Northern Estuaries Performance Measure
Water Quality

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Acceptance Status: Accepted

1.0 Desired Restoration Condition

Improve the quality of water released to tide towards promoting establishment, maintenance, and sustenance of a healthy, well-balanced assemblage of estuarine flora and fauna. Success in meeting restoration expectations will be measured by the degree in which constructed features and operational considerations sufficiently enhance estuarine water quality as appropriate for each of the estuaries being restored. Reservoirs, aquifer storage and recovery units, and storm-water treatment areas (STAs) planned as part of CERP are expected to reduce loadings of nutrients, solids and contaminants. The frequency and severity of algal blooms in response to improved control over nutrient enrichment is expected to decrease. Reduction in the frequency, volume and rate of discharge is expected to reduce sediment transport events, with an improvement in the stability and suitability of the sediment as habitat. As a result water clarity is expected to improve or remain appropriate for support of SAV. Improvements in nutrients, sediments, and algal bloom occurrence are expected to result in improved dissolved oxygen regime, with associated benefits on various fauna. A reduction in the concentration of contaminants in the upper sediments will reduce exposure of the benthic infauna, fish and other animals.

Caloosahatchee Estuary (CE): Specific Restoration Goals

Improved water quality at S-79 and the reduction of high flows and loads from Lake Okeechobee Regulatory Releases will reduce nutrient levels in the CE. This will produce the collateral benefits of preventing anoxic conditions in upper estuary and algal blooms and drift algae in the lower CE.

Indian River Lagoon (IRL): Specific Restoration Goals

Improved water quality as a result of reduced sediment, contaminant, and nutrient loads. Positive impacts are not expected to be limited to the IRL alone, but extend to the reef system neighboring the Fort Pierce inlet. Restoration targets are to reduce phosphorus and nitrogen loading. Full implementation of the Project is expected to reduce phosphorus and nitrogen loads; however, to achieve the restoration targets of Section 4.1.2 agricultural and urban BMPs will be required to supplement Project benefits by effectively addressing local point and non-point sources.

Lake Worth Lagoon (LWL): Specific Restoration Goals

The restoration goal for Lake Worth Lagoon is to minimize perturbation from excessive suspended sediment inflow and to improve estuarine water quality to protect and enhance estuarine habitats and biota. Although CERP restoration will only target the central portion of the lagoon by reducing suspended sediment inflow through the C-51 canal, it is expected that those benefits will extend to the northern and southern portions of the lagoon, thus increasing the spatial extent of flora and fauna throughout the lagoon.

Loxahatchee River Estuary (LRE): Specific Restoration Goals

The restoration goal for Loxahatchee River Estuary is to minimize perturbation from increased nutrient loading to the estuary, to improve estuarine water quality and to protect and enhance estuarine habitats and biota. Reduction in the incidence and duration of peak flow discharges through the S-46 structure will improve water quality conditions in the estuary thus increasing the spatial extent of flora and fauna.

St. Lucie Estuary (SLE): Specific Restoration Goals

Improved water quality as a result of reduced sediment, contaminant and nutrient loads. Positive impacts are not expected to be limited to the SLE alone, but extend to the Southern IRL and the nearshore reef system neighboring the St. Lucie inlet. Restoration targets are to reduce loading from 193 to 110 metric tons/year of phosphorus (43% reduction) and from 1166 to 816 metric tons/year of nitrogen (30% reduction). Full implementation of the Project is expected to reduce phosphorus and nitrogen loads by 68 and 278 metric tons/year, respectively, reducing the remaining load to 125 (36% reduction) and 888 (24% reduction) metric tons/year, respectively. To achieve restoration targets, agricultural and urban BMPs will be required to reduce local point and non-point loads by an additional 15 and 72 metric tons/year of phosphorus and nitrogen, respectively (USACE and SFWMD 2004).

1.1 Predictive Metric and Target

Predicted reductions in nutrients correspond to expected reductions in sediment loads and turbidity, decreases in algal bloom frequency and severity, reduction in contaminant transport, increases in water clarity and dissolved oxygen regime; however, the mathematical tools necessary to predict these associated improvements directly either do not exist, have not been calibrated, and/or will not be available within the required timeframes.

Caloosahatchee Estuary: Specific Predictive Metrics and Targets

The estimated average annual load of total nitrogen delivered at S-79 for with project conditions should be reduced by at least 10% from existing conditions, reducing mean annual nitrogen concentration in the estuary to 0.80-0.85 mg-TN/l or less. Current estimate of baseline condition is presented in Table 1 below. The suggested nitrogen regime would reduce the probability of chlorophyll a concentrations exceeding 11 ug/l, as estimated by the empirical relationship (Chamberlain and Hayword 1996):

$$Chl\_a_{ug/l} = 10^{-3} \cdot e^{(1.036*\ln(\deg C)*0.4446*\ln(TN_{ug/l})*e^{-0.001562*WaterColor_{units}})}$$

… given water temperature = 25˚ C. and improved water clarity as a represented by a water color = 50 units.

Reduce (goal is zero) the estimated number of occurrences of dry-season monthly average total nitrogen load exceeding 190 metric tons. Under existing conditions, the dry-season maximum desirable TN load is exceeded 45 times over a 36-year simulation period.

Reduce (goal is zero) the estimated number of occurrences of wet-season monthly average total nitrogen load exceeding 350 metric tons. Under existing conditions, the dry-season maximum desirable TN load is exceeded 60 times over a 36-year simulation period.

Reduce (goal is zero) the estimated number of occurrences of average annual total nitrogen load exceeding 3000 metric tons. Under existing conditions, the average annual desirable maximum TN load is exceeded 10 times over a 36-year simulation period.

Indian River Lagoon: Specific Predictive Metrics and Targets

An analysis of water quality and seagrass data from water quality stations in the IRL 1990-1999 indicated that appropriate targets for TP and TN are within the range 0.025 – 0.070 and 0.6 – 1.1 mg/l, respectively, with median values within that range of 0.053 and 0.676 mg/l, respectively (Crean et al. 2006). Current estimate of baseline condition is presented in Table 1 below.

Lake Worth Lagoon: Specific Predictive Metrics and Targets

Water quality parameters for Total Nitrogen and Total Phosphorus for Lake Worth Lagoon have been measured at the FDEP WQ stations from 2001 to 2005. This will be used as the baseline for prediction of the effects of CERP. Current estimate of baseline condition is presented in Table 1 below. The target for this metric is no increase above this baseline.

Loxahatchee River Estuary: Specific Predictive Metrics and Targets

Targets are no net increase in TP concentration and to reduce TN concentrations to the statewide median of 0.67 mg/l (Table 2 below). Current estimate of baseline condition is presented in Table 1 below.

St. Lucie Estuary: Specific Predictive Metrics and Targets

The target is to reduce current TP and TN concentrations to Florida Estuary median values of 0.081 and 0.72 mg/l, respectively, by reducing TP and TN loads by 57% and 30%, respectively. Water quality measured at the Roosevelt Bridge 1999-2004 indicates current baseline TP and TN of 0.187 mg/l and 1.03 mg/l, respectively (DBHydro SFWMD). Current estimate of baseline condition is presented in Table 1 below.

Table 1. Estimated baseline key water variables. Data shown is based on 1994-2005 data (except LWL 2001-2005, Caloosahatchee 1999-2005). ns = not sampled; * bottom DO taken at site 60 only, number shown is average of site 60 bottom samples only. Sites were selected from a suite of available sites believed to be most representative of baseline condition.

Estuary	Combined Key Sites*	TP	TN	Chl α	Water Color	Turbid-ity	Secchi Depth	DO mean	DO mean at bottom	%time bottom DO<4
Caloosahatchee	CES04, 05,06,07	0.111	0.94	13.0	83	4.0	0.9	6.5	4.6	22
IRL	IRL24, 26, 36, 37, 39, 40	0.058	0.71	5.8	12	5.9	1.2	6.8	5.6	10
LWL	18A, 10, 18B, 28A	0.067	0.67	7.2	32	3.1	ns	8.1	5.2	21
Lox	60,51, 72	0.039	1.29	10.1	42.5	3.6	1.2	6.2	5.8*`	3
SLE	HR1; SE02, 03, 08	0.189	1.09	9.7	62	8.4	1.0	6.3	4.1	42

Table 2. Recent 1990-2002 median values (50th percentile) of select parameters among all Florida's streams and estuaries (Hand 2004).

