Everglades Landscape Model

Agency/public review of ELM v. 2.1a:
ELM developers' response to reviews

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http://www.sfwmd.gov/org/wrp/elm/

ELM Review: Table of Contents

Document format/notes

For a preliminary determination of the level of acceptance of the ELM for CERP application, the REstoration COordination and VERification (RECOVER) Model Refinement and Development Team (MRT) sponsored an inter-agency and public review of the ELM in fall 2002. On **Aug 7, 2002**, a day-long workshop was held to allow the ELM developers to review the ELM structure and performance, demonstrate access to (the web-based) detailed documentation, and answer questions from the participating agency and public representatives. Comments were due to the developers by **Sep 6, 2002**. On **Oct 2, 2002**, a day-long workshop was scheduled to allow the ELM developers to respond to and discuss the reviewers' comments and questions.

- Eight scientists/engineers from six government agencies responded with written comments/questions; 4 of the reviewers were from the RECOVER MRT.
- This document summarizes reviewers' comments and questions, followed by a summary of ELM developers' responses <u>for presentation and discussion at the **Oct 2, 2002** workshop</u>.
- The reviewers' comments/questions were briefly summarized and categorized into a topical hierarchy for this document
- Not all reviewers adhered to the "MRT model review headings" (http://www.evergladesplan.org/pm/recover/mrt_model_review.shtml) that listed categories of: Questions, Concerns, Model Limitations, Use of the Model, Critical Recommendations, and Non-Critical Recommendations; where possible, the ELM developers tried to infer appropriate categorization
- Some reviewers provided comments and questions on the performance to be implemented in a future version of ELM; a separate "Future model version" section was created to accommodate those comments.
- Within each topic, summaries of reviewers' comments/questions are followed by the reviewer's initials in braces {XYZ}
- The subsequent response is either to individual comments, or to groups of related comments as appropriate
- Full text of reviewers' comments is provided in the Appendix

The documentation section of the ELM website
(**http://www.sfwmd.gov/org/wrp/elm/**)
is the publication-of-record for the
detailed responses to reviewers

Executive summary

ELM objectives

The Everglades Landscape Model (ELM) is a dynamic, process-oriented, spatially distributed simulation tool to evaluate Everglades ecological dynamics. The current model version being reviewed (v2.1a) has been calibrated to effectively match the observed data on water stage and total phosphorus concentration in the water column at some 40 point locations distributed throughout the greater Everglades. Earlier versions of ELM have also demonstrated good calibration for various soil attributes, periphyton biomass & succession, and macrophyte biomass & succession. As such, it is also effective as an aid in synthesis of the complex spatio-temporal dynamics of the Everglades system.

The ELM v2.1a objective is to be available as a tool to evaluate hydrology and phosphorus water quality at the regional and fine scale for CERP[1] Projects, CERP RECOVER[2], and other Everglades Project evaluations such as CSOP[3].

Review objectives

This ELM review was initiated by the RECOVER Model Refinement Team (MRT) as part of a series of model reviews. The SFWMM is being reviewed concurrent with ELM. Plans for reviewing other regional models such as the ATLSS[4] suite of models are in development. The MRT will likely develop a consensus on the extent to which each model should be used in CERP design and optimization. This MRT review was conducted by agency scientists and engineers with broad expertise in various disciplines, and designed to provide constructive, not necessarily independent, assessments of the ELMs' ability to provide useful simulations of Everglades management alternatives.

Response: overall summary

The comments and questions submitted by eight reviewers provided valuable input from a spectrum of disciplines. The ELM developers have carefully considered and replied to all recommendations made by the reviewers. At least one reviewer made it very clear that the ELM is an indispensable tool for ecological assessments, while another reviewer made it clear that the ELM should not be applied in its current version. The majority recognized the critical need for a regional simulation tool like ELM, to evaluate ecological responses to restoration alternatives, and they approved of the ELM with reservations. Most questions focused on details of performance in specific locations, the efficacy of particular numerical approaches, and the use of input data..

<u>This document is designed to clarify all aspects of the ELM that caused concern for reviewers. Our replies include quantitative assessments of prior model runs, along with new model runs at a variety of spatial scales.</u> Although extremely constrained by time (some of our responses could be expanded), we believe that the full scope of the

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1 Comprehensive Everglades Restoration Plan
2 REstoration COordination and VERification
3 Combined Structural and Operational Plan
4 Across Trophic Level System Simulation

reviewers comments on this version of ELM[5] have been addressed. We demonstrate here that the ELM is an appropriate tool for the task.

Response: general/conceptual

We concur with most comments, particularly the positive ones such as "appears to work well to predict regional and sub-regional trends" or "is an indispensable tool", or "ready for application to scenario evaluation". Contrary to some comments, we feel that the water quality calibration is sound and indicative of ELM's utility for surface water quality assessments throughout the Everglades. We make the point that the strength of the ELM is that it is explicitly designed for the varied environments of the Everglades wetlands and it is not constrained by designs of "traditional" water quality models.

One reviewer felt that the calibration results of ELM captured the spatial and temporal water quality and quantity trends for a 17-year period when hydrologic extremes (droughts and floods) were observed.. Another reviewer took the opposite view and flatly stated that the ELM must extend its historical simulation from 1979-95 to include a 1996-2000 "validation", demonstrating its (continued good) level of performance. In actuality, no model of natural systems can be validated and we present modern modeling views of determining the level of confidence in model applications, and show that the wide range of environmental conditions under which ELM has demonstrated a high level of performance.

We concur with reviewer(s) who would like to see an updated, multi-scale sensitivity analysis that we undertook on an earlier ELM version. This, and related uncertainty statistical evaluations, will provide ELM users with enhanced understanding of its utility. This was not expressed as a "Critical recommendation", and we concur that such analyses are highly desirable, but not absolutely essential to preclude the application of ELM in its current form.

There were policy concerns regarding the staffing level of the ELM team, wondering if the ELM had adequate resources to meet all of the goals. While an increased pool of experts to work with ELM would accelerate further refinements (in vegetation succession and other performance measures), we have a fully developed tool, with robust automated "post-processing" and web-posting routines that can turn model applications around very rapidly, even at our current staffing levels.

While some reviewers were very complimentary on our extensive web-based documentation that covers virtually all aspects of ELM, one reviewer expressed (not as a Critical Recommendation) concern that more documentation would be beneficial. We concur that we should ensure that every feasible aspect of the ELM should be transparently documented.

Sufficiently accurate data on boundary conditions is a concern of most models. While some short periods of time have less model accuracy than others in some locations, the demonstrated regional calibration performance, along with the variety of subregional model tests we have conducted, provided strong evidence that ELM responds appropriately to a variety of external forcings.

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[5] Time ran out before we could address a handfull of reviewer comments on aspects of the ELM capabilities that will be available in future versions.

Response: algorithms

It may be inferred that the reviewers felt that the ELM generally had appropriate algorithms relative to its objectives. However, while one reviewer deemed the model algorithms capable of providing a "good understanding of the Everglades at the ecosystem level", another reviewer said that the ELM needs a lot of work to be useable. Questions were raised whether the ELM had numerical dispersion errors in its fluxing routines for nutrients in surface water, along with related concerns regarding the predicted velocities.

Because numerical dispersion is explicitly associated with spatio-temporal scale of the model, we developed three (100, 500, 1000 m) scales of implementation for a short-term, worst-case model "stress test". From these scaling evaluations using a conservative tracer, and long term simulations of tracer and phosphorus distributions, we concluded that numerical dispersion did not introduce significant biases to ELM results. Flow velocities are consistent with available information on water budgets and nutrient gradients, though we do not have the measured velocities or tracer observations for direct verification.

One reviewer had harsh criticisms of two particular algorithms used in ELM hydrology: calculation of ET and Manning's n. We demonstrated that, rather than being "archaic" and lacking a south Florida basis, these (published) algorithms represented innovative responses to particular needs of this regional model, and are fully supported by recent advances in research results.

We feel that the algorithms in ELM "are in accord with the best understanding of what the major processes are in a typical wetland ecosystem", as one reviewer put it. There were a number of questions asking for clarification on some algorithm dynamics (to which we replied), and some questions that were actually related to outdated (published) routines in earlier versions.

The ELM is truly innovative, being an ecological simulation that fully integrates dynamic hydrology, biogeochemistry, and biology of a complex system across a heterogeneous landscape.

Response: data

A reviewer questioned whether the ELM uses time-varying concentrations in boundary condition inflows. We presented the method employed to do so for CERP project evaluations, but are interested in using DMSTA output when available.

There were significant concerns on the number of parameters used in ELM, and the ability to support those parameters with data. We discussed the manner in which the ELM was designed specifically to incorporate the basic processes responsible for general ecosystem dynamics, constraining the mechanistic level of detail to match that for which field and lab studies were available or pending.

There were questions on the vegetation and soil mapping data that are in use by ELM. These data are the best available, and appear to properly represent the characteristics of the landscape at the spatial grain of the ELM.

Adequate data on boundary conditions are always an issue with simulation models. We have made every effort to ensure quality in those data, and are making use of improved data sources as they become available. The ELM performance shows occasional periods when the model does not match observations, but the overall performance indicates the model can be applied to evaluate alternative management scenarios.

Review of current model version

1. General and/or conceptual topics

1.1 Critical importance

1.1.1 Appropriate use of ELM: comments

a) The model appears to work well to predict regional and sub-regional trends and as a means of comparing alternative project features. In some areas the model fails to predict high phosphorus peaks, which may be explained by poor boundary information. {MC}

b) The ELM is an indispensable tool for understanding the main ecological processes of production, decomposition, and material flows that occur in the Everglades. The model, being mechanistic and process-oriented, is the right type of model for its task. Only the careful accounting of mass balances and incorporation of the causal mechanisms in a model framework can provide the basis for understanding the system and the possibility for making predictions concerning the consequences of external perturbations. The other major type possible type of model for this application, an empirical regression model or set of models, would be of limited usefulness.{DD}

c) I think there is no doubt that ELM at this stage is ready for application to scenario evaluation. As with any model, output needs to be viewed as a possible projection of what may happen in the future, subject to uncertainty, not as an absolute prediction. {DD}

d) Testing and improvements on ELM should certainly continue. Active application of the model will accelerate ELM's comparisons with data and continued improvement. {DD}

e) Would like to know which leaders of CERP PDTs have targeted ELM as a tool to be used, and are they providing comments to the ELM review. This is important step to determine if ELM is appropriate for a project. {MH} We need to have a list of all CERP and non-CERP applications, by project, that will be requiring ELM modeling support, including total effort (e.g. man-months) for each anticipated modeling effort. {MW}

f) It is extremely doubtful that the currently-calibrated ELM can predict current or future conditions in the southern Everglades. The marl prairies and rocky glades do not fit the assumptions made for soils in the northern system. The differences in soil physics and chemistry argue strongly against transferability. {RK}

g) ELM is not a traditional water quality model, lacking major features that typically are included in water quality models, while including other features. These additional ELM features complicate calibration and raise calibration issues that would not normally be addressed in water quality modeling. These combined facts may reduce peer acceptance of ELM as an adequate tool for water quality planning and management. {MW}

Appropriate use of ELM: response

Response to a-d):

We agree that the performance of the ELM is more than sufficient for applications to evaluate water quality responses in the greater Everglades, and will continue model refinement for simulations of ecological processes across the landscape under widely varying conditions.

Departing from more limited (spatially and temporally) statistically-based models, an important aspect of the ELM design is the degree to which we have incorporated ecological (incl. hydrology) processes or mechanisms into the fully integrated algorithms which describe the emergent properties of the Everglades ecosystems across the region and over decadal time scales.

Response to e):
Project requests[6] for ELM applications (ordered by ~date of initial simulations):

CSOP (Modwaters/C111): (fall 2002; 1 –2 year alternative evaluations)

> The CSOP interagency team is finalizing the model performance measures, including expectations of using the SFWMM, NSM, ModBranch, ELM, and ATLSS. While the schedule and staff-time requirements are also being finalized, it is anticipated that the ELM will be required for water quality/ecological analysis of all runs produced by the SFWMM over the course of more than one year[7].

CERP: RECOVER: Initial CERP Update (fall 2002; 1 month evaluations)

CERP: Decompartmentalization Project (fall 2002; 1 –2 year alternative evaluations)

> The Project Management Plan (PMP) for the Decompartmentalization project (DECOMP) lists a number of models and Habitat Suitability Indices that will be used to evaluate alternatives. ELM is considered an essential component of the DECOMP project by the Project Deliver Team (PDT) because it is the only calibrated, ecological landscape model that attempts to capture oligotrophic, subtropical biogeochemical processes. The PMP for DECOMP estimated a 12 man-month ELM development period and a 12 man-month ELM implementation period.

CERP: C-111 Spreader Project (fall 2002; 1 year alternative evaluations)

CERP: L-31N Seepage Pilot Project (fall/winter 2002/03; 1 year alternative evaluations)

CERP: RECOVER: Programmatic Regulations (spring 2003)

Florida Coastal Everglades LTER[8] (spring 2003)

CERP: ASR (2005)

Response to f):
One reason we are not providing ELM regional performance measures for soils, macrophytes, and periphyton is the uncertainty associated with ELM performance relative to soil processes in the southern Everglades. Many parts of this region have low(er) organic content than the northern/central Everglades. While areas in the latter region have a long history of research and enhanced ecological-process understanding, the same level of understanding has not applied to the southern region. Until, perhaps, more recently, where a variety of projects (Noe et al. in review) (Jones et al. 2000, Newman et al. 2002) and expanded monitoring have provided critically important data that we are attempting to collate and synthesize for use in the ELM1979-2000 update.

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[6] Does not necessarily indicate a definitive acceptance of ELM for application

[7] Due to the intensive time committments for the ongoing MRT ELM review, the ELM team members have not been participants in the most recent CSOP model team meetings and do not have up-to-date details on schedules

[8] Long Term Ecological Research site, funded by National Science Foundation. H.C. Fitz and F.H. Sklar are formal Project Collaborators; see http://fcelter.fiu.edu

There is an important linkage between soil processes and the eutrophic/oligotrophic status of the surface waters, and ELM is the only simulation tool that explicitly integrates hydrologic and ecological processes in the soil, live plants, and water column. Using an earlier version 1.0 that has lower performance capabilities compared to v2.1, we have demonstrated the capability of the ELM to capture landscape drivers in these ecological units along eutrophication gradients in the northern Everglades (Fitz and Sklar 1999). The ELM explicitly uses bulk density of soils to determine the total available organic carbon and phosphorus, which influences the model's phosphorus sorption and mineralization dynamics. Calcium and carbonate fluxes are not incorporated, and we are evaluating the degree of complexity of additional algorithms, if any, that may be necessary to best reflect marl soil properties and their effects on nutrient cycling.

These soil-water column couplings are apparent and important for any wetland system[9,10] . The beauty of using the ELM approach for the southern Everglades is that despite the lack of an exact parameterization for the southern habitats, the calibration indicates that the processes are probably the same as in the northern wetlands. In other words, the ELM's existing dynamic equations/data effectively simulate AT LEAST water column TP transport and fate throughout the Everglades

Response to g):

It would have been helpful if the reviewer had listed the features that are lacking in the ELM that would tend to reduce calibration issues. We believe that even "traditional" models will have as many, if not more, calibration concerns. The design of the ELM was carefully considered from the outset, relating the objective to minimize model complexity with that to maximize ecological utility. It should be noted that ELM does not ignore previous water quality models. A thorough investigation of all approaches was performed early in the ELM development process. In fact, ELM incorporates many "traditional" algorithms. The difference is that ELM combines them with process-based algorithms that are known to be important to Everglades structure and function.

One of the major strengths of the ELM is that it goes beyond most "traditional" water quality models, with objectives of evaluating ecosystem processes across a regional landscape. "Traditional" water quality models come in many flavors and sizes, and, as with all models, have a wide range of uncertainties that need to be addressed relative to the objectives of their application. In particular, the wetlands of the Everglades (and elsewhere) have a variety of characteristics – such as intermittent wetting and drying of the habitats – that introduce complexities that are generally not well-treated in "traditional" water quality models. As this (and other, RK, DD) reviewer(s) noted, there are no other models that can meet the objectives of evaluating water quality (and particularly periphyton and vegetation) responses at the regional, decadal spatio-temporal scales that are operating in this heterogeneous Everglades landscape.

