Appendix 7B-3: Comprehensive Everglades Restoration Plan Adaptive Management Strategy

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Appendix 7B-3
Draft Benefits Evaluation and Analysis Methodology
October 24, 2006 Draft

Restoration Coordination and Verification (RECOVER)
Branch

INTRODUCTION

The overarching goal of the Comprehensive Everglades Restoration Plan (CERP) is to restore, preserve and protect the South Florida ecosystem while providing for other water-related needs of the region. Project teams formulate and evaluate alternative plans to 1) optimize the project's contribution to achieving the goals and purposes of the plan, and 2) select an alternative that maximizes net benefits, both monetary and non-monetary, on a systemwide basis, provided that the plan is justified on a next-added increment basis.

The US Army Corps of Engineers (USACE) Planning Guidance Notebook (Engineering Regulation 1105-2-100; USACE, 2000) and the CERP Programmatic Regulations (DOD, 2003) require CERP Projects to complete an evaluation of the monetary and non-monetary benefits and costs associated with a project. While quantification of monetary benefits of CERP projects is fairly straightforward, quantification of non-monetary ecological benefits has proven to be significantly more difficult. No universally applicable or accepted metric is available to quantify or measure ecosystem benefits. USACE planning regulations specify that restoration outputs must be evaluated in non-monetary metrics, with preference given to "units that measure an increase in ecosystem value" that are indicative of the social significance of project effects.

This document outlines a methodology, consistent with USACE guidance, to standardize the quantification and evaluation of ecosystem benefits associated with CERP projects. The methodology is based on the simplified CERP conceptual ecological models developed for the CERP Monitoring and Assessment Plan Assessment Strategy (RECOVER, 2006a). This methodology will enable project delivery teams (PDTs) to quantify ecosystem benefits in order to evaluate and compare alternatives, and to select an alternative that is justified on a next-added increment basis.

This draft methodology and document were developed by an interagency multi-disciplinary team led by the USACE Restoration Coordination and Verification (RECOVER) Branch. The team conducted interviews and round-table discussions to solicit input from planners and PDT members about their needs and the challenges associated with benefit quantification for CERP projects. Several agencies and groups reviewed and commented on initial drafts, including the US Fish and Wildlife Service, South Florida Water Management District, Everglades National Park, US Environmental Protection Agency and RECOVER Leadership Group.

PURPOSE

The purpose of this report is to describe and document the Benefits Evaluation Analysis Methodology (BEAM) developed for CERP projects to predict and quantify changes in ecological function (habitat quality and quantity) in response to project alternatives. This method is an effort to unify and standardize ecological benefit quantification for the CERP, and to minimize inconsistency due to the lack of a standardized protocol. The methodology is based on the best available science, while recognizing the needs of planners and policy makers to apply science to project decision-making. The methodology is flexible and can accommodate changes in scientific understanding surrounding current conceptual ecological models and new or revised performance metrics.

Need for Methodology

Methods for calculating benefits often rely on a number of species indicators, each with its own associated acreage, in an effort to amass enough ecosystem benefits to justify project authorization. These methodologies generally rely on two components, a quality component that describes the health or suitability of an area for a specific environmental function and a quantity component that describes the acreage associated with that function. The product of these two components is termed a habitat unit (HU) and typically represents an acre of optimal environment. The habitat unit approach is commonly employed for CERP projects, however specific and standardized guidance on how to determine individual quantity and quality components is not available for individual projects. Previous methodologies were generally based on terrestrial and aquatic communities at the regional scale and operated by defining a 0 to 1 value to communicate habitat functionality. Since the Central and Southern Florida Project Comprehensive Review Study (Restudy), several individual CERP projects have created their own methods to calculate ecosystem benefits as part of the project implementation report (PIR) process. These include the Indian River Lagoon (IRL)-South Project, Picayune Strand Project, and the Everglades Agricultural Area (EAA) Storage Reservoir Project. The methodologies for these projects also relied heavily on a quantity-quality relationship, though they incorporated differing weighting and aggregation techniques to communicate the importance of some habitat features over others. Still, a standard methodology to evaluate environmental benefits did not emerge from these examples, and future PIRs are still expected to develop and apply their own evaluation methodologies to justify project costs. This report provides a standardized quantification of benefits methodology for all CERP projects that will address the needs for consistency and scientific rigor for an ecosystem benefits methodology.

Evaluation Methodologies Considered

Methodologies examined during the Restudy included methodologies such as Habitat Evaluation Procedure (HEP), Wetland Rapid Assessment Process (WRAP), Wetland Value Assessment (WVA), Across Trophic Level System Simulation (ATLSS), Kissimmee River Environmental Restoration Procedure, GAP Analysis, Wetland Evaluation Technique (WET), Habitat Evaluation System (HES), and the Hydrogeomorphic Classification for Wetlands. The River of Grass Evaluation Methodology (ROGEM) was used for the Restudy although other methods were also considered.

Needs Methodology Should Address

Analysis of strengths and weaknesses of potential benefit quantification methodologies discussed above led us to several conclusions about an “ideal” methodology. A desirable environmental benefits evaluation methodology would provide output useful for comparing a range of restoration alternatives. The output should indicate the study area's responses to various alternatives, indicate, generally, which alternatives provide suitable improvement over the future without project condition, and feed into project cost effectiveness/incremental cost analyses.

Personal interviews with CERP planners and PDT members were conducted to solicit input, identify opportunities to improve current benefit quantification methods, and to better meet the needs of those quantifying environmental benefits for CERP restoration projects. The feedback received from interviews was grouped into four major categories: 1) characteristics of a successful benefits methodology, 2) needed areas of consistency, 3) needed implementation tools, and 4) how to address synergies among CERP projects. Listed below are the four categories and the identified needs under each.

1) A successful benefits methodology should do the following:

- Accurately characterize existing and projected future ecological functionality
- Rely on a set of scientifically justified indicators/performance measures that accurately capture the species or other factors that characterize the ecosystem
- Connect hydrologic outputs to ecological benefits to be used in the National Ecosystem Restoration (NER) benefits analysis (Because the USACE planning process emphasizes the importance of quantifying ecologic responses to hydrologic change, the connection between water resources projects and ecologic restoration must be made.)
- Address the technical significance of a restoration project's benefits to the ecosystems affected with regard to USACE planning guidance and a July 2005 planning memo from the Assistant Secretary of the Army emphasizing the need to address the public, technical, and institutional significance of project benefits (Woodley 2005)
- Be flexible enough to include performance measures applied at variable spatial scales in order to account for the total benefits afforded by a project
- Be flexible enough to incorporate a variety of habitat types/ecological zones rather than requiring a separate set of assumptions and methodology for each habitat type
- Be able to detect differences in systemwide benefits among project alternative plans (The methodology should be able to quantify the effects of each individual project alternative and enable understanding of the variability between alternatives.)

Needed areas of consistency are as follows:

- Standardized methods are needed to ensure the consistent calculation of habitat units among all CERP projects, including how to create suitability indices from hydrologic model output, how to weight and aggregate performance measures, and how to determine acreages associated with each quality index
- An accounting system is needed to clearly account for and track the benefits of all CERP projects, particularly adjacent projects with overlapping influences

Needed implementation tools are as follows:

- Consistent models or other statistical tools that can quantify hydrologic, water quality and ecological relationships with the necessary sensitivity to detect changes between alternative plans
- A way to include broad or directional ecosystem change when specific measurable predictions or targets are not available or technical expertise is the only available tool

How to address synergies among CERP projects is as follows:

- Need to quantify the ecological benefits of a project that provides the infrastructure necessary for other CERP projects to produce benefits
- Need a process for calculating benefits if one project has a detrimental effect (temporary or permanent) on a specific habitat type, while another has a positive effect (Is there a way to show a net HU increase?)

- Need to demonstrate the effects of groups of projects to enable reviewers to see the synergistic effects of projects

Recognizing that not all the needs identified through the literature review and the personal interviews could be addressed in this initial effort, the BEAM methodology focuses on providing many of the characteristics of a successful benefits methodology and addressing needed areas of consistency. Further refinement and coordination will be needed to address the sensitivity of predictive tools and methods of capturing project synergy through the existing USACE planning process.

Conceptual Approach of Methodology

This section conceptually discusses the principles on which the BEAM is based and how the issues identified by end users have been addressed.

Conceptual Ecologic Models

The primary objective of the CERP is to "get the water right," emphasizing the underlying assumption that hydrological regime restoration will result in ecological restoration. The need to relate hydrologic change with ecologic restoration is one of the basic tenets of any benefits quantification methodology.

