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DEVELOPMENT OF ENVIRONMENTAL CONSTRAINTS FOR THE PROPOSED JANE GREEN DETENTION AREA

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ERRATA

Page 16-31 - Where appears, change "Quercus Laurifolia" to "Quercus Hemisphaerica (Bart.)".

Page 44 - In line 9, "Species composition in riparian ecosystems is dependent on hydroperiod and depth of floodplain species to maintain their dominance" should read "Species composition in riparian ecosystems is dependent on hydroperiod and depth of flooding; disturbance of hydroperiod may drastically change the ability of floodplain species to maintain their dominance".

Page 57 - Insert above Hunt, Huck, R. B., 1979, Flora, vegetation and soils of the Bull Creek Watershed, Osceola County, Florida: M.A. thesis, university of North Carolina, Dept. of Botany, Chapel Hill, North Carolina, p. 208.

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ABSTRACT

A water management schedule for a proposed upland detention area in the Upper St. Johns River Basin was designed to allow maximum flood control benefits while protecting the forested riparian ecosystem. Flooding imposes severe stress on many vascular plants, ranging from leaf chlorosis to death, due to the anoxic conditions which develop in the soil. Establishment of elevation ranges for each community type and species composition was coupled with a review of species adaptations to inundation to determine a flood tolerance gradient. Independent factors such as depth, duration and timing of flood also affect tolerance, and were considered in the regulation schedule.

INTRODUCTION

BACKGROUND

Since the early 1900's, dikes and canals built within the Upper St. Johns River Basin (USJRB) between the Fellsmere Grade and US 192 have reduced the total historic floodplain as much as 82%. This decrease in water storage capacity has induced higher flood stages created by a given rainfall event and contributed to a reduction in the mean low stages.

During the 1950's and 1960's, the Corps of Engineers (COE) and Central and Southern Florida Flood Control District (CSFCD) combined efforts to produce a water management plan for the USJRB. The construction of valley and upland tributary reservoirs providing flood control, low flow augmentation and a water supply for municipal and agricultural use, was an important element of the plan (Figure 1).

Authorization for the design and implementation of the plan was given by the Flood Control Act of 1954 (Public Law 789, 83rd Congress, 2d session). Construction of Levee 73, extending from north of Taylor Creek in Orange County to south of Bull Creek in Osceola County (Figure 2), began in 1962 and was terminated short of completion in 1972 for environmental reasons. At the time the project was halted, Taylor Creek Reservoir had been impounded. However, gaps were left beside Wolf, Pennywash, and Jane Green Creek Structures in the southern section of the levee. As a result, these proposed reservoirs were never fully impounded. In 1972, CSFCD partially filled the gap at the Jane Green Reservoir to provide access to the structure (S161). Consequently, the stream was partially impounded to

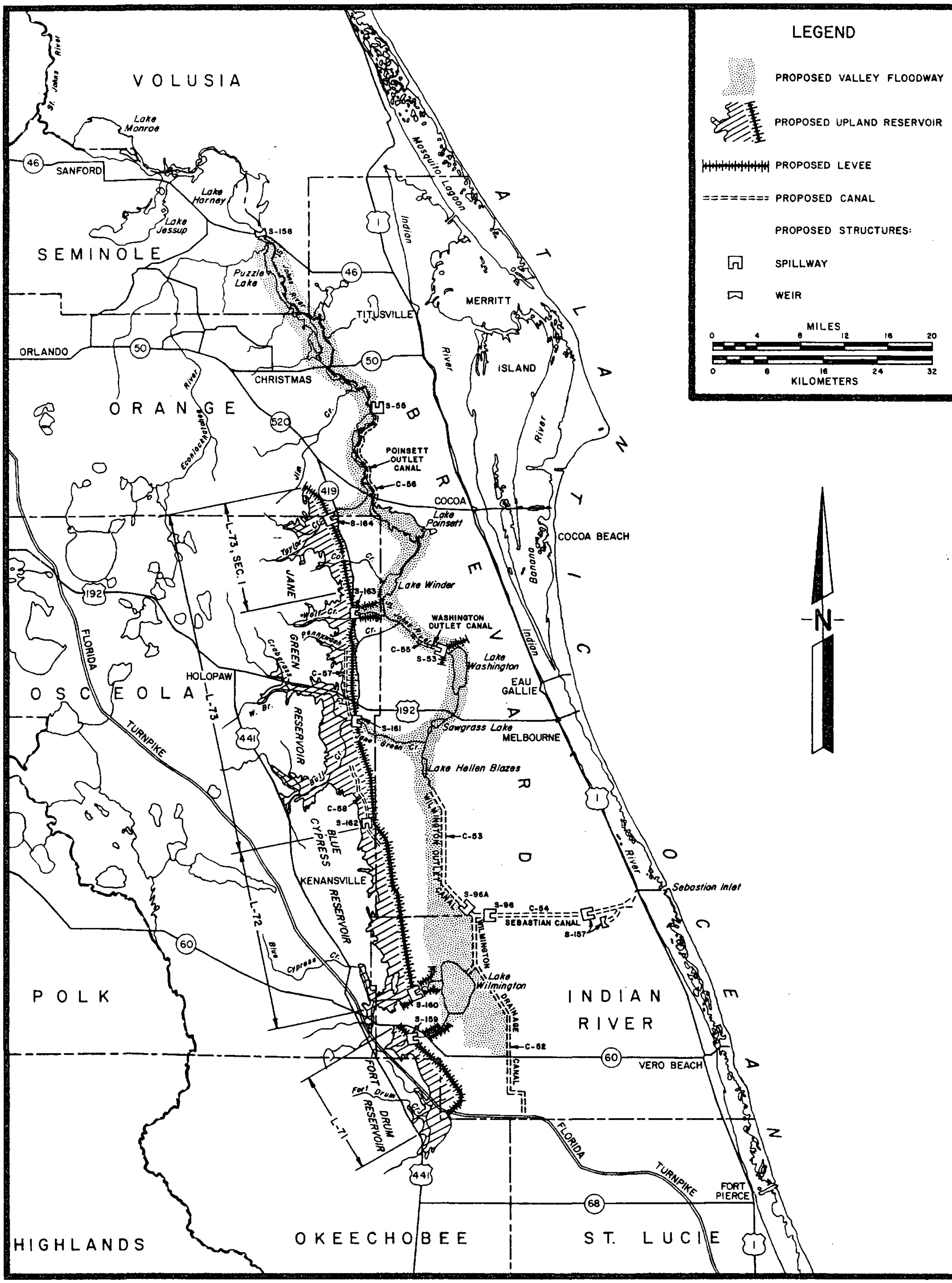

FIGURE 1. -- 1962 Corps of Engineers Upper St. Johns River Basin Plan.

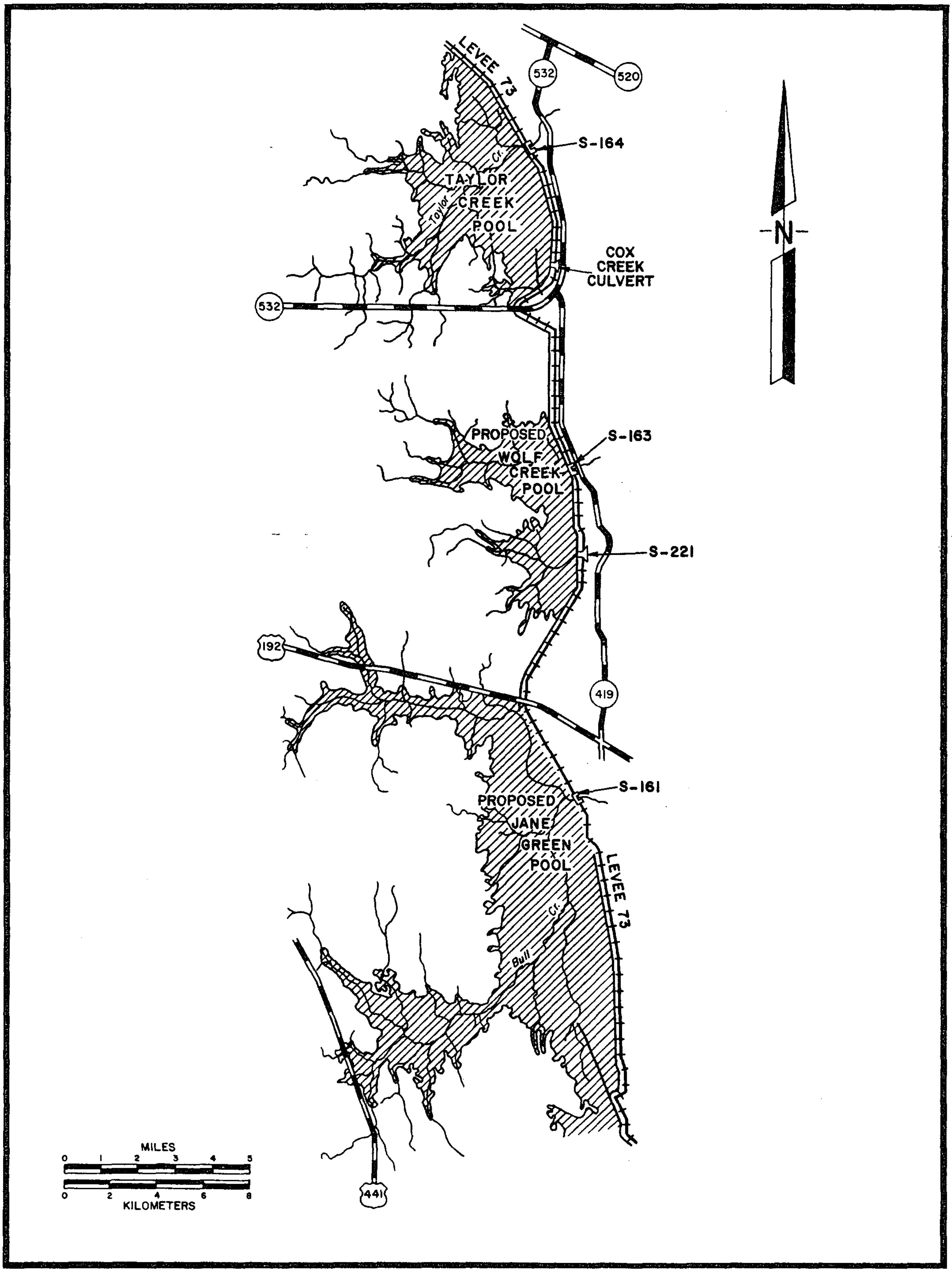

FIGURE 2. -- Levee 73 and Proposed Upland Detention Works.

the elevation of the S161 side gates, about six feet above base stream flow.

Complete closure of the gaps was postponed pending approval of the COE's environmental impact statement. In 1974, the draft statement was determined to be unacceptable to the State of Florida. Action on an alternative plan, presented by the COE to CSFCD in 1975, was delayed until presentation to the St. Johns River Water Management District (SJRWMD) Governing Board.

The SJRWMD had assumed responsibility to administer, operate and maintain COE and CSFCD water management structures in the Upper Basin in 1975. In 1976, the governing board rejected the altered COE plan and issued a conceptual plan for the area, Resolution 75-11 (Appendix 1).

This resolution recommended the existing Jane Green Reservoir system (Taylor, Cox, Pennywash, and Wolf Creek Pools) be modified for use as flood detention areas. Except during a flood event , flow through the L-73 structures would be unaltered. A study was recommended to determine the feasibility of structural modification to reduce water levels in the Jane Green Pool and to determine the impact of partial impoundment for flood detention. After a preliminary investigation (Stimmel, 1976), the gap was lowered to stream floor elevation in an attempt to reverse the apparent trend of stress and tree mortality due to partial impoundment.

OBJECTIVES AND SCOPE

This study was intended to further define the impact of impoundment and recommend constraints which would maximize flood control benefits while minimizing damage to the forested riparian ecosystem.

Vegetation damage was assumed to be the most critical potential impact of partial impoundment, affecting not only the water management function of the wetland forest, but also fish and wildlife habitat.

The project seeks to answer the following questions:

1. What are the flood tolerances of trees in Jane Green detention area?
2. What adaptations enable these trees to survive?
3. What measures can be taken to mitigate flood damage to vegetation?

Results of the investigation are presented in three major sections:

1. Results - Vegetation Survey
2. Discussion - Effect of Inundation on Woody Species
3. Summary and Recommendations - Proposed Water Management Schedule.

DESCRIPTION OF THE AREA

LOCATION

The proposed Jane Green detention area consists of 22,026 acres owned by the State of Florida, with the fee simple title held by the SJRWMD. Currently leased to the Florida Game and Fresh Water Fish Commission for game management, the land is referred to as the Bull Creek Wildlife Management Area. This area is located seven miles west of the St. Johns River in east-central Osceola County (Figure 3). Bull Creek and Crabgrass Creek drain the area, flowing in an easterly direction across the Pamlico scarp line, where Bull Creek and Crabgrass Creek converge to form Jane Green Creek.

FUNCTION

Within the Jane Green detention area are eight major ecosystems types: dry prairies, pine flatwoods, sand pine scrub, xerophytic oak woodlands, hardwood hammocks, freshwater marshes, cypress swamps and hardwood swamps. Each community has adapted to a range of soils, elevation and hydrologic regime, and provides specific wildlife food and habitat requirements. Mesic and hydric systems of the floodplain have adjusted to the shallow flooding regime of the streams and function as natural flood detention areas. Under high water conditions, floodplain species decrease the velocity of water flowing downstream, effectively detaining water for slow release as high stages diminish.

Species in the floodplain and throughout the Jane Green system are adapted to a particular water regime. The specific range of water levels to which an individual plant is adjusted depends on both its species and the inundation history of its location. Thus, altering the depth, duration, and extent of inundation impacts each affected ecosystem differently. Consequently, each ecosystem must be considered in the light of its species composition and inundation history, a history indicated by its elevation.

