Minimum Flow Criteria for the Caloosahatchee River Estuary

Final Peer Review Report

Submitted by

Dr. Edward J. Buskey (Chair)

Dr. James Pinckney, Dr. Jennifer Beseres Pollack, Dr. Winston Lung and Dr. Jian Shen

Executive summary

The South Florida Water Management District (SFWMD) has crafted a well-executed and well-documented set of field and laboratory studies and modeling efforts to reevaluate Minimum Flow Levels (MFL) for the Caloosahatchee River Estuary (CRE). MFL criteria are designed to protect the estuary from significant harm due to insufficient freshwater inflows, and are not guidelines for restoration of estuarine functions to conditions that existed in the past. MFL criteria have three essential components: 1) to establish the magnitude of minimum freshwater inflows to the estuary below which significant harm may occur 2) to determine the duration of high salinity conditions which result in significant harm to an estuarine resource and 3) to determine the return frequency of natural environmental conditions, such as a drought, that may result in significant harm. The MFL criteria effort for the CRE has been largely based on the salinity tolerance of *Vallisneria*, also known as tape grass, a freshwater aquatic plant that tolerates low levels of salinity. Tape grass is also thought to provide essential habitat and food for other estuarine fauna. The analysis of freshwater and salinity requirements for this species are quite complete based on existing data and scientifically sound. These studies have been supplemented by numerical modeling exercises to determine salinity distributions within the CRE under various scenarios, and also with studies of other valued ecosystem components (VEC) in the CRE. These studies on other VECs have been used mainly to supplement information to help set recommendations for the magnitude of inflows, and although the results for the range of inflow magnitudes needed to avoid significant harm vary between studies of different VECs, the varied results broadly support the recommendations for magnitude of flow needed at the S-79 structure, a dam which marks the upper boundary of the CRE. The MFL criteria are recommended to increase the inflow of freshwater to the estuary from the current 300 cubic feet per second (cfs) to a mean monthly flow of 400 cfs at S-79. Current flows during the dry season do not normally meet these criteria, so the increase will not take effect until the West Basin Storage Reservoir is completed (set for 2022). The reservoir

is the centerpiece of the recovery strategy for the CRE MFL, since *Vallisneria* populations have declined and not recovered within a 2 year time period. The recommendation for allowable duration of salinities exceeding the recommended levels has been set so that the daily average salinity at Fort Myers will not be greater than 10 PSU for more than 55 consecutive days. This recommendation is based primarily on *Vallisneria* loss and recovery data when exposed to changes in salinity. The other VEC studies are not as well developed as the *Vallisneria* studies to provide information on duration of the MFL criteria exceedance that would cause significant harm. Given the loss of extensive *Vallisneria* beds, and their failure to recover in recent years due to high salinities in the dry season, it would be prudent to further develop studies of one or more additional VEC species in the CRE in greater detail, especially one that can further support MFL duration requirements, in case the main VEC species does not recover even after the addition of the reservoir system to increase dry season flows. Benthic species are good candidates for VEC indicator species, and the SFWMD might consider the use of *Rangia* clams which are reported to have a requirement for low salinities for recruitment of larvae to their populations, and are found in the upper reaches of the CRE. Additional support for the MFL duration component was derived from analysis of blue crab catch data, which revealed the time needed for blue crab harvest to recover from reductions in average rainfall in dry seasons, and analysis of the periodicity in the time series of hydrologic and blue crab catch data was used to investigate return frequency. The return frequency component is set at one exceedance in a five year period and is primarily based on long term rainfall records which may change over time, so these should be periodically reviewed.

Introduction and overview

The MFL criteria are well defined for the CRE as the "limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area". The SFWMD defines significant harm as a "temporary loss of water resource functions which result from a change in surface or groundwater hydrology, that takes more than two years to recover". Protected water resource functions include "flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation and recreation".

