10.0 FUTURE UNCERTAINTIES

The Conceptual Ecological Models developed for the MAP are retrospective in nature, that is, they focus on those sources and stressors that were relevant to the deterioration of the South Florida Ecosystem over the past 100 years. Consequently, when developing the restoration plan these were the stressors that needed to be controlled and mitigated to return the current system to a pre-drainage state. However, these are not the only stressors that are operative on the system today, there are others. The IAT feels that these can be classified as "Future Uncertainties" and believes that these categories of stressors may pose a significant threat to the success of the restoration. The IAT has chosen to highlight three categories of stressors: contaminants, exotic species, and climate change. The intent is to have the Module Groups examine the role of these stressors in their assessments. Clearly, this is not a complete listing but serves only as a point of departure for the PIs to begin to think beyond the stressors in the current MAP CEMs.

10.1 Exotic Species

Successful restoration of the South Florida ecosystem, which includes the last vestiges of a once vast Everglades wetland, hinges on being able to reverse the environmental degradation that has occurred from human activities over the last 100+ years and prevent degradation from future human activities. While it is clear through the efforts of the Comprehensive Everglades Restoration Plan (CERP) and Restoration Coordination and Verification (RECOVER) programs that numerous factors (e.g., water quantity and quality, and abundance of flora and fauna) are involved in the restoration effort, the potential impact of invasive species has only recently become a high priority for the CERP planning.

It is estimated that over 32,000 exotic species (25,000 plants & 7,000 animals) have been introduced into Florida (Stein, Kutner & Adams 2000). Florida has approximately four to five thousand native species of plants and animals. The number of exotic species that have been introduced is eight times the total number of native species in the entire state.

Of the total of 32,000 exotic introductions, about 2,000 plant and 400 animal species have been documented as having reproducing free-living (naturalized) populations established in Florida. Of the 2,000 plant species 66 are documented as serious threats to natural areas, and an additional 63 are considered as serious potential threats and require careful monitoring. Of these, forty-eight species are documented to cause ecosystem level impacts, 14 species are documented to be directly impacting threatened and endangered species and rare habitats within Florida and 19 species are documented as being among the world's worst weeds (Holm 1977). Land management agencies in Florida spend a combined total of approximately $91 million each year trying to manage just a few of those 129 plant species.

Within the Central and Southern Florida Restudy Area just six species of invasive exotic plants have replaced approximately 1.9 million acres of habitat (Doren and Ferriter 2001). One species alone, Old World Climbing fern has spread exponentially during the last two years. Its current range covers over 125,000 acres across 7 South Florida

counties in Everglades habitat, and model predictions for this species estimates over 5 million acres covered by 2014.

The SFWMD in its 2006 South Florida Environmental Report provides an in depth discussion of the status of non-indigenous species in South Florida (Chapter 9). This report describes the extent of this problem within the context of each of the major Modules. This approach is particularly important in that it provides the Module Groups, module specific information that they will need to factor into their assessments.

The following are issues that the Module Groups should consider when conducting their assessments.

1) A major concern of the assessments is the need to consider the potentially irreversible alterations in ecological community structure and function caused by the replacement of native plants and animals.

    a. Carbon sequestration
    b. Nutrient cycling and nutrient mineralization
    c. Alterations in geomorphology including soil erosion, soil deposition and sediment accumulation, soil composition (i.e. soil types), soil decomposition, and changes in soil elevation
    d. Alterations of natural fire regimes (e.g., intensity, frequency, and seasonality
    e. Alterations in surface water flow, quantity and quality
    f. Alterations in salinity of soil and water
    g. Alteration in primary productivity, food web structure and energy flow patterns
    h. Alterations in channelization of wetlands, estuaries and coastal marshes
    i. Decreased recruitment of native plants and animals
    j. Alterations in water and nutrient uptake
    k. Alterations in population and stand structure in plants and animals
    l. Alterations in competitive ability and selective pressures on native species
    m. Increases in the natural background rate of species extinctions (natural rate is approximately 1 to 10 million years per species, current extinction rate due to habitat loss and invasive exotic species is approximately 500 years per species).

2) The irreversible reorganization of the Everglades' ecosystem resulting in a new altered stable state (structural and functional) that is entirely manifested by and dependent on invasive exotic species.