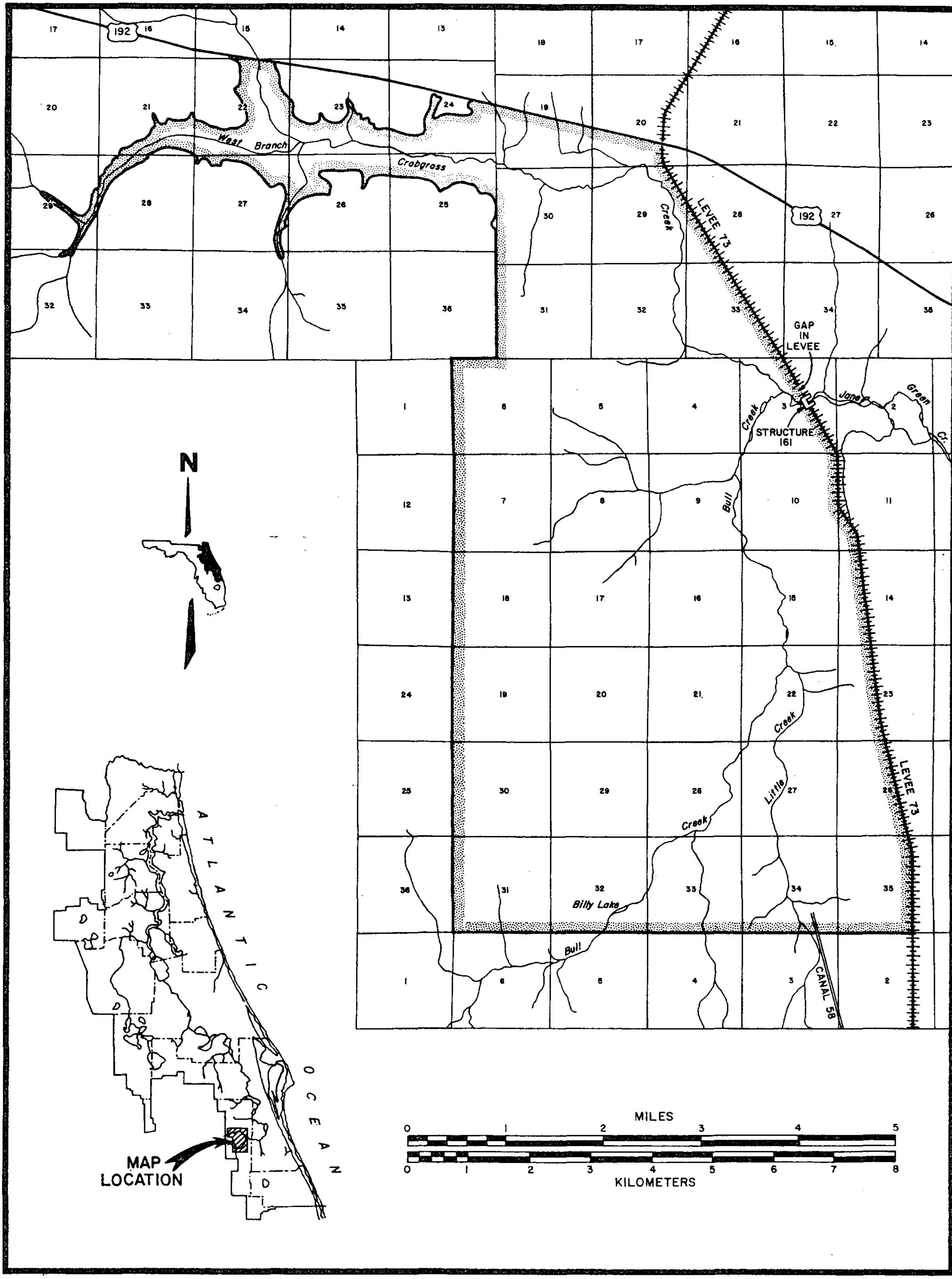

FIGURE 3. -- Study Area: Proposed Jane Green Detention Area Showing SJRWMD Fee Simple Ownership.

VEGETATION SURVEY

METHODS

Four transects were established to identify community types representative of the area of possible flood detention; two on Bull Creek and two on Crabgrass Creek (Figure 4). Each began in a upland community, crossed the creek bottomlands, and was terminated when a homogeneous upland community was reached on the other side of the creek. Lengths varied depending on the width of the floodplain.

Elevations were determined by referencing temporary bench marks at the beginning of each transect to National Geodetic Survey markers. Elevations were recorded every 100 feet along each transect.

Vegetation was identified for each community type, using the keys of Beal, (1977); Duncan and Foote, (1975); Fleming, et al., (1976); Hall, (1978); Harrar and Harrar, (1962); Godfrey and Wooten, (1979); Hitchcock, (1971); Kurz and Godfrey, (1962); Lakela and Long, (1976); Radford, et al., (1978); Small, (1972); and Tarver, et al., (1978). Dominant species of the canopy, subcanopy and understory (shrubs, vines and herbs) were identified. Changes in dominant vegetation within a community were noted and elevation determined for each community boundary encountered. Classification of community type generally follows Hartman, (1978). Within the creek valley, mesic and hydric hammocks exhibit similar canopy components and elevation ranges. Observation of the vegetation and density of the understory (shrubs and herbs) indicated a difference in moisture gradient, thus enabling mesic and hydric habitats to be identified.

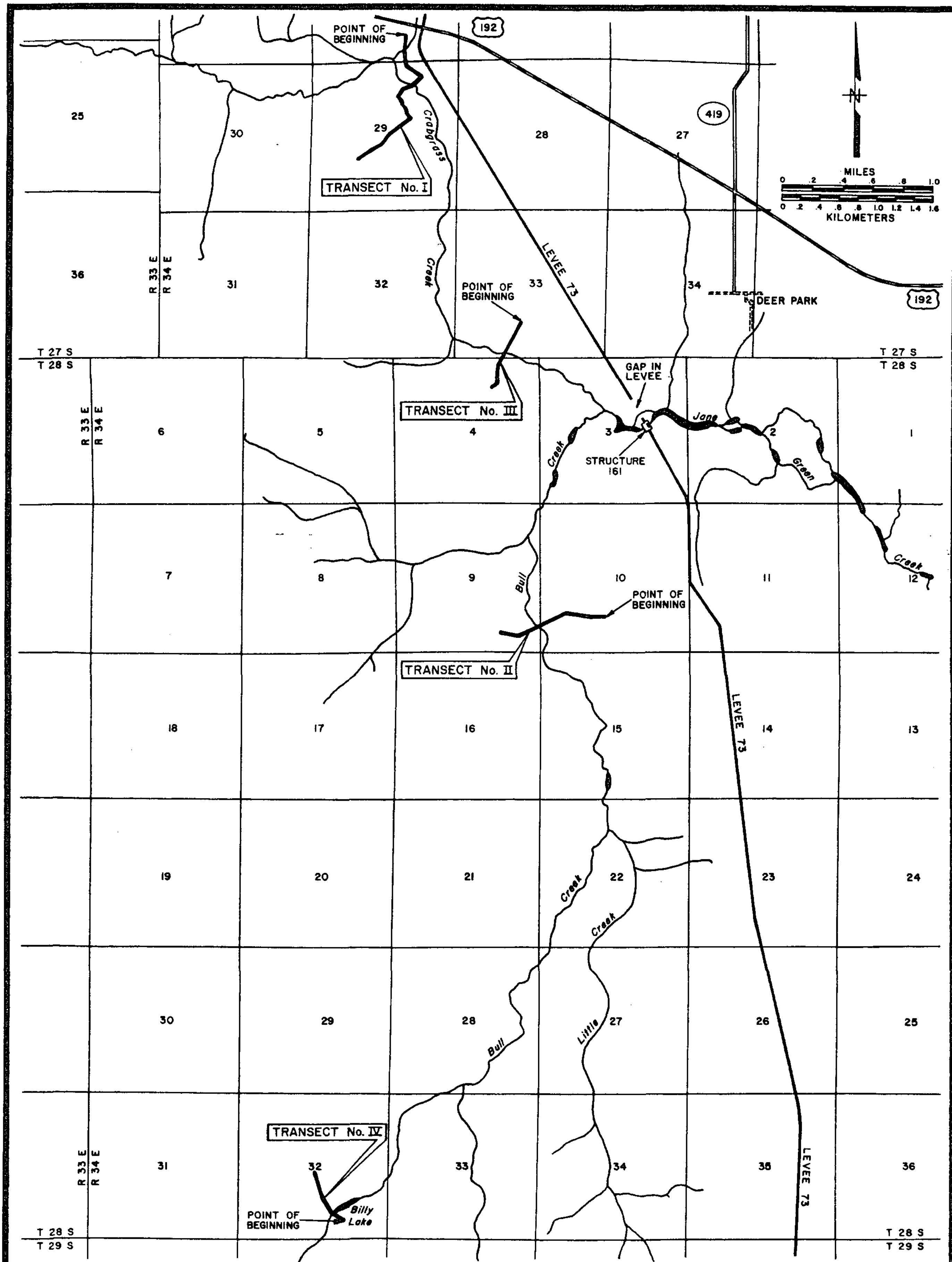

FIGURE 4. -- General Locator Map of Four Vegetation Transects in the Jane Green Detention Area.

RESULTS

The elevation and extent of the plant communities encountered along each of the study's transects are shown by Figures 5, 6, and 7. These profiles also exhibit a common pattern of vegetation distribution:

1. hardwoods tolerant of varying degrees of flooding occupy the floors of the creek valley, growing on sites ranging in elevation from 23 to 34 feet msl,
2. communities of less water-tolerant species dominated by saw palmetto (*Serenoa repens*) replace the hardwoods as the valley rises to an elevation of 25 to 37 feet msl, and
3. a transition from the hydric species of the valley floor to the more xeric species of the uplands is completed within this saw palmetto zone.

Above this transitional zone, saw palmetto persists but the vegetation is predominantly dry prairie species. Beyond the ends of the transects, at elevations approaching and exceeding 60 feet msl, the typical community type is sand pine/scrub oak.

Even in the upper elevations, communities are not homogeneous as local topography varies. For example, a xeric oak community interrupts the dry prairie near the end of Transect IV. Isolated hydric communities were also encountered in the uplands (Transects III & IV).

Tables 1-4 catalog the plant species recorded along each transect, and the extent of each species' association. Species are assigned to a structural component and dominant species indicated. The elevation range of each plant community is depicted in Table 5.

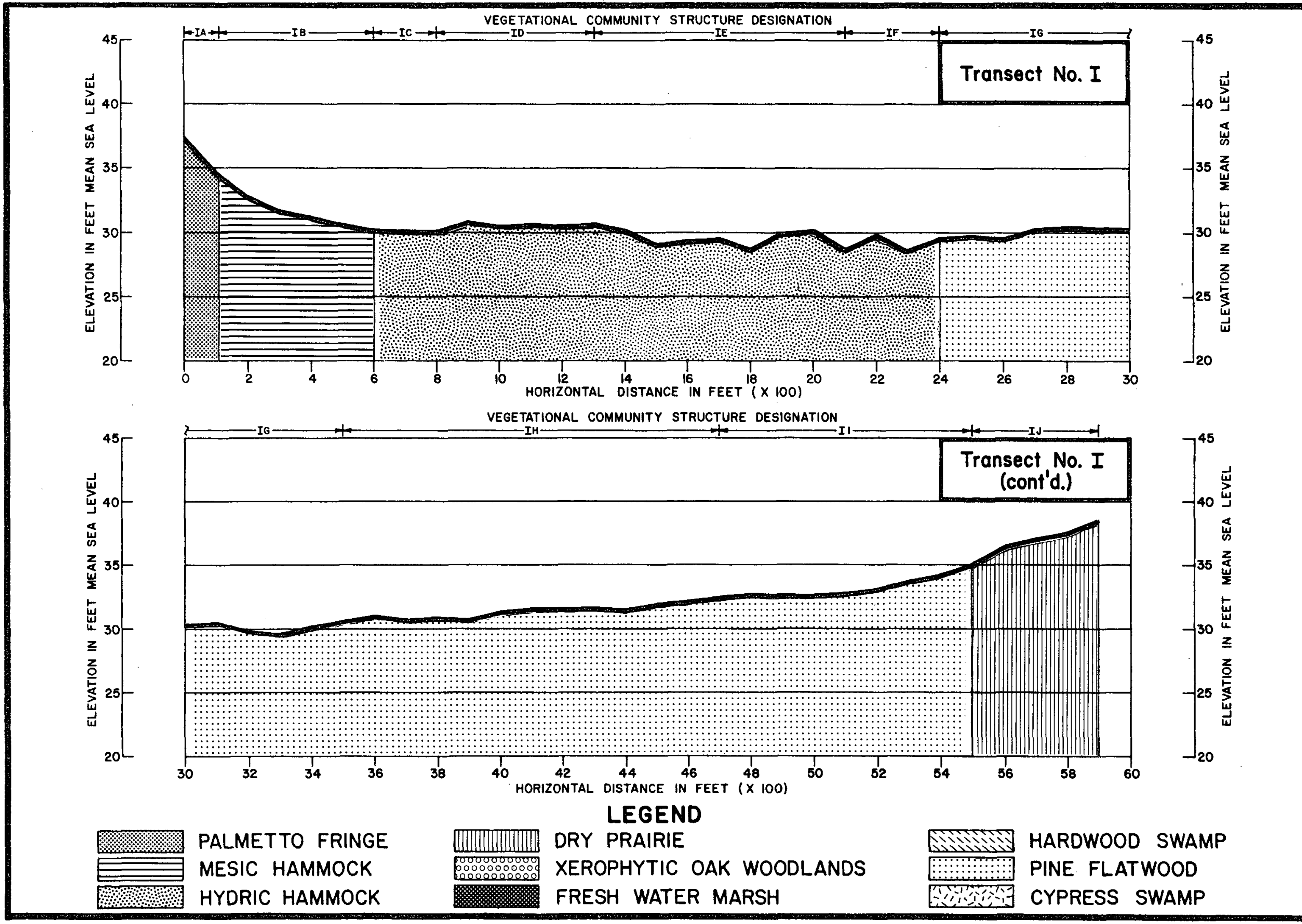

FIGURE 5. -- Location of Vegetational Communities in Relation to Elevation on Transect I in the Jane Green Detention Area.

