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WATER SUPPLY NEEDS AND SOURCES ASSESSMENT
ALTERNATIVE WATER SUPPLY STRATEGIES INVESTIGATION
WETLANDS IMPACT, MITIGATION, AND PLANNING-LEVEL COST ESTIMATING PROCEDURE

By

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EXECUTIVE SUMMARY

St. Johns River Water Management District (SJRWMD) is evaluating several potential consequences of possible water supply alternatives, one of which is changes to sensitive natural systems, particularly wetlands. Municipal water supply within the majority of SJRWMD is provided by high-quality, reliable, and inexpensive ground water. However, it is inevitable that increasing demands on ground water resources will affect the hydrology of existing ecosystems, resulting in environmental changes that may be considered unacceptable impacts under current regulatory policy. Through prior planning, unacceptable impacts to wetlands and other natural systems may be avoided or mitigated to acceptable levels.

BACKGROUND

SJRWMD has previously evaluated the potential impacts of increased ground water withdrawals on natural resources within the District through the year 2010. Based on this evaluation, areas in which water supply problems are now critical or will become critical in the future, called Water Resource Caution Areas (WRCAs), have been preliminarily identified. In general, the analysis predicts that increases in ground water withdrawals could result in adverse impacts to area water resources and native ecosystems, especially wetland systems, located near existing water supply wellfields. To reduce potential impacts, SJRWMD is investigating the technical, environmental, and economic feasibility of alternative water supply strategies, which include strategies to prevent or minimize environmental harm.

PURPOSE AND SCOPE

This technical memorandum (TM) E.1.f is the first in a series of four TMs researching the knowledge base in the following three areas:

- Detecting and avoiding detrimental changes to existing ecosystems related to proposed increases in groundwater withdrawals
- Assessing the feasibility of mitigation sequencing for avoiding impacts
- Where avoidance is not possible, providing compensatory mitigation for the impacts resulting from development of future water supply needs

Because the previous analysis by SJRWMD predicted that wetland communities within the WRCAs were more susceptible to harm than upland communities, the focus in this TM is on the potential impacts to wetland communities. The primary purpose of this TM is to review the background information and existing data on environmental changes attributable to water supply development in Florida. This TM also presents methodologies and major assumptions to be used in a planning-level application for the quantitative evaluation of wetland system impacts and for generating cost estimates of potential mitigation actions.

As part of developing the methodologies, this TM presents an overview of the factors affecting hydroperiod and biological responses of sensitive wetland ecosystems and the regulatory issues that could affect the consumptive use permit (CUP) process. Future TMs will present the mitigation cost estimating spreadsheet (TM E.1.h), a methodology for impact avoidance (TM E.2.d), and a conceptual design for a hydration/irrigation pilot project (TM E.2.g).

Summaries of the primary components of this TM are presented below.

REVIEW OF WETLAND HYDROLOGY LITERATURE

This section summarizes a review of the published literature, reports, and other available information relating to wetland hydrology; the relationship between hydrology and ecological values; and the effects of hydrologic alteration under the following broad categories:

- Characteristic hydrologic regime of major Florida wetland types
- Effects of altered hydrologic regime on wetland ecological structure and function
- Wetland hydrologic impact detection methodologies

The literature review indicated that wetland systems in Florida differ widely in their hydrologic regime characteristics; however, they can be arrayed along a hydrologic gradient based on the ranges of their respective hydrologic regime characteristics (depth, duration, frequency, seasonality of flooding). Furthermore, most wetlands also have some degree of internal zonation resulting from influence of elevation gradient on the hydrologic regime.

The effect of water table reduction on wetland systems constitutes a complex set of physical and biological responses. Numerous hydrologic factors and ecological responses are either inter-related or non-related, interdependent or independent, making the detection of causal impacts unclear and the assessment of overall ecological changes complicated. Potential causes of hydrologic alteration include both natural and culturally induced factors such as below-normal rainfall, below-normal ground water levels, surface drainage, and change in watershed runoff characteristics.

These conditions can occur singly or in combination within a wetland or its watershed, resulting in one or more physical effects associated with altered hydrology, such as soil subsidence, changes in dominant plant and animal species, and water quality degradation.

REGULATORY REVIEW

Review of SJRWMD's regulatory programs for consumptive use and surface water management showed that the two programs differ significantly in the manner in which potential adverse effects on natural systems are assessed and integrated into the permitting process. The new Environmental Resource Permit (ERP) Program provides an explicit approach for the applicant to assess potential impacts and likely mitigation requirements so that they can be incorporated into project planning.

With consumptive use permitting, there is more uncertainty as to the degree of impact. This uncertainty complicates the evaluation of whether the proposed use meets the criteria for reasonable and beneficial use and public interest. There are, however, significant opportunities to streamline the CUP program by organizing around the principles of ecosystem management, mitigation sequencing, and adaptive management.

PROJECTED HYDROLOGIC AND ENVIRONMENTAL CONDITIONS IN WRCAS

As part of its needs and sources study, SJRWMD developed a preliminary screening process review in which land areas within SJRWMD were identified by geographic information system (GIS) analysis as having a moderate-to-high likelihood of harm resulting from ground water development. Through its analysis, SJRWMD has predicted that the natural systems most at risk within these WRCAs are wetland communities. This analysis provides a good planning tool for the proposed next steps in the process:

1. Sensitivity analysis of criteria and assumptions used in the initial analysis
2. Additional review and assessment of regional factors known to affect the susceptibility of sensitive ecosystems
3. Further investigation of the site-specific factors known to affect a wetland's susceptibility to changes in hydrologic regime

MITIGATION RATIOS AND UNIT COSTS FOR USE IN THE WRCAS

Under current regulatory programs for the surface water program within the ERP program, SJRWMD uses mitigation ratios as guidelines for determining the compensatory mitigation for permittable impacts to wetlands. Mitigation ratios are intended to provide a means of addressing the uncertainty typically associated with the success of concurrent and post-impact mitigation efforts. Mitigation ratios include compensation for temporal displacement caused by the loss of ecological value as the mitigation area matures.

Mitigation ratios as a decisionmaking tool have evolved over time. Current applications are a blending of wetland science, practical application, and reasonable consensus among the regulators, the regulated community and the general public. Outside of straightforward applications of in-kind mitigation for filling impacts, the application of ratios can be problematic. More difficult types of applications are out-of-kind mitigation, impacts other than filling, and evaluation of wetland and upland preservation as mitigation options.

For the purpose of developing planning-level mitigation costs, the options available to water supply developers are assumed to be limited to a group of reasonable, practicable mitigation options, which will provide full compensation for projected loss of ecological value. The recommended ratios for initial use in the planning-level cost estimating procedure are median values for the ranges provided in the ERP guidelines. These values provide the initial best estimates; the final recommended values will be established in consultation with

SJRWMD staff after completion of a sensitivity analysis. The recommended starting values are as follows:

- **Creation and Restoration**—3.5:1 for forested wetlands; 2.75:1 for herbaceous wetlands
- **Enhancement**—12:1
- **Preservation**—35:1 for wetland preservation; 11.5:1 for upland preservation

Beyond the present application to develop planning-level cost estimates, the opportunity exists for SJRWMD to develop a more comprehensive approach to deriving mitigation ratios. Three broad approaches are proposed: an expanded traditional approach, a balance sheet analysis of ecological values, and a systems ecology approach based on energy analysis. All three methods could be used singly or jointly to refine the use and establishment of ratios.

Planning-level costs for mitigating potential impacts to wetlands within the WRCAs will be initially calculated with generalized unit costs for the major types of mitigation. SJRWMD supplied a unit cost for land acquisition. SJRWMD handles potential cash donations to District-approved mitigation projects on a case-by-case basis. The remaining unit costs for restoration, creation, and enhancement and for purchase of credits from a mitigation bank were based on the median value for the range of costs from a survey of selected recent projects within SJRWMD and throughout the state.

The unit costs recommended for use in the planning-level costing for mitigating impacts in the WRCAs are as follows:

- Wetland creation—$37,500 per acre
- Wetland restoration—$17,500 per acre
- Wetland enhancement—$13,750 per acre
- Land acquisition—$2,800 per acre for uplands and $800 per acre for wetlands (includes a $300 per acre land management activities)
- Purchase of mitigation bank credits—$30,000 per credit
- Cash contribution toward a SJRWMD-approved mitigation project will be assessed on a case-by-case basis

DEVELOPMENT OF IMPACT ASSESSMENT AND MITIGATION COSTING METHODS

The objective of reviewing the background information was to develop two methodologies: a wetland impact assessment methodology for assessing the impact of culturally derived ground water level reductions on wetlands and other sensitive ecosystems, and a migitation costing methodology for generating cost estimates of mitigation options to compensate for projected adverse impacts of ground water withdrawals.

Because permitting during project development will involve some level of mitigation sequencing, an integrated ecosystem impact assessment and mitigation sequencing framework is proposed as a method of organization. This integrated approach to impact minimization, avoidance, mitigation, and costing incorporates the organizing principles of ecosystem management, mitigation sequencing, and adaptive management.

Using these principles, an incentive-based approach to water use permitting is presented within this TM. This approach allows water supply projects to incur acceptable environmental changes, but requires that the changes be avoided, minimized, or accounted for through compensatory mitigation. The methodology is incentive-based in that the applicant is free to approach the mitigation process through several pathways. Thus, the methodology balances prudent water supply development with prudent environmental stewardship. This approach also can be used as an overall framework for a permitting program for the CUP process.

The impact assessment and mitigation costing methodologies can be used separately for addressing their respective goals, or can be linked as an overall planning and evaluation tool. Also, both methods can be used at three levels of detail: (1) regional-level planning and analysis, (2) screening analysis of conceptual projects or alternatives, and (3) detailed analysis of specific projects or alternatives.

Impact Assessment Methodology

The proposed wetland ecosystem impact assessment methodology is based on the relationship between change in the hydrologic regime within a wetland and resultant changes in the level of ecologic values. This methodology provides a means of quantifying the loss of wetland values for each significant wetland type and degree of hydrologic impact. The methodology provides specific recommendations for:

- Matching scale of methodology with inputs and outputs
- Hydrologic regime change assessment method
- Major wetland community types
- Target wetland hydrologic regime for each major wetland type
- Faunal indicator group
- Definition of adverse harm
- Categories of ecologic change

Matching scale of methodology with inputs and outputs. The scale of the assessment and costing methods must match the accuracy and precision of the inputs and expected outputs of the method. The inputs to the impact assessment process are the results of SJRWMD's GIS analysis, which consists of highly aggregated data. The output is expected to be planning-level cost estimates, which then dictate the level of precision and accuracy needed from the assessment method.

Hydrologic regime change assessment method. A hydrologic regime change assessment method based on wetland hydrographs is proposed. This method is flexible and allows a more detailed, site-specific assessment of hydrologic data. The method estimates the changes to the hydrologic regime by predicting changes in the hydrograph.

Target wetland community types. Ten major wetland community types are recommended: hydric pine flatwoods, hydric oak hammock, hydric palm hammock, wet prairie, floodplain swamp, shrub swamp, mixed hardwood swamp, cypress swamp, freshwater marsh, and ponds and sloughs.

Target wetland hydrologic regimes. Representative wetland hydrologic regimes are provided for each major wetland community type. The hydrologic regime for each type is summarized in a hydrograph, which can be used as the basis for defining the depth, duration, frequency, and seasonality of flooding.

Target faunal indicator group. Amphibians are recommended as the indicator faunal group. The breeding and reproductive requirements of amphibians can be related to the hydrologic regime characteristics of the wetland.

Operational definition of adverse harm. From a regulatory perspective, the assessment of change must be related to a means of deciding when an action is required. For the purpose of this application, the operational definition of unacceptable harm is based on the likelihood of changes in dominant species within the wetland community.

Categories and definition of ecologic change. Categories of change are proposed as the interval steps in a dehydration succession, starting with the original community type and eventually converting to an upland condition. Five categories of ecologic change (0, 25, 50, 75, 100 percent) are proposed. These categories are based on the degree of change in dominant species and, thus, are directly tied to the operational definition of harm.

Application of the Impact Assessment Methodology

It is expected that SJRWMD will provide acreage values for the potentially affected areas of the WRCAs and that these data will be categorized by major wetland type within each WRCA and by degree of predicted water table drawdown within each type within each WRCA.

Using these data inputs, the following analyses will be performed:

1. **Define baseline hydrological and ecological conditions.** To the extent possible, define characteristics of hydrologic regime, wetland type, dominant species of flora and fauna, and type of soils.

2. **Estimate water table drawdown.** Obtain prediction for mean water table drawdown in wetland of interest from SJRWMD.

3. **Estimate change in hydrologic regime.** Assess effect of drawdown on the hydrologic regime in wetland of interest using typical annual hydrograph and the summary relationships.

4. **Estimate effect of hydrologic change on dominant plant and animal species.** Using summary tables, relate hydrologic change to the likelihood of change in dominant species.

5. **Determine category of potential ecologic changes and percent loss of ecological value.** Assign predicted drawdown to category of potential ecological changes according to summary tables.

6. **Calculate potential mitigation acreage requirement**. Multiply the percent loss of ecological value by the acreage value of the wetland to determine the mitigation requirement relative to the ERP approach.

7. **Estimate final mitigation requirement**. Select mitigation options and apply recommended mitigation ratios to acreage determined in Step 6.

8. **Calculate planning-level mitigation cost**. Use unit costs to estimate planning-level costs for the desired mitigation options.

Mitigation Costing Methodology

A procedure was prepared to estimate the total cost of mitigating unacceptable environmental changes caused by pumpage in the WRCAs in the year 2010. Overall mitigation activities are subdivided into costing categories. For each category, a general procedure is given for estimating the costs associated with a given project. The proposed costing methodology is flexible because cost estimates can be generated at any level of detail, from planning level to conceptual level and detailed project costs.

The proposed wetland mitigation costing methodology is based on actual data from similar projects. Application of the costing tool consists first of comparing the planning-level costs of mitigation alternatives, and then developing detailed costs for specific alternatives. Potential mitigation options are wetland creation, wetland enhancement, wetland restoration, purchase of mitigation credits, land acquisition, land preservation, and cash contribution toward a SJRWMD-approved mitigation project.

The core of the cost estimating tool is a spreadsheet that allows the user to input selected site characteristics or specific aspects of a restoration activity and then incrementally generate a cost estimate. In addition, helpful tools and short cuts are provided in accessory spreadsheets, some of which are linked to the core spreadsheet. Upon acceptance by SJRWMD, the mitigation costing procedure will be used to estimate the cost of mitigating the projected unavoidable environmental impacts of future ground water withdrawals.

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INTRODUCTION

Ground water, the primary source of municipal water supply in the St. Johns River Water Management District (SJRWMD), is an excellent water supply source for the following reasons:

- Reliable source
- Minimal treatment costs because of quality
- With proper development and management, consistent quality over time

While ground water has been a generally high quality, reliable, and inexpensive source of municipal ground water supplies in the SJRWMD, it is unlikely that all additional future municipal water supply needs can be met by this source without causing some level of ecologic change. For this reason, SJRWMD is investigating the feasibility of alternative water supply strategies.

This technical memorandum (TM), which focuses on the methods for determining technical and economic feasibility of mitigating or avoiding the impacts associated with various water supply options, is the first in a series of TMs addressing the balancing of water supply needs with the protection and management of natural resources. Specifically, this TM presents a methodology for assessing potential ecologic impacts of water table declines, and another methodology for estimating the costs of mitigating these ecologic impacts. A summary of this investigation, beginning with background information, the purpose and scope, and methodology, is presented below.

PROJECT BACKGROUND

As part of its water supply needs and sources survey, SJRWMD previously evaluated the potential impacts of increased ground water withdrawals through the year 2010 (Vergara 1994). Based on this evaluation, several areas in which water supply problems are critical, or will become critical, were identified (Figure 1). These areas have been identified as Water Resource Caution Areas (WRCAs). Without careful planning now, future ground water withdrawals could adversely affect surface water resources and the natural environments dependent on those resources. In particular, wetland communities in portions of the WRCAs have been identified as being at risk for adverse impact.

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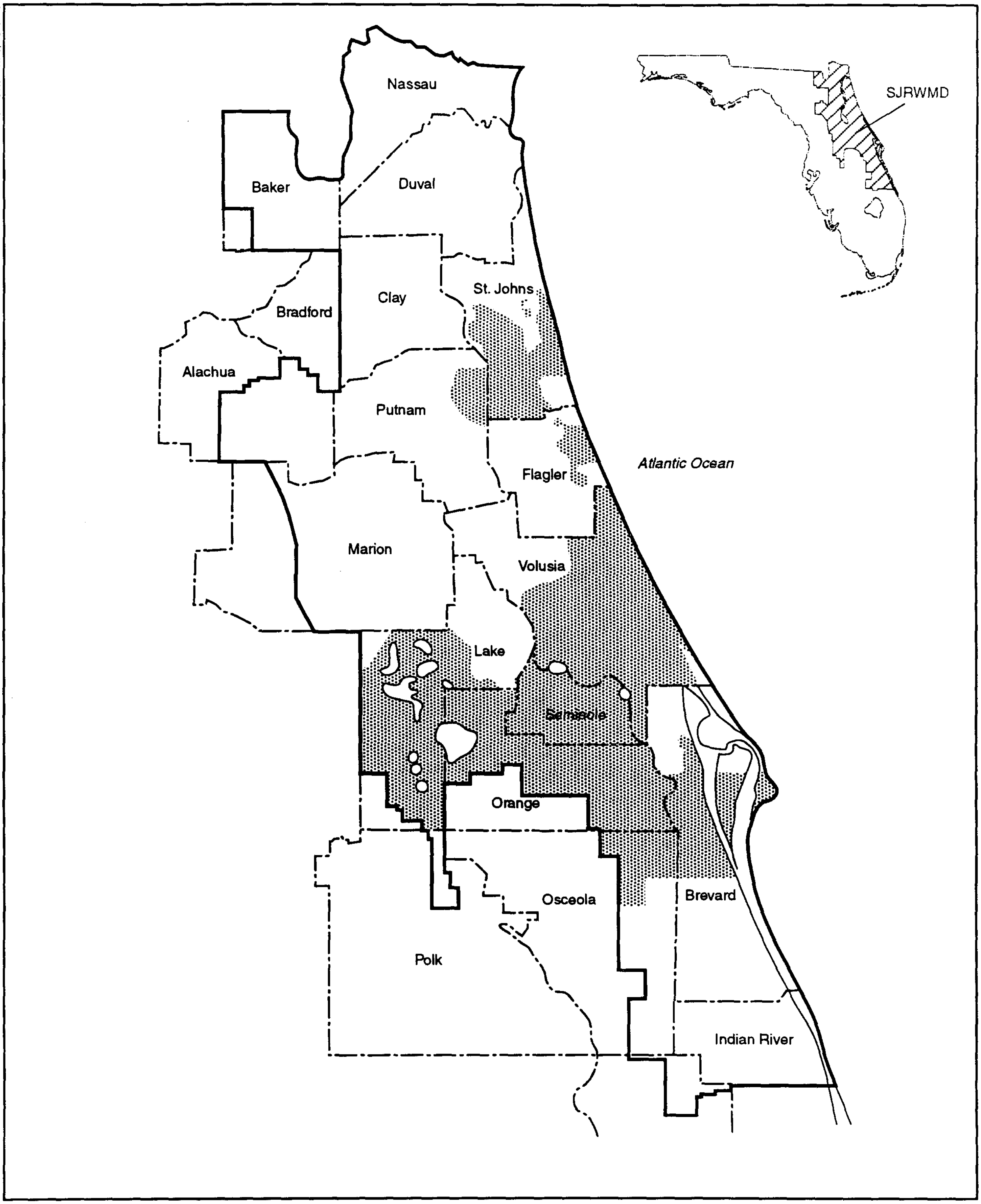

Figure 1. Water Resource Caution Areas in the St. Johns River Water Management District (Vergara 1994).

Water Resource Caution Areas
County Boundary
Distric Boundary

Scale in Miles
0 8 16

N

As part of this ongoing water supply needs and sources planning effort, SJRWMD is investigating the technical, environmental, and economic feasibility of alternative water supply strategies (Figure 2). This investigation is being conducted by CH2M HILL, other consultants, and SJRWMD staff. Methods of increasing supplies, increasing system storage, and reducing demand are being considered.

Options for increasing water supply include development of one or more of the following potential sources:

- Potable ground water
- Surface water
- Low quality ground water
- Artificial recharge
- Reclaimed water
- Water supply system interconnections

Increased system storage could include the use of reservoirs, aquifer storage recovery (ASR) facilities, or ground storage tanks. Reduction in demand could be achieved by numerous water conservation initiatives. In many cases, some combination of increased supply, increased system storage, and demand reduction is most effective in limiting environmental alterations and enhancing the cost-effectiveness of future water supply systems.

PURPOSE AND SCOPE

The overall scope of Task E, of which this TM is a part, assesses the technical, environmental, and economic feasibility of mitigating or avoiding impacts to native vegetative communities, and especially wetland communities, which could result from projected future (2010) ground water withdrawals in the WRCAs (Figure 1). Potential mitigation options being investigated for the wetland communities of concern in the WRCAs are as follows:

- Wetland creation
- Wetland enhancement
- Wetland restoration
- Land acquisition
- Land preservation
- Cash contribution toward an SJRWMD-approved mitigation project

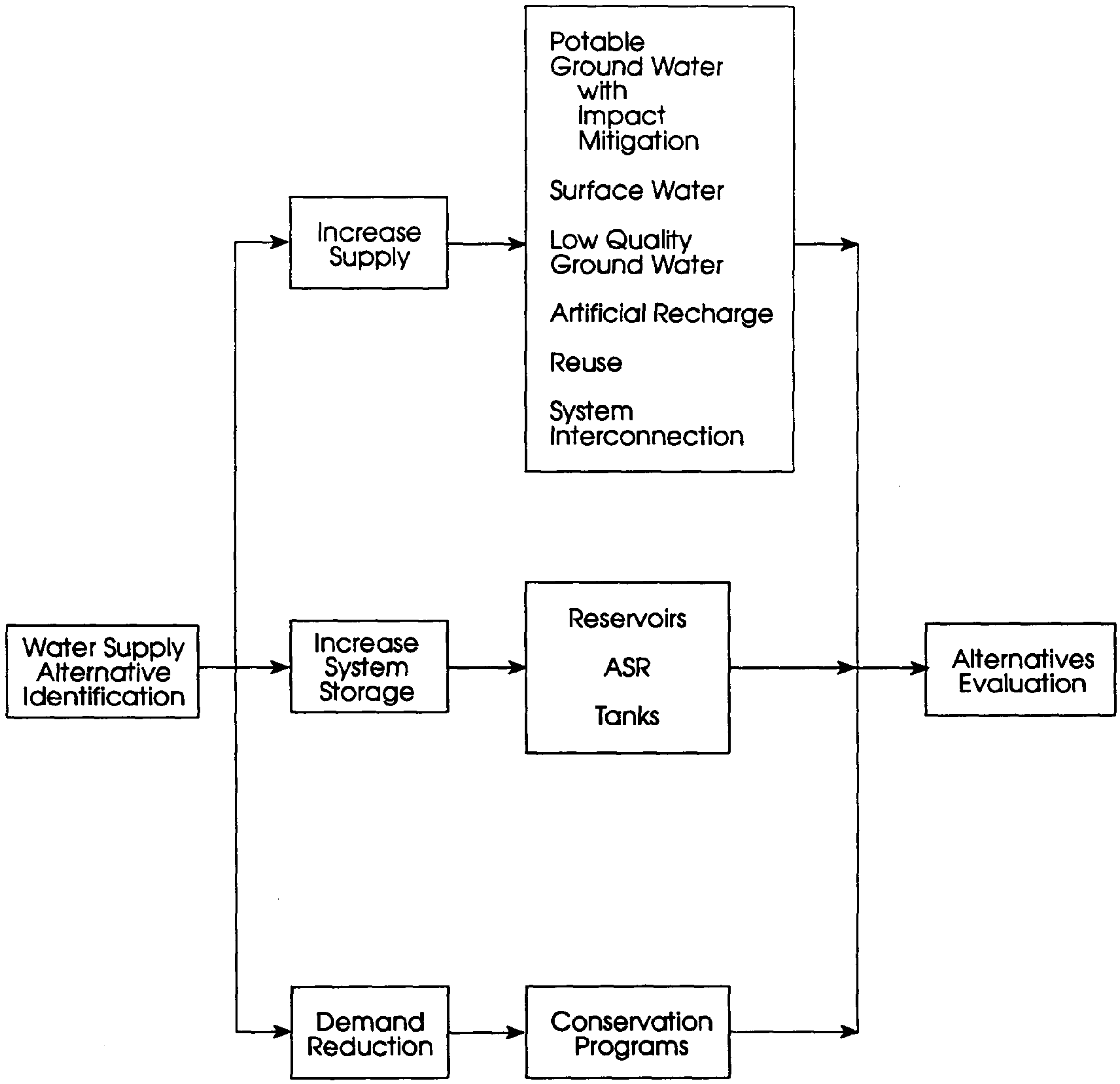

Figure 2. Water Supply Development Options for the SJRWMD.

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Subsequent efforts under Task E will address how impacts to native wetland communities in the WRCAs may be avoided by hydrating and irrigating potentially affected wetlands.

Because the previous analysis by SJRWMD predicted that wetland communities within the WRCAs were more susceptible to harm than upland communities, the focus in this TM is on the potential impacts to wetland communities. The primary purpose of this TM is to review the background information and existing data on environmental changes attributable to water supply development in Florida. This TM also presents methodologies and major assumptions to be used in a planning-level application for the quantitative evaluation of wetland system impacts and for generating cost estimates of potential mitigation actions.

As part of developing the methodologies, this TM presents an overview of the factors affecting hydroperiod and biological responses of sensitive wetland ecosystems and the regulatory issues that could affect the consumptive use permit (CUP) process. Future TMs will present the mitigation cost estimating spreadsheet (TM E.1.h), a methodology for impact avoidance (TM E.2.d), and a conceptual design for a hydration/irrigation pilot project (TM E.2.g).

METHODS

Methodologies were developed to support Tasks E1 and E2 as described in the contracted scope of services. The main purpose of these tasks is "to assess the technical, environmental, and economic feasibility of mitigating or avoiding the impacts to native vegetation that are projected to occur as a result of projected future ground water withdrawals in identified WRCAs."

Four TMs will be prepared under this scope of services. The primary elements of these TMs are listed below:

- **TM E.1.f.** This TM consists of a literature search and review, regulatory review, proposed costing procedure, and method for relating ecologic function to hydrologic impact.
- **TM E.1.h.** This TM will apply the costing procedure, which will be provided as an Excel spreadsheet.
- **TM E.2.d.** This TM will consist of an annotated bibliography, subject matrix, the results of interviews with key persons and visits to five sites, methodologies for project design, and implementation and cost of the pilot project.
- **TM E.2.f.** This TM will present the design and assess the construction and operation of a project. Five pilot projects will be recommended.

To evaluate the potential for wetland impacts associated with ground water withdrawals in SJRWMD, the following tasks were performed:

- Literature review
- Regulatory review
- Wetland screening process review

From the results of these tasks, which are described below, methodologies for evaluating and costing different types of mitigation were developed.

LITERATURE REVIEW

A literature review was conducted to obtain information documenting the ecologic effects of ground water withdrawal on wetlands within SJRWMD and other areas of the state. The literature review also included publications assessing the relationship between wetland functions and hydrology. Particular emphasis was placed on the effects of altered hydrologic conditions on vegetation and soils. From this review, sufficient information was obtained to support Tasks E.1 and E.2. Also, CH2M HILL will produce an annotated bibliography of relevant information as part of this effort, which will be included in TM E.2.d.

Approach

The literature review approach was developed during project team meetings within CH2M HILL and with SJRWMD staff. From those meetings, the following primary sources of information were identified: reports published by SJRWMD, reports prepared by consultants, journal articles, and technical reports prepared by state and federal agencies. To obtain this information, CH2M HILL:

- Requested reports from consultants that have conducted related hydrologic/ecologic studies in Florida.
- Requested a publications list from SJRWMD and other water management districts and from the University of Florida Center for Wetlands.
- Requested water resource reports and subcommittee documents pertaining to the effects of ground water withdrawal from the West Coast Regional Water Supply Authority (WCRWSA).
- Contacted other state and federal agencies and universities for reference lists or specific relevant documents.
- Performed key word literature searches in electronic databases for regional, state, and national publications.

The local electronic database search was conducted through the University of Florida Library User Information System (LUIS) and included the following databases: UF Libraries Catalog, Compendex-PLUS (Engineering Index), ABI/INFORM, Current Contents, Applied Science and Technology Index, Biological and Architectural Index, and General Academic Index. The national search of 33 databases was conducted through Knight-Ridder Information Systems (Dialog), an online, commercially available information service. This search was subsequently narrowed to nine databases. Keywords included wetland mitigation, hydroperiod alteration and reduction, wetland mitigation ratios, mitigation alternatives, mitigation banking ratios, ground water level, ground water level and wetland impact, and wetland impacts.

Subject Emphasis

During the literature review, the focus was on obtaining information on the following topics:

- Water regime and hydroperiod data from specific and typical Florida wetlands
- Effects of other measurable variables on Florida wetlands
- Impact detection methodologies
- Regulatory criteria
- Avoidance and mitigation of effects of ground water withdrawals
- Specific types of mitigation and their documented benefits
- Mitigation costs
- Mitigation ratios

Key Studies

Reports by Brown et al. (1983, 1991, 1992), CH2M HILL (1987), Environmental Science & Engineering (ESE) (1993a, b), and SFWMD (1995) were excellent sources of information, as were the reports on nine northern Tampa Bay wellfields and subcommittee reports prepared by the water management districts.

In the reports by Brown, the ecologic impacts of ground water withdrawal were identified by field methods, map coverage, and spatial data base analysis. CH2M HILL performed a comprehensive wetland protection program for the Ringling-MacArthur Reserve for Sarasota County. Field investigations conducted in 1980 and 1986 qualitatively described the hydrologic alteration of wetland plant communities in the Loxahatchee Slough (C-18) Basin.

ESE's report discusses the results of hydroperiod analyses within both the SJRWMD and the South Florida Water Management District (SFWMD), which helped determine the natural water regimes of wetlands within these areas. The ecologic monitoring performed to assess the impacts from the nine northern Tampa Bay wellfields examined the relationship between local hydrology and the effects on area vegetation and wildlife.

SFWMD documented the results of recent short-term studies that District staff and outside experts conducted to develop criteria for supporting the issuance of water use permits in south Florida (SFWMD 1995). The results were used to evaluate wetland impacts and develop appropriate criteria for application during the water use permitting process.

Finally, the environmental impact detection methodologies that were the subject of the subcommittee reports issued by the water management districts in February, May, and August 1994 (SWFWMD 1994) were also referred to.

Annotated Bibliography

A listing of the relevant documents identified during the literature review is provided in the Bibliography, along with the references that were used in preparing this TM. The annotation for these references will be prepared for the third TM (E.2.d). Microsoft Access will be used for organizing the annotated documents by author, title, date, and subject for sorting and retrieving. The data base can also be used for performing searches to determine the publications most relevant to a specific topic.

REGULATORY REVIEW

Appropriate sections of Chapters 40C-4 and 40C-2 of the *Florida Administrative Code (F.A.C.)*, SJRWMD's *Management and Storage of Surface Waters Applicant's Handbook*, and other relevant regulations associated with mitigating impacts to wetlands and native vegetation were reviewed. Discussions with SJRWMD staff were held to better understand the agency's position on mitigating the impacts of ground water withdrawals on wetlands and native vegetation.

The following regulations and reports were included in the review:

- Chapter 373, *Florida Statutes (F.S.)*
- Proceedings of the Subcommittee for Assessment of Hydrologic Effects of Ground-Water Withdrawals on Surface-Water Resources (SWFWMD 1994), an interagency review of the water management districts and Florida Department of Environmental Protection (FDEP) procedures
- Proceedings of the FDEP Incentive-Based Regulatory Alternatives Committee (FDEP 1994)

- Florida Water Plan 1995, an interagency publication produced by the water management districts and FDEP (FDEP et al. 1995)
- Proceedings of the Subcommittee on Impacts to Natural Systems, an interagency review by the water management districts and FDEP (Lowe 1994)

WRCA WETLAND SCREENING PROCESS REVIEW

As part of its needs and sources review, SJRWMD developed a screening process to identify wetland and other natural systems that were potentially at risk as a result of projected year 2010 ground water withdrawals (Kinser and Minno 1996). This information was reviewed, along with the other information prepared by SJRWMD in Technical Publication SJ94-7 (Vergara 1994), which assessed the effects from year 2010 ground water withdrawals on wetland vegetation in sensitive areas.

This effort included a review of the screening process, the assumptions used in the geographic information system (GIS) analysis, and the sensitivity of results to changes in the underlying assumptions.

MITIGATION RATIOS AND UNIT COSTS

Mitigation ratios are used by SJRWMD as guidelines for determining the compensatory mitigation for permittable impacts to wetlands. A set of recommended ratios is needed to estimate the mitigation requirements for predicted wetland impacts within the WRCAs. The recommendations are based on a review of ratios supplied by SJRWMD and the development and application of ratios within the federal wetland regulatory program.

Planning-level costs for mitigating potential impacts to wetlands within the WRCAs will be initially calculated with generalized unit costs for the major types of mitigation. Unit costs were developed for restoration, creation, and enhancement of wetlands; preservation of both uplands and wetlands; acquisition of both uplands and wetlands; purchase of mitigation bank credits; and cash contribution toward an SJRWMD-approved mitigation project.

SJRWMD supplied unit costs for preservation, land acquisition, and cash donations to the District-sponsored mitigation project. The remaining unit costs for restoration, creation, and enhancement and for purchase of credits from a mitigation bank were based on a survey of selected recent projects within SJRWMD and throughout the state.

DEVELOPMENT OF MITIGATION EVALUATION AND COSTING METHODOLOGIES

The primary purpose of this TM is to develop methodologies for estimating the environmental changes likely to result from water supply development and for evaluating mitigation techniques and their associated costs. The processes used for developing these methodologies are described below.

Impact Assessment Methodology

The impact assessment methodology estimates the changes that will occur in various types of wetland vegetation in the WRCAs as a result of changes in hydrologic conditions. To perform this estimation, other efforts were reviewed that attempted to quantify the loss of wetland function for each significant wetland type and the associated degree of hydrologic impact. From this information, a series of recommendations were developed for each key aspect of the methodology, such as:

- Scale matching
- Change in hydrologic regime
- Types of wetland communities
- Target hydrologic regime for each community type
- Faunal indicator group
- Definition of adverse harm
- Categories of ecologic change

Mitigation Costing Methodology

The specific goal of this effort was to identify a procedure that could be used for estimating the total cost of mitigating unacceptable impacts to wetland vegetation in the WRCAs caused by projected year 2010 pumpage. During this evaluation, planning-level unit costs for the following mitigation options were determined:

- Wetland creation
- Wetland enhancement
- Wetland restoration
- Purchase of mitigation credits
- Land acquisition

- Land preservation
- Cash contribution toward an SJRWMD-approved mitigation project

In developing the wetland impact mitigation costing methodology, the following four assumptions were made: (1) Unavoidable wetland impacts would require some form of mitigation; (2) early planning for these mitigation activities is a key element in overall project development; (3) the level of costing and details will vary from project to project; and (4) the cost estimating tool must be flexible to accommodate a variety of projects, differing levels of detail, and changing plans and goals.

The proposed methodology uses a spreadsheet tool that can generate three levels of cost estimates: planning, conceptual, and detailed construction. Unit costs were obtained from SJRWMD staff, from other similar projects, and from the mitigation banking industry.

HYDROLOGIC REQUIREMENTS OF FLORIDA WETLANDS

Wetlands in Florida follow natural and usually predictable fluctuations in depth and duration of inundation in response to seasonal patterns of rainfall and evapotranspiration. These fluctuations significantly influence the composition of vegetative and faunal communities and associated wetland functions. Climatic and cultural changes in the quantity and timing of hydrologic inflows and outflows can affect the pattern and range in water level fluctuations, leading to changes in wetland structure and function.

Through the CUP process, SJRWMD assesses environmental impacts of water supply development through the Public Use Test (Section 10.3[d], A.H.), which it requires for both onsite and offsite impacts. As no formal definition of *unacceptable harm* exists, undesirable impacts to biological diversity and productivity have been difficult to assess. This section provides a general description of the importance of hydrology, or the hydrologic regime, to wetland structure and function.

THE HYDROLOGIC REGIME

The water balance of a wetland is the net result of the differences between rainfall, surface run-off, ground water inflows, ground water recharge, surface water discharge, and evapotranspiration outflows. The hydrology of many wetlands is controlled in part by interactions between surface and ground water. Wetlands can receive ground water through seepage from surrounding higher elevations or discharge ground water, depending on the presence or absence of confining layers either in the soil horizon or the underlying strata, and the piezometric gradient between the surficial and lower aquifers. The relative rates of these internal processes define the hydrology of a wetland, which in undisturbed conditions is dominated by wetland plant species adapted to these hydrologic conditions.

The aspects of flooding within a wetland can be separated into components of duration (hydroperiod), depth, seasonality, and frequency. When considered together, these components define a wetland's *hydrologic regime.*

Effect of the Hydrologic Regime

The many types of freshwater wetlands in Florida include shallow emergent marshes, wet prairies, forested wetlands (mixed hardwood swamps, cypress domes and strands), deep marshes, ponds, sloughs, riverine marshes, swamp forests, and lake littoral marshes and forests. Each is dominated by particular species of vegetation typically associated with a particular range in depth and duration of inundation.

Because of internal/topographical variation, inundation frequencies and depths vary widely within a wetland. Shallow edges may only be saturated without inundation for a period of only days to weeks, while the deeper interior may be inundated to a depth of 3 feet or more throughout the year and may only be dry during years of less than average rainfall. A shallow interior wetland slope, coupled with an uneven microtopography, assures subtle but important variations in inundation frequency within a wetland.

Simplifying the hydrologic regime in terms of average annual values for depth, duration, and frequency of flooding is helpful in characterizing general conditions. In reality, however, a wetland is unlikely to experience an average year. Instead, the hydrologic regime will exhibit variation from year to year.

A complex hydrologic regime results from the seasonal, climatic, and topographic factors that affect the depth, duration, and timing of inundation within a wetland. For example, shallow Florida wetlands such as wet prairies and littoral zones of large marshes or lakes typically experience seasonal inundation of maximum depths ranging from 1 to 2 feet and annual duration varying from 3 to 8 months. During a drought year, these types of wetlands can undergo long periods of low stages, or dry completely. This natural process allows colonizing plants to germinate on available substrates and can, in some cases, initiate an ecologic succession toward a different type of vegetation. These drawdown periods may increase the potential for fire, a critically important factor affecting Florida wetland ecology, as wetland water levels are lowered during a severe drought. Conversely, a very wet year, during which the wetlands may be inundated for the entire year, can retard or reverse the successional trends initiated during drier periods.

Figure 3 illustrates the duration requirements of different Florida wetland communities by using data reported from a characterization of vegetation in the Florida Everglades (Shomer and Drew 1984).

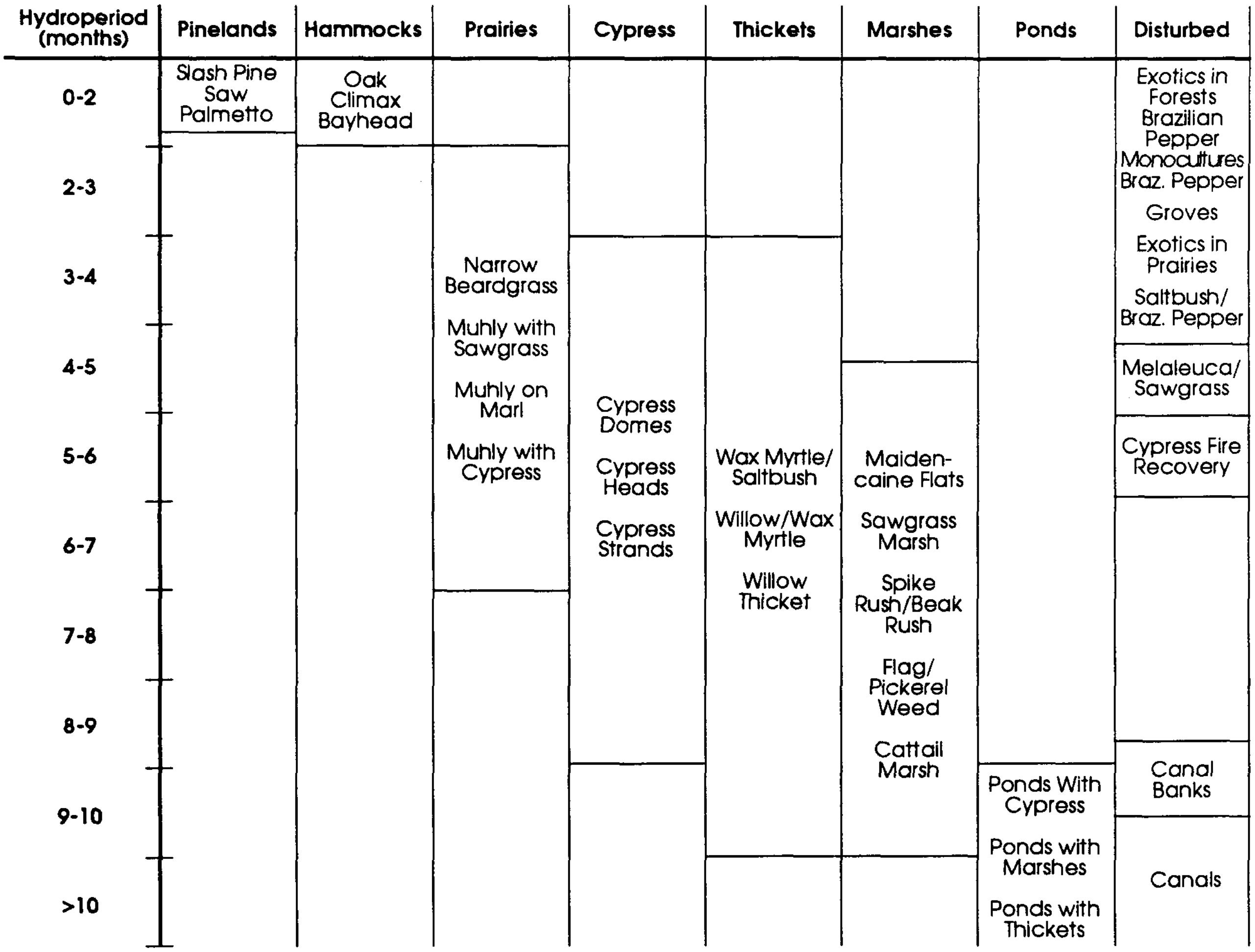

Figure 3. Comparative Ranges of Hydroperiods for Everglades Wetlands (Shomer & Drew, 1984).

