A Review of the Documentation for the South Florida Water Management Model (SFWMM)

Submitted to the

Hydrologic Systems Modeling Division, Planning Department

South Florida Water Management District
3301 Gun Club Road
West Palm Beach Florida 33416-4680

By

Daniel P. Loucks, Cornell University (Chair)
Wendy D. Graham, University of Florida
Conrad D. Heatwole, Virginia Tech.
John W. Labadie, Colorado State University
Richard C. Peralta, Utah State University

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Introduction

Early in February 1998, the South Florida Water Management District asked Professors Wendy D. Graham, Conrad D. Heatwole, John W. Labadie, Daniel P. Loucks, and Richard C. Peralta to serve on a panel to

- Review the Draft Documentation for the South Florida Water Management Model (SFWMM),
- Develop a series of questions, issues and areas for discussion during a site visit,
- Visit the District for a model familiarization session, and
- Prepare and submit a written evaluation of the model, with emphasis on the documentation that will include criticisms, specific recommendations for improvement, and responses to questions posed.

This report summarizes our evaluation of the Draft Documentation for the South Florida Water Management Model dated September 1997. Our comments are based on the contents of this Draft document, and on the discussions that took place during our meeting at the District during 26 - 27 February 1998. We have not observed the operation of the South Florida Water Management Model (SFWMM) itself, nor have we examined the code of that model. We are assuming the documentation accurately reflects the model as presently implemented. As requested of us, our comments are mainly focused on the model documentation rather than the model itself. The Appendix of this report contains the list of questions and responses prepared prior to the site visit.

Our report is divided into four sections based on the following questions, as specified in our scope of work:

- **Clarity and appropriateness of model documentation**. Are the objectives of the documentation clear? Are the objectives met? Is it readable? Are the figures clear? Are additional levels of detail required to serve the intended objectives? Can planners and decision-makers, after reading the documentation, better understand the purpose, scope, strengths and limitations of the model? Does the scope, structure, or format of the documentation need to be modified or expanded?

- **Hydrological Processes**. Does the SFWMM include all the important hydrological processes necessary in a computer model to be used in regional-scale water resources planning for an area such as South Florida? Based on the documentation and material presented in the site visit, are the modeling techniques and methodologies used in the SFWMM appropriate for the temporal and spatial scale of the model?

- **Model calibration and validation or verification processes.** Is the model calibration process adequate for a predictive model in water resources management? Based on available tools, procedures and data, is the model validation/verification procedure conducted in an appropriate manner?

- **Overall appropriateness of model** comparable to others outside South Florida. Is the level of sophistication of the SFWMM comparable to other modeling efforts outside South Florida directed towards addressing similar complex, regional-scale, water-related issues? Given the current state of the model (scale, sophistication of algorithms and degree of calibration), can it be considered an adequate tool for such an application?

This report contains five sections and an Appendix. The first four sections present our responses to the four items listed above. The fifth section of this report contains a list of comments and questions pertaining to specific chapters of the Draft Documentation. These comments and questions together with those contained in the Appendix, identify particular opportunities we believe could improve the clarity, consistency, and content of the model documentation. The Appendix contains the list of questions we prepared before our site visit, at the request of the District, and the District's written responses to those questions.

We wish to state clearly at the beginning of our report that we recognize our assigned task to review the Draft Document and to suggest ways that it might be improved is much easier than the writing of the Document itself. We also recognize that any effort devoted to implementing our suggestions involves real opportunity costs and trade-offs. There are other ways the District scientists and engineers can spend their time and money. We believe in the value of clear and complete documentation of models, especially those as complex as the SFWMM. We also believe the existing Draft Documentation can be improved. However, we are not in a position to determine the value to the District of any effort devoted toward that goal. Readers of this report should interpret our suggestions as just that. Only the District can determine whether or not it is worth spending additional resources on SFWMM documentation.

We commend the District's commitment to provide satisfactory documentation of the South Florida Water Management Model. We know of no one who likes to write documentation, and only a few who enjoy reading it, but any serious user of a model as complex and comprehensive as the SFWMM will need such documentation to understand the many assumptions upon which the model and its outputs are based. We also acknowledge the difficulties in committing adequate time and resources to keeping current the documentation of any model that is periodically being changed and updated. As significant changes are made to the model, and/or as the purposes of the model and its documentation change (i.e., as the intended audience changes), we recommend periodic in-house and possibly external reviews of the revised documentation.

We also commend the District for providing us a site visit as part of our review process. This visit helped us clarify a number of issues and questions, better understand the context and scope of model applications, and more fully appreciate (through the helicopter tour) the characteristics of the physical system being modeled.

We who have participated in this review want to acknowledge and thank Jayantha Obeysekera, Lehar M. Brion, and their colleagues in the Hydrologic Systems Modeling Division, Planning Department, South Florida Water Management District with whom we have had contact during this review period. Without their timely, complete and expert assistance, our work would have been much more difficult. We all continue to benefit from our occasional association with the District's scientists and engineers. We also acknowledge the exceptionally high quality of the work they perform in a unique and complex hydrologic and water management environment.

Clarity and Appropriateness of Model Documentation

We understand that the primary objective of the model's current documentation is to inform potential model users of the purposes and intended use of the model, the spatial and temporal resolutions of the model, and the hydrologic processes and operating policies or rules that are incorporated within the model. It is not, we believe, intended to assist model programmers or model operators. Based on this assumption, we believe the current version of the documentation does not meet this objective as well as it could. The clarity and detail in various sections of the documentation are uneven, the notation and style are not consistent, and some parts are more oriented to, but insufficient for, the needs of model programmers or model operators. We recommend that if a revised version of the documentation is to be prepared, it be done so as to reduce if not remove these inconsistencies.

The document should be consistent in the use of terms, mathematical equation format and notation, and units, e.g., avoid the use of [L] type units some places (p.35) and actual units [ft] elsewhere (p.45). Tables and figures should be able to stand alone, captions should be descriptive, and headings and labels should be meaningful.

The document should describe a single model version. We recommend that the document reference the latest model version. Where specific studies done in the past were done on earlier versions, (e.g. sensitivity analysis), identify the version, and briefly identify any differences that should be noted in considering the results. (It may be useful to add as an appendix a description of differences among the versions discussed in the documentation.)

In the beginning of the documentation it would be beneficial to include a more complete description of the model such as how the canals, structures, wells are represented within the grid cell discretization structure of the model.

We believe the preparation and insertion of a Model Objectives and Uses section immediately following, or as part of, the Introduction could improve the documentation. This new section of the documentation should be based on a clear

picture of the intended audience. It should indicate variables and areas of reasonable accuracy and of less than desired accuracy. This may reduce the likelihood of the model being used to evaluate performance measures for which it is unsuited.

This Model Objectives and Uses section of the documentation could begin with a more complete discussion of model objectives, uses, advantages and limitations. From discussions at SFWMD, we believe the model has been and will continue to be used to:

1) help the COE and SFWMD develop regulation schedules (rule curves),
2) predict the consequences of future system structural changes, and the attendant water management performance measures.

In this Model Objectives and Uses section examples of issues and questions the SFWMM is and is not capable of addressing should be discussed. This could include a more rigorous definition of "regional-scale" information related to the spatial and time-variations of climatic events and the range of operational strategies the water management and control structures the model is capable of simulating and evaluating. (For example questions such as "how 'big' does a structure have to be before the SFWMM can model its impacts", and "how 'major' does a change in operational strategy have to be before the model can distinguish its effects?" need to be addressed in this section.) In the past the model has been used to predict changes in regional hydrology associated with changing the canal operational levels by tenths of a foot. Is the model capable of accurately distinguishing between these types of subtle operational changes?

Some additional suggestions that we believe warrant consideration in any revision of the documentation include:

- The mathematical or logical concepts described in the section on General Characteristics of Supply Side Management seem to us to be expressed in a relatively cumbersome style compared to that of most other sections.
- In some sections, flow charts were included in order to aid in understanding of the logical processes, whereas for other sections (e.g., the discussion of the Lake Management Algorithm), flow charts and diagrams were not provided. More flowcharts with steps numbered and keyed to the text would help significantly.
- The judicious use of attached appendices can greatly enhance the readability of the documentation and understanding of the SFWMM. The format of the documentation could possibly be improved by placing some of the highly detailed material in attached appendices, such as:

  (1) the section on Governing Equations under Section 2.3 Overland Flow, which is highly tutorial in nature;
  (2) some of the details in the Section on Groundwater Flow (pg. 39) which provide mathematical details on the finite difference scheme used in the groundwater modeling;
  (3) details of the Modified Delta Storage Method (pg. 55);
  (4) details of the Lake Management Algorithm on pg. 62–a more descriptive flow chart could be included in the body of the report;

(5) some of the highly detailed material in the Section on WCA Structures for Regulatory and Water Supply Discharges (pg. 114);
(6) Part 3: Model Specifications should be placed in a separate User's Manual–only those actually running the model would be interested in this material;
(7) some of the detailed material in the sections on Sensitivity Analysis and Uncertainty Analysis, although interesting, should likely be placed in the appendices–the body of the report should include general information as to what these results mean and how they serve to further validate the model.

- A more rigorous defense of the level of sophistication chosen to model each process (and for choosing different levels of sophistication to model the same process in different regions) would strengthen the documentation.
- Some appropriate figures and tables could highlight were the model does well, and where it does not so well. These figures should show which performance measures the model can reasonably simulate and which it cannot address at this time.
- The order in which equations are implemented and variable values are computed needs to be clarified.

Hydrological Processes

We believe all the significant processes that describe the hydrology of the South Florida region, on a regional scale, have, in general, been properly and adequately included in the regional SFWMM. We recognize the uniqueness and complexity of the hydrologic processes that characterize South Florida. The methodologies used to model these hydrologic processes range from the quite empirical (i.e. the treatment of the unsaturated zone in the natural areas and canal routing outside the EAA) to the more physically based (i.e. treatment of overland flow and groundwater flow). Decisions regarding the level of sophistication required for modeling different hydrologic processes seem to have been made for practical (i.e. computational efficiency) reasons based on the modelers' collective intuition and hydrologic experience in the region. A more rigorous defense of the level of sophistication chosen to model each process (and for choosing different levels of sophistication to model the same process in different regions) would strengthen the documentation. For example, does the vadose zone need to be modeled in the non-irrigated areas?

Section 2 (Physical and Hydrologic Components) of the current documentation could be revised to deal with each hydrologic process more completely and consistently within its own subsection. A potential for confusion arises when the same physical hydrologic process (particularly evapotranspiration, and canal flow) is modeled differently and described using different terminology in different parts of the documentation. It would also be helpful to have a summary describing the processes that are modeled in each of the region's areas and canals, and to combine and/or avoid duplicate description of the ET components, specifically the EAA component (see Tables 2.2.3 and 3.3.1).

Additional sensitivity analysis may be warranted on the spatial interpolation of rainfall data. The model employs a Thiessen polygon or "nearest neighbor" approach to assigning rainfall data to each cell. This approach may result in errors for a 2 mi x 2 mi gridded system. For example, discontinuities in rainfall assignments can occur when an ungaged cell is assigned, say, zero rainfall to coincide with readings at the nearest gaging station, while another station slightly farther away may be recording significant amounts of rainfall. This "all or nothing" approach results in zero rainfall being interpolated over a large 4 square mile area. Although it may be true that the stochastic nature of daily rainfall in South Florida cannot be resolved, that does not prevent the use of alternative and perhaps more realistic spatial interpolation methods for assigning rainfall estimates to ungaged cells. This is of critical importance since rainfall input is the principal driving force in the South Florida system.

Additional attention may also be directed to the overland flow and canal routing algorithms. The diffusive wave method for overland flow routing appears to perform well. We understand the friction slope is assumed to equal the water surface slope making it possible to simulate backwater effects. The overland flow routine cannot simulate inertia dominated dynamic waves. We know the District has studied the impact of this. The results of these and other comparative studies oriented toward identifying the possible errors introduced by simplifying assumptions for flow routing could be included in the documentation. We fully expect these results justify the simplifying assumptions used.

Some additional discussion of the verification of operational rules contained in the model might be helpful. There are a number of operating rules and management policies included in the model. These rules include Lake Okeechobee release policies, canal stage triggers, nodal triggers, shortage rules, irrigation allocation schedules, etc. It is currently difficult to extract this information from the documentation since these rules are embedded in detailed discussions of the model structure. In addition, it is also difficult to distinguish between those which are "hard coded" in the model and those which can be adjusted through input data tables, etc.

Model Calibration and Validation or Verification Processes

We judge the model calibration process entirely adequate for a predictive model oriented toward water resources management. Based on available tools, procedures and data, the model validation/verification procedure has been conducted in an appropriate manner. These conclusions have been reached based more on what we heard during our discussions with the District, than on the information contained in the Draft Document.

The last section of the documentation, which details the calibration, verification, sensitivity analysis and uncertainty analysis, could be expanded to more completely reflect the actual work the SFWMD has done in this area. Based on the additional material presented by staff during the site visit, we are convinced that this section of the documentation does not do justice to the level of effort that has been expended.

The introductory section should clarify the application of the model with respect to the use of the historical weather data. This description should outline the conceptual approach taken with this model, explain why simulations are limited only to historical data. It should identify the benefits and limitations of this approach with respect to the usefulness of the model for policy analysis.

The introductory section should clarify the relationship between model calibration, verification and validation. The documentation is inconsistent with respect to the terms verification and validation. We believe the commonly accepted (standard) use of the terms is that "verification" is to make sure the code and algorithms are correct, and "validation" determines if the model is correct (i.e. does it appropriately represent the system being modeled). Some authors assume the opposite. Hence for the purposes of this report, we assume that verification or validation are essentially the same, indicating the code and algorithms are correct and that the model adequately represents the system being modeled.

The calibration of hydrologic models can be divided into two parts: calibration of the hydrologic or physical components and calibration of the management or administrative components of the system. The Draft Documentation describes the former much more thoroughly than the latter. This raises questions regarding the degree to which the operating rules and policies embedded in the SFWMM adequately mimic the day-to-day operations of the system, and how the structure of these rules were identified, calibrated, and verified. Calibration and verification of only the hydrologic components of the model may not be sufficient for a model designed to address complex water policy and design issues in South Florida.

Other suggestions for improving the clarity of the documentation regarding calibration and verification (or validation) include the following:

- A synthesis is needed of the calibration, verification and uncertainty analysis, which summarizes where the model is more and less accurate. The data that are actually used for the 'final' calibration, verification and prediction also needs to be clearly summarized.
- Plots of both the calibration and verification periods for the latest model version (3.4) should be presented.
- Maps and tables of the topography, land use, aquifer transmissivities, ET coefficients, Manning's n coefficients, seepage rate factors, and other parameter values resulting from the last calibration should be included.
- Criteria by which the calibration and verification were judged to by satisfactory (i.e. bias, mean square error, error percentiles, etc.) should be quantified and presented.
- Details should be presented on how the acceptable ranges of variation for the calibrated parameters were determined. Plots of bias percentiles versus the percent variation in parameter (which were shown at the on-site visit) should be included.
- The degree to which model parameters change when the model is re-calibrated should be discussed. If parameters change significantly when new data are added, the model's predictability might be questioned. On the other hand, if the

parameters remain stable from one calibration to another, this would build confidence in the model's predictions.

- More details on the sensitivity analysis should be given in the documentation. It should be more clearly explained how each parameter was varied, i.e., by a specified percentage (say +/- 95%) confidence interval value or (say +/- 100%) calibrated value, both simultaneously throughout the domain and at particular locations.
- Details on how the sensitivities were aggregated over space and time to derive the sensitivity matrix should be explained, and maps of the sensitivities (which were shown at the on-site visit) should be presented wherever possible.
- More details on the uncertainty analysis should be included in the documentation. Specifics on which parameters were included in the uncertainty analysis and how they were selected should be given. A discussion of how the spatial and temporal variability of the first-order uncertainties was handled should be included in the documentation.
- Details on how parameter confidence intervals were determined and a table of parameter variances should be presented.

The adequacy of the calibration depends on how the model will be used. This aspect of the calibration needs to be clarified. Model validation should include evidence that the model performs suitably for the intended uses of the model. The report needs increased detail in describing and illustrating the model's intended uses, and the accuracy of the model's outputs applied for those uses.

A discussion of the limitations of model output analysis based on the uncertainty analysis results would be very useful. Given the District's experience with the model, and its sensitivity and uncertainty analyses, what magnitude of hydrologic response does it think the model is capable of discerning? Maps could be used to show variables (and locations) which are particularly significant for the particular application. Results should be presented in a manner designed to illustrate how well the model predicts these variables (where and under what circumstances it is reasonably accurate, and where and under what circumstances it does not do so well). Model operators need to demonstrate model accuracy with respect to the performance measures the public and government agencies are most interested in. Also, if new reservoirs and canals will be added in some locations without model recalibration, an explanation would be useful of what modeling approaches will be used for these and what accuracy can be expected from the resulting model outputs.

Overall Appropriateness of Model

In our opinion the SFWMM is currently the best available tool to address regional water management issues in South Florida. The Draft Documentation clearly states that the SFWMM is a regional scale model, and that users of this model should always keep this in mind. It seems to us the level of detail incorporated in the various hydrologic components is consistent with the regional scope and the temporal scale of the model. The level of detail, particularly in the physical and hydrologic components, generally exceeds that of most other regional scale models known to us.

Few if any other regional water resources management models can match the scope and level of sophistication of the SFWMM. Although there are likely other modeling efforts that treat some of the components of the SFWMM in a more sophisticated fashion, we are unaware of any comparable modeling efforts which include all of the functionality embedded within the SFWMM. Perhaps among the most comparable modeling efforts is that pertaining to the management of water in the Central Valley of California. In this case, multiple agencies are using multiple models for multiple purposes, but with little coordination of the modeling studies in comparison to what we observe in the District.

Obviously there are areas where the sophistication of the algorithms, the computational efficiency, and the degree of calibration of the model can be improved. Indeed, we are aware that the modeling team is currently working in many of these areas. The main problem we believe the District faces in the use of its SFWMM is continued pressure to use it for applications that are outside the scope of the model, or for predicting performance measures with accuracy's that its spatial and temporal resolutions render it unable to predict. This phenomenon is not unique to the use of the SFWMM. Where model use is inappropriate, expensive water management decisions may be made based on imprecise model predictions, adding to the risk that those decisions may not be as effective or efficient as they could have been.

Hence, the documentation should anticipate how the model will be, and should be, used by various model users. It is better to state clearly just what the model can and can not do well in the documentation than to have a model user later state that the model is too inaccurate to do what that user or others had hoped or expected it to do based on incomplete or unclear documentation. Additional discussion on how model outputs can be used to develop regulation schedules and to evaluate performance measures would be very helpful.

Specific Comments and Questions to be Considered in Documentation Revisions

Prior to and during the site visit, we asked the District's hydrologic modeling scientists and engineers a number of questions concerning the contents of the current version of the Draft Documentation. The set of questions submitted to the District prior to our site visit and the District's answers to those questions are contained in the Appendix of this report. Additional useful information was provided during the site visit. The information given by the District's modeling team prior to and during our site visit should be expanded where deemed necessary and appropriate and incorporated into the final documentation.

Ch. 1. General Description

In Chapter 1, it would be useful to show the areas of normal surface water ponding and flows. Without this, the reader may not realize the importance of the surface

water diffusion equation and regions where it is applicable, or where it might coincide with canal overbank flows.