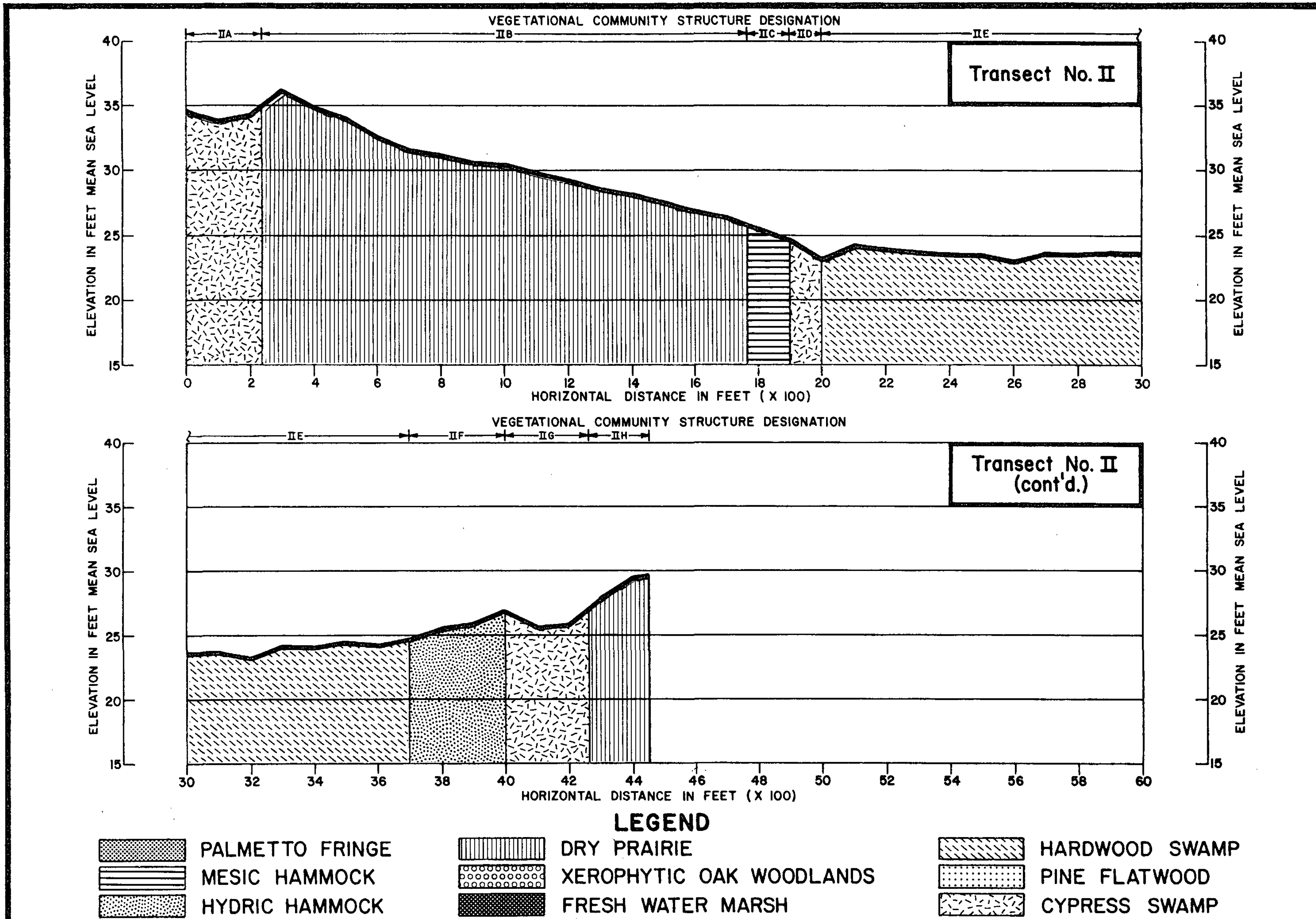

FIGURE 6. -- Location of Vegetational Communities in Relation to Elevation on Transect II in the Jane Green Detention Area.

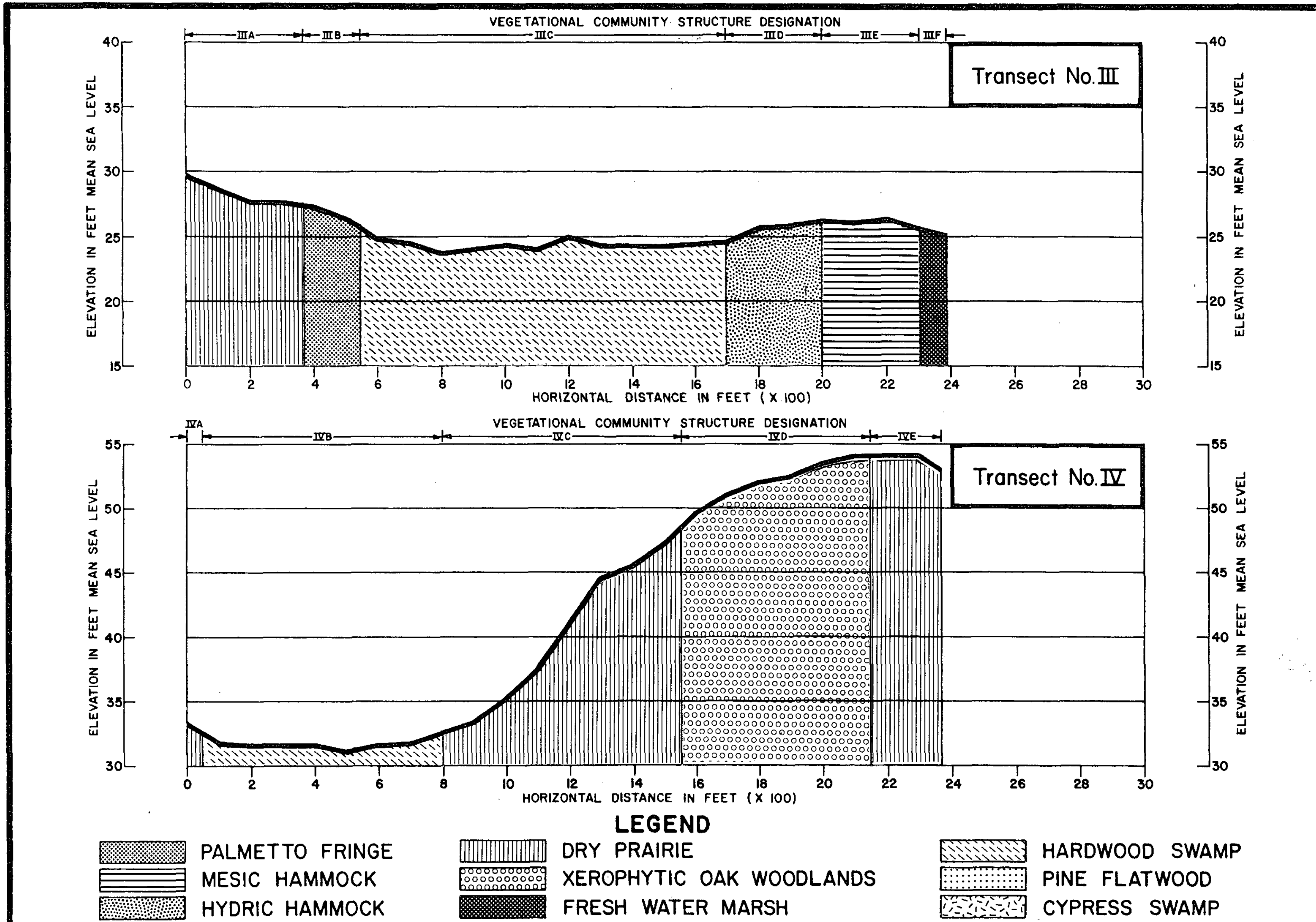

FIGURE 7. -- Location of Vegetational Communities in Relation to Elevation on Transects III and IV in the Jane Green Detention Area.

TABLE 1

VEGETATIVE COMMUNITY STRUCTURE FOR JANE GREEN DETENTION AREA

Crabgrass Creek Transect No. 1

Transect IA - Palmetto Fringe; 0 - 113 feet

Canopy	Sweetgum	- *Liquidambar styraciflua*
	Water Oak	- *Quercus nigra*
	Redbay	- *Persea borbonia*
	Magnolia	- *Magnolia grandiflora*
	Laurel Oak	- *Quercus laurifolia*
	Red Maple	- *Acer rubrum*
Shrubs	*Saw Palmetto	- *Serenoa repens*
	Gallberry	- *Ilex glabra*
	Wax Myrtle	- *Myrica cerifera*
Vines	Wild Muscadine Grape	- *Vitis rotundifolia*
	Yellow Jessamine	- *Gelsemium sempervirens*
	Blackberry	- *Rubus argutus*
Herbs	Cinnamon Fern	- *Osmunda cinnamomea*
	Chain Fern	- *Woodwardia areolata*
	Resurrection Fern	- *Polypodium polypodioides* var. *michauxianum*
	Resurrection Fern	- *Polypodium dispersum*

Transect IB - Mesic Hammock; 113 - 600 feet

Canopy	Magnolia	- *Magnolia grandiflora*
	Red Maple	- *Acer rubrum*
	Water Oak	- *Quercus nigra*
	Sweetgum	- *Liquidambar styraciflua*
	Sweetbay	- *Magnolia virginiana*
	Bald Cypress	- *Taxodium distichum*
Sub-Canopy	*Cabbage Palm	- *Sabal Palmetto*
	American Elm	- *Ulmus americana* var. *floridana*
	Red Mulberry	- *Morus rubra*
	Wild Orange	- *Citrus aurantium*
Shrubs	Wild Coffee	- *Psychotria nervosa*
	Elephant-ear	- *Colocasia esculentum*
	French Mulberry	- *Callicarpa americana*
	*Guiana Rapenea	- *Rapanea guianensis*

* Indicates dominance

Transect IB - Mesic Hammock: 113 - 600 feet (Continued)

<u>Herbs</u>	*Smart Weed	- <u>Polygonum hydropiperoides</u>
	Resurrection Fern	- <u>Polypodium polypodioides</u>
	*Cinnamon Fern	- <u>Osmunda cinnamomea</u>
	Lizard's Tail	- <u>Saururus cernuus</u>
	*Panic Grass	- <u>Panicum spp.</u>
	*Swamp Fern	- <u>Blechnum serrulatum</u>
<u>Vines</u>	Poison Ivy	- <u>Rhus radicans</u>
	Cat Brier	- <u>Smilax spp.</u>
<u>Epiphytes</u>	Bromeliads	- <u>Tillandsia spp.</u>
	Wild Orchid	- <u>Encyclia tampensis</u>
	Golden Hand Fern	- <u>Phlebodium aureum</u>

Transect IC - Hydric Hammock; 600 - 800 feet

<u>Canopy</u>	Red Maple	- <u>Acer rubrum</u>
	Blackgum	- <u>Nyssa biflora</u>
	Sweetgum	- <u>Liquidambar styraciflua</u>
	*Laurel Oak	- <u>Quercus laurifolia</u>
	Water Oak	- <u>Quercus nigra</u>
	Redbay	- <u>Persea borbonia</u>
<u>Sub-Canopy</u>	*Cabbage Palm	- <u>Sabal palmetto</u>
	American Elm	- <u>Ulmus americana</u> var. <u>floridana</u>
<u>Shrubs</u>	Saw Palmetto	- <u>Serenoa repens</u>
<u>Herbs</u>	Lizard's Tail	- <u>Saururus cernuus</u>
	Panic Grass	- <u>Panicum spp.</u>
<u>Vines</u>	Poison Ivy	- <u>Rhus radicans</u>
<u>Epiphytes</u>	Bromeliads	- <u>Tillandsia spp.</u>
	Orchid	- <u>Encyclia tampensis</u>
	Golden Hand Fern	- <u>Phlebodium aureum</u>

Transect ID - Hydric Hammock; 800 - 1,300 feet

<u>Canopy</u>	Laurel Oak	- <u>Quercus laurifolia</u>
	Red Maple	- <u>Acer rubrum</u>
	Bald Cypress	- <u>Taxodium distichum</u>
	Magnolia	- <u>Magnolia grandiflora</u>
	Water Hickory	- <u>Carya aquatica</u>
	Sweetgum	- <u>Liquidambar styraciflua</u>
<u>Sub-Canopy</u>	*Cabbage Palm	- <u>Sabal palmetto</u>
	Blue Beech	- <u>Carpinus caroliniana</u>

Transect ID - Hydric Hammock; 800 - 1,300 feet (Continued)

Shrubs	Evening Primrose	- Ludwigia sp.
	Wax Myrtle	- Myrica cerifera
	Saw Palmetto	- Serenoa repens
Herbs	Wild Coffee	- Psychotria nervosa
	Panic Grass	- Panicum spp.
	*Cinnamon Fern	- Osmunda cinnomomea
	Partridge Berry	- Mitchella repens
	Beak Rush	- Rhynchospora spp.
	*Swamp Fern	- Blechnum serrulatum
Vines	Poison Ivy	- Rhus radicans
	Cat Brier	- Smilax spp.
	Virginia Creeper	- Parthenocissus quinquifolia
Ephiphytes	Bromeliads	- Tillandsia spp.
	Wild Orchid	- Encyclia tampensis
	Golden Hand Fern	- Phlebodium aureum

Transect IE - Hydric Hammock; 1,300 - 2,100 feet

Canopy	Water Hickory	- Carya aquatica
	*Laurel Oak	- Quercus laurifolia
	Red Maple	- Acer rubrum
	Bald Cypress	- Taxodium distichum
	Carolina Ash	- Fraxinus caroliniana
	Sweetgum	- Liquidambar styraciflua
Sub-Canopy	Cabbage Palm	- Sabal palmetto
	Blue Beech	- Carpinus caroliniana
	American Elm	- Ulmus americana var. floridana
Herbs	Panic Grass	- Panicum spp.
	Beak Rush	- Rhynchospora spp.
	Lizard's Tail	- Saururus cernuus
	Cinnamon Fern	- Osmunda cinnomomea
Vines	Poison Ivy	- Rhus radicans
	Cat Brier	- Smilax spp.
Epiphytes	Bromeliads	- Tillandsia spp.
	Orchid	- Encyclia tampensis
	Golden Hand Fern	- Phlebodium aureum

Transect IF - Hydric Hammock; 2,100 - 2,400 feet

Canopy	*Laurel Oak	- Quercus laurifolia
	Sweetgum	- Liquidambar styraciflua
	Red Maple	- Acer rubrum
	Water Hickory	- Carya aquatica

Transect IF - Hydric Hammock; 2,100 - 2,400 feet (Continued)

Canopy	Slash Pine	- *Pinus elliottii*
	Bald Cypress	- *Taxodium distichum*
Sub-Canopy	*Cabbage Palm	- *Sabal palmetto*
	American Elm	- *Ulmus americana* var. *floridana*
	Blue Beech	- *Carpinus caroliniana*
	Blackgum	- *Nyssa biflora*
Herbs	Panic Grass	- *Panicum* spp.
Vines	Cat Brier	- *Smilax* spp.

