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Final Report

AN EVALUATION OF THE APPLICABILITY OF UPLAND BUFFERS FOR THE WETLANDS OF THE WEKIVA BASIN

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with

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Preface

This document is the product of a contract between the St. Johns River Water Management District and the Center for Wetlands, University of Florida to evaluate the applicability of upland buffers to the wetlands of the Wekiva River Basin. The purpose of this report is to develop critical insight concerning the need for, potential applicability of, and criteria for delineating upland buffers in the Wekiva Basin. In this report, we have reviewed the literature related to buffers, wetlands, wildlife habitat, transition zones, water quality and quantity, and other models and criteria for determining buffer zones. We have reviewed this information as a means of evaluating the need for an upland buffer to protect the water resources of the Wekiva River System.

Whether an upland/wetland buffer zone is desirable and/or necessary for the Wekiva River System is not a question in the minds of the authors. Our review of the literature; our understanding of the unique character of the Wekiva River System; our knowledge of the limitations of the criteria for issuing of permits for construction, operation, and maintenance of stormwater systems; the limits of jurisdiction under current wetlands regulation; and the expressed policies of the Governing Board of the St. Johns River Water Management District suggest that an upland buffer is desirable and necessary if the wetlands, waters, and wildlife of the Wekiva River Basin are to be preserved.

Two issues have surfaced during our study which need clarification as a prelude to the report. Both are related to the language in Chapter 373, Florida Statutes. In 373.413 and 373.416 a distinction is drawn between permits for construction and permits for operation and maintenance of water management systems. Both kinds of permits require that such systems cannot be harmful to the water resources of the District. Operation and maintenance permits are subject to an additional criterion: such activities cannot be inconsistent with the overall objectives of the District. Using one standard for construction and two for operation and maintenance is confusing. Operation and maintenance cannot be separated from construction, since once constructed, a system normally will be operated. Or to put it another way, if constructed, it seems backwards to then evaluate a permit for operation and find a system inconsistent with District objectives. Such a finding should be made prior to construction so that the project may be altered or redesigned to conform to District objectives. Thus, in our view, the review process for construction permit applications must also include operation and maintenance concerns. The District needs to review whether the constructed system will be harmful to the water resources and whether it will be consistent with the District's overall objectives during the construction permit review process.

The second issue is related to the definition of "water resources." We believe that one cannot separate the waters of the District from the overall aquatic system when determining harm to the resource. The water resource must include not only the abiotic substance (H_2O), but also the other abiotic substances and the biotic organisms that are carried and sustained by it. The water resource cannot be artificially dissected into parts which are regulated separatly (although it is attempted quite often, much to the detriment of the resource); for as the water goes, so the organisms, and vice-versa.

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I. INTRODUCTION

I.A. The Concept of Buffer Zones

The landscape is a mosaic of uplands and wetlands, developed lands and natural lands, and forests and fields. Somehow, without complete knowledge about how these pieces fit together, society must make decisions concerning how best to assemble the puzzle. Some decisions are easier than others, especially when there are no conflicting elements. Unlike a puzzle, however, the ease of adding a new land use to the landscape is inversely related to the number of pieces already on the board. As more and more land uses are added to the landscape, the decisions concerning placement require more and more thought.

The more pieces there are on the board, the more conflicts there will be between pieces. Most often, it is at the borders between pieces where conflicts arise. Decisions are easier to make when adjoining uses are not significantly different, i.e., when the existing land uses abutting the boundaries of a decision piece are similar to the proposed use of the piece in question. However, when adjoining uses are significantly different, consideration must be given to the interrelationships that are being created and to how one piece might affect surrounding pieces.

When uses are significantly different, or where the potential for conflict is serious, it is common practice to create a buffer between them. Thus we have buffers around airports, nuclear power plants, and bombing ranges. Demilitarized zones (DMZ's) between warring nations are often used to maintain peace. Zoning in urban areas uses successively lower-density districts to make transitions between high-density land uses and low-density residential districts. Buffer zones can be relatively narrow, like the grassed shoulders of highways which separate high-energy roads from forested landscapes, or quite wide, like the DMZ between North and South Korea. Generally, as the density of activity or the potential for conflict increases, the width of the buffer necessary to contain the negative effects increases proportionally. In addition, as the difference in activity level between bordering land uses increases, the width of the border must increase, since it is not the absolute magnitude of activity but rather the relative magnitudes of activity between neighboring uses that require buffering.

I.B. Buffers for Wetlands, Wildlife, and Water Quality

The differences between developed lands and wild lands are significant; the more intensely developed, the more the differences. Frequently, on developed lands the native vegetation is removed and replaced with exotics, drainage is improved, soil is compacted or covered with impervious materials, wildlife habitat is replaced with human habitat, and activity levels increase 10 to 100 times those found in the wild. The gradient in the intensity of noise, wastes, temperature, light, structure, and activity from undeveloped to developed lands is remarkable. It is this gradient that affects the edge between developed and wild lands, creating a new environment unlike the original and not at all similar to the developed land.

The edge between wild lands and developed lands is characterized by overflows of materials and energy that "flow" from high density to low. Water runs off developed land, carrying sediments and nutrients. Noise from developed land intrudes into the edge, disrupts natural activity, and interferes with the less intense communications of wildlife that are cues for territorial protection and breeding. Increased temperatures caused by removing tree canopy and paving the ground surface have marked effects on the forest microclimate.

Edges are common in the landscape, with or without development. In the wild landscape, however, sharp edges are hard to find. The lake edge is not a clean line; as the water level rises and falls throughout the year, it creates a littoral zone that is neither open water nor dry land, but somewhere in between. The sea edge is buffered by estuaries and coastal wetlands, which are neither open ocean nor dry land. The forest edge is a transition from the mature canopy with moist soils and minimal understory through a zone of more open canopy, with drier soils and dense understory, to the prairie with its xeric soils and lack of woody vegetation.

As the landscape is developed, the wild lands that surround cities retreat. If the world was a homogeneous flat plain and development happened as a simple outward progression from the central city, the edge would constantly be moving and little need would be generated for buffer zones between developed lands and undeveloped lands. However, the world is not homogeneous, but heterogeneous, having many differences, many patches, and many obstructions to development. The development process becomes patchy, areas are skipped, wetlands left, and parks created. Areas are set aside as wildlife habitat, or protected for water quality purposes, or left undeveloped as remnants to remind us of what the landscape was once like. The patches that are created in this manner undergo constant change as they "evolve" or succeed toward ecological communities that are islands in the developed landscape.

In Florida, under continuing growth pressure, the wild landscape has been mostly developed, leaving behind large and small islands of managed national, state, and local parks, along with many wetlands. Wetlands were first left behind because their development required a relatively greater commitment of funds and time than they were worth. Where the demand was high, in coastal areas for instance, wetlands were converted into dry lands and developed. Development skirted the swamps and marshes of inland areas not as a result of comprehensive planning, but because of piecemeal decisions made on a project-by-project basis. As land became more valuable and wetlands were threatened, state and local governments responded to increased pressure by enacting laws to protect the special values of wetlands recognized by society. Of primary concern was their function for maintaining clean, productive surface water and their value as very productive wildlife habitat.

In the minds of many, wetlands are now "protected." The Warren S. Henderson Wetlands Protection Act of 1983 established state permitting authority over activities in wetlands by virtue of the fact that they were defined as waters of the state. A methodology for determining state waters, developed as a rule (Ch. 17-4 FAC) by the Florida Department of Environmental Regulation, was required by the Henderson Act. The rule uses vegetation as a means of determining landward extent of state waters. Plant species normally found in wetlands are sorted into three broad categories: submerged species, transitional species, and "invisible" species. All plants not found on these plant lists are considered upland species. The rule then uses simple formulas that relate dominance of these species to determine the upland edge of "state waters." It is important to note that at no time does the rule or the original legislation (except in the name of the Act) delineate "wetlands". It only refers to a selective list of plant species. The intent of the rule and legislation is to protect state waters, which include areas that are dominated by certain plant species that indicate regular and periodic inundation. Wetlands can, and do, extend landward of this jurisdictional line.

The area immediately adjacent to and upland of the jurisdictional line is often a transition zone between wetlands and uplands. It is a zone that is wetland at times and upland at times, exhibiting characteristics of each and vegetated by species that are found in each. It is important to both the wetland and the upland as a seed reservoir, as habitat for aquatic and wetland-dependent wildlife species, as a refuge to wildlife species during high-water events, and as a buffer to the extreme environmental conditions of sharp vegetated edges.

To protect the values and functions of areas that are waterward of the jurisdictional line, attention must be given to the area immediately upland of the line. Wholesale alteration of this edge has immediate and potentially large-scale permanent impacts on the waterward area. Wetland-dependent wildlife species that are frequent users of this area are excluded, silt laden surface waters are no longer filtered, the microclimate is greatly affected and groundwaters may be diverted or drained. In the natural state the transition zone is a buffer zone both for the adjacent wetland and state waters and for the wildlife species that inhabit them. It should be recognized as such, and afforded some degree of development control.

I.C. Intent and Scope of the Report

This report is intended to provide a detailed review of the existing scientific understanding of upland buffer zones, their importance to the adjacent wetlands and waters, and the effects of alterations of these transitional areas on downstream water quality and quantity, and wetland wildlife habitat values. As we researched the topic, we found a dearth of information directly addressing buffer zones. However, there has been much recent interest in the literature concerning the impacts of edges on wildlife habitat values, and some recent investigations of the extent and species composition of transitional zones between wetlands and uplands.

The habitat values of transitional areas are related to between and within habitat needs of wildlife, the water quality values of buffer zones are related to protection of surface and groundwater, and their value related to water quantity issues is in their ability to mitigate adverse drainage impacts.

The report is organized in five parts with an appendix that gives lists of aquatic and wetland-dependent wildlife species that are characteristic of the Wekiva Basin. After the Introduction, the second section reviews the literature and summarizes and relates it to the concept of a resource buffer zone. The third section gives a brief physical and ecological description of the Wekiva Basin. The fourth section reviews the Water Management District's statutory criteria (Chapter 373 FS) and permit criteria in 40C-4, 40C-41, and 40C-42 FAC and relates them to protection of the water resources of the Basin. The fifth section develops a methodology for determining buffer zone requirements.

II. REVIEW OF THE LITERATURE

II.A. Significance of Buffer Zones

II.A.1. Ecological Significance of Transition Zones

The zone that lies between what are unconditionally identified as uplands and wetlands is a zone of transition (sometimes called an ecotone). In this zone, environmental conditions resemble neither the true wetland nor upland, but fluctuate and may resemble each during different times of the year or from one year to the next. Plant species that characterize transition zones may be an assemblage of both wetland species and upland species and may contain species that are not found in either of the two adjacent zones. It has long been held that highest species diversity occurs in areas of habitat overlap (MacArther and Pianka 1966, Allen 1962, Ranney 1977).

The Florida Department of Environmental Regulation (FDER), in its rules concerning the delineation and definition of landward extent of waters of the state, recognizes three main catagories of plants: submerged, transitional, and "invisible" species (Ch. 17-4.022 FAC). In an area dominated by transitional species, a preponderance of evidence that indicates it is regularly inundated is necessary before the area is considered a state water. In other words, without regular inundation, an area dominated by transitional species is not considered state waters, and by inference, therefore not a wetland.

Under 17-4.022 FAC, Florida does not recognize purely transitional areas as state waters, and as a result does not recognize them as important or necessary for protection under the Warren S. Henderson Wetlands Protection Act

(Chapter 430 Florida Statutes). However, their ecological significance as wildlife habitat and seedbanks, as well as their role in maintaining the integrity of the adjacent wetland community, is unrelated to their classification under 17-4.022 FAC. The FDER has chosen a cut-off based on dominance of "submerged" species to delineate state waters. The line so determined in most cases classifies all vegetation to the landward side as uplands. Most transition zones are to the landward side of the FDER jurisdictional line.

The role of transition zones as wildlife habitat for wetland-dependent species will be reviewed in subsequent sections, as well as their role as seedbanks. Generally, their ecological value stems from (1) direct use by wildlife and (2) seed sources for plant species that are more upland in growth requirements, yet are found within wetlands and are an important component of the community. Transition zones occupy the key upland fringe and as a result are the main source for seed material that contributes to the spatial heterogeneity of wetlands.

Wetland communities are not homogeneous. They are heterogeneous communities whose spatial variation in species composition is probably controlled by topography and ultimately by periods of inundation. Higher areas sometimes referred to as hummocks range in size from a few meters to several hectares. Hummocks have fewer periods of inundation and water depths are shallower, resulting in conditions that favor more "mesic" species. Lower areas are favored by those species that are tolerant of flooding. This heterogeneity of the wetland landscape is one of the key factors that gives it its diversity and wildlife value. Wildlife values are greatly enhanced as a result of the increased diversity of vegetation and undulating topography.

Studies of the Florida landscape indicate that the plant species diversity in transition zones is higher than the diversity of either the adjacent wetland or upland. Clewell (1982) found five community types on the Alafia River in central Florida along a gradient from wet to dry of which the "Moist Mesic Forest" seems to occupy that area that is transitional. The number of plant species found in this community exceeded all others by 25%. In Gross's (1987) study of 12 small-stream floodplain ecosystems in north and central Florida, 12 vegetation types were distinguished, using cluster analysis of which the three most diverse appeared to occur most often in the transitional areas. Studying methods for determining transition zones, Hart (1984) documented species composition of the wetland to upland continuum of eight wetland community types of north central Florida. She found that the transition zones were more diverse than either the wetland or upland and were different physiognomically from adjacent wetlands, yet were "....aligned more closely with wetlands than with uplands and were composed of species that tended to alternate between wetland and transition zones." The width of transition zones varied from a minimum of 10 m to a maximum of 30 m depending on the method used to delineate the zone and the type of wetland.

Wildlife species richness shows direct spatial relationships to the increased diversity of transition zones. Studies of forest edges (see Edge Effects on Wildlife) have documented increases in species richness and density of individuals within ecotones between habitats. Vickers et al. (1985) found that species richness and abundance of herpetofauna were greater along the edges of six wetlands in north central Florida than in either the wetland or upland habitat. Harris and Vickers (1984) found that virtually all mammals, because of their cursorial mode of locomotion and frequently herbivorous food habits, reside in "peripheral" areas, i.e., the transition zones. When water levels were increased, the movement of wildlife to the peripheral areas was also increased, suggesting the important role that transition zones play in providing refuge from wet-season increases in water levels in wetlands. The ecotone seems to play an even more important role when surrounded by clearcuts. Harris and McKlveen (1982) found a greater abundance and diversity of breeding birds in the ecotone between cypress wetlands and clearcut areas than in the ecotone between cypress and pinelands.

Classifying the bottomland hardwood ecosystem into five classes, Wharton et al. (1981) represented the transition to upland communities as the fifth class. They listed the importance of environmental factors to fauna in each zone. Of the five classes, the transitional zone ranked highest in importance overall and highest in 18 of 27 factors, among which are:

1. Retardation of "side flooding,"
2. Detritus source,
3. Diversity of oaks,
4. Availability of large variety of flora and fauna,
5. Diversity of forest strata,
6. Refuge from high water, and
7. Forage and cover for upland species.

The importance of the highest zones (transitional zones) of bottomland hardwoods to detrital food chains of downstream systems has been documented (Livingston et al. 1976, White et al. 1979). These studies showed that the infrequent pulses of organic matter and detritus form the higher zones in the floodplain after extreme flood and rainfall events correspond to peaks in fish production.

Topography plays an important role in controlling the width of transition zones. The transition zone between wetland and upland may be only a few meters in width or may extend for several hundred meters. In areas of very low relief, where the landscape has little or no slope, the transition zone may be extensive and ill-defined; yet, in landscapes where slopes are more prominent, the transition from upland to wetland may be far more abrupt. In studies of the central Florida landscape (Brown et al. 1984, 1985, and 1986), transition zones as wide as 30 m were delineated using species composition as the controlling variable. Gross (1987) found community types using cluster analysis that were dominated by transition zone vegetation on central Florida streams as wide as 80 m, but 40-m zones were more common.

II.A.2. Physical and Ecological Significance of Wetland Forest Edges

When forest is cleared and some forested remnants are left, as when the landscape is developed for agriculture or urban uses or clearcut during silviculture operations, the remaining forested patches contain induced edge where there once was a forest continuum. These forested tracts develop characteristic edge habitats that differ from habitat of interior forests. Ranney (1977), in a review of the literature on forest island edges, suggested that edge habitat differed from interior forests in at least six ways:

1. Tree species composition,
2. Primary production,
3. Structure,
4. Development,
5. Animal activity, and
6. Propagule dispersal capabilities.

The importance of edge is in its effects on the forested habitat and eventually on the suitability of the habitat for indigenous fauna. The conditions created when the forest continuum is cleared have detrimental long term consequences on the remaining forest system. Using current jurisdictional lines (Ch. 17-4.022 FAC) to determine the landward extent of state waters and given current development practices, the forest edge created between wetland and developed upland will coincide with the jurisdictionally determined line of regularly inundated wetland. In most instances this does not include transitional zones to the landward side of the jurisdictional line. The creation of an edge at this wetland/"upland" boundary opens the wetland to the many changes associated with edge conditions.

When a forested edge is created through clearing and/or partial removal of the forest canopy, steep gradients of solar radiation, temperature, wind speed, and moisture are incurred between the relative extremes of the open land and the forest interior (Wales 1967, 1972). Studies of characteristics of newly created edges (Gysel 1951, Swift and Knoeerr 1973, Trimble and Tryson 1966, Wales 1972, 1976) suggest that solar radiation is probably the most important physical parameter influencing conditions at the forest edge. The forest edge environment is characterized by increased solar radiation which in turn increases temperatures and decreases moisture content of soils and relative humidity when combines with effects of increased wind flows. Physical and structural manifestations of these changes include increase of shade-intolerant, xeric tree and shrub species and an increase of species associated with early stages of succession (Gysel 1951, Trimble and Tryson 1966, Wales 1972).

Of particular importance is the effect of increased wind speed on the newly created forest edge; especially when the edge is created at the wetland/upland interface. A major consequence of clearcutting is the loss of buffering of destructive wind speeds by the adjacent tree canopy. Tree wind-throws are common along newly created edges since edge trees not exposed to wind velocities of the open landscape are not structurally prepared for them. Wetland trees do not have deep-rooted growth habits, but instead rely on a root mat very near the soil surface to provide structural support in the relatively low bearing-capacity soils of most swamps. Windthrows are relatively more common in the deep organic soils of wetland ecosystems than in forested upland communities because of soil instability and difficulty of trees to anchor sufficiently.

The spatial effects of forest edge conditions are variable and are highly dependent on the way the edge is maintained. Ranney (1977) summarizes the spatial influences of newly created edges as between 5 and 20 m deep from the forest edge toward the interior. In a study of microclimate on Ft. George Island near Jacksonville, Florida, Hart (1985) determined that most of the microclimatic change between cleared areas and a forest interior in north and south directions occurred within 10 m of the edge, although on western facing edges, 25 m was often required for equivalent microclimatic change. Hart notes that the eventual closure of newly created edges by shrubs and vines will ameliorate negative microclimatic conditions and suggests the planting of fast-growing shrub species in some instances to speed up edge closure. Harris (1984) discusses the "three-tree-height" rule of thumb for the distance over which climatic effects of a surrounding clearcut will penetrate into an old-growth stand. Related to average tree heights of Florida wetland ecosystems, the three-tree-heights rule would suggest the penetration of influences as deep as 70 m.

Conceptually, to maintain the integrity of the wetland community and to insure faunal habitat for wetland-dependent species, buffers from 5 to 70 m in depth are necessary. Clearing at the wetland edge opens the wetland to significant changes. However, with a buffer that encompasses the transitional zone on the landward side of the wetland, negative impacts can be avoided.

Changes in abiotic parameters (due especially to increased solar radiation and wind) towards more xeric conditions along edges lead to corresponding changes in plant and animal communities (see Table 9 in Lovejoy et al. 1986) and in system properties such as nutrient cycling (Ranney 1977). Studies by

Levenson (1981) and Ranney et al. (1981) in Wisconsin have documented major edge effects on the vegetation of forest islands. They found that climatic structural edge influences extend at least 10 to 15 m into a forest on the east, north, and south sides and 30 m on the west side. Once established, characteristic edge associations composed of xeric-adapted and shade-intolerant species act as sources of propagules that invade the forest interior; forest islands below a certain size (about 5 ha in Wisconsin) may be entirely edge habitat in terms of their flora and vegetation structure (Ranney et al. 1981). Such changes may be essentially permanent. In Ohio, Whitney and Runkle (1981) found that small but persistent environmental differences associated with forest edges have greater long-term effects on tree species composition and structure than did severe but relatively brief disturbances associated with logging.

II.A.3. Water Quality Benefits of Buffer Zones

The water quality benefits of buffer zones are related to the ability of the zone to abate destructive water velocities and quantities of pollutants carried by surface runoff from uplands that may have a negative impact on downstream water quality, flora, and fauna. Soils of transitional areas are generally characterized by a low accumulation of organic matter (Gross 1987, Clewell 1982) but have accumulations of organic debris on the order of 1 to 5 tons per ha, depending on vegetative cover (Hewlett 1982). This organic debris can absorb about 98% of rainfall energy, minimizing erosion potential. Known as litter detention storage, it disperses the energy of water that would otherwise break bonds of soil materials and produces a slurry of mud and eroded soil. The kinetic energy of sediment transport increases rapidly as the second power of water velocity (Hewlett 1982) suggesting that as a slope increases or loses obstructions (such as vegetation) to uninterrupted flow, erosion potential increases dramatically.

Occupying topographic lows in the landscape, wetlands are particularly susceptible to erosional deposition from higher grounds and to erosional scouring as a result of increased water velocities from mismanaged upland surface waters. Maintaining undisturbed vegetation in transition zones can help to minimize these destructive forces. The Florida Division of Forestry's Silviculture Best Management Practices (BMP) Manual 1979) recommends a Discretionary Zone (DZ) for land occurring within 300 ft of a watercourse. This 300-foot-wide strip of land is considered the zone most influential to surface water quality. Recommendations are given for varying site sensitivities regarding the intensity level of activities such as construction of roads, site preparation, and harvesting practices. Within the DZ, two Streamside Management Zones (SMZ) are further delineated: a fixed primary and a variable secondary zone, each of which has been assigned special management criteria. The primary zone is 10 m from the edge of the watercourse,[1] while the secondary zone is from 10 to about 50 m from the water's edge. The width of the secondary zone is determined by the soil and topographic characteristics of the site. Within each of the SMZ's, recommendations for site preparation and harvesting are given relative to slope and soil erodibility.

Since the main objective of Silviculture BMP's is to minimize negative impacts on water quality, and since silviculture, by definition, is the

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[1]Sometimes the border of the SMZ's are referred to as "...the edge of the watercourse or lake..." (Florida Division of Forestry 1979); other times the SMZ is "adjacent to perennially open waters" (Riekerk and Winter 1982); still others as a "...strip of forest land surrounding all perennial streams and lakes 10 acres or larger" or as "a vegetated strip adjacent to a watercourse..." or as occurring "...along all perennial and intermittent streams..." (Florida Division of Forestry 1979). A strict definition of the watercourse's edge as related to 17-4 FAC may be important to help determine from what point the SMZ should be applied.

management of forests for their wood fiber, the BMP's are designed to maximize the forest area that can be harvested. If the goal was to minimize negative impacts on state water resources,[2] the primary and secondary zones would begin at the wetland edge and extend upland. In this manner the zones would occupy the area that is commonly termed the transition zone between upland and wetland and would insure minimum impacts to state waters.

It is generally agreed that the more sensitive a site is to sediment production, the wider the undisturbed vegetative buffer should be. Since sediment production can result in the deposition of materials in locations where they may have negative impacts, and since sediments provide a major vehicle by which pollutants are transported, every effort should be made to encourage the use of vegetative buffers to minimize sediment deposition in wetlands and water courses. The width and efficiency are variable. Karr and Schlosser (1977), relying on the work of Trimble and Sartz (1957), suggest a minimum width of buffers for conditions encountered in "municipal conditions" as 15 to 20 m for lowest (0 to 3%) slopes and as high as 80 m for slopes of 60%.

There has been much research on the effects of logging in close proximity to streams, especially in the northwest United States. Erman et al. (1977), in studies of logged landscapes with and without streamside buffers, found that buffers were very important in minimizing negative impacts as a result of erosion from logged lands, and that streams with narrow (less than 30 m) buffers snowed effects comparable to streams with no buffers. Generally, their

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[2]Waters of the state are those lands that are regularly and periodically inundated as defined by 17-4.022 FAC which includes areas dominated by "submerged" wetland vegetation. Thus to protect state waters and achieve Best Management Practices as they relate to these waters, the discretionary zone, primary zone, and secondary zone should be measured as distance from the edge of the wetland instead of the edge of the watercourse.

research on 62 northern California streams showed a strong correlation between buffer width and stream community diversity index. Streams with highest diversity indices had buffers greater than 50 m in width.

Streamside buffers in the high-relief landscapes that characterize most of the continental United States are generally measured from the channel bank. Where landscape relief is high, channel slopes are high, and associated floodplain ecosystems are narrow; and as a consequence, streamside buffers measured in this way probably adequately protect the resource. However, where landscape relief is low, as in the Southern Coastal Plain, terrain is flatter, stream channel slopes are lower, and associated riparian ecosystems are wider. The measurement of streamside buffers in low relief landscapes needs to reflect these important differences and begin at the upland edge of the riparian ecosystem.

Effects of Construction Activities

Darnell et al. (1976) summarized the effects of construction activities on riparian ecosystems and grouped them into three time related catagories:

1. Direct and immediate results which take place during the construction process;

2. Effects which occur during the period of stabilization following completion of the construction; and

3. Long-term effects of more or less permanent changes brought about by the construction itself or by subsequent human use and environmental management occasioned by the constructed facilities.

The water quality effects of construction activities within upland boundaries of riparian ecosystems can be grouped into the same time-related catagories, although for the sake of simplicity, the first two may be combined. The overall impacts of any construction activity vary depending on environmental features (e.g., physical characteristics such as slope, soils, and vegetative cover), timing, type of construction activity, and the care taken during the active construction phases. Long-term impacts associated with subsequent uses vary depending on environmental features, intensity of uses, and management practices.

During and immediately following construction the major impacts on water quality can be grouped into three broad classes:

1. Impacts associated with erosion of loose soils and their subsequent deposition in downslope wetlands;
2. Suspended sediment increases in surface waters, resulting in increased turbidity; and
3. Introduction of unusual levels of chemical compounds that may have negative effects on resident fish and wildlife populations.

The most obvious results of the deposition of eroded sediments in wetlands are the impacts associated with filling. When wetland soils are covered with additional depths of fill material, the most serious impact is loss of oxygen penetration to the root zone and resulting stress on vegetation. If the accumulation of sediment is deep enough, or if the sediment is fine enough to plug up soil pores so as to effectively starve roots of oxygen, death of vegetation results. Secondary impacts are experienced by wildlife as a result of the loss of habitat.

The authors have on numerous occasions witnessed the results of inadvertent filling along wetland edges throughout Florida. In most cases these results were caused by erosion of unstable soils during clearing and construction activities. The deposition of eroded material resembles a wedge of sediments where the bigger particles drop out of the sediment stream first and successively finer materials drop out farther into the wetland system. Depths of sediment are greatest along the periphery and taper off to shallower and shallower accumulations as the sediment stream penetrates into the wetland. In most instances the effects are immediate and dramatic. Where sediment depths are greatest, both understory and canopy plants are killed, and as the sediment wedge tapers off, tree kills are less noticeable, but the many varieties of understory vegetation with their shallower root systems are killed. Finally, at the farthest extreme of the sediment wedge, only the herbaceous vegetation is affected.

The net result of the deposition of eroded sediments within the limits of wetland communities is to shift the conditions of the transitional edge farther into the wetland. Dead and dying vegetation is replaced over time by early successional upland vegetation. The impacts are less a loss of water storage capacity (since the volume of sediments may be small compared to the overall volume of water stored in the wetland) as they are a loss of valuable wetland function and wildlife habitat.

If the disturbed area is close enough to surface waters, or if the configuration of the wetland is such that stormwater runoff from the upland edge can collect and form an intermittent stream, sediments eroded during construction phases may directly affect aquatic environments. In their review of impacts of construction activities in wetlands, Darnell et al. (1976) grouped the biological impacts of suspended and sedimented solids under the topics of turbidity, suspended solids, and sedimentation. Within each group they review the biological effects that have been documented in the literature. Their review is summarized in Table II.A.1.

The final water quality effect during the construction phase is related to the release of chemicals, the levels of which may be harmful to downstream fish aand wildlife or negatively affect ecosystem function. When areas are cleared, runoff increases, carrying with it increased volumes of soil and sediment. Large quantities of dissolved cations and other minerals are lost from the

Table II.A.1 Biological Effects of Sediments and Suspended Solids on Aquatic Environments (after Darnell et al. 1976)

Topic	Biological Effect
Turbidity	* Reduction of photosynthesis - eliminates phytoplankton, attached algae, and rooted vegetation, thus eliminating base of aquatic food chain * Decreased visibility - interferes with normal behavior patterns of higher aquatic organisms
Suspended Solids	* Temperature effects - water absorbs more radiant energy, inhibiting vertical mixing in calm waters or uniformly heating moving waters modifying oxygen content * Oxygen reduction - through inhibition of photosynthesis, heating, or increased COD and BOD * Reduction of primary production - inhibits light penetration, absorption of critical nutrients, removal of algae and zooplankton from suspension through adherence to particles * Effects on respiration - oxygen reduction can selectively eliminate aquatic animals that require oxygen for respiration, suffocation through clogging of gill filaments * Other effects - potential starvation of filter feeding animals, decreased visibility, interference with migration patterns of fish
Sedimentation	* Primary production - smothering and scouring, physical barrier to gas exchange * Bottom animals - scouring and blanketing with sediments * Fish populations - reduction of food supply, destruction of habitat, elimination of spawning areas, smothering of eggs and larvae

cleared areas and deposited in downstream areas. Borman et al. (1968) found cation losses from 3 to 20 times greater from clearcut watersheds than from undisturbed control watersheds. Riekerk et al. (1980) showed significant increases in sediment and higher nutrient cation loading of runoff from a clearcut, relatively low-gradient watershed after one year, but no significant differences after the second year. In watersheds composed of wet savanna forests of Florida's Lower Coastal Plain, Hollis et al. (1978) recorded significant loss rates of dissolved minerals including ammonium-nitrogen as well as phosphorus and suspended sediments.

Of less concern, unless a large-scale accident occurs, is the increase in petroleum products that may pass from construction sites into downstream wetlands and watercourses. Spills in maintenance yards and the general operation of equipment in and near wetlands increases the likelihood of increased contamination. In all, however, contamination from petroleum products during the construction phase should be of minor concern if proper care is taken.

Effects of Operation and Maintenance

Long-term water quality impacts associated with construction activities in areas adjacent to wetlands and watercourses is a function of subsequent human uses and management. Stormwaters running off developed lands carry both organic and inorganic materials, both suspended and in solution. Many of the organics are degraded through biological pathways or through chemical oxidation. As degradation occurs, oxygen is consumed causing decreases in available oxygen. Thus the breakdown of these compounds "demands" oxygen. Their presence and potential for negative water quality impacts is measured by tests for Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

The final land use of a developed area has a marked effect on the quality of stormwater runoff. The Florida Department of Environmental Regulation (FDER) (1978) summarized the work of Sartor and Boyd (1972) that compared the total solids loading from residential, commercial, and industrial land uses. Industrial areas were shown to have the highest loadings and commercial areas to have the lowest. Another stormwater study of three sub-basins (a forested, a suburban, and an urban basin) of Lake Jackson in northern Florida as reported in Wanielista (1975) and summarized by the FDER (1978) compared mean concentrations for various constituents in stream water under stormflow and baseflow conditions. The findings showed that the export from the urban watershed was greater for all constituents than from the forested or suburban watersheds, and that mean concentrations of suspended solid loadings from the urban basins and suburban basins were approximately 10 times and 5 times, respectively, those of the forested watershed.

In most time-related studies of the quality of urban runoff, a common finding is the difference in concentrations of constituents between the initial "first flush" and later runoff. Typically, the initial rainfall flushes the stormwater system, carrying with it large quantities of suspended solids and materials in solution. Later discharges have significant, but much lower, concentrations of pollutants.