Parameter	Estuaries	Streams
Total P, mg/l	0.10*	0.06
Total N, mg/l	0.67	1.05
Chlorophyll α, corrected, ug/l	7.2	4.2
Turbidity, NTU	3.1	2.5
Color, PCU	20	80

Secchi Depth, m	1.0	NA

* The median value among Florida's estuaries is biased high by those west-coast estuaries that receive runoff from geologically P-enriched drainage basins, i.e., basins supporting a viable phosphate mining industry; previously reported and utilized median for total P of 0.081 mg/l was based on analysis of adjusted 1989-98 data (Hand 1999, USACE and SFMD 2002).

1.2 Assessment Parameter and Target

Estimate of Current Baseline Condition

Estimates of Baseline Condition were based upon data extracted from a subset of sites representative of the estuarine condition most likely to undergo detectable change (Table 1). As this is a forecast, the actual subset of sites may change as experience with the growing dataset so warrants. In all cases, implementation of CERP should result in improvements to the suite of key baseline water quality parameters (Table 1), whereas success in that regard is defined as enhanced condition appropriate to the continuation, establishment and/or sustainability of the desired floral and faunal community. Expectations regarding water quality in the estuaries are not uniform. Baseline data may be comparatively analyzed pre- and post-CERP project implementation in a number of ways including, but not limited to, decreases or increases in mean or median value, decreases in the number of events higher or lower than appropriate threshold values (e.g., count of events higher than 30 ug/l chl a or dissolved oxygen concentrations lower than 2 mg/l), changes in the mean of the upper or lower 10% of values, and so forth. It is imprudent to implement a priori assessment protocols, as the exact identification of appropriate methodologies is forthcoming through actual implementation. The intent is that CERP will affect baseline condition toward improvement.

Nutrients

Specific targets for each estuary are provided in Section 1.1. Reductions in nutrient loads are sought for all estuaries; thus, targets include detection of significant downward trends at 90% confidence ($P \leq 0.10$).

Dissolved Oxygen

Target is to improve or maintain suitable conditions for establishment and maintenance of healthy, well-balanced biological communities. Bottom dissolved oxygen regime is most meaningful as regards biological response and success. Target is to meet and maintain regulatory requirement of 4 mg/l at bottom depth taking into consideration diurnal dissolved oxygen minima.

Jordan et al. (1992) developed dissolved oxygen targets for the Chesapeake Bay for the protection of desirable species of fish, mollusks and crustaceans. These targets recommended that dissolved oxygen is greater than or equal to 1.0 mg/l at all times everywhere in the water column; dissolved oxygen never falls within 1.0-3.0 mg/l for longer than 12 hours every 48 hours; monthly mean dissolved oxygen is greater than 5.0 mg/l at all times above the pycnocline (above the wedge of saltier water that typically exists as a function of tides); and dissolved oxygen is always greater than 5.0 mg/l in spawning and nursery areas. These considerations may be pertinent to the Northern Estuaries.

Algal blooms

Chlorophyll α is an indirect measure of the quantity of algae in water, the latter principally a response to nutrient and light availability. A decrease in mean chlorophyll concentration would be representative of a decrease in mean algal abundance, a decrease in nutrient availability, and suggestive of a decrease in frequency of bloom events. Reductions in nutrient loads is sought for all estuaries and is expected to translate into reductions in severity and frequency of algal blooms, and a net reduction in mean chlorophyll α concentration; the target in all estuaries would therefore be to document a beneficial trend. Trends in chlorophyll α should be determined by utilizing the methodology set forth in Florida's Impaired Waters Rule (IWR, 62-303 FAC) which calculates calendar-year means as a function of the average of the means of the four calendar-year quarters. This technique serves to dampen extreme events, would be more likely to reveal authentic trends, and must be employed in any case to evaluate condition against the threshold of defined impairment, 11 ug/l annual mean. In cases where the annual mean is currently >11 ug/l, reducing the chlorophyll concentration below this threshold of impairment is also a target and an indicator of success. Significance for detection of a downward trend should be based upon 90% confidence ($P \leq 0.10$).

Contaminants

Assessment of contaminants in the estuaries is limited to a once per year analysis of sediments and water column for toxic substances (Monitoring and Assessment Plan, RECOVER 2004). Target is a decrease in concentration and number of detections among the suite of analytes tested.

Water Clarity

CERP projects that will be constructed upstream from the estuary may affect water clarity in the estuary. Water clarity must be measured to determine if the projects are improving or degrading water clarity. For South Indian River Lagoon, water clarity targets were developed based on water quality conditions in healthy seagrass beds (SJRWMD and SFWMD 2002). The target is to maintain the median (50th percentile) values and to not exceed the 25th and 75th percentile on an average annual basis. From 1990 to 1999, 47% of measured PAR values exceeded the target. Similar information for the remaining estuaries is provided (Table 3) where data are available. Where data are not available, values are provided based on known locations of submerged aquatic vegetation (SAV) and recommended light requirements in the scientific literature.

Caloosahatchee Estuary: Specific Assessment Parameter and Target

Current nutrient levels in the estuary range from ND-0.575 mg/l of TP and 0.0045-2.68 mg/l of TN. A mean value for the estuary based on 1999-2005 data from stations affected by loading of the Caloosahatchee River is 0.060 mg/l TP and 0.87 mg/l TN (HB01, HB02, HB03, HB04, HB05, HB06, HB07, and HB99; compare to Table 2). Calculated molal N:P ratios for these stations was 32, well above the Redfield (Redfield 1963) ratio of 16, and which implies phosphorus limitation (Salnudo Wilhelmy et al., 2004).

Table 3. Specific water clarity targets are as follows for each estuary in the areas where SAV currently exists and/or its restorations is a goal.

	Secchi			PAR		
Water Body	**25 %tile**	**Median**	**75 %tile**	**25 %tile**	**Median**	**75 %tile**
Caloosahatchee Estuary						
Upper estuary (tape grass)	> 0.6	> 0.7	> 0.9	1) > -2.3	1) > -2.0	1) > -1.5
Halodule (Peppertree Point)	> 0.8	> 0.9	> 1.1	2) > -1.8	2) > -1.6	2) > -1.3
San Carlos Bay region	> 1.0	> 1.4	> 1.6	3) > -1.5	3) > -1.1	3) > -0.9
St. Lucie Estuary						
Midfork-A1A Bridge	> 0.8	> 0.9	> 1.1	> -1.8	> -1.6	> -1.3
South Indian River Lagoon	1.00	1.44	1.56	-1.5	-1.2	-1.0
Loxahatchee River Estuary	> 0.8	> 0.9	> 1.1	> -1.8	> -1.6	> -1.3
Lake Worth Lagoon	ns	ns	ns			

CES01 is closest to the estuary and at a logical location to measure loads, and as such can be used as a bellwether for prediction of CERP effects. TP concentrations at this station range from 0.02 to 0.36 mg/l with an average value of 0.11 mg/l (DBHydro SFWMD, 1999-2005). TN concentrations range from 0.524 to 2.43 mg/l with an average value of 1.28 mg/l (DBHydro SFWMD, 1999-2005). TN loading, as measured at CES01, needs to be reduced by 28 % to bring the system more in line with Florida's estuary median values (Table 1). A 28 % nutrient load reduction will achieve a TP concentration of 0.079 mg/l and a TN concentration of 0.92 mg/l.

Overall, nutrient loading limits should promote conditions where mean annual chlorophyll α < 11 µg/l, approaching 3.8 ug/l chlorophyll α where 25% incident light reaching a depth of 1.4 meters is germane to seagrass health (Doering and Chamberlain 2005). Different areas of the estuary require different targets, as there is a significant decrease in chlorophyll concentrations in the lower estuary and San Carlos Bay. These lower values coincide where seagrass begins (Area 5) and flourishes (San Carlos Bay). Doering (2005) suggested that chlorophyll α of < 5µg/l may be an appropriate threshold required to protect and restore seagrass in San Carlos Bay, and provided a provisional method for calculating nutrient loading limits. Reducing nutrient influx to keep upper and mid-estuary areas below the mean 11 ug/l delineation of impairment will further promote chlorophyll α values of < 5µg/l in downstream waters. The hydrologic performance measures for the Caloosahatchee aim to control larger discharges such that flows between 450 and 800 cfs account for 75% of the total volume. When flows are <800 cfs, chlorophyll α has historically been <5µg/l. Therefore, achieving the hydrologic targets should also help meet chlorophyll goals. Chlorophyll α values in San Carlos Bay that exceed 5µg/l may be unconnected with nutrient loading or chlorophyll values upstream because of the impacts of "red tide" on this area, and which have been attributed to the Gulf. Achieving desirable targets may require seeking lower loading rates than those based on Janicki (2003).