Hydroperiods increase as wetland depth increases. For example, cypress communities are inundated from 3 months (25 percent) to 9 months (75 percent) each year, while marshes are generally inundated from 4.5 months (37.5 percent) to 10 months (83 percent).

Brown and Starnes (1983) defined a narrower range in average water depths and hydroperiods for the major types of wetlands in Seminole County (Table 1). In their assessment, cypress hydroperiods averaged between 250 days (68 percent) to 300 days (82 percent) in length, while marshes were essentially inundated all year. These data indicate that differences in wetland hydroperiod characteristics may vary between regions within Florida, but all wetland types can dry down to or near wetland ground elevation.

Table 2 provides a summary of these and other data compiled from a number of studies conducted in central and southwest Florida. Wetland types are ranked in order of increasing hydroperiod, and average low and high water depths are provided where available. These data support the observation that wetland types are associated with a wide hydroperiod range, which generally defines the flooding tolerance of the community. The summary data also show that the hydroperiod range of a given wetland community may overlap with one to several other community types.

Because of topographical and related environmental gradients, Florida wetlands typically exhibit distinct zones dominated by different plant species, suggesting strong affinities by vegetative species for specific hydroperiods within a wetland type. Common vegetation zones in wet prairie marshes in southwest Florida have significantly different average depths and duration of inundation (Table 3). These data suggest that zone species dominance and composition will change in response to an increase or decrease in wetland hydroperiod.

Table 4 presents average hydroperiods proposed as assessment guidelines by WCRWSA for different wetlands identified by Florida Land Use, Cover and Forms Classification type. Figure 4 presents examples of the seasonal fluctuation in water levels expected for different wetland types in west-central Florida (ESE 1993b). These average hydrographs summarize the important hydrologic characteristics of depth, duration, frequency, and seasonality of flooding.

The hydrographs also reflect the typical seasonal hydrologic pattern for wetland communities throughout the state. Water levels during

Table 1. Characteristic hydroperiods and average high and low water levels in typical Seminole County, Florida, wetlands

Community Type	Average High Water (ft)	Average Low Water (ft)	Hydroperiod (No. of days/year)
Hydric Hammock	0.33	< 0	100-150
Wet Prairie	1.64	< 0	150-200
Bayhead	0.98	< 0	200-250
Mixed Hardwood Swamp	1.97	< 0	200-250
Cypress Dome	1.64	< 0	250-300
Deep Marsh	3.28	.66	~365
Shallow Marsh	2.3	< 0	~365

Note:

< 0 = Below ground surface.

Source: Brown and Starnes 1983.

Table 2. Observed flooding depth and duration of Florida plant communities

Community Type[a]	Hydroperiod (No. of days/yr)	Average Low Water (ft)	Average High Water (ft)
Mesic Hammock	28		
Low Pine Flatwoods	42-225		
Wet Prairie	57		
Shrub Swamp (Transitional)	50-60		
Cypress Dome	~105		
Marsh	135-255		
Oak-Palm Hammock	75-200	-1.37	1.45
Open Pine-Prairie	150-200	-1.88	1.93
Transitional Prairie-Pine	150-200	-1.98	2.03
Altered Wetlands (Average)	~173		
Evergreen Swamp (Melaleuca)	175		
Scrub Cypress	194		
Bay Swamp	210		
Hypericum Marsh	213	-2.63	1.39
Deep Freshwater Marsh	215		2.63
Spartina Bakeri Marsh	218	-3.21	1.26
Hydric Pine Flatwoods	225		.56
Cypress/Pine Swamp	225-238		
Shallow Cypress Swamp	238		
Shrub swamp (Shallow)	239		
Shallow Evergreen Swamp	243		.47
Deep Cypress Swamp	250		
Deeper Freshwater Marsh	254		.88
Polygonum Marsh	262	-2.99	2.07
Fraxinus-Salix Swamp	308	-2.30	2.06
Shrub Swamp (Deep)	310-350		
Unaltered Wetlands (Average)	~313		
Cladium Marsh	319	-1.80	1.68
Cephalanthus Scrub/Shrub	320	-2.36	1.84
Panicum-Rhynchospora Marsh	327	-1.83	1.87
Pond (Aquatic Bed)	327-355		
Mixed Emergent Marsh	338	-1.43	2.1

[a]Documented observed values may not reflect typical hydroperiods for some wetlands.

Sources:

Bays and Winchester 1986.

Brown 1991.

Brown and Starnes 1983.

CH2M HILL 1987.

CH2M HILL and Winchester 1988a, b, c.

ESE 1991a, b, c; 1992a, b.

Table 3. Separability of selected southwest Florida wetland vegetation zones based on average water depth and hydroperiod

Wetland Vegetation Zone (Increasing Hydroperiod)	Increasing Average Water Depth							
	Hypericum	Panicum-Rhynchospora	Mixed Emergent	Cladium	Cephalanthus	Fraxinus-Salix	Spartina	Polygonum
Hypericum		p <0.01	p <0.01	p <0.01	p <0.01	p <0.01	p >0.05	p <0.05
Panicum-Rhynchospora	p <0.01		p <0.05	p >0.05	p >0.05	p >0.05	p <0.01	p <0.01
Mixed Emergent	p <0.01	p >0.05		p <0.01	p <0.01	p <0.01	p <0.01	p <0.01
Cladium	p <0.01	p >0.05	p <0.05		p >0.05	p >0.05	p <0.05	p <0.01
Cephalanthus	p <0.01	p >0.05	p <0.05	p >0.05		p >0.05	p <0.05	p <0.01
Fraxinus-Salix	p <0.01	p >0.05	p <0.05	p >0.05	p >0.05		p <0.05	p <0.05
Spartina	p >0.05	p <0.01	p <0.01	p <0.05	p <0.05	p >0.05		p >0.05
Polygonum	p >0.05	p <0.01	p <0.01	p <0.01	p <0.01	p >0.05	p >0.05	

Legend:

- No significant difference between zones (p >0.05).
- Significant difference between zones (p <0.05).
- Highly significant difference between zones (p <0.01).

Source: CH2M HILL 1987.

Table 4. Typical hydroperiods for major wetland types in central Florida based on WCRWSA ecologic monitoring data and literature documentation

FLUC No.	Classification	Hydroperiod[a] (days)	Zone
510	Creek/swamp	270	Channel
523	Lakes (5 to 99 acres)	180 365	Littoral Pelagic
611	Bay swamp	60 150	Shallow Deep
613	Floodplain swamp (bottomland)	150 270	Shallow Deep
615	Gum swamp	120	Floodplain
616	Inland ponds/sloughs	180	
617	Mixed wetland hardwoods	90 180	Shallow Deep
621	Cypress swamp	210	
630	Wetland forested mixed	150	
641	Freshwater marsh	120 300	Shallow Deep
643	Wet prairie	90	
670	Modified wetland	300	

[a]Hydroperiods are rounded to the nearest 30-day increment.

FLUC = Florida Land Use Classification

Source: ESE 1993b.

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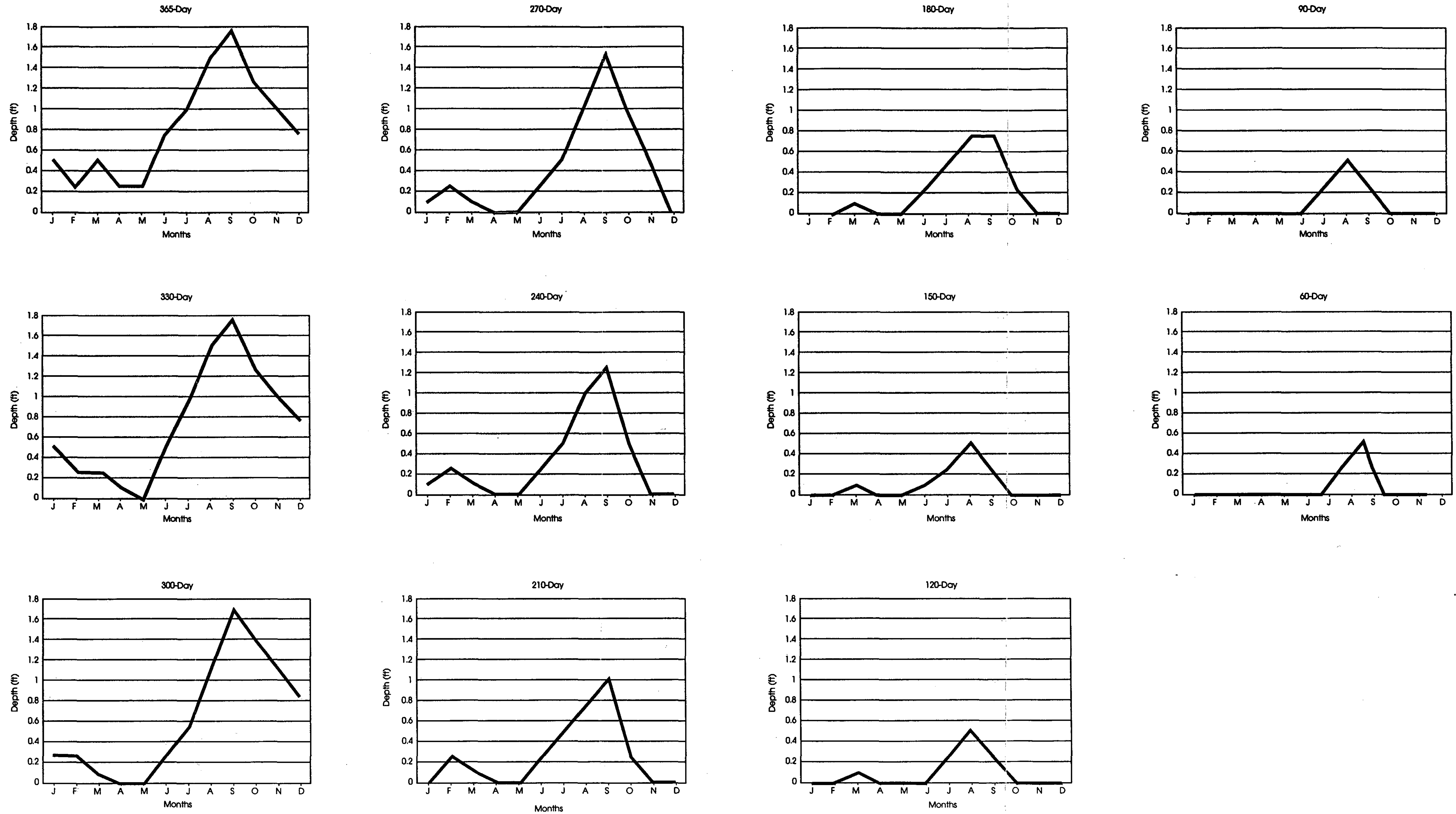

Figure 4. Generalized Hydrographs for Central Florida Wetlands (ESE 1993b).

winter are influenced by rainfall from frontal activity. During the spring dry season, water levels typically decrease, often declining below ground level. Water levels recover under the influence of convective storms throughout the summer, with maximum depths occurring between July and September. In the fall, water levels begin to decline again. The graphic representation of typical wetland hydrologic regime in Figure 4 illustrates the months during which inundated conditions exist and suggests a means of managing proposed alterations to vegetative communities.

Fire Frequency

Other factors with equal or greater influence on wetland community type include fire frequency, soil type, disturbance history, and adjacent habitat type (Shomer and Drew 1984). Fire is a natural component within the functioning of all natural ecosystems. All wetlands are fire-adapted to a particular fire regime. Common effects of fire in wetland communities include:

- Promotion of seed germination
- Stimulation of new plant growth, as evidenced by sprouting and coppicing
- Removal of encroaching upland plant species
- Cycling of nutrients and stored biomass

Inundation requirements were closely coupled with fire frequency by Duever et al. (1986) for other south Florida wetlands. For example, in the Big Cypress Swamp in Collier County, cypress was shown to require a hydroperiod ranging from 150 to 250 days, and a return frequency of severe fires of 30 to 100 years (Duever 1986). Marshes were shown to require a hydroperiod of 30 to 250 days, but a fire return frequency ranging from 1 to 5 years.

FACTORS AFFECTING HYDROLOGIC REGIME VARIABILITY

Hydrologic regime variability may be affected by a variety of natural and cultural factors, usually on a regional scale. These natural and cultural factors can affect one or more aspects of a wetland's water balance, such as inflows (precipitation and runoff), outflows (surface discharge, percolation, and evapotranspiration), and storage. Natural variability in rainfall (droughts and floods), temperature range (freezes and heat waves), wind (hurricanes and tornadoes), and geologic activity (sinkhole formation) result in a great inherent fluctuation in annual controlling factors. Human activities further affect these natural events.

Natural climatic variation in rainfall, evapotranspiration, and runoff can exert a profound influence on wetland hydrology, with reduced depths and hydroperiods during drought or high flooding levels and extended inundation during wet years. Occurrence of sinkholes within a wetland may increase wetland discharge to ground water. Natural blockage of inflows or outflows by eroded soils or fallen trees can change the rate of inflows, or increase the elevation or duration of standing water within a wetland.

Cultural influences in the form of modified land use, altered surficial drainage, channelized surface flow, and ground water drawdown may directly impact the established hydrologic regime of a wetland. Modifications to land use may include construction activities, altered fire frequency, off-road vehicle use, logging, cattle grazing, and vegetation planting. Surface water alterations, through drainage ditching and channelization or other landscape modifications, may be detrimental, depending on the degree of change to water levels and the overall water balance. The typical hydrologic impact of uncontrolled drainage ditching is to increase the discharge out of an upland or wetland system by drawing more water off during the dry season, and to accelerate increased outflow during the wet season (Bays and Winchester 1986).

Groundwater fluctuations may directly contribute to hydroperiod variation in wetlands by inducing recharge from the surficial aquifer to the deeper production aquifer, thereby lowering the water table. The magnitude of this effect varies with rainfall, changes in the potentiometric surface, and regional variation in pumpage (Bays and Winchester 1986).

EFFECTS OF GROUND WATER WITHDRAWALS ON FLORIDA WETLANDS

According to Lowe (1994), biological diversity and productivity are key to defining unacceptable harm to a system; therefore, it is critical to establish possible outcomes for proposed impacts based on system type. Appendix A presents documented wetland impacts, primarily culturally derived, that may result in the identified ecologic and physical responses.

This section summarizes the potential effects of ground water withdrawals on the major wetland ecosystems in Florida. The information in this section has been compiled from existing reports that were identified as part of the literature review. The following key sources provided most of the literature used in this evaluation:

- **Water Management Districts**. SJRWMD, SFWMD, and the Southwest Florida Water Management District (SWFWMD) were all contacted for information.
- **Water Supply Authorities**. WCRWSA was contacted for reports documenting the effects associated with ground water withdrawal.
- **Public Utilities**. The cities of Cocoa and St. Petersburg provided wellfield reports containing ecologic monitoring studies.
- **Academic Research**. The University of Florida Center for Wetlands provided information on current and past research.

TYPES OF EFFECTS

Ground water is the principle source of water in Florida (Vergara 1994). Because the projected demand for additional ground water supplies is expected to increase dramatically through the next decade, an evaluative methodology that incorporates both hydrologic and ecologic impacts and their relationships is crucial for prudent, effective management of the resource. Estimating the potential effects of altered hydrology on the major types of wetlands within the state is fundamental to this process.

Hydrologic Regime

Studies have documented that under certain conditions, lowering surficial aquifer ground water levels can reduce the depth, duration, and frequency of wetland inundations, resulting in changes to the ecologic structure and function of wetlands and other natural systems (Appendix A). Other natural and cultural factors affecting wetland hydrology documented in the literature include drought, flooding, sinkhole formation, ditching, lumbering, vehicular traffic, fire, grazing, and numerous developmental impacts.

In 1994, SWFWMD formed a subcommittee to evaluate technical approaches for assessing the effects of ground water withdrawal on surface water features and to incorporate these approaches into its water resources management plan. Impacts to ground water withdrawal caused by altered land use, including wellfield production and other water use factors, were examined as part of this process. Wetland variability and impacts were also assessed in WCRWSA's Environmental Management Plan (EMP) (WCRWSA 1994). A final report on impacts to natural systems related to ground water withdrawal was the product of a third subcommittee (Lowe 1994).

The effect of groundwater withdrawals on the hydrologic regime of a wetland is under the control of a great many factors, such as the following:

- Drawdown within the aquifer being pumped
- The nature and extent of confining strata between the pumped aquifer and surficial water table
- The presence or absence of confining strata underlying the wetland
- The characteristics of the wetland soil
- The controlling element of the water balance
- Seasonal variation in pumpage
- The size and landscape position of the wetland
- The degree of influence of other natural and cultural factors affecting the water balance

Because of this complex set of factors, it can be expected, and studies have shown, that some types of wetlands in particular settings exhibit a hydrology altered by pumpage-induced groundwater reduction, while other wetlands in the same or different physical settings show no discernible hydrologic alterations.

If pumpage-induced ground water reductions result in changes in the hydrologic regime of a particular wetland, potential hydrologic changes would include the following:

- Reduction in hydroperiod
- Reduction in average water levels and, potentially, seasonal high and seasonal low levels
- Reduction in the frequency of inundation
- Change in the seasonal distribution of inundation

The degree of any one of these hydrologic impacts can cover the full spectrum of response, from no measurable change through full reduction or loss.

Vegetation

Hydrologic regime alterations may affect the structure and species composition of the vegetative community. Table 5 shows several specific vegetative assemblages associated with hydrologically altered wetlands. This grouping of observed plant species includes invasive species that have been documented to encroach upon hydrologically altered wetlands without regard to whether the hydrologic change was natural or cultural in origin.

Table 6 lists herbaceous species found in southwest Florida wet prairies that can be used to characterize the extent of hydrologic alteration. This classification by vegetation structure was conducted in the Carlton Reserve in Sarasota County, which contains more than 1,100 freshwater wetlands, including marshes, wet prairies, swamps, heads, and river floodplains. Of the 26 wetlands studied, two experienced a water table decline, three were drainage ditched, and 21 remained unaltered throughout the study period.

The data summarized in Tables 5 and 6 and the studies cited in Appendix A indicate that the species composition within a wetland can change in response to hydrologic change. This is expected because ecosystems are dynamic entities that respond to a prevailing set of environmental conditions or forcing functions. As one or more forcing functions such as hydrology change, the biological community may change in response. This dynamic response of wetland vegetation is well documented in the ecologic literature regarding wetland ecosystem succession. Within the context of ecologic succession, the biological response of wetland communities to long-term hydrologic reductions can be described as a dehydration succession sequence.

Table 5. Observed vegetative changes associated with altered hydrology in representative Florida wetlands

Major Community Type	Typical Representative Species (Common Name)	Invasive Species
Cypress Dome	Pond Cypress Bald Cypress Blackgum Dahoon holly Red maple	Wax myrtle Myrsine Cajeput Boston fern Brazilian pepper Doddervine Climbing fern
Floodplain Forest	Blackgum (Swamp Tupelo) Sweetgum Laurel oak Willow Water oak Cabbage palm	Cabbage palm Pines Wax myrtle Blue beech Baccharis
Floodplain Slough	Waterlily Floating heart Spatterdock Other submergent species	Wax myrtle Willow Red maple Cattail Cabbage palm Punk-tree
Marsh/Wet Prairie	Beakrush Maidencane Spike-rush St. John's wort Pipewort Redroot Yellow-eyed grass	Sawgrass Cattail Beakrush Swamp fern Swamp lily Punk-tree
Hydric Pine Flatwoods	Slash pine Red maple Sweetbay Cabbage palm	Wax myrtle Saw palmetto Gallberry

Source: CH2M HILL 1987; Brown 1991; ESE 1993a, b.

Table 6. Vegetative response to water table decline in southwest Florida wet prairies

Group Number	Group Description
1	Invading species that are typically found in hydrologically altered wetlands: *Digitaria serotina, Eupatorium capillicolium, Eupatorium leptophyllum, Euthamia minor, Lippia nodiflora, Panicum verrucosum, Sesbania macrocarpa*
2	Facultative wetland species that typically increase in dominance with water table declines: *Andropogon virginicus, Amphicarpum muhlenbergianum, Blechnum serrulatum, Centella asiatica, Eleocharis vivipara, Echinochloa crus-galli, E. walteri, Eragrostis elliottii, Iva microcephala, Lycopus rubellus, Panicum hemitomon, Polygonum punctatum, Pluchea rosea, Rhexia mariana, Rhynchospora corniculata, Rhynchospora inundata*
3	Wetland plant species that maintain viable populations or which decrease slowly with water table declines: *Aristida lanosa, Boltonia diffusa, Cladium jamaicense, Ludwigia arcuata, Panicum rigidulum, Rhychospora tracyii, Sagittaria lancifolia, Spartina bakeri, Xyris elliottii*
4	Obligate wetland species that rapidly diminish in dominance with water table declines: *Bacopa caroliniana, Ceratophyllum demersum, Eriocaulon compressum, Hypericum fasciculatum, Nuphar luteum, Nymphaea odorata, Nymphoides aquatica, Pontederia cordata, Proserpinaca palustris, Utricularia foliosa*

Source: CH2M HILL 1987.

Soils

Drainage alteration, such as ditches, borrow pits, retention ponds, and control structures, may reduce the water storage capacity of the soil, thereby decreasing water volumes during drier times. Conversely, periods of increased rainfall may mask or eliminate water table drawdowns near wellfields, large barrow pits, and large ditches. If subject to prolonged exposure to air, wetland soils may oxidize and begin to shrink, subside, and form cracks that greatly reduce the structural stability for the wetland canopy as well as the wetland water retention capacity.

Summary of Causes and Effects

Table 7 presents potential causes and possible observed effects of hydrologic alterations. Key studies show that the effects of ground water withdrawal on wetlands are apparent on vegetation (composition shift), hydroperiod (reduced), soils (subsidence), and fauna (species composition shift). Changes in environmental variables can include ground water and surface water elevation fluctuations; soil subsidence; sinkhole formation; reduced hydroperiod; rainfall oscillations; differences in fire severity; water quality degradation; exotic plant species invasion; alterations in vegetative species composition, abundance, diversity, and productivity; and alterations in wildlife community composition.

Table 7. Summary table of observed symptoms and physical indicators

Potential Causes	Potential Observed Effects
Below normal rainfall	Soil subsidence
Below normal groundwater levels	Waterward vegetation shifts
Surface drainage	Sinkhole formation
Change in watershed runoff characteristics	Tree fall
	Upland vegetation shift
	Exotic species encroachment
	Five severity increases
	Productivity change
	Decreased species diversity
	Decreased number of species
	High water level variability
	Plant growth/mortality
	Water quality degradation
	Altered wildlife habitat
	Low potentiometric head and piezometric level
	Soil horizon changes
	Nutrient fluctuation

IMPACT DETECTION METHODOLOGIES

This section summarizes the existing methods for detecting impacts to hydrologic regime and wetland function. Detection is key to complying with SJRWMD's regulatory policy, which requires that environmental or economic harm from consumptive use must be reduced to an acceptable level. The techniques described in this section have been used for wetland monitoring programs implemented with the consumptive use permitting process. Evaluation of the effects requires reference to local ecologic conditions (Lowe 1994).

The following detection methodologies are used to monitor ecosystems:

- Remote sensing (aerial photography)
- Permanent photo stations
- Statistical methods
- Field methods
- Spatial data bases

Some methodologies are preferable for surface water feature impact detection (FDEP 1994), while others are better suited for wetland impacts (Table 8) (Lowe 1994; Brown 1991).

The ecologic impacts of ground water withdrawal can be identified by specific field methods, by map coverage, and by applying spatial data bases with associated statistical analyses (Appendix B). Brown (1991) recommended the following three-tiered approach to ecologic assessment:

1. **Qualitative assessment.** Involves water levels, soils, canopy condition, fire effects, plant and animal life, and human effects.

2. **Map coverage.** Involves the use of aerial photography and references to the Florida Department of Transportation's (FDOT's) Florida Land Use, Cover, and Forms Classification System (Level II) and Soil Conservation Service (SCS) digital analysis.

3. **Spatial data bases.** Involves projecting the effects of withdrawal on ecology.

Table 8. Summary table of ecologic variables and frequently used wetland system monitoring methodologies in Florida

Measured Variable	Detection Methodology			Comments
	Remote Sensing/ Permanent Photo Stations	Statistical Analysis[a]	Field Methods	
Hydroperiod [b,c]	Presence/absence of standing water	Modeling hydrographs regression	Staff gauge stage, recorder	*Modeling method; Hydrosim* [d]
Wellfield Production		Time series	Flow measurements	Frequency analysis similar to double mass curves Production also supplied by the operator Hydrologic modeling performed using Hydrosim for estimating hydrologic regimes of wetlands [d]
Vegetation	Aerial infrared photointerpretation	Time series, t-test, similarity indices, non-parametric tests	Field inspection, groundtruthing, transects, collection	Statistics may vary (Wilcoxon Rank Sum Test, signed Rank Test, etc.) [d] Using land use/land cover data, may generate power density, impervious surface, and LDI Index.
Soils/Substrate [b,c]	Aerial photointerpretation	Time series, data tabulation	Coring - hand auger, other field observations	See footnotes
Rainfall		Data tabulation, time series, double mass curves	Collection gages	*Double mass curve = graphical technique* [b] See footnotes
Groundwater Levels [b,c]		Time series t-test regression	Well monitoring	See footnotes
Wildlife		Data tabulation	Ground observations	See footnotes
Temperature		Data tabulation, time series	Collection gages	See footnotes

[a] Other Statistical Analyses: Simple regression and multiple linear regression.

[b] Hydraulics Parameters (Semi-confining): Aquifer performance tests, permeameter tests, mass balance analyses, sinkhole detection characterization, bottom sediment investigations

[c] Parameters and Thickness of Aquifer: Analyses of well cores, high-resolution seismic surveys, ground penetrating radar, gamma ray logging, aquifer performance tests.

[d] Field inspections include adventitious roots, stain lines, lichen lines, buttressing zonation.

Sources: Bays and Winchester 1986.
Brown 1991.
Brown and Starnes 1983.
CH2M HILL 1987; 1988a, b.
ES&E 1991a, b.; 1992a, b.
FDEP 1994.

APPLICATION TO EXISTING PROJECTS

Since the late 1970s, nine northern Tampa Bay wellfields (North Pasco Regional, Cosme-Odessa, Northwest Hillsborough Regional, Section 21, Cypress Bridge, Cross Bar, Cone Ranch, JB Starkey, and Cypress Creek) have been monitored to evaluate the effects of well production on the local ecology and surface hydrology. A summary of the detection methodologies used at the wellfields is presented in Table 9, while the monitoring programs for the wellfields are described in Table 10 (WCRWSA 1994; Brown 1991).

Each of Florida's water management districts has established its own definition of an unacceptable impact, which its individual monitoring program is designed to detect. Generally, the ecologic monitoring program established within a typical wellfield includes monthly or quarterly qualitative vegetation monitoring at specific stations. In addition, water level information is collected at wetland and open-water stations within most of the wellfields. Quantitative vegetation monitoring is typically conducted at select stations in specific months, usually May and September. Monitoring data collected usually include, but are not limited to, the following types of information:

- Qualitative and quantitative vegetation data
- Site photo-documentation
- Precipitation
- Water production
- Water distribution for public supply
- Ground water and surface water levels
- Stream discharge
- Water quality
- Regional aerial photographs
- Wildlife observations
- Water level in wetlands
- Sinkhole formation
- Substrate disturbances

The subsections that follow provide a rationale and brief description of some of the monitoring parameters and techniques typically used.

Hydrology

Water levels in wetlands, lakes, and streams are influenced by natural (rainfall, evaporation, geological structure) and cultural factors (land

Table 9. Summary of typical ecologic monitoring variables for wellfields in the northern Tampa Bay area

Measured Variable	Field Method	Statistical Analysis	Remote Sensing
Hydroperiod (max/min)	X	X	
Wellfield Production	X	X	
Groundwater Level	X	X	
Vegetative Cover and Condition	X	X	X
Wildlife Occurrence	X		
Precipitation	X	X	
Surface Water Level	X	X	X
Groundwater Quality	X	X	
Surface Water Quality	X		
Stream Discharge	X	X	
Sinkhole Formation	X		X
Site Disturbance	X		X
Soil Classification	X		

Sources:

Biological Research Associates 1992.
Environmental Science and Engineering 1993.
HDR Engineering 1993.
Henigar and Ray 1992.
University of South Florida 1993.
Water and Air Research 1994.

Table 10. General monitoring program for nine northern Tampa Bay wellfields

Well Field	Total Stations	Begin Year	Hydroperiod			Vegetation				Wildlife			Habitat	Reference
			Stations	Staf Sampling Frequency	Gauge Type	Stations	Freq	Parameters	Method	Type	Freq	Methods		
North Pasco Regional	37	1989	37	M	Quant Qual	10 37	Q M	Dom/Den/Imp/Cov Phen/Stress	Quadrat Observation	Quant Qual	Q M	Timed Counts Observations	Hardwood Swamp Forest Cypress Lake Marsh	HDR (1993)
Cosme-Odessa Well Field	55	1985	55	BW	Qual	37	M	Phen/Stress	Observation	Qual	M	Observations	Cypress Lake/Pond Longleaf Pine/Xeric Oak Pine/Mesic Oak Hardwood Swamp Forest	WAR (1994)
Northwest Hillsborough Regional	66	1982	66	B-W	Qual Quant	66 10	M Q	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual	M	Observations	Lake/Pond Hardwood Swamp Forest Cypress	WAR (1994)
Section 21 Well Field	31	1985	31	B-W	Qual	31	M	Phen/Stress	Observation	Qual	M	Observations	Cypress Lake/Pond Pine/Mesic Oak	WAR (1994)
Cypress Bridge	47	1992	47	BW	Qual Quant	47 10	M Q	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual Quant	M S	Observations Timed Counts	Marsh Blackgum Pond Hardwood Swamp Forest Cypress Lake Wet Prairie	HDR (1993)
Cross Bar Ranch	60	1978	60	BW	Qual Quant	60 10	M Q	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual	M	Observations	Cypress Marsh Lake/Pond	BRA (1992)
Cone Ranch	46	1988	46	M	Qual Quant	46 10	M B	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual	M	Observations	Cypress Marsh Hardwood Swamp Forest	H&R (1992)
J.B. Starkey	148	1983	60	BW	Qual Quant	60 10	M Q	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual	M	Observations	Cypress Marsh Lake/Pond Hardwood Swamp Forest Mesic Hardwood Hammock Flatwoods Wet Prairie	ESE (1994, 1995)
Cypress Creek	79	1976		BW	Qual Quant	60 10	M Q	Phen/Stress Dom/Den/Imp/Cov	Observation Quadrat	Qual	M	Observations	Cypress Marsh Lake/Pond Hardwood Swamp Forest Mesic Hardwood Hammock Flatwoods Wet Prairie	ESE (1991c)

Abbreviations:

BRA = Biological Research Associates
BW = Biweekly
Cov = Cover
Den = Density
Dom = Dominance
ESE = Environmental Science & Engineering
HDR = HDR Engineering
H&R = Henigar and Ray
Imp = Importance value
M = Monthly
Phen = Phenology
Q = Quarterly
Quad = Quadrat
Qual = Qualitative
Quant = Quantitative
S = Semiannual
Stress = Plant health
WAR = Water and Air Research

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use, ditching, borrow pit, and retention pond construction; drainage; wellfield production). The water level data collected for analysis may be used to interpret hydrologic trends within wetlands, lakes, and streams. These analyses include the interpretation of current and long-term trends in water level fluctuations and extremes, as well as hydroperiods.

A common method for assessing if a wetland is being affected by ground water drawdown involves comparing the wetland's water levels with those of nearby control wetlands, as well as with historic data (ESE 1993a). Some statistical modeling may be required for this effort. Numerical modeling techniques also may be used to simulate potential impacts of wellfield pumping or other ground water drawdown activities through statistical methods. Where there is a potential for substantial adverse hydrologic impacts to area wetlands, local modeling may aid in determining the extent of the impact.

Vegetation

Common wetland vegetative parameters measured include canopy basal area, density, and frequency and percent cover and composition of the shrub sub-canopy and herbaceous ground cover. The U.S. Fish and Wildlife Service (USFWS) National Wetland Indicator status is increasingly used to weight percent cover data to demonstrate vegetative dominance by obligate and facultative wetland plant species. Canopy measurements are typically made annually, and ground cover measurements may be made on a semi-annual or quarterly basis.

Aquatic Vertebrate Wildlife

Wildlife communities are typically monitored on a qualitative basis, with species lists developed by taxa group. Recent monitoring programs have instituted a timed census at fixed locations that allow comparisons of relative abundance to be made between stations and sampling visits.

Soils

Soil subsidence is assessed by performing repeated measurements of elevations in soil and vegetation. Changes in soil condition are typically described qualitatively during routine monitoring.

Aerial Photography/Remote Sensing

Aerial photographs are interpreted using a list of land use classification codes, usually Level III, as defined in the FDOT Land Use, Cover and Forms Classification System (FDOT 1995). Residential and commercial land uses, as well as ecologic communities, are typically delineated through the use of black and white aerial photographs at a scale of 1:24,000 and 1:4,800.

False color infrared images are often used when a higher degree of delineation of the landscape is desired, such as when evaluating landscape alterations. During this type of evaluation, slight changes in color indicate a change in spectral reflectance, which in turn indicates a change in vegetative composition or condition and water level. False color infrared photos are flown at a variety of scales, and are typically prepared at a scale of 1:24,000, or 1 inch = 2,000 feet.

Satellite Imagery

SPOT satellite imagery, which has a high (20-meter pixel) resolution, and LANDSAT imagery (30-meter pixel) are alternative sources of land use and cover information. These images are taken at a high altitude and may be in true color or false color.

Trend Analysis

The final report by the Subcommittee for Assessment of Hydrologic Effects of Ground-Water Withdrawals on Surface-Water Resources (SWFWMD 1994; Brown 1991) details data requirements and technical approaches for assessing ground water withdrawal impacts on surface water, as well as monitoring methodologies often used for assessing environmental impacts (Table 8).

CURRENT REGULATORY CRITERIA

This section reviews appropriate parts of Chapter 373 *F.S.*, Chapter 40C-2 *F.A.C.*, Chapter 40C-4 *F.A.C.*, the *Management and Storage of Surface Water Applicant's Handbook*, and other relevant regulations dealing with mitigating impacts to wetlands. This discussion incorporates information obtained from SJRWMD and other water management district staff.

An alternative to the typical permitting approach is also presented in this section. The alternative approach contains an incentive-based program, which advocates no net loss of ecologic values. Within the context of an incentive-based approach there are three key issues: ecosystem management, mitigation sequencing, and adaptive management.

CHAPTER 373, *F.S.*

Chapter 373 provides the basis for water management policy and regulation in Florida. Chapter 373 and supporting statutes and rules address the assessment of harm to natural systems within the context of water resource management. Issues relevant to the topics discussed in this TM include the establishment of minimum flows and levels and the permitting of consumptive uses of water. For both these issues, the *Florida Statutes* and associated rules seek to balance water use with resource protection and sustainability. The intent, concerns, and policies of the state's water resource rules and regulations are illustrated in the following excerpts:

1. Chapter 373.042(1) *F.S.* requires that the water management districts establish a minimum flow for all surface water courses as the "limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area."

2. The water management districts are also required to establish minimum water levels that are "the level of ground water in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area" (Chapter 373.0452[2] *F.S.*).

3. Chapter 373.233(1) *F.S.* says that to obtain a permit for water use, the applicant must establish that the proposed use meets the following three criteria: is a reasonable and beneficial use as

defined in Section 373.019(4); will not interfere with any recently existing legal use of water; and is consistent with the public interest. Water management district rules repeat these requirements; however, neither the statutes nor the rules provide standards for determining if these criteria have been met in each case.

4. Chapter 373.019(4) defines reasonable-beneficial use as the "use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest."

5. State water policy states that the waters of the state should be managed to conserve and protect natural resources (Chapter 62-40.110 *F.A.C.*).

6. As part of the general water policy, water management programs, rules, and plans should (1) reserve from use water that is necessary for the "protection of fish and wildlife" (62-40.310, paragraph 1,b) and (2) establish minimum flows and levels to protect water resources and the environmental values associated with marine, estuarine, freshwater, and wetlands ecology (62-40.310, paragraph 4,a and 62-40.410, paragraph 3).

7. In determining if a use of water is reasonable-beneficial, state water policy requires that many factors be considered. Among these are "the extent of water quality degradation caused (62.40.410, paragraph 2,m) and the "amount of water which can be withdrawn without causing harm to the resource" (62-40.401, paragraph 2,p).

8. State water policy also states that in determining the harm to water resources "...consideration should be given to the impact of the facilities on water quality; fish and wildlife; wetland floodplain and other environmentally sensitive lands..." (62-40.432, paragraph 4(b)1).

9. For minimum flows and levels, state water policy states that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows and levels, and environmental values associated with coastal, estuarine, aquatic, and wetlands ecology..." (62-40.4743, paragraph 1).

The CUP application process is governed by Chapters 373 and 120 *F.S.*, and Chapters 40C-1 and 40C-2 *F.A.C.*, and is affected by Chapter 62-40 *F.A.C.*

CHAPTER 40, *F.A.C.*

Each water management district regulates water use to control harm to affected natural systems. Each district approaches the task differently. The approach used by SJRWMD under Chapters 40C-2 and 40C-4 *F.A.C.* is provided below. For comparison, the approaches used by the other districts are summarized in Table 11.

In evaluating CUP impacts, both onsite and offsite effects are considered. The extent and amount of onsite and offsite harm caused by an existing use is assessed as a matter of policy under Florida's common law for water (Chapter 40C-4.301(1)(a)12 *F.A.C.*).

A proposed use is assessed similarly. The impacts of proposed uses on offsite wetlands and vegetation are specific evaluative criteria under the reasonable-beneficial use test (Sections 9.4.1)(b) and 9.4.3(c), respectively, *Applicant's Handbook*. Environmental impacts are also assessed under the reasonable-beneficial use test, which states that the environmental or economic harm caused by the consumptive use must be reduced to an acceptable amount. SJRWMD policy states that this provision is applied to both offsite and onsite impacts. The public interest test also offers broad authority for evaluation of impacts to natural systems.

Evaluation of the effects of ground water withdrawals is relatively comprehensive and objective. The vegetation of the area that will be potentially affected is sampled for species abundance, cover by each species, the total number of species, and the condition of the vegetation. Hydrologic sampling can include staff gauges and piezometer wells in associated wetlands. However, the rules and policy, discussed previously, do not specify the assessment methods or provide a definition of what constitutes harm to the environment.

In 1993, the Florida Legislature initiated the streamlining of wetlands permitting in Florida by transferring FDEP's Wetland Resource Alterations (i.e., dredge-and-fill) Program to the water management districts' Management and Storage of Surface Waters (MSSW)

Table 11. Summary of manner in which surface water and groundwater interactions are evaluated in water resource assessment projects conducted by the water management districts

	Procedures for Impact Analysis	Permitting Result
SJRWMD	Tolerance of wetland vegetation to water level changes is wetland-type specific.	Case-by-case basis.
	No specified drawdown criteria related to impact determinations.	Some evaluations are done through modeling, others with collected field data; recently, a combination of the two was used.
SWFWMD	Rely on presumptive hydrologic thresholds.	Performance standards are predetermined.
	Certain hydrologic alterations are expected to result in unacceptable environmental impacts.	To compensate for natural variability, site-specific criteria may be applied.
	If withdrawals are below presumptive thresholds, no unacceptable impacts will occur.	Special procedures and conditions of issuance are needed.
SRWMD	Several programs that address some aspects of surface water/ground water impacts.	Wide variability in approaches; at time inconsistent or time consuming, or both. Case-by-case approach.
SFWMD	Interactive regional model for predictive and planning purposes.	Model has limited applications to water supply planning where ground water is a significant issue.
NFWMD	Most surface water permitting is handled by FDEP	Case-by-case approach.

Program, creating a single permitting program called the Environmental Resource Permit (ERP). Within the districts' regulatory programs, the ERP is covered by Chapter 40C-4, *F.A.C.*

The relevance of the ERP to this TM is that it consolidates the districts' wetland regulatory program for surface water permitting. The former permitting process operated differently from the CUP process in regard to adverse impacts to wetland and surface water functions being assessed, mitigated, and permitted. Under the former MSSW program, an applicant was required to demonstrate that the project would not be harmful to the water resources of a district. The ERP requires balancing the public interest criteria and preventing harm to the water resource, with adverse impacts to wetlands and surface waters either avoided or offset by mitigation. In comparison to the CUP, this approach to mitigation is different because it provides a formal approach to impact assessment and a sequencing process for mitigating adverse impacts. The mitigation sequencing consists of avoidance, minimization and, finally, mitigation.

From the applicant's perspective, the ERP process has a more explicit approach to estimating impacts considered to be adverse by the districts and then finding the balance of avoidance, minimization, and mitigation that will result in issuance of a permit. Because this more definitive process provides sufficient clarity of goal, purpose, and understanding, the applicant can use it as the basis for project planning with few surprises.

Within the ERP process, the water management district must consider the extent to which an applicant has implemented practicable design modifications to reduce or eliminate adverse impacts to wetland or surface water functions, prior to approval of mitigation proposals. If mitigation is required, the ERP provides ranges of mitigation ratios as guidance for project-planning purposes.

CURRENT REGULATORY REVIEW

In the past several years, several interagency work groups, technical committees, and subcommittees have worked to address statewide water management issues. Each group has issued the following reports or interim working documents that directly address issues relevant to this TM:

- Groundwater Availability Conventions Committee's Subcommittee for the Assessment of Hydrologic Effects of Ground Water Withdrawals on Surface Water Resources (May 1994 report)
- Groundwater Availability Conventions Committee's Subcommittee for Impacts to Natural Systems (August 1994 report)
- FDEP's Incentive Based Regulatory Alternatives Committee (November 1994 document)
- FDEP's Ecosystem Management Implementation Strategy (June 1995 draft document)
- State of Florida Water Plan 1995 (August 1995 public workshop draft)

Collectively, these documents show the emerging direction in water resource management within both the state and water management districts. Several themes emerge across these documents:

- Regulation and planning must be approached on an ecosystem basis.
- Prudent water resources development must be balanced with long-term stewardship and protection of those resources.
- Current water management approaches often result in adversarial positions.
- Clear goals are needed in terms of defining harm or impact, and in defining the methods by which harm is predicted, detected, and monitored.
- Although uncertainty exists, it should not preclude the development of a clear course of action.
- Adaptive management provides an approach for managing uncertainties at both the technical and policy levels.