Understanding the process-based responses of the ecosystem(s) that result in changes to the habitats' structure (and function) is an ultimate goal of the ELM. Two very critical drivers of this landscape are hydrology and nutrient transport and cycling (or "water quality"). We are presenting this regional "water quality" functionality in ELM as an important component of the spectrum of ecosystem dynamics across the landscape. The ELM is a truly integrated model with respect to its basic ecological (hydrology, biology, chemistry) objectives. It is certainly true that other chemicals and toxins may be of significant interest for various objectives; we want to ensure that we meet our current objectives prior to investigating other important issues such as pesticide or mercury dynamics.

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9 http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/concl_content.htm

10 http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/tp/tp_ptser.htm

1.1.2 Calibration/validation: comments

a) Having been a reviewer of other major models (e.g., EPA's AQUATOX, NPS's Rocky Mountain National Park Elk-vegetation model), I find the methods used here to compare favorably with these other models. In fact, although it's difficult to compare models that have different objectives, I think that the care in systematic calibration and testing in ELM go beyond what I have seen for other models. My overall impression is that the uncertainties in ELM for key variables are smaller than those in AQUATOX. {DD}

b) No model of a complex ecosystem can take into account all of the processes that occur, or all of the spatial heterogeneity. There is much that is unknown, difficult to quantify, or too complex to represent. Therefore, approximations and, in some cases, guesses, have to be made. It appears that the authors of ELM have done a highly professional job of making a model that contains the right level of detail. Despite many legitimate difficulties, they are succeeding in calibrating and validating the model over a substantial area. {DD}

c) The calibration results for the earlier ELM version 1.0 follow empirical data on spatial trends very well. ELM Version 2.1 has been calibrated for hydrology and surface water quality at 40 monitoring locations across the Everglades. {DD}

d) While it is true that the developers' claim that "reasonable" choices of the exceedingly numerous parameters produced a "pretty good" fit of hydrology and water column phosphorus, there are certainly many other parameter combinations that would also produce a good fit. The complex ELM structure and its calibration cannot be trusted to provide "reasonable" forecasts for other sets of driving forces, and it is necessary to validate the model using the 1996-2000 data (with P reductions due to BMPs and STAs) <u>ELM can not be trusted</u> for forecasting for conditions outside the calibration envelope {RK}

e) The model needs to be updated with the '96-'00 water years in order to match the SFWMM calibration/validation period of record. {GB}

f) ELM needs to report bias, RMSE, efficiency, and r^2 not only for concentration, but also for proposed CERP performance measures. {MW}

Calibration/validation: response

<u>Response to a-c):</u>
We agree with the opinions expressed in this section. The calibration results indicate that the ELM captures the spatial and temporal water quality and quantity trends for a 17-year period when hydrologic extremes (droughts and floods) were observed for most of the Everglades.

<u>Response to d):</u>
We strongly disagree with this comment and the philosophy that a validation process is required to demonstrate the utility of the ELM. Validation is no longer considered the most credible way to evaluate model performance (Kleindorfer et al. 1998). "Verification and validation of numerical models of natural systems is impossible" (Oreskes et al. 1994). Logically, aka (Popper 1959), this appears to be true. Others (Konidow and Bredehoeft 1992, Beven 1993, Rastetter 1996) agree. In our opinion, we do not *have* to validate the ELM. To build confidence in the models' utility we only need to demonstrate that it performs in a manner consistent with objectives. A major utility of process-based models such as ELM is in synthesis of accumulated knowledge. Through this synthesis, we gain understanding of the system. And develop a self-consistent synthesis of the complex interactions in the bio-physical-chemical landscape (Rastetter 1996). With increasing knowledge of the system,

and increasing confidence in the model performance for particular objectives, we can think about making projections of potential ecological (or hydrological) responses to external change. But models of complex systems – whether they are simple black-boxed numerical interpretations such as the DMSTA, or complex numerical interpretations such as ELM, SFWMM, ATLSS models, Global Climate Models, – are not going to be "accurate" predictors of the future. These models still can be credible tools for evaluating potential scenarios of change. A credible, if imperfect, model is far better than reductionist "best guesses" when embarking on complex system changes – such as the restoring the Everglades, or ameliorating CO_2 increases in the atmosphere.

Very important for achieving credibility of a model is the demonstration of sufficiently high levels of performance under a wide range of conditions (external and internal). The longer the time scale over which observations are available for comparison, relative to the predictive time scales of the model, the more credible the model. We are in the process of acquiring and compiling 1996-2000 (and later) data to "validate[11]" ELM, or preferably, further demonstrate the credibility of this model as a potential forecasting tool. Most valuable for enhancing credibility would be the introduction of some suite of very different external inputs than those observed in prior years.

To demonstrate the inadequacy of a validation process, we used WCA-1 as an example of annual differences in P inflows during the 1979-2000 period. During the 1996-00 period, some STAs starting come on-line, Best Management Practices became reasonably effective, and observations show some reductions in TP concentrations (Figure 1) flowing into the Everglades. Phosphorus loads did not appear to have any dramatic decrease, and appear reasonably consistent relative to many of the years in the 1979-95 POR, both in terms of daily variations (Figure 2) and annual total loads (Figure 3). It certainly does not appear to contain significant departures from the 1979-95 period in terms of phosphorus or hydrologic dynamics. So even when an update indicates consistent levels of model performance, the process in itself does not sufficiently dictate "trust" in the model reliability. In actuality, this '96-'00 upgrade is merely a part of the process of refining a model: synthesizing new research and enhancing the model performance relative to objectives.

An important part of a model evaluation is how effective the code logic is, and how effectively it is parameterized to meet the performance goals. A reviewer pointed out that there could be other combinations of parameters that could provide a good model fit for TP concentration in the surface water. Indeed, with any model with a few parameters can have more than one combination of parameters to achieve a same/similar statistical fit of the model to observed data for one particular target variable. Fine tuned parameter sets for model calibrations are never unique (Spear 1997). It is likely that another combination of parameters could be found that will result in comparable performance of ELM predictions of TP concentration in the water column. However, in our testing of the model performance to different parameters, we explicitly evaluate more than just a single target variable to ensure that other components of this complex, interactive system remain within targeted boundaries. It is highly impractical to prove that no other combination of parameters could achieve the same result in a model such as ELM. It is more important to evaluate whether the proper mechanisms are responsible for model predictions. It should be noted that, spatially distributed models (such as ELM, SFWMM, etc) as a class have more parameters by definition than lumped, non-distributed models that treat heterogeneous space as one homogenous entity.

Recently there has been significant discourse on what is truly meant by "model validation", and the means by which to communicate the level of trust in the application of a particular model. Model validations include both conceptual validity and operational validation (Rykiel 1996, Parker et al. 2002). Conceptual validation checks if the theories, hypothesis,

[11] sensu the reviewers use of the term

assumptions, system structures and processes underlying the model are sound and justifiable. ELM has received favorable conceptual validation comments overall (see Appendix). Operational validation tests how well the model mimics the system. It does not, however, guarantee that the mechanisms contained in the model are scientifically complete and correct (Rykiel 1996). To re-iterate, we argue that it is impossible to validate models because the natural system is open and constantly evolving (Oreskes et al. 1994, Rastetter 1996, Oreskes 1998, Haag and Kaupenjohann 2001). As previously indicated, a simple dictum is operative: Models can only be falsified; they cannot be validated (sensu Popper 1959)..

Despite this discourse on the logic associated with traditional validation, we will in the relatively near future, conduct an evaluation of ELM output using the new 1996-2000 data. Immediately upon completing the 1996-2000 "validation" tests of ELM water quality using new boundary condition data, we will then 1) update ELM with new spatial data such as topography, soils, and vegetation attributes that were acquired since 1996; 2) modify process-related parameters to take advantage of insights from new process-based research; 3) incorporate new code such as fully dynamic stage boundary conditions (in cells along the model domain border). Because of these careful changes, we expect to enhance the performance and match of the model to observations. However, this updated version will no longer be valid in the strict sense of unchanged models tested against ever-increasing extents of boundary conditions. Instead, we need to evaluate how consistently the model performs under an increasing range of conditions; adding 6 months, one year, or five years to a model's Period of Record does not necessarily enhance credibility. Most important to enhanced model credibility is a demonstration of consistent, unbiased performance under very new boundary condition forcings (such as the 1994-95 high water years, or 1990 drought and associated changes in flows and loads).

Models are used to provide synthesis, reveal system properties, and outline system behavioral possibilities (Joegensen et al 1995; Rastetter, 1996; Haag and Kaupenjohann, 2001). It is the communication with model stakeholders that is essential to effect model validation and conformance with its intended purpose and performance criteria (Korfmacher 1995, Kleindorfer et al. 1998, Parker et al. 2002). ELM will be constantly updated and evolve, but it will not be "validated" under all conditions.

Response to e):
Agreed. The post-1995 period saw dramatic increases in research results that greatly increased our understanding of the landscape, and will be greatly advancing the state of the ELM performance. Prior to modifying other data (such as parameters, topography, others) and code, we will be extending the Period of Record (POR) of the ELMv2.1a and demonstrate its performance. We are finalizing the QA/QC procedures for preparing the time-varying boundary condition flows, TP concentrations, and meteorology for application to this extension of the ELM historical POR (from 1979-95 to 1979-00).

Response to f):
Good point. Most modelers report the uncertainty associated with the major state variables of their models. We have documented the R^2 and RMSE for stage calibration[12], annual mean and variance estimates for model & observatons for TP concentration[13], and fine-scale visual time series plots for both calibration variables[14]. We have expanded upon those techniques to include model-observation sensitivy and cross correlation analyses, with examples shown in Figure 4 for stage data. This analysis will be completed for all stage calibration points, and and these methods, including spectral analyses, may be useful for the (albeit more limited)

[12] http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/hyd/graphics/HydCompStats.pdf
[13] http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/alt.htm click on Example variability plots
[14] http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/ptser.htm

sampling frequency of water quality data. It was never our intention to focus RMSE and other measures of variance solely on concentration and stage data. Documentation for ELM will quantify (to the extent possible) uncertainty of modeled soil and plant mechanisms such as decomposition, accretion, and photosynthesis, as well as state variables such as plant biomass and soil TP. For the ELM to have significance for CERP beyond water quality it will need to be evaluated within the context of Performance Measures, including those for periphyton, fish, cattail, tree islands, flows, and soil quality.

1.1.3 Model uncertainty analysis: comments

a) Combined uncertainty of hydrology and phosphorus dynamics could translate into inability to evaluate water quality with ELM. Example is the handful of times that ELM underpredicts stage over 17 calibration period in WCA-1: if used as a forecasting tool, ELM would classify these periods falsely as too shallow to be sampled for P compliance criteria. {MH}

b) Need to repeat the sensitivity analysis that was performed on a very early version of model, particularly with respect to level of sensitivity of model relative to performance measure objectives. {MH}

c) Will you do any sensitivity analysis relative to the choices made as to the variables and parameters selected for vegetation modeling in the southern and central Everglades areas? What independent data sets will you use for sensitivity analysis and model calibration and verification? {TA}

Model uncertainty analysis: response

Response to a):
No model will have perfect predictions at all points in space and time. Actually, the combined uncertainty of plant uptake, biomass accumulation, ET, groundwater-surface water interactions, etc. all account for the uncertainty in a landscape model such as ELM. Models, like ELM, attempt to capture whole system dynamics because the "whole is greater than the sum of its parts." The value of a larger perspective is the very complexity that adds to its uncertainty. The interactions, linkages, and feedbacks of ELM are critical to understanding water quality trends. The cost of a larger perspective is the combined uncertainty. This occurs as occasional under or over predictions. Don't look for exact concentrations at all times and locations in this, or any model.

Response to b):
We agree that a repeat of the sensitivity analysis that was performed on an earlier version[15] is needed. We are planning a more detailed, multi-scale analysis prior to and after the v2.1 update. We expect this to shed light on uncertainties, dependencies, and options for management. This analysis will provide insight into the modeled system and uncertainties, but will not alter the value of the water quality predictions of v2.1a.

Response to c):
The sensitivity analysis is not designed to evaluate alternative model structures, but explore the behaviors of the current structure. The choices that were made on the type and number of state variables is simply a matter of how we conceptualize the Everglades from a systems ecology perspective. A more specific alternative structure is needed for a more detailed response. However, the values of these state variables and their associated parameters are suitable for a sensitivity analysis (see reply above). The sensitivity analysis does not need independent data; classical "validation" (sensu above section) requires data independent of

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[15] http://www.sfwmd.gov/org/wrp/elm/pubs/sensitivity.htm

those used in calibration. Please see "Calibration/validation response" section above for discussion of this important topic.

1.1.4 Model extent & boundary conditions: comments

a) Every effort should be made to update the model so it can accept dynamic boundary conditions. {GB}

b) Every effort should be made to expand the model extent to cover all natural areas in the Everglades system. {GB}

Model extent & boundary conditions: response

Response to a):
Much of the code is written to do so, for boundary conditions from models at any scale.

Response to b):
Pending analysis of pre-CERP boundary conditions (re. hydrology and nutrients), the next version will extend into most of the Model Lands; it is unclear whether the BCNP northern boundary of ELM necessitates a change.

1.1.5 Policy: comments

a) The decision by the CERP partners to not pursue development a more traditional regional water quality model may have severe consequences on the validity of CERP decisions, future adaptive management, and on our ability to defend CERP decisions to stakeholders and taxpayers. Development and calibration of a (non-ELM) "traditional" Everglades water quality model would not be easy, and I do not know of an off-the-shelf model that would fulfill CERP needs. But selecting ELM as our regional water quality model requires a level of commitment (money and manpower) beyond that which would have been required if a more traditional water quality model were selected. ELM could serve many of the water quality modeling needs of CERP, and might prove itself capable other valuable analyses that would not be provided by traditional water quality modeling. {MW}

b) A major commitment is needed to build ELM into a useable tool for water quality decision support. The ELM is far more complex and ambitious in its scope than the SFWMM, but staffing levels supporting the SFWMM are far greater than those allocated to ELM. Current and planned effort levels allocated to ELM development are inadequate. With dramatic increases in resources, ELM might be ready for credible project evaluations in as little as 18 months. {MW}

c) Three policy paths are offered: 1) continue ELM at current resource level; 2) continue ELM at current resource level, and initiate a new "traditional" water quality modeling effort (that could fail to produce model adequate for CERP); 3) provide increased resources to ELM. Option 1 is unacceptable. Alternatives 2 and 3 likely would require similar investments of human resources. At this time, I would support either alternative 2 or 3. {MW}

d) I am vitally concerned that there are not adequate resources being provided to support the level of modeling effort that will be required to support CERP decision making and project design. [MW indicated that a table, not in the review doc, be a starting point for project resource needs evaluation] {MW}

e) <u>The current version of ELM is probably the preferred starting point</u> for development of a trustworthy model. There are many features that are very good for the intended purposes; probably more so than any of the existing competitor models. Rather than continuing to "review" ELM, it would be preferable to immediately embark on the necessary fixes. Commitments of manpower are needed, above and beyond any plans I have heard for the near future {RK}

Policy: response

Response to a):

There is no standard, traditional approach for modeling water quality for oligotrophic, subtropical wetland systems. The reviewer may be referring to a number of well-calibrated, lake pollution models. However, there is no logic to the assumption that ELM is naturally inferior to some other type of water quality model. In fact, we would argue just the opposite. Water quality models for lakes and open water systems may produce even more “severe consequences on the validity of CERP decisions, ” because of the use of inappropriate assumptions. If, for the moment, we assume that there is a less expensive “traditional” water quality modeling approach, then we would still recommend using ELM for CERP because: 1) it provides the framework for predicting vegetation succession (not something found in more “traditional” models), and 2) it provides for the integration of new environmental data and findings (something required for the CERP Adaptive Monitoring and Assessment Plan). This multi-functional framework may be considered by the District and ACOE as justification for an increase in “level of commitment.”