Ch. 2 Physical and Hydrologic Components:

Chapter 2 should contain the source(s) of aquifer hydraulic conductivity or transmissivity values used in the model and those areas for which conductivity or transmissivity values are based on earlier study calibrations, and cite those studies.

Please use a different variable name and definition for the variable currently termed DPTHRNFF. This is the amount of water being pumped from surface drains located around and in irrigated fields.

Please include within the model documentation the impact of assuming a constant land use distribution for the entire calibration area when in fact actual land use changes can significantly affect hydrology with time.

p. 93: In the approach used to model "neutral_case" flows, can changes in the canal structure be represented? If so, how? Page 93 (10 lines up) implies that an "intervening diversion" can be added, but it is not clear from the description how this case would be handled.

P 101. There is no description of the ASR model beyond a brief description of the rules for injection/recovery. Is the storage volume modeled or is it simply considered to be an infinite source/sink? Is the general framework incorporated such that an ASR could be implemented anywhere in the SFWMM domain?

p. 126: At the end of the WCA model section it is not clear what is modeled, since it appears the operating rules are still undefined. Clarify what options for managing the WCAs can be represented in the current version of the SFWMM model?

Clarify the information represented in Fig 3.3.5. I.e. What are a-c-e and b-d-f ? What do the variables in the figures mean (cuflow, smflow, slflow, ...)?

Ch. 4 Data input and Output and Ch. 5 Model Structure

Does this information serve the intended users of this documentation? If so, is it sufficient? If not, could it be removed from this document and placed in a separate document on model operation.

Ch. 6 Calibration

If calibration focuses primarily on monthly values, does this also reflect the time frame for use/application of the model for analysis?

In Part 3, calibration, please include prediction of extent of ponded areas. Please also provide contour maps of the ponded free water surface areas simulated by the model.

Contrast the extent of the ponded areas predicted in the model with remotely sensed data (such as satellite imagery). It seems that otherwise there is very little way of showing how well the model is predicting the extent of ponding.

Please confirm the extent to which calibration methods have been applied to flows in canals where there is both unknown canal-aquifer interflow and overbank flow into the canal from the adjacent land surface. Please clarify how various data with varying accuracy's are being used in such calibrations? Please plot on a map the residuals (calibrated minus observed or vice versa) of aquifer head or ponded free water surface elevations (please distinguish between the two if possible...i.e. indicating when the well location is ponded and when it isn't in the field and in the model). This gives one an idea of how much confidence to have in head values predicted to result at different locations for difference management alternatives.

In the calibration, consider whether it is desirable to interpolate to estimate aquifer head value actually at the well locations, rather than trying to compare model cell heads with head at observation wells. The interpolation might be useful in areas where there is only slight to moderate change in head between cells. (Also, please do not try to match head at an observation well close to a significantly pumping well. If you do want to illustrate the difference between cell head and head in a significant cone of depression, please tell the reader that you are not trying to calibrate to the observed head).

In summarizing conclusions from the calibration, please include a table and figures describing relative model reliability in terms of space and circumstances. For example, identify whether the model is particularly weak in certain locations under drought conditions or when specific unusual management practices or operational decisions are invoked. Similarly you can identify those areas and circumstances for which the model works well. On the web site this can be related to the endangered species habitats or other threatened habitats.

Ch. 7 Sensitivity Analysis

The sensitivity analysis mentions "coastal PET" which should be changed to be consistent with earlier terminology.

References

We believe it would be useful to add as an appendix containing a reference list of publications related to the use of the SFWMM, and include citations to those references in the documentation as appropriate.

Distribution of Documentation on Web.

During our site visit we had the opportunity to see how model results and documentation are being distributed on the World Wide Web. We recognize that writing documentation that will be included in a written report is not at all the same as writing it for distribution, and interactive use, over Internet. However, given the fact

that the documentation is already in the form of a report, and that any revisions will likely be oriented toward improving that written report, it seems to make sense to use the report when creating any Web pages containing documentation. Certainly the documentation could be downloadable from the Web. Important sections of the documentation could be contained on web pages (involving the conversion of those pages to .html or .htm format) that could be easily accessed from keywords contained in a table of contents, an index, and/or on other web pages. If, on the other hand, one were starting from the beginning, the web pages could be built to back up the help files provided for model users.

Appendix - Additional Questions, Comments and Responses

This appendix contains the unedited list of questions submitted to the District by the members of the review panel, together with the District's written responses. These questions, submitted as requested, were our means of getting the District's opinions regarding certain issues, of identifying potential sources of confusion or uncertainty, and of identifying areas where clarification of the Draft Documentation might be helpful. These questions therefore add to the comments and suggestions for documentation improvement made above.

Wendy D. Graham, University of Florida

Ch. 1. General Description:

1. p. 2 , last paragraph: What is meant by "calibration" versus "verification of the predictive ability". From my reading of Chapter 6 it appears that the model has been calibrated using data from the years 1965-1995. Was any data set aside to be used for verification purposes only?

ANS: In the SFWMM, calibration is synonymous to history-matching. Given a set of (calibrated) model parameters, the model can be shown to adequately replicate historically-recorded system response (stages and flows), i.e. the model is well-calibrated. We assume that if the model is well-calibrated, then under a condition different than what historically happened, e.g. a different way of operating a particular pump, we feel confident that the system response, as predicted by the model, will be reasonable. Predicting system response is the primary use of the model. The better the calibration, i.e., more historical data matched, the better verification or increased confidence we have about the model.

The calibration period is limited between 1979 and 1990, inclusive, primarily because of two reasons: (1) historical stages and discharges to be matched during calibration should be fairly concurrent with the assumed time-invariant land use in the model (1988 District land use information with some updates to reflect 1995 conditions especially in the developed areas); and (2) historical stage and flow data become more and more sparse as the starting calibration date is pushed back into the past, and thus, the value of historical stage and flow-matching becomes less significant from a regional standpoint. Model parameters were adjusted to match

historical stages and flows in the 1979-1990 period. Verification was performed for the 1991-1995 time period only. Given the same set of parameters which were "calibrated" for the 1979-1990 time period, the model was rerun for the 1991-1995 time period so that we can see how well/bad the assumed parameter values were in replicated 1991-1995 stages and flows. the period 1991-1995 is our verification period.

2. p. 5, 3rd paragraph: What topography and land use are used in the latest calibration of the model? Similarly what seepage rate factors and aquifer transmissivities were used? Can maps of these and other model properties and parameters be included in this document?

ANS: Model topography was originally based on a 1963 Corps of Engineers contour map of South Florida. Updates, primarily due to soil subsidence, were performed based on several surveys conducted by the District, Corps of Engineers and the U.S.G.S. Land use classification was based on SFWMD Land Use and Land Cover Classification Code reduced to one assigned use type per grid cell. Vegetation types, a basis for further subdivision of land use classification in the natural areas, were field-verified. Yes, maps will be incorporated in the next release of the documentation.

3. p. 7, 1st paragraph: What is meant by "ET which occurs above the land surface"? Is this ET from ponded water? Maybe this is more appropriately termed "ET which occurs at the land surface".

ANS: A possible replacement to the sentence could be:
"The loss of water to the atmosphere is considered by the model as evaporation (where the rate depends on simulated height of canopy due to vegetation) when water is ponded and evapotranspiration when water level is below land surface.

B. Ch. 2 Physical and Hydrologic Components:

1. p. 12, 2nd paragraph: I do not understand the sentence "The above assumptions imply there is no feedback mechanism between lake rainfall characteristics and lake structure operating rules within the 1965 to 1995 operating period." If this important please clarify.

ANS: The above sentence should be reworded as:
"Some studies have shown that man-caused landscape changes influence weather in South Florida. The time series of rainfall distribution for Lake Okeechobee (and the rest of the model domain) is fixed in all SFWMM simulations although landuse patterns can vary from one simulation to the next.

2. p. 14, near bottom of page: Doesn't the last sentence in point 1 really belong in point 2?

ANS: Yes.

3. p. 16, 1st paragraph: Are you stating that the unsaturated zone actually does not exist in non-irrigated areas, or do you mean that since it is not modeled as a dynamic system the model removes ET from either ponded water or the saturated zone?

ANS: The second interpretation. The fifth sentence on the first paragraph will be edited accordingly.

4. p. 16, equation 2.2.1: Is the evapotranspiration coefficient assumed to be the same for the marsh and "no-water" zones? If so why not simplify the equation and include the "no-water zone" with the marsh zone in the parentheses. If it is kept out because the no-water zone is limited by rainfall and thus treated differently, this difference should be reflected in the equation.

ANS: solution 1: combine 2 terms and explain in the text solution 2: include a MAX operand in Eq. 2.2.1. We will do one of the two in the next release.

5. p. 18, equation 2.2.5: How are net radiation, soil heat flux, crop canopy resistance and aerodynamic resistance obtained or estimated for the ten stations? It seems unlikely that this information is available form historical meteorological data.

ANS: Basic meteorological input data for reference crop ET calculations were max. temp, min temp, dew point temp, skycover and wind. FAO 1990 recommended equations were used to estimate the parameters in the Penman-Monteith equation from these data.

Net radiation was calculated as difference between net shortwave radiation and net longwave radiation. Net shortwave radiation is a function of skycover and extraterrestrial solar radiation for location and day of year. Skycover estimates were available for West Palm Beach, Miami IA. Skycover from these stations was assigned to the remaining 8 stations on a nearest station basis.

Soil heat flux was calculated as a function of current and antecedent air temperatures and the constants - soil heat capacity and soil depth.

Crop canopy resistance was calculated as a function of the leaf area index for clipped grass (assumed to have a constant height of 12 cm), and the average daily stomatal resistance of a single leaf assumed to be constant = 100 s/m.

Aerodynamic resistance was calculated as a function of the crop height, and wind speed.

6. p. 20: Why is the unsaturated zone not simulated in non-irrigated areas?

ANS: The addition of the unsaturated zone module to the LEC developed areas was done as a means of quantifying the effects of water restrictions on irrigation supplies. The previous version of the SFWMM did not have a water restriction simulation component for the LEC. Irrigation demands were not explicitly quantified for the LEC until the LEC unsaturated zone was added to the SFWMM circa 1992-93 (note

the EAA has a form of unsaturated zone accounting to estimate irrigation demands). For non-irrigated areas like the WCAs and ENP, there was no driving need to build an unsaturated zone accounting scheme.

7. p. 20: Equation 2.2.7 and accompanying Table 2.2.1 seem to imply that if the water table drops below a cutoff elevation no ET will occur even if infiltration and percolation occur as a result of rainfall. This does not seem realistic.

ANS: If infiltration and percolation raise the level of the water table above the cutoff elevation then ET will occur else no ET is assumed. I agree that there are limitations to this assumption. In the Future model SFRSM this limitation is addressed by permitting effective precipitation (that which does not run off) to recharge the unsaturated zone and evapotranspire before it percolates to the water table.

8. p. 22 and 23, Tables 2.2.2 and 2.2.3: Do these coefficients apply only to non-irrigated areas or to irrigated areas also? Are truck crops, sugar cane, irrigated pasture and agricultural land uses considered non-irrigated?

ANS: Each grid cell in the model will have a land use type equal to only one of those listed in Table 2.2.2 or 2.2.3. The coefficients apply to non-irrigated and irrigated areas. Truck crops, sugar cane, irrigated pasture and agricultural land uses are considered irrigated. The differentiation of irrigated and irrigated areas only apply if both exist in one 2x2-mile grid cell, as in the case of grid cells defined in the urban areas, sometimes referred to as Service Areas in the documentation. Grid cells entirely denoted as agricultural, are irrigated.

9. p. 24: Does the ET-Recharge/AFSIRS model use the same potential ET interpolated from the 10 stations discussed on p. 20? If so why does ET in equation 2.2.10 not always equal ETU? In other words if AFSIRS applies enough irrigation so that ET is satisfied and the unsaturated zone is returned to field capacity why would there be any need for ET from the saturated zone?

ANS: The AFSIRS/ET-Recharge model does use the ET interpolated from the 10 stations. ET does not always equal ETU because of the different scales and assumptions in the SFWMM and AFSIRS model. The AFSIRS model may simulate sufficient water in the unsaturated zone to meet crop requirements. When this preprocessed ETU is used in the SFWMM there may not be a greater demand than was simulated by AFSIRS, in which case ET > ETU and the deficit is taken from the saturated zone to maintain mass balance.

10. p. 26, 1st paragraph: What is the modified Penman-Monteith equation? Which are the "significant variables" that were identified and approximated in this new equation? Is this different than how ETR is calculated for the non-irrigated areas?

ANS: The Penman-Monteith equation was modified according to the FAO 1990 recommendations for estimating meteorological parameters. The variables that are approximated are as in the answer to your question 5, i.e. Net Radiation approximated

using sky cover, soil heat flux approximated using air temperature, and crop canopy resistance a constant. (Lehar - Jeff Giddings should look at this question too)

11. p. 26, 1st paragraph: Are equation 2.2.11 and equation 2.2.7 the same, i.e. does Kc=KVEG? What is the "supplemental requirement" referred to at the top of p. 27?

ANS: Equation 2.2.11 is a general ET function. Equation 2.2.11 is specific to AFSIRS (Smajstrla,1990). The latter equation assumes that the water table does not encroach upon the root zone. "Supplemental irrigation requirements can be met from the water table" (top of p.27). This sentence refers to the major way of applying water to crops in the EAA -- seepage irrigation.

12. p. 39, 2nd paragraph: Is transmissivity really allowed to vary with saturated zone thickness? Is incorporation of this non-linearity important given all the other approximations in the SFWMM? How much does the transmissivity vary due to water table fluctuations? It seems like this variation would be well within the accuracy with which transmissivity is estimated. If transmissivity is allowed to be temporally variable, it should be indexed in the equations on p. 40-43 to show at which time it is being estimated.

ANS: Transmissivities are parameters normally used in the solution of groundwater flow in confined aquifers. The SFWMM deals with an entirely unconfined aquifer (Biscayne and Floridan aquifers) in South Florida. Non-linearity may not be important considering that transmissivities may only vary a small amount (assuming a 10-ft water table fluctuation) and , thus, will not significantly affect the calculated heads, i.e. the model is not highly sensitive to temporal variation in transmissivities. However, proper application of Equation 2.4.3 on page 39 for unconfined aquifers as given in Wang and Anderson (1982) requires time-varying transmissivities. This feature does not significantly impact total model execution time. A time-index for transmissivities will be included in the revised documentation.

13. p.47, last paragraph: what is meant by "satisfactory" results. What were the criteria by which the acceptability of the results was judged?

ANS: The calibration results for canals, e.g. on pages 189-190, provide a rough criteria for acceptability of results.

14. p. 49, equation 2.5.1: All terms in this equation and following equations on this page need to be defined here. Some of the notation (i.e. OVLNF, SEEP, QSTR) does not appear to be consistent with notation elsewhere in this chapter.

ANS: The revised documentation will contain these changes.

15. p. 50, 3rd paragraph: What is meant by historical value? Is this the historical average daily, average monthly, annual average? What is the definition of "maintenance level"?

ANS: Historical values pertaining to stages as used in SFWMM as initial and/or boundary conditions refer to either average daily or end-of-day stage. Maintenance levels correspond to the desired minimum water levels in the coastal canals to prevent saltwater intrusion (see p. 237 for definition). Because a strong interaction exists between canal levels and water table in coastal areas, controlling canal levels in these areas is an effective way of keeping the water table high enough to prevent saltwater from entering the local groundwater and contaminating any nearby coastal wellfields.

16. p. 50, last paragraph: It would be helpful to know where structures G-089, G-155 and G-136 are located. Can a map of all structure locations be provided here?

ANS: The revised documentation will contain these changes.

17. p. 51, last paragraph: What is the tidal value? Is this low tide, high tide, or average tide level?

ANS: The long-term mean monthly historical value is a set of twelve values obtained in the following way. A time series of daily historical tidal value is calculated by taking the arithmetic average of the high high and low low readings for each day. A time series of mean monthly historical values is derived from the time series of daily historical tidal values by taking the mean (one value per month for the period of record) monthly values of the latter time series. The long-term mean monthly historical value is equal to the average January, February, March, . . ., November, and December values derived from the time series of mean monthly historical values.

C. Ch. 3. Policy and System Management Components:

1. p. 81-89: I am confused by the discussion of ET and irrigation requirements here (particularly on first half of p. 86) and how this relates to discussion in Ch. 2.

ANS: Chapter 2 will include all details regarding ET in the EAA. Discussions during the site visit should clarify issues related to ET in the EAA.

2. p. 91, 2nd to last paragraph: Why is it important to allow the slope of the water surface to vary with time in the EAA and not elsewhere in the SFWMM?

HSM: Ideally, it would be desirable to estimate hydraulic slope in all the canals. However, the special attention being given to the EAA canals is due to the reality that they are the major arteries and potential bottle neck for delivering water supply from Lake Okeechobee (source of water) to the Everglades (environmental enhancement and protection) and the Lower East Coast developed area. In addition to water supply releases during dry periods, it is very important that water levels in the Lake be carefully regulated due to the potential threat for large wind tides in the Lake. A key performance measure often considered in water supply plans is the ability to keep excess Lake water in the regional hydrologic system rather than making discharges to tide. The capacity of these canal reaches is again a key point. When considering water supply deliveries, other canal conveyance limitations are adequately represented by the capacity of the control structures (when compared to historical water supply

deliveries). Refinements to the modelling effort have been continually made over the years based on issues being addressed and computer capacity.

The addition of the backwater profile computation for the primary EAA canals was driven by the need to simulated the features that affect the conveyance capacity of those canals. During the LEC Water Supply Plan development, ideas for improving the flow-through conveyance capacities of the primary EAA canals were proposed and required the capability to simulate different pump intake levels, spillway crest elevations, canal cross-sections, etc. The SFWMM was modified to include the backwater "lookup tables" in order to accommodate this need. It may be desirable to include a more-sophisticated routing scheme for other canals, but there has not yet been a driving need to use more than mass-balance routing (with fixed hydraulic gradient) for those canals. Ideas for improving this can be discussed. And pros/cons for full-equations canal routing should also be discussed; USGS experience with MODBRANCH was a useful lesson (so. Fla. canal profiles are flat, or nearly flat nearly all the time).

3. p. 92, 2nd paragraph: Why has design discharge not been historically achieved?

ANS: This depends on several factors, probably the most recognized is the uncertainty of the weather phenomena. The design is for an extreme event. Although it is reassuring to know the design capacity exist in case of realization of the extreme event, there are often undesirable scouring and environmental effects that may occur at the design capacity. Also a portion of the design capacity is reserved for unexpected extreme events. Normally, if excess water is being released from the Lake, it is an indication that the climate is already in a wet regime and increase likelihood of such an extreme event may be increased. The much larger capacity of the outlets to the east and west may have therefore been preferred.

4. p. 143-149: Again I am a little confused by the discussion of ET and irrigation requirements here and how this relates to discussion in Ch. 2.

ANS: refer to question C.1. above.

5. p.132ff: Are there operating rules for flood control as well as water supply? If so shouldn't they be summarized here along with the water supply rules?

ANS: Section 3.5 focuses on the major operational feature of the Lower East Coast of Florida -- water supply. Operating rules for flood control for the area exists. Essentially a flood control water level in each canal triggers a release to tide. It will be discussed briefly in the same section on the revised documentation.