Transect IG - Pine Flatwoods; 2,400 - 3,500 feet

Canopy	*Slash Pine	- *Pinus elliottii*
Sub-Canopy	*Cabbage Palm	- *Sabal palmetto*
	Laurel Oak	- *Quercus laurifolia*
Shrubs	*Saw Palmetto	- *Serenoa repens*
	Sweetgum	- *Liquidambar styraciflua*
	Persimmon	- *Diospyros virginiana*
	*Wax Myrtle	- *Myrica cerifera*
	Chapman Oak	- *Quercus chapmanii*
	Red Maple	- *Acer rubrum*
	St. John's Wort	- *Hypericum* spp.
Herbs	Panic Grass	- *Panicum* spp.
	Tick Seed	- *Coreopsis leavenworthii*
	Broom Sedge	- *Andropogon* spp.
	White Top Sedge	- *Dichromena colorata*
	Yellow-eyed Grass	- *Xyris ambigua*
	*Wire Grass	- *Aristida stricta*
	Meadow Beauty	- *Rhexia cubensis*
	Marsh Pink	- *Sabatia grandiflora*
Vines	Sensitive-brier	- *Schrankia microphylla*
	Cat Brier	- *Smilax* spp.
	Wild Muscadine Grape	- *Vitis rotundifolia*

Transect IH - Pine Flatwoods; 3,500 - 4,700 feet

Canopy	*Slash Pine	- *Pinus elliottii*
Sub-Canopy	*Cabbage Palm	- *Sabal palmetto*

Transect IH - Pine Flatwoods; 3,500 - 4,700 feet (Continued)

Shrubs	*Saw Palmetto	- Serenoa repens
	*Wax Myrtle	- Myrica cerifera
	Laurel Oak	- Quercus laurifolia
Herbs	Pink Eupatorium	- Eupatorium incarnatum
	Dog Fennel	- Eupatorium capillifolium
	Panic Grass	- Panicum spp.
	Tick Seed	- Coreopsis leavenworthii
	Broom Sedge	- Andropogon spp.
	Black Root	- Pterocaulon pycnostachym
	*Wire Grass	- Aristida stricta
Vines	Blackberry	- Rubus argutus
	Cat Brier	- Smilax spp.

Transect II - Pine Flatwoods; 4,700 - 5,500 feet

Canopy	*Slash Pine	- Pinus elliottii
Sub-Canopy	*Cabbage Palm	- Sabal palmetto
Shrubs	*Gallberry	- Ilex glabra
	*Wax Myrtle	- Myrica cerifera
	*Fetter-bush	- Lyonia lucida
	*Saw Palmetto	- Serenoa repens
	Winged Sumac	- Rhus copallina
	Laurel Oak	- Quercus laurifolia
	Sand Live Oak	- Quercus virginiana var. maritima
	St. John's Wort	- Hypericum spp.
Herbs	Pink Eupatorium	- Eupatorium incarnatum
	Broom Sedge	- Andropogon spp.
	*Wire Grass	- Aristida stricta
	Meadow Beauty	- Rhexia cubensis
Vines	Blackberry	- Rubus argutus
	Wild Muscadine Grape	- Vitis rotundifolia
	Cat Brier	- Smilax spp.

Transect IJ - Dry Prairies; 5,500 - 5,900 feet

Shrubs	*Saw Palmetto	- Serenoa repens
	Gallberry	- Ilex glabra
	St. John's Wort	- Hypericum spp.
	Tar Flower	- Befaria racemosa
	Myrtle Oak	- Quercus myrtifolia

Transect IJ - Dry Prairies; 5,500 - 5,900 feet (Continued)

Herbs	Pteridium Fern	- *Pteridium aquilinum*
	Black Root	- *Pterocaulon pycnostachum*
	*Wire Grass	- *Aristida stricta*
	Broom Sedge	- *Andropogon spp.*
Vines	Wild Muscadine	- *Vitis rotundifolia*

TABLE 2

VEGETATIVE COMMUNITY STRUCTURE FOR JANE GREEN DETENTION AREA

Bull Creek Transect No. II

Transect IIA - Cypress Swamp; 0 - 230 feet

Canopy	*Pond Cypress	- Taxodium ascendens
	Slash Pine	- Pinus elliottii
	Red Maple	- Acer rubrum
Shrubs	Laurel Oak	- Quercus laurifolia
	Wax Myrtle	- Myrica cerifera
	Persimmon	- Diospyros virginiana
	Sea Myrtle	- Baccharis halimifolia
	Fetter-bush	- Lyonia lucida
Herbs	Lizard's Tail	- Saururus cernuus
	Cinnamon Fern	- Osmunda cinnamomea
	Dog Fennel	- Eupatorium capillifolium
	Carex Sedge	- Carex spp.
	Saw Grass	- Cladium jammicense
	Pickerelweed	- Pontederia lanceolata
	Marsh Pennywort	- Hydrocotyle umbellata
Vines	Poison Ivy	- Rhus radicans
Epiphytes	Wild Orchid	- Encyclia tampensis
	Bromeliads	- Tillandsia spp.

Transect IIB - Dry Prairies; 230 - 1,768 feet

Canopy	Slash Pine (scattered)	- Pinus elliottii
Sub-Canopy	Cabbage Palm (scattered)	- Sabal palmetto
Shrubs	*Saw Palmetto	- Serenoa repens
	Gallberry	- Ilex glabra
	*Fetter-bush	- Lyonia lucida
	Stagger-bush	- Lyonia ferruginea
	Winged Sumac	- Rhus copallina
	Blueberry	- Vaccinium myroinites
	Tar Flower	- Befaria racemosa
	French Mulberry	- Callicarpa americana
	Wax Myrtle	- Myrica cerifera
	Myrtle Oak	- Quercus myrtifolia
	Chapman Oak	- Quercus chapmanii

* Indicates dominance

Transect IIB - Dry Prairies; 230 - 1,768 feet (Continued)

Herbs	False-hoarhound	- *Eupatorium rotundifolium*
	Dog Fennel	- *Eupatorium capillifolium*
	*Big Bluestem	- *Andropogon spp.*
	*Wire Grass	- *Artistida stricta*
	Pteridium Fern	- *Pteridium aquilinum*
	Black Root	- *Pterocaulon pycnostachyum*
Vines	Sensitive-brier	- *Schrankia microphylla*
	Wild Muscadine Grape	- *Vitis rotundifolium*

Transect IIC - Mesic Hammock; 1,768 - 1,900 feet

Canopy	Live Oak	- *Quercus virginiana*
	Laurel Oak	- *Quercus laurifolia*
	Cabbage Palm	- *Sabal palmetto*
	Slash Pine	- *Pinus elliottii*
Shrubs	St. John's Wort	- *Hypericum spp.*
	Saw Palmetto	- *Serenoa repens*
	Queens Delight	- *Stillingia sp.*
	Wax Myrtle	- *Myrica cerifera*
Herbs	Button Weed	- *Diodia virginiana*
	Yellow-eyed Grass	- *Xyris ambigua*
	Broom Sedge	- *Andropogon spp.*
	Dog Fennel	- *Eupatorium capillifolium*
	Tick Seed	- *Coreopsis leavenworthii*
	Pink Eupatorium	- *Eupatorium incarnatum*
	Centella	- *Centella asiatica*
Vines	Poison Ivy	- *Rhus radicans*
Epiphytes	Wild Orchids	- *Encyclia tampensis*
	Golden Hand Fern	- *Phlebodium aureum*
	Resurrection Fern	- *Polypodium polypodioides*
	Bromeliads	- *Tillandsia spp.*

Transect IID - Cypress Swamp; 1,900 - 2,000 feet

Canopy	*Bald Cypress	- *Taxodium distichum*
Sub-Canopy	Honey-locust	- *Gleditsia aquatica*
Shrubs	Primrose Willow	- *Ludwigia sp.*
Herbs	*Carex Sedge	- *Carex spp.*
	Pink Eupatorium	- *Cupatorium incarnatum*
	Tick Seed	- *Coreopsis leavenworthii*
	Pickerelweed	- *Pontederia lanceolata*

Transect IID - Cypress Swamp; 1,900 - 2,000 feet (Continued)

Herbs	Marsh Pennywort	- *Hydrocotyle umbellata*
	Centella	- *Centella asiatica*
Vines	Poison Ivy	- *Rhus radicans*
Epiphytes	Wild Orchids	- *Encyclia tampensis*
	Bromeliads	- *Tillandsia spp.*

Transect IIE - Hardwood Swamp; 2,000 - 3,700 feet

Canopy	Bald Cypress	- *Taxodium distichum*
	Red Maple	- *Acer rubrum*
	*Carolina Ash	- *Fraxinus caroliniana*
	Laurel Oak	- *Quercus laurifolia*
Sub-Canopy	Cabbage Palm	- *Sabal palmetto*
Shrubs	Wax Myrtle	- *Myrica cerifera*
Herbs	Carex Sedge	- *Carex spp.*
Vines	Poison Ivy	- *Rhus radicans*
Epiphytes	Wild Orchids	- *Encyclia tampensis*
	Bromeliads	- *Tillandsia spp.*

Transect IIF - Hydric Hammock; 3,700 - 4,000 feet

Canopy	Bald Cypress	- *Taxodium distichum*
	Red Maple	- *Acer rubrum*
	Carolina Ash	- *Fraxinus caroliniana*
	*Laurel Oak	- *Quercus laurifolia*
Sub-Canopy	*Cabbage Palm	- *Sabal palmetto*
	Honey-locust	- *Gleditsia aquatica*
	Swamp Dogwood	- *Cornus stricta* (Lam.)
Herbs	Carex Sedge	- *Carex spp.*
	Marsh Pink	- *Sabatia grandiflora*
	Panic Grass	- *Panicum spp.*
Vines	Cat Brier	- *Smilax spp.*
	Poison Ivy	- *Rhus radicans*
Epiphytes	Bromeliads	- *Tillandsia spp.*
	Wild Orchids	- *Encyclia tampensis*
	Golden Hand Fern	- *Phlebodium aureum*

Transect IIG - Cypress Swamp; 4,000 - 4,261 feet

Canopy	Slash Pine	- *Pinus elliottii*
	Red Maple	- *Acer rubrum*
	*Bald Cypress	- *Taxodium distichum*
	Redbay	- *Persea borbonia*
	Blackgum	- *Nyssa biflora*
Sub-Canopy	Cabbage Palm	- *Sabal palmetto*
	American Elm	- *Ulmus americana*
Shrubs	Wax Myrtle	- *Myrica cerifera*
	Swamp Dogwood	- *Cornus foemina*
Herbs	Lizard's Tail	- *Saururus cernuus*
	Pickerelweed	- *Pontederia lanceolata*
Vines	Cat Brier	- *Smilax spp.*
	Poison Ivy	- *Rhus radicans*
Epiphytes	Bromeliads	- *Tillandsia spp.*
	Wild Orchids	- *Encyclia tampensis*
	Golden Hand Fern	- *Phlebodium aureum*

Transect IIH - Dry Prairies; 4,261 - 4,463 feet

Canopy	Slash Pine	- *Pinus elliottii*
Shrubs	Gallberry	- *Ilex glabra*
	Wax Myrtle	- *Myrica cerifera*
	Fetter-bush	- *Lyonia lucida*
	*Saw Palmetto	- *Serenoa repens*
Herbs	*Wire Grass	- *Aristida stricta*
	Windmill Grass	- *Chloris spp.*
	Panic Grass	- *Panicum spp.*
	Bluestem	- *Andropogon spp.*
	Pitcher Plant	- *Sarracenia minor*
	Black Root	- *Pterocaulon pycnostachyum*
	False-Hoarhound	- *Eupatorium rotundifolium*
	Yellow-eyed Grass	- *Xyris ambigua*
	Grassy-leaf Aster	- *Heterotheca graminifolia*