Response to b):

Since the ELM is already a useable tool for water quality decision support, no new “major commitment” is needed. However, we agree that the ELM is a lot more complex than the SFWMM and receives less staffing support than the SFWMM. We appreciate this concern for current and planned level of support for ELM and agree that implementation of ELM for CERP, Mod Waters, C-111, operations, 404 Permit, and others will require some new or some re-allocation of resources.

Response to c):

The purpose of this review is to evaluate the ability of ELM to predict water quality as a function of hydrological alteration. Budget and resource information for the last ten years of ELM development was never provided to this panel. It is difficult to understand how any of these three approaches can be substantiated at this time. However, to venture our personal opinion, option 1 will produce water quality data in a timely manner; option 2 will not produce a new model in a timely manner; and option 3 may produce ELM predictions of vegetation succession and soil quality in a timely manner.

Response to d):

As stated above, current funding is adequate for water quality and quantity. Additional resources may decrease the time needed for complete implementation.

Response to e):

The features that are trustworthy and very good are the very features that make it applicable for CERP and better than anything else. Although we agree that commitment to manpower is essential for further development and “necessary fixes,” we do not agree that continued reviews of ELM are not necessary. Internal and external reviews of District science is an important policy to continue to maintain high quality products and improvements.

1.1.6 Other: comments

a) Critical Recommendations: None – This model has a tough job to do. {MC}

Other: response

Response to a):

A tough job, but we're doing it (and still manage to smile!).

1.2 Non-critical importance

1.2.1 Calibration/validation: comments

a) Would like to see calibration of model along the "F" transect of the nutrient gradient in WCA-2A. {MH}

b) There are periods of time during which ELM predicts lower concentration in the length of the North New River Canal (Reach19 in ELM) than observed at the S-10A-D structures. How much of this is attributed to the ELM using a canal flux algorithm that assumes homogeneity along the entire reach? How might this translate into P levels in the water column in the marsh long those 2A transects? {MH}

c) ELM may be at a level 3, approaching 2 [define] with respect to water quality, but calibration may need to be at a higher resolution for locations such as this in order to have confidence in using ELM for specific projects. {MH}

d) Is there any way to compare parameter values between ELM and DMSTA? For example, is there an analog to c* in ELM? Can you calculate the fraction of P in accreted plant material permanently lost to peat accretion? {MW}

Calibration/validation: response

Response to a):

Most extensive sampling along this gradient started in 1995-96; we will show full model performance in ELM v2.x. However, the improved performance of ELM 2.1a relative to v1.0 (Fitz and Sklar 1999) can be seen in this example of the ELM-WCA2A implementation[16] Figure 5. While the earlier version significantly overestimated TP close to the inflows, the v2.1a is much more consistent with the trend along the gradient.

Response to b-c):

The homogeneity of canal reaches is potentially part of the occasional underestimates of TP concentrations that are observed in this specific location; other reasons are boundary conditions (from S-5, S-6). We have minimized numerical dispersion that would emanate from long, homogeneous canal reaches by partitioning them with "virtual" structures that reduces the length (volume) along which a constituent (tracer or nutrient) is assumed homogenous (completely mixed). Selection of this segmentation by virtual structures is based upon the best professional judgement regarding path lengths of flow and model performance relative to hydrology and constituent flows. There is a practical limit on the number of sub-reaches that are effective in this empirical approach to canal segmentation. The ELM at $1km^2$ resolution is appropriate for evaluating ~1km gradients. As shown in later portions of this review response, the model can be rescaled for specific objectives (given adequate staff resources).

Response to d):

Given that the DMSTA parameters are statistical representations of the entire (biotic and abiotic) ecosystem within a two-way black box (into and out of soil), there are no equivalent grand parameter aggregations in ELM process-related parms. We have no plans to sacrifice the ELM generality and applicability to the varying soil and vegetation attributes across system by using such an approach. We are under the belief that the DMSTA performs well

[16] In the past we have used the acronym "CALM", or Conservation Area Landscape Model for this ELM-WCA2A implementation. We have sufficient meteorological and flow data to run this implementation through 1996.

for its objectives, and hope to use the DMSTA output for ELM boundary conditions from STAs. With a different set of objectives, the ELM goes beyond water quality to simulate interactive dynamics of nutrient cycling, hydrology, vegetation and periphyton. ELM and DMSTA results, however, can be compared through aggregated ELM response variables. For example, ELM P budgets track input and output from a variety of live and dead P storages.

1.2.2 Model documentation: comments

a) Excellent on-line documentation. {MC}

b) The documentation is (by necessity) not absolutely complete and doesn't account for every detail that is probably in the model. {DD}

c) As with any model that is used by a large number of individuals, the ELM needs to have comprehensive documentation including a user's manual and a programmer's manual. An adequate peer review of the model or its applications will not be possible until acceptable documentation is available. {MW}

d) Do you follow procedures for model code and model input data self-documentation (commenting)? Is there a prescribed style for commenting procedures for code and for data? Do you maintain a list of known bugs? {MW}

e) How are locations specified in model input? By cell number or (preferred) by some geographic location? {MW}

Model documentation: response

<u>Response to a-b):</u>
We strove to produce the most thorough, detailed, publicly accessible model documentation for south Florida models via our web site; some details remain to be added to the complete documentation.

<u>Response to c-d):</u>
ELM is not <u>currently</u> intended for application by any individual other than the developers. As needs/requests arise, and with adequate staffing levels to provide enhanced training opportunities, we can aid other agencies in proper use of ELM code and data. We provide sufficient documentation in the code for interested parties to understand the code intent and function. Importantly, we also provide pseudo-code that is automatically generated from UnitModel.c code, and pseudo code for other dynamic spatial modules. We have invested very significant efforts in producing databases (and spreadsheets) that document the parameters and research that supports those parameters. All ELM input data is fully supported by metadata; output data have embedded metadata or links to files that describe its properties (i.e., linked metadata). We don't have a list of non-existent (smile) bugs. Geographic locations in input files are: 1) in UTM NAD 1927 coordinates for the canal vector data file (& GRASS GIS) that is used by any scale application of the model; 2) in UTM NAD 1927 coordinates for point locations of water control structures, with a relational database that generates the row,col grid cell locations for models at any scale.

1.2.3 Boundary Conditions: comments

a) Given that vegetation coverage is constant/static for the duration of a water management model period of simulation, and the ELM is anticipated to allow for dynamic vegetation coverage over the period of a simulation, how sensitive are stages and/or flows predicted by the ELM to imported flows? For example, if over the duration of an ELM simulation, vegetation types/densities downstream of one or more structures are predicted to change, would the flows predicted by the water management model for those structures be any different if the predicted change in vegetation were fed back into the water management model?{SK}

b) Are errors in phosphorus predictions attributable to lack of reliable volume (flow) calculations in model? Have volume sensitivity tests been done? {MC}

c) Have the algorithms [in general?] been calibrated at sites that have controlled boundary conditions? {MC}

d) Are there plans to make the ELM compatible with the HSE model? This is complicated by the difference in spatial grid structure. How difficult is it to transform ELM to a random triangular grid structure? {MW}

Boundary Conditions: response

Response to a):

At this time only the habitat type is static. Vegetation biomass does increase or decrease with changes in water quality and hydrology. As a result, even in this version of ELM vegetation changes - particularly over long time scales and broad spatial extents – can have direct and indirect effects on hydrology. However, at this point in ELM model performance (under the calibration period), the vegetation effect on hydrology appears to be mostly local in scale, and does not appear to have significant effects on availability of water for flows through structures[17]. It is possible that some small differences in stage between the ELM and the SFWMM are due to local vegetation effects. It should be noted here that we have the option of running hydrology without dynamic ecology by deselecting all ecological modules in the runtime script, thereby evaluating the indirect influences of vegetation at certain times of the year and at particular locations..

Response to b-c):

Deviations of model predictions from observations can result from a wide variety of model dynamics, and flow velocities (volumes) are one such potential source of error. Calibration and sensitivity tests to a variety of conditions are our primary tool for estimating uncertainty at this point in time of model refinement/development. As tracer and/or in-marsh velocity measurements become available for the ELM historical(calibration) POR (as occurring with the addition of 1996-2000 POR), we will be validating or modifying the choice of parameters even further (after our “validation” or extended model performance evaluation). We have used the ELM-WCA2A implementation extensively in model testing: a primary advantage of this multi-scale implementation is the controlled boundary conditions.

Response to d):

We have had numerous internal discussions with our colleagues developing the HSE[18], and the ELM and HSE teams have expressed a long term goal of ELM integration with HSE. The HSE and ELM developers have the immediate goals of producing high performance models for applications. Many, but not all, “hooks” appear to be available to provide the hydrological dynamics needed for ecological simulations. This integration, if it indeed does occur, will be a future task.

1.2.4 Other: comments

a) Is this review limited to the Calibration of ELM, or have specific case studies been simulated and available for review? {MH}

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[17] ELM prints warning messages to a debug file, Driver1.out, on any occasion of insufficient headwater volume to meet demand by structure flows

[18] Hydrologic Simulation Engine of the Regional Simulation Model, in development by the SFWMD Hydrologic Systems Modeling Division

Other: response

Response to a):

This review is intended to evaluate the performance of the model – no case studies of CERP projects that use the ELM are available for analysis.

2. Detailed algorithm topics

2.1 Critical importance

2.1.1 General algorithms: comments

a) I believe that the ecological processes included, plus rigorous accounting for the flows of energy and cycling of nutrients, allow ELM to provide a good understanding of the Everglades at the ecosystem level, as well as making reliable projections possible.{DD}

b) ELM needs a lot of work to be useable. Modern south Florida research results need to be woven in as replacements for archaic and inappropriate "place-holder" pieces put in place during previous development. {RK}

c) The use of a two dimensional vertically averaged finite difference algorithm with fixed time step for overland flow is notorious for producing (erroneous) numerical dispersion of solute (e.g., tracer) flow. Another model with finite difference solutions in south Florida had tracer transport predictions that are now known to be badly in error. Thus, although ELM has the capability to provide animated cartoons of tracer movement through south Florida, it is unlikely that these represent reality. {RK} Is there any evidence that ignoring dispersion of dissolved and suspended material transport is acceptable? Is numerical dispersion generally larger than typical surface water dispersion levels? {MW}

d) To maintain stability, it is generally required that the mass advected for each constituent in each cell be less than the resident mass. Does ELM check for stability this or similar conditions within each cell and canal segment? {MW}

e) Water velocities and discharges between cells is not directly calibrated. I am concerned that modeled velocities may be unrealistic. A simple way to greatly improve the credibility of the model is to demonstrate that it can simulate concentration of a conservative solute; without this demonstration, we should give little credibility to modeled transport and velocities. {MW}

General algorithms: response

Response to a-b):

We have invested a great deal of time and effort to use tested algorithms and employ innovative algorithms to accommodate the objectives of the ELM. In keeping with the ELM philosophy of maintaining the simplest algorithms that are supported by available data (for parameterization and calibration), we will maintain the existing codes until further data and/or process-understanding necessitates modifications. We believe that each “novel algorithms”, developed from original research or modified from standard algorithms, was needed to capture subtropical structure and function Our development of an algorithm for the relationship of Manning’s n and water depth is fully supported by recently collected data (see later section “Surface & groundwater hydrology” for details). This model development process is very dependent upon available data.

For example, the Michaelis-Menton enzyme kinetic (or Monod) equation is often a standard water quality equation for plankton/algal nutrient limitation, used effectively by well-accepted water quality models such as WASP (Ambrose et al. 1993, Wool et al. in press). ELM originally used this formulation (Fitz et al. 1996), which describes a hyperbolic relation between ambient nutrient concentration and plant nutrient uptake. However, as we further scrutinized the model behavior at low nutrient levels, particularly with respect to plants adapted to the oligotrophic conditions of the Everglades, we saw the need to develop a different formulation[19] to better reflect periphyton and macrophyte growth at very low ambient phosphorus availability. Recent measurements of high of alkaline phosphotase activity at low phosphorus concentrations were found to justify this improved formulation. In another example, we introduced dynamic stoichiometry (dynamic stocks of both carbon and of phosphorus in organic matter) into ELM v2.0 because it had become apparent that under highly dynamic nutrient gradients this was necessary to properly calibrate both the rates and storages of plants and soils.

We are fully integrated into “modern” sources of research in the Everglades, with the ELM being a integral part of the advanced research being conducted on an ecosystem/landscape level in our SFWMD Everglades Division[20]. We are the dynamic ecosystem and landscape model that is associated with the Florida Coastal Everglades LTER[21], and are making the ELM web site a resource that will feed back to all research efforts as a data and model synthesis service. These relationships are a two-way interaction. The ELM is a tool that has been used to evaluate potential water flows and nutrient loads for pre- and post-hoc evaluations of transect data, and it will be providing more hypothesis-testing functions in the future as we finalize the next ELM v2.x. Of course, a vital component of this model-research interaction is the presentation of important gaps in system knowledge, and the “appetite” of the ELM for enhanced process-level data.

Response to c): Dispersion

Objectives:

In this detailed response section, we will i) evaluate the theoretical rate of numerical dispersion across different spatio-temporal scales and water velocities, ii) evaluate the magnitude of numerical dispersion in ELM simulations at 3 spatial scales in hypothetical “stress tests” under very short term, high dispersion conditions, iii) evaluate the long-term, cumulative effects of scale-varying numerical dispersion in ELM simulations at 2 spatial scales, and iv) compare the magnitude of any numerical dispersion in ELM with the magnitude of the actual dispersion process that occurs in these wetlands.

Background&Methods:

There are a variety of mechanisms that result in water movement and transport of dissolved/suspended matter in hydrologic systems, and they can be conceptualized in two basic forms: *advection* and *diffusion*. *Advection* results from a unidirectional flow, such as water coursing down a river. This action of an advected water mass does not change the concentration of a mass of a solute within the water parcel, and thus does not affect the gradient of the solute within the system as the water parcel moves downstream. *Diffusion* can generally be considered to be the movement of mass due to random water motion or mixing (Chapra 1997). Molecular diffusion results from the random movement of water molecules, while turbulent diffusion is a similar type of random movement that occurs at much larger scales such as eddies. The effect is to distribute mass of solutes in the system, smoothing the gradient of concentration. The process of dispersion is closely related to diffusion in that dispersion also results in the

[19] http://www.sfwmd.gov/org/wrp/elm/struct/detail/eqns/vert/v2.1a/ELM_PScode_vert.pdf

[20] http://www.sfwmd.gov/org/wrp/wrp_evg/2_wrp_evg_glades/2_wrp_evg_glades.html

[21] Long Term Ecological Research site, funded by National Science Foundation. H.C. Fitz and F.H. Sklar are formal Project Collaborators; see http://fcelter.fiu.edu

lateral spread of the mass or concentration of the solute in the system. One may consider dispersion to be a special class of diffusion, at least with respect to the results of the processes. Dispersion, however, is the result of velocity differences across space, as opposed to random motion of water. It may be apparent that the spatial and temporal scale of observing, or modeling, the system is a critical characteristic that must be considered when exploring the contributions of these flux processes.

In dynamic modeling of flowing, spatially distributed (e.g., gridded) systems, the numerical solution technique has an effect on the accuracy of the model prediction. Use of an explicit, finite difference technique (such as used in ELM), is known to result in numerical errors that have the effect of dispersing the concentration of a solute in the system (Chapra 1997), (many others). Note that numerical dispersion (errors) have the same effect on solute gradients that real diffusion/dispersion in the observed system. Horizontal flows in ELM only consider advective flow, and do not employ the full advection-diffusion equations[22].