Stormwater management rules generally recognize the potential for downstream water quality impacts from urban and suburban areas, and while there is some variation in regulation throughout the state, generally they address the problem through retention of a prescribed amount of the initial rainfall from a storm event. This treatment method assumes that through retention of the first flush, a majority of the constituents that would enter surface waters are retained. However, most stormwater systems, while retaining this first flush, accumulate the remaining stormwater in the same retention basin, diluting initial concentrations with the added waters. Under these conditions, if the rainfall event is large enough, the diluted first flush is discharged along with remaining stormwaters to receiving water bodies. The net result is little if any retention of the pollutant carried by the storm runoff. Recently, more stringent regulations have been put into effect in the Wekiva River Basin that require off-line retention to avoid this problem.

The problems associated with degradation of water quality as a result of the operation and maintenance of a stormwater management system once a development is in place may be little affected by a buffer requirement. The potential impacts on water quality from the combined effects of increased runoff and increased concentrations of pollutants that result from urbanization are not so much functions of how close the developed areas are to wetlands and watercourses as they are of land use, size of the development, and stormwater system design. However, potential impacts from systems designed to allow portions of a development to discharge without treatment may be mitigated through a buffer requirement. In many instances, where slopes prohibit stormwaters to be collected into a system, portions of the lowest areas in the development (typically those closest to and abutting the wetland/watercourse edge) may discharge directly. A buffer requirement in these situations would allow for some treatment of stormwaters if they were allowed to sheetflow through the buffer area.

II.A.4. Water Quantity Benefits of Buffer Zones

The construction and subsequent operation of urban land uses within areas adjacent to wetlands and watercourses affect the quantity and timing of waters that flow over the lands and often surficial groundwaters beneath the developed lands. The effects are the result of both construction-related activities and operation and management-related activities. During construction, the volume of runoff increases, since removed vegetation and surface accumulations of organic matter can no longer act to retard runoff, and transpiration is greatly reduced.

Studies of water yield from watersheds having varying degrees of clearing show strong relationships between the amount of disturbance and water yield. One study in north central Florida by Riekerk et al. (1980) found water yield increases of 165% from a clearcut, highly disturbed watershed and over 65% from a minimally disturbed watershed. In a later study Riekerk (1985) found 2.5-fold and 4.2-fold increases in runoff from minimally and maximally disturbed watersheds, respectively. In most studies, the effects of disturbance on runoff volumes decreases markedly from 2 to 3 years after treatment as vegetation again plays a role in the site's hydrologic balance. The net effects of clearing are reflected in higher soil moisture levels which may contribute to higher stream baseflow and greater direct runoff during storm events.

Once vegetation has been removed, it is quite common for groundwater table elevations to increase as a result of decreased transpiration. In areas of existing high water tables, soils can become saturated and extremely difficult to work without extensive "drainage improvements." Stormwaters are often routed through temporary swales and ditches into downstream areas to minimize flooding while drainage and stormwater systems are being constructed. Such practices can add significantly to construction-related water quality impacts and alter quantity and timing of surface water discharge.

Typically, areas immediately adjacent to floodplain and seepage wetlands are dominated by seasonally high water tables. This is a predominate aspect of the lands adjacent to the floodplain wetlands throughout the Wekiva River Basin. Lowering of water tables to accommodate construction-related activities and as a permanent consequence of development can reduce groundwater elevations and intercept groundwater flows to adjacent wetlands. Of all the impacts of development, when the mitigating effects on surface water of properly designed retention/detention systems are taken into account, the loss and interception of groundwaters has the most profound consequences. Drainage in areas with high water tables is a widely accepted practice that allows development of lands that would otherwise be difficult to develop. Positive drainage "dewaters" the upper portions of the soil, which lowers the surrounding groundwater elevations. The effects spread radially from the drainage system with the actual amount of decline in water table elevation dependent on the elevation of the drainage system and soil properties and topography of the surrounding lands. Wang (1978) and Wang and Overman (1981) found the effects of a 10-foot lowering of the groundwater table to extend up to 1 mile from drainage ditches in south Florida. While this is probably not typical throughout Florida, it does indicate the magnitude of the problem.

The impact of lowered water tables on adjacent wetlands is a reduction in hydrologic function. Where adjacent wetlands are depressional wetlands that intercept the groundwater table, lower water table elevations reduce depths of surface waters and shorten hydroperiods. Under extreme conditions the wetland may remain dry throughout the year. In areas dominated by seepage wetlands, lowered water table elevations result in a reduction or even a cessation of groundwater seepage and subsequent drying of the wetland. The long-term, wide-scale effects of general drainage practices throughout the state have been discussed by Brown (1986) and are pervasive. While immediate ecological changes resulting from drainage are subtle--to the untrained eye, no change is observable--the long-term consequences are loss of hydrological functions, gradual replacement of wetland vegetation with upland types, and consequent loss of habitat values for aquatic and wetland-dependent wildlife species.

The maintenance of setbacks or buffers in areas immediately adjacent to wetlands and watercourses can have significant impact in minimizing these effects. A properly sized buffer between construction activities and downstream wetlands can slow down and filter runoff and mitigate the drawdown effects of drainage ditches on adjacent wetlands. It cannot be stated strongly enough that the lowering of water tables to accommodate development is probably the single most important impact affecting adjacent wetlands, and that a properly sized buffer will go a long way toward minimizing these impacts.

II.A.5. Edge Effects on Wildlife

The question of how wide a buffer zone must be to maintain biological integrity cannot be answered without considering the problem of edge effects.

Edge is defined as the place where plant communities meet or where successional stages or vegetative conditions within plant communities come together (Thomas et al. 1979). Edge effects have been investigated intensively in wildlife management ever since 1933, when Aldo Leopold's classic text was published. Evidence of a positive edge effect (i.e., an increase in species richness or density of individuals near an edge in contrast to adjoining habitat types) has been reported for birds (Lay 1938, Beecher 1942, Galli et al. 1976, Laudenslayer and Balda 1976, McElveen 1977, Gates and Gysel 1978), mammals (Bider 1968, Forsyth and Smith 1973), and several other groups of organisms.

Most of the early studies of edge effects were concerned with documenting an increase in wildlife abundance near edges. They implied that managing land to increase edge will also increase wildlife. Edge habitat has high cover density and food availability for many animals, and it is an index of carrying capacity for species that require two or more habitat types for survival (Johnson et al. 1979, Thomas et al. 1979). Hence, Leopold (1933) described game (wildlife) as "a phenomenon of the edge" because wildlife "occurs where the types of food and cover which it needs come together." Subsequently, edge became a fundamental principle of wildlife management (e.g., Allen 1962, Dasmann 1964), and some wildlife management texts went so far as to urge managers to "develop as much edge as possible" (Yoakum and Dasmann 1971). Ghiselin (1977) suggested that an edge index based on the amount of edge or ecotone present is useful as an indicator of relative animal productivity between similar habitats.

Unfortunately, these wildlife management recommendations were naive about the consequences of edge management on nongame animals, on plant communities, and on regional diversity patterns (reviewed in Noss 1983). In a management context, there are two types of edge: inherent edge and induced edge (Thomas et al. 1979). Inherent edge is a natural phenomenon that represents the juxtaposition of community types and a continuum of successional stages in the landscape mosaic. This natural heterogeneity is in large part a product of the natural disturbance regime of fire, flood, treefalls, windthrows, landslides, and other events (White 1979, Sousa 1984, Pickett and White 1985). Moreover, this natural heterogeneity may be the primary determinant of wildlife composition and diversity in a region (reviewed in Noss 1987).

Induced edge, on the other hand, is a product of manipulation of habitat by humans. It is closely tied to the process of habitat fragmentation that produces sharp contrasts between vegetation types. Simple geometry shows that small habitat islands have larger edge-to-interior ratios than do similar shaped large habitat islands. As a natural landscape is fragmented into disjunct pieces of habitat in a sea of developed land, the proportion of edge habitat in the landscape increases. Thus, species that are restricted to habitat interiors gradually are replaced by species characteristic of edge habitats. The latter species are generally opportunistic or "weedy" and do not need reserves for survival (Diamond 1976, Whitcomb et al. 1976, 1981, Noss 1983). Conservation biologists therefore recognize that interior species dependent on large tracts of undisturbed habitat should receive priority attention in conservation plans.

The recognition of negative edge effects associated with induced edge was a major breakthrough in wildlife ecology. Until the mid-1970s, the attention of most wildlife scientists was focused on relatively small tracts of land (i.e., on local diversity) and on the small subset of animal species that could be hunted. Under these circumstances, induced edge habitat can be seen as favorable. Species such as white-tailed deer, bobwhite quail, cottontail rabbit, and ring-necked pheasant often increase under such circumstances, as does the species list of individual management units. But if one focuses on regional and global diversity, and on entire ecosystems (including nongame animals and endangered species of plants), the negative consequences of induced edge are all too clear. The end result is often a landscape that has lost its native character and is dominated by weeds that are either alien to the region or were previously restricted to recently-disturbed patches (Faaborg 1980, Samson 1980, Noss 1981, 1983, Samson and Knopf 1982, Harris 1984, Noss and Harris 1986).

The negative effects of induced edge are easier to understand when one considers that edge is more than a one-dimensional boundary between habitat types. Effects of an open, disturbed habitat penetrate some distance into an adjoining wooded natural area; hence, edge has a width of influence. Much of this influence is ultimately climatic. Lovejoy et al. (1986), summarizing the status of their research on forest fragmentation and induced edge effects in Amazonia, recognize an abiotic class of edge-related changes that includes temperature, relative humidity, penetration of light, and exposure to wind.

The type of habitat on the outside of a forest edge will determine the nature of edge effects. A general principle is that the greater the contrast between habitat types, the greater the edge effect (Harris 1984). When a forest is fragmented, the matrix which surrounds it is usually some type of early successional habitat. (Housing subdivisions would generally fall in this category.) This secondary successional habitat is a constant source of weedy plant and animal propagules that invade the forest fragment and alter species composition and relative abundances (Janzen 1983). Opportunistic animals that achieve artificially high densities in the early successional habitat often invade pristine areas, exerting abnormally high levels of trampling, browsing, and seed predation; this can destroy a natural area as surely as can a chainsaw (Janzen 1983, 1986). Bratton and White (1980) reported that manipulation of habitat to support a huntable deer herd can result in heavy browsing in adjacent natural areas and further endanger a number of rare plant species.

The effects of habitat fragmentation and induced edge on animal communities (especially birds) has been particularly well studied over the last two decades. Application of island biogeography theory (MacArthur and Wilson 1967) to habitat islands have led to recommendations for the design of nature reserves. Nature reserves and forest fragments have been portrayed as islands because they are patches of natural habitat in a matrix or sea of culturally modified land (Terborgh 1974, Diamond 1975, Sullivan and Shaffer 1975, Wilson and Willis 1975, Diamond and May 1976, Forman et al. 1976, Galli et al. 1976, and many others). Most early work on this problem was essentially a confirmation of the familiar species-area relationship (Arrhenius 1921, Gleason 1922, Preston 1960, 1962): larger pieces of habitat support more species. There are many potential explanations for the species-area relationship. Three general explanations are (1) larger areas support more kinds of habitats (and thus more habitat-specific species), (2) larger areas offer bigger "targets" for organisms dispersing across the landscape, (3) larger areas maintain larger populations that are less vulnerable to extinction due to random or deterministic population fluctuations, and (4) larger areas support animals of large territory and home range size that cannot be supported in small areas. Any one of these explanations is powerful enough to support the general recommendation that nature reserves should be as large as possible (e.g., Soule and Wilcox 1980, Frankel and Soule 1981, Schonewald-Cox et al. 1983, Harris 1984, Soule 1986).

The process of habitat fragmentation is accompanied by insularization of fragments, i.e., isolated pieces of habitat surrounded by dissimilar habitat begin to resemble islands in many of their ecological dynamics. Eventually, fewer native species will be found in a habitat islands than in sample areas of equal size within extensive blocks of habitat (Miller and Harris 1977). Alternately, species richness may not change much, or may even increase, with habitat insularization, but species composition will shift towards edge species at the expense of area-dependent interior species. These edge species are generally common in the developed landscape and do not need reserves of any kind for survival (reviewed in Noss 1983).

In New Jersey, Forman et al. (1976) found that forest islands contained more bird species than did sample plots of equal size within extensive forests, but the additional species were primarily birds of the forest edge. Forest interior birds were limited to the larger forest islands. Since then, the changes in avifauna that occur with forest fragmentation have been thoroughly documented (for the most extensive treatment, see Whitcomb et al. 1981). In Florida hardwood hammocks, Harris and Wallace (1984) documented area-dependence in a number of bird species. In the Wekiva River bottomland hardwood forest, breeding bird species that have been shown elsewhere to be area-dependent and vulnerable to negative edge effects include the red-eyed vireo and the Acadian flycatcher, both near the limits of their ranges in this area (H. Kale, Florida Audubon Society, pers. comm.).

More generally, the species most vulnerable to extinction in fragmented landscapes are large animals with large home ranges (i.e., top carnivores), ecological specialists, and species with variable populations that depend on patchy or unpredictable resources (Terborgh and Winter 1980, Karr 1982, Wright and Hubbell 1983). The characteristically small populations of these species are vulnerable to problems related to environmental stochasticity, demographic stochasticity, social dysfunction, and genetic deterioration brought on by inbreeding or genetic drift (Frankel and Soule 1981, Shaffer 1981, Schonewald-Cox et al. 1983, Soule and Simberloff 1986).

Biotic aspects of edge effects have played a major role in the ecological deterioration that accompanies fragmentation. Some effects of edge on vegetation were discussed above. Because animal communities respond to vegetation structure (e.g., MacArthur and MacArthur 1961, Roth 1976), any edge-related changes in vegetation will cause corresponding changes in animal communities for a certain distance into a habitat interior. But there are more insidious processes at work. The opportunistic animals that are attracted to edge (or to the early successional habitat outside) often prey on, out compete or parasitize interior species, sometimes with disastrous consequences to the latter's populations.

Most of the research on faunal deterioration near edges has been done on birds. Whitcomb et al. (1976) provided evidence that, in areas where forest has been reduced to isolated fragments, avian brood parasites (brown-headed cowbirds), nest predators (small mammals, grackles, jays, and crows), and non-native nest-hole competitors (e.g., starlings) are usually abundant in the urban-agricultural matrix and often invade small forest tracts and narrow riparian strips. Gates and Gysel (1978) found that a field-forest edge attracts a variety of open-nesting birds, but such an edge functions as an "ecological trap." Birds nesting near the edge had smaller clutches and were subject to higher rates of predation and cowbird parasitism than those nesting in either adjoining habitat interior. Brown-headed cowbirds, which were not found east of the Mississippi River before widespread forest fragmentation, are a particularly noxious species. Half or more of the songbird nests within 200 m of the edge may be parasitized, reducing reproductive success for some species below the level of population sustainability (Brittingham and Temple 1983). Brown-headed cowbirds have been increasing in number and are moving south in Florida, and they will undoubtedly become more problematic as forests continue to be fragmented; meanwhile, the ecologically similar shiny cowbird, which has caused severe problems in parts of the Caribbean (Post and Wiley 1976, Post and Wiley 1977), has been moving north and was reported in Florida in 1986.

Experimental studies of nest predation have documented significantly higher predation rates in small forests compared to large forests, in forests surrounded by suburbs compared to forests surrounded by agricultural land, and at decreasing distances to forest edge (Wilcove 1985, Wilcove et al. 1986).

This abnormally high predation rate is related to the artificially high densities of many opportunistic animals near forest edges and in disturbed habitats (including suburbs; Wilcove et al. 1986). A primary reason why these opportunistic animals (which in Florida include raccoons, opossums, gray squirrels, armadillos, house cats, and blue jays) achieve such high densities is that the large predators (e.g., panthers, wolves, and bears) that once regulated their populations have been extirpated or greatly reduced (Matthiae and Stearns 1981, Whitcomb et al. 1981, Wilcove et al. 1986). The deleterious effects of increased nest predation may extend 300 to 600 m inside a forest border (Wilcove et al. 1986). More generally, Janzen (1986) suggests that managers can expect serious edge effects (including problems related to heavy use by humans and domestic animals) anywhere within 5 km of a reserve boundary.

The studies discussed above suggest that any forest tract has a "core area" that is relatively immune to deleterious edge effects and is always far smaller than the total area of the forest (Temple 1986). Relatively round forest tracts with small edge-to-interior ratios would thus be more secure, whereas thin, elongated forests (such as those along riparian strips) may have very little or no core area and would be highly vulnerable to negative edge effects.

II.A.6. Regional Habitat Needs of Wildlife: Corridors

A great deal of recent literature in the fields of island biogeography and conservation biology has discussed the effects of inbreeding and genetic drift on wildlife due to genetic isolation and small population sizes (e.g., Miller 1979, Soule 1980, Senner 1980, Wilcox 1980, and Franklin 1980). Inbreeding has the effect of decreasing population heterozygosity (genetic variation) by increasing the probability that progeny will receive duplicate alleles from a common ancestor. This loss of genetic variation can have both immediate and future implications for a species' survival. Inbreeding can lower species vigor and fecundity within a few generations (Soule 1980). The very reduced population of Florida panthers may be suffering from the effects of inbreeding. All five males examined have had greater than 93% abnormal sperm (Roelke 1986). Over the long term, inbreeding can also limit the ability of a population to evolve to meet changing environmental conditions (Soule 1980, Harris et al. 1984).

Other literature has questioned the effectiveness of fragmented parks and preserves in maintaining viable populations of animals which require large home ranges or activity areas (Pickett and Thompson 1978, Lovejoy and Oren 1981, Harris and Noss 1985, Harris 1984, Noss and Harris 1986, Noss [in press]). In Florida, bears may range over 15,000 ac and bobcats over 5,000 ac. An otter may require several miles of linear river and riparian habitat (Harris 1985). To maintain viable populations of these and other far-ranging animals, large blocks of land are needed.

One proposed management alternative for providing for these wildlife needs is the use of wildlife corridors (Diamond 1975, Butcher et al. 1981, Forman and Godron 1981, Harris 1983, Noss 1983, Harris 1984, Harris and Noss 1985, Noss and Harris 1986, Wilcove and May 1986, Noss [in press]). Wildlife corridors can be defined as strips or parcels of land which allow safe passage of wildlife between larger blocks of habitat. This contiguity effectively increases the size of protected lands and their ability to maintain viable wildlife populations. Genetic variation is maintained because genetic material is carried freely back and forth across the corridor and among large habitat blocks by dispersing wildlife. Dispersing animals can recolonize areas which have suffered from local extinctions (Fahrig and Merriam 1985). Large carnivores such as panthers, bears, bobcats, and otters which require large home range sizes would be free to continue their natural movement between habitat blocks which would otherwise be rendered inaccessible to them by physical barriers. They gain the increased resource base needed to support top-level carnivores. In addition to serving as travel routes, corridors also serve as habitat for some species.

Evidence of wildlife use of travel corridors comes from a variety of sources at several scales. In the extreme, land bridges between continents have historically acted as wildlife corridors (Simpson 1940, Simpson 1965). The Bearing Sea land bridge allowed the migration of many animals, including man, into North America from Siberia. The Isthmus of Panama similarly allowed the migration of wildlife between North and South America. Other paleontological research has pointed to the development of a broad, flat corridor which formed along the Gulf coast of Florida during the glacial lowering of the sea level. Webb and Wilkins (1984) found that during these periods Florida's wildlife was highly influenced by fauna which had migrated into Florida from South America and southwestern North America. Riverine gallery forests in Brazil apparently act as mesic corridors which have allowed Amazonian forest species to invade and become components of the xeric cerrado fauna (Redford and da Fonseca, 1986).

On a smaller scale, habitat corridors have also been shown to be important for wildlife. Riverine forest corridors are known to be important habitats for many species. The maintenance of streamside strips of vegetation is an important management tool for maintaining gray squirrel populations within pine plantations (McElfresh et al. 1980). Turkeys have been successfully managed in a mosaic of poor habitat (short-rotation pine plantations) by maintaining hardwood and mature pine trees in travel corridors. These corridors allowed the turkeys to move widely among foraging and roosting areas (Gehrken 1975). Several species of birds have been found to regularly use fencerows and hedgerows as safe travel routes (Bull et al. 1976). MacClintock et al. (1977) found that a small forest fragment connected by a corridor to an extensive forest block was characterized by birds typical of the forest interior, while similar but isolated forest fragments were not. Johnson and Adkisson (1985) noted that blue jays used vegetated fencerows as travel routes apparently because they afforded some escape cover from hawks. Wegner and Merriam (1977) found that small mammals and many birds travel more frequently along fence hedgerow corridors than across open fields. Wildlife populations in isolated blocks of forest have been shown to have lower growth rates than populations in forest blocks tied together by corridors (Fahrig and Merriam 1985).

The relevance of wildlife corridor management to the Wekiva River Basin lies in the presence of a large number of parks and preserves in the area. Many wildlife species in Rock Springs Run State Reserve, Wekiva Springs State Park, Lower Wekiva River State Reserve, and Kelly Park will be adversely affected if an adequate corridor is not preserved. While several types of corridors have been defined (Forman and Godron 1981), two are perhaps most important for a discussion of the Wekiva River Basin. "Line" corridors are narrow and are entirely edge habitat, while "strip" corridors are wide enough to maintain interior conditions. This distinction between edge and interior habitat is important (see previous discussion on edge effects) as some interior species cannot live or even migrate through extensive edge habitats (Forman and Godron 1981). Edge effects are a function of corridor width. Beyond the deleterious effects of edge, width also has other effects on corridor function. A wide corridor may provide actual habitat for an animal while a narrower one may simply provide a travel route. A study of cypress domes showed that certain species of birds were excluded from smaller cypress domes (McElveen 1978). Stauffer (1978) found that bird species richness increased significantly with the width of wooded riparian habitat, where some species were restricted to wider strips. Tassone (1981) reported similar results from a study of hardwood leave strips. Interior forest species such as Acadian flycatchers were only infrequently found in corridors less than 50 m. Hairy and pileated woodpeckers required minimum strip widths of 50 to 60 m, while the parula warbler required at least 80 m. He suggested that leave strips must be a minimum of 100 m on larger streams to take advantage of their intrinsic wildlife value. Corridors which provide habitat should be much more effective in connecting larger habitat blocks than those which only provide paths for travel. Forman (1983) has stated that width is the most important variable affecting corridor function.

An upland buffer along the Wekiva River floodplain would maintain the width of the corridor, allowing it to function more efficiently as a wildlife corridor. This would be particularly true where the river floodplain is narrow. Narrow sections may act as barriers through which some animals are reluctant to pass. An upland buffer would allow continued movement and provide a refuge for some terrestrial wetland species during periods of high water. It would also encourage use of the corridor by upland species which do not make regular use of wetland habitats (Forman 1983).

In addition to providing dispersal pathways for animal wildlife, floodplain corridors are also important in plant dispersal. Flood waters collect and disperse large numbers of seeds from both wetland and upland plants (Wolfe 1987, Schneider and Sharitz [in press]). This dispersal of upland seeds may be very important in maintaining the diversity of upland plant species on topographic highs or islands within the floodplain (Schneider and Sharitz [in press]). Wharton et al. (1982) noted that these upland areas within the floodplain are very important for wildlife habitat. Upland seeds carried onto the floodplain originate in the wetland-upland ecotone and from smaller tributaries feeding the river. Protection of this ecotone, which may extend 10 to 35 m in Florida (Hart 1981), and the adjacent upland would ensure continued input of seeds to the floodplain.

In summary, width is probably the most important variable affecting corridor function (Forman 1983). Several forest interior species are known to be excluded when corridor width falls below a critical level, which is a function of edge effects and home range requirements. Increasing the width of the Wekiva River corridor by maintaining an upland buffer can only increase its effectiveness in providing both a travel route for dispersing wildlife and high-quality habitat.

II.A.7. Between-habitat Needs of Wildlife

Between-habitat needs refer to wildlife utilization of more than one habitat type to fulfill their requirements. Several authors have substantiated the close association and interaction of wildlife in wetland and adjacent upland communities. Fredrickson (1978) reported that various species more commonly associated with either wetlands or uplands depend on seasonal or daily shifts into different habitat types to escape flooding, to forage, to disperse, or to hibernate. Examples that he cited are turkey, river otter, swamp rabbit, deer, bobcat, and gray fox. Other species such as raccoon, gray squirrel, tree frogs, and many woodland bird species occur with similar frequency in both wetlands and uplands.

Bottomland hardwoods are integrally coupled to the surrounding uplands (Wharton et al. 1982). Terrestrial lowland fauna may be coupled to the uplands; for example, deer base their home range in floodplains and graze in uplands. Conversely, upland forms such as the black racer, slimy salamander, and pine vole may use the floodplain during drydowns. Although many species breed in both habitat types, their densities may differ considerably between adjacent areas. However, the lower-density populations may serve as important recruitment sources. The greenbelts of bottomland hardwoods also provide routes for migration and restocking.

Many semiaquatic Florida turtles, such as the mud turtle and snapping turtle, loaf and feed in marshes but need sandy upland sites to lay eggs (Weller 1978). The river cooter is an example of a turtle which is largely confined to water but must trek to adjacent uplands to deposit eggs (Patrick et al. 1981). Documented cases of Florida aquatic turtles laying eggs several hundred yards from a river are not uncommon (P. Moler, Florida Game and Fresh Water Fish Commission, pers. comm.). Weller (1978) also indicated a need for more information relating to the wetland-upland interface. He wrote, "Upland areas often serve as buffers, nesting areas, or food resources for wetlands wildlife but their relative importance is undocumented."

The eastern indigo snake is classified as a wetland species but frequently occurs in dry, sandy areas (Kockman 1978). Speake et al. (1978) found that indigo snakes concentrated on the higher ridges of sandhill habitat during winter and moved down into streambottom thickets in summer. Shelter provided by gopher tortoise burrows is critical to the survival of this snake while it is in upland areas.

Many wildlife species need both uplands and wetlands to satisfy their food requirements. Peak mast production occurs at different times of the year in uplands and lowlands (Harris et al. 1979). Winter and spring is the fruiting season for most bottomland species, while upland plants bear fruit in the summer and fall. Correspondingly, both upland and wetland nesting birds often concentrate in wetland areas during the non-nesting season (Wharton et al. 1981). Landers et al. (1979) found that black bears also respond to seasonal differences in mast production. In North Carolina, they shift their food preferences from predominantly bottomland species in the winter and spring to predominantly upland fruits and nuts in summer and fall. Florida bears primarily inhabit swamps in the center of the state but are long distance travellers utilizing both wetlands and uplands (Williams 1978). They eat acorns, palmetto berries and the terminal bud ("swamp cabbage") of the cabbage palm.

Wild turkeys may be found in a variety of wet and dry habitats and normally depend on acorns as a staple food in Florida. But they also have been known to eat crawfish occasionally. (Wild turkeys were recently reintroduced into the Rock Springs Run State Reserve on the Wekiva River.) During the egg-laying season, female wood ducks eat a large percentage of invertebrates obtained from the wetland-upland transitional areas (Fredrickson 1979). Pileated woodpeckers nest and roost primarily in wet hardwoods and cypress habitats but forage in uplands (Hoyt 1957, Jackson 1978). Conner et al. (1975) did not find any pileated woodpecker nest trees farther than 150 m from water in southwestern Virginia.

Jennings (1951) observed that gray squirrels in the Gulf Hammock region of Levy County, Florida, were dispersed through all habitats while food was plentiful in the fall. When red maple and elm began to bud and produce seed in mid-January, the squirrels began to concentrate in the hydric hammocks and swamps to utilize this food source. As upland foods became available in the spring and the lowland areas flooded, the squirrels moved to higher elevations.

Kantola (1986) found higher fox squirrel densities in ecotone or transitional areas than in upland areas on the Ordway Reserve in Putnam County, Florida. But she also reported that home-range size and use within ecotones and uplands may vary with seasonal food abundance, reproductive activity, and climate.

Between-habitat needs may vary among sites because of differences in habitat quality. More than 33% of the 30 small vertebrates species caught by pit-fall traps in the floodplain of the Chattahoochee River in Georgia were classified as upland species (Wharton et al. 1981). In contrast, only 14% of 21 small vertebrates sampled by the same method along the Alcovy River in Georgia received the same classification. This dissimilarity was attributed to vegetation structural differences in the floodplain.

Numerous researchers have been interested in the response of small mammals to flooding. Most studies concluded that floodplains were marginal habitats for these species. However, Batzli (1977) found that Illinois floodplain populations of the white-footed mouse were remarkably similar in density, adult survival, and age structure to those in the adjacent upland areas. The exchange of individuals between these two communities consisted mainly of a few floodplain mice occasionally moving into the uplands. He suggested that mature trees with abundant holes and cavities may be necessary refuges for small mammal survival during flooding.

In a blackwater creek bottom in South Carolina's inner Coastal Plain, Gentry et al. (1968) found that the abundance of the cotton mouse, short-tailed shrew, and southeastern shrew were 2, 3, and 10 times greater, respectively, in the bottomland hardwood than in the adjacent uplands. Golden mouse specimens were collected only from the hardwoods.

Because wetlands are often the last lands to be developed, some species normally considered upland wildlife are sometimes forced to adapt to wetlands that can supply their habitat needs (Schitoskey and Linder 1978). When uplands required by animals are destroyed, animals may concentrate in the nearby wetlands. Ozoga and Verme (1968) reported that deer mice, which are usually abundant in uplands, were also found in wetlands. White-tailed deer, an edge species, is known to adapt well to the swamps and lowland areas (Verme 1961, Verme 1965, Sparrowe and Springer 1970). Weller and Spatcher (1965) found that upland bird species such as the meadowlark and mourning dove nested in unflooded portions of wetlands.

High densities of prey species also attract adaptable upland predators such as the skunk, raccoon, and red fox. Bailey (1971) found that striped skunk densities were greater in narrow wetlands than in adjacent uplands where cultivation and other development adversely affected upland feeding sites. This situation is suspected to cause an abnormally high predation rate on waterfowl eggs by skunks.

Bobcats in the Welaka Reserve showed a preference for bottomland hardwoods (Progulske 1982). More than 20% of the 269 recorded locations of two radio-collared bobcats from July 1980 to December 1981 were in this type of overstory habitat. Although the other locations were spread among seven different upland habitat types, their need for wetlands is obvious.

Melquist and Hornocker (1983) found that although Idaho otters generally followed stream beds, they often took shortcuts across peninsulas formed by stream meanders. Overland travel of up to about 3 km was recorded. Extensive cross-country movements considerably reduced the distance an animal would normally have had to travel to reach the same destination by water. However, these movements also subjected the animals to highway hazards. Three of nine known mortalities were road-kills. In Great Britain, Chanin and Jefferies (1978) reported that in some areas dead otters were found repeatedly at the same location on roads over a number of years.

In a report that synthesized extant literature for southeastern bottomland hardwood swamp habitats, Wharton et al. (1982) stated that bottomland animals do not occur in the same distinct zonal pattern as plants ranging from aquatic to upland ecosystems. Wetland wildlife inhabitants move freely into irregularly flooded or dry zones over the year. They also noted that some overlap among zones occurs, especially in the transitional areas characterized by periodic annual flooding and a duration of flooding during a portion of the growing season. Their examples of overlapping species that might occur along the Wekiva River are mole salamander, slimy salamander, narrowmouth toad, spadefoot toad, cricket frogs, chorus frogs, box turtle, five-lined skink, southeastern five-lined skink, brown snake, garter snake, ribbon snakes, rat snakes, kingsnake, southern black racer, coachwhip snake, barred owl, downy and red-bellied woodpeckers, cardinal, turkey, common yellowthroat, wood thrush, eastern wood peewee, white-breasted nuthatch, Swainson's warbler, carolina wren, yellow-throated vireo, cotton mouse, golden mouse, short-tailed shrew, least shrew, southeastern shrew, woodrat, marsh rabbit, pine vole, and eastern mole.

The use of various bottomland hardwood ecological zones by wildlife differs by species, season and flooding regime (Larson 1981). Some are site specific during the breeding period while at other times they may use a broad range of ecological zones. Larson also referred to many of the species examples used by Wharton et al. (1981).

Many studies have documented utilization of adjacent uplands by wetland wildlife species. Removal or alteration of this important habitat type could destroy critical requirements for many species and thus render the riverine system in that area no longer habitable for them.

II.A.8. Within-habitat Needs of Wildlife

Within-habitat needs refer to requirements of wildlife species within the habitat areas they occupy. Habitat alterations and land use changes can affect adjacent resident wildlife populations by fragmenting habitat to nonfunctional sizes and shapes and by introducing disturbance factors above the tolerance levels of some species. Because of the paucity of Florida-specific data, we authors have included information from research conducted in other states. Although not actual descriptions of local species/habitat relationships, there is no reason to believe that similar situations do not exist in Florida.