The Everglades ecosystem is comprised of major ecosystem components, each with its own hydrological-ecological relationships. Fortunately, much is known, at least conceptually, about the relationships between hydrology and ecology in the Everglades. A set of conceptual ecological models was published in *Wetlands* in December 2005 (Barnes 2005, Browder et al. 2005, Crigger et al. 2005, Davis et al. 2005a, 2005b, Duever 2005, Havens and Gawlik 2005, Ogden 2005, Ogden et al. 2005a, 2005b, Rudnick et al. 2005, Sime 2005, VanArman et al. 2005). These conceptual ecological models are simple, non-quantitative models that explain the affects of major anthropogenic stressors on South Florida ecological regions. Their purpose is to show how ecosystems are stressed and to identify the sources of this stress. Each model identifies attributes in the natural system that are the best indicators of the changes that have occurred as a result of stressors. The conceptual ecological models outline the ecological linkages between stressors (e.g., changes to flow, hydropattern) that drive ecosystem responses of attributes (e.g., American oyster, wading bird communities), as well as the most appropriate performance measures for each attribute. These models take into consideration all drivers, stressors, and attributes for the system, regardless of whether they will be affected by CERP implementation.

A simplified set of conceptual ecological models has been developed for the CERP. These are presented and discussed in the Draft *2006 Assessment Strategy for the Monitoring and Assessment Plan* (RECOVER, 2006a). The BEAM uses the relationships depicted in the simplified conceptual ecological models to link hydrological changes resulting from CERP project implementation with ecological changes in the South Florida ecosystems. These relationships are defensible and based on the best available, peer-reviewed science.

Interim Goal Indicators

The CERP conceptual ecological models represent all influences on the ecosystem and necessarily include a large number of ecosystem attributes, or indicators that could be measured. A successful CERP evaluation methodology must focus on a core set of indicators that can be affected by CERP projects and that create a coherent, integrated set of indicators of ecosystem health to tell the story of Everglades' restoration.

The BEAM methodology uses RECOVER's recommended CERP interim goal indicators (RECOVER, 2005) to represent this focused group. Recommendations for the interim goals and their indicators were developed by RECOVER, pursuant to Water Resource Development Act (WRDA) 2000 (US Congress, 2000) and the Programmatic Regulations for CERP (DOD, 2003).

Interim goals are a means by which the restoration success of the plan may be evaluated throughout the implementation process. Interim goal indicators are aspects of the natural or urban systems that are related to the goals and purposes of the CERP that we will keep monitor as CERP projects are constructed. They are a core set of indicators that can be both predicted and measured to determine whether CERP is achieving expected levels of ecosystem restoration. They are ideal indicators of CERP's restoration success (i.e., ecosystem benefits) because they have the following characteristics:

- Are consistent with the goals and purposes of the CERP
- Address physical and biological aspects of the CERP
- Are consistent with the CERP Monitoring and Assessment Plan: Part I Monitoring and Supporting Research (RECOVER 2004a) and the draft CERP System-wide Performance Measures (RECOVER, 2006b)
- Are predictable and easily interpreted
- Maintain balance among physical stressor-based indicators and biological attribute-based indicators
- Include indicators from all regions of South Florida affected by the CERP
- Represent enough indicators to adequately track representative responses for the major goals of the plan without having so many as to be duplicative of the key goals
- Represent different response times (i.e., both short-term and long-term responses to the affects of CERP implementation)

All of the proposed interim goal indicators have undergone a thorough independent peer review process, which can be viewed at the following link: http://www.evergladesplan.org/pm/recover/recover_docs/igit/122804_rec_igit_peer_report.pdf).

In summary, the BEAM uses both the conceptual ecological models and the interim goal indicators to establish the indicators of ecosystem health expected to be affected by CERP implementation. Utilizing these peer-reviewed, consensus-based foundations to understand the complicated South Florida ecosystems ensures that the benefits determined with the BEAM represent scientifically-based resources to restore the system and maintains consistency.

Performance Measures

RECOVER has developed a set of system-wide performance measures. The indicators are derived from the conceptual ecological models discussed above. The BEAM uses hydrologic modeling to obtain performance measure output necessary to calculate environmental benefits. It is recommended that PDTs use CERP system-wide performance measures to quantify ecosystem benefits since they have been vetted through a large scientific body and represent consensus on restoration targets and evaluation methods.

The BEAM methodology is robust and flexible enough to add or delete specific performance measures as needed. In cases where the RECOVER systemwide performance measures are insufficiently developed or do not capture ecological response adequately, project delivery teams can develop their own performance measures for use with the BEAM methodology if it is sensitive to project-level changes and can be justified through the conceptual ecological models. If the new project performance measure fills a gap in the existing set of systemwide performance measures, RECOVER will potentially adopt/apply the metric for system-wide use if it can be applied at the system level.

Broad or Directional Change

At the current time, the primary hydrologic modeling tool used to provide performance measure output is the South Florida Water Management Model (SFWMM), version 5.4.

Individual projects are able to utilize sub-regional hydrologic models and in some instances localized water quality models. In many instances, however, predictive tools with the necessary sensitivity are not available to document all expected project benefits.

When project benefits are expected, but only broad or directional information is available to describe these potential benefits, best professional judgment methods will be required to determine quality index values for the metric. Because the use of expert opinion and the interpretation of ecological response using broad or directional change are subjective in nature, it is recommended that PDTs contact RECOVER for technical assistance and vetting through an interagency scientific body if they choose to pursue this avenue.

In order to use qualitative or directional information to categorize alternative plan performance in a quality index, the standardized quality index descriptions may be used to categorize the expected ecological response into the appropriate qualitative class and corresponding quality index score. However, clear documentation of index category justification is required. Supporting evidence such as peer-reviewed manuscripts, agency reports, and experimental confirmation are needed. Correlation alone is not sufficient to justify categorization of performance. Information such as the range of rates of phosphorus uptake in varying storm water treatment areas, settling rates in reservoirs, etc., should be explored during the categorization process. Project teams should take care to not artificially drive differences in alternatives. Where uncertainty exists it is important to capture the range of potential variation of alternative performance. If the variance across the alternatives is too high (potentially overlapping performance), biological justification for categorization may not be warranted (or there may be no net lift).

Citations similar to those in CERP system-wide performance measure documentation sheets (http://www.evergladesplan.org/pm/recover/eval_team_perf_measures.cfm) should be included to justify index values derived from semi-quantitative and directional data. It is extremely important that the project teams consult with the appropriate scientists when assigning performance index values. Consultation with the appropriate RECOVER scientific sub-teams will provide wider acceptance of categorizing qualitative output. In general, qualitative indexing should be a limited component of project justification and benefits analysis.

Detection of Differences among Project Alternatives

In their current form, the CERP system-wide performance measures are not always sensitive enough to differentiate between individual project alternatives. Because many of the system-wide performance measures are based on long-term averages, the effects of extreme conditions are often dampened. By averaging high and low conditions, rather than evaluating the effects of high and low separately, sensitivity is lost.

Currently, CERP system-wide performance measures are tied to the SFWMM, which is used to predict hydrologic conditions in South Florida. The SFWMM is based on a two-mile by two-mile resolution grid. This resolution often does not provide the needed detail to determine differences in alternative performance. This is not surprising since a two-mile transect across the Everglades landscape could potentially cross several habitat boundaries. By crossing habitat boundaries, the SFWMM tends to average what might be a strong and clear signal in a single habitat type. Additionally, the model resolution does not always match the resolution of the biotic response. RECOVER recognizes the sometimes limited application of the existing suite of performance measures when coupled with the SFWMM.

One of the key methods to increase sensitivity in the near-term is to evaluate extreme wet and extreme dry years separately, or to consider the seasonality of events. Biologically, this is often more significant than the average condition. It is the extremes that can rapidly drive landscape patterning and community structure in the Everglades. For example, excessive and persistent extreme low water conditions can leave the landscape susceptible to a higher incidence of unnatural fire regime, which can rapidly alter the landscape by burning vegetation and potentially removing peat. Conversely, extreme high water conditions resulting from major storms and subsequent water management also drive structure and function by rapidly increasing water levels and flow. Increased water levels and flow have differential effects on peat accretion, tree island health, and ridge and slough pattern maintenance. The effects from these extreme high and low events can be extraordinarily destructive, potentially requiring decades to recover fully. As feedback through monitoring and assessment is used to refine the existing performance measures, it is likely that sensitivity will be increased and differentiation between project alternatives will become clearer. Guidance on evaluating seasonal or extreme year data is provided in the individual technical appendices of this document.

While the BEAM includes guidance provided by performance measure developers on the appropriate seasonality or temporal application of the performance measures, improving the sensitivity of existing CERP system-wide performance measures at the detailed level is outside the scope of the current BEAM effort. In this case, the scientific foundation on which the BEAM is built must be strengthened and developed.

