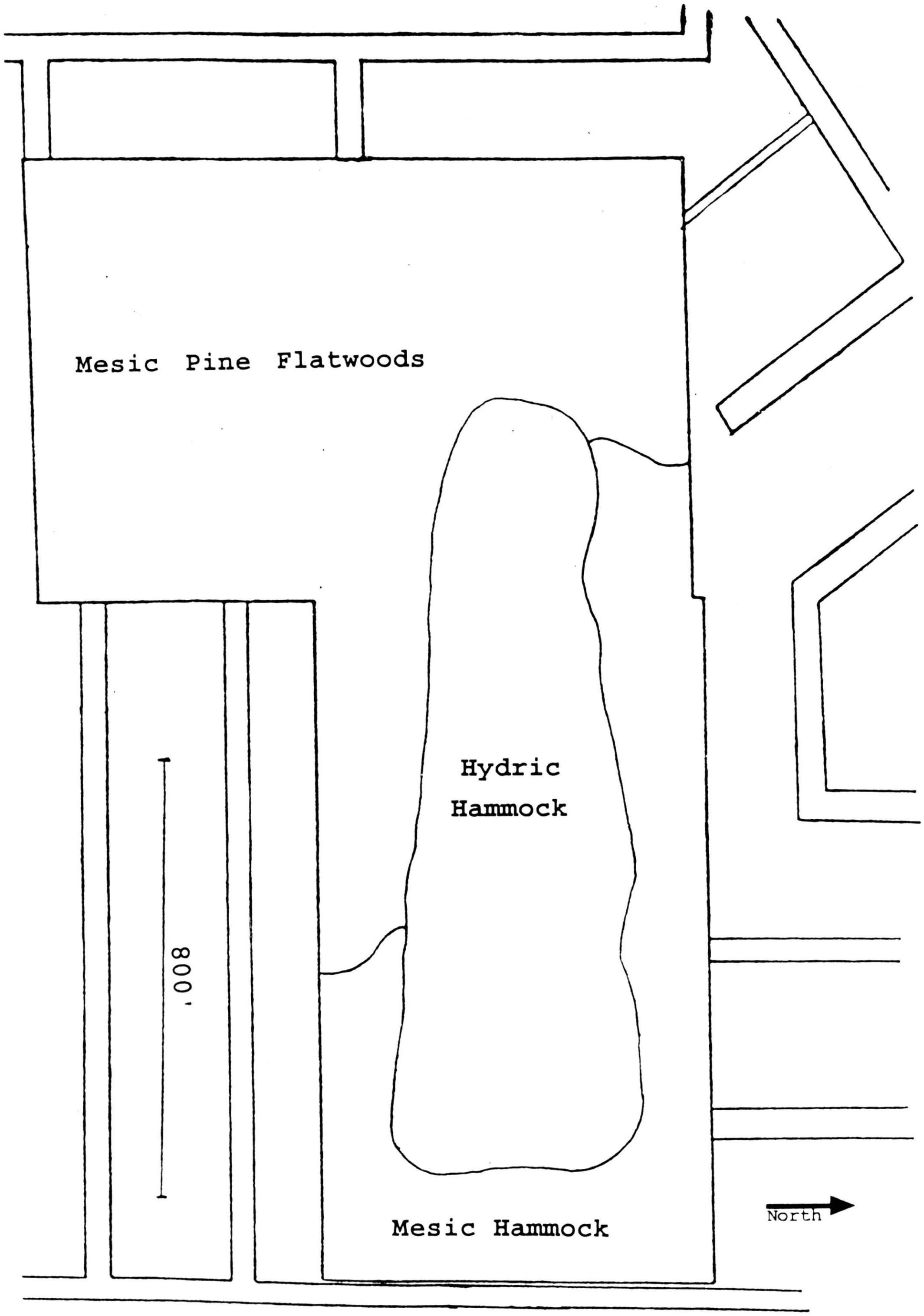

Figure 4. This map shows the approximate boundaries of the three habitat types located on SMD 48.

middle of the site and is dominated by sweetbay magnolia as well as live oak and cabbage palm. The hydric hammock is located within an area of lower elevation (<10 feet above sea level) where water gathers during the summer rainy season. The depression can be located on old stormwater drainage maps like the one shown in Figure 5 (circa 1924).

An examination of aerial photographs from 1938 shows that the Interbay peninsula was dominated by pine flatwoods with smaller areas of hydric and mesic hammock, cypress domes, and tidal swamps and marsh. Large-scale development of the southern half of the peninsula began in the early 1940's with the construction of MacDill Air Force Base. However, urban development, including roads, railroads, and drainage structures existed in the south Tampa region as early as the 1920's. During the early 1900's, many areas were cleared and planted with Bahia grass to be used as improved pasture for livestock (pers. comm., W.G. Saalman, III, USDA). By 1948, 14% of the land in Hillsborough County was converted to improved pasture (Sipe et al. 1979). These impacts not only deforested the region, but also fragmented the remaining forest into isolated remnants.

There is an extensive network of drainage structures located on the SMD 48 property today (Figure 6). Two open drainage ditches (approx. 6 ft. deep) enter the site on the northwest corner and converge to enter an underground storm sewer system which flows east to MacDill Avenue. A third open

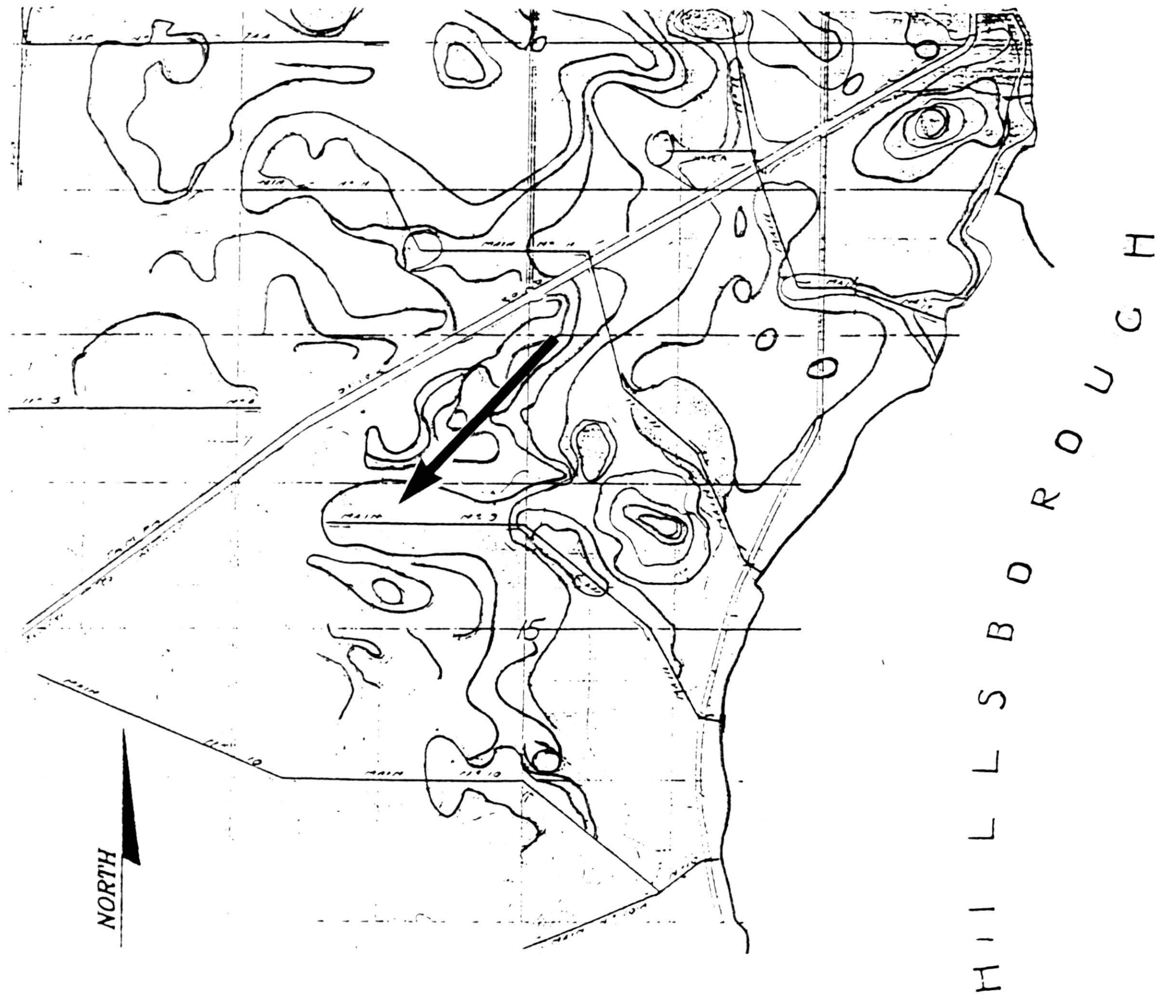

Figure 5. This 1924 map of stormwater drains located on the Interbay peninsula shows the main storm sewer line (No. 9 - black arrow) which runs through the center of the hydric hammock (map courtesy of the City of Tampa Water Dept.).

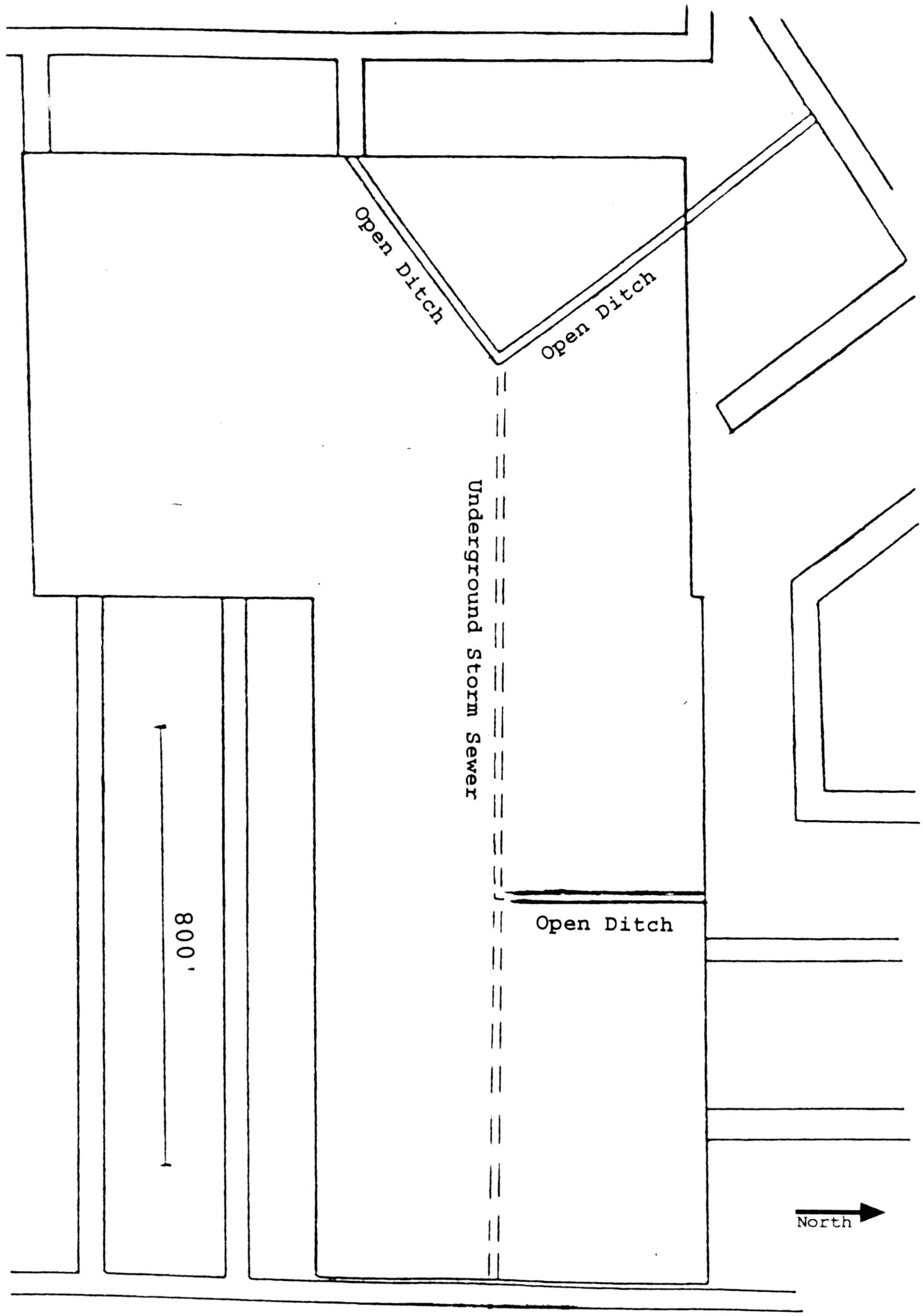

Figure 6. This map shows the locations of the underground storm sewer and other open ditches on SMD 48.

ditch (approx. 2 ft. deep) flows into the underground system from the north. The two deeper open ditches cut directly through an area of mesic flatwoods while the underground storm sewer and shallower open ditch cut directly through the hydric and mesic hammock areas. The underground system was installed around 1924 (Figure 5), while the larger open ditches were installed between 1972 and 1976 (deduced from aerial photographs).

In addition to the installation of the ditch system, a portion of the hydric and mesic hammocks were cleared prior to 1938 (Figure 7). This area was planted with Bahia grass and converted to improved pasture (pers. comm., W.G. Saalman, III USDA). The area was used as pasture until the late 1950's, when secondary forest growth was allowed to regenerate (deduced from aerial photographs).

The above examples demonstrate how human impacts can affect once pristine habitats. Within Florida, land clearance for agricultural and developmental purposes has created a landscape in which once dominant ecosystem types have been fragmented into smaller and smaller remnants. The following chapter describes the reduction and fragmentation of pine and hardwood forests within Florida and Hillsborough County. An examination of habitat fragmentation (and its attendant human impacts) which led to the current makeup of the SMD 48 property was performed using historical aerial photographs. The results of this effort are the focus of the next chapter.

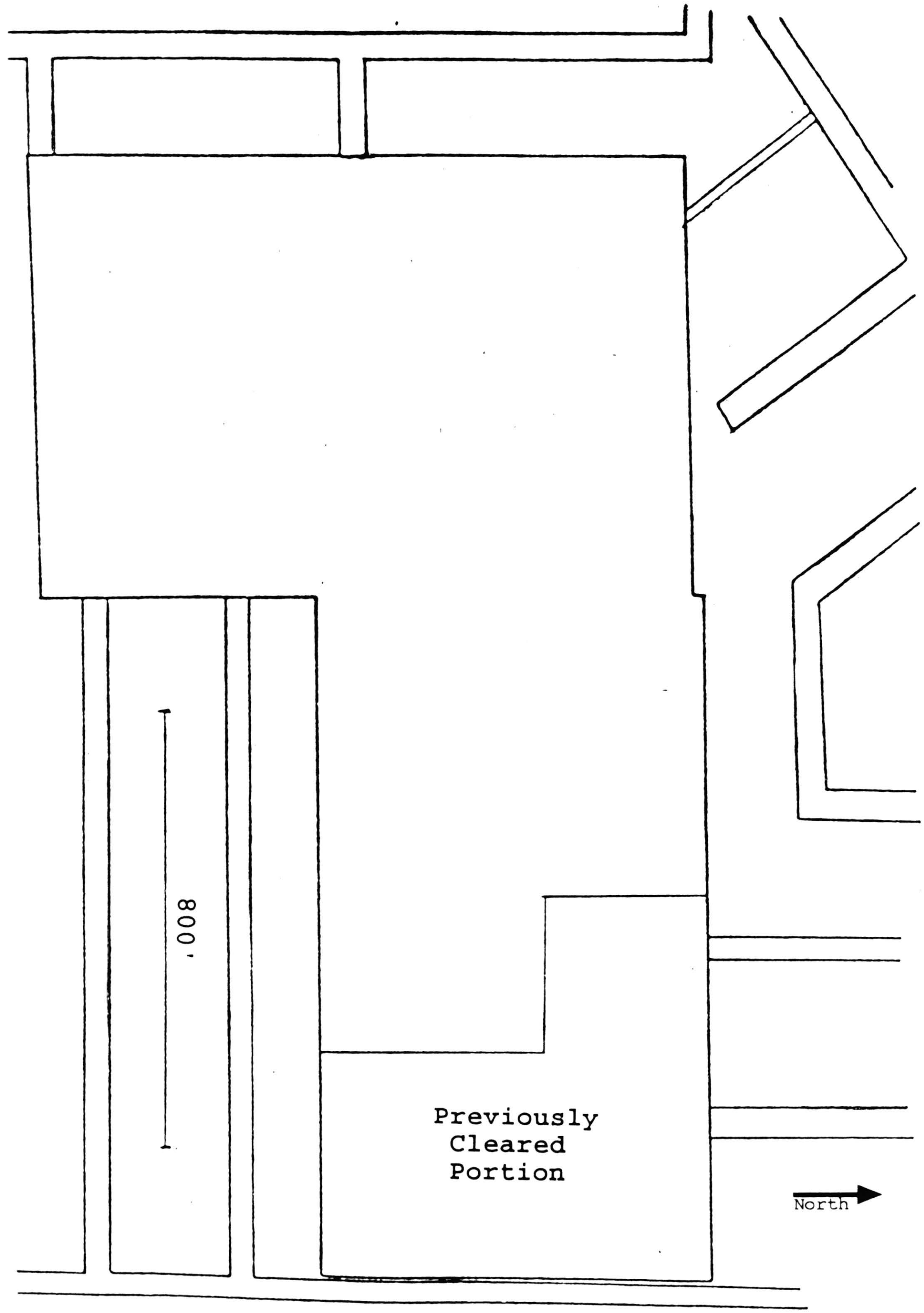

Figure 7. This map shows the approximate area that was cleared for pasture prior to 1938.

The following chapters address the most significant impacts to the SMD 48 property resulting from forest fragmentation. Chapter Three will focus on the impact of ditching on hydrology and soils within SMD 48's hydric hammock. Chapter Four will focus on the detrimental effects of exotic plant invasions on SMD 48, while Chapter Five discusses the effects of fire exclusion.

CHAPTER TWO

THE PROCESS OF FOREST FRAGMENTATION

Land Use and Habitat Change Within Florida

As previously stated, this chapter focuses on land use and habitat changes that occurred on the Interbay peninsula which led to the creation of SMD 48. These changes are documented through the use of historical aerial photographs. However, before presenting these photographs, it is important to examine the historical land use and habitat changes that occurred in both Hillsborough County and Florida in order to appreciate that habitat destruction and fragmentation is not unique to the Interbay peninsula. The following paragraphs focus on these broader issues.

The Florida landscape has changed dramatically since pre-settlement times (circa 1820) and, particularly, within the last 60 years (Kautz 1993). Kautz (1993) provided quantitative information on land use and land cover changes in Florida between the years 1936 and 1987. These changes are shown in Figure 8. While areas of forest and marsh have declined, there has been a subsequent rise in the amount of agricultural and urban lands present in the state. Pine forests (e.g. pine flatwoods) have experienced a sharp decline

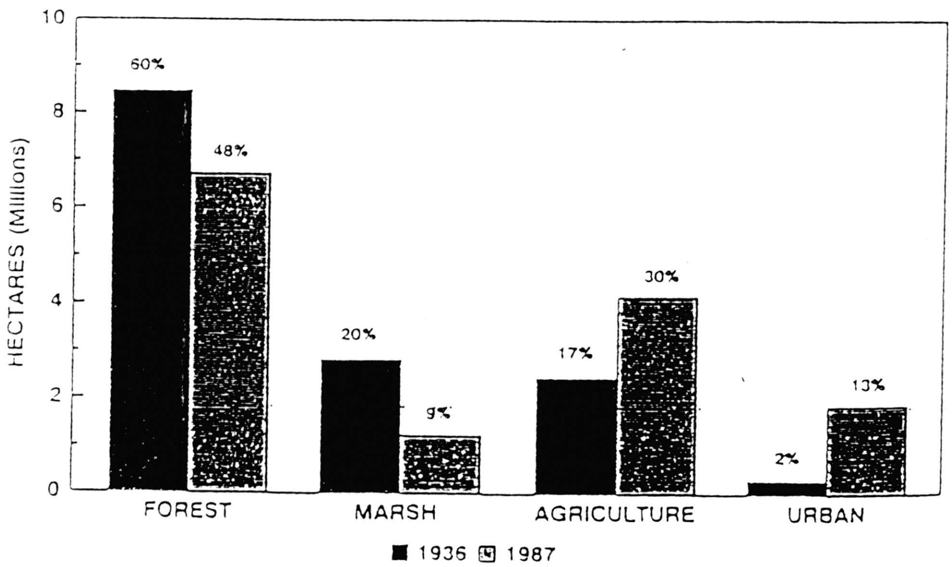

Figure 8. The above diagram shows gross changes in major land cover and land use in Florida between 1936 and 1987. The numbers above each bar are percentage of total land area (from Kautz 1993).

in area since 1936. These forests covered approximately 6.00 million hectares (ha) in 1936, with longleaf pine forests comprising 3.09 million ha of this (Kautz 1993). By 1987, pine forests declined by 49% to 3.06 million ha, while longleaf pine forests declined by 88% to 0.38 million ha (Kautz 1993; Kautz et al. 1993)! This major decline in pine forest coverage is no accident. According to Usher (1987), the fragmentation process is generally not random. For example, in Florida, much of the land that was cleared for pasture was located on pine flatwoods (especially longleaf pine) because the land was relatively well-drained (and, therefore, easier to clear than a wetland), the soils could usually support various grass species for livestock, and pine flatwoods were the most abundant community type in the state (Abrahamson and Hartnett 1990; Davis 1967). Well-drained flatwoods are also excellent home-building sites in central Florida, thus leading to a probable further decline in pine flatwoods in the future. Abrahamson and Hartnett (1990) and Kautz (1993) agree that future urban and agricultural development will cause a decline in the pine flatwoods community type as well as its fragmentation into smaller remnants.

Hardwood forests (e.g. mesic and hydric hammocks) have a different development history than pine forests. Between 1936 and 1970, hardwood forests increased from 1.91 million ha to 3.41 million ha (Kautz 1993). In some areas, this increase

was due to selective logging of pines in pine forests which led to a rapid invasion of hardwoods (Kautz 1993). In other areas, fire suppression allowed hardwoods to invade fire-dependent pine forests (Kautz 1993; Moore and Goodwin 1994; Pyne 1984; Wade and Lunsford 1989; Wright and Bailey 1982). By 1987, however, hardwood forests declined by 13% to 3.03 million ha (Kautz 1993). This decline is likely due to the expansion of urban and agricultural areas in the state (see Figure 8). Since pre-settlement times (circa 1820), approximately 26% of Florida's hardwoods forests have been destroyed (Davis 1967; Kautz et al. 1993). Hydric hammocks along the Gulf coast between Wakulla and Hernando Counties (see Figure 35 in Chapter Three) comprise one of the largest remaining stands of hardwood forest in the state (Kautz et al. 1993; USDA-SCS 1981; Vince et al. 1989).

The driving force behind the loss and fragmentation of Florida's diverse habitats is the growth of Florida's human population. Between 1830 and 1990, Florida's population increased from 34,730 to 12.94 million people (Kautz 1993). Hillsborough County has experienced similar growth rates and, subsequently, similar rates of habitat destruction. The following section details the growth of Hillsborough County since the early 1800's as well as the effects of this growth on land use and land cover within the county.

Land Use and Habitat Change Within Hillsborough County

Since 1820, Hillsborough County transformed from a sparsely inhabited area to a major urban center. Accompanying this increase in population has been the wholesale destruction of the county's pristine ecosystems. Sipe et al. (1979) have divided the growth of Hillsborough County into five periods: Primitive (2000 B.C.-1820), Territorial (1821-1879), Railroad (1880-1900), Boom and Bust (1901-1948), and Present (1949-1979). These periods are based on "the commonality of events and outside influences impinging on the county" (Sipe et al. 1979,9). The Primitive Period is characterized by the Indian culture, which was based entirely on the sustainable use of natural resources in the county with no outside influences. The Territorial Period is based on the increase in the number of European settlers coming into the county. These settlers brought with them a higher technology and the beginning of a trade system with the outside world. In response to an increase in population, the Federal government began to map unexplored areas of the county in order to build roads to outlying areas. This tied in nicely with the Armed Occupation Act of 1842, in which the Federal government provided 160 acres of free land to those persons who would occupy and defend it (Sipe et al. 1979). This led to an increase in land clearing for farming and grazing purposes.

The Railroad Period is based on the development of the railroad, which brought settlers and tourists into both the populated and unpopulated areas of the county. Trade also increased during this period as well as residential development in some of the county's more rural areas.

The Boom and Bust Period is based on a series of booms (World War I, real estate speculation, and World War II) and an equal number of busts. During WWI, Tampa was a major ship-building city with over 25 ships constructed during the war (Ferrell 1980). However, once the war ended, the demand for new ships decreased dramatically and several thousand workers were out of jobs. The real estate boom of 1925-26 revived the county's economy due, in part, to "1) the mobility of an emerging middle class brought on by the development and sale of inexpensive automobiles; 2) the rapid expansion of the county's highway network; and 3) the technology which enabled the development of low-lying islands and bay bottomlands" (Sipe et al. 1979,21). After the 1929 depression, Florida and Hillsborough County received large amounts of money from the Federal government in order to revive the state and local economy. During World War II, the county was brought out of the depression as MacDill Air Force Base became established and ship-building contracts were renewed. A large number of the soldiers who were transferred to Hillsborough County remained here to raise families, thus further increasing the population and development of the county. The development of

machinery based on gasoline and other fossil fuels during this period resulted in large scale disturbances of the county's natural ecosystems. Finally, Sipe et al. (1979,21) describe the Present Period as "an era of rapid population growth and urbanization." This time period (which would include those years from 1949 to the present day) has seen a major increase in the amount of land development and urban sprawl. The following paragraphs outline the decline of Hillsborough County's pine and hardwood forests and subsequent increase in agricultural and urban lands.

In Figure 9, the distribution of natural systems within the county during the Primitive Era (c. 1820) is shown, while in Figure 10, the distribution of land uses and ecosystem types within the county is shown for 1948. In Figure 9, it can be seen that a majority of the county was covered with pine forests (70%), while significant wetland areas included hydric hammocks (12%) and cypress domes and strands (7%). Included within the "pineland" system are pine flatwoods, sandhills, and sand pine scrub (Sipe et al. 1979). Mesic and xeric hammocks occupied only 0.22% of the land at this time. In Figure 10, it can be seen that much of the pineland was converted into agricultural (44%) and urban (9%) uses. Improved pasture accounted for approximately one-third of all agricultural land. Mesic and xeric hammocks now covered 5.2% of the total land area. This increase is due to excessive logging of pines and fire suppression, which allowed hardwoods

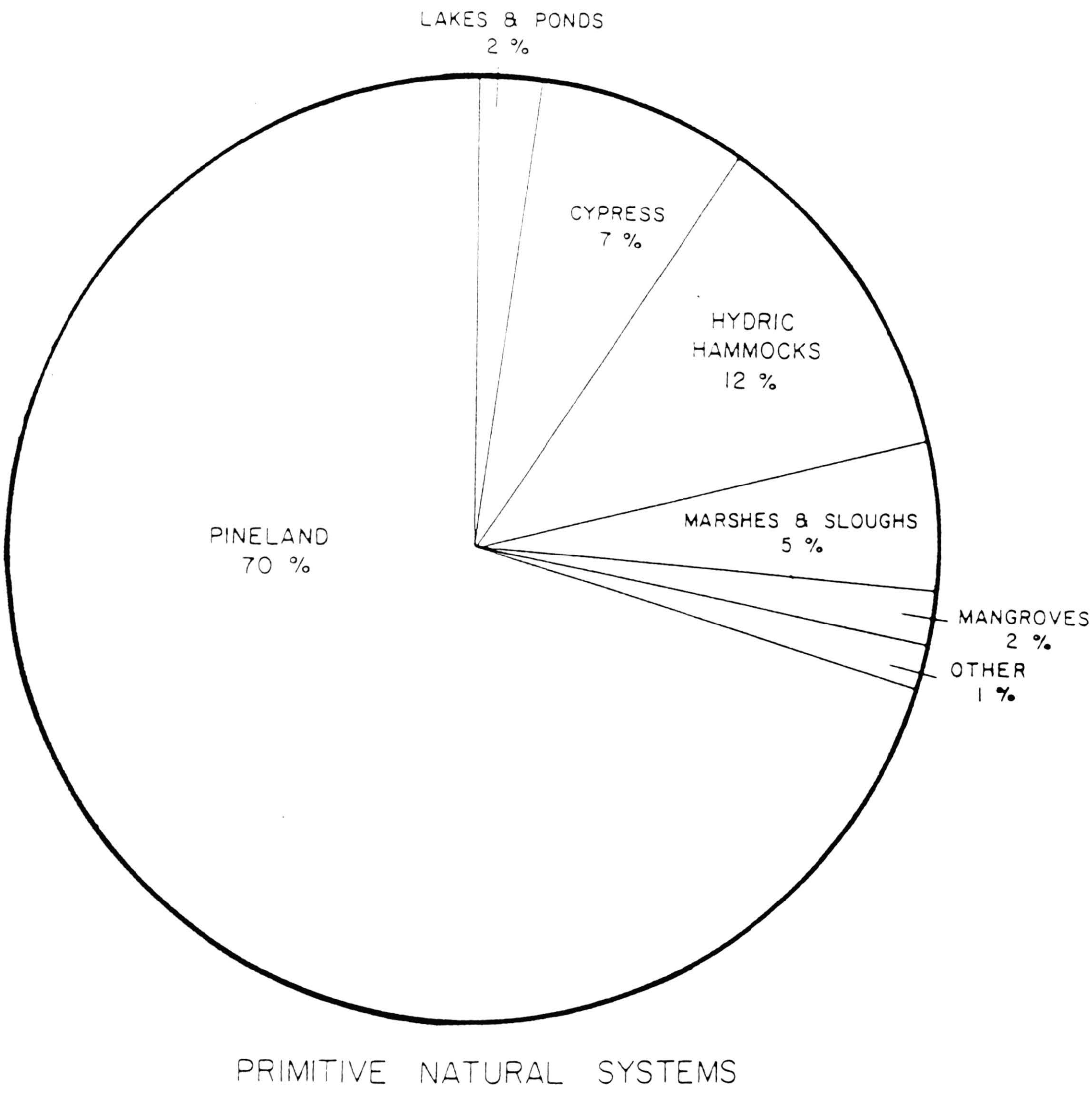

Figure 9. Pie diagram showing the distribution of natural ecosystems in Hillsborough County in 1820 (from Sipe et al. 1979).