D. Ch. 4 Data input and Output:

No problem, given that this document is not intended to be a users manual.

E. Ch. 5. Model Structure:

No problem.

Ch. 6 Calibration:

1. General: Were there separate calibration and verification periods utilized in the calibration. If so, how did the fit in the calibration period compare with that of the verification period. If not, how can predictive capability be assessed? Were statistical summaries of the various estimators of model fit calculated? If so can they be presented here?

ANS: The most recent calibration/verification effort succeeded the date of the draft SFWMM documentation report. Version 3.4 was calibrated for the 1979-90 period and verified for the 1991-95 period. The verification plots demonstrate the predictive ability of the SFWMM. The same type of plots were developed for the calibration and validation; those plots also summarize the "goodness-of-fit" statistics for the history matching. See pp176-192 for more.

2. p. 169, point 2: I do not understand this point.

ANS: Previous to any inclusion in the model, an attempt is made to asses and improve the quality of any hydro climatological data, before the data is used during calibration or any other regular model run. During calibration, historical flow values are used as much as possible. This means that for a channel reach bounded by two structures, historical flows for these two structures are given as boundary conditions and they are read as input data to the model. Using these historical flows, calibration will attempt to reproduce stages at the two structures as close as possible. For the case of the coastal structures, which discharge directly to tide, historical flows were considered highly uncertain. It was therefore decided to simulate flows at these structures and then do a comparison between historical (although highly uncertain) and simulated flows.

3. p. 176, last paragraph: Why are end of month values compared for the groundwater monitoring wells instead of average monthly levels (as was done for the canals)?

ANS: The use of the average monthly values for comparisons of canal stages seeks the filtering of noise and the faster response of the canal system, as compared to the groundwater system. Canal stages tend to exhibit more variability, as compared to a groundwater response. Also, larger deviations in terms of values and timing between historical and simulated stage hydrographs are expected for the canal system due to its coarser representation in the model. These considerations prompted the use of mean monthly stages in the canal system. On the other hand, it has been realized that comparison of mean monthly and end of the month may not be the most adequate. In the most recent calibration efforts, comparison of weekly values (4 values per month) has been implemented. Mean weekly and end of the week values are still used for canal stages and groundwater stages respectively, which means that the calibration process still sees the canal stages as a noisier process, as compared to groundwater stages.

4. p. 179, point 2: Was land use used as a calibration parameter? This would seem odd.

ANS: No. It was a typo. It should read "overland roughness coefficient" instead of "land use type".

5. p. 180, point 5: Are summaries of the final values of these statistical summaries available? If so can they be presented here?

ANS: Yes, they are available. They will be included as an appendix to the revised documentation.

G. Ch. 7 Sensitivity Analysis:

1. p. 193, second to last paragraph: Over what range of values was the calibration assumed to be valid? How was this determined?

ANS: In general parameters were varied one at a time until it became obvious that the parameters were out of an acceptable range for achieving reasonable results in several different regions of the model. These experiments are discusses in more detail in the thesis by Trimble (1995). The compartmentilization of South Florida with different combinations of land uses in each compartment creates an interesting way for understanding the sensitivity of the model output to varying input parameters for each process. Since, coefficients are not varied independently for the improvement of any one water budget but describe characteristics for the whole model domain, the modeler can conclude with greater confidence that a coefficient is within a reasonable range.

2. p. 194, Table 7.1.1: These ranges of variation seem extremely low. How were these determined and what were they used for? How does the +/- 50% variation of roughness coefficient referred to in last paragraph of p. 194 relate to the Manning's n percentage of variation of "up to 25%" recommended in Table 7.1.1?

ANS: Table 7.1.1 is outdated. It will be updated.

3. p. 195, second paragraph: I do not follow this normalization procedure. Also, were the sensitivities calculated by doubling and halving the calibrated parameter value or by varying them in the range recommended in Table 7.1.1? This is confusing.

ANS: A presentation (by W. Lal and/or P. Trimble) will be made on this topic during the site visit.

4. p. 195: Were the parameters changed simultaneously throughout the modeled domain are just in one cell at a time to compute the sensitivities? If the parameter (e.g. hydraulic conductivity) was only varied at a particular location or particular region of the domain this location needs to be specified. According to equation 7.1.1

the sensitivity of each output variable to each input parameter at each node is calculated separately. Was this done? If so which locations do the sensitivities in Figures 7.2.1-7.2.5 represent? Similarly, the sensitivities must be a function of time. Are these average sensitivities plotted in Figures 7.2.1-7.2.5, or sensitivities at a particular time?

ANS: The intense amount of execution time and data processing needed for varying one cell at a time or even one region at a time made such an effort undesirable unless absolutely required. The unique compartmentalization of the south Florida lends itself to varying one parameter at a time throughout the model domain and safely analyzing the sensitivity of that parameter in a specific region. 'x' and 'y' do not represent locations in Equation 7.1.1. They represent the change in jth performance measure per change in the ith parameter being tested.

5. p. 201: How is the parameter resolution matrix calculated? How is "well-resolved" quantified? How is the parameter resolution matrix related to the correlation matrix?

ANS: Once the sensitivity matrix is formed, additional information can be determined about the relationship between computed output variables and parameters by use of the method of matrix .factorization known as singular value decomposition. The use of this method and related theorems are described in the literature (Noble and Daniel, 1975; Forsythe et al., 1977; and Menke, 1984). Singular value decomposition (SVD) is more suitable for dealing with errors in data, roundoff errors and linear dependents than other more efficient mathematical schemes. It allows for the matrix inversion even if the matrix is rank deficient or ill conditioned. The sensitivity matrix would become rank deficient if there is at least one parameter that has no significant influence on any of the selected observations, or if there is at least one observation that is not sufficiently influenced by any parameters (Lal,1995). This method allows for determination of model characteristics such as parameter space resolution matrix, the parameter covariance matrix, and parameter correlation matrix. The covariance matrix is also known as the uncertainty matrix. SVD is based on the fundamental theorem that matrix A can be decomposed into three matrices such that:

$$Amxn = Umxk\ (kxk\ VTkxn \qquad (18)$$

where U contains k eigenvectors of length m which are associated with the columns (simulated values) of A, V contains k eigenvectors of length n associated with the rows (parameters) of A, and (is a diagonal matrix of k non-negative eigenvalues called the singular values of A. k is the number independent equations among the simultaneous equations. The singular values are usually arranged in order of decreasing size. Some of the singular values may approach or equal zero. In this case (is partitioned into a sub-matrix (p of p non-zero singular values and several zero matrices. The decomposition then becomes:

$$A = Up(pVpT \qquad (19)$$

where Up and Vp consist of P columns of U and V, respectively. The other portions of the eigenvector matrices are canceled by the zeros in (. The remaining diagonal elements give the sensitivity of the linearly combined model outputs to the linearly combined parameters.

The U and V matrices can give additional information about the parameter behavior. The parameter resolution matrix R and the information density matrix S are defined by the U and V matrices as follows:

$$Rmxm = VVT \tag{20}$$

and

$$Snxm = UUT \tag{21}$$

where R is a measure of the independence of parameters. When R equals or nearly resembles the identity matrix, then the model parameters are more easily resolvable. At times, parameters may not be individually resolvable, but may be resolvable as groups of parameters. This type of resolution is characterized by groups of dominant elements in the matrix. The S matrix is the information density matrix and is a measure of the independence of the data. An analysis of columns of A will indicate data distribution among the model outputs. It is possible from such an analysis to determine which data provides the same information as other data.

The covariance of the estimated parameters may be defined for both singular and non-singular sensitivity matrices using the SVD methodology as follows:

$$Cov = V((2/(2)VT \tag{22}$$

where

Cov	is the parameter covariance matrix,
(2	is the error variance at a observation site.

A value of one is used for (2 to obtain the relative values of the matrix elements (Lal,1995). The very small or zero diagonal terms again must be dropped in this application of SVD.

The covariance matrix can be used to obtain the correlation matrix as follows (Uhrhammer, 1980):

$$(2i,j = Covi,j2 / (Covi,i \;\; Covj,j) \tag{23}$$

where

(is the parameter correlation matrix

Independent parameters are most desirable when examining uncertainties of model outputs due to the parameter uncertainties. The analysis of a large number of parameters may be simplified by grouping sets of parameters that are dependent on one another but independent of other parameters or group of parameters. These groups of parameters are then treated as a single parameter. The method of SVD is used to

understand the relationships between parameters and to isolate groups of parameters that are dependent on one another.

Even insignificantly small parameters may have high correlations. Resolution on the other hand reflects the importance of the matrix to the overall system as well. The latter gives both correlation and sensitivity information.

reference: Lal, A. M. W., "Calibration of riverbed roughness", ASCE Journal of Hydraulics, 121(9),September 1995, pp 664-671.

H. Ch. 8 Uncertainty Analysis:

1. p. 204: How many parameters were included in the model output variance computations (equation 8.1.1). The model sensitivities should be temporally variable. At what time were the sensitivities calculated for use in equation 8.1.1?

ANS: Seven key parameters were included: 1) Wetland ET (WLET), 2) Groundwater hydraulic conductivity (GWHC), 3) Groundwater-canal hydraulic conductivity (CHHC), 4) Detention parameter (DET; depth of surface ponding before overland flow is initiated), 5). seepage coefficient for various levee seepage coefficients (SEEP), 6) Roughness coefficient for overland flow (RC), Coastal ET parameter. The temporal variations of many key parameters are illustrated in the original uncertainty analysis (Trimble,1995a). Copies will be made available at presentation. Performance measures are used to summarize how well the regional hydrologic system is meeting certain water management objectives during the simulation period.

2. p. 205: How were parameter confidence intervals (which were used to get parameter variances) obtained? What were the resulting variances for each parameter? Were these determined by node, or as an average over the modeled domain?

ANS: In order to estimate the parameter variance and sensitivity coefficients, a series of model runs are made with historic flows assigned at major control structures where reliable flow data exist. Parameters are incrementally varied one at a time with larger departures of parameter values from the original calibrated parameters estimated each incremental step. This process is continued until the calibration is no longer considered valid. To better refine the relationship between the parameter and the model output, additional intermediate model runs were made for many of the parameter .

After completing this process, a probability distribution must be estimated for each parameter. As suggested by Loucks and Stedinger (1994), if a normal probability distribution of the likelihood of each parameter value is assumed to exist, the high and low parameter values are approximated to be the 5-95 percentile range for a normally distributed variate. A reasonable value for the variance may then be approximated by the following relationship:

$$\mathrm{Var}(Pi) = [(P95 - P05)/3.3]2 \qquad (12)$$

where

Var (Pi) is the variance of the ith parameter,

P95 is the upper limit of the 90% confidence band,
P05 is the lower limit of the 90% confidence band.

With a normal distribution, the distance between the mean value and the high-low values is 1.645 and 3.3 standard deviations, respectively. In this study, a normal distributions for the likelihood of each parameter value was assumed. Arguments could be made for and against this approximation for the different parameters. Beck (1987) cites several studies in which estimates from first-order approximations of uncertainty were compared to the Monte Carlo sampling approximations. In many cases, the results were not significantly different from those generated with Monte Carlo sampling. Loucks and Stedinger (1994) suggested that the most likely case for inaccurate first-order approximations of uncertainty is for non-linear systems. Especially those non-linear systems for which the feasible range of parameter values is large. The sensitivity analysis and the singular value decomposition of the sensitivity matrix will help determine if the regional system behaves linearly.

3. p. 205 : What is the basis for and what are the assumptions underlying equation 8.1.3?

ANS: This equation is derived from the theory of simple regression analysis. When comparing for instance historical and simulated stages, a scatter plot can be used to asses the goodness of the comparison. A scatter plot shows the 45(line (perfect agreement) and how the historical and simulated values plot around it. If a linear regression model is fitted to the data, then equation 8.1.3 can be used to draw confidence bands and asses in this way how close the results are to the perfect agreement line. Hopefully, the regression results would show an intercept value close to zero and a slope close to unity. Also, the denominator in the last term for the expression in brackets should be (n-1) (2.

4. p. 207-213: What parameter variances were used to generate these tables? What sensitivities (i.e. sensitivity to change in what locations at what times) were used to generate these tables?

ANS: Flavelle (1992) has suggested a methodology that uses linear regression of the model output versus measured data to evaluate model bias and uncertainty. The regression coefficients are useful as a measure of bias and the standard error and serve as estimates of model uncertainty. In a perfect model, simulated values versus observed data presented graphically would generate a slope of unity with an intercept of zero and would have no regression error. When model bias exist, the regression line will have a slope different than unity and/or an intercept different than zero. When uncertainty exist in the observation data but the model is perfect, the regression line for a perfect model would be unity, but the standard error of regression would have a value other than zero. In actual application of this technique, uncertainty may be due to model parameter or algorithm uncertainty, or data measurement uncertainty.

The uncertainty band for individual values predicted by the regression equation was estimated with the following relationship (Lal, 1994b; Walpole et al.,1972):

$$Y = a + b\,x \;_\; se\,[\,1 + 1/n + (x-xm)2/((n-1)(2)]\,.5\;t.95 \qquad (24)$$

where

a is the regression coefficients for Y intercept,
b is the regression coefficient representing the slope of the regression line,
x is the value simulated by the model,
xm is the mean simulated value,
Y is the observed value,
(is variance of x,
t is the student t value for a one tail 95 percent confidence interval,
se is the square root of the unbiased estimator reflecting variation about the regression line.

The estimator se2 represents the sum of squares of the errors about the regression line divided by the number of degrees of freedom. The number of points used for determining the regression equation minus two is equivalent to the degrees of freedom.

Lal (1994b) applied this methodology to the SFWMM interior wetland nodes of the Everglades in an effort to obtain an estimate of the uncertainty for the Natural System Model output variables (Fennema et al., 1994). The Natural System Model simulates the hydrology of south Florida in a natural state prior to the impacts of drainage and development. It uses many of the same algorithms as the SFWMM. An application of this technique will also be made in this study. The Lower East Coast Service Area will be included in order to gain a better understanding of the model uncertainty within this developed regions.

5. p. 214, 1st paragraph: Isn't scatter of the data about the regression line a measure of the reliability of the regression as a predictor rather than the reliability of the SFWMM model algorithms?

ANS: What is being evaluated here is how close is the data to a perfect agreement line. The data pairs are made of historical and model simulated values. The objective is to evaluate how close historical and simulated values are, by using simple linear regression. The perfect agreement line would be

simulated = a * historical + b, with a=1 and b=0

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1. Within the grid model framework, how are canals and associated structures represented? This is not described in the model overview section (Ch 1). What is the spatial representation, and how are these components linked to the grid model? (There is some description of canal segment/reach on p.47).

ANS: A map will be generated to address this question.

2. How/where are wells represented in the model? (There is mention of wells at a number of points, but I do not recall any specific discussion of how they are included in the model spatial structure and how/where withdrawals are accounted for.)

ANS: Wells are represented as sink (or negative recharge) in terms of the groundwater flow equations (Eq. 2.4.3 on page 39) R-term. Daily total pumpage volume is input (see page 154) for each grid cell in the model (Units are converted from million gallons to cfs-day within the code).

3. Why should simulation be limited only to historical data (i.e. gauged period) (p.5)? (Rainfall and PET can be generated.)

ANS: In theory, it is feasible, and probably desirable, to generate synthetic sequences of equally likely realizations of such hydrologic tine series as rainfall and PET. However, given the spatial (over 600 raingages) and temporal (daily time step) characteristics of these input time series, it is probably not practical to develop multivariate, seasonal stochastics models for rainfall and PET for generating synthetic data. The SFWMM uses the 31-year historical period (1965-1995) which includes several severe droughts and wet periods. This historical period appears to include a wide range of hydrologic conditions that may be present in hydrologic regime of South Florida.

Given the high dimensionality of the stochastic modeling problem, the use of spatial and temporal disaggregation methods for stochastic modeling may be the only practical means for generating synthetic sequences. This approach may be explored for SFRSM.

SFWMM simulations have traditionally been limited to the historical data (and sequence thereof) period. Currently, SFWMM simulations span the 1965-95 period (31 years). This period is representative of south Florida's wide interannual and seasonal variability, and includes several major droughts and wet periods. We have considered using synthetic rainfall and reference ET to drive the simulations, but have not yet implemented long-term (>2yr) simulations using synthetic data. A joint project with the U.S. Army Corps of Engineers in 1995 used the ENP submodel of the SFWMM and a design storm for simulating performance under a prescribed low frequency (high return period) event. Ideally, we would run many continuous simulations driven by stochastically-generated input (not just rainfall and reference et), and present the results via statistical summaries. However, we have not yet been able to dedicate resources to developing synthetic spatial time-series rainfall data. Furthermore, our deterministic simulations have provided meaningful (and perhaps more understandable) results to our non-technical decision-makers. Decision-makers who recall previous extreme events have a better "feel" for the results of an alternative plan's performance when the plan's performance is summarized for that historical extreme event.

4. How does the constraint of simulating only the historical record restrict (and/or benefit) the usefulness of the model for policy analysis?

ANS: Assuming that the 31-year historical period includes a wide range of hydrologic conditions, one can expect that the model simulations will provide a good understanding of the performance of a particular alternative or scenario. If the future hydrologic regime (say next 50 years) is going to be wetter (or drier) than the 31-year historical period used by the model, then there may be a problem with the decisions made by the results of the model. Currently, the art of making long range climatic predictions is not well developed and the most practical approach to address this issue is through sensitivity analysis.

5. Levee seepage coefficients are determined through regression (p. 38). Why then, should these be later calibrated? Which coefficients are shown in Table 2.4.1 pre- or post- calibration?

ANS: The set of 10 (regression) equations is an approximation of levee seepage in the SFWMM in an attempt to model a local phenomena, but with a significant contribution to the overall water budget, within the framework of a large-scale (2 miles x 2 miles) model. The coefficients in these equations represent model parameters which were derived based on a limited set (2 years of daily stage data) of water levels heads within a limited number of levee transects to be applied to over 150 miles of levees. Considering the heterogeneity of the area, an adjustment (calibration) of these coefficients is not undesirable. Most coefficients are post-calibration values.

6. Is a negative value for the L-36 B1 coefficient reasonable (flow inversely related to head)??

HSM: Not only (1 appears unreasonable, but also (2 reflects a sign which is opposite to the results for all the other levees. When examining the results of the regression analysis, it was realized that the L-36 levee presented the lowest determination coefficient (0.47) among all the others most of which were close to 0.90. Further review of the seepage equation for the L-36 is therefore required. The region around L-36 represents the one of the less permeable levees compared with the entire South Florida East Coast Protective Levee System. What these results might be showing is that the seepage in this levee is determined mostly by the materials ((0 > 0) and not by the head differentials ((1 = (2 = 0).

7. Page 53: In the LOK model, the lake is simulated as a point with a uniform water level. What is the actual variation in LOK water elevations? What impact might any variation have on the reliability of the model?

ANS: In June of 1930 change in storage after ET was 1.94 million acre-feet. This is equivalent to more than 3.5 feet in one month. (the area of the Lake is approximately 450 thousand acres. Of course, there would be large regulatory releases during the same period. During wet periods several million acre-feet may need to be released to tide in a single season of the year for flood protection. During droughts the Lake can

go from the low point of the regulation schedule 15.6 to minimum capacity 10.5 feet in about 12 months.