This numerical dispersion (error) is very sensitive to scale: numerical dispersion is increased by increasing the size of the model grid, and/or by increasing the number of temporal iterations per unit of time (i.e., decreasing the model time step, *dt*). Additionally, this spatio-temporal relationship is a non-linear function of the modeled system's water velocity. Figure 6 demonstrates this relationship for scales that are pertinent to the ELM. There are two important points to note. 1) The Everglades operates at velocities that are likely well under 5 cm•sec^{-1}, with measured velocities (Lee and Carter 1999, Ball and Schaffranek 2000, Schaffranek and Ball 2000, DBEnvironmental 2002, Noe et al. in press) in northern and southern regions of the Everglades generally less than 1-2 cm•sec^{-1}, (though Ball and Schaffranek (2000) measured a peak of 4.7 cm•sec^{-1} downstream of outflows from the L-31W canal apparently due to a pump test of the S-332D structure and releases due to tropical storm Harvey (Schaffranek and Ball 2000). 2) At the 3000 m model grid scale (slightly smaller than that of the 2 mile SFWMM), numerical dispersion is very high at all velocities.

While these numerical diffusion estimates are useful to understand the magnitude of the *potential* effect on ELM results, we developed three ELM implementations at three different spatial scales in order to evaluate the *actual* effect on ELM results. For this quick[23] evaluation, we created model grids that covered the WCA-2A hydrologic basin at 100, 500[24], and 1000m grid length resolutions. We then performed a suite of model experiments Figure 5b using these WCA-2A implementations (ELM-WCA2A) and the regional ELM: 1) a short-term (91-day) hypothetical model "stress test" in WCA-2A to evaluate numerical dispersion under extreme conditions at three spatial scales; 2) a long-term (16-year) evaluation of historical flows on tracer and phosphorus (numerical) dispersion at two spatial scales; and 3) a long-term (17-year) evaluation of the effect of a newly developed "Anti-Numerical Dispersion" algorithm at the regional, 1km^2 scale.

The stress test was designed to instigate the most extreme (numerical and actual) dispersion conditions at these spatial scales under actual Everglades elevational slopes and vegetation densities (& flow resistances). A 1km^2 region in the northern area of the domain was inoculated with a conservative tracer at a concentration of 1 mg•L^{-1} (Figure 7). Twelve, 8.0 km^2 Indicator Regions were drawn (using GIS) in series down-slope of the inoculation region. The ELM budget algorithms (previously developed) calculate the

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[22] http://www.sfwmd.gov/org/wrp/elm/struct/detail/eqns/raster/RastFlux.htm

[23] The several week time period for responding to all reviewers' comments limited the extent to which we could complete all necessary tasks for the review.

[24] The 500 m grid for WCA-2A was previously developed, and used in evaluations of ELM v1.0 performance in the well-studied region (Fitz and Sklar 1999).

dynamic budgets of a variety of model variables (water, tracer, and various storages of phosphorus) at the model output step (e.g., daily, monthly, etc) needed for a particular experiment. For this experimental suite, we turned off the water management infrastructure and managed flows[25], thus having rainfall as the only hydrologic inflow. No further tracer was introduced into the system during the simulations. In order to provide a hydrologic gradient to induce flows, we made an extreme gradient whereby the initial water depth was truncated at zero at all points southern ~half of WCA-2A, while the northern section had the January 1, 1980 initial depth on the order of almost 1 m deep (Figure 8).

The historical flows tests were designed to evaluate the extent of numerical dispersion under the boundary flow conditions from 1979(80)-1995, during which the Everglades was subjected to extremes of severe flooding and severe drought. The 500 m and 1000 m implementations of ELM-WCA2A were run under the same boundary and initial conditions, employing the time steps (*dt*) that are currently being used in the 500 m and 1000 m implementations of ELM[26]. For the WCA2A historical tests, we inoculated all inflows from the S-10D structure at a tracer concentration of 1 mg•L^{-1}. For the (1000 m) regional ELM historical flows test, we inoculated all inflows from the S-8 structure at a tracer concentration of 100 mg•L^{-1} (with the higher concentration used in order to trace flows over much longer distances than in WCA-2A).

Results:

In the “stress test” simulations, a “wall” of water that was initially 80-90 cm high rushed downslope in the Everglades, rapidly reducing the head slope and in about 10 days all downstream indicator regions reached equal depth, followed soon by equilibration to elevation-induced differences in ponded depth (Figure 9). This high volume flow produced a short period of very high flow velocities that exceeded 10 cm•sec^{-1} for a very brief period of time, followed by more natural velocities less than 2 cm•sec^{-1}. Because there were no managed (water control structure) inflows or outflows in these stress tests, the flows within the marsh decreased to low or negligible levels.

Spatial distributions of these dynamics provide a useful visualization of the spatial and temporal patterns of the numerical dispersion, or lack thereof. The ELM web site provides a variety of animated difference maps that demonstrate the magnitude of the behavior at different combinations of time steps and spatial scales. A snapshot of the difference between the 100m and 500m models (Figure 10) shows that after 14 days, the 100m model still has a highly localized tracer distribution relative to a somewhat dispersed plume in the 500m model. Figure 11 shows a more diffused plume in the 1000m model relative to the 100m version; the central peak is approximately the same in all of the spatial implementations.

The time series graphics (Figure 12) of the tracer mass[27] as it down the series of Indicator Regions demonstrated the relative level of dispersion associated with the model at different scales. The 100m scale model showed little evidence of numerical dispersion at normal or moderate velocities, as the peak of the tracer declined insignificantly as the mass moved several kilometers through Indicator Region (IR) 6 through 9, with extremely sharp distributional peaks. At the 500 m scale, the lower values of each IR peak relative

[25] User simply selects either true or false for the water management switch at runtime
[26] Time step evaluations for hydrologic performance, including the process of decreasing *dt* until the model results no longer changed. Further evaluations of the *dt* can be made from output in the recent stress test published on the web site.
[27] These data are from mass budget data and are not concentrations in the water column; other plots that combined depth estimates showed concentration trends were the same as mass.

to the 100m model was indicative of increased numerical dispersion (e.g., IR6=0.24 and 0.14 Mg in the 100m and 500m models, respectively), but with only low attenuation of the peaks in IRs 6 through 9. At the 1000m scale, there was a further decline in the peak (e.g., IR6=0.11), and similar attenuation from IR6 to IR9. Note that in all cases, the flows declined to low or negligible values after 2-3 weeks, and the tracer mass ceased to move significantly. Figure 13 provides another visual perspective on these results, comparing the different scale models on individual graphs of each IR.

The long-term, cumulative impact of any potential differences in numerical dispersion do not appear to be significant. When running the ELM-WCA2A for the 1980-95 period, with all historical flows from S-10D inoculated with 1 mg•L^{-1} tracer, the two scales (500 m and 1000 m) of model implementation had very similar tracer accumulations along the Indicator Regions from the inflow region to central WCA-2A (Figure 14)[28]

Discussion:

It is apparent from the dynamics of the tracer in the 100m model that extremely little numerical dispersion was present. Moderate amounts of numerical dispersion were evident in the 500m and 1000m models. However, this numerical dispersion is of the same order of magnitude as dispersion estimates for a wetland system such as this. DBEnvironmental (2002) provided estimates of various hydraulic parameters that were obtainable from tracer dye studies in the Cell 4 wetlands of STA-1W. One of the estimated parameters they provided was the dispersion number D_n, which is a function of the dispersion coefficient D(m^2•d^{-1}), the nominal water velocity u (m•d^{-1}), and the pathlength of flow l (m) as follows:

$$D = D_n \cdot u \cdot L$$

They reported D_n ranging from 1.25 – 2.75 (dimensionless) from the Cell 4 dye study. Using a mean measured velocity for (for a different period but similar hydraulic conditions) of 0.54 cm•sec^{-1}, a path length of about 3000 m, a dispersion coefficient D would be roughly 1.5 – 4 million m^2•d^{-1}. While this estimate from somewhat incomplete data could possibly be an overestimate, it becomes clear that the **numerical dispersion in ELM (ca. 200,000 m^2•d^{-1} for a similar velocity) does not introduce bias to predictions of gradient dynamics**, as the actual dispersion is at least the same order of magnitude as numerical dispersion in the ELM applications.

It could be argued that ELM should expand the purely advective equations of flow, and include a dispersion component to the flow. For this model review exercise, we created an Anti-Numerical Dispersion (AND) algorithm into the flux equations, based simply on the well-known equation describing the behavior of the explicit solution technique. If actual rates of dispersion were known for the Everglades, the AND algorithm could be expanded to include the true dispersion estimates with another simple (related) equation (Wool et al. in press):

$$\frac{dM_{i,k}}{dt} = \frac{E_{i,j}(t) \cdot A_{i,j}}{L_{i,j}} \left(C_{j,k} - C_{i,k} \right)$$

where:

[28] The significant difference in the Indicator Region immediately adjacent to the canal/inflow structures was due to the hasty rescaling of the 500 m resolution Indicator Regions to 1000 m,which did not accomodate the different extents of canal-cell interaction geometries and thus the two scales of implementation had different areas of exchange with the inflow canal/structures.

$M_{i,k}$ = mass of nutrient "k" in cell "i", g

$C_{i,k}$, $C_{j,k}$ = concentration of nutrient "k" in cells "i" and "j", g/m^3 (mg/L)

$E_{i,j}$ = dispersion coefficient (time function) for exchange "i,j", m^2/day

$A_{i,j}$ = interfacial area shared by cells "i,j", m^2

$L_{i,j}$ = mixing length between cells "i,j", m

The algorithms for the AND and the actual dispersion cancel each other's effects, and the result is dependent upon the (velocity-varying) dispersion coefficient. Given the very good ELM performance in calibration of water quality along gradients in the Everglades, and the inherent uncertainty of true dispersion coefficients, it does not appear useful to increase the ELM complexity with an algorithm for which a critical coefficient is relatively unknown.

Response to d), Numerical stability:
The hydrologic algorithms of the ELM[29] have explicit numerical constraints at every iteration to ensure that no more water (and associated solute/constituents) is fluxed from a cell/canal-reach to an adjacent cell/canal reach than is present in the donor cell/canal.

Response to e), velocity calibration:
Given the very good model performance in predicted ET rates[30] and stages[31], and the very good consistency check with SFWMM hydrologic budgets (including ET, surface, and groundwater flows)[32], and the very good calibration of a variety of nutrient (and biological) metrics along small scale and large scale (regional) nutrient gradients[33], we feel that the uncertainty associated with predicted ELM flows does not warrant such dire "little credibility" characterizations.

Because the period of record for the v2.1a historical (aka calibration or performance assessment) simulation is currently limited to 1979-1995, we have not been able to find data of an adequate spatial and temporal quality (and high signal:noise ratio) to perform a quantitative model-observation test. Marsh velocity measurements collected (at point locations) since 1995 will be potentially valuable to attempt to ascertain that the flows predicted by ELM are consistent with the ranges of those measurements under low and high flow conditions. When these data become available on specific measured water velocities and on natural or man-induced experimental tracers in the ELM spatial and temporal domains, we will use those data to evaluate the predicted flows in ELM.

2.2 Non-critical importance

2.2.1 Surface & groundwater hydrology: comments

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[29] http://www.sfwmd.gov/org/wrp/elm/struct/detail/eqns/raster/RastFlux.htm
[30] http://www.sfwmd.gov/org/wrp/elm/pubs/implement.htm
[31] http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/hyd/hyd_ptser.htm
[32] http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/subreg/subreg.htm, clickable image map data, and see "ELM<->SFWMM notes" on bottom of map
[33] http://www.sfwmd.gov/org/wrp/elm/pubs/implement.htm, http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/tp/tp_ptser.htm

a) Is there an anisotropic feature built into the calculation of flow direction such as would be the case in fine-scale ridge and slough regions? If not, can this directionality be developed for model code? {SK}

b) Information from the SICS model indicates the need for ELM to have density effect on surface water flows in areas of the estuarine/freshwater interface. {GB}

c) The ELM evaporation model equations and coefficient do not match those in the original publication source. That published model was calibrated for northern Utah, and the ELM uses arbitrary factors to adjust resulting evaporation. The net radiation used by ELM (to drive the evaporation model) is calculated from a published radiation model, which itself uses many arbitrary coefficients rather than the data from south Florida. ELM transpiration is computed from calculated vapor pressure deficit coupled to a stomatal resistance component. The first part is essentially an alternate and duplicative computation with evaporation. The second part is questionable, since a published south Florida study showed transpiration in excess of evapotranspiration. This combined evaporation plus transpiration approach is in need of re-examination, and probably replacement. Use the south Florida SFWMD and USGS ET research to investigate these issues. {RK}

d) The use of Manning's equation for overland flow can be forced to work if the "n" value is appropriately selected as a function of depth and flow. ELM is parameterized to a depth relation based on published work for agricultural crops in Oklahoma. That relationship is seriously at odds with data from south Florida, reported over the past twenty years Unpublished USGS data may also be available for some of the vegetation types. This archaic approach is probably in need of replacement. Use the south Florida SFWMD and USGS ET research to investigate these issues. {RK}

e) The three {RK}examples (ET, Manning's, numerical dispersion) above clearly illustrate the patchwork, non-Floridian character of some of the ELM internals. I see no fatal flaw in any of the three cases, but all three need some serious reconsideration and revision. And I have no faith in current results produced from these faulty structures. {RK}

Surface & groundwater hydrology: response

Response to a):

Adding a directional feature to the internal homogeneity of the ELM grid cells is feasible, but has not been created at this time.

Response to b):

Adding a density effect on flows in salinity/freshwater interaction, or a simple proxy for the physics behind the process, could be implemented if is definitively determined[34] to be a critical need for the ELM fresh/saltwater interface

Response to c):

The ELM uses a simple evaporation model (Christiansen 1968) as the foundation for calculating potential evaporation from ponded surface water and potential transpiration by plants. This evapotranspiration (ET) algorithm considers the continuum between physical and biological controls on transpiration, with this transition dictated by the vegetation (canopy) type and water availability. Simulating the total ET dynamics across a

[34] We assume that density effects are indeed very important in the fresh-salt water interface, based on discussions/presentations by E. Swain and C. Langevin (USGS), developers of the Southern Inland and Coastal Systems nuerical model for the SE region of ENP. We need to ascertain the best method to produce a simple, easy-on-the-cpu, algorithm - as the Gulf/Bay boundary is a very small portion of the full ELM domain.

heterogeneous region of widely varying plants and hydroperiods, we explicitly consider canopy morphology, and the very different interactions that forested canopies vs. grassland canopies have with the lower atmospheric boundary layer – the degree of coupling between these dynamic canopies and local atmospheric gradients.

In the component that relates more to biological control, we calculate a potential transpiration that is based on the leaf canopy conductance, the water saturation deficit of the local (canopy) environment, and water stress of the plant. In the other component, the potential evaporation model is used to determine the potential rate of evaporative flux given the solar radiation, temperature, humidity and wind speed. For the ELM, the degree to which these two (physical and biological) processes control the total transpirative flux depends on the extent to which the saturation deficit at the canopy surface is decoupled from the saturation deficit in the atmosphere above the boundary layer of the canopy (Jarvis and McNaughton 1986), here taken to be the mixed Planetary Boundary Layer on the order of hundreds of meters in height. This (0-1) decoupling factor is an approximate scaling measure that varies with gross canopy morphology, with forests generally being near 0.2 and grasslands being near 0.8 (strongly decoupled).

The use of these two approaches along a bio-physical continuum is not duplicative calculation, but considering scaling theory and incorporating some of the understanding gleaned from studies in canopies varying from those of trees (Ewel and Smith 1992) to gramminoids (Koch and Rawlik 1993). Again, USGS (German 2000)v and SFWMD (Abtew 1996) hydrologic research has been evaluated in testing the algorithm, with good performance. For consistency with other models, however, in the next version of the ELM we may (relatively easily, given the ELM structure) substitute a different ET method for gramminoid canopies, maintaining the overall structure of the module objectives.

