Northern Estuaries Performance Measure Salinity Envelopes

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1.0 Desired Restoration Condition

The restoration goal is to re-establish salinity regimes suitable for the maintenance of healthy, naturally-diverse and well-balanced estuarine ecosystems. Accomplishing restoration will require ameliorating inordinate canal discharges (including regulatory releases from Lake Okeechobee) and insuring sufficient dry-season flows necessary to avoid ecologically damaging high and low salinity extremes. Success in meeting restoration expectations will be measured by the degree in which constructed features and operational considerations sufficiently enhance estuarine flora and fauna as appropriate for each of the four estuaries being restored.

Caloosahatchee Estuary: Specific Restoration Goals

Re-establish a salinity range favorable to juvenile marine fish, shellfish, oysters and submerged aquatic vegetation (SAV). Re-establish consistent, clear, clean, freshwater flows that maintain low salinities in the upper estuary. Re-establish more stable salinities and ranges in the lower estuary that the seagrasses can tolerate.

Lake Worth Lagoon: Specific Restoration Goals

Manage flows through the C-51 canal where ecological benefits realized in the area most sensitive to freshwater discharge (e.g., potential oyster habitat) may translate into benefits in the northern and southern portions of the lagoon, thus increasing the spatial extent of flora and fauna throughout.

Loxahatchee River Estuary: Specific Restoration Goals

Improved freshwater deliveries to the Northwest Fork of the Loxahatchee River will reverse saltwater intrusion in the upstream reaches of the Northwest Fork. Reducing the frequency and duration of peak freshwater discharges through S-46 will decrease excessive salinity variability (i.e., re-establish more natural salinity regimes), which will benefit estuarine flora and fauna (e.g., seagrasses and oysters).

St. Lucie Estuary: Specific Restoration Goals

Maintain a salinity range favorable to fish, oysters and submerged aquatic vegetation (SAV), which necessarily requires addressing high volume, long duration discharge events from Lake Okeechobee, the C-23 and C-24 watersheds.

1.1 Predictive Metric and Target

Caloosahatchee Estuary: Specific Predictive Metrics and Targets

The target is based on optimization model outputs, natural variation that would occur during the period 1965-2000, and desirable salinity conditions for existing and potential aquatic resources within the CE. Targets are based on freshwater discharges from the C-43 canal at the S79 structure where the mean monthly inflow should be maintained between 450 and 2,800 cfs. Targets were developed to reduce minimum discharge and high flow events to the estuary to improve estuarine water quality and protect and enhance estuarine habitat and biota.

Low Flow

• Ultimately, the low flow target is no months during October to July when the mean monthly inflow from the Caloosahatchee watershed, as measured at S79, falls below a low-flow limit of 450 cfs (C-43 basin runoff and Lake Okeechobee regulatory releases).

High Flow

• Ultimately, the high flow target is no months with mean monthly flows greater than 2,800 cfs, as measured at the S79, from Lake Okeechobee regulatory releases in combination with flows from the Caloosahatchee River (C-43) basin.

Frequency of Flows

• The frequency distribution of monthly average freshwater inflows through S-79 for the entire period of record has been found to be important for protecting and restoring estuarine resources, while further promoting biotic diversity. Approximately 75% of the flows from S-79 should be in the 450-800 cfs range and most of the remaining inflow should be in the 800 to 2800 cfs range.

Lake Okeechobee Regulatory Releases

• The alternative with the least daily discharge volume, the fewest number of total days of discharge, and the fewest number of consecutive days is preferred. Special consideration is provided for pulse releases that may benefit the estuary.

<u>Tape grass and Seagrass Goals</u>

Seagrasses at the river mouth need high salinities (over 20 psu (Doering and Chamberlain 2000)) and clear water (Dennison et al., 1993) (low blue light attenuation) and no time periods of greater than 1 week at salinities below 10 PSU (e.g., Moffler and Durako, 1987) or blue light levels below 5 % of surface irradiance. Tape grass needs low salinities < 10 psu and clear water (Kemp et al., 2004), and no continuous time periods of salinities > 20 psu. Restoration goal of 100% tape grass, turtle grass or manatee grass coverage to 3 m mlw.

Lake Worth Lagoon: Specific Predictive Metrics and Targets

The Lake Worth Lagoon can be subdivided into three zones: northern, central, and southern. The northern and southern zones of the lagoon will be evaluated for salinities appropriate for seagrasses, while the central portion of the lagoon will be evaluated for salinities suitable for oyster recruitment and sustainability. Management of freshwater discharges into the lagoon as demonstrated below will maximize the potential growth of these VECs.

Central Zone:

A minimum salinity target of 15 parts per thousand (ppt) for the Lake Worth Lagoon was selected based on the habitat requirements of oysters (*Crassostrea viriginica*) for the central portion. A target of 15 ppt was selected for the American oyster because this is a mid-range salinity that meets the requirements for all life stages (see table below).

OYSTER STAGE	**SALINITY**	**REFERENCE**
Adult tolerance	5 – 30 ppt (optimum 10 – 28 ppt)	Loosanoff, 1965 in Rudolph, 1998
Adult	Large mortality occurs during prolonged periods of freshwater releases where salinities reach 2 ppt	Sellers and Stanley, 1984
Adult	Mean size greatest where surface salinities 8 – 22 ppt	Mote Marine Laboratory in Rudolph, 1998
Spat	Optimum growth at 15 – 22 ppt	Sellers and Stanley, 1984
Larvae	Maximum survival and growth >12.5 ppt	Sellers and Stanley, 1984
Spawning	Inhibited < 7.5 ppt	Sellers and Stanley, 1984
Gonadal maturation	Inhibited by low salinity < 5 ppt	Sellers and Stanley, 1984

Northern and Southern Zones:

Based on the requirements of three species of seagrass found within LWL, a minimum salinity of 20 ppt is considered an appropriate target (see table below). Kenworthy (1991) found no mortality at salinity concentrations as low as 15 ppt, but quick death at 5 ppt, with the threshold apparently somewhere between 5 and 15 ppt. While 15 ppt appears low in regard to the requirements of Halodule wrightii at different life-stages, extensive mortality was found only after prolonged exposure to conditions below 9 ppt. Optimal growth of seagrass beds is expected to occur within the northern and southern portions of the lagoon.

SEAGRASS SPECIES	**SALINITY**	**REFERENCE**
Halophila johnsonii	No stressful physiological response, as measured by photosynthesis and respiration, at salinities of 15, 25, and 35 ppt	Kenworthy and Dipiero, 1991
Halophila johnsonii and H.	Death within 3 days at 5 ppt	Kenworthy and Dipiero, 1991

decipiens		
Holodule wrightii	Normal tolerance range 5 – 55 ppt	Woodward-Clyde 1998
Halodule wrightii	Vigorous growth at 23 – 37 ppt	McMahan, 1968 in Rudolph 1998
Halodule wrightii	Flowers at 26 – 36 ppt	McMahan, 1968 in Rudolph 1998
Halodule wrightii	Adverse effects 2+ weeks <9 ppt	Moffler and Durako, 1987 in Rudolph, 1998

Target:

In an attempt to accomplish these targets, two upper limitations are recommended: (1) elimination of the devastating high flow events of 1,000 cfs or greater and (2) elimination of flows greater than 500 cubic feet per second (cfs) for extended periods of time (7-days or greater). To attain this salinity threshold, the targets are as follows:

- Inflows should be maintained between 0 and 500 cfs based on a 7-day moving average.
- High flow events of 1,000 cfs or greater, based upon a 2-day moving average, should not occur.
- Flows greater than 500 cfs based on a 7-day moving average should be eliminated. (Rudolph 1998).