Concentration of dissolved oxygen in the bottom waters of the upper and mid-estuary has declined (Doering and Chamberlain). The target is to halt that decline and reverse it through control of nutrient inputs and the resulting algal response.

Indian River Lagoon: Specific Assessment Parameter and Target

A high percentage of observed values (Table 4) exceed South IRL median water quality targets (Crean et al. 2006), which denotes the degree to which water quality might improve for the enhancement and protection of seagrass resources in the South IRL (SJRWMD and SFWMD 2002). The assessment target is to document a decrease in the frequency of concentrations which exceed the median value.

Table 4. Summary of observed concentrations from all forty South IRL water quality stations (July and October data from 1990 - 1999) which exceed median nutrient target values.

Parameter	Median Value	No. of Samples	Number of Observations which exceed Target		Percent Values which exceed Median Target
			Dry Season	Wet Season	
Total Phosphorus (mg/l)	0.053	1230	178	240	34

Total Nitrogen (mg/l)	0.692	1124	236	329	50

Lake Worth Lagoon: Specific Assessment Parameter and Target

The Palm Beach County Department of Environmental Resources Management is currently working with the United States Geological Survey to evaluate suspended sediment loads to LWL. This study will assess sediment loads both before and after the planned diversion of the west basin of the C-51 Canal. A rating curve estimator has been developed to relate flow to suspended solids at the S-155 structure (Lietz and Debiak 2005). Estimates of average annual sediment load at the S 155 structure have ranged from 1203 to 37015 kilograms (kg). Mean annual loads are estimated at 3519 kgs and median annual loads are estimated at 3863 kg. Reduction in sediment loads achieved by a reduction of flow due to the west basin diversion, which is expected to reduce flow to the LWL via the C-51 Canal by approximately 50%, or down to approximately 4000 tons per year, should result in a reduction of suspended sediment inflow to about 4000 tons per year. Construction of a sediment trap and/or the implementation of upstream BMPs will further reduce sediment inflow and will be measured against the pre- and post-diversion baselines. Management of suspended sediment into the lagoon as demonstrated below will maximize the potential growth of seagrass, oysters, and other flora and fauna.

To attain this level of suspended sediment inflow reduction, the targets are as follows:

- Prevention of redirection of water from other basins to the C-51 Canal following the west basin diversion
- Reduction of suspended sediment volume to 4000 tons per year following west basin diversion.
- Further reduction of suspended sediment inflow to 2000 tons per year through the construction of a sediment trap on the C-51 Canal, and/or through the implementation of upstream BMPs

Water quality parameters for TN and TP for Lake Worth Lagoon have been measured by FDEP and will be used as the baseline for prediction of the effects of CERP (Table 1). TP and TN concentrations range from 0.02 - 0.26 and 0.025 – 0.982 mg/l, respectively. Based upon the mean baseline values, the molal N:P ratio is 24, this is above the Redfield ration of 16 (Redfield et al 1963) which suggests phosphorus limitation (Salnudo-Wilhelmy et al 2004).

Average TP and TN values for the LWL estuary are 0.067 mg/l and 0.74 mg/l, respectively (FDEP data 2001-2005). The target is no increase over baseline condition.

Loxahatchee River Estuary: Specific Assessment Parameter and Target

The target is continued absence of algal blooms and no increase over baseline conditions. The molal N:P ratio is over 70, and being above the Redfield ratio of 16 suggests phosphorus limitation (Salnudo-Wilhelmy et al 2004).

Saint Lucie Estuary: Specific Assessment Parameter and Target

The molal N:P ratio (based upon baseline values) in the open estuary is 28, which is above the Redfield ratio of 16 and suggestive of phosphorous limitation (Salnudo-Wilhelmy et al 2004). A reduction goal of 30% is recommended of TN to the estuary is necessary to maintain this limitation (Chamberlain and Hayward 1996), which would result in a TN concentration goal of 0.72 mg/l as measured at the Roosevelt Bridge (U.S. 1). The TP concentration goal for the St. Lucie Estuary is 0.081 mg/l at the Roosevelt Bridge (USACE and SFWMD 2002). Achieving the 81 ppb goal (for TP) in the estuary requires reducing current TP concentrations by 57 %.

Reductions in nutrient loading would reduce frequency and severity of algal blooms, which in turn would improve the oxygen regime. Reducing the rate of sediment deposition would allow time for typically fine-grain organic sediments to stabilize and compact, which in turn would reduce sediment oxygen demand and improve both dissolved oxygen regime and water clarity.

2.0 Justification

Estuaries have existed as the interface between freshwater and the sea over geologic time, and in consequence a multitude of plant and animal species have become dependent on being able to utilize and successfully survive estuarine condition and its afforded habitats. Quality of water is a determinant factor as to the degree to which an estuary may successfully sustain these diverse communities. Freshwater, in the process of flowing from the land to the sea, transports materials that may range in type and size from dissolved organic matter to large grains of sand dependent upon the type of terrain the water must transverse and the velocity at which the water moves. Estuaries provide an area of relative quiescence and dynamic chemistry where substances are naturally deposited. As such, estuaries are ephemeral formations, typically lasting from a few thousand to a few ten-thousands of years.

Water quality encompasses very broad suites of many measurable attributes that result from substances either dissolved or suspended in water, a number of which are of concern (see Surface Water Quality Standards, 62.302 FAC). Furthermore, among aquatic ecosystems, estuaries are uniquely complex systems, since they act as sinks for substances delivered in freshwater flows, possess mixing and flow patterns controlled by the ebb and flow of tide and tidal-influence, and exhibit interrelated chemistries connecting atmosphere, water and sediment (the latter process further complicated by density-stratification). Key water quality characteristics of concern for estuaries in the Northern Estuary Module are nitrogen and phosphorus nutrients, algal bloom dynamics, dissolved oxygen regime, water color, turbidity, sedimentation rates, and toxic chemicals; however, these characteristics are inter-related (Figure 1) and cannot be adequately nor properly evaluated except within the context of their interdependencies in delineating acceptable from unacceptable water quality conditions. This Performance Measure is accordingly constrained to consider water quality from the perspective of sustainable and desirable estuarine ecological response.

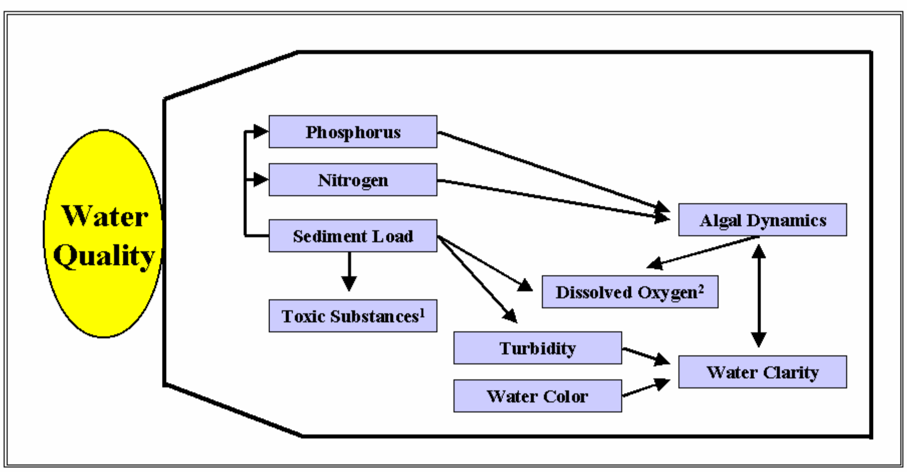


Figure 1. Inter-relationships of key water quality characteristics. Notes: 1. Toxic substances are also carried in dissolved state, although in most cases subsequently becoming bound to sediment phase. 2. Dissolved oxygen concentration is result of reaeration, temperature, sediment oxygen demand, etc. in addition to algal growth dynamics.