The CRE has been highly modified by humans since the 1880's, with the construction of several water control structures, canals and dredging within the CRE that improved flood control, water supply and storage, and navigation and recreation. The highly modified estuary's primary need for protection now appears to reside in issues of freshwater inflow quantity and quality. Anthropogenic alterations to the estuary reduced the water storage capacity within the watershed and altered the delivery of fresh water to the CRE, but current MFL criteria must work within the limitations of these physical modifications. The CRE experiences a natural shift in rainfall with the seasons, creating a wet season and a dry season (November – April); the MFL criteria normally would take effect mainly during the dry season within the CRE.

The July 2017 report is a re-evaluation of the MFL review from 2000, which raised concern that the previous MFL criteria were too dependent on limited scientific data about a single species, *Vallisneria*. The 2000 review panel recommended application of a hydrodynamic salinity model, a population model for *Vallisneria*, and others. A total of 11 scientific studies were conducted in recent years focusing on the effects of freshwater inflows on hydrodynamics, water column and benthic habitats and other faunal indicators. The criteria used to establish MFL recommendations were based on a combination of the EPA's Valued Ecosystem Component (VEC) approach and the habitat overlap concept of Browder and Moore (1981). The scientific information available for formulation of MFL criteria is much stronger with the addition of several new VEC indicator studies (oysters, benthic communities, blue crab catch, etc.). The inclusion of the habitat overlap concept of Browder and Moore (1981) greatly strengthens the MFL criteria, compared to the previous reliance on a VEC approach based mainly on a single species, and the assumption that this species (*Vallisneria*) also had an important role in providing habitat and food for other species. The dynamic overlap concept is grounded in the understanding that estuaries serve a nursery function for a variety of economically and ecologically important species and that salinity distribution affects the survival and diversity of species using the estuary for this nursery function.

The MFL criteria considers three aspects of the flow in terms of potential significant harm to the estuary: the magnitude of the flow (the volume of freshwater entering the estuary), the duration of time that flows can be below the recommended level before causing significant harm, and the return frequency, or the number of times MFLs can be violated over a number of years before it results in significant harm, recognizing that natural climatic variability will be expected to cause freshwater inflows to fall below recommended levels at some natural frequency. A violation of MFL criteria occurs when MFL falls below the recommended minimum flow magnitude for a longer duration and/or with a greater frequency than specified for a body of water such as the CRE. Magnitude of flow is based on monthly averages at the S-79 structure, which is estimated to account for ~80% of freshwater inflows to the CRE. The MFL is based on current freshwater flows in the CRE rather than historical flows before the extensive man-made alterations of the watershed and estuary. This is the necessary and appropriate approach. The magnitude component is based on the salinity requirements of *Vallisneria*, along with results from the 11 studies modeling salinity and considering the salinity requirements of other VECs. The duration component is based mainly on the estimates of loss rate of *Vallisneria* shoots when salinity rises above 10 and the recovery rate of these shoots when salinities fall back below 10. Return frequency was determined based on long term rainfall records rather than flow measurements from S-79, which is well justified.

The MFL magnitude of flow criteria are recommended to increase from the current 300 cfs to a mean monthly flow of 400 cfs at S-79. An exceedance would occur when mean monthly flow falls below this level, unless the West Basin Storage Reservoir is not operational or the daily average salinity at Fort Meyers has not been > 10 for more than 55 consecutive days (duration). An MFL violation occurs when an exceedance occurs more than once in five years (return frequency). Current flows during the dry season do not meet these criteria, so they will not take effect until the West Basin Storage Reservoir is completed (set for 2022) and has been tested and monitored for 1-2 years. Modeling efforts indicate that once operational, the reservoir will capture enough freshwater during the wet season and this can be released during the dry season to meet the new MFL criteria during most water years.