8. Are the questions posed regarding EAA Canal Conveyance (p.91) specifically addressed by the SFWMM? In particular can the SFWMM address "..what improvements can be made to increase this [conveyance] capacity?" It seems these questions have been answered by Trimble (1995b) and this section should be reworded to more clearly reflect what the SFWMM can and cannot do.

ANS: In general, different types of applications of the water management model can be made. With one approach a model run may be initiated that assumes a doubling of the conveyance capacity. If the results are desirable from a regional hydrologic perspective than it may be desirable to design such a system to see whether implementing the design is cost effective. Another application may be for refinement of operational rules. It should be kept in mind that discharges seldom if ever reach design capacity when delivering water from the Lake to WCAs. Generally a capacity is reserved for unexpected extreme local runoff. It should also be kept in mind that though this model is run on a daily time step, system performance is judge for weekly, monthly, seasonally and overall.

9. In the approach used to model "neutral_case" flows, can changes in the canal structure be represented? If so, how? Page 93 (10 lines up) implies that an "intervening diversion" can be added, but it is not clear from the description how this case would be handled.

ANS: Yes, changes in the canal structure can be represented in the model. "Neutral_case" flows refer to no lateral flow (no runoff and no demand) conditions, and not the with- or without- intervening structure conditions. The model is limited to simulating a scenario of one intervening structure (weir or pump) in the Miami and North New River Canals at 19.3 miles and 24.6 miles upstream of pump stations S8 and S7, respectively (see page 94). The sizes of these diversions can be varied by specifying a different rating curve. The extent of these changes can be made more flexible but are limited to changes to structure sizing. The location of the intervening structure are fairly established based on the footprints reserved for the Stormwater Treatment Areas (see pp. 96-100). The entire approach is a substitute to performing a hydraulic routing through the Everglades Agricultural Area canals.

10. There is no description of the ASR model beyond a brief description of the rules for injection/recovery. (p.101) How is the ASR modeled? Is the storage volume modeled or is it simply considered to be an infinite source/sink? Is the general framework incorporated such that an ASR could be implemented anywhere in the SFWMM domain?

ANS: An ASR is modeled similar to an "expanding/contracting bubble" of storage. They are initialized with zero storage. The (simplifying) assumption in the model is that only a fraction of the injected water (the ASR efficiency) is extractable any time in the future. The losses may be due to transmission losses (injection and recovery) and storage losses (mixing with deep aquifer saline water and migration of ASR

storage flume. Physically, ASR well will be located in deep confined aquifers below the surficial aquifers which define the lower boundary of the SFWMM domain. ASR can be viewed as an external sink/source whose capacity is limited only by the assumed ASR efficiency and pumping capacities.

11. How is flow in the WCA modeled? The description mentions 2x2 mile cells (p.114), but how this is used is not clear. (Is a WCA represented by conservation of mass with instantaneous redistribution of water?)

ANS: The WCAs are modeled just like any other part of the system, considering using 2x2 grid cells. This allows the natural flow to be modeled using a flow domain that is continuous with the rest of the model. Levees restrict flow between cells wherever appropriate. WCA's have 2-D sheet flow as in any other part of the model, except the lake. The only disadvantage with the 2X2's is due to lack of boundary conformity.

12. At the end of the WCA model section (p.126), it is not clear what is modeled, since it sounds like operating rules are still undefined. What is included in the current version of the SFWMM model?

ANS: No operating manual containing rules for making environmental deliveries to the Water Conservation Areas (WCAs) exist. However, for modeling purposes, the SFWMM has code to handle a variety of strategies for making environmental releases, e.g. meeting stage and/or flow targets. The model can be used to look at alternative ways of making environmental targets.

13. Is there some rationale in using [L] type units some places (p.35) and actual units (e.g. [ft]) elsewhere (p.45)?

ANS: Units will be made more consistent in the revised documentation.

14. Page 54: "Water surface area is directly proportional to lake evapotranspiration." Is this what you mean to say? If so, you will need to explain it to me.

ANS: There might be some confusion on the distinction (water surface area or lake evapotranspiration) between dependent and independent variables. The sentence should be reworded as: "Evapotranspiration is proportional to lake water surface area."

15. Are the values in Table 2.2.3, Columns "LU7", "LU8", "LU9" multiplied by the KCALIB factor before being used to calculate ET in the model? (This is what I understand the text to say. If so, a footnote to clarify this should be added to the table.)

ANS: No. The KVEG values for LU7, LU8 and LU9 represent "already calibrated" values. They are the product of KCALIB and KVEG given in Table 3.3.1. I agree that there should be a footnote to Table 2.2.3 stating that The KVEG values in the Table represent values that have already been modified by the calibration process.

16. What are the three conditions represented in Fig 3.3.5 (i.e. a-c-e and b-d-f)? What do the variables in the figures mean (cuflow, smflow, slflow,) ?

ANS: Figure 3.3.5 is a schematic of an approximate routing procedure used in the SFWMM. The U.S. Army Corps of Engineers' flood routing package HEC-2 was used to calculate a set of backwater profiles for two canal-structure configurations for each of the four major EAA canals, a-c-e and b-d-f in Fig. 3.3.5. The SFWMM essentially performs a flow-balancing procedure wherein, in order to establish flow equilibrium (steady-state condition) the discharges and stages along each canal segment and across structures for a given configuration must be identical. The labels in Fig.3.3.5 are 3-part variable names used in the model to designate: (1) canal versus structure; (2) upstream/upper, middle or downstream/lower; and (3) flow or headwater/tailwater. Thus, cuflow is the canal flow on the upstream canal in b-d-f; smflow is the discharge through the middle structure; and slflow is the discharge through the lower structure.

17. Clarify what is meant by "model calibration is performed on a regular basis" (p169)

ANS: The model is updated continuously in order to address increasing demands for hydrology-related questions in South Florida. These updates reflect enhancements to both physical and management algorithms, as well as extension of historical meteorological inputs to the model: rainfall and evapotranspiration. To ensure that the model performs adequately after such updates are done, model parameters are recalibrated regularly. Depending on the extent of the updates, a recalibration is normally done after two or three versions of the model are established using the UNIX Source Code Control System (SCCS). Refer to question 18.

18. Page 169, 170, 172 refers to SFWMM v3.2 and v2.8. How does this compare with v2.1 mentioned in the Preface (Page xi).

ANS: (Note: Page xi reads version 2.10 instead of version 2.1). As mentioned at several points in the documentation, the model is being continuously modified, enhanced and improved, in both the modeling algorithms and the source code. The model is maintained under source code control, using the SCCS utility in Unix. Anytime a major modification is completed for the model, a new version is created under SCCS. The following is a summary of major changes between V2.10 and V3.2:

Major modifications introduced in V3.2:
1. Source code modified such that model is able to simulate 1965-1995. Time dependent data was extended through 1995.
2. Lake Okeechobee ET computation based on reference Et for three stations, instead of PAN ET: Belle Glade, More Heaven and Port Mayaca.
3. Open water coefficient in the equation for Lake Okeechobee ET computation changed from 0.865 to 1.1. This change is linked to the change reported in 2.
4. New stage-marsh area relationship for Lake Okeechobee developed and introduced (Lehar Brion).

5. This version was developed and used for the Lake Okeechobee Regulation Schedule Study (This version has much greater flexibility in simulating operational \schedules for Lake Okeechobee).
6. This version includes revised topo (elevation) data for Holeyland and Rotenberger, based on USFWS data.
7 Tract calibrated at two key locations.
8. Conveyance capacities for the four major canals from Lake Okeechobee to the South were decreased. In previous versions, regulatory releases from the lake were made as long as the elevation in the canals (just D/S from the lake) were below 13.5 ft. In this version the D/S controlling elevation was brought down to 12.0 ft, by direct recommendation from OMD.
9. Preliminary recalibration of the EAA (1979-1989, pre-bmp period) and verification (1990-1995, bmp period).
10. New set of EAA parameters derived for the estimation of the effects of EAA BMP's on runoff and irrigation demand. Base period (10/78-09/88) runoff was reduced by approximately 18%; while irrigation demands were not reduced. BMP Replacement water time series was re-computed and extended for the entire simulation period (1965-1995).
11. Results for versions 3.1 and 3.2 were compared for the common period 1965-1990, for both the 1990Base and the 2010Base. Results for many indicators compared well. Differences found in the results were explained in terms of the modifications presented above.
12. Version 2.10 runs under SunOS while versions 3.1 and 3.2 run under Solaris 2.5. Version 3.1 is the Solaris carbon copy of version 2.10.

19. If calibration focuses primarily on monthly values, does this also reflect the time frame for use/application of the model for analysis?

ANS: Our more recent SFWMM calibration used weekly history-matching for surface and groundwater stages. Discharge data is less accurate and more difficult to calibrate to, so monthly, seasonal and annual values are used for history matching. Simulated flows are not summarized at finer than a monthly basis. Simulated daily stages are displayed on many outputs, but statistical summaries of weekly and monthly outputs are used most often for making relative comparisons among simulation scenarios.

20. How does the calibration specification of matching within 1% (p171) correspond with Fig 6.1.2 and fig 6.1.3 where values look to be much greater than 1% difference.

ANS: The calibration spec on p171 is really more of a calibration result. The result is for the mean monthly history matching, and the individual monthly values will vary from historical (observed) by more than 1%. The goal of the EAA calibration is to match the mean monthly (and therefore mean annual) values as closely as possible. The other statistical and graphical comparisons demonstrate the goodness-of-fit for other time scales.
Incidentally, the most recent EAA calibration/validation is reasonable at the daily time step. However peaks are somewhat underestimated.

21. Has there been any calibration of the LOK component of the model?

ANS: The Lake model is based on a simple mass balance technique. The water available is based on historic water level and flow data and a simple accounting procedure. A normally rather small adjustment in available water is made because the simulated area of inundation is different than historical.

22. The sensitivity analysis mentions "coastal PET" which I don't remember being mentioned earlier. What is it?

ANS: This refers to ET computed for the Lower East Coast Service Area based on the AFSIRS model.

John W. Labadie, Colorado State University

1. Why did the General Description Section (Section 1) not begin with a discussion of model objectives and uses that is, discussing the kinds of issues the SFWMM can help resolve what questions does it answer who are the users; and what are the expected benefits? The Section begins with an Introduction and Historical Background, and then delves immediately into discussion of the Model Characteristics. I would suggest insertion of a Model Objectives and Uses Section immediately following the Introduction

ANS: Above suggestions will be included in the revised documentation.

2. Why is a simplified estimation procedure used for assessing distributed rainfall for cells without gages? It would seem that there are much better spatial interpolation methods that could be used than the "next closest station" method. The rationale given on pg. 14 that it was "chosen primarily because of its simplicity" is not acceptable when considering that rainfall is by far the most important input to the model. Also, the power of modern computing machinery allows us to go beyond the simplified methods of the past. Much more explanation is needed in the documentation to explain the rationale behind this decision.

ANS: SFWMM and NSM use a time-varying (daily), spatial rainfall database that was generated using rainfall records at more than 600 rainguges distributed throughout the District. In the absence of a more rigorous spatial interpolation scheme, cell-by-cell rainfall was estimated using a "nearest station" technique which is equivalent to the popular Thiessen polygon approach. Given the numerous instances of missing rainfall periods in the records of such a large network, this method proved to be the most efficient means for generating rainfall input data for nearly 2000 cells on a daily basis for 31 years.

More sophisticated spatial interpolation techniques such as Kriging and Optimal Interpolation are available but their applicability is not practical at this time for simulating daily rainfall over a large spatial area. For example, Abtew et al (1993) recommended multiquadratic, kriging, and optimal interpolation techniques but the rainfall data used for their analysis was not daily but monthly. Vanlent (1994)

evaluated the raingauge network in South Florida and suggested that the current rainfall network is unable to resolve the stochastic structure of daily rainfall. He also concluded that no gages are redundant if daily rainfall values are required everywhere in the District.

It is recognized that the rainfall input is probably the most important excitation in the system and therefore, its accurate estimation, both temporally and spatially, is important. With installation of several NEXRAD stations in South Florida, extensive information on spatial and temporal variation of future rainfall events is expected. Current plans call for using this information in SFRSM.

Reference:
Abtew, W., J. Obeysekera, and G. Shih, Spatial Analysis for monthly rainfall in South Florida, Water Resources Bulletin, AWRA, Vol. 29, No. 2, April 1993.

Vanlent, Thomas. J., Assessment of the Rain Gage Network in the South Florida Water Management District, A report submitted to the National Park Service, College of Engineering, South Dakota State University, Brookings, South Dakota, 57007.

3. Minor comment: use of fn to represent functions is somewhat misleading (e.g., eq. 2.2.2) better to just use At = f(Ht) .

ANS: Above suggestion will be included in the revised documentation.

4. On pg. 17, it is unclear if surface areas are averaged over a day or if initial day surface areas are assumed. Would the use of averaged surface areas (which would require time consuming iteration procedures) improve model accuracy can they change very much over a daily time interval?

ANS: Lake Okeechobee surface areas are not averaged over a day.

5. Why is there an inconsistency between the way rainfall and PET are spatially estimated? Please explain and justify in more detail.

ANS: The rainfall and PET (reference ET) discretizations are different due to the large differences in density of the rainfall and reference ET data. Data used to estimate reference ET (solar radiation, temperature, relative humidity or dewpoint, and windspeed) is available at only about 10 locations regionally. Conversely, there is a large number of rainfall stations regionally (>200?). The nearest neighbor methodology using all available rainfall data seems to produce reasonable spatial estimates of daily rainfall.

Although we recognize that use of radar-rainfall estimates is most desirable for calibration purposes, that technology has not yet been utilized. The inverse-distance weighting method for estimating reference ET is more appropriate than a nearest-neighbor approach; this is primarily due to the longer distances between reference ET stations & also that there is enough variability between stations to make

the nearest-neighbor (similar to Thiessen polygons) approach produce sharp discontinuities midway between stations.

6. It would be nice if a table describing the various land use types could be included with Table 2.2.3, such as the information given in Table 2.5.1.

ANS: The names for LU1 through LU14 are given on the page facing Table 2.2.3 in Table 2.2.2. If needed a table that gives a more detailed description of each of the land uses could be developed. LU2 which is defined as Agricultural should be modified to Citrus to be more explicit.

7. Material given on the top of pg. 24 is the type of information that should be included in the Model Objectives and Uses Section as suggested above.

ANS: Above suggestion will be included in the revised documentation.

8. Is there any need to consider an expanding crop root zone during the season? It is not clear if the root zone depth is constant throughout the calculations or can change over time. Please amplify.

ANS: The root zone is constant temporally. For the land covers that are being modeled this is a valid assumption. All of the natural areas are covered with perennial vegetation so root depths are expected to remain relatively constant with time. This applies to the Fresh Marsh, Sawgrass, Wet Prairie, Scrub and Schrub, STA Wetland, Forest, Mangrove and Melaleuca land uses. The same holds true for the urban areas where vegetation is constant year round, and for the agricultural areas under citrus and irrigated pasture . For sugar cane and truck crops the root distribution over the 4sq. mile cell can be thought of as the average root distribution over the year. It would likely change with different crops and varying stages of growth for each field but is assumed to remain relatively constant over the 2x2 mile cells.

9. If the AFSIRS are based on irrigation needed to avoid crop stress then how is crop stressed defined? Are you assuming some type of MAD level?

ANS: Stress would occur when the root zone water content fell below the management allowable depletion (MAD). For each crop a MAD value is defined for each crop growth stage.

10. Is calculation of upward flow necessary in the crop root zone water balance calculations? If not, then why not?

ANS: The elevation of the water table is taken into account in each cell. Upward flow is not calculated explicitly but the elevation of the water table affects actual ET out of the root zone. Within the root zone itself there is a water balance with inflows (infiltration, precipitation) and outflows (ET, percolation).

11. It appears that the assumptions used to numerically calculate the diffusion flow model for simulating overland flow conform more to the kinematic wave assumptions. If this is incorrect, please explain.

ANS: This is not true. The model uses true water surface slope instead of the bottom slope to compute the flow from one cell to another. In kinematic flow, only the bottom slope is used. An explanation of the specific SFWMM overland flow algorithm is also explained by Lal, A. M. W., "Performance comparison of overland flow algorithms", ASCE Journal of Hydraulics, 1998 April.

12. On pg. 35, is canal-aquifer conductivity adjusted to consider decreases in conductivity due to siltation in the canals? If so, what assumptions are made?

ANS: Siltation and its effects on conductivity are not considered directly. The effects siltation (along with other local canal phenomena) would be indirectly considered through the calibration of the CHHC parameter.

13. The canal routing procedure appears to be a Muskingum type hydrologic routing method. With strong backwater effects existing in the canals, wouldn't it be better to employ fully dynamic models instead? Wave effects in the canals due to various control schemes could significantly deviate from the wedge-shaped profile assumptions that are used in the canal routing scheme. If not directly including fully dynamic routing in the SFWMM, at least a fully dynamic simulation should be conducted for error checking purposes.

ANS: I think this poses an interesting question, for which some work is already being done in the HSM Division. W. Lal is looking at the problem of using the full equation, use of the diffusion equation or use of more simplified approaches, like the current algorithm. A complete answer to this issue will take substantial time and effort. This effort should include the analysis of historically recorded stage hydrographs at adjacent structures in the same canal, in an attempt to infer which are the dominant components in the canal flow process. This could be achieved trough using different type of models or equations to describe the process. Another issue that needs to be considered at this point is the temporal and spatial resolution of the model. Given the daily time step used by the model, it is necessary to asses what will be achieved by moving into more detailed equations, which for sure will require time steps shorter than daily. More detailed models will also require more detailed spatial information in terms of describing the geometry of the channel and corresponding structures. Finally but not least, we can not forget that the SFWMM is a regional planning tool, and that the current channel routing algorithm seems to be doing a decent job. So far, none of the model calibration or regular runs have shown unreasonable stage or flow values in the canals. Whenever problems have been detected, such as large flows due to instability, changing the values for some of the parameters in the canal algorithm seemed to take care of the situation.

The canal method is basically a level pool method in which the free surface may be tilted in one direction (the slope of the hydraulic grade line is assumed constant). The mass balance equation is solved together with a set of equations representing inflows

and outflows to/from the reach. These inflows and outflows, for each cell intersected by the reach, are function of the canal stage at each cell, which at the same time depends on the slope of the hydraulic grade line and the assumed stage at the downstream end of the reach. Mass balance and inflow and outflow equations are solved for one unknown, i.e. stage, by allowing the water surface profile to move up and down, always with the same slope.

The canal routing method used is similar to the overland flow routing method. They both use a diffusion flow modeling approach. With both methods, backwater effects are completely taken into account. However, diffusion flow models do not consider dynamic effects coming from canal transients, etc. Considering that the SFWMM model is used for long term simulations, canal transients are not considered to affect long terms components of the solution. The inertia terms of the governing equation which can represent these transients are not included in diffusion models. There are many reasons for this.

Canal flow in South Florida is mainly governed by gravity and friction forces. Inertia forces are parts of the vector equation governing force balance. When the canal takes a sharp bend or has a discontinuity due to a structure, the inertia forces break their continuity, and diminish to negligible levels. The strong interaction of canal flow with overland and ground water flows make the inertia effects still more negligible.

It is true however that the results have to be compared with results using dynamic simulations. This is being carried out now.