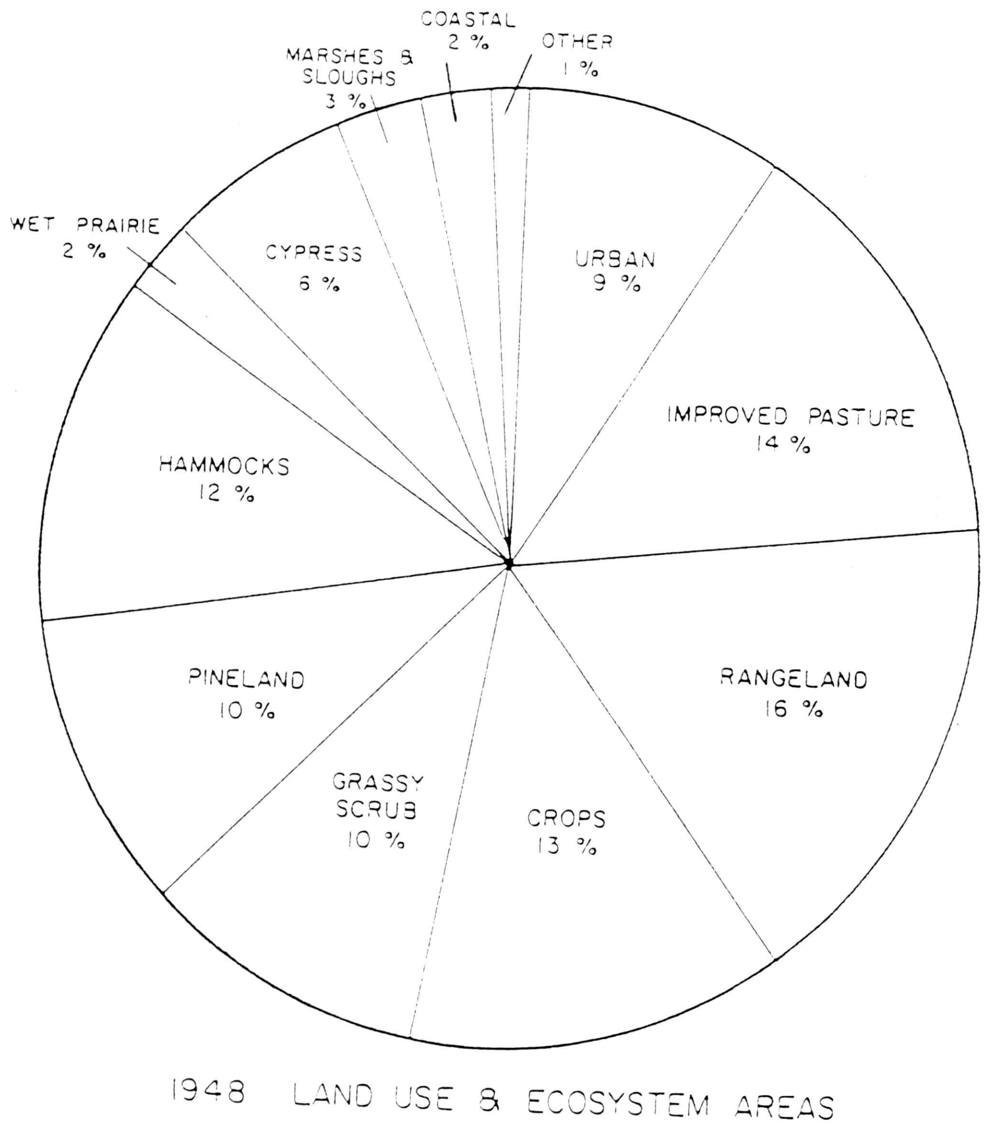

Figure 10. Pie diagram showing land use and ecosystem areas in Hillsborough County in 1948 (from Sipe et al. 1979).

to invade former pine forests (Leighty et al. 1958). At the same time, hydric hammocks declined to 6.6% of the total land area.

Figure 11 shows the percentage distribution of land use and ecosystem areas for 1978. Between 1948 and 1978, the amount of both urban and agricultural land increased significantly, from 9% to 22% for urban land and 44% to 51% for agricultural land. Improved pasture accounted for two-fifths of all agricultural land. The growth of Hillsborough County between 1948 and 1976 has been described as an "expansion of the urban areas, a preference for high and dry land for development, or development along or near bodies of water" (Hillsborough County Planning Commission 1973,1-16). Therefore, it is not surprising that pineland, which once occupied over 70% of the county's land area, accounted for just 2% in 1978. Mesic and xeric hammocks again increased their coverage to 6.01% of the total land area in 1978 due to continued fire suppression (fire suppression may have increased due to rapidly expanding urban/suburban areas). Within the last 18 years, the county has experienced even more development and urban sprawl, thus leaving little doubt that "urban" land use accounts for much more than 22% of the total land area of the county in 1996.

The increased agricultural and urban development within Hillsborough County has led to forest fragmentation and the creation of isolated habitat remnants (Figure 12). The

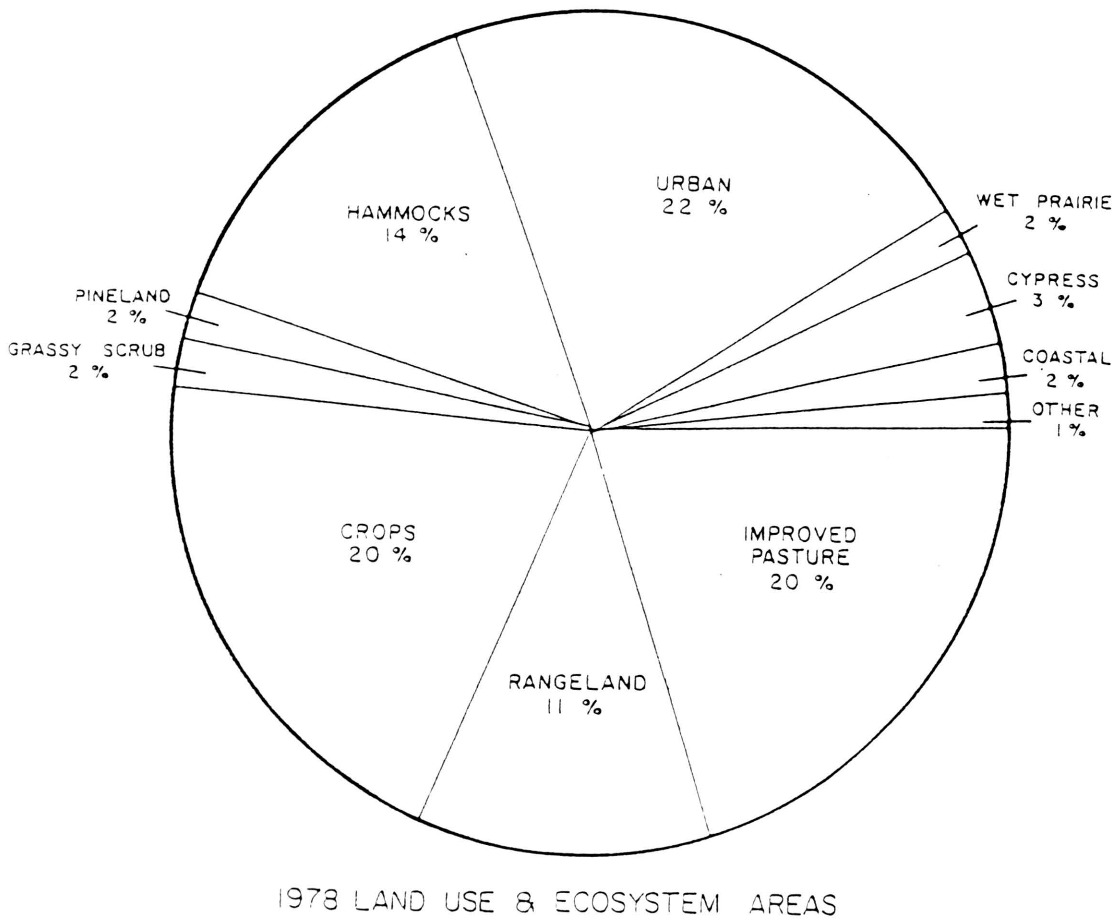

Figure 11. Pie diagram showing land use and ecosystem areas in Hillsborough County in 1978 (from Sipe et al. 1979).

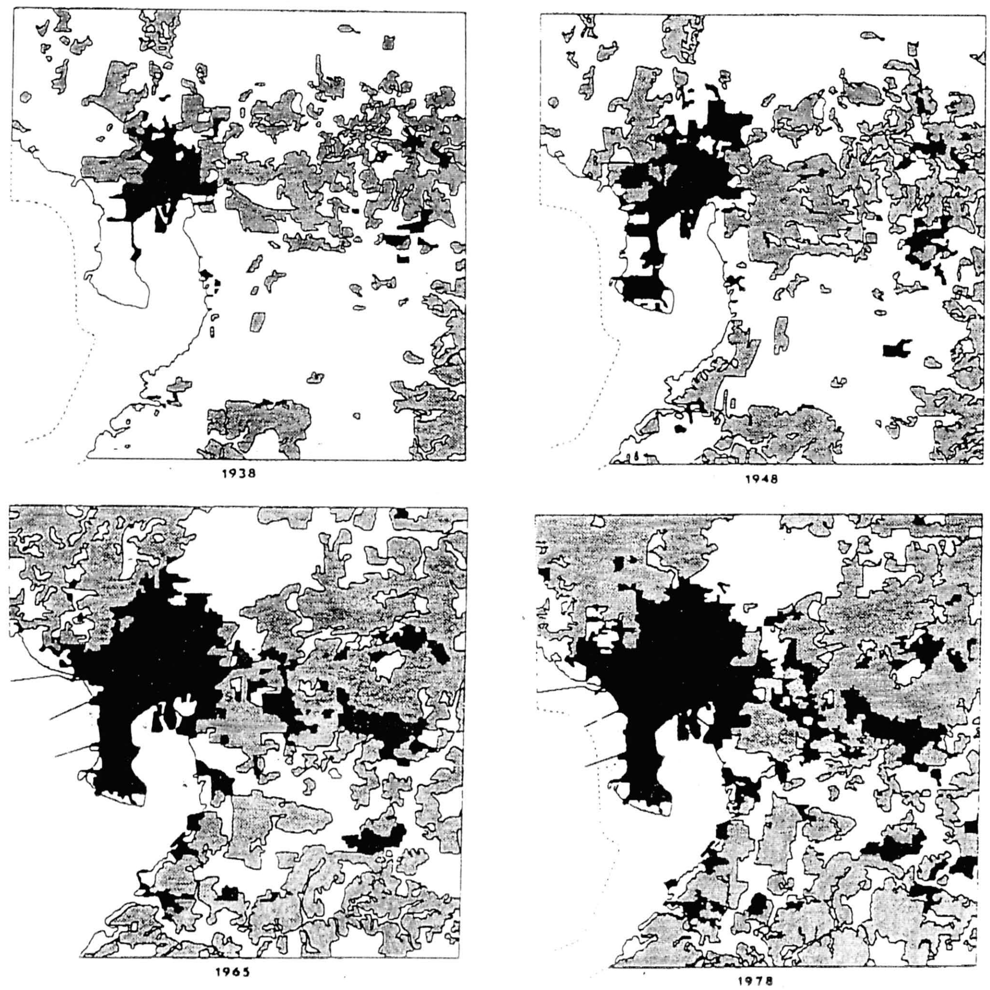

Figure 12. The above figures show the growth of urban (black) and agricultural (grey) areas in Hillsborough County for 1938, 1948, 1965 and 1978. White areas represent natural habitat (after Sipe et al. 1979).

following section describes the fragmentation process and its attendant human impacts which created the SMD 48 property. Historical aerial photographs are used to accomplish this task.

Creation of an Urban Forest Fragment in South Tampa

As mentioned earlier, one of the goals of this paper is to document the land use and land cover changes on the Interbay peninsula which led to the creation of the SMD 48 forest fragment. This was accomplished through interpretation of historical aerial photographs. Four major components of aerial photograph interpretation were considered when analyzing the photographs: tone, texture, pattern, and association. Tone can vary from black to white to various shades of gray in black and white photographs. In the black and white aerial photographs which I analyzed, darker shades of gray usually represented areas of open rangeland (also called southern "rough") while lighter shades of gray denoted areas of improved pasture (usually cleared and planted with Bahia grass). Texture is the result of tonal changes that define a characteristic arrangement of tones (Paine 1981). Texture can range from smooth to coarse. Areas of cypress trees, for example, have a smooth texture in vertical aerial photographs, while hydric hammocks have a coarse texture due to the more extreme differences in height and crown width of

individual trees. Pattern is also important and deals with the spatial arrangement of objects, either man-made or natural (Holz 1973). Man-made patterns include agricultural patterns (e.g. improved pasture, row crops), highways, and residential developments. Natural patterns are much less uniform and difficult to detect unless familiar with the particular study area. Finally, association is perhaps the most important element in interpreting aerial photographs. This involves "a reasoning process that uses all the principles of interpretation to relate an object to its surroundings" (Paine 1981,259). A mangrove stand, for example, would not be found in the middle of an area of mesic pine flatwoods. It is found in coastal areas. These four elements (tone, texture, pattern, and association) allowed me to interpret the following aerial photographs, black and white and blueprint, more accurately.

Historical Aerial Photographs

The aerial photographs reviewed include four small-scale photographs dating from 1938, 1948, 1957, and 1976 and four large-scale photographs dating from 1968, 1972, 1985, and 1994. Each of the small-scale photographs consist of SMD 48 (outlined in black) and an area surrounding SMD 48 bounded by Interbay Boulevard to the north, South MacDill Avenue to the east, Himes Avenue to the west, and MacDill Air Force Base to the south (except for 1957 photograph, which was part of an

incomplete set). This portion of the Interbay peninsula has experienced much of the same development pressures as the rest of the peninsula. Each of the large-scale photographs shows a clear delineation of habitats on SMD 48 as well as changes within these habitats. Processes such as secondary succession and hardwood invasion into pine flatwoods can be seen through analysis of these large-scale photographs.

1938

This aerial photograph (Figure 13) shows the larger study area (including SMD 48) in its pre-development state. Many of the natural ecosystem types that were present on the Interbay peninsula are found within this area. Those areas containing widely spaced trees (seen as small black dots) are pine flatwoods (green arrow), while areas containing large clumps of trees (wider, closely spaced dots) are usually hydric and/or mesic hammocks (blue arrow). Scattered flatwoods marshes (yellow arrow) are identified by their somewhat circular shape and dark center (which identifies the presence of water). These marshes (also called seasonal ponds) are usually shallow (less than one meter deep), small (ten to a few hundred meters across), and are characterized by short hydroperiods (wet in summer and early fall, dry in winter and spring) (Kushlan 1990). It is likely that these marshes formed in sinkholes, which are evidence of karst activity. The marshes often support wet prairie vegetation, which can

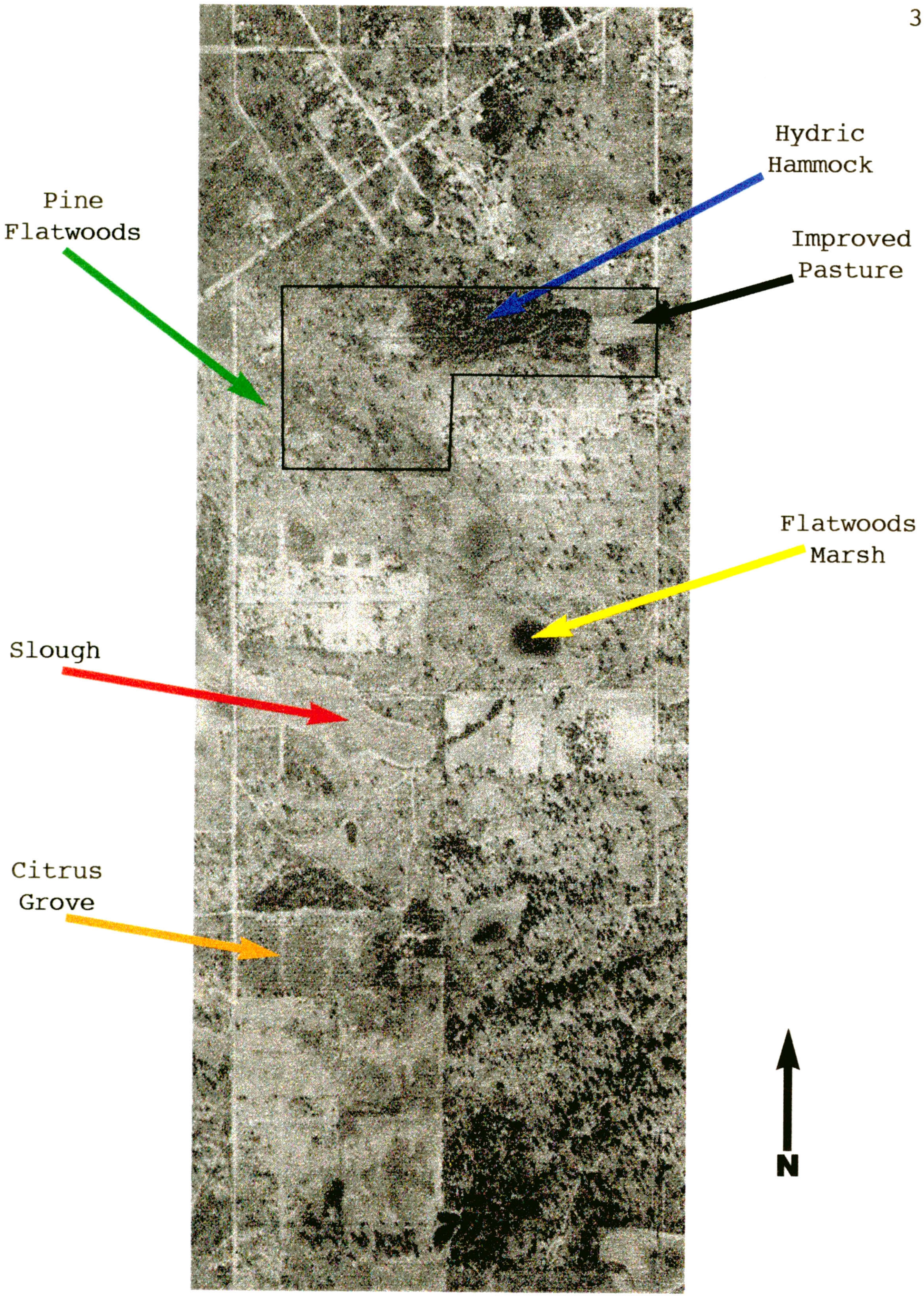

Figure 13. This 1938 aerial photograph shows SMD 48 and surrounding areas (Scale: 1″=759′).

tolerate alternating cycles of flooding and drying (Kushlan 1990). Several sloughs (areas of lower elevation within the flatwoods) are also present and support marsh vegetation. These sloughs (red arrow) can have a light or dark tone depending upon the amount of water in these areas (e.g. darker in summer, lighter in winter).

Although residential development was sparse in this area of the Interbay peninsula, an extensive network of roads, bringing new residents, was being extended from the northern part of the peninsula into this area. A small amount of residential development is seen adjacent to Interbay Blvd. at the top of the photograph. Two other human impacts in this area include the creation of improved pasture through clearcutting and the development of agriculture. The black arrow points out an area of improved pasture, which has a lighter tone due to the absence of thick ground cover (personal comm., William G. Saalman, III, USDA). The areas of improved pasture also have distinct, humanly-created shapes (e.g. right angles, square or rectangular shapes, etc.). The orange arrow points out agricultural areas where citrus trees were planted. These areas are identified by the straight rows of trees characteristic of citrus groves throughout Hillsborough County and Florida.

SMD 48 (outlined in black) contained several distinct habitat types including pine flatwoods, hydric hammock, mesic hammock, and a flatwoods marsh system (no longer present in

1996). The destruction of the flatwoods marsh is shown later through an examination of the larger-scale photographs. In addition to those natural habitats mentioned, an area of cleared forest also exists within the eastern portion of the site. This area was used as improved pasture (it includes two on-site residences), although a small clump of large, specimen-sized live oaks (still present today) were spared from destruction. This remnant is visible in the southeast corner of the pasture, thus shedding light on the probable habitat type(s) that existed here before a clearing took place (either mesic or hydric hammock). A full explanation of secondary succession and its relationship to former and current habitat type(s) within this pasture will be given later.

1948

This aerial photograph (Figure 14) shows new development pressures impinging upon the boundaries of SMD 48. MacDill Air Force Base (black arrow) developed to the south of SMD 48 and soon spurred a new period of residential growth in the Interbay area. Scattered residences are visible to the west and north of SMD 48, while the two residences located on the property itself are now clearly visible (yellow arrow). Although there were many landscape changes in areas surrounding SMD 48, there was little change in habitat on SMD 48. All habitat types are still present and the cleared area

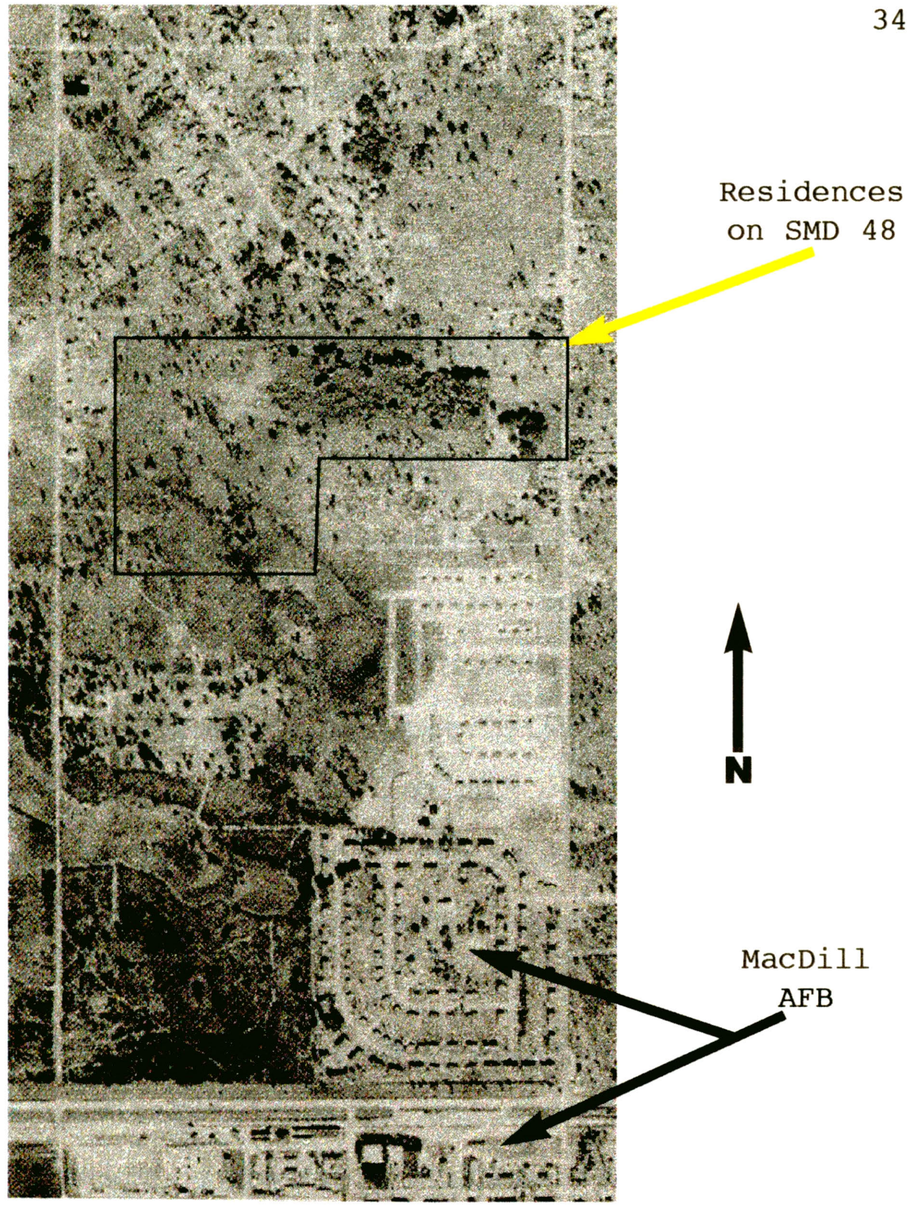

Figure 14. This 1948 aerial photograph shows SMD 48 and surrounding areas (Scale: 1″=759′).

is still used as improved pasture (shown by its lighter tone and small number of trees).

1957

Due to an incomplete set of aerial photographs, I was unable to obtain a photograph showing the development of areas to the extreme south of SMD 48. This photograph (Figure 15), however, does show the presence of new residential development surrounding SMD 48. The "Peninsula Heights," "Tropical Pines," and "Crescent Park" subdivisions (red, green, and yellow arrows, respectively) are impinging upon SMD 48 from the south, while a new park called the "Skyview Recreation Area" (black arrow) was created to the north. These areas are defined by their structured, geometric patterns and lighter tones.

In addition to the occurrence of habitat changes outside of SMD 48, there is habitat change within SMD 48 as well. The area that was formerly improved pasture was left fallow. New trees (with large crown width) are now visible within this area. Eventually, this area will succeed to mesic hammock dominated by live oak and cabbage palm (shown in later photographs). This process of forest regrowth after a disturbance is called secondary succession (Spurr and Barnes 1980).

Although it is difficult to predict the former habitat type(s) present here before this area was cleared for improved

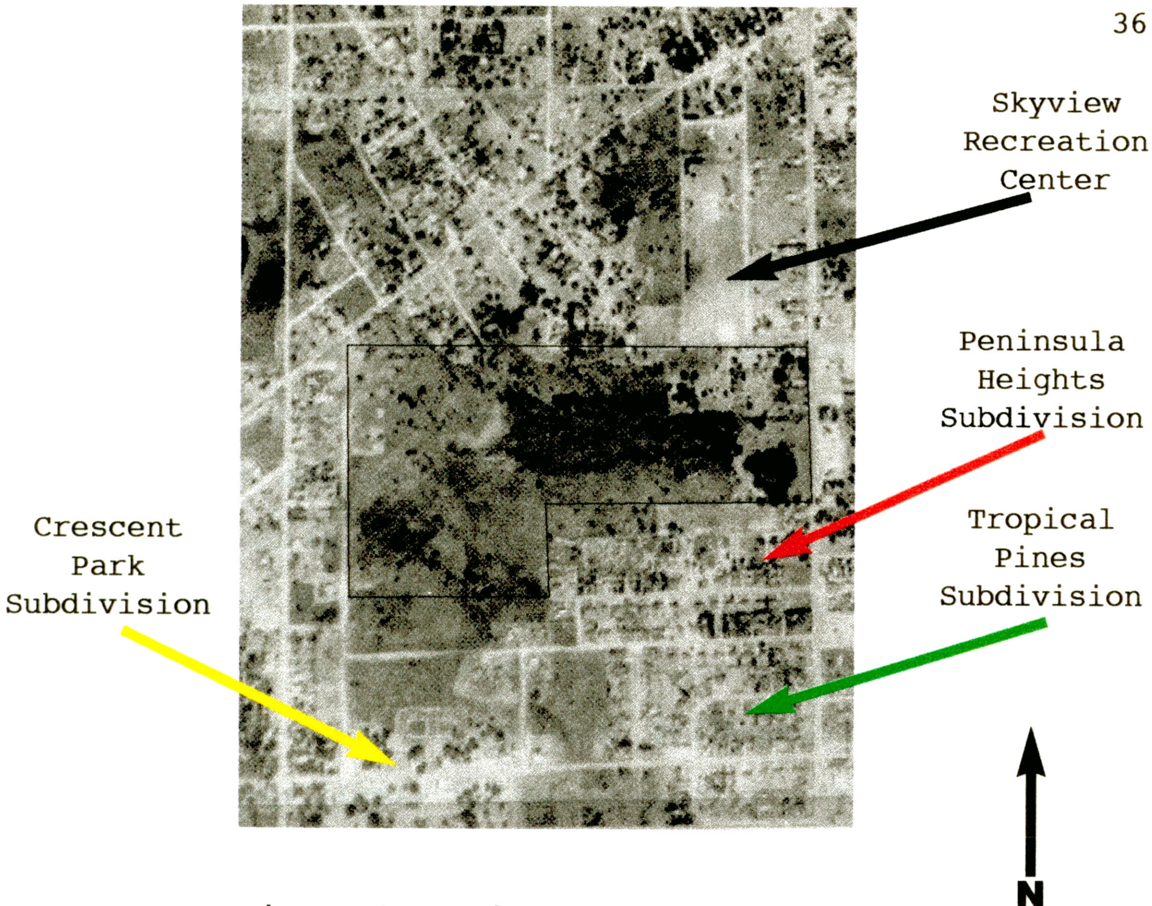

Figure 15. This 1957 aerial photograph shows SMD 48 and surrounding areas (Scale: 1″=759′).

pasture, evidence points to mesic hammock as the dominant habitat type in this portion of SMD 48. There are three reasons for this conclusion. First, the clump of oaks located in the southeast corner of the pasture is likely a remnant of a more extensive area of mesic hammock dominated by live oak. Second, this area in later years has succeeded to mesic hammock due to the presence of nearby seed sources (oak trees) as well as buried seeds and seedlings suppressed by mowing and/or grazing activities. Third, there are very few pine trees located in this area today and there is a lack of typical flatwoods vegetation (e.g. gallberry). This indicates that the pasture likely did not consist of pine flatwoods (or, at least, was not dominated by it). The following large-scale photographs from 1968 and 1972 show how this pasture has changed back to mesic hammock.