The cornerstone for the MFL recommendations in the CRE has been to use *Vallisneria*, a freshwater aquatic plant that tolerates oligohaline salinities as a Valued Ecosystem Component (VEC) and sentinel species for freshwater inflows that will serve as an indicator of the cumulative effect of reduced freshwater inflows on the CRE. At the time of the development of the 2001 MFL criteria, *Vallisneria* beds were estimated to occupy ca. 640 acres of the upper estuary. Assuming that this species provides essential habitat for recruitment of estuarine dependent species, *Vallisneria* may also fill the role as a sentinel for the habitat overlap concept of Browder and Moore (1981). An extensive series of field, laboratory/mesocosm and modeling efforts have made significant progress in determining the effects of salinity on the abundance of *Vallisneria*. Salinity may be the most important water quality issue affecting this SAV species, but there are other factors that may also be important, but are less well characterized. Certainly light availability is generally considered as a major factor affecting the distribution of submerged aquatic vegetation (SAV) species. It is suggested that colored dissolved organic matter (CDOM) is the major factor affecting attenuation of light in the CRE, but other factors including chlorophyll (phytoplankton) and other suspended particles also contribute to attenuation of light reaching SAV on the bottom of the estuary. Light attenuation increases with increasing freshwater inflows to the CRE due to added CDOM and nutrients that may stimulate phytoplankton growth. This complicates the role of freshwater inflow on *Vallisneria* abundance. In addition there may be other loss factors such as grazing (herbivory) losses or disease.

One issue with the use of *Vallisneria* as a VEC is that it once was widely distributed in the CRE, but its re-establishment after periods of drought has been limited. It would be very useful to directly demonstrate that *Vallisneria* also serves as essential habitat for estuarine dependent species, or serves other essential ecological functions, but the reduction in the extent of this species in the CRE makes it difficult, if not impossible, to carry out studies within the CRE to quantify this role. This was one of the major issues brought up by the 2000 MFL Scientific Peer Review (Edwards et al., 2000). It was reported that the SFWMD is carrying out a study of

Vallisneria habitat utilization in the Loxahatchee River Estuary as a surrogate for the CRE. However, this may be a moot point if *Vallisneria* does not increase in abundance in the CRE, and may call into question the wisdom of using this species as the centerpiece for MFL determinations, if it is no longer a major habitat type in the CRE. What would be the current criteria for determining that “significant harm” was being done to the CRE based on a decline in *Vallisneria* abundance? What degree of loss would be thought to take more than 2 years to recover? It is unclear how large scale recovery of *Vallisneria* might occur within the CRE: would this recovery be due to regeneration from below ground biomass, or from dormant or transported seeds? Is there information on how long below ground biomass can persist for possible regeneration of plants after the above ground biomass has been lost? Is there any information on the presence of seed banks in the CRE sediments that would allow for re-establishment of *Vallisneria* beds? Is there information on how long seeds can remain viable under conditions of higher salinity? Is germination stimulated by the return of lower salinities? Future research should focus on addressing these questions.

The SFWMD has expanded the number of indicators used to derive MFL criteria that would be more broadly applicable to a wider, more representative range of estuarine fauna and flora. Using a combination of the VEC and the habitat overlap approach of Browder and Moore (1981), the goal is to produce favorable salinity conditions relative to important stationary habitat types such a submerged aquatic vegetation, benthic infauna, etc., and to not truncate salinity distribution in a way that would produce suboptimal salinities for mobile organisms downstream of the S-79 dam, or compress their preferred habitat. It is inherently easier to develop MFL criteria for VEC that are not motile, such as rooted submerged aquatic vegetation, or benthic organisms such as oysters or other molluscan shellfish that need lower salinity water, but cannot easily move in the estuary as salinity zones change. One possible VEC indicator species which has not been considered in the CRE is the brackish water clam *Rangia cuneata*. These clams are of ecological significance because of their role as filter feeders, converting detritus and phytoplankton into biomass that is consumed by higher tropic levels including fish, crustaceans and water fowl (LaSalle & de la Cruz, 1985). Prior research from the southeast US coast and Gulf of Mexico indicates that *Rangia cuneata* has strict salinity requirements for reproduction and recruitment of larval stages into adult populations of ca. 2-10 PSU (Cain, 1973), and that these requirements rather than needs of adult physiology are thought to control the habitable salinity range of this species (Hopkins et al., 1973, Cain 1975). As a result, *Rangia cuneata* has recently become one of the primary indicator species for establishing estuarine inflow regimes for Texas estuaries (e.g. GSMA BBEST, 2011).