An overview of the documents is provided in the following sections.

May 1994 Interagency Subcommittee Report—Assessment of Hydrologic Effects of Ground Water Withdrawals on Surface Water Resources (SWFWMD 1994)

The Subcommittee for Assessment of Hydrologic Effects of Ground Water Withdrawals on Surface Water Resources reviews policies practiced by SJRWMD, SWFWMD, SFWMD, and SRWMD. Several of the subcommittee's conclusions presented in the May 17, 1994, report highlight the rapidly evolving understanding of surface water and ground water interactions. These conclusions indicate that many resource management and regulatory decisions are associated with uncertainty. This realization argues for *adaptive management* and an *ecosystem management approach* to mitigation. These new approaches are discussed in the next three sections. Excerpts from the committee's report are presented below and discussed in the following section:

- "All assessments of the effects of ground-water withdrawals on surface-water resources should address cumulative impacts, and to the greatest degree possible, rely on a multidisciplinary approach ...both local and regional analyses are often necessary to evaluate cumulative impacts, and impact assessments should include both numerical modeling and empirical data analysis, including statistical modeling."
- Regarding management procedures and technical approaches, the committee stated that "the understanding of surface-water/ ground-water interactions are changing very rapidly. The findings presented in this report with regard to modeling and data analysis should be considered appropriate for the time they were written and subject to future revision."
- In SJRWMD, the committee stated that "modeling is used mainly as a tool to determine magnitudes of impacts and to assist in the development of monitoring plans.... there is recognition that the ground-water models used in these evaluations are limited due to lack of spatial and temporal data for model verification."
- The committee concluded that "for many waterbodies, data will be insufficient for the development of a good local model or meaningful data analysis" and that "thorough data collection and research is needed to more accurately evaluate impacts on specific waterbodies.

August 1994 Interagency Subcommittee Report—Impacts to Natural Systems (Lowe 1994)

The subcommittee's work included the following two key activities:

1. Defining unacceptable impacts to natural systems
2. Determining if presumptive hydrologic criteria can be taken as evidence of unacceptable impacts

The subcommittee's joint recommendation is a definition of unacceptable harm that focuses on species. The following is a definition of unacceptable harm to natural systems:

> "Anthropogenic effects on hydrology that have caused, or are expected to cause, directly or indirectly, singly or cumulatively, by their extensiveness, intensity, duration, or frequency, one or more of the following for more than five years:
>
> 1. Local or regional extirpation of one or more native species.
> 2. Onsite, local, or regional reduction in abundance or reproductive success of a listed, endemic, or regionally rare native species.
> 3. Onsite, local, or regional reduction in abundance or reproductive success of keystone species.
> 4. Local or regional reduction in abundance or productivity of a commercially or recreationally significant population of a species.
> 5. Onsite replacement of the dominant species group of the flora or fauna such that another species or group of species becomes dominant or a significant increase occurs in the onsite abundance or productivity of nuisance, exotic, or uncharacteristic species."

The subcommittee concluded that no presumptive criteria could be recommended. This conclusion came, in part, from the realization that there is great variation in the hydrologic status of most natural systems in Florida. The subcommittee report also provided the following 10 guiding principles:

1. To define the threshold between acceptable and unacceptable harm, the desired ends (goals) of management and regulatory decisions must be clear.
2. In absence of a clear definition of unacceptable harm and of procedures for accounting for the accumulation of harm, the long-term and cumulative effect of many local decisions cannot be predicted. A patchwork of both local and regional areas of

reference is required for tracking and accounting for the accumulation of harm.

3. Assessment of anthropogenic effects on natural systems requires measurement of changes within the area directly affected, but the significance of the observed changes cannot be evaluated without reference to the surrounding landscape and region.

4. Reductions in water levels are not harmful to natural systems unless there are harmful biological effects. Thus, harm should be biologically defined.

5. Significant biological harm can occur before the threshold of unacceptable harm is attained

6. The salient values of natural systems are the production and maintenance of biological diversity and the production of biomass used for food, materials, recreation, and commerce.

7. Not all species are of equal value in the maintenance of biological diversity and the production of useful biomass. Thus, the threshold of unacceptable harm should differ with the species group.

8. Although the definition of harm is biological, specific operational definitions need not be biological. Nonbiological presumptive thresholds for unacceptable harm are based on known or reasonable predicted relationships between abiotic and biotic factors.

9. Species are useful units for evaluating and tracking harm to natural systems because, compared to higher and lower levels of biological organization that are less abstract, they are more easily identified. However, community, ecosystem, and landscape level attributes also can be useful as indicators in certain cases.

10. Criteria defining thresholds for unacceptable harm should be as nearly binary as is feasible and the number of criteria should be minimal.

November 1994 FDEP Committee Report—Incentive-Based Regulatory Alternatives Committee (FDEP 1994)

The Incentive-Based Regulatory Alternatives Committee was an FDEP committee whose main objective was "...to develop a pathway to implement the principles of ecosystem management, incentives for using this holistic approach and criteria for its application."

This committee struggled with developing their common goal "of incentive-based changes to the present regulatory process" that would yield "net environmental benefit." The committee stated that "we are doomed to disappointment because of the difficulty in defining exactly what it [net environmental benefit] means." The principles of ecosystem management used by the committee were those established by Dr. Edward Grumbine (FDEP 1994). In particular, principles No. 3 and 4, below, corroborate the themes discussed in this TM:

1. "Connectiveness—Focus on any one level of natural systems is not sufficient...must recognize the connections among all levels...a systems perspective."
2. "Ecologic Integrity—Manage to protect, maintain, and restore native diversity, ecologic patterns, and the processes that maintain diversity."
3. "Evaluation/Auditing—Track the results of actions so that success or failure may be evaluated quantitatively. Evaluating/auditing creates an ongoing feedback loop of useful information."
4. "Adaptive Management"—Assume development of scientific knowledge is ongoing and that management is a learning process where incorporating the results of previous actions allows managers to remain flexible and adapt to uncertainty."
5. "Humans are Critical—People cannot be separated from nature. Humans are fundamental influences on ecologic patterns and processes, and are in turn affected by them."

One of the problems with the current system that inspired some of this committee's work was described as "the rigid, highly compartmentalized regulatory structure of the Department and other regulatory agencies effectively impedes permitting agents from reviewing applications....with an ecosystem perspective." The committee's solution: the creation of multi-agency permitting teams to provide "a holistic evaluation during which time the principles of ecosystem management can be addressed."

June 1995 FDEP Draft Report—Ecosystem Management Implementation Strategy (FDEP 1995)

Another FDEP committee produced the report, *Ecosystem Management Implementation Study* (June 12, 1995, draft). This report was the culmination of the work of 12 committees comprised of over 300 Florida citizens. Some of their conclusions and recommendations strengthen those of the previously discussed committee, as well as those presented in this TM. This 12-committee group stated that:

> "Regulators are forced to apply regulations with little or no flexibility. There needs to be a mechanism by which more balance and common sense can be achieved between conservation objectives and individual objectives." Most of the recommendations of this committee include the following concept, which are becoming rapidly familiar:
>
> - Integrated, flexible approach to management
> - Net environmental benefit
> - Regulatory change
> - Partnerships
> - Incentive-based regulatory alternatives
> - Cross-media efforts to produce collaborative solutions
> - Place-based management

August 1995 Interagency Draft Plan—*Florida Water Plan 1995* (FDEP 1995)

The *Florida Water Plan 1995* is an integrated, coordinated plan prepared jointly by FDEP and the five water management districts to implement their statutory water management responsibilities, in partnership with other agencies, units of government, and interested parties. The plan provides statewide and regional water management goals, priority issues, action steps, and schedules to meet the population's water needs, while maintaining, protecting, and improving the state's natural systems (FDEP 1995).

The *Florida Water Plan 1995* is based on the following two fundamental ecosystem management principles:

- Water resources must be managed to meet the water needs of people, while maintaining, protecting, and improving the state's natural systems.

- Effective management of water resources requires collaboration and cooperation among all affected parties.

The *Florida Water Plan 1995* recognizes the competing pubic interests required in statewide planning and that social and economic considerations such as water supply, protection of private property rights, economic development, and public involvement are integral to water resource planning. The Florida Water Plan provides a summary of key water management issues and also provides specific strategies for addressing those issues. Of relevance to this TM are the general issues and those for natural systems (Table 12).

AN ALTERNATIVE APPROACH

A new or revised approach is needed to address problems with the current regulatory approach to controlling impacts of ground water withdrawals on natural systems, especially wetland and aquatic systems. Three organizing themes are proposed to develop an alternative approach to natural systems management and impact mitigation: ecosystem management, mitigation sequencing, and adaptive management. Descriptions of these organizing themes follow.

Ecosystem Management

Florida has embarked on a statewide program to implement an ecosystem approach to its regulation and management of wetland and water resources. FDEP and the water management districts have been key players in developing this program. As noted earlier, the ecosystem management concept is intended to encourage innovation, incentive-based regulatory alternatives, and more coherent and integrated efforts to provide alternative solutions to environmental problems.

The 1993 Legislature and the Governor directed FDEP to develop a concept for implementing ecosystem management in Florida. This directive was based on the conclusion that the state's environmental regulatory program was not part of an integrated system of environmental management and that it often resulted in adversarial relationships and litigation between regulatory agencies, applicants, landowners, and the public. Thus, opportunities to develop cooperation, stewardship, partnership, and mutual benefit in achieving environmental objectives or net environmental benefits were precluded.

Table 12. Issues and strategies developed in the *Florida Water Plan 1995*

Issue	Strategy
General	
Inadequate links between land and water planning, and between planning and program implementation, causing program conflicts and inefficiencies.	• Improve linkages between land and water planning, and between planning and implementation
Failure of the government, private sector, and general public to take responsibility for sustaining Florida's water resources is hindering effectiveness of water management efforts.	• Promote joint responsibility for sustaining water resources.
Water management within the state has not been approached on a comprehensive watershed basis, which has impaired our ability to protect water resources and related natural systems.	• Promote and implement watershed and ecosystem approaches. • Improve land acquisition and land management programs to enhance protection and management of water resources on a watershed or ecosystem basis.
Better information is needed to support water resource protection, restoration, and management actions	• Ensure that collection of water data is coordinated, directed at answering priority management questions, and is analyzed in a method useful for making water management decisions. • Where understanding of water resource issues is deficient, apply adaptive management techniques and balance uncertainty in favor of avoiding irretrievable long-term commitments that may jeopardize water resources on the long-term public interest.
Natural Systems	
Florida's ecosystems are increasingly threatened by water-related problems associated with rapid population growth and land use changes.	• Use authorities, programs, and technical expertise of FDEP and the WMDs to promote ecosystem management. • Maintain and enhance biodiversity and biological productivity. • Implement effective water resource permitting. • Maintain and, where feasible, restore the hydrologic patterns of watersheds and ecosystems. • Ensure close coordination between establishment of mitigation banks and public land acquisition programs.
Establishment of minimum flows and levels for Florida's water courses, lakes, and aquifers is essential for water managers to have a sound basis for determining and preventing cumulative impacts to water resources and natural systems caused by water withdrawals	• Expedite the establishment of minimum flows and levels for priority water courses, lakes, and aquifers. • Prevent water withdrawals from causing significant harm to water resources and associated natural systems.

The current property rights movements at both the state and federal levels are outgrowths of this process. Thus, there is a clear opportunity for an alternative by which more balance and common sense can be achieved between development and resource conservation and management. Ecosystem management has been presented as an organizing framework from which to develop alternative approaches to environmental resource regulation and management.

FDEP currently defines ecosystem management as "an integrated, flexible approach to management of Florida's biological and physical environments—conducted through the use of tools such as planning, land acquisition, environmental education, regulation, and pollution prevention—designed to maintain, protect and improve the state's natural, managed and human communities." Most importantly, the ecosystem management concept is intended to encourage innovation, incentive-based regulatory alternatives, and coherent, integrated efforts to produce collaborative solutions to environmental problems.

Mitigation Sequencing

Each regulatory program within the state and, in particular, SJRWMD has a different focus. For example, there are different permitting approaches within the ERP program and the CUP process. One of the current problems with the CUP process is the approach to addressing observed and predicted impacts.

With many state and federal permitting programs, the mitigation process is a sequence of the following three steps:

1. Avoiding impacts as much as practicable
2. Minimizing unavoidable impacts
3. Mitigating the remaining unavoidable impacts

Also, within the federal and state wetland programs, there is a presumption that some degree of change or impact is permittable. During the permitting process, the sequencing steps seek to clearly define practicable alternatives with minimum impacts. In addition, the third step in the process provides for compensatory mitigation for unavoidable, yet permittable, impacts. Thus, development is not precluded. Development activities can occur, but not at the expense of the resource base because resource protection goals are met through the sequencing process.

The sequencing approach offers flexibility to applicants because of the options an applicant has to make a project permittable. Some flexibility is provided at each step in the process. Therefore, within the process, the applicant is not constrained to a single solution or approach. With multiple options available, an applicant has some opportunity for creativity and innovation in meeting resource protection goals, as well as the ability to select a least-cost alternative from a group of feasible alternatives.

With surface systems permitting (i.e., dredge-and-fill and MSSW), an applicant can mitigate permittable impacts on wetlands and natural systems. However, in the CUP process, this mitigation sequencing is not an explicit part of the permitting process; still, the same steps are typically used. With consumptive use permitting, as compared to dredge and fill permitting, there is more uncertainty as to the degree of impact. Typically, if an impact is projected to occur or is detected, the applicant or permittee is first encouraged to consider options for eliminating or avoiding the impact. If elimination or avoidance is impractical or economically infeasible, the applicant or permittee is encouraged to investigate mitigation alternatives. The District's CUP process, like its water supply planning process, also includes evaluation of the projected cumulative impacts of proposed ground water withdrawals. These cumulative impacts and the associated component impacts of individual water users are important considerations when investigating mitigation or avoidance options. Figure 5 presents an explicit mitigation sequencing approach for the CUP process.

Adaptive Management and the Mitigation Process

One of the emergent themes within the mitigation and restoration community is adaptive management. Simply stated, adaptive management is "learning by doing." Adaptive management incorporates monitoring information to adjust to changing environmental, economic, and management circumstances.

Adaptive management is both a conceptual approach and an implementation strategy. The approach recognizes that our estimates of the course of action for managing natural systems are based on our best, but often incomplete, knowledge of the system and its response to various outside forces. Realizing this, our efforts to manage must proceed as best efforts, the results of which are to be monitored, assessed, and modified as needed. It is an implement-observe-adjust

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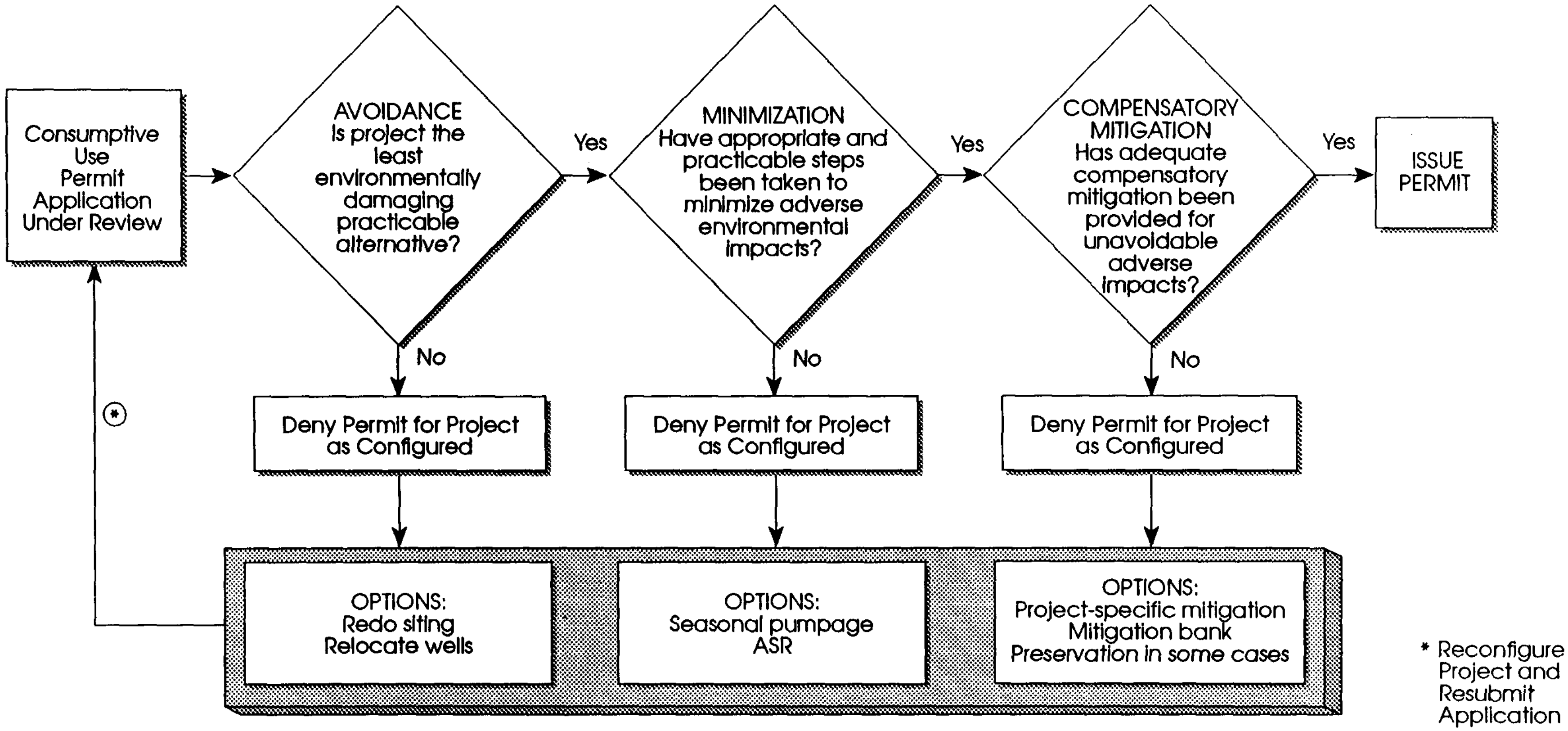

Figure 5. Mitigation Sequencing Process.

(as needed) feedback loop, which provides a self-correcting approach to environmental management. Thus, the mitigation efforts or sequencing tied to the review and permitting of a specific activity are also the best estimate, which must also be self-correcting to achieve the optimal common goal.Teal (1995) provides a number of conclusions that can result from adopting the principle of adaptive management:

1. We do not have to fully understand the natural system we are managing because we will be following its response over time. We can adjust actions based on the system's response—we can learn as we go.

2. We do not need to have rigid expectations about system performance and timing, but can adjust in terms of how we find the system progressing toward the final goal.

3. We do need a clearly stated final goal.

4. We must have monitoring systems to detect what is happening. This will give us the relevant information needed to assess the validity of our current management activities and progress toward the goal.

Within the context of a regulatory program that must balance water use with environmental protection, adaptive management provides both a conceptual planning tool and a practical implementation tool. At the conceptual level, it provides guidance on how to deal with the uncertainty associated with attempts to manage environmental systems. At the implementation level, adaptive management will provide a process to get started, along with a process for self-correction and improvement as our knowledge increases.

Regarding policy development, Walters (1986) warns that "adaptive policy design stresses the use of methods and concepts that are often not simple to explain, demand the explicit admission of ignorance, and place a premium on imagination rather than on precision of thinking." Despite the warning, adaptive management provides us with a powerful policy design tool. Walters (1986) also presents his views on adaptive attitudes and adaptive tactics for policy development. Table 13 summarizes the strategic changes in attitude that an adaptive management approach promotes, while Table 14 summarizes adaptive tactics for policy development and presentation.

Table 13. Conventional versus adaptive attitudes about the objectives of formal policy analysis (Walters 1986)

Conventional	Adaptive
Seek precise predictions	Uncover range of possibilities
Build prediction from detailed understanding	Predict from experience with aggregate responses
Promote scientific consensus	Embrace alternatives
Minimize conflict among actors	Highlight difficult tradeoffs
Emphasize short-term objectives	Promote long-term objectives
Presume certainty in seeking best action	Evaluate future feedback and learning
Define best action from a set of obvious alternatives	Seek imaginative new options
Seek productive equilibrium	Expect and profit from change

Table 14. Conventional versus adaptive tactics for policy development and presentation (Walters 1986)

Conventional	Adaptive
Committee meetings and hearings	Structured workshops
Technical reports and papers	Slide shows and computer games
Detailed facts and figures to back arguments	Compressed verbal and visual arguments
Exhaustive presentation of quantitative options	Definition of few strategic alternatives
Dispassionate view	Personal enthusiasm
Pretense of superior knowledge or insight	Invitation to and assistance with alternative assessments

OVERVIEW OF PROPOSED INTEGRATED APPROACH

The proposed integrated approach methodology incorporates the three organizing principles of ecosystem management, mitigation sequencing, and adaptive management. Using these principles, the incentive-based approach to water use permitting is developed. This approach allows the water supply developer to incur environmental impacts, but requires that the impacts be accounted for through compensatory mitigation. The methodology is incentive-based in that the applicant is free to approach the mitigation process through several pathways. Thus, it balances prudent water supply development with prudent environmental stewardship. Adaptive management will come into play as a conceptual overlay and will aid in refinement and implementation of the methodology. This approach has been termed "learn as you go."

The integrated methodology consists of the following three linked components:

- Impact assessment
- Impact avoidance and minimization
- Mitigation of residual impacts

The following sequential actions are contained within those three components:

- Inputs from ground water drawdown analyses
- Assessment of hydrologic regime impact
- Determination of change in ecologic value
- Evaluation of mitigation strategies
- Development of mitigation plan
- Development of cost estimates for mitigation alternatives

Figure 6 is a flow chart of the proposed integrated mitigation and costing methodology.

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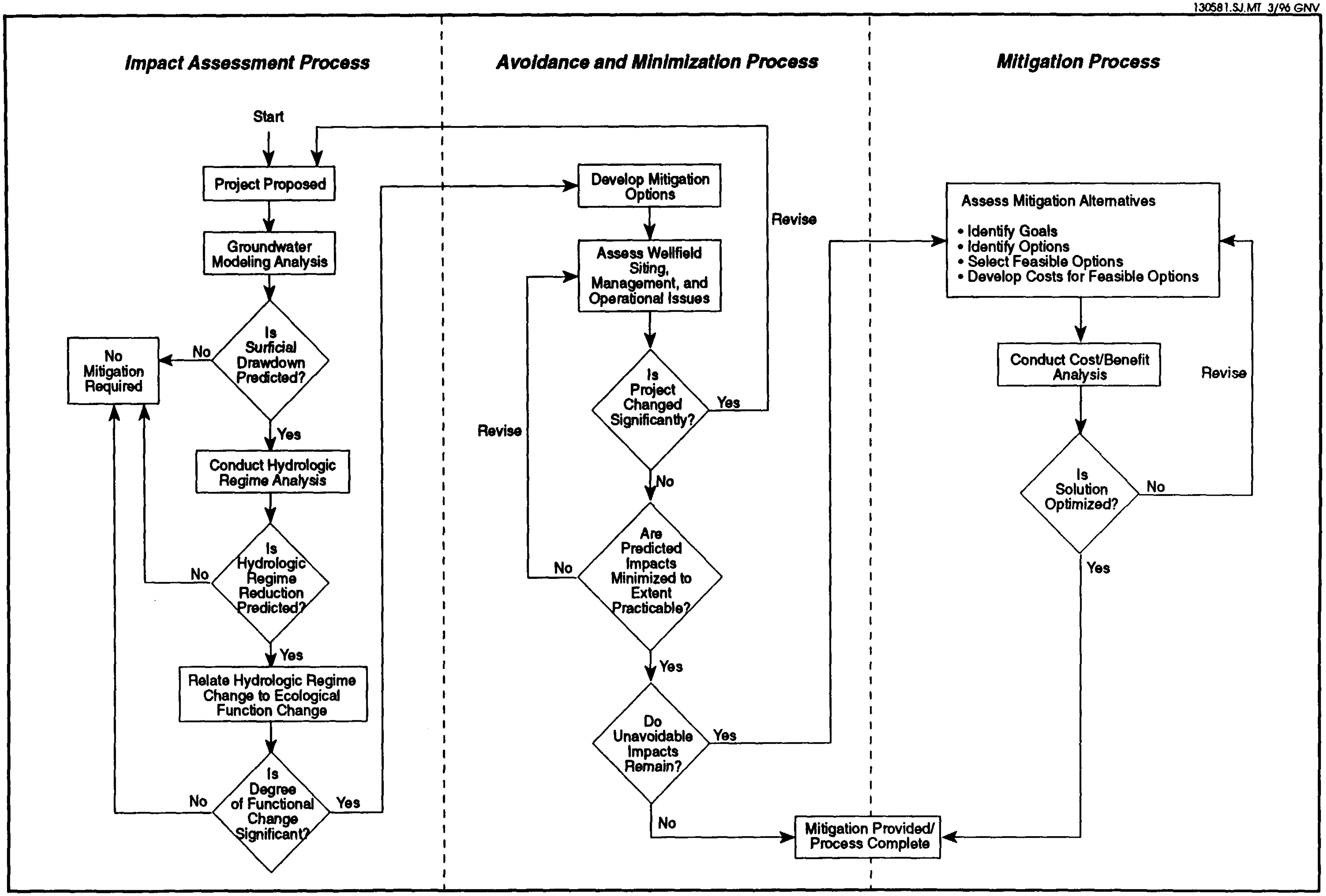

Figure 6. Proposed Integrated Impact Assessment, Mitigation, and Costing Methodology.

PROJECTED HYDROLOGIC AND ENVIRONMENTAL CONDITIONS IN WRCAS

This section of the TM provides a review of SJRWMD's screening process for identifying areas that would be negatively affected by future water supply withdrawals. These areas are predicted to experience a moderate-to-high likelihood of harm to native vegetation as a result of projected year 2010 ground water withdrawals.

SJRWMD's screening process is described in Technical Publication SJ94-7 (Vergara 1994). An expanded discussion of the analysis is provided in Kinser and Minno (1996), who identified areas expected to be affected by ground water withdrawals within SJRWMD's planning window of 1988 to 2010. In Kinser and Minno's work, a GIS model was developed to estimate the likelihood of harm to native plant communities from ground water withdrawals. The model was developed using soil permeability, plant community sensitivities to dewatering, and projected declines in the water table of the surficial aquifer system. Based on this GIS analysis, areas within SJRWMD predicted to have natural systems susceptible to harm were those associated with proposed new wellfields and the expansion of existing wellfields.

IDENTIFICATION OF WRCAS

Overview of Screening Process

Areas within SJRWMD were screened using GIS techniques and the following several steps:

- Step 1. Develop definition of harm.
- Step 2. Develop GIS layers for soils, vegetation, and water table drawdown.
- Step 3. Conduct overlay of vegetation and soils; assign polygons the least sensitive category.
- Step 4. Conduct overlay of harm with water table; assign polygons final rating.
- Step 5. Ranking for special areas.

The process is shown schematically in Figure 7. A brief description of each step follows.

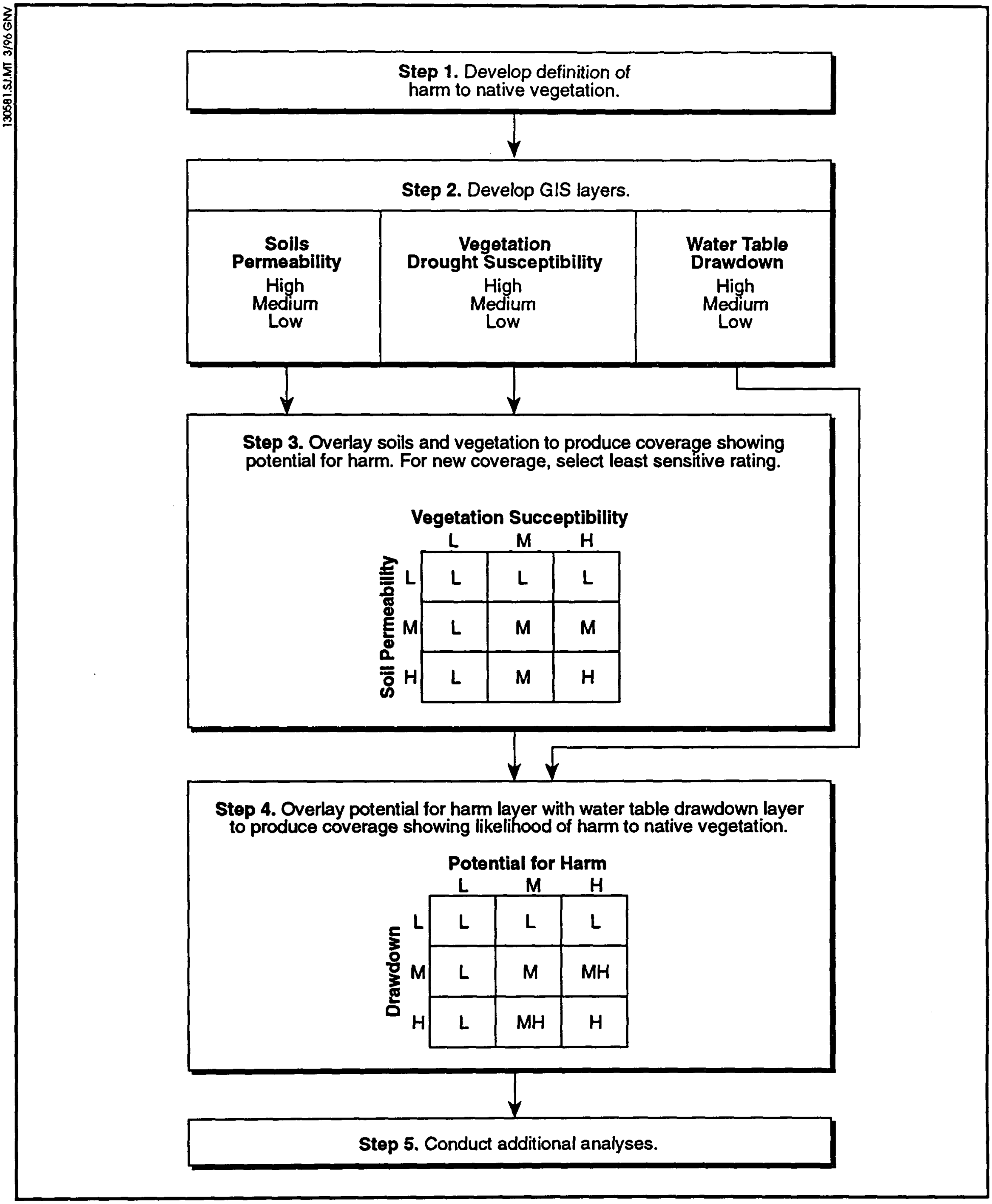

Figure 7. Screening Process for Identification of Areas Likely to Experience Harm to Native Vegetation as a Result of Water Table Drawdown (Kinser and Minno, 1996).

Step 1. Develop definition of harm to native vegetation.

The determination of harm used in the Kinser and Minno (1996) analysis was based on criteria for soils, vegetation, and water table layers, with the mapping unit meeting the following three conditions:

1. Soils are susceptible to dewatering.
2. Vegetation is sensitive and unable to compensate for a lowered water table.
3. Elevation of the water table has to decline significantly.

Step 2. Develop GIS layers for soils, vegetation, and water table drawdown.

Specific mapping and associated attribute data were developed by Kinser and Minno (1996) for soil, vegetative communities, and the water table. This information is described below.

Soils Mapping. The State Soil Geographic Data Base (STATSGO) was used as the basis for creating the soils coverage in the GIS. The STATSGO mapping resembles a countywide general soil association map. The map units or polygons in the STATSGO mapping represent broadly defined landscape units with similar soils and vegetative characteristics. Attribute data for soil permeability within each map unit was the primary variable used in developing the GIS coverage. Permeability categories were assigned values of high, moderate, or low, based on the most limiting horizon. Data for the soil series within a given polygon were averaged over the mapping unit.

Vegetative Community Mapping. Dominant vegetation within each STATSGO polygon was determined by photointerpretation. Vegetative community types were rated according to their sensitivity to dewatering. Community types included xeric upland, mesic hardwood hammock, pine flatwoods, freshwater swamp, freshwater marsh, mangrove swamp, and saltmarsh. The ratings for sensitivity to drawdown effect were low, medium, and high for the xeric, mesic, and hydric community types, respectively.

Water Table Drawdown Mapping. Declines in the water table were rated on a scale of relatively high, medium, and relatively low, as follows:

- **Relatively high**—Projected declines of more than 2.5 feet
- **Medium**—Projected declines of 1.0 to 2.5 feet
- **Relatively low**—Projected declines of less than 1.0 feet

Step 3. Conduct overlay of soils and vegetative layers.

Using the GIS, the soils and vegetative coverages were overlaid to identify the potential for harm to native vegetation. Potential for harm was considered to be the least sensitive of the two categories (Figure 7).

Step 4. Conduct overlay of potential for harm layer with water table drawdown layer.

An overlay of these two layers was created using the GIS. The resultant polygons in the new coverage were assigned rankings of low, moderate, and high potential for harm according to the matrix (Figure 7).

Step 5. Ranking of Special Areas.

The screening analysis also addressed several problem areas such as converted agricultural areas and highly impacted urban areas. Agriculturally developed areas, such as muck farms on the former marshes of Lake Apopka, and highly impacted urban areas were reclassified for their final map to the category of low likelihood for harm because they no longer support native vegetation.

RESULTS OF SCREENING PROCESS

Based on the GIS analysis, the areas within SJRWMD predicted by Kinser and Minno (1996) to have natural systems susceptible to harm were identified (Figure 8). The areas are associated with proposed new wellfields and expansion of existing wellfields in the following areas:

- Central St. Johns County
- Northern Flagler County
- Central Volusia County
- Northern Orange County
- Seminole County
- Northern Brevard County

Tables 15 through 17 summarize some of the key analyses from the Kinser and Minno (1996) report. These summaries indicate that the criteria and assumptions used in the GIS analysis can have dramatic effects on the land area identified as being at risk. Therefore, changing the assumptions or adding more detailed data could change the results by an order of magnitude.

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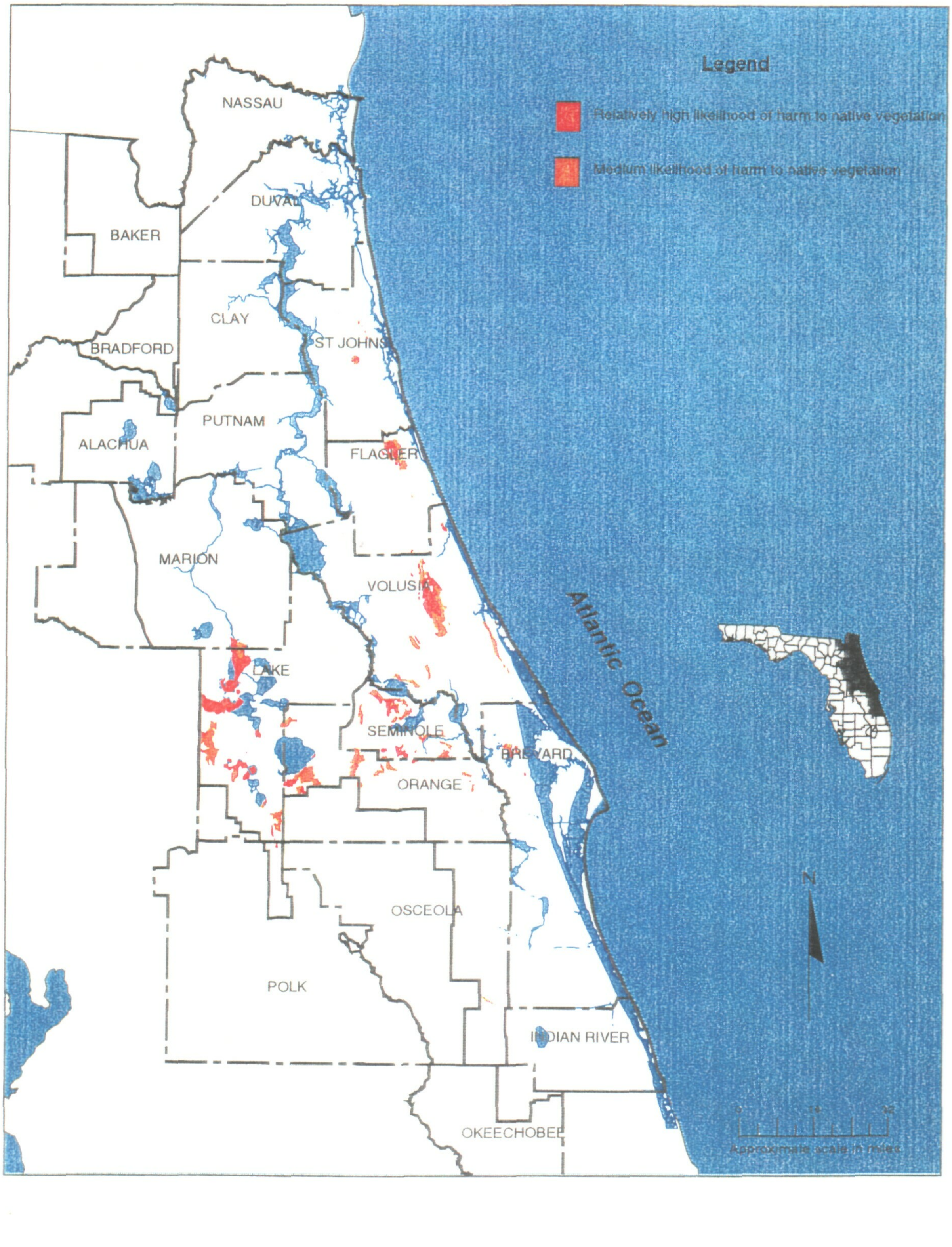

Figure 8. Relative Likelihood of Harm to Native Vegetation from Modeled Ground Water Withdrawals, 1988-2010 (Kinser and Minno, 1996).

Table 15. The extent of soils with high, moderate, and low permeabilities in the St. Johns River Water Management District

Permeability Class	Acres	Square Miles	Percent
High	1,038,149	1,622	13
Moderate + high[a]	2,616,039	4,088	33
Moderate	1,357,067	2,120	17
Low	2,230,514	3,485	29
Water	596,217	932	8
Total	7,837,986	12,247	100

[a]This mixed class consists of map units having approximately equal amounts of moderate and high permeability soils.

Table 16. Potential extent of harm to natural communities in the St. Johns River Water Management District from ground water withdrawals in 2010

Category	Classification[a]	Acres	Square Miles	Percent[b]
Soil	High potential for harm	562,811	879	7
	Moderate potential for harm	2,761,492	4,315	35
	Low potential for harm	3,917,465	6,121	50
Water	Not classified	596,218	932	8
Total		7,837,986	12,247	100

[a] Relative scale.

[b] Does not reflect overlay zones for sandhill lakes and low topography.

Table 17. The estimated extent of potential natural communities in the St. Johns River Water Management District

Community	Acres	Square Miles	Percent
Swamp	661,078	1,033	8
Freshwater marsh	356,541	557	4
Mangrove swamp	6,288	10	<1
Salt marsh	134,535	210	2
Mesic hardwood hammock	300,112	469	4
Flatwoods	4,059,383	6,343	52
Xeric upland	1,723,832	2,693	22
Water	596,217	932	8
Total	7,837,986	12,247	100

Source: Kinser and Minno 1996.

Table 15 summarizes the areal extent of soil permeability groups within SJRWMD. An estimated 63 percent of SJRWMD has soils with moderate to high permeability, thus meeting the first definition of harm—soils are susceptible to dewatering. Table 16 summarizes the potential extent of harm to natural communities within SJRWMD. Only 7 percent of the land area is in the high potential for harm category; however, an additional 35 percent is in the moderate potential for harm category. If actual site conditions verify these categories, additional analyses will be critical in defining the extent of the WRCAs.

Table 17 summarizes the areal extent of major plant communities within SJRWMD. Those vegetative community types rated as having high potential for harm—freshwater and coastal wetlands—account for nearly 12 percent of land area within the SJRWMD. Mesic communities—primarily flatwoods—account for another 56 percent. Because some of the flatwoods will be at the wetter end of the moisture gradient, the percent of land area in the high potential category may be 15 to 20 percent.

Based on this information, the most appropriate uses for the analysis are for Districtwide planning and assessment. Beyond the planning level, more detailed information will be required. Because site-specific factors have a great bearing on the degree of ecologic impacts associated with water table drawdown, finer levels of analysis can only be accomplished with more detailed and accurate spatial and attribute data.

CONCLUSION

SJRWMD's screening process described by Kinser and Minno (1996) has provided an initial assessment of areas potentially at risk of harm from future water supply impacts. Any Districtwide analysis will have to be based on a series of simplifying assumptions. The nature of such a screening process is that it evolves, with additional levels of detail added as needed. In anticipation that this screening process will be ongoing, the following additional tasks are recommended:

- An overall sensitivity analysis of the key assumptions
- Identification of the critical site-specific factors to be addressed in future analyses

In regard to site-specific factors, soils data were necessarily general for a Districtwide screening. However, previous experience in wetland systems in central Florida has shown that differences in wetland types and site-specific conditions are strong determinants of the effects of water table drawdown. For example, the degree to which a wetland has an underlying confining layer is an important characteristic. This characteristic is influenced to some degree by the regional soil; however, there are many exceptions.

Another important site-specific characteristic is the degree of permeability of the underlying wetland soils. Other factors being equal, permeable wetlands will be more susceptible to drawdown effects than will wetlands with confining layers. For example, investigations at the City of Cocoa's wellfield showed that wet prairie systems on the wellfield had amorphous confining layers in the soil profile (CH2M HILL 1990a, b). In contrast, forested wetlands typically had well developed confining layers of compacted fine-grained material (mix of clay, silt, and muck). Because of the controlling effects of these site-specific differences, drawdowns of more than 1 foot may not harm well-confined wetlands, whereas drawdowns of less than 1 foot may be of concern in permeable wetland systems.

As a result of these field data, an ecologic monitoring program for the wet prairie communities located in the vicinity of the production wells was included as a special condition to the City's CUP.