To that end, RECOVER scientists are working on two different fronts to address the sensitivity issue in the longer term. First, RECOVER is working with the developers of the Regional System Model (RSM), the successor of the SFWMM, to determine the needs and constraints of migrating existing performance measures to RSM. RSM is a variable mesh triangular grid ranging from 0.5 miles to 1.5 miles on a side. With increased resolution the effects of spatial averaging may be minimized, and thereby increase sensitivity of existing performance measures. On a second front, as referred to above, adaptive management will be used to refine model parameter estimates, model rate constants, and regional aggregation, leading to a closer approximation of natural scales and likely increasing sensitivity. A sensitivity analysis will be conducted to investigate the effects of aggregation methods and current parameter estimates on response output. Recommendations will be provided to increase the sensitivity of existing methods. This is a long-term effort, and will require several years to complete.

In addition to the SFWMM and RSM, the ATLSS will be available for alternative performance evaluations in the near future. ATLSS, similar to RSM, is based on a much smaller grid size than the SFWMM. In theory, this will provide more biologically/ecologically-relevant scales at which to apply performance measures.

Standardized Documentation and Methods

Under current practice, each PDT is expected to independently develop a methodology to quantify their project alternatives' ecologic benefits to the local area as well as the broader South Florida ecosystem. The calculation of each project's benefits is completed using different methodologies, resulting in no ability to compare or relate benefits across projects in a synergistic manner. The need for consistency among project benefit calculations is twofold. First, all projects provide benefits to one system. In order to compare project benefits and relate the benefits of multiple projects to system health, the indicators and methods to index, weight, and aggregate performance levels for restoration must be consistent among all projects. Secondly, the standardization of benefits calculations and related documentation will enable a more efficient and streamlined review.

This methodology includes the following standardizations to bring greater consistency to CERP project benefits calculations:

- A standard set of scientifically defensible performance measures of ecosystem health based on conceptual ecological models and interim goals indicators recommended by RECOVER.
- A standard method to index hydrologic model output for each performance measure on a 0 to 1 scale with specifically designated performance categories developed by

RECOVER scientists. These categories correspond to a quality index for each performance measure with both the qualitative description of each category as well as the hydrologic performance necessary to reach that condition. Descriptions of how each index was established are documented on the CERP system-wide performance measure documentation sheets:
http://www.evergladesplan.org/pm/recover/eval_team_perf_measures.cfm

- Standardized methods to aggregate and weight individual performance measure quality indices. Each performance measure typically corresponds to one of the hydrologic stressors in the conceptual ecological models. The aggregation and weighting methods provided in the BEAM use the ecological relationships depicted in the conceptual ecological models and documented in scientific literature to guide the combination of individual performance measure quality indices to determine the performance of the ecologic indicator of ecosystem health.
- Standardized methods to aggregate the ecological indicators to calculate the total health of each region in South Florida from Lake Okeechobee to Florida Bay. Again, the aggregation methods provided guide the calculation of regional ecosystem health based on the selected interim goal indicators.
- Standardized acreages for each ecological region in South Florida. The BEAM uses the basic assumption that restoring the quantity, quality, timing and distribution of water will result in ecological restoration for entire regions. The standardized acreages used to calculate ecosystem benefits represent the community health of the region.
- Standardized graphical output to convey the health of each key indicator. One of the key lessons learned from other large restoration programs is the need to clearly and concisely communicate expected ecosystem benefits to the public and stakeholders.

Synergies among CERP Projects and Overlapping Benefits

The Programmatic Regulations (DOD, 2003) require CERP projects to select the alternative that maximizes net benefit to the system, as long as it is justified on a next-added increment (NAI) basis. This analysis calculates benefits of a tentatively selected alternative plan, assuming no other yet-to-be authorized CERP projects are in place at the end of the planning horizon (i.e., 2050). Therefore, when calculating NAI benefits, there is potential for two separate projects to account for the same benefits to a particular region. Given the nature of NAI analysis and the conditions under which it is conducted, such calculations are unavoidable, and it is inappropriate to attempt to add benefits calculated for the NAI analyses for separate projects that affect the same area. It is also inappropriate to try and subtract benefits expected from other projects from the total benefits possible within an area.

In the case of system-wide formulation, in which each project calculates benefits of its tentatively selected plan assuming all CERP projects are in place at the end of the planning horizon, calculation of each project's contribution to total system-wide benefits may be desirable. This methodology provides a mechanism to determine 1) the total number of benefits possible within the ecosystem (i.e., if each ecosystem indicator scored "fully restored" using the provided quality indices), and 2) the total number of benefits expected by CERP based on the CERPA model run, the "future with-CERP" run evaluated in the Initial CERP Update. Documenting total system benefits is the first step in trying to determine the effects of individual projects within the system formulation framework. The CERP assertion that the whole will be greater than the sum of its parts is easily described but not so easily demonstrated using the existing planning guidance. Further planning efforts warrant the investigation of a means to quantify the synergistic benefits among CERP projects.

Addressing Technical Significance of Ecosystem Benefits

The USACE Planning Guidance Notebook (ER 1105-2-100) states that projects that produce non-monetized benefits (i.e., ecosystem restoration projects) should explain the significance of their calculated benefits. The concept of significance is generally presented in three categories: institutional, public and technical significance. Technical significance is determined based on scientific knowledge or judgment of critical resource characteristics. The full category of technical significance encompasses:

- Scarcity
- Representativeness
- Status and trends of benefits
- Connectivity
- Limiting habitat
- Biodiversity

The BEAM explicitly addresses the representativeness, the status and trends of benefits, connectivity, and biodiversity of the ecosystem at community levels.

Representativeness. All of the indicators presented in the BEAM exemplify a healthy ecosystem and represent the desired restoration condition. Furthermore, the indicators have undergone peer review to ensure they are representative of both ecosystem health, and the ability to demonstrate the effects of CERP implementation.

Biodiversity. The selection of several indicators of ecosystem health for each habitat incorporates the variation of biological communities and acknowledges the interactions between ecosystem function.

Status and Trends of Benefits. Each indicator is also accompanied by qualitative descriptions that describe its physical attributes, extent of degradation, and functional sustainability that can be evaluated at different points in the period of record to determine whether the resource is declining or imperiled.

Connectivity. In future iterations of the BEAM, the concept of connectivity will be incorporated to address habitat fragmentation and the removal of barriers within the landscape. In a more general sense, the BEAM incorporates the connectivity of South Florida at two levels. First, the flows restored through CERP implementation provide a system-wide connection from Lake Okeechobee south to Florida Bay. The hydrologic performance measures used in the BEAM describe the overall performance success of CERP in reestablishing those connective flows. Second, the designation of total ecosystem boundaries within the BEAM encompass the idea of connected habitat and the propagation of benefits throughout that habitat. CERP benefits evaluations are conducted at a system scale to emphasize the connectivity between all the eco-regions of South Florida.

BEAM Assumptions

The BEAM is primarily applicable to regions within the boundaries of the SFWMM. Projects that do not utilize SFWMM output, or do not have compatible output for the structures or flows upon which the CERP system-wide performance measures are based, will not currently be able to utilize the BEAM to determine project benefits without adapting it to available model output. Regardless of the type of model output available, the components of the BEAM that 1) identify the indicators of system health, 2) identify ecological stressors and their relationship to indicator health, and 3) provide the qualitative descriptions of indicator health for each of the index categories are applicable to all projects.

The BEAM assumes that direct impacts to the quantity, quality, timing and distribution of water flows will provide the conditions necessary and sufficient to restore ecological structure and function. For example, the restoration of appropriate quantity and timing of freshwater flows to estuaries will affect salinity, which will improve nursery habitat and seagrass beds, which will impart benefits to fish communities and, ultimately, to the larger estuarine system. This approach embraces the idea of community or ecosystem health rather than individual species health.

The BEAM recognizes that one of the defining features of the Everglades landscape is connectivity. Landscape variability and connectivity are essential components of the Everglades that interact to maintain and re-establish population and community health. It is because of connectivity that the BEAM includes potential dispersal, propagation and diffusive effects when calculating benefits.

The BEAM is a framework to organize and use information and as such is reliant upon the performance measures and predictive tools, which provide that information. The BEAM provides a means to combine the output for CERP system-wide performance measures based on their relationships to key ecological drivers (e.g.. hydrology, sheet flow, water quality, salinity); however, it is constrained by the availability of performance measures and predictive tools to evaluate CERP performance. Ultimately, the BEAM provides the process for aggregating individual performance to a community-level response and is dependent on the availability of performance measures and predictive tools to do so.

The sensitivity of the BEAM and its ability to differentiate among project alternatives is in many cases a reflection of the limitations of current predictive tools and performance measures.

As additional performance measures and predictive tools are developed and vetted through RECOVER, they will then be inserted into the present version of the BEAM.

BEAM METHODOLOGY

The following section provides a detailed description of BEAM methodology application, from identifying the indicators of system health to calculating the habitat units for specific project alternative plans.