Response to d):
This is actually another good example of ELM innovation. We developed a novel algorithm that incorporates the effects of dynamic vegetation height and biomass on hydrologic flows (Fitz et al. 1996, Fitz and Sklar 1999), and which is fully supported by recent Everglades-specific data: it is far from "archaic". The positive relationship of Manning's n with increased depth has been demonstrated by USGS (Everglades-specific) flume and Everglades field studies (Lee and Carter, Jenter and Schaffranek 1996, Carter et al. 1999a, Carter et al. 1999b, Lee and Carter 1999). As pointed out by Jenter and Schaffranek (1996), "...for a uniform stand of sawgrass with no litter layer, the value of n increases with flow depth."; detailed data were provided to show this. We use this relationship in the ELM Manning's n calculation (Fitz et al. 1996, Fitz and Sklar 1999), and it is used by the USGS SICS[35] model. As water depth further increases[36], the ELM algorithm decreases Manning's n as the plants bend and are overtopped by water in a strata with no vegetation resistance.

Response to e):
We agree that there are no "fatal flaws" in the ELM. We hope that the publications, model documentation, and further elaboration in this review-response document is convincing evidence of the excellent performance and flexibility of the ELM. Considering the multiple points we raise in the prior two responses, other discussion in this review response document (such as numerical dispersion), and the demonstration of model performance that is highly supportive of the model objectives, we disagree with the reviewer's "patchwork" characterization of the ELM. The ELM is a unique tool for the innovative synthesis of Everglades dynamics. And of course, we certainly have many plans to improve the ELM functionality as we synthesize new information – a sign of a healthy model.

[35] Southern Inland and Coastal Systems numerical model for the SE region of ENP
[36] To a habitat-specific threshold depth

2.2.2 Water management network: comments

a) Can the ELM simulate structure operation rules based on internal head-water and tail-water conditions? {SK}

b) If ELM uses SFWMM flows through structures, but uses different ET, infiltration and overland flow resistances, the ELM water budget contains inconsistencies. {RK}

Water management network: response

Response to a):
Yes, code has existed for rule-based water control structure flows in the early (pre-1.0) versions. But because operations are determined by internal and external (to ELM) hydrologic conditions, such an approach of simulating the complex management rules using only ELM-internal conditions is not technically accurate under the types of management rules in effect today (and in the future). The SFWMM does a very good, verified job at water management simulation, and it is not feasible for ELM to attempt to mimic that for management evaluations.

Response to b):
The results show otherwise, at least for the scale of applications relative to the objectives of the model. The degree of consistency is demonstrated in the budgets[37] and the stage hydrographs[38], which show no significant bias or departure from the SFWMM results at either the basin scale or stage at point locations

2.2.3 Ecological dynamics: comments

a) The components and mechanisms built into the ELM (Unit Model) are in accord with the best understanding of what the major processes are in a typical wetland ecosystem. The model also is consistent with other models of the same level of detail developed for wetland or shallow aquatic system. A lot of decisions had to be made concerning the level of detail to use, and I think that good judgment was used in all decisions. {DD}

b) Details of nutrient cycling, such as the nitrogen cycle, are vastly simplified. Simplification of the N cycle may not make too much difference, but need more information on ELM modeling of the P cycle, especially the possible complexing with calcium. {DD}

c) Are all nutrients strictly conserved? {DD}

d) Are there data for direct periphyton effects on macrophytes (e.g., smothering young shoots) that would support that mechanism being incorporated into ELM? {DD}

e) Include more than one algal type, especially taking into account changes in the algal composition as a function of P concentration {DD}

f) It may possibly be useful to elaborate on the consumer module, at least into a few functional types. {DD}

g) Because of the significant effects fire has on vegetation, soils, and potentially they interaction of soil and nutrients, a fire module should be added. It is unlikely that a water quality model would fully calibrate (especially over a 30+ year period of record) until and unless fire effects are taken into account. {GB}

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37 http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/subreg/hyd/hyd_budg.htm
38 http://www.sfwmd.gov/org/wrp/elm/results/cal_ver/elm2.1/ptser/hyd/hyd_ptser.htm

h) If aerial TP deposition is simulated as an equivalent rain water concentration, this may significantly distort seasonal patterns of P deposition. Wet and dry deposition should be modeled separately. {MW}

Ecological dynamics: response

Response to a):
We concur with this assessment.

Response to b):
Nitrogen is not currently simulated; the reviewer refers to an early publication on pre-v.1.0 (Fitz et al. 1996). Nitrogen will be incorporated, however, the first cut will be a nitrogen settling module until sufficient data are available to parameterize a more realistic representation.

Response to c):
Nutrients (currently phosphorus) and tracer/salt are strictly conserved, and verified via detailed, cumulative budget error analyses – max errors are associated with canal-cell interaction algorithm (effectively same as SFWMM, but constraining the relaxation error to very small height diffs); max error accumulated after 17 yr simulation is approx 2 $ng \cdot m^{-2}$ ($2 \cdot 10^{-6}$ $mg \cdot m^{-2}$) across ELM domain; largest positive error per 30-day period is 0.4 $ng \cdot m^{-2}$ ($4 \cdot 10^{-7}$ $mg \cdot m^{-2}$) largest negative error per 30-day period is –0.4 $ng \cdot m^{-2}$ ($4 \cdot 10^{-7}$ $mg \cdot m^{-2}$). Evaluations made for all basins and Indicator Regions at the budget output time step, usually 30 days.

Response to d):
We are not aware of data indicating such a constraint. The ELM does not have that mechanism, but could provide a simple algorithm to accomplish that if data indicated it was a critical mechanism that constrains new vegetative growth at the scale(s) of the model.

Response to e):
Since ELM v1.0, we have simulated two community types of periphyton: the native, or oligotrophic, and non-native, or eutrophic periphyton communities. These two communities have significantly different responses, in the model (Fitz and Sklar 1999) and in the field (McCormick et al. 1996), to phosphorus concentrations in the water column.

Response to f):
We do not currently implement the consumer module (from the earliest model version (Fitz et al. 1996)) in any simulation, and have not focused any attention on that component since initial conceptualization/development.

Response to g):
We believe that the calibration for surface water quality demonstrates appropriate level of performance. We will be integrating a fire module into a future ELM version.

Response to h):
We have considered modeling wet and dry P deposition separately and conceptualized its method. However, the uncertainties associated with atmospheric deposition data make us question whether we can properly support such a distinction.

3. Detailed data topics

3.1 Critical importance

3.1.1 Boundary Conditions: comments

a) Has ELM incorporated any of the existing time-series data (or a stochastic component) on actual outflow concentrations (STAs)? {MH}

Boundary Conditions: response

Response to a):

STA daily phosphorus concentrations in outflow are calculated to match the long-term target concentrations. The total daily data sets for all STA inflows, outflows and phosphorus concentrations were based on Goforth and Piccone (2001). In this report, the "daily STA outflow phosphorus concentrations were calculated as a constant fraction of the daily inflow concentrations, where this fraction was derived as the ratio of the target outflow loads to the total inflow loads for the 1979-88 design period. The result was a time series of variable outflow phosphorus concentrations that preserved the target STA outflow concentrations". The procedure, however, tends to generate high daily concentrations when there is a relative high inflow over outflow ratios in the STAs. While the artificial high outflow phosphorus concentrations during high inflow and low outflow periods were truncated at 200 ppb, the pulsing outflow phosphorus concentrations may bring unexpected results if used directly in the ELM simulation to evaluate STA downstream impact.

For ELM model input , a simple mass balance method with a first order settling function is used to estimate outflow phosphorus concentrations that match the average target concentrations for the design periods 1979-88.

Once the baseline STA daily outflow phosphorus concentrations for the 31 year baseline conditions are calculated for each targets, regression equations of outflow versus phosphorus concentrations in the outflow are estimated as:

$$c_{out} = e^{a + b \cdot \ln(flow)}$$

Where C_{out} is phosphorus concentration in ppb and STA outflow is in Acre-foot. These regression equations are then used to estimate STA phosphorus concentrations in daily outflow for input to ELM under the 2050wProj SFWMM v.4.4 structure flows condition.

3.2 Non-critical importance

3.2.1 Boundary Conditions: comments

a) Model results are limited by field data availability and reliable boundary conditions; must get better boundary data if results are to improve. {MC}

b) Are any sources of atmospheric P deposition beyond ["a uniform level across the whole system"] being modeled? This is a concern because spatially varying rainfall leads to spatially varying P deposition in rain. Why is the global parameter for P concentration in rain being increased from 0.020 to 0.10 mg/L in the next version? {MH}

Boundary Conditions: response

Response to a-b):

For the pending update of the ELM POR to 2000 (from 1995), we revisited critical boundary flow data (structure flows and concentrations). In this process, we found that the SFWMD database[39] contained revisions to flow data that were previously in use by hydrologic models

[39] DBHYDRO

(including years prior to 1995). These revisions, necessary for increased accuracy, were made by SFWMD Environmental Monitoring and Assessment Department staff, and are one reason for the Hydrologic Modeling Division to be currently evaluating/revising the calibration of SFWMM v5.0. With new flows, daily phosphorus concentration data[40] for ELM boundary condition input also changed. For the extension of the ELM POR to 2000, we will necessarily have to use the entire new data set for temporal (1979-2000) consistency within a simulation. Additionally, we will be using new, fine scale topography[41], for which we are in the final stages of filling in missing regions (not yet sampled by USGS) for the entire ELM domain. We are also revising some detailed aspects of the ELM initial vegetation map, modifying (lowering) total atmospheric deposition of P, and using the new rainfall time series from HSM's SFWMM, among other improved data sets.

3.2.2 Model parameters: comments

a) Where did the max floc depth parameter of 0.1 m come from; floc depths may vary up to ~0.2m. {MH}

b) Where did the (global) particulate P settling velocity parameter of 0.4 m/d come from? {MH}{RK} Assuming this settling velocity in the model is only a function of water depth, why isn't it also a function of velocity (and presence/absence of vegetation)? {MH}

c) There are far too many parameters that can be adjusted in the model, and there is a lack of data to support these numbers. {RK}

d) There are hard-wired coefficients in the model and unlisted fudge factors that do not appear in the databases; they need justification. There should be more parameters in the model when needed (such as a foliar absorption coefficient) {RK}

Model parameters: response

Response to a):
A maximum floc depth of 10 (and perhaps up to ~15) cm was observed in a large number of samples from WCA-2A[42] and some other regions. Some researchers estimate that the value in central WCA-3A may be 20cm or more. In the current implementation of ELM, this is not a sensitive parameter, but we will increase it to ~20-30, after evaluation of all available data. We do not currently plan on presenting floc as an Everglades performance measure, and the primary role in the current model is the provision of the mechanism for highly labile, rapid turnover of P, particularly in eutrophic zones.

Response to b):
The settling velocity used in ELM[43] is applied to the particulate, high-concentration phosphorus found in predominately in high-loading, high concentration areas downstream of inflow structures. The value is in the range of very fine silts of low density (Ambrose et al. 1993, Wool et al. in press) and of various suspended algal species (Bowie et al. 1985). The arrival at the currently used value was based upon those physical estimates, and calibrated to concurrently match general values of soil P accumulation, water column P, and periphyton P uptake in the highly eutrophic regions downstream of inflow structures such as those in

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[40] Generated by C. Mo of SFWMD EMA using the inter-agency standard program that interpolates sparse (ca. monthly/bi-weekly) nutrient concentration observations to daily concentration estimates for all days when there is non-zero flow through water control structures.
[41] http://sofia.usgs.gov/projects/elev_data/ Original point data generally at 400m resolution.
[42] S. Newman, pers. comm.
[43] Used in the full ELM. An independent set of spatially-varying total phosphorus settling rates was used in the ELM module that emulates the abandoned Everglades Water Quality Model (while turning off all ELM ecological dynamics).

WCA-2A. Implicit in this settling dynamic is also the microbial uptake of P (in water column and soil/floc surface) that is not an explicitly simulated process in ELM.

Response to c-d):

The ELM was explicitly designed to simulate the critical ecosystem processes for which data are available. As a result, the ELM is intermediate within the spectrum of model complexity that ranges from purely statistical models (aka any P settling rate model) to the highly mechanistic forumulations such as the WWQM (HydroQual 2000). We have made significant efforts to maintain a "useful" level of simplicity in each ecosystem module, and a significant part of the past, and ongoing, development is in developing the most simple approach to attain the fundamental ecosystem response. ELM complexity arises from the fact that it is a complex system simulation, with multiple *simple* modules that dynamically interact. The parameters are maintained and documented in a desktop database and spreadsheet for evaluation by reviewers. Sorting the parameters by their degree of importance, or sensitivity, reveals that the majority of "global" parameters (that don't vary with habitat) are of little importance to a particular "real" Everglades implementation, but exist in order to apply the model to other regions and/or to rapidly test the model for testing/debugging purposes (such as the "stress test" described above in the numerical dispersion analysis). The number of parameters that are important in ELM does increase as the number of habitats increase. However, many of the parameters that are maintained within the Habitat-specific parameter database do not change with habitats; they may be changed with habitat if research shows that significant differences exist. Figure 15 demonstrates these issues in a series of perspectives on the relative importance of these parameters as they are applied in the current version of ELM.

3.2.3 Spatial data: comments

a) Are definitions available for the vegetation types in the 1995 ELM land use map?. There is concern about using the Welch map for ENP, and whether ENP staff concur with its use. Several land use maps are presented on the web with different levels of aggregation/classification: how are they used? {GB}

b) What is the explanation for the pattern of soil P depicted in your regional map- i.e., an area of elevated P extending south of western Shark Slough down to the area west of Long Pine Key and then eastward to Taylor Slough? Is there a model artifact or were assumptions made in the absence of field data? {TA}

Spatial data: response

Response to a): Vegetation mapping

Definitions for the vegetation map are derived from the classification system (Madden and Rutchey), aggregating the vegetation classes into more general community types. The vegetation map used in the current version of ELM, along with much of the other spatial data, are in the "ELMhome:Landscape:ELM data" section of the web site[44]. At another location of the web site[45] are regional, south Florida maps of historical (1900, 1953, 1973) vegetation and land use (Costanza 1975), made available in order to inform people of the large scale land use trends in south Florida. They are not used as data for the ELM. The web site also displays maps of satellite imagery that classified cattail encroachment in WCA-2A from 1973-91 (Jensen et al. 1995). These maps are not directly used as data for the ELM[46]; rather, the photointerpreted 1991 and 1995 cattail maps of Rutchey and Vilchek (1999) were

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[44] http://www.sfwmd.gov/org/wrp/elm/land/elmdata/data_sum.htm

[45] http://www.sfwmd.gov/org/wrp/elm/land/sfla/sfla73.htm

[46] Although the 1982 cattail map was used as a basis to initialize the vegetation map for the WCA-2A implemntation of ELM v1.0

(aggregated to 500m and) used for calibration targets for ELM v1.0 (Fitz and Sklar 1999). Ken Rutchey, lead in vegetation mapping at SFWMD, provided the following assessment of the utility of the Welch et al. (1999) map of vegetation in ENP/BCNP:

> In my opinion, the Welch et al. maps represent the best available information and I say this because there really is nothing that comes close to this effort in comparison. There have been some issues with the maps, such as cattail not being mapped correctly south of Tamiami Trail, which is critical and which we (the District) have corrected. There have also been some qualitative comments from Greg Desmond (USGS) and Jack Meeder (FIU) about the accuracy of the maps in the mangrove transition zones. However, these observations haven't been quantified in any matter. Tom Armentano, as noted in his comments, has stated that the maps don't capture or are unreliable in areas where herbaceous-gramminoid marsh types of several kinds occur at varying scales. This is true, but with any mapping project there are going to be limitations on what you can accurately delineate based on the scale of the base data you are working from. All these types of comments can lead some people to believe that maybe the whole mapping project is questionable for the entire area. We will never know for sure unless we do some type of overall QA/QC for the entire map area - this would be an extensive effort and it isn't going to be performed by the District. Welch et al. (1999) stated that "Although funds for more extensive accuracy evaluations were curtailed by the Parks, it is estimated that the average overall classification accuracy averages better than 85 percent for the entire study area." Some preliminary checks of some 88 points by Welch et al. (1999) found an average value of 90 percent accurate. Overall, it is my best professional judgement that the Welch et al. maps that were produced for ENP and Big Cypress are the best available. There might be areas where there are some discrepancies, but overall based on what I know now; I believe these maps to be accurate except where noted below Tamiami Trail.
>
> There have been other vegetation mapping efforts (e.g., GAP, Florida Land Use Classification System) where people might ask why we aren't using them for the ELM. A group representing multiple State and Federal people checked the WCA3 map (Rutchey and Vilchek unpublished) along the Tamiami Trial and it was deemed accurate at every location visited. This gave this mapping effort great credibility with other agencies. Also we have now visited more than 2300 ground truth sites for the construction of this map – this is a monumental effort and is seldom done for vegetation mapping efforts. Other published vegetation mapping work done by Rutchey and Vilchek (Rutchey and Vilchek 1999) show that overall accuracy of that map using similar methods was 95%. I posture that the overall accuracy of this latest WCA3 map for the first dominant vegetation category will also be on the order of 95%. The bottom line here is that this makes a good base to test the accuracy of other mapping efforts that have been attempted in this area. J. Godin has done this (Figure 16), showing that the GAP and FLUCS maps were less then satisfactory to poor in accuracy. I believe that analysis reinforces that we are currently using the most accurate maps for the ELM.