TABLE 3

VEGETATIVE COMMUNITY STRUCTURE FOR JANE GREEN DETENTION AREA

Crabgrass Creek Transect No. III

Transect IIIA - Dry Prairies; 0 - 350 feet

Canopy	Slash Pine	- *Pinus elliottii*
Shrubs	Wax Myrtle	- *Myrica cerifera*
	St. John's Wort	- *Hypericum spp.*
	*Saw Palmetto	- *Serenoa repens*
	Fetter-bush	- *Lyonia lucida*
	Gallberry	- *Ilex glabra*
	Chapman Oak	- *Quercus chapmanii*
	Sweetgum	- *Liquidambar styraciflua*
	Blueberry	- *Vaccinium myrsinites*
Herbs	Black Root	- *Pterocaulon pycnostachyum*
	Dog Fennel	- *Eupatorium capillifolium*
	Yellow-eyed Grass	- *Xyris ambigua*
	Broom Sedge	- *Andropogon spp.*
	Marsh Pink	- *Sabatia grandiflora*
	*Wire Grass	- *Aristida stricta*
	Pteridium Fern	- *Pteridium aquilinum*
	Pitcher Plant	- *Sarracenia minor*
Vines	Sensitive-brier	- *Schrankia microphylla*
	Cat Brier	- *Smilax spp.*
	Wild Muscadine Grape	- *Vitis rotundifolia*

Transect IIIB - Palmetto Fringe; 350 - 530 feet

Sub-Canopy	Laurel Oak	- *Quercus laurifolia*
	Sweetgum	- *Liquidambar styraciflua*
	Persimmon	- *Diospyros virginiana*
Shrubs	*Saw Palmetto	- *Serenoa repens*
	St. John's Wort	- *Hypericum spp.*
	Gallberry	- *Ilex glabra*
Herbs	Cinnamon Fern	- *Osmunda cinnamomea*
	*Swamp Fern	- *Blechnum serrulatum*
Vines	Cat Brier	- *Smilax spp.*
	Wild Muscadine Grape	- *Vitis rotundifolia*

* Indicates dominance

Transect IIIC - Hardwood Swamp; 530 - 1,700 feet

Canopy	Sweetgum	- Liquidambar styraciflua
	Laurel Oak	- Quercus laurifolia
	*Red Maple	- Acer rubrum
	*Carolina Ash	- Fraxinus caroliniana
	*Bald Cypress	- Taxodium distichum
	Redbay	- Persea borbonia
Sub-Canopy	Cabbage Palm	- Sabal palmetto
Shrubs	Wax Myrtle	- Myrica cerifera
	Primrose Willow	- Ludwigia sp.
	Guiana Rapanea	- Rapanea guianensis
Herbs	Cinnamon Fern	- Osmunda cinnamomea
	Lizard's Tail	- Saururus cernuus
	Pickerelweed	- Pontederia lanceolata
	Swamp Fern	- Blechnum serrulatum
Vines	Poison Ivy	- Rhus radicans
	Virginia Creeper	- Parthenocissus quinquefolia
	Cat Brier	- Smilax spp.
Epiphytes	*Bromeliads	- Tillandsia spp.
	Wild Orchids	- Encyclia tampensis
	Golden Hand Fern	- Phlebodium aureum

Transect IIID - Hydric Hammock; 1,700 - 2,000 feet

Canopy	Red Maple	- Acer rubrum
	*Laurel Oak	- Quercus laurifolia
Sub-Canopy	Cabbage Palm	- Sabal palmetto
	Blue Beech	- Carpinus caroliniana
Shrubs	Primrose Willow	- Ludwigia spp.
Herbs	Panic Grass	- Panicum spp.
	Carex Sedge	- Carex spp.
	Foxtail Grass	- Setaria spp.
	White-top Sedge	- Dichromena colorata
	Tick Seed	- Coreopsis leavenworthii
	Swamp Fern	- Blechnum serrulatum
Vines	*Poison Ivy	- Rhus radicans
Epiphytes	Bromeliads	- Tillandsia spp.
	Wild Orchid	- Encyclia tampensis
	Golden Hand Fern	- Phlebodium aureum

Transect IIIE - Mesic Hammock; 2,000 - 2,300 feet

<u>Canopy</u>	*Cabbage Palm	- <u>Sabal palmetto</u>
<u>Sub-Canopy</u>	*Laurel Oak	- <u>Quercus laurifolia</u>
<u>Shrubs</u>	*Saw Palmetto	- <u>Serenoa repens</u>
	*Wax Myrtle	- <u>Myrica cerifera</u>
	St. John's Wort	- <u>Hypericum spp.</u>
	American Elm	- <u>Ulmus americana</u>
<u>Vines</u>	*Poison Ivy	- <u>Rhus radicans</u>
	Wild Muscadine Grape	- <u>Vitis rotundifolia</u>
	Cat Brier	- <u>Smilax spp.</u>
<u>Epiphytes</u>	Golden Hand Fern	- <u>Phlebodium aureum</u>
	Bromeliads	- <u>Tillandsia spp.</u>

Transect IIIF - Fresh Water Marsh; 2,300 - 2,389 feet

<u>Canopy</u>	Bald Cypress	- <u>Taxodium distichum</u>
<u>Shrubs</u>	Red Maple	- <u>Acer rubrum</u>
	Saw Palmetto	- <u>Serenoa repens</u>
	Button Bush	- <u>Cephalanthus occidentalis</u>
<u>Herbs</u>	Windmill Grass	- <u>Chloris spp.</u>
	Prairie Iris	- <u>Iris hexagona</u>
	Pickerelweed	- <u>Pontederia lanceolata</u>
	Pink Eupatorium	- <u>Eupatorium incarnatum</u>
	Panic Grass	- <u>Panicum spp.</u>

TABLE 4

VEGETATION COMMUNITY STRUCTURE FOR JANE GREEN DETENTION AREA

Bull Creek Transect No. IV

Transect IVA - Dry Prairie; 0 - 47 feet

Canopy	Slash Pine	- *Pinus elliottii*
Shrubs	*Saw Palmetto	- *Serenoa repens*
	Wax Myrtle	- *Myrica cerifera*
	Fetter-bush	- *Lyonia lucida*
Herbs	Pitcher Plant	- *Sarracenia minor*
	Hat Pin	- *Eriocaulon decagulare*

Transect IVB - Hardwood Swamp; 47 - 800 feet

Canopy	*Carolina Ash	- *Fraxinus caroliniana*
	*Bald Cypress	- *Taxodium distichum*
	Laurel Oak	- *Quercus laurifolia*
	Red Maple	- *Acer rubrum*
Sub-Canopy	American Elm	- *Ulmus americana*
	American Holly	- *Ilex opaca*
	Cabbage Palm	- *Sabal palmetto*
	Honey-locust	- *Gleditsia aquatica*
Herbs	*Carex Sedge	- *Carex spp.*
	Smart Weed	- *Polygonum hydropiperoides*
	Lizard's Tail	- *Saururus cernuus*
	Swamp Fern	- *Blechnum serrulatum*
Vines	Cat Brier	- *Smilax spp.*
	Poison Ivy	- *Rhus radicans*
Epiphytes	*Bromeliads	- *Tillandsia spp.*
	Wild Orchids	- *Encyclia tampensis*
	Golden Hand Fern	- *Phlebodium aureum*

Transect IVC - Dry Prairie; 800 - 1,600 feet

Shrubs	*Saw Palmetto	- *Serenoa repens*
	Winged Sumac	- *Rhus copallina*
	*Fetter-bush	- *Lyonia lucida*
	Blueberry	- *Vaccinium myrsinites*
	Wax Myrtle	- *Myrica cerifera*

* Indicates dominance

Transect IVC - Dry Prairie; 800 - 1,600 feet (Continued)

Shrubs	Chapman Oak	- *Quercus chapmanii*
	Dwarf-live Oak	- *Quercus minima*
	Sea Myrtle	- *Baccharis halimifolia*
	Gopher Apple	- *Chrysobalanus oblongifolius*
Herbs	Black Root	- *Pterocaulon pycnostachyum*
	Pteridium Fern	- *Pteridium aquilinum*
	False-Hoarhound	- *Eupatorium rotundifolium*
	Paw-Paw	- *Asimina reticulata*
	*Wire Grass	- *Aristida stricta*
Vines	Cat Brier	- *Smilax spp.*
	Sensitive -brier	- *Schrankia microphylla*

Transect IVD - Xerophytic Oak Woodlands; 1,600 - 2,000 feet

Canopy	*Sand Live Oak	- *Quercus virginiana* var. *maritima*
Shrubs	Saw Palmetto	- *Serenoa repens*
	Stagger-Bush	- *Lyonia ferruginea*
	American Holly	- *Ilex opaca*
	Fetter-bush	- *Lyonia lucida*
	Gopher Apple	- *Chrysobalanus oblongifolius*
	Chapman Oak	- *Quercus chapmanii*
	Myrtle Oak	- *Quercus myrtifolia*
Herbs	*Wire Grass	- *Aristida stricta*
	Black Root	- *Pterocaulon pycnostachyum*
	Goldenrod	- *Solidago spp.*
	Hat Pin	- *Ericocaulon decangalare*
	Bahia Grass	- *Paspalum spp.*
Vines	Sensitive-brier	- *Schrankia microphylla*

Transect IVE - Dry Prairie; 2,100 - 2,350 feet

Shrubs	*Saw Palmetto	- *Serenoa repens*
	*Fetter-bush	- *Lyonia lucida*
	*Stagger-Bush	- *Lyonia ferruginea*
	Wax Myrtle	- *Myrica cerifera*
	Tar Flower	- *Befaria racenosa*
	Blueberry	- *Vaccinium myrsinites*
	St. John's Wort	- *Hypericum spp.*
	Gopher Apples	- *Chrysobalanus oblongifolius*

Transect IVE - Dry Prairie; 2,100 - 2,350 feet (Continued)

Herbs	*Wire Grass	- *Aristida stricta*
	Broom Sedge	- *Andropogon* spp.
	Black Root	- *Pterocaulon pycnostachyum*
	Hat Pin	- *Ericocaulon decangalare*
	Marsh Pink	- *Sabatia grandiflora*

Transect IVF - Wet Prairie; 2,350 - 2,364 feet

Shrubs	Pond Cypress	- *Taxodium ascendens*
	*St. John's Wort	- *Hypericum brachyphyllum*
Herbs	Chain Fern	- *Woodwardia virginia*
	Yellow-eyed Grass	- *Xyris ambigua*
	Spike Rush	- *Eleocharis vivipara*
	Bahia Grass	- *Paspalum* spp.
	*Panic-Grass	- *Panicum hemitomon*
	Beak Rush	- *Rhynochospora* spp.

TABLE 5

RANGE OF ELEVATION FOR PLANT COMMUNITIES

	Plant Community	Elevation Range MSL		Distance on Transect
		Maximum	Minimum	Feet
Transect I	Palmetto Fringe	37.0	34.2	0 - 113
	Mesic Hammock	34.2	30.0	113 - 600
	Hydric Hammock	30.0	28.1	600 - 2400
	Pine Flatwoods	35.0	29.5	2400 - 5500
	Dry Prairie	38.5	36.3	5500 - 5900
Transect II	Cypress Swamp	34.7	33.5	0 - 230
	Dry Prairie	36.0	26.0	230 - 1768
	Mesic Hammock	25.0	24.5	1768 - 1900
	Cypress Swamp	24.5	24.0	1900 - 2000
	Hardwood Swamp	24.3	23.0	2000 - 3700
	Hydric Hammock	26.5	24.3	3700 - 4000
	Cypress Swamp	26.5	25.3	4000 - 4261
	Dry Prairie	29.2	26.5	4261 - 4463
Transect III	Dry Prairie	29.5	27.5	0 - 350
	Palmetto Fringe	27.5	25.5	350 - 530
	Hardwood Swamp	25.5	23.5	530 - 1700
	Hydric Hammock	26.0	24.5	1700 - 2000
	Mesic Hammock	26.5	26.0	2000 - 2300
	Freshwater Marsh	25.5	25.0	2300 - 2389
Transect IV	Dry Prairie	33.0	32.5	0 - 47
	Hardwood Swamp	32.5	31.0	47 - 800
	Dry Prairie	49.5	31.0	800 - 1600
	Xerophytic Oak Woodland	53.5	49.5	1600 - 2148
	Dry Prairie	54.0	53.5	2148 - 2350
	Freshwater Marsh	54.0	53.0	2350 - 2364

DISCUSSION OF THE EFFECT OF INUNDATION ON WOODY SPECIES

GENERAL EFFECTS OF FLOODING

Atmospheric oxygen diffuses through the pore spaces between particles and aggregates of a well-drained soil in amounts adequate to support aerobic root respiration. Flooding the soil drastically decreases the rate of oxygen diffusion into the soil pore spaces. Aerobic microbial activity, along with root respiration, may totally deplete the oxygen content in the inundated soils within a few hours (Scott and Evans, 1955) to a few days (Meek and Stolzy, 1978). Replenishment of oxygen is hindered by diffusion rates as slow as 1/10,000 the rate in well-drained soils (Gambrell and Patrick, 1978). Hence, oxygen demand quickly exceeds replenishment and anaerobic conditions result.

As oxygen is depleted, soil microorganisms utilize electron acceptors other than oxygen for respiratory oxidations. Consequently, numerous mineral elements become reduced. Increased soluble levels of iron, manganese and aluminum cations which accumulate in inundated soils may be phytotoxic in low concentrations (Keeley, 1979; Gambrell and Patrick, 1978). Other toxins produced through anaerobic metabolism include butyric acid, monocarboxylic acids, hydrogen sulfide and ethylene. Ethylene generation may be responsible for plant stress symptons of leaf epinasty and abcission (Armstrong, 1975).