As noted by Brown (1991), the degree of impact to the integrity of a confining layer is also influenced by the size of the wetland, landscape position, adjacent land uses, and the following factors:

- Small wetland systems are more likely to be affected than larger wetland systems.
- Shallower wetland systems are more likely to be affected than deeper wetland systems.
- Isolated wetlands are more likely to be affected than wetlands connected to the surface water drainage system.

Some of the landscape level features, such as size and degree of connectivity, can be addressed through GIS analysis. The analysis of other factors will probably require the collection of additional information.

In conclusion, the review of SJRWMD's screening process can be summarized as follows:

1. The GIS model is well adapted to a Districtwide level screening analysis. As is the case with any screening analysis, two types of errors typically occur: errors of exclusion (areas that are excluded that should be included) and errors of inclusion (areas that are included but should be excluded). Therefore, the areas identified will undoubtedly contain some types of wetlands that will not be affected by drawdowns, while other areas will contain some types of wetlands that will be affected by drawdowns of lesser magnitude. Additional insight and estimates into the type and magnitude of exclusion and inclusion errors should be conducted.

2. The analysis is greatly affected by the selected operating definition of "harm." The definition has three conditions that must be met, each of which has a series of assumptions. Therefore, there is a wide range possible for the outcome of this determination. A sensitivity analysis of the impact of these assumptions on the final mapping should be conducted.

3. The existing analyses should be expanded to address the sensitivity of key screening criteria.

4. The existing analysis should be extended to address specific factors that can influence a wetland's susceptibility to drawdown impacts, such as wetland size and degree of isolation.

5. Subsequent analyses and fine tuning should help identify the wetland systems specifically at risk.

6. The analysis is a critical first step in development of an impact assessment methodology. SJRWMD's work will dovetail with this mitigation assessment task.

7. The GIS model can be linked to a mitigation costing model to generate planning-level estimates.

APPROACHES FOR MITIGATING EFFECTS OF GROUND WATER WITHDRAWALS ON WETLANDS

This section addresses current approaches to wetland mitigation that include wetland impact avoidance, minimization, and mitigation, as well as specific technologies considered applicable for mitigating ground water withdrawal impacts. Avoidance of impacts on native vegetation is addressed through development of recommendations concerning the hydration/irrigation of potentially impacted wetlands and the assessment of costs related to hydration/irrigation projects.

CURRENT APPROACHES TO WETLAND MITIGATION IN FLORIDA

Compensatory mitigation for wetland impacts caused by dredging, filling, or surface water management may be mitigated through one or more of the following approaches:

- Wetland creation
- Wetland enhancement
- Wetland restoration
- Purchase of mitigation credits
- Cash contribution toward a SJRWMD-approved mitigation project
- Land acquisition
- Land preservation

These approaches are briefly discussed below.

Wetland Creation

Wetland creation is the conversion of a non-wetland or upland area into a wetland. Wetland creation typically includes excavating upland soils, such as a pine flatwoods, into a shallow graded basin that has been planted with native wetland vegetation. Created wetlands can include marshes, wet prairies, and forested wetlands. Success in creating wetlands that exhibit measurable wetland functions is difficult because of significant uncertainties in predicting post-construction hydroperiod, plant growth, and colonization. Salvaging and spreading wetland soils in a created wetland significantly increases the potential for success.

Wetland Enhancement

Wetland enhancement consists of improving the ecological value of wetlands that have been degraded in comparison to their historic conditions. Wetland enhancement may range from removing non-native vegetation, such as melaleuca or Brazilian pepper, to backfilling constructed drainage works to restore natural wetland hydrologic regime.

Wetland Restoration

Restoration of a wetland is the conversion back to historic conditions of those wetlands that currently exist as a land form that differs from the historic condition. Restoration, which requires human action, may range from removing a causeway or roadway constructed across a wetland and re-establishing original wetland grade, to removing earthen fill to restore the original grade and hydrologic regime.

Purchase of Mitigation Credits

Instead of creating, restoring, or enhancing a wetland, wetland impacts may be mitigated by purchasing mitigation credits, which are units of measure that represent the increase in ecologic value resulting from restoration, enhancement, preservation, and creation activities.

Cash Contribution Toward a District-Approved Mitigation Project

A permit applicant seeking approval for work in wetlands may be able to contribute to SJRWMD funds that are designated for a mitigation project or program instead of directly engaging in wetland creation, restoration, or enhancement activities. This approach would be particularly appropriate in cases where project-related impacts may be relatively minor and the perceived benefits of SJRWMD's project are seen as significant and beneficial. This mitigation approach yields little or no risk to the applicant.

Land Acquisition

A permit applicant may compensate for project impacts by purchasing wetlands or by giving land to SJRWMD or a suitable land management agency or organization, such as The Nature Conservancy. This approach can remove sensitive lands from private ownership and place them under public control and protection.

Land Preservation

Another alternative to creating, restoring, or enhancing wetlands is through preserving land from future development. This approach minimizes risk to the applicant and may be particularly desirable when the land to be preserved is designated as having a high ecologic value.

SPECIFIC TECHNOLOGIES FOR MINIMIZING AND MITIGATING GROUND WATER EFFECTS

In some cases, ground water drawdowns have adversely impacted wetlands and other natural systems. As a result of these experiences, technologies and wellfield management approaches have tried to avoid, minimize, and mitigate these impacts. By default, these efforts have become a part of the mitigation sequencing process.

The following technologies used to avoid, minimize, and mitigate the effect of lowered ground water elevations on wetlands and other natural systems are discussed below:

- Augmentation
- Pumpage rotation
- Surface water diversion
- Alternative water sources
- ASR
- Reduction or cessation of withdrawals
- Wetland creation
- Wetland restoration and enhancement
- Wetland mitigation banking

Augmentation

Augmentation of wetlands and lakes exhibiting chronically low water elevations and associated plant species changes has been implemented at a number of locations in southwest Florida. Commonly, water is pumped from adjacent production wells and allowed to fill the wetland to a designated elevation, such as the normal pool or seasonal high water elevation. WCRWSA has practiced this process at more than a dozen wetlands in Pasco County. In some cases, water is pumped continuously at low rates; in others cases, water flow to wetlands has been controlled by an electronic transducer that is activated when water levels decrease to a predetermined elevation.

Typically, however, water application has been manually controlled according to a visual inspection of the wetland to be augmented.

Few records on the quantities and effects of augmentation of wetlands with ground water are available. Ecologic concerns associated with augmentation include the potential for the chemical composition of the pumped ground water to be significantly different from normal surface water, yielding changes in wetland plant and microbial community composition. A related concern is the need for wetland augmentation schedules to mimic natural seasonal water level fluctuation. Hydrologic concerns include the circular dilemma inherent in using a regulated resource to compensate for effects of consumptive use of the resource and the potential loss of water to the atmosphere through evaporation.

Lakes have been similarly augmented in southwest Florida. Pinellas County has augmented lakes near the Eldridge-Wilde Wellfield for more than 10 years. SWFWMD has permitted wells for augmentation for nearly 20 years in some parts of northwest Hillsborough County. Two lakes, Round Lake in Hillsborough County and Mountain Lake in Polk County, have received special hydrologic study (Belanger et al. 1993). These studies have shown that the volume of water needed to maintain lake levels is small, with losses from evaporation of about 10 percent.

Pumpage Rotation

Ground water withdrawal effects may be moderated for water withdrawal systems consisting of multiple wells distributed over a large area through selective rotation of pumping between wells. This approach is only possible when alternative ground water or surface water sources are available to compensate for the supply made unavailable by pumpage reduction. Because this method of impact management is proposed for implementation at wellfields on the WCRWSA Central Loop System, its long-term success and practicability are not yet known.

Surface Water Diversion

Surface waters may be diverted seasonally or periodically to replenish wetlands or lakes that demonstrate chronically low water elevations. This approach has been feasible in selected parts of northwest Hillsborough County, and is currently being studied for implementation by SWFWMD and members of WCRWSA.

Use of Alternative Water Sources

Reclaimed water and stormwater may be available for seasonal or periodic use to replenish low wetland and lake levels, but the use of this potentially significant water source is currently constrained by water quality and public health concerns.

Aquifer Storage and Recovery

ASR may be a viable management alternative for wetland and lake management. Under this approach, water would be harvested from surface flows during the wet season and stored underground in large, natural limestone reservoirs at depths of about 1,000 feet. Water could be extracted during the dry season to be selectively used for augmentation or as a source of supply that would allow other ground water wells to be rested, thereby lessening the drawdown effect.

Reduction or Cessation of Withdrawals

Reduction or cessation of ground water withdrawals should have a restorative or mitigating effect for surface water systems with altered hydroperiods. This was the experience at the Starkey Wellfield in the early 1980s when pumpage was shifted 2 miles east from a wellfield that had been operational for 10 years. Some recovery of water levels was observed; however, historic water elevations were not achieved, suggesting that long-term pumpage or regional changes caused by development may have significantly affected wetland hydrology.

Wetland Creation

New wetlands could be created to replace wetlands that have been significantly altered by reduced hydroperiod, assuming that the wetlands could be located in areas where the hydrologic fluctuation is known.

Wetland Restoration and Enhancement

Wetlands could be managed to remove or control infestation by non-native exotic plant species or native plant species that significantly alter the character of an affected wetland. Reduction of fuel load and overall ecologically based land management approaches could help manage, and therefore mitigate, the successional changes observed in wellfield wetlands. Alternatively, wetlands located outside the influence of pumping could be restored or enhanced as mitigation for effects observed on the wellfield.

Wetland Mitigation Banking

Wetland changes measured at a wellfield could be mitigated by purchasing mitigation credits from a regional mitigation bank or by establishing a mitigation bank specifically to compensate for anticipated wetland impacts. The credits needed to participate in a mitigation bank may possibly be discounted to account for the functions still retained by the affected wetlands.

MITIGATION RATIOS AND UNIT MITIGATION COSTS

The impact assessment and mitigation costing methodology, which is described in the following section of this TM, will be used at a planning level to identify a mitigation requirement for compensating for the adverse effects of water table reduction. A component of this mitigation evaluation involves the use of mitigation ratios to match the level of impact with the appropriate level of compensatory mitigation. This section provides a recommendation for the ratios and unit costs to be used for subsequent planning-level cost estimating aspects of the project. This section also provides recommendations for conducting a more in-depth analysis and accurate derivation of mitigation ratios.

BACKGROUND

SJRWMD has identified mitigation ratios in the ERP *Applicant's Handbook*. For general types of mitigation, a range of values is provided as guidelines for the permitting process. SJRWMD's ERP mitigation ratios are as follows:

- Creation and Restoration
  - 2:1 to 5:1 for forested wetlands
  - 1.5:1 to 4:1 for herbaceous wetlands
- Enhancement
  - 4:1 to 20:1
- Preservation
  - 10:1 to 60:1 for wetland preservation
  - 3:1 to 20:1 for upland preservation

Mitigation ratios have been gradually developed at the state and federal levels over the last two decades through the application of mitigation requirements for individual permitting decisions. According to Kruczynski (1990), the idea of mitigation ratios occurred through a practical blending of science, regulatory goals, and public input. At present, ratios are widely used for dredge-and-fill permitting at both the state and federal levels. Within the context of dredge-and-fill impacts, the historic rationale behind mitigation ratios is to address the uncertainty associated with providing compensatory mitigation for the ecologic values lost or affected, such as the loss of wetland community structure or function.

Historically, replacement at a ratio of more than 1:1 was warranted because of the uncertainty of success and temporal loss of function caused by the time needed for a system to mature. Within the context of the federal program, Kruczynski (1990) provides the following summary of mitigation ratios:

- **Restoration**. If it has been demonstrated that a particular wetland type can be restored, then a mitigation ratio of 1.5:1 should be required. Higher ratios can be justified on the basis of uncertainty that a particular project will be successful and to compensate for the time it takes the restored system to become fully functional. The ratio can be reduced to 1:1 if wetland restoration is performed "up front" and the restored wetland has been determined to be fully functional.
- **Creation**. Wetlands creation involves some risk. If it has been demonstrated that a particular wetland type can be created, then a mitigation ratio of 1.5 or 2:1 should be required. Higher ratios can be justified on the basis of uncertainty that a particular project will be successful and to compensate for the time it takes the restored system to become fully functional. The ratio can be reduced to 1:1 if the wetland mitigation effort is performed up front, assuming the created wetland has been determined to be fully functional.
- **Enhancement**. Wetlands targeted for enhancement are already performing wetland functions. Thus, demonstrating a net improvement could be difficult. Because of this uncertainty, a ratio of 3:1 should be required. This ratio could be lowered to 2:1 if the enhancement can be clearly demonstrated and is successfully completed up front.
- **Wetland Preservation**. According to the author, wetland preservation should be considered compensatory mitigation only under unusual circumstances, such as when the wetlands to be preserved are at risk.

Typically, ratios have been used for onsite, type-for-type (i.e., in-kind) replacement mitigation. Analysis of mitigation requirements becomes more complex when offsite and out-of-kind mitigation options are considered. The analysis is further complicated by the many types of wetland communities, the varying degree of success rates, and the difficulty of ranking and exchanging different wetland values.

Attempts to apply ratios to wetland impacts other than filling also can complicate the analysis. In the case of water table drawdown impacts, the changes can be subtle or can take long periods of time to manifest themselves, or both. Thus the application of ratios to compensatory mitigation associated with the impacts of water table drawdowns is less straightforward than for fill impacts.

ALTERNATIVE APPROACHES FOR DEVELOPING MITIGATION RATIOS

Mitigation ratios have developed into workable guidelines for the decisionmaking process. Thus, they have been derived on the basis of practicality, and not from a detailed quantitative basis (Kruczynski 1990). It is unlikely that ratios will ever be purely quantitative because of their use in the regulatory decisionmaking process. In this context, the value judgments, public input, and regulatory policy directives are arguably as important as the scientific input for ultimately identifying the most workable solution for defining a set of ratios that will be accepted by the public, the regulators, the regulated community, and the courts.

Several broad approaches are available for setting ratios for application in policy development, planning, and regulatory actions. Three feasible approaches that SJRWMD might want to consider are as follows:

- An expanded traditional approach
- Landscape-level application of ecologic value
- An ecologic energetics method known as emergy analysis

While the three approaches differ, individually and together they can be leveraged to develop a basis for generating mitigation ratios.

Expanded Traditional Approach

The existing application and regulatory structure for using ratios has evolved over the last two decades. As a refinement of the present approach that treats the mitigation ratio as a static endpoint, Kruczynski (1990) suggests an expanded matrix approach that provides a more detailed basis for mitigation decisionmaking. This method promotes greater discussion on the assumptions and value judgments that must be made to achieve currently developed ratios.

Kruczynski (1990) also provides guidance on selecting mitigation options. His recommendations are based on the following key assumptions:

- **Mitigation type**. Restoration is preferred over creation, which in turn is preferred over enhancement. The nominal values assigned to each of these three categories are 3, 2, and 1, respectively
- **Timing**. Up-front mitigation is preferred over concurrent mitigation, which in turn is preferred over post-impact mitigation. The values assigned to each of these categories are 3, 2, and 1, respectively
- **Community Type**. In-kind mitigation is preferred over out-of-kind. The values assigned to these two categories are 3 and 1, respectively
- **Location**. Onsite mitigation is preferred over offsite. The values assigned to these two categories are 3 and 1, respectively

Figure 9 (Kruczynski 1990) graphically summarizes the array of possible mitigation options. The assigned values for each of the four levels of mitigation can be summed to yield a total. Ratios can be derived comparatively as a ratio of scores in which the numerator is the score for the acceptable type of mitigation and the denominator is the score for the proposed mitigation alternative.

For example, if the preferred type of mitigation is up-front, onsite, in-kind restoration, then a mitigation value can be calculated for that mitigation option. Other mitigation options can be compared to the preferred option as a ratio of their scores. If this is done for the options shown in Figure 9, the range of mitigation ratios ranges from 1 to 3. This range is within the general guidelines recommended by Kruczynski (1990).

The application above, however, depends on the assignment of values and does not take into consideration the preservation option. Thus, this method contains some inherent assumptions and notable gaps. However, this approach could be used to develop a matrix for SJRWMD. If done within the context of its rule-making procedures, the final product would be a balance of science, regulatory and policy issues, public input, and acceptance by the governing board. This process would involve, at a minimum, consensus in the following areas:

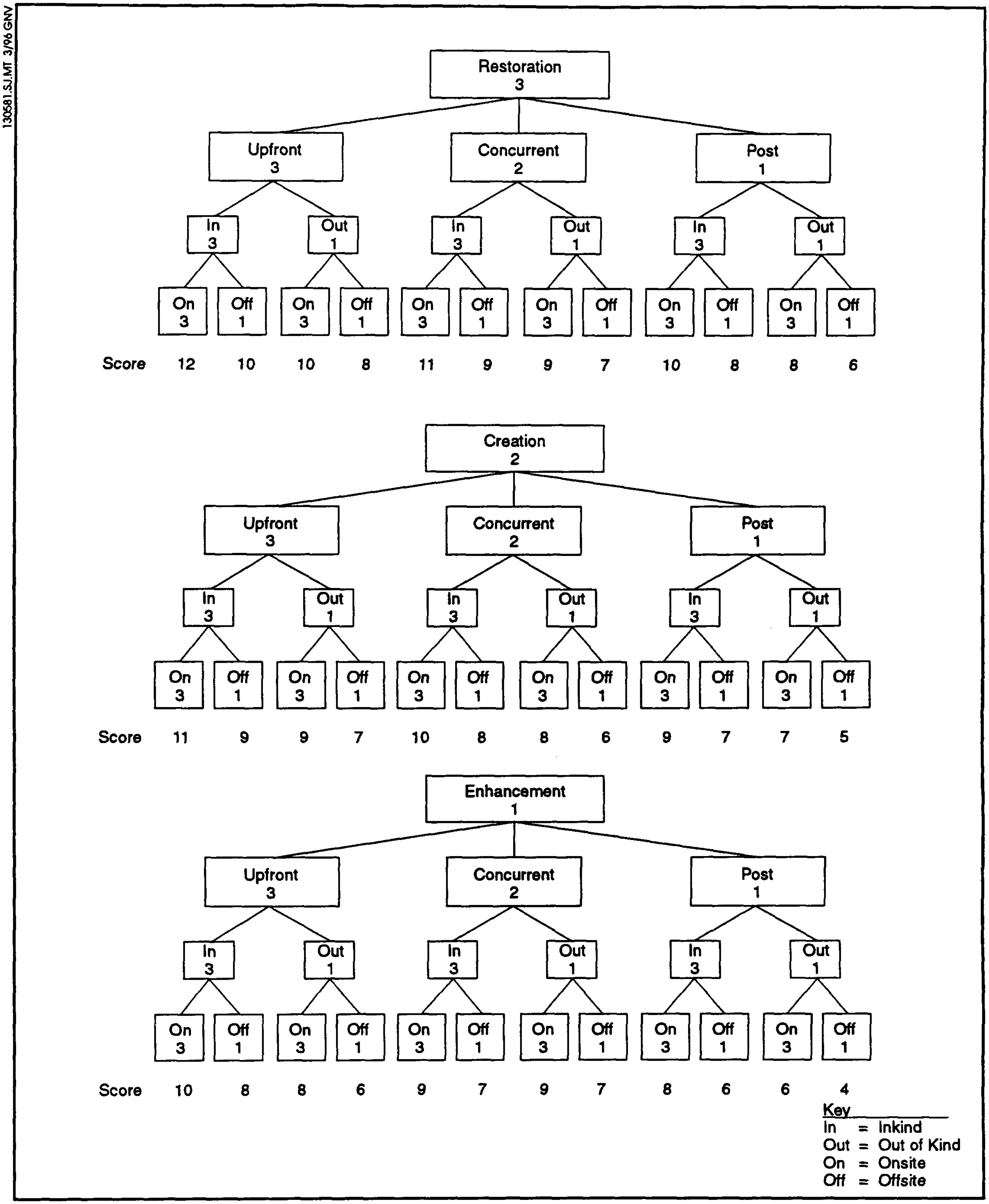

Figure 9. Options to be considered in the preparation and evaluation of mitigation plans.

(Source: Kruczynski 1990)

- Types of mitigation options considered
- Number of parameter levels within each option
- Range of values used at each level
- Assignment of values to each option at each level
- Method by which ratios are calculated

Landscape-Level Ecologic Value Approach

The landscape-level or ecologic value balance sheet approach recognizes that uplands, wetlands, and aquatic ecosystems all possess a number of ecologic values. These values are often attributed to functional and structural aspects of the various community types. By applying this method, the ecologic values likely to be lost or diminished by the proposed activity are assessed and the mitigation actions required to replace those lost values are determined. Ideally, this exercise should be in the form of a balance sheet of losses and gains to determine the required level of mitigation. Weighted values could be calculated from the size of the affected area in the following manner:

Change in Value X Land Area = Weighted Resource Impact Value

Likewise, mitigation options could be screened for their ability to compensate for the lost or diminished ecologic values.

One of the key issues in using this approach is determining the ecologic values to be tracked during the mitigation process. Most ecologic values can be divided into structure and function of the ecosystem (Table 18). These values can then be tracked by using the balance sheet method. As an example, Table 19 (Christianson 1986) provides a general summary of the ecologic values across different ecosystem/land use types within SWFWMD. Using a matrix of ecologic values, different types of ecosystems can be compared. Through these comparisons, it can be determined if an adverse effect on one or more ecologic values within one ecosystem type can be provided by another type through the use of out-of-kind mitigation. This comparison is provided in Table 20, which is a matrix of ecologic values, with assessments of the degree to which a value trade-off can be provided by a particular type of mitigation.

The summaries in Tables 19 and 20 show that many of the wetland functions, structural elements, and aspects of uniqueness can be provided by different types of wetland communities and even by upland communities. Included in this grouping are such activities as

Table 18. Functional, structural, and uniqueness elements of ecologic values of wetland ecosystem

Functions	
Hydrologic	Convey flood waters Act as barriers to waves Prevent erosion Store flood waters Recharge aquifers
Water Quality	Stabilize sediments Retain sediments Remove or transform hazardous chemicals Remove or transform nutrients Maintain water quality
Biological Productivity	Primary productivity Secondary productivity
Habitat	Provide feeding areas Provide breeding areas Provide dispersal corridors Provide watering areas Provide staging areas Provide shelter
Structure	
Physical	Soils Hydrologic regime
Biological	Plants Animals
Uniqueness	
Habitat	Rare or critical habitat
Species	Protected species

Table 19. Relative ecological values of various ecosystems

	Urban Builtup	Cropland/ Pasture	Tree Crops	Range-land	Coniferous Forest	Hardwood Forest	Tree Plantations	Streams/ Waterways	Lakes	Wetland Hardwood Forest	Wetland Coniferous Forest	Marsh	Wet Prairie	Disturbed Lands	Trans/Com Utilities
Water Quality Enhancement	low	low	low	med.	high	low	low	low	med.	high	med.	low	high	low	low
Evapotranspiration	low	high	med.	med.	med.	low	med.	high	high	low	med.	med.	med.	low	low
Net Primary Productivity	low	low	high	low	high	med.	high	low	low	med.	med.	high	high	low	low
Gross Primary Productivity	low	low	low	low	low	low	low	low	low	high	high	high	high	low	low
Hydroperiod	low	low	low	low	low	low	low	high	high	med.	med.	high	low	med.[a]	med.[a]
Water Depth	low	low	low	low	low	low	low	high	high	high	high	high	low	med.[a]	med.[a]
Recharge	low	med.	high	med.	med.	high	med.	low	high	low	med.	med.	med.	med.[a]	med.[a]
Peat Depth	low	low	low	low	low	low	low	low	low	med.	high	high	high	low	low
Fire Frequency	low	low	low	high	high	low	med.	low	low	low	med.	high	high	low	low
Wildlife Habitat	low	low	low	med.	high	high	low	low	high	high	high	high	med.	low	low

[a]Variable values.

Source: Christianson 1986.

Table 20. Summary of selected mitigation options to provide compensation for impacts to specific ecological value

Functional and Structural Components of Wetland Systems			Wetland Creation	Wetland Enhancement	Wetland Restoration	Purchase of Mitigation Banks Credits	Cash Contribution	Land Acquisition Wetlands	Land Acquisition Uplands	Preservation Wetlands	Preservation Uplands
Functions	Hydrologic	Convey flood waters	Yes	Yes	Yes	Yes	Yes	Yes	Yes, some uplands	Yes	Yes, some uplands
		Act as barriers to waves	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Prevent erosion	Yes	Yes	Yes	Yes	Yes	Yes	Yes, some uplands	Yes	Yes, some uplands
		Store flood waters	Yes	Yes	Yes	Yes	Yes	Yes	Yes, some uplands	Yes	Yes, some uplands
		Recharge aquifers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Water Quality	Stabilize sediments	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Retain sediments	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Remove or transform hazardous chemicals	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Remove or transform nutrients	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Maintain water quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Biological Productivity	Primary productivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Secondary productivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Habitat	Provide feeding areas	Yes	Yes	Yes	Yes	Yes	Yes	Yes for some species, but not for those with need for standing water	Yes	Yes for some species, but not for those with need for standing water
		Provide breeding areas	Yes, overall needs for aquatic and wetland dependent species can be met	Yes, overall needs for aquatic and wetland dependent species can be met	Yes, overall needs for aquatic and wetland dependent species can be met	Yes, overall needs for aquatic and wetland dependent species can be met	Yes, overall needs for aquatic and wetland dependent species can be met	Yes, overall needs for aquatic and wetland dependent species can be met	Yes for some species, but not for those with need for standing water	Yes, overall needs for aquatic and wetland dependent species can be met	Yes for some species, but not for those with need for standing water
		Provide dispersal corridors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Provide watering areas	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
		Provide staging areas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Provide shelter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Structure	Physical	Soils	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
		Hydrologic regime	Yes, if hydrographs are similar	Yes, if hydrographs are similar	Yes, if hydrographs are similar	Yes, if hydrographs are similar	Yes, if hydrographs are similar	Yes	No	Yes	No
	Biological	Plants	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	No, community type does not match	Yes, if community type matches	No, community type does not match
		Animals	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	No, community type does not match	Yes, if community type matches	No, community type does not match
Uniqueness	Habitat	Rare of critical habitat	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	No, community type does not match	Yes, if community type matches	No, community type does not match
	Species	Protected species	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	Yes, if community type matches	No, community type does not match	Yes, if community type matches	No, community type does not match

productivity measures, ground water recharge, and water quality enhancement. When the values to be lost or diminished are not compensated by a certain mitigation option, it is typically because one or more specific and typically unique structural components of the community are not present, or a particular species or species group is not present or cannot be supported.

For example, upland forests and wetland forests may provide a similar amount and type of roosting habitat; however, the bird species using this habitat may differ. Likewise, while the overall primary and secondary productivity of forested uplands and wetlands may be similar, this similarity may be a result of different assemblages of species.

In conclusion, the effect of water regime reductions on wetland communities can affect many of a community's ecologic values. The ecologic values balance sheet approach to impact analysis can recognize the values affected and provide a means by which mitigation options can be screened. The variety of tools available for determining the specific characteristics for the individual values within each ecosystem type include existing literature, monitoring studies, site-specific studies, and functional analysis procedures, such as the Wetland Evaluation Technique (WET) (Adamus et al. 1987), Hydrogeomorphic Method (HGM) (Trott et al. 1996), and Habitat Evaluation Procedure (HEP) (U.S. Fish and Wildlife Service, 1980). Because this approach allows determination of the required mitigation and provides a screening tool for identifying the mitigation options providing compensation, it also can be used to develop ratios.

The landscape-level analysis also is appropriate for project-specific applications. At the planning level, the approach could be implemented using a GIS. Mitigation alternatives could be scored, and the ecologic accounting could be addressed at multiple levels (i.e., site, watershed, regional, and Districtwide). Comparison of assessments made at multiple levels could provide some refinement of the best available mitigation options.

Systems Ecology Approach

The greatest shortcoming of current approaches to mitigation is that, except in simple cases, dissimilar units ("apples to oranges") are compared. When evaluations of options other than onsite, in-kind mitigation are required, assumptions and value judgments must be made during the decisionmaking process. Thus, selecting a method of mitigation is typically difficult or the option in question is precluded.

Because trade-offs often must be made between ecosystems, a tool that can quantify the "public value" of the different types of environments is necessary. Comparing energy values of flows and storages within ecosystems and the human economy offers a means of making such comparisons. Developed within the fields of ecologic energetics and environmental economics, these analytical methods avoid the problems inherent in comparing options on the basis of tradeoffs between unlike units.

One approach, *emergy analysis* (which originates from the term *embodied energy*) (Odum 1996), provides a powerful mechanism for guiding mitigation planning, natural resource management, and environmental decisionmaking. Emergy evaluation can be used to define the mitigation credit in terms of comparable units ("apples to apples") so that credits can be assigned to the trade-off areas according to their values within a common currency system.

Environmental Accounting, by H.T. Odum (1996), details how emergy analysis can be useful in permitting and resource management decisionmaking. The book provides a theoretical basis, calculations, and sample applications relevant to the water resources and mitigation issues associated with projects such as SJRWMD's. Through emergy analysis, the key structural and functional aspects of an impact can be compared with the values of mitigation options by using a common currency. Value within the method is provided by a concept of transformity.

In his book, Odum uses emergy analysis to obtain the following types of information:

- Value of ecosystems (by their flows and storages)
- Value of endangered species
- Value of biodiversity
- Water storage functions
- Impact assessment
- Cumulative impact assessment
- Screening of mitigation options
- Value of keystone species

Examples of emergy used in the context of environmental analysis and decisionmaking are provided in Table 21.

Table 21. Applications of emergy analysis to natural resource management concerns and environmental analysis and decisionmaking

Value of nature parks	DeBellevue et al. 1976
Water resources project development	Brown 1986
Ecotourism and sustainable development	Brown and Murphy 1995
Carrying capacity of the Green Swamp	Brown et al. 1975
Public policy development	Odum 1996
Management of tropical ecosystems	Odum 1995
Evaluation of wetland restoration alternatives	Odum 1996
Fisheries management	Campbell 1995
Estuarine wetlands	Kemp et al. 1995

UNIT MITIGATION COSTS

Planning-level costs for mitigating potential impacts to wetlands within the WRCAs will be initially calculated with generalized unit costs for the major types of mitigation. Unit costs are provided for restoration, creation, and enhancement of wetlands; preservation of both uplands and wetlands; acquisition of both uplands and wetlands; purchase of mitigation bank credits; and a cash contribution toward an SJRWMD-approved mitigation project. SJRWMD supplied unit costs for preservation, land acquisition, and cash donations to the District-sponsored mitigation project. The remaining unit costs for restoration, creation, and enhancement and the purchase of credits from a mitigation bank are based on a survey of selected recent projects within SJRWMD and throughout the state.

Unit costs for several mitigation options, such as creation, restoration, and enhancement, can vary over several orders of magnitude, depending on such factors as wetland type, site conditions, and the intensity of the mitigation effort. For example, the range of costs for wetland creation projects can range from several thousand dollars per acre to over $100,000 per acre. This range makes it difficult to arrive at a recommendation for unit costs without providing limiting assumptions.

For the purpose of developing planning-level costs for SJRWMD, the following conditions are assumed:

- The goal is to identify reasonably practicable mitigation options and exclude unlikely options.
- For a given mitigation need, more than one option will be available to meet that need.
- The mitigation options identified will provide compensatory mitigation for the projected loss in ecological value.
- For those options with a wide range of costs, median values will be used as the best available initial estimate. These median values will be used as the starting point for a sensitivity analysis. The final values will be established in consultation with SJRWMD staff after completion of the sensitivity analysis.

- Within a given mitigation option, a range of economic trade-offs are possible between the ecological value of the mitigation and its cost. The trade-offs are assumed to be of equal total cost to the applicant or project developer. For example, for a given type of mitigation, an alternative with a mitigation ratio of 10:1 and a unit cost of $10,000 per acre is economically equivalent to an alternative with a ratio of 20:1 and unit cost of $5,000 per acre.

Based on costing information supplied by SJRWMD, known costs for other projects in the state, and information supplied by permitted and planned mitigation banks, the following considerations also were taken into account during the cost estimating process:

- **Wetland Creation.** The cost of wetland creation varies greatly, depending on initial site conditions and numerous other factors. The cost for these projects typically ranges from $15,000 to $60,000 per acre.

- **Wetland Restoration.** Restoration projects also can vary in the type, nature, and extent of restoration required. Thus, unit costs also can vary $5,000 to $40,000 per acre.

- **Wetland Enhancement.** As with creation and restoration, the type, nature, and extent of enhancement activities can vary, also causing unit costs to range from about $2,500 to $25,000 per acre.

- **Land Acquisition.** SJRWMD has identified its costs for land acquisition as being $2,500 per acre for uplands and $500 per acre for wetlands. Costs may be significantly higher for small parcels or parcels within certain drainage basins. An additional cost of $300 per acre for land management should be included.

- **Purchase of mitigation bank credits.** The price of mitigation bank credit varies according to market conditions within the watershed. Thus, general costs also can be expected to vary according to market conditions. Based on permitted and planned banks within SJRWMD and an adjacent area of the state, credits are being marketed at $20,000 to $40,000 per credit.

- **Cash contribution toward a SJRWMD-approved mitigation project.** SJRWMD handles cash contributions toward specific SJRWMD-approved projects on a case-by-case basis.

Based on the information above, the unit costs recommended for use in the planning-level cost estimate for mitigating impacts in the WRCAs are as follows:

- Wetland creation—$37,500 per acre
- Wetland restoration—$17,500 per acre
- Wetland enhancement—$13,750 per acre
- Land acquisition—$2,500 per acre for uplands and $500 per acre for wetlands, plus $300 per acre for land management activities
- Purchase of mitigation bank credits—$30,000 per credit
- Cash contribution toward a SJRWMD-approved mitigation project will be handled on a case-by-case basis

SUMMARY AND RECOMMENDATIONS

SJRWMD's ratios have been developed for use as guidelines in traditional dredge-and-fill permitting projects. However, the following shortcomings are associated with applying ERP ratios to the effects of water table drawdown:

- It is hard to recognize subtle effects, such as those caused by ground water level changes.
- Out-of-kind mitigation is difficult to address.
- It is difficult to include upland values and functions in the decisionmaking process.
- The process ignores many of the functions and values that are supplied, limiting the analysis to one or two issues.
- The process does not recognize a parity situation.

For the purpose of developing planning-level mitigation costs, it is assumed that the potential options available to water supply developers will be limited to a group of reasonable and practicable mitigation options. Reasonable and practicable options are also assumed to have a high certainty of success, thus high ratios associated with high levels of uncertainty will not be used as a basis for generating reasonable cost scenarios. Because of the assumption of success, for the group of recommended mitigation ratios, each option is assigned a value from the middle of the range.

For the purpose of developing planning-level costs, the approach also makes two other assumptions. First, it assumes that at the given ratio the mitigation effort will result in full replacement of the loss in ecological value projected to occur through drawdown. With this assumption, the uncertainties, which typically dictate the use of a mitigation ratio at the higher end of the range, will have been addressed. Secondly, because of the assumption of replacement of ecological value, the approach allows an economic trade-off by an applicant in balancing the value of the mitigation effort against the cost of that effort. Thus, for a given total mitigation cost, the applicant may choose between an alternative with a high ratio and a low unit cost or a low ratio and a high unit cost.

The ERP program provides a range of values for mitigation ratios. Median values from ratio ranges provided in the ERP program will be used as the best available estimate for developing costs. Their values will be used for the costing model and as the starting point for a sensitivity analysis. The actual mitigation ratio parameter values for the final costing model will be established in consultation with SJRWMD staff after completion of the sensitivity analysis. The recommended initial starting values for ratios are as follows:

- Creation and restoration
  - 3.5:1 for forested wetlands
  - 2.75:1 for herbaceous wetlands
- Enhancement
  - 12:1
- Preservation
  - 35:1 for wetland preservation
  - 11.5:1 for upland preservation

The methodology to be used in the sensitivity analysis, which will be developed in consultation with SJRWMD staff, will assess the effects of varying all model parameters.

Beyond the present effort to develop planning-level costs, the opportunity exists for SJRWMD to develop a more comprehensive approach to deriving mitigation ratios. The initial steps in this process should be established with input from planners, scientists, policy developers, regulators, the general public, and the regulated community. One approach would be to jointly use the three alternative approaches presented in this section, which would provide a suitable means of developing mitigation ratios for SJRWMD's projects.

Planning-level costs for mitigating potential impacts to wetlands within the WRCAs will be initially calculated with generalized unit costs for the major types of mitigation. SJRWMD supplied a unit cost for land acquisition. SJRWMD handles potential cash donations to a SJRWMD-sponsored mitigation project on a case-by-case basis. The remaining unit costs for restoration, creation, and enhancement and for purchase of credits from a mitigation bank were based on the median value for the range of costs from a survey of selected recent projects within SJRWMD and around the state.

The unit costs recommended for the initial planning-level cost estimate for mitigating impacts in the WRCAs are as follows:

- Wetland creation—$37,500 per acre
- Wetland restoration—$17,500 per acre
- Wetland enhancement—$13,750 per acre
- Land acquisition—$2,800 per acre for uplands and $800 per acre for wetlands. These costs include $300 per acre for land management activities.
- Purchase of mitigation bank credits—$30,000 per credit
- Cash contribution toward a SJRWMD-approved mitigation project will be handled on a case-by-case basis

IMPACT ASSESSMENT AND MITIGATION COSTING METHODOLOGIES

This section of the TM presents two methodologies, one for impact assessment and one for mitigation costing. Together they will be used to estimate the total cost of mitigating unacceptable adverse impacts to native vegetation within the WRCAs for a range of mitigation options. The proposed impact assessment method relates projected changes in hydrologic conditions to a degree of impact for the various types of native vegetation within the WRCAs. The overall assessment and costing method has the following benefits:

- It is flexible.
- It can be used to derive planning-level estimates.
- It is consistent with the existing CUP review process.
- It can be refined with more detailed site-specific information to address specific projects.

For addressing their respective goals, the two methodologies can be used separately or can be linked as an overall planning and evaluation tool. Regardless of how the methods are used, they can be used at the following three levels of detail:

1. Regional-level planning and analysis
2. Screening analysis of conceptual projects or alternatives
3. Detailed analysis of specific projects or alternatives

During the subsequent tasks and phases of this project, both tools should be used at all three levels.

SCALE-MATCHING PRECEDING METHODOLOGY DEVELOPMENT

The first application of the impact assessment and costing method will be to estimate the range of costs for mitigating unacceptable adverse impacts to wetland communities within the WRCAs. The accuracy of these costs will directly influence the accuracy and precision required of the assessment and costing method. In this application, the costs will be used for comparison with other work efforts underway for the water supply alternatives analysis. At this point in the analysis, the cost estimates will be planning-level estimates, with an accuracy of

±50 percent. This range then defines the accuracy of the expected output of the first application.

For the proposed impact assessment and costing methodologies, SJRWMD will be relied on to supply the following two types of information:

1. The predicted water table reductions within the wetland communities in the WRCAs
2. Site characteristics for soils, vegetation type, and species composition; elevation gradients; landscape position; and connectivity to the regional drainage network

Possible Approaches

The predicted water table reductions will probably be derived as described in Kinser and Minno (1996) from SJRWMD's steady-state ground water model. The site characteristics will be obtained from SJRWMD's GIS analysis, also summarized by Kinser and Minno (1996). As described earlier in this TM, this GIS analysis is based on highly aggregated information for soils and vegetation. Thus, the method of assessment and subsequent costing will be done with regional-level, aggregated information provided by SJRWMD.

Scale-Matching Recommendation

The guiding principle in regard to scale-matching the impact assessment method with inputs and outputs is that the expected output—planning-level cost—is the highest level of accuracy that can be supported by the available inputs. This level then dictates the accuracy needed from the method of assessment. The proposed methodology can be used at the planning level and at higher levels; however, its application for more detailed analysis of specific sites or projects will require the use of more detailed site-specific information.

IMPACT ASSESSMENT METHODOLOGY

A brief review of the key information for each of the following major elements of the assessment is presented in this section:

- Hydrologic regime change assessment methods
- Target wetland hydrologic regimes
- Faunal indicator groups

- Definition of adverse harm
- Categories of ecologic change

Hydrologic Regime Change Assessment Methods

Wetland assessment techniques are numerous and have been evolving for the last 15 to 20 years; examples include the WET (Adamus et al. 1987), HGM (Trott et al. 1996), and evaluation of planned wetlands (EPW) (Bartoldus et al. 1994). However, these approaches are not specific enough for the needs of this project, although specific elements may provide useful guidance. In particular, in the case of HGM, the development of elements specific to Florida wetland types has not been accomplished. In fact, few methods have been specifically developed to address the prediction and analysis of hydrologic alterations resulting from ground water reductions, and still fewer studies have tried to directly relate hydrologic regime alterations with changes to specific ecologic values and functions.

Possible Approaches

The review of available information showed that the following various approaches have been used or recommended for relating hydroperiod impacts to functional losses:

- Minimum flows and levels
- Presumptive criteria or performance standards
- Site-specific hydrologic regime evaluations
- WCRWSA's EMP
- Reference or control system
- Multivariate analysis

These approaches are described below.

Minimum Flows and Levels Approach. A minimum flows and levels approach can be used by SJRWMD to define hydrologic criteria presumed to be required to prevent harm to the ecologic integrity of the natural systems of interest. The approach used by SJRWMD to establish minimum flows and levels for surface waters and aquifers is grounded in statistical hydrology. The approach has not been applied to the major types of wetlands in SJRWMD, so substantial data collection synthesis and analysis would be required. To relate hydrology to ecologic functions, these relationships must be developed, whether by quantitative analysis, presumption, or best professional judgment.

Presumptive Criteria or Performance Standards Approach. SFWMD and SWFWMD have set presumptive impact criteria for determining harm to natural systems from ground water reductions. These criteria presume that environmental impacts would be acceptable if hydrologic alterations do not exceed the following types of thresholds:

- A cumulative 1-foot drawdown in the water table at the edge of a lake or wetland
- One foot of yearly surface volume from a lake

The hydrologic presumptions, which have been used as guidelines, can be superseded by site-specific data indicating that another hydrologic threshold might be more appropriate.

SWFWMD staff have developed environmental performance standards for their water use permitting process. Along with hydrologic presumptions, the performance standards have been used to assess potential impacts to three classes of natural systems—wetlands, lakes, and streams. The performance standards are general, narrative definitions that describe unacceptable impacts. For example, the wetland performance standards are as follows:

1. Wet season water levels shall not deviate from their normal range.
2. Wetland hydroperiods shall not deviate from their normal range and duration to the extent that wetland plant species composition and community zonation are adversely impacted.
3. Wetland habitat functions, such as providing cover, breeding, and feeding areas for obligate and facultative wetland animals, shall be temporally and spatially maintained, and thus not adversely impacted as a result of groundwater withdrawals. Habitat for threatened and endangered species shall not be altered to the extent that usage by those species is impaired.