Overall, the SFWMD has crafted a well-documented set of field and laboratory studies and modeling efforts to establish MFL levels for the CRE. This effort has been largely based on the salinity tolerance of *Vallisneria*, a freshwater aquatic plant that tolerates low levels of salinity.

The analysis of freshwater and salinity requirements for this species are quite complete and very impressive. This has been supplemented by studies of other valued ecosystem components (VEC) in the CRE, and these appear to have been used mainly to complement information to help set recommendations for the magnitude of inflows. However the recommendations for allowable duration of salinities exceeding the recommended levels and return frequency seem to be based primarily on consideration of *Vallisneria* data. The other VEC studies are not as well developed to provide good information on these parts of the MFL criteria. Given the loss of extensive *Vallisneria* beds, and their failure to re-establish themselves in recent years, it might be prudent to further develop studies of a second VEC species in the CRE in case the main VEC species does not become re-established, even after the addition of the reservoir system to increase dry season flows.

Additional Comments from members of the scientific panel

Dr. James Pinckney

The SFWMD staff were able to adequately and suitably address most of the comments and questions detailed in my written review of the *Technical Document to Support Reevaluation of the Minimum Flow Criteria for the Caloosahatchee River Estuary* draft at the Peer Review session held in Ft. Myers. Overall, the SFWMD provided a convincing, scientifically-based justification for increasing the MFL to 400 cfs for the Caloosahatchee River at the S-79 lock and dam. Although not perfect, with implicit uncertainty common for ecological forecasting, their conclusions are based on the best available data and analysis of those data. In the text below, I detail recommendations for future modeling and monitoring efforts for this project.

The *in vivo* measurements of fluorescence should be frequently calibrated using discrete samples for the measurement of *in vitro* (extracted) measurements of chlorophyll *a* concentrations. Do not rely on single point calibrations for instrument measurements of fluorescence to calculate chlorophyll *a* concentrations. High concentrations of CDOM in the river and estuary could interfere with fluorescence measures. Furthermore, HPLC-based measurements of photopigment concentrations would provide a measure of phytoplankton community composition to complement the simple measures of chlorophyll *a* concentrations.

The spectral quality of light should be incorporated into the *Vallisneria* theoretical and empirical models. The high concentrations of CDOM absorb much of the “photosynthetically useful” wavelengths of light such that total PAR may not be a good measure of light availability. Vertical profiles of *in water* irradiance should be obtained using a submersible spectroradiometer that quantifies the irradiance at different wavelengths. These data could be used to “fine tune” the models for a more accurate assessment of irradiance effects on *Vallisneria* photosynthetic rates.

Additional studies should be conducted to closely monitor any *Vallisneria* transplantation experiments. The possible effects of grazers on the success of these efforts need to be evaluated and quantified. This has major implications for the use of *Vallisneria* as a VEC component as well as future measures of the potential success of the increased MFL for re-establishing *Vallisneria* distributions in the Caloosahatchee River.

There must be closer cooperation and data transfer between Florida DEP and the SFWMD with regard to water quality implications for the increased MFL. Cooperative efforts will lead to a more complete picture of the forecast conditions likely to occur after the 400 MFL is established.

Dr. Jennifer Beseres Pollack

In general, the approach used by SFWMD to reevaluate the MFL for the CRE was scientifically sound and made use of the best available data, monitoring, and modeling.

