

22J – HYDROLOGY, HYDRAULICS, AND ENVIRONMENTAL MODELING STUDIES

This account describes the modeling and investigative efforts to formulate, evaluate and optimize feasible plan alternatives. The modeling tasks will involve 1) collecting existing and limited new hydrologic and hydraulic data, 2) selection and/or enhancement/development of appropriate hydrologic and hydraulic models, and 3) modeling of existing conditions, future without project conditions, and ecosystem restoration alternatives. Integral to analysis of alternatives will be the application of the SJRWMD's Pollutant Load Reduction (PLR) Model (which is an integration of CH3D hydrodynamic, water quality, and submarine light field models) with a submersed aquatic vegetation (SAV) model to evaluate the potential seagrass response of the Lagoon to any one or a combination of alternatives. These efforts are discussed in the following paragraphs.

Lagoon Hydrodynamic Models

Large-scale (medium resolution) analysis of circulation and salinity changes resulting from potential alternatives will be performed with the PLR Model (specifically its CH3D model component). This large-scale circulation and salinity analysis will be provided by the SJRWMD. For example, complete or partial removal of bridge causeways can be analyzed to determine whether one or some of the many causeways that span the Lagoon could be breached/modified as an effective means to improve Lagoon flushing, water quality, and the potential for seagrass expansion (see sections below that describe the water quality and seagrass model components).

As necessary, fine-scale (high-resolution) circulation and salinity modeling will be needed to analyze specific construction alternatives such as culverting or adding bridge spans within causeway bridges. Examples of high-resolution models that could be applied for detailed analysis are the hydrodynamic models RMA2 or ADCIRC. These same models could be employed to perform detailed analyses of other proposed modifications, for example, at the inlets, Atlantic Intracoastal Waterway, spoil islands and shoals.

Another important application of models is the assessment of proposed reductions to discharges and concomitant pollutant loadings from major tributaries or canals on the Lagoon's circulation and water quality. Again, the large-scale PLR model would be utilized to assess the environmental impacts of such reductions, while fine-scale models may be utilized to evaluate structural alternatives. Also, analytical techniques may be undertaken to assess the efficiency and risks associated with different treatment and/or BMP design alternatives. The focus areas for these watershed projects are the major drainages including water control districts in southern Brevard County and in Indian River County (Indian River Farms, Vero Lakes, Sebastian River, Fellsmere, and eastern 1/3 Melbourne-Tillman), as well as C-54 and the major natural tributaries: St. Sebastian River, Turkey Creek, Crane Creek, and the Eau Gallie River.

An assessment of available field data will be undertaken to determine the need for the acquisition of new field data for calibration of the fine-resolution models. Also, it may be necessary to feed the results of the fine-resolution models into the PLR Model to verify or refine earlier assessments of water quality/clarity and seagrass. The means by which the output of the fine-resolution model is processed as input to the PLR Model for additional assessment work will also need to be developed by the SJRWMD and USACE.

It is assumed that no extensive additional numerical modeling would be necessary for potential muck removal alternatives. The quantity and location of muck to be removed will be determined by existing or limited new bathymetry and/or core borings.

Watershed Models – Evaluation of Hydrologic Impacts

As mentioned above, additional efforts to develop watershed models using a tested model (e.g., HSPF, MIKESHE, HEC-HMS/HEC-RAS, or FEMWATER 123) will be required to evaluate potential positive and negative impacts of alternative plans (e.g., proposed discharge regulation schedules for canals, modification of canal structures, canal bank stabilization and erosion controls, in-canal sediment retention designs). For example, a range of C-54 discharge reductions can be modeled to examine whether there would be significant seagrass or water quality impacts to the IRL-N study area, and to ensure, through coordination with SJRWMD, impacts that may occur in the Upper St. Johns River Basin (USJRB) do not violate the authorized flood control project (e.g., flood elevation and duration frequencies). Both watershed and finite-element/fine-mesh models will need to be calibrated and be able to interface with each other and the PLR Model, at least via common intermediate file formats.

Watershed modeling efforts will concentrate primarily on the Water Control Districts (WCDs) and other sub-basins that have available public lands or where there is a good potential for land acquisition. These areas include the Fellsmere Water Control District and the Sottile Canal/North Prong of Sebastian River. Evaluations of watershed alternatives would be focused on public land holdings and on the use of reservoir, STA and /or a variety of BMPs. The prospect of utilizing existing or proposed project features in the Upper St. Johns River Basin for additional water storage and treatment may also be investigated.