The water use permitting approach has a presumption, which states "The district presumes that a withdrawal will not cause unacceptable impacts if the withdrawal of water, combined with other withdrawals, does not lower the water table by more than 1 foot." The presumptive criterion approach does not meet the needs of an impact assessment methodology that can relate changes in hydrology to changes in ecologic value. Performance standards, however, can provide some guidance for defining an operational definition of adverse harm.

Site-Specific Hydrologic Regime Evaluation. Permit-specific methods have been used by applicants in support of CUP requests. Several of these methods have specifically addressed potential impacts to the hydrologic regime of wetlands in the project area. For example, hydrologic regime evaluations were used by the City of Cocoa in support of CUPs for its wellfield expansion and for the withdrawal of water from the Taylor Creek Reservoir. The method, as applied in each of Cocoa's CUPs, was developed jointly by the City, their consultant, and SJRWMD staff. Application of the methods and their evolution is described in Dunn (1989) and technical reports by CH2M HILL (1990a, b; 1991; 1996). In addition, the method is similar to the approach developed by WCRWSA (1994) in its environmental management plan, which is described briefly in the section, WCRWSA Environmental Management Plan, on page 99.

City of Cocoa Wellfield Expansion. In 1989, the City of Cocoa applied to SJRWMD for expansion of its existing wellfield. The City had requested new wells that would pump from both the Floridan and intermediate aquifers. During the permit review process, a question was raised as to whether the pumping from the proposed new wells would adversely impact the native vegetation and existing land uses on the surrounding areas of Deseret Ranch. A subsequent ground water modeling analysis indicated that the confining units between the Floridan aquifer and the surficial water table were sufficiently thick to negate any effect from Floridan pumpage on the surficial water table.

The analysis did, however, indicate that the requested pumpage from the shallower intermediate aquifer could, under seasonal conditions, cause declines of about 0.5 feet in the surficial water table. Based on this estimate, a field assessment of the wetland communities in the vicinity of the wells was conducted. The field assessment consisted of onsite investigations that resulted in detailed mapping of wetland types, identification of dominant plant species, estimation of annual inundation characteristics, characterization of soil profiles, and investigation of the presence of shallow confining layers.

The information obtained from the field surveys indicated that the types of wetlands in the area of concern differed in degree of confinement. The analysis concluded that forested wetland communities typically had well-developed confining layers within the soil profile. In contrast, the wet prairie communities lacked well-defined confining layers within the soil profile. From this it was concluded that a hydrologic regime within wet prairie wetland types would be more susceptible to a hydrologic reduction associated with a water table decline. Because of their greater susceptibility, it was reasoned that water table drawdowns on the order of 0.5 feet could potentially induce changes in the dominant species, including encroachment of upland and transitional species. Based on this analysis, the CUP included a special condition requiring the City of Cocoa to initiate a wetland monitoring program.

City of Cocoa Taylor Creek Reservoir. In 1990, the City of Cocoa submitted another CUP application requesting to withdraw surface water from the Taylor Creek Reservoir. The major environmental concern was the potential for adverse effects to occur from the proposed surface water withdrawal on the floodplain communities in the downstream reaches of Taylor Creek and the St. Johns River. The analysis included an assessment of the change in hydrologic conditions, followed by assessment of the potential for changes in the dominant species in the floodplain communities.

A modeling effort was used to define baseline hydrologic conditions and the change in conditions that could result from the proposed surface water withdrawals. Transect surveys provided profiles of topography and plant community distribution. The model was calibrated with historical records of stages in the creek and discharge from the reservoir. By using the model, hydrographs and stage duration relationships for each community type were established. By simulating the proposed withdrawal in the model, the effect of the withdrawal on the hydrologic regime for each community type was examined. Using the predicted changes in the hydrologic regime and the species composition of each community type, the probability of significant shifts in dominant species within each community type was assessed.

WCRWSA Environmental Management Plan. WCRWSA's proposed EMP details a method for tracking changes in the hydrologic regime of wetlands potentially affected by water table declines. WCRWSA has developed an approach that addresses management of its wellfields with "the intent of monitoring for detection of adverse impacts, reducing potential impacts created by water production and how those impacts will be addressed and mitigated once they are detected." The plan uses a decisionmaking flow chart to determine how impacts are detected and the steps that will be taken to correct or account for the impacts caused by wellfield production (Figure 10).

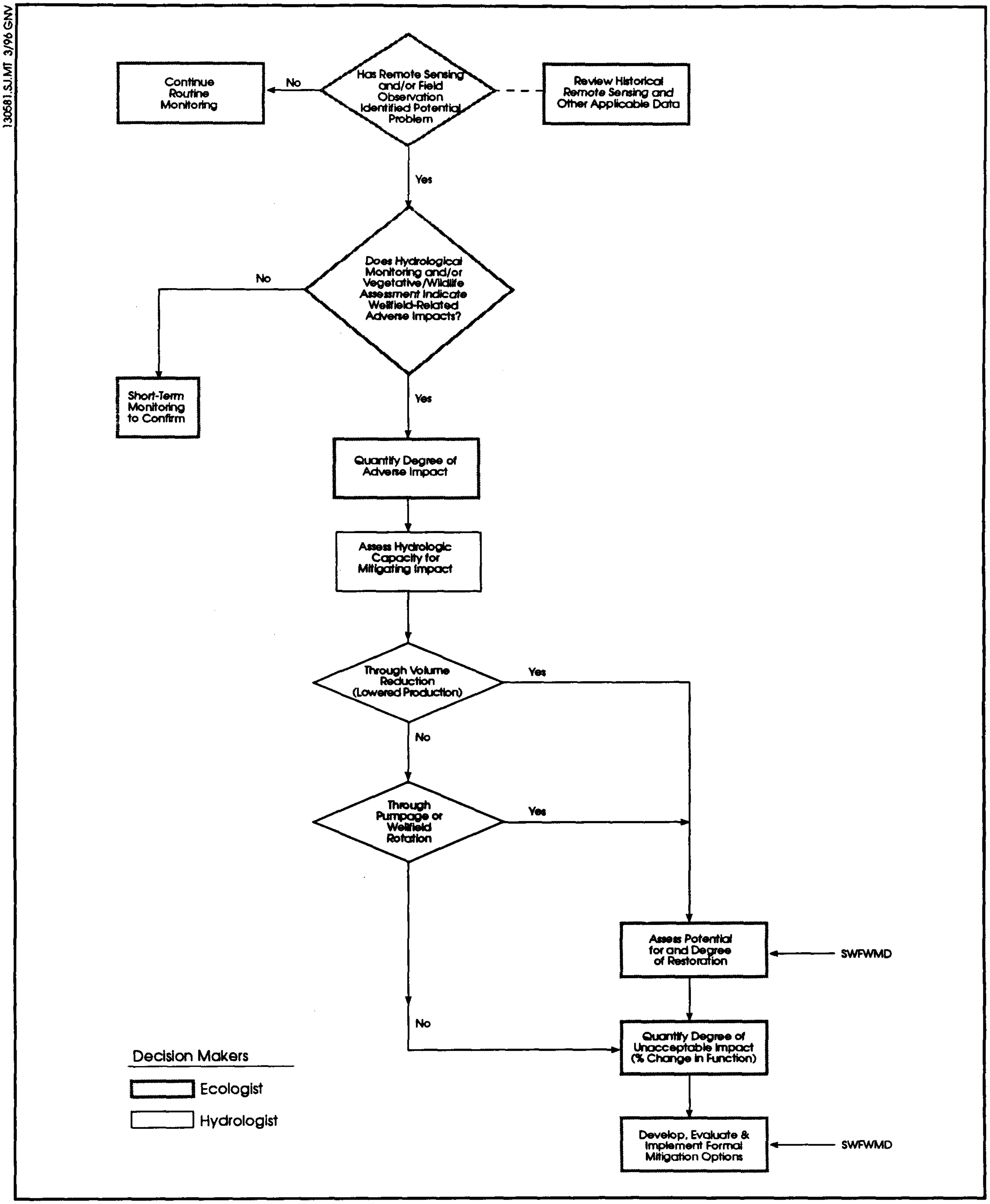

Figure 10. Flow Chart of West Coast Regional Water Supply Authority Environmental Management Plan (WCRWSA 1994).

The plan includes definitions of hydrologic impact and specific hydroperiod ranges for different types of wetlands that are common to the region in which SWFWMD permitted wellfields are found. In addition, the EMP allows consideration of habitat quality for amphibian species. Within the EMP, a wellfield-induced wetland hydrologic impact is defined as follows:

"The annual duration of inundation in a wetland is reduced to a period less than that determined to be normal for wetlands of the same type, or

The annual depth of inundation in a wetland is decreased to depths less than those determined to be normal for wetlands of the same type, and

Wellfield operation has brought about the reduction of duration of inundation or the decrease in the depth of inundation."

Reference or Control Systems. With a sufficient long-term data base and a detailed monitoring program, changes in hydrologic regime characteristics and ecologic functions in the wetlands of interest can be compared to unaffected reference or control systems that are presumed to be outside the influence of the potential impact. This approach is, in fact, a monitor-and-compare approach that has been used for a number of years for wellfields in the northern Tampa Bay area. The value of this method depends on the adequacy of the study design and data collection efforts. However, even if the data sets are robust enough to account for natural variation and other complicating factors, this approach still depends on the use of a clear definition of what constitutes significant adverse change.

Multivariate Analysis. If sufficient data existed for relating hydrologic regime characteristics to ecosystem structure and functions, it might be possible to use multivariate techniques to develop statistical relationships for predicting degree of impact as a function of degree of change in the chosen hydroperiod characteristic. While this could be a promising means of analysis, it has not been done for the major types of wetlands in Florida or elsewhere in the United States.

Recommended Approach

To meet the needs of this project, a generalized version of the site-specific hydrologic regime evaluation is recommended. The proposed approach involves using the hydrograph of the wetland community of interest to define the key aspects of the hydrologic regime, in particular the duration, depth, and seasonality and frequency of inundation. The predicted change in conditions—for example, water table decline—is used to generate a new hydrograph for yielding estimates of the changes in hydrologic parameters.

This method is flexible and can be applied at different levels. For planning-level analyses, a generalized hydrograph for typical annual conditions can be used for initial assessments. If, however, more detailed regional or site-specific baseline monitoring data on hydrology have been collected, the generalized hydrograph can be modified to reflect actual site conditions.

The hydrograph not only provides a visually simple summary of the hydrologic regime of the wetland, but also provides a tool for conducting a simple graphical analysis of expected hydrologic change. Change in the wetland hydrograph is easily estimated by overlaying the predicted water table drawdown on the hydrograph to produce a new hydrograph of the future conditions. Because the hydrograph provides a concise summary of the hydrologic regime, effects on depth, duration, seasonality, and frequency of flooding can be readily estimated.

Figure 11 provides a summary of the hydrograph analysis for a wetland with a typical 360-day hydroperiod. In addition to the typical hydrograph, a plot of the relationship between reduction in stage and hydroperiod is also provided. The plot indicates the degree of hydroperiod reduction that would result from a given amount of water table decline. For example, if the water table within a wetland that had a 360-day hydroperiod and an annual hydrograph, as shown, was reduced by 1.8 feet, the hydroperiod would be reduced to zero. The method can be tailored to the characteristics of the hydrologic regime for the community types of interest because a similar summary and analysis can be prepared for each individual hydrograph.

Target Wetland Community Types and Hydrologic Regimes

Following the characterization of changes in hydrologic regime, the next step in the analysis is to relate the changes in hydrology to the biological community. To do this, the target communities and their characteristic hydrologic regimes must be defined.

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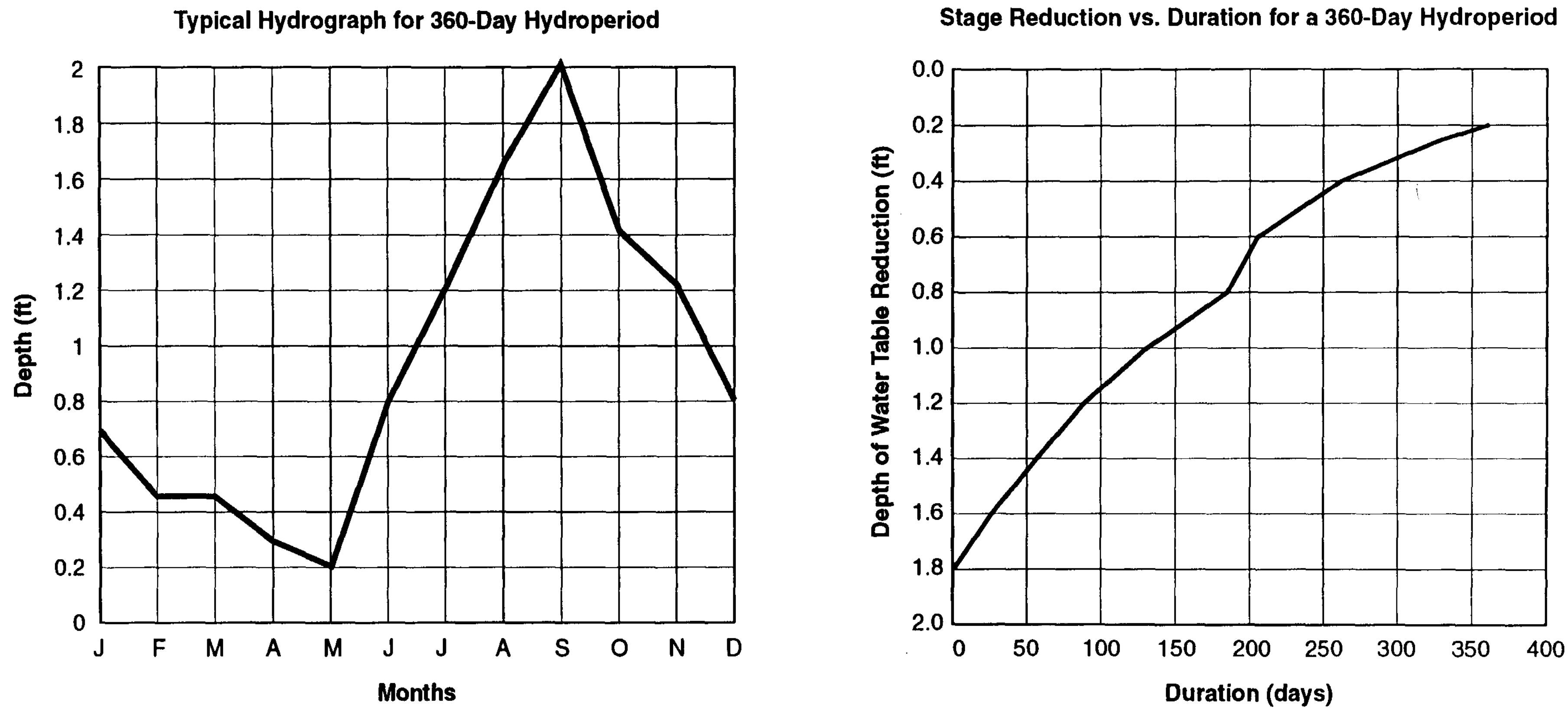

Figure 11. Typical Hydrograph for Florida Wetland with a 360-day Hydroperiod (a); Stage Reduction vs. Duration Plot for Hydrograph (b)

Possible Community Types and Hydrologic Regimes

Based on SJRWMD's analysis, the assessment and cost estimating procedure for the WRCAs will probably include the major community types cited by Kinser and Minno (1996). As noted earlier, SJRWMD's GIS analysis used aggregated data for vegetative community type and soils. In anticipation that a finer level of community delineation might be useful for mitigation costing, the following community types, along with their Florida Land Use, Cover and Classification System (FLUCCS) designation code (FDOT 1985), can be considered:

Community Type	FLUCCS Classification
Xeric to mesic uplands	412, 413
Hydric flatwoods	411
Hydric oak hammock	434
Hydric palm hammock	434
Shrub thicket (wax myrtle, mixed species, willow)	646
Floodplain swamp	615
Cypress swamp (shallow, normal, deep)	621
Mixed hardwood swamp	630
Wet prairie	643
Freshwater marsh (shallow, normal, deep)	641, 644, 645
Pond and slough	520, 560

The typical annual condition and range of variation for the hydrologic regime parameters and a typical annual hydrograph can be established for each of the major types of wetlands from existing information. Once the hydrologic regime for a community type has been characterized, the potential for the community to undergo change as the hydrology is altered can be assessed. As the hydrologic regime is altered through water table reductions, the conditions become less optimal for the original community type and more optimal for a another "drier" community type along the hydrologic gradient. Movement up the hydrologic gradient defines a community succession driven by dehydration. The concept of a dehydration succession is an underlying principle for the impact assessment methodology.

Each of the major community types can be arrayed along the hydrologic gradient. Figure 12 provides a summary of the range of hydroperiods for many of the major wetland community types. The community types are arrayed generally from shortest to longest hydroperiod, thus generally defining the hydrologic gradient and potential successional relationships. Once an average or typical hydroperiod condition is selected, a typical annual hydrograph for that condition can be defined. The hydrograph provides an analytical tool for assessing the community changes that would likely result from a reduction in the water table.

The downward shift of the hydrograph also simulates a shift along the dehydration succession gradient. Because plant species differ in their competitive ability along the hydrologic gradient, with other controlling factors being equal, as the hydrologic regime changes, a long-term shift in species composition may take place. This is the proposed basis for assessing the likelihood of change in the mix of dominant vegetative species.

For example, a given level of water table reduction could shift the hydrologic regime of a deep marsh to that of shallow marsh. This change in hydrologic conditions would be expected to drive some level of change, although not a dramatic one, in species composition. Likewise, further levels of reduction could result in hydrologic conditions more similar to a wet prairie or, in a case of still further reductions, to an upland pine flatwoods.

Recommended Community Types and Hydrologic Regimes

The recommended general community types with average hydroperiods are provided in Figure 13. Typical hydrographs for each of the wetland types are provided in Appendix C.

Faunal Indicator Group for Hydrologic Change

Since SJRWMD's CUP permitting decisions consider the effects of water supply development on both plant and animal communities, a faunal indicator group is appropriate for inclusion in the impact assessment methodology. Because the mitigation costing task will be done at a planning level without site-specific information, a single indicator group was sought. This indicator group should reflect the overall habitat quality for wetland- and aquatic-dependent species.

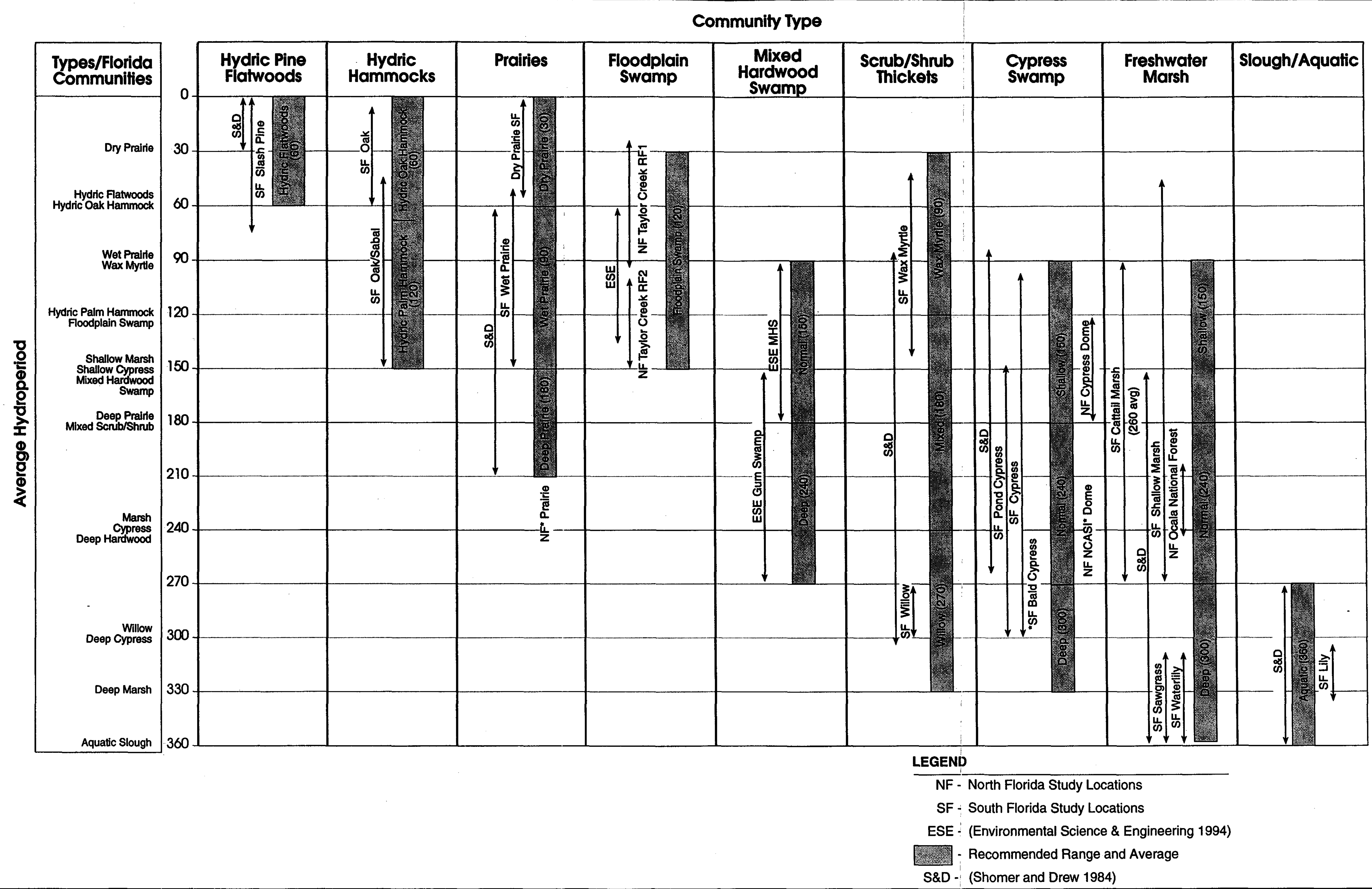

Figure 12. Hydroperiod Summary by Community Type for Major Wetland Types in Florida

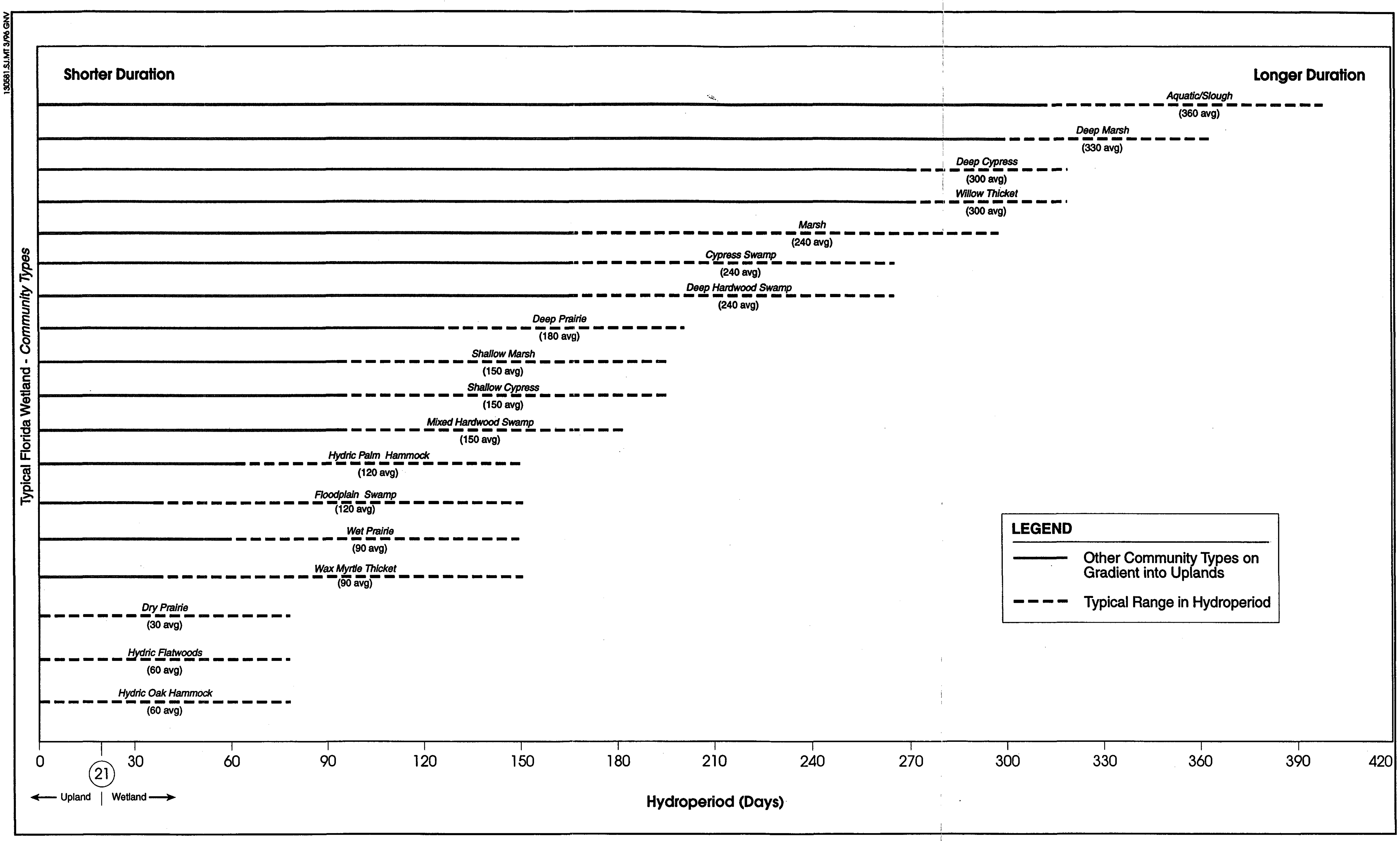

Figure 13. Recommended Values forTypical Annual Hydroperiod by Community Type

(Source: CH2M HILL 1996)

Possible Faunal Indicator Groups

The indicator group could be either an invertebrate or vertebrate. Invertebrates include aquatic insects, freshwater crustaceans (amphipods, crayfish), aquatic annelids (worms), zooplankton, and terrestrial insects found predominantly in wetlands. Adamus and Brandt (1990) cite several disadvantages in using aquatic invertebrates as indicator organisms, among them are difficulty of identification, low public recognition of importance, naturally great spatial variation, and community composition potentially affected by selective predation. For these reasons, the invertebrates would not be useful as the indicator faunal group and it is assumed that one or more of the vertebrate groups would better represent the concerns typically addressed by SJRWMD in permitting decisions.

Within the vertebrate group, possible indicator groups include mammals, birds, fishes, reptiles, and amphibians (Appendix D). In selecting the indicator group, the following issues should be considered: degree of mobility of the species within the group, the degree of dependence of the group on wetland and aquatic conditions, and degree to which other factors affect population size. Information on these topics for each group, presented below, is adapted from Adamus and Brandt (1990).

Mammals. Defining wetland dependency for mammals as a group is difficult. Adamus and Brandt (1990) conclude that indicator assemblages of mammals most sensitive to water-level changes remain speculative for most of the country, and that the effects of drawdown have not been well documented. While one or more mammals may use each wetland type, difficulties arise because of the relatively large home range of many. In addition, mobility and frequent use of non-wetland habitat contribute to great temporal and spatial variations.

Because of these factors, the effect of an altered hydrologic regime may not be reflected by indicator species of mammals because of the ability of mammals to move freely in and out an impacted area. These factors also make it difficult to ascribe cause and effect. However, in mammals, these same factors provide a broad integration of landscape-level condition.

Birds. As for mammals, defining a wetland-dependent bird species is somewhat difficult. Adamus and Brandt (1990) cite categories of wetland dependency such as diet, energetics-metabolism, structural habitat, duration of need, and seasonality of need. As for plant and other animal groups, the degree of wetland dependency ranges from birds that spend their entire life in wetlands to those with only limited use of wetlands. Mobility is also another significant issue. The daily and seasonal movement patterns of most birds are equal to or greater than the areal extent of the effect expected from possible pumpage impacts.

In general, the habitat requirements, life histories, and species assemblages of wetland birds are known. However, in spite of this information, community level responses to stressors, including hydrology, have been difficult to determine. Because most birds are extremely mobile, they may more accurately reflect the overall integrated condition of the landscape than the condition in a particular wetland.

Fishes. Few freshwater fish spend their entire life in wetlands, and some types of wetlands that typically lack standing water for some portion of the year do not usually have fish. Fish community structure has been described for rivers and lakes, and indices of ecologic integrity have been developed for some of these aquatic systems. However, similar information has not been developed for wetlands (Adamus and Brandt 1990).

Fish are important in some wetland types, but relatively unimportant in others. Several types of wetlands have depauperate fish communities in terms of biomass, species diversity, and absolute numbers. Examples of this latter condition are wetlands that are seasonally inundated or go dry for some period of time, or both. Wetlands that normally contain surface water but become briefly dehydrated can have fish populations that rapidly increase upon reflooding. This response, however, assumes that fish have access into and out of the wetland as water levels change. However, this is not true for isolated wetlands and many headwater wetlands. Thus, fish have limited value in the general wetland assessment application.

Reptiles and Amphibians. This faunal assemblage includes turtles, frogs, salamanders, snakes, crocodilians, and lizards. Life histories of amphibians differ considerably from those of reptiles. However, with few exceptions, most spend all or some critical part of their life in wetlands. In addition, when compared with birds and mammals, herptiles (and especially amphibians) have limited home ranges and reduced mobility.

Several studies have documented that amphibians are sensitive to changes in hydrologic regime within wetlands. Changes in water levels alter the quality and quantity of habitat and may trigger immigration, emigration, and breeding of particular species and, possibly, their predators (Penchman et al. 1988).

Taxa that are characteristically found in seasonally flooded wetlands are more resistant to water-level reductions or drought than those more typically found in permanently flooded habitats (Minton 1977). In a study of ditched and unditched cypress domes in north Florida, Vickers et al. (1985) found no change in the numbers, number of species, or species diversity in ditched and unditched cypress swamps. They did, however, find that species richness declined and terrestrial species became more abundant with ditching. Information on general habitat requirements for species in Florida is summarized by Ashton and Ashton (1988).

Recommended Faunal Indicator Group

Table 22 summarizes the key advantages and disadvantages for using each of the faunal groups as an indicator group. Amphibians have been recommended as indicator species for changes on wetland conditions. Beiswenger (1988) has suggested an approach for using assemblages of anuran amphibian species (frogs and toads) as indicators of wetland condition. WCRWSA's EMP (1994) suggests the use of anuran species to define habitat requirements. The hydrologic regime requirements for amphibians can be defined as the duration of flooding required for the various species to complete their reproductive cycle.

Table 23 provides a summary of the metamorphosing requirements for the common species expected to occur in wetlands within the WRCAs. Based on the metamorphosing requirements, there are several broad groups:

- Group 1: 360 days or more (bullfrog, river frog, pig frog)
- Group 2: 90 days or more (spring peeper, gopher frog, southern leopard frog)
- Group 3: 60 to 90 days (Florida cricket frog, green tree frog, Florida chorus frog, bronze frog)
- Group 4: 45 to 90 days (squirrel treefrog, pinewoods treefrog, southern toad)
- Group 5: 30 to 60 days (oak toad, eastern narrowmouth toad)

Table 22. Summary of advantages and disadvantages of major faunal groups for use as indicators of hydrology changes

Taxon	Advantages	Disadvantages
Fish	Integrate broad, longer-term, landscape-level impacts because of their mobility, high trophic position, and longer life span	Absent in many wetlands or only present for brief periods of time
	Absent from isolated wetlands with complete, sustained drawdown	Mobility may make it difficult to ascribe source of mortality
	Easily identified	
	Presumptive indicator of hydroperiod	
Amphibians and Reptiles	Small home range relative to larger vertebrates	Presence can be strongly influenced by natural dispersal conditions
	Sensitive to hydroperiod alteration	
	Present in most inland wetland types	
	Easily recognized	
Birds	Easily recognized	Highly mobile
	Present in most wetland types	Large home range for many
	Suitable indicator of degradation occurring at the landscape scale	Migration for many
	Simple sampling and identification	Source of mortality can be distant
	Integrate broad, longer-term, landscape-level impacts because of their mobility, high trophic position, and longer life span	Hunting can be a source of mortality for some species
		Great temporal and spatial variation
Mammals	Easily recognized	Relatively large range
	Present in most wetland types	Great temporal and spatial variation
	Integrate broad, longer-term, landscape-level impacts because of their mobility, high trophic position, and longer life span	Mobility and frequent use of non-wetland habitat makes it difficult to locate specific causes of mortality in the habitat

Table 23. Summary of frog and toad breeding requirements for common Florida species

Species	Breeding Season	Breeding Habitat	Tadpole Metamorphose Time (days)
Oak Toad	April/October	Shallow ponds	30
Southern Toad	mid-March/October	Any water body	30-60
Florida Cricket Frog	mid-April/Fall	Water body with open or grassy edges	45-90
Gray Treefrog	Spring/Summer	Shallow wooded ponds, ditches, gum swamps	30-60
Green Treefrog	mid-April/late October	Lake and pond edges, marshes, forested wetlands	60
Spring Peeper	Winter	All types of ponds and cypress heads	90
Pinewoods Treefrog	Mid-April/Summer	Temporary ponds, cypress or bayheads, roadside ditches	30-60
Barking Treefrog	April/August	Ponds, wetlands	45-60
Squirrel Treefrog	Late Spring/ Summer	Temporary ponds and roadside ditches	30-60
Little Grass Frog	March/April	Flooded grassy meadows, roadsides, permanent ponds and cypress heads	10
Florida Chorus Frog	Early December/ March	Roadside ditches, flooded fields, and cypress heads	60
Eastern Narrowmouth Toad	Early Spring/ Summer	Any water body	30
E. Spadefoot Toad	Any time during year	Temporary ponds after heavy rains	10
Gopher Frog	Winter-Spring/ Sometimes Summer	Permanent ponds, cypress	93
Bullfrog	April/Summer	Lakes, ponds, permanent water bodies	>360
Bronze frog	Late Spring/Early Summer	Streams, cypress heads, and permanent ponds	60
Pig frog	April/Summer	Marshes, lakes, permanent water bodies	>360
River frog	April/July	Lakes and streams	>360
S. Leopard Frog	Winter/Spring	Any water body	90
Source: Ashton and Ashton 1988.			

- Group 6: 10 to 30 days (little grass frog, eastern spadefoot toad)
- Group 7: less than 10 days

The breeding and life history characteristics of these species groups can be used to correlate potential changes in species composition to changes in the duration and seasonality of flooding. A particular species can be expected to be lost from a site if the season and duration of flooding fall below the breeding requirement threshold. Conversely, if the change in hydrologic regime is such that breeding requirements are still met, then that species group will not be considered to be adversely affected.

Figure 14 provides a graphical summary of the suitability of wetland habitat for the individual amphibian species groups as a function of hydroperiod duration. Habitat suitability in this usage is defined as meeting or exceeding the hydroperiod required for successful reproduction for the individual amphibian group. Figure 14 provides a tool for assessing the potential for a given assemblage of amphibians to find suitable habitat in a wetland with a given hydroperiod. Once the hydroperiod of a given wetland is estimated, other factors being equal, the potentially occurring amphibian groups can also be estimated. This approach assumes that if the habitat meets or exceeds the reproductive thresholds, then the species group is potentially present. For example, if a wetland had a hydroperiod in excess of 360 days, it could support all seven species groups. In contrast, if the wetland had an annual flood duration of less than 10 days, then only Group 7 would be expected to be present.

Figure 14 also can be used to assess the effect of a change in hydrologic regime on amphibian populations. The effect of hydrologic change is simply determined by comparing the species groups potentially present under the respective hydroperiods of starting versus changed conditions. For example, if the original hydroperiod was 300 days and was predicted to change to 180 days, there is no predicted loss of a species group because both conditions can support species groups 2, 3, 4, 5, 6, and 7. If, however, the predicted reduction was from 300 days to less than 60 days, then of the six original groups (2, 3, 4, 5, 6, and 7) only four groups (4, 5, 6, and 7) would find suitable habitat.

As indicated in Figure 14, the habitat requirements can be divided into three zones:

- **Zone 1.** Hydroperiods greater than 360 days. Under these conditions of long-term flooding, all seven amphibian groups are potentially present.

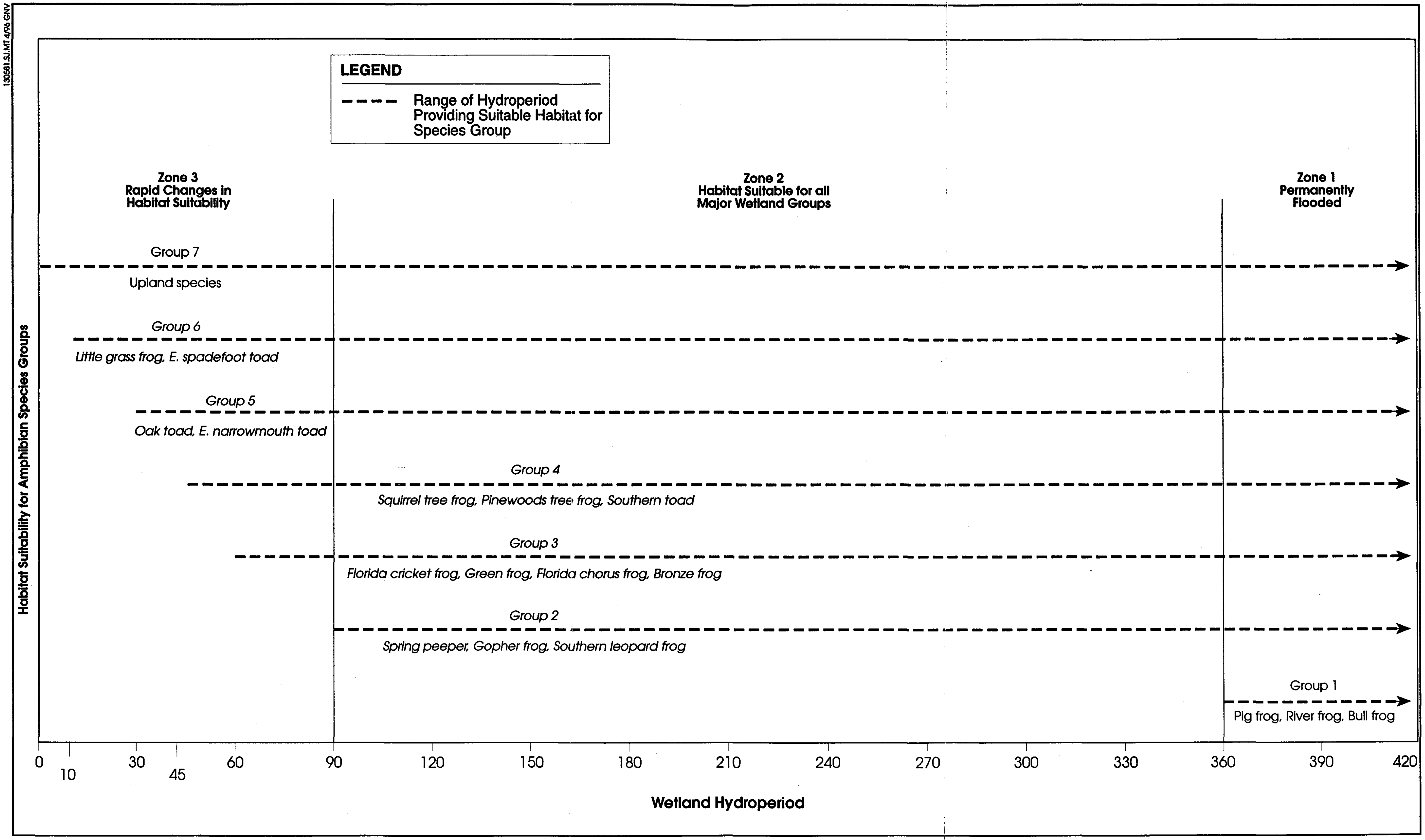

Figure 14. Habitat Suitability for Amphibian Species Based on Hydroperiod.

(Source: CH2M HILL 1996)

- **Zone 2.** Hydroperiods of greater than 90 days, but less than 360 days. Within this hydroperiod range, most of the amphibian groups, with the exception of Group 1, can be expected to be present.

- **Zone 3.** Hydroperiods less than 90 days. For wetlands in this range of hydroperiods, there can be significant differences in the amphibian assemblage that can be supported.

In summary, most species groups can potentially be present over a wide range of hydroperiods. As the hydroperiod is reduced to 90 days or less, however, then successive species groups may no longer find suitable habitat for successful breeding. Thus, in a dehydration succession, rapid changes in the species composition of the amphibian population would be expected as hydroperiods decreased to less than 90 days.

Definition of Adverse Ecologic Harm

For developing the assessment and costing methodologies, the predicted changes in hydrologic regime must be related to long-term changes in ecosystem values, such as function and structure. Establishing this relationship is difficult because there are many structural and functional aspects of wetland systems, which do not all respond in the same way to hydrologic changes.

Possible Categories

For the purpose of illustration, Figure 15 provides a graph of the following expected types of change in wetland function as a result of reduction in hydrologic regime:

- **Type 1.** Wetland functions are unaffected by hydroperiod reductions (water quality treatment potential, flood flow attenuation).
- **Type 2.** Wetland functions decline nearly linearly with hydroperiod reduction (fish populations).
- **Type 3.** Wetland functions change in a non-linear manner (water fowl usage).
- **Type 4.** Functions increase following hydroperiod reduction (usage by small mammals, tree growth).