Loxahatchee River Estuary: Specific Predictive Metrics and Targets

The Loxahatchee River can be subdivided into two major zones: (1) Northwest Fork, and (2) Estuary. The Northwest Fork will be evaluated for base flows and salinities appropriate for freshwater swamp communities, i.e., saltwater wedge near river mile 7.5. The Estuary will be evaluated for salinities appropriate for seagrasses.

Restorative flow targets for the Northwest Fork of the Loxahatchee River are defined as "variable dry season flow between 50 cfs and 110 cfs, with a mean monthly flow of 69 cfs over Lainhart Dam, while providing an additional 30 cfs of flow from the downstream tributaries" (SFWMD 2006). Such flows will effectively reverse saltwater intrusion in the upstream reaches of the Northwest Fork, and shift the typical distribution of the saltwater wedge downstream of river mile 7.5.

Freshwater discharge targets for the estuary are based on mean daily salinity conditions in the estuary (i.e., at river mile 1.74) and based on ecological requirements of manatee grass (*Syringodium filiforme*). Flood control discharges that result in the mean daily salinity equaling or falling below 15 ppt for a period of 6 days should not occur (Ridler et al 2006).

St. Lucie Estuary: Specific Predictive Metrics and Targets

SFWMD has performed extensive monitoring of the SLE as well as flows and loads from the associated basins and Lake Okeechobee (RECOVER 2006a). Flows were classed into sized flow events and flow events were subsequently correlated to representative median salinities. A discharge/salinity relationship was established for very low salinities using these classifications. Flow ranges of 725-3280 cfs produced salinities that ranged from 1-5 ppt. Flows of 2000 cfs, the mid-range of this flow class, would result in a salinity of 3 ppt, a salinity implicated in the oyster mortality of 1998 and 1999. Kenworthy and Dipiero (1991) found that such low salinities would result in *Halodule wrightii* mortality. Therefore, 3 ppt and 2000 cfs are threshold values for survival.

Evaluation targets were developed from natural systems modeling of the Indian River lagoon (NSM-IRL) from the Hydrologic Simulation Program Fortran (HSPF) and historic flow data using the 1965 - 2000 36-year rainfall period of record. The target salinity gradients in St. Lucie Estuary were determined by a hydrodynamic salinity model (Morris 1987) combined with estimates of salinity requirements for two indicator species in the estuary: shoal grass (*Halodule wrightii*) and American oyster (*Crassostrea virginica*). The salinity envelop target at the Roosevelt Bridge (mid-estuary) is a salinity range of 12-20 ppt).

The interim target flow numbers as of June 1, 2006 are as follows:

- 63 months where mean flow is less than 350 cubic feet per second (cfs).
- 24 Lake Okeechobee regulatory discharge events (14 day moving averages > 2000 cfs)
- 36 Local basin flow > 2000 CFS (based upon 14 day moving averages > 2000 cfs)

This target is the minimum condition for defining restoration per RECOVER 2006 and will the basis for a .5 normalized score.

Full restoration targets are estimated to be:

- 31 months where mean flow is less than 350 cubic feet per second (cfs).
- 0 Lake Okeechobee regulatory discharge events (14 day moving averages > 2000 cfs)
- 28 Local basin flow > 2000 cfs (based upon 14 day moving averages > 2000 cfs)

No more than 12 months of mean monthly greater than 2000 CFS, based upon the assumption that flows in excess of 2000 cfs produce salinities below 3 ppt at Roosevelt Bridge.

1.2 Assessment Parameter and Target

Caloosahatchee Estuary: Specific Assessment Parameter and Target

Vallisneria americana (tape grass)

A mean monthly inflow of at least 300 ft^3/sec (cfs) is needed from S-79 to ensure that the average monthly salinity at Ft. Myers (Yacht Basin) is $\leq$ 10 ppt (target maximum salinity for tape grass) and daily average salinity does not exceed 20 ppt more than once in two consecutive years. This estimated minimum flow level (MFL) depends on about 200 cfs of additional flow from the downstream tidal basin between S-79 and Ft. Myers. However, violations of the salinity criteria commonly occurs during dryer than normal periods in the dry season when the combined tidal tributary flows are < 200 cfs. Therefore, a minimum flow of 300 from S-79 is not enough. Greater frequency of flows that approach 500 cfs is needed from S-79 in order to achieve the intended salinity goals.

At the other extreme, mean monthly flows that exceed 2,800 cfs should be minimized, because greater flows cause more than half the estuary upstream of Shell Point to become freshwater and salinity near Shell Point drops to levels that threaten many of the species in this region. Mean monthly inflows greater than 4,500 cfs from S-79 causes: salinity and other water quality parameters in San Carlos Bay to decline below desired levels; and the entire estuary upstream of Shell Point to approach freshwater conditions.

Crassostrea virginica (American oyster)

Volety et al. (2003) recommended freshwater inflows for the protection and enhancement of oyster recruitment and survival around Shell Point and San Carlos Bay, which are consistent with the flows outlined above for SAV. "Flows between 500 and 2000 cfs would result in salinities of 16-28 ppt at all stations, conditions that are favorable to sustain and enhance oyster populations in the Caloosahatchee Estuary." Under current water management practices, oysters in the Caloosahatchee are not stressed by low flows of < 300 cfs from S-79. However, complete cessation of discharges during the winter will increase salinities in areas normally associated with lower salinity, and result in the migration of marine predators and pests. They further speculate that oyster spat that recruit to downstream areas also will be exposed to higher salinity and heavy predation pressure resulting in very little survival. However, the greatest threat to oysters under current water management practices is due to high flows that exceed 3,000 cfs for extended periods (2-4 weeks). This is especially true for summer months during peak spawning, juvenile recruitment, and oyster growth. Volety et al. (2003) recommends that when freshwater releases are necessary, repeated pulses of < 1 week duration during winter months be made instead of sustained releases of freshwater during summer or winter months. Interpretation of these results also indicates that such pulses would be least damaging during December through February, before increased spawning and recruitment begins at upstream locations.

Salinity preferred by oysters will be maintained if the target flow frequency distribution is achieved, especially if 75% of the flows are between 450 and 800 cfs.

Lake Worth Lagoon: Specific Assessment Parameter and Target

The minimum desirable salinity is 15 parts per thousand (ppt).

Loxahatchee River Estuary: Specific Assessment Parameter and Target

In the Northwest Fork the specific assessment parameter and target are the accomplishment of the restorative flows outlined in the *Restoration Plan for the Northwest Fork of the Loxahatchee River*, which will result in a downstream shift in the typical location of the saltwater wedge (to approximately river mile 7.5). In particular, dry season freshwater discharges into the Northwest Fork and flowing over Lainhart Dam should be between 50 cfs and 110 cfs, with a mean monthly flow of 69 cfs, and an additional 30 cfs of flow should be achieved through the downstream tributaries (SFWMD 2006).