The purpose of this Performance Measure is to define CERP expectations regarding water quality improvements brought about by implementation of CERP, and to provide a tool with which to evaluate and assess those improvements. The evaluation and assessment methodologies will relate these CERP components to water quality improvement. This will isolate the effects of CERP's reservoirs, STAs and other water quality components. Although other state and local efforts, e.g. the State's Total Maximum Daily Load program (TMDL), are expected to compliment and supplement CERP-afforded improvements in water quality; implementation of effective agricultural and urban Best Management Practices (BMPs) and associated efforts are outside the purview of CERP and are not addressed by this Performance Measure.

Not only are key water quality characteristics ecologically intertwined, but CERP's effects will influence multiple, rather than single, water quality factors as an unavoidable consequence of water and soil chemistries and associated biological processes, i.e., CERP will de facto impact key factors as a group. All conceivable variants of CERP implementation, i.e., storage in reservoirs, passage through STAs, re-hydration of wetlands, mediation or re-direction of flows, etc., is expected to beneficially impact water quality condition in the receiving estuaries. The degree to which water quality will be affected is a function of the various mix of options considered appropriate; however, all composites of these options will affect water quality in a generalized manner. Specifically, no CERP component is expected to, nor can it, address one and only one water quality parameter affecting the estuarine water quality environment. The Performance Measure aims to measure water quality improvements afforded by CERP implementation as a function of this group response among key factors such as Lake Okeechobee releases and 5 year trends.

The Northern Estuaries Module encompasses five estuarine systems, namely the Caloosahatchee, Loxahatchee, and Saint Lucie estuaries, and the Indian River and Lake Worth Lagoons. Although numerous definitions may be applicable, in general "water quality" refers to the ability of a body of water to support its intended beneficial uses, i.e., those functions and processes of an estuary. Estuaries play a key role among aquatic ecosystems, bridging the gap between freshwater and saltwater ecosystems and the ecological function thereof. Conditions adverse to the sustenance and maintenance of estuarine function often translate otherwise localized impacts to the nearshore reef community or other nearby estuaries, effectively expanding the scope of concerns regarding water quality onto a regional stage. Land use and land management practices have been shown to influence quality and quantity of stormwater runoff, which in turn, pose point and non-point source pollution threats to the biological well-being of estuaries (e.g., Osborne and Wiley, 1988; Dauer et al., 2000).

Extensive development of the watershed has changed the source and character of water entering the estuaries, from a historical drainage pattern dominated by wetland and forested land uses to that of urban and agricultural stormwater runoff. The modifications inherent in the original Central and Southern Florida (C&SF) Project resulted in increases in quantity and rate of water entering the estuaries. These modifications also served to extend the expanse of the estuaries' drainage basins. The combined effect of changes in land use, expansions in acreage drained, and the manner in which water is delivered to the estuaries has resulted in varying degrees of degradation of water quality.

Efforts currently underway to retain, re-direct, treat, or otherwise better control water deliveries holds the promise of ameliorating excess nutrient loading, reducing sediment and turbidity causing conditions, improving water clarity, decreasing intensity and frequency of algal blooms, and limiting pathways whereby toxic compounds would otherwise enter the estuaries. Judiciously managing water will result in improved estuarine water quality, i.e., will better address the intrinsically linked factors from which value judgments about quality of water are derived.

It is generally understood that periodic loading of nitrogen and phosphorus from land runoff coupled with a general shallow geomorphology drives and limits estuarine productivity. Changes in primary production induced by increased nutrient loading can result in changes in species abundance, distribution, and diversity, leading to alteration of the estuarine community structure (Livingston, 2001). For comparison purposes, current estimates of median values among all Florida estuaries for the subset of key estuarine water quality parameters is presented in Table 2.

Nutrient enrichment can adversely affect seagrass beds by stimulating growth of epiphytic and planktonic algae that inhibit transmittance of light (Duarte 1995, Valiela et al. 1997). Changes in phytoplankton and epiphytic algal growth rates also affect the type and availability of food for each trophic level within the estuarine ecosystem. Community shifts as a result of excessive nutrients may also result in predominance of toxin-producing algae, i.e., harmful algal blooms (HAB). HAB may cause or contribute to fish kills and may pose adverse health effects to humans who may come in contact or merely be in close proximity to the affected water. The concentration of algae present in a waterbody is typically determined by measuring its chlorophyll content; FDEP has promulgated 11 ug/l (mean annual) corrected chlorophyll a as a delineation threshold for impairment among Florida's estuaries (62-303 FAC). Algal blooms resulting from elevated nutrients can amplify diurnal swings in dissolved oxygen, can be followed by subsequent precipitous drops in dissolved oxygen content (Doering and Chamberlain 2005).

Low dissolved oxygen (DO) concentrations in the water column can increase mortality, reduce growth rates and alter the distribution and behavior of aquatic organisms (Diaz and Rosenberg 1995, Breitburg 2002). Mortality can occur rapidly from short-term exposure (less than 6 to 12 hours) to low oxygen concentrations (Breitburg 2002). Continuous exposures to even moderate reductions in DO can substantially reduce growth rates of both fishes and invertebrates (for review see USEPA 2000); best evidence of this is from aquaculture studies – for example, Davis (1990) reports that DO is the most critical aspect of water quality for red drum, *Sciaenops ocellatus*, and that growth reduction is apparent when DO levels drop below 4 mg/L. However, many species exhibit behavioral responses (e.g., blue-crab migrations, Bailey and Jones 1989, as cited by Tomasko 1997, etc.) that allows them to avoid not only lethal oxygen concentrations, but also those that would require greatly increased respiration effort and reduce growth; emigration leading to reduced densities of fishes can begin at oxygen concentrations approaching 3 to 4 mg/l (Diaz and Rosenberg 1995, Breitburg 2002, USEPA 2003). Although the breakpoint for hypoxia and community change in the benthos was considered to be 2 mg DO/l, a study by Ritter and Montagna (1999) suggest it may occur at 3 mg DO/l. Impacts from hypoxia induced community change can lead to altered sedimentary processes (e.g., bioturbation, etc.) and, as a consequence, altered geochemistry (Diaz and Rosenberg 1995). Habitat squeeze from low DO can interrupt seasonal migrations for spawning or of organisms seeking optimal temperatures. Because they are limited in their behavioral avoidance, eggs and larvae can be more vulnerable to low DO (Breitburg 2002). Moreover, in many species, eggs and larvae have higher DO requirements than adults (Breitburg 2002; for tolerances of red drum larvae, see Miller et al. 2002, for newly set (3-4 days) eastern oysters *Crassostrea virginica*, see Osman and Abbe, 1994; as cited in U.S. EPA, 2000). Finally, a recent study by Pedersen et al. (2003) linked meristem anoxia and sulfide intrusion in *Thalassia testudinum*, and possible sulfide toxicity and seagrass die off, to low nighttime oxygen levels in the water column. Habitat loss due to depressed DO can be far greater than if based solely on concentrations thought to be lethal (extracted from Rumbold 2004). The difference between overall mean dissolved oxygen and bottom depth dissolved oxygen is an indicator of, among other things, the function between depth of water and sediment oxygen demand. Improvements in sediment suitability, loading and reductions in nutrients and severity and frequency of algal blooms should be reflected in an improved oxygen regime.

In addition to the input of nutrients, heavy metals and pesticides from stormwater runoff may cause or exacerbate water quality problems in coastal water bodies. Many of these contaminants are toxic to marine organisms and, at elevated concentrations, can adversely affect the structure and function of biotic communities

(Pait et al., 1992; Kennish, 1999). They may also result in genetic and morphological deformations in fish and other aquatic animals (Browder and Bernstein 2001).