Response to b): Soil mapping

The regional soil map shown ELM workshop presentations (available on the web site) is a inverse-distance weighted, nearest neighbor interpolation of (original data from) the REMAP (Stober et al. 1998) 1995-96 soil sampling efforts for the region outside of WCA-2A. This method was used instead of kriging because it does not extrapolate the data beyond neighboring points. The pattern and magnitude of soil TP in this map is real, and not the result of any individual data point skewing the spatial pattern/magnitude (and does not come from any simulation model result). Contour maps in Stober et al. (1998) reflect the same original data (but the kriging done for that publication was not described with respect to methods or checks on the associated semivariogram, and thus perhaps should be used only for broad, general pattern visualization).

The ELM data initial condition (1979) soil TP map on the web site[47] is a backward-in-time extrapolation (Fitz et al. in press) combination of data from the sampling efforts of REMAP in 1995-96 and the University of Florida/SFWMD in the early 1990s (cited below). For the next version of ELM (greater than v2.1b), we are nearing completion of a thorough geostatistical analysis of those and all other available (Reddy et al. 1994a, Reddy et al. 1994b, Newman et al. 1997, Stober et al. 1998, DeBusk et al. 2001, Stober et al. 2001) soil data. In particular, we are using a variety of statistical techniques to evaluate the relationships among nutrient loads, hydrology, soils, and vegetation (outside of the simulation predictions) in order to improve our understanding of these dynamics and provide a synthesis for Everglades researchers.

[47] http://www.sfwmd.gov/org/wrp/elm/land/elmdata/tpsoil.htm

Review of future model version

1. General and/or conceptual topics

1.1 Non-critical importance

1.1.1 Calibration/validation: comments

a) ELM has been shown to simulate the strong P gradients and dominant vegetation types in WCA2A, (i.e. Cladium vs Typha) but P, periphyton and macrophyte patterns are much more complex in the relatively unaltered Everglades. How will you achieve reliable simulations given data limitations on variables such as macrophyte and periphyton distribution and biomass ? Twenty-nine vegetation cover types are presented in a legend. How will you parameterize the key components of each of these for modeling purposes? {TA}

b) At the 1 km2 scale, how are tree islands and sawgrass strands handled? How do you deal with their roles in flow and in nutrient distribution? {TA}

Calibration/validation: response

We would like to respond to these insightful comments on future ELM regional performance. However, we ran out of time to provide written responses.

2. Detailed algorithm topics

2.1 Non-critical importance

2.1.1 Ecological dynamics: comments

a) There is some evidence that Everglades vegetation types are more dynamic than some have thought, depending on fluctuations in key hydrological variables and stochastic events like fire. In long-term simulations (e.g., 31 years) how will ELM handle vegetation shifts (not to mention the accompanying changes in properties such as flow resistance, evapotranspiration and nutrient uptake) that may occur one or more times within the simulation period? {TA}

b) How are peat accretion and its effects upon nutrients vegetation type and hydrology handled in the model? {TA}

c) Does ELM predict any other vegetation succession other than cattail, and does it predict that outside of WCA-2A (as published in ELM v.1.0)? {GB}

d) Are there plans to add a sulfur cycle, mercury cycle, and DO concentration to the model? {MW}

e) A fire module should be added {GB}

f) ELM should eventually migrate towards being able to describe vegetation succession in as mechanistic a way as possible. {DD}

g) If land use is currently static, the model should be expanded to include a vegetation succession module that covers not just cattail invasion but vegetation responses to changing hydrology, as well {GB}

Ecological dynamics: response

We would like to respond to these insightful comments on future ELM regional performance. However, we ran out of time to provide written responses.

3. Detailed data topics

3.1 Non-critical importance

3.1.1 Spatial data: comments

a) Vegetation maps have limited reliability in areas where herbaceous-gramminoid marsh types of several kinds occur at varying scales. How will you accurately delineate the marsh community level differences that, despite being difficult to handle via mapping, are ecologically important? {TA}

Spatial data: response

Please see the section “Review of current model version/ Detailed data topics/ Non-critical importance/Spatial data response”

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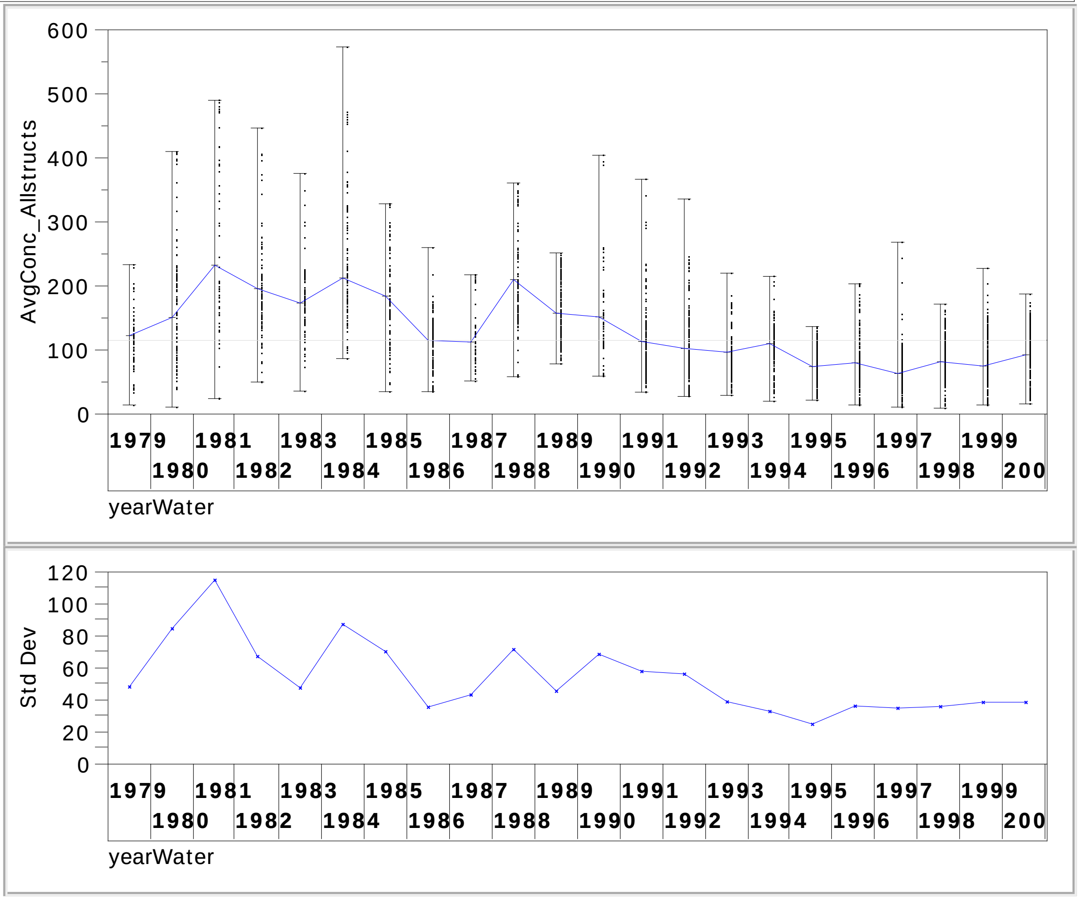
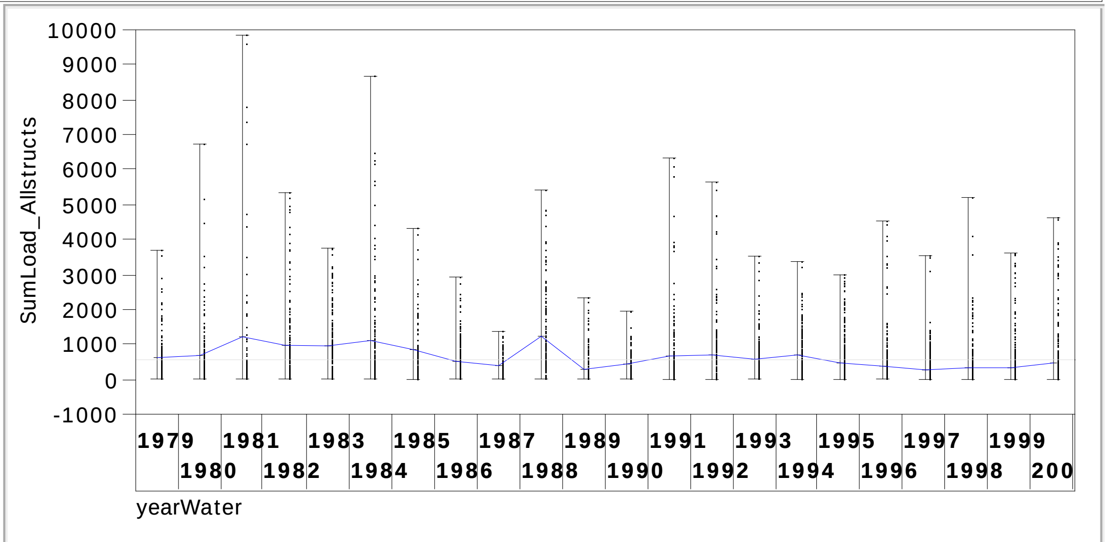
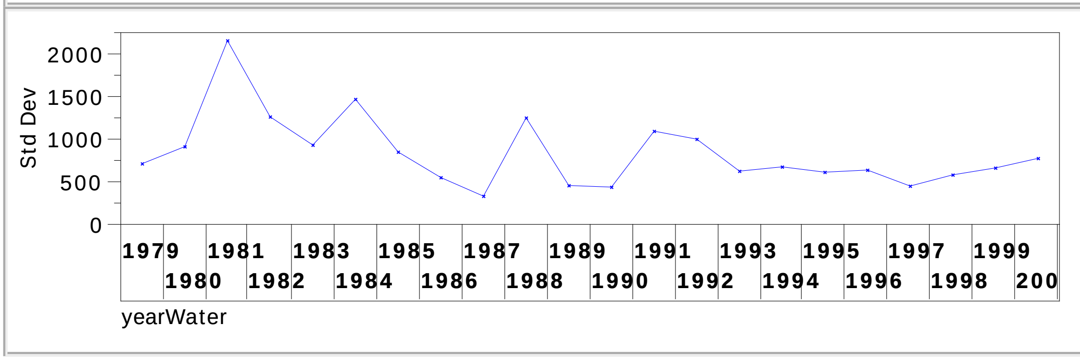
Figures

Variability Chart for AvgConc_Allstructs



Variability Chart for SumLoad_Allstructs





Chart

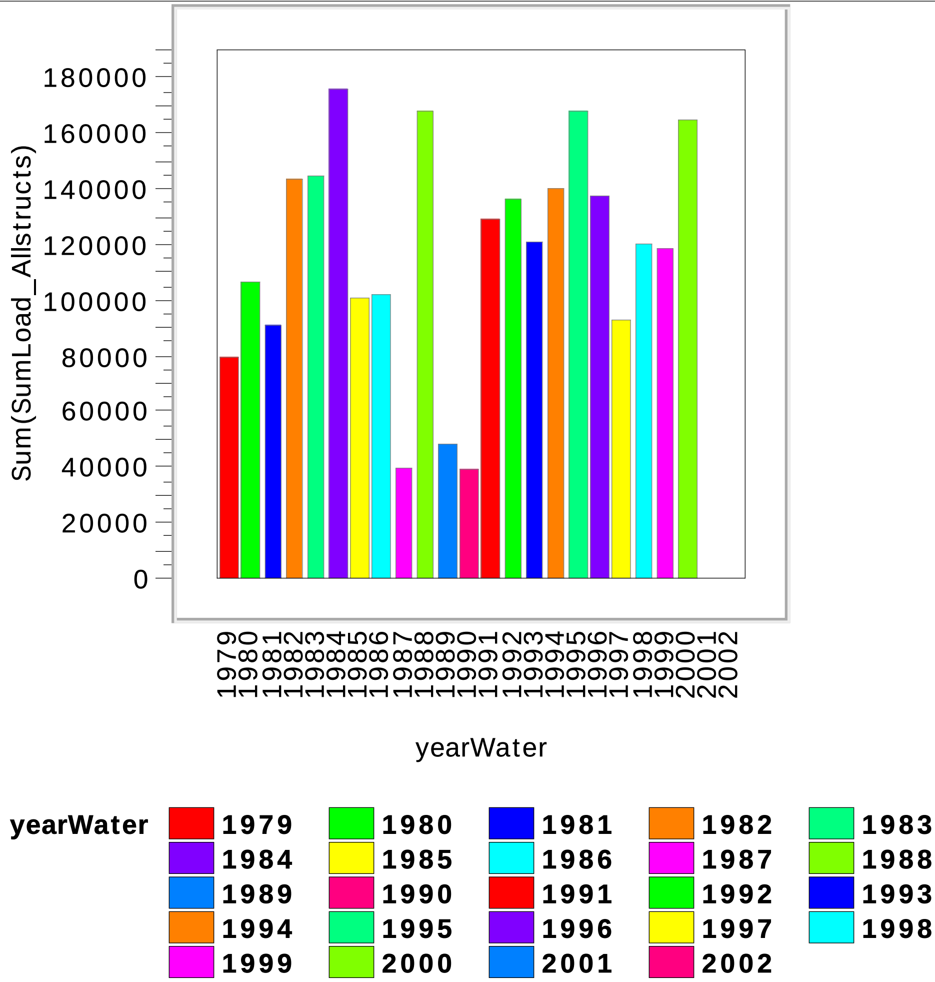
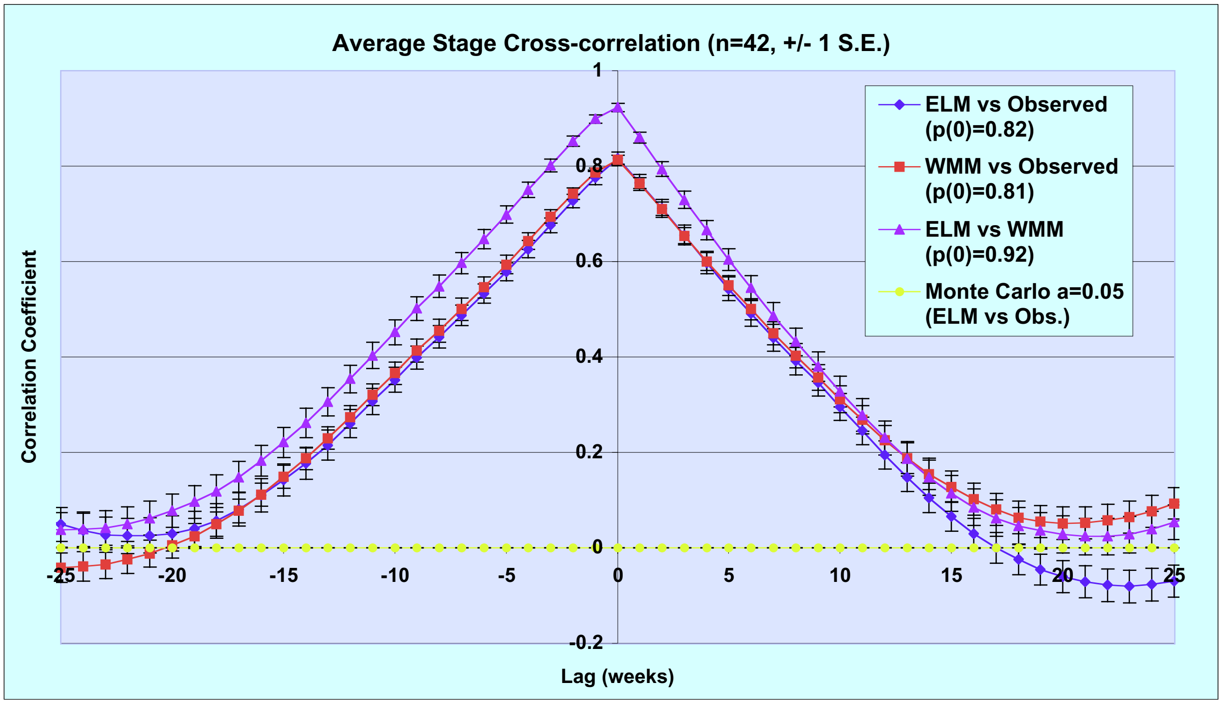