The diffusion flow method used in the model does not consider a wedge shaped profile because the current method, without a wedge shape can take into account all the terms of the St Venant equation, except the inertia terms. The wedge effect adds an additional degree of freedom which is needed when modeling full equations.

14. I would suggest that the legend for Table 2.5.1 make reference to eq. 2.3.19 for clarity sake.

ANS: Above suggestion will be included in the revised documentation.

15. Please explain why OVLNF and SEEP are functions of the assumed end-of-day stage, and not the beginning of stage day? (Pg. 49).

ANS: The end-of-day stage approximation is potentially more stable. Future releases may consider using an average stage.

16. Description of the Lake Management Algorithm on pg. 62 is difficult to follow (especially the description of "nodal triggers")- perhaps a flow chart of some kind would improve understanding.

ANS: Above suggestion will be included in the revised documentation.

17. The shortage rules embodied in the model are critical to its use in long-term management studies. How were these rules developed? Should they be considered for possible adjustment? (Pg. 71)

ANS: The basis for the water shortage rule for the Lake Okeechobee service area (known as the Supply-Side Management Plan) is described in the referenced report by Alan Hall. The operational experience gained through the 1981-82 and 1988-89 droughts led to the development of the Plan. The rules are candidates for modification through ongoing planning studies. The benefit of the SFWMM's detailed simulation of the Supply-Side management plan is that the code was designed flexible enough to make modifications via data changes. So alternative drought management rules can be simulated relatively easily.

18. On pg. 70, reference is made to following "target distribution of inflows to the estuaries." It is my understanding that these "target distributions" are actually probability distributions (frequency based) on mean monthly freshwater inflows. If this is the case, then how does the SFWMM compute frequency distributions during the simulation? If it does not do this, then what are these "target distributions?"

ANS: The SFWMM does not compute frequency distributions as far as meeting estuarine targets are concerned. A time series of estuarine flows (daily discharge for 31 years) whose probability distribution was considered ideal for supporting a "healthy" estuarine environment was obtained from Upper District Planning Division who, in turn, was involved in establishing estuarine targets for the Caloosahatchee and St. Lucie estuaries. The success of meeting estuarine targets is not gauged by how well the target flows are met but by how well the resulting probability distributions are met. By matching the said time series of flows into the estuary, the SFWMM is guaranteed to meet the target probability distributions. The above model algorithm is not practical from an operational point of view but provides insight on a planning level.

19. Pg. 71 refers to calculation of amount of water available for use based on "anticipated rainfall." Does this mean that SFWMM includes some kind of a rainfall forecasting module? How is "anticipated rainfall" calculated?

ANS: No, the SFWMM does not include a rainfall forecasting module. "Anticipated rainfall" refers to average rainfall condition over the period of record from dry season 1970 to wet season 1990. Water availability (or unavailability) is based on a comparison between current available water, i.e. Lake storage plus average rainfall and average water consumption plus average ET for the remainder of the dry season.

20. I understand the general concept of the "borrowing" allocation, as discussed on pg. 73, but it is not clear to me why it is needed? What is the advantage of borrowing early when this might create larger deficits later? Is it assumed that enough "credits" will be acquired during the season to "pay back" the borrowed flows? Please amplify.

ANS: The concept of borrowing is included in the supply-side management scheme in order to be responsive to crop growth patterns in the field. Some crops require much more water during the early weeks of the dry season and depending on the farmers decision to plant more of such crops, then "borrowing of allocation" provides them with a short-term guarantee for more water for irrigation. It is true that this operational flexibility may create larger deficits later in the dry season. However, it is limited in two ways: (1) borrowing can only be done on the first half of the dry season and (2) the maximum allowable monthly allocation that can be borrowed is limited to one-third of the corresponding month at the second half of the season. There are only two distinct seasons in south Florida: the 7-month dry period starting in November and the 5-month wet season starting in June. An argument that can be made with regards to borrowing allocation during the early dry season is that this operational flexibility is not necessary and probably not detrimental to the second half of the dry season because of the latter's proximity to the next wet season.

21. The discussion on pg. 146 on conditions for declaring water use restrictions is confusing. Why is an "evaluation of salinity levels at key monitoring points within the area" important for this determination? Perhaps this was explained earlier, but I must have missed it.

ANS: Declaring water use restrictions in the LEC is done to prevent the future occurrence of (1) more severe shortage in public water supply and (2) further advance of the saltwater front into the coastal wellfields. Since increased salinity levels at key monitoring points indicate inland migration of the saltwater front due primarily to depressed (freshwater) groundwater levels (a direct indication of excessive water use by groundwater pumping), a determination of salinity levels can be used to trigger water use restrictions.

22. I also must have missed discussion of the "four levels of drought intensity," mentioned on pg. 147 how were these determined?

ANS: The four levels of drought intensity refer to the four stages, or trigger levels, at groundwater monitoring cells which trigger the four water restriction phases. If groundwater levels drop below the phase 1 trigger stage for a prescribed duration, a phase 1 water restriction is "declared" in the simulation. If water levels at the monitoring cell continue to drop below the phase 2 trigger level for a prescribed duration, then a phase 2 restriction is "declared" in the simulation, etc. The trigger levels are determined as a separate calibration effort. The goal of this calibration is to mimic the duration and intensity of historical water restrictions.

23. The statement on pg. 157 about the need for UNIX workstations may be a little outdated if you are using a Sparc 20, the Pentium II 333 under NT (with up to 512 megs of memory), or even under LINUX, will dramatically outperform it. I would admit that an ULTRA Sparc 300 would be comparable but also much more expensive. The old distinctions we have relied on in the past between so-called workstations and pc's is now becoming quite blurred. I think this statement needs to be modified in light of these new developments.

ANS: The second sentence in item 4. on page 157 can be reworded as:
"The UNIX workstation environment has provided the SFWMM modelers with enormous number-crunching power and storage capacity since the start of the decade. Recent advances in PC hardware and software development can provide an alternative operating environment for the SFWMM, e.g. Pentium II 333 running under the Windows NT."

Daniel P. Loucks, Cornell University

A. General Questions

1. Who is the audience for this model documentation?

ANS: The model documentation is a reference manual that serves as a repository of the overall structure (data, algorithm, output) of a large-scale hydrologic computer model that simulates the hydrology an corresponding management of the water resources system in South Florida. Its audience is broad-based: water managers and planners who are looking for an analytical tool to help them in their decision-making processes; hydrologists and modelers who need information, by way of a large-scale model, to be the basis for building their own larger-scale or smaller-scale models for South Florida; individuals and interest groups who desire to be familiar with the assumptions, limitations and capabilities of the SFWMM so as to actively participate in an informed discussion that involves the SFWMM, e.g. USACE Restudy Project for South Florida; etc.

2. Does the SFWMM model meet the needs of the District with respect to the

- *spatial and temporal detail and precision appropriate for various levels of planning and decision making?*
- *availability and cost of required input data?*
- *computational power and time required for model solution?*
- *user control of model operation and editing and display of data?*
- *options for displaying, analyzing and comparing the results?*
- *ease of calibration and verification?*
- *ease of modifying and upgrading or extending the model*
  - *by district personnel?*
  - *by consultants?*

ANS: The discussions during the site visit should shed more light on these general questions.

3. Does the documentation serve the needs of the District with respect to

- *clearly explaining the hydrologic science and the code that incorporates the science into the model?*
- *clearly explaining the range of management options at various sites in the District and how they are implemented?*

· *clearly explaining the logic of the program at various levels including all the assumptions made and their impacts on the model results?*

· *its readability or clarity, its structure or organization (as reflected in the table of contents), its illustrations and tables and their labeling, etc.?*

ANS: These needs are the end goals of the entire process of reviewing of the DRAFT Documentation for the South Florida Water Management Model.

4. Is all of the detail in this documentation sufficient for, and needed by, the desired audience, or is it too detailed for some of the intended audience yet not detailed enough for others of the intended audience? In other words is the level of detail necessary and sufficient for the intended audience and is it organized in a way that makes it easy for all intended audiences?

ANS: The objective of establishing the right amount of detail is definitely a function of the intended audience of any documentation. Since the audience of the SFWMM documentation is broad-based, it is understandable that the depth by which some of the topics are discussed will either be to narrow as well as too broad depending on the type of audience. The documentation does not intend to satisfy all its intended audience to the utmost level. The documentation should generate enough curiosity from any type of reader/audience -- enough to prompt him/her to investigate further -- via SFWMM technical notes, memoranda or reports in printed and/or electronic format. Consistency of level of detail with respect to a particular type/s of audience is a secondary goal. Clarity is of higher priority.

5. Is there any need to plan for the extension of this model to include, for example,

· *water quality of both surface and groundwaters?*

· *ecological impacts of alternative land and water management policies or practices?*

· *simulation of the use of real-time optimization as a management tool?*

ANS: The room for increased model capability is almost limitless. However, the South Florida Water Management Model will not be extended to include any one of the above capabilities. The development of future models from the District may address these issues. A clearer description of the future direction of the SFWMM and other on going modeling efforts from other divisions/departments will be touched briefly during the discussion sessions.

6. How is the model going to be maintained and updated as new requirements are identified and as new computational technology becomes available?

ANS: The Hydrologic Systems Modeling Division maintains and updates the SFWMM and other hydrologic models at the District. The decision on upgrading the SFWMM (either due to new requirements being identified or new computational technology becoming available) or including features into the next-generation regional simulation model, SFRSM, is driven by priorities within the District. Some of these priority-setting procedures will be the topic of discussion during the different sessions of the 2-day site visit.

7. Is there adequate discussion in the documentation of how the model can simulate different management policies, water allocation decisions, etc.?

ANS: The different management policies, and water allocation decisions that the model can do are many and complex, some of which are proposed and may not even be scheduled for active discussion among the managers at the District. Discussion of some policies are available in written form by way of official District publications which caters both to individuals in the technical and legal fields. The major ones, e.g Supply-Side Mangement, are adequately discussed, in modeling terms, in the model documentation.

8. What is the relationship between the current SFWMM and the 'next generation' regional simulation model being developed? Will the new one replace this model? Is the new model the SHE model?

HSM: The development of the "South Florida Regional Simulation Model" continues on a parallel track. The SFRSM considers hydrology separately from operations and management. Two teams have been established to address each of these components. Throughout the development of the Hydologic Simulation Engine (HSE) and Management Simulation Engine (MSE), the methods used in the SFWMM are evaluated, and are potentially recast into SFRSM's Object Oriented framework. Eventually, a comprehensive SFRSM will replace the SFWMM. In the meantime, interim HSE and MSE products are being released and applied to selected problems.

The SFWMM was developed during late 70s and early 80s and has served as the primary regional simulation model in South Florida for nearly two decades. New initiatives such as the Everglades Restoration, and Water Supply Planning have placed new demands for information from regional simulation models. The South Florida Regional Simulation Model (SFRSM) will be the next generation SFWMM that will be developed using recent advances in computer technology, in particular, GIS, Databases, and Object-Oriented Model Development. The new SFRSM will also make use of the more realistic, accurate and efficient numerical algorithms to simulate hydrology and water management in South Florida using a variable mesh structure. The existing algorithms and procedures in SFWMM that are efficient and accurate will be duplicated while searching for ways to improve them or develop new ones. The new methods will be tested and published in peer-reviewed journals before they are implemented in SFRSM.

It is expected that the new SFRSM will eventually replace the existing SFWMM and years of development and testing will be needed before SFRSM becomes fully operational for the entire system. The new model (SFRSM) is not the European SHE based model under development by WRE.

9. Is the spatial resolution of SFWMM (2x2-mile grid) considered adequate? Are the data sufficient for this resolution, or for a smaller grid size?

ANS: 2X2 mile resolution has many unique features that make it suitable for the SFWMM. At the beginning, it may have been selected to reduce run time. This is still one reason. There are other reasons such as the availability of only 1 days data for many parts of the system. I
An extensive description of the reasons can be given during the presentation.

10. What are the computational and informational impacts of say a 1x1-mile square grid resolution?

ANS: A comparison of the costs/benefits of the 1x1 over 2x2 is sufficient.
Ther are several issues associated with scale:
a. Original development considered a variable scale, but data limitations and complexity of coding a flexible scale precluded timely model development. SFRSM will provide flexible scale.
b. Coarseness of data (topo, hydrogeologic parameters, rainfall, et, etc) do not allow scale finer than ~ 1x1.
A 1x1 submodel of the ENP region was developed and has been used for some projects which required finer resolution. 2x2 scale has proven sufficient for regional-scale evaluations.
c. Appropriate computational time step for overland flow determined to be ~6hrs for 2x2 grid size. Finer grid requires shorter timesteps which increase execution time and limit practical applications. 2x2 achieves desired balance between scale, regional-level of model application, and computational resource requirements.

11. Could the model be modified to incorporate variable spatial resolution, as appropriate given the available data and level of detail needed for decision making?

ANS: Time spent for code modification to incorporate variable spatial resolution would probably be very similar to building a new model that incorporates other requirements as well as new computational technologies.

12. Are Figures 1.3.1 clearly labeled and described?

ANS: Figures 1.3.1a-d show overlapping model sub-domains. An explanation of why and how these overlaps exist will be discussed in different sessions of the site visit.

13. Why are months used in the simulation when the simulation time steps are daily? Could the output be summarized in other than monthly periods if desired by the user?· Could the output be summarized in other than the geographic areas specified in Figure 1.3.5 if desired by the user?

ANS: Raw model outputs are in daily time steps. Accumulation of output in monthly periods (averages or totals) are done to aid analysis of results of a long-term simulation (daily for 31 years for SFWMM). Weekly, seasonal and annual summaries are also available. Other post-processing utilities were created since the initial release of the DRAFT Documentation. A demonstration will be made during some of the sessions.

14. Is the notation used on pages 13 and 14 clear? (For example, inserting possible subscript values for the subscripts themselves, what would P3, 2 or X5 represent?)

ANS: See 15.

15. Since this document uses abbreviations extensively, would it be useful to have a list of abbreviations and a short definition for each?

ANS: The glossary and abbreviations sections will be expanded in the next release of the documentation.

16. Would a subject index be useful?

ANS: Yes.

B. Physical and Hydrological Components

1. In equation 2.1.4, would it be preferable to define a set of stations in cell C, and express the sum over all stations in that set as ?n ? C?

ANS: Perhaps there is a better way to express this computation. Conceptually, the cell rainfall assignments are very simple -- find the functioning station nearest to the cell centroid, and assign that value. The only deviation occurs when a cell has more than one functioning station within its boundary. In this case, and arithmetic average is used.

2. Is there any reason why zero values would not be expected in a continuous record of rainfall, as seems to be implied in #1 on page 14?

ANS: This may be clarified by expressing that rainfall has a mixed distribution, composed of a discrete part and a continuous part. The discrete part is the mass at zero, which represents the probability of rainfall being zero. This is a discrete distribution. The continuous part represents the positive values (i.e. greater than zero) rainfall can take.

3. On page 16 and elsewhere, would it be clearer if the non-index subscripts of variables (e.g., w, m and n) be expressed as capital letters so they are not confused with index subscripts?

ANS: The next release of the documentation can adopt this notation for clarity.

4. On page 20, 26, 27, 53, 55 and elsewhere some lists of variables do not have their units defined. Would it be easier for the careful reader if they were defined or are those units obvious?

ANS: Some of the units are not obvious. More variable listings will include units in the next release of the documentation.

5. Is it always best to maintain field capacity, even during periods of water shortages, as implied on page 25?

ANS: In the ET-recharge model which is used as a pre-processor to the SFWMM, irrigation demands are determined by meeting the crop requirements completely. When an allowable depletion of the root zone is reached the unsaturated zone is refilled to field capacity, allowing the ET-recharge pre-processor to determine the quantity and frequency of irrigation to avoid crop stress. These irrigation requirements are treated as target demands in the SFWMM. The targets are not always met during water shortages, resulting in decreased yields during dry periods.

6. Are the values in Tables 2.2.2, 2.3.1, 2.4.1, and 2.5.1 on pages 22,33, 38 and 48 respectively, calibrated values?

ANS: Yes. The calibration however was less on parameters in Table 2.2.2 and more on ET and Mannings. Parameters in 2.2.2 are not very sensitive, and therefore it is not easy to make adjustments based on these sensitivities.

7. During a simulation time step, are there any iterations among adjacent grid cells with respect to (especially surface) water flows? If not, how is balancing achieved?

ANS: The ADE method used is essentially an explicit method, and there no iterations are involved. The quantity of water passing from one cell to the other is computed, and is distributed one time to obtain water levels at the next time step.

C. Policy and System Management Components

1. How (on page 54) is lake water surface area directly proportional to lake evaporation (as opposed to the opposite)?

ANS: The sentence was stated backwards. It should say:
"Lake evapotranspiration is directly proportional to water surface area."

2. Is the second paragraph on page 55 clear to SFWMD readers?

ANS: The SFWMM assumes that runoff generated from drainage basins to the north of the lake will not deviate from their historical values unless a particular scenario changes these discharges. Hence historical values are used for drainage into the lake from the north unless otherwise specified by a particular management/operational scenario.

3. Is not the outflow from LOK a management decision, and if so why is the historical release considered in equation 3.1.5 (on page 56)?

ANS: The term qouthist represents only a subset of all LOK outflows. All LOK outflows are a result of a management decision. However, the term qouthist represents

those outflows that are typically small enough that they have minimal effect on the overall Lake budget and thus, can be assumed to not change during a simulation. They are included in the simulation (as part of the modified-delta storage term) to establish a LOK water budget that balances within the model precision. The modified-delta storage concept is the same concept that the Corps of Engineers have been using in generating their LOK water budget. They refer to it as the "net water supply" term.

4. Could not different management policies affect evaporation?

ANS: Different lake management policies result in different lake evaporation.

5. Is the discussion and motivation for the use of MDS on pages 56 and 57 clear to everyone but me?

ANS: An explanation of the MDS concept can be made during the site visit.

6. Are management policies coded in software or are they input data driven?

ANS: Relatively less complex and straightforwrd management policies are input data driven, e.g. stages associated with LOK regulation schedule. However, more complex policies, e.g. proposed management policies that combine water supply, flood control and environmental releases in the Lakebelt Area, are still coded in software. More, if not all, input data driven policies are to be incorporated in the next generation of the regional simulation model, the SFRSM.

7. How is forecasting done within the simulation model as mentioned on page 73?

ANS: Forecasting is not implied in the discussion of supply-side management of LOK deliveries to its service areas. For instance, "anticipated rainfall" on p. 71 refers to average rainfall condition over the period of record from dry season 1970 to wet season 1990. Also, "projection of lake stage" on p. 73 refers to a simple estimation (not forecasting) of the lake stage if average rainfall, evapotranspiration and water consumption is to occur for the remainder of the dry season. Water availability (or unavailability) is based on a comparison between current available water, i.e. Lake storage plus average rainfall and average water consumption plus average ET for the remainder of the dry season.

8. Does not LOK_ET depend on surface area, which in turn depends on management policies, and if so how can the values be specified in tables 3.2.2 and 3.2.3?

ANS: LOK_ET in Tables 3.2.2 and 3.2.3 represent average monthly Lake Okeechobee evapotranspiration for the 8-month dry season beginning in October and ending in May of the following year. It is not the model-simulated LOK ET but is a parameter used in Supply-Side Management calculations. They can be changed to reflect a more representative average condition for the simulation period.