Other specific comments are below:

Methods

Multiple ecological indicators were evaluated to document effects of freshwater inflow on biota of the CRE, but it is unclear how these bioindicators were selected. The term “bioindicators” describes species, communities or biological processes used to assess environmental quality and variability. However, not all species, communities and biological processes function as successful bioindicators. Bioindicators should be sensitive to certain stressors in the ecosystem (in this case, flow or salinity), and should react to those stressors in a predictable way. For example, a number of papers have demonstrated that benthic organisms are able to serve as indicator species due to their ability to reflect changes in salinity (see Montagna et al. 2013 for review).

In contrast, the bioindicator species and communities within the MFL Technical Document appear to have selected based on available data, rather than due to the characteristics that define bioindicators. For example, within the ichthyoplankton and juvenile fish data set, there are likely certain species that respond more predictably to changes in salinity than other species. One way to assess this is to examine log-normal relationships of different species with salinity and/or flow. Species that demonstrate no trend (e.g. abundance, biomass) do not serve as good indicators, and could be removed from the analyses.

Additional research and monitoring needs

Additional analysis of the available data sets is warranted to better identify suitable bioindicators of flow/salinity within the CRE (rather than calling all biota indicators).

As was discussed, one additional useful VEC in the CRE may be *Rangia cuneata*, which has been shown to demonstrate predictable responses to changes in salinity. A monitoring program to assess abundance and size distribution of these bivalves over time and across different salinity/flow regimes would provide useful information to guide management decisions regarding the MFL.

Additional research is warranted to better understand the response of biological indicators to flow duration and return frequency, as well as to determine tolerances of biological indicators to salinity variability rather than just average salinity.

The panel was unanimous on the fact that water quantity cannot be examined without considering water quality as well. Future research should focus on integrating the existing water quality database from Florida DEP to assess the likely interactive effects of flow/salinity on DO, as well as the effects of temperature. Other variables such as nutrients should also be examined for relationships with flow, particularly during the dry season.

Dr. Winston Lung

The relationship between low flow and salinity response (Component Study 2)

The travel time from S-79 to the Ft. Myers salinity station is not explicitly accounted for in the analysis. While the regression between the average monthly salinity at Ft. Myers and the average monthly inflow at S-79 show correlation, a more precise relationship should include the travel time between these two locations. That is, the salinity at Ft. Myers has a certain time lag of the inflow at S-79 due to the system memory. Note that the estuarine system is not under steady-state conditions at any given time. As such, a time lag resulting from a low inflow at S-79 would take time to show its impact on salinity downstream from S-79. Further, monthly averaged inflows may miss the transient pulses of inflows.

Three-Segment Chlorophyll a *Model (Component Study 3)*

Although this analysis uses a good amount of historical data to support the analysis, a more robust–yet straightforward–analysis is recommended to enhance the results. It would be wise to take more advantage of the CH3D hydrodynamic model results by using the temporally and spatially collapsed mass transport for this analysis. The hydro model provides a significant amount of information to develop a simple 1-D mass transport for this effort. For example, the 3-D hydrodynamic results can be averaged in space to obtain 1-D flows between the three segments. [It is not clear how the mass transport was developed for the 3-segment model from the technical details of the draft report.]

Note the results of 4/12/12 APRS study are associated with very low inflows from S-79, resulting in significant salinity intrusion. The high chlorophyll *a* levels on 4/1/12 are due to the long residence time in the upper estuary under a very low inflow condition.

Another suggestion is to compare the results of the 3-segment model with the APRS data (i.e. from Figures A-18) by assuming each of the 3 segments is completely mixed and the model results of salinity and chlorophyll *a* can be plotted against the three curves of APRS results on that figure.