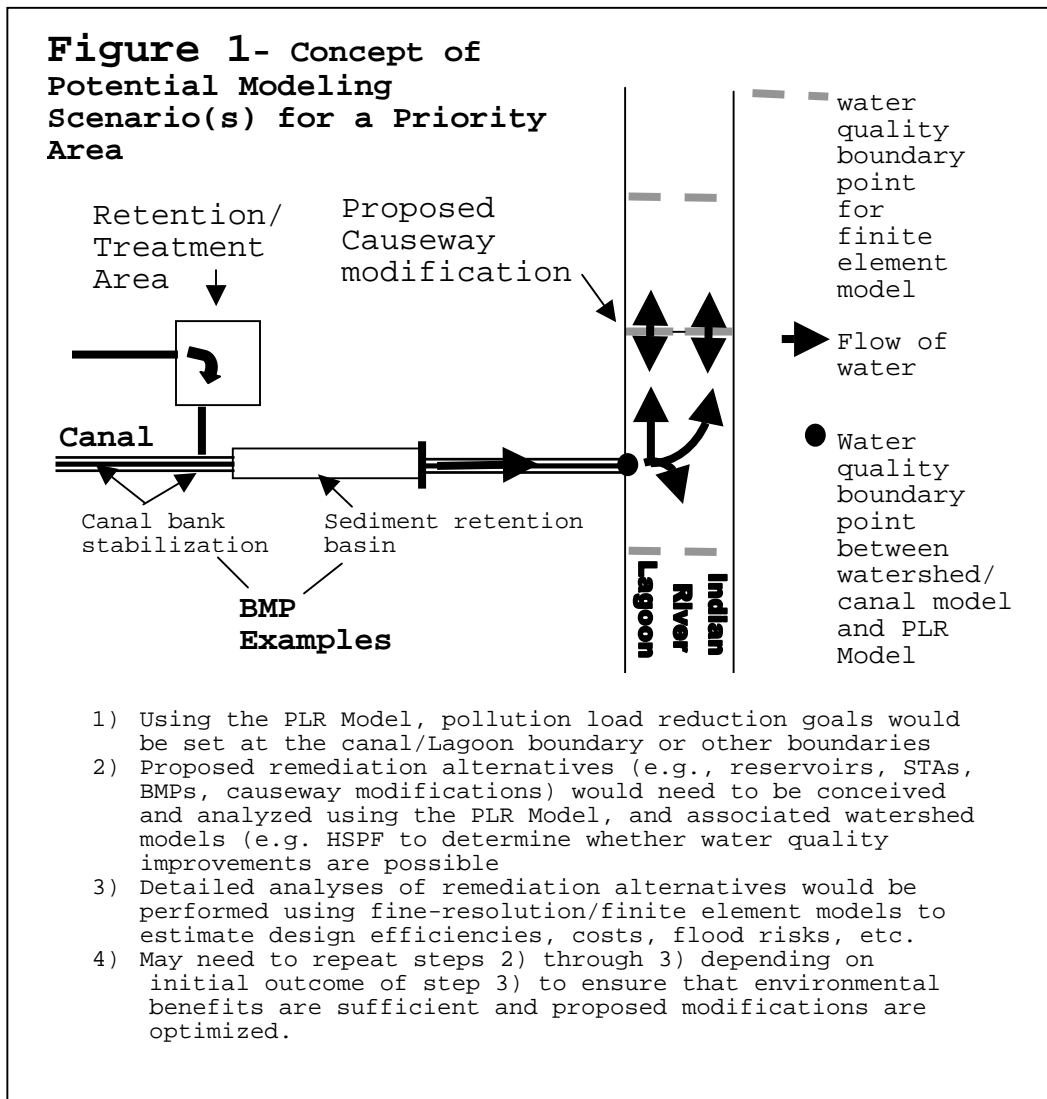
Evaluations within the remaining WCDs (Sebastian River WCD, Vero Lakes WCD, Indian River Farms WCD and Melbourne-Tillman WCD) would be largely limited to a wide range of potentially feasible BMPs. Teams of USACE, SJRWMD, WCD and county/city representatives should be established in the initial study phase to begin inventorying and collecting the necessary information/data in order to identify a range of specific BMP alternatives for a particular WCD or sub-basin.