Manatee grass (*Syringodium filiforme*) is a highly productive seagrass species occurring in the Loxahatchee River estuary, and past studies have shown manatee grass to be susceptible to altered freshwater discharges and excessive salinity fluctuations (SFWMD and FDEP 2006, Ridler et al. 2006). Therefore, the following salinity threshold target with duration is established for manatee grass at river mile 1.74: ≤15 ppt for 6 days, because mean daily salinity ≤15 ppt for 6 days (over a 30 day period) resulted in significant mortality of *Syringodium filiforme* in the Loxahatchee River estuary.

Saint Lucie Estuary: Specific Assessment Parameter and Target

Reestablish a salinity range most favorable to juvenile marine fish, shellfish, oysters and submerged aquatic vegetation. This is estimated at 12 to 20 parts per thousand (ppt) as measured at the US-1 Highway Roosevelt Bridge over the estuary, and has been chosen as a Valued Ecosystem Component (for more information on oysters see NE-5).

2.0 Justification

The Northern Estuary Module encompasses five estuarine systems, namely the Caloosahatchee, Loxahatchee, and Saint Lucie estuaries, and the Indian River and Lake Worth Lagoons. The Indian River Lagoon is not addressed by this Performance Measure, since "salinity envelope" in the lagoon is not an issue. Under natural conditions estuarine environments may experience substantial variation in salinity due to storm events, changes in season, and decadal cycles in regional weather patterns. On geologic time scales, plants and animals have adapted to estuarine variability to the extent that many species rely upon estuaries for habitat, complex reproductive cycling, sanctuary from predation, and sustenance of key elements of an expanded food web including birds, marine fish and mammals, etc. The manner in which freshwater inputs are balanced via tidal exchange with the open ocean defines the salinity envelope, which may be differ among estuaries as a consequence of unique morphology, degree of connection with the sea, tidal height, and so forth. Salinity patterns directly influence productivity, population distribution, community composition, predator-prey relationships and food web structure in the inshore marine habitat (Myers and Ewel 1990, Kennish 1990).

The volume, distribution, circulation, and temporal patterns of freshwater discharges to all four of the estuaries within the Northern Estuaries Module were altered due to construction and operation of the Central and Southern Flood Control District (C&SF) canals, and the resultant urban and agricultural development afforded by enhanced drainage and flood protection. These alterations have placed severe stress upon these ecosystems. Large volume freshwater discharges cause sudden drops in salinity and exacerbate transport of organic and inorganic sediments. Drainage systems designed to rapidly remove water from the land often do not afford time necessary for natural processes to absorb contaminants and nutrients, to the extent that large volume freshwater discharges may also transport large loads of nutrients and other contaminants into the estuarine environment. When stress repeatedly exceeds the resiliency of an estuarine system to absorb and ameliorate adverse conditions, negative effects will be compounded and estuarine ecosystem quality will decline. Examples include: decreased spatial extent of submerged aquatic vegetation (SAV), increased harmful algae blooms, declines in desirable fish species, and changes in the macroinvertebrates community such as loss of oysters (Haunert 1988).

2.1 Caloosahatchee Estuary

The Caloosahatchee River is the major source of freshwater for the Caloosahatchee Estuary (CE) and southern Charlotte Harbor aquatic environment. The river bisects its watershed and now functions as a primary canal (C-43) that conveys both runoff from the Caloosahatchee watershed and regulatory releases from Lake Okeechobee. The canal has undergone a number of alterations to facilitate this increased freshwater discharge and flood protection. These alterations include: channel enlargement; bank stabilization; the development of an intricate network of canals within the watershed; and the addition of three lock and dams. The final downstream structure, Franklin Lock and Dam (S-79), demarcates the beginning of the estuary, and acts as a barrier to salinity and tidal action, which historically extended to nearly the LaBelle area.

Because of water management practices, the watershed of the Okeechobee is now larger than it was historically, and the water coming into the lake is higher in nutrients. This high nutrient water can not flow south as it would originally because of the Hoover Dike and Everglades restoration P loading limits. Much of the high nutrient high turbidity water is directed west to the Caloosahatchee. The watershed of the Caloosahatchee is also larger because of water management practices, and runoff amounts are higher. This results in fast swings in local watershed inputs of freshwater as opposed to slower sheet-flow or groundwater discharge. The groundwater and sheet-flow inputs are preferred since the water gets filtered, and the flow rate changes gradually and is sustained longer than it is the existing fast runoff system.

Alterations to the Caloosahatchee River and watershed have resulted in a drastic change in freshwater inflow to the downstream ecosystem. The resulting large fluctuation of salinity and water quality can adversely impact estuarine biota (Chamberlain and Doering 1998a; Sklar and Browder 1998).

An important upper estuarine feature is the freshwater-brackish submerged grass, *Vallisneria americana* (tape grass), which when present is located near the shoreline in the upper estuary to a depth of about 1.0 m. Its greatest coverage occurs from Beautiful Island to just past the Ft. Myers bridges (Hoffacker et al. 1994, Chamberlain and Doering 1998b). During times of extended low inflow conditions, when salinity is too high, this grass becomes very sparse and can disappear completely (Chamberlain et al. 1995, Doering et al. 2002, SFWMD 2000).

Downstream, sparse beds of the seagrass *Halodule wrightii* (shoal grass) extend up from San Carlos Bay to nearly the Cape Coral Bridge (Hoffacker et al. 1994, Chamberlain and Doering 1998b). Like tape grass, it is restricted to the shoreline margins and historically represented a valued ecosystem component of the estuary. Oysters also exist near the mouth at Shell Point and historical accounts of the river indicate that oysters were once a more prominent feature in the area upstream (Sackett 1888). Both shoal grass and oysters in this area of the estuary are sensitive to high freshwater inflows from S-79 (Chamberlain and Doering 1998b, Doering et al. 2002, Volety et al. 2003).

The dominant biological features in the San Carlos Bay area are its numerous mangrove islands and many kilometers of mangrove shoreline, which are often closely associated with oysters and large meadows of seagrass. Because of its biotic richness and aesthetic appeal, San Carlos Bay supports a wide variety of recreational and fishery activities with significant economic value. The natural resources of this area are also negatively affected by large freshwater releases and are threatened by long-term shifts in water quantity and quality (Chamberlain and Doering 1998b, Doering et al. 2002, Volety et al. 2003). Recent environmental investigations in the CE have resulted in an estimate of the optimum quantity of water needed by the CE to protect key biota. These species, or Valued

Ecosystem Components (VECs), help sustain the ecological structure and function of the estuary by providing food, living space, and foraging sites for other naturally occurring estuarine species. Oysters and submerged aquatic vegetation (SAV) represent VECs in the CE. Limits on water quantity and related water quality, such as salinity, will protect these species and should lead to a healthy and diverse estuarine ecosystem.

Research results (Chamberlain et al. 1995, Doering et al. 1999 and 2001, Doering and Chamberlain 2000, and Kraemer et al. 1999) were used to determine optimum salinity envelope for SAV in the Caloosahatchee Estuary. A steady-state salinity model (Scarlatos 1988, Bierman 1993) and a statistical model of salinity (SFWMD 2000) were used to estimate mean monthly flows from S-79 that will establish a desirable salinity range in the geographic locations of SAV, without adverse effects on benthic invertebrates, ichthyoplankton, and zooplankton (Chamberlain et al. 1995, 1999, 2001; Chamberlain and Doering 1998b, Doering et al. 2002 SFWMD 2000 and 2002a). An upgraded, fully hydrodynamic model has been developed and is under refinement. An early version of this model has been used to verify and improve estimates of inflow requirements based on model prediction of salinity distribution in the estuary.