Data Analysis

As indicated in my original review, additional effort on data analysis is recommended to better document the existing water quality conditions. A simple first step would be to look into the monitoring data gathered at the CES water quality stations for dissolved oxygen (DO), chlorophyll *a*, nutrient components, water temperature, salinity, total suspended solids using the data from the past decade (i.e. 2005 – 2015). For example, it would be informative to see the temporal trends of chlorophyll *a* and DO at CES03. In addition, the spatial profiles of nutrients, chlorophyll *a*, and DO in any given year of this period would be also interesting to see. Much of this effort would play a major role in the analysis of interplay between the model results (eventually) and field data to gain additional physical insights into the system.

Water Quality Modeling of the Caloosahatchee River Estuary

As suggested in the draft document, the development and implementation of a hydrodynamic-water quality modeling framework with greater spatial resolution could greatly benefit quantification of the inflows required to support optimal levels of phytoplankton and other water quality column indicators. The modeling framework used in the Caloosahatchee River TMDL by Florida Department of Environmental Protection (FDEP) is readily available for use in this analysis. The latest TMDL model work by Tetra Tech, Inc. for FDEP is a much-improved effort over the earlier work by Dynamic Solutions a decade ago. Such an effort by the District can be combined with the above data analysis work to produce an excellent interplay of model results and data.

I strongly recommend that the District provide support for its staff to carry out these technical tasks so the MFL development can achieve a much more solid technical base.

Dr. Jian Shen

There are numerous models used in this reevaluation including a watershed model, a three-dimensional model, a SAV model, a water quality model, and empirical models. For those models related directly to salinity simulation are reviewed as follows:

1. Watershed Model (WaSH)

Although the watershed model is not directly used for the 11-component study to derive the MFL directly, the watershed model is a key component in the modeling system for evaluating the recommended MFL. It provides ungauged lateral flows from the tidewater watershed for the hydrodynamic model (CH3D). Considering the unique hydrologic features in Caloosahatchee River Estuary (CRE), such as its high water table, significant infiltration due to gentle elevation gradient, and high soil hydraulic conductivity, the hydrologic processes combine surface runoff, groundwater transport, and interactions of surface and groundwater on the watershed and in the channel and reservoir. The flow routing is improved by implementing the shallow water momentum equation instead of using the steady-state rating curve method of HSPF, which can better simulate time-varying flow in the stream. The ground water module enables the simulation of the movement of ground water. The newly developed WaSH model is one of the advanced watershed models for simulating hydrologic processes in this unique tidal region of the CRE watershed. The model was calibrated from 2008-2010 and verified from 2011-2012 against USGS flow monitoring data. The median correlation (R^2) and model skill (NSE) are 0.71 and 0.7, respectively, for eight calibrated stations. Considering some ungagged flow during the observation and uncertainty associated with rainfall data, the model skill assessment suggested that the model is well-calibrated and it is adequate for application in the MFL study.

The model predictions were compared against daily observations collected by FDEP, SFWMD, and USGS. To improve the rigor of model performance, the comparison of accumulative flow distribution can be performed, which can show if the distribution of flow is well simulated or if there is any deficiency in the flow distribution. It will be valuable to add the mean and standard deviation of the flow at each station in tables for both measured and modeled flows, which will provide good information showing that the variations of flow are being simulated statistically. The model has low skill at the Orange River, which is partially due to ungauged flow at this station. A footnote added to the table will be good to reference this station to others.

During the public meeting, the question of change of lateral flow and trend of runoff in the tidal water region was raised. As the model simulation was conducted from 1967-2012, this long-term result can be analyzed to address the question. It will be good to include the results in Chapter 3.