The SJRWMD is developing annual loading models for all of the IRL watersheds, both gauged and un-gauged (using HSPF and the SJRWMD's Pollutant Load Screening model). The models provide annual mean discharges and total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) values for each basin based on State of Florida NURP parameters. These values can be disaggregated to smaller time steps for use as boundary conditions for the PLR model wherever event-oriented models, such as HSPF, are not available.

Over the next two years, the SJRWMD will implement a set of hydrologic HSPF-based watershed models covering the entire watershed of the IRL. This work effort shall be completed in time to provide a complete set of daily discharges and monthly loadings from all watersheds, and the data and related information will be made available to the IRL-N Feasibility Study as they are completed. The data and related information shall include GIS land-use and soil-type coverages, rainfall time series, discharge and loading time series, and completed sub-basin models. The discharge and loading time series from the HSPF models will be used to size the upland water storage and treatment areas that will be critical in reducing freshwater discharges to the Lagoon. However, the HSPF models are not sufficient for designing the detailed hydraulic structural features such as canals, pumps and weirs necessary to convey, distribute and discharge water associated with the water storage and treatment areas. Specific hydraulic modeling conducted by the USACE will be required for design of these appurtenances. Likewise the HSPF model is not appropriate for designing or evaluating most types of BMPs. An analytical and literature search approach to BMP evaluation is likely. Detailed analysis utilizing some hydraulic models is required for evaluating certain BMP options, particularly in-canal alternatives that could potentially impact flood control, such as in-line reservoirs, vegetated littoral zones, canal sediment basins and discharge modifications to water control structures.

Detailed assessments of BMPs, based initially on SJRWMD HSPF modeling, will be conducted by the USACE. The detailed evaluations will use information provided by SJRWMD and/or the WCD's but may also require additional, detailed measurements of stream cross-sections, locations and geotechnical data on any available land for in-canal settling basins (easements, rights-of-way, etc.), selection of design storms, and analyses of potential flooding risk. When obvious that a BMP will not adversely affect flood control, the efficiency of the BMP in reducing sediment or nutrient loadings will be established through literature search and/or published load reduction data for similar BMP's. The recommendations from BMP studies on specific canals or tributaries will include modified daily discharges and monthly loadings for the PLR model, which in turn will be applied to evaluate changes in impact to the Lagoon. As explained later, other than the Lagoon PLR model, no additional rigorous water quality modeling is anticipated for BMP assessments.

An example of how various hydrologic and hydraulic models along with the PLR models may be applied in iterative fashion to evaluate watershed BMP options and additional restoration scenarios (e.g., causeway removal) is shown in Figure 1.



Water Quality Models (as part of the PLR Model and Selected Watershed Models)

Important aspects of water quality modeling include salinity, nutrients, dissolved oxygen (DO), light fields, and major biological components (phytoplankton, macroalgae and seagrass biomass). It is expected that the PLR Model will be used to predict environmental impacts such as water quality changes caused by potential modifications to features within the Lagoon proper, to upland areas, and/or to watershed inflows. It is assumed that no other rigorous water quality modeling development and/or application, beyond the PLR Model assessments, will be required to evaluate BMPs in the interior portions of the watershed,

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including all feeder canals.

There are two important considerations with respect to Lagoon modeling. First, it is important to quantify the effects of changing fresh water flows and concomitant change in pollutant loading on both the phytoplankton and seagrass condition of the Lagoon. This evaluation is needed because hydrologic restoration could stimulate algal blooms, which could eventually be detrimental to seagrass health and growth. Second, the effects of changing salinity on seagrass health and growth should also be examined. Accurately predicting the response of the seagrass coverage to any change in surface water discharge and pollutant loading is thus essential.

The SJRWMD has a significant modeling effort already underway to develop seagrass-based Pollutant Load Reduction Goals (PLRGs) for the IRL-N study area. This modeling effort will analyze the long-term interaction of critical processes (salinity, nutrients, turbidity and light extinction, etc) that can impact seagrass growth. PLRGs and their associated water quality targets will be tested using the PLR Model based on varying the pollutant input to the model until the model output indicates a good probability that water quality conditions would be restored to help enable seagrass acreages to expand to pre-determined coverage targets.