1968

Each of the habitat types present within the 1938 aerial photograph of SMD 48 are present in this 1968 large-scale aerial photograph (Figure 16). The hydric hammock (red arrow) is defined by its coarse texture resulting from extreme differences in height and crown width of individual trees. The pine flatwoods (green arrow) have a darker tone than improved pasture due to the presence of thick ground cover (southern "rough"). Widely spaced pine trees are visible within the flatwoods. The flatwoods marsh system (yellow

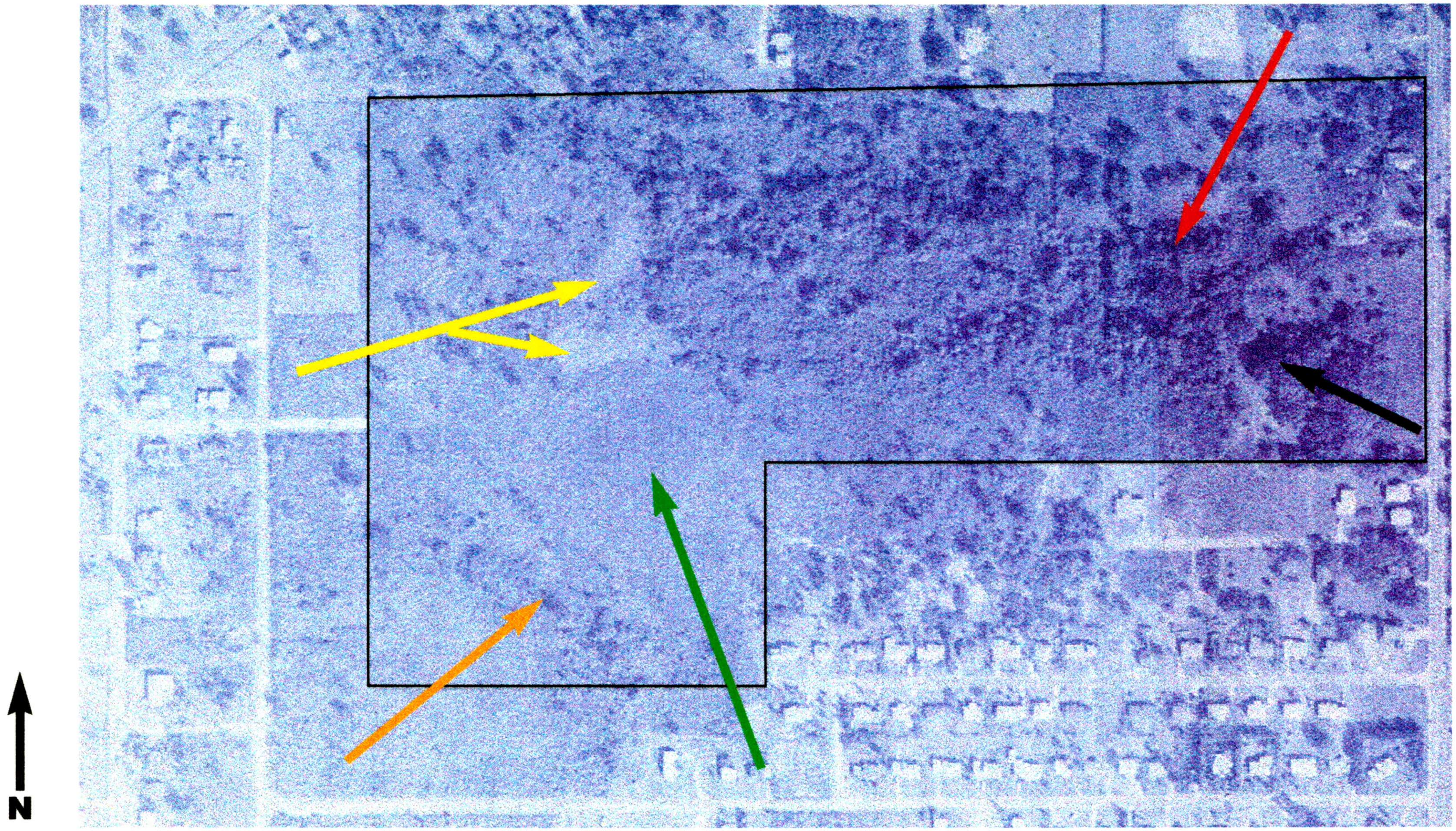

Figure 16. This 1968 aerial photograph shows SMD 48 (Scale: 1"=400'). Red arrow = hydric hammock; green arrow = pine flatwoods; yellow arrows = flatwoods marsh system; black arrow = mesic hammock; orange arrow = area of hardwood invasion within pine flatwoods.

arrows) can be identified by its somewhat circular (although irregular) shape and lighter tone signifying the absence of water. Although difficult to observe in this aerial photograph, the old underground storm sewer runs directly beneath this flatwoods marsh, almost dividing the marsh into two separate systems. This storm sewer likely lowered water levels in the marsh which may account for its lighter tone. Eventually, this flatwoods marsh will disappear due to the expansion of the ditch system.

Finally, the area which was once improved pasture is now succeeding to mesic hammock (black arrow). The clump of oaks in the southeast corner is expanding into the hydric hammock, while other individual live oaks and cabbage palms are becoming established. Several gaps in the canopy remain, however, because this process is still ongoing. Another area of SMD 48 where succession is occurring is within the southernmost portion of the pine flatwoods (orange arrow). This area is invaded by various hardwood tree species as a result of fire exclusion. As will be discussed later, pine flatwoods is a fire-dependent community type that can succeed into other community types if not subjected to fire at regular intervals. This area of hardwood invasion will expand as the years pass.

1972

This aerial photograph of SMD 48 (Figure 17) shows the continuing expansion of mesic hammock into the former improved

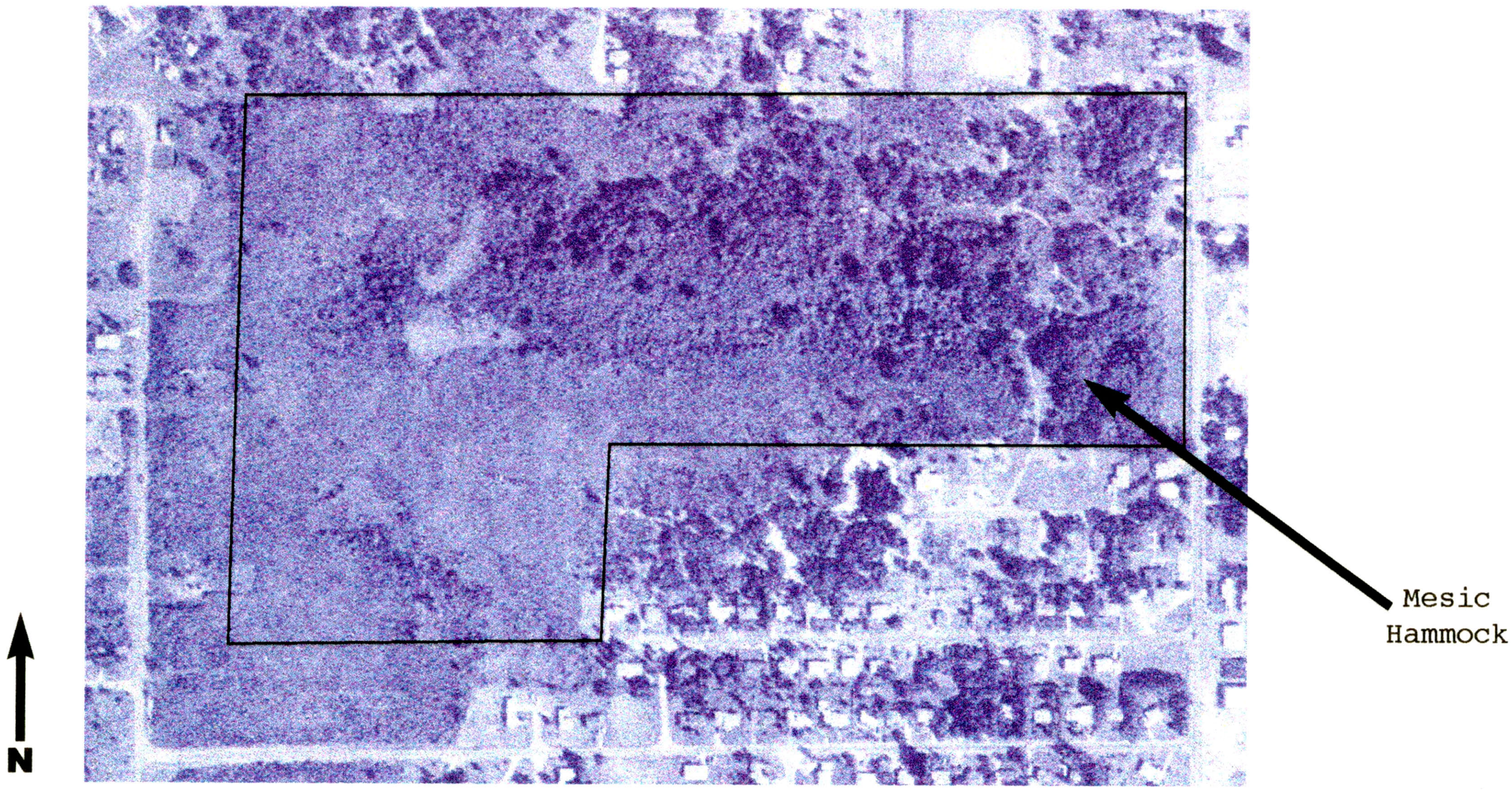

Figure 17. This 1972 aerial photograph shows SMD 48 (Scale: 1″=400′).

pasture (black arrow). Thick clumps of trees (mostly oaks) are evident within this area. The rest of SMD 48 has undergone little visible change.

1976

This small-scale photograph (Figure 18) shows how residential development has completely surrounded SMD 48. Much of this development was spurred by the growth of MacDill Air Force Base (green arrow) in the 1950's and 60's. In addition to landscape changes outside of SMD 48, several changes have occurred within this forest fragment. The mesic hammock (black arrow) continued to expand so that fewer canopy gaps are noticeable. The area of hardwood invasion in the pine flatwoods also expanded (red arrow). Finally, the two large, open ditches mentioned earlier were constructed in the flatwoods and tied into the underground storm sewer. As will be shown in the following aerial photographs, the creation of these new ditches (blue arrows) severely impacted the flatwoods marsh system (yellow arrows) and ultimately led to its destruction.

1985

This aerial photograph (Figure 19), although a relatively poor image of the study area, does illustrate that the flatwoods marsh system (yellow arrows) became fragmented into two smaller marshes that were invaded by hardwood trees from

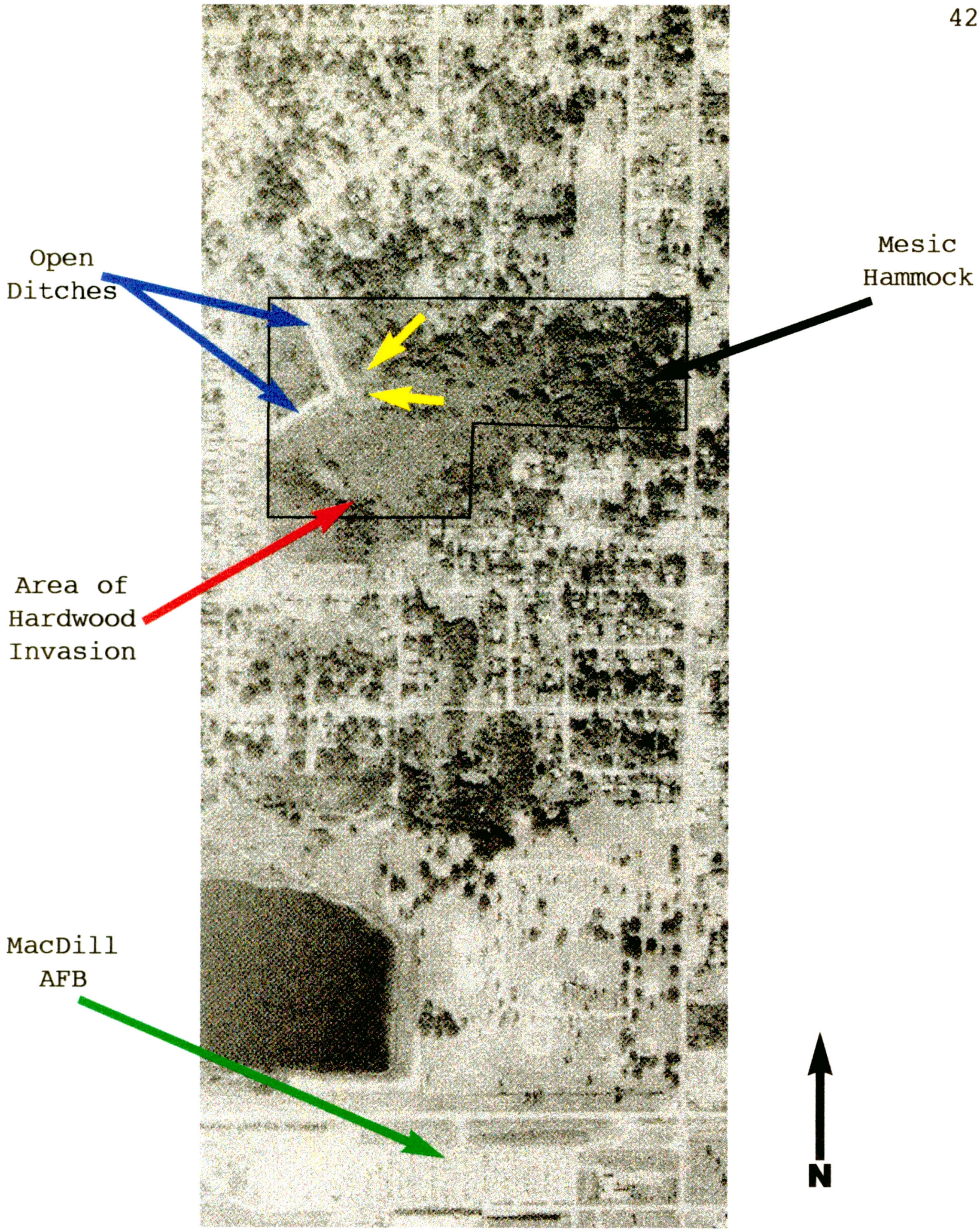

Figure 18. This 1976 aerial photograph shows SMD 48 and surrounding areas (Scale: 1″=759′). Yellow arrows = flatwoods marsh system.

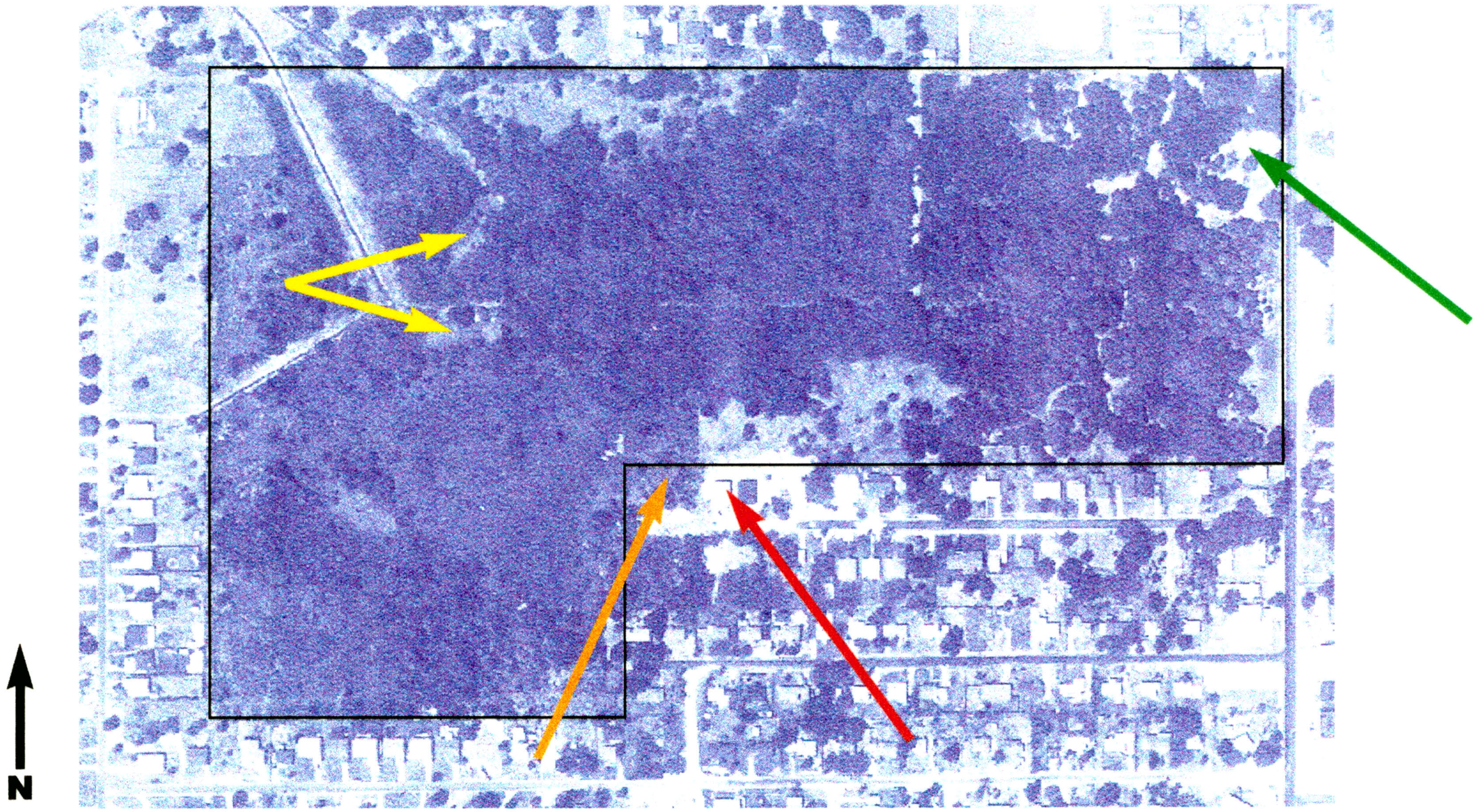

Figure 19. This 1985 aerial photograph shows SMD 48 (Scale: 1″=400′). Yellow arrows = flatwoods marsh system; red arrow = growth within Peninsula Heights subdivision; orange arrow = pine flatwoods; green arrow = canopy gaps.

the adjacent hydric hammock. The marshes are, thus, decreasing in size. There could be several reasons for this decline since 1976. First, the two open ditches could have lowered the surface water table in this area of the flatwoods, thus resulting in a lowering of the water level within the marsh. Second, the expanded ditch system could have removed any standing water more quickly, thus resulting in a drying of the marsh system. Once the marsh was sufficiently dry, hardwood invasion occurred. Evidence of this is shown in the 1994 aerial photograph of SMD 48. Also evident in this 1985 aerial photograph is the continued expansion of the mesic hammock (fewer canopy gaps are present) and the ongoing growth of the Peninsula Heights subdivision (red arrow). As a result of this new housing construction, pine flatwoods (orange arrow) were destroyed. The three on-site residences that had appeared in earlier photos, however, were removed from SMD 48. The green arrow shows the former location of these residences (now canopy gaps).

1994

As can be seen in this large-scale aerial photograph (Figure 20), the process of enveloping fragmentation is now complete. The Peninsular Heights subdivision is built out and lots to the east were developed or cleared. At this point in time, SMD 48 is owned by Hillsborough County. Three major changes occurred within SMD 48 since 1985. First, the mesic

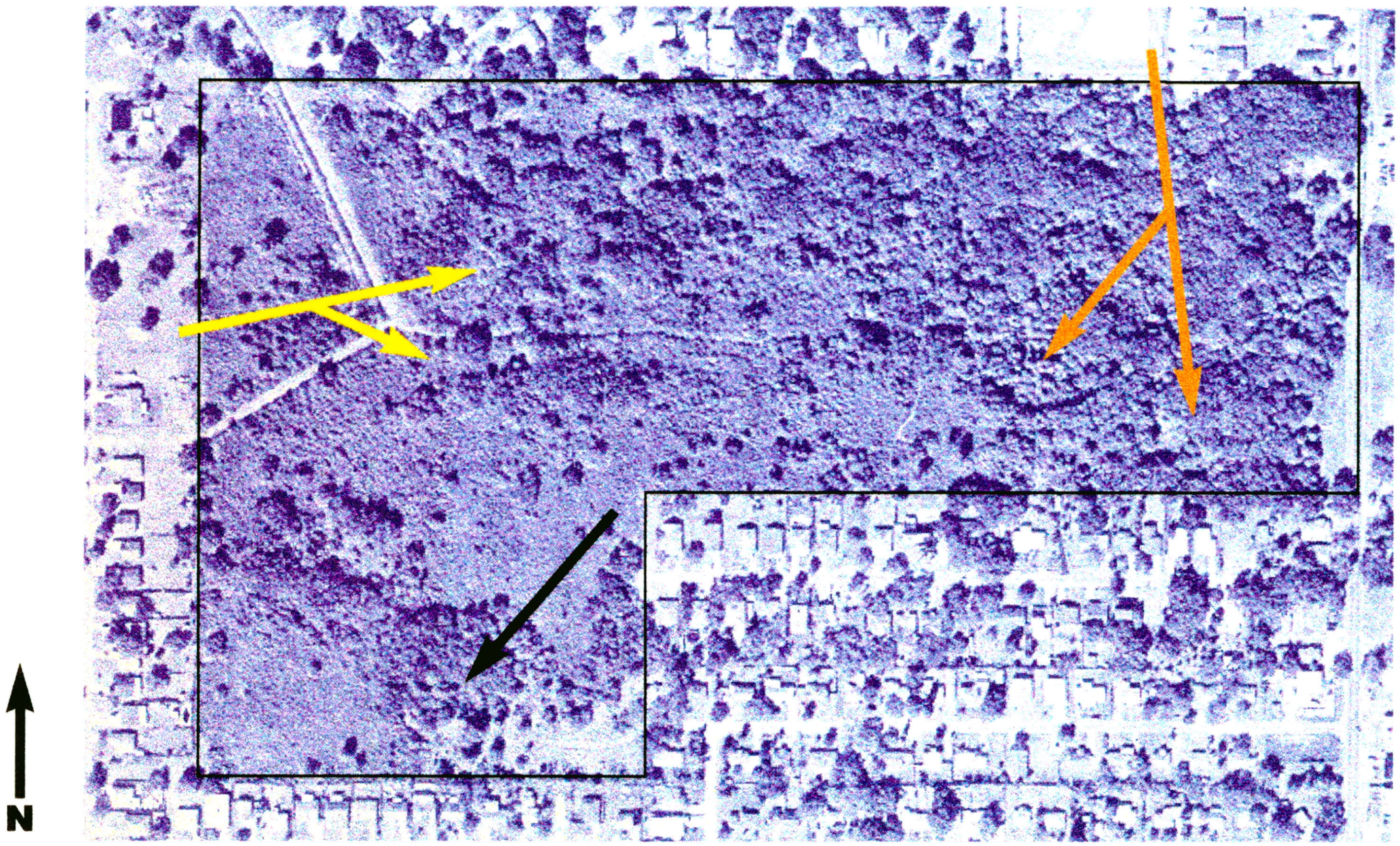

Figure 20. This 1994 aerial photograph shows the final boundaries of SMD 48 (Scale: 1″=400′). Orange arrows = cabbage palm and live oak trees; yellow arrows = former location of flatwoods marsh system; black arrow = area of hardwood invasion within pine flatwoods.

hammock continued to expand so that few gaps within the canopy remain. This hammock is dominated by live oak and cabbage palm (orange arrows), species typical of mesic hammocks throughout the state. Second, the former flatwoods marsh system (yellow arrows) completely disappeared. As mentioned earlier, the two large open ditches apparently led to the drying of this marsh system, thus leading to hardwood invasion in this area. Third, the area of hardwood invasion within the southern portion of the flatwoods (black arrow) increased in size due to fire exclusion. The larger crown width of oak species (e.g. live oak) in this area contrasts sharply with the sparse tree cover within the adjacent flatwoods.

Several of the fragmentation effects and human impacts briefly mentioned in this chapter will be explored in greater detail in the following chapters. Chapter Three will focus on the effects (or non-effects) of ditching on hydrology and soils within SMD 48's hydric hammock. Chapter Four will focus on the detrimental effects of exotic plant invasions on SMD 48, while Chapter Five discusses the effects of fire exclusion.

CHAPTER THREE

EFFECTS OF HUMAN IMPACTS ON HYDROLOGY AND SOILS WITHIN A HYDRIC HAMMOCK

Introduction

As stated earlier, this chapter examines the impact of ditching on hydrology and soils within SMD 48's hydric hammock. Although not always fragmenting forces, ditch systems can alter hydrologic and soil conditions which often lead to vegetation changes within affected habitats. Urban forest fragments, especially, are subject to changes in hydrology due to the abundance of underground sewer systems, open runoff ditches, and pavement which characterize most major cities today. As previously stated, several open ditches and an underground storm sewer are located on SMD 48. The rest of this chapter focuses on the effects of this ditch system on hydrology, soils, and vegetation within SMD 48's "hydric hammock" wetland.

Hydric hammocks are considered "wetlands" because they are characterized by short hydroperiods of three to five months (Ewel 1990) and contain vegetation that can withstand wet soils for long periods of time. According to the Classification of Wetlands and Deepwater Habitats of the

United States developed by Cowardin et al. (1979), a hydric hammock is defined as a palustrine forested wetland with a seasonally flooded water regime (Figure 21). Hydric hammocks are typically found in depressions within a pine flatwoods matrix or adjacent to rivers or marshes. This community is fed by the surficial aquifer in most areas, but may actually be directly connected to the Floridan Aquifer in some areas of limestone outcroppings (Vince et al. 1989; Lewis and Estevez 1988). The soils within hydric hammocks formed over areas of soft and hard limestone within sandy and loamy marine sediments (Vince et al. 1989). The soil here is considered to be a "mineral" soil with a relatively low organic matter content (Mitsch and Gosselink 1993). The soil profile is made up of horizons with the O and A horizons containing more organic matter than the lower horizons.

Direct impacts to the hydrology of a wetland can result in changes to both soils and vegetation (Rowell 1986; Ewel 1990; Vince et al. 1989; Wolfe and Drew 1990; Mitsch and Gosselink 1993). The impact of ditching is especially severe in areas where the water table is close to the surface (as in hydric hammocks) (Kimble 1992).