2. Three-dimensional model

A three-dimensional model has been developed to support this study for CRE. The non-orthogonal Curvilinear Hydrodynamic Three-dimensional Model (CH3D) was applied for estuary for the reevaluation. This model is one of the hydrodynamic models that have often been used for the dynamic simulation for estuaries and coastal seas. The model has the advantage of representing the complex geometry well compared to other curvilinear grid models, such as the Environmental Fluid Dynamic Code (EFDC) and the Regional Ocean Model (ROM). The model is adequate for simulating dynamics and transport processes for CRE. The essential background information for the model is well presented. The model used both hourly and daily continuous tide, current, and salinity data for the model validation. The correlation coefficient (r) between modeled results and observations is larger than 0.84 and the average RMS ranges from 2.25 to 2.95 for daily salinity prediction, which is satisfactory for a 3D model performance. The model results demonstrate that the model has a good predictive skill for both hourly and daily salinity based on model skill assessments for both model calibration and verification. The model application in CRE is published in a peer-reviewed journal. The model is capable of conducting hydrodynamic simulations for the CRE.

The model has been used to investigate how the historical anthropogenic alterations of the system may have affected estuarine ecosystems and their functions, which provide valuable information for understanding how CRE has changed over the years. One interesting finding is that refilling the navigation channel has a profound effect with a five-fold reduction in the dry season salinity distribution, suggesting that the channel deepening is the main cause of the salt intrusion. The study provides the good information for stakeholders to understand the challenges between anthropogenic activities and the preservation of environment integrity and ecological services.

All the analyses conducted to determine MFL were based on historical observations. For an estuary, the time required for salinity adjustment from a high salinity to a low salinity differs depending on the duration of low flow. The total flow needed for the recovery of low salinity is different. For example, a 729-cfs flow in 2009 after a long dry period was needed for this recovery, while the recovery needed less discharge to reduce salinity for other periods. One question is that if the MFL could be maintained all the time, would the salinity meet the established criterion? The application of the CH3D model to evaluate the established MFL with and without freshwater supply from the reservoir provides an answer to the question. The approach is sound. It demonstrates that the effect of implementation of MFL to reduce the salinity level during dry period.

The model simulation of the change of salinity due to a sea-level rise of 5 -20 cm in 20 years ranges from 2-3 psu. The results agree with many published studies for the influence of sea-level rise on salinity changes in other estuaries.

A lack of information in Chapter 3 is the along-estuary salinity distribution. In fact, this model can be used to show the distribution of the along-estuary salinity in conjunction with the use of observations, and demonstrate wet-dry seasonal salinity distribution and stratification, which will provide good information for the justification of using surface salinity to show that an estuary is well-mixed in shallow habitat regions.

Minor editing.
Table A-4, title is incorrect. It is flow, not salinity.

3. Regression model for flow and salinity (component 2)

The key relationship that needs to be addressed is the MFL and salinity at Ft. Myers. One of the goals of the MFL is to ensure that salinity remains below 10 psu at Ft. Myers. The empirical analysis (component 2) shows that there is a high correlation between monthly salinity at the Ft. Myers Station and monthly mean flow from S-79, which can explain 82% of the variance based on data from WY1993-WY2013. The underlying model physics can be explained by the steady state dispersion salinity equation (A.1), assuming a constant salinity boundary condition and a constant dispersion coefficient. As the salinity variation at Ft. Myers also depends on lateral inflow, wind, and salinity at the mouth of the estuary, the large daily, seasonal to inter-annual variation can be expected. Compared to the daily salinity distribution, it appears that the other impact has been largely filtered under the monthly time scale. Although it is steady state analysis, the relationship shows that the empirical model has a good predictive skill for the monthly scale of flow and salinity.

Public Comments

Thoughtful public comments on the meeting presentations and SFWMD documents related to the Reevaluation of the Minimum Flow Criteria for the Caloosahatchee River Estuary were submitted by a number of municipal and citizen groups. Many of the comments expressed concerns that the proposed minimum flow rules would not meet the goal of protecting the ecological functions of the CRE from significant harm. Several comments cite the loss of large stands of *Vallisneria* during the period when the original MFL standards were in place. Concerns were expressed that the new proposal of mean monthly freshwater inflows of 400 cfs at the S-79 structure, and an exceedance requirement of 55 consecutive days of salinity exceeding 10 PSU at Fort Meyers would not allow for re-establishment of *Vallisneria*. This was of special concern because these new requirements will not be in force until the Recovery Strategy is in place, and the construction of the West Basin Storage Reservoir is complete, which is expected to be in 2022. Some concern was also expressed about the possibility of poor quality of water stored in this reservoir that speculated about the possibility of high nutrient loads and the formation of cyanobacterial blooms in the reservoir. It is expected that the recovery strategy will only be employed after several years of testing to ensure the water quality in the reservoir.