Temple (1986) found that 16 of 43 bird species encountered on 49 Wisconsin study areas occurred less frequently, if at all, in smaller-sized forest fragments. Fragment-sensitive birds did not occur regularly in fragments that were large in total area but lacked a secure core area more than 100 m from edges at which forest adjoined non-forested habitat. Large stretches of linear habitats without sufficient core areas were not utilized by sensitive species which included three (hairy woodpecker, pileated woodpecker, and acadian flycatcher) that have been recorded in a partial listing of Wekiva wildlife residents (Florida Dept. of Environmental Regulation, 1983). Of the 13 other sensitive species, it is highly likely that six (tufted titmouse, blue-gray gnatcatcher, wood thrush, yellow-throated vireo, American redstart, and hooded warbler) nest along the Wekiva and the remaining seven (least flycatcher, veery, chestnut-sided warbler, cerulean warbler, ovenbird, mourning warbler, and scarlet tanager) overwinter along the Wekiva. Stauffer and Best (1980) predicted that the scarlet tanager would be absent from riparian strips in Iowa less than 200 m wide.

Galli et al. (1976) and Stauffer (1978) found the number of breeding bird species increased significantly with the width of wooded habitats in New Jersey and Iowa. Of the 46 species recorded in New Jersey, 18 were size-dependent species, limited to a particular range of forest sizes from the largest down to a specific minimum size. The minimum areas varied from 0.8 to 10.3 hectares and are considered characteristic of each species. As the habitat size increased, new species appeared when their minimum habitat size requirements were fulfilled. An example of a size-dependent species that requires a large wooded riparian habitat is the red-shouldered hawk. This species, which is a common year-round resident in Florida, was not found in any of the New Jersey sites less than 10.3 hectares (about 25 ac). Of the 32 species that occurred in Iowa wooded riparian habitats, 16 restricted breeding to relatively wide plots.

Bird species diversity is also strongly influenced by vegetation composition and structural heterogeneity or diversity within a habitat type (MacArthur et al. 1962, MacArthur 1964, Weller 1978). This type of heterogeneity is a function of foliage height and cover diversity. The vertical and horizontal stratification of plants within a forest habitat is positively correlated with the number of bird species that reside there. Therefore, land-use conversion of the most diverse portion of a wooded riparian habitat would have significantly greater negative impacts on the overall avian community than conversion of the least diverse portion. Transition or ecotone areas containing both wetland and upland plant species are typically the most diverse (Wharton et al. 1982).

Fragment-sensitive species or species that require large tracts of undisturbed, closed-canopy forest are also referred to as interior species. Tassone (1981) found that many forest interior bird species in Virginia were most common in riparian buffer widths above a mean value of 62 m, and certain species occurred very infrequently below different minima. Examples are the northern parula (80 m), yellow-throated vireo (70 m), Louisiana waterthrush (60 m), hairy and pileated woodpeckers (50 to 60 m), and acadian flycatcher (50 m). All of these species also breed in Florida's riparian areas. Tassone (1981) concluded that several other species, observed too infrequently to estimate width requirements, may also be sensitive to buffer width. He suggested:

> Until more extensive research is done, strips should be left 60 or more meters in width if it is desired to provide breeding habitat for these species. They should also be situated as corridors between other hardwood and pine-hardwood stands whenever possible. Strips located on larger streams should be 100 or more meters in width to make full use of the intrinsic wildlife values associated with the riparian zone.

Small and Johnson (1985) recommended that riparian buffer strips be 75 m wide to protect woodland bird communities in Maine. Johnson's (1986) study of the tolerance levels of some woodland breeding species supported this suggestion.

Fragmentation also affects squirrel populations. In an eastern Texas study of clearcut effects conducted two to four years after tree harvest, gray and fox squirrels were abundant in mature woody riparian zones wider than 55 m but were rare in riparian zones narrower than 40 m (Hedrick 1973). The highest squirrel density index was calculated for the widest stringer study plot (185 m).

The home-range size requirement for an individual gray squirrel is about two acres (Burt and Grossenheider 1964). Larger Wekiva wildlife residents require larger areas. For example, home-range sizes for individual gray foxes and bobcats in Welaka, Florida, is about 625 and 4,580 ha, respectively (Progulske 1982). Any actions that reduce suitable contiguous habitat below these home-range sizes will prevent individual animals from occupying those areas. Of course, viable self-sustaining wildlife populations require considerably larger home ranges than do of individuals.

Aside from the fragmentation factor, various human activities may alter behavior patterns or cause undue stress to some wildlife individuals in adjacent habitats. This is a relatively new aspect of wildlife biology, and very little research data are available regarding the effects of specific human activities on different wildlife species.

Noise associated with construction, operation, and maintenance of developments can cause harmful impacts on wildlife. Animals that rely on their hearing for courtship and mating behavior, prey location, predator detection, homing, etc., will be more threatened by increased noise than will species that utilize other sensory modalities. However, due to the complex interrelationships that exist among all the organisms in an ecosystem, direct interference with one species will indirectly affect many others. Unfortunately, few data are available that demonstrate the effects of noise on wildlife. Much of what is found in the literature lacks specific information concerning noise intensity, spectrum, and duration of exposure.

A few laboratory studies have documented decreased nesting and aversion reactions of small mammals in response to various sound frequencies (Sprock et al. 1967, Greaves and Rowe 1969). Other research has focused on the use of noise for damage or nuisance control. Diehl (1969), Crummett (1970), Hill (1970), and Messersmith (1970) reported on the success of using sound to repel rodents, bats, rabbits, deer, and birds.

The Environmental Protection Agency (1971), Ames (1978), and others have reported on the physiological responses of laboratory and farm animals to different noise stimuli. These data suggest that chronic sound may cause stress on wild animals which in turn may affect reproduction.

Most people can easily relate to auditory interference, annoyance, hearing damage, sleep interference, and stress-related effects of noise. And in response to public demands, many noise-control ordinances have been enacted to reduce these adverse impacts. However, it is doubtful that these laws sufficiently protect wildlife species.

van der Zande et al. (1980) found that breeding densities of three open grassland bird species were significantly reduced within 500 m of quiet rural roads and 1,600 m of busy highways in The Netherlands. They suggested that disturbance is also caused by farms, other buildings, and plantations.

Although Robertson and Flood (1980) found no significant differences in several vegetation variables between developed and undeveloped sites along Ontario shoreline areas, bird species diversity was negatively correlated with disturbance. A greater number of species was found in the natural areas than along shorelines where cottages were present and boat use was high. Several species which also nest in Florida (yellow-billed cuckoo, yellow-throated vireo, American redstart, and pileated woodpecker) were more abundant in, or restricted to, the less disturbed transects.

The Florida Game and Fresh Water Fish Commission is in the process of developing habitat protection guidelines for threatened and endangered species to provide land-use decisionmakers with recommendations and management practices that would integrate protection for these habitats in the context of large-scale developments. Many of these recommendations will address within-habitat needs such as those identified in <u>The Recovery Plan for the Bald Eagle</u>

in Florida (Murphy et al. 1984). This U.S. Fish and Wildlife Service document states that no human activity should occur within 750 ft (250 m) of active eagle nests and that the building of housing developments should be restricted within 750 to 1,500 ft (500 m) of active nests. Potential bald eagle nesting sites are currently abundant along the Wekiva.

Predation and harassment of wildlife by cats and dogs are other detrimental effects of development adjacent to wildlife habitat areas. Although relationships between domestic animals and wildlife are not fully understood, there is enough information in the literature to justify a legitimate concern. Several authors have documented the occurrence of wildlife prey in the diets of free-ranging cats and dogs and the effects of their predatory behavior on individual wildlife animals and populations (Errington 1936, McMurry and Sperry 1941, Bradt 1949, Hubbs 1951, Parmalee 1953, Eberhard 1954, Korschgen 1957, Smith 1966, Corbett et al. 1971, Gilbert 1971, Jackson 1971, Gavitt 1973, George 1974, Gill 1975, van Aarde 1980).

Cats can be especially devastating on local wildlife populations. Hunting is a feline instinct, and predation rates are not related to hunger (Davis 1957, Holling 1966, Holling and Buckingham 1976). Bradt (1949) reported that a single cat, who regularly consumed domestic food, killed over 1,600 mammals and 60 birds in Michigan during an 18-month period.

van Aarde (1980) found that free-ranging cats associated with households utilized open fields, edges, and timber areas. Home range sizes for females and males were 30 to 40 ha (about 100 ac) and four to eight square km (about four sections), respectively. In an Illinois study, the average home range for females and males was 112 and 228 ha, respectively (Warner 1985). These free-ranging rural cats spent about 40% of their time on farmsteads. Approximately

73% of the radiolocations of these cats occurred in edge areas such as roadsides, field interfaces, farmstead perimeters, and waterways.

Beck (1973) reported that the average home range for free-ranging dogs in Baltimore was about four acres. Schaefer (1978) reported that dogs in rural Iowa traveled up to two miles to kill pastured sheep.

Alteration of natural vegetation or other components of wildlife habitat may make modified areas unsuitable for some species. As these unsuitable areas encroach upon natural areas, core habitat fragments become smaller and the number of supported species is reduced. Various forms of disturbance can also adversely affect adjacent wildlife populations. An upland buffer would reduce or eliminate negative disturbance impacts associated with development.

II.B. Review of Buffer Zone Regulations

In this section methods and models for determining requirements and physical dimensions of buffer zones are presented. Buffer zones are normally considered to protect quality and wetland-dependent wildlife and to reduce the potential for negative impacts on a wetland resulting from adjacent upland development.

The determination of buffer requirements (i.e., widths in relation to land use, soils, topography, etc.) for the most part are not quantitative, but rely on what is felt to be qualitative evidence for the necessity of buffering development impacts. Never-the-less, there are numerous rules and regulations that have been promulgated throughout the country that require buffers around wetland areas.

The Pinelands Area

One of the most noteworthy buffer zones is that developed by the New Jersey Pinelands Commission. The Pinelands Area (also known as the Pine Barrens) is an area of about 445,000 ha of an interrelated complex of uplands, wetlands, and aquatic communities in southeast New Jersey. It is a largely undeveloped region within the Northeast Urban Corridor and was designated as the country's first National Preserve in 1978. In the next year the State of New Jersey passed the New Jersey Pinelands Protection Act that in essence called for the preservation, protection, and enhancement of the significant values of Pinelands land, water, and cultural resources.

In response to both federal and state legislative mandates, the Pinelands Commission developed a Comprehensive Management Plan to preserve and protect the unique and essential character of the Pinelands ecosystem. In the plan, wetlands protection is fostered through a regional land allocation program, a land acquisition program, and a wetland management program. The management program prohibits most development within wetlands and also requires an upland buffer around wetlands. The required "transition or buffer area" established between proposed development and adjacent wetlands measures 300 ft wide, and except for those regulated uses which have been described, no development may occur within the area.

Rationale for the width of the Pinelands buffer is derived from areal nutrient dilution models (Harlukowicz and Ahlert, 1978; Trela and Douglas, 1979 and Browne 1980) that were used to predict the travel distance necessary for groundwaters laden with nutrients (from septic tank leachate) to be diluted to background levels. Depending on the values used for input variables to the model, it predicted distances to attain background concentrations of 2 mg/l NO_3-nitrogen of between 325 ft and 600 ft.

Since the implementation of the Pinelands Comprehensive Management Plan, 327 development applications that involved wetland issues have been reviewed by the Pinelands Commission. More than one third of these were considered inconsistent with the plan because they proposed development within wetlands or within 300 ft of wetlands (Zampella and Roman, 1983).

Figures compiled by Zampella and Roman (1983) show that more than over half of the development applications that involved wetland issues were consistent with the wetland management provisions of the plan. However, among the conditions imposed on these projects was the need to establish and maintain a buffer adjacent to wetlands. Approximately one third of these applications were required to maintain the maximum buffer of 300 ft, while the remainder were required to maintain variously sized buffers which averaged about 135 ft in width.

The Pinelands scheme of determining wetland buffers uses a Wetlands Buffer Delineation Model that evaluates relative wetland quality, and relative impacts of development. Prior to evaluating wetland quality a determination of the presence of threatened or endangered species is made, and if the wetland is known to support resident and/or breeding populations and if the wetland area is critical to their survival, the wetland is ranked having the maximum relative wetland value index and is, assigned a buffer of 300 ft. The following qualities, values, and functions are evaluated as part of the wetlands evaluation scheme and are evaluated after determination of presence of threatened and/or endangered species is made:

Vegetation quality,
Surface water quality,
Potential for water quality maintenance,
Wildlife habitat, and
Socio-cultural value.

Each of the five general factors listed above has a score from 1 to 3, where 3 is high value. A wetland is scored for each factor, and scores are summed and divided by 5 to obtain a Relative Wetland Value Index.

Next, Potential for Impacts is evaluated by ranking the following factors:

> Potential for site-specific wetland impacts,
> Potential for cumulative impacts on a regional basis, and
> Significance of watershed-wide impacts.

Once ranked, the scores for each of the potential impact factors are summed and divided by 3 to obtain an average score for the Relative Potential for Impacts Index.

To assign buffer areas, the final step is to average the Relative Wetland Value Index and the Relative Potential for Impacts Index to obtain a Buffer Delineation Index. This final index is used to determine the buffer distance in three different Land Capability Areas using a table of assigned values.

The strengths of the methodology are: (1) Wetland attributes and the potential for on- and off-site impacts are evaluated for each individual wetland and each development proposal on a case-by-case basis. Depending on the type of wetland, existing terrain, existing land use designations, and type of development, the buffer varies from a minimum of 50 ft to a maximum of 300 ft. (2) The method is quantitative and repeatable thus insuring some degree of consistency. (3) It does not require detailed scientific information about a wetland.

State of Nev Jersey

The House of the State of New Jersey has passed a bill whose short title is "Freshwater Wetlands Protection Act." As of this writing the State Senate has not acted upon the bill the ace would establish

> ...a transition area adjacent to all wetlands having the following purposes:

(1) Ecological transition zone from uplands to wetlands which is an integral portion of the wetlands ecosystem providing temporary refuge for wetlands fauna during high water episodes, critical habitat for animals dependent upon but not resident in wetlands, and slight variations of wetland boundaries over time due to hydrologic or climatic effects:

(2) Sediment and stormwater control zone to reduce the impacts of development upon wetlands and wetland species.

The bill would also establish the width of the transitional area as no greater than 150 ft and no less than 75 ft for freshwater wetlands of exceptional resource value, no greater than 50 ft and no less than 25 ft for freshwater wetlands of intermediate resource value, and no transitional area for wetlands of ordinary resource value. The act prohibits the following activities in transition areas:

Removal, excavation or disturbance of the soil;
Dumping or filling with any material;
Erection of structures;
Placement of pavements; and
Destruction of plant life which would alter the existing pattern of vegetation.

New York State Wetlands Protection Act

The recent adoption of the Freshwater Wetlands Act (6 NYCCR) protects wetlands 12.4 ac or greater in size. The Act recognizes ten specific functions and benefits which freshwater wetlands provide for the public and for the environment. To achieve the goals of the Act to protect, preserve, and conserve New York's freshwater wetlands, the statute makes provisions for mapping, classification, regulation and local government protection. The act provides for the regulation, of a 100-foot buffer adjacent to wetland boundaries. Provisions exist in the law to extend the 100-foot adjacent area if necessary to protect the wetland.

California Coastal Act of 1976

The California Coastal Act (Public Resources Code, Division 20) established the California Coastal Commission which in turn prolmugated the Statewide Interpretive Guidelines (SIG) to assist in the application of various Coastal Act policies to permit decisions. The SIG has set standards for siting development adjacent to environmentally sensitive habitat areas (ESHA). Wetlands are considered environmentally sensitive habitat areas, as are estuaries, streams, riparian habitats, lakes, and portions of open coastal waters. "Adjacent to" is defined as situated near or next to, adjoining, abutting, or juxtaposed to an ESHA. This usually means that any proposed development in an undeveloped area within of up to 500 ft of an ESHA will be considered to be adjacent and subject to critical review.

Criteria for establishing buffer areas around ESHA's are designed to provide essential open space between the development and the ESHA. Development allowed in a buffer area is limited to access paths, fences necessary to protect the habitat area, and similar uses which have either beneficial effects or at least no significant adverse effects. The buffer is not itself part of the ESHA, but it is a "screen" that protects the habitat area from adverse environmental impacts caused by development. Widths of buffer areas are variable depending upon site analysis. It is usually a minimum of 100 ft; however, it may reduce for small projects (defined as single family home or one commercial office building). Additionally, provisions are suggested that the 100 ft may be reduced if the applicant can demonstrate that it is not necessary to protect the resource. Standards for determining the appropriate width of the buffer area:

1. Biological significance of adjacent lands,
2. Sensitivity of species to disturbance,
3. Susceptibility of parcel to erosion,
4. Use of natural topographic features to locate development,

5. Use of existing cultural features to locate development,
6. Lot configuration and location of existing development, and
7. Type and scale of development proposed.

Humboldt County, California

Humboldt County's Southcoast Plan defines riparian corridors and limits development within them. It defines riparian corridors to include the uplands on both sides of streams as follows:

> Riparian corridors on all perennial and intermittent streams shall be, at a minimum, the larger of the following: (i) 100 ft, measured as the horizontal distance from the stream transition line on both sides; (ii) 50 ft plus four times the average percent of slope, measured as a slope distance from the stream transition line on both sides; (iii) where necessary, the width of riparian corridors may be expanded to include significant areas of riparian vegetation adjacent to the corridor, slides, and areas with visible evidence of slope instability, not to exceed 200 ft. (Humboldt County Planning Department 1981, as cited by Ray et al. 1984)

Uses in the riparian corridor have been limited to minor facilities, minimal timber harvest, maintenance of existing facilities, residential wells, road and bridge replacement, and tree removal for disease control. There must be, at a minimum, replanting of vegetation for any approved disturbance, and any trees that have visible evidence of current use as nesting sites by hawks, owls, eagles, osprey, herons, or egrets must be retained.

Massachusetts Wetlands and Floodplain Protection Act

The Massachusetts Wetlands and Floodplain Protection Act recognizes three types of wetlands: 1) land areas bordering water bodies; 2) land under water bodies; and 3) land subject to tidal action, coastal storm flowage, or flooding. These wetlands must border on a listed water body with 50% or more wetland vegetation or within the 100-year floodplain. Permits are required for virtually any development activity in, near, or affecting jurisdictional areas. Work within a 100-foot buffer zone around wetlands may require a permit since the Act defines "bordering" as a distance of 100 ft. The regulation provides that the extent of protection is to be 100 ft landward from wetland resources or 100 ft landward from the water elevation of the 100-year flood, whichever is greater.

<u>Rhode Island Coastal Resources Management Program</u>

The General Laws of the State of Rhode Island, Title 46, Chapter 23, establishes the Coastal Resources Management Council (CRMC). The CRMC has developed the Coastal Resources Management Program. The Program establishes setbacks ranging from 50 to 180 ft from the inland boundary of coastal features such as beaches, wetlands, cliffs, banks, rocky shores, and existing manmade shorelines and apply to the following activities:

Filling, removal, grading;
Residential buildings;
Sewage disposal systems;
Industrial, commercial, recreational structures; and
Transportation facilities.

The setback minimum in areas not designated as Critical Erosion Areas is 50 ft, and within Critical Erosion Areas it is 30 times the calculated average annual erosion rate, which has been determined to vary between 75 and 180 ft.

In addition to setback requirements, the program establishes Buffer Zones defined as land areas on or contiguous to a shoreline feature that is retained in its natural and undisturbed condition by the applicant. Buffer zones must be tailored to on-site conditions and the specific alterations and activities that are taking place. Further, the determination of the boundaries of a buffer zone need to balance the property owners' rights to enjoy their property with the Council's responsibility to preserve and, where possible, to restore ecological systems. There are four benefits of buffer zones as follows:

1. Erosion control,
2. Prevention of water body pollution,

3. Preservation and enhancement of scenic qualities, and
4. Protection of flora and fauna.

The buffer zones are established according to values and sensitivities of the site as assessed by the Council's staff engineer and biologist, and the area may be wider than the setback distance. The buffer must be maintained by the applicant as an undisturbed area and in its natural condition.

Marion County, Florida

The Board of County Commissioners of Marion County, Florida adopted an emergency ordinance (Marion County Ordinance No. 73-4) in June of 1973

> "...prohibiting dredging, filling, earth moving, and landclearing, and underbrushing except mowing, pruning, and care of existing lawns and planted trees and shrubs for a distance of 500 ft from the water's edge upon either side of Rainbow River or Blue Run in Marion County, Florida, between Rainbow Springs and the northern city limits of the city of Dunnellon...."

Cross Creek Buffer Requirement

In an amendment to its Comprehensive Plan, the Alachua County Commission adopted a 300-foot setback line from lakeshores for most development in a designated area in the southeast part of the county known as Cross Creek. The only construction allowed within the setback zone are structures such as docks built for access to the lake. The setback line is measured upland from the jurisdictional line set by the Department of Environmental Regulation or the St. Johns River Water Management District, or, where the lakeshore has been cleared, from the 100-year floodplain line. The setback width of 300 ft was determined qualitatively. The plan amendment is currently being rewritten. A new version expected to be completed by the second week of October 1987, may require a variable setback line based on such factors as soils, slope, habitat, and groundwater, with a minimum setback of 75 ft. (John Hendricks, Alachua County Department of Environmental Services, pers. comm.)

Hillsborough County Wetland Buffer Requirement

A 30-foot buffer around "conservation areas" and a 50-foot buffer around "preservation areas" are required by Hillsborough County. The former category includes most freshwater wetlands and Class III waters; the latter includes saltwater wetlands, Class I waters, and critical habitats. These categories originated in the Conservation Element of the county's Comprehensive Plan adopted in the mid-1970s. That document set a policy to require "appropriate buffers" around those areas, but no width or formula to calculate width was set forth. However, in the definition of "natural shoreline"--another category of conservation area--a 30-foot width was mentioned as one way to delimit natural shorelines, and that number was applied by county zoning staff in rezoning applications involving freshwater wetlands. The larger buffer was required around preservation areas because they are considered to be more sensitive than conservation areas, but no formula was used to establish that width.

Both buffers were adopted by the Hillsborough County Commission in a 1985 ordinance (revised in 1987) and as part of its zoning code. A variety of uses are permitted within the buffer zone, such as detention ponds, stilted structures, and boardwalks, but impervious surfaces are prohibited. Removal of natural vegetation is discouraged but not prohibited. (Charner Benz, Hillsborough County Planning and Growth Management Group, pers. comm.)

II.C. Summary: Resource Buffer Zones

Effects of activities in the upland areas immediately adjacent to floodplain wetlands may be separated into three time-related catagories:

1. Direct and immediate impacts which occur during the construction phase,

2. Impacts which occur immediately following the construction phases during the period of stabilization, and

3. Long-term impacts that are permanent as a result of the alterations themselves or subsequent use and/or management of the altered areas.

These development impacts affect three broad sets of parameters normally considered of particular importance from a regulatory perspective. They include:

1. Water quality,
2. Water quantity, and
3. Aquatic and wetland dependent wildlife.

Thus each of these attributes may be affected during construction, immediately following construction, or in the long term through human uses and management.

Water Quality. The need for a buffer to insure that water quality is not degraded as the result of upland development in areas immediately adjacent to floodplain wetlands of the Wekiva River Basin is related to two potential sources of degraded waters. The first is sediments carried by surface waters from developed lands into down-gradient wetlands and waters. The second is dissolved pollutants and suspended particulate matter that degrade water quality through what might be termed chemical pathways. These include nutrients, pesticides, and particulate organic matter which increase nutrient loading, may be harmful to aquatic plant and animal life, or increase BOD. Both sources of degraded water may come from the result of runoff during construction, during the period immediately following construction as the landscape stabilizes, or as a result of urban stormwater runoff long after the period of initial urbanization.

Loss of valuable wetland functions as a result of sedimentation may be the most serious impact during construction activities. Sedimentation causes loss of soil properties and vegetation that are characteristic of wetlands and loss of wildlife habitat. In addition, sediments may carry significant amounts of pollutants and nutrients. Siltation and sedimentation of the wetland edge result from increased water velocities acting on soils susceptible to erosion, removal of ground cover in adjacent areas, or increased volumes of stormwaters entering the wetland that carry increased amounts of sediments.

Where the waterward lots of a development are not incorporated into the stormwater management system, the potential for long-term decreased water quality after the construction phase is related to surface runoff from driveways and lawns and groundwaters carrying increased levels of nutrients and pesticides/herbicides from lawn care practices. While the rule criteria of the District requires specific stormwater management practices to mitigate water quality impacts from stormwaters, the rules allow 10% of the developed area to be "unconnected," that is, to receive no treatment.

Water Quantity. The water flowing into the waters and wetlands of the Wekiva River Basin is derived from three general sources. The first is groundwater (or surficial groundwater) that becomes surface seepage where ground surface elevations intersect the zone of saturation. This usually occurs on inclines near the base of sandy slopes and is characterized by surface soils that are saturated, shallow ponding of seepage waters, and small seeps that coalesce into undefined flowing surface streams. The second source is surface runoff as sheet flow from adjacent higher ground during and immediately following rainfall events, and the third source from artesia flow of deep groundwaters.

Development in the zone immediately upland from the floodplain wetland edge may have dramatic impacts on the quantity of water from surface and surficial groundwater sources. Seepage is usually derived from rains that have recharged groundwaters in higher sandy soils and are moving downslope over a broad front thus, seepage areas tend to extend over the toe of the slope in a perpendicular line across the slope where the ground surface intersects the groundwater elevation. The site of seepage is usually dominated by floodplain vegetation. Alteration of the ground surface elevation through excavation in areas immediately upslope from the site of seepage may intersect the groundwater plain, and if positive drainage is maintained, can lower groundwater levels and essentially cut off further downslope seepage. If no positive outfall is maintained, the effects of excavations immediately upslope from seepage sites may have only minor impacts, since waters may be intercepted and discharged on the upslope side of the excavation, but may become groundwaters through recharge on the downslope side.

In most areas where seepage is present, groundwater elevations immediately upslope are quite near the soil surface and are not conducive to many land uses. General engineering practices in areas with high water tables is to lower water table elevations by drainage or raise ground elevations by filling to make such areas more suitable for development. While filling may have little impact on subsurface water flows, drainage has the overall effect of short-circuiting groundwater flows, cutting off potential groundwater seepage downslope, and increasing surface discharge elsewhere.

The effects of development on surface water flows in areas immediately upslope of the wetland edge are more easily seen and more direct. Impervious surfaces and sod increase runoff coefficients significantly over coefficients characteristic of natural lands. If these waters are not intercepted by a stormwater management system, they enter the wetlands and eventually the waters of the river. The increased volumes and velocities may cause significant degradation of downslope communities. However, under most development conditions, these waters are required to be routed through a stormwater management system, thus lessening the burden of the downslope communities. Yet these very requirements may in effect decrease sheetflow from rainfall events, since intercepted surface waters are routed elsewhere. The obvious implications of altered surface runoff and water quality have already been discussed.

The temporal differences of impacts on ground and surface water quantity before, during, and after construction may be significantly different. Construction practices may dictate that surface waters and groundwaters be routed differently than will be the case after construction, or that groundwaters be temporarily drained to facilitate construction activities. Once construction is completed and the stormwater system is under operating, the impacts on surface and groundwater quantity may vary little over time. Generally, stormwater discharge requirements within the Wekiva River Hydrologic Basin are designed to minimize negative impacts to surface waters through detention/retention, off-line treatment, and additional criteria. However, these requirements, and the fact that typically all lands within a project are engineered as part of the stormwater system, have the effect of isolating developed land. Contributions of overland flow runoff to downslope communities are minimized under such circumstances, since normal engineering practices are to discharge collected stormwaters at one or several point sources.

Aquatic and Wetland-Dependent Wildlife. Construction, operation, and maintenance of developed areas immediately adjacent to Wekiva River wetlands will result in both direct and indirect impacts on aquatic and wetland dependent wildlife. Noise during construction will interfere with vocalizations necessary for courtship, mating, prey location, and predator detection. Although this hindrance will be only temporary, there is no way to predict long-term consequences. After individuals disperse to less noisy territories, they may or may not return. Chronic and acute noises of occupied residential communities will cause less severe impacts. However, auditory interference and stress-related effects will still occur in close proximity to these developed areas. A vegetated buffer will help to attenuate harmful sounds.

Domestic animal harassment and predation on wildlife will also increase when pets are brought into adjacent developments. Development covenants and local laws usually require owners to leash their pets. However, the probability of a few free-ranging dogs and many free-ranging cats is quite high. Because cats tend to spend most of their prey-searching time in edge areas, an upland buffer will help to alleviate cat predation on wetland wildlife species.

Indirect impacts on wildlife will be related to habitat alteration resulting from construction. The removal of natural uplands vegetation adjacent to the wetlands will cause the originally mesic community along the outer edge of the wetlands to become more xeric. Drier community species will invade and eventually dominate this area. The ultimate result will be a reduction in the wetlands and a corresponding decline in those species that are wetland-dependent. In some areas, the width of the wetlands may become too small, and the species composition will change because those with larger spatial requirements will no longer be present. Increased predation and parasitism associated with sharp induced edges will also encroach farther into the forest.

Wetland-dependent species that require uplands to fulfill at least some of their life functions will extirpated from the Wekiva River Basin if there is no access to these uplands. An upland buffer adjacent to the wetlands will be needed to protect this necessary habitat element.

III. LANDSCAPE ECOLOGY OF THE WEKIVA RIVER BASIN

III.A. Landscape Perspective

III.A.1. Physical Description

Topography. The landscape of the Wekiva River Basin is a complex mosaic of wetland and upland habitats distributed over approximately 130 sq mi in north central Orange County, southeastern Lake County, and western Seminole County. The basin contains the physiogeographic province known as the Wekiva River Plain. Its topography is flat to gently rolling. Elevation declines towards the northeast, where the Wekiva Plain merges into the valley of the St. Johns River.

On the western side of the upper Wekiva River, the land slopes gently upward to the sandhills, from whence it rises abruptly to elevations of 120 to 195 ft above sea level. Sandhills and sloping terraces separate large tracts of swampy lowlands and determine the circuitous route by which the waters of Rock Springs Run State Reserve flow southeastward. These waters turn north below the confluence of Wekiva Springs Run and the Little Wekiva River. North of this confluence, the floodplain narrows and turns to the northeast above State Road 46. The floodplain broadens out again where the Wekiva River joins Blackwater Creek and the St. Johns River in the Lower Wekiva River State Reserve (DNR, 1985, 1987).

Along the west bank of the Wekiva River upstream (south) of its confluence with the Little Wekiva, elevation rises gradually towards the northwest from 15 ft above sea level along the river to approximately 35 ft above sea level.

Beyond the 35-foot contour, the land surface rises abruptly into upland sandhill tracts in the north central section of Rock Springs Run State Reserve. Downstream (north) of the Wekiva/Little Wekiva confluence, the floodplain narrows abruptly, and the flow gradient increases rapidly to 1.6 ft/mi. The flow gradient in this stretch of the central Wekiva River is one of the steepest in east-central Florida, and the elevation along this section of the Wekiva rises much more steeply above the narrowed floodplain than it does in the flat swamps of the upper and lower sections. The width of the Wekiva/Little Wekiva floodplain narrows to about 1,000 ft along the central portion of the river, decreasing rapidly from its maximum dimensions of about 5 mi east/west by 3 mi north/south in the Wekiva Swamp. The floodplain broadens out once again in the Lower Wekiva River State Reserve (near the confluence with Blackwater Creek) to a width of 1 mi at the Wekiva's confluence with the St. Johns River (DNR, 1985, 1987).

Blackwater Creek is a major tributary of the Wekiva which drains the watershed lying just north of the Wekiva Basin. Its watershed covers approximately 125 sq mi, nearly all of which is in southern Lake County. Blackwater Creek's headwaters are in Lake Dorr, and its floodplain varies in width from 800 ft at State Road 44A to over a mile along its upper and lower reaches. Another major tributary, Seminole Creek, joins Blackwater Creek at the eastern edge of Seminole Swamp. Seminole Swamp extends north and west from the confluence of Blackwater and Seminole creeks, covering an area of about 3 mi east/west and 1.5 to 2 mi north/south. This swamp lies between State Road 46A and State Road 44 in southern Lake County. Blackwater Creek flows into the lower Wekiva near the confluence of the Wekiva and the St. Johns. The waters of the Wekiva River Basin merge with those of the St. Johns and flow northward to enter the Atlantic Ocean at Jacksonville, Florida (DNR, 1985, 1987).

The wetlands of the Wekiva Swamp's northern end connect with the lower reaches of Seminole Swamp through a narrow wetland corridor (not shown on all maps) which bisects the lands lying above the west bank of the Wekiva River and the northern borders of Wekiva Swamp. This wetland strip is an extremely important feature of the basin. It provides a wildlife corridor through which animals can move between these otherwise disjunct wetland communities (see Noss and Harris, 1986).