Toxic conditions are most likely to develop in soil zones containing a high percentage of organic matter, which determines the rate and intensity of reduction. Land not subject to previous flooding may produce greater concentrations of toxins in a shorter period of time than periodically flooded areas. High temperatures during the summer months also accelerate the production of phytotoxins.

The type and degree of injury sustained by plants under flood varies with species, flooding regime and soil characteristics. Plant symptoms associated with anaerobiosis include leaf chlorosis, epinasty and abcission, decreased transpiration rate, death of primary and/or secondary roots, absence of fruiting, increased susceptibility to pathogens, and death (Gill, 1970; Hook and Scholtens, 1978).

Although flooding imposes extreme stress on plant life to the extent that some species cannot withstand more than 2-4 days (Hook and Scholtens, 1978), there are species, usually endemic to wetland environments, which are tolerant of some degree of oxygen deprivation. The extent to which plants tolerate flooding appears to be dependent on adaptations characteristic of wetland species. These adaptations, discussed in subsequent sections, include the ability to: switch to anaerobic metabolism and tolerate accumulation of metabolites, transport oxygen from plant parts above the water level, and exclude or tolerate soil toxins (Armstrong, 1975; Hook and Scholtens, 1978). An understanding of survival mechanisms should aid in predicting how plant communities of the Jane Green detention area will respond to unaccustomed levels of inundation.

PHYSIOLOGICAL ADAPTATIONS

Green plants capture the energy of sunlight and store it in the bonds of glucose molecules. Before this energy is used a number of other transformations may intervene, but the overall cycle is completed when the stored energy is released from glucose by a series of reactions collectively called respiration. "Glycolysis" refers to the initial stages of respiration during which the glucose molecule is prepared for the complete extraction of its bond energy and processing into plant tissue. Glycolysis ends in the production of pyruvate and two molecules of ATP per molecule of glucose. Discrete amounts of energy are carried by the adenosine triphosphate (ATP) molecule to the site of its utilization.

If oxygen is present, respiration is termed "aerobic" and 36 more molecules of ATP per glucose molecule are wrung from products of pyruvate before respiration is complete. If respiration is anaerobic, the aerobic chain of reactions is shortened, ethanol, lactate or some other partial end-product is produced and no further energy is evolved.

Thus flooding may deprive a plant of the energy necessary to maintain life by excluding oxygen from plant roots. Vital processes can be maintained by accelerating the rate of the relatively small energy production of glycolysis. However, this strategy creates a problem for the plant: the end products of anaerobic respiration become toxic to the plant as they accumulate but their production is essential since a buildup of pyruvate shuts down glycolysis altogether.

Several researchers (Taylor, 1942; John and Greenway, 1976; Wignarajah and Greenway, 1976; Grineva, 1963 and Hook, et al., 1971; Keeley, 1979) have documented evidence of accelerated anaerobic respiration in tolerant plants under inundation; that is, increased concentrations of ethanol in plant tissues and increased activity of the enzymes that catalyze ethanol production. Contrary to this finding, other studies have found accelerated ethanol production and enzyme activity in plants which do not tolerate flooding well (Crawford, 1966, 1967; Crawford and McManmon, 1968; Karlsen, 1925; Chirkova, 1976; Fulton and Erickson, 1964). Under flooding stress, the concentration of the products of anaerobic respiration is higher in flood-tolerant plants but the relative increase in concentration is greater in non-tolerant plants (Hook and Brown, 1973).

Apparently, both tolerant and non-tolerant species are forced to a greater reliance on the energy production of glycolysis as flooding proceeds. By their nature, tolerant species would be growing in a location where they would already have been subjected to some flooding and some degree of need for anaerobic respiration. The essential difference in flood-tolerant and non-tolerant plants as classes does not seem to be the presence or absence of the toxic products of anaerobic respiration but the ability of tolerant plants to deal with the toxins.

Three primary physiological tolerance mechanisms have been detected:

1. the outright removal of toxic compounds from the plant by excretion from the roots,
2. the neutralization of toxic compounds by their metabolization, and
3. the avoidance of a buildup of toxic compounds by conversion of the precursor of pyruvate (phosphoenolpyruvate) into a non-toxic compound (malate).

Physiological adaptations are short-term strategies; over time the plant adapts with visible changes in the structure of its tissues (morphological adaptations) (Keeley, 1979).

MORPHOLOGICAL ADAPTATIONS

Species capable of surviving inundation can adapt physiologically, morphologically or by a combination of both. The need for anaerobic respiration is lessened by morphological adaptations which facilitate the internal transport of oxygen from the atmosphere to the roots in some flood tolerant plants.

Aeration of higher plants is accomplished through 1) stem lenticels, 2) leaf stomata, and 3) direct gaseous diffusion between the roots and soil atmosphere. For these mechanisms to be effective in mature trees, the bark must be permeable to gases and transport pathways well-defined to allow gaseous diffusion to internal tissues.

Lenticels

In woody species, lenticels at the stem base provide an important entry point for oxygen passage to the phloem, particularly when the root system is inundated. Seedlings subject to periodic or continuous flooding develop prolific hypertrophic lenticels, believed to be more pervious to gas exchange than lenticels in the unflooded stage (Hook and Scholtens, 1978). Armstrong (1969) and Hook, et al., (1971) determined that obstruction of lenticels, particularly those above the water level of partially inundated seedlings, substantially reduced aeration. Lenticels in some seedlings with apparently well defined diffusion pathways (white willow (*Salix alba*), tupelo (*Nyssa sp.*)) play a dual role, allowing oxygen to enter and excreting internal ethanol, acetaldehyde and ethylene (Hook and Scholtens, 1978). As discussed in the section on physiological adaptations the ability of a plant species to tolerate inundation may depend on its ability to exude the end products of glycolysis.

Quantitive data is lacking on the permeability of bark of mature trees. However, Hook and Brown (1972) theorize that cambium permeability may be a function of site specific evolutionary adaptations. In mesic and xeric environments where soil water may be limited but air is not, the cambium is relatively impervious to gas exchange. Conversely, when air is a limiting factor and soil water is not, as in hydric species, the cambium is pervious to air. Seedlings of the hydric plant species water tupelo (Nyssa aquatica) and green ash (Fraxinus pennsylvania) receive sufficient oxygen through the lenticels to oxidize their root systems. In the more mesic sweetgum (Liquidambar styraciflua), the cambia is highly resistant to gas exchange; consequently, only short periods of inundation can be tolerated (Hook and Brown, 1972; Armstrong, 1978).

Stomata

Although stomata of leaves supply oxygen in herbacious species and in tree cuttings and seedlings, resistance to gas movement, and high oxygen consumption during the long journey down the stem make it ineffectual in the aeration of mature trees (Coutts and Armstrong, 1976).

Roots

Wetland plants adapt to anoxia by replacing the secondary root system with new roots of low diffusional resistance. These adapted roots are succulent, less fibrous than the original roots and have a weakly or nonsuberized epidermis (Hook and Scholtens, 1978). Roots of wetland species will also develop voluminous intercellular gas spaces, aerenchyma. These highly porous cortical or phellogenic zones lessen resistance to gas flow, providing a diffusion pathway from the lenticels to the roots. Internal ventilation, in addition to fulfilling root respiratory requirements may also be essential for protective oxidation reactions in and around the roots (Armstron, 1975, 1978). Phytotoxins may be oxidized through the radial diffusion of oxygen from the root system to the surrounding anaerobic soil. Plant enzymes and microbes associated with roots can also cause these oxidation reactions to occur (Armstrong, 1975). Rhizosphere oxidation appears to occur only in the better aerated trees (Hook and Brown, 1972), and is an indicator of flood tolerance. Nonwetland plants accustomed to well-aerated habitats, do not exhibit the same degree of response. Low porosity of internal tissues hinders ventilation and the ability to oxidize phytotoxins in the rhizosphere.

FLOOD TOLERANCE CHARACTERISTICS

Tree species exhibit a wide range of flood tolerance, varying from species living with roots and stems constantly flooded to those that can not tolerate more than two to four days inundation (Hook and Scholtens, 1978). Species distribution along a soil moisture gradient, from hydric to xeric, can be assumed to be the results of genetic processes operating under specific selective regimes over long periods of time (Hook and Brown, 1972). Even within the same species, natural selection produces genetically differentiated populations specifically adapted to particular hydrologic regimes (Turresson, 1922, 1925; Gill, 1970; Keeley, 1979).

Evaluation of all morphological and physiological adaptations is important when determining a species' flood tolerance. Researchers consider root adaptations to be the key factor in distinguishing relative flood tolerances of species distributed along a moisture gradient. The following discussion is a summary of characteristics of relative flood tolerance.

Intolerant Species

Upland species growing on well-drained soils have limited capacity for surviving flooding, typical of plants seldom exposed to inundation under unaltered conditions. If flooded, the root system deteriorates and no new roots are formed. Thus, root respiration drops to very low levels. Flooded seedlings of intolerant species die within two days to four weeks. Survival of mature trees is also poor. Most species of oak (Quercus sp.) and elm (Ulmus sp.) typify this category. Conifers, with the exception of bald cypress (Taxodium distichum), are generally not considered to be flood tolerant (Hook and Scholtens, 1978). Slash pine (Pinus elliottii) seedlings in the leaf stage experienced 73% mortality when subjected to 14 days inundation (Briscoe, 1957). Research on conifers, however, is incomplete.

Moderately Tolerant Species

Mesic and floodplain species are more flood tolerant than upland species. Although the original secondary root system deteriorates when inundated, the primary root system survives, and new secondary roots may be initiated. Adventitious roots may also develop in response to anaerobic conditions. The response of mesic seedlings to inundation is intermediate between upland and swamp populations, in root respiration, growth, and accumulation of toxins. Under temporary flooding regimes, mesic and floodplain species have relatively high survival rates. Red maple (Acer rubrum) and sweetgum are characteristic of this response category. Green ash which can oxidize its rhizosphere but not tolerate excess toxins, is considered moderately tolerant to tolerant.

Tolerant Species

Species of the swamp environment are, predictably, very tolerant of flooding. Portions of the original root system deteriorate under flooding; however, larger, more succulent roots originate with an increased capacity for alcoholic fermentation. These roots are capable of extensive oxidation of their rhizosphere and toleration of toxic compounds. Cypress (Taxodium sp.) and water tupelo are generally considered flood tolerant species.

Intraspecific Tolerance Variation

Investigation of the flooding tolerance of a single species (Nyssa sylvatica) distributed along a gradient from upland, to floodplain, to swamp sites indicated respective responses characteristic of intolerant, moderately tolerant, and tolerant plants (Keeley, 1979). Thus, selection pressures produce an upland genotype of Nyssa sylvatica, capable of tolerating drained conditions, a flood tolerant genotype of swamp Nyssa sylvatica, and a floodplain phenotype capable of limited adaptation to drained and flooded conditions.

ADDITIONAL FACTORS DETERMINING THE SURVIVAL OF TREES UNDER INUNDATION

Although survival of trees under flood depends primarily on morphological and physiological adaptations, and inundation history, certain flooding and seasonal characteristics are also significant. Depth, season, duration and frequency of flooding may affect not only individual species, but also the entire structure of plant communities.

Depth of Flooding

Plant injury during flooding increases as soil saturation progresses, from partial to complete inundation. A species that can survive a certain period of soil saturation or of partial inundation will often succumb to the same period of complete inundation (Gill, 1970). Lower solubility of gases in water, high turbidity, and decreased light intensity has a detrimental effect on completely inundated terrestrial vegetation.

Research at Rodman Reservoir (Harms, et al., 1973) indicates that increasing depth directly correlates with increasing mortality rates. However, the degree of root mortality corresponding to increasing depth varied according to each species' flood tolerance, with red maple succumbing quickly, Carolina ash (Fraxinus caroliniana) and bald cypress showing less pronounced effect, and swamp typelo (Nyssa sylvatica var. biflora) the least susceptible. Red maple and Carolina ash, found extensively in the Jane Green detention area, predominately exist in swamps with a shallow, periodic flooding regime, rather than in deeply flooded swamps (Harms et al., 1973). Adaptations that suffice during their accustomed water regime are apparently inadequate for prolonged or deep flooding. Species of the Jane Green detention area have adapted to a hydrologic regime consisting of short periods of high water and longer periods of shallow flooding.

The ability of woody species to tolerate deep flooding often depends on the ability to adapt to the change in soil conditions. The deeper and longer a site is flooded, the greater the buildup of toxic compounds that can kill or limit the growth of new roots (Harns, et al., 1973). Deeply flooded mature trees may be unable to produce a functional root system in reduced soil before flood reservoirs are exhausted.

Futhermore, internal aeration provided by the lenticels to the roots may be obstructed in species not adapted to rapidly rising water levels. If lower stem lenticels are an important point of oxygen entry, sudden flood may severely limit the root oxygen supply, thus causing death. In those species prone to flooding, the rise in water level is accompanied by proliferation of adventitious roots arising from hypertrophied lenticels just below the new water surface (Armstrong, 1975).

Seasonal Effects

The time of year inundation occurs can be a limiting factor to community growth and survival. Flooding is most critical during the growing season; inundation during the dormant season has a lesser effect, regardless of duration (Gill, 1970; Hall and Smith, 1955; Williston, 1962).

During a normal growing season, in unstressed conditions, starch accumulates in the parenchymatous tissues of plants, peaking in late summer or early fall prior to leaf drop. Under flooding stress, photosynthesis is reduced. If stress is severe and continuous, surplus food may not be produced, forcing previously stored food to be utilized and ultimately killing the tree unless stress is relieved (Harms, et al., 1973).