There is an extensive network of ditches located on SMD 48 that funnel urban stormwater underground through the center of the hydric hammock (see Figure 6). This chapter will examine the possible effects (if any) of these ditches on the hydrology and soils of the hydric hammock. In many cases,

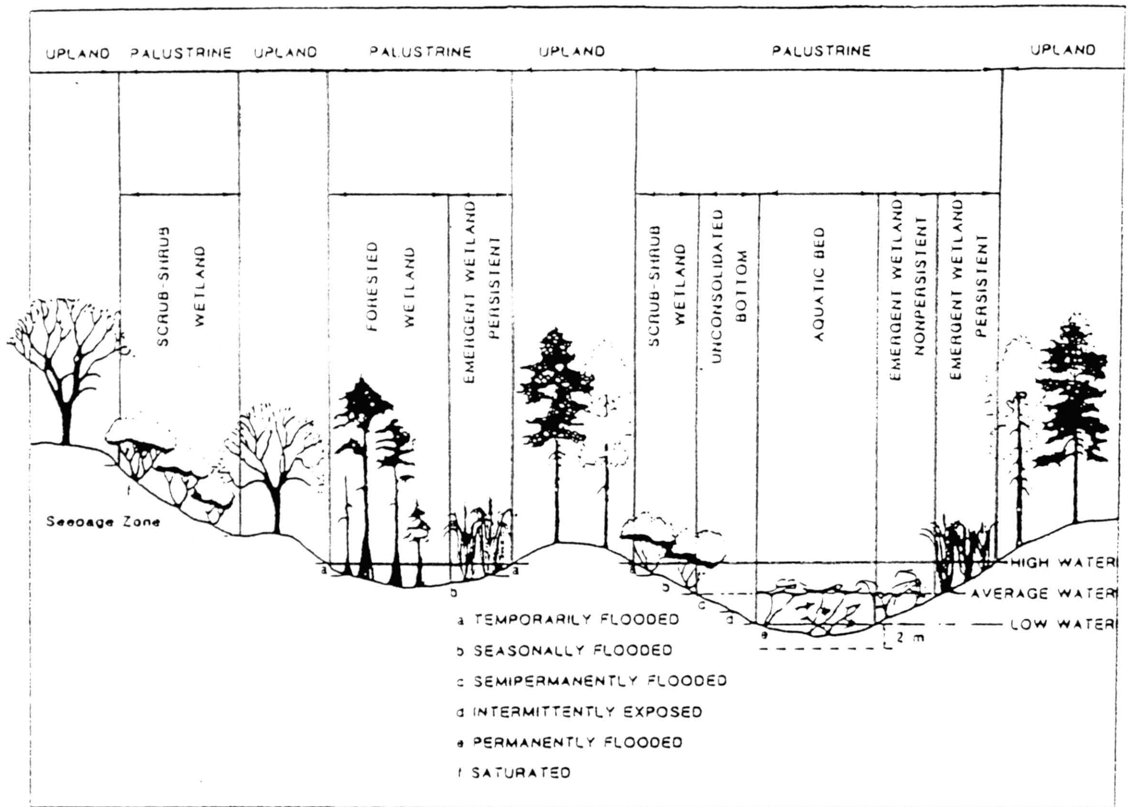

Figure 21. The above figure shows habitats within the Palustrine system. A hydric hammock is considered a palustrine forested wetland with a seasonally flooded water regime (from Cowardin et al. 1979).

stormwater ditches can channelize water flow where there previously existed a natural sheet flow toward the lowest portion of the wetland. This channelization tends to increase the rate and amount of runoff out of the system, ultimately leading to a lowering of the surface water table and drying of the soil. However, if the ditch(es) becomes clogged with soil or debris, the water can back up and pond near the ditch(es), thus raising the surface water table in this area and affecting soil characteristics due to constant saturation. Other changes may follow this change in hydroperiod and soils. These include vegetation changes, an increase or decrease in litter decomposition rates, and a change in microclimate within the hammock.

The hydric hammock occupies the middle of SMD 48 and is dominated by sweetbay magnolia as well as live oak and cabbage palm. The hydric hammock is located within an area of lower elevation where water gathers during the rainy season (summer). This depression can be located on old stormwater drainage maps like the one shown in Figure 5 (circa 1924). The elevation within the hydric hammock is less than ten feet above sea level.

Soil Types

According to the 1989 Soil Survey of Hillsborough County, Florida (Doolittle et al. 1989) there are three soil types present on the site: Immokalee-Urban land complex, Malabar

fine sand, and Pomello-Urban land complex, 0 to 5 percent slopes. According to this survey, the pine flatwoods and mesic hammock areas are located on the Immokalee and Pomello soils, while the hydric hammock is roughly located within the Malabar soil area. Malabar soil is considered a "wetland" soil that is "nearly level and poorly drained" and present in "low lying sloughs and shallow depressions on the flatwoods" (Doolittle et al. 1989). Within this soil type, the water table is usually within 10 inches of the surface and "shallow flooding" can occur during heavy rains (Doolittle et al. 1989). This description is consistent with the typical landscape position and hydrologic regime associated with hydric hammocks. A representative sample of Malabar soil should include the following horizons: A(0-4 in.); E(4-12 in.); Bw(12-30 in.); E'(30-50 in.); Btg (50-66 in.); and Cg(66-80 in.).

According to the <u>1916 Soil Survey of Hillsborough County, Florida</u> (Mooney et al. 1916), a portion of the property is comprised of Norfolk fine sand, hammock phase (Figures 22 and 23). This soil type consists of a .....

> "slightly loamy fine sand, dark gray or brownish gray to light gray to a depth of 6 to 10 inches and pale yellow or amber yellow below. It is probable that a substratum of clay, limestone, or hardpan occurs at no great depth. It lies at elevations ranging from one foot to twenty feet above the water level with the permanent water table not far below the soil surface. Uncleared areas

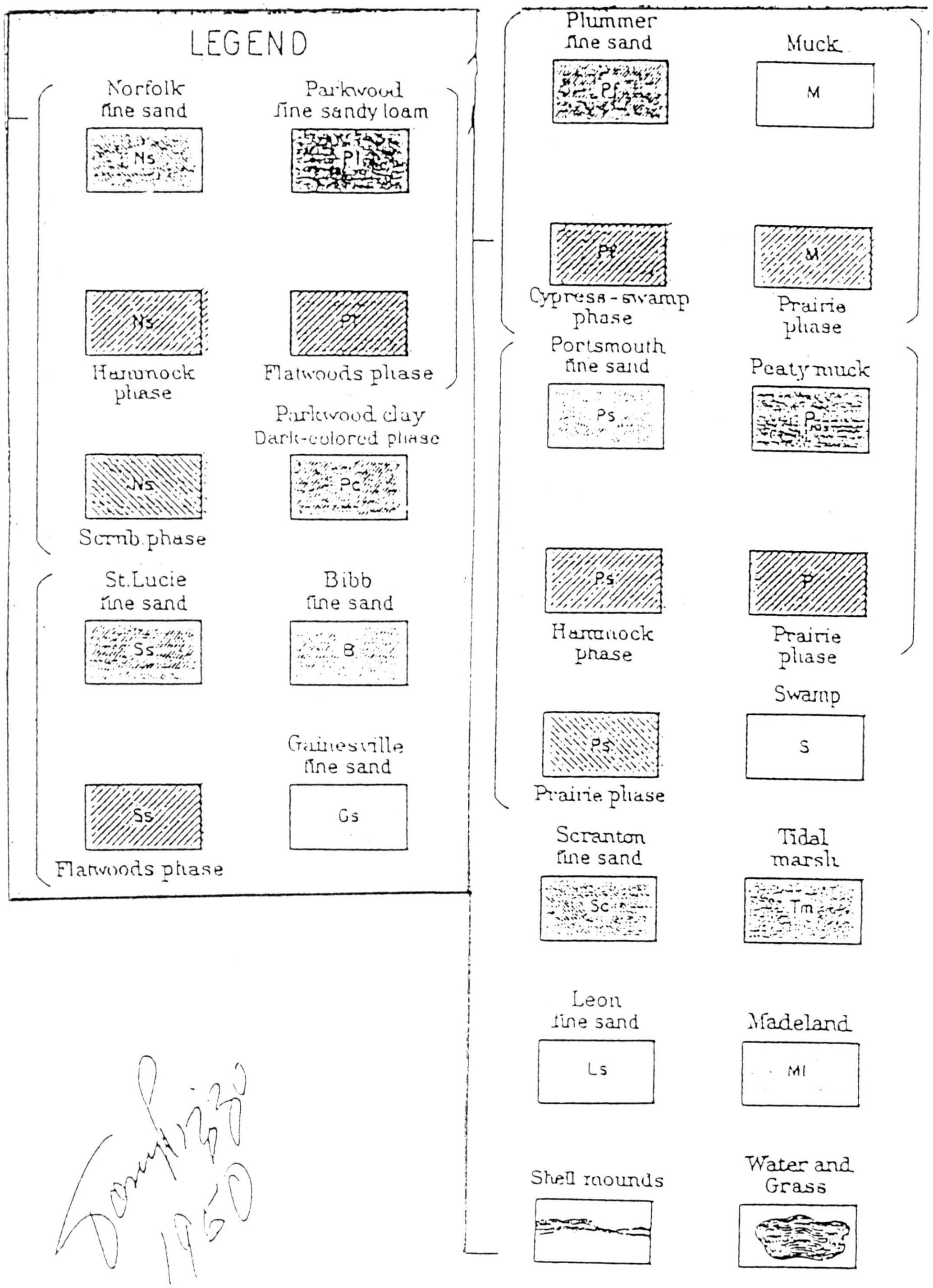

Figure 22. Legend for the <u>1916 Soil Survey of Hillsborough County, Florida</u> (from Mooney et al. 1916).

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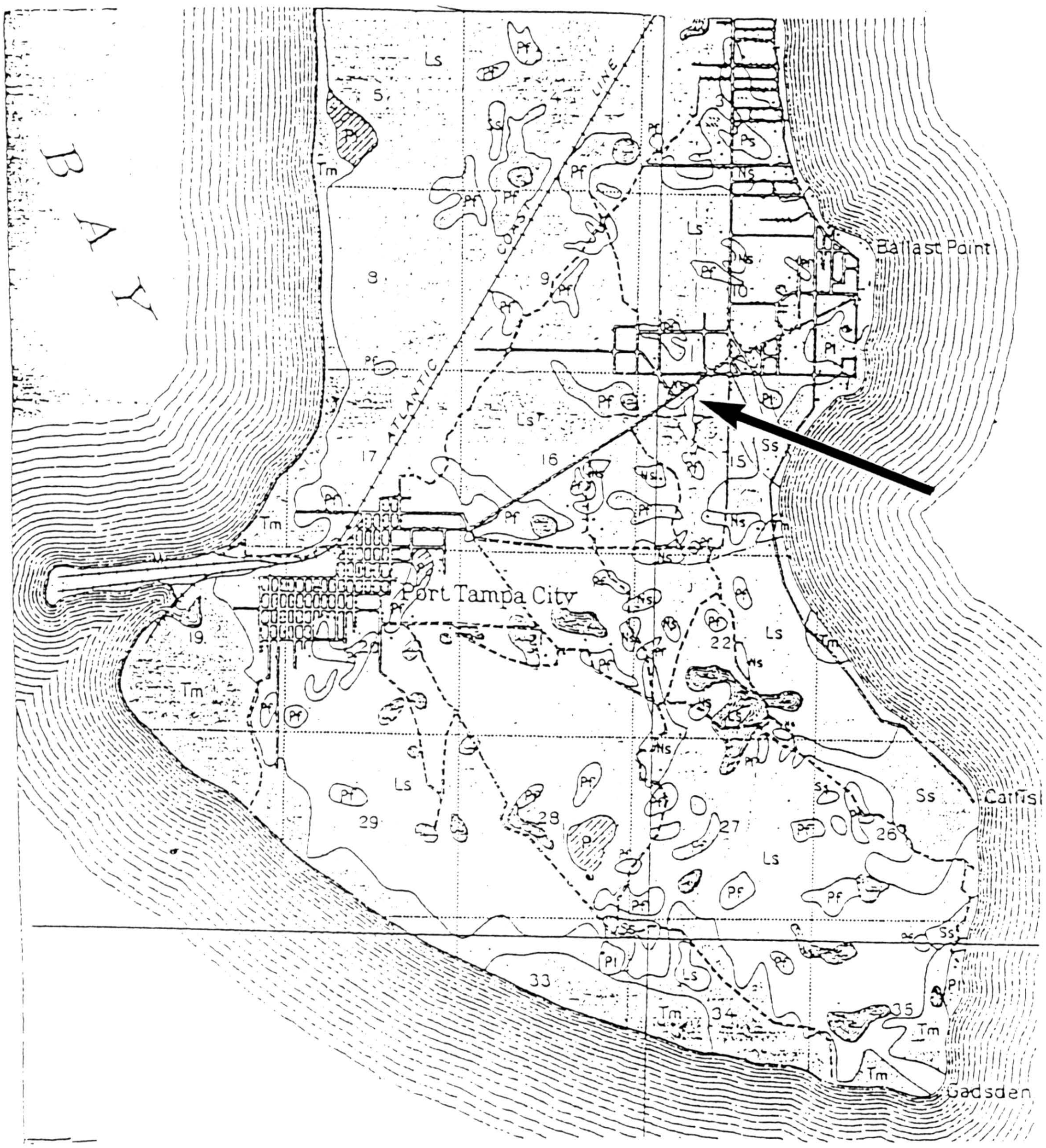


Figure 23. This soil map from the 1916 Soil Survey of Hillsborough County, Florida shows that the hydric hammock (black arrow) on SMD 48 is comprised of Norfolk fine sand, hammock phase (after Mooney et al. 1916).

> support a heavy hammock growth, consisting mainly of live oak, hickory, and magnolia, with some cabbage palmetto, longleaf pine, and other trees, and usually a rather thick undergrowth of shrubs. It is known locally as 'hammock land,' 'oak hammock,' and 'hickory hammock'" (Mooney et al. 1916,766).

Although generalized and strictly qualitative, the above description from the 1916 soil survey is a relatively accurate portrayal of the soil, elevation, vegetation, and depth to water table that characterize the hydric hammock portion of the property today.

Other Impacts

In addition to the possible impact of ditching on the water table and soil, a portion of the hydric and mesic hammocks were cleared prior to 1938 (see Figure 7). As mentioned earlier, this portion was converted to improved pasture and planted with Bahia grass (pers. comm., W. G. Saalman, III, USDA) and stayed this way until the late 1950's. During this time period, some possible effects on the soil within this cleared portion include increased saturation due to a decrease in evapotranspiration as well as a decrease in organic matter due to the absence of trees and shrubs. However, it is possible that water within this cleared portion may have drained off of the property more quickly than normal because the natural vegetation was not present to intercept the rainfall and release the water more gradually and there

may have been sheetflow toward the storm sewer system. However, it is possible that the surface water table could have risen during this time period due to a decrease in ET. This, though, is mere speculation and could not be proven today because the vegetation has grown back quickly since the late 1950's to the point where live oak and cabbage palm dominate the overstory in this area.

The remainder of this chapter will review the effects of the current ditch system on the soil and water table within the original hydric hammock ecosystem. Possible effects of any change in soil or water table depth on vegetation will also be discussed.

Methodology

The field methods involved: (1) the excavation of three soil pits in undisturbed areas within the hydric hammock; and (2) making observations about soil horizon characteristics and their relationship to water table depth. Each pit was dug near a sweet bay magnolia tree (the tree most characteristic of the wetter portions of the hammock) to ensure that the pits were within the boundaries of the hydric hammock (as opposed to the mesic hammock areas dominated by live oak). Figure 24 shows the locations of the three pits. Soil samples were taken after making initial observations and each pit was photographed and videotaped. Recorded observations of soil horizons and samples include: Munsell color, depth of

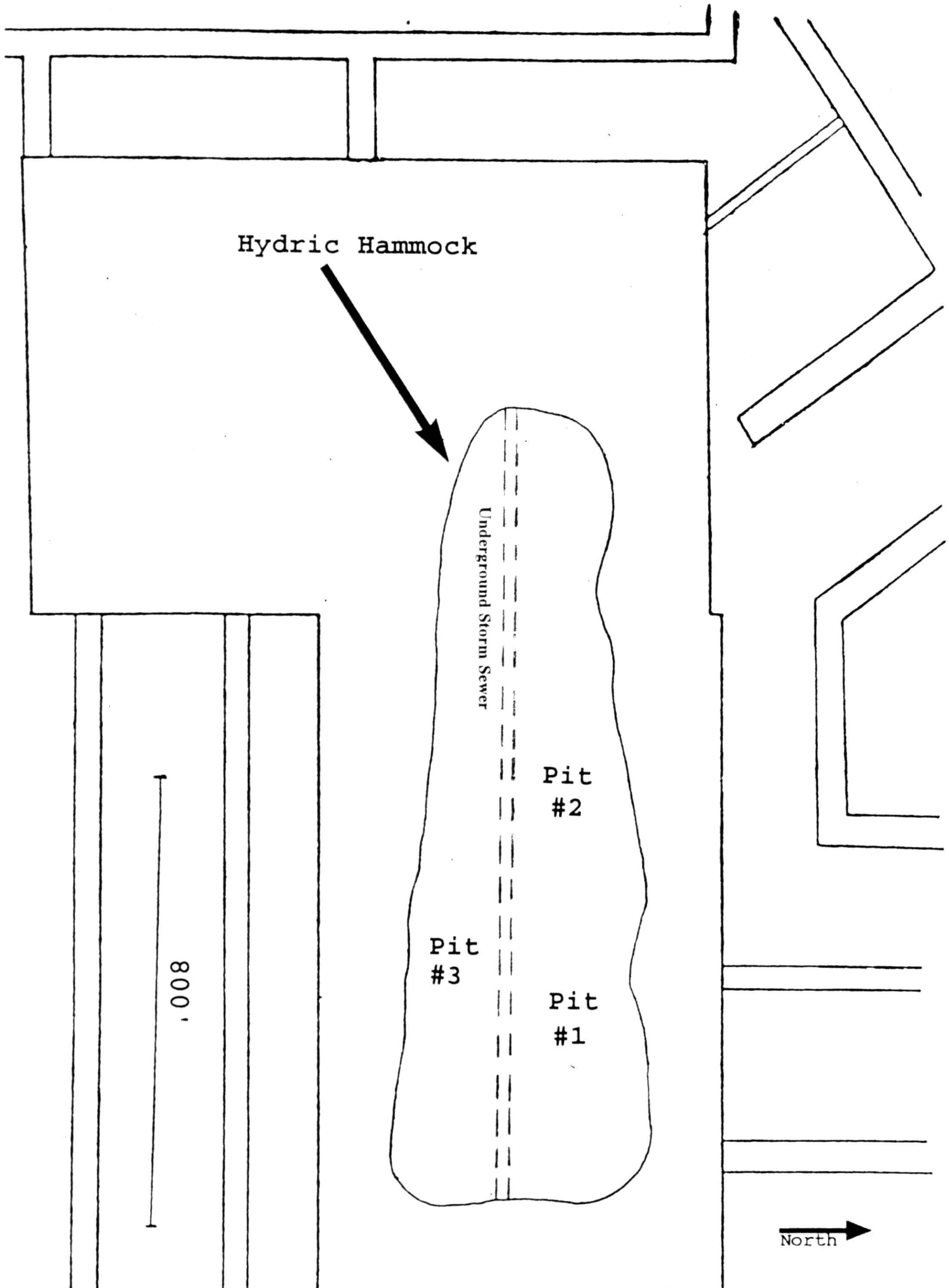


Figure 24. The above map shows the approximate locations of soil pits #1, #2, and #3.

horizons, boundary types, soil texture, soil structure, soil consistence, and presence of mottling and iron concretions. Depth to water table was recorded for each pit and preliminary conclusions drawn regarding the relationship between soil horizon characteristics and potential rise or fall of the surface water table. Other site characteristics recorded include: vegetation types, condition of the ditch system, and presence or absence of any loose rock fragments or outcroppings in the area.

Results

The following sections describe the soil horizon characteristics found in each soil pit. The depth of each horizon in each of the three pits is shown in Figures 25 - 27.

<u>Pit 1 - Horizon Characteristics</u>

0: 0 to 2.5 inches; dark gray (10YR 4/1) fine sand; weak fine granular structure; friable; many fine and medium roots; clear smooth boundary.

A1: 2.5 to 10 inches; very dark gray (10YR 3/1) fine sand; weak fine granular structure; friable; many fine and medium roots; gradual smooth boundary.

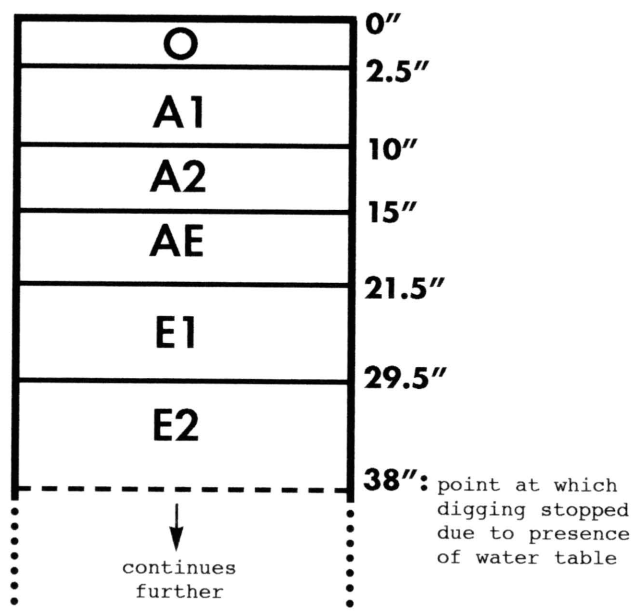
A2: 10 to 15 inches; black (10YR 2/1) fine sand; weak fine granular structure; friable; few fine and medium roots; gradual smooth boundary.

AE: 15 to 21.5 inches; dark grayish brown (10YR 4/2) fine sand; single grained; friable; few fine roots; gradual wavy boundary.

E1: 21.5 to 29.5 inches; grayish brown (10YR 5/2) fine sand; many coarse prominent reddish brown (2.5YR 4/4) mottles; single grained; slightly sticky and nonplastic; gradual smooth boundary.

E2: 29.5 to 38 inches; very pale brown (10YR 7/3) fine sand; many coarse prominent reddish brown (2.5YR 4/4) mottles; single grained; sticky and nonplastic; gradual smooth boundary.

Soil Profile : Pit #1



Scale:0.5" = 10"

Figure 25. Soil profile of Pit #1.

Soil Profile : Pit #2

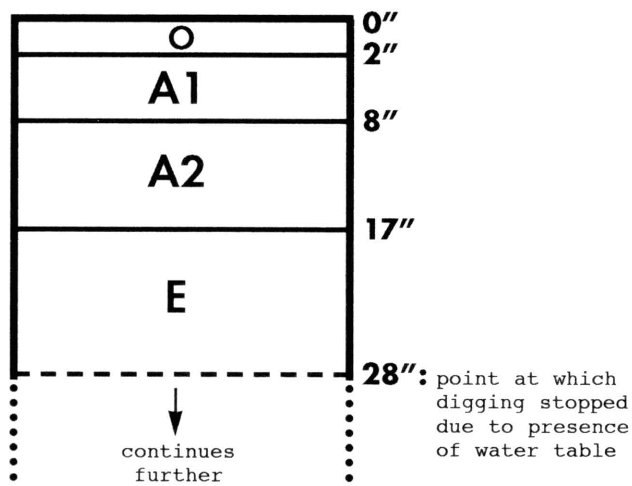


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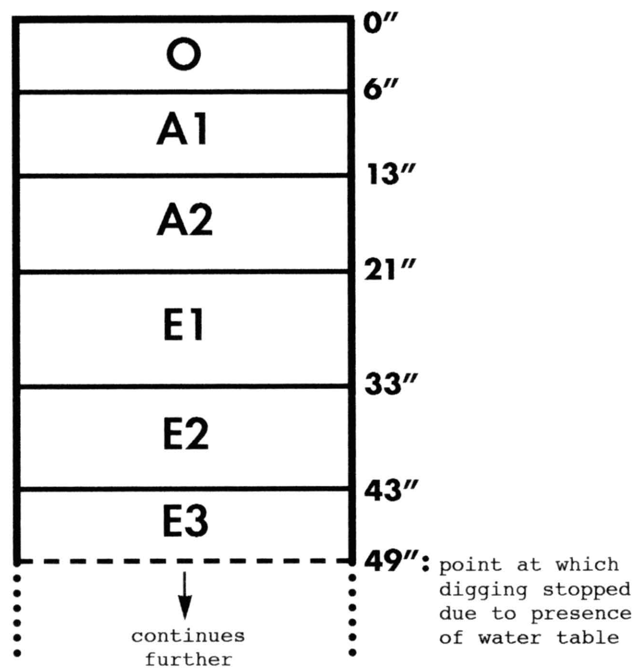
Figure 26. Soil profile of Pit #2.

Soil Profile : Pit #3



Scale:0.5″ = 10″

Figure 27. Soil profile of Pit #3.

Hit water table at 38 inches which prevented further digging. Photo of pit is shown in Figure 28.

Pit 2 - Horizon Characteristics

O: 0 to 2 inches; very dark gray (10YR 3/1) fine sand; weak fine granular structure; friable; many fine and medium roots; clear smooth boundary.

A1: 2 to 8 inches; dark brown (10YR 3/3) fine sand; weak fine granular structure; friable; many fine and medium roots; gradual smooth boundary.

A2: 8 to 17 inches; dark yellowish brown (10YR 4/4) fine sand; weak fine granular structure; slightly sticky and nonplastic; many fine and medium roots; gradual smooth boundary; large iron concretions.

E: 17 to ? inches; light gray (10YR 7/2) fine sand; many coarse prominent reddish brown (2.5YR 5/4) mottles; single grained; very sticky and nonplastic.

Hit water table at approximately 28 inches which prevented further digging. Photo of pit is shown in Figure 29.

Pit 3 - Horizon Characteristics

O: 0 to 6 inches; very dark gray (10YR 3/1) fine sand; weak fine granular structure; loose; many fine and medium roots; clear smooth boundary.

A1: 6 to 13 inches; grayish/dark grayish brown (10YR 4.5/2) fine sand; weak fine granular structure; loose; many fine and medium roots; gradual smooth boundary.

A2: 13 to 21 inches; dark brown/brown (10YR 4/3) fine sand; weak fine granular structure; friable; few fine roots; gradual smooth boundary.

E1: 21 to 33 inches; light gray (10YR 7/2) fine sand; few medium distinct reddish brown (2.5YR 4/4) mottles; single grained; slightly sticky and nonplastic; gradual smooth boundary.

E2: 33 to 43 inches; very pale brown (10YR 7/3) fine sand; single grained; slightly sticky and nonplastic; clear smooth boundary.

E3: 43 to ? inches; very pale brown (10YR 7/4) fine sand; single grained; very sticky and nonplastic.

Hit water table at 49 inches which prevented further digging. Photo of pit is shown in Figure 30.

Figure 28. The above photo shows the dark A horizons, light E horizons, and high water table present at pit #1 (photo by author, October 1995).

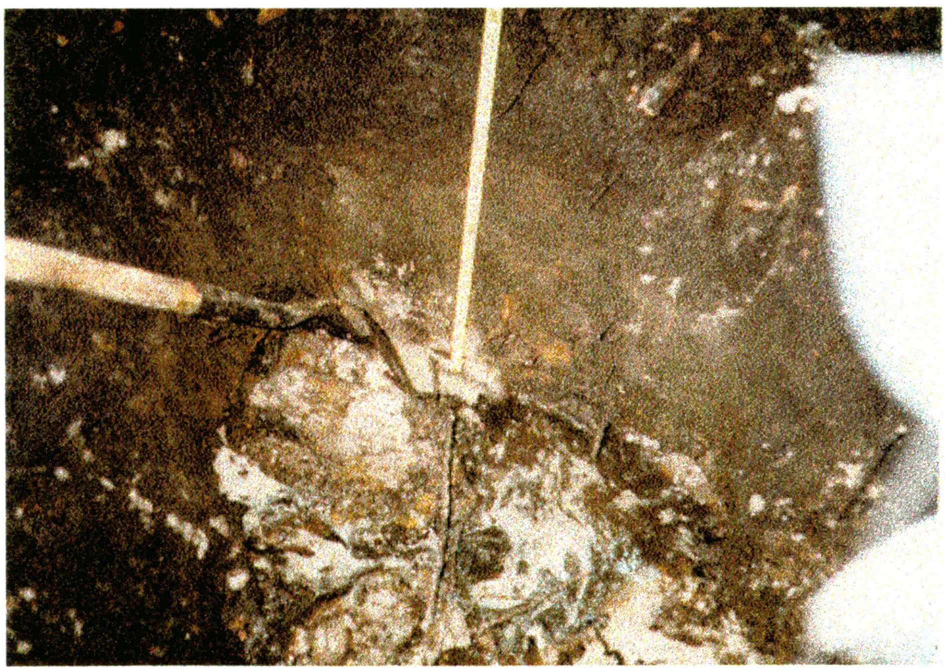


Figure 29. The above photo shows the very dark A horizons, a very light E horizon, and a high water table at pit #2 (photo by author, October 1995).

Figure 30. The above photo shows the thick A and E horizons present at pit #3 (photo by author, October 1995).

Other field observations include: prominent vegetation types, rock types, and the condition of the storm sewer and ditch system. The major overstory trees within the hydric hammock are sweetbay magnolia, cabbage palm, and live oak. The major understory vegetation includes various ferns (exotic and native), saw palmetto, and young cabbage palms. Large pieces of limestone rock were found near pit #1, as well as near the storm sewer system. Severe ponding was found along the western portion of the storm sewer and a stand of exotic Brazilian pepper trees was found in this same area.

Discussion

Before discussing the actual results of the soil investigations, it will be beneficial to examine the geology of the area as well as characteristics of the fluctuating water table. Any possible effects of ditching on the wetland will then be discussed and compared with on-site observations.

Geology and Soil Formation

In order to understand the composition of the soil in a particular area, it is important to know the regional geology as well as the particular ecosystem type under consideration. The Florida Plateau, since the early Cretaceous period (approximately 140 Million Years Before Present), has consisted of the Florida peninsula and adjacent continental

shelf (Puri and Vernon 1964). This plateau formed as a result of the deposition of thick layers of limestone and dolomite on what was formerly a shallow sea floor (Vince et al. 1989). Outcroppings of early Tertiary (approximately 15-55 MYBP) limestones are abundant within the Ocala Uplift District and west-central Florida (Vince et al. 1989; Riggs 1984). The Ocala Uplift District (Figure 31) was produced as a result of "Post-Oligocene orogeny," which are crustal changes which led to deformation of the coastal-plain floor (Brown et al. 1990). Today, this area is characterized by karst topography where sinkholes are abundant due to the ease in which limestone is dissolved by water. Phosphorous, deposited as phosphorites during the Miocene period, is abundant within this area as are thick deposits of sand (Riggs 1984). However, soils adjacent to Tampa Bay, including those within this hydric hammock, are derived from carbonate-rich, siliceous sands of marine origin as opposed to a mixture of phosphate and silica (Lewis and Estevez 1988). Much of the phosphate reserves lie within the eastern portion of Hillsborough County, further from the bay. Most of Hillsborough County's soils, however, consist of marine sands overlying clay-covered limestone. The clay can be found in lower soil horizons as a result of limestone weathering in place and is not translocated from the above nutrient-poor marine sands, which have a very low clay content.