The basin's diverse topography engenders a wide range of habitats, ranging from submerged aquatic plant associations to upland sandhill communities. Local soil characteristics and elevational effects combined with past and present disturbances influence the development of the various plant communities found within the Wekiva Basin.

Geology and Hydrology. The Wekiva Plain was formed by Pleistocene terrace sands deposited during times of elevated sea level which occurred during interglacial periods of the Pleistocene. The most recent extended saltwater incursion probably occurred during the Sangamonian interglacial about 100,000 to 200,000 years ago, when sea levels were about 20 ft above those of the present time (Bloom, 1983). Dunes were built up during the dry and windy periods of earlier and later glacial periods (Watts and Hansen, in press). These sands overlie the older marine limestones, clays, and marls of the Hawthorne Formation, which rest upon the deeper, porous Paleocene limestones and dolomites containing the Floridan Aquifer (Heath and Conover, 1981). The non-sedimentary bedrock of the Florida peninsula upon which these marine deposits have accumulated lies at least 4,100 ft below the present ground surface and ties in with the crustal rock of the continental plate.

Soils in the Wekiva Basin can be grouped in five associations. The Freshwater Swamp Association occurs in the Wekiva River floodplain and the disturbances to the natural vegetation and wildlife. Indeed, fire is an essential ecological component of several endemic plant communities native to the region.

Lakes and sinkholes are scattered throughout the basin as the result of the formation and subsequent collapse of solution cavities within the upper layer of the underlying Hawthorne Formation limestone bedrock. Sudden surface collapses due to sinkhole formation have in recent years swallowed buildings, automobiles, and sections of roads in the suburbs of nearby Orlando. The prevalence of sinkhole formations in the regions bordering the southern edge of the Wekiva Basin dictate caution in siting industrial and residential development.

The same forces which create sinkholes also created the many artesian springs for which the Wekiva Basin is renowned. The water in these springs comes from the Florida aquifer in deep Paleocene limestones and dolomites via faults in the overlying Hawthorne Formation. Crevices and solution channels have penetrated the otherwise impervious clay and marl layers of the Hawthorne Formation and dissolved the underlying limestone. These provide the means for developing surface outlets for artesian springwaters.

The major springwater sources of the upper Wekiva River are Wekiva Springs (48 million gallons per day [MGD]), Rock Springs (42 MGD), Sanlando Springs (14 MGD), and Sheppard Springs (11 MGD). More than two-thirds of the Little Wekiva River's flow is provided by a combined discharge of 14 MGD from Seminole, Palm, and Starbuck Springs. Springflows from the Floridan Aquifer comprise most of the Wekiva River's water volume, which averages 186 MGD at State Road 46 (DNR, 1985, 1987). Reductions in flow of several major springs during the past two decades have been attributed to water withdrawals from numerous deep disturbances to the natural vegetation and wildlife. Indeed, fire is an essential ecological component of several endemic plant communities native to the region.

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Two man-made springwells at Wekiva Falls with a combined flow of 40 MGD enter the Wekiva just south of State Road 46. Withdrawals from these deepwater wells may be partly responsible for the recent decrease in springflow volume from various natural springs in the Wekiva Basin. However, cutting off upstream springflows from Wekiva Falls may not have particularly adverse effects on lower Wekiva River wetlands. The proximity of this source to the confluence of Blackwater Creek and the St. Johns River and the steep flow gradient in this section of the Wekiva River tend to reduce the importance of this water source to the ecology of the Lower Wekiva Aquatic Preserve region. The natural channelling of the river into a relatively restricted wetland zone caused by the increase in flow gradient tends to mitigate the negative impacts on wetlands of the lower Wekiva River from reduced flows caused by the Wekiva Falls wells.

Further drawdowns in the regional water table due to over-exploitation of water resources from the Floridan Aquifer will have major impacts on the wetland habitats of the Wekiva Basin. Since about 70% of the Wekiva River's water comes from springs, any reduction in springflow volumes will adversely affect the size, distribution, character, and quality of state-domain wetlands, waterways, and aquatic habitats in the Wekiva Basin (DNR, 1987).

Climate. The Wekiva Basin lies in the southernmost latitudes of the humid subtropical climate zone of the southeastern United States. About two-thirds of the precipitation in the basin falls between June and September. On average, 10 to 15% of the annual rainfall occurs from December to February. Annual rainfall averages 52 inches, with most rain deposited during brief, heavy showers and thunderstorms (Heath and Conover, 1981). Tropical storms, including hurricanes, contribute on average about 15% of the precipitation from June to November. Rainfall events greater than 30 inches within a single 24-hour period have been recorded during hurricanes at some Florida locations, and such events are possible in the basin if a severe hurricane moves through central Florida (Yoho and Pirkle, 1985). Tornadoes are not uncommon in central Florida, and torrential rains and high winds typically accompany the storm fronts which spawn these dangerous and sometimes highly destructive storms.

The average temperature for the central Florida region is 72 degrees F.; ambient temperatures of 85 degrees F. or higher can occur during all months of the year. Arctic air masses sometimes penetrate into the region during winter months, bringing usually brief but occasionally intense episodes of sub-freezing temperatures (Yoho and Pirkle, 1985; Heath and Conover, 1981). Record freezes occurring during the past few years have devastated the citrus industry in Lake County and most of north central Florida. Tens of thousands of acres of orange groves were severely damaged or killed outright during sometimes week-long periods of sub-freezing temperatures. Whether these recent spates of unusually cold winter weather in central Florida represent a long-term trend toward harsher winter climates is unknown.

The effects of these hard freezes do not seem to be as severe on native wildlife and plants as they are on agricultural crops, with one major exception. Populations of manatees (<u>Trichechus manatus</u>) in northern and central peninsular Florida suffer high mortality rates from cold stress and related causes during extended periods of freezing weather (T.J. O'Shea, USFWS, pers. comm.; see O'Shea et al., 1985). Although the artesian springheads of the St. Johns River valley create warm water refuges (72 degrees F.) for manatees, the animals must leave areas of warmer water to feed. As food plants become increasingly scarce near warm-water refuges, manatees are forced to travel farther and farther in search of food, increasing their exposure to colder water temperatures and the risk of collisions with boats (see Hartman, 1979). Radio-tagged manatees from Blue Spring on the St. Johns River have been sighted in the Wekiva River, and residents have reported seeing manatees in the Wekiva (Beeler and O'Shea, 1978).

Solar insolation is generally high in central Florida. Clear skies predominate throughout much of the year, but morning ground fogs and rain clouds often reduce direct sunlight penetration for brief periods. The relatively high insolation and temperature regimes characteristic of Florida combine to produce high evapotranspiration rates. In peninsular Florida, surface water and groundwater losses to evaporation and transpiration may approach or exceed the amount of water gained from precipitation (Heath and Conover, 1981). The potential for such a water deficit demonstrates the importance of springflows from the Floridan Aquifer to the maintenance of surface-water levels in the Wekiva Basin. The preservation of existing wetland ecosystems in the central and upper Wekiva River Basin is absolutely dependent on continued supply of springflow waters at present levels (DNR, 1987).

III.A.2. Biological Description

Ecological Communities. The Wekiva Basin is a unique natural ecosystem. It lies in the zone where tropical and temperate floras overlap. Tropical plant species at the northern limits of their range grow side by side with temperate-zone plants (DER, 1983). The distribution of plant species in various plant communities varies according to specific site characteristics, and species typical of one community may frequently occur in another (see Hart, 1984). Some species have fairly rigid microhabitat requirements, while others occur in wide ranges of soil, shade, and moisture conditions. The soil characteristics and disturbance history of a given area may result in the anomalous presence or absence of species or species groups. A knowledge of prior disturbance history (fires, logging, farming, ranching, etc.) is important in determining the extent to which present vegetation conditions reflect native vegetation patterns or the presence of human-altered plant communities (Noss, 1985). For example, selective logging has greatly reduced the abundance of cypress trees in the mixed hardwood swamp community of Rock Springs Run State Reserve (DNR, 1985).

Rigid separations among plant communities do not typically occur within most natural biotas. The distinct edges (abrupt ecotones) associated with fire-maintained communities and human-altered landscapes are exceptions. For the most part, categories for community types are general constructs devised for analysis and identification of gross habitat characteristics. Despite the overlap between community types, these recognized associations reflect important biological differences among various communities and special interactions or interdependencies among the constituent species of each community.

The flows of numerous artesian springs from the Floridan Aquifer, together with groundwater drainage from the surrounding watershed, have created the vast network of stream channels and associated floodplains, lakes, and sinkholes which support extensive areas of hydric and mesic habitats in the Wekiva River Basin. The basin's landscape is dominated by wetland and lowland plant communities but is interdigitated by relatively limited and patchily distributed areas of transitional and upland habitats.

Deep-water and shallow-water herbaceous marsh communities inhabit the stream channels and flooded regions, grading into the hardwood swamp vegetation which also occurs on permanently flooded sites. Bottomland hardwood communities (swamps and bayheads) grade into hydric hammocks where groundwater seeps riverward from upland communities and into mesic hammocks and flatwoods in areas of higher elevation. Drier upland communities in the region include pine sandhill, xeric hammock, and sand pine/oak scrub. Sinks and ponded areas support cypress domes and patches of wet prairie and mesic hammock (DNR, 1985, 1987; Brown and Starnes, 1983).

Wildlife. Many of the Wekiva Basin's wildlife species are locally ubiquitous mammals which are common throughout the region or not restricted to one specific plant community or habitat type. These include black bear (*Ursus americanus*), white-tailed deer (*Odocoileus virginiana*), feral hog (*Sus scrofa*), bobcat (*Felis rufus*), river otter (*Lutra canadensis*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis marsupialis*), raccoon (*Procyon lotor*), two shrews, several bats, cotton mouse (*Peromyscus gossypinus*), wood rat (*Neotoma floridiana*), and two cottontail rabbits. Most of the ubiquitous species of the Wekiva Basin frequent swamps, and other species--including wood duck (*Aix sponsa*), pileated woodpecker (*Dryocopus pileatus*), and many songbirds--require forested wetlands for nesting and/or foraging habitats.

Many of these species require large expanses of diversified habitat mosaics. For example, black bears, sandhill cranes (*Grus canadensis*), and wild turkey (*Meliagris gallipavo*) need between-habitat diversity (presence of a patchwork of different habitats) within their home ranges to support the extensive daily or seasonal shifts in activity among various plant communities. Species such as bats, pileated woodpeckers, and water turtles, which typically forage and live within one habitat, may utilize quite different habitats for dispersal, reproduction, or hibernation. Other species, such as river otters, have large home ranges and travel widely among various habitat patches, even though most of their activities are conducted in one habitat type (in this case, aquatic wetlands).

In describing the faunal communities of the Wekiva Basin, the focus will be upon typical species associations within given habitat types. As noted in reference to plant communities, these associations are, for the most part, flexible. Overlaps and omissions in the presence of species within community types may occur. However, the upland communities of the Wekiva Basin are exceptional in having several characteristic and interdependent (commensal) species which are entirely restricted to specific upland habitats. The wetland faunal communities include many species of restricted distribution (such as fishes or the endemic snail and crayfish species), as well as a large complement of more freely ranging forms which utilize several wetland habitat types.

Aquatic wildlife communities are comprised of species which are largely or entirely dependent upon aquatic ecosystems (rivers, lakes, springs, ponds: places where standing or flowing water is present to some degree at any given time) for at least part of their life cycle. These communities include animals such as toads and tree frogs which spend their adult lives in terrestrial habitats but which require aquatic habitats for breeding and the development of young (larvae or tadpoles). Aquatic communities in the Wekiva Basin region support a great diversity of wildlife, ranging from microscopic protozoans and invertebrates to the massive American alligator. Literally hundreds of species of snails, mussels, crayfish, insects, fishes, birds, amphibians, reptiles, and mammals share aquatic habitats with a broad spectrum of aquatic plant life. The aquatic plant community provides critical resources such as food, shelter, and oxygen for animals in aquatic environments and is the base of the aquatic food chain.

The aquatic plant communities in the rivers, springs, and floodplains of the Wekiva Basin support populations of numerous fishes, including various types of bass, sunfish, mullet, catfish, pickerel, shad, crappie, perch, shiner, topminnow, killifish, molly, and bowfin (see appendix for scientific names of species not detailed in this discussion).

The wetland herpetofauna of the region is exceptionally diverse and contains many aquatic forms. Amphibians which are largely or entirely dependent upon aquatic habitats include sirens, amphiumas, newts, bullfrogs, pigfrogs, and leopard frogs. The largely aquatic reptiles of wetland habitats in the region include American alligators, softshell turtles, cooters, mud turtles, alligator snapping turtles, stinkpots, water moccasins, and several non-poisonous water snakes. In contrast to amphibians--which typically lay their eggs in water--reptiles need terrestrial or semi-terrestrial sites in which to incubate their eggs. Some reptile species (especially turtles) must travel some distance from the water into adjacent upland habitats to find patches of sunlit, sandy soil necessary for successful nesting.

Some of the invertebrates of the Wekiva Basin (including three endemic snails of the genus Cincinnatia and the threatened Wekiva Springs Aphaostracon snail) are restricted to springhead habitats. The threatened Orlando Cave crayfish is an endemic form restricted to habitats in the Little Wekiva River system. Other important invertebrates of the basin are apple snails and burrowing crayfish. The apple snail is the primary food of the limpkin, a large snipe-like bird found in wetland habitats that support populations of this golf-ball-size snail. Burrowing crayfish spend part of the year in vertical burrows which are dug in muddy soils in non-flooded wetland and transitional zones. Excavated soil from the burrow is formed into a nearly cylindrical cone rising as much as 6 inches above ground level. Crayfish emerge from these burrows periodically to forage and breed. Crayfish are an important food source for many larger vertebrates, including various fish, bird, and mammal species.

Many species of birds found within the Wekiva Basin are dependent upon aquatic and wetland habitats for foraging and/or nesting habitats. Osprey, anhinga, wood stork, egrets, herons, ibises, bitterns, ducks, snipe, gallinules, coot, limpkin, and grebes are characteristic of the open wetland and aquatic habitats of the region. Bald eagles (USFWS: Endangered; FGFWFC: Threatened) are expected to occur as transients in the aquatic communities of the area even if no resident individuals are known at the present time. The resident wood stork (Mycteria americana) has been classified as an endangered species by both state and federal agencies (FGFWFC, 1987). Sandhill cranes (threatened) utilize marsh, wetland, and upland sites in the Wekiva Basin. Other resident species such as the little blue heron (Florida caerulea), tricolored heron (Egretta tricolor), snowy egret (Egretta thula), and limpkin (Aramus guarauna) have been designated as Species of Special Concern (SSC) by the Florida Game and Fresh Water Fish Commission (FGFWFC, 1987). The wetlands bird community of the Wekiva region is exceptionally diverse. Encroachment upon wetland habitats will directly and indirectly affect these attractive and often highly visible components of the Wekiva Basin wildlife community.

Typical mammals of the aquatic marsh communities in this region include river otter, round-tailed muskrat (Neofiber alleni), raccoon, rice rat (Oryzomys palustris), and marsh rabbit (Silvilagus palustris). Otters and raccoons range widely among other habitats, while round-tailed muskrat, marsh rabbit, and rice rat are usually associated with marsh, swamp, or wet prairie communities.

The bottomland hardwood associations (hardwood swamp and bayhead communities) typically occur as closed-canopy woodlands which are distributed either as extensive wetland forests in flooded basins or as gallery forests along stream and lake margins. These communities represent a transitional gradient between strictly aquatic and terrestrial environments and retain characteristics of both. Consequently, the wildlife associated with swamp and bayhead communities includes species of both aquatic and terrestrial affinities. The Wekiva Basin swamps and bottomland hardwoods support not only numerous aquatic forms, but also many typically terrestrial animals, including black bear, white-tailed deer, turkey, opossum, gray squirrel (Sciurus carolinensis), cotton mouse, wood rat, gray fox (Urocyon cinereoargentus), and striped skunk. The Wekiva Basin and the nearby southern portion of the Ocala National Forest constitute perhaps the best remaining areas of suitable bear habitat in central Florida (DER, 1983). The Florida black bear (Ursus americanus floridanus) is unique among North America's extant black bear populations in that its large size is commensurate with that of the ancestral black bears of Ice Age times (Kurten and Anderson, 1980). Management strategies keyed to protection of black bear populations and habitat requirements should benefit virtually all other wildlife in the Wekiva Basin.

The largely terrestrial habitats of the uplands include pine flatwoods, pine sandhills, and sand pine/oak scrubs. Flatwoods are used by bear, deer, spotted skunk (Spilogale putorius), cotton rat (Sigmodon hispidus), cotton mouse, diamondback rattlesnake (Crotalis adamanteus), and various other ubiquitous species. Flatwoods provide good cover and shelter for animals that forage in adjacent habitats, move between habitats, and seek refuge from high floodwaters during storms. The truly upland habitats of the region are the pine sandhill and sand pine/oak scrubs of the dry dune-ridges. Typical wildlife species of these upland habitats include the gopher tortoise (Gopherus polyphemus, SSC) and its many associated commensal (interdependent) species, including the gopher frog (Rana sphenocephala, SSC), the Florida mouse (Peromyscus floridanus, SSC), and the eastern diamondback rattlesnake. Pocket gophers (Geomys pinetis; also known as salamander or sandy-mounder) occur in more open habitats of deep, well-drained, sandy soils on high ridges in the Wekiva Basin. Longleaf pine sandhills are the preferred habitat of the Sherman's fox squirrel (Sciurus niger shermani, SSC). This species has been decimated over the past century by logging of mature pines in the sandhill communities. Reduced populations survive in remnant turkey oak forests, and the species may occur around cypress domes in flatwoods and in a few other upland ecotone situations (DER, 1983). The logging of mature longleaf pines and conversion of sandhill communities into citrus and slash pine plantations have severely affected the structure, composition, and distribution of sandhill ecosystems. The preponderance of listed species among the typical wildlife of the once widespread sandhill community is an indication of the extent to which this habitat has been disrupted by development.

The sand pine/oak scrub community contains several highly specialized endemic species such as scrub lizard (Sceloporus woodi), sand skink (Neoseps reynoldsi, threatened), and Florida scrub jay (Aphelecoma coerulescens coerulescens, threatened). Many sandhill wildlife species also utilize scrub habitats and range freely between adjacent scrub and sandhill habitats. The acorns of various oak species common in these habitats are an important seasonal food for black bear, deer, turkey, and feral hog populations of the Wekiva Basin.

III.B. Wetland Communities

Wetlands habitats of the Wekiva Basin can be subdivided loosely into three major community types. These are the aquatic herbaceous marsh community of stream channels and springheads, the mixed hardwood swamp community of the river floodplains, and the hydric hammock community of groundwater and surface runoff seepage wetlands. Marshes and swamps are characterized by saturated or flooded soils which are subject to regular and extended periods of inundation by standing or flowing water. Hydric hammock soils are saturated but only occasionally inundated.

Marsh vegetation consists of submerged, emergent, and floating herbaceous plants. Swamp vegetation consists of water-tolerant trees and shrubs. Gradual shifts in plant species composition occur according to the regularity and depth of immersion for ground-level vegetation in floodplain habitats. The presence of surface water will greatly affect the types of wildlife species which are present at any given time.

III.B.1. Aquatic/Marsh Communities

The freshwater marshes of Florida are critically endangered. Freshwater marshes are vulnerable to changes in water levels, water quality, hydroperiod, and fire regimes. Drainage of marshes for development and agriculture has eliminated much of Florida's freshwater marsh habitat. Heavy recreational use, particularly when associated with off-road vehicle and boat traffic, can drastically alter the structure and composition of vegetation within marshes and inhibit the vital ecosystem functions of these communities.

The freshwater marsh is a critical resource for many species of birds, fishes, reptiles, mammals, and amphibians in the Wekiva Basin. Undisturbed areas of freshwater marsh provide excellent cover and travel routes for many wildlife species. The vegetation of freshwater marshes filters surface runoff that feeds rivers and lakes. Soil particles are trapped within the vegetation matrix, and plant roots stabilize the soil surface both above and below the water level. Dense rafts and mats of marsh plants protect the stream banks from strong current flows and help prevent erosion during periods of high water and storm floods. Marsh plants fix and store nutrients and soil particles filtering in from the surrounding landscape, thus helping to prevent eutrophication.

The deepwater marsh communities (Water Hyacinth/Coontail/ Watergrass: *Eichhornia*/*Ceratophyllum*/*Echinochloa*) are dominated by rooted or free-floating aquatic herbaceous plants, and they typically occur on permanently flooded sites with water depths of 3 to 6 ft (Brown and Starnes, 1983). This community is found in the main channels and deeper sections of spring runs in the Wekiva Basin, with maximum development in sites not shaded by streamside tree canopy. These high-gradient, fast-moving streams tend to flush out the organic debris and compounds which stain the waters of blackwater swamp systems. High flow rates and steep gradients also create clearwater stream conditions within large tracts of hardwood swamps.

The large springflows of the upper Wekiva River system generate clearwater alkaline streams with high flow rates and clean, sandy bottoms. These calcareous springflows are rich in phosphorous and other nutrients and support luxuriant aquatic plant growth. Other representative plants of this habitat include water lily (*Nymphaea odorata*), hydrilla (*Hydrilla verticullata*), water-lettuce (*Pistia stratioides*), and duckweed (*Lemna* spp.). The common water hyacinth (*Eichhornia crassipes*) is a weedy exotic which has invaded aquatic habitats throughout Florida. This species has become the dominant aquatic plant in many localities within the region, severely encroaching upon important native species such as eelgrass and coontail. Elimination of water hyacinth is a desirable but presently unachievable management goal.

Shallow-water marsh communities (Cutgrass/Maidencane/Cattail/ Arrowhead: Leersia/Panicum/Typha/Sagittaria) typically occur in sites which may be flooded only seasonally but which have water depths of 6 inches or more during the growing season (Brown and Starnes, 1983). Other representative species include sawgrass (Cladium jamaicense), sedges (Carex spp.), and rushes (Juncus spp., Elocharis spp., and Rynchospora spp.) These shallow-water herbaceous plant associations typically occur in the shallower sections of stream channels and along stream margins within the Wekiva Basin.

Wet prairie communities are similar to shallow marsh communities in terms of both their constituent species and flooding regimes. Water depths range from 0.5 to 2 ft in the growing season. Sometimes called grassy ponds, sloughs, or prairie lakes (DNR, 1985), the wet prairie is a grass/herb plant community associated with seasonally and permanently flooded areas of upland habitats (see below for a more detailed discussion of this community).

III.B.2. Mixed Hardwood Swamp Community

The shallower waters in floodplains and along the margins of lakes and streams in the Wekiva Basin support large tracts of swamp and bottomland hardwood vegetation. This community is comprised of cypress species and a variety of deciduous hardwood trees that grow on saturated and flooded soils. Nutrient availability is generally low, but wildlife habitat value is high. Swamps assimilate organic and inorganic wastes and pollutants, store water, and impede the movement of floodwaters. By slowing down the rate of water flow, swamps help to minimize erosion, promote infiltration, and facilitate the settling out of debris, silt, and nutrients carried by floodwaters. These functions improve water quality, stabilize water flows in streams and rivers, and help to maintain high groundwater levels in the region. Swamps provide habitat for many wildlife species and are used as travel corridors by wildlife in developed areas.

The mixed hardwood swamp (cypress/tupelo/water ash: *Taxodium*/*Nyssa*/*Fraxinus*) and bayhead (red bay/loblolly bay/pond cypress: *Persea*/*Gordonia*/*Taxodium*) community occurs on poorly drained sites which are regularly or permanently flooded (Brown and Starnes, 1983). Tannins and humic acids from plant debris color and acidify the waters in swamps and in their drainage streams. These blackwater systems tend to occur in the low-gradient streams and basins of cypress and hardwood swamps where organic debris accumulates on stream bottoms and in backwaters. Blackwater Creek is a typical example of this distinctive stream type.

Pure stands of cypress stands and old cypress trees are no longer common in the swamps of the Wekiva Basin. Old-growth cypress has been selectively logged from swamps throughout Florida during the past century (see DNR, 1985; Monk, 1968). Fluctuations in water level are required for cypress regeneration: cypress seeds must be soaked before they will germinate, but they will not germinate if they are underwater. Other important species of the mixed hardwood swamp are red maple (*Acer rubrum*), American elm (*Ulmus americana*), water hickory (*Carya aquatica*), buttonbush (*Cephalanthus occidentalis*), and bluestem palmetto (*Sabal minor*) (Brown and Starnes, 1983). The American elm was formerly common and widespread throughout eastern and central North America, but in the past century the introduction of Dutch Elm disease, an exotic pathogen, has nearly exterminated this species throughout much of its range (see Davis, 1981). However, this species still survives as a common element in the floodplain forests of the Wekiva Basin.

III.B.3. Hydric Hammock Community

In some areas between the mixed bottomland hardwoods and the upland communities along the Wekiva River, seepage of groundwater from uplands is the dominant source of water. The topography of these areas is flat, and the soils are poorly drained and almost constantly saturated with seepage water. Although subject to occasional flooding, the hydroperiod in hydric hammocks is shorter than in the adjacent swamps.

Hydric hammock communities support more plant species than any other wetland type in the Wekiva Basin. Among the species are popash (*Fraxinus caroliniana*), live oak, laurel oak (*Quercus laurifolia*), red maple, southern magnolia (*Magnolia virginiana*), red cedar (*Juniperus siliciola*), cabbage palm, saw palmetto (*Serenoa repens*), tulip poplar (*Liriodendron tulipfera*), pond pine (*Pinus serotina*), slash pine (*Pinus elliotii*), sweet gum (*Liquidambar styraciflua*) wax myrtle (*Myrica cerifera*), and several vines and ferns (Brown and Starnes, 1983). The hydric hammock is excellent wildlife habitat and is used by ubiquitous mammals and birds as well as by numerous reptiles and amphibians.

This community is very sensitive and vulnerable to changes in groundwater hydrology in upland areas. Drawdowns caused by nearby wells and diversion of groundwater via retention ponds and ditches in uplands can interrupt the supply of seepage water to hydric hammocks, causing the soil to dry out and, eventually, species composition to shift toward more mesic and fewer wetland species. Lowering the water table also makes hydric hammock more vulnerable to fire, a disturbance to which these ecosystems are not adapted.

III.C. Transitional Communities: Mesic Hammock and Scrubby Flatwoods

In the Wekiva Basin, the transitional communities between the wetlands and the uplands are largely ecotonal in character, occurring as edges or borders around the larger areas of swamp. Distinct separations between the swamp, bayhead, and lowland hammock communities occupying floodplain habitats of the Wekiva Basin are typically absent. Transitional species of the wetland/upland ecotone include hydric and mesic hammock forms such as cabbage palm, saw palmetto, tulip poplar, pond pine, slash pine, and sweet gum (Brown and Starnes, 1983).

Scrubby flatwoods associations form ecotones between the mesic flatwoods and the xeric sandhill and scrub communities. Scrubby flatwoods occupy sites which are sufficiently well-drained so that there is no standing water present even under extremely wet conditions. Pines (slash, sand, and longleaf) are typically present but scattered within a matrix of shrubby oaks and palmettos. Scrub oak (*Q. inopina*), Chapman's oak (*Q. chapmanii*), and sand live oak intermix with saw palmetto and scrub palmetto (*Sabal etonia*) to form a generally thick shrub layer 1 to 2 m high. Herbaceous cover tends to be sparse. Lichens (*Cladonia* spp.) and spike moss (*Selaginella arenicola*) provide considerable ground cover except on recently burned sites. Fire is important in determining the structure and composition of scrubby flatwoods vegetation, which is intermediate in character between flatwoods and sandhill/scrub communities.

III.D. Upland Communities

The drier, sandy soils of the uplands support scrubby flatwoods on their lower edges and longleaf pine sandhill and sand pine scrub on better-drained and slightly higher sites. Longleaf pine-turkey oak sandhills and sand pine-oak scrub are distinct in structure and composition from flatwoods communities. These communities occur as savanna or scrub formations on the well-drained upland soils of the Wekiva Basin and are subject to frequent burning. Differences in past burning regimes and local soil characteristics strongly affect the particular vegetation characteristics of these communities (see Kalisz and Stone, 1984). These habitats are home to a number of important endemic species and are particularly sensitive to changes in natural disturbance regimes (see Monk, 1968).

Upland habitats have been severely disturbed by past and present management practices, and major ecological components cannot become reestablished following certain types of human-caused disturbances (Means and Grow, 1985). In many respects, these specialized uplands communities are at the greatest risk from development at present (see Means and Grow, 1985). They occupy substrates and soils which are often preferred over those of wetland sites for agriculture, silviculture, industry, and residential development. As a consequence, few large tracts of native upland vegetation and wildlife survive at the present time. Those upland communities which remain have been subjected to major changes in vegetation regimes and wildlife species diversity as the direct result of human disturbance. Such human-caused changes in the ecology of upland terrestrial communities can greatly alter the movement of water, soil, and nutrients into adjacent wetlands and regional watersheds (see Odum, 1971, 1983).

III.D.1. Pine Flatwoods Communities

Flatwoods are fire-adapted communities which occur on moderately to poorly drained soils of terraced lands above the floodplain in areas subject to periodic burning. Wildfires tend to kill off most typical hardwood hammock tree species while leaving the fire-tolerant forms, especially pines and palmetto, as local dominants. Exclusion of fire will result in succession to bottomland hardwoods or mesic hammock on most flatwoods sites (Monk, 1968).

The dominant species in the basin's mesic pine flatwoods community are pines, scattered oaks, and saw palmetto (*Pinus* spp./*Quercus* spp./*Serenoa repens*). A dense shrub layer carpets the understory level. Pines of flatwoods habitats include longleaf pine, slash pine, and pond pine. Live oak and dwarf live oak (*Q. minima*) are often present. Saw palmetto is usually the dominant shrub species, with dwarf live oak, fetterbush (*Lyonia lucida*), staggerbush (*Lyonia fruticosa*), dwarf huckleberry (*Gaylussacia dumosa*), and wax myrtle as secondary components. Saw palmetto, threeawn grass (*Aristida patula*), greenbriar (*Smilax* spp.), and gallberry (*Ilex glabra*) are typical understory species.

Flatwoods often contain patchily distributed areas of cypress dome, bayhead, mesic hammock, wet prairie, sandhill, and scrub vegetation due to variations in topography, soils, and soil moisture regimes. Standing water may be present in flatwoods during periods of high precipitation and elevated groundwater levels.

Longleaf pine was formerly dominant on drier sites, while slash pine and pond pine tend to be dominant on more mesic soils. Repeated selective harvesting of longleaf pines, changes in fire regimes, and conversion of flatwoods and sandhills to agriculture during the past century have greatly affected the distribution and abundance of native longleaf pine communities (Monk, 1965, 1968; Means and Grow, 1985). Slash pine is now the dominant tree on many former longleaf sites. Pond pine becomes dominant in acidic, poorly drained flatwoods where soil pH is less than 4.5, while slash pine occurs primarily on more neutral soils (Monk, 1968).

III.D.2. Wet Prairie Communities

Wet prairies typically occur in sinks and depressions within areas of low topographic relief which receive water through runoff from adjacent higher ground. Patches of wet prairie vegetation are commonly found scattered throughout the flatwoods and sandhills of the region. Shrubs and small trees, such as primrose willow (*Ludwigia* spp.) and elderberry (*Sambucus simpsonii*), are sometimes present in wet prairies. Characteristic herbaceous plants include panicum grasses (*Panicum tenerum*, *P. dichotomum*, etc.), sloughgrass (*Scleria* spp.), swamp lily (*Crinum americanum*), and sundew (*Drosera* spp.). The wet prairie is fire-adapted, and frequent burning will maintain wet prairies on sites which would otherwise succeed to hydric or mesic woodland. These grassy patches increase habitat diversity in flatwoods landscapes and provide accessory foraging habitats for important wetland wildlife species. Because wet prairies are dependent on surface water runoff to supply water (Brown and Starnes, 1983), drawdowns of water tables in flatwoods by ditching can eliminate wet prairies and reduce habitat diversity in upland regions.

III.D.3. Pine Sandhill Communities

The pine sandhill community is a savanna-type formation of scattered trees and open woodlands having a well-developed ground cover of grasses, forbs, and scattered shrubs. Characteristic species are longleaf pine, turkey oak, and wiregrass (*Pinus palustris*/*Quercus laevis*/*Aristida stricta*). Fire is an important ecological component of sandhill environments and maintains the characteristic open pine woodland and sparse understory vegetation. Burns occur naturally in sandhill communities at about 3- to 5-year intervals, usually started by lightning strikes (Means and Grow, 1985). These frequent fires preserve the dominance of longleaf pine and inhibit succession to xeric hammock vegetation (Kalisz and Stone, 1984). Sand pine may also invade sandhill communities when fire is suppressed (Kalisz and Stone, 1984).