A stressed condition may not be manifest immediately. In some cases, trees and entire systems under stress will appear to function normally, then meet with a sudden, irreversible decline. Decline occurs when energy necessary to maintain existence is greater than the energy being supplied (Green, 1947). It is important to relieve stress early enough in the growing season to permit a buildup of food reserves prior to the next stress or dormancy period. However, food reserves are not completely replenished until photosynthesis returns to normal over the next two to three growing seasons and the root system completely regenerates (Harms et al., 1973).

Stress during growing season inundation is also created by increasing water temperatures, resulting in an increase in soil metabolic activity and consequently, soil reduction (Hook, pers. com.). Demaree (1932) reported higher floodwater temperatures accelerated the mortality of bald cypress. Water temperatures above 70°F are considered instrumental in the death of seedlings inundated during the growing season (Johnson, 1972).

Duration and Frequency

Flood duration during the growing season, along with depth, affects survival of trees. For any species, greater injury and lower survival results with increased periods of flooding (Yeager, 1949; Hall and Smith, 1955; Harms, et al., 1973).

Because of increased susceptibility to injury, even the most flood tolerant species need to be unflooded at least 55 to 60% of the growing season (Gill, 1970). Woody species, including ash (*Fraxinus sp.*), water tupelo, red maple, and American elm (*Ulmus americana*) whose root crowns were flooded more than 54% of the growing season, over an 8 year period, died (Hall and Smith, 1955). Figure 8 depicts the health of trees representative of those found within the study area, inundated during the growing season.

If above normal flooding occurs annually during the growing season, it could affect not only individual species, but ultimately the entire community structure. Diversity of a community may be inversely proportional to the length of time during the growing season that soils are saturated. Species composition in riparian ecosystems is dependent on hydroperiod and depth of floodplain species to maintain their dominance (K. Ewel, 1978). Resilience, the ability of an ecosystem to return to its previous state after perturbation, diminishes with repeated incidences of stress. Such elasticity can be destroyed by such events as successive cutting, impoundment, etc., until the community is unable to regenerate itself (J. Ewel, 1971).

The ability of a system to remain established hinges on the germination and growth requirements of seedlings, which may be more limiting than the survival requirements for adults (K. Ewel, 1978). Woody species cannot colonize a habitat flooded more than 40% of the growing season (Gill, 1970), although once established they may survive subsequent inundation depending on individual flood tolerance.

Germination

In Florida, red maple and Carolina ash have spring and summer fruiting periods (Ward, 1978), although germination of Carolina ash and bald cypress has been observed as late as November in the Oklawaha Basin (Harms, et al., 1976). Ward, (1972) reports that seeds of red maple and Carolina ash do not remain viable for long periods and suggests the seeds would not survive

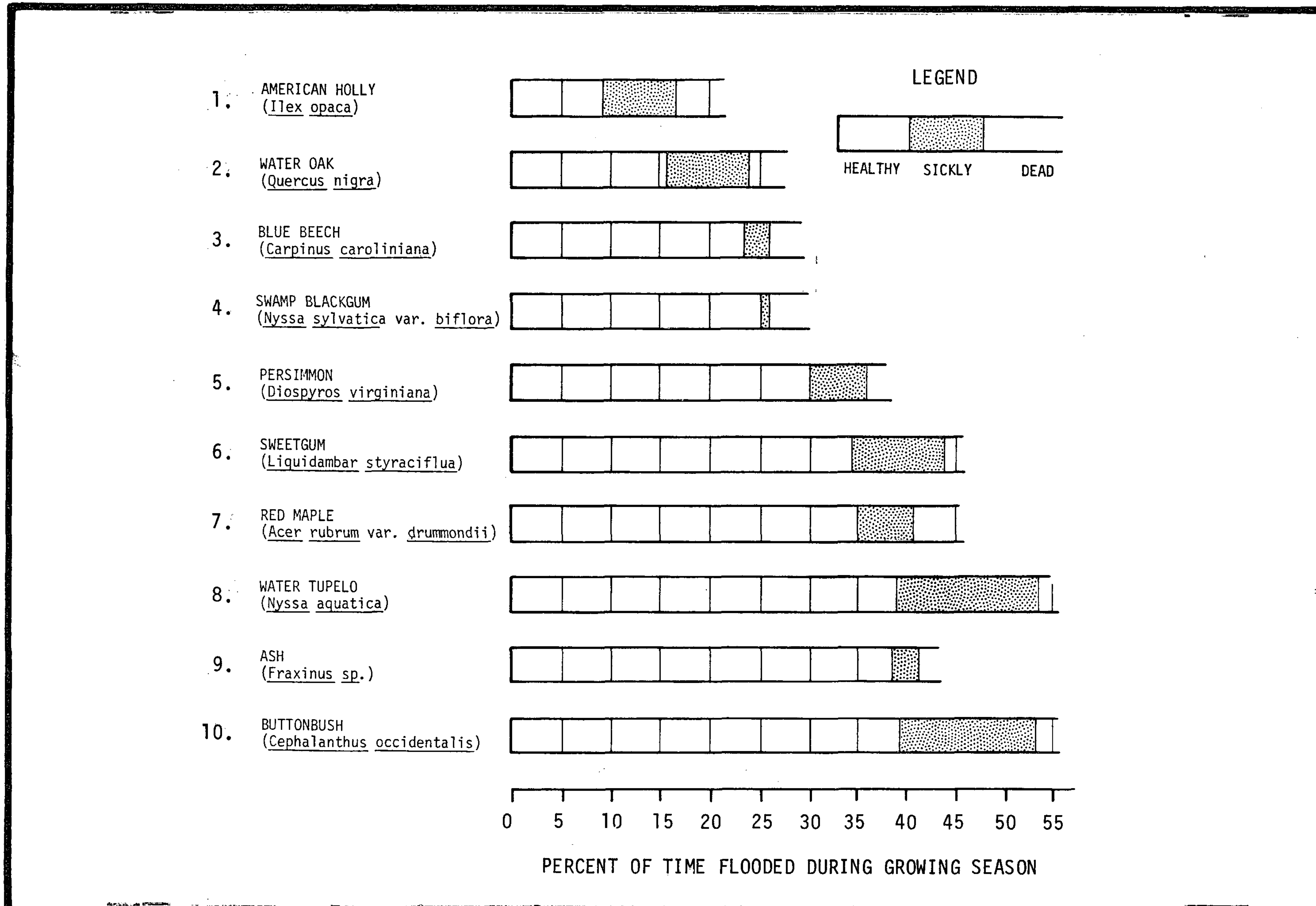

FIGURE 8. -- Tolerance of Woody Species to Flooding in the West Sandy Dewatering Project (Adapted from Hall and Smith, 1955).

immersion. However, in experiments with red maple, Hosner (1957) determined that although the seeds failed to germinate while soaking in water from 4 to 32 days, germination proceeded rapidly when removed from the water. Bald cypress and water tupelo can survive lengthier immersion, some as long as 30 months and 12 months, respectively (Demaree, 1932; Briscoe, 1957).

Very few species can endure those rigorous conditions. Seeds of most upland species are seriously injured after 10 days immersion; injury may be manifest after just 3-5 days immersion (Baker, 1977). Ralston (1955) reports a loss in viability of slash pine seeds after 7 days immersion. Although seeds of water tupelo survived 12 months immersion, seeds of swamp tupelo, had less than 1% viability after the same length of time (Briscoe, 1957).

Seedling Response

Regardless of conditions determining seed viability, establishment of seedlings almost invariably requires exposure to the air (Hall and Smith, 1955; DuBarry, 1963). Seedlings in the cotyledon stage are most sensitive to flooding. Fifty percent of slash pine seedlings in the cotyledon stage died after only 2 days immersion; 100% succumbed in 4 days (Briscoe, 1957). Bald cypress cotyledons died in 2 weeks during submersion (Demaree, 1932).

Tolerance to immersion increases with age, and consequently, height of the seedling to some extent. Bald cypress and water tupelo continued growth as long as the stem tip was maintained above water (Shunk, 1939); but Ward (1972) reported renewed immersion would kill one year bald cypress seedlings. Three foot seedlings of water tupelo, Carolina ash, and sweetgum tolerated 4 weeks of complete inundation during the growing season in experiments performed by Baker (1977). All species except for Carolina ash lost their foliage during the flooding period. One week after drawdown, 95% of the water tupelo survived, resprouting from the root collar; 19% of the green ash continued growth from the original stem. Nevertheless, many trees living one week after dewatering died at the end of the growing season. In the end, water tupelo and Carolina ash were determined to be tolerant of eary growing season flooding; sweetgum was intermediate.

In contrast, Hosner (1958) determined flood tolerance of green ash (Fraxinus pennsylvania), sweetgum and box-elder (Acer negundo) was 16 days or less during the growing season.

Penfound, (1949), Eggler and Moore (1961) reported the results of the management of a former cypress/gum swamp converted to a reservoir in Louisiana. Management practices consisted of spring/summer flooding, followed by fall/winter drawdown. After 4 years, flooding in excess of 2 feet resulted in the death of 3% of the bald cypress, 67% of the water tupelo and 86% of the buttonbush. After 18 years, 100% of the buttonbush and water elm, and 72% of the water tupelo were dead. Surviving water tupelo had sprouted from the stumps of broken and decayed trees.

Despite the dependence of growing season survival on individual conditions and species, most researcher conclude flood tolerance in the dormant season is much greater, if water is removed prior to growing season (Baker, 1977; Ward, 1972; Yeager, 1949; Hall and Smith, 1955).

SUMMARY AND RECOMMENDATIONS

From the literature review, it can be seen that flood tolerant species adapt to inundation by a combination of physiological and morphological adaptations. Adaptations include proliferation of lenticels, root adaptations that facilitate oxidation of the rhizosphere, the initiation of anaerobic respiration, and the ability to tolerate or exude the toxic end products of anaerobic respiration.

Location along a soil moisture gradient, from xeric to hydric, not only indicates tolerance of different species, but may also point to site specific evolutionary adaptations within a species. Natural selection results in genetically differentiated populations of a species which are adapted to a specific hydrologic regime (Turresson, 1922, 1925; Keeley, 1979). Thus, a species such as *Nyssa sylvatica* found on upland, floodplain, and swamp sites would exhibit responses ranging from intolerant, to moderately tolerant, to tolerant, according to location.

Extremes of flood depth and duration may override a species' locational adaptive advantage. Yeager (1949) observed that in the same tree species found on a moisture gradient along a reservoir (upland, mud, and water levels), mortality increased with flooding depth over an extended period, regardless of location. Even a species able to tolerate flooding to a considerable depth for short periods may die when subjected to saturated soil for extended periods of time.

Flooding is most critical during the growing season when plants accumulate starch reserves necessary for survival over periods of stress and dormancy. Limitation of flooding to a maximum of 40% of the growing season and flood frequency to 2-3 year or greater intervals is recommended. This period would allow time for regeneration of roots and starch reserves as well as for seedling establishment.

Based on the adaptational characteristics of tree species in the Jane Green Detention Area, a regulation schedule was devised to allow flood control while minimizing environmental damage (Table 6, Figures 9 and 10).

Table 6 -- Jane Green Detention Area
Regulation Schedule

Elevation	Duration (days)	
	March 15 - Oct. 31	Nov. 1 - March 15
35 - 45.0 ft.	2	2
30 - 34.9 ft.	14	14
26 - 29.9 ft.	30	60
23 - 25.9 ft.	60	90
less than 23 ft.	90	120

There are a few critical areas that may be adversely impacted by the regulation schedule, namely, the dry prairies and hydric hammocks of the lower elevations of Transect 2 and 3. Therefore, we recommend that the area be monitored during and after flooding, and the schedule revised accordingly, if necessary.

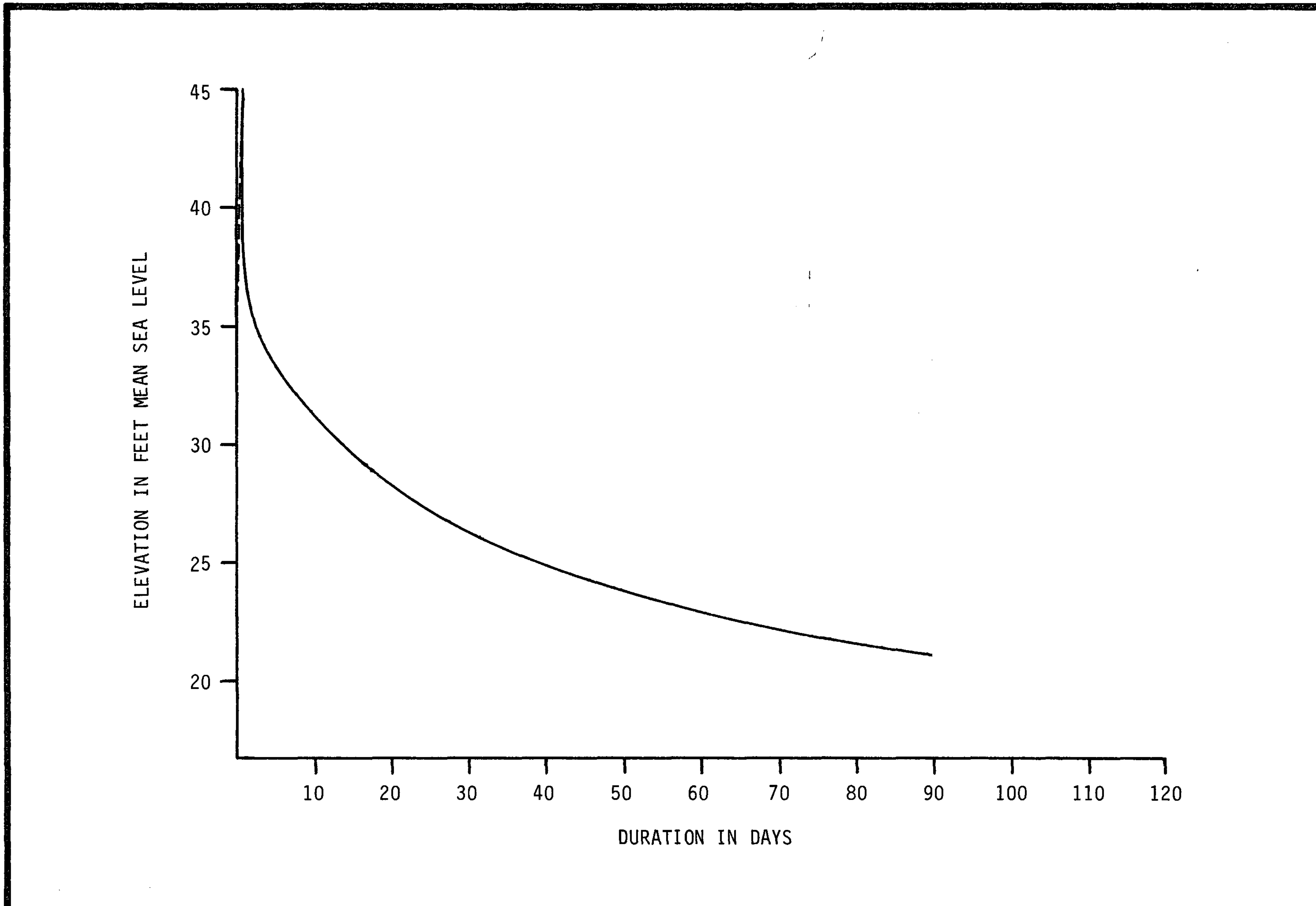

FIGURE 9. -- Proposed Inundation Schedule for Jane Green Detention Area Growing Season (March 15 - October 31).