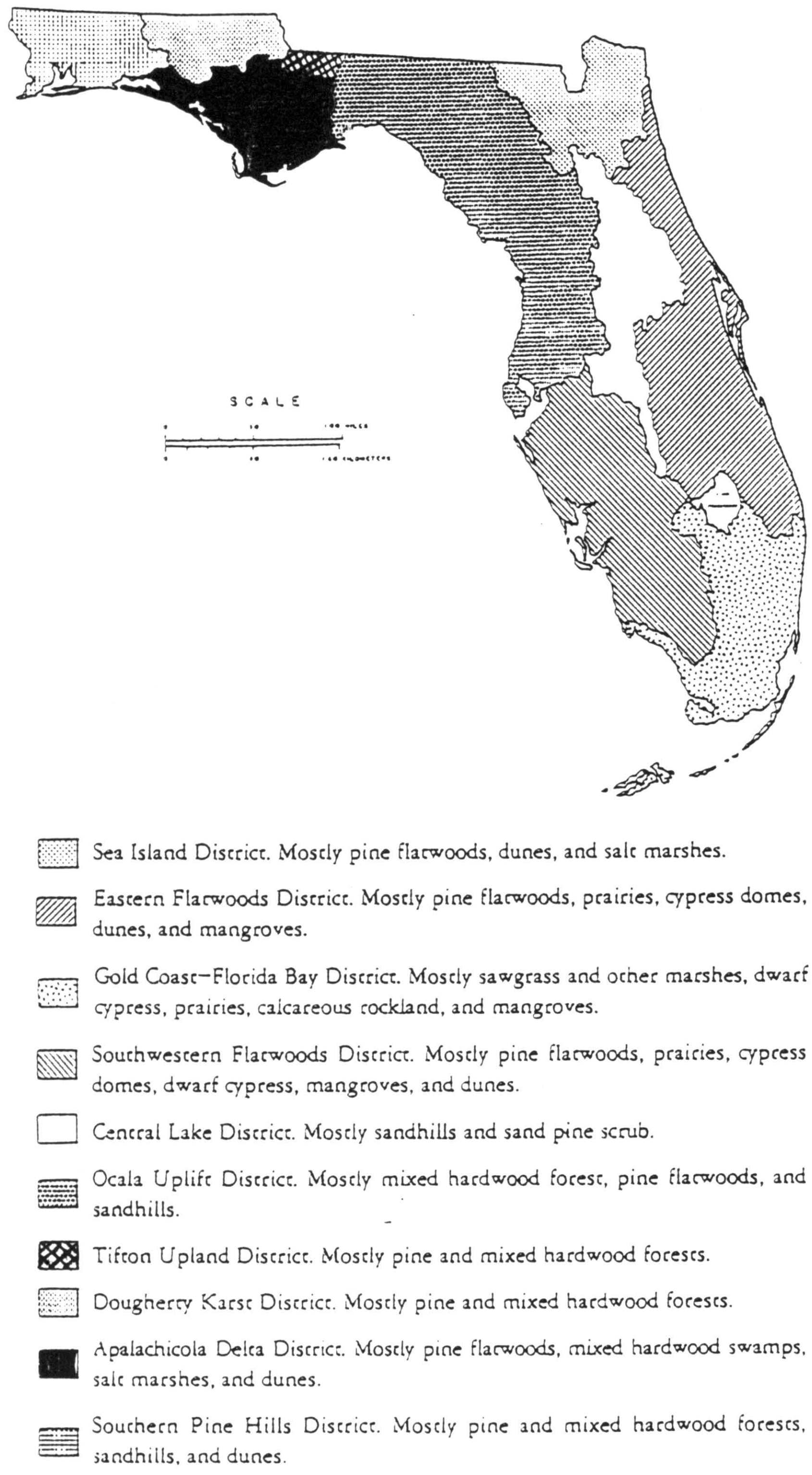


Figure 31. This habitat map of Florida shows the approximate area of the Ocala Uplift District (after Brown et al. 1990).

The hydric hammock under consideration is located within the <u>Tampa Plain</u> section of the Ocala Uplift District (Figure 32). This area is characterized by karst landscape within the Tampa Limestone Formation (Figure 33). Hydric hammock soils consist mostly of sandy marine sediments over soft and hard limestone. These soils are nearly level and somewhat poorly to poorly drained (U.S. Soil Conservation Service 1981; Florida Natural Areas Inventory 1990). Within hydric hammocks along west-central Florida's Gulf coast, there are many areas where marine sands overlie shallow limestone bedrock (Vince et al. 1989). Large pieces of limestone were spotted in several areas of the hydric hammock on SMD 48 (especially near pit #1 and the main storm sewer system). The presence of limestone within this wetland indicated that a 2B horizon may be present further down in the soil solum where the limestone has weathered and left behind clay. A 2B horizon forms where there is a geologic break in the soil. In October 1995, these horizons were not found due to a very high water table present at all three pits (which prevented further digging into any lower horizons). A later soil excavation in March 1996 found a 2Bg horizon above a layer of limestone approximately 3 1/2 feet below the soil surface. Since this 2Bg horizon is present, the soil could no longer be classified as a Malabar soil (Figure 34), which has a Btg horizon. The clay present in this horizon appears to be a result of limestone weathering in place based upon its position directly above the limestone

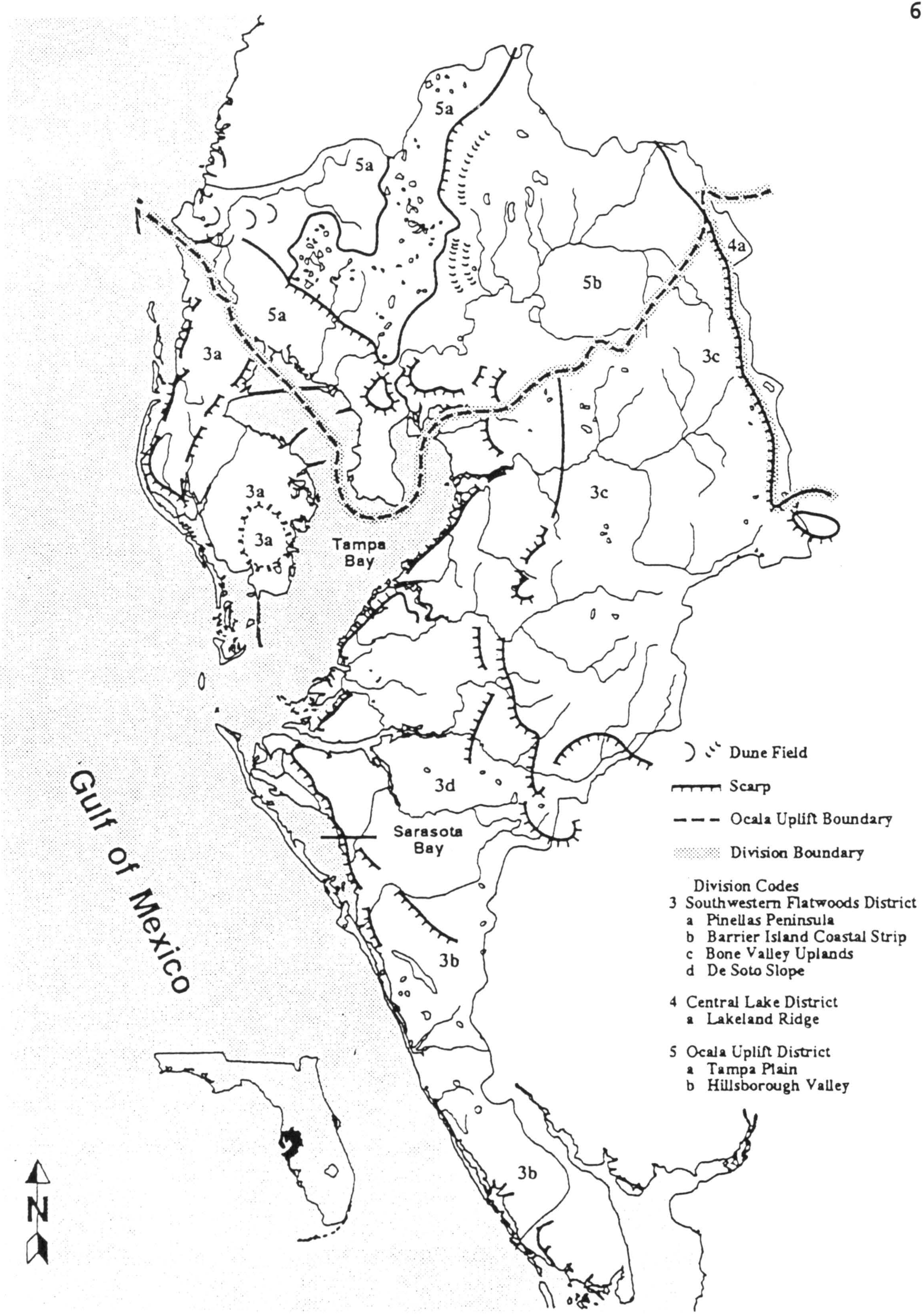


Figure 32. This physiographic map of the Tampa Bay watershed shows that the Interbay peninsula is found within the Tampa Plain section of the Ocala Uplift District (from Wolfe and Drew 1990).

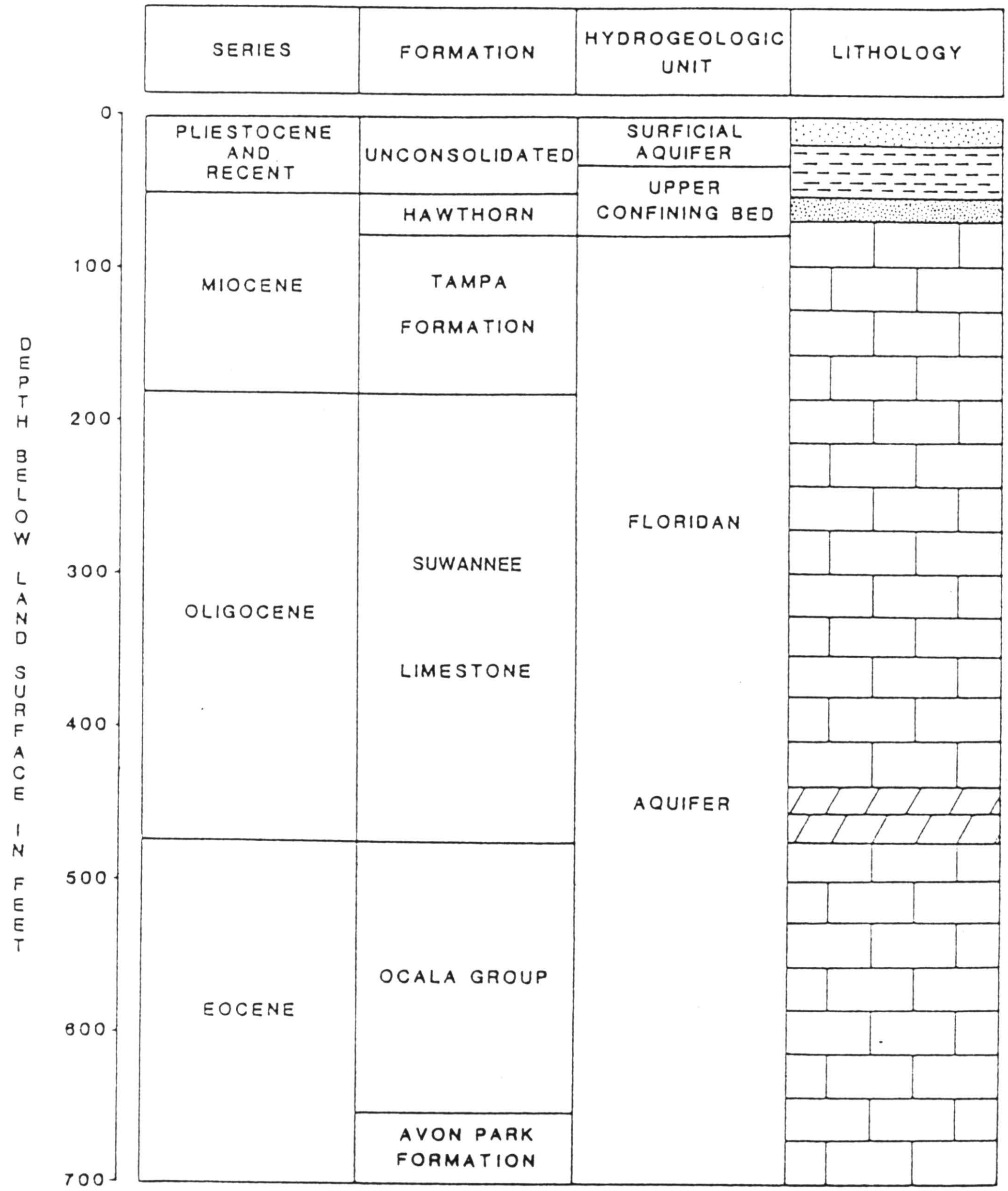


Figure 33. This figure shows the hydrogeology of the Tampa Bay area. The Tampa Plain section of the Ocala Uplift District is characterized by Karst topography related to the Tampa Limestone Formation. Also, the Hawthorn Formation comprises a portion of the confining layer between the surficial and Floridan aquifers (from Lewis and Estevez 1988).

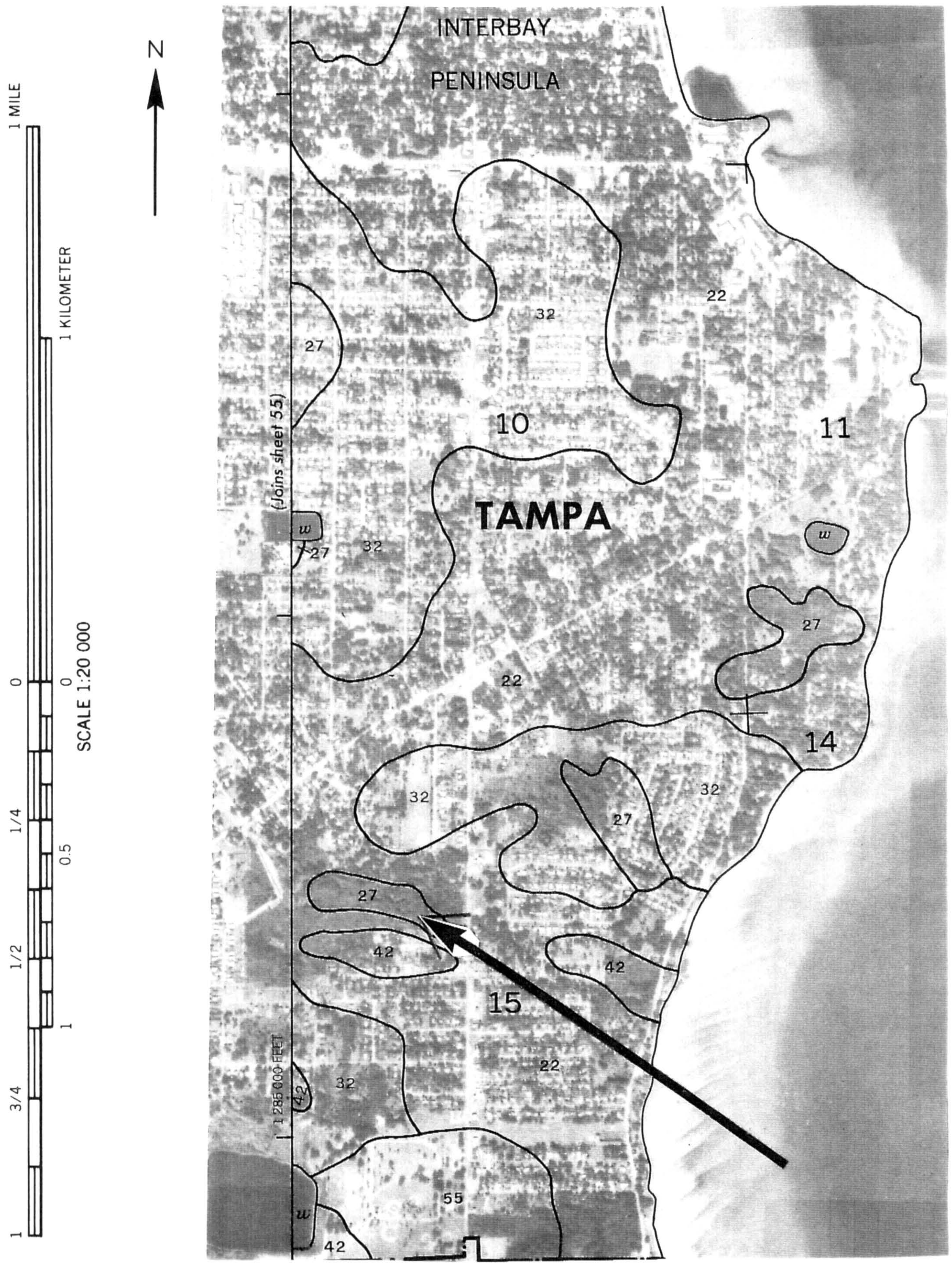


Figure 34. This aerial photo from the <u>1989 Soil Survey of Hillsborough County, Florida</u>, shows what is claimed to be Malabar soil (#27-black arrow) within the hydric hammock on SMD 48 (after Doolittle et al. 1989).

layer and the presence of limestone fragments within this horizon. Therefore, the clay has formed within the lower portion of the soil solum and has most likely not been translocated.

Geology, Water Table, and Soil Interactions

In order to understand the soils and parent material in the study area, the geologic setting is reviewed. The effect of the water table on soil characteristics is also discussed.

During the Pleistocene epoch, there were several glacial periods when much of world's water was locked up as ice and, as a result, sea level was lowered. There were also several interglacial periods when this ice melted and caused sea levels to rise. This rising and lowering of sea level created a series of terraces along Florida's gulf coast. Today, some of the largest stands of hydric hammock occur on these eroded terraces adjacent to the Gulf of Mexico (Figure 35) (Vince et al. 1989). Here, both limestone and the water table are close to the surface. The hydric hammock on SMD 48 is located within the Pamlico terrace region adjacent to Tampa Bay (Figure 36) (Roush 1985). This region was intermittently inundated and exposed during the Peorian interglacial and Late Wisconsin glacial periods, respectively (Lewis and Estevez 1988). Today, this area is approximately eight to twenty-five feet above sea level, with areas near the bay at the lower end

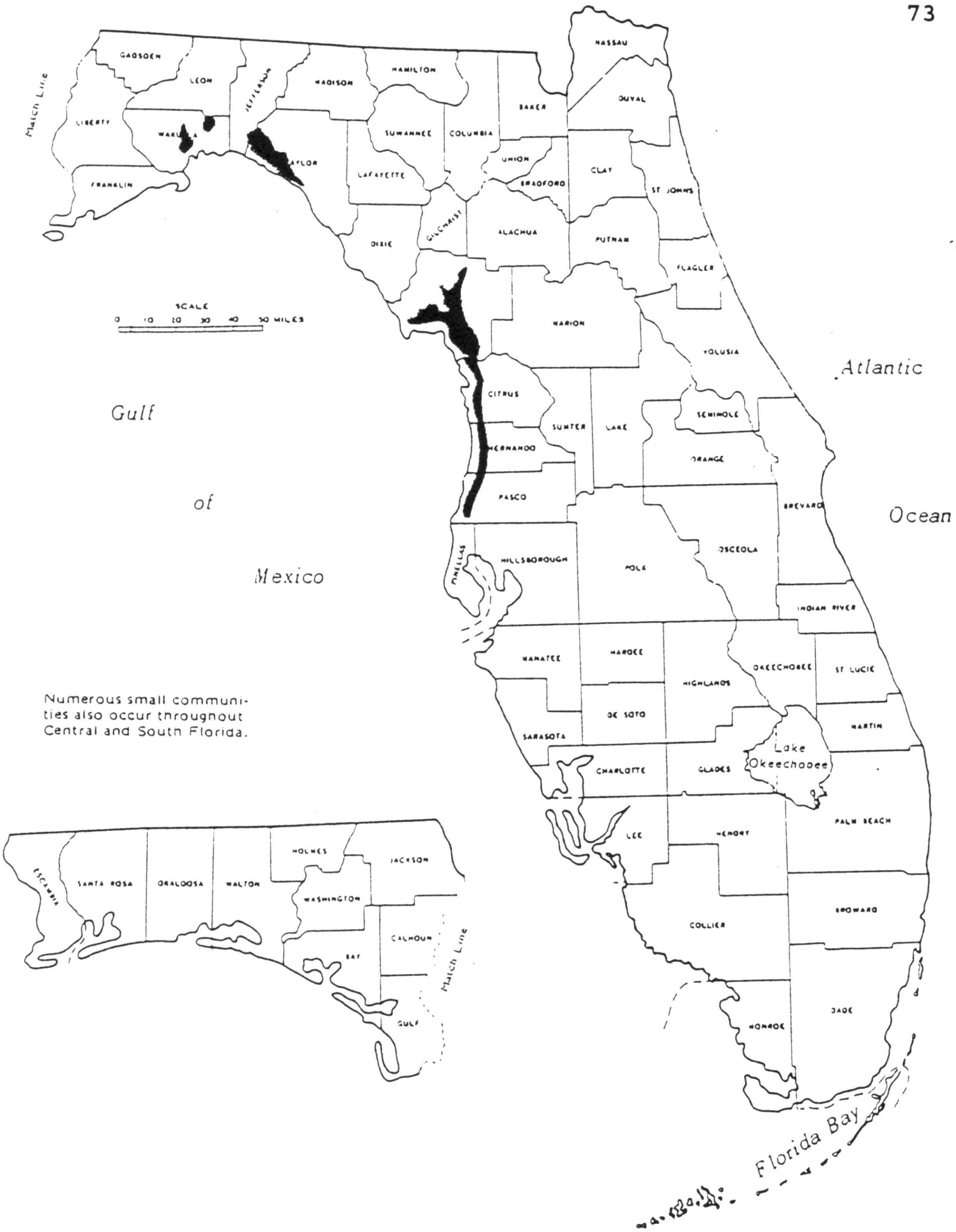


Figure 35. This map shows that the largest stands of hydric hammock occur on smoothed terraces near the Gulf of Mexico (from USDA-Soil Conservation Service 1981).

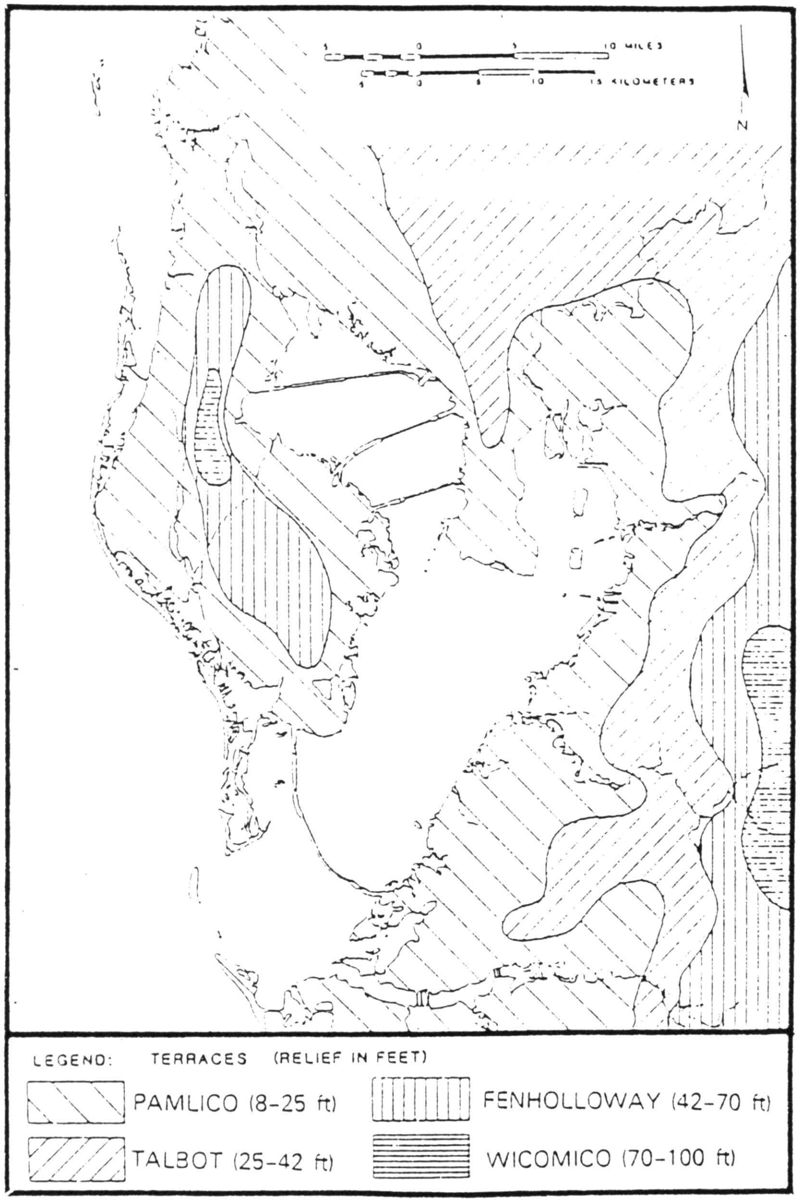


Figure 36. This map shows the terraces within the Tampa Bay area. Much of the Interbay peninsula (including the hydric hammock within SMD 48) is located within the Pamlico terrace region (from Roush 1985).

of this range. During the Peorian interglacial period, carbonate-rich siliceous sands were deposited near Tampa Bay within the Pamlico terrace region. Today, much of this area, including much of the Interbay area and the entire study site, is characterized by marine sands overlying clay with limestone (or marl in south Hillsborough County) near the surface.

There are two aquifer types located in the Tampa Bay area: the surficial and Floridan. These two aquifers are separated by the Hawthorn Formation, a confining layer composed of clay, silt, limestone, and dolomite (Wolfe and Drew 1990). The surficial (water table) aquifer consists mostly of fine and clayey sand mixed with areas of limestone, marl, clay, and shell. This aquifer is present within much of the Tampa Bay area. There are, however, areas where the limestone of the Floridan aquifer or Hawthorn Formation outcrops at or near the surface. Here, ground water rises to the surface under hydrostatic pressure as artesian flow amid outcroppings of limestone or marl. Some hydric hammocks along the gulf coast are present where the limestone of the Floridan aquifer outcrops or comes close to the surface of the soil. The hydric hammock on SMD 48 was found to have a layer of limestone approximately 3 1/2 feet below the soil surface. This indicates that the hammock is fed by the Floridan aquifer. This hammock, therefore, receives a constant flow of water from below. Gleying present in the 2Bg horizon above

the limestone indicates the presence of saturated conditions near the soil surface even into the dry season (March).

As was mentioned earlier, hydric hammocks are seasonally flooded wetlands that are dependent upon rainfall and a seasonal high water table to saturate the soil. During the summer months in central Florida, the water table rises within hydric hammocks as rainfall increases. The soil becomes saturated and oxygen content decreases. During the winter months in central Florida, the water table lowers within hydric hammocks as rainfall decreases. The soil is then aerated and oxygen content increases. This rising and lowering of the water table is typical of many inland and coastal hydric hammocks (Vince et al. 1989). Evidence of a fluctuating water table was found on the site by observing soil characteristics.

In all three pits, reddish-brown mottles were found in the E horizons. Mottling is typically found in soils where a fluctuating water table leads to oxidation and reduction of iron (Saheed and Hussain 1992). The red mottles indicate that the water table has recently lowered with the onset of the dry season and oxygen has been allowed to penetrate the soil. In addition to the mottling found in all three pits, large iron concretions were found within the A2 horizon in pit #2. These concretions also form as a result of oxidation-reduction reactions and indicate a fluctuating water table. Thus, the presence of both mottles and iron concretions suggest that the

soil has a high water table during the rainy season. This water table was very close to the surface (between 2 1/2 and 4 1/2 feet deep) and no soil evidence was found that indicated the presence of any unusual (e.g. humanly-influenced) patterns of drying or wetting of the soil.

Ditching, Water Table, and Soil Interactions

Open ditches, storm sewer systems, and canals can have negative effects upon soils, water table depth, and vegetation within wetland systems. Both the hydroperiod and groundwater level of many hydric hammocks are altered by these structures (Vince et al. 1989). Impacts on other wetland types are also documented (Rowell 1986; Schomer et al. 1990; Ewel 1990; Mitsch and Gosselink 1993). The following paragraphs describe examples of wetland changes resulting from the construction of artificial drainage structures.