The BEAM is a tiered methodology, as illustrated in Figure 1:. The tiered structure was created to enable those applying the methodology to build a strong case describing how individual hydrologic-based performance measures affect the pieces of the ecosystem (i.e., drivers) that drive the health of certain key species (i.e., indicators) that indicate regional ecosystem health. This tiered approach will also enable scientists and those interested in the technical aspects of the methodology to see detailed calculations, while enabling an integrated view of ecosystem health at the upper tiers for effective communication with decision-makers and stakeholders.

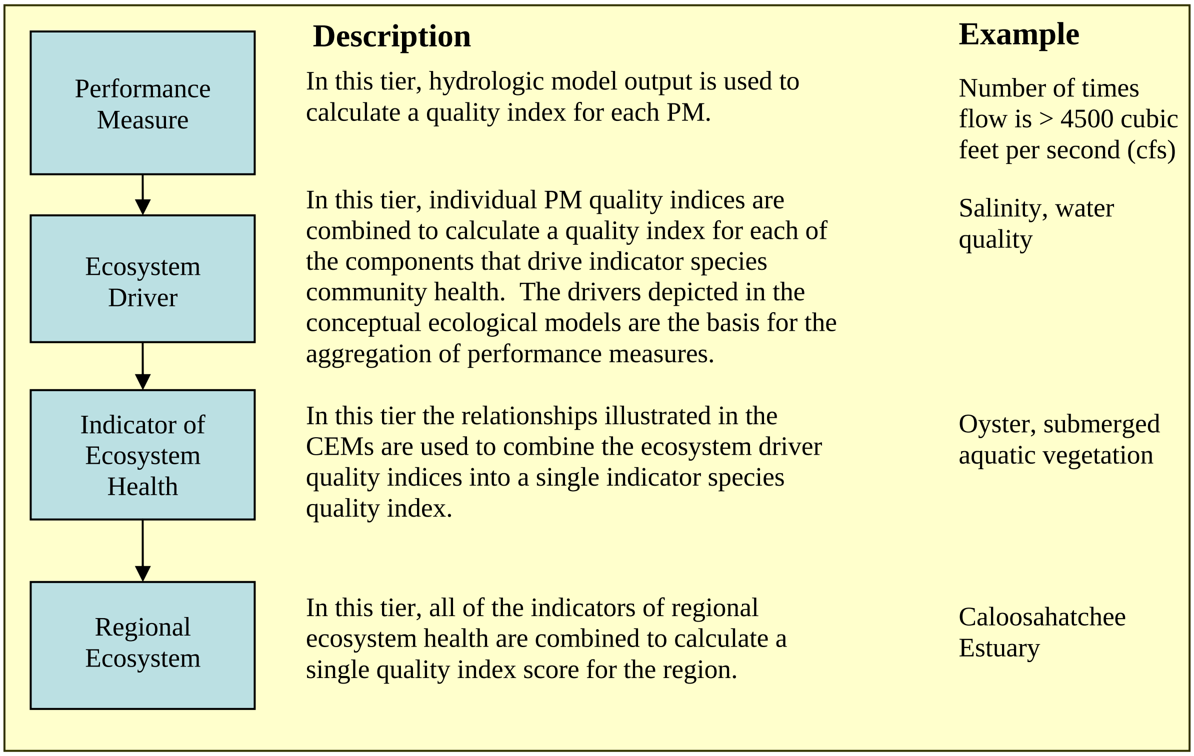

Figure 1: Tiered structure of the BEAM

The methodology includes the eight basic steps outlined in Figure 2. A more detailed description of each step follows.

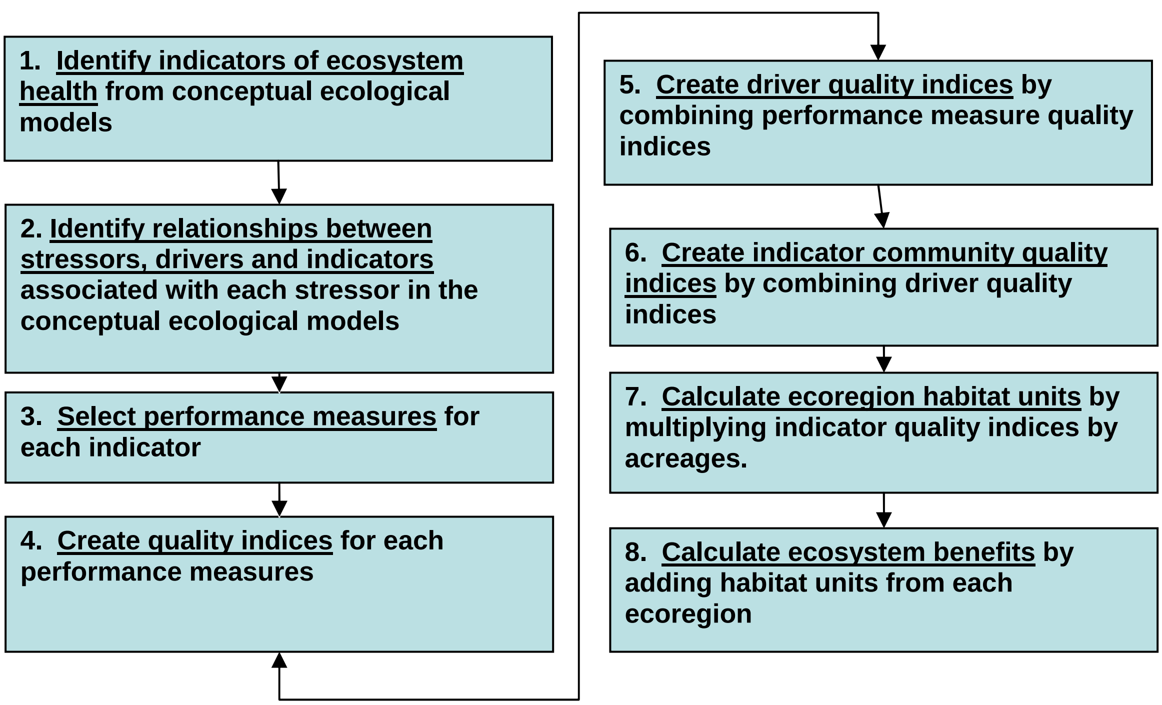

Figure 2: BEAM Methodology Steps

1. Identify the indicators of ecosystem health for each region of South Florida that the project may affect, based on the conceptual ecological models and the interim goal indicators.
2. Identify the ecological relationships and drivers that link stressors to the health of the indicator species.
3. Identify the subset of CERP system-wide performance measures that link hydrologic change expected through project implementation to changes in indicator health. From this subset, identify those performance measures for which predictive tools are currently available. If necessary, identify any other performance measures or predictive tools needed and initiate performance measure and tool development. Coordinate with RECOVER sub-teams if development of new predictive tools or performance measures is anticipated.
4. Index performance measure hydrologic model output on a 0 to 1 scale, with 1 representing the target, the restored condition, and 0 representing full degradation of the indicator. The index value represents a performance measure quality index value. Do this for each performance measure.
5. Mathematically combine the performance measure quality indices into a quality index for each ecosystem driver. The drivers relevant to each indicator species is depicted in the conceptual ecological model for that indicator. For example, salinity, sedimentation, temperature, adult density and hydrodynamics are all drivers of the indicator, oysters as shown in Figure 4 below.
6. Mathematically combine the ecosystem driver quality indices to determine an indicator quality index, for each indicator used. In the oyster example used above, the quality index for each of the drivers would be combined into a single indicator quality index for oysters. The relationships in the conceptual ecological models and scientific literature are the basis for combining the effects of multiple driver indices into an indicator quality index. The indicator quality index may employ weighting factors as needed to represent the relationships that determine indicator health.
7. The resulting indicator quality indices are aggregated to achieve a total quality score for each ecological region of the South Florida ecosystem unbiased by each region’s size. In the case of the estuarine environment, indicator indices for oyster, submerged aquatic vegetation, fish, and infaunal benthic communities may be combined to calculate an estuarine quality index value.
8. Finally, the ecological region quality indices are converted to habitat units by multiplying them by the standardized acreages for each ecological region the project alternatives affect. The results of this analysis will be a set of tables that will provide both summary data and the tables used to create them, providing the transparency needed by reviewers and decision-makers.

Methodology Application Example

An example of applying the BEAM is provided here. For simplicity, a single indicator will be investigated. The same procedure would be carried out for each applicable indicator presented in the appendices and the results would be tabulated for system-wide benefits associated with each project alternative.

The example project is a water storage reservoir with a purpose to attenuate high stages in Lake Okeechobee, improve the seasonality of water deliveries to the ridge and slough landscape, and reduce the frequency and severity of releases to the Caloosahatchee and St. Lucie Estuaries. The habitat that will be used in this example is the Caloosahatchee Estuary.