Research results reported by Volety et al. (2003) further demonstrated the importance of *Crassostrea virginica* (American oyster = oyster) as a VEC. They found that a greater abundance of decapods and fishes were associated with clusters of live oyster compared to dead-articulated clusters, while the structure provided by both living and dead oysters shells supported a greater abundance than no shells. Species richness and dominance were higher for samples with oyster clusters (dead or live) compared to controls with no oyster shell. This study points out that, “perhaps the real significance of living oysters to habitat value lies not only in creating a three-dimensional structure, but also in maintaining this structure of clusters through time.” Individual oysters may die, leaving empty compartments for reef residents, but “mass mortality within a cluster results in the disarticulation of the oysters shell.”

Volety et al. (2003) in their field and lab research evaluated the survival of oyster adults and juveniles, as well as oyster health, the prevalence and intensity of disease, and oyster recruitment success. The results were compared to environmental factors, including salinity and freshwater flow from S-79. Oysters grow best at a salinity of 14 to 28 parts per thousand (ppt). Infection by the oyster pathogen, *Perkinsus marinus*, increases during higher salinity and temperature. Field studies during this research determined that the prevalence of infection was high, but disease intensity was low, because temperature and salinity act antagonistically (i.e., high summer temperature occurs during the wet season and lower salinity). Therefore, freshwater releases to diminish *Perkinsus marinus* are generally not advised during warm summer months because of the potential threat to oyster populations from further lowering salinity.

The greatest oyster growth and recruitment occurs during the wet season, but slower growth, poor spat production, and excessive valve closure occurs at salinities below 14 ppt. During their study, salinity conditions were best suited for oyster growth just upstream of Shell Point. However, this upstream area is also the most vulnerable to high mortality when large releases cause salinity to fall below threshold tolerance, sometimes for prolonged periods. The Volety et al (2003) report suggests, “that while adult oysters are tolerant, salinities of 5 ppt or lower will result in > 95% mortality of juvenile oysters.” High juvenile mortality can occur when exposed to this salinity for just a week. Experimental results indicate that adults are able to tolerate salinities as low as 5 ppt up to 8 weeks, but can not tolerate salinities lower than 3 ppt, which can occur upstream of Shell Point when S-79 discharges exceed 4,000 cfs. Therefore, high discharges can limit population survival and abundance in this region where they were historically present. As a restoration note, Volety et al. (2003) indicated that because of high spat recruitment at intermediate salinities, along with good growth rates and low disease, it is very feasible to develop oyster reefs upstream of Shell Point by strategically placing oyster clutch in suitable areas, if provided the ability to control current [high] freshwater inflows.

Oysters in southwest Florida spawn continuously, with peak recruitment (spat settlement) occurring during May to November. Recruitment near Shell Point and possibly upstream begins to peak in March, a full 3 months earlier than in San Carlos Bay, thus making these newly settled juveniles vulnerable to large releases from S-79, which have often occurred during this period to regulate Lake Okeechobee water level for flood protection. Large freshwater flows at this time and during the summer also expose oyster larvae to lethal low salinities, or flush the larvae to more downstream locations where there may not be suitable substrate for settlement.

2.2 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 two permanent inlets, North Lake Worth Inlet (Palm Beach Inlet) and South Lake Worth Inlet (Boynton Beach Inlet), 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.

Salinity is a key ecological variable that controls important aspects of community structure and food web organization (Myers and Ewel 1990). Altered estuarine salinity has resulted in large decreases in the spatial extent of submerged aquatic vegetation (SAV) in the Lake Worth Lagoon. The lagoon could experience an increase in diversity of estuarine fauna if the large fluctuations in salinity were controlled. Management of freshwater discharges into LWL will maximize the potential growth of such valued ecosystem components (VECs) as oysters (*Crassostrea viriginica*) and seagrasses (represented by *Halophila decipiens, H. johnsonii*, and *Halodule wrightii*). The species listed were selected because they represent key estuarine components that are currently present in the Lagoon, but are impacted by anthropogenic alteration of lagoon habitats. Oysters are particularly susceptible to high flows which drastically lower salinity levels in LWL during the spawning season. One key component of spawning success is the requirement of salinities of approximately 10 ppt or greater" (Lorio and Malone 1994).

2.3 Loxahatchee River Estuary

The hydrologic conditions of the Loxahatchee Basin have been extensively altered by the construction of canals, channelization of natural waterways, drainage and/or impoundment of wetlands, increases in ground water withdrawals for water supply and stabilization of Jupiter Inlet to the Atlantic Ocean. Construction of the C-18 canal resulted in severance of the Northwest Fork of the Loxahatchee River from its headwaters, the Loxahatchee Slough, while construction of the S-46 flood control structure (connecting the C-18 with the Southwest Fork) resulted in an artificial connection between its headwaters and the downstream estuary. These modifications to the system resulted in insufficient base flows to the Northwest Fork and excessive flows into the Southwest Fork during storm events. Consequently, the Northwest Fork has been degraded by receiving too little freshwater during dry periods and the estuary has been degraded by receiving too much freshwater during storm events.

Insufficient baseflows to the Northwest Fork of the Loxahatchee River resulted in extensive change to the riparian vegetation between river mile 6 and 10 (SFWMD 2006). Within the span of a decade or two following World War II, the giant cypress trees living along much of the Northwest Fork of the Loxahatchee River died because of saltwater intrusion. As the riparian habitat changed, the native fauna, including otter, alligator and largemouth bass, all retreated upstream within Jonathan Dickinson State Park, especially along the floodplain of Kitching Creek (Dent and Ridler 1997).

Excessive freshwater discharges to the estuary through S-46 have resulted in the degradation of oysters and seagrass habitats (SFWMD 2006). In particular, flood control discharges through S-46 reduce minimum daily salinity and increase salinity variability throughout much of the estuary. Lowered salinity and highly variable salinity conditions are known to stress estuarine organisms, in particular seagrasses (Ridler et al. 2006). Therefore, there is a need to reduce the frequency and duration of peak discharges (excessively large freshwater discharges) through S-46 to the Southwest Fork of the Loxahatchee River.

From 1970 through 1980, a great deal of attention was given to the problem of saltwater intrusion into the river. A summary of the major efforts includes the work in the early 1970s by the U.S. Geological Survey (USGS) under Harry Rodis and later by Ben McPhearson and others. Dewey Worth and the South Florida Water Management District (SFWMD) analyzed the saline environment in the estuary and northwest fork of the river in 1980. The Jupiter Inlet District (JID) commissioned a series of studies over a fifteen-year span beginning in 1975 (Dent and Ridler 1997).

These reports described the process of saline intrusion and defined the conditions present, set goals for holding the encroaching salt water below Kitching Creek and recommended actions needed to achieve the goal. The first and most significant technical recommendation was made by Rodis in 1971 who called for a minimum 50 cubic feet per second (cfs) flow in the vicinity of the State Road 706 bridge and the Lainhart dam (Dent and Ridler 1997). This recommendation resulted in the installation of a culvert in the C-18 canal. This structure, G-92, allowed water from the Loxahatchee Slough and the C-18 canal to be directed to a conveyance canal, C-14, and into the uppermost reach of the northwest fork of the Loxahatchee River. A three way operational accord was developed with the SFWMD installing the structure, the South Indian River Water Control District (SIRCD) allowing the use of the C-14 canal and the Loxahatchee River Environmental Control District (LRECD) providing the personnel to operate the structure. In the mid-1980s, the SFWMD took three important steps to enhance the ability to provide the requested minimum flow. Operating protocols were improved which caused greater amounts of water to be held in the C-18 basin, two dams were rebuilt in the freshwater reach of the northwest fork, and the G-92 structure was replaced with a larger culvert, and provided automatic operational controls (Dent and Ridler 1997).