Rowell (1986) describes the effects of an extensive network of ditches on the hydrology and vegetation of Wicken Fen, Cambridgeshire, England. This network (Figure 37) has led to a year-round lowering of the water table and overall drying of the soil (Rowell 1986). It also led to a cessation of winter flooding due to the lowering of the water table. This overall drying of the wetland led to an invasion of nearby woody species and reedgrasses that have historically been absent in the fen. Rowell (1986) explains how a regular

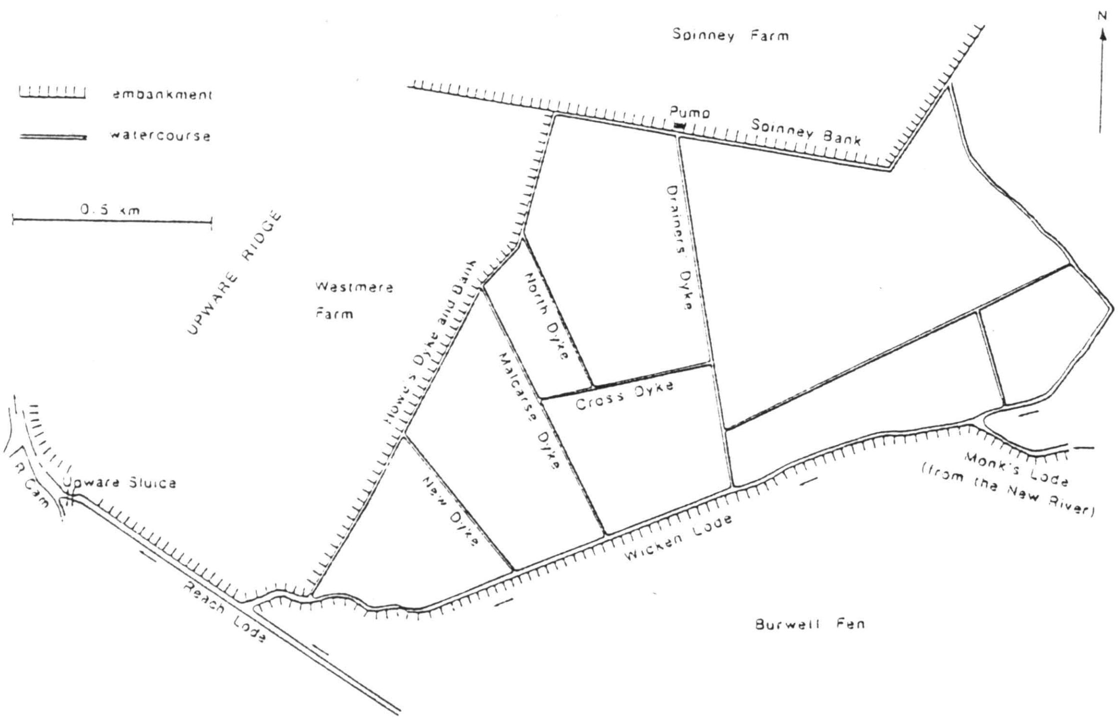
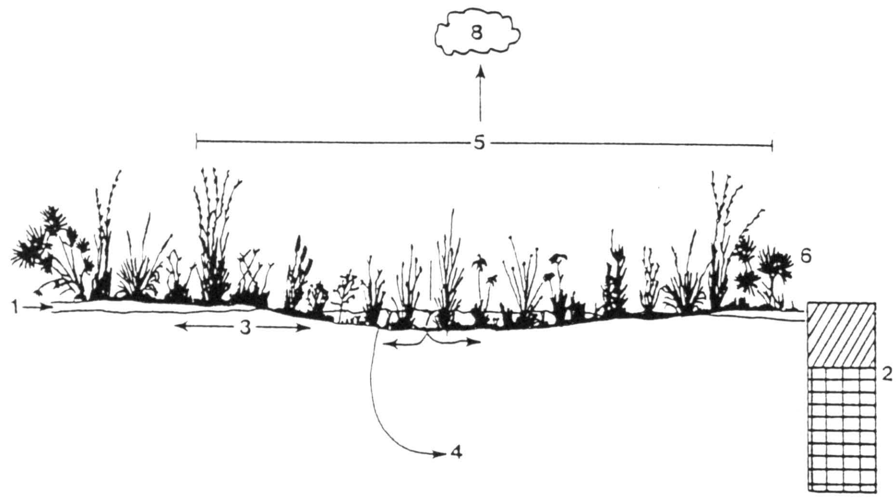


Figure 37. This map shows the various areas of the drainage system affecting Wicken Sedge Fen (from Rowell 1986).

system of pumping water into this ditch system during the summer months allows the typical wetland species to return, while excluding the woody species. Within Florida's hydric hammocks, a lowering of the water table also can affect plant species composition as well as soil characteristics. A prolonged lowering of the water table may result in a change from hydric to mesic conditions. Sweetbay magnolia, for example, could eventually be replaced by live oak as the dominant species within some hydric hammocks (live oak cannot withstand saturated soil conditions year-round; sweetbay can). Also, the soil may lose some of its wetland characteristics through drying. Mottling may disappear and decomposition of organic matter may accelerate due to an absence of high water. No evidence was found on SMD 48 to indicate a widespread change in soil moisture or species composition. Mottles, iron concretions, an abundance of humus in the A horizons, and a high water table all indicate that this hydric hammock soil has not been severely (if at all) impacted by the storm sewer and ditch system (Figure 6). No widespread change in plant species composition was observed within the hydric hammock -- sweetbay magnolia and cabbage palm dominated the wetter areas while live oak dominated the drier areas. It can be hypothesized that although the storm sewer and smaller ditch may drain the hammock's surface waters more quickly than would natural drainage, the vegetation within the hammock may provide a long holding period for this water thereby reducing

the rate of sheetflow to these structures during heavy rains. Also, these structures may be too shallow to severely impact the rate of runoff from the entire wetland. Areas adjacent to these structures may be more vulnerable to flooding than areas further away. On-site evidence of flooding near the western portion of the underground storm sewer is discussed below.

Ditch and canal systems can not only lower the surface water table, but can also increase the water level in a wetland during periods of heavy rain (Figure 38) (Schomer et al. 1990). In severe cases, such as the Tampa Bypass Canal, a deep canal may penetrate the underlying confining layer, thus creating artesian flow (Lewis and Estevez 1988). In other cases, a ditch or canal system may become clogged with sediments washing into the system from upstream areas. Once this happens, the water can no longer flow through the system. The water then backs up and saturates the soil until ponding occurs. The latter scenario is likely occurring in the western portion of the underground storm sewer system on SMD 48 (see Figure 6). This storm sewer is very old (circa 1924) and in poor shape. Sediments from urban areas upstream have likely blocked some of the runoff from moving toward MacDill Avenue. As a result, an area extending approximately twenty feet to the north and south of the western portion of this storm sewer has become saturated with water and ponded. In time, the soils in this area may become more acidic and affect



Parameter or Process	Impact
1. Groundwater table fluctuations	Canals lower top of groundwater table; seasonal fluctuations dampened or shifted generally to lower lows and higher highs.
2. Penetration into subsurface strata	Canals may penetrate into deeper strata (aquifer) below surficial sediments; aquifer drainage is facilitated, water quality affected.
3. Groundwater flow gradient	By lowering water table, seasonal, recharge-discharge cycle disrupted; thus hydroperiods change, availability of soil moisture changes, saline waters intrude.
4. Water storage and exchange	Stored groundwater may be discharged or tidal-exchange factor increased, thus changing extremes of drought and flood as well as background water quality.
5. Shallow-water habitat and fish and wildlife	Area of wetland habitat decreases, replaced by upland and deep-water habitats; shallow-water dependent wildlife have less habitat, deep-water and upland-dependent species favored, aquatic weeds favored.
6. Terrestrial vegetation and wildlife	Shift from mesic to xeric conditions, promotes fire and early-succession communities, invasion by exotics. Wildlife also shift according to available habitat and other factors.
7. Water quality	Turbidity, color, dissolved oxygen, pH, conductivity, inorganic ions, metals, and other parameters may change with depth, groundwater drainage, sediment removal by canals.
8. Evapotranspiration	Wetland habitat loss, excess discharge, lower soil moisture, lower water table, increased depth and storage in open canal reservoirs change the nature and magnitude of ET.

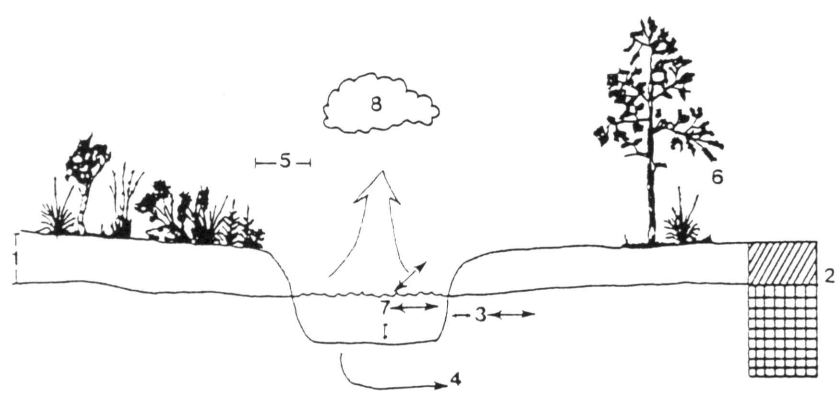


Figure 38. The above table shows the effects of canals on a variety of hydrologic and other processes (from Schomer et al. 1990).

plant species composition on the site. Brazilian pepper, an exotic species which can tolerate extremely wet soil conditions, has already begun to colonize this disturbed area.

Conclusions

One purpose of this field project was to determine whether or not stormwater ditching within a hydric hammock had either decreased soil moisture (lowered the water table) or increased soil moisture (raised the water table). Three soil pits were excavated and soil horizons were analyzed in the field. No evidence was found that indicates a widespread drying or flooding of this wetland soil. Mottles, large iron concretions, an abundance of humus in the A horizons, the presence of light gray E horizons, and a high water table (normal for late October) all indicate that this hydric hammock soil has not been severely impacted by the network of drainage structures on the site. A major reason for this was found in a later soil investigation conducted in March 1996, during central Florida's dry season. This excavation revealed that a thin 2Bg horizon had resulted from the weathering of a lower layer of limestone. This limestone layer is located approximately 3 1/2 feet below the soil surface with the 2Bg horizon situated directly on top of this layer, indicating that the limestone has weathered in place. Both the presence of this underlying limestone and gleying within the 2Bg horizon indicate that this hydric hammock is connected to the

Floridan aquifer (as opposed to a fluctuating surficial aquifer). Thus, the ditch system should not have a great effect on the hydrology of the hammock because this area is receiving a constant flow of water from the Floridan aquifer system.

Although a majority of the hydric hammock soil has not been affected by the ditch system, one small area near the western portion of the main storm sewer line is experiencing localized ponding due to an accumulation of sediments in the line. These sediments, which were likely deposited by urban runoff, are blocking the water flow in this localized area and causing the soil to become waterlogged. This waterlogged soil may become more acidic if there is standing water for a long period of time. Brazilian pepper, an exotic plant species, can withstand waterlogged soil for extended periods and has, consequently, invaded this localized area. However, no widespread shift in plant species composition was found within the hydric hammock, thus further indicating no widespread flooding or drying of the soil here (other than that which is normal for a hydric hammock).

In addition to the above conclusions, this study also concludes that the soil within the hydric hammock is not Malabar soil due to the presence of a 2Bg horizon, not a Btg. In this hydric hammock's soil, clay is not translocated but, rather, is formed in place from the weathering of a bottom layer of limestone.

CHAPTER FOUR

EXOTIC PLANT INVASIONS AND EDGE EFFECTS

Introduction

As previously mentioned, this chapter will focus on exotic plant invasions occurring on SMD 48. However, it is important to understand the origins of these exotic plant species, when and how they arrived in Florida, and the characteristics that make them "invasive." Florida has experienced many landscape changes which make it an easy target for invasive exotic plant species. Urban forest fragments, in particular, have characteristics that make them susceptible to exotic plant invasions. The end result of these invasions is a loss of plant diversity and/or complete ecosystems. The following pages discuss these topics in full.

Before discussing exotic (or "non-indigenous") plant invasions, it is first necessary to define exactly what an "exotic" species is, as well as the term "invasive." According to MacDonald et al. (1989,217), an exotic species is defined as:

> "one which occurs in an area as a result of the intentional or accidental movement of the species by humans from its natural distribution range. To be classified as 'invasive,' the exotic species must be capable of establishing self-sustaining populations in areas of natural or semi-natural vegetation (i.e. untransformed ecosystems)."

Invasive exotic plant species can have several negative impacts upon various ecosystem types. These include the alteration of natural fire and hydrologic regimes, shading out of native vegetation, changes in soil fertility, and the creation of habitat suitable for other invasive exotics (Jensen and Vosick 1994). The following sections will describe exotic plant invasion and its effects in Florida, and, specifically, within and adjacent to the SMD 48 property. The role of edge effects with respect to exotic plant invasion will also be discussed.

Exotic Plant Invasions in Florida

Many of the exotic invasive plant species now present in Florida and many areas of the United States have their origins in "that part of the Old World which encompasses the eastern and southern fringes of the Mediterranean Basin and the adjacent Mediterranean Irano-Turanian steppes of the Middle East" (Heywood 1989,46). According to Mooney and Drake (1989), these are the regions where agriculture first originated and, therefore, were subjected to a long history of

land disturbance. As a result, those plants that co-evolved with agricultural practices (e.g. soil disturbance) have characteristics that make them successful invaders (Mooney and Drake 1989). In addition, these Old World regions were major centers of trade and, thus, sources of plant materials. This eventually led to their spread throughout the New World with the arrival of Europeans in the early 1500's. The Europeans brought with them various exotic species of fruit, including pineapple, guava, papaya, and citrus species (Austin 1978). These species, although non-indigenous to Florida, were not invasive and posed little threat to native plant species. However, as Florida's human population increased in the early 1900's, a greater number of exotic plant species were imported into the state (Gordon and Thomas 1994). The importation of ornamental exotic species became extremely common during this time period, and eventually affected most of Florida's native ecosystems. In fact, over forty-five percent of Florida's most invasive plants were once imported for ornamental purposes (Gordon and Thomas 1994). In the late 1800's, the United States Department of Agriculture (USDA) began to collect various forage and grain crops from abroad and imported these into the United States (Austin 1978). In the 1930's, the USDA imported ornamentals as well for a total of 300,000 plant introductions between 1898 and 1967 (Gordon and Thomas 1994). These introductions have led to exotic plant

invasions in many areas of Florida (Ewel 1986; Jensen and Vosick 1994).

There are a number of factors that make Florida particularly susceptible to exotic plant invasions. Two of the most important factors include insularity and amount of new or disturbed habitat (Simberloff 1986, 1994). As was shown in chapter one, the amount of disturbed land in Florida is increasing every year, resulting in a highly fragmented landscape full of residential developments, agricultural fields, and other altered land uses. According to White and Pickett (1985,3), a disturbance can be defined as "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability or the physical environment." For example, where there has been extensive soil disturbance in Florida (e.g. phosphate mining in central Hillsborough County) there are usually a number of invasive exotics present (e.g. cogon grass and Brazilian pepper). Both openness and disturbance of the land are essential for colonization by exotic plant species (diCastri 1989; Ewel 1986; Rejmanek 1989). Insularity refers to the idea that the southern third of the Florida peninsula (including the Everglades) is a habitat island surrounded on three sides by water and on the fourth by frost (Simberloff 1994). This habitat "island," not unlike an oceanic island, is characterized by an "impoverished" native flora and, as a result, is easier to

invade than a continental area (Ewel 1986; Myers and Ewel 1990). Both habitat disturbance and insularity have made Florida an easy target for invasive exotics.

Two other characteristics of Florida's environment (human and physical) have made Florida susceptible to exotic invasion. First, the limited number of freezes in central and south Florida have allowed many exotics to expand their range (e.g. Brazilian pepper) (Simberloff 1994). Second, Florida's highly developed transportation system (airports, highways and ports) and booming tourist industry have allowed exotic plants to invade the state from other areas of the country and world. In fact, 85% of all plant shipments into the United States pass through Miami (Office of Technology Assessment 1993). In 1990, this number totalled 333 million plants (Office of Technology Assessment 1993). Once an exotic plant species becomes established, it can be naturally spread through various pathways including wind, water, and animals. Specific examples of different natural dispersion methods will be discussed in a later section.

Several of Florida's most invasive exotic plant species have been listed and categorized by the Florida Exotic Pest Plant Council (EPPC), a non-profit organization founded in 1984. The goal of the EPPC is to develop education, funding, and support programs for control of invasive exotic plant and animal species (Gordon and Thomas 1994). In 1993, the EPPC compiled a list of Florida's most invasive exotic plant

species and grouped them according to degree of invasiveness. According to Schmitz (1994,12-13), there are three categories of invasive exotic plant species which are defined as:

> "Category 1 - Species that are widespread in Florida and have an established potential to invade and disrupt native plant communities; Category 2 - Species that are localized but have a rapidly expanding population, or that have shown a potential to invade and disrupt native vegetation in other areas, or in countries with climates similar to that of Florida; Category 3 - Species that are widespread and can form dense, monotypic populations, but are primarily found on disturbed sites such as roadsides, agricultural lands, and canal embankments."

Hillsborough County contains twenty-five of these plant species - the fourth largest amount in the state behind Broward (96), Palm Beach (78), and Dade (55) Counties (Gregg 1994). The SMD 48 property contains several species that are listed in each of these three categories. These species (Category 1 and 2) are listed in Table 1 along with dates and reasons for introduction. The approximate locations of the largest stands of these species are shown in Figure 39. The following paragraphs describe four of the most invasive species that are located on or adjacent to the SMD 48 property. These four species are: air potato, Australian pine, Brazilian pepper, and melaleuca.

Table 1

Dates of and Reasons for Introduction of Selected Category One and Two Invasive Exotic Plant Species*

Species and Common Name	Introduction to Florida	Reason for Introduction
Category One		
Abrus precatorius (rosary pea)	pre-1932	ornamental
Casuarina equisetifolia (Australian pine)	1887	ornamental, agriculture (forage, pulp), windbreak
Cinnamomum camphora (camphor tree)	pre-1933	ornamental
Dioscorea bulbifera (air potato)	1905	agriculture
Lantana camara (lantana)	1804	ornamental
Melaleuca quinquenervia (melaleuca)	1906	ornamental, agriculture
Melia azedarach (Chinaberry)	c. 1830 SC & GA	ornamental
Schinus terebinthifolius (Brazilian pepper)	1840's	ornamental
Category Two		
Colocasia esculenta (taro)	1910	agriculture
Eugenia uniflora (Surinam cherry)	1913	agriculture (fruit)

Continued on next page

Table 1 (Continued)

Leucaena leucocephala (lead tree)	1898	agriculture (biomass energy crop)

* Adapted from Gordon and Thomas (1994)

AP = air potato LT = lead trees

BP = Brazilian pepper Mel = melaleuca

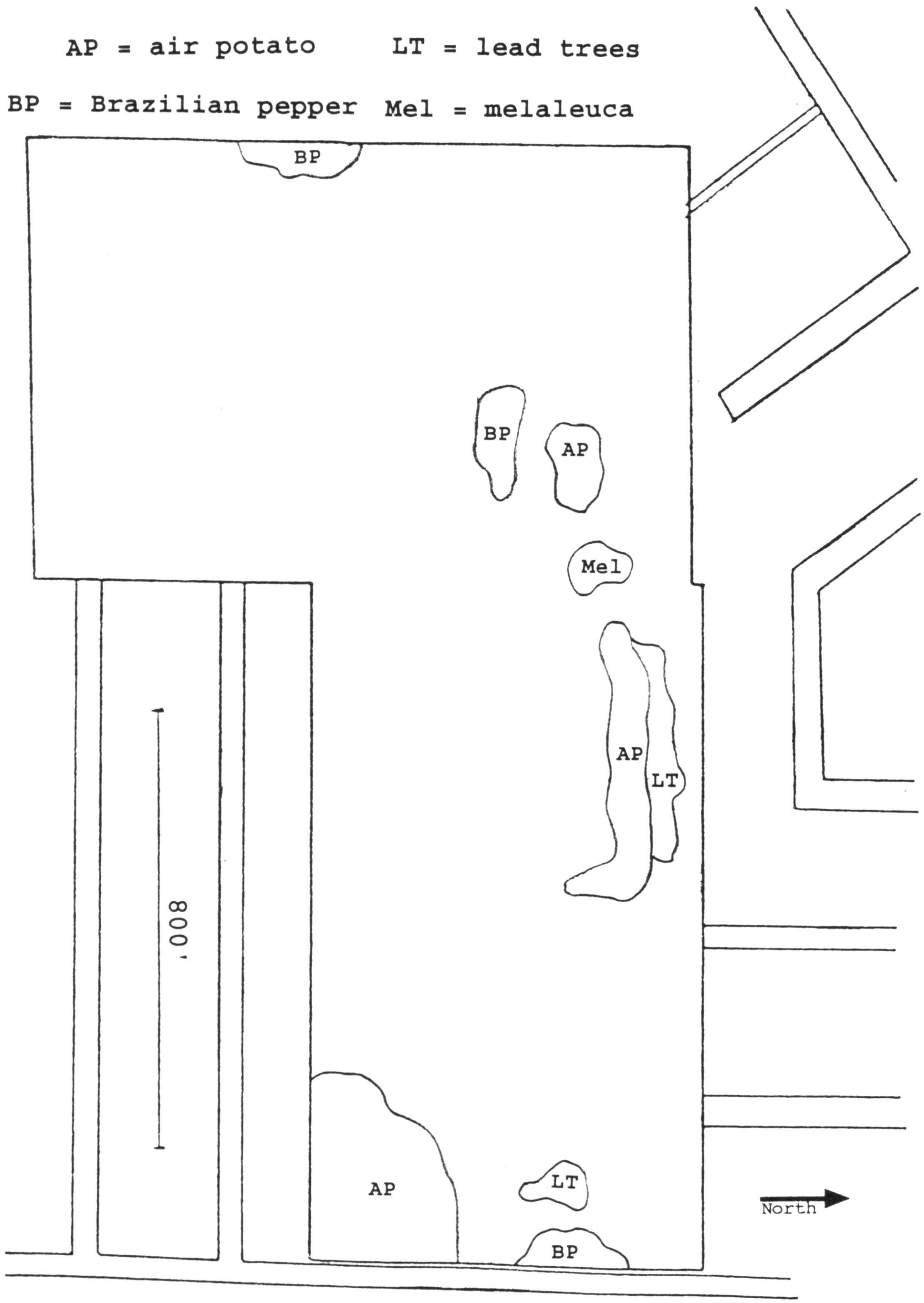


Figure 39. Map showing the largest stands of invasive exotic plant species on SMD 48.

Air potato (Dioscorea bulbifera) is a Category 1 invasive exotic species that is usually found in mesic and hydric hammocks throughout Florida as well as disturbed habitats. The ability of air potato to completely cover native trees and shade out understory vegetation makes it one of Florida's most dangerous exotic species. Figure 40 shows a portion of the air potato infestation within the mesic hammock portion of the SMD 48 property. Underneath these vines, there is little or no understory vegetation. Although air potato seeds (called "tubers" - see Figure 41) are heavier and more difficult to spread than other types of exotic seeds, they can drop from the spreading vines which wind their way through tree canopies. Many areas of Florida have been invaded by air potato including mesic and hydric hammocks within the Withlacoochee State Forest and tropical hardwood hammocks in Dade County (Hardin 1994; Horvitz 1994). Many of the tropical hammocks in Dade County, for example, are forest fragments located in an urban landscape. Horvitz (1994) found that several invasive exotic plant species (including air potato) had invaded these hammocks after Hurricane Andrew created tree fall gaps which allowed light to reach the forest floor. Therefore, instead of a natural regeneration process, these fragments were invaded by nearby exotic plant species that are now common in Dade County. In fact, Dade County has one of the highest numbers of invasive exotic plant species in the state (55) (Gregg 1994). If a major hurricane were to hit

Figure 40. The above photo shows the invasive nature of air potato (photo by author, August 1995).

Figure 41. Air potato "tubers" litter the surface of the soil within the mesic hammock (photo by author, February 1996).

Tampa, it is likely that any tree canopy damage on SMD 48 would result in the spread of air potato and other invasive exotics located on or adjacent to the property.

Australian pine trees are located within the Skyview Recreation Area (mentioned earlier) adjacent to SMD 48 (Figure 42). Australian pine (Casuarina spp.) is another Category 1 invasive exotic plant species. This exotic species was originally planted to form windbreaks around agricultural fields, houses, and canals throughout central and south Florida (Schmitz 1994). As this species quickly spread, it began to colonize several areas of beachfront property along both the Gulf and Atlantic coasts. Today, many inland areas of disturbed habitat (including forest fragments) are being colonized by Australian pine. Australian pine displaces native understory plants for three reasons. First, its thick canopy of needles tends to shade the ground underneath the trees. Second, Australian pine usually forms monospecific stands so that all other vegetation is crowded out. Third, the needles that fall to the ground form a dense litter layer which blocks most sunlight from reaching the top layer of soil (Mazzotti et al. 1981). This lack of sunlight prevents native vegetation from growing underneath the trees, thus nearly eliminating competition for resources. If Australian pine invaded SMD 48 from the nearby park, then this forest fragment would suffer the consequences described above.

Figure 42. An Australian pine stand is located adjacent to SMD 48 (photo by author, February 1996).

Brazilian pepper (a Category 1 species) is located on several areas of SMD 48, especially near the edges of the property. Brazilian pepper (Schinus terebinthifolius) is a rapid invader of both disturbed and undisturbed areas of central and south Florida. The spread of Brazilian pepper is facilitated by several animal species (especially robins). The seeds are consumed and dispersed over a wide area. Once seedlings are established, Brazilian pepper grows rapidly and can form dense, monospecific stands, thus shading out competing understory vegetation (Ewel 1986). In central and south Florida, Brazilian pepper can invade several ecosystem types, including pine flatwoods and hydric and mesic hammocks. Figure 43 shows a stand of Brazilian pepper invading an area of pine flatwoods near the western edge of SMD 48. Since the edges of SMD 48 are highly disturbed areas (e.g. soil and vegetation disturbance), it is possible that Brazilian pepper could invade this "ecotone" and spread to adjacent areas. Signs of this already exist (Figure 44) and are discussed in the next section on "edge effects."

Melaleuca (Melaleuca quinquenervia) is a Category 1 species that has invaded a small area of the northern edge of SMD 48 (within the mesic hammock). Melaleuca has the typical characteristics of a Category 1 species: high population growth rates, good seed dispersal mechanisms, and the ability to withstand a wide range of environmental conditions (Schmitz 1994). Melaleuca tends to form dense, monospecific stands and

Figure 43. Brazilian pepper is invading several portions of pine flatwoods within SMD 48 (photo by author, February 1996).

Figure 44. Brazilian pepper seedlings are beginning to colonize disturbed edge habitat near the western portion of SMD 48 (photo by author, February 1996).

can invade a wide range of ecosystem types, including pine flatwoods and hydric and mesic hammocks (Clark 1994). It is especially successful in transitional habitats ("ecotones") and disturbed areas (Doren and Jones 1994). In south Florida's Big Cypress National Preserve, for example, the spread of melaleuca was aided by its planting in adjacent homesites and hunting camps (Pernas 1994). Several homeowners surrounding SMD 48 have planted melaleuca for ornamental purposes, and its further spread into the site through thousands of windblown seeds is inevitable. One significant stand of melaleuca in the adjacent Skyview Recreation Area was removed in 1995 and replaced with oak species (Figure 45). It is likely that the seeds from this stand of melaleuca contributed to the creation of the stand now present on the northern edge of SMD 48 (Figure 46).

The following section describes the relationship between edge habitat and exotic invasion. Several exotic plant species (both invasive and non-invasive) were established along the edges of SMD 48 and displace native species at these locations and further inward. Various concepts relating forest fragmentation to increased edge habitat are discussed as well as the effects of this edge habitat on SMD 48.

Edge Effects

Edges can be defined simply as the places where two ecosystems come together. Edges form transition zones from

Figure 45. These oaks have replaced a melaleuca stand that was adjacent to the northern edge of SMD 48 (photo by author, February 1996).

Figure 46. This photo shows the base of the melaleuca stand now present on the northern edge of SMD 48 (photo by author, February 1996).

one set of environmental conditions to another (as well as from one set of plants to another). These zones are called ecotones. Some ecotones cannot be easily recognized due to an edge that is abrupt. One example is a large cliff dropping into the ocean. Other ecotones, however, are the result of a gradual transition between two or more different habitats such as forest types.

Thomas et al. (1979) describes two types of edges. Inherent edges are long-term, relatively stable features of the landscape. An example of an inherent edge is an area where hydric hammock grades into mesic hammock due to a rise in topography and a subsequent decrease in soil moisture. Although inherent edges are permanent landscape features, they can be changed by erosion, flooding, and various human activities. Induced edges are short-term phenomena created by changes in vegetation. They exist wherever two different successional stages come together and are created by storms, logging, and other natural and man-made disturbances. Many induced edges last only a few years or decades until one of the successional stages progresses enough so that the differences between the ecosystems are no longer noticeable and the edge disappears. There are, however, areas where induced edges are maintained for relatively long periods of time. For example, there are various woodland-pasture edges in Britain that have survived for many centuries (Rackham 1980). The man-made edges of SMD 48 are very abrupt in many

areas where native vegetation stops and neighborhood backyards begin. These edges are particularly vulnerable to exotic plant species because of their proximity to backyard and roadside seed sources, increased light availability, and high disturbance levels (Brothers and Spingarn 1992). Many forest-interior species, such as ferns, may be vulnerable to increases in temperature and wind speeds (Bierregaard, Jr. et al. 1992). These factors can affect the forest microclimate and lead to changes in soil moisture and plant species composition near these edges (Kapos 1989). Several Category 1 and 2 invasive exotic plant species are established along the edges of the SMD 48 property, including Brazilian pepper, lead trees (Figure 47), air potato, rosary pea, lantana, and Chinaberry (Figure 48). Lead trees and air potato migrated into the middle of the hydric and mesic hammocks where light gaps are prevalent. In addition to these invasive exotics, several non-invasive exotics moved onto the edges of the site from adjacent backyards. These include both Queen Palm (Figure 49) and Bamboo (Figure 50).