3) The loss of native habitat.

4) The development and implications of anoxic bacteria and low level of dissolved oxygen in wetlands and waterways resulting from infestations of exotic vegetation.

5) The alteration or elimination of natural vegetation community structure or abundance.

6) The occurrence of faunal shifts.

7) The potential hydrologic impacts.

8) The potential loss of biodiversity within the Everglades ecosystem.

9) The impacts and physical damage and loss to water control and conveyance structures such as canal banks, pumps, etc.

10) The reduction of habitat available for native and migratory birds.

Given the current and potential impacts of non-indigenous organisms in South Florida, scientists are obliged to begin to factor these species into restoration models, and research must be carried out to understand the distribution, biology, and impacts of these non-indigenous organisms. The idea of dealing with non-indigenous organisms in an all-taxa approach is a nascent study, but it is sure to emerge as an important field of science given global trade and the virtual "open barn" situation. Organisms will continue to arrive and will continue to establish breeding populations in South Florida. The abundance of non-indigenous plants in South Florida may be accelerating this process, as animals are arriving not only without their natural enemies but also into a hospitable environment that includes plant species from their native range. It is probably no coincidence that the Burmese python prefers levees covered with Burma reed in the Everglades.

10.2 Implications of Climate Change and Climate Variability upon CERP

Given its geographic scope and multi-decadal planning and implementation horizons, the success or failure of CERP will to no small degree be determined by the degree to which management decisions are consistent with and adapt to not only global climate change (e.g., sea level rise, sea surface temperature change, atmospheric carbon-dioxide and large scale changes in precipitation patterns) but also inter-decadal climatic variability in the coupled ocean-atmosphere (e.g. the Atlantic Multi-decadal Oscillation (AMO), El Nino/La Nina, Sahel drought and tropical storm impacts). Local "climatically relevant" phenomena such as desertification will not only complicate interpretation but will have to be specifically considered with regard to CERP assessments, evaluations and recommended management alternatives.

With its low relief and extended coastline, South Florida is particularly sensitive to sea level rise (Titus and Richman, 2000). Global models vary widely but predictions for global sea level rise by 2050 range from 6" to as much as two feet. Limited data suggests local sea level rise over the same period may be as much as 6" although the geophysical mechanism for this rise is unclear and it may represent a more temporary steric phenomenon. Together this rise would markedly change the mangrove estuarine shorelines and move them well inland along the northern perimeter of Florida Bay and

the Southwest Florida Shelf (Maul and Martin, 1993; Wanless et al, 1994). It could also deepen basins in Florida Bay and significantly alter residence times and flushing rates (Rudnick et al, 2006).

Global changes in precipitation pattern for the entire North American continent are forecast in conjunction with global warming and a rise in atmospheric (and upper mixed layer) carbon dioxide concentration. The condition of the coral reefs off the Florida Keys has been proposed as an indicator of overall ecosystem condition. With increasing dissolved carbon dioxide the calcification upon with coral growth depends is significantly depressed (Langdon et al, 2005).

Perhaps even more significant than these global climate change trends is climate variability. The phase of the AMO is closely correlated with rainfall over South Florida indeed with inflow into Lake Okeechobee (Enfield et al, 2001) Recent results indicate a greater than 90% probability of a phase shift in the AMO over the thirty year span of CERP construction (Enfield and Cid-Serrano, 2006). In addition, both AMO phase and drought conditions in the Sahel desert in West Africa have been linked to the incidence of major tropical storms (Wang et al, 2005; Goldenberg et al, 2000). These patterns suggest that the 30 year model runs on which the design of the Comprehensive Everglades Restoration Plan is based encompassed a period of much lower rainfall than we can expect during the coming decades of CERP implementation.

Tropical storms can not only markedly affect water supply and flood protection but can significantly impact shallow estuarine tropical ecosystems in particular their retention of sediment. Model studies suggest that changes in land use in Florida related to increased population pressures and agricultural development have already markedly reduced convective rainfall as much as 10% (Pielke et al, 1999).

In short, restoration alternatives need to be evaluated in light of both systematic trends (both global and regional) and regional climate variability to encompass the range of conditions the ecosystem is likely to experience.