The calibrated PLR Model (i.e., the integrated CH3D hydrodynamics, water quality, and light or optical model) covers the area from Ponce de Leon Inlet to St. Lucie Inlet, well within but also beyond the IRL-N Study area. The PLR Model consists of approximately 440 by 40 cells and six layers. Fifteen major watersheds contribute freshwater discharges and pollutant loadings to the IRL-N study area. Currently the IRL-N Study area is divided into eight segments for assessment of PLRGs. A preliminary assessment of flushing characteristics of the eight segments was conducted and reported by the University of Florida. Additionally, the PLR Model should be able to predict water level and flow, salinity, nutrients in the water and sediment columns, DO, phytoplankton, color, wave-induced re-suspension of sediments, approximately 20 water quality components, and light attenuation. This model has been calibrated by U.F. with data collected in 1997 and 1998. These data include water level; salinity; wind; barometric pressure at hourly intervals; evaporation; daily mean tributary discharge; monthly water quality and optical parameters; and four, event-oriented, water quality sampling periods at five different fixed station locations.

The PLR Model has a connection to an ArcInfo GIS application for the purpose of setting input data sets and visualizing output from the model. A bathymetric survey was contracted for the IRL in 1995. The survey was completed, the data are stored in the SJRWMD GIS database, and a contour map of depths was produced. These data were used to complete the model grid.

The PLR model and a separate model for submersed aquatic vegetation (SAV: seagrass, macroalgae) will be delivered by SJRWMD contractors in June 2002. After

delivery, SJRWMD staff will install and test the models, to verify the PLR model with data collected from 1999 through 2001, and to conduct sensitivity studies. One sensitivity study deals with groundwater. Provided sensitivity tests determine that groundwater inputs are significant, SJRWMD may develop a groundwater flow and transport model for the lagoon. This model could provide a spatially-variable annual mean seepage inflow to the lagoon for direct input to the PLR model. All of these test and verification steps will require about a year of effort (well into 2003) before beginning the PLRG development process.

Discharges and loadings to the IRL are being quantified by means of a GIS-based set of watershed models. Event-oriented hydrologic models (HSPF) of Sebastian River and Turkey Creek basins have been completed and can provide a basis for extrapolation of model parameters to the ungauged watersheds. Annual loadings of TN, TP, and TSS have been estimated for both gauged and ungauged basins using the District's PLSM (Pollution Load Screening Model), based on land use, soil types, NURP loading parameters, and annual mean rainfall. In FY 2002 these estimates will be refined to daily discharges and monthly loading estimates using the GIS-based watershed model and the period-of-record precipitation for the IRL. In addition, an attempt will be made by SJRWMD to predict monthly changes in the nutrient and optical constituent variables in estimated discharges from the ungauged watersheds. This project is planned for completion in July 2003.

Since the PLR Model was designed for multi-year predictions of changes in water quality and light attenuation, it has a relatively coarse grid that is not suitable for detailed assessments of circulation. If a more detailed circulation model of sub-regions of the lagoon is required, the PLR Model could provide boundary condition data as input to the USACE's fine-resolution models.

Submersed Aquatic Vegetation (SAV) Model

The PLR Model for the Lagoon, being developed by SJRWMD, will have hydrodynamic, salinity, water quality, light, and biological model components. The main biological component of interest is submersed aquatic vegetation (SAV), primarily seagrass, but it also includes macroalgae and epiphytic algae on seagrass blades. A SAV model is being developed by SJRWMD separately from the PLR Model, yet the intention is to investigate whether direct integration of the SAV model with the PLR Model will be useful. This decision depends on whether enough data are available to justify any feedback from SAV to the water quality (nutrients) component of the PLR Model. Alternatively, and probably more likely, the SAV model can be run independently from PLR Model, but based on the PLR Model output, in order to generate a predicted seagrass growth response.

The SAV model is focused primarily on interactions of the seagrass or macroalgae growth with light, salinity, temperature, and nutrients. This model will include the impact of various levels of these parameters, as predicted by the PLR Model, on SAV primary productivity, respiration, net growth, and biomass. To date, only rough predictions can be

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made of the potential distribution of seagrass, based primarily on light availability, which is the primary limiting factor. The dynamic nature of the large biomass of drift algae in the Lagoon (greater than seagrass biomass) will be measured and incorporated.

SJRWMD's work to develop an SAV model for Lagoon restoration is ongoing. For this IRL-N Feasibility Study a need is not anticipated to develop or utilize complex models that would integrate seagrass dynamics within a dynamic physical and water quality model. A more detailed approach will be worked on in the future, but may not be possible within the timeframe of this Study.