Edge effects take on even more importance when the forest fragment is small (e.g. <50 acres). In the case of the SMD 48 property, "ecosystem dynamics" are probably driven by "external" rather than internal forces (Saunders et al. 1991). This is due to the fact that fragmentation increases the ratio of forest edge to interior and of nonforest to forest (Hill 1985). Therefore, a smaller fragment has a smaller core area

Figure 47. Lead trees have become established on the northern and eastern edges of SMD 48 as well as the interior of the property (shown here) (photo by author, November 1995).

Figure 48. Chinaberry has become established on the western edge of SMD 48 (photo by author, February 1996).

Figure 49. Queen palm trees have become established on SMD 48 due to their presence in adjacent backyards (photo by author, February 1996).

Figure 50. This small stand of Bamboo is beginning to colonize an area near the eastern edge of SMD 48 (photo by author, February 1996).

which can be highly affected by physical and biological changes associated with edges (Janzen 1983; Harris 1988). Size, however, is only one factor that affects the amount of edge around an area. In the case of smaller reserves, shape also plays a factor in the amount of edge present (Diamond 1975). For example, long, thin fragments have proportionally more edge than square or round fragments (Diamond 1975). The eastern portion of the SMD 48 property is very thin, and, not surprisingly, contains the majority of the exotic species located on the site (see Figure 39).

Although identification of invasive exotic plant species (and any nearby seed sources) is important for initial site analyses, it is even more critical for devising a site management plan. Chapter 6 describes various methods of controlling some of the most invasive exotic species found on the site.

CHAPTER FIVE

THE ROLE OF FIRE

Introduction

Fire plays a significant role in shaping many ecosystems throughout the United States. In particular, the southeastern United States (including Florida) was influenced by particular fire regimes since before European settlement. Pyne (1984) describes a fire regime as consisting of both a biota (a particular fuel type) and fire history (a particular pattern of fire occurrence and behavior). A fire regime, however, consists of a human as well as a physical component. According to Pyne (1984,224-25), "most fire regimes are the product, directly or indirectly, of human activities; their fire history cannot be separated from human history." U.S. fire policy changed several times over the last 100 years as did fire policy in the South and Florida. In addition to policy changes, the United States, and more recently, Florida, underwent intensive land use changes which turned once vast areas of forest into smaller and smaller fragments. Many of these fragments are no longer subject to naturally-occurring fires (e.g. fires caused by lightning) and, therefore, must be burned according to a prescribed burn plan.

As mentioned earlier, this chapter discusses the ecological role of fire within the habitats located on SMD 48. However, in order to understand how this role has been altered over the years, it is important to review past fire policies in the United States, the South, and Florida. Through a brief examination of these policies at each level, one can gain a clearer understanding of how attitudes toward fire have changed. For example, suppression of wildfire in the 1950's was based upon a reactive policy (conflagration control), while in the 1970's an active policy of prescribed fire was widely accepted as a means to reduce wildfire hazard as well as a method of ecological management. In Chapter Six, a prescribed burn plan is developed for SMD 48. This plan describes weather, fuel moisture, and other conditions deemed important by the USDA Forest Service and other related agencies while tailoring these conditions to those biotic characteristics specific to SMD 48.

U. S. Fire History

Early Fire Practices

According to Pyne (1984), fire in the United States has assumed four types of patterns. Fire has occurred due to lightning as well as fire practices of the American Indians and European immigrants. Although lightning has shaped natural fire regimes in the United States, there are three other patterns that have contributed to U.S. fire history.

These are: a fire pattern that facilitated hunting and gathering practices, a pattern used for shifting cultivation and sedentary agriculture, and a pattern for an industrialized landscape (Pyne 1984). The American Indian used fire for several reasons, the most important being hunting. Fire was used to surround and drive game to a particular area. In Florida, this practice was used for killing both deer and alligators. The American Indian also used prescribed fire for cultivating and harvesting natural grasses, berries, and nuts. Eventually, these fire practices were passed on to the European colonists.

Once the Europeans arrived in the United States, American fire practices changed dramatically. These changes in fire practices were tied to land use changes under what Pyne (1984) terms the <u>reclamation</u> and <u>counterreclamation</u>. The American reclamation refers to that time period when forests and other natural areas were reclaimed as arable land, thus reducing the incidence of wildfires. The reclamation was characterized by large drainage projects, sedentary agriculture, and the importation of ornamental and cereal crop plant species, all of which altered natural fire regimes. This agricultural reclamation ended with a counterreclamation characterized by spreading industrialism. During this counterreclamation, formerly arable land was abandoned and used either for industrial or forestry purposes, while undisturbed grass lands were converted to agricultural areas. Some abandoned lands

reverted to forest, while others were incorporated into urban areas. Many of the abandoned lands that were replanted or which reverted to forest were eventuallty managed by the U.S. Forest Service. The following section describes various fire management policies that were implemented by this agency over the past ninety years and details the consequences of these policies on the American landscape.

U. S. Forest Service

The U.S. Forest Service was created in 1905 to assume control over millions of acres of land. Fire control on these lands was a major issue for this agency throughout the twentieth century. Between 1910 and present day, the Forest Service developed a history of fire control defined in terms of four problem fire types: the frontier fire (1910-1929), the backcountry fire (1930-1949), the mass fire (1950-1970), and the wilderness fire (1970-present) (Pyne 1982).

In the summer of 1910, several wildfires spread throughout the West, consuming millions of acres of forest and creating the need for a comprehensive fire policy. By 1914, the Forest Service adopted a program of "systematic fire protection" which focused on creating governmental fire control policies and planning procedures (Pyne 1984; Wright and Bailey 1982). In the 1930's, the Forest Service became responsible for managing "backcountry" lands acquired during the Roosevelt Administration. These backcountry lands were

located in remote areas and included cutover forests, marginal farmland, and disturbed grasslands (Pyne 1982, 1984). Also during this time period, many states acquired vast areas of forest, thus making fire protection critical not only for future land investments, but also for natural resource protection. In 1935, the Forest Service implemented a 10 A.M. Policy, which dictated control of a fire by 10 a.m. the morning following its initial discovery (Pyne 1984). This policy remained in effect until the 1960's.

By the 1950's, emphasis shifted toward controlling the "mass" fire. The concept of "conflagration control" directed fire control methods and techniques during the 1950's and 60's (Pyne 1984). The idea was to pool all resources in such a way that small, hot fires would not escalate into raging wildfires (Pyne 1984; Wright and Bailey 1982). Fuelbreaks, air tankers, and helicopters were used to fight fires during this period. This form of management was successful. In 1970, however, these techniques failed as wildfires ravaged forests in California and Washington. At this point, the Forest Service realized that fuel types (e.g. live and dead plant material) were the most important factors influencing fire intensity. Thus, "fuel modification" replaced conflagration control as the major concept behind wildfire control (Pyne 1984). From 1970 to the present day, prescribed burning techniques have been used to reduce fuel loads in many areas, thus reducing the risk of wildfires in these areas. Prescribed burning has

the added benefit of creating open habitat and forage for many animal species. Thus, fire today is recognized as a beneficial management tool as opposed to a danger that must always be suppressed.

The South

The southern forest occupies 193 million acres between Virginia and east Texas and can be divided into the Lower Coastal Plain (pine flatwoods), Upper Coastal Plain, and Piedmont regions (Figure 51) (Wright and Bailey 1982). The South has a fire history that is influenced by lightning, native Indians, and European colonists. Bartram (1792), regarding his 1773 observations of fire in the Coastal Plain, wrote "It happens almost every day of the year, in some part or the other, by Indians for the purpose of rousing game and also by lightning" (Harper 1958,132). In most areas of the South, the fire regime that existed when the European colonists arrived was shaped by the American Indian. The colonists quickly adopted many of the Indian fire practices, including herding and hunting (Wright and Bailey 1982). However, once the reclamation began in the 1800's, fire suppression became important for the protection of farmland. A policy of fire suppression continued through the 1930's due to the creation of large state forests and other protected areas (Pyne 1984). By the 1960's, both the U.S. Forest Service and related state agencies realized the benefits of

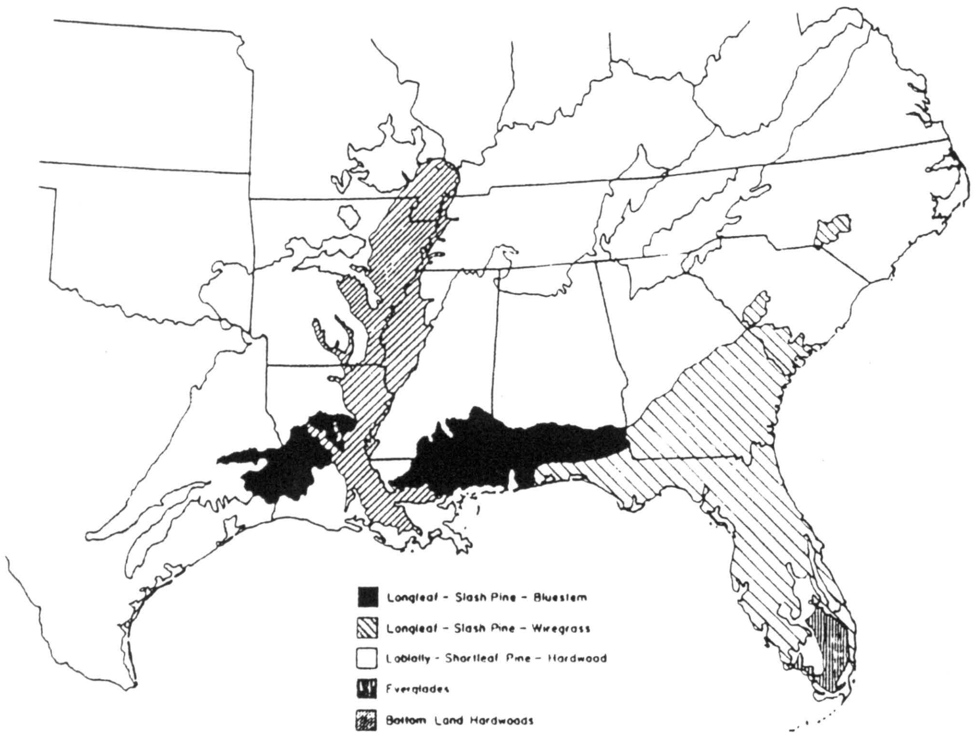


Figure 51. This map shows the major vegetation types in the southeastern United States (from Wright and Bailey 1982).

prescribed fire. Since many areas of the South (including Florida) feel the effects of fire exclusion rather quickly due to a mild climate, prescribed fire was used to control "southern rough" in these areas (Abrahamson and Hartnett 1990). Southern rough is that fuel mixture which characterizes the understory of pine forests throughout the South (e.g. saw palmetto, wiregrass, gallberry). Prescribed burning is used in pine plantations throughout the South in order to limit hardwood invasion and in other forested areas to reduce the risk of wildfire.

Florida

Florida's fire history, like that of the South and the rest of the U.S., is influenced by three factors: lightning, native Indians, and European colonists. The following paragraphs explain how these factors influenced Florida's varied fire history.

Before the arrival of European colonists and probably up until the twentieth century, lightning-originated fires were common in Florida (Abrahamson and Hartnett 1990). In 1528, Cabeza de Vaca, the first Spanish explorer, was amazed at the number of lightning strikes that hit the state's pine trees (Landers 1991). Bartram (1792) also commented on the large number of fires caused by lightning (Harper 1958). Florida's lightning fire season begins in early spring, reaches its peak in May and June, then tapers off in July and August on through

September (Komarek 1964). Figure 52 shows a yearly distribution of lightning fires and thunderstorm days in Florida for 1962 and 1963 combined. A greater number of lightning fires occur in May and June because surface fuels have not yet become moisture laden from daily thunderstorms (Moore and Goodwin 1994). Therefore, the number of lightning fires peaks about one month before the peak number of thunderstorm days. It is not surprising that the greatest number of lightning fires and thunderstorm days are so closely related. Florida has the greatest number of thunderstorm days per year in the U.S. (Winsberg 1990) and, historically, Florida has the greatest number of lightning fires as evidenced by the former vast extent of the fire-dependent pine flatwoods community type.

In addition to lightning, Indians also influenced Florida's fire regime. There is some question as to whether or not Florida's Indian tribes should be considered a part of the state's "natural" fire regime (Snyder 1991). I will leave this debate for another forum, while admitting that these Indian tribes influenced Florida's fire regime for thousands of years (see Myers and Peroni 1983). Widmer (1988) suggests that humans were a part of south Florida's landscape for thousands of years with the most recent pre-European occupation belonging to the Calusa Indians in southwest Florida (Snyder 1991). In the Ocala National Forest in north-central Florida, there is evidence that longleaf pine stands

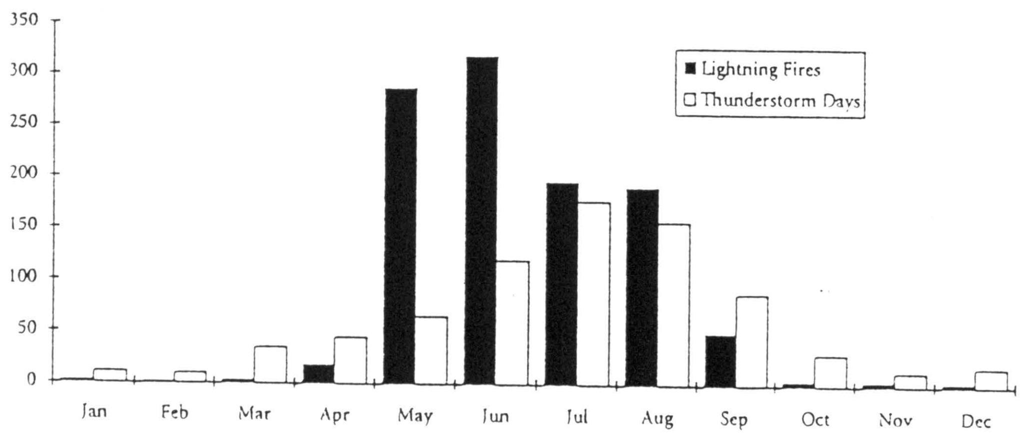


Figure 52. The above graph shows a yearly Distribution of lightning fires and thunderstorm days in Florida for 1962 and 1963 combined (from Moore and Goodwin 1994).

persisted within sand pine scrub due to burning by prehistoric Indians (Kalisz et al. 1986). In other areas of north and central Florida, both lightning fires and fires set by Indian tribes prevented slash pine from colonizing longleaf pine flatwoods (Abrahamson and Hartnett 1990). Snyder (1991) suggests that fires occurred at all times of the year in south Florida due to Indian presence and lightning. It is clear that both Native Americans and lightning shaped Florida's pre-European fire regime and, therefore, habitat types within the state.

Once the Europeans entered the area and the State of Florida was created, many of the Indians were either killed or driven out of the state. This was followed by an increase in the settlement of the state by frontiersman and, eventually, the creation of industrial logging operations and agricultural development. These factors, along with federal and state fire policies, altered the fire regime that existed for thousands of years. Consequently, several of Florida's fire-dependent habitats (e.g. pine flatwoods) underwent successional change. Oaks and other hardwood species began to invade pine forests, while heavy fuel loads began to accumulate in these areas. By the early 1940's, the Florida Forest Service became concerned about these heavy fuel loads after a series of catastrophic wildfires occurred in 1943 (Bonninghausen 1962). These wildfires emphasized the need for a prescribed burning program within the Forest Service. Until 1950, the Florida Forest

Service used prescribed fire only as a means of reducing heavy accumulations of fuel (e.g. southern rough) beneath pine forests (Bonninghausen 1962). However, by 1950 (and up to present day) the service's prescribed burning policy was amended to include ecological management (e.g. preparation of seedbeds, control of hardwoods) as one of the major uses for prescribed fire (Bonninghausen 1962).

More recently, prescribed fire is used in areas which no longer burn naturally (due to fire exclusion). Both urban and agricultural expansion have led to the creation of forest fragments that are "cut off" from larger forested areas. As mentioned earlier, SMD 48 experienced several habitat changes as a result of forest fragmentation. The following sections describe the role of fire in both pine flatwoods and hydric hammocks and detail the effects of fire exclusion on these habitats (especially pine flatwoods) within SMD 48.

Fire in Pine Flatwoods

As mentioned earlier, about one-third of SMD 48 consists of mesic pine flatwoods characterized by longleaf pine, saw palmetto, wiregrass, some slash pine, and gallberry. This typical flatwoods association is dependent upon fire to maintain stability and prevent succession (Abrahamson and Hartnett 1990). The understory species are highly flammable and help to spread fire throughout the flatwoods. Longleaf pine, however, is extremely fire-resistant due to its bark

characteristics. Fahnestock and Hare (1964) found that where bark surface temperatures varied from 550° to 1470°, cambial temperatures only varied from 100° to 180° F. This tolerance of high temperatures allows longleaf pine to survive even hot fires, while fire-sensitive hardwood species are killed. Williamson and Black (1981) found that higher fire temperatures under longleaf pine (caused by highly flammable pine needle litter) helped eliminate several nearby oak species. In addition to controlling hardwood invasion in flatwoods, fire is also necessary for longleaf pine to regenerate (Abrahamson and Hartnett 1990). Historically, summer fires expose the surface of the flatwoods soil by burning off a majority of the understory vegetation (Moore and Goodwin 1994). By autumn, longleaf pine seeds fall to the ground and germinate. Longleaf pine seedlings then go through a "grass" stage for three to fifteen years where root growth occurs horizontally, but there is no vertical tree growth (Moore and Goodwin 1994). This growth pattern allows for abundant food storage and maximum fire protection (there are no exposed branches that could burn) (Abrahamson and Hartnett 1990). Once the diameter of the root collar reaches about one inch, the seedling quickly shoots upward (Moore and Goodwin 1994). Most longleaf pine seedlings reach a height of five feet in one year, at which time they are less susceptible to fire damage (Moore and Goodwin 1994).

Fire is also critical to the survival of wiregrass. Wiregrass is a "keystone species" that is of central importance in maintaining longleaf pine flatwoods (Landers 1994). Schmitz (1994) defines a keystone species as one that "modifies the environment in a way that allows other existing native plant species, especially the dominant ones, to exist." Wiregrass (along with fallen pine needles) comprises the primary fuel load for fires in frequently burned flatwoods (Landers 1994). As was mentioned earlier, longleaf pine regeneration is tied directly to fire. Wiregrass also depends upon fire to regenerate. Spring and summer fires allow wiregrass to flower and release its seeds (Abrahamson and Hartnett 1990). Without fire, other ground cover plant species such as saw palmetto can cover and shade out wiregrass (Figure 53).

Historically, Florida's pine flatwoods have burned quite frequently (Abrahamson and Hartnett 1990). In some areas of the state, fire occurs as often as one year, while in other areas it occurs every five to ten years (Platt et al. 1991). However, Florida's increase in urban and agricultural development resulted in a highly fragmented landscape with altered fire regimes (Kautz 1993; Miller et al. 1983; Peroni and Abrahamson 1986). Specifically, pine flatwoods burn less often than in previous centuries (Abrahamson and Hartnett 1990). Prolonged periods of fire exclusion in pine flatwoods result in the degradation of this habitat type. The effects

Figure 53. A few sparse pockets of wiregrass still exist within the fire-excluded pine flatwoods (photo by author, February 1996).

of fire exclusion include: an increase in fire hazard due to fuel buildup; hardwood (e.g. oak species) and slash pine invasion; brown-spot disease among longleaf pines; a decrease in the number of pines due to the lack of a mineral seedbed for pine seedlings; and the shading out of native grasses and other small ground cover species (Abrahamson and Hartnett 1990; Moore and Goodwin 1994; Wright and Bailey 1982).

All of the above effects, with the exception of brown-spot disease, were observed at SMD 48 at some time. A majority of the pine flatwoods acreage on SMD 48 has not burned since an intense fire swept through half of the property in 1971 (personal comm., Robert Cummins, adjacent homeowner). As a result of this 25-year absence of fire, fuel loads have reached dangerous levels. Saw palmetto, one of the most flammable understory flatwoods species, has grown to a height of five feet in some areas (Figure 54). This tends to not only create a fire hazard during drier periods, but also makes the area more difficult to burn during wetter periods due to moisture retention and lack of air and sunlight reaching the soil surface. The growth of this saw palmetto also crowded out many areas of wiregrass, leaving only a few pockets throughout the flatwoods. Florida grapevine (Vitis sp.) has spread throughout the entire flatwoods area (Figure 55), covering nearly all of the saw palmetto and smothering even the largest longleaf pines (Figure 56). The dead longleaf pine shown in Figure 57 was previously covered with

Figure 54. Much of the saw palmetto within the pine flatwoods has become unusually thick and high due to fire exclusion (photo by author, November 1995).

Figure 55. Fire exclusion has resulted in the spread of Florida grapevine throughout the pine flatwoods (photo by author, September 1995).

Figure 56. Florida grapevine has even smothered longleaf pine trees on the property (photo by author, September 1995).

Figure 57. The dead longleaf pine in the foreground was once smothered by Florida grapevine (photo by author, September 1995).

Florida grapevine and probably died due to a lack of sunlight which impeded photosynthetic processes (personal comm., Angel Meana, ELAPP).

As was mentioned in Chapter One, several hardwood species have invaded the flatwoods due to fire exclusion (Figure 58). The two most invasive hardwood species are live oak and turkey oak. According to H. R. Delcourt and P. A. Delcourt (1977), fire exclusion causes longleaf pine flatwoods to succeed to a southern mixed hardwoods association. In addition, mesic pine flatwoods succeed more rapidly than xeric pine flatwoods (Abrahamson and Hartnett 1990). For example, fire-excluded flatwoods adjacent to hydric hammocks are quickly invaded by species common to these wetland habitats (Peroni and Abrahamson 1986). This is happening on SMD 48 where the pine flatwoods grade into mesic and hydric hammock. Live oak is invading this ecotone and moving into the flatwoods. In drier areas within the flatwoods, turkey oak is invading. This hardwood invasion threatens to not only displace and shade out ground cover species native to pine flatwoods (e.g. wiregrass), but also alter the natural fire regime. Oak leaves do not burn very well and tend to hold moisture within the top layer of soil (personal comm., Rob Heath, ELAPP), thus making the spread of fire difficult. Thus, hardwood invasion into flatwoods tends to promote a continuous cycle of fire exclusion by changing both fuel moisture and type. In addition to hardwood invasion, the longleaf pine flatwoods

Figure 58. This photo shows a combination of small and large hardwood tree species invading the pine flatwoods (photo by author, February 1996).

have experienced some invasion by South Florida slash pine. This pine species is usually restricted to moist areas near ponds (e.g. flatwoods marshes) that frequently escape fire. However, slash pine will invade longleaf pine sites that have been excluded from fire for five to six years (Wright and Bailey 1982). Since SMD 48's longleaf pine flatwoods have not burned in over 25 years, it is highly likely that some of this slash pine invaded the site as a result of fire exclusion.

Fire is essential to the survival of longleaf pine on SMD 48. Without a regular cycle of fire, longleaf pine seeds have little chance of reaching the soil and germinating due to the presence of heavy fuel loads (live and dead) in the understory. If a seedling does become established, then it would have to compete for both water and light in order to survive in the thick understory vegetation. In fact, many areas within SMD 48's flatwoods resemble more of a dry prairie system than true pine flatwoods. This may result from fire exclusion, which has prevented the creation of a mineral seedbed for longleaf pine seedlings. In addition to hindering longleaf pine establishment, fire exclusion can lead to an outbreak of brown-spot disease among young longleaf pine trees. Fire consumes the inoculum of brown-spot disease in fallen pine needles, thus preventing the spread of this disease (Wright and Bailey 1982). Although no evidence of brown-spot disease was found on SMD 48, this problem could arise in the future if the flatwoods are left unburned.

Fire in Hydric Hammocks

Fire is not a common occurrence in most hydric hammocks for two reasons: the presence of saturated soils and a lack of highly flammable ground fuels. However, hydric hammocks do occasionally burn during periods of drought when heavy fuel loads (especially cabbage palm litter) are present (Vince et al. 1989). Most fires that occur in both hydric and mesic hammocks originate in adjacent habitats (e.g. pine flatwoods) (Platt and Schwartz 1990). Therefore, the edges of hydric hammocks (e.g. mesic hammocks) are subject to fire more often than the interior portions (Simons et al. 1989). In fact, fire keeps both hydric and mesic hammocks from encroaching into adjacent fire-dependent habitats (e.g. pine flatwoods). For example, Clewell et al. (1982) found that fire suppression in pine flatwoods led to an expansion of hydric hammock near the south prong Alafia River system in Hillsborough County, Florida. In Myakka River State Park (Sarasota County), fire suppression in a freshwater marsh allowed hydric hammock to invade this area as well (Vince et al. 1989). As was mentioned earlier, the hydric and mesic hammocks on SMD 48 are expanding into the pine flatwoods due to fire exclusion in the flatwoods. Prescribed burning in the flatwoods should stop this expansion.

Both fire frequency and intensity within hydric hammocks help determine the vegetative makeup of these areas. Many of the hardwood species found in hydric hammocks are susceptible

to fire (e.g. live oak and sweetbay magnolia). Cabbage palm, however, is extremely fire-tolerant and can survive very intense fires. According to Vince et al. (1989), less frequent and intense fires favor both live oak and cabbage palm, while fires of greater intensity favor only cabbage palm (e.g. cabbage palm hammocks). The hydric hammock on SMD 48 is dominated by several specimen-sized live oak and sweetbay magnolia trees, some of which are in excess of 200 years old (personal comm., Rob Heath, ELAPP). This suggests that intense fires were probably a rare occurrence in this hydric hammock. In addition, the mesic hammock on SMD 48 is dominated by both live oak (specimen-sized) and cabbage palm, further indicating that less frequent and intense fires penetrated this hardwood hammock system.

CHAPTER SIX

DISCUSSION

Introduction

Aerial photographs illustrate that the Interbay peninsula underwent a series of land use changes which severely altered the natural landscape of the area. What was an area dominated by pine flatwoods with scattered hammocks and marshes is now covered with residential developments, office parks, and an air force base. These land use and habitat changes occurred rapidly since the 1940's and led to the creation of a forest fragment called the South MacDill 48 ("SMD 48") property.

As demonstrated throughout this paper, forest fragmentation and its attendant human impacts affected SMD 48 in a variety of ways. Habitat degradation and change resulted from alteration of hydrology, forest clearing, exotic plant invasion, and fire exclusion. These changes, however, are not unique to SMD 48. As mentioned in Chapter Two, both Florida and Hillsborough County experienced large increases in population which resulted in an expansion of urban and agricultural areas. This expansion destroyed much of the state and county's pine and hardwood forests. Florida's longleaf pine forests, which once ranged from south-central Florida into southern Georgia, declined 88% between 1936 and

1987 (Kautz 1993; Kautz et al. 1993). Many of the state's natural habitats, including pine flatwoods and hydric hammocks, were not only destroyed, but also fragmented into small remnant patches of forest. Today, many of these remnants are undergoing physical and biological changes resulting from forest fragmentation. Two of these changes include exotic plant invasion and fire exclusion discussed in Chapters Four and Five, respectively.

The introduction of invasive exotic plant species to Florida in the late 1800's and early 1900's resulted in their establishment throughout the state. As mentioned in Chapter Four, both habitat disturbance and insularity have made Florida an easy target for invasive exotics. Urban forest fragments, in particular, are at great risk for exotic plant invasions due to: (1) their close proximity to exotic seed sources (highways and backyards); (2) soil and/or habitat disturbance; and (3) edge effects. Invasive exotic plant species crowd out native plant species and tend to reduce species diversity in areas they colonize. Many invasive exotic plant species, such as Australian pine and melaleuca, form dense stands that shade out native vegetation. This has resulted in the decline of many native habitats on a statewide and local level.

Another effect of forest fragmentation is fire exclusion. Before European settlement, much of Florida's landscape was subject to fire on a periodic basis. Fire occurred due to

lightning and the fire practices of several Indian tribes. Widespread forest clearing and urbanization, however, have reduced the incidence of wildfire and led to unchecked hardwood tree growth in several pine flatwoods areas of Florida. Eventually, fire-excluded pine flatwoods succeed to southern mixed hardwood forest. Florida's rapid population growth and increasing urbanization have fragmented the landscape so that many areas of pine flatwoods no longer burn on a regular basis, if at all. Urban forest fragments containing pine flatwoods are invaded by hardwood tree species due to fire exclusion resulting from local fire suppression practices and the isolation of the fragment from larger areas of similar vegetation. The end result of severe hardwood invasion is the loss of the pine flatwoods community type on a local and statewide level.

Although exotic plant invasion and fire exclusion have impacted many of Florida's habitat types, their effects can be lessened or reversed through the development of appropriate management strategies. The following pages describe the development of a management plan for SMD 48 that focuses on eliminating exotic plant species, reversing the effects of fire exclusion in some areas of pine flatwoods, and controlling illegal dumping and trespassing on the site. It is hoped that some form of this plan will be useful to those scientists managing fragmented habitats throughout Florida, especially in or near urban areas.