Step 1: Identify Indicators of Ecosystem Health

Within the Caloosahatchee Estuary, three key indicators of ecosystem health have been established through the CERP conceptual ecological models and the interim goal indicators:

- American oyster communities
- Submerged aquatic vegetation communities
- Fish communities

The conceptual ecological models (Figure 3) for these indicators (in yellow) represent our primary understanding of the ecosystem and the role that these indicators play in the health of the entire estuary. Therefore, we assume that achieving healthy populations of indicator species represents restoration of the entire estuary. A quality value for each indicator will be calculated and aggregated to determine a single quality index for the Caloosahatchee Estuary.

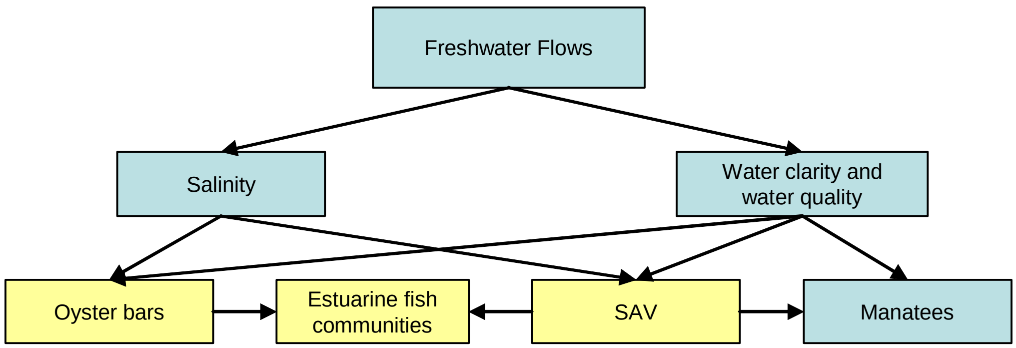

Figure 3. Simplified conceptual ecological model for the Caloosahatchee Estuary from the CERP Monitoring and Assessment Plan Part 1 (RECOVER, 2004).

Step 2: Identify Ecological Relationships Affecting Indicator Species Health

The indicator conceptual ecological model we will work through first is the American oyster (Figure 4) (RECOVER, 2006b). The conceptual ecological model represents the relationships that will ultimately determine the health of the selected indicator. In many cases, water management practices put in place by CERP implementation will be used to determine environmental benefits to the system.

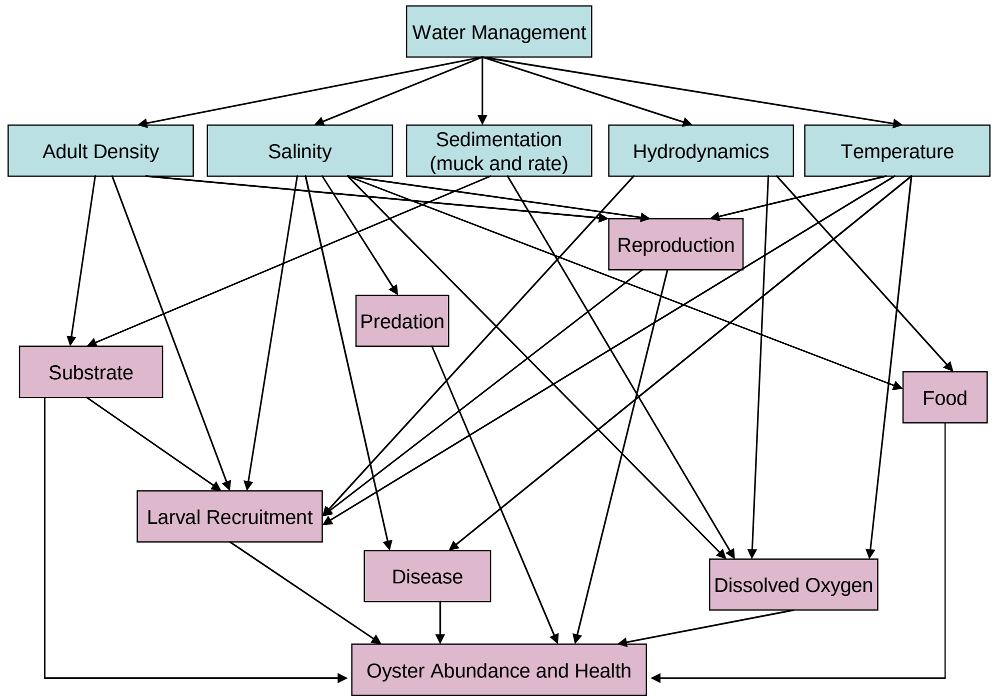

Figure 4. Simplified American oyster conceptual ecological model for the Caloosahatchee Estuary

Step 3: Identify CERP System-wide Performance Measures and Relevant Interim Goal Indicators

As previously discussed, interim goal and performance measure indicators are used as the basis for the BEAM. **Table 1** presents the relevant interim goal indicator and corresponding performance measures for American oysters in the Caloosahatchee Estuary. In this case, CERP effects on salinity will be used as the measure of indicator health and sustainability. The performance measure contains five specific targets: frequency of low flow events, frequency of moderate high flow events, frequency of extreme high flow events, frequency within the desired flow envelope, frequency of moderate high flow events due to Lake Okeechobee regulatory releases.

Table 1. Interim Goal and System-wide Performance Measure Indicators for the American Oyster Conceptual Ecological Model.

Interim Goal Indicator(s)	Performance Measure(s)
1.1 American Oysters in Northern Estuaries	NE-3 Caloosahatchee Estuary Salinity Envelope: NE3a – Frequency of low flow events NE3b – Frequency of moderate high flow events NE3c – Frequency of extreme high flow events NE-3d – Frequency within the desired flow envelope NE-3e – Frequency of moderate high flow events due to LO regulatory releases

At the current time, this salinity performance measure is the only performance measure associated with determining oyster health; however, performance measures for other conceptual ecological model components such as sedimentation rate or temperature could also be developed and incorporated to determine oyster health. Alternatively, the development of an oyster habitat suitability index could be used in place of multiple stressor-based performance measures.

Step 4: Index Performance Measure Hydrological Output

Each CERP system-wide performance measure has an associated evaluation method based on hydrologic model output. To move from hydrologic model output (e.g., the SFWMM, MIKE-SHE, or WASH 123) to environmental benefit, RECOVER sub-teams developed standard quality indices. The index for each performance measure is comprised of three parts: a numeric index value, a qualitative description of indicator health, and a quantitative description of performance measure output used to correlate predictive model output to one of the index values. The numeric index value represents the 0 to 1 quality score usually associated with benefit calculations.

For benefits quantification under the current framework, it was necessary to interpret existing performance measures in terms of index values. Six distinct categories were developed to classify performance. The six-category structure was chosen in order to capture quartile performance bounded by end classes. The categories are broken into four twenty-percentile categories with each end-member class representing the extreme 10% of high and low values for a given habitat type. This percentile distribution parallels many of the classes used in the design of ecological experiments. The BEAM combines the statistical theory used in studying ecological distributions. The classes used by Daubenmire (1952) and those used for Braun-Blanquet methodology (Braun-Blanquet, 1926; Poore, 1955; Mueller-Dombois et al. 1974) are a recognition that end member classes are needed in order to reduce bias or leveraging effects. The Daubenmire coverage classes use 0-5 % and 95-100% classes to minimize the leveraging effect of extreme values.

For example, if a mean coverage class is used as the index score and there are two different classes (0 to 5) and (0 to 25), having a coverage of 2 would provide a vastly different ranking (2.5 versus 12.5). Automatically, coverage would be overestimated in the larger range. Similarly, the Braun-Blanquet method uses end member classes, using a 0% to 5% class and then jumping to 6% to 25%. The method the BEAM employs integrates varying statistical approaches while recognizing the limitations and uncertainty associated with model output. The classes selected for BEAM were derived from understanding of biological and hydrologic uncertainty, understanding of statistical distributions, and recognition that project planning must be able to differentiate alternative plan performance.

Each BEAM category corresponds to a specific indicator condition described under the qualitative description. These conditions range from fully restored to fully degraded, and are accompanied by a narrative describing the ecological conditions of the indicator associated with each category. By standardizing the categories and qualitative descriptions, index values are comparable across metrics and even across regions. The quantitative descriptions provided under each category provide the specific performance measure output values that correspond to that ecological condition. **Table 2** represents an example of the index for the Caloosahatchee Estuary salinity envelope performance measure.

Table 2. Qualitative and quantitative description of index values for oysters in the Caloosahatchee Estuary.