The upland dune formations of the Wekiva Basin are dominated by pine sandhill communities containing patchily distributed areas of sand pine/oak scrub (Pinus clausa/Quercus spp.) and xeric hammock. Pines and turkey oaks are typically the principal overstory components. The relative dominance of turkey oaks and pine species other than longleaf and the absence of old-growth longleaf in the region's sandhill communities are due to selective logging in these communities.

Sandhills have a more or less continuous herbaceous ground cover dominated by wiregrass. Shrubs and hardwoods other than oaks are typically present at low densities (Laessle, 1958). Other common plants of sandhill habitats are bluestem grasses (Andropogon stolonifera, A. tenarius), persimmon (Diospyros virginiana), prickly pear (Opuntia ammophila), blueberries (Vaccinium spp.), gopher apple (Chrysobalnus oblongifolius), and spike moss. Shrub rosemary (Ceratiola ericoides) is often common in sandhill communities but does not usually occur in dense stands. Individual rosemary bushes are usually ringed by narrow perimeters of bare soil. This phenomenon is caused by the release of an allelopathic chemical from the rosemary which inhibits the growth of other plants within its immediate vicinity.

The high primary productivity of sandhill habitats provides a rich food base for a wide variety of wildlife. Turkey oak acorns are important to mast-feeders such as deer, turkey, and feral hog. Sandhill communities support a characteristic fauna which includes Sherman's fox squirrel and gopher tortoise with its host of commensal wildlife species.

Sand pine scrub and oak scrub occur on various upland sites within the Wekiva Basin (DNR 1985, 1987). Sand pine and oak scrub are characterized by a mixed scrub oak understory dominated by scrub live oak, myrtle oak (Q. myrtifolia), and Chapman's oak (Q. chapmanii). Sand pine is variably present in the scrub habitats of the Wekiva Basin. Differences in burning and disturbance regimes probably account for the absence of sand pine in some scrub communities of the Rock Springs Run State Preserve (DNR, 1985). Shrubs such as staggerbush, rosemary, and wild olive (Osmanthus americana) may also be present. Scrub hickory (Carya floridana), a Florida endemic, is present in the scrub habitats of the Wekiva Basin. Common herbaceous plants of scrub habitats in the region include blueberries, gopher apple (Chrysobalnus oblongifolius), prickly pear (Opuntia compressa), spike moss, and wiregrass. Lichens (Cladonia spp., Usnea spp., and others) grow on patches of bare soil or as epiphytes on the bark of woody plants.

Patches of xeric hammock (live oak/sand live oak/red oak/American holly/deer moss: Quercus virginiana/Q. geminata/Q. falcata/Ilex opaca/Cladonia spp.) occur within the upland sandhill habitats. Pine sandhill and sand pine scrub communities will be succeeded by xeric hammock vegetation if the absence of fire is prolonged (Monk, 1968). Exclusion of fire allows regeneration of hardwoods and prevents the continued recruitment of pines. The leaf litter of xeric hammock plants is fire-resistant, so that patches of hammocks within large sandhill tracts typically remain unburned even though ground fires have spread throughout the surrounding pine-dominated landscape. The prevalence of natural and human-caused wildfires in the Wekiva Basin over the past centuries has limited the significance of this community type in the region.

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IV. STATUTORY & DISTRICT CRITERIA RELATED TO BUFFER ZONES

Questions have been raised concerning the authority of the District to enact requirements which restrict or preclude the construction and operation of systems within the Wekiva River Basin. The rulemaking related to the Wekiva Basin has been the subject of serious concern, and much debate has resulted. An earlier draft of the Wekiva Basin Rule had requirements that buffered the river from impacts, but was withdrawn following considerable controversy, and staff was directed to revisit the issue. Following several drafts of proposed language for buffer requirements, a Petition for Administrative Determination of Invalidity of Proposed Rule was filed that alleged the proposed rule constitutes an invalid exercise of delegated legislative authority or is otherwise invalid.

The statutory authority granted the Governing Board of the District related to the enactment of requirements that restrict or preclude the construction, operation, or maintenance of systems is clearly stated, but somewhat general. Broad rulemaking authority has been granted by the Legislature (Chapter 373, FS). The Board may adopt reasonable rules that are consistent with the law and reasonably necessary to effectuate its powers, duties, and functions. Rules adopted by the Board must be reasonably related to the purposes of Chapter 373. The Board cannot act in an arbitrary and capricious manner and should have before it competent and substantial evidence to support a proposed rule.

Two questions related to the statutory authority given in Chapter 373 (FS) have occurred to us. First, in Sections 373.413 and 373.416 the Legislature enacted two statutory provisions related to water management systems; the former addressing construction of systems and the later addressing operation and maintenance of systems. As a result, an arbitrary distinction is made between construction and operation and maintenance. Second, the statute does not provide a definition for the term "water resources."

IV.A. Statutory Criteria, Sections 373.413 & 373.416, FS

Sections 373.413 and 373.416 draw a distinction between permits required for construction or alteration of dams, impoundments, reservoirs, or works (373.413, FS) and permits required for maintenance and operation of same (373.416, FS). In the former, the District may require permits to assure that construction or alteration of any system will not be harmful to the water resources of the District. In the latter, the District may require permits to assure that the operation or maintenance of a system will not be harmful to the water resources of the District and will not be inconsistent with the overall objectives of the District. The distinction between the harm that may result from construction activities and harm that may arise from operation and maintenance is a confusing one in light of the review a permit application may receive. Can the District evaluate an application for construction based only on harm to water resources, or can the application also be evaluated relative to the overall objectives of the District?

Conceptually it may be relatively easy to separate impacts on water resources that result from development activities into those that occur during construction and those that may result from the operation and maintenance of that which has been constructed. From a resource management perspective, however, it is not an easy distinction to make. Determining the harm to water resources during construction and following construction is not too difficult, but what is difficult is separating the consideration of these potential impacts when determining if a permit for construction should be issued. To issue a permit for construction of a system or work and evaluate only the potential impacts to water resources without evaluating its impact on the overall objectives of the District once the system is in place is like basing the decision to operate on a patient only upon his/her chances of living through the operation, with no regard as to whether the organ removed is essential for survival after the operation. The distinction is an artificial one at best.

If the overall objective is to manage the water resources of the District and insure that the construction, operation, and maintenance of works are not harmful to them, the District must evaluate potential harm resulting from operation and maintenance concurrently with potential harmful impacts resulting from construction. Foregoing sections of this report have established that while impacts caused by construction and those resulting from operation and maintenance can be separated for discussion purposes, they are intimately interconnected, and they must both be considered if the potential impacts are to be evaluated, understood, and resolved. To manage the water resources of the District effectively, all relevant information and potential consequences of any decision must be evaluated during application review. To do otherwise cannot possibly result in effective resource management.

In this light, when the District reviews a construction permit, not only should potential harm to water resources be evaluated (Chapter 373.413 FS), but District staff should also determine if it is consistent with the overall objectives of the District (Chapter 373.416 FS).

The second question is also important in permit evaluation. In evaluating a permit for construction and/or operation and maintenance, the District strives to assure that the system or work will not be harmful to the water resources of the District. In a narrow sense, water resources can be thought of as the water only. Then harm would constitute affecting the quality or quantity of water (the abiotic substance). In a broader sense, however, water resources must be thought of as not only the water (the H_2O) but as the combined biotic and abiotic components--the ecological system of plant and animal life and abiotic elements that are the whole resource. It is not easily dissected or decomposed into two distinct parts for the purposes of management, since the quality of the resource is a complex functional interrelationship of abiotic substances and living organisms. The management of one aspect without regard for the other may at times run counter to sound management of the whole.

A working definition of water resources should include the entire resource, and may be something like the following:

> Water Resource - The combined abiotic substances and biotic organisms that constitute the aquatic systems of ground and surface waters.

IV.B. Rule Criteria, 40C-4, 40C-41 and 40C-42, FAC

Chapter 40C-4, FAC, implements the permitting program in a manner that is consistent with the objectives and policies of the St. Johns River Water Management District and the declared water policy of the State of Florida. In essence it declares that surface water management permits will be required prior to the construction, alteration, operation, maintenance, removal, or abandonment of any dam, impoundment, reservoir, appurtenant work, or works. To obtain a permit, each applicant must give reasonable assurance that such activity will not adversely affect navigability, recreational development, or public lands; endanger life, health, or property; **adversely affect the availability of water**; be incapable of being effectively operated; adversely affect existing agricultural, commercial, industrial, or residential developments; **cause adverse impacts to the quality of receiving waters; adversely affect natural resources, fish, and wildlife**; increase the potential for damage to off-site property or the public; increase the potential for flood damage; or otherwise be inconsistent with the objectives of the District, among others (emphasis added). The chapter also establishes size thresholds for which permits are required.

In addition to the above, the District's Applicants Handbook states that State Water Policy (Chapter 17-40, FAC) is used as guidance to determine harm to water resource and that consideration should be given to the impacts of facilities on recreation; navigation; **water quality; fish and wildlife; wetlands, floodplains, and other environmentally sensitive areas**; saltwater or pollution intrusion; reasonable beneficial uses of water; **minimum flow levels**; and other factors related to the public health, safety, and welfare; among others (emphasis added).

Further, the Handbook states that the District recognizes that

> ...wetlands are important components of the water resource because they serve as spawning, nursery and feeding habitats for many species of fish and wildlife, and because they provide important flood storage and water quality benefits.

Review criteria are provided to determine whether a system will meet District objectives regarding hydrologically related environmental functions. Except when threatened or endangered species are involved, the District will only consider off-site impacts on aquatic and wetland-dependent species relative to the functions currently being provided by the wetland to these types of fish and wildlife. An applicant must provide assurance that a proposed system will not cause changes in the habitat of off-site aquatic and wetland-dependent species; the abundance and diversity of off-site aquatic and wetland-dependent species; and the food sources of off-site aquatic and wetland-dependent species.

Chapter 40C-41, FAC establishes basin-specific surface water management permitting criteria for the Wekiva River Basin that are in addition to the District-wide criteria specified in Chapters 40C-4 and 40C-40, FAC. The Wekiva River Basin Rule was adopted in March 1987, establishing permitting standards as follows:

1. RECHARGE - Three inches of runoff from all directly connected impervious areas must be retained within the project area for projects or portions of projects in Most Effective Recharge Areas. As an alternative, applicants may demonstrate that the post development recharge capacity is equal to or greater than the pre-development recharge capacity.

2. STORAGE - A system may not cause a net reduction in flood storage within the 100 year floodplain of a stream or other watercourse which has a drainage area upstream of more than one square mile and which has a direct hydrologic connection to the Wekiva or Little Wekiva Rivers or Black Water Creek.

Definitions of Most Effective Recharge Areas and directly connected impervious areas are given in 40C-41, as follows:

> ...Most Effective Recharge Areas have been defined by the U.S. Geological Survey as areas which have 10-20 inches of recharge per year... Most Effective Recharge Areas can be more accurately defined by soil types. The Soil Conservation Service has categorized soils according to hydrologic characteristics. Those soils determined by SCS to be Type "A" Hydrologic Soil Group shall be considered to be Most Effective Recharge Areas...Directly connected impervious areas are those impervious areas which are connected to the surface water management system by a drainage improvement such as a ditch, stormwater, paved channel, or other man-made conveyance. Stormwater that is retained must be infiltrated into the soil or evaporated such that the storage volume is recovered within 14 days following a storm event.

In addition, when stormwater management systems discharge to Class I, Class II, or Outstanding Florida Waters, Chapter 40C-42, FAC provides for further treatment of stormwaters as follows:

> (10) Stormwater discharge facilities which directly discharge to Class I, Class II, and outstanding Florida Waters shall include an additional level of treatment equal to fifty percent of the treatment criteria specified in Section 40C-42.035(1) (b) or Section 40C-42.041(5) and shall provide off-line retention or off-line detention with filtration of the first one-half inch of run-off of the total amount required to be treated.

In all, the criteria in 40C-41, and 40C-42 recognize the special values of the water resources of the Wekiva River Basin and were designed to afford additional protection. Rule criteria are generally designed to protect water resources (both quality and quantity of surface water and quantity of recharged groundwater) as a result of the construction, operation, and maintenance of a work or system. In most instances, however, specific construction techniques and specific engineering of a project's stormwater management system are not adequately addressed by criteria simply because these are outside the purview of the review criteria. Language may be inserted in conditions for permits that require particular attention be paid to minimizing impacts during construction from erosion and siltation, for example, but "accidents do happen." In other words, there are two significant potential gaps in the rule criteria related to water quality that an appropriately designed buffer rule will overcome. The potential gaps are as follows:

1. Water quality impacts resulting from construction activities in the areas immediately adjacent to wetland; and

2. Water quality impacts resulting from portions of projects constructed adjacent to wetlands, but not directly connected to the stormwater management system.

While the existing rule criteria recognize the importance of recharge in the Wekiva River Basin to maintain both the quality and quantity of groundwaters, the "discharge" of groundwaters that are of particular importance to maintenance of ecologically significant hydric hammocks and floodplain wetlands of the Basin is not addressed in the present rules. These wetland systems are particulary sensitive to the lowering of the groundwater table. The District's policy regarding the lowering of groundwater tables found in Section 10.6.3 of the Applicants handbook states:

> It is presumed that an adverse impact will result if the system causes the groundwater table to be lowered; a) more than an average three feet lower over the project area than the average dry season low water table; or b) at any location, more than five feet lower than the average dry season low water table; or c) to a level that would drain adjacent surface water bodies below a minimum level established by the Governing Board pursuant to Section 373.042, FS.

In most instances, in areas adjacent to the floodplain wetlands of the Wekiva Basin a lowering of the water table from 3 to 5 ft would severely impact hydrologic functions, draining groundwater, disrupting seepage regimes, and diverting surface waters. The net result would be the disruption of ecological functions and loss of wildlife habitat. Thus a third potential gap in the protection of the water resources of the Wekiva River Basin and the importance of the groundwater table to seepage and floodplain wetlands that an appropriately designed buffer may overcome is as follows:

3. Water quantity impacts resulting from excavations and general lowering of the groundwater table in areas adjacent to seepage wetlands.

Finally, while it is the policy of the District to evaluate permit applications using review criteria that expressly states consideration should be given to impacts on fish and wildlife, wetlands, floodplains, and other environmentally sensitive areas, present rule criteria in 40C-41 or 40C-42 do not address these factors. Recognizing the special significance of the wetland and wildlife resources of the Wekiva River Basin, a fourth potential gap in protection of the resources may be overcome with an appropriate buffer as follows:

4. Impacts to flora and fauna resulting from loss of habitat and disturbance as a consequence of construction, operation, and maintenance of systems in areas adjacent to wetlands.

Further discussion related to water quality and water quantity issues is given next to better explain the rationale for recommending a buffer to minimize negative impacts of development in areas immediately adjacent to the wetlands and watercourses of the basin.

Water Quality Issues. The potential for significant degradation of water quality during construction is directly related to the proximity to the resource and the type of construction activity. Given in Figure IV.1 is a plan view of an area along a section of river typical of the Wekiva River. The figure illustrates a typical wetland/upland interface and two typical residential development patterns. In the first type of development, lots and housing units are built up to the wetland line, and some clearing of canopy and understory is required. In the second type of development, because the wetland/upland edge is generally the lowest elevation of the project site, retention/detention basins are constructed along the edge, requiring complete removal of vegetation and excavation. Both development patterns could be constructed under current permit criteria.

Where lots and house construction occur adjacent to the wetland edge, typically, the downslope areas are wholly or partially excluded from the stormwater management system. This results from the fact that the edge of the floodplain generally is the lowest elevation, and either the back of lots must be filled to elevations so that surface waters flow toward the front of the lot, or the back portions of lots are excluded from the management system. The size of lots on the floodplain edge dictate to a large degree how much land is excluded from the management system and allowed to sheetflow stormwaters downslope to the wetland edge. While this development pattern may minimize disturbances along the edge from clearing and digging, surface waters running downslope from these areas are not subject to treatment by the stormwater system and can cause significant water quality problems both in the short term during construction and in the long term during use and management.

If the area upslope from the wetland edge is to be excavated for detention or retention ponds, initial clearcutting, additional heavy equipment for digging, and placement of spoils contribute additional potential water quality problems. The clearcutting required exposes soils to even greater erosion potential since all vegetation must be removed and the ground surface is scraped clean in preparation for digging equipment. The heavy equipment associated with excavations and earthwork necessary to contour basin side slopes and surrounding lands contribute to significant potential construction-related "accidental infringement" into the downslope wetlands/water resources. Finally, spoil placement in adjacent areas and filling along the wetland line expose the downslope wetland/water resource to potential sedimentation from newly excavated non-stabilized soils.

Figure IV.2 is a cross section of a floodplain swamp, transition zone, and uplands typical of portions of the Wekiva River Basin. In the top drawing the undisturbed condition is shown. In the bottom drawing the effects of clearing and construction activities in areas immediately adjacent to the wetland line are summarized. Under these conditions, protective ground cover and litter are scraped off the soils, leaving them bare and easily washed downslope during construction. The resulting erosion and deposition will significantly affect

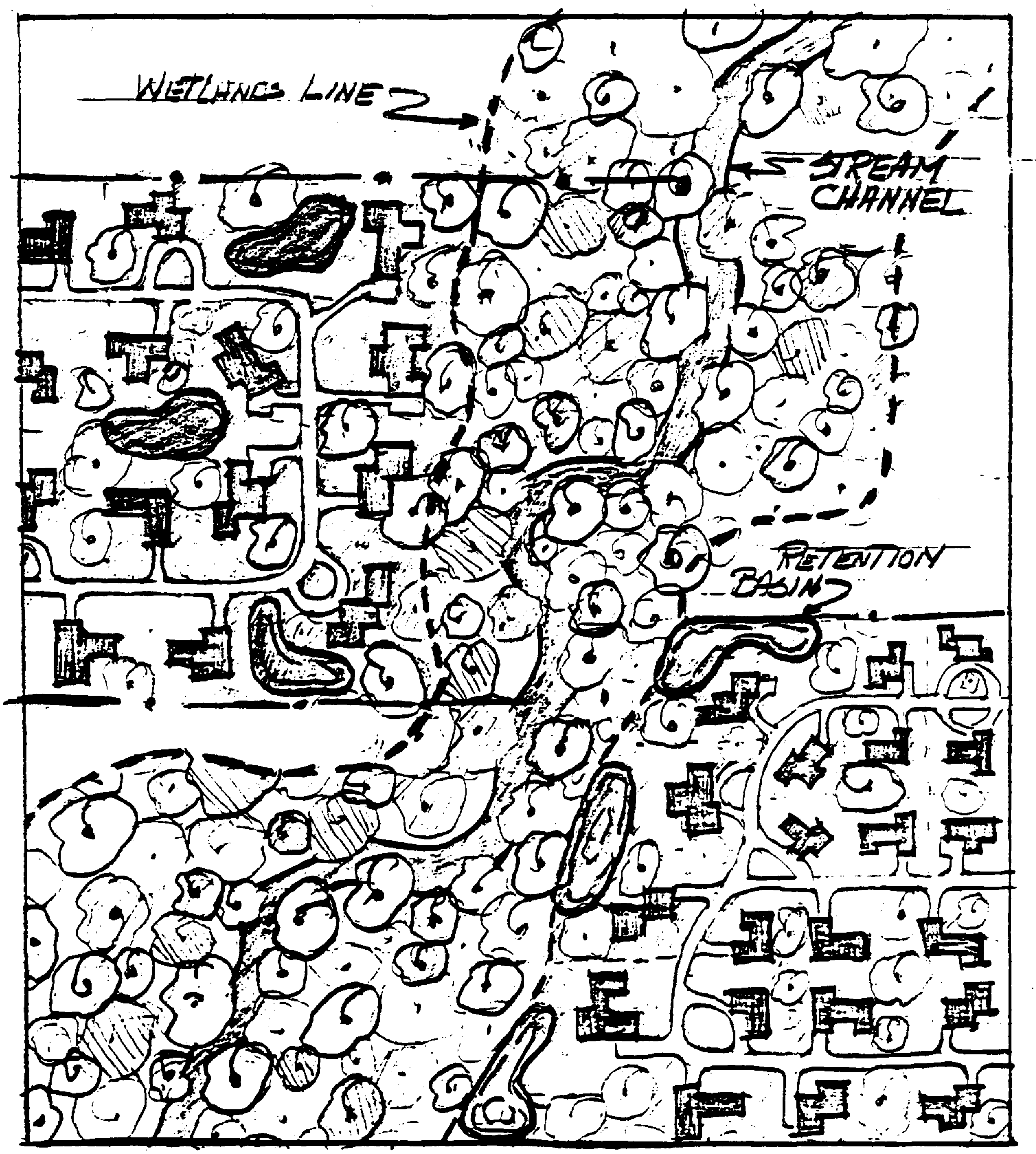

Figure IV.1. Drawing of two development patterns typical of the Wekiva River Basin. The development pattern in the upper portion of the drawing has housing down to the wetlands line and stormwater retention/detention ponds in the upland portions of the development. The development in the lower portion of the drawing has stormwater retention/detention basins constructed immediately adjacent to the wetlands line. The former development scheme minimizes water quantity impacts, but may cause water quality impacts. The latter scheme will impact water quantity, but storm water system may minimize water quality impacts.

those wetlands/water resources that are waterward of the construction line. While precautions might be taken, such as installation of barriers to impede and/or filter silt laden runoff, there is no assurance that the precautions will be effective or that they will remain in place long enough for the area to stabilize.

Degradation of water quality as a result of construction and long-term runoff from developed lands may be easily avoided by providing a construction setback or buffer that can act as a sediment trap, dissipate destructive velocities, and minimize water quality problems through filtration of surface runoff.

Water Quantity Issues. Criteria in 40C-4, 40C-41, and 40C-42 related to water quantity are generally concerned with recharge of groundwaters in areas of significant recharge potential and with surface runoff patterns. Not protected and of special significance in river systems like the Wekiva are seepage at the base of sandy slopes that maintain saturated soils and standing and flowing surface waters at seepage locations.

Shown in Figure IV.3 are the groundwater relationships of the sandy, well-drained ridges along the upland fringes of the Wekiva floodplain and the seepage areas at their bases. It is at these seeps that groundwaters become surface waters and contribute base flow to the Wekiva. In the natural condition waters exiting at the seepage edge are typically low in nutrient content, having recharged through the sparse scrub vegetation of the sandhills and filtered through several hundred (or thousand) feet of well-washed sand. Upon exit from the soil, the newly emerged surface waters support a unique assemblage of vegetation (often referred to as a hydric hammock) adapted to constant saturation and periodic inundation with oligotrophic waters. The wetland line typically coincides or is just landward of these areas.

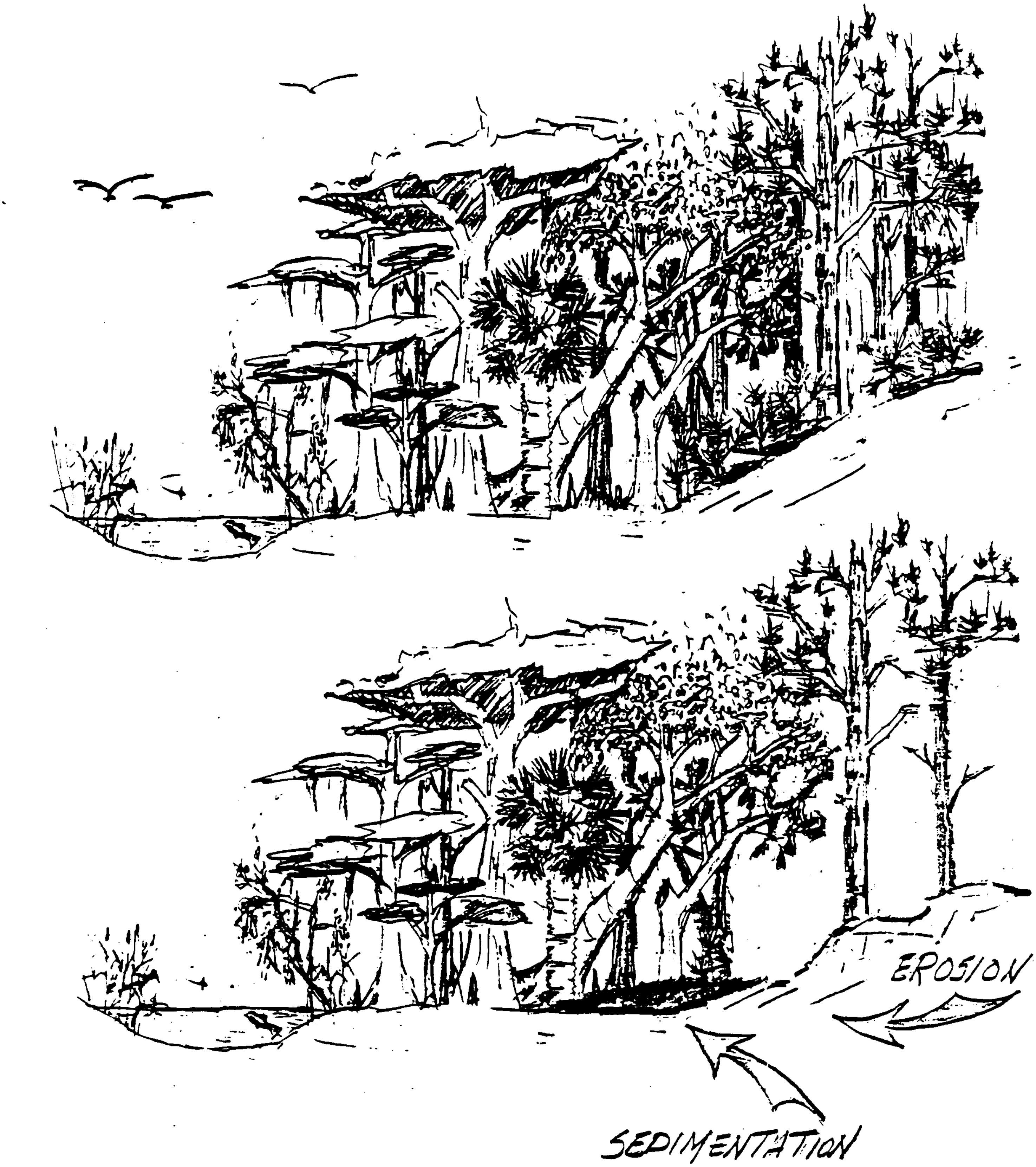

Figure IV.2. Cross section drawing of the floodplain and adjacent uplands showing the natural condition in the upper drawing, and the consequences of clearing and development in the bottom drawing.

The bottom drawing in Figure IV.3 summarizes the effects of excavations in the area immediately landward of the wetland line on the quantity of seepage water exiting in downslope locations. Where excavations are deep and interrupt groundwater flows, seepage areas are "robbed" of sustaining groundwaters, as they are routed through the stormwater management system and discharged at outfall points, or are exposed to surface evaporation in water retention/detention systems. The net effect on total quantity of water that may leave a project site when the effects of increased impervious surfaces and the stormwater management systems are factored in is not easily determined. However, it is quite apparent that the loss of seepage waters will significantly alter species composition in seepage wetlands and have potential consequences on dry season base flows of the Wekiva.

Potential negative consequences of lowered water tables and intercepted groundwater flow to downstream hydric hammocks and floodplain forests can be mitigated through implementation of a buffer zone requirement in the Wekiva Basin. While its function will be to insure high groundwater elevations in close proximity to seepage wetlands, it may also serve a role in insuring maintenance of high water quality.

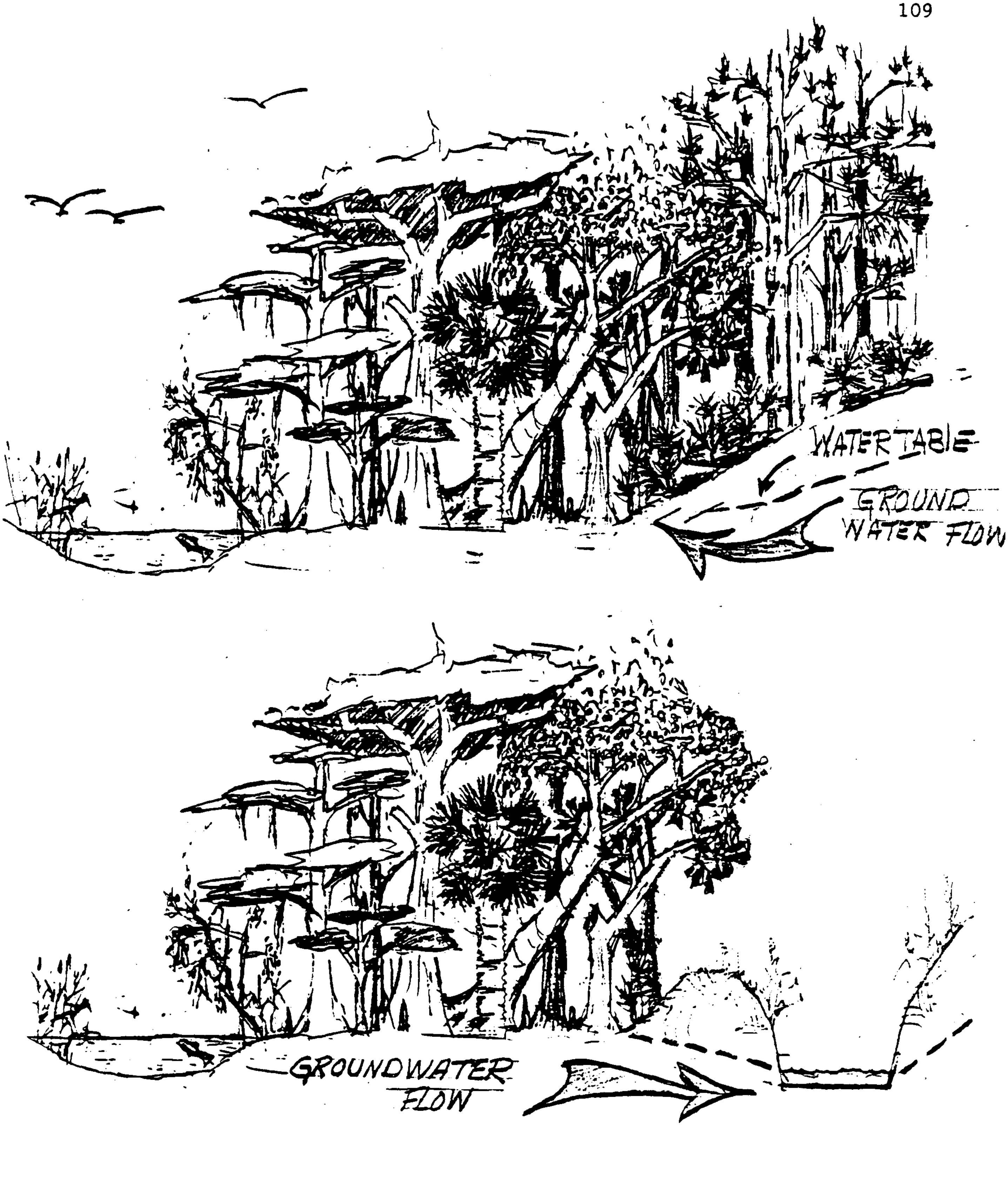

Figure IV.3. Cross section drawing of the floodplain and adjacent uplands showing the natural condition in the upper drawing, and the effects of construction of drainage ditches or retention/detention structures in close proximity to the wetlands edge on groundwater table.

V. DETERMINATION OF BUFFER ZONE REQUIREMENTS

Given in this section is a description and rationale for the methodology for determining buffer zone requirements. The need for a buffer zone to effectively protect the special values of the water resources of the Wekiva Basin is based on three potential impacts of the construction, maintenance, and operation of works. They are related to impacts on water quality that result from construction and long-term use, impacts that may result from alterations of groundwater tables, and impacts on aquatic and wetland-dependent wildlife habitat.

This section is organized into three parts. First an overview of the methodology is presented that discusses the parameters that control the determination of a buffer zone width. Second, methods for the determination of buffer zones are given, with formulae where appropriate. Finally, sample sections of the Wekiva River and Black Water Creek are used to describe each of the controlling parameters and to display the resulting buffer widths.

V.A. Overview of the Methodology for Determination of Buffer Zones

Four factors are used to determine the width of buffer zones to protect the water resources of the Wekiva River System. The four factors are (1) the Water Management District wetland line (40C-4 FAC), (2) the erodibility of soils in the zone immediately upland of the wetland line, (3) the depth of the groundwater table below the soil surface in the zone immediately upland of the wetland line, and (4) the habitat requirements of aquatic and wetland-dependent wildlife species.