Selection, Development and Application of Appropriate Models

There are specific steps involved with the selection, development and use of models for the IRL-N Feasibility Study. These steps are generally described below.

1. *Identify Performance Measures and Requirements.* Performance measures may include items such as period of record; time step of outputs; compatibility with other models; capability to model certain processes and features; sensitivity to restoration alternatives; and the capability to meet required physical, chemical, and biological criteria and responses.
2. *Establish a Model Evaluation Group.* A standing peer review committee that is composed of recognized expert modelers who are independent of the Study, the USACE, the SJRWMD, and east central Florida interests will be established by this Study. The MEG will review the progress of the Study's modeling at least twice per year and advise Study managers, the PDT, and contractors regarding the technical aspects of the modeling process, including calibration and verification.
3. *Select Models.* This will involve the review and selection of the most suitable models based on performance measures. Models will be evaluated based on empirical relationships, spatial definition, run times, platform availability and linkage to other models. Several available model codes will be evaluated for use. The MEG, as well as the PDT, will evaluate model capabilities, and the model deemed most appropriate to satisfy identified performance measures will be selected for continued development.
4. *Develop Standard Data Sets.* This will involve the development of a large, standard information base adequate for the calibration and verification of models. These data sets are expected to include watershed, hydrodynamic, water quality, and macrophyte data from the Study area. Model-to-model interface capabilities must also be considered.
5. *Develop Boundary Conditions.* Appropriate boundary conditions required for the selected models will be developed.
6. *Calibrate/Validate Models.* Models will be calibrated and validated using appropriate data so that accuracy may be assessed for the range of model

- capabilities.
7. *Develop and Assess Scenarios.* The models will be run to evaluate how selected restoration scenarios or BMP alternatives influence the Lagoon. The alternative assessment typically may include up to five simple scenario assessments.
 8. *Report Results.* The methodology, its validation, and scenario assessment will be documented.

Hydraulic Design

The hydraulic analysis will include site-specific hydraulic modeling and design. The hydraulic designs will be of sufficient detail such that further engineering design, including structural and mechanical/electrical design, and cost estimation may be performed. Additional hydraulic data may be collected, feature designs will be optimized using computer models and/or empirical methods, and CADD plates illustrating project features will be developed. Hydraulic design efforts must be comprehensive such that engineering design and cost estimation may be performed. Coordination with other engineering disciplines will be necessary since hydraulic design parameters for the selected plan features will be used in all of the engineering design efforts. Structural and mechanical/electrical plates will be developed from hydraulic data sheets, performance rating curves and tables, and pertinent geotechnical information. The engineering design effort will consider utilities relocation, borrow and disposal sites, and construction scheduling. Finally, engineering design data will be used to develop MCACES cost estimates for the construction of selected plan features.

Review Hydrologic Data

This task includes the review of all data from the hydrologic modeling effort. Hydrologic model inputs for each of the alternative technologies will be reviewed to obtain local groundwater elevations, start-stop criteria for pump stations, and headwater or tailwater elevations for other structures. These data will be used in the hydraulic analysis.

Collect Additional Hydraulic Design Data

Additional data may be necessary to complete the hydraulic analysis and design. These data may include, but are not limited to, historic water stage and flow data, survey elevations, geotechnical information such as seepage rates and slope stabilities, and as-built drawings from existing structures.

Perform Hydraulic Analysis

This task uses the data that was developed during hydrologic modeling plus any

additional data that was collected to analyze the hydraulic properties of the alternative and selected plan features. The analyses may be performed using empirical methods or computer models such as HEC-RAS.

Develop Hydraulic Design

Design features of hydraulic structures include canal/culvert cross-sectional areas and lengths, water control features such as gates or stoplog risers, invert/crest elevations, erosion armoring, pump sizes and mixes, etc. These features are optimized to meet hydraulic requirements and minimize cost.

The USACE Hydraulic Engineer will coordinate with Design Branch to complete the designs. Structural engineers will use the hydraulic design parameters to develop engineering drawings and construction methods. They will address such concerns as foundation and loading conditions, material quantities and borrow/disposal areas, utilities relocations, site access, and vehicular traffic control. Mechanical and electrical engineers will design features such as pumps, water control gates, and telemetry. The design efforts will lead to a scope of work for the recommended plan. The scope of work can be used to estimate budget and schedule requirements to construct the plan features, to advertise the Request for Proposals, and to contract Architectural and Engineering firms to perform the work.