Sediment loads and suspended matter also adversely impact estuarine systems. Activities such as construction, agriculture, and canal maintenance result in the erosion of upland soils consisting of sands, clays and silts. These sediments may become suspended particularly when water velocity is allowed to become sufficiently high and transported to the estuary. Large areas of anaerobic muck can result with an associated decrease in benthic invertebrate diversity (Reed 1975, Deis et al. 1983, FWC/FWRI 2005), and inhibit colonization by seagrass. Fine-grained sediments may remain in suspension or may be easily re-suspended by wave and wind action, resulting in increase turbidity and attenuation of light penetration of the water column, which can further hinder seagrass growth even in areas with suitable substrate. Nutrient loads, and in particular phosphorus loads, are often highly correlated with sediment loads and turbid water (e.g., Christiansen et al. 2000). Heavy metals and organic chemicals (e.g., pesticides) are typically hydrophobic or carry an electrical charge such that they become bound to particulate matter, and are of concern where sediments accumulate (e.g., Haunert 1988, Trefry et al. 1990, Trefry et al. 1992). The potential of contaminated sediments to adversely affect benthic organisms and the associated foodweb is well documented (e.g., Heil 1986, Trocine and Trefry 1996, Hameedi 2005).

Many parameters inhibit light penetration in an estuary. Water color and particulate matter suspended in the water (i.e., turbidity and/or plankton) can decrease the quality of photosynthetically-active radiation (PAR) reaching submerged plants, and can be a major factor controlling depth of coverage (SFWMD and SJRWMD 2002). Submerged aquatic vegetation (SAV) is a critical key habitat and a source of food required to support balanced and healthy estuarine communities of fish and shellfish. In the Chesapeake Bay, TSS >20 mg/L was associated with a lack of or decline in SAV, and expansion of beds occurred when growing season median chlorophyll α concentrations were <15 ug/L. Short period algal blooms (chlorophyll α concentration >30 ug/L) did not seem to be detrimental to well established SAV populations.

Caloosahatchee Estuary

Discharges at S-79 contain 70 to 80 percent of the nutrient load delivered to the Caloosahatchee Estuary (CE). Waste load allocation studies conducted over twenty years ago in the Caloosahatchee Estuary by the Florida Department of Environmental Regulation (DeGrove 1981) concluded that the estuary had reached its nutrient loading limit as indicated by elevated chlorophyll α and depressed dissolved oxygen levels. Janicki (2003) determined that nitrogen loads were more responsible for degraded water quality in the estuary than phosphorus, and calculated that achieving an annual average chlorophyll-a concentration of 11 ug/l would require reducing the nitrogen load at S-79 to less than 190 metric tons/month during the dry season, 350 tons/month during the wet season, and an annual cumulative load less than 3000 tons/year. Recent estimates of average load (Crean and Irican 2005) indicate that on average (1993-2003) 2,905 and 233 metric tons of total nitrogen and total phosphorus, respectively, enter the estuary annually, with nitrogen loads in excess of 3000 tons/year occurring 30 to 40% of the time. McPherson and Miller (1990) concluded that increased nitrogen loading to the Caloosahatchee Estuary would result in undesirable increases in phytoplankton and benthic algae. Doering and Chamberlain (1998) reported that about 25% of the observed dissolved oxygen concentrations in the upper estuary were below 2 mg/l, and that hypoxic events were most prevalent during the warmer months between May and October; since measurements were not taken just before dawn when dissolved oxygen concentrations are typically at their lowest values, low dissolved oxygen conditions are likely more widespread and more frequent.

In the lower Charlotte Harbor, red drift algae is becoming an increasing problem as it affects SAV and its epiphytes. This has become an increasing problem, particularly in the San Carlos Bay region (near the mouth of the Caloosahatchee), and has been attributed to episodic large canal discharges that abruptly increase nutrient loading and concentration (Doering and Chamberlain, 1998). Lapointe and Bedford (2006) determined, via isotopic nitrogen relationships, that Lake Okeechobee discharges coupled with local stormwater runoff were significant factors responsible for documented algal blooms. Meeting water quality goals for the Caloosahatchee Estuary should translate into positive water quality benefits in nearby water bodies.

CERP promises significant changes in the volume and timing of freshwater entering the estuary. CERP projects constructed upstream from the estuary will have a measurable effect on Lake Okeechobee releases and will reduce nutrient loads. Doering and Chamberlain (1998) concluded that the lowest oxygen, highest chl. *a*, and highest nutrients were found in the upper estuary, which resulted in poor water quality relative to areas closer to the ocean. Therefore, meeting water quality goals for this area should insure meeting requirements downstream as well. Doering and Chamberlain (2004) reported that 88-92% of TN loading into the downstream estuary from surface waters was from the discharge at S-79, and that nutrient loading is primarily a function of discharge rather than concentration. SFWMD (2006) estimated that Lake Okeechobee contributed 28 % of the TP and 55 % of the TN to the estuary. Freshwater inputs increase water color to the extent that productivity in low salinity waters may be limited by restricted light penetration. As the nutrient-rich, colored river water is progressively diluted by seawater, light availability increases. Availability of appropriate wavelengths of light to support photosynthesis may be more important than nutrient availability for aquatic plant growth in parts of the estuary (McPherson and Miller 1990). Discharge from S-79 dominates downstream estuarine water quality based on the overwhelming dominance of the Caloosahatchee River as a source of nutrients and other materials to the downstream estuary (Doering and Chamberlain 2004).

CERP projects such as C-43 RSTA, Lake Okeechobee Watershed, Picayune Strand, Lake Okeechobee Regulation Schedule, Lake Park Restoration, Henderson Creek Belle Meade and Caloosahatchee Back Pumping and Stormwater Treatment are intended to reduce flows and improve water quality in the Caloosahatchee estuary. Water quality measured at the S-79 structure would strategically integrate water quality effects of CERP features and would effectively track load reduction to the estuary. This performance assessment and evaluation methodology will isolate the effects of reduction in loads from Lake Okeechobee and effects of C-43 improvements on water quality at this point.

Indian River Lagoon

Urban and agricultural development in the South Indian River Lagoon watershed has increased nutrient (TP and TN) loading rates to the lagoon, with the largest inputs of freshwater and associated nutrients from the St. Lucie River and C-25 canal. Large freshwater releases have the ability to impact seagrass beds and associated benthic infaunal communities in the lagoon nearest to these sources.

Undesirable algal blooms (as defined by chlorophyll a concentrations above 30 ug/l) have been frequent in the IRL, and are symptomatic of excess nitrogen and phosphorus from stormwater runoff. Current estimated nutrient loads to the IRL from the C-25 are 31 and 243 metric tons/yr of TP and TN, respectively (USACE and SFWMD 2004).

A strategic monitoring location is where the C-25 canal enters the IRL, at the S-50 structure (Water Quality station C25S50). Water quality parameters measured at this location will integrate the effects of CERP features on water quality and will represent loads from the C-25 basin. This location corresponds to a water quality sampling location identified in MAP section 3.3. This performance assessment and evaluation methodology will isolate the effects of the C-25 STA improvements on water quality at this point.

Lake Worth Lagoon

Historically a freshwater system, Lake Worth Lagoon was converted in the late 1800s and early 1900s into an estuarine system with the construction of Palm Beach and Boynton Beach inlets and the Intracoastal Waterway. As an estuary, the lagoon has developed to serve as spawning, nursery and feeding grounds for many fish and invertebrate species that sustain and mature into important inshore and offshore recreational and commercial species. The most significant source of freshwater to the Lake Worth Lagoon is the C-51 Canal which drains 158 square miles and contributes approximately 50% of the total inflow (PBC ERM and FDEP, 1998).

Suspended matter transported into Lake Worth Lagoon has blanketed a large area of the estuary with a layer of anaerobic muck. This muck has been attributed with decreases in benthic invertebrate diversity (Reed 1975, Deis et al. 1983, FWC/FWRI 2005), and has prevented colonization by seagrass, an important component of the estuarine community. The sediment load has been implicated in increased nutrient load via adsorbed nitrogen and phosphorus (Christiansen et al. 2000). Reduction of excessive nutrient loading to LWL will maximize the potential growth of such valued ecosystem components (VECs) as oysters (*Crassostrea virginica*) and seagrasses (represented by *Halophila decipiens*, *H. johnsonii*, and *Halodule wrightii*). These species are key estuarine components currently present in LWL but impacted by anthropogenic stressors.

A strategic monitoring location is where the C-51 canal at the S-155 structure enters the LWL (Water Quality station S155_S). This structure integrates the effects of CERP that affect water delivery and sediment load to LWL. In particular, the North Palm Beach Project (with storage and sediment traps) will affect flows and loads to LWL. The performance measure evaluation methodology will isolate these effects. The assessment methodology will be based upon the methodology identified in MAP 3. 3, Table 10.