Control of Illegal Dumping and Trespassing on SMD 48

Illegal dumping and trespassing are now occurring on the site. The fact that SMD 48 is completely surrounded by residential development in a highly urbanized area makes this fragment particularly susceptible to these activities. A range of garbage types including bottles, cans, yard trash, furniture, and a rusted-out vehicle can be found throughout the site. Vagrants and local residents occasionally camp on the site (Figure 59), leaving trash and burned-out campfires behind. Others have intentionally cut down or burned cabbage palms and oaks within the hydric and mesic hammocks. These activities put SMD 48 at risk for wildfire, thus endangering fire-sensitive plant species and nearby homes. Currently, Hillsborough County plans to fence the entire 48 acres along with, perhaps, one or two access points for the general public. This, along with routine security patrols by the members of ELAPP's "resource management team," should help control any undesirable activities which could degrade the site.

In addition to documenting habitat degradation and change within SMD 48, it is important to develop management plans for controlling exotic plant species and reversing the effects of fire exclusion. The following sections describe these management plans and how they should be implemented.

Figure 59. The above photo shows a makeshift shelter used by trespassers on SMD 48 (photo by author, August 1995).

Exotic Plant Control on SMD 48

There are several methods used to control invasive exotic plant species. Glisson (1994) lists three categories of control methods that are used within Florida's state park system. These categories are: (1) manual, mechanical, or physical; (2) herbicide; and (3) mechanical followed with herbicide. Glisson (1994) outlines advantages and disadvantages associated with each control method. Advantages for manual, mechanical, and physical methods include the removal of individual plants as well as no herbicide cost or application required. Disadvantages may include greater soil disturbance (which could lead to further exotic invasion), inefficient treatment for some species (e.g. Brazilian pepper seedlings), and time consumption. Advantages associated with herbicide use include the efficient treatment of a particular plant or an area invaded by exotic plants as well as little or no soil disturbance. Disadvantages include the high cost of herbicide and equipment and possible toxicity for aquatic organisms. Advantages associated with the mechanical method followed by herbicide use include the removal of the majority of the plant(s) in question and penetration of light to the soil surface in formerly monospecific stands. However, this method can be time consuming and herbicide must be applied to the plant/stand immediately after it is cut. In addition to the above methods, fire can be used to control some exotic

species. There is usually a particular method(s) that works best for each invasive exotic plant species found in Florida. Three of the most studied invasive exotics with respect to control and management are Australian pine, Brazilian pepper, and melaleuca. As was mentioned earlier, these species have either invaded or are in danger of invading SMD 48.

There are two methods used to control Australian pine. The first method involves simply cutting down the tree and spraying the stump with herbicide. The second method involves girdling the tree until the cambium is exposed and then spraying the wound with herbicide. According to Doren and Jones (1994), large diameter trees (8") should be treated by applying a 12" wide band of herbicide, while smaller trees (6" diameter) should be treated with an 8" wide band of herbicide. Seedlings can be controlled by either hand pulling or foliar application. I have found that an herbicide called "Garlon 4" works well for Australian pine. Garlon 4 is a broad spectrum herbicide that kills most plants that it comes in contact with (Langeland 1990). The Australian pine stand located adjacent to SMD 48 should be cut down completely and stump sprayed not only for ecological reasons (complete elimination of an invasive species), but also for aesthetic and safety reasons (a stand of dead Australian pines is not only unsightly, but also unsteady in high winds).

There are two methods used to control Brazilian pepper. The first method involves cutting down the tree and spraying

the stump. The second (and most common) method involves spraying a band of herbicide around the trunk so that a "circle" of spray covers the bark. Ewel et al. (1982) found that basal bark spraying of Brazilian pepper was the most effective way to destroy the plant. In addition, this method has little impact on surrounding vegetation and soils. Seedlings can simply be killed by foliar application of herbicide. Garlon 4 is currently the most effective herbicide used to kill Brazilian pepper (personal. comm., Nick Toth, HCELAPP). Prescribed fire, although important for reducing this plant's invasive potential in the short-term, has generally proved ineffective in the long-term (Lewis, III 1994; Thayer and Ferriter 1994). Oftentimes, new seedlings will sprout near the base of the plant after it has burned. Prescribed fire within slash pine forests in Everglades National Park, however, restricted the establishment of Brazilian pepper in these areas (Doren and Jones 1994). Prescribed burning within the pine flatwoods portion of SMD 48 may stop future encroachment of Brazilian pepper into this area. However, current and future management goals should concentrate on herbicides (especially Garlon 4) because these have proven effective at killing both large trees and seedlings.

There are several methods used to control melaleuca. These include chemical methods (cut stump for larger trees, foliar applications for seedlings), physical methods

(prescribed burning), and pulling seedlings by hand. The stand of melaleuca now present on SMD 48 is large enough to be cut down and stump sprayed. Any future seedlings can be either hand-pulled or foliar sprayed. Although prescribed fire is used to kill dense, monospecific stands of melaleuca in Everglades National Park (Doren and Jones 1994), it has also killed native trees adjacent to these stands due to the intense heat created by the ignition of melaleuca leaves (Clark 1994). Therefore, it is unwise to burn the melaleuca stand located on SMD 48 because of the possibility of starting a crown fire within the mesic and hydric hammocks which could kill vulnerable hardwoods as well as endanger nearby homes. In addition, the current stand is small enough so that cutting down the trees and spraying the stumps with herbicide is cost-effective, whereas, in some areas of Everglades National Park, burning hundreds of large stands is the only realistic method of controlling melaleuca due to time and budget constraints.

All of the other invasive exotic plant species located on SMD 48 can be controlled through either herbicide use, e.g. air potato, Caesar's weed; prescribed burning, e.g. chinaberry; or hand-pulling, e.g. air potato "tubers". Boyter, Jr. (1994) suggests creating a "strike team" to coordinate efforts focused on controlling invasive exotics. The Hillsborough County Parks and Recreation Department's "Resource Management Team" (a division of ELAPP) is a good example of this approach. The "Resource Management Team" uses

a variety of methods (e.g. manual, herbicide, physical) to control invasive exotics on ELAPP properties. Although controlling exotic invasion within the publicly-owned properties is important for native plant and ecosystem survival, it is also important to control invasive exotics on adjacent properties in order to limit their further spread into these protected areas. Lewis, III (1994) has proposed targeting a "regional exotic plant control zone" for the purpose of protecting nature preserves. This zone may include both public and private lands. A central core area (e.g. nature preserve) is chosen as the first site of exotic control. A series of concentric rings are then drawn around this core area representing "distances from the core that include land parcels that need to be characterized as to the presence of exotic species" (Lewis, III 1994). Thus, identification and control of invasive exotics in areas surrounding the core are of the utmost importance for preserving the protected core. Figure 60 shows an example of this technique applied to SMD 48. SMD 48 is the core area while surrounding public and private lands are within the regional exotic plant control zone. Although this plan may seem rather simple, it would likely be difficult to implement for two reasons. First, there could be ethical concerns regarding the use of public time and money on private lands. Herbicides, in particular, are quite expensive and may be better used on other ELAPP sites where exotic plant invasion

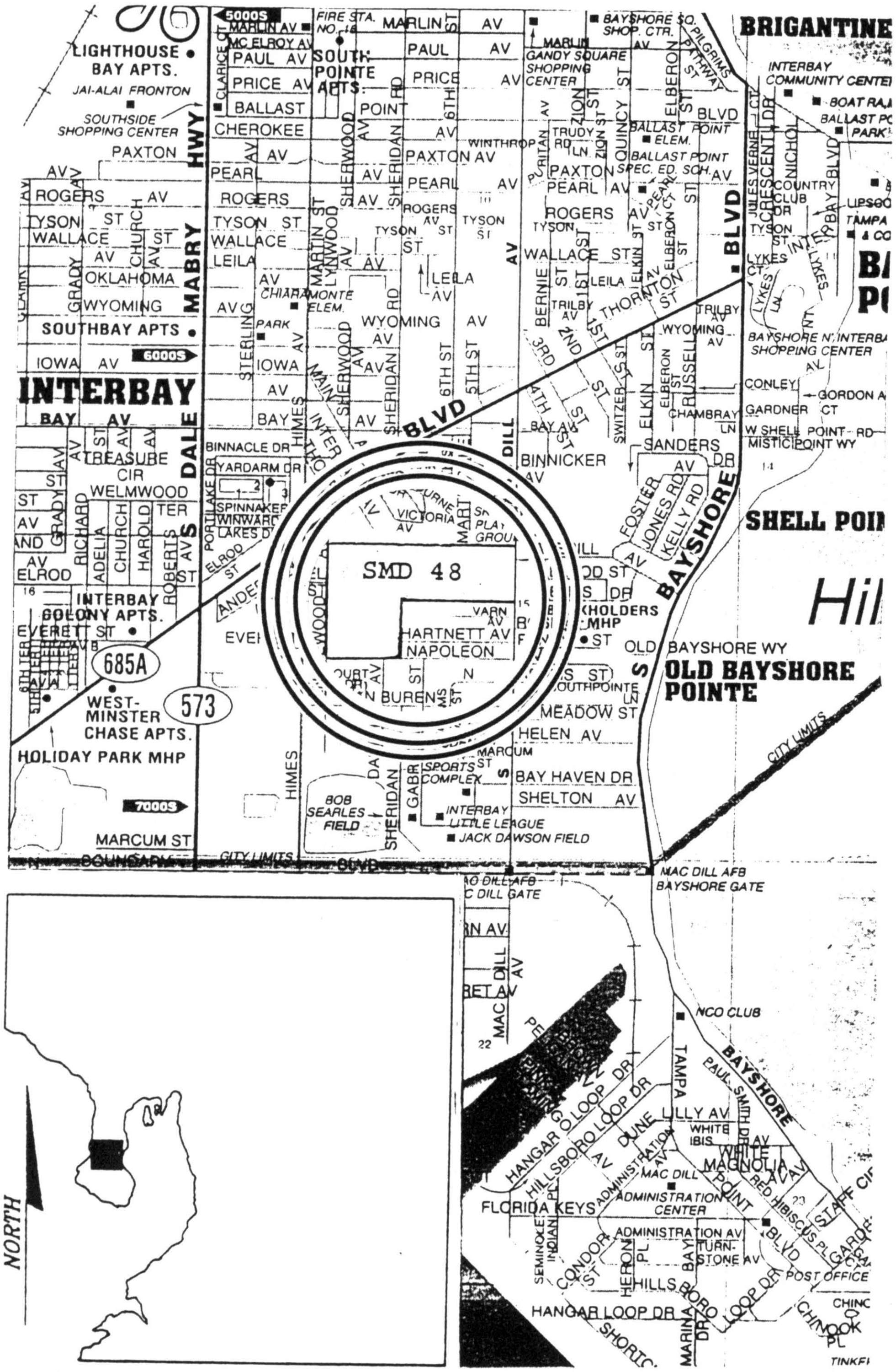


Figure 60. The above map shows the regional exotic plant control zone with SMD 48 as the central core area.

is a problem. Second, many private landowners are unaware of the problems that invasive exotic plants can cause and, therefore, have planted these species as ornamentals. Consequently, many of these landowners may take offense at being asked to remove their favorite plants. Education and awareness of exotic invasion may convince some landowners to allow the county and/or city to remove their exotic plants. However, many landowners may not allow this, thus jeopardizing the long-term success of the plan. If an initial survey of residents' opinion shows widespread disapproval of the plan, then the public's time and money would be better spent on controlling invasive exotic plants only within SMD 48 and surrounding public lands.

The Use of Prescribed Fire

During the past thirty years, the use of prescribed fire has increased in both the United States and the South (Pyne 1982). According to Wade and Lunsford (1989,2), prescribed burning is defined as "fire applied in a knowledgeable manner to forest fuels on a specific land area under selected weather conditions to accomplish predetermined, well-defined management objectives." Before a prescribed burn can be conducted, a fire use plan must be written. According to Pyne (1984), this plan should consist of three parts: (1) objectives of burning a particular area; (2) a fire prescription; and (3) a burning plan. The prescription refers

to those environmental conditions that will be needed to burn successfully. The burning plan (e.g. a map of the prepared burn area) describes how the prescribed burn will be conducted in the field. Before writing any fire use plan, however, the amount and type of fuel to be burned must be documented. The following section describes the major fuel types found within the pine flatwoods portion of SMD 48, while the rest of the chapter is devoted to developing a fire use plan for the pine flatwoods. Since hydric hammocks rarely burn, this area (including the mesic hammock) will be excluded from fire.

Fuel Characteristics

According to Pyne (1984), there are three major fuel types that influence fire intensity: ground, surface, and aerial. The surface layer is usually the most important factor in sustaining a fire. Within pine flatwoods, this surface fuel layer consists of plant species found within "southern rough." This rough usually consists of moderately volatile fuels, including saw palmetto, gallberry, and wiregrass (Wright and Bailey 1982). Even when large amounts of this fuel accumulate, it can still be burned safely with low temperatures, low wind speeds, and high humidities (Mobley et al. 1973). In some areas where large amounts of rough have accumulated (e.g. SMD 48), it may be necessary to conduct several burns to reduce fuel loads.

The ground fuel layer found within pine flatwoods is called duff. Duff is simply all the dead fuels that are located on the ground surface (Pyne 1984). Within pine flatwoods, duff usually consists of fallen shrub leaves and pine needles as well as dead wiregrass. With the exception of those areas of hardwood invasion, the duff within SMD 48's flatwoods consists of these dead fuels. According to Pyne (1984) duff is an important factor in prescribed burns for two reasons. First, the thickness of the duff and the moisture content of its lower levels determine how long the fire will smolder and how much fuel will be reduced. Second, duff protects the soil from the fire's intense heat and helps reduce the amount of erosion during those days and weeks after the fire.

Aerial fuels consist of the bark, branches, and leaves within the crowns of trees. Within pine flatwoods, aerial fuels usually consist of pine needles and branches with occasional hardwood species being consumed. For a crown fire to develop, the tree canopy must be dense, continuous, and live along with having low fuel moisture (Pyne 1984). Within pine flatwoods, especially those that are frequently burned, crown fires are not very common because the pines are widely-spaced, although individual trees can be consumed during intense wildfires. On the other hand, hydric and mesic hammocks with a continuous overstory and an abundance of

cabbage palm (an easily ignited species) are susceptible to intense crown fires (e.g. SMD 48).

The heavy buildup of surface and ground fuels within SMD 48's pine flatwoods and the property's close proximity to adjacent homesites will dictate how the fire use plan will be written. Again, the hydric and mesic hammocks will be excluded from fire for two reasons. First, these areas rarely burn and an intense surface or crown fire may result in the damage or death of several specimen-sized hardwoods (e.g. sweetbay magnolia and live oak). Second, a crown fire in these areas could result in numerous firebrands (hot, flaming airborne material) landing on roofs and backyards, thus possibly setting homes on fire and creating large amounts of smoke in the area.

Objectives of Prescribed Burning on SMD 48

There are several reasons why prescribed fire should be used within SMD 48's pine flatwoods. These include: reduction of heavy fuel loads, preparation of seedbeds for longleaf pine and wiregrass, partial management of hardwood invasion, and control of brown-spot disease among longleaf pine seedlings. In order to accomplish these goals safely and efficiently, a <u>backfire</u> should be implemented. A backfire is a fire that backs into the wind and should be used when a heavy fuel load is present in order to maintain good control

of the fire (Mobley et al. 1973). A headfire, on the other hand, is a fire that moves with the wind and is most effective for killing shrubs and trees (e.g. hardwood species) (Fahnestock and Hare 1964). Headfires are fast-moving, intense fires that are difficult to control. A headfire can produce a large number of firebrands, which may result in spot fires outside of the burn area. Therefore, a headfire would not be appropriate for SMD 48 because of the risk to nearby homes and the possibility of killing even the most fire-resistant pine trees. The heavy surface fuel load within the flatwoods could also carry a headfire into the hydric and mesic hammocks, possibly igniting a crown fire. Figure 61 shows the difference between a backfire and a headfire. A backfire moves much more slowly than a headfire and is less intense, thus making it the most appropriate firing technique for this site.

Weather and Fuel Considerations

In order for a prescribed burn to be successful, there are several weather and fuel conditions which must be present on the morning of the burn. The following paragraphs describe the desired weather and fuel conditions that are needed to conduct a safe and efficient burn on SMD 48.

In order to maintain good control of this backfire and keep its intensity to a minimum, low air temperatures are a must. Thus, the SMD 48 burn should be conducted during winter

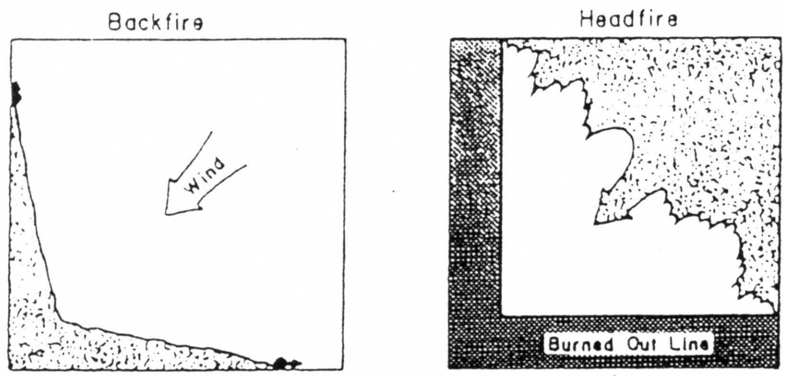


Figure 61. The above diagrams show the difference between a backfire and a headfire (from Wright and Bailey 1982).

or early spring in order to take advantage of low temperatures occurring after the passage of a cold front. According to Wade and Lunsford (1989) and Wright and Bailey (1982), good prescribed burning conditions for heavy southern rough often exist for 1 - 2 days after the front has passed. During this time period, the weather conditions are very predictable: low temperatures, steady winds, and low relative humidities are usually present. Summer burns are much less predictable due to high air temperatures and are usually conducted to kill hardwood species that have invaded pine forests. However, since a summer burn on SMD 48 is not advisable due to the area's urban location and the possibility of pine death, many of the larger hardwood species that have invaded the flatwoods may never be killed. In most cases, a winter (dormant season) fire causes less root kill than a summer burn (Wade and Lunsford 1989). Thus, only the smallest invading oak trees and seedlings may be killed during the SMD 48 burn.

Three other important factors related to prescribed burning after the passage of a cold front are wind direction, wind speed, and the number of days since rain. The Tampa Bay area usually experiences either west or northwest winds for a couple of days after a front has passed. These winds are needed when burning SMD 48 so that smoke is blown away from smoke-sensitive areas on the Interbay peninsula and into Hillsborough Bay. These smoke-sensitive areas include nearby subdivisions, MacDill AFB, Dale Mabry Highway, Crosstown

Expressway, and Port Tampa (see Figure 2). Two other smoke-sensitive areas, south MacDill Avenue and Bayshore Boulevard, may be impacted by smoke and should be posted with signs indicating that a prescribed burn is in progress. In addition to wind direction, wind speed is a very important factor when conducting a burn. According to Wade and Lunsford (1989) and Sackett (1975), relatively higher winds (e.g. 10 - 15 m.p.h.) help to dissipate the heat of a backfire, thus resulting in less crown scorch (and less pine death) than a fire that backs into lower-speed winds. Also, higher wind speeds are usually steadier in direction and occur most often after the passage of a cold front (Wade and Lunsford 1989). These steady winds make the prediction of smoke dispersion patterns much easier. When burning SMD 48, winds should be blowing from the west or northwest at 10 - 15 m.p.h. to take advantage of the above factors.

The passage of cold fronts through Florida and the Tampa Bay area during winter and early spring makes it easy to predict when rainfall will occur, and, thus, when to burn safely. According to Wright and Bailey (1982), fires in the South are usually conducted in winter and early spring as backfires in heavy rough 24 to 48 hours after a cold front has produced at least 0.5 to 1.0 inch of rain. Adequate rainfall is important in the days or hours before burning so that the fire intensity will be manageable and soil moisture can protect tree roots and microoganisms (Wade and Lunsford 1989).

A prescribed burn on SMD 48 should take place no later than 1 - 2 days after a cold front has delivered at least 0.5 inches of rain. This moisture should keep the fire intensity low (important in this urban area), while protecting surface root systems within the flatwoods.

Finally, two elements that are critical to the success of a prescribed burn are relative humidity and fine-fuel moisture. Relative humidity can be defined as "the amount of moisture in the air compared to the total amount the air is capable of holding at that temperature and pressure" (Wade and Lunsford 1989,15). Although relative humidity usually drops after the passage of a cold front, a prescribed burn can usually be conducted safely if relative humidity is between thirty and fifty-five percent (Mobley et al. 1973; Wade and Lunsford 1989). If a prescribed burn is conducted when the humidity falls below thirty percent, the fire can become too intense, thus making spot fires a more likely occurrence (Wade and Lunsford 1989; Wright and Bailey 1982). If the humidity is above sixty percent, many areas become difficult to ignite (Britton and Wright 1971). Since SMD 48 is located in such a highly developed area, it may be best to set the minimum relative humidity at forty percent (slightly above the required minimum) to prevent firebrands from becoming a threat to adjacent homes.

Relative humidity and fine-fuel moisture are closely related variables (Mobley et al. 1973). Measurements of fine-

fuel moisture are conducted in the upper litter layer consisting of freshly fallen pine needles and other leaves (Wade and Lunsford 1989). The preferred range of fine-fuel moisture for conducting prescribed burns is between seven and twenty percent (Mobley et al. 1973). However, in areas of the South where there has been a heavy buildup of fuels, a fine-fuel moisture of twenty to twenty-five percent is recommended to keep fire intensity manageable (Wade and Lunsford 1989). When fine-fuel moisture is below seven percent, fire can damage root systems and cause spot fires in nearby areas (Mobley et al. 1973; Wade and Lunsford 1989). When fine-fuel moisture is above thirty percent, there is much less danger of spot fires, but many portions of the burn area may be left untouched by fire (Bunting and Wright 1974; Wade and Lunsford 1989). Since there is a heavy fuel load within SMD 48's flatwoods, it would be wise to burn this area only if the fine-fuel moisture is at least twenty percent. At this level, fire intensity is more manageable and nearby homes are better protected against firebrands.

If the above fire prescription is followed as closely as possible, then the prescribed burning objectives mentioned earlier can be accomplished safely and efficiently. The following section describes how the burn will be conducted in the field to ensure the safety of nearby residents.

SMD 48 Prescribed Burning Plan

Figure 62 shows a map of the burn plan for SMD 48. Red signifies areas to be burned and includes only pine flatwoods. Green signifies areas that are to be excluded from fire. These areas include both the hydric and mesic hammocks as well as the area of hardwood invasion within the southwest portion of the property. The risk of a crownfire in these areas is too great to justify burning them. Burning in these areas could damage some of the fire-sensitive hardwood species and send firebrands into adjacent backyards and/or rooftops, creating a serious emergency. Therefore, these areas need to be surrounded by firelines (shown in black). A fireline is simply an area that has been cleared of fuel. Firelines are usually cleared by tractors (either a bulldozer or tractor-plow) and must be wide enough to keep fire from moving into a protected area. A fireline approximately eight feet wide has already been cleared around the perimeter of the property (not for prescribed fire purposes, but for the eventual installation of a fence around the site). This fireline should be adequate to protect those backyards adjacent to the flatwoods. Finally, blue signifies those points where the backfire should be started against a northwest wind. There are a total of four starting points (as opposed to one) needed to burn the entire flatwoods area due to fragmentation caused

Figure 62. Map of the burn plan for SMD 48. Red = areas to be burned; green = areas to be excluded from fire; thick black lines = firelines; blue = starting points for prescribed fire.

by the ditch system and hardwood invasion. The two large ditches will act as firelines due to an absence of fuel on both sides of each ditch. The fact that there will be four distinct burn areas surrounded by firelines should make this flatwoods burn much easier to monitor and control.

Finally, in order to ensure that surrounding homes are adequately protected from fire, either the Tampa Fire Department or the Division of Forestry should accompany the Hillsborough County Resource Management Team to the site on the morning of the burn. These agencies bring manpower and expertise to the burn and can help squelch any spot fires occurring outside of the designated burn areas. Another important safety measure is to inform nearby residents of the burn at least one week before it is likely to occur. This is usually done by handing out brochures that outline the benefits of prescribed burning (e.g. reduction of wildfire hazard) and give the names and work telephone number of the preserve managers in charge of conducting the burn. Therefore, if any residents have questions or concerns about the burn, they can contact the Hillsborough County Resource Management office. It may also be possible for the preserve managers to conduct a prescribed fire seminar at a neighborhood meeting.

Although there is a heavy fuel load within the pine flatwoods portion of SMD 48, this area can be burned safely if all the guidelines mentioned in this chapter are followed.

Fire exclusion resulting from enveloping fragmentation has relegated SMD 48 to a future of prescribed fire instead of a natural cycle of summer wildfires.

CHAPTER SEVEN

CONCLUSIONS

The major conclusions from this research are:

1. A series of aerial photographs dating from 1938 to 1994 reveal that rapid urbanization occurred on the Interbay peninsula in south Tampa which led to the destruction of most natural habitats in the area. The "South MacDill 48" property is one of the few areas that was spared from development and it is now a remnant patch of forest amidst a sea of development. This property consists of three habitat types that were typically found on the Interbay peninsula before 1940: pine flatwoods, hydric hammock, and mesic hammock.

2. It was found that an existing ditch system located on the property has had little or no effect on soil characteristics or water table within the hydric hammock. The presence of a limestone layer close to the soil surface indicates that this hydric hammock is connected to the Floridan aquifer. A 2Bg horizon located directly above this limestone indicates that the soil within the hydric hammock is not Malabar soil, which has a Btg horizon.

3. Due to its close proximity to exotic plant seed sources, SMD 48 has been invaded by a large number of invasive

exotic plant species. These exotic species can be eradicated through manual and/or chemical methods.

4. Urban development surrounding SMD 48 has resulted in this forest fragment being excluded from fire. As a result, hardwood tree species have invaded pine flatwoods on the property. This hardwood invasion can be controlled through the use of prescribed fire.

Although this study has focused on the process of forest fragmentation and its effects on SMD 48 (as well as local and statewide concerns regarding forest fragmentation), it is also necessary to focus on the actual <u>importance</u> of conserving this particular forest fragment and the habitats and species located within. I will contend that a combination of arguments regarding the "intrinsic" value of species/ecosystems, the "aesthetic" value of species/ecosystems, and the "zero-infinity dilemma" could be used to determine the relative importance of conserving SMD 48 and the distinct ecosystems located within. I will begin this argument by discussing the concept of "intrinsic" value.

According to Callicott (1986,140) something has intrinsic value if

> "it is valuable <u>in</u> and <u>for</u> itself-if its value is not derived from its utility, but is independent of any use or function it may have in relation to something or someone else. In classical philosophical terminology, an intrinsically valuable entity is said to be an 'end-in-itself,' not just a 'means to another's ends.'"

Intrinsic value (in its purest sense), however, cannot be given to a particular species or assemblage of species because only the human consciousness can assign "value." Therefore, something can be intrinsically valuable for its own sake and for itself, but not in itself (i.e. independent of human consciousness) (Callicott 1986). For example, the only "rights" that a particular species or ecosystem type have are those that human beings grant to them. Regan (1986,78), however, argues that while species themselves are not intrinsically valuable,

> "the complex event formed by a natural phenomenon such as a species, a human being's knowledge of it, and that human being's pleasure resulting from such knowledge, does have intrinsic value. Destruction of species decreases the number and type of such complexes possible and, consequently, decreases the potential intrinsic value in the world."

I would argue that this belief applies not only to particular species, but entire ecosystems as well. Following this argument logically, it is therefore important to protect the distinct ecosystem types located on SMD 48 for one major reason: The decline in area of pine flatwoods and hydric hammocks in both Hillsborough County and Florida indicates that each of these ecosystem types will be a rare commodity in the near future and, therefore, must be protected whenever possible. Although this argument is debatable, it does not

separate itself from the role of the human consciousness in assigning "value.

Other scientists, environmentalists, and philosophers describe the "aesthetic" value of a particular species of ecosystem type. While rejecting the idea that species must be assigned intrinsic value, Sober (1986,78) suggests that those who believe that a species has "aesthetic" value might "see the damage done when a species becomes extinct as analogous to the damage done when a great work of art is destroyed." Using this analogy, it is therefore important to preserve and manage SMD 48 because it is one of the last remaining forest fragments on the Interbay peninsula and contains an assemblage of ecosystems that are either scarce or no longer remain on the peninsula. This was, in fact, one of the major reasons why this property was purchased in 1992 (personal comm., Rob Heath, ELAPP).

The final argument focuses on the "zero-infinity dilemma." According to Norton (1986,121), "if too many species are lost by increments from an ecosystem, an area, or the worldwide biotic community, a catastrophic ecosystem breakdown could occur." Although extinctions of species have occurred for millions of years, it is the magnitude of these extinctions occurring today that has many scientists worried. Many believe that the "downward diversity spiral" has already begun, and each species loss increases the risk that the next loss will result in catastrophe (Norton 1986). Therefore,

according to this argument, it is important to protect all species (and ecosystems) in order to prevent catastrophe. Those who subscribe to this theory would argue that protecting and managing the ecosystems located on SMD 48 is, therefore, an important goal because this forest fragment (although relatively small) adds to the planet's biodiversity and keeps us one step further from total ecological collapse. Since pine flatwoods and hydric hammocks have declined dramatically in area in both Hillsborough County and Florida, some might argue that it is even more critical that these ecosystems be protected, no matter how small their area.

Any or all of these arguments could be used to discuss the importance of preserving and managing the ecosystems on SMD 48.

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