Sum(SumLoad_Allstructs)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
yearWater
yearWater
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

Fig. 4a



Average Stage Cross-correlation (n=42, +/- 1 S.E.)
Correlation Coefficient
Lag (weeks)
ELM vs Observed (p(0)=0.82)
WMM vs Observed (p(0)=0.81)
ELM vs WMM (p(0)=0.92)
Monte Carlo a=0.05 (ELM vs Obs.)
1
0.8
0.6
0.4
0.2
0
-0.2
-25
-20
-15
-10
-5
0
5
10
15
20
25

Fig 4b

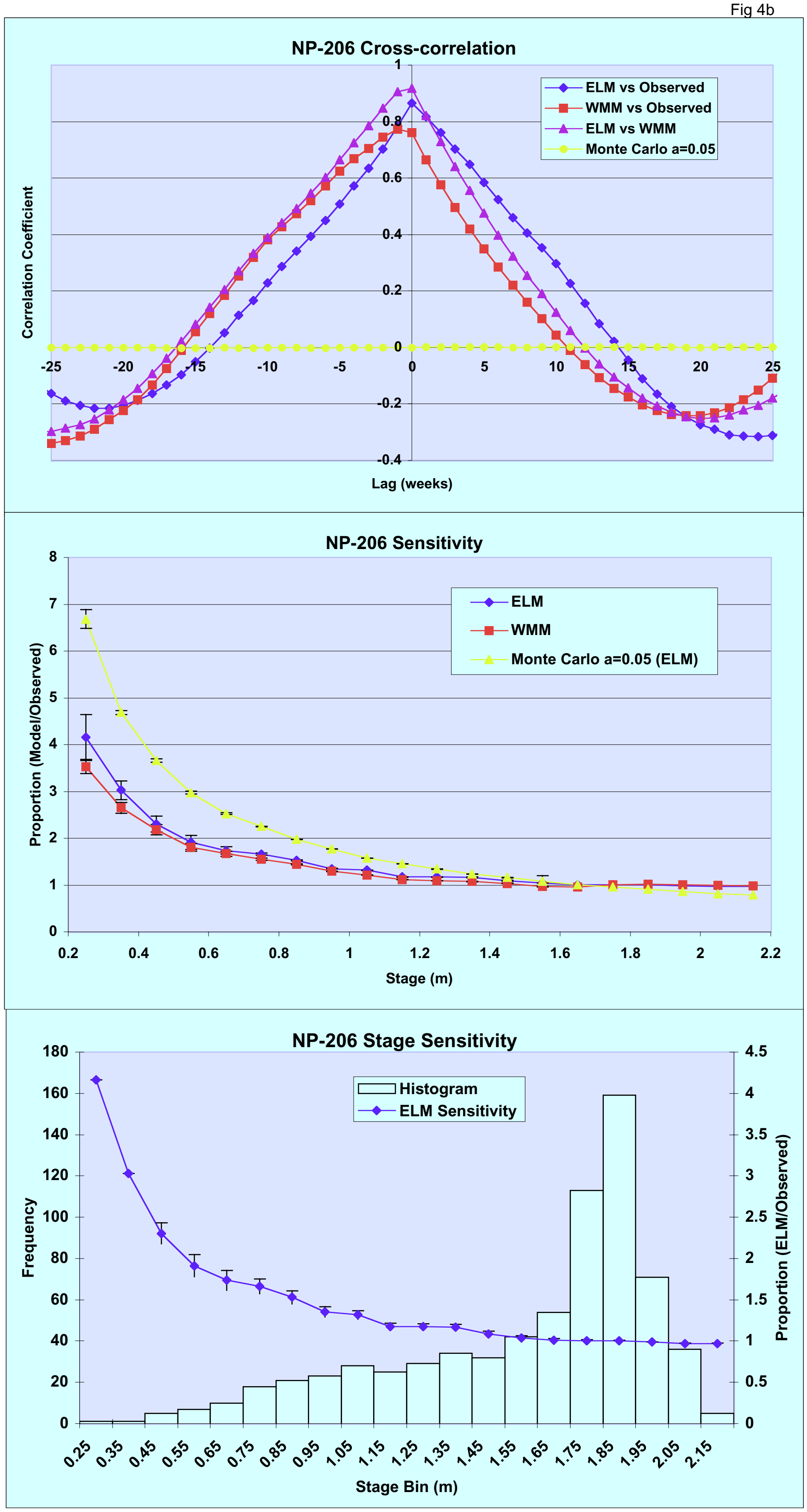
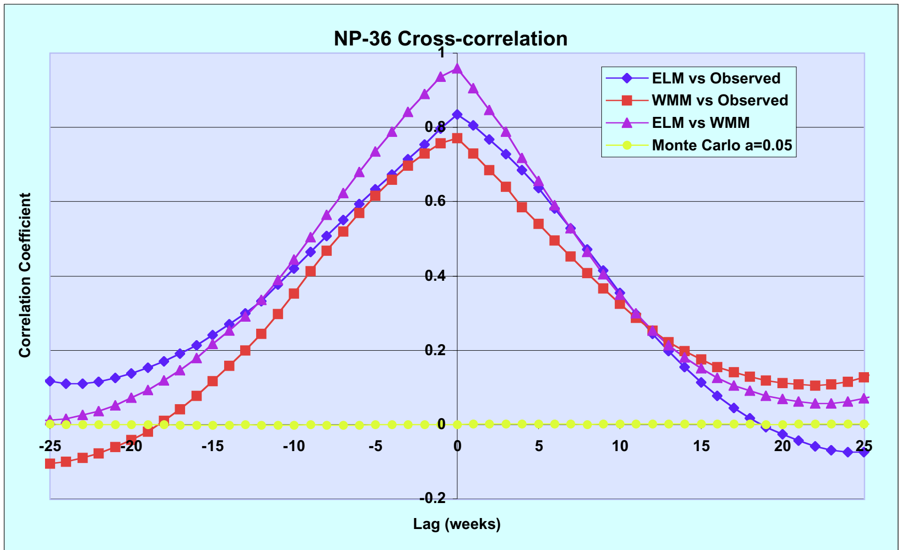
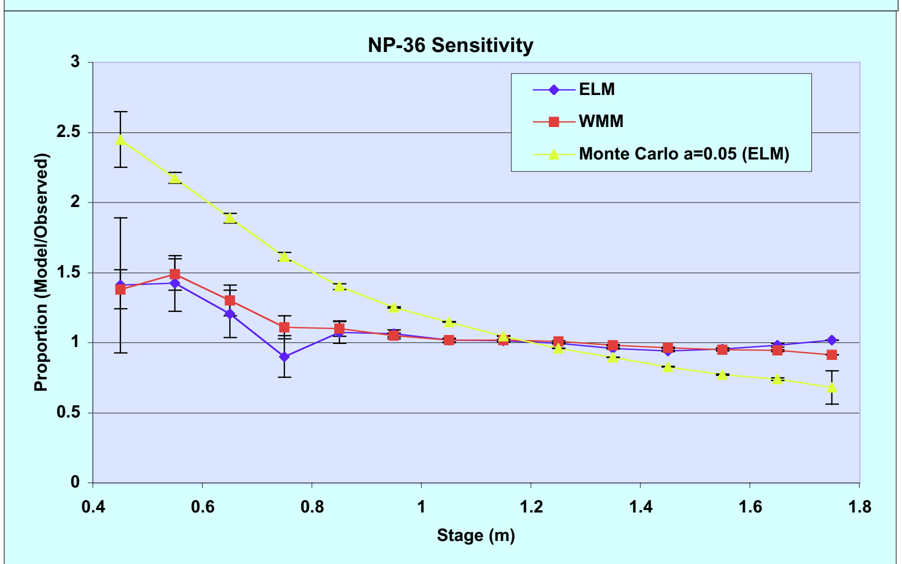
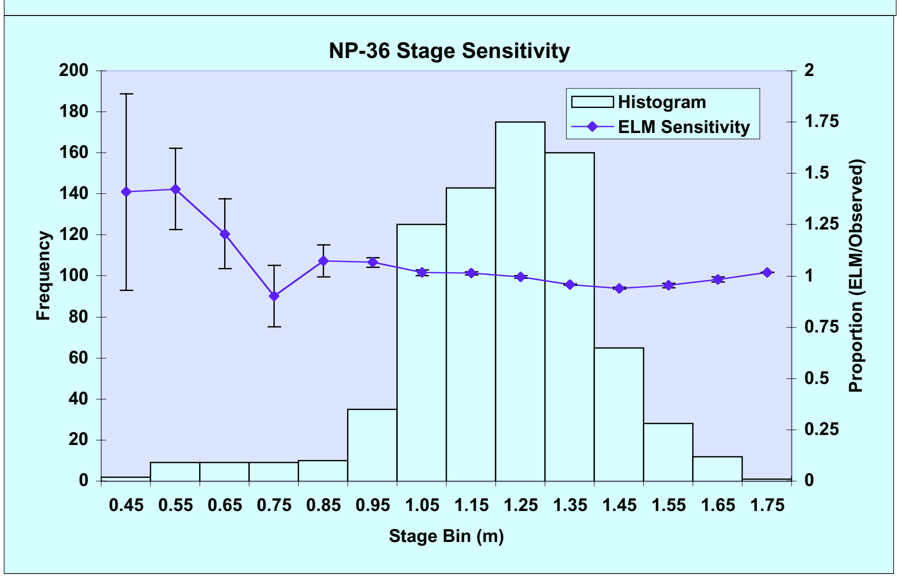

NP-206 Cross-correlation
Correlation Coefficient
Lag (weeks)
ELM vs Observed
WMM vs Observed
ELM vs WMM
Monte Carlo a=0.05
NP-206 Sensitivity
Proportion (Model/Observed)
Stage (m)
ELM
WMM
Monte Carlo a=0.05 (ELM)
NP-206 Stage Sensitivity
Frequency
Proportion (ELM/Observed)
Stage Bin (m)
Histogram
ELM Sensitivity

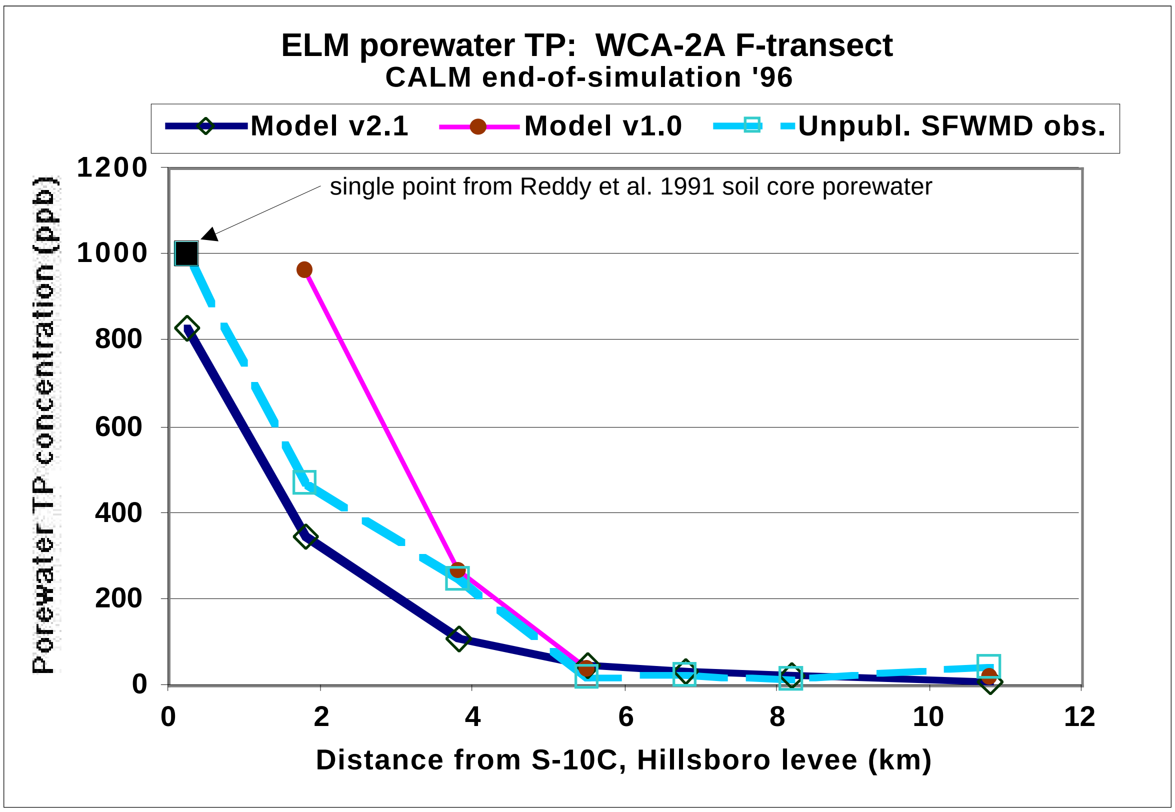
Fig 4c


NP-36 Cross-correlation
ELM vs Observed
WMM vs Observed
ELM vs WMM
Monte Carlo a=0.05
Correlation Coefficient
Lag (weeks)
1
0.8
0.6
0.4
0.2
0
-0.2
-25
-20
-15
-10
-5
0
5
10
15
20
25

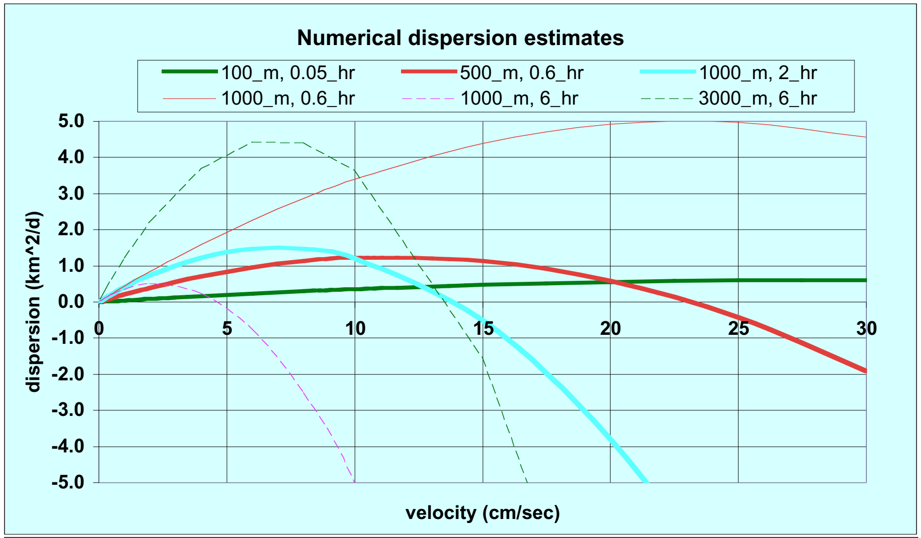

NP-36 Sensitivity
ELM
WMM
Monte Carlo a=0.05 (ELM)
Proportion (Model/Observed)
Stage (m)
3
2.5
2
1.5
1
0.5
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8