Index Value	Qualitative Description	Quantitative Description (number of times exceeded)
1.00-0.91	Fully Restored. High coverage of healthy oyster beds; oyster beds provide valuable habitat for gastropods, polychaete worms, decapod crustaceans, boring sponges, fish, and birds.	NE-3a = 0-69 NE-3b = 0-26 NE-3c = 0-7 NE-3d = 0.91-1.00 NE-3e = 0-1
0.76-0.90	Minimum Alteration/ Structure and Function are Sustainable. Fluctuating loss and increase of oyster bed coverage, resulting in declining or recovering populations of other invertebrates, fish, and birds; oyster population is sustainable.	NE-3a = 70-90 NE-3b = 27-41 NE-3c = 8-15 NE-3d = 0.76-0.90 NE-3e = 2-10
0.51-0.75	Partially Sustainable. Current condition with oyster habitats partially in place, but altered hydrology not allowing restoration. Increasingly fluctuating loss and increase of oyster bed coverage, resulting in declining or recovering populations of other invertebrates, fish, and birds.	NE-3a = 91-128 NE-3b = 42-66 NE-3c = 16-28 NE-3d = 0.51-0.75 NE-3e = 11-27
0.26-0.50	Minimally Sustainable. Some loss of oyster bed coverage, resulting in declining populations of other invertebrates, fish, and birds; small oyster population is sustainable.	NE-3a = 129-167 NE-3b= 67-91 NE-3c = 29-42 NE-3d = 0.26-0.50 NE-3e = 28-44
0.11-0.25	Mostly Degraded/Unsustainable. Significant loss of oyster bed coverage; oyster population is barely sustainable.	NE-3a = 168-190 NE-3b= 92-106 NE-3c = 43-49 NE-3d = 0.11-0.25 NE-3e= 45-54
0.01-0.10	Fully Degraded. Indicates poorest condition for the estuary. With high influx of freshwater, entire populations of oysters die, particularly during the summer months when oysters are spawning. Alternately, overly high salinity results in epizootic outbreaks (namely Dermo), which also results in mass mortality of oysters.	NE-3a = 191-205 NE-3b = 107-116 NE-3c = 50-55 NE-3d = 0.01-0.10 NE-3e = 55-61

There are various ways to determine the appropriate class and index value for performance measure output in the index table:

- Ranges of hydrologic performance output that correspond to each qualitative category description may be used. For example, 0 to 3 occurrences over the period of record corresponds to the fully restored category. In this instance, the average index value for the category should be used unless otherwise specified (i.e., 0.95)

- A standard numeric equation that results in a direct calculation of the quality index score based on performance measure output may be provided.

When no quantitative tool is available to link performance measure output to a quality index value, a PDT can use scientific or technical expertise (best professional judgment) to determine which qualitative condition the project alternative is expected to produce. This method might also be employed for qualitative or directional change for which refined numeric predictions are not available. The professional judgment needs to be supported by referenced literature, results from pilot studies, and/or data and field results for similar restoration actions. Documentation similar to that seen on the CERP System-Wide Performance Measure Report documentation sheets is necessary. PDTs should coordinate with RECOVER if best professional judgment is used in lieu of vetted performance measures to ensure broad scientific participation and support.

For the example presented, the performance measure (NE-3d) documents the frequency of flows within the salinity envelope (i.e., the number of weeks mean monthly flow is between 450-2800 cfs [raw score]). This number is used in Equation 1 to determine the performance measure index value.

Equation 1

$$IndexValue = \frac{rawscore}{POR\#\,weeks}$$

The SFWMM output and corresponding quality indices are presented in **Table 3** for the alternative under consideration in our example project. Similar equations have been established for the frequency of extreme high flow events (NE-3c), frequency of moderate high flow events (NE-3b), low flow events (NE-3a) and Lake Okeechobee regulatory releases (NE-3e). **Table 4** summarizes the quality scores for each of these performance measures.

Table 3. NE-3d Frequency of weekly flows within the salinity envelope and corresponding quality index scores

Performance Measure	2050 FWO	Alt-1
SFWMM output for NE-3d (# weeks)	216	390
NE-3d Quality Index Score (# weeks/POR weeks)	0.51	0.82

Table 4. Summary of performance measure quality indices

Performance Measure	Quality Index Score, 2050 FWO	Quality Index Score, Alt-1
NE-3a	0.59	0.94
NE-3b	0.96	0.96
NE-3c	0.51	0.84
NE-3d	0.51	0.82
NE-3e	0.40	0.40

Step 5: Calculate Ecosystem Driver Quality

Once quality index scores have been calculated for each performance measure, they must be aggregated to represent all the components that drive ecosystem health for the indicator species (i.e., American oyster). Based on the relationships depicted in the oyster conceptual ecological model, adult density, salinity, sedimentation, hydrodynamics, and temperature are all drivers for oyster health. The CERP system-wide performance measures all relate to one driver of oyster health, establishing an appropriate salinity envelope for oyster recruitment and development. Therefore, the performance measure quality indices will be aggregated to obtain a single quality index for salinity. Equation 2 and Equation 3 should be used to calculate the salinity indices. A summary of the results for the example project is presented in **Table 5**.

Equation 2 $$HighSalinity = NE3a$$

Equation 3 $$LowSalinity = \frac{(NE3b + NE3c + NE3d + NE3e)}{4}$$

Table 5. Summary of quality index scores for salinity, ecosystem driver

Ecosystem Driver	Quality Index Score, 2050 FWO	Quality Index Score, Alt-1
High Salinity	0.59	0.94
Low Salinity	0.60	0.76

Step 6: Calculate Indicator Quality Index

The quality index scores calculated in the previous step for the appropriate ecosystem drivers, will be aggregated to calculate a single quality index score for oyster health in the Caloosahatchee Estuary. Equation 4 is used to aggregate the high salinity and low salinity scores calculated in the previous step. In the current example, salinity is the only ecosystem driver available. If performance measures and corresponding calculations for sedimentation, temperature, or adult density had been developed, then the quality indices for those ecosystem drivers would also be included in the calculation of the oyster quality index.

Equation 4 $$OysterCEM = (0.2 * HighSalinity) + (0.8 * LowSalinity)$$

The BEAM has developed and applied a weighting for the calculation of the oyster indicator quality index. A weighting has been placed on the importance of the frequency of high salinity events versus low salinity events. Large volume releases from Lake Okeechobee cause large volumes of freshwater over a short period of time to enter the estuary causing a sudden drop in salinity. This sudden drop can lead to significant mortality in the oyster population, and decreased growth, reproduction and spat recruitment (Volety et al. 2003). The pulse releases that lead to drastic and prolonged reductions in salinity are more harmful to oyster communities than periods of low flow and high salinity. Although extreme droughts and prolonged periods of low flow can also negatively impact oysters by making them prone to disease and predation, these high salinity events are not as damaging to the oyster populations. Therefore, they are weighted less in the overall indicator quality index score (Volety, pers. comm., Volety et al. 2003, Tolley et al. 2004, and Volety et al. 2004). Weighting of conceptual ecological model components is supported by the methodology because it is supported by scientific literature. The weightings and supporting references that should be used for each quality index developed and applied in the BEAM are specified in the worksheets for each indicator. **Table 6** summarizes the quality index scores for each of the alternatives in the example project.

Table 6. Summary of quality index scores for American oyster, indicator of ecosystem health in the Caloosahatchee Estuary

Indicator of Ecosystem Health	Quality Index Score 2050 FWO	Quality Index Score Alt-1
American Oyster	0.59	0.79

Step 7: Aggregate Indicator Quality Indices to Calculate Total Quality Index for Ecological Region

The community or ecosystem health approach that forms the basis of the BEAM operates on the assumption that a core set of scientifically supported indicators can be used to indicate the health of the entire ecosystem or region. The methodology provides guidance on how to aggregate the indicators to achieve a total quality index for the estuary.

Table 7 provides the conceptual ecological model indicator quality index for the indicators in the Caloosahatchee Estuary. Some indicators do not have the established targets, quantitative relationships, or the predictive tools necessary to determine environmental benefits. Nevertheless, they are included in the BEAM as placeholders until the supporting information needed to use these indicators is available. Equation 5 outlines how the full suite of indicators would be combined to calculate the total quality index for the estuary. Equation 6 outlines how the available indicators should be combined until the full suite of indicators is available. **Table 8** presents the ecosystem quality index for Caloosahatchee Estuary.

Table 7. Conceptual ecological model indicator quality indices for the Caloosahatchee Estuary

Indicator of Ecosystem Health	Quality Index Score, 2050 FWO	Quality Index Score, Alt-1
Oyster	0.59	0.79
Fish	Not available	Not Available
Submerged Aquatic Vegetation	0.59	0.85

Equation 5

$$CE = \frac{(Oyster + Fish + SAV)}{3}$$

Equation 6

$$CE = \frac{(Oyster + SAV)}{2}$$

Table 8. Ecosystem quality index for Caloosahatchee Estuary.

Ecosystem	Quality Index Score, 2050 FWO	Quality Index Score, Alt1
Caloosahatchee Estuary	0.59	0.82

Step 8: Calculate Habitat Units

The quality index calculated in the example project is relevant for the Caloosahatchee Estuary. A similar process would be carried out for each ecological region of South Florida. Each regional quality index is multiplied by the designated acreage for that region to calculate habitat units (**Table 9**).