9. Is rainfall assumed to be the same each year, based on tables 3.2.2 and 3.2.3?

ANS: Yes, they are assumed to be the same each year. Similar to the explanation to the previous question, the rainfall defined in Tables 3.2.2 and 3.2.3 are parameters which represent average hydrologic condition over the simulation period.

10. Is the assumption in the last sentence in the next to last paragraph of page 89 always true?

ANS: For a -day time step, this is probably almost always true considering the extent of secondary and tertiary canals existing in the EAA. A good set of EAA calibration is an indirect way to justify this assumption.

11. Could this SFWMM be converted for use in simulating a real-time decision making process, for the purposes of training as well as understanding how and what decisions are made by system operators in practice?

ANS: SFWMM has always been used as a planning tool and was never designed to be a tool for real-time decision making. Given the complexity of the model and the code, it would be a difficult task to convert the existing model to include a real-time simulation option. The enormous amount of input data necessary to run SFWMM are generally not available on a real-time basis and it is probably not feasible to implement such as option without a major change in data collection and processing procedures. District however, has used other simpler models in "forecast mode" in that past. Also, see the answer to Question 12.

12. Would such real-time simulation exercises be of value to the District?

ANS: Real-time simulation for Flood Control may be valuable to the District operations in certain situations. The SFWMM is a planning tool by design and such a model may not be appropriate for near real-time applications. However, the "position analysis" concepts implemented in such approaches as "Extended Streamflow Prediction (ESP)" can be valuable to the District operations. In such an approach, the model will be initialized for the current conditions in the system and various historical hydrologic conditions will be simulated for next year or two to gain information that would be useful for making current operational decisions. Perhaps, past years characterized by certain climatic conditions such as El Nino can be given a higher weight in simulations, if such a condition currently exists or is likely to occur in the near future. The District is already using other simpler models for "position analysis" and will likely investigate the feasibility of implementing this option in SFRSM.

13. Can the assumptions listed on page 97 and 98 be changed if desired?

ANS: Yes, they can be changed. Changes in the numerical values of assumed flow and stage capacities are input data driven. Operating policies, to some extent, can also be modified from one model run to the next by simple changes in the input data sets.

14. How do the irregular areas shown on pages 106, 108, 109, and 111 to 113 fit into the 2x2-mile grid?

ANS: The irregular areas are approximated as jagged edges along the model boundary. A visual representation of these areas will be shown throughout the entire 2-day site visit.

15. How are different policies implemented in the model, and how are they compared? What are the performance criteria and how are priorities among conflicting performance criteria set?

ANS: Different policies (management alternatives) are implemented through operational and structural changes in a particular model run. Model runs are compared using a set of performance measures that compare different model runs with base runs. Targets on the performance measures allow objective analysis of the relative performance of different alternatives. In many cases the Natural System model is used as an environmental target. There are of necessity trade-offs between achieving performance targets in the different areas.

16. Do water supply needs (as discussed on page 138) include withdrawals to consumption sites (e.g., irrigation) as well as canal water levels?

ANS: Water supply needs do not directly include withdrawals to consumption sites, e.g. irrigation. A strong interaction between canal water and water table exists in the highly permeable South Florida. Maintaining canal levels guarantee a steady recharge to groundwater which, in turn, are tapped by public water supply wellfields as well as areas where irrigation is pumped from below the water table. Direct canal withdrawal for irrigation purposes are limited due to water quality constraints. (ask Jeff Giddings about this!)

17. Are Figures 3.3.5 (page 95) and 3.5.3 (page 139) and 3.5.6 (page 148) well-described and understandable to SFWMD personnel?

ANS: Figures related to EAA conveyance calculations (Fig. 3.3.5), water supply needs calculations (Fig. 3.5.3) and water restriction trigger cell definition (Fig. 3.5.6) are probably understandable for SFWMD whole are modelers. Figures 3.5.3 and 3.5.6 can be understood more clearly if the corresponding discussions in the documentation are followed. Figure 3.3.5 is a schematic of an approximate routing procedure used in the SFWMM. The U.S. Army Corps of Engineers' flood routing package HEC-2 was used to calculate a set of backwater profiles for two canal-structure configurations for each of the four major EAA canals, a-c-e and b-d-f in Fig. 3.3.5. The SFWMM essentially performs a flow-balancing procedure wherein, in order to establish flow equilibrium (steady-state condition) the discharges and stages along each canal segment and across structures for a given configuration must be identical. The labels in Fig.3.3.5 are 3-part variable names used in the model to designate: (1) canal versus structure; (2) upstream/upper, middle or downstream/lower; and (3) flow or headwater/tailwater. Thus, cuflow is the canal flow on the upstream canal in b-d-f; smflow is the discharge through the middle structure; and slflow is the discharge through the lower structure.

18. How are conflicts resolved over allocations to competing users?

ANS: This is one of the most powerful uses of the SFWMM. Several scenarios can be (and have been) run, each with operational rules favoring one use over another. Resulting performance of system as measured by model output (performance measures) are used to provide alternative actions to decision-makers. Typically, balanced decisions are made.

Note, typically solutions are sought which expand the total supply instead of having to deal with allocating limited supplies of inexpensive water. Thus, water will continue to become more expensive in south Florida.

19. How often in the program is the groundwater system updated, and what are the impacts in computer time and accuracy by changes in that time?

ANS: It is updated once every time step cycle, but the direction of the computation is alternated in each of the cycle, in all four directions. A full cycles is completed every 4 days. The reason for the alternation in direction is to improve the order of accuracy, even though there is no theoretical proof that it indeed increases the order. Some of the ADE characteristics may apply in the method too. There is a good probability that the alternating direction would balance out some part of the first order error that making the method and the solution more symmetric. The method used however is at least first order in accuracy as in the case of MODFLOW or UNET.

For ground water flow, it is easy to show that the numerical error is much smaller with even larger time steps. To match the OL flow numerical error, the GW flow time step has to be increased over 50 times. More information in Lal (1998).

D. Data Input and Output

1. Is this level of detail necessary and sufficient for the intended audience?

ANS: There exists opposing arguments to expand or to reduce the amount of detail in this section of the documentation due to differences in opinion between users of the model versus users of the documentation. A suggested compromise is to keep the current level of detail and provide additional levels of detail in a separate publication.

2. Is there an operating manual for the model?

ANS: There is no operating manual for the model. However, some form of a training manual/user's guide should come out of the HSM training program which is scheduled to commence in the fall of this year.

E. Model Structure

1. Is SFWMM v2.1 the latest version of the model?

ANS: No. The latest version of the model is v3.4. Some of the changes (progression of changes) between V2.1 and V3.4 will be mentioned briefly during the discussions.

2. Is the level of detail given here necessary and sufficient for the intended audience?

ANS: There exists opposing arguments to expand or to reduce the amount of detail in this section of the documentation due to differences in opinion between users of the model versus users of the documentation. A suggested compromise is to keep the current level of detail and provide additional levels of detail in a separate publication.

3. After a simulation run, is there any way to help the user focus in on just those output data that were unsatisfactory, i.e., the locations and times where unsatisfactory events occurred as indicated by unsatisfactory values for one or more performance criteria variables?

ANS: Yes. A demonstration of the performance measure graphics will be made during the 2-day site visit.

F. Calibration

1. How was calibration carried out, by trial and error or by some systematic procedure? If the latter, what was the procedure?

ANS: The model calibration effort could be characterized as a systematic trial-and-error procedure. The history-matching portion of the calibration procedure involves adjusting evapotranspiration parameters, overland flow roughness parameters, et al, (which are unique to each vegetation class) to achieve maximum goodness-of-fit (as measured by statistics including bias, RMS error, coefficient of determination, and graphical fit, etc) at all stations within that vegetation class. Often a small improvement in performance at one station, or monitoring point, is at a small expense at another station. When this is achieved, an optimal calibration is considered to have been achieved. In the developed areas, where the canal network is highly dense, adjustment of canal parameters: CHHC and canal operating levels) is a primary focus.

2. Given the errors shown in Figures 6.1.6 and 6.1.7, is the model output accuracy satisfactory? Do you think a simpler model might obtain the same precision?

ANS: Figures 6.1.6 and 6.1.7 have to be examined together with Figures 6.1.2 and 6.1.3, which are the corresponding time series. From these figures, it is evident that the model has the capability to describe not only the year to year variation in EAA runoff and supplemental flow, but also the seasonal and in most of the cases the month to month variation. The results in these graphs represent probably the best ever EAA calibration achieved with the model. In some cases, large calibration errors are present, but the SFWMD staff believes these results are satisfactory, given data and model limitations and uncertainties, specially spatial resolution.

In regard to the use of a simpler model, it is necessary to define such a model. Certainly, linear regression models on an annual basis do not show the same predicting capabilities as does the SFWMM. Other type of models, such as monthly transfer function models, have yet to be tried. The big challenge will be to include in these models the management component. The reader has to realize that the results for the EAA are eachieved while the rest of the system is also being simulated. No simpler model will provide this benefit.

3. Are the results shown in Figures 6.2.4 to 6.2.10 adequate?

ANS: Additional results should be posted on the web or included in a separate appendix to limit unnecessarily thick documentation.

4.Do you have sufficient records of past hydrology and actual operating decisions in which to accurately calibrate?

ANS: The District probably has over 30 years of hydrologic data and if needed, they can be used for calibrating any regional scale model that has a time step of a day or more. Although, records of major changes to the system operations (such as changes to regulation schedule) are available, records of day to day operational decisions are not available in a useful form. The approach used by SFWMM however is to rely on the hydrologic data measured or estimated at major control points in the system as a surrogate for changes (if any) in operational practices. By using the flows estimated at control structure in the "calibration mode", the need to know the operational history exactly is avoided.

G. Uncertainty Analyses

1. Might not the model itself be another source of error or uncertainty, along with its input parameters and data?

ANS: Absolutely. There are numerical errors. There is a paper by Lal, A. M. W. "Performance comparison of overland flow algorithms", ASCE Journal of Hydraulics, 1998 April, describing the error analysis and the tun times of the SFWMM.

2. Is the last sentence on page 205 sufficient clear to everyone?

ANS: This sentence will be clear to people with a basic academic formation in statistics, and more specifically in simple linear regression analysis theory. On the same token, the phrase could be deleted and the term under consideration described as the standard error of the regression line, which will again require a minimum knowledge in simple linear regression theory.

3. How can the results of these uncertainty analyses be made clearer to readers of this documentation?

ANS: There are many more articles that can be added to the list of references, using the web. The documentation only contains the summary.

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1. p xii, para 2. Someplace early in the report please clarify/summarize the intended purpose for using the model. Exactly what decisions will be made based upon model results (what heads or flows occurring where and how often). This involves enhancing and summarizing existing discussions of trigger points.

ANS: The purpose of the SFWMM is to evaluate regional-scale hydrologic impacts of alternative structural and/or operational changes to south Florida's primary water control system. Typical decisions made with the model are planning-level decisions that lead to further more-detailed analysis and design. One common use of the SFWMM is to assess the hydrologic impacts of alternative operational schedules, or rules, for the primary system reservoirs. Refer to SFWMM fact sheet for more info.

2. p 5, para 1, line 3. Is lake/aquifer interflow truly insignificant for the volume balance of the lake? This interflow differs from lake/levee interflow.

ANS: It is generally believed to be insignificant.

3. p 5, para 2, line 10. It is difficult to accurately estimate stream-aquifer (s/a) interflow without iterating to assume appropriate surface water and groundwater heads. How much error results from this approach, and isn't that error greater than the error resulting from the relatively minor changes in s/a parameters made in the sensitivity analysis?

ANS: The answer is exactly the opposite in my opinion. This is one thing unique about S. Florida. Rainfall, ET and other uncertainties are much larger than computational errors. As a result, there is no incentive to iterate between time steps.

The method that is used in the model is equivalent to the explicit method in numerical computations in which the values in the previous time step are used for computing the flow rates, and therefore the new values. The error is of course first order, which would be the same as one would get using a fully implicit method, in which one would have carried out sequential iterations. Stability is the only major concern, which has never been encountered duting runs, because the groundwater system is approximately 100 times slow as one would expect.

The new SFRSM has coupled OL/GW features which at least make the computations more efficient.

4. P 8,9, Fig. 1.3.3. Can you augment the flowchart so one can see when data (for example heads or saturation) from the previous day or time step are used to compute system responses for the next period? It would help if the steps were numbered so they can be referred to in later text.

ANS: The suggestion can be done but a balance within the entire documentation should be preserved for all flowcharts in the documentation. Extra level of detail will definitely be helpful as Fig. 1.3.3 gets referred to in later text.

5. P 16, Eq 2.2.1. This equation causes the same evapotranspiration rate to be applied to marshes and to dry areas of Lake Okeechobee. Is this intentional?

ANS: This is the intention since the dry areas are basically still marsh in which the soil may be very wet and have a high et rate. The ET from dry regions is limited by water available.

6. P 16, para 3, line 1. The no-water zone ET is assumed to be limited by the total lake monthly rainfall. The use of the word total implies that the units of this limit in ac-ft? If so, why would dryland ET volume be limited by the volume of rainfall on the lake? One might think an alternative limit could have units of ft, and assume that rainfall is constant across the entire wet and dry portions of the lake area.

ANS: Total for the month over the dry regionof the Lake surface that usually may be wetted at higher Lake water levels.

7. P 17, Eq 2.2.2. I suggest using fn1 to indicate difference between this function and that of Eq 2.2.3. The two functions are different aren't they?

ANS: They are different. They will be changed in the next release of the documentation.

8. P 17, Eq 2.2.3. The condition for applying this equation seems to disagree with the definition provided for fn(Ht) at the top of page 18. Is there disagreement?

ANS: The definition for fn(Ht) at the top of page 18 should say "stage-area relationship for Lake Okeechobee."

9. P 20, 6th line from bottom. If ET comes only from ETS and ETP, does this mean that there is no unsaturated zone assumed in non-irrigated areas? Please clarify.

ANS: Yes. In the natural areas, i.e. the water conservation areas and the Everglades National Park ponded conditions are predominant. At times when there is drydown below the ground surface in these areas, a linear decrease in ET with depth to the water table is assumed. Hence the unsaturated zone is not modeled explicitly in non-irrigated areas.

10. P 20-24. The section organization implies that all irrigated areas are in the Lower East Coast. Is this correct?

ANS: A change in section organization (include discussion of ET calculations for the Everglades Agrcultural Area into Chapter 2) will clarify the fact that irrigated areas are both in the Lower East Coast and the Everglades Agricultural Area

11. P 20-24. Why does the section entitled "Irrigated Areas in the Lower East Coast" not cite Tables 2.2.2 and 2.2.3? If procedures for irrigated areas do not use Tables 2.2.2 and 2.2.3, why are irrigated crops included in those two tables which are part of a section entitled Non-irrigated Areas?

ANS: A section reorganization mentioned in the previous question will clarify this confusion in the next release of the documentation.

12. P 21, Fig 2.2.3. The figure and the Note at the bottom of the figure concerning KMAX seem to disagree with Table 2.2.2. The Note says that KMAX for wetlands is 1.0, while the table says it is 1.1. Is this intentional? Please clarify.

ANS: Figure 2.2.3 and Table 2.2.2 are consistent with each other. In Table 2.2.2 KMAX = 1.0 for Fresh Marsh, Sawgrass, Wet Prairie, Scrub and Schrub, Forest and Mangrove. KMAX = 1.1 for Urban and Agricultural Land Uses and Melaleuca. (Note: in the latest version of the model, SFWMM v3.4 KMAX = 1.1 throughout.)

13. P 21, Fig 2.2.3. Are you happy with the employed values of KMAX. A recollection based on conversations concerning FAO work, is that evaporation from a free water surface sometimes is about 1.05 times that of reference turf grass (rather than equal to it). Also, sugarcane evapotranspiration can equal about 1.25 times that of reference turf grass. Your values might be more accurate for Florida, so I won't push the point. Later I will indicate that sensitivity analysis on evapotranspiration might reasonably be in a range of + 30%, rather than the +100% and -50% used in your report.

ANS: The values in table 2.2.3 have already been adjusted by KCALIB in the calibration of the model. They represent values which include the effects of roads and buildings, and in the case of crops such as sugarcane - an amalgamation of fields at different stages of growth including fallow areas. A value of 1.1 is used for open water.

14. P 22, first two lines. Why should one want to adjust field evapotranspiration to model evapotranspiration in cells? I would rather see a weighted evapotranspiration for each cell based on the relative area of the different vegetative covers. If a grid cell is the upper limit on the size of a BEA (p 25), why not use such weighting to better estimate evapotranspiration in a cell based on BEAs? Why pick only one vegetation or land cover for each cell?

ANS: In the Lower East Coast the ET-Recharge model is used to pre-process evaporative demands using land-use units smaller than 1 grid cell. In fact 1 acre is considered the smallest land use unit. In this case after processing each individual land use a weighted ET is determined ofr each cell. In the remainder of the model the land use is far more extensive and one land cover per cell is reasonable.

15. P 22. Please clarify when you use the static ET parameters of Table 2.2.2 and when you use the monthly values of Table 2.2.3.

ANS: They are both used in conjunction with each other. In Table 2.2.2 the open water ponding depth, open water ET coefficient , and depth of shallow and deep root zones are considered constant or static for each land use. The calibrated crop coefficients in Table 2.2.3 vary from month to month for each land use. As described in Table 2.2.1 and Figure 2.2.3, ET is a function of reference crop ET, the static coefficients, the crop coefficient for that particular month and the position of the water table below the surface or the depth of ponding above the surface.

16. P 26, third line from bottom. Is a BEA "relatively" impervious/pervious? What BEAs are impervious-a shopping mall? Is the vertical flow direction being spoken of?

ANS: ETUmax is varied as a function of the relative perviousness of each BEA. The perviousness varies from low density residential to medium to high density residential areas and industrial areas. ETU is in the vertical direction.

17. p 30, para 2, line 8. What stability criterion is used?

ANS: If the explicit method, or the predecessor to the ADE method was used, the stability criterion would have been what you would get from Von Neuman analysis as dt < 1/4 dx^2/K (See Lal, 1998, ASCS(HY)). The ADE is made unconditionally stable by the method explained in the report. Stability (Von Neuman sense) defined as u^(n+1)/u^n < O(dt) is still valid with the volume cutoff used with the ADE because the algorithm usese the mininums of three quantities (eq 14,15, Lal, 1998), which are of the same order of magnitude. Some plots are available in the paper to show that even at beta > 20, the model is stable.

18. P 30, para 2, last two lines. When does the model use time steps of less than one day? Is this action automatic?

ANS: The model uses 6 hour time steps to improve numerical accuracy. This is only important in the deep portions of the model, and the shallow portions can still use many days. The ground water portion of the model can use at least 50 day time steps, even with an explicit model.

19. P 38, bottom para. How well do these regression expressions fit the simulated results? What are their r squared values?

ANS: Seepage regression equations for most of the levees do extremely good, while a few perform bad. R2 values oscillate between 0.47 and 0.99. The second worst value was 0.60, with most of the values being higher than 0.88. Values for the standard error of the regression were relatively small, as compared to the different magnitudes of seepage found in the Levee Protective System. No graphs showing the data and the fitted plane are available at this point in time. They could be prepared later on. However, bear in mind that the seepage regression coefficients were modified slightly later on, as part of the calibration effort.