Loxahatchee River Estuary

The Loxahatchee River has experienced decreased flows in the dry season and large discharges from the S-46 structure during times of heavy basin runoff, most frequently in the wet season. Urban and agricultural development in the Loxahatchee River Estuary watershed has increased nutrient (TP and TN) loading rates to the river and estuary. This increase in nutrient load has the potential to continue to increase and cause future problems in the estuary. As larger volumes of freshwater are introduced back into the Northwest Fork and other natural tributaries of the Loxahatchee it must be of sufficient quality as to not cause adverse increases in nutrient concentration. CERP effects upon this estuary are limited to regulating flows over the Lainhart Dam (G-92) by collateral effects of the North Palm Beach Project

Saint Lucie Estuary

The St. Lucie Estuary (SLE) is one of the largest brackish water bodies on the east coast of Florida, and spans northern Martin and southern St. Lucie counties. The SLE is a primary tributary to the South Indian River Lagoon. The inner SLE is comprised of the North Fork and South Fork of the St. Lucie River, and has a total surface area of about 6.4 square miles. The two forks converge to form a single middle estuary with a surface area of 4.7 square miles. The middle estuary extends east for approximately 5 miles until it meets the Indian River Lagoon (IRL), just before opening to the Atlantic Ocean at the St. Lucie Inlet. The SLE has been highly altered at both its landward and seaward ends. The system was essentially a freshwater river until 1892 when the St. Lucie Inlet was dug, providing direct ocean access and creating an estuary. The South Fork of the estuary was connected to Lake Okeechobee in 1924 by construction of the C-44 canal. This canal provided a navigable connection to Lake Okeechobee and a route for discharge of excess Lake Okeechobee water to the South Fork of the Estuary. These discharges control high lake levels that jeopardize the integrity of the levee surrounding Lake Okeechobee. To control water levels in Lake Okeechobee, periodic high-volume freshwater releases have been made to the estuary via C-44 that have varied in duration from days to months and have turned the entire estuary to fresh water. During the 1950s, the watershed was enlarged when the North Fork was connected to the C23/C-24 system that drains much of St. Lucie County. Watershed runoff from the North Fork drainage basins flows quickly into major canals that transverse the coastal ridge (C-23, C-24) instead of being detained, evaporated, cleansed and attenuated by natural systems.

Increases in the quantity and decreases in the quality of water released to the SLE, as a result of the modifications inherent in the original Central and Southern Florida (C&SF) Project, has resulted in degradation of water quality in the estuary. Increases in nutrient loading has resulted in increased incidence and severity of algal blooms, loss of extent and density of seagrass beds, and increased rate of detrital accumulation of reducing estuarine sediments, which in turn have resulted in hypoxia, failure to meet Class III marine dissolved oxygen standards, and degradation of benthic faunal communities

Undesirable algal blooms (chlorophyll a concentrations above 30 ug/l) have been frequent in the SLE, and are considered symptomatic of excess nitrogen and phosphorus in stormwater runoff. Current estimated nutrient loads to the SLE are 192 and 1,166 metric tons/y of TP and TN, respectively (USACE and SFWMD, 2004). Water quality data analysis indicates that inorganic nitrogen loads correlate with total phosphorous loads delivered to the estuary, and that the concentration of TN and TP in the estuary are similarly correlated. Total phosphorous was therefore determined to be a suitable surrogate for nitrogen species (SFWMD and USACE 2002). The IRL South project delivery team recommended a target of 81 ppb phosphorous as an interim SLE water quality goal.

South IRL CERP project components that will be constructed upstream from the estuary were designed to help contribute to an overall reduction in nutrient levels. Reservoirs were sized to meet the salinity envelope goals for the estuary and the associated Stormwater Treatment Areas (STAs) were designed to treat water pumped from the C&SF canals into reservoirs before it is then released back into the system. It was calculated that 30% of the total runoff would be captured in an average wet year for an overall nutrient reduction of 24% (SFWMD and USACE, 2002). In a dry year STAs could conceivably treat 80% of the total runoff for an overall nutrient reduction of 64%. If the 24%-64% load reduction can be achieved by reservoirs and STAs, the average concentration at the Roosevelt bridge (mid estuary) should decrease by 30 ppb due to project implementation. If the load reduction is maintained over time and other project components such as muck removal are implemented, the concentration is expected to go down further. A 10% reduction from agricultural and urban Best Management Practices (BMPs) is also assumed to contribute to meeting the overall nutrient concentration target. This performance measure will be used to determine the effects of these planned projects on nutrient loading into the estuary.

A strategic monitoring location is the estuary at the Roosevelt Bridge (bridge west of and adjacent to the US1 bridge). This location is mid estuary and lies at the confluence of the C-23, C-24, and C-44 canals. Water quality parameters measured at this location would integrate effects of CERP features on water quality and is representative of loads delivered to the estuary. This structure integrates the effects of CERP that affect water delivery and nutrient loads to the St. Lucie Estuary. This performance evaluation methodology will isolate the effects of reduction in loads from Lake Okeechobee and effects of C-23, C-24 and C-44 improvements on water quality at this point. The assessment methodology will be based upon the methodology identified in MAP 3. 3, Table 10.

It is not expected that the South IRL CERP project alone will achieve the water quality goals for the SLE, but that further advancement of BMP technologies and implementation, as well as other programs that fall under the state's total maximum daily loads (TMDL) mandate will also be needed. Development of TMDL's for the SLE and South IRL is underway and expected to be completed by 2008. The state's TMDL process includes the development of a Basin Management Action Plan which sets forth the various projects and programs needed to reduce the pollutant loading. BMP implementation is currently well underway in the southern IRL watershed. Development of an agricultural BMP program for Martin, St. Lucie, and Okeechobee counties began in late 1998 and was approved by the EPA in 2000. Actual implementation of BMPs began in 2001. Urban BMP implementation includes five programmatic efforts which are completed or currently underway in Martin and St. Lucie counties and the cities of Port St. Lucie, Stuart, Ft. Pierce, and Sewall's Point, including: St. Lucie River stormwater retrofits (e.g., baffle boxes to capture sediment and debris), totaling $65 million through 2005; development of National Pollution Discharge Elimination System (NPDES) regulations for new construction will be completed by 2008; completion of wastewater utility re-use (Martin County now re-uses 100% of wastewater); and high priority septic to wastewater utility retrofits, expected to be completed by 2012.

3.0 Scientific Basis

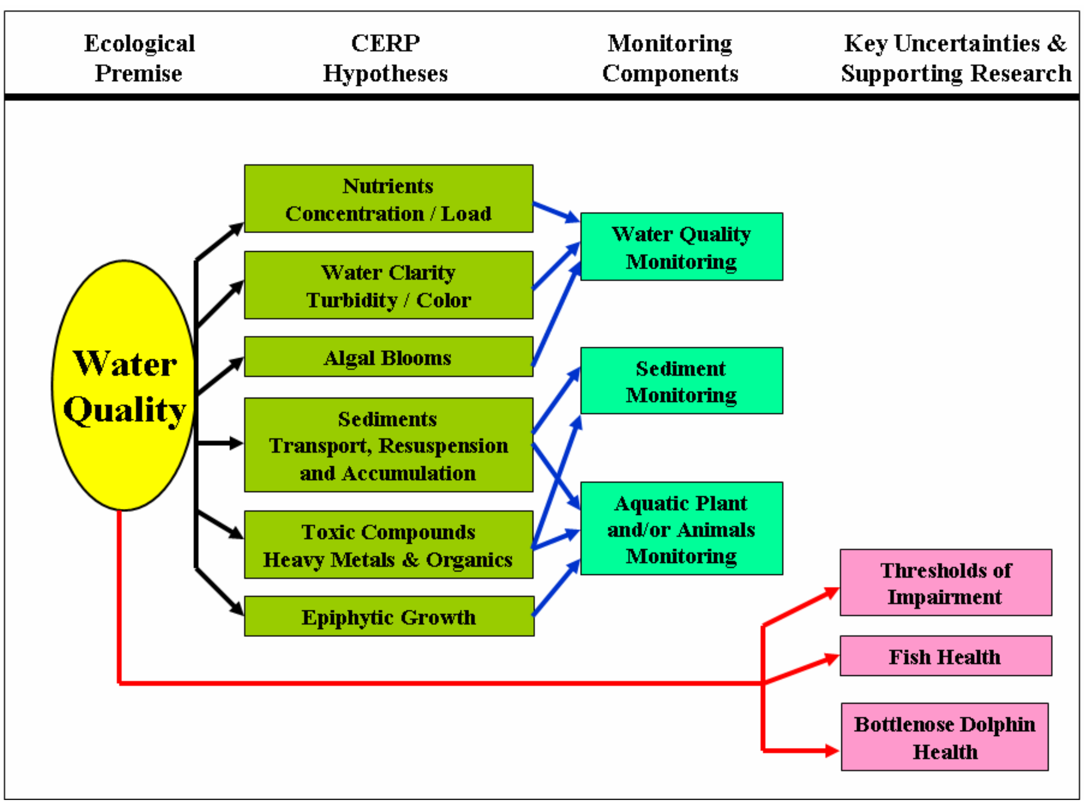
3.1 Relationship to Conceptual Ecological Models