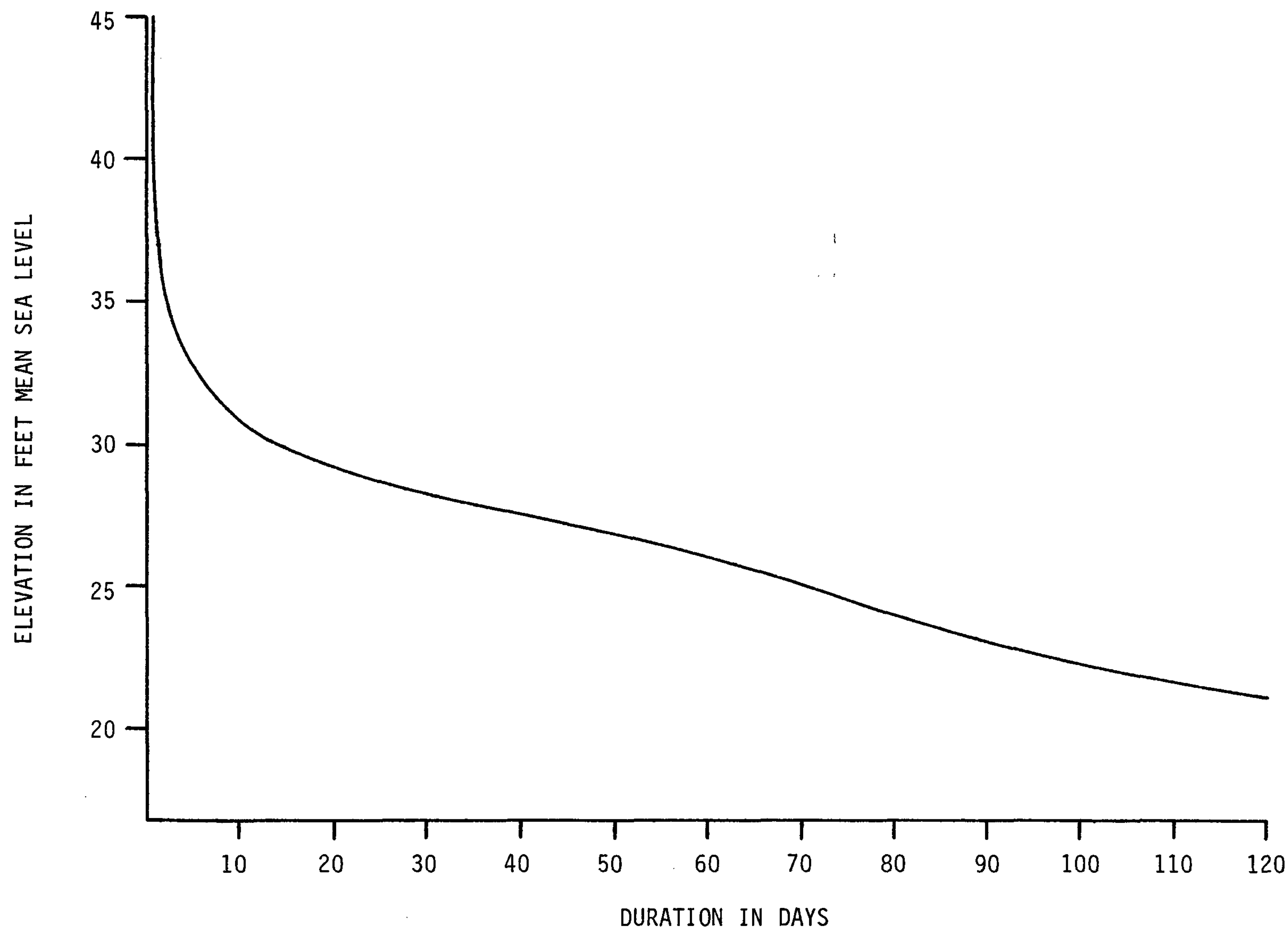

FIGURE 10. -- Proposed Inundation Schedule for Jane Green Detention Area
Dormant Season (November 1 - March 15).

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APPENDIX

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
ROUTE 2 BOX 695
PALATKA, FLORIDA 32077
TELEPHONE 904-325-5383

RESOLUTION NO. 75-11

CONCEPTUAL PLAN FOR FLOOD CONTROL, WATER SUPPLY,
WATER QUALITY ENHANCEMENT, PUBLIC RECREATION,
FISH AND WILDLIFE, AND RESTORATION BENEFITS
FOR THE UPPER ST. JOHNS RIVER BASIN

WHEREAS, the St. Johns River Water Management District is the regional agency designated by Chapter 373, Florida Statutes, to manage the Upper Basin of the St. Johns River effective December 31, 1976, and;

WHEREAS, this Basin is currently under the jurisdiction of the Central and Southern Florida Flood Control District who has assumed the role of local sponsor for the United States Corps of Engineers' Congressionally authorized Upper St. Johns River Project, and;

WHEREAS, the design of this project as planned in 1962 and amended in 1969 was presented by the U.S. Corps of Engineers in an Environmental Impact Statement released in 1973, and;

WHEREAS, this project was determined to be unacceptable to the State of Florida as a result of the A-95 Review of the Environmental Impact Statement in 1974, and;

WHEREAS, the U.S. Corps of Engineers and the Flood Control District have modified the original authorized project and have offered a new recommended plan for conceptual approval to the State of Florida in July of 1975, and;

WHEREAS, an agreement was made between the Governing Boards of the "Flood Control District" and the "St. Johns" on August 20, 1975, to coordinate their total water resource planning and development program in the Upper St. Johns River Basin, and;

WHEREAS, a contractual management agreement was also executed on this same date between the Governing Boards of the "Flood Control District" and the "St. Johns" giving the St. Johns River Water Management District the responsibility to administer, operate and maintain the water management works of the U.S. Corps of Engineers and the "Flood Control District" in this basin, and;

WHEREAS, the Constitutional Amendment presented to the electorate on March 9, 1976, was successfully passed state-wide thereby creating the presumption of implementing legislation vesting ad valorem taxing authority in the St. Johns River Water Management District, and;

WHEREAS, this taxing authority may allow the "St. Johns" to participate as a local sponsor for Federal Water Resource Projects as provided in 373.103, Florida Statutes, delegated to the St. Johns River Water Management District by the Florida Cabinet on August 20, 1974;

NOW, THEREFORE, BE IT RESOLVED that the Governing Board of the St. Johns River Water Management District endorses and supports the following conceptual St. Johns River Water Management District approach for Flood Control, Water Supply, Water Quality Enhancement, Public Recreation, Fish and Wildlife and Restoration Benefits for the Upper Basin of the St. Johns River:

1. That portion of the existing Jane Green Reservoir System consisting of the Taylor Creek Pool, the Cox Creek Pool, the Wolf Creek Pool and the Pennywash Creek Pool, which are formed by Levee 73 could be modified to temporary flood detention reservoirs. Under this approach, each of these four creeks would be allowed to flow uninterrupted at their base elevation through gated culverts

under Levee 73 and continue to flow through their unchannelized watercourses into the St. Johns River Valley. When specific high water stages were reached in the St. Johns River Valley adjacent to these creeks, these gated culverts would be individually closed and impoundment of water begun in the appropriate detention area affected. When high water stages receded below specific elevations in the St. Johns River Valley adjacent to these creeks, impounded water would be discharged on a regulated schedule until the reservoirs were dry. These discharge schedules would be hydrologically determined to minimize downstream flooding, erosional and water quality problems and upstream inundation damage in the reservoirs.

2. The Jane Green Pool of the Jane Green Reservoir System might be similarly structurally modified to allow for complete drawdown to the creek elevation, however, since the entire reservoir area is owned by the "Flood Control District" in fee simple estate, we recommend a feasibility study be completed by the St. Johns River Water Management District to determine the design impact of partially impounding this pool for public water supply, public recreation, fish and wildlife as well as flood control benefits.

3. The existing Canal 57 which was designed to interconnect and divert water between the five pools of the Jane Green Reservoir Complex should be redesigned to eliminate uncontrolled inter-basin diversion.

4. Since the diversion of water via canal flows between basins which are tributary to the Upper St. Johns River and diversions of water via canal flow within the one-in-one-hundred year floodplain of the Upper St. Johns River are both occurring on the western side of the Upper St. Johns River, we support urgent cooperation and

negotiations with these upland landowners to mitigate these diversions and partially restore these flows to approximate their historical entrance into the hydrologic regime of the Upper St. Johns River.

5. Based upon present information available to this Board, Water Control Structure S-162, designed to discharge water from Jane Green Pool via Canal 58 into the Levee 72 Borrow Canal should not be constructed.

6. Based upon present information available to this Board, the Levee 72 Borrow Canal designed to divert water stored in the Jane Green Pool southward via the Blue Cypress Detention Area into the proposed Lake Wilmington Reservoir should not be constructed.

7. The Blue Cypress Detention Area, if constructed at all, could be modified to only temporarily impound the Blue Cypress Creek Drainage. An extensive hydrologic analysis of the Blue Cypress Lake ecosystem should be conducted by the St. Johns River Water Management District to determine the necessity for any upland construction in the area of Blue Cypress Creek. This study would determine the hydrologic capabilities of the existing floodplain lands under the ownership or control of the "Flood Control District" in the Blue Cypress Lake ecosystem to safely contain the Standard Project Flood in conjunction with the use of the existing Canal 54 for discharge of flood waters into the Coastal Basin. This analysis would also determine the number of acres of additional floodplain lands which could be acquired by negotiation or purchase in the Blue Cypress Lake ecosystem by trading or recovering the Water Resources Development Account monies originally expended to acquire fee simple and flowage easement lands in the Blue Cypress Detention Area. This study would also evaluate other alternatives for water management in the area between Blue

Cypress Lake and the Fellsmere Grade, if necessary, to provide temporary flood detention to absolutely minimize the loss of freshwater to tidewater through C-54.

8. Based upon present information available to this Board, the Lake Wilmington Reservoir, as currently planned, including the proposed Canals C-52, C-53S and C-53N, Water Control Structure S-96A and all appurtenant works should not be constructed.

9. The Board will consider, upon demonstrating technical justification, that where possible and practical, canals and levee systems located on "Flood Control District" fee simple ownership in the St. Johns River Valley would be appropriately modified and/or restored to the original marsh elevations to induce sheet flow over the extensive marshes in public ownership. This construction is felt to be essential to protect and enhance the Class I and Class III waters of the St. Johns River, to prevent the movement of floating aquatic plants into the St. Johns River, to raise groundwater levels in the marsh, and to restore the ability of these marshlands to retain the rainfall of the wet season for maintenance of higher stages downstream during the dry season.

10. Since the diversion of the Class I waters of the St. Johns River into the tidewaters of the Indian River and Atlantic Ocean represent a significant loss of stage and flow to the headwaters of the St. Johns, we support the development of the most cost-effective and environmentally sensitive design for returning this water to the St. Johns Basin via backpumping or gravity flows while retaining the design capability for regulated discharge to tidewater for flood control purposes.

11. We support the additional negotiated acquisition of marshlands lying within the one-in-one-hundred year floodplain of the Upper St. Johns River for flood storage, improvement of water quality, maintenance of downstream stage and flow, fish and wildlife benefits and public recreation.

12. Based upon present information available to this Board, the Lake Washington Reservoir, including Water Control Structure S-53 and Canal C-55 and all appurtenant works, should not be constructed since the St. Johns River Water Management District plan should provide adequate water quality and water quantity for public water supply benefits in Lake Washington without impoundment.

Provided that the specific implementation of any concept expressed herein will not and cannot be accomplished without further and detailed hearings. This is an expression of intent on behalf of the Board that detailed plans will not be approved without a full hearing of the positions of all citizens affected or interested.

Further, the staff of the Board is instructed to proceed with essential detailed analyses and tests within the confines of the fiscal resources of the St. Johns River Water Management District for implementation of the aforesaid conceptual approaches and submit all results to the Board for consideration.

PASSED AND ADOPTED, this 17th day of March, 1976.

George Brown

Chairman, Governing Board

ATTEST:

Assistant Secretary