Because of the detailed nature of the data required to determine the need for and extent of upland buffers, determinations must be made on a case-by-case basis. However, in the final part of this section we have included maps and figures of the relevant data for a typical sections of the river system to illustrate the methodology's application.

Controlling Parameters

The parameters that control the width of the required buffer are related to the need to protect water quality and quantity and aquatic and wetland-dependent wildlife, both during and following construction of any development project in areas immediately adjacent to the floodplains of the Wekiva River System. It is important that construction and operation are considered simultaneously, since a project cannot be operated unless it is built, nor is it realistic to assume that it will not be operated should it be built. The descriptions and rationale for the following parameters reflect this important integration. Some parameters result from the need for protective measures during construction, others from the need for measures after construction, and still others result from both.

(1) 40C-4 Wetland line. The wetland line is the landward extent of wetlands using the methodology outlined in 40C-4 (FAC) and Chapter 16 of the *Applicant's Handbook*. The determination is made by District staff using dominant vegetation, soils, and other indicators of wetland conditions. The line so determined in most cases is the same as the jurisdictional line set by the Florida Department of Environmental Regulation (17-4 FAC) for demarcation of the landward extent of state waters.

The wetland line defines the waterward boundary of the area for which buffer zone requirements are to be determined.

(2) Soil Erodibility. Soil erodibility is a function of slope and soil type. Used in combination, both factors determine the potential for soil erosion and subsequent sedimentation in downslope areas.

(a) Slope. Ground surface slope is expressed as percent slope and is determined by measuring the change in elevation over a distance of 300 ft landward of the wetland line. The slope is an indicator of the erosion potential of soils during and immediately following construction activities and/or site preparation. The steeper the slope, the greater the potential for soils to be eroded by surface runoff during rain events.

(b) Soil Type. The soil type may be determined by consulting the USDA SCS Soil Survey for the county in which the development project is located, or it may be determined in the field by a qualified soil scientist.

Highly erodible soils in combination with steep slopes dictate severe limitations on removal of vegetative cover; gentle slopes with highly erodible soils or steep slopes with minimally erodible soils dictate moderate limitations; and gentle slopes with minimally erodible soils dictate slight limitations. A formula is used to calculate the exact buffer requirement (see Section V.B).

(3) Depth to Water Table. The depth to the groundwater table in areas immediately upland of the wetland line is an important indicator of groundwater interaction with downslope wetlands. Where the water table is near the surface and slopes toward the wetland, the area is dominated by discharging groundwaters, and a buffer to avoid drainage of the wetlands is warranted. The depth to the groundwater table may be determined by field measurements (although it should be understood that one measurement at one point in time does not give a true picture of average year-to-year, season-to-season

conditions) or through field determination of soil type and interpretation of county soil survey data.

Excavations in areas where the water table is near the surface in the zone immediately upslope from seepage wetlands (i.e., where the hydraulic gradient is toward the wetland area) intercept groundwater flows and have the potential to drain wetlands on the downslope side of the excavations. Where these conditions are present, a setback is warranted to insure that proposed development activities do not diminish the quantity of water entering the downslope wetlands.

(4) Wildlife Habitat Requirements. The old adage that an ounce of prevention is worth a pound of cure is particularly appropriate to wildlife conservation. Loss of habitat is the greatest threat to many of Florida's wildlife species. One approach to alleviating this threat would be to monitor each species and to take protective action if it is determined that any given species is declining. This approach is risky in that such a determination may be made too late to reverse the decline. Another approach would be to prevent any change in the amount of habitat available to each species, but this is neither practical nor possible. It is better to formulate a general method to accommodate the wildlife of a given region as a whole. The practical solution, then, is to determine the amount of harm that is acceptable and to prevent it from increasing.

By far, the most common cause of wildlife population reduction is landscape alteration through agriculture, silviculture, or construction activities. Altering or changing natural conditions to which species are adapted often harms native wildlife communities by destroying key conditions that make a given site suitable habitat. An obvious example is the removal of snags (dead trees) that are essential nesting structures, food sources, and perches for many birds, mammals, reptiles, and amphibians. A common misconception is that no harm is done because there are plenty of other undeveloped areas containing the same requirements. On the contrary, other areas that have the necessary elements for a particular species are probably already occupied at a saturation level, leaving no room for individuals that are ousted by development occurring elsewhere. Therefore, the most effective method of protecting wildlife resources in the Wekiva River Basin would be to preserve areas in their most natural conditions and in large enough parcels so that self-sustaining populations can be maintained.

Buffer requirements to protect aquatic and wetland-dependent wildlife species are related to four factors: habitat suitability; spatial requirements; access to upland and/or transitional habitat; and noise impacts on feeding, breeding, and other life functions. Wetland-dependent species are those which depend on wetland communities for at least some of their essential requirements.

(a) Habitat Suitability. Food, cover, and water are life-sustaining elements for all species. If every requirement for an animal is available in a particular area, the area is considered to be suitable habitat for that species; if one or more of a species' requirements is not available, the area is unsuitable. Some species are extremely specialized. For example, the Everglades or snail kite has an exclusive diet of only one snail species, *Pomus depressus*. Others, such as the raccoon, are generalists and can readily substitute many items to fulfill their needs.

Several methods have been developed recently to determine if sites are suitable for a given species. These methods are based on availability of food, cover and water requirements, and various parameter measurements have been shown to be associated with these requirements. Examples of the parameters used for this report are tree canopy closure and tree height.

(b) Spatial Requirement. Every animal requires a certain amount of space to carry out life functions such as feeding, courtship, and nesting. Spatial needs are highly variable, even within species. Differences are associated with many factors, including sex and age of the animal, time of year, availability and distribution of food and cover, and social structures. In general, larger species tend to have greater spatial requirements. Obvious comparisons are the black bear versus the cotton mouse and the red-shouldered hawk versus the mockingbird. Also, species with more unpredictable and unevenly distributed food sources require more space to satisfy their nutritional needs. For example, marsh rabbits have small spatial requirements relative to their size because they eat grasses and forbs which are plentiful within small areas. Conversely, gray squirrels need relatively larger territories to find mast, which is unevenly distributed.

It should be realized that the Wekiva River acts as a border to many species living in the river basin. Even those that can swim or fly across the river are affected by the impacts of increased predation and disturbance factors associated with the edge ecotone created at the water/forest interface.

Because many forest-dwelling, wetland wildlife species utilize more than one habitat type, their spatial requirements can often be satisfied even if a portion of the forested area does not fit the definition of a wetland community but does fulfill other habitat suitability criteria. In most cases, areas immediately landward of the wetland line that are cleared for agriculture or silviculture or which are planted in monocultural pine plantations will not be suitable habitat for wetland-dependent species. Where these situations occur, buffer zone requirements are not as sensitive to wildlife considerations as they might be if the area had a continuous, relatively natural, forest canopy. For this reason, it is essential that serious consideration be given to whether or not agriculture and silviculture should be exempt from buffer zone requirements where the protection of aquatic and wetland-dependent wildlife species is of particular importance.

Although it is difficult to rationalize the use of wildlife considerations when the canopy has been removed, mitigation of previous adverse impacts on wildlife could be addressed by replanting the would-be buffer zone (determined by the application of the other factors) with native tree species to reestablish wildlife values.

(c) <u>Access to Upland or Transitional Habitat</u>. Several wetland-dependent wildlife species must have access to upland or transitional habitat regardless of the landward extent of the wetlands. For example, many semiaquatic turtles need sandy and relatively warm upland sites to lay eggs. Elimination of such habitats could extirpate numerous wetland-dependent species from the Wekiva River Basin.

(d) <u>Noise Impacts</u>. Noise can interfere with signals and directly affect wildlife behavior. Many species rely on vocalizations for warnings, mate recognition, detection of separated young, and to establish territorial boundaries. Background noise can interfere with these vocalizations and cause direct reductions in populations or dispersal to less noisy areas. Sudden loud noises can disturb or harass some individuals and cause harmful stress which affects reproduction and other life functions.

To protect aquatic and wetland-dependent species from noise interference, buffer zones between the point of noise generation and the habitat are warranted. The distance of buffer necessary for protection from noise is related to both the level of noise and the space through which the noise passes. Dense vegetation diminishes the level of noise more quickly than open ground; pavement tends to propagate noise better than vegetated grasslands. The required buffer depends upon the characteristics of the intervening area.

V.B. Determining Buffer Zone Requirements

The order in which each of the four parameters is calculated or measured is important. The 40C-4 wetland line must be determined first, since all determinations are based on the establishment of this line as the waterward boundary of the buffer zone. Once the wetland line is established, the order in which the remaining parameters are determined is of little consequence.

Since the requirements for a buffer zone depend on a dynamic landscape where the relationships between the controlling variables are not constant, each of the parameters must be calculated. The spatial frequency at which the calculations are made (i.e., how often the buffer zone lines need to be determined along the waterward edge of a proposed development) depends on the variation in the measured parameters. If there is no reason to believe the parameters and their relationships to each other are different along the entire length of the water-ward edge of the proposed development, each parameter needs to be determined only once. However, if the parameters appear to change significantly, more determinations are necessary. The exact number of determinations is a function of the relative changes in slope, soil type, water table elevation, and forest canopy and vegetative structure. In most cases, estimates of the relative changes in parameters can be made using topographic and soils maps and aerial photographs.

Final buffer zone widths are set by determining the controlling parameter, i.e., the parameter that results in the widest buffer zone. The following paragraphs detail methods for determining buffer widths based on each of three parameters (water quality, water quantity, and wildlife habitat suitability).

(1) 40C-4 Wetland line. The wetland line is determined using the methodology outlined in Part III, Section 16 of the Applicants Handbook.

(2) Water Quality Maintenance. The requirement for a buffer zone for maintenance of water quality is related to the filtering capacity and roughness of natural undisturbed vegetation to minimize inputs of sediments and destructive velocity of waters. The potential for erosion and subsequent sedimentation is a function of the erodibility of soil and slope. The velocity of water varies as the square root of slope (Manning's formula), and the potential for a particle of soil to be moved is a function of erodibility and velocity of water over the surface. Thus a simple relationship of slope and erodibility may be used to determine buffer widths as follows:

$$B_w = \frac{S^{1/2}}{E} \qquad (1)$$

where:

B_w = the width of the buffer in ft;
S = average slope of the land in ft per 100 ft; and
E = erodibility factor; use 4 for soils with SCS erosion factors (k) of 0.1, use 3 for soils with k = 0.15, use 2 for soils with k = 0.17, and 1 for soils with k > 0.17.

Using Equation 1, the required buffer for an average slope of 3% and soils with low erodibility factor (E = 4) would be 43 ft. The buffer required for soils with the same slope and erodibility factors of 3 and 2 are 57 ft and 87 ft, respectively.

Table V.1 lists pertinent soil properties for many soil types found in and adjacent to wetlands in the Wekiva River System. It highlights some of the important constraints likely to be encountered within the Basin. The second column lists k factors (erosion factors) that can be used in determining the erodibility factor.

Table V. 1. Soil properties and interpretation.

Soil type	K Erosion[1]	Depth to W. Table[2]	Hydrol. Group[1]	Limitations[2] S.Tank	Bldg.	Excav.
Albany sand, 0-5%[1]	.10	15-40"	C	M	M	M
Anclote fine sand[1]	.10	0-10"	D	S	S	S
Anclote & Myakka	.10	0-10"	D	S	S	S
Astatula sand, dark, 0-5%	.10	>120"	A	Sl	Sl	M
Blanton fine sand, high, 0-5%[3]	.17-.28	18-30"	A	Sl	Sl	S
Blanton fine sand, low, 0-5%[3]	.17-.28	18-30"	A	M	M	S
Cassia sand	.10	10-40"	C	S	S	S
Delray fine sand[3]	.15	+12-0"	A/D	S	S	S
Delray fine sand, shallow[3]	NA	0	NA	VP	-	IN
Delray fine sand, high[3]	.15	0-12"	A/D	S	S	S
Emeralda fine sand	.10	0	D	S	S	S
Felda fine sand[3]	.17-.28	0-12"	B/D	S	S	S
Immokalee fine sand[3]	.17-.20	0-12"	A/D	S	S	S
Iberia & Manatee	.10-.28	0	D	S	S	S
Immokalee sand[3]	.17-.20	0-12"	A/D	S	S	S
Leon fine sand[3]	.17-.20	0-12"	A/D	S	S	S
Leon fine sand, 0-2%[3]	.17-.20	0-12"	A/D	S	S	S
Myakka sand	.10	0-10"	D	S	S	S
Myakka & Placid sands, 2-8%	.10	0-10"	D	S	S	S
Ocilla sand	.10	40-60"	C	M	M	M
Paola sand, 0-5%	.10	>80"	A	Sl	Sl	Sl
Plummer fine sand[3]	.17-.28	0-12"	A/D	S	S	S
Pomello fine sand[3]	.17-.20	12-30"	A	M	Sl	S
Pomello fine sand, 0-5%[3]	.17-.20	12-30"	A	M	Sl	S
Pomello sand	.10	30-40"	C	M	M	M
Pompano fine sand[3]	.15	0-12"	A/D	S	S	S
Pompano fine sand, shallow phase	.10	0	D	VP	-	IN
Placid sand	.10	0	D	S	S	S
Pompano fine sand[3]	.15	0-12"	A/D	S	S	S
Sandy alluvial land[3]	-	-	-	S	S	S
Swamp	.10	+24"-0	D	+S	+S	+S
Tavares sand	.10	40-60"	C	Sl	Sl	M
Tavares sand, white subsurf.	.10	40-60"	C	Sl	M	M
Wabasso sand	.10	0-10"	D	S	S	S
Wauchula sand	.10	0-10"	D	S	S	S

Table V. 1. Continued. (footnotes)

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[1]K Erosion is a measure of the rate at which a soil will erode. Values are expressed as tons of soil loss per acre per unit of R (rainfall factor) from continuous fallow on a 9% slope 73 feet long.

Hydrologic Group is a relative index of runoff rate. A = low runoff potential, B = moderately low runoff potential, C = moderately high runoff potential, and D = high runoff potential. When two letters are given, the first applies to the drained condition while the second applies to the natural condition.

Source for K factors and hydrologic groups, unless otherwise noted: U.S. Soil Conservation Service Soil Interpretation Sheets (provided by SCS office in Gainesville, Florida, September 1987) for Lake, Orange, and Seminole counties.

[2]Depth to water table = depth to seasonally high water table. The range reflects year-to-year variation. Standing water above the soil surface is indicated by a "+".

Limitations apply to septic tank drainage fields, dwellings without basements or foundations for low buildings, and shallow excavations (ponds or below-ground basements).

Sources for depth to water table and limitations are the Soil Survey of Orange County, Florida (1960), Soil Survey of Seminole County, Florida (1966), or Soil Survey of Lake County Area, Florida (1975) except where otherwise noted. Sl = slight, M = moderate, S = severe, and +S = very severe. The Orange County Soil Survey does not include a rating for building suitability. Ratings for septic tank drainage fields range from very poor (VP) to poor (P) to fair (F) to good (G). It does not rate soils for excavated ponds, but only describes the elevation [high (H) or medium (ME)], shallow water table (SH), or inundated (IN).

[3] Source: Soil Survey Supplement, Seminole County, Florida (1975).

The above formula is included as a means of providing a framework from which hydrologists, soil scientists, and engineers working in conjunction might develop nomographs or equations better suited for the conditions encountered in the Wekiva River Basin. A derivation of the Universal Soil Loss Equation, while requiring very specific information, may be a better means of determining buffer zone widths for protection of water quality if an allowable field soil loss can be established, although any soil erosion has the potential to cause disruption of downstream waters and wetlands. Without the detailed analysis required by the more sophisticated methodologies, the above equation is given as an example for determining the buffer requirements for protection of water quality.

(3) Water Quantity Maintenance. The buffer width required for protecting water quantity is related to the drainage impacts of lowered water tables on adjacent wetlands. The lowering of groundwater tables is accomplished through drainage structures that cause transient groundwater flows toward the structure in the upper portions of the shallow aquifer (water table aquifer). The effect of water table drawdown diminishes with distance from the structure. Current regulations of the District allow an average drawdown of 3 ft throughout a development project, with no one area having a drawdown greater than 5 ft. The width of the buffer depends on the drawdown anticipated as a result of the drainage structures and the hydraulic conductivity of the soil. Using a design drawdown (depth to which groundwaters are to be lowered) in the vicinity of a structure, the buffer required to minimize drawdown effects on adjacent wetlands can be calculated using a derivation of the Theis equation as follows:

$$h_o - h = (2.3\ Q/4\ pi\ K\ D)(\log\ [2.25\ T\ t/r^2\ n]) \qquad (2)$$

and substituting:

$$Q = K\ s\ D\ L \qquad (3)$$

and

$$t = 4 D n/pi K s^2 \quad (4)$$

where:

$h_o - h$ = acceptable drawdown at wetlands edge taken as 0.25 ft.
Q = discharge
D = depth of ditch or basin
L = length of ditch or basin
K = hydraulic conductivity, taken as 10 ft/day
s = slope of water table surface
T = K x depth of ditch
t = time in days
S = coefficient of storage, taken as 0.2
r = distance radially from ditch or basin
n = porosity.

Equation 2 may be simplified and rearranged to solve for the distance, r, where the drawdown will be equal to 0.25 ft in terms of the length, L, of ditch or basin. Substituting the buffer width, B_w, for the distance, r, the equation is then stated as follows:

$$B_w = (1.69D/s)(10^{-[1.3/sL]}) \quad (5)$$

The solution of Equation 5 is trivial for very small ditch lengths.

The assumption is made that a drawdown of 0.25 ft at the wetland edge is acceptable. The buffer distances for drawdowns of 1, 2, 3, and 5 ft with a ditch length of 300 ft are 78, 156, 235, and 392 ft, respectively.

Determining drawdowns in unconfined water table aquifers where conditions vary from one site to the next is a very complex task, and the methodology presented here is likely to be controversial. Be that as it may, the above formula may be used to determine a buffer width based on gross assumptions concerning such factors as hydraulic conductivity and coefficient of storage, among others. It is a much simplified version of much more complex relationships. Without a detailed analysis of the conditions and soils characteristic of the Wekiva Basin--which are beyond the scope of this report--the simplified relationships expressed in Equation 2 may be used as guides to determine effective setbacks to minimize drawdown effects. The authors suggest that groundwater hydrologists, engineers and ecologists be consulted to better define parameters more precisely and to formulate an acceptable methodology for determining drawdown effects.

(4) Maintaining Habitat Suitability

Specific quantitative data are not currently available for all of the wildlife species in the Wekiva River Basin. However, we were able to obtain information on several of the more sensitive forest-dwelling wetland-dependent species which would be adversely affected by landscape alterations (Table V.2). Areas that are suitable for these species would, of course, also be suitable for less sensitive species. The following are minimum standards that are required for an area to be considered suitable for a full spectrum of wildlife along the Wekiva River.

1. Tree canopy height greater than 50 ft;
2. Tree canopy closure greater than 70%;
3. Average tree crown diameter greater than 15 ft;
4. More than 3 trees of at least 20 inches dbh/ac;
5. More than 0.1 snags greater than 20 inches dbh/ac;
6. Average shrub height greater than 2 ft but less than 15 ft; and
7. Shrub canopy closure greater than 70%.

(a) Calculating Spatial Requirements. The amount of suitable contiguous habitat required to support at least one individual of most species living in the Wekiva River Basin is a circular area of 5.17 ac (diameter = 536 ft). This was derived by combining information from several references (see Table V.2). First of all, many forest interior songbirds do not live in plots smaller than 1 ac (diameter = 236 ft). Other data suggest that individuals found in some of the smallest plots were probably living in stressful and unhealthy environments. Negative edge effects have been shown to affect species within 300 ft of forest boundaries. Ideally then, the minimum diameter

Table V.2. Minimum habitat suitability and spatial requirements of some of the most sensitive wetland dependent wildlife species in the Wekiva River Basin.

Species	Habitat Types	Minimum Habitat Suitability	Minimum Spatial Requirements in Suitable Habitat Areas	
			Distance Upland from River Edge of Timber	Total Width Including River
Florida cooter and other aquatic turtles[1]	aquatic, all wetlands, sandy uplands	uplands for nesting, water for food	(50 ft of uplands)	
wood stork[2]	cypress swamps, shallow fresh water	large cypress trees for nesting, water for food		300 ft from large cypress trees
Pileated woodpecker[3,4]	all forested wetlands	- tree canopy closure > 25% - > 3 trees of at least 20 in. dbh/acre - > 0.1 snags (>20 in. dbh)/acre	197 ft	4,221 ft
Red-shouldered hawk[5,6,7]	all forested wetlands	- tree canopy height > 17.7 m - tree canopy closure > 70% - avg. tree crown diam. > 8 m	795 ft	2,606 ft
Song birds[4,5,8,9]		- shrub canopy closure > 20% - avg. shrub ht. > 0.5 m but < 5.0 m	236 ft	
Indigo snake[10]		wetlands for most of the year but gopher tortoise burrows in winter	(300 ft of uplands)	

Table V.2 (page 2 of 2)

[1]Weller, M.W. 1978. Management of Freshwater Marshes for Wildlife. Pages 276-84 *in* R.E. Good, D.F. Whigham, and R.L. Simpson (eds.), Freshwater Wetlands: Ecological Processes and Management Potential. New York, NY: Academy Press.

[2]Palmer, R.S. 1962. Handbook of North American Birds: Volume 1, Loons through Flamingos. Yale University Press, New Haven. 567 pp.

[3]Schroeder, R.L. 1983. Habitat suitability index models: Pileated woodpecker. U.S. Dept. Int., Fish. Wildl. Serv. FWS/OBS-82/10.39. 15 pp.

[4]Tassone, J.F. 1981. Utility of Hardwood Leave Strips for Breeding Birds in Virginia's Central Piedmont. MS Thesis. Blacksburg, VA: Virginia Polytechnic Institute and State College, 83 pp.

[5]Galli, A.E., C.F. Leck, and R.T.T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93:356-64.

[6]Bryant, A.A. 1986. Influence of selective logging on red-shouldered hawks, *Buteo lineatus*, in Waterloo Region, Ontario, 1953-1978. Canadian Field-Naturalist *100*(4):520-25.

[7]Bednarz, J.C. and J.J. Dinsmore. 1982. Nest-sites and habitat of red-shouldered and red-tailed hawks in Iowa. Wilson Bull. 94(1):31-45.

[8]Sousa, P.J. 1982. Habitat suitability index models: Veery. U.S. Dept. Int., Fish. Wildl. Serv. FWS/OBS-82/10.22. 12 pp.

[9]Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: A comparison of two models. Pages 301-04 *in* J. Verner, M.L. Morrison and C.J. Ralph (eds.), Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. Madison, WI: The University of Wisconsin Press.

[10]Speake, D.W., J.A. McGlincy, and T.R. Colvin. 1978. Ecology and management of the eastern indigo snake in Georgia: A progress report. Pages 64-73 *in* R.R. Odum and L. Landers (eds.), Proceedings of the Rare and Endangered Wildlife Symposium, Aug. 3-4, 1978. Georgia Dept. Nat. Res. Tech. Bull. WL 4.

of a stress-free suitable habitat area should be 836 ft (300 ft + 236 ft + 300 ft). However, it is assumed that edge effects along the river are not as severe as those along the uplands, and the average of 236 and 836 (536 ft) is recommended as the minimum width necessary to prevent harmful effects of development on individual wetland-dependent animals. Self-sustaining populations require suitable areas many times larger. Their spatial needs can be easily satisfied by protecting a minimum width of 536 ft of suitable habitat landward from the edge of the forest along both sides of the river. In some situations, the wetland area will be sufficient and no upland buffer is needed to fulfill this requirement. Where wetlands are relatively narrow but forest canopy continues into the uplands, an upland buffer will be needed.

Although some large species such as the red-shouldered hawk need correspondingly wider areas, it is our opinion that the requirements of these low-density nesting birds are satisfied by the large wetland areas within the existing designated wetlands along the Wekiva River. The 536-foot width is believed to be sufficient contiguous habitat to satisfy corridor requirements of large mammals such as black bear, river otter, and bobcat.

(b) Calculating Necessary Access to Uplands or Transitional Habitat. Enough upland or transitional habitat must be preserved adjacent to the wetlands so that semiaquatic turtles can find suitable safe areas to lay their eggs. Although a narrow upland strip of sandy soil would provide the necessary substrate, nests constructed in this type of environment would be subjected to high predation rates associated with edges. A minimum 50-foot upland buffer along the entire length of the river is recommended for turtles.

Areas where gopher tortoises are present within 300 ft of the adjacent wetlands should be protected so indigo snakes in the wetlands can continue their seasonal movements into upland gopher tortoise burrows. In these situations, the buffer should include the entire gopher tortoise area.

(c) Calculating Buffers for Noise Impacts. The effects of noise on wildlife breeding, feeding, and territorial protection is not completely understood, although data suggest that noise more than human presence that drives wildlife from areas surrounding developed land. A simple method proposed by Brown (1981) for determining buffer sizes necessary to attenuate highway noise to acceptable levels was to utilizes forested areas to reduce noise levels to background levels. Using the following equation,[3] noise level at the source can be related to vegetation of the buffer zone to determine buffer width necessary to reduce noise levels to background (40 dBA).

$$B_w = \ln (40/N_i)/-Ac \qquad (6)$$

where:

B_w = buffer width in ft
A_c = attenuation coefficient. Use .002 for paved buffer, .0037 for nonforested buffer, and .0053 for heavily forested buffer
N_i = noise level of source. Use 50 dBA for residential areas, 60 dBA for nonarterial general traffic, 70 dBA arterial traffic, and 70 dBA for commercial areas

The required buffers to reduce average residential noise levels (50 dBA) to background (40 dBA) is 60 ft when the buffer is cleared or 42 ft when the buffer is forested.

V.C. Illustration of Buffer Zone Determinations

Given in this section are several maps of portions of the Wekiva River Basin and Black Water Creek Basin depicting relevant information and highlighting examples of buffer width determinations for controlling

[3] The equation is derived from data presented in several studies (Eyring 1946, Weiner and Keast 1959, Embleton 1963, and a summary by Robinette 1972).

parameters. The information shown on each of the maps has been derived from aerial photographs, USDA SCS soil surveys, and USGS topographic maps. The scale of the original information determines the resolution at which buffer widths can be graphically depicted. As a result, the resolution of these maps is not sufficient to locate buffer requirements accurately at a scale that is suitable for actual determinations. Instead, maps and data should be compiled at a scale of about 1" = 100 ft, or possibly 1" = 200 ft, to render the zone in which buffer determinations are to be made in sufficient detail.

The areas chosen for these illustrations were selected because of the variety of conditions that are illustrated within relatively small geographic locales. Whether these areas can ultimately be developed was not taken into consideration, so to the astute observer, it may be obvious that portions of the areas are in state ownership. No attempt has been made to single out these areas for any purpose other than for their illustrative value.

Tables V.3, V.4, and V.5 list ranges of buffer widths generated using the above equations and a given set of parameter values. It is important to note that there is an infinite range of buffer widths and that the values shown are only representative possibilities. The variables in the equations are to be determined in the field on a site-by-site basis.

(1) 40C-4 Wetland Line. Given in Maps V.1 and V.6 are simplified vegetation maps to show the forest canopy and wetland line. The wetland line was drawn from interpretation of aerial photographs and is an estimate of the line that would be determined using field verification of the dominance of wetland vegetation.

(2) Wildlife Habitat Suitability. Also shown on Maps V.1 and V.6 are the three habitat buffer zones. When forest canopy is absent, the buffer zone resulting from spatial requirements of wildlife is not determined and is only

shown when the wetland line is waterward of the necessary 536 ft. The transitional habitat buffer is shown as a 50-foot zone landward of the wetland line, and the noise attenuation buffer is drawn based on the vegetative characteristics of the intervening area between the habitat line and the area reserved for development. The most landward line is then drawn as the wildlife buffer.

(3) Water Quality Buffer. Shown on Maps V.2, V.3, V.7, and V.8 are slope and generalized soil characteristics derived from SCS soil surveys that are used in calculating buffer zone requirements to minimize erosion and sedimentation. The indicated buffer zone requirement is a function of the erodibility of the soil and slope of the ground surface in the area immediately landward of the wetland line. Where two or more soil types occur along the 300-foot survey swath, either the dominant type was used or an average value was taken if the soils were evenly distributed.

(4) Water Quantity Buffer. Shown on Maps V.4 and V.9 are generalized water table characteristics that are used to determine the buffer zone required to minimize adverse impacts from water table drawdown. A design drawdown of 3 ft was used to calculate buffer zone requirements. The assumption was made that if water table elevations were between 0" and 12", then a full drawdown of 3 ft was necessary. In like manner, if the water table elevation was between 12" and 24" or between 24" and 36", the drawdown was taken as 2 ft and 1 foot, respectively.

(5) Composite Buffer. Given in Maps V.5 and V.10 are the composites derived by taking the most landward buffer boundary determined by each of the four controlling parameters.

Table V.3. Sample buffer widths (ft) determined by water quality criteria (refer to Equation 1, Section V.B.2)

	Erodibility*			
Slope % **	1	2	3	4
3.9	198	99	66	49
6.9	263	131	88	67
7.9	281	140	94	70
10.0	316	158	105	79

* Erodibility factors are interpreted as follows:

1) Most erodible soils (K > 0.17) or no. 2 soils with no vegetative cover.
2) Soils with (K = 0.17) conditions or medium soils (3) with no vegetation.
3) Medium erodibility (K = 0.15) or good soils (4) with no vegetative cover.
4) Good soils (K = 0.10) with vegetative cover.