Public comments also expressed concern that the magnitude of freshwater inflow was based on the mid-point of requirements for multiple species with different salinity requirements, rather than being set by the most sensitive species for which data is available. Concerns were also expressed over the extensive use of mathematical models to predict the effects of MFL on the CRE, and that more weight should be given to direct monitoring data from the CRE. There is also concern that the rapid population growth and changing land use patterns in the watershed were not adequately addressed in MFL standards.

These are all valid concerns that could be used to argue for increased MFL magnitude and/or shortened duration requirements for MFL exceedance, and if implemented could speed the re-establishment of VECs within the CRE. However, the SFWMD MFL is only designed to set the lower boundary for freshwater inflows to prevent significant harm to the VECs of the CRE. It is not intended to establish restoration criteria, and it must be based on the best available science. Since the recovery strategy has not yet been implemented, and will not be implemented until completion of the new reservoir, it is difficult to predict the outcome of the newly proposed MFL standards. The SFWMD has used the best available science to establish the minimum flow levels to prevent significant harm, and there has been significant investment in a recovery strategy to allow increased freshwater inflows into the CRE during the dry season. It will not be possible to determine the validity of these MFL criteria until the recovery strategy has been fully implemented.

Conclusions

The SFWMD followed the recommendation of their Governing Board to initiate additional monitoring and research to aid in reevaluation of MFL for the CRE. The draft report produced in July 2017 thoroughly considers the results of monitoring, experimental studies and modeling efforts to establish new MFL criteria. The external scientific panel reviewed this document, participated in field trips to view the CRE and the freshwater control structures, and attended a public meeting to discuss our scientific concerns and hear public comments on the MFL plan. It is clear that the prior MFL for the CRE, which was based on the salinity tolerance of a single species (*Vallisneria*), was not sufficient to prevent significant damage to this resource, and a recovery plan was implemented to allow for higher minimum flows at the S-79 structure through the construction of Caloosahatchee River C-43 West Basin Storage Reservoir. The scientific panel provided an initial review of the July 2017 draft report, and the SFWMD staff addressed our submitted questions and concerns at the public meeting in August 2017. This report presents the final conclusions of the review panel, and final comments on the SFWMD MFL draft report. The connections between salinity levels, freshwater inflows and VECs were clearly established for *Vallisneria* with a combination of monitoring in nature, mesocosm experiments and modeling efforts. The loss of *Vallisneria* areal extent in the CRE over the past decades has made primary reliance on this VEC to determine MFL less useful. The component studies of other VECs were generally not as comprehensive or complete, but added strength to the overall validity of the MFL recommendations for the necessary magnitude of freshwater inflows. In particular the clear delineation of salinity zones among the macrobenthos infauna, and the analysis of catch data for blue crabs provided strong support for the VEC and habitat overlap approach used to determine MFL criteria. The review panel recommends that the SFWMD continue to develop studies of these and other VEC to provide additional information for determining the magnitude of freshwater inflow needed to avoid significant damage to the CRE ecosystem. It is also important to develop additional VECs to support their determination of the duration of exceedance of the MFL salinity of 10 PSU at Fort Meyers that does not lead to significant damage to the CRE estuary. We also recommend that water quality characteristics (water clarity, nutrient concentrations, oxygen concentrations) be incorporated into future determinations of MFL criteria for the CRE.

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