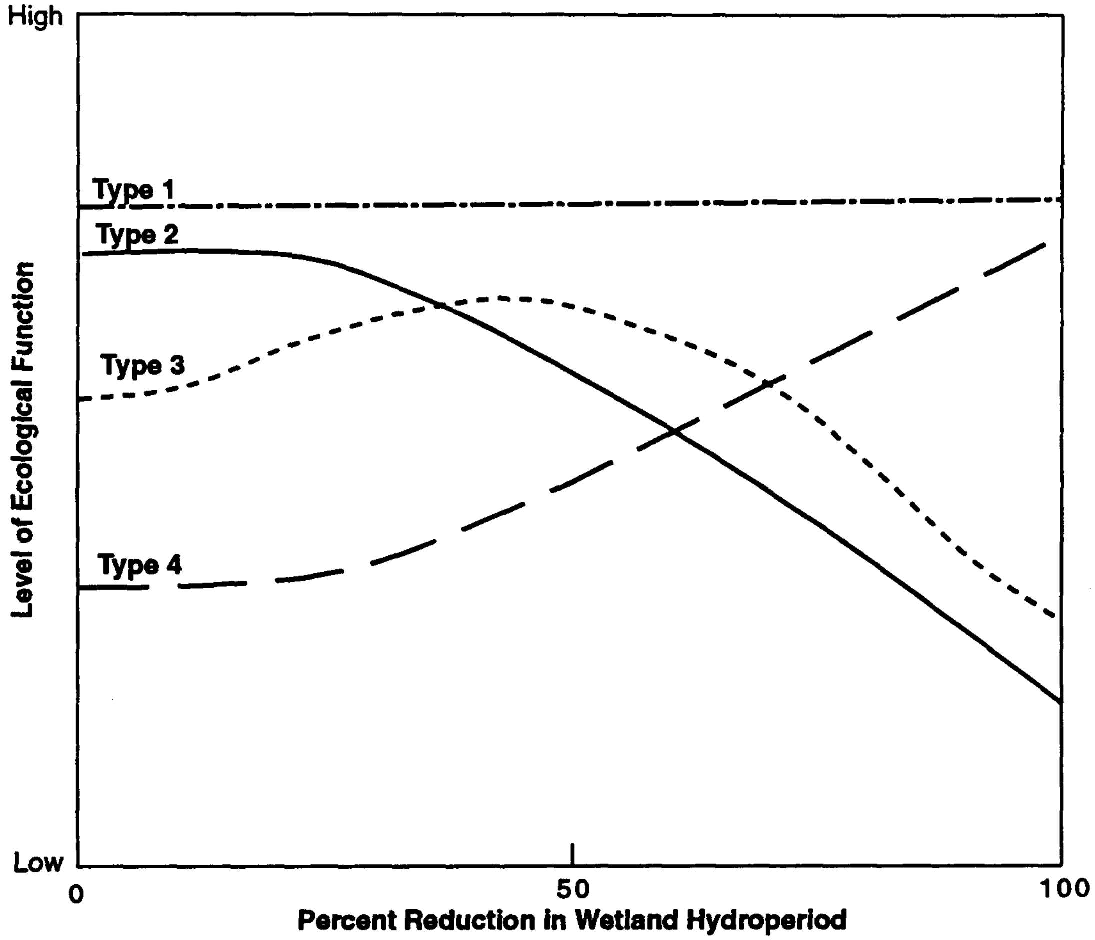

Figure 15. General Response Curves for Change in Ecological Functions Resulting from Hydroperiod Reduction.

Because of the variable response of individual wetland functions, the process of relating hydroperiod reduction to an overall change in ecologic function is not simple. Furthermore, wetland function cannot be assumed to be negatively affected by all change in conditions (Lowe 1994). In addition, wetland function cannot always be assumed to change whenever the structure of the biological community changes (Adamus and Brandt 1990). Some changes in community composition may be compensatory, so new species replace the function of original species, while overall community biomass and sometimes species richness do not change (Cairns and Pratt 1986; Herricks and Cairns 1982).

A clear definition of what constitutes adverse harm is needed to attain the goal of assessing change in the ecologic values of wetland systems caused by decreased water table levels. For the purposes of this TM, an operational definition can be used. An operational definition is intended to be used as a planning-level tool and is not a suggestion for regulatory change. Definitions of harm or impact to natural systems caused by reductions in the water table have been developed by others (Lowe 1994; WCRWSA 1994) (Table 24).

Recommended Operational Definition

Because the focus of the mitigation costing effort is primarily concerned with changes in native vegetation and wetland-dependent fish and wildlife populations, an operational definition of unacceptable change for plant and amphibian communities will be used. The following proposed working definition is from Part 5 of the definition of unacceptable harm by Lowe (1994):

> "Unacceptable changes to flora and fauna will be indicated by replacement of the dominant species group such that another species or group of species becomes dominant or a significant increase in the on-site abundance or producti-vity of nuisance, exotic, or other uncharacteristic species occurs."

Categories of Ecologic Change

Following from the operational definition of harm, reductions in hydrologic regime can be related to their effect on wetland-dependent flora and fauna. To determine the magnitude of the effect of a given decrease in the water table, the reduction must be related to its potential to cause a shift in the dominant species, according to the operational definition of unacceptable change.

Table 24. Existing definitions of impact or harm

I. Hydrologic Impact—WCRWSA

A. Wellfield-Induced Wetland Impact

The annual duration of inundation in a wetland is reduced to a period less than that determined to be normal for wetlands of the same type

or

The annual depth of inundation in a wetland is decreased to depths less than those determined to be normal for wetlands of the same type

and

Wellfield operation has brought about the reduction in duration of inundation or the decrease in the depth of inundation.

B. Wellfield-Induced Lake Impact

A lake will be determined to be adversely impacted by wellfield production when the lake is located in an area demonstrated to be affected by wellfield-induced water table or Floridan aquifer drawdown AND investigation of the lake has shown that the lake has undergone a period of abnormally low levels, which has impaired its ecologic functions or its aesthetic and visual values, or both.

a. An area demonstrated to be affected by wellfield-induced water table drawdown has been shown by means of monitor well data or hydrologic model to have post-production water table elevations consistently or quantifiably lower, or both, than pre-production (or best estimate of preproduction) water table elevations.

b. Abnormally low lake levels, water surface elevations that are chronically below the adopted low management level (if lake has adopted levels), based on best available data. For lakes not having adopted lake levels, "low lake levels" will indicate surface water elevations usually below the historical levels, based on best available data.

c. Impairment of ecologic function occurs when:

1. The original littoral zone is stranded, or
2. Water quality degradation occurs, or
3. Thermal refugia is eliminated, or
4. Establishment of nuisance species is accelerated or expanded due to photic zone changes.

d. Impairment of aesthetic/visual values occurs when excessively broad areas of beach are permanently exposed or when the depth of the lake is reduced to the point at which normal recreational activity is not possible.

C. Biological Impact

Vegetative Impact is based on 1) shift in wetland species as recognized by the District; or 2) shift in NWI index to species composition more indicative of drier conditions; or 3) shift from obligate (OBL) species that are indicative of stable water levels to OBL species that are indicative of pulsating water levels (development of "modified" NWI index list to be determined in cooperation with the District).

Wildlife Impact is any potential negative relationship between hydrologic alteration and usage by wetland-dependent wildlife species.

Table 24 (Continued). Existing definitions of impact or harm

II. Unacceptable System Harm–Florida Subcommittee
Definition: Anthropogenic effects on hydrology that have caused, or are expected to cause, directly or indirectly, singly or cumulatively, by their extensiveness, intensity, duration, or frequency, one or more of the following for more than 5 years:
1. Local or regional extirpation of one or more native species.
2. Onsite, local, or regional reduction in abundance or reproductive success of a listed, endemic, or regionally rare native species.
3. Onsite, local, or regional reduction in abundance or reproductive success of keystone species.
4. Local or regional reduction in abundance or productivity of a commercially or recreationally significant population of a species.
5. Onsite replacement of the dominant species group of the flora or fauna such that another species or group of species becomes dominant or a significant increase in the onsite abundance or productivity of nuisance, exotic, or uncharacteristic species occurs.
Interpretation of the general statement reveals the following salient aspects:
"Anthropogenic effects on hydrology" - This portion of the statement clarifies that the source of harm must be a human-induced change in hydrology. Thus, human-induced changes to hydrology must be distinguished from those due to natural factors.

Sources: SJRWMD 1994; WCRWSA 1994.

Possible Categories

The extreme ranges of potential effects define the endpoints. At the low-impact end, there is a level of hydrologic change for which no change in dominant species is expected. In this case, based on the definition of harm, no mitigation would be required. At the other end of the range is a significant shift in species composition for both flora and fauna and hydrology toward upland conditions, which result in the site no longer being considered a regulated wetland under SJRWMD's guidelines. In this case, the mitigation requirement would be 100 percent of the area affected under the assumption that non-jurisdictional areas could be filled or otherwise used for development.

Between the two extremes, several other categories of vegetative change are possible, with the intermediate categories representing the intermediate stages of change in dominant species of plants and animals of a dehydration succession. This view of successional change is based on the Gleasonian model of wetland succession (van der Valk, 1981; Dunn 1989b; Mitch and Gosselink, 1993) in which the community composition is determined by the life history characteristics of the species present and the prevailing environmental conditions. Each life history type has its own unique set of characteristics and associated response to prevailing environmental conditions, which act as a "sieve" in determining the species composition of the wetland. As environmental conditions such as the hydrologic regime change, so does the action of the sieve and, therefore, also the species present. Five categories of change are proposed: (1) no change in the mix of dominant species, (2) some changes in the mix of dominant species, but wetland type and species assemblages remains the same (for example, cypress swamp will remain cypress swamp), (3) a shift in both the mix of dominant plant and animal species and wetland community type (for example, cypress swamp will trend toward cypress mixed with slash pine), (4) a significant shift in dominants and hydrologic regime, resulting in a short hydroperiod wetland or transitional upland community, or both, and (5) a shift to uplands conditions.

Recommended Categories of Ecologic Change

The following five categories of ecologic change are recommended:

- **Category 1.** Water table reductions are limited to the range of conditions in which the dominant plant and amphibian species and the community are adapted; thus, no short- or long-term shift in dominants is predicted.
- **Category 2.** Water table reductions create a hydrologic regime that will support species more characteristic of lower flood levels or shorter hydroperiods, or both. Some shift in the mix of dominant species in one or more vegetative strata are expected in the long-term; however, the wetland type remains the same. Also, the amphibian assemblage is little changed.
- **Category 3.** Further water table reductions occur, with the long-term shift in dominant plant and amphibian species resulting in a shift of wetland type to one that is in a "drier" position along the dehydration succession gradient (a shift from cypress swamp to hydric hammock). However, the hydrologic conditions remain conducive to wetland viability; therefore, the community remains a wetland functionally, structurally, and jurisdictionally.
- **Category 4.** Even greater water level reductions occur, further shifting the community's position along the dehydration succession gradient and possibly resulting in a species shift to a very short hydroperiod wetland community or an upland transitional community.
- **Category 5.** Severe water table reductions occur, inducing long-term changes in the community so that the area is no longer a jurisdictional wetland under SJRWMD's regulatory program.

Each of these categories can be assigned a mitigation percentage between 0 and 100 percent, based on the degree of shift toward the condition of being non-jurisdictional. For the purpose of mitigation costing, it is recommended that values of 0, 25, 50, 75, and 100 percent be used for categories 1 through 5, respectively.

Categories of change can be assigned to each wetland type. Because a deep wetland can undergo a wider range of changes along a dehydration succession than a shallow wetland, one or more of the middle categories listed above may not measurably or meaningfully apply to shallow types of wetlands. Appendix C provides a summary of the proposed vegetative change category information for the major wetland types expected to be addressed in the analysis, such as hydric flatwoods, hydric hammock, wet prairie, scrub shrub thicket, floodplain swamp, mixed hardwood swamp, cypress swamp, freshwater marsh, and pond and slough. The summary tables provided in Appendix C present a dehydration succession sequence for each wetland type, along with sequential changes in the hydrologic regime parameters.

Details of the costing method are provided at the end of this TM. Initial application of the costing method for generating the planning-level mitigation costs for the WRCAs will be accomplished with a tabular summary of unit costs.

APPLICATION OF THE IMPACT ASSESSMENT METHODOLOGY

The general approach to the impact assessment methodology has been described in preceding sections of this TM, with recommendations made for the following key elements:

- Hydrologic regime change assessment methods
- Target wetland hydrologic regimes
- Faunal indicator groups
- Definition of adverse harm
- Categories of biological change

These elements form the basis of the impact assessment methodology (Figure 16).

The first application of the impact assessment methodology will be presented in the second TM (E.1.h) and will be a planning-level estimate of the total cost of mitigating the unacceptable effects on native vegetation within the WRCA. During this first application of the methodology, CH2M HILL and designated SJRWMD staff will confer at appropriate points in the process to reach consensus on such items as assumptions, data quality, and protocols. Planning-level costs will be developed for WRCA inventory data provided by SJRWMD. Input data will be derived from SJRWMD's best available GIS information and previous analyses (Vergara 1994; Kinser and Minno 1996). SJRWMD will provide acreage values for the potentially affected areas of the WRCAs. It is anticipated that this information will be arranged in categories by major wetland type within each WRCA and by degree of predicted water table drawdown within each type within each WRCA.

As part of the initial application of the impact assessment and costing methodology, a sensitivity analysis of the input parameters will be conducted. The approach and assumptions to be used in the sensitivity analysis will be developed in consultation with SJRWMD staff. It is anticipated that the sensitivity analysis will be performed on the effects of varying all input parameters. The final parameter values will be established in consultation with SJRWMD staff after completion of the sensitivity analysis.

Procedural Steps

The impact assessment and costing process consists of the following eight steps:

1. Define baseline hydrological and ecological conditions.
2. Obtain estimate of water table drawdown.
3. Estimate the effect of water table drawdown on the wetland's hydrologic regime.
4. Estimate the effect of hydrologic change on dominant plant and animal species.
5. Determine the degree of ecological change.
6. Calculate the acreage of impact.
7. Calculate the final mitigation requirement.
8. Calculate the planning-level mitigation costs.

These eight steps are illustrated in Figure 16 and described below.

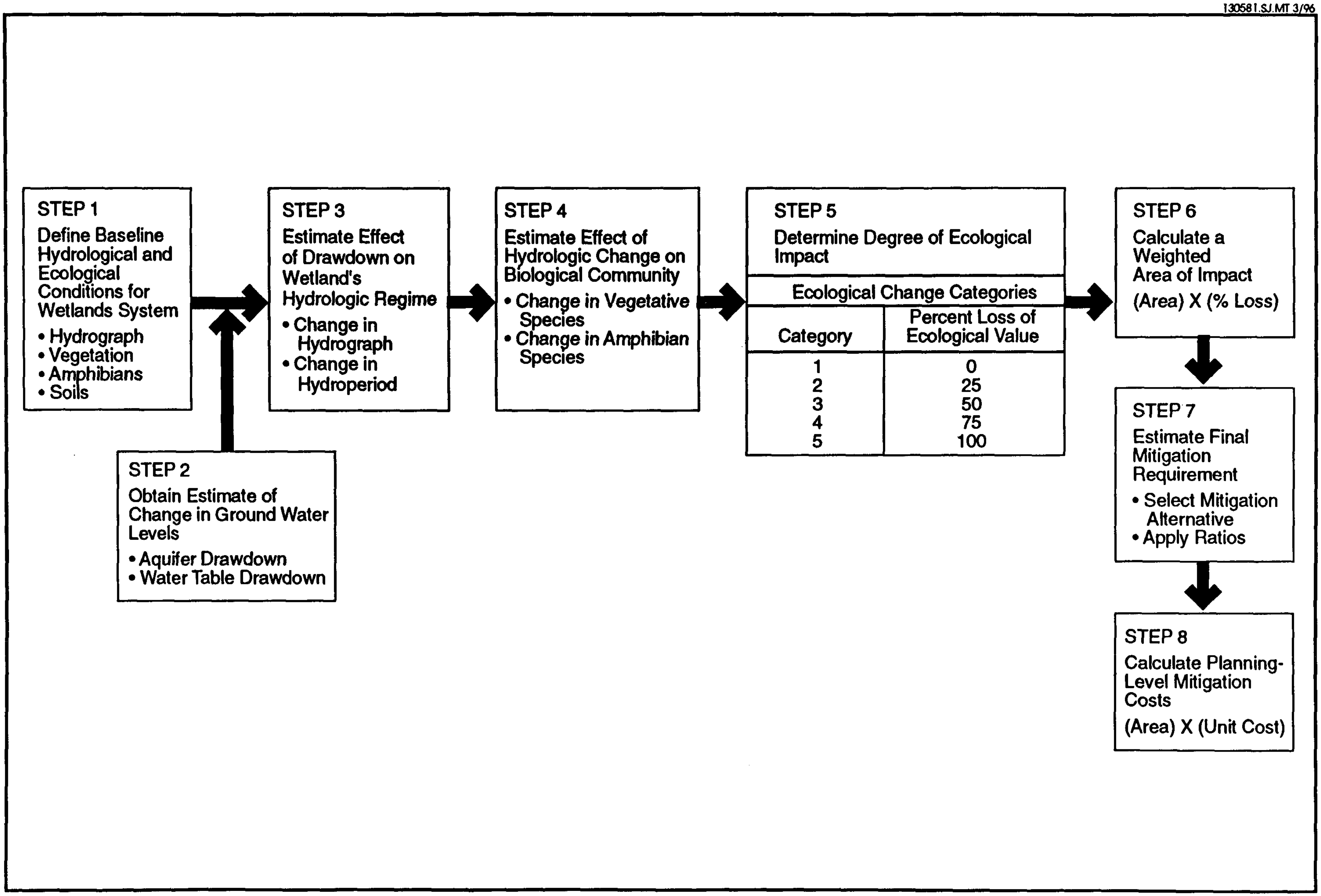

Figure 16. Proposed Impact Assessment Methodology

Step 1. Define Baseline Conditions for the Wetland of Interest

Define the existing or baseline conditions for the wetland of interest by assessing such characteristics as hydrologic regime, wetland type, dominant species for flora and fauna, and type of soils. For the first application of this methodology under Task E, the baseline information will be supplied by SJRWMD from previous work done in support of the needs and sources survey. The data used to define ecological conditions will be SJRWMD's best available level of GIS information.

Step 2. Obtain Estimate of Water Table Drawdown

Obtain the prediction for mean water table drawdown in the wetland of interest from SJRWMD. The Floridan aquifer drawdown is expected to be derived from SJRWMD's steady-state groundwater model. The estimate of water table drawdown in the wetland of interest, based on the predicted Floridan drawdown, will be calculated by SJRWMD staff.

Step 3. Estimate the Effect of Predicted Water Table Change on the Wetland's Hydrologic Regime

Assess the effect of estimated water table drawdown on the hydrograph for the wetland by using the summary tables and figures in Appendix C. Using the baseline conditions defined under Step 1, select the appropriate summary page in Appendix C that corresponds to hydroperiod duration (e.g., 300 days). The summary page for a given hydroperiod contains a typical hydrograph (bottom left graph), a plot of change in hydroperiod as a function of the depth of water table drawdown (bottom right graph), and a summary spreadsheet. Using the predicted depth of water table drawdown, as estimated in Step 2, the reduction in hydroperiod can be estimated from the hydroperiod decline graph (bottom right) on the summary page. Also, using the predicted drawdown, a new hydrograph reflecting the changed conditions can be generated. Figure 12 provides a summary of hydroperiods for the major types of wetland communities in the WRCAs, while Figure 13 provides recommended mean annual hydroperiod values for the major community types.

Step 4. Estimate the Effect of Hydrologic Change on Dominant Plant and Animal Species

Assign predicted drawdown to the appropriate category of potential changes to dominant plant and animal species according to the tabular spreadsheet on the appropriate summary page of Appendix C.

Specifically, using the predicted hydroperiod, as determined in Step 3, read across the cells in the spreadsheet for the row corresponding to the hydroperiod for the selected wetland type until the predicted hydroperiod is within range. The column of that cell in the spreadsheet will provide summary information regarding the general category of ecological change and percent loss of ecological value.

Step 5. Determine the Category of Degree of Ecological Change and Associated Percent Loss of Ecological Value

The spreadsheet column determined in Step 4 defines the category of ecological change (one of five possible categories) and the percent loss of wetland value (range between 0 and 100 percent). Categories of ecological change have been defined in terms of the operational definition of adverse harm.

Step 6. Calculate Potential Acreage of Impact

Multiply the percent of ecological value loss, as determined in Step 5, times the acreage value of the wetland affected to determine the acreage of impact.

Step 7. Calculate Final Mitigation Requirement

Select mitigation options and apply the recommended ratios to the acreage determined in Step 6 to generate a final mitigation requirement. For the initial application of the methodology, CH2M HILL will recommend preferred mitigation options for each land area assessed. The recommendations will be based on wetland type, site characteristics, degree of predicted hydrologic change, and other relevant site-specific and regional characteristics.

Step 8. Calculate Planning-Level Mitigation Costs

Using the final mitigation requirement, as estimated during Step 7, and recommended unit mitigation costs provided in this TM, estimate planning-level costs for the desired mitigation options.

Example Application

The following example of a hypothetical cypress swamp demonstrates the application of the methodology:

- **Step 1. Define baseline conditions for the wetland of interest.** The potentially affected wetland is a 100-acre cypress swamp with an estimated average annual hydroperiod of 240 days. From the summary page for the 240-day hydroperiod wetland in Appendix C, a seasonal high water depth of 1.25 feet within the swamp is predicted from the hydrograph (lower left graph on summary page)

- **Step 2. Obtain estimate of water table drawdown.** For this example, the water table drawdown is given as 1 foot.
- **Step 3. Estimate effect of predicted water table change on wetland's hydrologic regime.** Using the predicted 1-foot depth of water table drawdown, the hydroperiod reduction can be estimated from the hydroperiod decline graph (bottom right) on the summary page. The predicted hydroperiod is approximately 40 days, a reduction of 200 days from the baseline condition of 240 days.
- **Step 4. Estimate effect of hydrologic change on dominant plant and animal species.** Using the table on the summary page, locate the cypress swamp under the listed community types in the left hand column. Reading across the cells in the hydroperiod row for cypress swamps, a 40-day hydroperiod falls within the 0- to 60-day range in the fourth data column. For the cypress swamp community, a change to a transitional pine-cypress or hydric hammock community is predicted, while for the amphibian community, the loss of two to five species groups is predicted.
- **Step 5. Determine the category of degree of ecological change and associated percent loss of ecological value.** The fourth data column, as selected in Step 4, defines Category 4 of ecological change, which corresponds to a transition to upland conditions for both vegetative and amphibian communities. Category 4 corresponds to a 75-percent loss of ecological value.
- **Step 6. Calculate potential impact acreage.** Multiplying a 75-percent loss in ecological value by the 100-acre area yields 75 acres of affected wetland area.
- **Step 7. Calculate final mitigation requirement.** For this example, the selected mitigation option is wetland restoration. The recommended ratio for forested wetlands is 3.5:1. Seventy-five acres at a ratio of 3.5:1 yields an overall mitigation requirement of 262.5 acres.
- **Step 8. Calculate planning-level mitigation costs.** Using the 262.5-acre mitigation requirement, as estimated during Step 7, and the recommended unit mitigation cost of $17,500 per acre for wetland restoration, the estimated planning-level cost for the selected mitigation option is $4,593,750.

MITIGATION COSTING METHODOLOGY

The literature regarding mitigation costing is limited. Recent reviews and summaries by King (1994a through 1994d) provide some perspective on the range of costs for mitigation projects throughout the country. This information is helpful in assessing the gross differences in cost associated with project type, project goals, project size, and regional effects; however, it does not provide guidance on how to approach specific projects. Cost estimation for mitigation projects typically follows standard engineering design practice, which uses cost curves for planning- and conceptual-level estimates and develops more specific unit costs for more detailed project design estimates.

Recommended Mitigation Costing Method

Because costing methodologies or guidance documents are not common in the literature, we have selected an approach used previously by CH2M HILL for projects similar to SJRWMD's. This approach (CH2M HILL 1995) was developed to meet the costing needs of large-scale wetland restoration projects such as the Estuary Enhancement Project (EEP) on Delaware Bay for Public Service Electric and Gas.

A procedure was prepared to estimate the total cost of mitigating unacceptable impacts to native vegetation in the WRCAs caused by year 2010 pumpage for the following mitigation options:

- Wetland creation
- Wetland enhancement
- Wetland restoration
- Purchase of mitigation credits
- Land acquisition
- Land preservation
- Cash contribution toward an SJRWMD-approved mitigation project

The procedure is designed to address projected impacts in the WRCAs. In addition, the methodology is flexible so it can accommodate changes in the boundaries of such areas.

The costing methodology includes dividing the overall mitigation costs into cost categories. For each cost category identified, a general procedure for estimating the cost is provided. In some cases, development of costs will require site-specific field observations or measurements derived from a conceptual-level design for the site. In other cases, the site-specific costs will be derived from a cost curve developed from numerous data points.

Mitigation Cost Estimating Tool (MCET)

The costs associated with potential mitigation and restoration projects are important in prioritizing restoration efforts, selecting lands for acquisition, and setting budget allocations. With the MCET, the user can easily and quickly generate the necessary level-of-cost estimate. Table 25 provides a preliminary list of mitigation activities that may be needed for a variety of project types.

Table 25. Checklist—Design/construction activities that may be needed for a restoration project

Activities[a]	Selection Criteria[b]
Design	
Predesign Investigations	All sites. (Information is developed that will identify site-specific restoration activities.)
Design	All sites.
Permitting	All sites.
Surveying	All sites.
Land Acquisition	All sites.
Construction—Site Works	
Access Roads	Temporary access for construction.
	Permanent public access or management-related access.
	Replace or re-route existing roads after restoration.
Water Control Structure	Breach existing berms or construct a weir or dam.
Site Regrading	Construction activity of any kind.
Ditch Construction	New ditch to bring water to site or to drain an impounded site.
Berm Construction	New berm to contain water or to protect adjacent areas from restoration flooding.
Berm Improvement	Enlarge an existing berm to control water.
Exotic/Nuisance Species Control	Nuisance or exotic plant species onsite.
Wetland Vegetative Restoration	
Planting	Create wetlands or new upland communities.
Seeding	Create or restore large-scale marsh communities.
Water Brought to Site	Offsite source of water needed to restore wetlands.
Public Access/Recreation/ Education	Boardwalk, foot bridge, boat ramp, trails, signs, fencing, parking.
Mobilization/Demobilization	Construction or site work activity of any kind.

Table 25 (Continued). Checklist—Design/construction activities that may be needed for a restoration project

Activities[a]	Selection Criteria[b]
Operation & Maintenance (O&M)	
O & M	Construction activity of any kind.
Monitoring	Wetland alterations that have measurable success criteria.
Fire Management	Vegetative community alteration and management by fire.
Trust Fund	Long-term care by a third party.
Contingencies	
Design	Difficult Design Considerations
Permitting	Difficult Permitting Considerations
Construction Bid and Scope	Difficult Construction Considerations
Creditable Acres	All Sites.[c]

[a] The selected activities should be included in the cost estimating spreadsheet rollup.

[b] If your project meets the criterion, you should include this activity in the project restoration cost estimate.

[c] The number of acres that can be credited as mitigation will be used to calculate the cost-per-credit of the project (total project cost divided by the creditable acres).

Key Aspects of MCET

The method divides the overall restoration activities into costing categories. For each category, a general procedure was generated for estimating the costs associated with a site. All categories may not apply to every site. In some cases, site-specific field observations or measurements derived from a conceptual design will be required to develop the mitigation costs.

Cost estimates can be generated at any level of detail required, from planning level to conceptual and detailed levels.

Planning Level Costs

Generate order-of-magnitude cost estimates derived from cost curves and generalized unit costs for typical mitigation options.

- **Conceptual Project Costs**. Generate project costs for conceptual projects where some of the general project details are known.
- **Detailed Project Cost**. Generate specific costs for a project based on detailed project design.

The core of the cost-estimating tool is a spreadsheet that allows the user to input selected site characteristics or specific aspects of a mitigation activity and to incrementally generate a cost estimate. In addition, helpful tools and short cuts are provided in accessory spreadsheets, some of which are linked to the core spreadsheet. Accessory spreadsheets include a checklist to help the user decide the design and construction activities needed for a proposed mitigation or restoration project; an on-screen worksheet (for user input) that is linked to the core spreadsheet; an on-screen summary table that shows the user immediate results from the selections made on the on-screen worksheet; and cost curves from which some of the cost estimates are generated and linked back to the core spreadsheet. An MCET guidance manual will be developed to supplement the spreadsheets and cost curves (Figure 17).

Costs will be summarized using the categories established for the water supply options being considered in SJRWMD's water supply alternatives investigation, including the following:

- Construction costs
- Land cost
- Total capital costs
- Operation and maintenance (O&M) costs
- Equivalent annual cost
- Unit operation costs

Upon acceptance by SJRWMD, the procedure will be used to estimate the cost of mitigating the projected impacts of future ground water withdrawals within areas projected to experience moderate-to-high likelihood of harm to native vegetation. The work product for this effort will include a spreadsheet that can be updated or revised as needed. For this effort, the impact of maximizing ground water withdrawals will be provided by SJRWMD.

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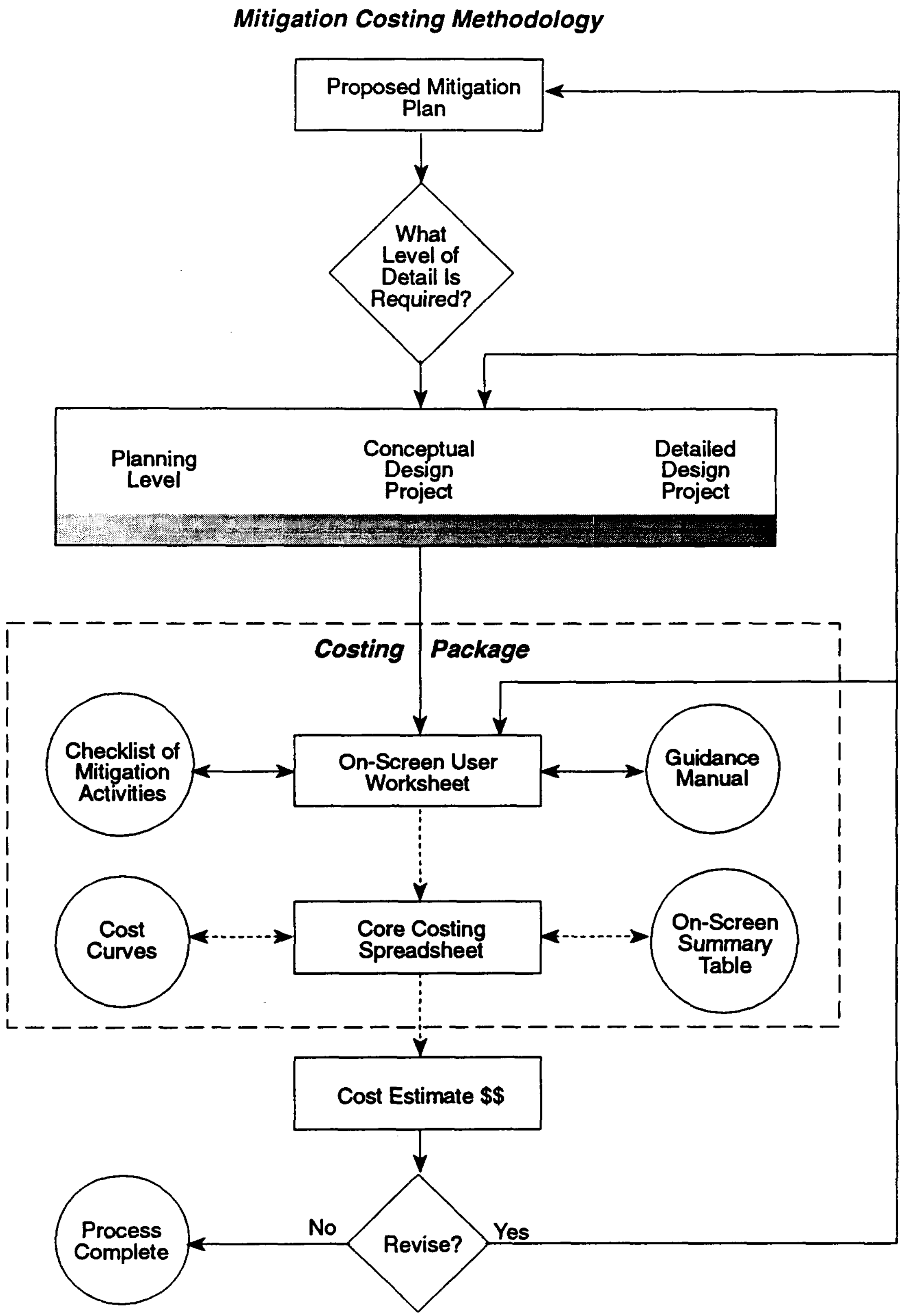

Figure 17. Proposed Mitigation Cost Estimating Methodology.

Preview of the Guidance Manual for the MCET

The guidance manual provides the details, assumptions, and criteria used to develop the cost estimating tool. The checklist of activities is a page reference to the details of a given cost category. All cost categories may not apply to every mitigation project. Criteria are provided in the manual and on the activities checklist for selecting the appropriate cost categories. The assumptions associated with the cost estimating methodology for each category will be summarized in the guidance manual.

A general approach will be warranted for activities such as predesign investigation, design, permitting, surveying, and land acquisition. The costing method recommended for each phase is described below.

Predesign Investigations. Predesign investigations will include such activities as a baseline biological inventory and habitat characterization, an environmental assessment, engineering data assessment, and archaeological investigation. The level of effort for these tasks will depend on site conditions, especially the size of the site. The level of effort will also be affected by the presence or absence of uplands in the project area. Costs for each predesign investigation will increase according to the areas of the parcel. Cost curves will be generated for this category.

The criterion for selecting this costing element is that all sites will require predesign investigations. The following types of information obtained in the predesign investigations will help formulate site-specific restoration and permitting strategies:

- **Biological Inventory**. Conduct baseline inventory of flora and fauna; characterize habitat conditions.
- **Environmental Assessment**. An impact assessment report is needed to support construction-related permitting.
- **Engineering Data Collection**. Site-specific studies are required for hydraulic modeling and design activities.
- **Archaeological/Historical Survey**.

Design. The level of effort will depend on site conditions, especially the size of the site. Costs for each design will increase according to the size of the area for which active intervention is required. All sites will have an associated design cost, which will be obtained from cost curves.

Permitting. The level of effort will depend on site conditions, especially the size and type of restoration activities. Costs for permitting will increase according to the complexity of the proposed restoration activities. All sites will have a permitting cost that includes preparation of draft permits and responses to requests for additional information.

Surveying. Surveying will be required for design and permitting activities. Property surveys will also be required for land acquisition. Wetland delineation surveying will be required for areas proposed for construction activities. At most locations, spot elevations will have to be obtained throughout the site in support of the design effort. Cross sections of ditches and canals may be required with certain restoration activities.

Land Acquisition. Land acquisition costs will be based on guidance provided by SJRWMD to ensure that the land cost estimates developed for the mitigation alternatives are directly comparable to the land cost estimates developed for other water supply alternatives.

Construction. Construction costs items are estimated from units costs, which in turn are generated from a series of backup costs and assumptions regarding the nature of the effort or activity (Figure 18).

Figure 18. Site Works Example

Access Roads. The level of effort will depend on the cumulative length of the temporary and permanent access roads to be constructed. These lengths will be estimated as part of the conceptual design activity. The round-trip haul distance must be determined on a site-by-site basis. Structural fill material and coarse aggregate must satisfy the following specifications:

Characteristic	Criteria
Material Finer Than No. 200 Sieve (max. %)	10
Crushed Fragments (min. %)	55
Compact Unit Weight (min. lb/cu. ft)	70
Deleterious Shale (max. %)	2
Friable Particles (max. %)	0.25

Access roads may be required for the following three reasons:

1. Temporary access for construction activities
2. Permanent public access or management-related access requirements
3. Replacement or re-routing of existing roads that will be flooded after restoration is complete.

In many instances, roads may be constructed initially for equipment access, but will be retained to serve permanent access functions. The length of temporary and permanent access roads will be estimated as part of the conceptual design activity. Based on the assumptions listed below, costs can be estimated as shown in the following table:

Item	Measurement	Unit Cost
Temporary Access Road		
Cost for Construction	Feet of Road	$/lf of Road
Cost for Removal	Feet of Road	$/lf of Road
Cost for Regrading and Seeding after Removal	Feet of Road	$/lf of Road
Permanent Access Road		
Cost for Construction	Feet of Road	$/lf of Road

1. All roads will be shell rock surfaced.
2. Dump truck and excavator access will be available to all construction areas.
3. All temporary access roads will consist of a single lane, 16 feet wide (12-foot lane with 2-foot shoulders). The road profile will consist of 6 inches of compacted coarse aggregate over a geotextile underlayment.

Figure 18 (Continued). Site Works Example

4. All temporary access roads will be removed after completion of restoration activities. The aggregate and subgrade will be excavated and disposed of offsite. The affected areas will be regraded and conservation seeded. The removal of access road will generate 0.6 cubic yards of waste per linear foot.

5. The temporary access road profile will be used for existing roads requiring improvements prior to construction.

6. All permanent gravel access roads will be 24 feet wide. The road profile will consist of 12 inches of coarse aggregate, compacted in 6-inch layers over a geotextile underlayment.

7. For permanent shell rock access roads, some preparation of the road subgrade was assumed, including minor grading, compacting, and localized excavation of weak subgrade materials, followed by replacement with structural fill. The cost for preliminary soil testing of subgrade is included.

8. Temporary access road profile and construction costs will be used for existing roads requiring improvements prior to construction.

SUMMARY OF RECOMMENDATIONS

Impacts to wetlands and other natural systems are one of several potential consequences of the water supply alternatives being evaluated by SJRWMD. This TM is the first in a series that investigates the feasibility of mitigation sequencing for providing compensatory mitigation for impacts resulting from the development of future public supply needs.

This TM summarizes the relevant background information, identifies the availability of impact assessment data, and presents methodologies and assumptions for the quantitative evaluation of wetland system impacts and for generating cost estimates of mitigation actions. As part of the methodology development, the TM also presents an overview of the factors affecting hydroperiod and biological responses and the mix of regulatory issues that may bear on the CUP process.

Based on the information contained in this TM, the following 14 recommendations are presented for SJRWMD's consideration:

1. Acceptance of the proposed wetland impact assessment and mitigation costing methodologies.
2. The unit costs recommended for use in planning-level costing are as follows:
   - Wetland creation—$37,500 per acre
   - Wetland restoration—$17,500 per acre
   - Wetland enhancement—$13,750 per acre
   - Land acquisition—$2,500 per acre for uplands and $500 per acre for wetlands, plus $300 per acre for land management activities
   - Purchase of mitigation bank credits—$30,000 per credit
   - Cash contribution toward a SJRWMD-approved mitigation project will be handled on a case-by-case basis
3. Matching the accuracy and precision of the assessment and costing methods to that of their inputs and expected outputs.
4. The recommended mitigation ratios for creation and restoration (3.5:1 for forested wetlands; 2.75:1 for herbaceous wetlands),

enhancement (12:1), and preservation (35:1 for wetlands; 11.5:1 for uplands).

5. A hydrologic regime change assessment method based on wetland hydrographs.
6. A finer level of community definition consisting of 10 major wetland community types: hydric pine flatwoods, oak hydric hammock, cabbage palm hydric hammock, wet prairie, floodplain swamp, shrub swamp, mixed hardwood swamp, cypress swamp, freshwater marsh, and ponds and sloughs.
7. The use of hydrographs to characterize the hydrologic regime (depth, duration, frequency, seasonality of flooding) for each wetland type.
8. The use of amphibians as the indicator faunal group because their breeding and reproductive requirements are best related to the hydrologic regime.
9. An operational definition of unacceptable harm based on the likelihood of changes in dominant species.
10. The five categories of ecologic change, which are based on the degree of change in dominant species and, thus, are directly tied to the operational definition of harm.
11. Relation of mitigation requirements to the following categories of change: 0, 25, 50, 75, and 100 percent.
12. The use of the following eight-step impact assessment and cost process:
    - Step 1. Define baseline hydrological and ecological conditions.
    - Step 2. Estimate water table drawdown.
    - Step 3. Estimate effect of water table drawdown on wetland's hydrologic regime.
    - Step 4. Estimate effect of hydrologic change on dominant plant and animal species.
    - Step 5. Determine percent loss of ecological value and degree of ecological change.
    - Step 6. Calculate potential impact acreage.

- Step 7. Estimate final mitigation requirement.
- Step 8. Calculate planning-level mitigation costs.

13. Use of the integrated costing methodology at all three levels (planning, conceptual project, and detailed project).
14. Performance of an expanded sensitivity analysis on the key assumptions, criteria inclusion/exclusion errors, and definition of harm used in SJRWMD's screening analysis.