The indicator for this performance measure is a stressor in the following conceptual ecological models:

Regional Models (RECOVER 2004b), see following diagram

St. Lucie Estuary and Indian River Lagoon
Loxahatchee
Lake Worth Lagoon
Caloosahatchee Estuary

Conceptual Ecological Models (See the following diagram)
Water Quality



3.2 Relationship to Adaptive Assessment Hypothesis Clusters

The Conceptual Ecological Models (CEMs) are diagrammatic representations of key processes which affect environmental condition. The CEMs for Estuaries, as an ecological class of environmental systems, were presented in RECOVER (2004) and subsequently published in a special edition of the peer-reviewed journal Wetlands (Vol. 25, No. 4, 2005).

Ecological Premise: The pre-drainage condition of the Northern Estuaries (Caloosahatchee, St. Lucie, Indian River Lagoon, Lake Worth Lagoon and Loxahatchee River) was characterized by freshwater inflow primarily from direct rainfall and historically-local runoff from a basin characterized by expansive wetland and undeveloped upland areas. These pre-C&SF conditions resulted in low nutrient and contaminant inputs to the estuaries compared to present conditions.

CERP Hypothesis 1: Operation of constructed CERP features within the Northern Estuaries will result in a significant, measurable reduction of nutrient and contaminant loads transported to the estuaries. These reductions will reduce the frequency and intensity of blooms and epiphytic algal growth, improve water clarity and net dissolved oxygen regime, and lead to expansion or continued maintenance of healthy seagrass and associated faunal communities.

Ecological Premise: Large volumes of high velocity freshwater releases necessary to afford flood-protection across expanded basin boundaries have served to facilitate the transport of sediment and sediment-bound nutrients and contaminants into the estuaries. Introduction of organically-enriched fine silts and clays can result in increases in turbidity with attendant decreases in water clarity and adverse effects on SAV. Re-suspension of these materials by wind and wave action can exacerbate turbid conditions and inhibit seagrass growth in deeper waters. Unconsolidated sediments may blanket substantial areas of the estuary bottom and provide unsuitable substrate for both SAV or faunal (e.g., oysters) colonization. Unstable organic-rich sediments can adversely affect water-column oxygen content, with trickle-down faunal community consequences. Accumulation of sedimentary "muck and ooze" may sequester and concentrate toxic substances with adverse consequence to estuarine benthic communities, fish health and/or dolphin populations.

CERP Hypothesis 2: The restoration of hydrology toward Natural Systems Model (NSM) conditions within the Northern Estuaries will result in a reduction in the transport of sediment and sediment-bound nutrient and contaminant loads. This will be accomplished by reducing the frequency, rate, and/or volume from inflow structures, by direct capture and treatment of flow, and/or creation of operational opportunities for sediment and sediment-bound loads to precipitate in locations other than the estuary. Restoration of volume, timing and spatial distribution of freshwater flows will reduce anthropogenically-induced stress on estuarine populations by improving estuarine sediment quality, reducing nutrient and contaminant loads, increasing water clarity and seagrass expanse, decreasing algal blooms, and improving dissolved oxygen regime..

4.0 Evaluation Application

4.1 Evaluation Protocol

The following are evaluation (predictive) protocols for each estuary:

Caloosahatchee Estuary

A three part evaluation protocol consists of evaluating TP and TN concentrations at the S-79 structure, evaluating nutrient loads associated with Lake Okeechobee releases and evaluating the impact of CERP projects on loads at C-43.

Evaluation Protocol

1. The following protocol should be used to evaluate trends in TP and TN concentration at CES01.

    a. Score concentrations of both TP and TN as a percent towards reaching the goal

    b. The goal being 50% for TP of 79 ppb (0.079 mg/l) and 50% for TN of 0.92 mg/l, this would be a 28% load reduction

    c. Reaching the goal for both these parameters would have a score of 100%

    d. This value will account for 33.3% of the weight for the water quality score

2. The following protocol should be used for evaluating Lake Okeechobee releases for both TP and TN.

    a. TP estimates

        i. Estimate Lake Okeechobee deliveries through S-77 for project condition and base (2000) conditions
        ii. This would be based upon 2X2 runs for with project 2050 conditions
        iii. These would be annual averages in ac-ft/yr
        iv. Estimate Lake Okeechobee TP concentration based upon a 5 year trend at S-77, for example, the 5 year trend using data from January 2001 through October 2006 is TP = .127 mg/l
        v. Multiply volume (ac-ft/yr) x concentration (mg/l) x 1234.926 to obtain load in metric tons (1000 kg)
        vi. Calculate reduction in load to the Caloosahatchee Estuary by comparison of the 2000 and 2050 project conditions
        vii. Success would be percent reduction towards 28% reduction of the Lake Okeechobee load

    b. TN estimates

        i. Estimate Lake Okeechobee deliveries through S-77 for project condition and base (2000) condition
        ii. This would be based upon 2X2 runs with project 2050 conditions
        iii. These would be annual averages in ac-ft/yr
        iv. Estimate Lake Okeechobee TN concentration based upon a 5 year trend at S-77, for example, the 5 year trend using data from January 2001 through October 2006 is TN= 1.719 mg/l
        v. Multiply volume (ac-ft/yr) x TN concentration (mg/l) x 1234.926 to obtain load in metric tons (1000 kg)
        vi. Calculate load reduction based upon this
        vii. Success would be percentage towards 55% reduction of load from Lake Okeechobee.

    c. Evaluate trends in key parameters compared to the baseline values presented in Table 1

    d. This value will account for 33.3% of the weight for the water quality score

3. The following protocol should be used to evaluate the impact of CERP projects on loads at C-43

a. Estimate TP and TN load based upon a 5 year trend at the S-79 structure (station CES01), for example, the 5 year trend using data from January 2001 through October 2006 is TP= .115 mg/l and TN = 1.38 mg/l

b. Estimate flows from the 2X2, MikeShee or similar model that produces S-79 flows

c. Multiply volume (ac-ft/yr) x concentration (mg/l) x 1234.926 to obtain load in metric tons (1000 kg)

d. Estimate volume and footprint of all reservoir alternatives

e. Estimate load reduction created by the various water quality features

   1) Use Eutromod or Florida Lakes model from South Florida Water Management District

   2) Load reduction would be based upon:

      i. Annual flows to component (2X2 flows)

      ii. Volume of component (ac-ft)

      iii. Estimated storage time t

      iv. Average influent concentration

      v. Estimate effluent concentration reduction. TP= $\log_{10}(TP) = \log_{10}[TP_i/(1+K_{TP}t)]$, TN= $\log_{10}(TN) = \log_{10}[TN_i/(1+K_{TN}t)]$

      vi. Calculate load reduction = (TP in – TP out) x ac-ft/yr x 1234.92

      vii. Compare load reductions from S-79 loads

f. This value will account for 33.3% of the weight for the water quality score

Indian River Lagoon

Evaluate TP and TN concentrations at the S-50 structure (station C25S50).

Evaluation Protocol

1. The following protocol should be used to evaluate trends in TP and TN concentration at C25S50

   a. Score concentrations of both TP and TN as a percent towards reaching the goal

   b. The goal being 50% for TP of 81 ppb (0.081 mg/l) and 50% for TN of 0.67 mg/l

   c. Reaching the goal for both these parameters would have a score of 100%

Lake Worth Lagoon

Evaluate sediment loading at the C-51 structure based upon the USGS sediment load estimator (Lietz and Debiak et al 2005).