** Numbers shown represent upper limits of slope categories.

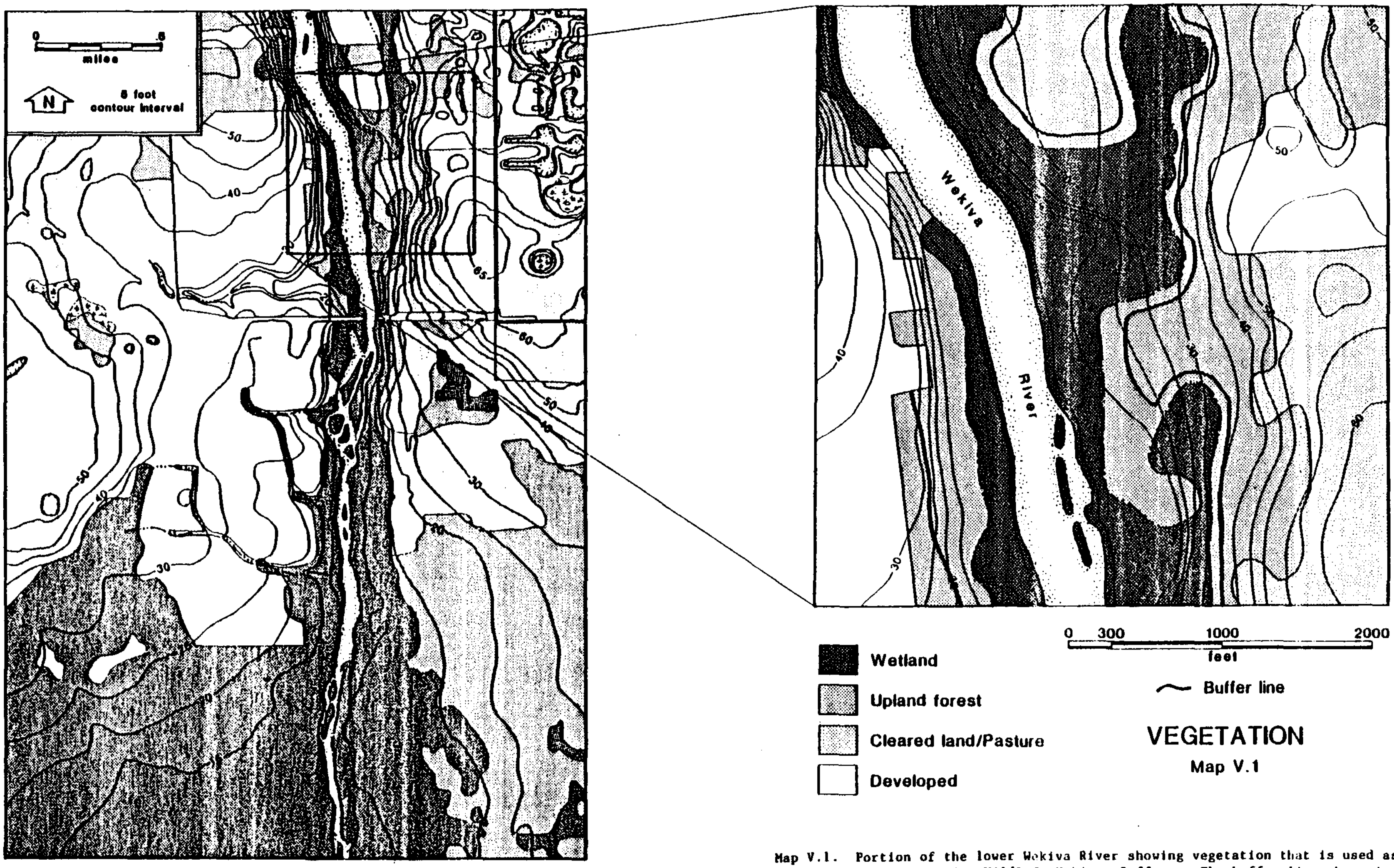
Table V.4. Sample buffer widths (ft) determined by water quantity criteria (refer to Equation 5, Section V.B.3)

	Drawdown (ft)			
Slope % *	1	2	3	5
3.9	56	112	168	280
6.9	28	57	85	142
7.9	24	49	73	121
10.0	19	37	56	93

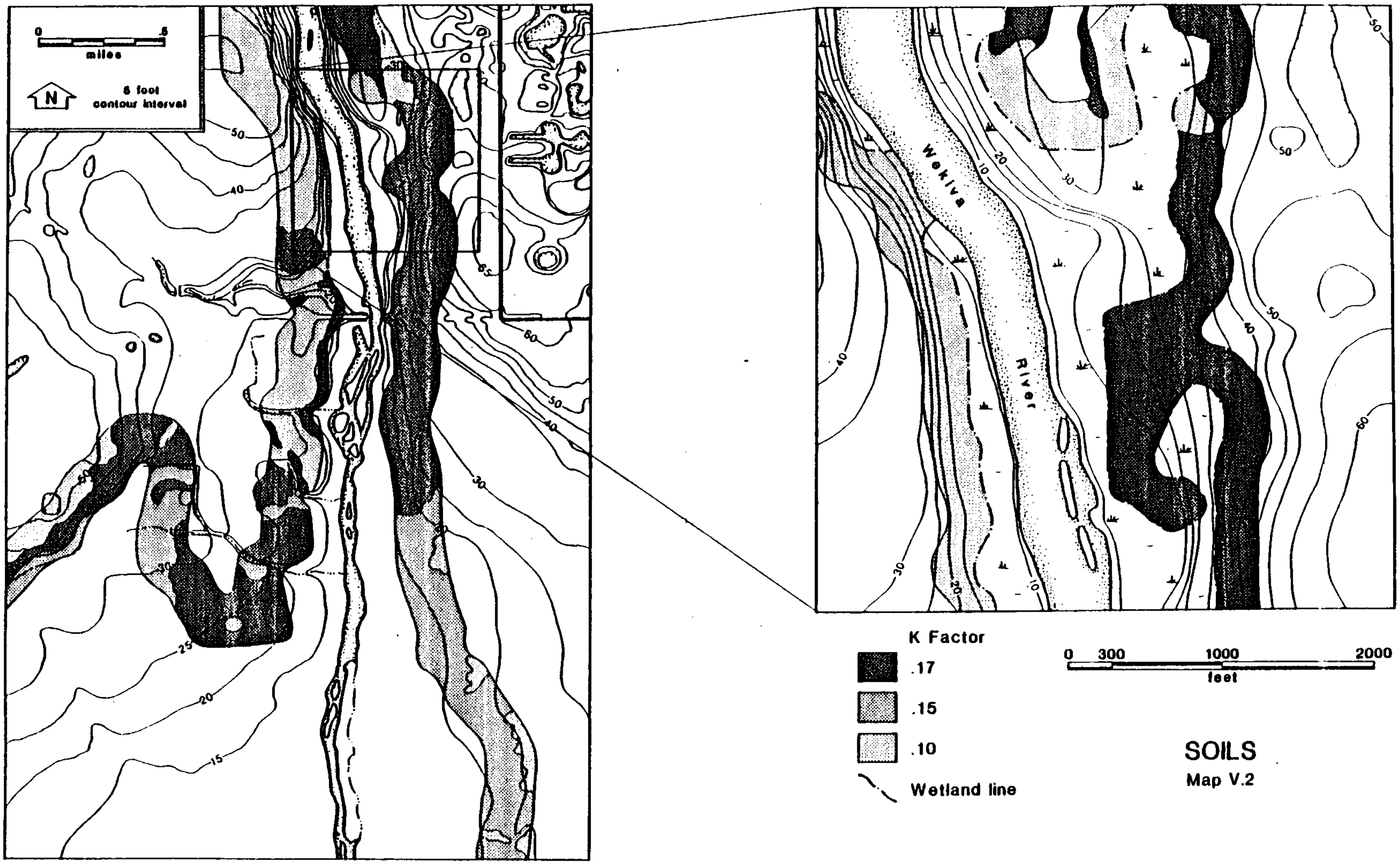
* Numbers shown represent upper limits of slope categories. The slope of the groundwater table was assumed to equal that of the ground surface in the area immediately adjacent to the wetland line.

Table V.5. Sample buffer widths (ft) determined by noise attenuation criteria (refer to Equation 6, Section V.B.4)

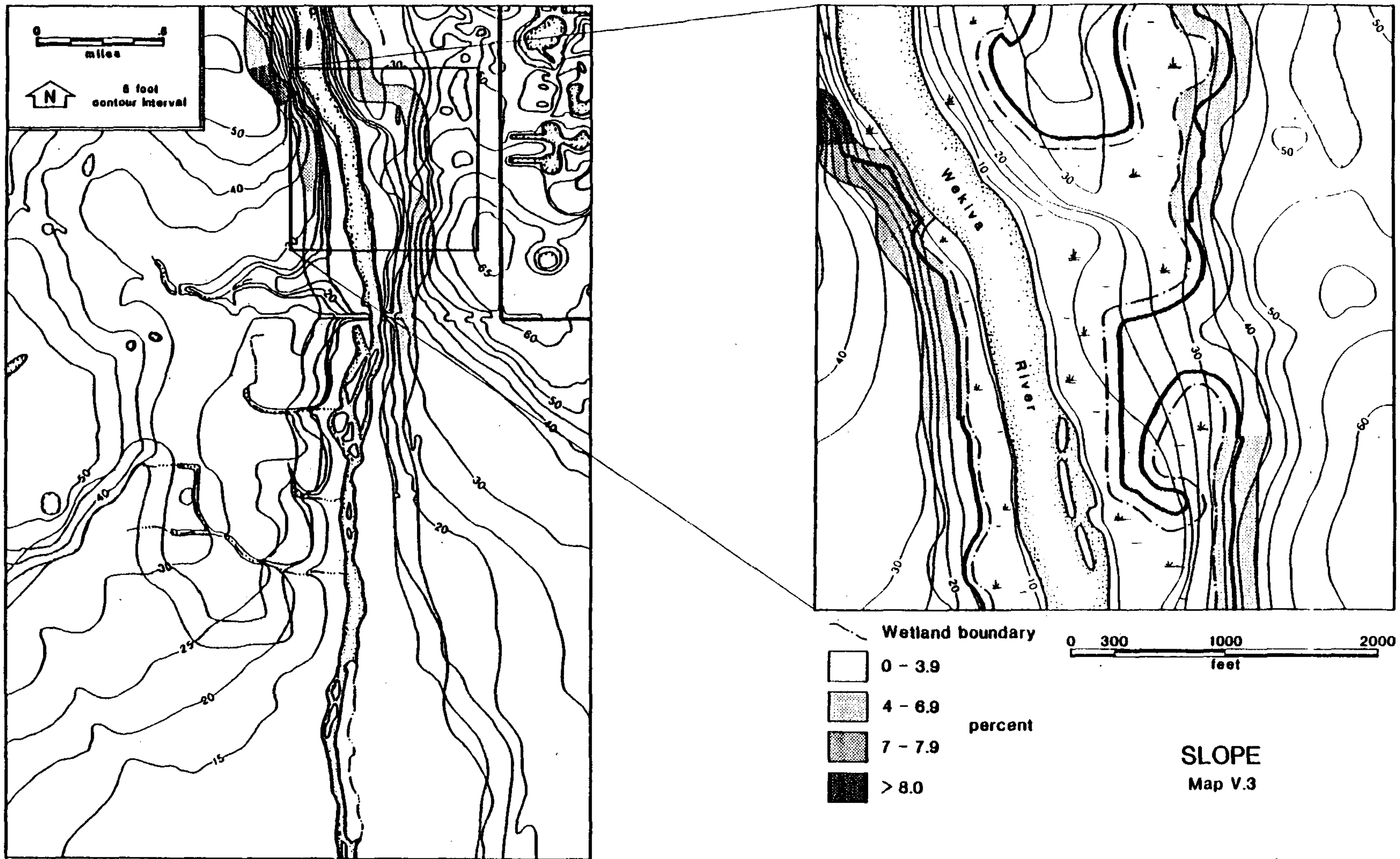
	Noise Level (dBA)		
Buffer Type	50	60	70
Canopy	42	76	105
No Canopy	60	110	151
Paved	112	203	280



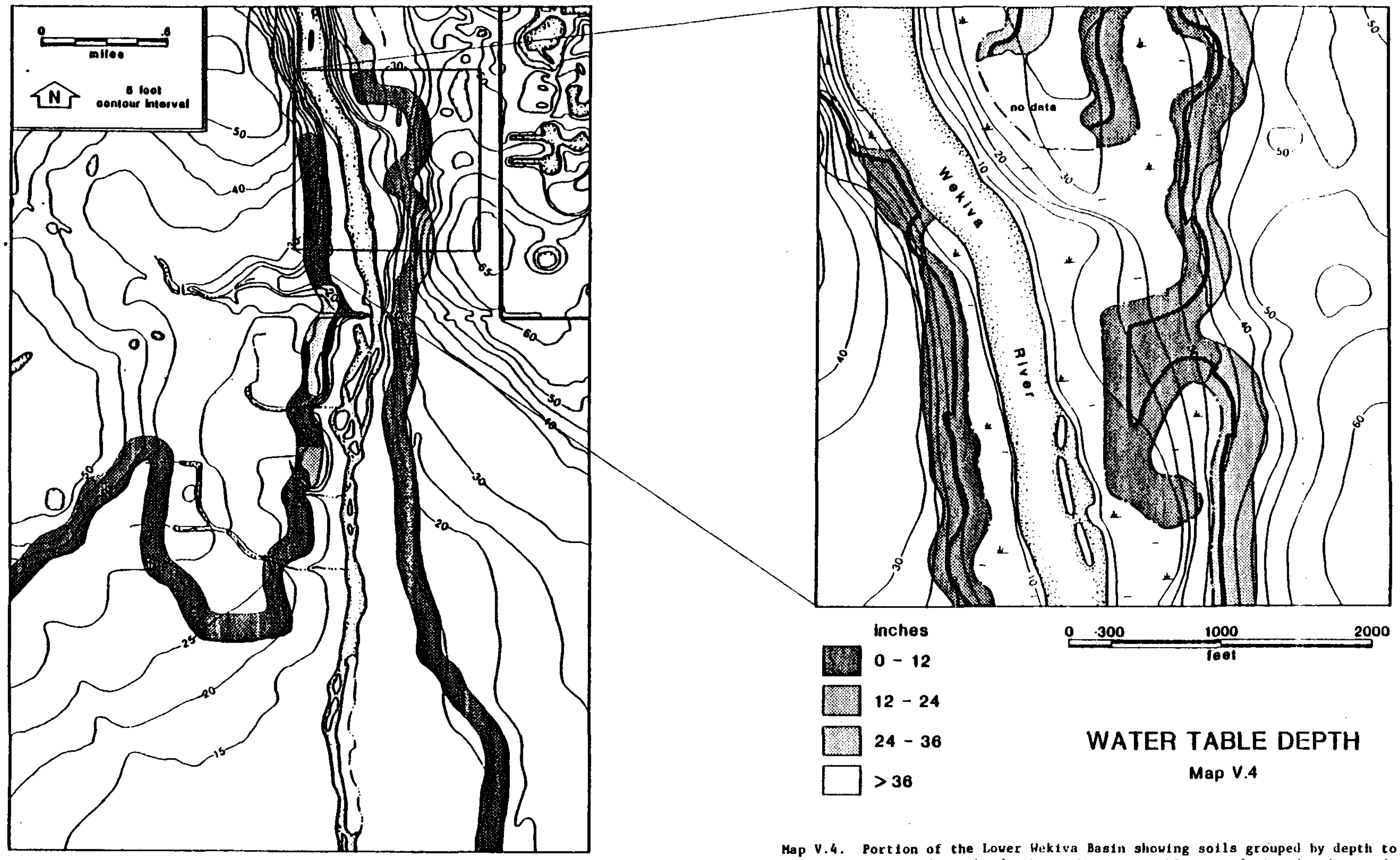
Map V.1. Portion of the lower Wekiva River showing vegetation that is used as the basis for determining Wildlife Habitat Buffers. The buffer line shown in the detailed map above is calculated using either the Habitat Suitability Index, the Transitional Habitat Line, or the Noise Attenuation Line.



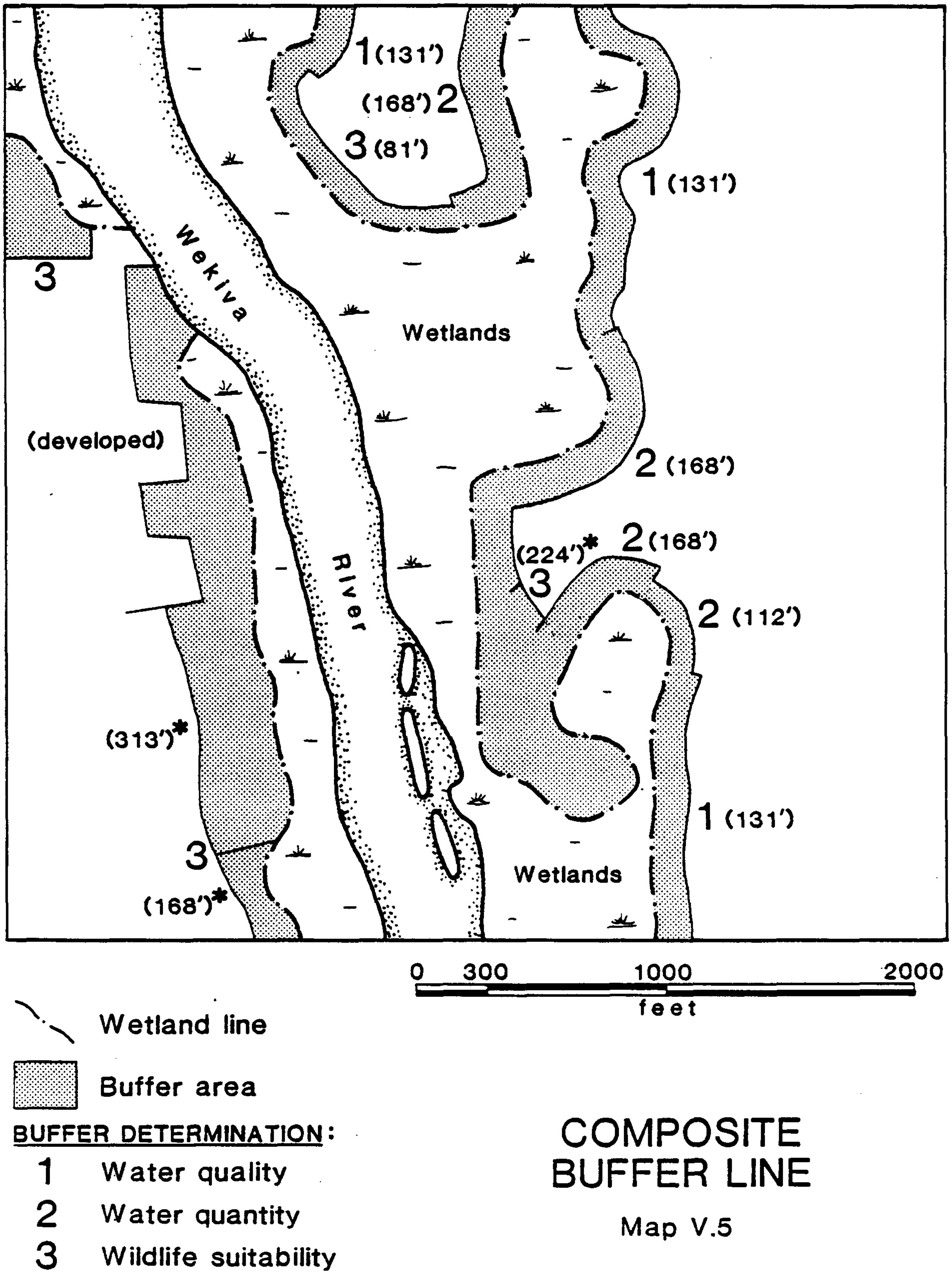
Map V.2. Portion of the lower Wekiva River Basin showing soils grouped by their erodibility factors. These data are used in conjunction with slope given on Map V.3 to determine the Water Quality Buffer.



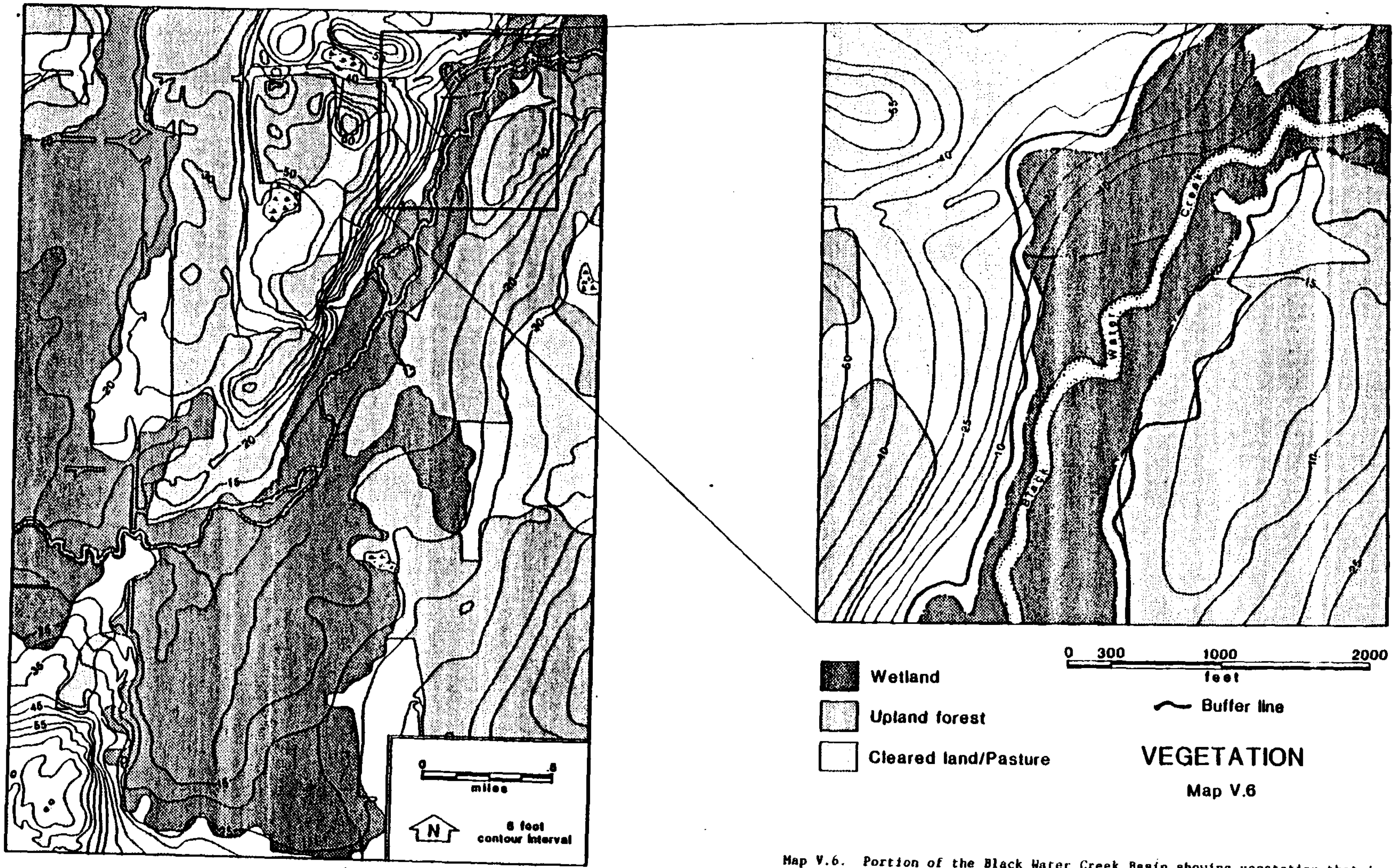
Map V.3. Portion of the lower Wekiva River Basin showing land surface slope. These data are used in conjunction with soil erodibility factors from Map V.2 to determine the Water Quality Buffer. The heavy line indicates the extent of buffer required.



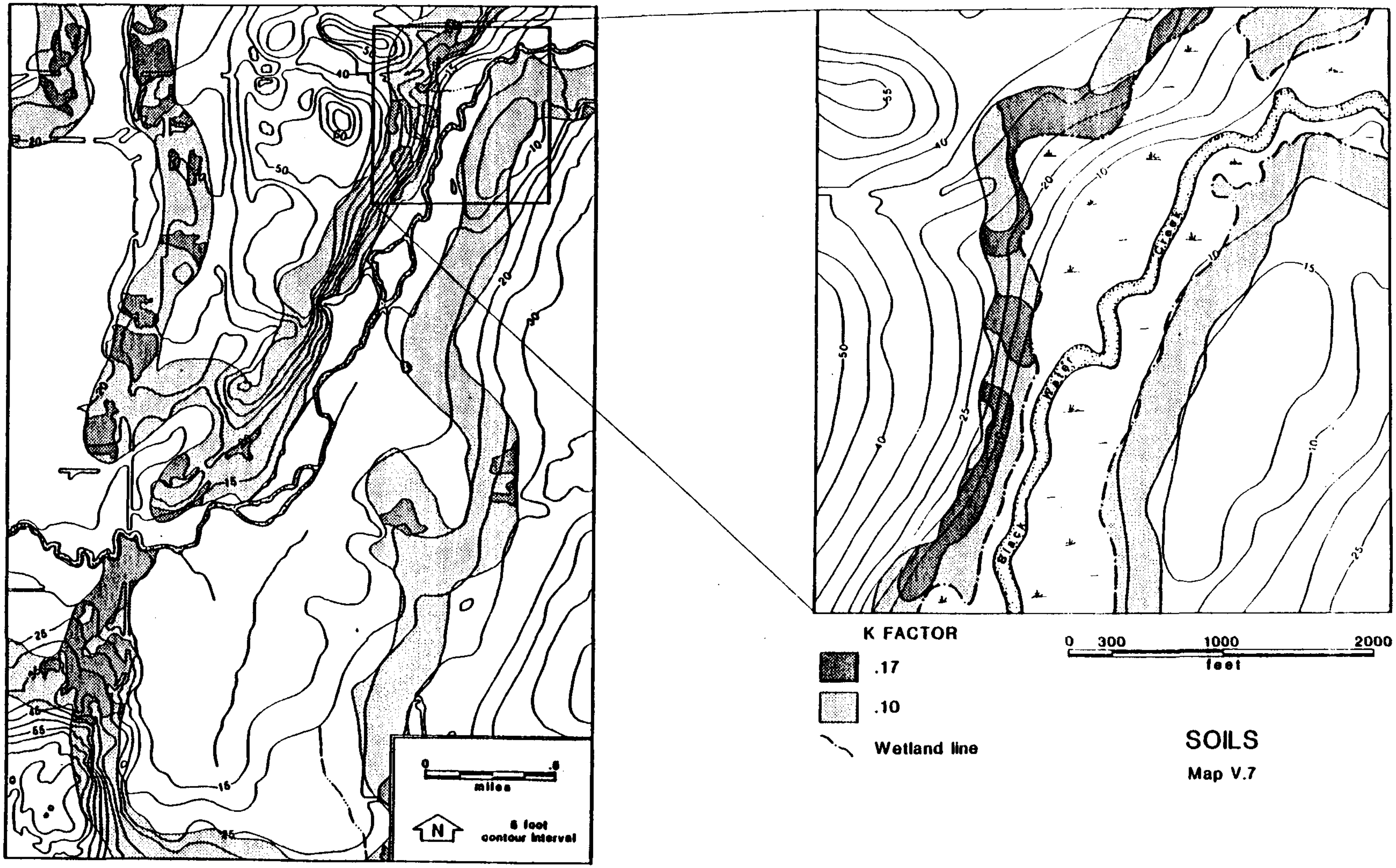
Map V.4. Portion of the Lower Wekiva Basin showing soils grouped by depth to water table. Based on the depth to the water table, the design drawdown and then the required Water Quantity Buffer are determined. With increasing depth to water table, design drawdown decreases. The heavy line indicates the extent of buffer required.



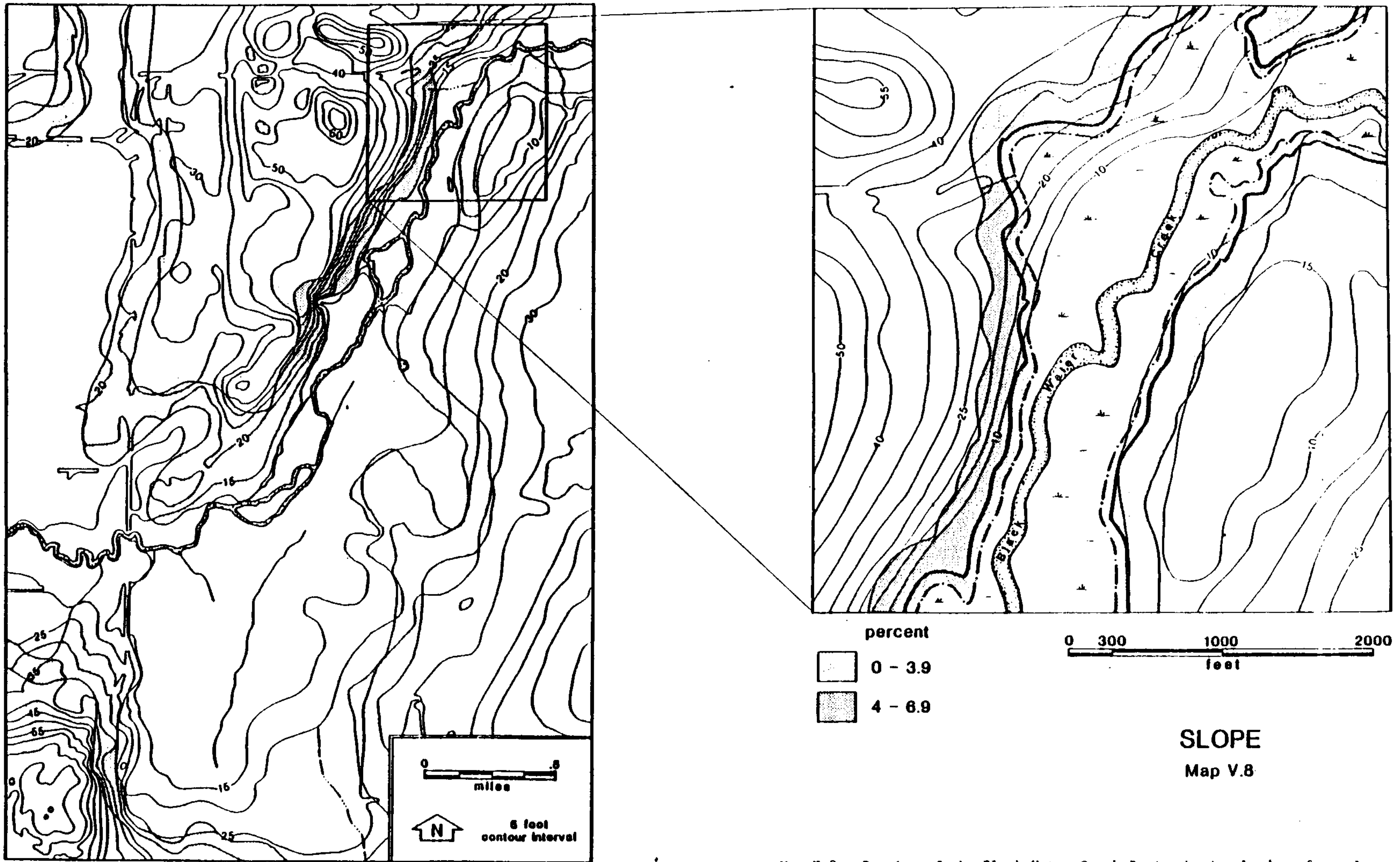
Map V.5. Portion of the lower Wekiva River Basin showing the composite Buffer Zone Requirements in the area immediately adjacent to the wetland line. Numbers in parenthesis are buffer widths in feet from the wetland line. Buffer widths shown with an * are averages of the different distances from the wetlands line that results from measuring wildlife suitability from the stream bank.



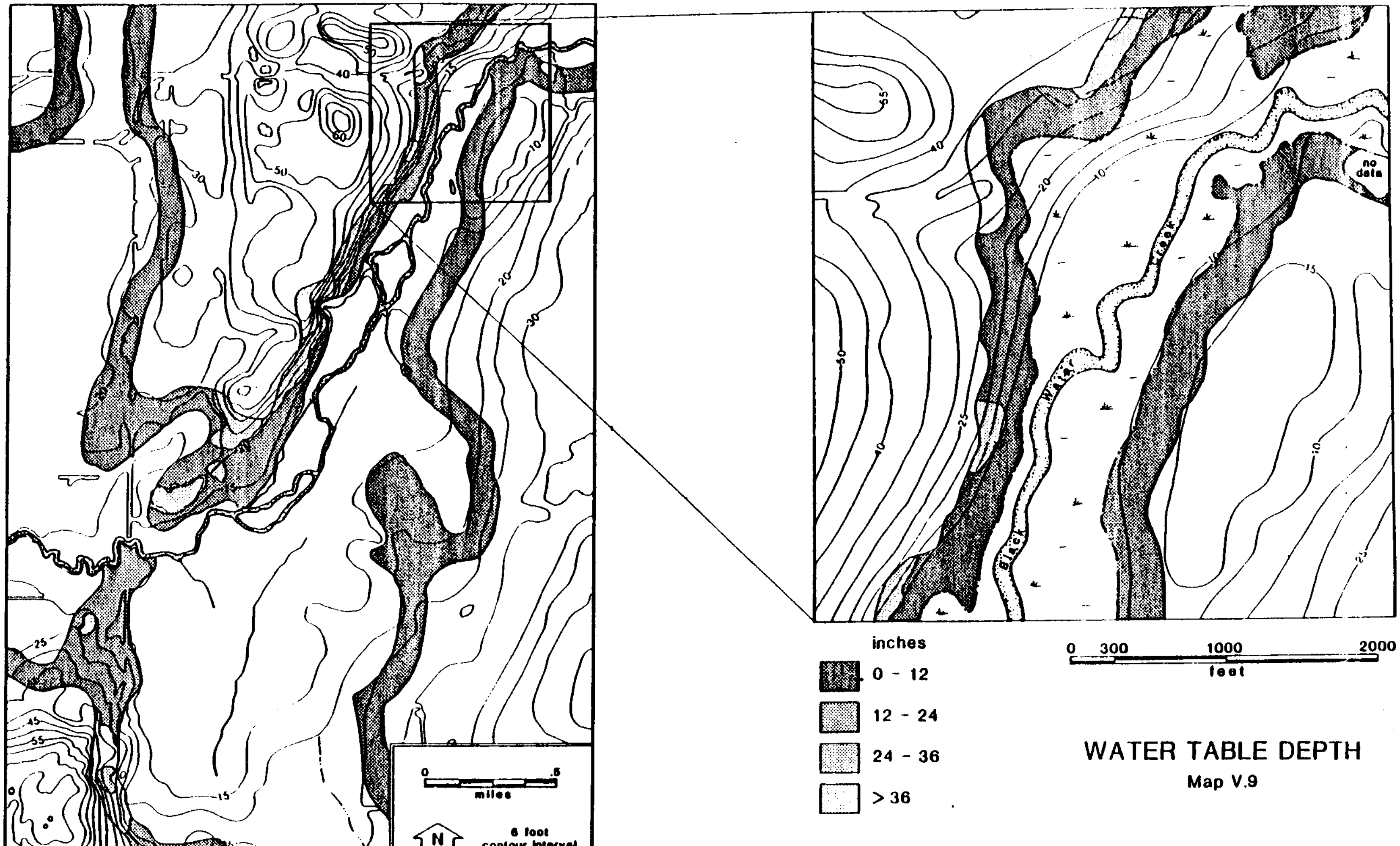
Map V.6. Portion of the Black Water Creek Basin showing vegetation that is used as the basis for determining Wildlife Habitat Buffers. The buffer line shown in the detailed map above is calculated using either the Habitat Suitability Index, the Transitional Habitat Line, or the Noise Attenuation Line.