The early technical research on the Northwest Fork of the Loxahatchee River lead to the federal 'Wild and Scenic River' designation of the Northwest fork of the Loxahatchee in 1985. Along with the recognition came the establishment of the Loxahatchee River Management Coordinating Council (LRMCC) and the formulation of a management plan. The original management plan endorsed the 50 cfs minimum flow requirement at the Lainhart dam and encouraged further investigation to more accurately project future needs (Dent and Ridler 1997).

Three additional initiatives were enacted in the 1990s as measures to retard the further migration of saline waters and begin 'turning the tide' to reclaim a portion of the lost habitat.

1. The JID constructed earthen and rock dams to seal off certain channels through the mangroves that had been created within the past twenty-five years and were acting to short cut the historic meandering flow pattern of the northwest fork and re-establish the longer flow routes for the river. Salinity studies conducted by the LRECD demonstrated that the construction was successful in lowering the concentration of salt water above the closures.

2. The LRECD in 1994, after new salinity and flow relationships were recorded and analyzed, presented the new data, compared it to USGS data generated 10-20 years earlier and suggested that the 50 cfs minimum flow at the Lainhart dam requirement for the river should be modified. The new recommended flow requirements incorporate a seasonal element and set new minimum needs in a range between 70 to 110 cfs.

3. Remnant portions of the historic Loxahatchee slough were purchased in recent years and planning for its beneficial management began (Dent and Ridler 1997).

In 2006 the *Restoration Plan for the Northwest Fork of the Loxahatchee River* was approved by the SFWMD Governing Board and the Secretary of FDEP. The plan calls for a daily variable flow that is based on a seasonal hydrograph to the Northwest Fork. Scientific and modeling analysis resulted in the identification of a Preferred Restoration Flow Scenario. This scenario, LV90 – TV60, will result in variable dry season flow over Lainhart Dam between 50 cfs and 110 cfs, with a mean monthly flow of 69 cfs, while providing an additional 30 cfs of flow from the downstream tributaries. These restorative flows will provide adequate freshwater flows to protect and enhance the riverine floodplain, maintains conditions for the propagation of cypress trees in the tidal floodplain, and promotes a healthy estuarine system in the Northwest Fork of the Loxahatchee River. This scenario includes seasonal variation, including rainfall driven monthly and daily flow variability necessary for restoration.

By implementing the Preferred Restoration Flow Scenario it is expected that saltwater intrusion will be reversed and portions of the tidal floodplain will be restored to a freshwater swamp system where during the dry season the proposed restoration flows will push the salinity wedge from its current location, near RM 9, downstream to a location near RM 7.5. This scenario is also designed to minimize impacts on the estuarine ecosystems. The low salinity zone, located between RM 9.5 and RM 5.5 requires a salinity range of 2 ppt - 8 ppt during the dry season to function as a nursery for many saltwater fishes. Although restorative flows will move the appropriate salinity range downstream, the low salinity will remain within an area that will provide suitable habitat for juvenile fish development. The optimal salinity range for oysters is from 10 ppt to 20 ppt, which is currently located between RM 6 and RM 4. With increased flows during the dry season through the Northwest Fork these salinity levels will be moved downstream and the upstream oyster beds at RM 6 will be lost. However, the majority of the oysters are located downstream of RM 5 and will not experience harmful drops in salinity levels. The addition of oyster substrate near RM 4 will mitigate the loss of oysters at RM 6. The Preferred Restoration Flow Scenario will have minimal impact on seagrasses in the Central Embayment area.

In addition, the SFWMD has teamed up with other agencies to model the Loxahatchee Slough, to provide optimal water elevation ranges for protection of this valuable ecosystem. Increased water storage in the Loxahatchee Slough and C-18 Canal should facilitate increased freshwater deliveries to the Northwest Fork. The majority of the supplemental flows are planned to come from the L-8 Reservoir and delivered by a conveyance system that is included in the North Palm Beach County CERP Project, Part 1.

2.4 Saint Lucie Estuary

The St. Lucie Estuary (SLE), located on the southeast coast of Florida, flows into the Indian River Lagoon and the Atlantic Ocean. Historically, this estuary was a fresh water system influenced by ephemeral ocean inlets. When the St Lucie Inlet was permanently established in 1898, the system became an estuary, characterized by abundant mangroves, submerged oyster bars and submerged aquatic vegetation (SAV). Agricultural and urban drainage projects beginning in the 1910s expanded the area that now drains into the estuary to its present size of almost 775 square miles. Major drainage canals constructed in the watershed include the C-23 and C-24 canals. The SLE is connected to Lake Okeechobee by the C-44 canal, which is used for navigation and regulatory releases from Lake Okeechobee. As a result, freshwater flow into the estuary tends to be excessive in the wet season and occasionally insufficient in the dry season. The estuary has also been degraded by thick deposits of mucky silt that cover large portions of the bottom and make it unsuitable for SAV and oysters. These sediments also become re-suspended by wind, current and boat traffic resulting in diminished light penetration through the water column.

There has been a continued decline in the spatial coverage of beds of SAV in the St. Lucie Estuary. Studies have shown that the only areas in the St. Lucie Estuary that currently support SAV are in the lower estuary near Hell Gate Point (Woodward-Clyde 1999). The SAV identified in these recent studies were primarily shoots and not actual beds. Shoal grass (*Halodule wrightii*) was the dominant species throughout most of this area, with Johnson's seagrass (*Halophila johnsonii*) as the secondary species. The only other documented occurrences of SAV during that study was a very small amount of Widgeon grass (*Ruppia maritima*), wild celery or tape grass (*Vallisneria americana*) and common water nymph (*Najas guadalupensis*) in the South Fork of the estuary as well as a small area of Widgeon grass (Ruppia maritima) in the North Fork. *Halodule wrightii* and *H. johnsonii* exist near the mouth of the St. Lucie Estuary, but are sometimes extirpated during periods of high flow. A very small population of *V. americana* reoccurs by seed periodically in the upper estuary during periods of exceptional water quality conditions.

The average maximum depth that "healthy" seagrasses will grow in the St. Lucie Estuary is 1.7 meters (Virnstein and Morris 1996). The St. Lucie Estuary has approximately 922 acres of suitable habitat. This acreage is based on South Florida Water Management District 1999 aerial photography.

In the St. Lucie Estuary, oysters have been identified as VECs. Oysters are natural components of southern estuaries and were documented to be abundant in the system. The American oyster is the dominant species in these oyster reef communities. Oyster bars provide important habitat and food for numerous estuarine species including gastropod mollusks, polychaete worms, decapods crustaceans, various boring sponges, fish and birds. Over 300 macrofauna species can live in oyster beds and over 40 species may live in a single oyster bed (Wells 1961). Oysters are also an important commercial and recreational resource. Salinity is important in determining the distribution of coastal and estuarine bivalves. Adult oysters normally occur at salinities between 10 and 30 parts per thousand (ppt) but they tolerate a salinity range of 2 to 40 ppt (Gunter and Geyer 1955). Short pulses of freshwater inflow can greatly benefit oyster populations by killing predators, such as the southern oyster drill and the whelk, that cannot tolerate low salinity water (Owen 1953), while excessive freshwater inflows may kill entire populations of oysters (Gunter 1953, Schlesselman 1955, MacKenzie 1977).