Evaluation Protocol

1. The estimator relates Total Suspended Solids (TSS) concentration to S-155 daily flows. Where
   TSS (mg/l) = 5.12 + .0063*Q

   where Q = flow from S-155

   a. From the USGS historical flow record a mean annual loading would be 3526 kg/yr
   b. From the USGS historical flow record the median annual loading would be 3862 kg/yr
   c. Targets ranging from 4000-8000 kg/yr have been proposed
   d. The worst year on record for hydraulic loads was 1947, when 37015 kg that were delivered to LWL
2. Use 2X2 model runs of daily structure flows to calculate annual load to LWL. This would be based upon flow weighted concentrations.
3. Calculate annual loads for the period of record based upon S-155 flows.
   e. Calculate for each alternative
   f. Calculate for 2050 future without
4. A water quality loading target of 3526 kg/yr is desirable

Loxahatchee River Estuary

Evaluate TP and TN concentrations at strategic points representative of major inflow routes (e.g., Southwest Fork, and Northwest Fork).

Saint Lucie Estuary

A two part evaluation protocol consists of evaluating TP and TN concentrations at the Roosevelt Bridge (station SE10) and evaluating nutrient loads associated with Lake Okeechobee releases.

Evaluation Protocol

1. The following protocol should be used to evaluate trends in TP and TN concentration at SE10
   a. Score concentrations of both TP and TN as a percent towards reaching the goal
   b. The goal being 50% for TP of 81 ppb (0.081 mg/l) and 50% for TN of 0.67 mg/l
   c. Reaching the goal for both these parameters would have a score of 100%
   d. This value will account for 50% of the weight for the water quality score
2. The following protocol should be used for evaluating Lake Okeechobee releases for both TP and TN.

a. TP estimates

   i. Estimate Lake Okeechobee deliveries through S-308 for project condition and base (2000) condition
   ii. This would be based upon 2X2 runs for with project 2050 condition.
   iii. These would be annual averages in ac-ft/yr
   iv. Estimate Lake Okeechobee TP concentration based upon a 5 year trend at S-308, for example, the 5 year trend using data from January 2001 through October 2006 is TP = .235 mg/l
   v. Multiply volume (ac-ft/yr) x concentration (mg/l) x 1234.926to obtain load in metric tons (1000 kg)
   vi. Calculate reduction in load to St. Lucie Estuary by comparison of the 2000 and 2050 project conditions.
   vii. Success would be percent reduction towards 28% reduction of Lake Okeechobee load.

b. TN estimates
   i. Estimate Lake Okeechobee deliveries through S-308 for project condition and base (2050) condition
   ii. This would be based upon 2X2 runs with project 2050 condition
   iii. These would be annual averages in ac-ft/yr
   iv. Estimate in Lake TN concentration based upon a 5 year trend at S-308, for example, the 5 year trend using data from January 2001 through October 2006 is TN= 1.933 mg/l)
   v. Multiply volume (ac-ft/yr) x TN concentration (mg/l) x 1234.926 to obtain load in metric tons (1000 kg)
   vi. Calculate load reduction based upon this
   vii. Success would be percentage towards 55% reduction of load from Lake Okeechobee.

c. Evaluate trends in key parameters compared to the baseline values presented in Table 1

d. This value will account for 50% of the weight for the water quality score

4.2 Normalized Performance Output

Caloosahatchee Estuary

Nutrient Performance Measure Score

Nutrients at CES01 WQ station	TN (mg/l)	TP (mg/l)	TN Score based on direction of concentration	TP Score based on direction of concentration	Aggregate Score	Description
Current	1.28	0.11	0	0	0	Failure
Target	.92	0.079	50	50	100	Success

Lake Okeechobee Regulatory Loads

2x2 output for 2000 (k ac-	2x2 output for project (k ac-	LOWQM Estimated 2000 base (.08 mg/l)	LOWQM Estimated for CERP (in mg/l)	2000 base load (acft) x (mg/l) x conversion (1234.429	2000 base load (acft) x (mg/l) x (1234.42	2050 CERP load condition (acft) x (mg/l) x	Comparison % improvement

ft/yr)	ft/yr)			6) = MT	96) conversion = MT	(1234.4296) conversion = MT	
369	69	.08	.055				
369	69		(53.10)				

4.3 Model Output

Not available at this time. Estimates of nutrient load reductions may be possible from evaluating hydrologic model.

4.4 Uncertainty

Uncertainty associated with estuarine water quality performance measures is low for post-implementation assessment where relationships among water quality factors are understood and well-documented in the scientific literature; however, uncertainty is higher for predictive evaluation due to the current level of sophistication of available models which require reliance on hydrologically-based estimation of capture and transport of load and resultant concentration.

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

Monitoring shall be in accordance with CERP Monitoring and Assessment Plan: Part 1 Monitoring and Supporting Research - Northern Estuaries Module section 3.3.3.1 and South Florida Hydrology Monitoring Network Module section 3.5.3.3 (RECOVER 2004).

5.2 Assessment Approach

Interpretation of individual parameter performance should be resolved within context of holistic overview of key water quality characteristics as they promote or fail to promote desired floral and faunal communities. Assessment objective is to develop and sustain the ability to detect, against a backdrop of natural variability, significant trends ($P \leq 0.10$) in key parameters as presented in, but not limited to Table 1. In those cases where background concentrations are targets, the target is no detectable change. Trends may be either toward or away from goals, or state of no change.

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

WASH and/or other estuarine water quality model.

6.2 Assessment Tools Needed

Caloosahatchee Estuary

Water Quality monitoring network in coordination with collocated SAV monitoring stations (MAP table 3-12) particularly stations 6 and 7. Development of SAV and water quality classifications based upon ground truthing stations of the Remote Sensing Pilot study (Corps 2005) of salinity and sea grass beds

Indian River Lagoon

Continuation of water quality monitoring.

Lake Worth Lagoon

Continuation of water quality monitoring (currently by Palm Beach County Department of Environmental Resources Management).

Loxahatchee River Estuary

Continuation of water quality monitoring (currently by Loxahatchee River District)

Saint Lucie Estuary

Water quality monitoring and power analysis. Change to a system of realtime continuous monitoring in conjunction with biological monitoring.

7.0 Notes

This Performance Measure supersedes and addresses NE-5 St. Lucie Estuary Nutrient (TP and TN) Loading and Concentration (Last Date Revised: Sep 26, 2005), NE-6 Lake Worth Lagoon Nutrient (TP and TN) Load and Concentration (Last Date Revised, Dec 6, 2005), NE-7 Caloosahatchee Estuary Nutrient (TP and TN) Loading and Concentration (Last Date Revised Sep 9, 2005), NE-8 Loxahatchee River Estuary Nutrient (TP and TN) Load and Concentration (Last Date Revised Oct 8, 2005), NE-9 South Indian River Lagoon Nutrient (TP and TN) Load and Concentration (Last Date Revised Aug 22, 2005), NE-10 Northern Estuaries Contaminants (Toxicants and Pathogens, Last Date Revised Sep 21, 2005), NE-11 Northern Estuaries Water Clarity (Last Date Revised Dec 5, 2005), NE-16 Northern Estuaries Algal Bloom Frequency (Last Date Revised Dec 5, 2005), and NE-17 Lake Worth Lagoon Sedimentation (Last Date Revised Sep 2, 2005)..

8.0 Working Group Members

Estuary	Group Members (Agency)
Caloosahatchee Estuary	Robert Chamberlain (SFWMD), Peter Doering (SFWMD), Tomma Barnes (SFWMD), Patti Sime (SFWMD), Greg Graves (SFWMD), Gretchen Ehlinger (EPJV), Ed Brown (USACE)
Indian River Lagoon	Ed Brown (USACE), Patti Sime (SFWMD), Greg Graves (SFWMD), Gretchen Ehlinger (EPJV), Ed Brown (USACE)
Lake Worth Lagoon	Eric Hughes (USEPA), Ben Harkanson (PBCERM), Dianne Hughes (FDEP), Doug Chaltry (USFWS), Don Deis (EPJV), Ed Brown (USACE), Patti Sime (SFWMD), Greg Graves (SFWMD), Gretchen Ehlinger (EPJV), Ed Brown (USACE)

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