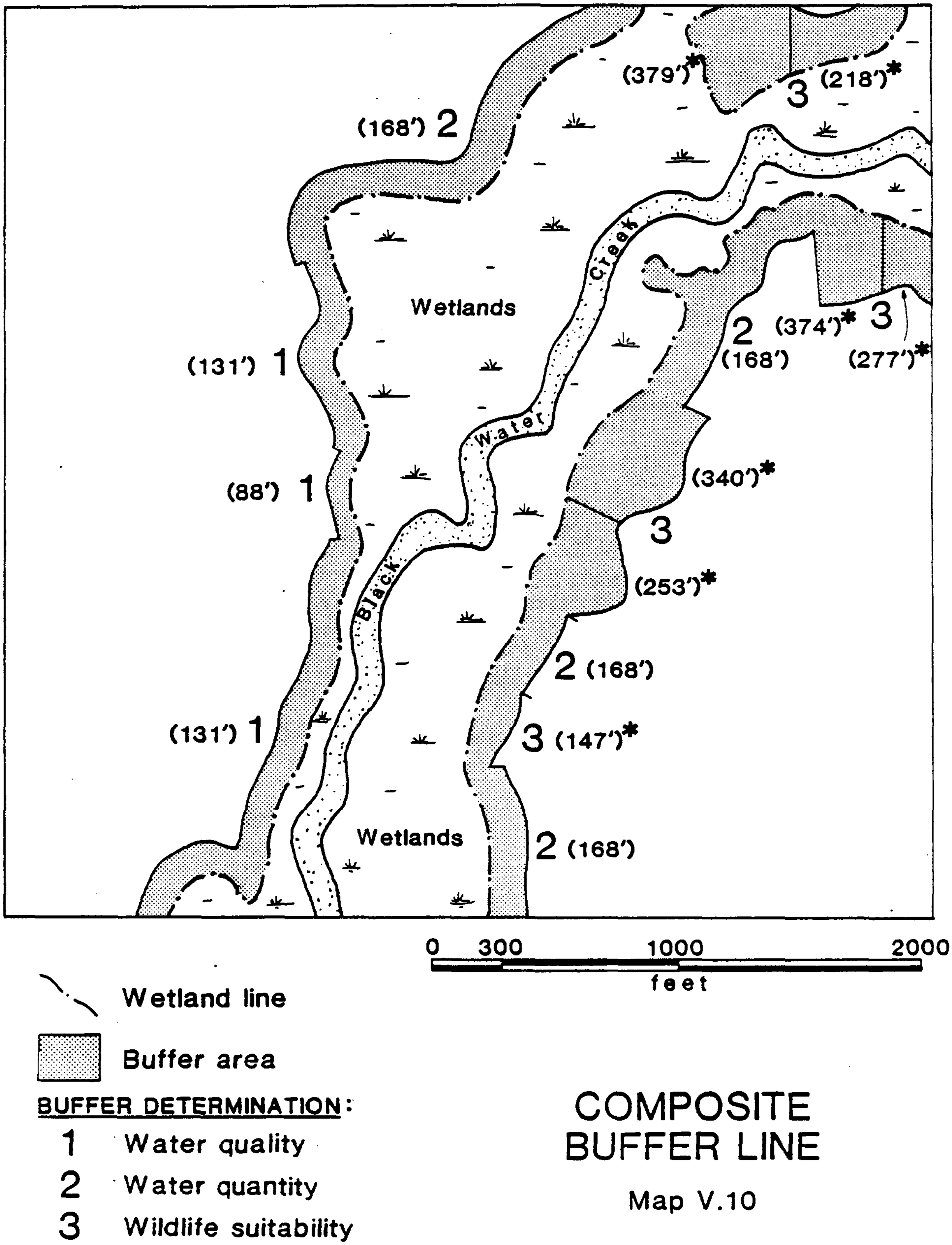
Map V.7. Portion of the Black Water Creek Basin showing soils grouped by their erodibility factors. These data are used in conjunction with slope given on Map V.8 to determine the Water Quality Buffer.



Map V.8. Portion of the Black Water Creek Basin showing land surface slope. These data are used in conjunction with soil erodibility factors form Map V.7 to determine the Water Quality Buffer. The heavy line indicates the extent of buffer required.



Map V.9. Portion of the Black Water Creek Basin showing soils grouped by depth to water table. Based on the depth to the water table, the design drawdown and then the required Water Quantity Buffer are determined. With increasing depth to water table, design drawdown decreases. The heavy line indicates the extent of buffer required.



Map V.10. Portion of the Black Water Creek Basin showing the composite Buffer Zone Requirements in the area immediately adjacent to the wetland line. Numbers in parenthesis are buffer widths in feet from the wetland line. Buffer widths shown with an * are averages of the different distances from the wetlands line that results from measuring wildlife suitability from the stream bank.

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APPENDIX A

WILDLIFE ASSOCIATED WITH WEKIVA RIVER BASIN

TABLE A-1. Fish species of the Wekiva River Basin area.

Scientific Name	Common Name
Amia calva	Bowfin
Anguilla rostrata	American eel
Aphredoderus sayanus	Pirate perch
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Elassoma evergladei	Everglades pygmy sunfish
Elassoma okefenokee	Okefenokee pygmy sunfish
Enneacanthus gloriosus	Bluespotted sunfish
Enneacanthus obesus	Banded sunfish
Erimyzon sucetta	Lake chubsucker
Esox americanus	Redfin pickerel
Esox niger	Chain pickerel
Etheostoma fusiforme	Swamp darter
Fundulus chrysotus	Golden topminnow
Fundulus lineolatus	Lined topminnow
Fundulus seminolis	Seminole killifish
Gambusia affinis	Mosquitofish
Heterandria formosa	Least killifish
Ictalurus brunneus	Snail bullhead
Ictalurus catus	White catfish
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Jordanella floridae	Flagfish
Labidesthes sicculus	Brook silverside
Lepisosteus osseus	Longnose gar
Lepisosteus platyrhincus	Florida spotted gar
Lepomis auritus	Redbreast sunfish
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis marginatus	Dollar sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Lucania goodei	Bluefin killifish
Micropterus salmoides	Largemouth bass
Morone saxatilis	Striped bass
Mugil cephalus	Striped mullet
Notemigonus crysoleuca	Golden shiner
Notropis chalybaeus	Ironcolor shiner
Notropis emiliae	Pugnose minnow
Notropis hypselopterus	Sailfin shiner

TABLE A-1. Fish species of the Wekiva River area (continued).

Scientific Name	Common Name
Notropis maculatus	Tail light shiner
Notropis petersoni	Coastal shiner
Notropis welaka	Bluenose shiner
Noturus gyrinus	Tadpole madtom
Noturus lephtacanthus	Speckle madtom
Percina nigrofasciata	Blackbanded darter
Poecilia latipinna	Sailfin molly
Pomoxis nigromaculatus	Black crappie

TABLE A-2. Relative abundance of amphibian species in Wekiva River Basin habitats.*

Scientific Name	Common Name	Habitat Types			
		HH	HS	CS	ST
Acris gryllus	Cricket frog	-	-	-	-
Amphiuma means	Amphiuma	-	-	-	-
Bufo quericus	Oak toad	-	-	-	-
Bufo terrestris	Southern toad	-	c	u	-
Desmognathus auriculatus	Dusky salamander	c	u	-	-
Eleutherodactylus planirostris	Greenhouse frog	c	c	u	-
Eurycea quadridigitata	Dwarf salamander	c	u	u	u
Gastrophryne carolinensis	Narrowmouth toad	c	c	u	c
Hyla cinerea	Green frog	c	u	c	c
Hyla crucifer	Spring peeper	c	-	-	-
Hyla femoralis	Pinewoods treefrog	-	u	u	-
Hyla gratiosa	Barking treefrog	-	u	u	-
Hyla squirella	Squirrel treefrog	c	c	c	u
Limnaoedus ocularis	Little grass frog	-	u	u	u
Notophthalmus perstriatus	Striped newt	-	u	u	-
Notophthalmus viridescens	Penninsula newt	-	-	-	-
Pseudacris nigrita	Southern chorus frog	-	u	c	-
Pseudacris ornata	Ornate chorus frog	-	-	-	-
Pseudobranchus striatus	Dwarf siren	u	u	u	u
Rana areolata	Gopher frog	c	-	-	-
Rana catesbeiana	Bullfrog	u	u	u	u
Rana grylio	Pig frog	-	u	u	u
Rana heckscheri	River swamp frog	u	-	-	-
Rana utricularia	Leopard frog	u	c	c	u
Scaphiopus holbrooki	Spadefoot toad	c	u	u	-
Siren intermedia	Lesser siren	u	c	c	c
Siren lacertina	Greater siren	u	u	u	c

HH = Hydric hammock habitat
HS = Hydric swamp habitat
CS = Cvpress swamp habitat
ST = Swamp thicket habitat

* = All species wetland dependent
c = Common
u = Uncommon
- = Possible but no data available

TABLE A-3. Relative abundance of reptile species in Wekiva River Basin habitats.

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
Agkistrodon piscivorus*	Eastern cottonmouth	c	u	c	u
Alligator mississipiensis*	American alligator	u	-	-	-
Anolis carolinensis	Green anole	c	c	c	c
Cemophora coccinea	Scarlet snake	-	-	-	-
Chelydra serpentina*	Snapping turtle	u	-	u	-
Cnemidophorus sexlineatus	Six-lined racerunner	-	-	-	-
Coluber constrictor	Black racer	c	c	u	-
Crotalus adamanteus	E. diamondback rattlesnake	c	-	-	-
Deirochelys reticularia*	Chicken turtle	-	u	u	-
Diadophis punctatus	Southern ringneck snake	c	-	-	-
Drymarchon corais	Indigo snake	c	u	u	-
Elaphe guttata	Red rat snake	c	-	-	-
Elaphe obsoleta	Yellow rat snake	c	u	u	u
Eumeces egregius	Mole skink	-	-	-	-
Eumeces inexpectatus	Five-lined skink	c	-	-	-
Farancia abacura*	Mud snake	-	u	u	c
Farancia erytrogramma*	Rainbow snake	-	-	-	-
Gopherus polyphemus	Gopher tortoise	-	-	-	-
Heterodon platyrhinos	Eastern hognose snake	-	-	-	-
Heterodon simus	Southern hognose snake	-	-	-	-
Kinosternon bauri*	Striped mud turtle	-	u	u	u
Kinosternon subrubrum*	Florida mud turtle	-	-	-	-
Lampropeltis getulus	Florida kingsnake	c	u	u	c
Lampropeltis triangulum	Scarlet kingsnake	c	u	u	c
Masticophis flagellum	Eastern coachwhip	u	-	-	-
Micrurus fulvius	Coral snake	c	u	u	-
Neoseps reynoldsi	Sand skink	-	-	-	-
Nerodia cyclopion*	Green water snake	-	u	u	-
Nerodia fasciata*	Banded water snake	c	u	u	u
Nerodia taxispilota*	Brown water snake	u	u	u	-
Opheodrys aestivus	Rough green snake	c	u	u	u
Ophisaurus attentuatus	Slender glass lizard	-	-	-	-
Ophisaurus ventralis	Eastern glass lizard	-	-	-	-
Pituophis melanoleucus	Pine snake	-	-	-	-
Pseudemys floridana*	Florida cooter	u	u	u	-

TABLE A-3. Relative abundance of reptile species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
*Pseudemys nelsoni**	Florida red-bellied turtle	-	-	u	-
*Regina alleni**	Striped swamp snake	-	u	u	u
Rhadinaea flavilata	Pine woods snake	-	-	-	-
Rhineura floridana	Florida worm lizard	-	-	-	-
Sceloporus undulatus	Southern fence lizard	-	-	-	-
Sceloporus woodi	Florida scrub lizard	-	-	-	-
Scincella laterale	Ground skink	-	c	u	u
*Seminatrix pygaea**	Black swamp snake	-	u	u	-
Sistrurus miliarius	Dusky pygmy rattlesnake	c	u	u	u
*Sternotherus odoratus**	Stinkpot turtle	-	u	u	-
Storeria dekayi	Brown snake	c	u	u	-
Storeria occipitomaculata	Red-bellied snake	-	-	-	-
Tantilla coronata	Southeastern crowned snake	-	-	-	-
Terrapene carolina	Box turtle	-	u	u	-
Thamnophis sauritus	Ribbon snake	-	u	u	c
Thamnophis sirtalis	Eastern garter snake	-	u	u	u
*Trionyx ferox**	Florida softshell turtle	-	u	u	-

HH = Hydric hammock habitat
HS = Hydric swamp habitat
CS = Cypress swamp habitat
ST = Swamp thicket habitat

* = Wetland dependent species
c = Common
u = Uncommon
- = Possible but no data available

TABLE A-4. Relative abundance of bird species in Wekiva River Basin habitats.

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
Accipiter cooperii	Cooper's hawk	c	u	u	u
Accipiter striatus	Sharp-shinned hawk	c	c	u	u
Actitus macularia*	Spotted sandpiper	-	-	-	-
Agelaius phoeniceus*	Red-winged blackbird	u	c	c	c
Aimophila aestivalis	Bachman's sparrow	-	-	-	-
Aix sponsa*	Wood duck	-	c	c	-
Ammodramus henslowii#	Henslow's sparrow	-	-	-	-
Ammodramus leconteii*#	LeConte's sparrow	-	-	-	-
Ammodramus savannarum	Grasshopper sparrow	-	-	-	-
Anas americana*#	American widgeon	-	-	-	-
Anas clypeata*#	Northern shoveler	-	-	-	-
Anas crecca*#	Green-winged teal	-	-	-	-
Anas discors*	Blue-winged teal	-	-	-	-
Anas fulvigula*	Mottled duck	-	-	-	-
Anhinga anhinga*	Anhinga	-	u	u	-
Anthus spinoletta*#	Water pipit	-	-	-	-
Aphelocoma coerulescens	Scrub jay	-	-	-	-
Aramus guarauna*	Limpkin	-	c	c	-
Archilochus colubris	Ruby-throated hummingbird	c	c	u	-
Ardea herodias*	Great blue heron	-	-	-	-
Athene cunicularia	Burrowing owl	-	-	-	-
Aythya collaris*	Ring-necked duck	-	-	-	-
Bombycilla cedrorum#	Cedar waxwing	c	c	c	u
Botaurus lentiginosus*	American bittern	-	-	-	-
Bubo virginianus	Great horned owl	u	u	u	u
Bubulcus ibis	Cattle egret	-	c	c	-
Buteo brachyurus*	Short-tailed hawk	u	u	u	-
Buteo jamaicensis	Red-tailed hawk	u	u	u	u
Buteo lineatus*	Red-shouldered hawk	c	c	c	c
Butorides virescens*	Green heron	-	c	u	u
Cairina moschata*	Muscovy duck	-	-	-	-
Calidris alba*#	Sanderling	-	-	-	-
Calidris alpina*#	Dunlin	-	-	-	-
Calidris mauri*#	Western sandpiper	-	-	-	-
Calidris minutilla*#	Least sandpiper	-	-	-	-

TABLE A-4. Relative abundance of bird species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
Campephilus principalis*	Ivory-billed woodpecker	-	-	-	-
Caprimulgas carolinensis	Chuck will's widow	c	c	u	-
Caprimulgas vociferus#	Whip-poor-will	c	u	u	u
Cardinalis cardinalis	Northern Cardinal	c	c	c	c
Carduelis tristis#	American goldfinch	c	c	c	c
Carpodacus purpureus#	Purple finch	-	-	-	-
Casmerodius albus*	Great egret	-	c	c	u
Cathartes aura	Turkey vulture	u	u	u	u
Catharus fuscescens*#	Veery	-	-	-	-
Catharus guttatus#	Hermit thrush	c	c	u	-
Catharus ustulatus#	Swainson's thrush	-	-	-	-
Ceryle alcyon*	Belted kingfisher	-	-	-	-
Chaetura pelagica	Chimney swift	-	-	-	-
Charadrius vociferus*	Killdeer	-	-	-	-
Chordeiles minor	Common nighthawk	-	-	-	-
Circus cyaneus*	Northern harrier hawk	-	-	-	u
Cistothorus platensis*#	Sedge wren	-	-	-	u
Coccyzus americanus	Yellow-billed cuckoo	c	c	u	u
Colaptes auratus	Common flicker	c	u	u	-
Colonus virginianus	Bobwhite	u	u	-	u
Columbina passerina	Ground dove	-	-	-	u
Conotopus virens	Eastern wood peewee	-	-	-	-
Coragyps atratus	Black vulture	u	u	u	u
Corvus brachyrhynchos	Common crow	-	u	c	-
Corvus ossifragus*	Fish crow	c	c	c	c
Cyanocitta cristata	Blue jay	c	c	c	-
Dendroica caerulescens#	Black-throated blue warbler	-	-	-	-
Dendroica coronata#	Yellow-rumped warbler	c	c	c	c
Dendroica discolor	Prairie warbler	c	c	u	c
Dendroica dominica*	Yellow-throated warbler	c	c	c	-
Dendroica magnolia#	Magnolia warbler	-	-	-	-
Dendroica palmarum#	Palm warbler	c	c	c	c
Dendroica petechia	Yellow warbler	-	-	-	-
Dendroica pinus	Pine warbler	-	-	-	-
Dendroica striata#	Blackpoll warbler	-	-	-	-

TABLE A-4. Relative abundance of bird species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types			
		HH	HS	CS	ST
Dendroica tigrina#	Cape May warbler	-	-	-	-
Dryocopus pileatus*	Pileated woodpecker	c	c	u	u
Dumetella carolinensis	Gray catbird	c	c	c	c
Elanoides forficatus*	Swallow-tailed kite	u	c	u	-
Empidonax virescens*	Acadian flycatcher	c	-	-	-
Eudocimus albus*	White ibis	-	u	c	-
Euphagus carolinus*#	Rusty blackbird	-	-	-	-
Falco sparverius	American kestrel	-	-	-	-
Florida caerulea*	Little blue heron	-	u	c	-
Fulica americana*#	American coot	-	-	-	u
Gallinago gallinago*#	Common snipe	-	-	-	c
Gallinula chloropus*	Common gallinule	-	-	-	-
Gelochelidon nilotica*	Gull-billed tern	-	-	-	-
Geothlypis trichas*	Common yellowthroat	c	c	c	c
Grus canadensis*	Sandhill crane	-	-	-	-
Haliaeetus leucocephalus*	Bald eagle	u	u	u	u
Himantopus mexicanus*	Black-necked stilt	-	-	-	-
Hirundo rustica	Barn swallow	-	-	-	-
Hydranassa tricolor*	Tricolored heron	-	u	c	-
Hylocichila mustelina*	Wood thrush	-	-	-	-
Ixobrychus exilis*	Least bittern	-	-	-	-
Lanius ludovicanus	Loggerhead shrike	u	-	-	u
Larus delawarensis*#	Ring-billed gull	-	-	-	-
Laterallus jamaicensis*	Black rail	-	-	-	-
Leucophoyx thula*	Snowy egret	-	c	c	u
Limnodromus griseus*#	Short-billed dowitcher	-	-	-	-
Limnodromus scolopaceus*#	Long-billed dowitcher	-	-	-	-
Limnothlypis swainsonii*	Swainson's warbler	u	u	u	-
Lophodytes cucullatus*	Hooded merganser	-	c	c	-
Melanerpes erythocephalus	Red-bellied woodpecker	c	c	c	u
Meleagris gallopavo*	Turkey	c	c	u	u
Melospiza georgiana*#	Swamp sparrow	-	u	-	c
Melospiza melodia#	Song sparrow	-	-	-	c
Mimus polyglottus	Mockingbird	u	u	u	c
Mniotilta varia#	Black and white warbler	c	c	c	u

TABLE A-4. Relative abundance of bird species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
Molothrus ater	Brown-headed cowbird	-	-	-	-
Mycteria americana*	Wood stork	-	-	c	-
Myiarchus crinitus*	Great-crested flycatcher	c	c	c	-
Numida meleagris	Guinea fowl	-	-	-	-
Nycticorax nycticorax*	Black-crowned night heron	-	u	u	u
Nycticorax violacea*	Yellow-crowned night heron	-	u	c	c
Otus asio	Screech owl	c	c	c	u
Pandion haliaetus*	Osprey	-	-	-	-
Parula americana*	Northern parula	c	c	c	-
Parus bicolor	Tufted titmouse	c	c	c	-
Parus carolinensis	Carolina chickadee	c	c	c	-
Passer domesticus	House sparrow	-	-	-	-
Passerculus sandwichensis*#	Savannah sparrow	-	-	-	c
Passerina cyanea	Indigo bunting	-	-	-	-
Phalacrocorex auritus*	Double crested cormorant	-	-	-	-
Pheucticus ludovicianus#	Rose-breasted grosbeak	-	-	-	-
Picoides borealis	Red cockaded woodpecker	-	-	-	-
Picoides pubescens	Downy woodpecker	c	c	c	-
Picoides villosus	Hairy woodpecker	c	-	u	-
Pipilo erthophthalmus	Rufous-sided towhee	c	c	-	c
Piranga rubra	Summer tananger	c	c	c	-
Plegadis falcinellus*	Glossy ibis	-	-	-	-
Pluvialis squatarola*#	Black-bellied plover	-	-	-	-
Podilymbus podiceps*	Pied-billed grebe	-	-	-	-
Polioptila caerulea	Blue-gray gnatcatcher	c	c	c	c
Pooecetes gramineus#	Vesper sparrow	-	-	-	-
Porphyrala martinica*	Purple gallinule	-	-	-	-
Porzana carolina*#	Sora	-	-	-	u
Progne subis*	Purple martin	-	-	c	c
Protonotaria citrea*	Prothonotary warbler	-	-	-	-
Quiscalus major	Boat-tailed grackle	-	u	u	c
Quisculus quiscula	Common grackle	c	c	c	-
Rallus elegans*	King rail	-	-	-	c
Rallus limicola*	Virginia rail	-	-	-	u
Regulus calendula#	Ruby-crowned kinglet	c	c	c	c

TABLE A-4. Relative abundance of bird species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types			
		HH	HS	CS	ST
Rostrhamus sociabilis*	Everglades kite	-	-	-	-
Rynchops niger*	Black skimmer	-	-	-	-
Sayornis phoebe#	Eastern phoebe	c	c	c	c
Scolopax minor*	American woodcock	u	u	-	c
Seiurus aurocapillus#	Ovenbird	-	-	-	-
Seiurus motacilla*	Louisiana waterthrush	-	-	-	-
Seiurus noveboracensis*#	Northern waterthrush	-	-	-	-
Setophaga ruticilla	American redstart	-	-	-	-
Sialia sialis	Eastern bluebird	-	-	-	-
Sphyrapicus varius#	Yellow-bellied sapsucker	c	c	c	-
Spizella passerina#	Chipping sparrow	-	-	-	-
Sterna antillarum*	Least tern	-	-	-	-
Sterna forsteri*	Foster's tern	-	-	-	-
Strix varia*	Barred owl	c	c	c	u
Sturnella magna	Eastern meadowlark	-	-	-	-
Sturnus vulgaris	European starling	-	-	-	-
Tachycineta bicolor*#	Tree swallow	-	u	u	c
Thryothorus ludovicianus	Carolina wren	c	c	c	c
Toxostoma rufum	Brown thrasher	c	u	u	u
Trigna flavipes*#	Lesser yellowlegs	-	-	-	-
Trigna melanoleuca*#	Greater yellowlegs	-	-	-	-
Troglodytes aedon#	House wren	u	c	u	c
Turdus migratorius	American robin	u	c	c	c
Tyrannus tyrannus	Eastern kingbird	-	-	-	-
Tyto alba	Barn owl	u	u	-	u
Vermivora celata#	Orange-crowned warbler	c	c	u	u
Vermivora ruficapilla#	Nashville warbler	-	-	-	-
Vireo flavifrons	Yellow-throated vireo	-	-	-	-
Vireo griseus	White-eyed vireo	c	c	u	c
Vireo olvaceous	Red-eyed vireo	c	c	u	-
Vireo solitarius#	Solitary vireo	c	c	c	-
Wilsonia citrina*	Hooded warbler	-	-	-	-
Zenaida macroura	Mourning dove	c	u	u	u
Zonotricha albicollis#	White-throated sparrow	-	-	-	c

HH = Hydric hammock habitat
HS = Hydric swamp habitat
CS = Cypress swamp habitat
ST = Swamp thicket habitat

= Migrant species
* = Wetland dependent species
c = Common
u = Uncommon
- = Possible but no data available

TABLE A-5. Relative abundance of mammal species in Wekiva River Basin habitats.

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
Blarina carolinensis	Short-tailed shrew	u	-	-	-
Cryptotis parva	Least shrew	-	u	u	-
Dasypus novemcinctus	Armadillo	-	c	u	u
Didelphis virginiana	Opossum	c	c	c	c
Eptesicus fuscus	Big brown bat	-	-	-	-
Geomys pinetis	Pocket gopher	-	-	-	-
Glaucomys volans	Flying squirrel	-	c	-	-
Lasiurus intermedius	Yellow bat	-	-	c	-
Lasiurus seminolus	Seminole bat	-	-	-	-
*Lutra canadensis**	River otter	u	u	u	-
Lynx rufus	Bobcat	c	c	u	-
Mephitis mephitis	Striped skunk	c	u	-	-
Mustela frenata	Long-tailed weasel	-	-	-	-
Myotis austroriparius	Southeastern myotis bat	-	-	-	-
*Neofiber alleni**	Florida muskrat	u	-	-	-
Neotoma floridana	Wood rat	c	u	-	-
Nycticeius humeralis	Evening bat	-	c	c	-
Ochrotomys nuttalli	Golden mouse	c	-	-	-
Odocoileus virginianus	White-tailed deer	c	u	u	u
*Oryzomys palustris**	Rice rat	c	u	-	c
Peromyscus floridanus	Florida mouse	-	-	-	-
Peromyscus gossypinus	Cotton mouse	c	c	c	c
Peromyscus polionotus	Oldfield mouse	-	-	-	-
*Pipistrellus subflavus**	Southern pipistrele bat	-	-	-	-
Plecotus rafinesquii	Eastern big-eared bat	-	-	-	-
*Procyon lotor**	Raccoon	c	c	c	c
Reithrodontomys humulis	Eastern harvest mouse	-	-	-	-
Scalopus aquaticus	Eastern mole	-	-	-	-
Sciurus carolinensis	Gray squirrel	c	c	u	-
Sciurus niger	Fox squirrel	-	-	-	
Sigmodon hispidus	Cotton rat	c	u	u	c
Spilogale putorius	Spotted skunk	-	-	-	-
Sorex longirostris	Southeastern shrew	c	-	-	-
Sus scrofa	Feral pig	u	c	c	c
Sylvilagus floridanus	Cottontail rabbit	-	u	u	-

TABLE A-5. Relative abundance of mammal species in Wekiva River Basin habitats (continued).

Scientific Name	Common Name	Habitat Types HH	HS	CS	ST
*Sylvilagus palustris**	Marsh rabbit	-	u	u	c
Tadarida brasiliensis	Free-tailed bat	-	-	-	-
*Trichechus manatus**	West Indian manatee	-	-	-	-
Urocyon cinereoargenteus	Gray fox	c	-	-	-
*Ursus americanus**	Black bear	c	-	-	-
Vulpes vulpes	Red fox	-	c	-	-

HH = Hydric hammock habitat
HS = Hydric swamp habitat
CS = Cypress swamp habitat
ST = Swamp thicket habitat

* = Wetland dependent species
c = Common
u = Uncommon
- = Possible but no data available

TABLE A-6. Designated plant and animal species of the Wekiva River Basin.

Scientific Name	Common Name	Designation A	B	C
Plants				
Bonamia grandiflora	Florida bonamia	E	UR1	
Dennstaedtia bipinnata	Cuplet fern	E		
Dryopteris ludoviciana	Florida shield fern	T		
Encyclia tampensis	Butterfly orchid	T		II
Habenaria repens	Water spider orchid	T		II
Nemastylis floridana	Fall-flowering ixia	E	UR2	
Ophioglossum palmatum	Hand adder's tongue fern	E	UR5	
Phlebodium aureum	Golden polypody	T		
Rhapidophyllum hystrix	Needle palm		UR5	
Sabal minor	Bluestem palmetto	T		
Spiranthes sp.	Ladies tresses	T		II
Thelypteris hispidula	Hairy tri-vein fern	T		
Thelypteris interrupta	Spready tri-even fern	T		
Thelypteris ovata	Ovate maiden fern	T		
Tillandsia fasciculata	Stiff-leaved wildpine	C		
Tillandsia setacea	Needle-leaved wildpine	T		
Tillandsia utriculata	Giant wildpine	C		
Zamia floridana	Florida coontie	C		II
Invertebrates				
Aphaostracon asthenes	Blue spring aphaostracon		UR2	
Aphaostracon monas	Wekiwa spring aphaostracon		UR2	
Cincinnatia parva	Blue spring snail		UR2	
Cincinnatia ponderosa	Ponderous spring snail		UR2	
Cincinnatia wekiwae	Wekiwa spring snail		UR2	
Procambarus acherontis	Orlando cave crayfish		UR	
Amphibians				
Rana areolata	Gopher frog	SSC	UR2	
Reptiles				
Alligator mississipiensis	American alligator	SSC	T	II
Drymarchon corais couperi	Eastern indigo snake	T	T	
Gopherus polyphemus	Gopher tortoise	SSC	UR2	
Neoseps reynoldsi	Sand skink	T	UR2	
Pituophis melanoleucus mugitus	Pine snake	SSC	UR2	
Sceloporus woodi	Florida scrub lizard		UR2	

TABLE A-6. Designated plant and animal species of the Wekiva River Basin (continued).

Scientific Name	Common Name	Designation A	Designation B	Designation C
Birds				
Aimophila aestivalis	Bachman's sparrow		UR2	
Aphelocoma coerulescens coerulescens	Florida scrub jay	T	T	
Aramus guarauna	Limpkin	SSC		
Athene cunicularia	Burrowing owl	SSC		II
Campephilus principalis	Ivory-billed woodpecker	E	E	
Circus cyaneus	Marsh hawk			II
Falco sparverius paulus	American kestral	T	UR2	II
Falco sparverius sparverius	Eastern kestral			II
Florida caerulea	Little blue heron	SSC		
Grus canadensis pratensis	Florida sandhill crane	T		II
Haliaeetus leucocephalus	Bald eagle	T	E	I
Hydranassa tricolor	Tricolored heron	SSC		
Leucophoyx thula	Snowy egret	SSC		
Mycteria americana	Wood stork	E	E	
Pandion haliaetus	Osprey		T	II
Picoides borealis	Red cockaded woodpecker	T	E	
Rostrhamus sociabilis	Snail kite	E	E	
Sterna antillarum	Least tern	T		
Mammals				
Lutra canadensis	River otter			II
Lynx rufus	Bobcat			II
Mustela frenata penninsulae	Florida weasel		UR2	
Myotis austroriparius	Southeastern myotis bat		UR2	
Neofiber alleni	Florida muskrat		UR2	
Peromyscus floridanus	Florida mouse	SSC	UR2	
Peromyscus polionotus decoloratus	Pallid beach mouse	E	UR3	
Plecotus rafinesquii	Eastern big-eared bat		UR2	
Sciurus niger shermani	Sherman's fox squirrel	SSC	UR2	
Trichechus manatus latirostris	West Indian manatee	E	E	I
Ursus americanus floridanus	Florida black bear	T	UR2	

DESIGNATION:

A = Florida Game and Fresh Water Fish Commission (animals) or Florida Department of Agriculture and Consumer Services (plants)
B = United States Fish and Wildlife Service
C = Convention on International Trade in Endangered Species (CITES)

CODES:

E = Endangered
T = Threatened
SSC = Species of special concern
C = Commercially exploited

I = Appendix I species
II = Appendix II species

UR1 = Under review for federal listing, with substantial evidence in existence indicating at least some degree of biological vulnerability.

UR2 = Under review for listing, but substantial evidence of biological vulnerability and/or threat is lacking.

UR3 = Still formally under review for listing, but no longer being considered for listing due to existing pervasive evidence of extinction.

UR5 = Still formally under review for listing, but no longer considered for listing because recent information indicates species is more widespread or abundant than previously believed.