The American oyster, *Crassostrea virginica*, are highly valued as food, but their ecological significance remains under-appreciated and under-studied (Coen et al. 1999a). Individual oysters filter 4-34 liters of water per hour, removing phytoplankton, particulate organic carbon, sediments, pollutants, and microorganisms from the water column. This process results in greater light penetration immediately downstream, thus promoting the growth of submerged aquatic vegetation. Although oysters assimilate the bulk of the organic matter that they filter, the remainder is deposited on the bottom where it provides food for benthic organisms. Furthermore, the oyster's ability to form large biogenic reefs (Coen et al. 1999b) qualifies it as a keystone species. Oysters and the complex, three-dimensional, reef structure they form, attract numerous species of invertebrates and fishes.

Historic oyster acreage was calculated from a 1940-1960 GIS coverage developed by Woodward-Clyde under contract to the South Florida Water Management District (Woodward-Clyde Inc. 1998a). The estimate of approximately 1,400 acres represents an interpretation of anecdotal information and general oyster location accounts found through a literature review (Woodward-Clyde Inc. 1998b), and is based on the only known source of information. In 1997, 207 acres of oyster habitat were identified in the St. Lucie Estuary (Woodward-Clyde 1998a), which equates with an 85% loss in oyster cover. Shell mining, dredge and fill activities, altered freshwater inflow, changes in hydrodynamics, and increased “mucky” sediments from canal discharges (which greatly decreased availability of suitable hard bottom substrate needed for recruitment) – contributed to these losses. Large freshwater discharges from Lake Okeechobee and the St. Lucie Estuary watershed occurred in Spring 1998 and Summer 1999, killing more than 90% of the remaining oysters. These flows were above 2000 cfs and produced salinities below 1 part per thousand (ppt) DBHydro dataset (2006). Subsequent to this event, some recruitment has been documented by the comprehensive study part of RECOVER’s Monitoring and Assessment Plan which began in January 2005. This study will provide baseline monitoring to provide an accurate accounting of changes in coverage and health of oysters in the St. Lucie Estuary.

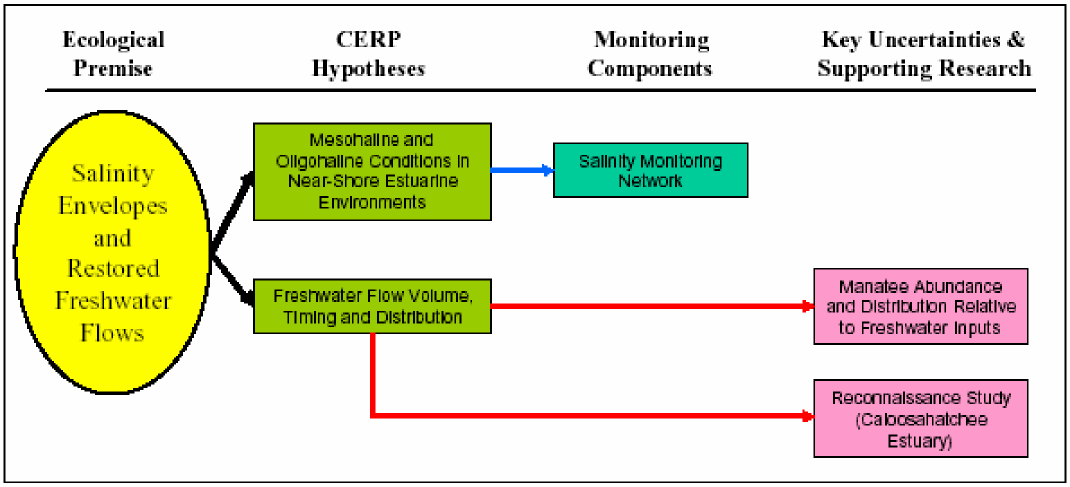
3.0 Scientific Basis

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



3.2 Relationship to Adaptive Assessment Hypothesis Clusters

Ecological Premise: Prior to water management, natural patterns of freshwater inflow to the Caloosahatchee Estuary, sustained an ecologically appropriate range of salinity conditions in the river and estuary with fewer high and low salinity extremes.

CERP Hypothesis: The construction and operation of water storage and treatment facilities in the C-43 basin as well as water storage projects around and in the headwaters of Lake Okeechobee will help regulate flows which will in-turn provide a salinity envelope that avoids ecologically damaging high and low salinity extremes.

3.2 Lake Worth Lagoon

Ecological Premise: Prior to water management, and post inlet construction natural patterns of freshwater inflow to Lake Worth Lagoon sustained an ecologically appropriate range of salinity conditions in the lagoon with fewer high and low salinity extremes.

CERP Hypothesis: The construction and operation of water storage, water diversion and treatment facilities in the Northern Estuaries regions will provide salinity envelopes that avoid ecologically damaging high and low salinity extremes.

3.3 Loxahatchee River Estuary

Ecological Premise: Prior to water management (post inlet maintenance), natural patterns of freshwater inflow into the Loxahatchee River and Estuary, achieved an ecologically appropriate range of freshwater, oligohaline and estuarine salinity conditions with fewer high and low salinity extremes.

CERP Hypothesis: The construction and operation of water storage and treatment facilities in the Loxahatchee River watershed will provide appropriate freshwater inflows through the Northwest and Southwest Forks, Kitching, Cypress and other freshwater tributaries as well as elevated levels of groundwater flow through the rehydration of watershed wetland systems. Increased base flows and decreased frequency and duration of flood control discharges through S-46 will provide for more stable and appropriate salinity envelopes that avoid ecologically damaging high and low salinity extremes.

3.4 Saint Lucie Estuary

Ecological Premise: Prior to water management, (post inlet construction) natural patterns of freshwater inflow to the St. Lucie Estuary and Indian River Lagoon sustained an ecologically appropriate range of salinity conditions in the estuary with fewer high and low salinity extremes.

CERP Hypothesis: The construction and operation of water storage and treatment facilities in the Northern Estuaries regions will improve the quantity, timing and distribution of flows into the estuary which will in turn provide a salinity envelope that avoid ecologically damaging high and low salinity extremes.

4.0 Evaluation Application

4.1 Evaluation Protocol

Caloosahatchee Estuary

The South Florida Water Management Model (SFWMM) version 5.0 and a 36-year rainfall period of record will be used. The output is a bar chart displaying the number of months mean monthly flows are greater than the target flows.

Hydrologic Performance Targets (HT) to achieve the ecological targets:

HT 1a. For each alternative, compare the number of times that the mean monthly inflows from the Caloosahatchee watershed fall below a low-flow limit of 450 cfs at S-79 during October to July. The alternative with the fewest number of times that flows fall below 450 cfs will be considered better for protecting aquatic vegetation, oysters, and fish communities.

HT 1b. For each alternative, compare the frequency that the mean monthly low-flow limit of 450 cfs through S-79 was not met for just one month (not followed by another month below 450 cfs), as well as the frequency for 2, 3, 4…etc. consecutive months. The water management alternative with the fewest number of consecutive months with average flows below 450 cfs will be considered better for protecting estuarine aquatic resources.