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Appendix A

Potential Causes, Effects, and Physical Indications of Altered Hydrologic Regimes

Table A-1. General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
I. Surface Drainage and Changes on Watershed Runoff Characteristics	1. Ditching/draining may reduce hydroperiod by 50 percent (b) 2. Rainfall influential on water level [e,u] 3. Dewatering techniques (draining, flood control measures) often reduce hydroperiod [j] 4. Manmade drainage may exacerbate impacts to wetlands [h]
II. Soil Subsidence	1. Reduced hydroperiod [c] 2. Oxidation of soils [m] 3. Fire burns peat rapidly, [m] diminishing soils [b] 4. *Drought may cause soil oxidation* [e] 5. Dewatering techniques may cause soil oxidation [j] 6. Clearing may cause soil subsidence [j]
III. Waterward Vegetation Shifts	1. Inverse relationship between flood duration and number of wetlands species may exist 2. Fire may be second only to reduced hydroperiod as most influential on wetland environments [h] 3. Aquatic weeds may increase with increased flooding [c] 4. Reduced drought may cause greater wetland affinity [e] 5. Increased rainfall usually increases wetland affinity [e] 6. Marshes *of sedges/grasses become more emergent assemblages* with raising or stabilization of water tables [CC] 7. Marshes or sedges/grasses become pine flatwoods with lowering of water levels [CC]
IV. Sinkhole Formation	1. Rapid and extreme water level changes may promote cavern roof collapse
V. Tree Mortality	1. Lack of inundation may lead to treefall [p] 2. Proximity to wellfields may affect tree growth [e] 3. Resumption of historic hydrology may reduce treefall [e] 4. *Floodplain forests have least treefall, as altered hydrology not tied to forest through groundwater* [e] 5. Leaning/falling trees may be associated with long-term dewatering [y] 6. High litter accumulation may be caused by long-term dewatering [y]

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
VI. Upland Vegetation Shift	1. Inverse relationship may exist between number of species in a wetland and duration of flooding [b,c] 2. Reduction of hydroperiod may shift species from pine flatwoods to hardwood forests [b] 3. Oak-palm hammocks can survive cool surface burns [b] 4. Increased flooding may cause emergents to die [c] 5. Wetland vegetation returns to normal after end of drought if dry period not of too long duration [b,e] 6. Reduction in wetland vegetation may result from increased drought [e] 7. Additional water stress from greater demand may harm wetlands [e] 8. Dewatering techniques (draining, flood control, wells) may stress wetland vegetation (especially herbaceous) [j] 9. Clearing may reduce wetland habitat and plants [j] 10. Fires may be second only to decreased hydroperiod in altered wetland succession [h] 11. Slash pine may invade cypress in response to drought, drawdown, well pumpage, decreased flooding [w] 12. Periodic fires do not significantly affect vegetation composition of normally dry cypress domes, but may kill off small pines [w] 13. Trend in vegetation from well pumpage may shift from obligate and FACW to FAC and FU [x] 14. Deep groundwater pumping may stress wetlands vegetation due to limiting water [CC] 15. Marshes of sedges/grasses may shift from pine flatwoods with lowering of water levels [CC] 16. Wetlands may transition into shrubby upland habitat from groundwater drawdown [DD]
VII. Below Normal Rainfall	1. Weather pattern shifts (USGS; National Weather Service) 2. Drought cycle (USGS; National Weather Service and SCS data) [e] 3. Possible reduction of local vegetation results
VIII. Below Normal Groundwater Levels	1. Water table may fall from altered hydrology [c] 2. Water table increases may restore former hydrology [c] 3. Ditching may cause water table to fall (Montague; Twilley) [b] 4. In dry seasons, water level >1 to 2 feet lower than normal in unditched wetlands [b] 5. Greater water level variation occurs in dry seasons [e] 6. Levels rise with increased rainfall , although level of increase greater in undetected, then ditched, wetlands[b, e, h]

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
VIII. Below Normal Groundwater Levels	7. Drawdown effects suggested by high variability [e] 8. High monthly rainfall equals decreased drought and the reverse situation [e] 9. Low monthly rainfall produces a groundwater minima and the reverse [e] 10. Low temperatures and higher water levels may lower groundwater levels [e] 11. Normal water level fluctuations key to maintaining wildlife systems [j] 12. Timing of wet/dry cycle also key to system maintenance [j] 13. Direct rainfall and rainfall-derived inflow chief factor affecting increasing water levels [h] 14. Evapotranspiration, discharge through outlets, and soil seepage chiefly decrease water levels[h] 15. *Rainfall intensity, size/slope sides, and soil permeability influences surface water levels* [h] 16. Wetland/aquifer gradient affects groundwater level [h]
IX. Exotics Species Encroachment	1. Exotics may increase in stressed aquatic environments [d,e] 2. Fire may retard hardwood forest fruiting and succession [b] 3. Ditching may promote exotics; reduce productivity of native species (Montague; Twilley) 4. Increased flooding may lead to species shifting [c] 5. Low exotics invasion in unaltered wetlands [d] 6. Low invasion with return of normal hydrologic conditions [d,e] 7. Drought may encourage invasion [e] 8. Altered hydrology may alter species habitats and composition, allowing exotics in [e] 9. *Dewatering techniques (draining, flood control, wells) may encourage exotics encroachment* [j] 10. Clearing may allow exotics into system [j] 11. *Fire may allow exotics into system* [j]
X. Fire Severity Increases	1. *Decreased water levels may promote severe fires* [h] 2. Reduced hydroperiod may alter vegetation, resulting in increased fires and severity [j] 3. *Fire cycles very important to maintaining plant communities* [h] 4. Severe fire may be caused by long-term dewatering techniques [y]
XI. Productivity Change	1. Primary productivity may shift downward as flooding increases or decreases too far and too rapidly [e] 2. Productivity usually high in unaltered wetlands, although this differs on basis of separability [d]

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Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
XI. Productivity Change	3. Mammals less restricted to wetlands; less food/water dependent on them [e, j] 4. Lower surface water levels may decrease productivity of amphibians and reptiles [e] 5. Freshwater fishes may be negatively impacted by disturbed wetlands (food source) [j] 6. Dewatering may produce long-term effects [j] 7. Marsh and swamp species are usually the most severely impacted from reduced hydrology [j] 8. The NET effect on the ecosystem may be <u>negative</u> from altered hydrology [j] 9 Ditching may retard productivity of wetland native species (Montague; Twilley) 10 Drawdown timing changes may also lower fish productivity [j]
XII. Decreased Species Diversity	1. Species diversity may decrease when system stressed through increased flooding (Montague) [c] 2. Usually high plant diversity in unaltered wetlands [d] 3. Wildlife diversity usually high in unaltered wetlands [d] 4. Drought may reduce cypress dome and marsh diversity [e] 5. Wellfield proximity may impact diversity of nearby species [e] 6. Highly severe fires may reduce diversity [j] 7. Lower water levels may alter community structure [j] 8. Ditching may increase terrestrial species in cypress domes [j] 9. Reduced hydrology may change foodweb characteristics [j] 10. Fluctuating water levels may shift wildlife utilization [j] 11. Water depth is limiting to species who await prey in the water [j] 12. Hydrologic regime important to diversity of many species because protection and food source; must be normal for normal functioning [j] 13. Fire frequency, soil type, disturbance and adjacent habitats may determine plant types within ecological communities [h] 14. Water fowl usage may decline by 93% due to river channelization [AA] 15. Wading bird density and diversity may decline due to river channelization [AA]
XII. Decreased Species Diversity	16. High/low water levels may severely impact wildlife [j] 17. Increased predation from too high/low water levels in water bodies of wetlands may alter fish community structure [j] 18. Community balance maintenance depends upon normal annual water cycle [j]

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
XIII. Decreased Number of Species	1. Drought can reduce number of mammals, vertebrates, amphibians, reptiles, and aquatic birds [e, j] 2. Drought can lead to abandoned rookeries [e] 3. Reduced water levels may lead to abandoned rookeries [e] 4. Increased flooding can cause reproductive failure in some species [j] 5. Number of invertebrates may decline due to drawdown and food availability decrease [z] 6. Some fishes may be reduced or eliminated by river channelization [AA] 7. Largemouth bass fisheries may decline from channelization [AA] 8. Alligator nests may decline from channelization effects [AA] 9. Bald eagle nests may decline from stream channelization [AA] 10. Fish kills may result from lower water levels and lower water quality [j] 11. Bald eagle nesting may decline 74% due to river channelization [AA] 12. Wetland habitat loss decreases populations [j] 13. Drought may reduce total # amphibians and reptiles [e] 14. Copulation requires consistent hydrologic regimes [j]
XIV. High Water Level Variability	1. Proximity to wellfields may cause higher variability [e] 2. Ditching in cypress domes may cause less persistent surface water and increased variability [j]
XV. Plant Growth/Mortality	1. Growth of some species (i.e., popash) usually not affected by proximity to wellfields [e] 2. Cypress domes and marshes may be susceptible to drawdown effects [e] 3. Wellfield effects less significant on herbaceous vegetation [e] 4. Additional water stress during drought may be harmful to system functioning[e] 5. Cypress domes may not be severely harmed by clear-cutting [w] 6. Less wetland growth may result from lower surface and groundwater levels from well production [x] 7. Tree rot associated with long-term dewatering [y] 8. Increased plant growth observed may be due to well-timed drawdown and associated nutrient release [z] 9. Certain plants (emergents) may not be affected by timed drawdown; others (submergents) may decrease [z] 10. Some drawdown important to germination of wetland plants [z] 11. Greater tree growth rates as wetter conditions return [BB] 12. Seedling growth and recruitment/flowering indirectly controlled by hydrologic regime [EE]

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
XVII. Water Quality Degradation	1. Water quality may fall with falling water levels [i] 2. DO levels may fall due to river channelization [AA]
XVIII. Altered Wildlife Habitat	1. Drainage may produce habitat loss, especially to marsh systems [i] 2. Dewatering techniques (draining, flood control, wells) may diminish habitats [i] 3. Marshes and cypress swamps may be most negatively impacted from altered hydrology [i] 4. Clearing may diminish wildlife habitat [i] 5. Fire may diminish habitats [i] 6. Decreased water levels may degrade water quality and diminish habitats [i] 7. Too high/low water levels may severely impact systems [i] 8. Bald eagle nests, alligator nests, and some fisheries may decline or be eliminated due to stream channelization [AA] 9. Water level fluctuations influence habitat values of wetlands [i] 10. Snail kite not very affected by hydrologic alteration and water level fluctuations [i] 11. Altered hydrologic cycle may negatively impact freshwater fish use of wetlands [i] 12. Alligator nests may decline from channelization [AA] 13. Increased flooding may negatively impact some wildlife habitats (alligators, turtles) [i] 14. Higher water levels and longer hydroperiods can harm tree islands [i]
XX. Low Potentiometric Head and Pieziometric Level	1. Pumping lowers potentiometric head, allowing the surficial aquifer to drain, lowering the water table [y] 2. Pumping lowers the piezometric surface in a related fashion [y]
XXI. Soil Horizon Changes	1. Inundation marked by dark color surfaces [y] 2. Inundation marked by light gray color in sub-surface horizons with organic streaking or mottling [y]
XXII. Nutrient Fluctuations	1. Nutrients released due to soil oxidation [z] 2. Nutrients released due to drawdown reflects on soil constituent [z] 3. Aerobic nitrification may result from drawdown and exposure of soils to oxidation [z] 4. Plant remains decay, oxidize and release nutrients [z]

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Parameter	Physical Indicator
XXIII. Movement of Water Marks and Lichen Lines	1. Buttressing indicates inundation over time [y] 2. Water stains and marks indicate inundation [y]
XXIV. Root Exposure	1. Cypress roots may be exposed due to soil subsidence from dewatering, well pumping, or lowering of water levels [DD, e, j]

Sources:
(a) CH2M HILL/Winchester, 1986.
(b) CH2M HILL, 1987.
(c) CH2M HILL/Winchester, 1988.
(d) Brown 1991.
(e) ES&E, Dec. 1991
(f) ES&E, Feb. 1992.
(g) Brown, et. al., 1983.
(h) Bays/Winchester, 1989.
(i) ES&E, 1991a.
(j) ES&E, 1991b.
(k) ES&E, Jan. 1992.
(l) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); CRWF Ecological Monitoring WY 92 (Henigar & Ray); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).
(m) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).
(n) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).
(o) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).
(p) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); CYWF Sixth Annual Report WY 1993 (USF/HDR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).
(q) NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA)

Table A-1 (Continued). General summary table of potential causes and observed effects and physical indicators of altered hydrologic regimes

Sources:

[r] NPRWF Ecological Monitoring WY 1993 (HDR); NWHR Ecological Monitoring WY 94 (WAR); CYWF Sixth Annual Report WY 1993 (USF/HDR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); CRWF Ecological Monitoring WY 92 (Henigar & Ray); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).

[s] NPRWF Ecological Monitoring WY 1993 (HDR); CYWF Sixth Annual Report WY 1993 (USF/HDR); Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); CRWF Ecological Monitoring WY 92 (Henigar & Ray); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).

[t] Cross Bar Ranch WF Ecological Monitoring WY 1992 (BRA); Cypress Creek WF Ecological Monitoring Report, WY 91 (ESE).

[u] E.M.P., 1994

[v] ESE, 1993.

[w] Marois & Ewel, 1983.

[x] BRA, 1989.

[y] Gilbert, et.al., 1988.

[z] Kadlec, 1962.

[AA] Perrin, 1986.

[BB] BRA, 1987.

[CC] Rochow, 1985b.

[DD] Dooris, 1990

[EE] Gerriitsen, 1989.

[FF] NPRWF, 1993 (HDR).

[GG] NHRE, 1994 (WAR).

[HH] CBWF, 1993 (USF/HDR).

[II] CBRWF, 1992 (BRA).

[JJ] CRWF, 1992 (H&R).

[KK] STWF, 1993 (ESE).

[LL] CCWF, 1991 (ESE).

NOTE: Observations in [e] are for short-term hydrologic alterations and are inconclusive in some situations. Qualitative monitoring stations did not find wetlands overall to have been permanently impacted by short term drought or wellfields.

Appendix B

Summary of Wellfield Methodologies

Table B-1. Detailed summary of general wellfield methodologies

General Method		Specific Technology	Description	Source
I. Field Method	1	Staff Gage	•verticle incremented measuring rod •measures change in water level	ff, aa, hh, ii, jj, kk, 9
	2	Current Meter	•staff gage calibrated to rotating cups or propellars to measure stream flow	
	3	Continuous Recording Rain Gage	•gage which measures water levels using a continuous strip recorder or punch-tape recorder	aa
	4	Flow Meter	•uses methods described below such as slug tests, aquifer performance tests, or permeameter tests to measure pumping rate	
	5	Piezometer	•tube or pipe open to atmosphere on the top and groundwater on bottom	hh, jj
	6	Monitoring Wells	•measure water quality or groungwater level	ff, aa, hh, ii, jj, kk, 9
	7	Quantitative Vegetative Monitoring	•establishment of linear transects to serve as centerline for plots and quadrats using steel rebar encased in 0.hh "PVC pipe for permanent quadrat markers •percentage of cover for all plant species, leaf litter, and/or bare ground in each quadrat estimated quarterly •estimate number of schrubs, species, and DBH for trees in tree plots	ff, aa, hh, ii, jj, kk, 9
	8	Qualitative Vegetative Monitoring	•visually identify disturbances, note changes in vegetative composition (presence or absence of species) •visual inspection, health	d, ff, aa, hh, ii, jj, kk
	9	Quantitative Wildlife Monitoring	•timed opportunistic observations-typically 15 minutes at each site recording all visual and aural observation-notes	ff, aa, hh, ii, jj, kk
	10	Qualitative Wildlife Monitoring	•random visual observations	d, ff, aa, hh, ii, jj, kk
	11	Groundwater Sample Collection	•Samples collected from discrete depths using air lift sampling tube (analysis for Chloride, Sulfate, Total Dissolved Solids in accordance with WUP protocols	ii
	12	Soil Analysis	•visuall comparison of soil to referenced wetland soil under natural conditions	d
	13	Soil Analysis	• examine soil levels near base of trees for signs of root exposure	d, aa
	14	Soil Classification	•catagorize as well drained, moderately well drained,or poorly drained	d
	15	Soil Cover Analysis	•soil type digitized from Soil Conservation Service	d,ff
	16	Drainage Ditches	•classified as (1)lakes, ponds, reservoirs (2)canals and channelized streams (3)roadside/large drainage ditch (4) agricultural ditch •map/plot drainage features	d
	17	Fire Effects	•observations of condition of tree boles and understory vegetation for indications of servere burn	d, ff, aa, hh, ii, jj, kk
	18	Evidence of Human Activity	•signs of cattle grazing •*presence of refuse* •signs of extreme human presence-bike trails, cutting, digging, mowing, agricultural practices, water turbidity •development/signs of construction	d, ff, aa, hh, ii, jj, kk
	19	Attainment/Analysis of Well Cores	•estimates lateral extent and thickness of aquifers and semiconfing units using core samples of subsurface strata obtained from drilling wells	u
	20	Collection/Analysis of Drill Cuttings	•masses of materials are shorn off by drilling mechanism as it penetrates the hydrological formation	u, jj
	21	High Resolution Seismic Surveys	•lateral extent and thickness of aquifers and semiconfining units are determined by mapping locations of boundries of chronostratigraphic layers above and within the Floridan aquifer	u
	22	Ground Penetrating Radar	• lateral extent and thickness of aquifers and semiconfining units are determined by mapping locations of boundries of chronostratigraphic layers above and within the Floridan aquifer-*not useful when clay is present*	u
	23	Gamma-Ray Logging	•borehole geophysical technique to determine extent and thickness of hydrogeological layers that exibit contrasting levels of gamma-ray radiation	u

Table B-1 (Continued). Detailed summary of general wellfield methodologies

General Method		Specific Technology	Description	Source
			•gamma ray intensity monitored by lowering sensors down well bores •graph the intensity of natural gamma rays in subsurface strata versus well bore-hole depth	
	24	Aquifer Performance Tests	•pump production well to induce aquifer drawdown, which is observed by one or more observation wells at known distances from the pumping well •compare observed drawdown to theoretical drawdown derived from an analytical solution of groundwater flow equation •leakance estimates usually appear to be unrealistically high (limited applicability)	u u
	25	Slug Tests	•introduce or remove a known volume of water into or from aquifer via well or piezometer •observe amount required for water level in well to return to initial position •infer transmissivity or hydraulic conductivity of aquifer by comparing observed variation in water level with time to that resulting from an equation representing an idealized aquifer	u
	26	Permeameter Tests	•insert a sample of aquifer material into standpipe of known cross-sectional area •allow water,under a known gradient, to flow through after the sample is completely saturated •measure resulting volumetric flow rate •estimate verticle hydraulic conductivity using Darcy's equation of groundwater motion	u
	27	Mass-Balance Analyses	•estimates composite leakance of material between the bottom of the surface water body and regional aquifer system using hydraulic head of aquifer nearby the surface water and stage of the surface water body and Darcy's equation of groundwater motion	u
	28	Sink-hole Detection and Characterization	• uses ground penetrating radar •high resolution siesmic monitoring	u
	29	Groundwater Sampling	•collect samples from monitoring wells at descrete depths using PVC air sampling tube	aa
	30	Bottom Sediment Investigations	•Measure thickness and collect samples of bottom sediments using probe rods	u
II. Data Base	1	Land Use/Land Cover Classification	•interpretation of aerial photographs to determine land classifications •land cover classification used Level II as defined in FDOT Land Use,Cover and Forms Classification System, 1985 • group residential and commercial areas into six subclasses based on density of impervious area •select representative samples of single, multifamily, and mobile home developments-generating 4 classes of single family residential, 2 classes of multifamily, and 2 classes of mobile homes •black and white aerial photos	d
	2	Impervious Surface Cover	•select representative samples of each land type(impermiable surfaces, including buildings and pavement) and ink on acetate overlays, raster scanned, and measure using GIS software	d
	3	Land Development Index	•measure the percent of urban, agricultural, and natural covers using a grid •multiply each percent cover by weighting factor and than sum to obtain LDI for each cell •LDI =(9 * %urban + 2 * % agricultural + % natural)/90	d
	4	Power Density Index	•measure complexity of given land use/land cover in energy/time required to operate and maintain lanscape unit using multipliers from previous studies of energy budgets of land use and cover for urban, agricultural, and natural ecological communities	d
			•multiply land use/cover data by appropriate power density multiplier and sum to determine total power density	
	5	Ditch Density Index	•measures drainage density that accounts for drainage ditched of differing size using weighted method •determine drainage areas by using 15 x 15 grid and total length of each ditch sum by cell •multiply summarized ditch databy appropriate weight factor and DI index derived for each cell	d

Table B-1 (Continued). Detailed summary of general wellfield methodologies

General Method		Specific Technology	Description	Source
			•DI = 0.5 * (agricultural ditches) + 1.0 * (major and roadside ditces) +2.0 * (canals and channelized streams)	
	6	Water Table Depth and Differential	•average surficial aquifer depth for seasonal high and low were derived from soil data, where each soil type was wet season or dry season water table depths using data from SCS soil surveys •weighted average wet and dry season depths were computed for each wetland based on area of each soil type	d
	7	Bentsson (198jj) Water Drawdown Model	•quasi-three dimentional finite-difference simulation model of aquifer drawdown that simulates impacts on water table	d
III. **Agency**	1	West Coast Regional Water Supply Authority (WCRWSA)	•organization which supplies water to Tampa area	ff, aa, hh, ii, jj, kk
	2	United States Fish and Wildlife Service (USFWS)	•national organization in charge of fish and wildlife management •*National Plant List (Reed, Jr., 1988) and wetland affinity index*	ff, aa, hh, ii, jj, kk
	3	South West Florida Water Management District	•management organization for southwest Florida	aa, jj
	4	National Geodetic Vertical Datum	•vertical datum, serves as a control point	aa, hh, ii, jj, kk
	5	United States Geological Survey (USGS)	•collects and maintains data, incuding mapping and aerial photography, for surface and groundwater systems	ff, aa
	6	National Oceanic and Atmospheric Adeministration	•weather service organization	kk, 9
	7	Florida Game and Fresh Water Fish Commission	•organization in charge of fish and wildlife management in the state of Florida	aa
IV. **Remote Sensing**	1	photographs	•photographs for vegetation, disturbances, and gages	ff, aa, hh, ii, jj, kk
	2	aerial photographs	•black and white, infrared	ff, jj,ii, kk
V. **Statistical Analysis**	1	linear regression	•assumes linear relationship exists between independent and dependent variables-for every change in x there is a constant change in y •log or other transformations can be used on data that is not normally distributed prior to performing regression • Y = a + bX •Student t-test should be performed to check reliability of regression	u, aa, hh, ii, jj, kk
	2	AVOVA	•used to test for significant differences in wetland surface water hydrology between groups of stations located inside and outside 1-ft drawdown contour	ii, kk
	3	Independence of indices	•indices of development status were derived from land use/land cover data base (LDI,power density, impervious area) •three correlation matrices for the indices of development status and hydrologic function using 400-meter spacial data base •matrix correlations are given for entire wetland data set, non-wellfields, and wetland wellfields to explain which variables may have acted independently •low correlations => variables more independent of each other •low correlations => variables more independent of each other	d
	4	Sensitivity of indices	•related to whether predictors of alterations in hydrolic parameters like runoff and groundwater table, and resulting impacts on wetland function •establish relationship between urbanization and wetland quality sought measuring parameters thought to have direct impacts on surficial aquifer level •measured impervious surface, power density, LDI, and DI	d
	5	Spacial Influences of Urbanization	•analyze influences of development on two spacial scales	d
			•landscape scale evaluates landscape-scaled activities that might effect wetland quality-develop indices of development status using one square mile area around each wetland to test if there was a perceivable relationship between what happens in larger landscape and wetland ecological quality-based on previous work (d, in press) and analysis of groundwater drawdown by Wang and Overman (19jj8)	

Table B-1 (Continued). Detailed summary of general wellfield methodologies

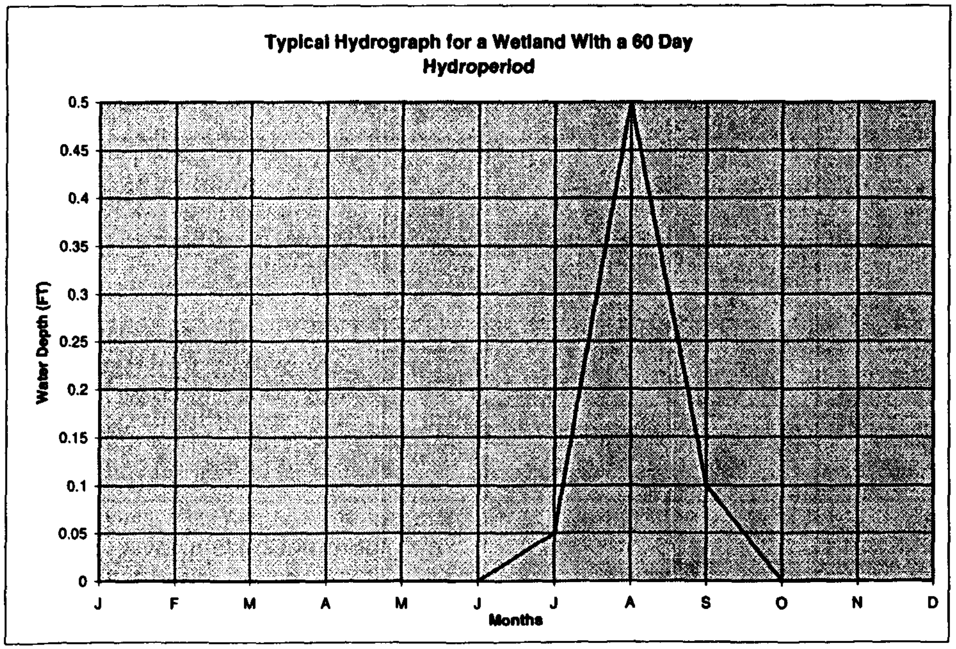
General Method		Specific Technology	Description	Source
			•local scale was an area with radius of 400 meters surrounding each wetland-derived from analytical analysis of drawdown inpacts (d and Schaefer 198jj; d, Schaefer, and Brandt 1989)	
	6	Temporal Influences of Urbanization	•Use of aerial photographs to interpret land use/land cover •field measurements of wetland quality ranking •ground truthing	d
	7	multicolinery test	•measure strength of interrelkationships amoung independent variables by calculating variance factor	aa
	8	double mass curves	•originally developed to check rain gage consistancy but can also be applied to stream flow •cummulative plot of data from one collection point against similar data from another collection point	u
	8 9	Frequency Analysis	•used to determine changes in distribution of flow ranges •flow for various river reaches are categorized in a series of flow ranges and either graphed or tabulated to identify flow characteristics and distribution	u, jj
	10	Correlation Analysis	•process by which the degree of association between samples of two variables is defined, usually by a correlation coefficient-measuring how each variable tracks one another	u
	11	Moving Averages	•determines long-term trends in data by removing short-term fluctuations •constuct a time series of averages over short time periods for entire record and calculate averages for each period, changing each subsequent period by dropping one year and adding the next-resulting in a smooth data curve	u
	12	Multiple linear regression	•involves analysis of more than one variable that may influence a dependant variable •varius combinations of development indices and groundwater levels •Y = a + b1X + ...BnX	d, u, aa, ii
	12	Systat [R]	•statistical software package used to graphically and statistically analyze potential impacts of wellfield pumpage on hydraulic and chemical parameters	kk
	13	Periodic Regression	•regress hydrologic parameter against time and the effect of the unknown variable on the parameter changes over time	u
VI. Modeling	1	Modular Three-Dimensional Finite Difference Groundwater Flow Model (MODFLOW)	•finite difference model used to simulate three-dimentional flow in multiple aquifers •horizontal flow simulation based on aquifer properties •verticle interchange between aquifers simulated as leakage based on hydraulic hed differences between aquifers and leakance coefficients of the aquitaeds •solves for head iteratively using a finite-difference stronly implicit procedure	d

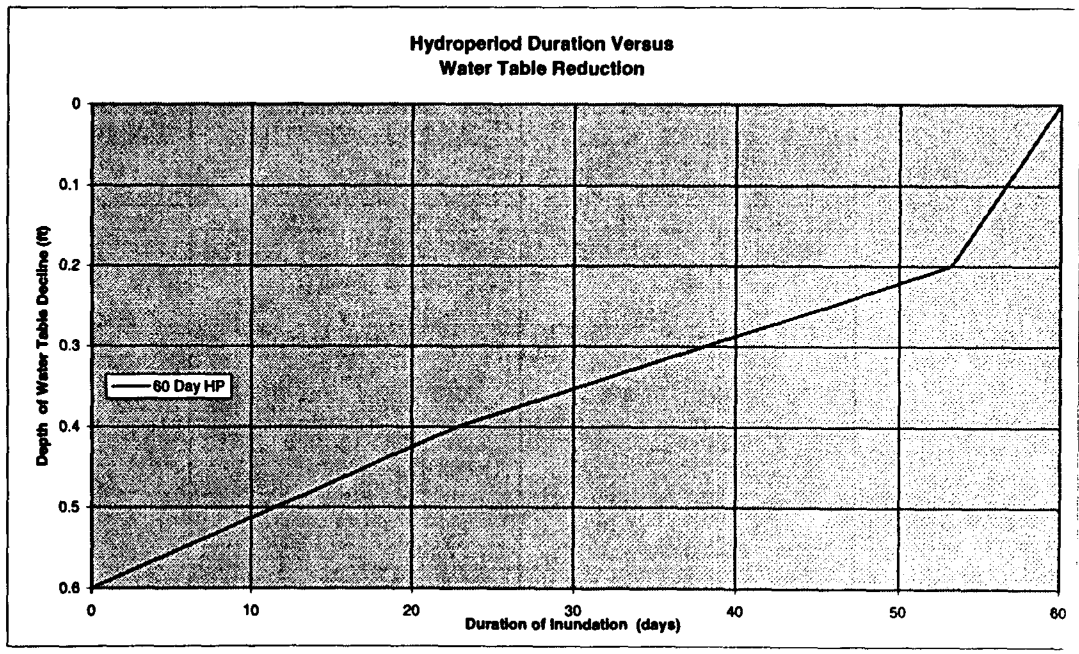
Appendix C

Summary of Hydrologic Regime Characteristics and Ecological Change Categories for Major Wetland Types

SUMMARY FOR WETLAND TYPES WITH 60 DAY HYDROPERIODS

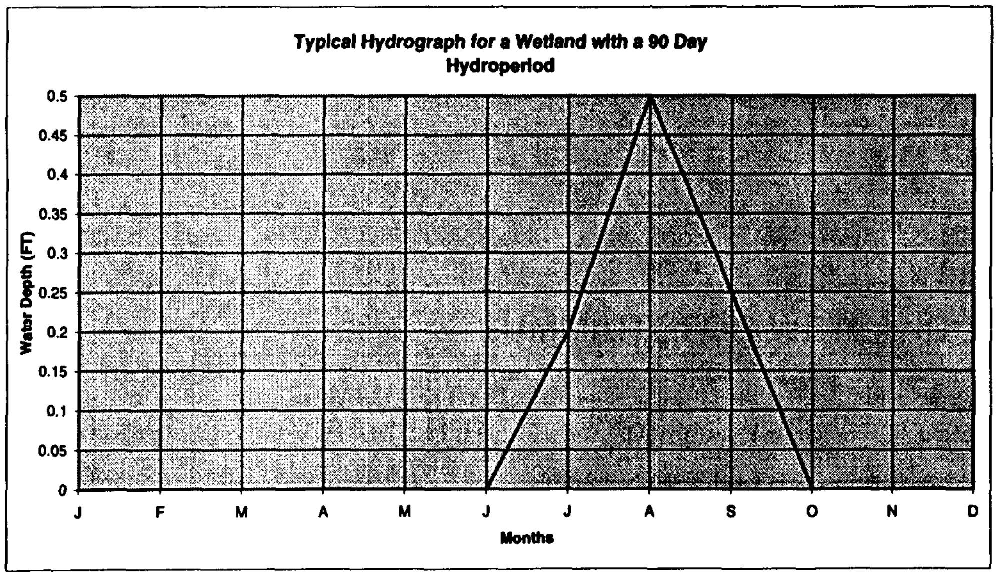
COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE			
	Category 1	***Category 2***	***Category 3***	***Category 4***
% Loss of Ecological Value:	0	33.3	66.6	99.9
Ecological Change Category:	*No change in dominant plant/animal species*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: ***a. Dry Prairie***	Dry Prairie	Dry Prairie	Pine/Prairie	Upland Community
Annual Hydroperiod (days):	60-45	45-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.25	0.25-0.15	0.15-0	0
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 4 5,6,7	Habitat for Groups 5,6,7	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only
Community Type: ***b. Hydric Flatwoods***	Hydric Flatwoods	Hydric Flatwoods	Transitional Flatwoods	Upland Community
Annual Hydroperiod (days):	60-45	45-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.25	0.25-0.15	0.15-0	0
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 4 5,6,7	Habitat for Groups 5,6,7	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only
Community Type: ***c. Hydric Oak Hammock***	Hydric Oak	Hydric Oak	Transitional Hammock	Upland Community
Annual Hydroperiod (days):	60-45	45-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.25	0.25-0.15	0.15-0	0
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 4 5,6,7	Habitat for Groups 5,6,7	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only

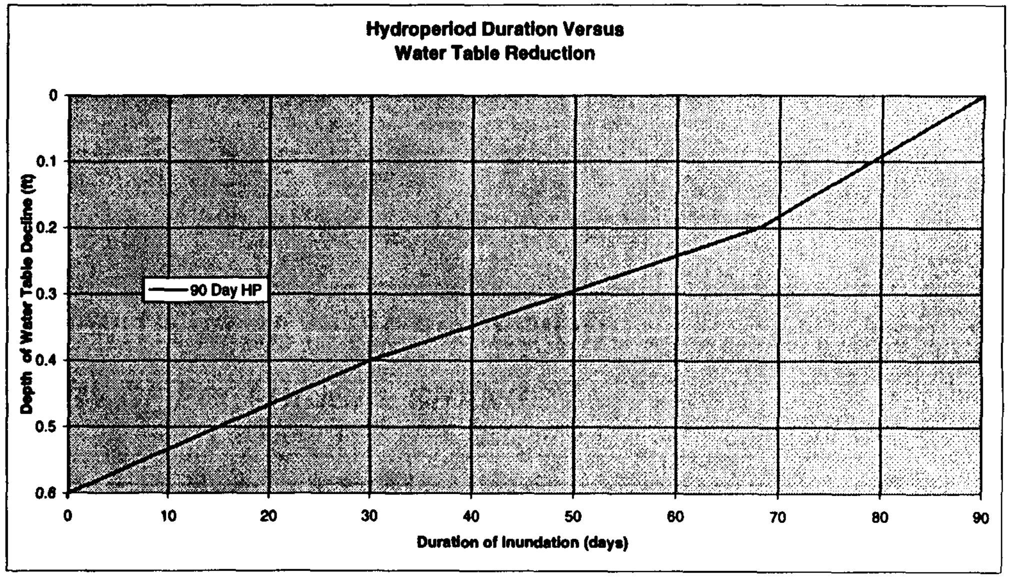




SUMMARY FOR WETLAND TYPES WITH 90 DAY HYDROPERIODS

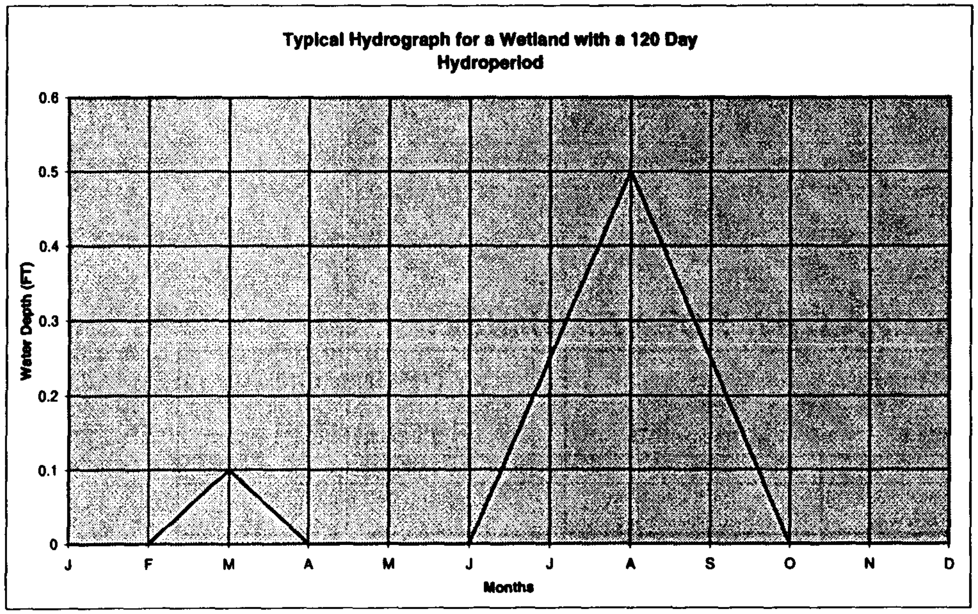
COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE Category 1	Category 2	Category 3	Category 4	Category 5
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	*No change in dominant plant/animal species*	*Some dominant species change/ wetland type remains same*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: ***a. Wet Prairie***	Wet Prairie	Wet Prairie	Dry Prairie	Pine/Prairie	Upland Pine Forest
Annual Hydroperiod (days):	90-75	75-45	45-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.4	0.4-0.15	0.15-0.1	0.1-0.0	0.0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 3,4 5,6,7	Habitat for Groups 4,5,6,7; Potentially for Group 3	Habitat for Groups 5,6,7	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only

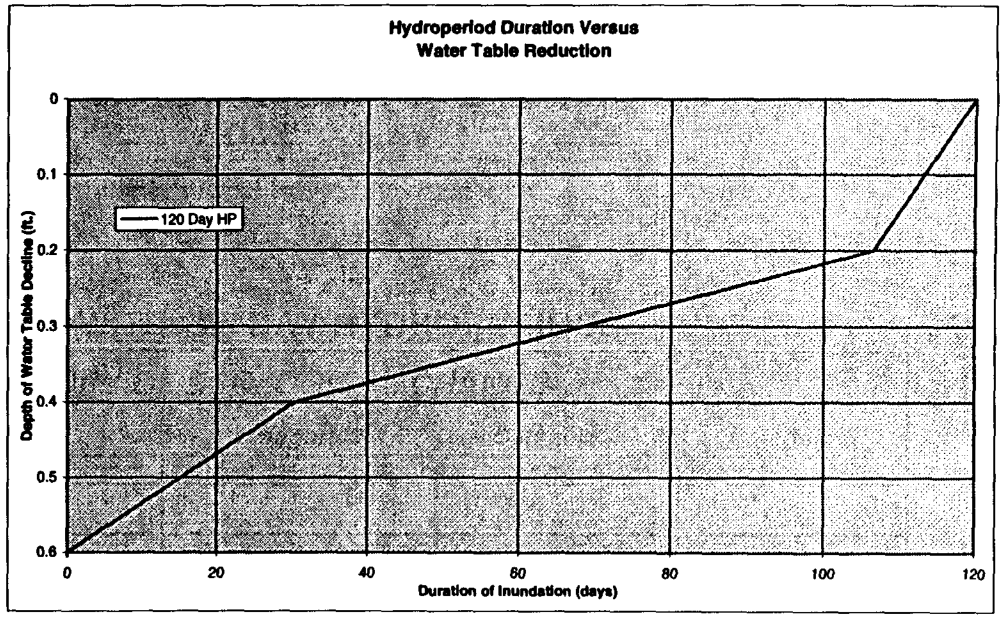




SUMMARY FOR WETLAND TYPES WITH 120 DAY HYDROPERIODS

COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE Category 1	Category 2	Category 3	Category 4	Category 5
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	***No change in dominant plant/animal species***	***Some dominant species change/ wetland type remains same***	***Change in dominant species and wetland type***	***Transitional to upland condition***	***Upland conditions prevail***
Community Type: ***a. Hydric Palm Hammock***	Hydric Palm Hammock	Hydric Palm Hammock	Hydric Palm/Oak	Transitional Palm/Oak	Upland Forest
Annual Hydroperiod (days):	120-90	90-60	60-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.25	0.25-0.17	0.17-0.1	0.1-0.0	0.0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 3,4,5,6,7	Habitat for Groups 5,6,7; Group 4 potentially present	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only

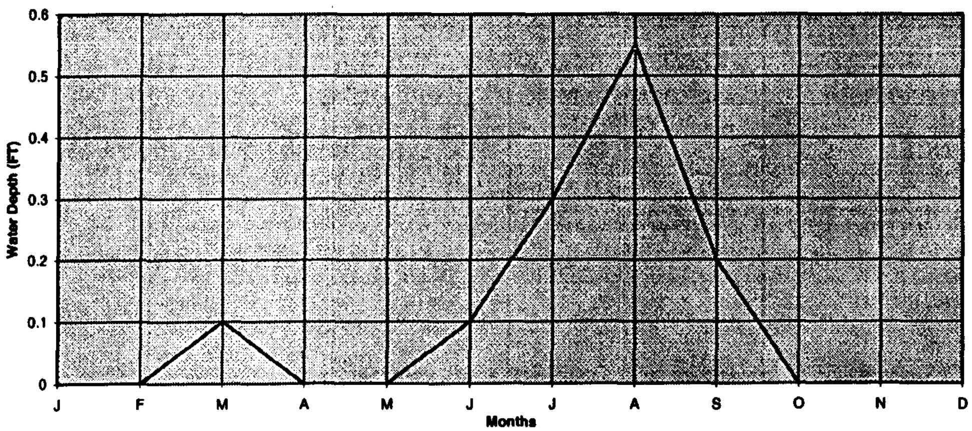




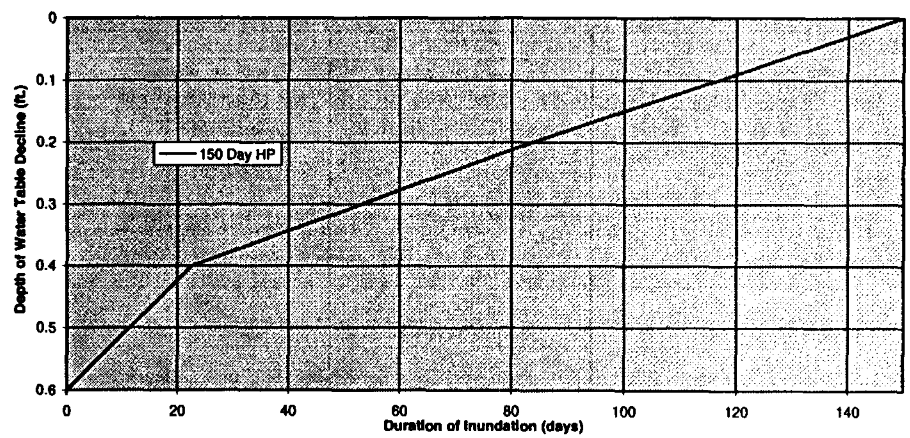
SUMMARY FOR WETLAND TYPES WITH 150 DAY HYDROPERIODS

COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE				
	Category 1	***Category 2***	***Category 3***	***Category 4***	***Category 5***
% Loss of Ecological Value:	**0**	**25**	**50**	**75**	**100**
Ecological Change Category:	***No change in dominant plant/animal species***	***Some dominant species change/ wetland type remains same***	***Change in dominant species and wetland type***	***Transitional to upland condition***	***Upland conditions prevail***
Community Type: ***a. Shallow Marsh***	Shallow Marsh	Shallow Marsh	Wet Prairie	Dry Prairie/Pine	Upland *Forest*
Annual Hydroperiod (days):	150-120	120-90	90-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.48	0.48-0.35	0.35-0.15	0.15-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 5,6,7; Groups 3 & 4 potentially present	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only
Community Type: ***b. Shallow Cypress***	Shallow Cypress	Shallow Cypress	Cypress/Pine	Pine/Cypress Hydric Hammock	Upland *Forest*
Annual Hydroperiod (days):	150-120	120-90	90-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.48	0.48-0.35	0.35-0.15	0.15-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 5,6,7; Groups 3 & 4 potentially present	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only
Community Type: ***c. Hardwood Swamp***	Hardwood Swamp	Hardwood Swamp	Mixed Hardwood/Pine, or Hydric Hammock	Pine/Hardwood, or Hydric Hammock	Upland *Forest*
Annual Hydroperiod (days):	150-120	120-90	90-30	<30	0
Annual Maximum Depth (ft.):	0.5-0.48	0.48-0.35	0.35-0.15	0.15-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 5,6,7; Groups 3 & 4 potentially present	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only