20. p 39. Is vertical flow between the aquifer and Lake Okeechobee insignificant in the Lake water balance? Please justify that conclusion in the text (this refers to comment of p 5, para 1, line 3)..

ANS: I am not afamilar with any studies indicating vertical flow to the aquifer. It is possible but I have never seen the term included in past water budgets.

21. p 40. How do heads computed by Saul'yev explicit method compare with those from ADI, SSOR etc. commonly applied in codes such as MODFLOW.

ANS: The answer is in the paper Lal, 1998 (ASCE(HY) April 1998).

22. p 40, para 3. Does this mean it takes 4 simulated days to have gone through the full sequence?

ANS: Yes.

23. p 41. What is done for edge cells? I assume no arithmetic mean is used there.

ANS: Arithmetic mean is not used for edge cells.

24. p 44, para 2, lines 5-7. Does this mean there is no soil moisture, not even field capacity or wilting point? What happens if the water table rises to the ground surface? Please identify where this process/approach is applied/discussed in the text.

ANS: In non-irrigated areas like the Everglades, there is no unsaturated zone accounting in the SFWMM. The discussion of the solution for water table rising above & falling below the land elevation is described on pages 45-46.

25. p 45, para 2. Can you more clearly introduce this section, beginning with 'prior to the solution of the groundwater flow equations' and ending with Eq. 2.4.22. That will help it be obvious that it explains how p 45, line 2 is implemented.

ANS: "Prior to the solution of the groundwater flow equations, if ponding exists, the known heads are rest to include . . ." should be restated as "Prior to the solution of the groundwater flow equations, if ponding exists, the known heads are temporarily reset to include . . ."

Line 2 on page 45 should read: "For modeling purposes, this variablehas an upper limit of land surface elevation."

*26. p 45, para below Eq. 2.4.21. Can you justify use of (1-S)*pond as a residual ponding term for this unconfined aquifer? Please clarify why some of the ponded head does not contribute to the groundwater flow. In the model, can there be unsaturated soil profile beneath ponding during or by the end of a time step? Can you clarify how the sequence of actions during the time step addresses this?*

HSM: to be discussed

27. p 45, para beneath q. 2.4.21, last sentence. Does this mean the vertical thickness of what is called the unsaturated zone is fixed? Cannot the unsaturated zone change in thickness? Figure(s) are needed, perhaps more than one to show how the computations are performed.

ANS: With the approximation explained in the paragraph below Eq. 2.4.21, one can say that the vertical thickness of the unsaturated zone is fixed. The unsaturated zone thickness can change but for the size of the grid cell (2,560 acres) and high water table conditions (10 feet below land surface is not unusual) that exist in the entire modeling domain, a non-varying unsaturated zone thickness is probably not a bad approximation.

28. p 45, line 9. Why mention a confined aquifer. Aren't we dealing only with an unconfined aquifer?

ANS: We are dealing only with an unconfined aquifer for the entire modeling domain. It should state unconfined aquifer storage coefficient to be consistent with the definition of variables given on page 39.

29. p 45, last sentence. Why does percolation increase if the water table encroaches upon the unsaturated zone? Why can raising water levels only raise soil moisture to field capacity? Can the unsaturated zone shrink in size in the model?

ANS: This approach was adopted in the model for simplicity. Raising water levels so as to raise soil moisture to field capacity can be done in the model. However, this implies that the soil column will start draining back to the saturated zone which, in turn, will further raise the water table. At the scale (grid cell size) we are dealing with, this assumption with regards to the dynamics of the unsaturated zone is probably adequate.

30. p 46, line 3. Can you clarify the possible range of soil moistures for the different areas in the SFWMM? Please do this in terms of wilting point, field capacity, saturation, as well as normal hydrogeologic terms.

HSM: to be discussed

31. p 44-46. Can you provide more introduction to the reasons for performing specific actions, and provide the introductions close to the discussion of the actions? p 46, Fig 2.4.4. Please ensure all terms are defined, possibly before the discussion of pages 44-45. It would even be good to more clearly see what is being done at different stages within a time step, and from time step to time step (for example, if ponding from one step does not soak into the ground until the next period).

ANS: The procedure outlined on pp 44-46 is non-standard and is something that is worth expanding based on the above example. Due to time constraints, a complete response to this question cannot be completed at this time. The next release of the documentation will address this need.

32. p 47. Can you clarify what the initial cross-section of the canals look like when constructed?

ANS: The current version supports only rectangular crossections. Width is assigned to a canal, and is applied uniformly along the entire length of canal.

33. p 47, para 1, last sentence. This seems to refer to the next to the last step before the end-of-month diamond in Fig 1.3.3 on page 9. Please explain the iteration stopping criterion?

ANS: No. The iterative procedure used to calculate end-of-day is performed in the "CHNLF" subroutine, the top step on page 9. The SUM_TRIG_HEADS subroutine refered to uses "probes" which are inserted at selected locations in the model to track water levels. This information is used to determine the relative severity of water restrictions within the respective service areas. Within the iteration, error is espressed as depth by dividing the error volume (CHSTOR-ACVOL) by the canal surface area. Iterations continue until this depth is less than 0.01 ft up to a maximum of 30 iterations.

34. p 47, para 3, line 5. Before "The Manning's equation', please begin a new paragraph and insert 'For overflow situations'. Is it correct to do this?

ANS: Yes, it is correct to do that.

35. p 47, para 3, line Is it always the case that the total length of a canal in a cell is 2 miles? What if a canal crosses the cell diagonally or only partially, or if more than one canal merge in a cell?

ANS: The length of canal in a cell is determined by its orientation. The user defines canal location by listing the impacted cells along with an orientation code (1-east/west 2- north-south; 3-diagional). Partial penetration into a cell is not supported. More than one canal can be assigned to a cell.

36. p 47, para 3, line 3. Is 'overbank flow' equal to OVCNF? Here and elsewhere please include (perhaps in parentheses) the variable names/acronyms in the text when discussing the flow and computational processes.

ANS: The next release of the documentation should address this concern.

37. p 49, second sentence after Eq. 2.5.1. If QSTR (in and out) are not implicit functions are they explicit or assumed inputs?

ANS: In general, they have been computed previously or read in as a time series. They are assumed to be not dependent on canal stage.

38. p 51. How well does the model compute fresh water outflow to the ocean? Can you contrast the simulated values with those estimated in other studies?

ANS: Refer to calibration/validation results. Important to recognize the high degree of uncertainty in processed historical discharge data. Few, if any, other studies have been performed to estimated coastal discharges.

39. p 53. What parameters or flows involved in LOK water budget are calibrated? How might assumptions concerning lake/aquifer interaction affect the accuracy of the calibration.

ANS: Not calibrated. Simply an accounting procedure. Past studied (Shih et al) have completed water budgets using traditional calibration techniques.

40. p 54, bottom paragraph, line 2. What is 'groundwater movement in the lake'?

ANS: should say interflow between the groundwater system and the Lake.

41. p 54, bottom paragraph, line 5.Does the ft in cfs/mile/ft refers to a head difference between lake and other free water surface?

ANS: Yes.

42. p 55, Eq. 3.1.2. How can one justify omitting seepage and groundwater flow in this LOK water budget?

ANS: They are relatively small. When they do occur, they are to the service areas which may than use the water or pump it to another portion of the system. Since we compute storage changes in the Lake bases on historical changes the seepage volume is therefore accounted.

43. p 56, Eq 3.1.3. I question either the explanation or the validity of this equation. Line 1 says the simulated components differ from the historical values...true. However, for the equation to be valid, if the left hand side (LHS) is really the difference between simulated and historic changes in storage, then the right hand side (RHS) simulated terms need to be the differences between simulated and historic inflows and outflows.

An alternative approach is to develop the resulting expression by algebraic subtraction of the historic from the simulated volume balances.

delSsim = (Inflowssim - Outflowssim)
- delShist = (Inflowshist - Outflowshist)
delSsim - delShist = (Inflowssim - Outflowssim) - (Inflowshist - Outflowshist)
delSsim = (Inflowssim - Outflowssim) + delShist - (Inflowshist - Outflowshist)
= (RFsim + qinsim - ETsim - qoutsim) + delShist - (RFhist + qinhist - EThist - qouthist)

Assuming simulated and historic rainfall (and seepage and any lake/aquifer interflow) values are identical:

delSsim = qinsim - ETsim - qoutsim + MDS
where MDS = delShist - qinhist + qouthist + EThist

ANS: O.K.

44. p 56 Based on the preceeding comment, I suggest the development of equations 3.1.8 and 3.1.9 can be presented more simply than they are now. At the end of the development you can state that Eq. 3.1.9 is the MDS presented previously by Trimble (1986). The current presentation on pages 55 and 56 is confusing to me.

ANS: O.K.

45. p 58, para 2. What error results from treating LOK as a lumped system and using one-day time steps?

ANS: Need clarification on definition of the term "error". If it is related to the error in Lake water budget, then a further discussion of the Modified Delta Storage should help to clarify.

46. p 63, note concerning WCA-1 and WCA-2A.. Can you clarify why a groundwater observation well is being used to trigger lake releases, and why the reference changes when head in an observation well drops beneath ground surface elevation?

ANS: It is not evident why the section on Lake Mgt Algorithm contains the discussion of WCA operations. The ops that is listed for WCA-1 is the field operation. When the marsh dries out (1-8T gage), the operational decisions are then based on the 1-C gage (canal).

47. p 65, bottom paragraph. Do all canals attain steady flow conditions within a one day time step?

ANS: Within most segments of canals, water levels even out and transients die down in 1 day.

48. p 68, 7th line from the bottom.. Can you provide a figure/table with all pertinent structures numbered and located? (Something like Fig 3.5.1 would be helpful.) It should also show the subbasins referred to in Table 3.2.1. of page 72.

ANS: The suggested change will be made in the next release of the documentation.

49. p 73, topic 5. Is a 'borrowing allocation' for an individual entity or for the entire lake?

ANS: "Borrowing allocation" is done by a single entity: the entire agricultural area around Lake Okeechobee. This entity have a single source of water (Lake Okeechobee) where it gets its entire allocation.

50. p 74, topic 7, lines 4 and 5. Please clarify that allocations borrowed during the first half of the dry season must be returned four months later. In line 5 if 'current month' means 'corresponding month', please make the substitution.

ANS: Supply-side management will be explained in the discussions during the 2-day site visit. Allocations increase for the current month when borrowing occurs. Allocations decreases decrease if some of the borrowed allocation is returned. No substitution is necessary.

51. p 80. Can you provide a summary table showing which canals employ which type of modeling? Somewhere in the text please clarify that the canals are unlined, and what the constructed and existing cross-sectional shapes are.

ANS: Yes, this may be a helpful clarification for the report.

52. p 81, Fig 3.3.2. Does a G-# refer to a gate number?

ANS: The letter G followed by a number designates a South Florida Water Management District control structure. The G structures were built by the SFWMD. The letter S followed by a number designates a Central and South Florida Project control structure. The S structures were built by the Army Corps of Engineers (Cooper, R., An Atlas of the Everglades Agricultural Area Surface Water Management Basins, SFWMD, 1989). S and G structures can be pump stations, gated spillways, gated culverts or culverts with risers and stop logs.

53. p 81, para 1. How does seepage irrigation maintain a watertable at a 1.5 ft depth? Please describe seepage irrigation. Are no subsurface or surface drainage systems used to help maintain that depth to water?

ANS: "The EAA basin is serviced by a complex network of primary and secondary water supply, flood control, irrigation and drainage systems. The primary canals (Miami, North New River, Hillsboro and West Palm Beach) ..... The secondary system consists of farm pump stations, mains, farms laterals, field ditches and culverts that are owned and operated by the farmers. The purpose of the secondary system is to supply supplemental water from the primary canals to the farms and to remove excess water (drainage/runoff) from the farms to the primary system. The water table is high, and subsurface storage of water in the soils is limited. Generally, stages in the primary canals are higher than water levels in the in the farm mains, and irrigation water is withdrawn by gravity, while excess water is pumped out." (Abtew, W. and N. Khanal, Water Budget Analysis for the Everglades Agricultural Area Drainage Basin, Water Resources Bulletin, American Water Resources Association, Vol. 30, No. 3, June 1994).

Crop requirements in the EAA are first satisfied by rainfall. Supplemental irrigation from Lake Okeechobee is required whenever rainfall plus local storage are not sufficient to satisfy the plants requirement. When the depth to water table is increasing, seepage irrigation starts in the secondary canals, by allowing inflow from the primary canals. This will increase water depth in the secondary system. Since the

water table is being depleted, a gradient will form from the secondary canal system to the groundwater system. Water is transferred from the secondary canal to the groundwater by exfiltration or seepage from the canal. Water is taken from the saturated zone into the unsaturated zone by capillary rise, which is observed to be large in the muck soils found in the EAA.

During storm events, the process is reversed to remove excess unwanted runoff. A portion of the rainfall may reach the secondary canals as surface runoff, but the vast majority of it does it through infiltration, percolation and ground water discharge into the secondary canal system (drainage).

There are no subsurface or surface drainage systems used to help maintain that depth to water at the filed or farm scale, other than the ones described above.

Finally, it must be pointed out that the above description is for the farm operations. It does describe the modeling algorithm.

54. p82. Hydrologic modeling differs for the different subareas and different canal types or surface water bodies. It is challenging to remember all these differences simultaneously. Could you provide a summary table that summarizes the differences? The table could, for example, indicate that in the EAA the water level is kept at 1.5 ft below land surface and the mechanism used to do that.

ANS: The HSM Division staff will produce the table in the near future and include it in the next revision of the SFWMM documentation. Right now, it will be difficult to produce the table in such a short notice.

55. p 82 , para 2. Please clarify that the capillary fringe is ignored, although it can be saturated, and mention how high the capillary fringe is for representative soils.

ANS: Yes. The capillary fringe is ignored.

56. p 82, definition of DPTHRNFF. Doesn't DPTHRNFF = POND + (SOLMX - SOLCRNF) imply that SOLCRNF is the equivalent depth of water in a fully saturated soil? Assuming no freezing conditions and constant water density throughout the year, SOLCRNF should not change during the year. This disagrees with the time-varying definition of SOLCRNF on page 83. Also, it implies a time-varying soil parameter rather than the management goal I infer from the word 'desirable' in the definition of SOLCRNF.
Also, how does the definition of DPTHRNFF change from the initial definition?

ANS: All the computations for simulation of the EAA runoff and demand are performed with equivalent depth of water. This means that SOLCRNF represents a portion of the soil column as if it were saturated. However, this is a computational artifice, so that homogeneous magnitudes are added. SOLCRNF is not a soil property, but a soil related parameter intended to represent EAA farm managements practices which is allowed to vary on a monthly basis. It may represent different management practices, different dominant crops and/or different growing stages

during the year. They may be used to represent the introduction of new management practices such a BMPs. The EAA is not simulated on a filed by filed of farm by farm basis. The secondary canal system is not even simulated. The way these parameters are calibrated, since stages and soil moisture levels are not measured at the interior of the EAA, is by matching simulated EAA runoff and supplemental irrigation supply to the corresponding historical values, in terms of timing and volume.

The definition of DPTHRNFF also intends to establish how the initial value for that day for DPTHRNFF is computed. The value of DPTHRNFF gets updated again later on during the computation process.

57. p 83, definition of GWMAXDP. This implies that the water table can get farther than 1.5 feet below the ground surface, and seems to contradict a statement in paragraph 2 of p 82 that the water table is maintained at 1.5 feet beneath ground surface (GS). It also seems to contradict the drawing of Figure 3.3.3. If the confusion results because different situations exist during different stages of a sequence of computations, wouldn't it help to have more than one figure?

ANS: There are cases, under shortage conditions, when the depth to the water table goes beyond 1.5 ft. On the other hand, it can also be smaller than 1.5 ft under extreme wet conditions. The 1.5 ft must be understood as a management target, which reflect the way in which farms and fields are operated on a daily basis. The 1.5 ft provides an adequate root zone for plant growth and its size is also adequate for providing oxigenated water to the unsaturated zone.

58. p 83, definition of PERC_IRRIG. What happens if insufficient irrigation water is applied to raise the water table to the base of the soil column?

ANS: This may be an indication that the EAA and probably the entire Lake Okeechobee Service Area are under Supply Side Management and cutback conditions. Once there is enough water available from rainfall or from the regional system, the water table gets replentished to a depth of 1.5 ft. (See also answer to question 57)

59. p 83, definition of S. Usually the term storage coefficient is used for confined aquifers. Is this your intent?

ANS: For this case the term specific yield would be more appropriate. This term is borrowed from the form of the ground water equation used in the model, which is the equation for unconfined aquifers, but it is applied to unconfined aquifers for the SFWMM case. This makes sense since in south Florida the appearance of ponding is given by the surfacing of the water table.

60. p 82 and 83. Use of the word 'desired' in the definitions of SOLCRT and SOLCRNF imply these are management goals. It is difficult to reconcile that with the attendant statements that these are calibration parameters. Does this mean management does not know what soil moisture they are attaining? (One might argue these terms are being used as fudge factors within the calibration.) The same comment applies to fracdph_max and fracdph_min.

ANS: These parameters are management parameters. Some of the reasons for which they were selected for calibration are discussed in the answer to question 56. SOLCRT represents the level at which supplemental water has to be brought for irrigation into the particular cell. SOLCRNF represents the level at which runoff remaoval has to be initiated. These represent managing decisions and not soil properties.

61. p 83, Definition of SOLMDPH. Isn't rewording the definition of SOLMDPH necessary? Rather than saying it is the equivalent depth of water that can be stored, shouldn't one indicate it is the equivalent depth of what can drained due to gravity from a saturated soil? If the soil moisture ever drops below field capacity, more than this amount can then be stored in (added to) the previously unsaturated soil. Alternatively one can use 'specific yield' in the definition.

ANS: SOLMDPH is simply the maximum equivalent depth of water that can be stored in the soil column. Any moisture in excess of SOLMDPH results in ponding.

62. p 83, definition of SOLCRT. Please clarify why this should be a calibration parameter.

ANS: SOLCRT as well as SOLCRNF are management parameters used in the regional scale simulation of the EAA. Since the EAA is heavily managed, simulation of EAA runoff and supplemental irrigation requirements is dependent on the overall response of field scale management. Thus, management parameters must be determined in the calibration/verification process.

Also see answer to questions 56 and 60

63. p 83, paragraph above Eq 3.3.1, line 1. If each time step is of one day duration, please reaffirm that here.

ANS: Each time step is of one day duration.

64. p 84, definition of KCALIB. Isn't this coefficient primarily an adjustment to compensate for assuming a single land cover in each cell? Instead, why not weight the different soils and land covers in each cell to yield weighted KFACT values? That removes what seems to be an unnecessary fudge factor.

ANS: KCALIB is not applied to each cell but rather to an entire land use. The theoretical KVEG values were obtained for unique land uses at a small scale. In a regional scale model it is impractical and well nigh impossible to obtain land cover and soils at a scale smaller than the 2x2 mile grids, so the KCALIB values adjust the theoretical values up to the model scale which includes aggregations of different stages of crop growth and takes into account pervious areas such as roads and buildings. (refer also to answer to Q 13).

65. p 85, definition of DDRZ. Except for sugar cane, I don't think one considers the saturated zone as being a root zone. Most crops roots die when immersed. Since water levels are generally kept at 1.5', and alternative definition is desirable for DDRZ.