HT 1c. For each alternative, compare the frequency that the mean monthly low-flow limit of 450 cfs through S-79 from the watershed was not met for just one year (not followed by another year with months below 450 cfs), as well as the frequency for 2, 3, 4…etc. consecutive years. The water management alternative with the fewest number years and consecutive years with average monthly flow occurrences below 450 cfs will be considered better for protecting estuarine aquatic resources.

HT 2a. For each management alternative, compare the number of times that mean monthly inflow from the watershed exceeds 2,800 cfs at S-79. The alternative with the fewest number of times that this criterion is exceeded at any time of year will be considered better for protecting both SAV and juvenile oysters at Shell Point and upstream. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

HT 2b. For each alternative, compare the frequency that the mean monthly inflow from the watershed, measured at S-79, exceeds 2,800 cfs for just one month (not followed by another month above this limit), as well as the frequency for 2, 3, 4… etc. consecutive months. The alternative with the fewest consecutive months that violate this criterion throughout the year will be considered better for protecting estuarine resources, including juvenile oyster recruitment and survival. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

HT 3a. For each alternative, compare the number of times that mean monthly and mean weekly inflows from the watershed exceed 4,500 cfs at S-79 (weekly is important for protecting oyster recruitment and survival). The alternative with the least number of times flows exceed these limits will be considered better for protecting the estuarine resources, including those downstream in the San Carlos Bay region. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

HT 3b. For each alternative, compare the frequency that mean monthly and mean weekly inflows from the watershed, measured at S-79, exceeds 4,500 cfs for just one month and 1 week (not followed by another month or week above this limit), as well as the frequency for 2, 3, 4…etc. consecutive months and weeks. The alternative with the fewest number of consecutive months and weeks that violate this criterion will be considered better for protecting aquatic resources, including juvenile oysters. Additionally, a better ranking will be given to the alternative with the least number of consecutive discharge periods above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

HT 4. For each alternative, compare the number of days that regulatory discharges from Lake Okeechobee are made to the Caloosahatchee River. The alternative with the least daily discharge volume, the fewest number of total days of discharge, and the fewest number of consecutive days will be preferred. Special consideration will be provided for pulse releases that may benefit the estuary.

HT5. For each alternative, compare the frequency distribution of monthly average freshwater inflows through S-79 for the entire period of record being evaluated. The alternative that maximizes, up to 75% of the flows from S-79 in the 450-800 cfs range and almost all the remaining inflow in the 800 to 2800 cfs range will be considered the most desirable for protecting and restoring estuarine resources, while further promoting biotic diversity.

Lake Worth Lagoon

The South Florida Water Management Model (SFWMM) is used to predict flows at selected structures including the S155. The graphic output will depict the percentage of the period of record (POR) that the salinity criteria were not met for the Lake Worth Lagoon. The graphic output will include the percent of days, based upon the modeled POR, that:

1. The 2-day moving average is 1,000 cfs or greater and

2. The 7-day moving average is 500 cfs or greater.

3. The target is zero percent for events 1,000 cfs or greater, and events above 500 cfs.

Loxahatchee River Estuary

The Lower East Coast Sub-Regional (LECsR) MODFLOW Model will be used to simulate long-term freshwater inflows from tributaries into the Loxahatchee River and Estuary for various alternatives. This information will provide the input needed for the Hydrodynamic/Salinity Model (RMA) and Long-Term Salinity Management Model (LSMM). The long-term salinity management model (LSMM) was developed from RMA results to predict tidally averaged salinity in response to various alternatives. These salinity models will be used to help assess the effect of various flows from S-46 and the other tributaries on salinity conditions throughout the system. Evaluation of alternative model runs will follow the same approach explained in the Chapter 7 of the Restoration Plan (SFWMD 2006). For the estuary, results of alternative model runs will be compared by determining the total number of days within the period of record that did not meet target salinity thresholds for various portions of the system (e.g., river mile 7.5, river mile 1.74). Models runs with more days of non-compliance will be considered less desirable and potentially detrimental to the system.

Saint Lucie Estuary

The SFWMM version 5.0 will be used to predict flows from the C-44 canal, including Lake Okeechobee regulatory releases. The watershed hydrology model (WASH) will be used to predict flows from the C-23, C-24 and C-25 canals.

4.2 Normalized Performance Output

1.2.2 Caloosahatchee Estuary

An index comparing the alternatives on the scale of 0-1 will be developed.

1.2.2 Lake Worth Lagoon

Not available at current time.

1.2.2 Loxahatchee River Estuary

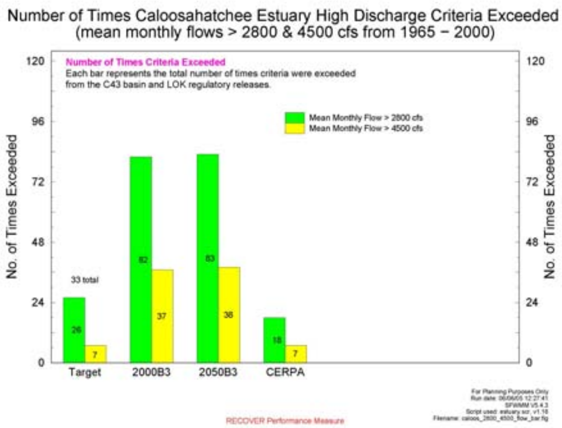
Not available at current time.

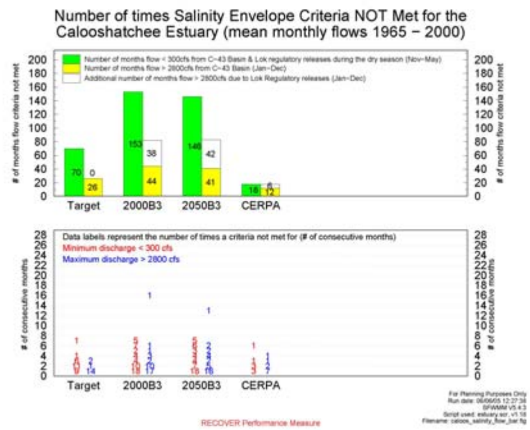
1.2.2 Saint Lucie Estuary

Parameter	2000B3 Conditions	CERP A Outer Bounds	Full Restoration
Number of months flow is less than 350 CFS	130	63	31
Number 14 day moving average LO Regulatory Releases	57	24	0
Number of 14 day moving average > 2000-CFS from local basins	72	36	21
Normalized score	0	.5	1.0