Table 9. Habitat units for the Caloosahatchee Estuary

Ecoregion	Ecoregion Quality Index Score	Ecoregion Acreage	Habitat Units, 2050 FWO	Habitat Units, Alt1
Caloosahatchee Estuary	0.59	71,000	41,890	58,220

Spatial Component of Methodology

The total quality index calculated for the region is only half of the needed information to calculate environmental benefits. A spatial component is necessary to convert index values into habitat units, which are then used as the measure of a project's ecosystem benefits (relative to the future-without-project condition). The BEAM's focus on community health provides the basis for standardizing acreages for each region (and or habitat type) of the South Florida ecosystem.

Current methods followed to quantify benefits in the CERP and other programs vary from the simple to the complex in the methods used to define the spatial extent of project effects. In some instances, each indicator species is assigned its own affected area footprint, and these footprints are added like vertical layers within the ecosystem to calculate a total affected acreage. In other instances, project teams attempt to define/delineate the exact boundary of project influence (identify where the effect of the water from their project ends). While ecologically justified, neither of these approaches embraces the community habitat view on which the BEAM is based. In addition, teams have spent considerable time and effort in their attempts to delineate such areas.

Single Species-based Acreages

Some previous methodologies have calculated quality and acreage scores for individual species within the ecosystem, then summed for the region. This approach relies on a species management approach in which the only benefits attributed to a project are those which are directly manifested in the chosen species. Using single species to calculate species footprints and then adding them can have the unintended impact of disassociating complex communities that should be viewed as a whole. As additional species are identified and their footprints are added to the benefits calculation, habitat units are increased as more vertical layers are accumulated. Adding the lift from individual species does not provide a means to cap the predicted habitat units provided by a project, and it would be possible to claim more acres of benefit than are physically present in the ecosystem.

Connectivity and Regional Benefits

Within the species-focused management approach, there is the implicit assumption that only direct benefits to those species and their footprints are identified as ecosystem benefits. The BEAM recognizes that the species identified within the methodology are *indicators* of ecosystem health. While the importance of healthy oyster and seagrass beds is acknowledged in our example, the function that these species play in the larger ecosystem context (and the prerequisite conditions necessary for proper function) is the basis for determining a project's benefits. The nursery habitat, foraging conditions, and other ecosystem functions supplied by the indicator species translate to a healthy environment throughout the estuary, not just confined to the specific species footprints. It is because of connectivity that the BEAM includes areas of potential dispersal, propagation and diffusive effects when calculating benefits.

Community Approach to Acreage

The BEAM operates on the premise that CERP should not focus on single species management, but rather should manage for communities and habitat types. The essence of the historic South Florida ecosystem is far more than a sum of individual species; therefore, the approach of determining environmental health based on total ecosystem health is favored over formulating and evaluating restoration alternatives from a species perspective. The community approach incorporates the view that the species within the methodology are indicators of broader ecosystem health, that benefits to the ecosystem reach farther than the immediate species footprints, and that the community approach to restoration will benefit all components of the system. Additionally, the community approach provides a mechanism to evaluate multiple, sometimes incompatible goals simultaneously.

The community-based approach employed by the BEAM recognizes the contribution of each individual project in reaching the restoration targets for a particular ecosystem. The restoration of the ecosystem structure and function was illustrated in the Restudy through the implementation of 68 projects. Each project provided a percentage of the conditions necessary to re-establish healthy lake, estuarine and marsh communities. Through the BEAM community-based approach, each project will eventually be able to calculate its individual contribution toward the total system benefits of reestablishing those healthy ecosystems.

Standardized Acreages

To standardize the calculation of ecosystem benefits among projects, the ecosystem boundaries have been defined for each of the South Florida regions and are presented in **Table 10**. In some regions (e.g., Greater Everglades, Florida Bay, Biscayne Bay) there are sub-regions for which quality indices are calculated on an individual basis. This practice is required to 1) look at the performance of areas that are hydrologically distinct, and 2) enable the BEAM to capture and account for the variability among sub-regional areas. An area weighting is applied to these regions to ensure that their contribution toward the quality index of the entire ecological region is proportional to their size within that region. The standardized acreages will eventually be documented in an appendix to this document.

Table 10. Acreages for South Florida ecoegions

Ecoregion	Sub-region Area (acres)	Total Ecoregion Area (acres)
Lake Okeechobee		427,500
* Lake Okeechobee Pelagic Zone	255,158	
*Lake Okeechobee Nearshore Zone	73,500	
*Lake Okeechobee Littoral Zone	98,842	
St Lucie Estuary		7,927
Lake Worth Lagoon		7,458
Caloosahatchee Estuary		71,000
Loxahatchee Estuary		1,178
Everglades Ridge and Slough		1,126,752
Everglades Southern Marl Prairies		330,967
Everglades Mangrove Estuaries		771,000
Big Cypress Regional Ecosystem		729,000

Biscayne Bay		273,920
Florida Bay		448,000

System Benefits

Using the total quality index and the standardized acreages specified in the BEAM, the calculation of total system ecological benefits becomes an exercise in multiplication and addition. Just as important as the final calculation, however, is the presentation of ecological benefits in a manner that clearly demonstrates the project's effects on ecosystem health, structure and function. **Figure 5** was developed to concisely summarize the total quality health for each region of South Florida from Lake Okeechobee to Florida Bay using the scientifically supported indicators of ecosystem health on which the BEAM is based. This graphic representation of ecological benefits provides a simple snapshot for managers, decision makers and stakeholders and is easily produced with BEAM.

The Role of Monitoring and Adaptive Management

As with most processes, change is expected as new policies are adopted, new technical capabilities are developed, and new scientific discoveries are made. In concert with the CERP Adaptive Management Strategy (RECOVER, 2006c), this methodology acknowledges and incorporates the need to improve CERP scientific and planning tools as these changes take place.

Updates to the CERP Conceptual Ecological Models

The relationships between hydrology and ecology that are currently depicted in the CEMs for each region reflect our understanding of the ecosystem. More importantly, the CEMs graphically represent the set of operating hypotheses that CERP monitoring and assessment activities are analyzing. For example, the linkage between hydrologic conditions, fish prey density, vegetation, and wading bird foraging condition suitability is conceptually represented, but the exact impact and interrelation of these components can only be verified through data collection and analysis. Each will be assessed to determine the exact relationships that drive each component of the CEMs. As the hypotheses that link these CEMs become better understood, some of the linkages, or the importance of some factors over others in determining total ecosystem health may change. As CERP's system-wide scientific body (i.e. RECOVER) proposes these changes, they will be incorporated into the evaluation methodology. The incorporation of this information should serve to improve the scientific defensibility of the methods used to calculate ecological benefits.

Updates and Refinements to Indicators and Performance Measures

The indicators proposed in the BEAM are based on the IG/IT indicators as the core set of indicators used to define Everglades restoration success. As mandated in the Programmatic Regulations, the indicators for IG/IT and their associated predictions of CERP performance will be reviewed and refined no less than every five years (DOD 2002). There is the potential for new indicators to be added in response to new ecologic understandings and changing social values. Because one of the criteria to be an IG/IT indicator is a clearly defined link to the CERP CEMs, the BEAM provides the framework for the incorporation of these indicators into the existing calculations.

In addition to the anticipated updates to IG/IT indicators, RECOVER is constantly refining and improving existing performance measures. These improvements could include more detailed evaluation procedures, refined targets, improvements to performance measure index values, etc. All changes to the CERP System-wide performance measures will be conducted in accordance with the RECOVER performance measure approval process (RECOVER, 2006b).