ANS: A better definition than DDRZ is the extinction depth. This is the depth of the water table at which ET by capillary action of the roots in the root zone ceases.

66. p 85, last paragraph, first line. This says that ponding and rainfall initially increase moisture in the soil column. This seems to disagree with EQ 3.3.3 and the equation just above Eq. 3.3.6. That expression indicates that soil moisture on day t is updated based on the ponding in day t-1.

ANS: The statement on p. 85 should be changed to: "Initially, rainfall is assumed to increase moisture in the soil column."

67. p 86, 4th para, item 1. This says if ponding exists ETU =ETMX. Eq. 3.3.3 said that if ponding existed in day t-1, ETU = ETMX. Don't these disagree?

ANS: There is no disagreement. . . . That section of the documentation summarizes the components of ET given by equations 3.3.3 - 3.3.5 for ponding and non-ponding conditions at time t. To be discussed.

68. p 86, first two lines after Eq. 3.3.7. This might be a matter of terminology, but rather than using 'equivalent depth of the desired maximum moisture content' shouldn't you use 'equivalent depth of the saturated moisture content'?

ANS: No. The terminology is fine. Water is taken from the soil and removed from the basin before the soil is fully saturated.

69. p 87, para 1. Why wouldn't the 1.5' desired depth differ with crop?

ANS: The EAA is comprised of 80% sugar cane (~400,000 acres). Secondly, the depth of soil column is more a function of location of bedrock relative to land surface which is not solely crop dependent. A foot and a half is the optimal depth for sugar cane production in the EAA.

70. P 82-89. Some of the above questions might not arise if Figure 1.3.3 were more detailed and/or steps were numbered, and the numbers referred to in the text.

ANS: This will be addressed in the discussions.

71. P 87, bottom paragraph, line 2. Why shouldn't one be using SOLMDPH (or a term including field capacity or specific retention) instead of SOLCRNF?

ANS: SOLCRNF is the correct term. Soil moisture content greater than SOLCRNF is considered excess that potentially can be removed from the basin if sufficient capacity

exists or recharge the water table if water table has declined due to drought conditions. SOLMDPH is just the depth of the soil column.

72. P 88, para 1. In the model, is it possible to have runoff even if soil moisture in the entire soil column has not reached saturation?

ANS: Yes. Runoff occurs when the soil moisture content is greater than SOLCRNF. In general, water is removed from the soil before the entire soil column has reached saturation.

73. P 88, bottom paragraph, line 1. Please mention whether the model assures that sufficient irrigation is always provided to bring soil moisture to SOLCRT. Are there any management scenarios in which insufficient irrigation water will be provided for this to occur? Would it be accurate to replace "The model assumes" with "The model assures"?

ANS: SOLCRT is the soil moisture content at or below which requires supplemental water for irrigation from outside source(s), i.e., SOLCRT is a trigger for supplemental water , not a soil moisture content to be maintained. The maximum supplemental delivery from outside sources for irrigation is the volume required to meet crop requirements. Crop requirements are met if: 1) sufficient available water from outside sources exist; 2)there is sufficient capacity; and 3) it is not limited by policy. Thus, there is no assurance that crop requirements will be met.

74. P 88, bottom para. Please mention what water term is used within the groundwater flow equation(s).

ANS: Variable names PERC_IRRIG or PERCt (Eq. 3.3.8 on page 87) would contribute to the RECHARGE term in the groundwater equation.

75. P 89, para 1. Here or sooner it would be good to clarify how SOLCRT is determined. The process differs for subirrigation versus surface or sprinkler irrigation systems.

ANS: SOLCRT was determined from the calibration/verification process. Once the EAA calibration is completed, a check is mdae on the reasonableness of the ET and timing of ET reduction (ET < crop requirement). During the calibration process, SOLCRT is assumed and SOLCRNF and ET coefficients are adjusted so that the simulated runoff leaving the EAA and supplemental requirements sufficiently match historical data.

76. P 90, para 2. Is FRACT determined via a function? If so, please clarify.

ANS: FRACT is determined by a function dependent on simulated excess volume of water that could potentially leave the EAA basin.

77. P 90, bottom para. Please clarify the ramifications of not simulating interbasin transfers through the Cross and Bolles Canals.

ANS: Interbasin transfers occur in the real system, but the magnitude is unknown due to lack of measured data. Calibration results are good assuming no interbasin transfers. For this reason and other practical considerations, the interbasin transfers are assumed to be small. The model should not, and is not, used to estimate interbasin transfers.

78. P 91, para 1, last sentence. Somewhere one should see a clarification of how basin irrigation requirements are determined. If a single cell has a nonzero irrigation requirement (DPH), does that mean the basin has a nonzero irrigation requirement?

ANS: No, not necessarily. Excess water, if any, is assumed to help meet irrigation requirements within the basin before supplemental water is delivered from Lake Okeechobe.

79. P 91, para 3, item 1. Please clarify the "above regulation" terminology.

ANS: "above regulation" means "within the release zones of the regulation schedule".

80. P 92, para 2 and 3. The wet season discharge percentages are lower than those of the dry season. Is this due to seasonal vegetation changes or to the need to leave capacity for storm runoff as discussed in para 3. Since equation 3.3.24 leaves capacity for storm runoff, I suspect the cause is the vegetation changes, but am not sure. Please clarify.

ANS: It is for storm runoff. This is the same percentage as in the paragraph and the equation.

81. P 92, para above Eq. 3.3.24. Can the lake stage ever not be above regulation during the wet season?

ANS: Yes - & for that case the flow-through conveyance capacity calculation is not needed for regulatory discharges.

82. P 92, line beneath Eq. 3.3.24. Please clarify the "water supply conditions" terminology.

ANS: water supply discharges

83. P 93, para 2, item 4. How long does it take to reach steady flow conditions in the different canal reaches? What are the ramifications of this on the canal modeling results?

ANS: Steady-flow condition is assumed by the canal routing procedure. Essentially, HEC-2 is embedded in the model but is limited by the number of possible configurations as far as alternative configurations that could be tested within the EAA

84. P 96, para 1, item 3, and p 97, item 5. Please clarify. I assume this means increase the hydroperiod to what it was before channelization projects.

ANS: Yes, it means increasing the hydroperiod to what it was before channelization projects.

85. P 98, Fig 3.3.7. Please clarify where one can look to see what all the acronyms refer to.

ANS: A definition of the variable names will be part of the next release of the documentation. An ftp site currently in use for the USACE Restudy project contains a definition of the variables shown in Fig. 3.3.7. A demonstration of the entire Restudy WEB site will be made during the 2-day site visit.

86. P 101, definitions of LSEEP and GWIN. I infer that LSEEP does not include reservoir/aquifer interaction, and that GWIN does not include canal/aquifer interaction. Are these comparable to the Qls and Qus of Figure 2.4.1 on page 36? Does seepage only flow out from reservoirs and never into reservoirs in SFWMD? Is reservoir/aquifer interflow always in one direction and which direction is that? Is GWIN a source or sink of the groundwater flow system and equations, or is it horizontal groundwater flow? A picture might help.

ANS: Concur that a sketch may help facilitate the explanation.

87. p 103, Tab 3.3.8. Estuary pulse releases are mentioned. Please clarify what these are or where they are discussed in the report.

ANS: The discharges in a pulse release simulate a natural hydrograph pattern. The response of the receiving body would similar to that of a rainstorm in an upstream watershed. This release concept in conjunction with the normal tidal cycles allows the estuarine system to absorb the fresh water without drastic or long-term salinity flucutations. A pulse release is typically 10 days in duration with a peak discharge on day 2 or 3.

88. P 117, para 1. Please clarify any correlations between zones shown in Figs 3.4.9-11 and Fig 3.3.8.

ANS: Fig 3.4.9-11 are actual operating schedules which are currently used in practice. Fig 3.3.8 is conceptual - an idea proposed by a study for including injection of Lake water into an ASR (Aquifer Storage and Recovery) System.

89. p 124, definition of A beneath Eq. 3.4.1. Is seepage always into the canal from the aquifer? What are the consequences of always assuming that canal stage is at its minimum (canal bottom)? Doesn't this induce more error than the range of parameter changes invoked during the sensitivity analysis?

ANS: The canal stage being at its minimum does not imply that it is at the canal bottom. The direction of seepage between the canal and the aquifer depends on the

difference between the canal stage and the mean stage in the grid cell through which the canal passes through. The definition of floor elevation, is stated on the first paragraph of page 124.

90. Where is groundwater model parameter calibration discussed?

ANS: to be discussed

91. P 130, Eq. 3.4.3. What is the purpose of the K pan evaporation coefficient?

ANS: Refer to Appendix in (Neidrauer and Cooper, 1989) for details on the ENP-Shark Slough Rainfall Plan.

92. P 130, definition of q(t) below Eq. 3.4.3. If Q(t) is Qtarget(t), please use the subscript in the definition of q(t).

ANS: Q(t) is not the target. Q(t) could be better defined as the historical discharge into the Shark River Slough during week t.

93. P 135, item 4. Please clarify where the groundwater head is derived from in order to compute the interflow.

ANS: Reference to section on "Canal-Groundwater Seepage" pp. 34-35 should be mentioned here.

94. P 137, para 1. It would be helpful to briefly clarify how necessary volume is converted into necessary flow rates. This reader is left with questions concerning travel time and how long it takes for the canal volume to be converted into flows needed to supply downstream users. Also, please clarify whether this volume is the need for a single time step?

ANS: The mass balance referred to on page 137, paragraph 1 is done in volumetric units equal to cfs-day (note: 1 cfs-day =1.9835 acre-feet). Travel time is shorter than a day for canal water.

95. P 142, definition of seepi beneath Eq. 3.5.3. Please clarify that this interflow is also used in the groundwater flow equations. If some flows have different names in the groundwater flow and surface water volume balance equations, it would be helpful to have a table that shows all terminology.

ANS: The interflow term seepi is used in the groundwater flow equation. It is a component of the recharge term R (Eq. 2.4.3) and is described in greater detail in Section 2.4, specifically discussions

96. P 143, Eq. 3.5.4. Is it possible that instead of (i-1j=1 (Where I-1 is a superscript and j=1 is a subscript), what is meant is (ij=1, j 1 (Where I is a subscript and j=1, j(1 is a subscript?

ANS: O.K.

97. P 143, Eq. 3.5.4. If the "water required" might not always be deliverable, it would be more clear to use "desired" instead of "required". Is it true that the water required might not always be deliverable?

ANS: Water required might not always be deliverable. "Desired" would be clearer than "required".

98. P 143, Eq. 3.5.7. This equation is written such that for I=1, AVi = AVVOL. Is that what is intended?

ANS: Yes, that is the intended use: there is no prioritization of supply because there is only one outflow structure.

99. P 145, para 2, line 14. Some readers will think there is a difference between water requirement and water delivered. I suggest replacing "requirement" with "delivered".

ANS: Yes, the suggestion will be incorporated in the next release of the documentation.

100. P 149, Eq. 3.5.9. Please justify this equation. Normally one wants regression expressions that resemble some process. This expression is the product of three length units raised to potentially different powers. I would prefer a more realistically based expression even if its r-squared were lower.

ANS: In order to estimate water use in drought situations, it was necessary to modify the AFSIRS model to deal with situations where not enough water is available to meet full crop ET. In consultation with Professor Jim Jones of the Agricultural Engineering Department at the University of Florida, Peter Thompson and Professor Gary D. Lynne of the Food and Resource Economics Department at the University of Florida developed "The Modified AFSIRS Program for Drought Impact Analysis" in May, 1991. This program uses the Stewart equation, as described in FAO Irrigation Paper 33, Yield Response to Water, by Dooorenbos and Kassam. This equation can be written as:

$$1-(Yact/Ymax)=B*(1-ETact/ETmax) \qquad (1)$$

where: Ymax = maximum (unrestricted) yield;
Yact = actual (water restricted) yield;
ETmax = maximum (unrestricted) evapotranspiration; and
ETact = actual (water restricted) evapotranspiration.

As programmed by Thompson and Lynne, the modified AFSIRS model generates daily net irrigation requirements needed to achieve user-specified percentages of maximum yield, given specific climatic input (daily potential ET and daily rainfall) and user-specified input on soils, irrigation system type and efficiency and water management practices. The problem which equation 3.5.9 in the documentation

addresses is the estimation of realized ET, which can be converted to yield reduction, through algebraic manipulation of equation (1) above, given different combinations of irrigation rainfall and potential ET. The functional form used is a generalized Cobb-Douglas production function, a standard economic production function, where realized yield (as described by realized ET) is a function of the amounts of three inputs used (potential ET(energy) and two forms of water input, irrigation and rainfall. The coefficients b, c, and d represent the marginal products, respectively, of irrigation water (applied according to rules specified by the use in the input data set), rainfall, and potential ET. It is important to note that problems can arise in the naive application of this model. In particular, net irrigation and monthly rainfall were set to a small (0.01) positive value when observed or simulated values of 0 were obtained. Second, the equation is not used when water is not a limiting resource, that is when application of equation (3.5.9) would result in realized ET greater than crop specific potential ET.

references:

Lynne, G. D. and P. Thompson, (1991), Agricultural Field Scale Irrigation Requirements Simulation: The Modified AFSIRS Program for Drought Impact Analysis, Food and Resource Economics Department, Institute of Food andAgricultural Sciences, University of Florida, Gainesville.
Doorenbos, J. and A. H. Kassam(1979) , Yield Response to Water, FAO Drainage and Irrigation Paper 33, FAO, Rome.

101. P 170, para 3 or later in the section. Please clarify which parameters PEST was used to calibrate.

ANS: to be discussed

102. P 170, para 3 and bottom para, line 4. Are "irrigation requirements" the same as "desired irrigation amounts". Unless defined earlier, some readers will not know whether this is water that is being delivered or water desired (in time of water shortage they might differ). Similarly "water demand" and "water delivered" should be defined early in the report.

ANS: "Irrigation requirements" are the same as "desired irrigation amounts".

103. P 171, next to last paragraph. I am concerned that the product of two calibration parameters is being used. Too many degrees of freedom are permitted if one is calibrating fracdph_max multiplied by SOLCRNF.

ANS: to be discussed

104. P 171, next to last paragraph. What are the limits imposed on fracdph_min and fracdph_max?

ANS: to be discussed

105. P 171, next to last paragraph. Please clarify the physical properties expressed by SMAX and SMIN. How do these relate to field capacity, wilting point, or some soil suction value?

ANS: SMAX and SMIN represent the equivalent depths of the ratios fracdph_max and fracdph_min respectively. SMAX would represents desired maximum water content something less than saturation and SMIN represents a desired minimum water content something greater than the residual water content. SMAX and SMIN are management parameters.

106. P 174, Fig 6.1.4. Someplace earlier in the report I thought a statement was made that simulated and historical flows were within 1% of each other. That seems to disagree with what is shown for February.

ANS: The goal of 1% matching is desired to be met the majority (not all) of the time.

107. P 175, Fig 6.1.6. Some simulated monthly flows differ significantly from historical values. Please describe under what situations these large errors occurred.

ANS: to be discussed

108. P 176, bottom para, lines 3-5. This is a little unclear. It sounds as if you are only calibrating to the levels of the last day of the month. This is still a daily comparison, albiet only for one particular day out of 30.

ANS: See answer to question 3, in F. Ch. 6 Calibration, submitted by Dr. Wendy Graham.

109. P 177, para 1, item 2. Please clarify why volume constraints would prevent overland flow from being described as a diffusion process.

ANS: Hopefully, this will be clear in the oral presentations. There is no question that we are modeling the diffusion flow equations. However, the volume constraint used in the O/L flow routine is part of the numerical procedure in order to make it stable. What it creates is a smaller numerical error when compared to the explicit method, but an error nevertheless. This new form of "smaller numerical error" is interpreted as "non-diffusive flow". The actual fact is that any numerical error causes deviations of the flow away from the governing equations, and not just the error due to cut off.

110. P 180, line 6, last word. Is this a canal stage or groundwater stage?

ANS: The last word on `page 180, line 6 should change from "stage" to "groundwater stage".

111. P 182, para 2, line 2. The top line within Figs 6.5.3a and b indicate cell (27,26). That differs from the text which says the figures refer to cell (27,28).

ANS: The text should say (27, 26).

112. P 182, para 5, line 7. Why is aquifer parameter calibration not pertinent or discussed? Perhaps improved representation of canal/aquifer interflow might not be justified.

ANS: to be discussed

113. P 184, Fig 6.2.4. How close is this monitoring point to pumping well(s). What are the transmissivity, storativity and pumping rate(s)? What are the drawdowns at those wells? I have seen fairly small drawdowns near large pumping wells in the Biscayne Aquifer, and wonder whether the 8 ft difference between simulated and observed level is really due to pumping.

ANS: to be discussed

114. p 187, para 1. The impression I have before this paragraph is that the model was not being used to make detailed day-by-day operational decisions. The intent of model usage should be clarified early in the report.

ANS: We agree with the recommendation. The model does make operational "decisions" based on daily state variables; however the interpretationof model output is typically from monthly and sometimes weekly aggregations. Alternative suggestions are welcome.

115. p 187, para 2. Might iterating or cycling significantly improve accuracy?

ANS: to be discussed

116. P 187, para 3. Can you briefly mention what the drought policies were that might have induced the error? That way one would know what policies the model might not accurately represent. If the same policies might be implemented in the future, the model might be needed then. Can you recommend corrective actions that would improve model accuracy for those situations.

ANS: to be discussed

117. P 189, Fig 6.2.8b. Please explain the large errors or 1982-3, and suggest corrective action if justified.

ANS: Page 187, para 2 discusses the Fig 6.2.8b calibration results. The G-54HW canal stage calibration was included as an example of the limitations of the canal routing algorithm.

118. P 194, bottom para, line 3. Please clarify how many simulations were made to evaluate the range for each parameter.

ANS: to be discussed

119. P 194, bottom para, 2nd and 3rd line from bottom. Please clarify why you use much smaller ranges than the + 50% recommended by Trimble.

ANS: to be discussed

120. P 195, para 1. Please clarify how probability distributions functions were developed that the confidence values are based on. Were they were built using from the ranges of Table 7.1.1. What mean and variance values are used?

ANS: to be discussed

121. P 195, para 2, line 4. Please clarify which parameters are doubled and which are halved. In some figures the same parameter symbol may be above or below the zero line for different sites.

ANS: to be discussed

122. P 201, para 2. Please describe the proof that the parameters are well resolved, even if you are using the correlation matrix instead of an unseen resolution matrix.

ANS: to be discussed

123. P 206, para 1. Rather than using certainty bands and uncertainty bands interchangeable, why not be consistent? Also, wouldn't the term confidence interval be more widely understood.

ANS: We agree.

124. p 206, before item 1. Why is LECSA1 not discussed?

HSM: to be discussed

125. P 214, para 1. Please clarify whether this is based on calibration alone, or on post-calibration variation of parameter values about their best calibrated values.

ANS: to be discussed

126. P 214. I think this section belongs ahead of the parameter uncertainty analysis.

ANS: to be discussed

127. P 214, item 1. Please add another row to the tables to show the average values for the LECSAs.

ANS: to be discussed

128. P 214, bottom para, and Figs 8.2.1-8.2.5. These should be explained a little more. The confidence zones look like they are parallel to the perfect model rather than to the least-squares regression model. Is the intent to show that any point lying within the band has at least a 90% probability of being represented acceptably by the model?

ANS: to be discussed.