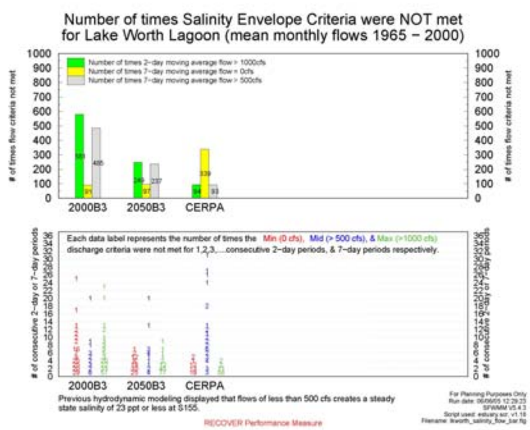
4.3 Model Output

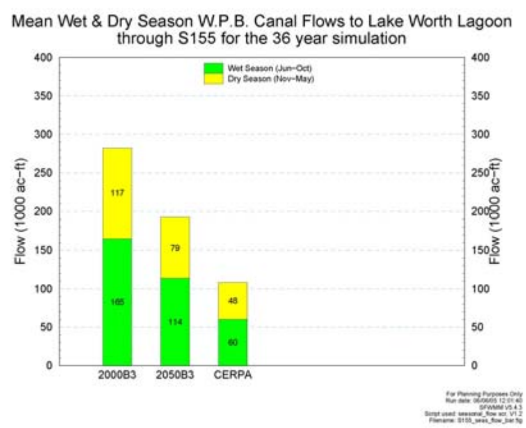
1.2.2 Caloosahatchee Estuary





1.2.2 Lake Worth Lagoon

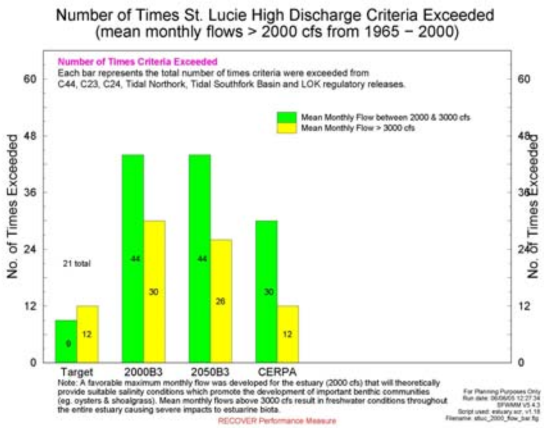


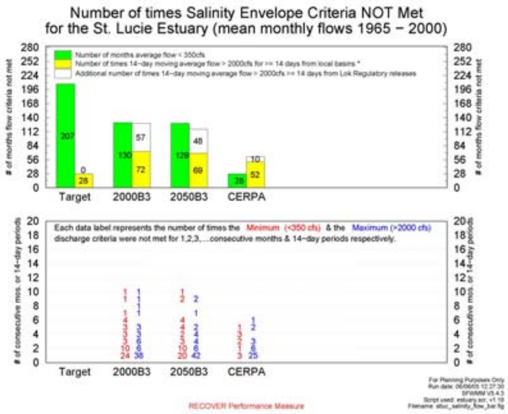


1.2.2 Loxahatchee River Estuary

No example currently available

1.2.2 Saint Lucie Estuary





4.4 Uncertainty

Uncertainty associated with salinity-based estuarine performance measures, targets and evaluation protocols is low. Future modeling within the context of refined end-state targets will better define salinity envelope targets in terms of duration, seasonality, and appropriate salinity levels

5.0 Monitoring and Assessment Approach

5.1 MAP Module and Section

See *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 2004a).

5.2 Assessment Approach

NA

6.0 Future Tool Development Needed to Support Performance Measure

6.1 Evaluation Tools Needed

1.2.2 7.1.1 Caloosahatchee Estuary

SFWMM, CH3D, as well as local and region models like the Mike-She model to quantify the flows reaching S-79 and the downstream tributaries.

1.2.2 7.1.2 Lake Worth Lagoon

None identified at this time.

1.2.2 7.1.3 Loxahatchee River Estuary

None identified at this time.

1.2.2 7.1.4 Saint Lucie Estuary

SFWMM and HSPF models were used, future models would include WASH and RMA 2 and 4.

6.2 Assessment Tools Needed

1.2.2 Caloosahatchee Estuary

Assessment tools include the graphical displays of data, as well as, the results of the Habitat Suitability Index (HSI) models that will determine habitat unit changes for the base conditions and the final selected alternative. HSI model development is being planned for SAV (tape grass and seagrasses), oysters, blue crabs, sea trout, and an assortment of commercially and ecologically important zooplankton groups.

Additional Information Needs and Recommended Assessment Studies:

1. Define and assess appropriate attributes (specific species and/or community values) to ascertain if this project's ecological goals are attained and there is a discernable positive effect on the estuary, specifically including SAV, oyster, and fish as follows:
    a. Routinely (at seasonally important intervals) monitor SAV coverage, density, and canopy height to at least 1.5-2.0 m depth at key species locations.
    b. Routinely monitor (at seasonally important intervals) oyster survival and recruitment at key locations.
    c. Routinely monitor (seasonally) water quality, including temperature, D.O., salinity, nutrients, chlorophyll, suspended solids, blue light at depth, and water clarity along the longitudinal axis of the estuary (S-79 – Sanibel Causeway and into lower Pine Island Sound and Matlacha Pass).
    d. Monitor routinely (at appropriate seasonal intervals) species and biotic groups of concern as separately defined in performance measure documents and the CE conceptual model. At a minimum, insure the Monitoring Assessment Plan (MAP) effort within RECOVER is being fulfilled.
2. Scientifically assess and publicly agree what constitutes desirable natural variability (predevelopment conditions) related to salinity and causal freshwater inflow from S-79 and the tidal basin.
3. Install and monitor flow gages in downstream tidal tributaries to begin assembling a long term data set to: verify model predictions of flows; determine actual amount and timing of tidal tributary flows related to MFL requirements for achieving the salinity criteria; and to help assess flow effects on biota being monitored for CERP (RECOVER).
4. Monitor S-79 discharge adherence to the selected alternative flow distribution.
5. Continue to maintain and monitor existing seven salinity recorders and other permanent sensors in the Caloosahatchee Estuary. Install new sensors to monitor salinity and other water quality parameters of concern at key locations for VEC. Suggest additional sensors be located in western San Carlos Bay, lower Pine Island Sound, and Matlacha Pass.
6. Assess limits of SAV morphology for providing suitable habitat as a VEC and its relationship to flow, salinity, and water quality conditions.

Finish development of the tape grass model; Caloosahatchee Hydrodynamic/Salinity Model; a water quality model component; habitat suitability models; and a seagrass model for the lower estuary.

1.2.2 Lake Worth Lagoon

None as yet identified.

1.2.2 Loxahatchee River Estuary

None as yet identified.

1.2.2 Saint Lucie Estuary

Salinity monitoring needs to continue, RMA 2 and 4 need to be run and the oyster model described in NE-5 needs to be developed and used to fine-tune the salinity envelope.

7.0 Notes

This Performance Measure supersedes and addresses NE-1 St. Lucie Estuary Salinity Envelope (Last Date Revised: September 9, 2005), NE-2 Lake Worth Lagoon Salinity Envelope (Last Date Revised: September 9, 2005), NE-3 Caloosahatchee Estuary Salinity Envelope (Last Date Revised: September 9, 2005), and Loxahatchee River Estuary Salinity Envelope (Last Date Revised: September 21, 2005).

8.0 Working Group Members

Caloosahatchee Estuary	Robert Chamberlain (SFWMD), Peter Doering (SFWMD), Tomma Barnes (SFWMD), Patti Sime (SFWMD), Gretchen Ehlinger (EPJV)
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Loxahatchee River Estuary	Eric Hughes (USEPA), Rick Dent (LRD), Albrey Arrington (LRD), Pat Walker (SFWMD), Gretchen Ehlinger (EPJV)
Saint Lucie Estuary	Ken Konyha (SFWMD), Patti Sime (SFWMD), Dan Haunert (SFWMD), Gretchen Ehlinger (EPJV)

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