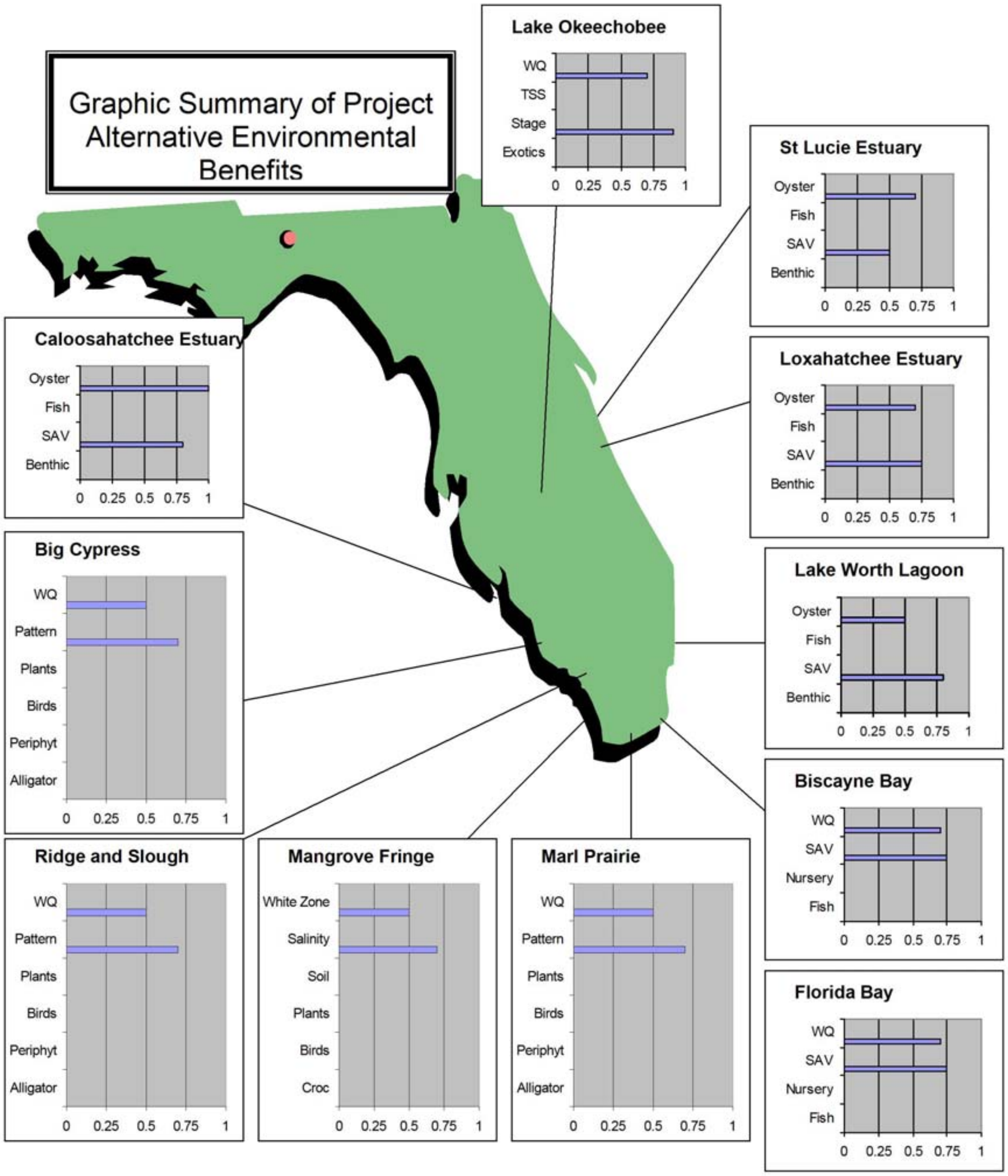

Figure 5. Graphical summary of environmental system benefits

New Predictive Tools

The primary predictive tool used at this time is the SFWMM. Hydrologic surrogates predicted using this model are translated through the quality indices to ecological benefits. As more robust, dynamic population models or hydrologic suitability indices are developed, they will likely replace the aggregation of these hydrologic metrics. The updated models/indices will include the same components that are currently included in the average aggregate conceptual ecological model index scores, but will provide a single quality index score rather than relying on the aggregation of several hydrologic metrics. The advent of ecologic models and suitability indices will ultimately simplify the proposed methodology by providing a single score for each conceptual ecological model, thereby eliminating much of the aggregation and weighting currently included.

In addition to the creation of ecological suitability indices, the CERP is in need of the predictive tools necessary to quantify and relate changes in water quality expected from CERP implementation. Water quality is an important ecological driver in a majority of the CERP conceptual ecological models, and is included in the BEAM where CERP system-wide performance measures are available. The development of predictive tools and accompanying performance measures is a critical gap in CERP's ability to demonstrate ecological benefits to many parts of the South Florida Ecosystem.

Quantifying the Effects of These Changes

While these changes can be incorporated in the methodology framework proposed, the methodology is transparent and can be easily deconstructed to determine the influence of any one metric or change. The tiered system on which the methodology is based enables the user to step into the calculation process and evaluate how the revised information may have changed benefit calculations for previous applications.

WHEN AND HOW TO APPLY BEAM

The Civil Works Planning Process

The BEAM can be used throughout the USACE Planning Process to determine the ecosystem benefits associated with project alternative plans. This section briefly highlights some of the considerations for employing the BEAM during different stages of the planning process.

Development of Management Measures and Formulation of Alternatives

PDTs can use the BEAM as a compass when brainstorming the initial set of management measures and formulating alternatives. Knowing that the BEAM is the context in which benefits accounting will occur can allow the PDT to develop an initial array of alternatives that directly addresses key issues. This will facilitate a more efficient plan formulation process. Using the BEAM as an end point can also assist the formulation of alternatives that can have a degree of separation from one another which will allow for easier selection and tradeoff analysis between alternatives and will also allow for more "room" between alternatives for modifications as future generations of alternatives are produced as the study progresses.

Screening Alternative Plans

The BEAM can be a measuring tool to gage the performance of alternatives in total and against one another and to screen out non-cost effective plans. It can also guide the team as to what is important to add or delete from alternatives in the optimization process plans move from concepts to more detailed levels during the study. For example:

In early plan formulation, the BEAM could be used to help screen management measures and alternatives. In some situations, previous modeling may be utilized in the BEAM for this screening process.

Evaluation and Comparison of Alternative Plans

Project alternative plans can be developed and evaluated in an iterative process involving modeling, evaluation, and refinement of an alternative, or multiple alternatives could be developed then modeled and evaluated at once. Regardless of the method employed, the evaluation analysis centers on an alternative's performance within the context of the rest of CERP (i.e., the 2050 condition with the selected alternative in place with the rest of CERP). The BEAM can be used to determine the ecosystem benefits associated with each alternative and provide the benefit information needed to complete Cost Effective/Incremental Cost Analysis (CE/ICA) and identify the most cost effective and best buy alternative.

Refining the Tentatively Selected Plan

Following the CE/ICA and identification of the best buy plan, an alternative is selected as the tentatively selected plan (TSP). From this point, the TSP design and operations may be refined to maximize project benefits. In the past, optimization focused on maximizing project benefits and meeting project objectives. The BEAM provides a tool to determine how refinements to alternative design and operations will translate to system ecosystem benefits. Using this tool, TSP refinement can focus on maximizing ecosystem benefits to the broader South Florida ecosystem outside the project footprint.

Next Added Increment Analysis for Tentatively Selected Plan

As described in Program Guidance memoranda, the alternative plan selected as the TSP must be justified using next added increment analysis. This analysis evaluates the project alternative plan's performance at the end of the planning horizon (i.e. 2050) including other authorized CERP projects. The BEAM can be used to calculate NER benefits for project alternative plans ultimately used as part of the next-added increment justification analysis.

Environmental benefits within the Project Implementation Report

The BEAM represents a large step forward in standardizing the quantification of environmental benefits for restoration projects; however, it is only a portion of the information that will ultimately convey the justification for project implementation. This section briefly outlines some of the components that can be employed to narrate and demonstrate benefits in the project implementation report (PIR).

Significance of Project Benefits

Project benefits can be used to demonstrate the public, institutional, and technical significance of a restoration project. The BEAM's basis on scientifically peer reviewed relationships substantiates the technical significance of restoring the hydrology and water quality necessary to restore the ecosystem. The BEAM does not address the institutional and public significance of a restored Everglades ecosystem; however information that documents these aspects of the restoration project should also play a role in the PIR.

Describing Linkages between Hydrologic Change and Environmental Benefits

The BEAM provides the framework to not only calculate a project's expected environmental benefits, but also to provide necessary structure to the discussion of environmental benefits. The logical progression from hydrologic change, to indicator health, to total ecosystem health outlined in the BEAM mirrors the narrative required to convey how hydrologic change imparted by CERP will result in South Florida restoration.

Graphical Tools

A picture is worth a thousand words, especially when trying to communicate difficult concepts such as the practical difference among similar alternative plans or the synergy between CERP projects. Graphical tools that utilize the environmental benefits calculated by the BEAM can be developed to show quality indices of different alternative plans over time to differentiate among alternatives. Graphics to demonstrate how benefits are expected to increase between NAI analysis and system formulation could also be developed to emphasize that each project is only a contribution toward the greater goal of CERP restoration.

Risk and Uncertainty

It is not the intention of the BEAM to imply a level of accuracy and certainty regarding predicted levels of ecological benefit incommensurate with the levels of uncertainty implicit in ecosystem restoration. The BEAM itself is an organizational tool that provides guidance on the aggregation and weighting of individual performance measures to quantify the expected ecological function resulting from various planning alternatives. The BEAM is reliant upon available sources of information and predictive tools as input to the methodology, and as such incorporates the various uncertainties inherent in these inputs. This section outlines general areas/sources of uncertainty present in the performance measures, predictive tools, and the BEAM itself.

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