Typical Hydrograph for a Wetland with a 150 Day Hydroperiod



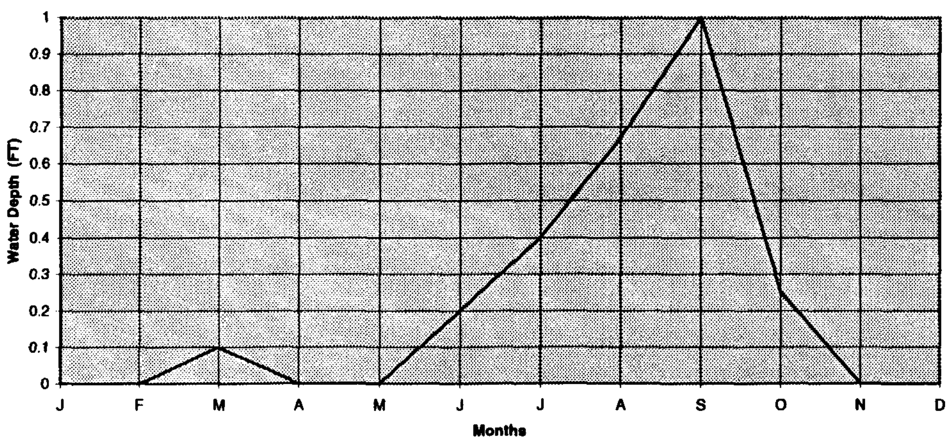
Hydroperiod Duration Versus Water Table Reduction



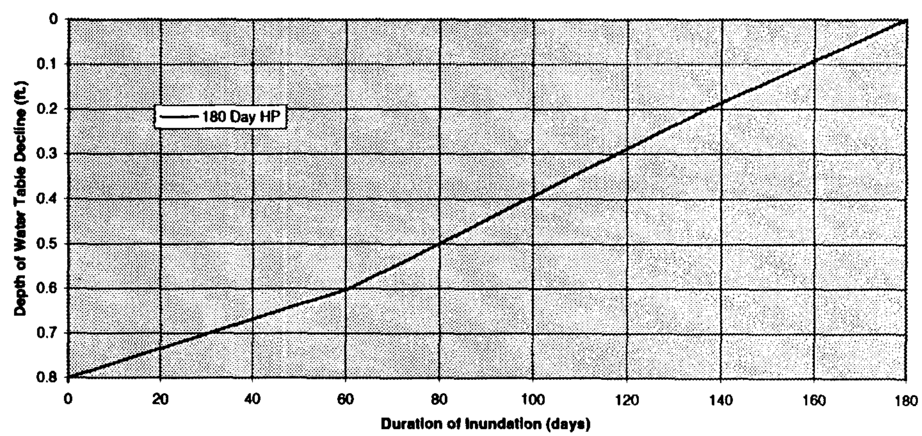
SUMMARY FOR WETLAND TYPES WITH 180 DAY HYDROPERIODS

COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE				
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	*No change in dominant plant/animal species*	*Some dominant species change/ wetland type remains same*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: **a. Deep Prairie**	Deep Priaire	Wet Prairie	Dry Prairie	Pine/Prairie	Upland Pine Forest
Annual Hydroperiod (days):	180-150	150-60	60-30	<30	0
Annual Maximum Depth (ft.):	1.0-0.6	0.6-0.14	0.14-0.0	0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 3,4,5,6,7; Group 2 potentially present	Habitat for Groups 5,6,7; Group 4 potentially present	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only
Community Type: **b. Mixed Scrub/Shrub**	Mixed Shrub Swamp	Mixed Shrub Swamp	Transitional Shrub	Shrub/Pine	Upland Pine Forest
Annual Hydroperiod (days):	180-150	150-60	60-30	<30	0
Annual Maximum Depth (ft.):	1.0-0.6	0.6-0.14	0.14-0.0	0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7	Habitat for Groups 3,4,5,6,7; Group 2 potentially present	Habitat for Groups 5,6,7; Group 4 potentially present	Habitat for transitional and upland groups only (Groups 6 & 7)	Habitat for upland Group 7 only

Typical Hydrograph for a Wetland with a 180 Day Hydroperiod

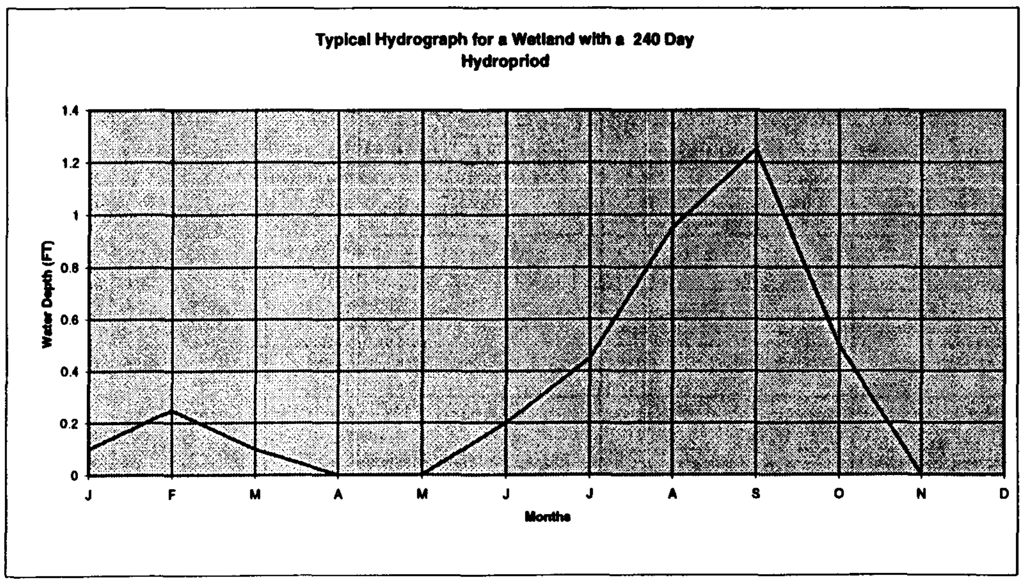


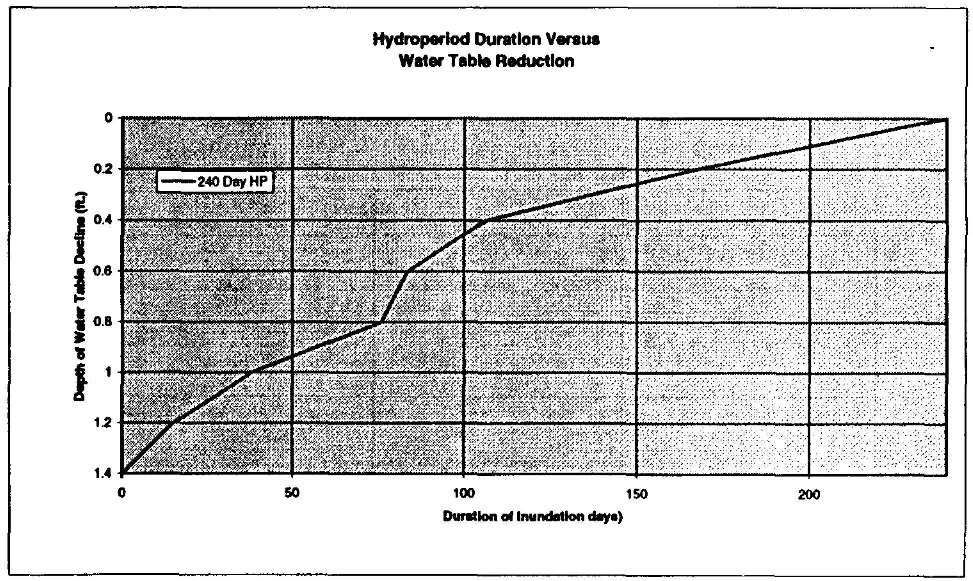
Hydroperiod Duration Versus Water Table Reduction



SUMMARY FOR WETLAND TYPES WITH 240 DAY HYDROPERIODS

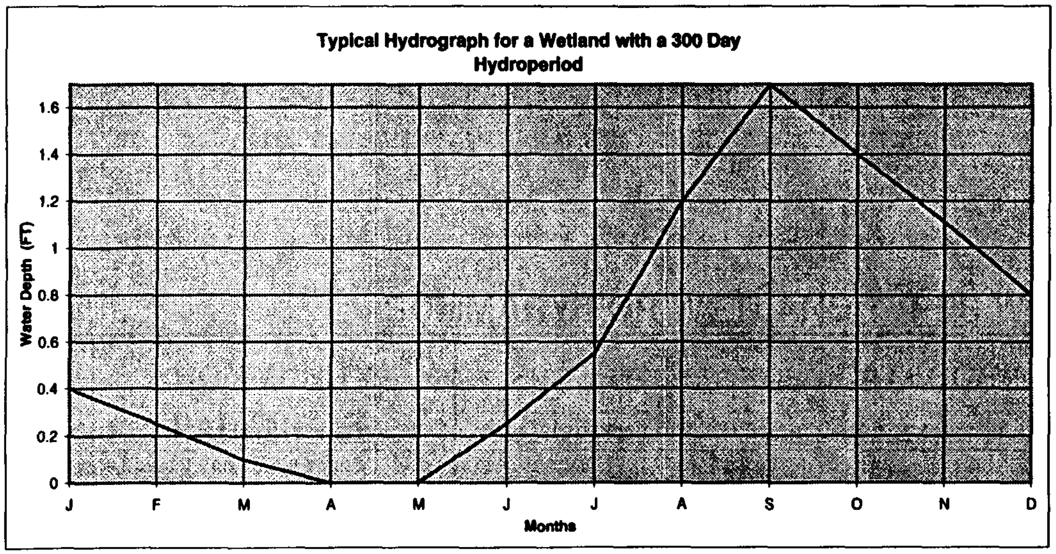
COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE				
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	*No change in dominant plant/animal species*	*Some dominant species change/ wetland type remains same*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: **a. Marsh**	Marsh	Shallow Marsh	Wet Prairie	Pine/Prairie	Upland Pine Forest
Annual Hydroperiod (days):	240-180	180-90	90-30	<30	0
Annual Maximum Depth (ft.):	1.25-1.1	1.1-0.7	0.7-0.2	0.2-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 5,6,7; Potentially for Groups 3 & 4	Habitat for transitional/ Upland Groups 6 & 7 only	Habitat for upland Group 7 only
Community Type: **b. Cypress**	Cypress	Cypress	Cypress/Pine Cypress/Hardwood	Hydric Hammock Pine/Cypress	Upland Forest
Annual Hydroperiod (days):	240-150	150-90	90-60	60-0	0
Annual Maximum Depth (ft.):	1.25-1.0	1.0-0.7	0.7-0.35	0.35--0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 3,4,5,6,7	Habitat for upland Group 7 Potentially for transitional Group 6 and for 4 & 5	Habitat for upland Group 7 only
Community Type: **c. Gum Swamp**	Gum Swamp	Gum Swamp	Mixed Hardwood Swamp	Pine/Hardwood Hydric Hammock	Upland Forest
Annual Hydroperiod (days):	240-180	180-90	90-60	60-0	0
Annual Maximum Depth (ft.):	1.25-1.1	1.1-0.7	0.7-0.35	0.35-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 3,4,5,6,7	Habitat for upland Group 7 Potentially for transitional Group 6 and for 4 & 5	Habitat for upland Group 7 only

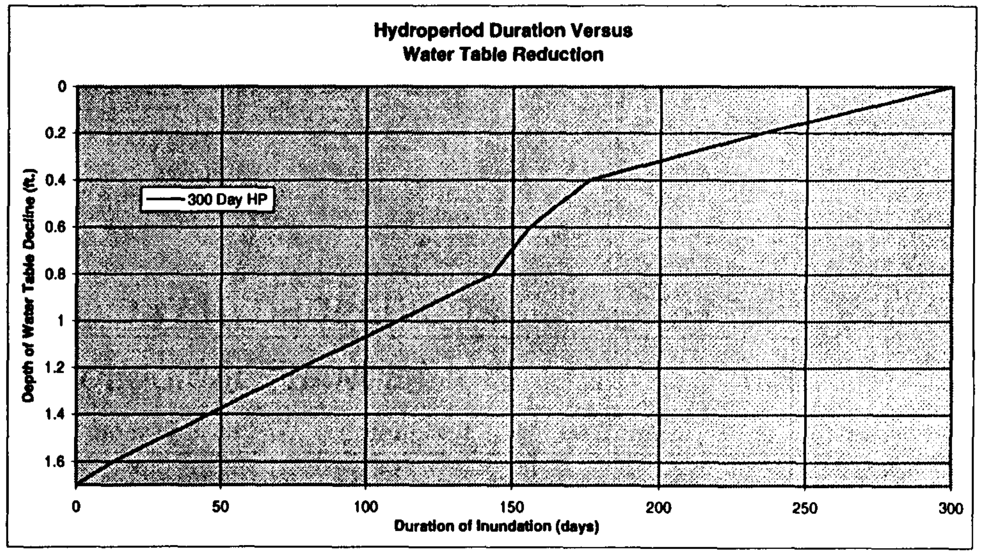




SUMMARY FOR WETLAND TYPES WITH 300 DAY HYDROPERIODS

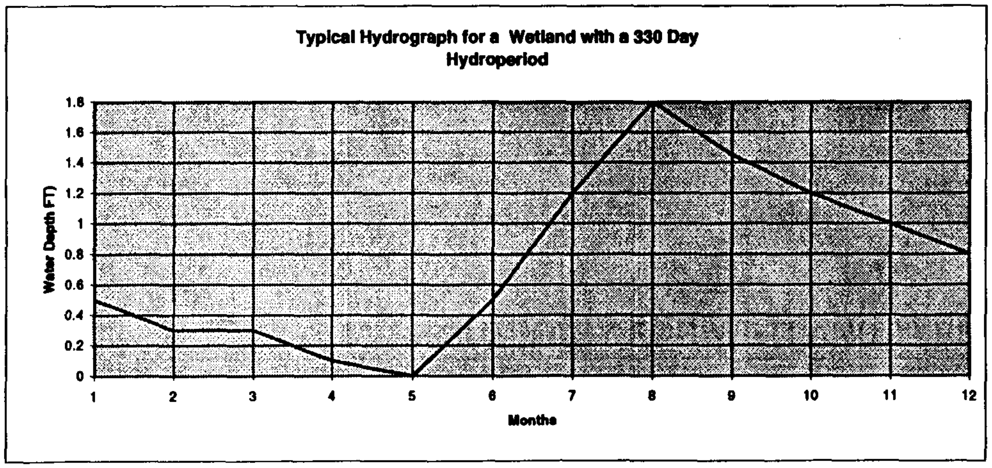
COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE: Category 1	Category 2	Category 3	Category 4	Category 5
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	*No change in dominant plant/animal species*	*Some dominant species change/ wetland type remains same*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: **a. Deep Cypress**	*Deep Cypress*	*Cypress*	*Cypress/Pine*	*Pine/Cypress*	*Upland Pine* Forest
Annual Hydroperiod (days):	300-240	240-150	150-60	60-0	0
Annual Maximum Depth (ft.):	1.7-1.5	1.5-1.1	1.1-0.4	0.4-0.0	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 2,3,4,5,6,7	Habitat for Groups 3,4,5,6,7; Potentially for Group 2	Habitat for upland Group 7 Potentially for transitional Group 6 and for 4 & 5	Habitat for upland Group 7 only

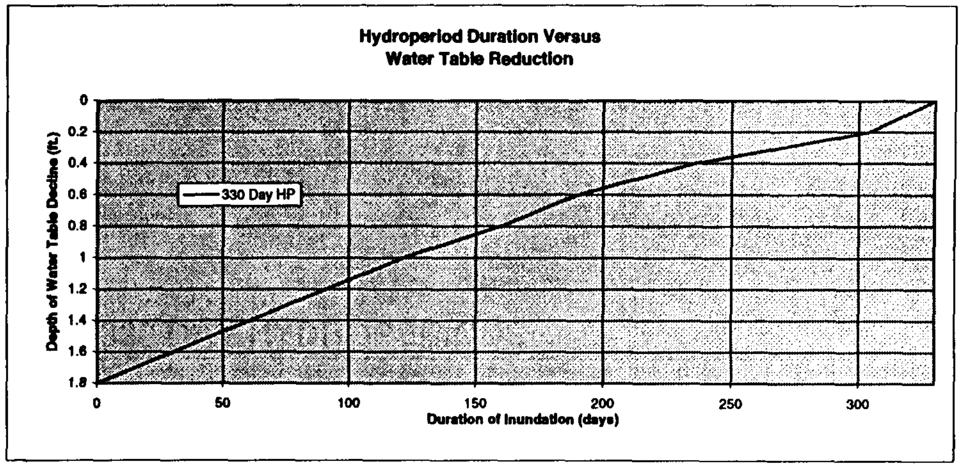




SUMMARY FOR WETLAND TYPES WITH 330 DAY HYDROPERIODS

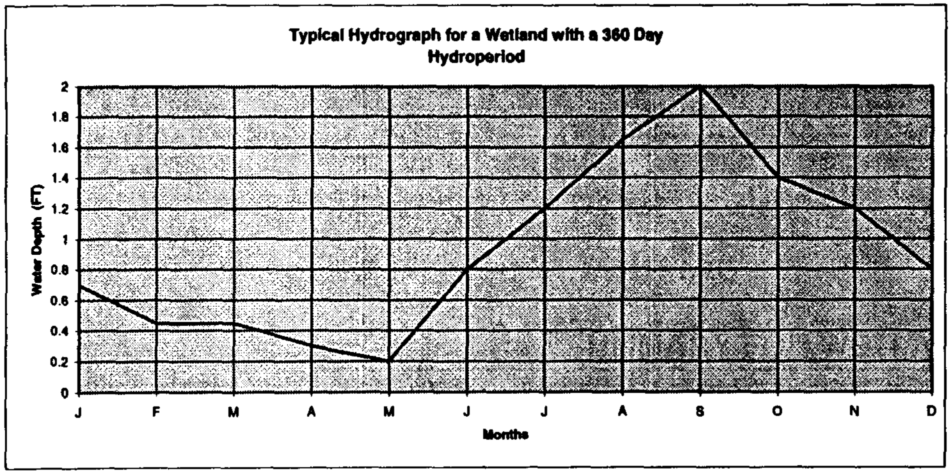
COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE				
	Category 1	***Category 2***	***Category 3***	***Category 4***	***Category 5***
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	***No change in dominant plant/animal species***	***Some dominant species change/ wetland type remains same***	***Change in dominant species and wetland type***	***Transitional to upland condition***	***Upland conditions prevail***
Community Type: ***a. Deep Marsh***	Deep Marsh	Marsh	Wet Prairie	Pine Prairie/ Dry Prairie	Upland Pine or Hardwood
Annual Hydroperiod (days):	330-270	270-90	90-30	<30	0
Annual Maximum Depth (ft.):	1.8-1.5	1.5-0.6	0.6-0.2	0.2-0.0	0.0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7; Group 1 not present	Habitat for Groups 2,3,4 5,6,7; Group 1 not present	Habitat for Groups 5,6,7 Potentially for Groups 3 & 4	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only

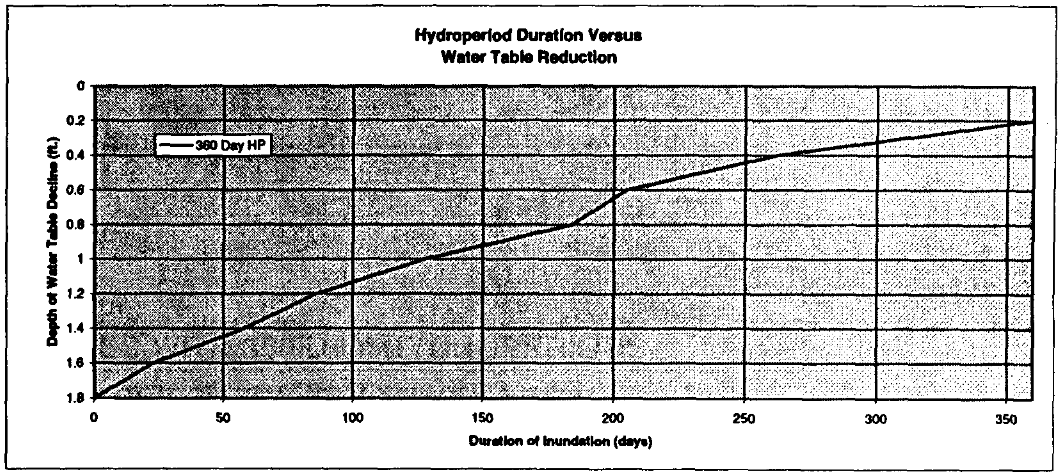




SUMMARY FOR WETLAND TYPES WITH 360 DAY HYDROPERIODS

COMMUNITY PARAMETER	CATEGORY OF ECOLOGICAL CHANGE Category 1	Category 2	Category 3	Category 4	Category 5
% Loss of Ecological Value:	0	25	50	75	100
Ecological Change Category:	*No change in dominant plant/animal species*	*Some dominant species change/ wetland type remains same*	*Change in dominant species and wetland type*	*Transitional to upland condition*	*Upland conditions prevail*
Community Type: **a. Aquatic Slough**	Slough	Marsh	Wet Prairie	Pine/Prairie	Upland Community
Annual Hydroperiod (days):	360-300	300-90	90-30	<30	0
Annual Maximum Depth (ft.):	2.0-1.7	1.7-0.6	0.6-0.45	0.45-0.2	0-(-1.0)
Habitat Suitability for Amphibian Assemblages:	Habitat for Groups 2,3,4 5,6,7; Group 1 not present	Habitat for Groups 2,3,4 5,6,7; Group 1 not present	Habitat for Groups5, 6 & 7 Potentially for Groups 2,3,4	Habitat for transitional and upland groups only (Groups 6, & 7)	Habitat for upland Group 7 only





Appendix D

Common Vertebrate Species Found in Florida Wetlands

Table D-1. Mammals associated with Florida wetlands

Species Common Name	Species Latin Name	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Flatwood Marsh	Shallow Intermittent	Permanent Herbaceous	Swamp Thicket
Opposum	*Didelphis marsupialis*	C	C	C	C	C	U	U	C
Short-tailed Shrew	*Blarina carolenesis*	U	--	--	U	C	--	U	--
Southeastern Shrew	*Sorex longirostris*	C	--	--	--	--	--	--	--
Least Shrew	*Cryptotis parva*	--	U	U	--	C	--	--	--
Eastern Mole	*Scalopus aquaticus*	--	--	--	--	C	--	--	--
Northern Yellow Bat	*Vespertillionidae*	--	--	C	--	--	--	--	--
Evening Bat	*Vespertillionidae*	--	C	C	--	--	--	--	--
Armadillo	*Dasypus novemcinctus*	--	C	U	C	--	U	U	U
Marsh Rabbit	*Sylvilagus palustris*	--	U	U	--	C	C	C	C
Eastern Cottontail	*Sylvilagus floridanus*	--	U	U	--	C	--	U	--
Gray Squirrel	*Sciuris carolinensis*	C	C	U	--	--	--	--	--
Southern Flying Squirrel	*Glaucomys volans*	--	C	--	--	--	--	--	--
Fox Squirrel	*Sciuris niger*	--	--	--	--	C	--	--	--
Marsh Rice Rat	*Oryzomys palustris*	C	U	--	U	C	U	C	C
Eastern Harvest Mouse	*Reithrodontomys humulis*	--	--	--	--	U	U	U	--
Cotton Mouse	*Peromyscus gossypinus*	C	C	C	C	C	U	C	C
Golden Mouse	*Peromyscus nuttalli*	C	--	--	--	C	--	--	--
Hispid Cotton Rat	*Sigmodon hispidus*	C	U	U	U	C	C	C	C
Eastern Woodrat	*Neotoma floridana*	C	U	--	--	--	--	--	--
Florida Muskrat	*Neofiber alleni*	U	--	--	--	U	U	--	--
Red Fox	*Vulpes vulpes*	--	C	--	--	--	--	--	--
Gray Fox	*Urocyon cinereoargenteus*	C	--	--	--	C	--	--	C
Raccoon	*Procyon lotor*	C	C	C	--	C	C	C	--
Striped Skunk	*Mephitis mephitis*	C	U	--	--	C	--	--	--

Table D-1 (Continued). Mammals associated with Florida wetlands

Species Common Name	Species Latin Name	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Flatwood Marsh	Shallow Intermittent	Permanent Herbaceous	Swamp Thicket
Black Bear	*Euarctos americanus*	C	--	--	--	C	U	U	--
River Otter	*Lutra canadensis*	U	U	U	--	U	U	U	--
Bobcat	*Lynx rufus*	C	C	U	C	C	U	U	--
Feral Hog	*Sus scrofa*	U	C	C	--	C	C	C	C
White-tailed Deer	*Odocoileus virginianus*	C	U	U	U	C	C	C	U

U = Uncommon.
C = Common.
B = Breeding Ground.
-- = Rare or no data.

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Pied Billed Grebe	*Podilymbus podiceps*	P	--	--	--	--	--	--	C
Anhinga	*Anhinga anhinga*	P	--	R	R	--	--	--	C
Green Heron	*Butorides virescens*	P	--	C	R	--	R	R	C
Little Blue Heron	*Florida caerules*	P[a]	--	R	C	--	--	C	C
Cattle Egret	*Bubulcus ibis*	P	-	C	C	-	-	C	R
Great Egret	*Casmerodius albus*	P[a]	--	C	C	--	R	C	C
Snowy Egret	*Leucephoyx Thuls*	P[a]	--	C	C	--	R	C	C
Louisiana Heron	*Hydranassa tricolor*	P[a]	--	R	C	--	--	C	C
Blk.-Crowned Night Heron	*Nycticorax nycticorax*	P[a]	--	R	R	--	R	--	C
Yellow-Crowned Night Heron	*Nycticorax violacea*	P	--	R	C	--	C	--	C
Least Bittern	*Ixobrychus exilis*	P[a]	--	--	--	--	--	--	C
American Bittern	*Botaurus lentiginosus*	W	--	--	--	--	--	R	C
Wood Stork	*Mycteria americana*	P[a]	--	--	C	--	--	C	C
Glossy Ibis	*Plegadis falcinellus*	P[a]	--	--	--	--	--	C	C
White Ibis	*Eudocimus albus*	P	--	R	C	--	--	C	C
Mottled Duck	*Anas Fulvigula*	P	--	--	--	--	--	C	--
Green-Winged Teal	*Anas carolinensis*	W	--	--	--	--	--	C	C
Blue-winged Teal	*Anas discors*	W	--	--	--	--	--	C	C
American Widgeon	*Anas americana*	W	--	--	--	--	--	--	C
Northern Shoveler	*Anas clypeata*	W	--	--	--	--	--	--	C
Wood Duck	*Aix sponsa*	P	--	C	C	--	--	--	R
Ring-necked Duck	*Aytheya collaris*	W	--	--	--	--	--	--	R
Hooded Merganset	*Lophodytes cucullatus*	W	--	C	C	--	--	--	--
Turkey Vulture	*Cathartes aura*	P	R	R	R	R	R	C	R

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Black Vulture	*Coragyps atratus*	P	R	R	R	R	R	C	R
Shallow-tailed Kite	*Elanoides forficatus*	S	R	C	R		--	--	--
Sharp-shinned Hawk	*Accipiter striatus*	W	C	C	R	R	R	--	--
Cooper's Hawk	*Accipiter cooperii*	W[a]	C	R	R	R	R	--	--
Red-tailed Hawk	*Buteo jamaicensis*	P	R	R	R	R	R	R	R
Red-shouldered Hawk	*Buteo lineatus*	P	C	C	C	C	C	R	C
Short-tailed Hawk	*Buteo brachyurus*	P[a]	R	R	R	--	--	--	--
Southern Bald Eagle	*Haliaetus leucephalus*	P[a]	R	R	R	R	R	R	C
Marsh Hawk	*Circus cyaneus*	W	--	--	--	--	R	C	C
Osprey	*Pandion halisetus*	P	C	R	C	--	--	--	R
American Kestrel	*Falco sparverius*	P[a]	--	--	--	--	--	R	--
Bobwhite	*Colinus virginianus*	P	R	R	--	--	R	R	--
Turkey	*Meleagris gallopavo*	P	C	C	R	R	R	R	--
Sandhill Crane	*Grus canadensis*	W[a]	--	--	--	--	--	C	C
Limpkin	*Aramus guarauna*	P[a]	--	C	C	--	--	C	--
King Rail	*Rallus elegans*	P	--	--	--	--	C	C	C
Virginia Rail	*Rallus Limicola*	W	--	--	--	--	R	R	C
Sora	*Porzana carolina*	W	--	--	--	--	R	C	C
Black Rail	*Laterallus jamaicenais*	W	--	--	--	--	--	R	R
Purple Gallinule	*Porphyrala martinica*	S	--	--	--	--	--	R	R
Common Moorhen	*Gallinula chloropus*	P	--	--	--	--	--	R	C
American Coot	*Fulica americana*	P	--	--	--	--	R	R	C
Killdeer	*Charadrius vociferus*	P	--	--	--	--	--	C	C
Black-bellied Plover	*Squatarola squatarola*	P	--	--	--	--	--	--	R
American Woodcock	*Philohela minor*	W	R	R	--	R	C	R	--

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Common Snipe	*Capella gallinago*	W	--	--	--	--	C	C	C
Spotted Sandpiper	*Actitus macularia*	W	--	--	--	--	--	--	R
Greater Yellowlegs	*Tringa melanoleuca*	W	--	--	--	--	--	C	C
Lesser Yellowlegs	*Tringa flavipes*	W	--	--	--	--	--	C	C
Lesser Sandpiper	*Calidris minutilla*	W	--	--	--	--	--	C	C
Dunlin	*Calidris alpine*	W	--	--	--	--	--	--	R
Western Sandpiper	*Calidris mauri*	W	--	--	--	--	--	--	R
Sanderling	*Calidris alba*	W	--	--	--	--	--	--	R
Short-bill Dowitcher	*Limnodromus griseus*	W	--	--	--	--	--	R	R
Long-bill Dowitcher	*Limnodromus acolopaceus*	W	--	--	--	--	--	R	R
Black-necked Stilt	*Himantopus mexicanus*	S	--	--	--	----	--	C	C
Ring-billed Gull	*Larus delawarensis*	W	--	--	--	--	--	R	R
Gull-billed Term	*Gelochelidon nilotica*	S	--	--	--	--	--	R	R
Forater's Term	*Sterna forsteri*	P	--	--	--	--	--	--	R
Least Term	*Sterna albifrons*	S	--	--	--	--	--	--	R
Black Skimmer	*Rynchops niger*	P	--	--	--	--	--	--	R
Mourning Dove	*Zenaida macroura*	P	C	R	R	--	R	C	--
Ground Dove	*Columbigallina passerina*	P	--	--	--	--	R	R	--
Yellow-billed Cuckoo	*Coccyzus americanus*	S	C	C	R	C	R	--	--
Barn Owl	*Tyto alba*	P	R	R	--	R	R	R	R
Screech Owl	*Otus asio*	P	C	C	C	R	R	--	--
Great-horned Owl	*Bubo virginianus*	P	R	R	R	--	R	R	--
Florida Burrowing Owl	*Speotyto cunicularia*	P	--	--	--	--	--	R	--
Barred Owl	*Strix varia*	P	C	C	C	C	R	--	R
Chuck Will's Widow	*Caprimulgas carolinensis*	S	C	C	R	C	--	--	--
Whip-Poor-Will	*Caprimulgus vociferus*	W	C	R	R	R	R	--	--

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Chimney Swift	*Chaetura pelagica*	S	--	--	--	--	--	--	C
Ruby-throated Hummingbird	*archilochus colubris*	S	C	C	R	--	--	--	--
Common Flicker	*Colaptes suratus*	P	C	R	R	R	--	--	--
Pileated Woodpecker	*Dryocopus pileatus*	P	C	C	R	R	R	--	--
Red-bellied Woodpecker	*Melanerpes erythocephalus*	P	C	C	C	C	R	--	--
Yellow-bellied Sapsucker	*Sphyrapicus varius*	W	C	C	C	C	--	--	--
Hairy Woodpecker	*Picoides villosus*	P[a]	C	--	R	--	--	--	--
Downy Woodpecker	*Picoides pubescens*	P	C	C	C	R	--	--	--
Great-grested Flycatcher	*Myiarchus crinitus*	S	C	C	C	C	--	--	--
Eastern Phoebe	*Sayornis phoebe*	W	C	C	C	C	C	R	R
Acadian Flycatcher	*Empidonax virescens*	S	C	--	--	--	--	--	--
Tree Swallow	*Iridoprocne bicolor*	W	--	R	R	C	C	C	C
Purple Martin	*Progne subis*	S	--	--	C	--	C	C	C
Blue Jay	*Cyanocitta cristata*	P	C	C	C	C	--	--	--
Common Crow	*Corvus brachyrhynchos*	P	--	R	C	--	--	C	--
Fish Crow	*Corvus ossifragus*	P	C	C	C	R	C	C	C
Carolina Chickadee	*Parus carolinensis*	P	C	C	C	R	--	--	--
Tufted Titmouse	*Parus bicolor*	P	C	C	C	R	--	--	--
House Wren	*Troglodytes aedon*	W	R	C	R	R	C	--	--
Carolina Wren	*Thryothorus ludouicianus*	P	C	C	C	C	C	--	--
Short-billed Marsh Wren	*Cistothorus platensis*	W	--	--	--	--	R	C	R
Mockingbird	*Mimus polyglottus*	P	R	R	R	--	C	R	--
Gray Catbird	*Dumetella carolinensis*	W	C	C	C	C	C	--	--
Brown Thrasher	*Toxostoma rufum*	S	C	R	R	R	R	--	--
American Robin	*Turdus migratorius*	W	R	C	C	C	C	--	--
Hermit Thrush	*Hylocichla guttat\a*	W	C	C	C	C	--	--	--

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Blue-gray Gnatcatcher	*Polioptila caerules*	P	C	C	C	C	C	--	--
Ruby-crowned Kinglet	*Regulus calendula*	W	C	C	R	C	C	--	--
Water Pipit	*Anthus spinoletta*	W	--	--	--	--	--	U	R
Cedar Waxwing	*Bombycille cedrorum*	W	C	C	C	R	R	--	--
Loggerhead Shrike	*Lanius ludovicianus*	P	R	--	--	R	R	R	--
White-eyed Vireo	*Vireo griseus*	P	C	C	R	C	C	--	--
Solitary Vireo	*Vireo solitarius*	W	C	C	C	C	--	--	--
Red-eyed Vireo	*Vireo olivaceous*	S	C	C	R	--	--	--	--
Black and White Warbler	*Mniotilta varia*	W	C	C	C	C	R	--	--
Orange-crowned Warbler	*Vermivora celata*	W	C	C	R	R	R	--	--
Northern Parula	*Parula americana*	S	C	C	C	--	--	--	--
Yellow-rumped Warbler	*Dendroica coronata*	W	C	C	C	C	C	R	R
Yellow-throated Warbler	*Dendroica demonica*	P	C	C	C	--	--	--	--
Prairie Warbler	*Dendroica discolor*	W	C	C	R	C	C	--	--
Palm Warbler	*Dendroica palmarum*	W	C	C	C	R	C	C	R
Common Yellowthroat	*Geothlypis trichas*	P	C	C	C	R	C	C	C
Red-winged Blackbird	*Agelaius phoeniceus*	P	R	C	C	--	C	C	C
Boat-tailed Crackle	*Quiscalus major*	P	--	R	R	--	C	C	C
Common Crackle	*Quiscalus quiscula*	P	C	C	C	--	--	--	--
Brown-headed Cowbird	*Molothrus ater*	W	--	--	--	--	--	C	--
Summer Tanager	*Piranga rubra*	S	C	C	C	R	--	--	--
Cardinal	*Cardinalis cardinalis*	P	C	C	C	C	C	--	--
American Goldfinch	*Carduelis tristis*	W	C	C	C	C	C	U	--
Rufuos-sided Towhee	*Pipilo erthrophthalmus*	P	C	C	--	C	C	R	R
Savannah Sparrow	*Passerculus sandwichensis*	W	--	--	--	--	C	C	R
Grasshopper Sparrow	*Ammodramus savannarum*	W	--	--	--	--	--	R	--

Table D.1 (Continued). Birds associated with Florida wetlands

Species Common Name	Species Latin Name	Season	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Swamp Thicket	Shallow Intermittent	Flatwood Marsh
Henslow Sparrow	*Passerherbulus henslowii*	W	--	--	--	--	--	R	--
LeConte's Sparrow	*Passerherbulus candacutus*	W	--	--	--	--	--	R	--
Vesper Sparrow	*Pooecetes gramineus*	W	--	--	--	--	--	R	--
White-throated Sparrow	*Zonotricha albicollis*	W	--	--	--	--	C	--	--
Swamp Sparrow	*Melospiza georgiana*	W	--	R	--	--	C	R	C
Song Sparrow	*Melospiza melodia*	W	--	--	--	--	C	--	--
Total Common Species			48	51	44	24	30	36	42

[a]Refers to species listed by Florida Committee on Rare and Endangered Plants and Animals as "Endangered, Threatened, and Rare." Included are species of special concern, refering to mostly wetland species whose habitats are being reduced.

Notes: Based on U.S. Fish and Wildlife (USDI) information, the table includes those birds expected to be found within the wetland ecosystems already defined. Transients and accidentals were excluded from this list.

P = Permanent resident.
W = Winter resident.
S = Summer and/or breeding resident.
C = Abundant, common, and uncommon: these are all regular visitors to the appropriate seasons in decreasing degree of abundance.
R = Rare and very rare: these birds reflect small percentages of the populations in their habitats and/or occupy very specific habitats.

Table D-1 (Continued). Amphibians associated With Florida wetlands

Species Common Name	Species Latin Name	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Flatwood Marsh	Shallow Intermittent	Permanent Herbaceous	Swamp Shrub
Greater Siren	*Siren lacertina*	U	U	U	--	U	--	C	C
Lesser Siren	*Siren intermedia*	U	C	C	--		--	--	C
Dwarf Siren	*Pseudobranchus striatus*	U	U	U	--	C	--	C	U
Dusky Salamander	*Desmognathus auriculatus*	C	U	--	--	--	--	--	--
Dwarf Salamander	*Eurycea quadridigitata*	C	U	U	--	--	--	--	U
Striped Newt	*Notophthalmus perstriatus*	--	U	U	--	U	--	U	--
Narrow-mouthed Toad	*Gastrophyrne carolinensis*	C	C	U	C	C	B	B	C
Spadefoot Toad	*Scaphiopus holbrooki*	C	U	U	--	C	--	B	--
Southern Toad	*Bufo terrestris*	--	C	U	U	C	--	C	--
Oak Toad	*Bufo quercicus*	--	--	--	U	--	C	B	B
Spring Peeper	*Hyla crucifer*	C	--	--	--	--	--	--	--
Green Treefrog	*Hyla cinerea*	C	U	C	U	C	C	C	C
Barking Treefrog	*Hyla gratiosa*	--	U	U	--	C	B	B	--
Pinewoods Treefrog	*Hyla femoralis*	--	U	U	--	C	B	B	--
Squirrel Treefrog	*Hyla squirella*	C	C	C	U	--	B	B	U
Little Grass Frog	*Limnaoedus ocularis*	--	U	U	U	C	C	C	U
Cricket Frog (Southern)	*Acris gryllus*	--	--	--	--	U	--	C	--
Southern Chorus Frog	*Pseudacris nigrita*	--	U	C	--	U	B	B	--
Greenhouse Frog	*Eleutherodactylus planirostris*	C	C	U	--	--	--	--	--
Gopher Frog	*Rana aeolata*	C	--	--	--	--	--	B	--
Leopard Frog	*Rana utricularia*	U	C	C	U	C	C	C	U
Pig Frog	*Rana grylio*	--	U	U	--	--	C	C	U
Bullfrog	*Rana catesbiana*	U	U	U	--	U	--	--	U

Table D-1 (Continued). Reptiles associated with Florida wetlands

Species Common Name	Species Latin Name	Hydric Hammock	Hardwood Swamp	Cypress Swamp	Bay Forest	Flatwood Marsh	Shallow Intermittent	Permanent Herbaceous	Swamp Shrub
River Swamp Frog	*Rana heckscheri*	U	--	--	--	--	--	--	--
American Alligator	*Alligator mississippiensis*	U	--	--	--	U	--	C	--
Snapping Turtle	*Chelydra serpentina*	U	--	U	--	U	U	C	--
Musk Turtle	*Sternotherus odoratus*	--	--	--	--	--	--	C	--
Mud Turtle	*Kinosternon bauri*	--	--	U	--	--	U	C	U
Eastern Box Turtle	*Terrapene carolina bauri*	--	U	U	--	C	C	C	--
Chicken Turtle	*Deirochelys reticularia*	--	U	U	--	--	C	C	--
Florida Softshell Turtle	*Trionyx ferox*	--	U	U	--	--	C	C	--
Florida Red-bellied Turtle	*Chrysemys nelsoni*	--	--	U	--	--	C	C	--
Peninsula Cooter	*Chrysemys floridana-peninsularis*	U	U	U	--	U	C	C	--
Striped Mud Turtle	*Kinosternon bauri*	--	U	U	--	--	U	U	U
Stinkpot	*Sternotherus odoratus*	--	U	U	--	--	C	C	--
Green Anole	*Anolis carolinensis*	C	C	C	--	C	U	U	C
Southern Fence Lizard	*Sceloporus undulatus undulatus*	--	--	--	--	C	--	--	--
Glass Lizards	*Ophisaurus sp.*	--	--	--	--	C	--	C	--
Six-lined Racerunner	*Cnemidophorus sexlineatus*	--	--	--	--	--	--	--	--
S.E. Five-line Skink	*Eumeces inexpectatus*	C	--	--	--	C	--	C	--
Ground Skink	*Lygosoma laterale*	--	C	U	U	--	--	--	U
Florida Green Water Snake	*Natrix cyclopion floridana*	--	U	U	--	--	U	C	--
Brown Water Snake	*Nerodia taxispilota*	U	U	U	--	U	--	--	--
Banded Water Snake	*Nerodia*	C	U	U	--	U	C	C	U
Striped Swamp Snake	*Regina alleni*	--	U	U	--	--	C	C	U
Black Swamp Snake	*Seminatrix pygaea*	--	U	U	--	--	U	U	--