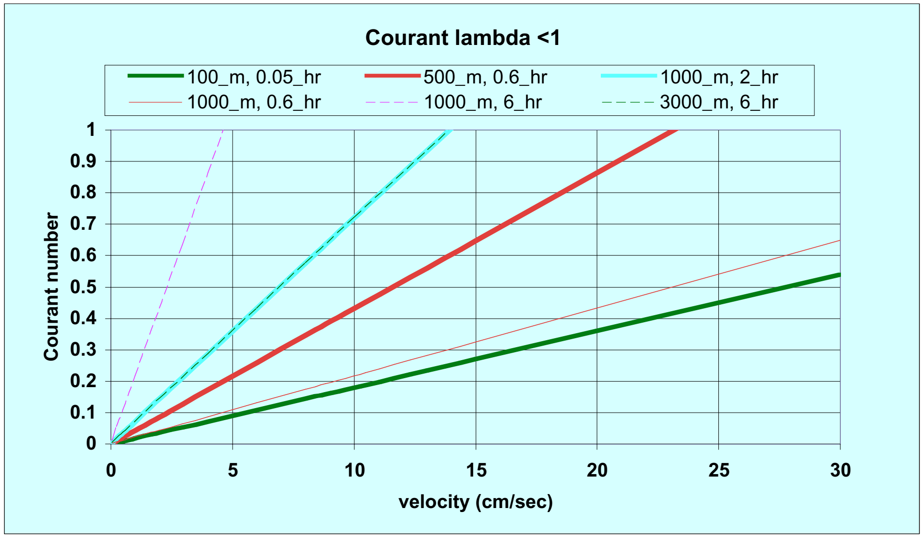

NP-36 Stage Sensitivity
Histogram
ELM Sensitivity
Frequency
Proportion (ELM/Observed)
Stage Bin (m)
200
180
160
140
120
100
80
60
40
20
0
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
0.45
0.55
0.65
0.75
0.85
0.95
1.05
1.15
1.25
1.35
1.45
1.55
1.65
1.75

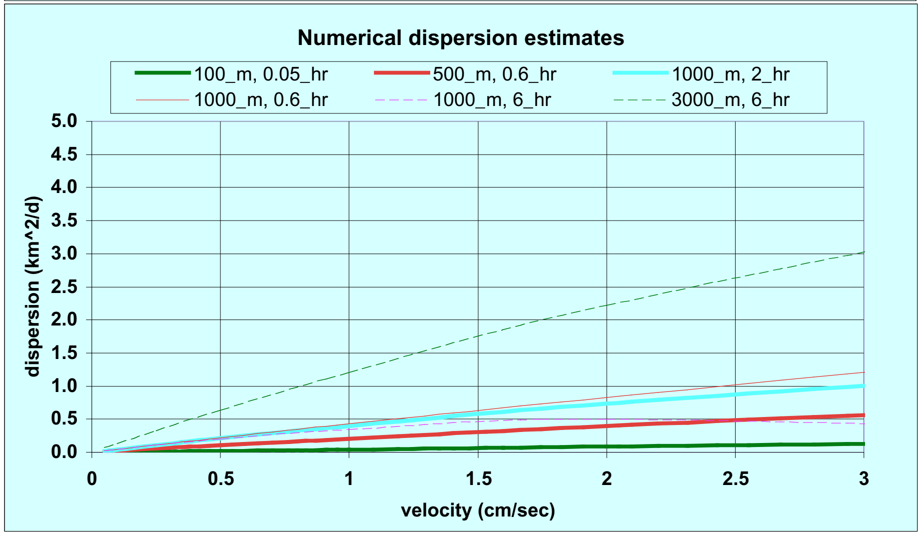
5

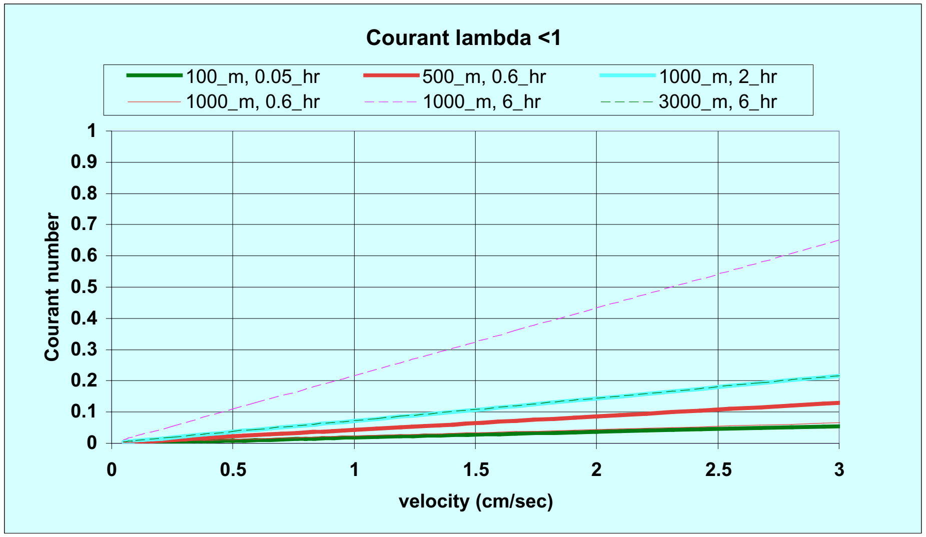

ELM porewater TP: WCA-2A F-transect
CALM end-of-simulation '96
Model v2.1
Model v1.0
Unpubl. SFWMD obs.
single point from Reddy et al. 1991 soil core porewater
Porewater TP concentration (ppb)
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
Distance from S-10C, Hillsboro levee (km)

6


Numerical dispersion estimates
100_m, 0.05_hr
500_m, 0.6_hr
1000_m, 2_hr
1000_m, 0.6_hr
1000_m, 6_hr
3000_m, 6_hr
dispersion (km^2/d)
velocity (cm/sec)


Courant lambda <1
100_m, 0.05_hr
500_m, 0.6_hr
1000_m, 2_hr
1000_m, 0.6_hr
1000_m, 6_hr
3000_m, 6_hr
Courant number
velocity (cm/sec)


Numerical dispersion estimates
100_m, 0.05_hr
500_m, 0.6_hr
1000_m, 2_hr
1000_m, 0.6_hr
1000_m, 6_hr
3000_m, 6_hr
dispersion (km^2/d)
velocity (cm/sec)


Courant lambda <1
100_m, 0.05_hr
500_m, 0.6_hr
1000_m, 2_hr
1000_m, 0.6_hr
1000_m, 6_hr
3000_m, 6_hr
Courant number
velocity (cm/sec)

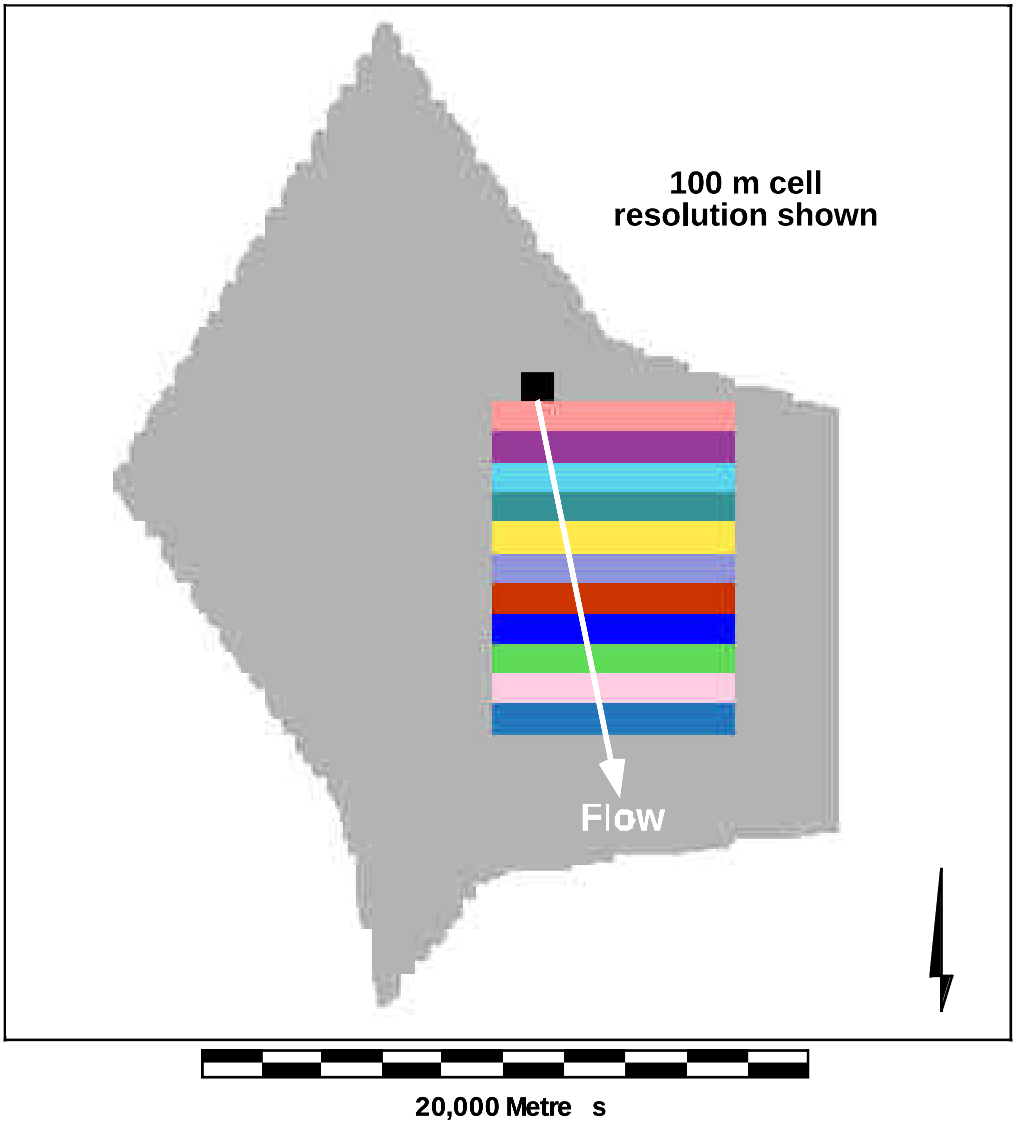
Dispersion and spatio-temporal scale: ELM simulations

27-Sep-02 ELM v.2.1a; v.2.1b codes the AntiNumericalDispersion algorithm

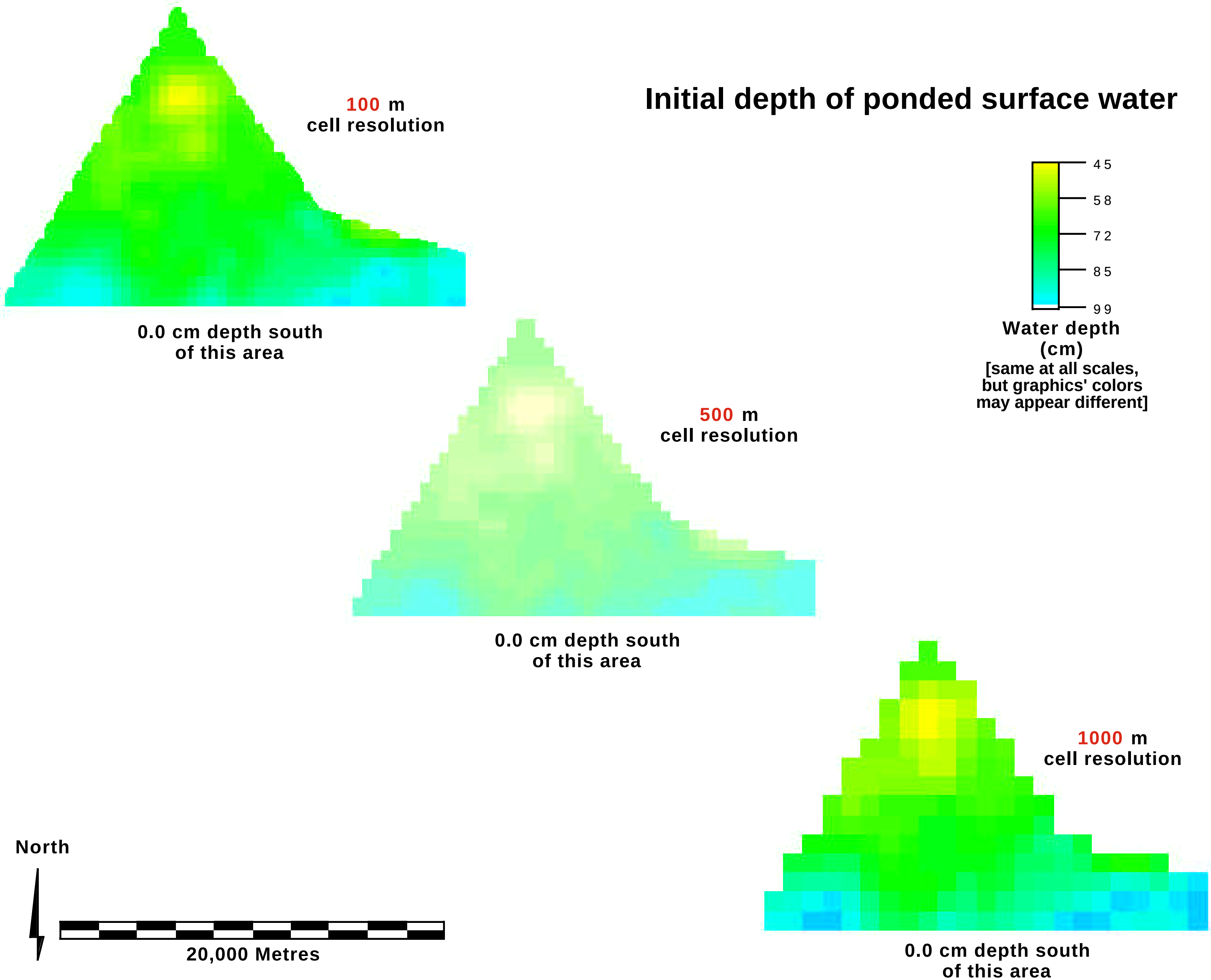
Extent Spatial	Extent Spatial (km^2)	Extent Temporal (yr)	Grain Grid size (m)	Grain dt (iter/day)	Grain dt (hr)	ANDisp	Std.	WatMgmt	Ecology	Succession	Attribute(s)	Parms	icMaps
GreaterEvgl	10394.0	17.00	1000	12	2.00	0.00	**	On	On	Off	Std. calib	Std	Std
GreaterEvgl	10394.0	17.00	1000	12	2.00	0.25	**	On	On	Off	Std. Calib	Std	Std
WCA2A	422.0	0.25	1000	6	4.00	0.00		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	0.25	1000	12	2.00	0.00	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	0.25	1000	24	1.00	0.00		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	0.25	1000	6	4.00	0.25		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	0.25	1000	12	2.00	0.25	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	0.25	1000	24	1.00	0.25		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	20	1.20	0.00		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	40	0.60	0.00	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	80	0.30	0.00		Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	40	0.60	0.25	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	40	0.60	0.50	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	433.5	0.25	500	40	0.60	0.75	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	428.8	0.25	100	900	0.03	0.00	**	Off	Off	Off	WaterWall & Innoculate	Std; & icSaltSfWat innoc.	Std; & WaterWall & Innoc.
WCA2A	422.0	16.00	1000	12	2.00	0.00	**	On	On	Off	Std. Calib	Std	Std
WCA2A	433.5	16.00	500	40	0.60	0.00	**	On	On	Off	Std. Calib	Std	Std

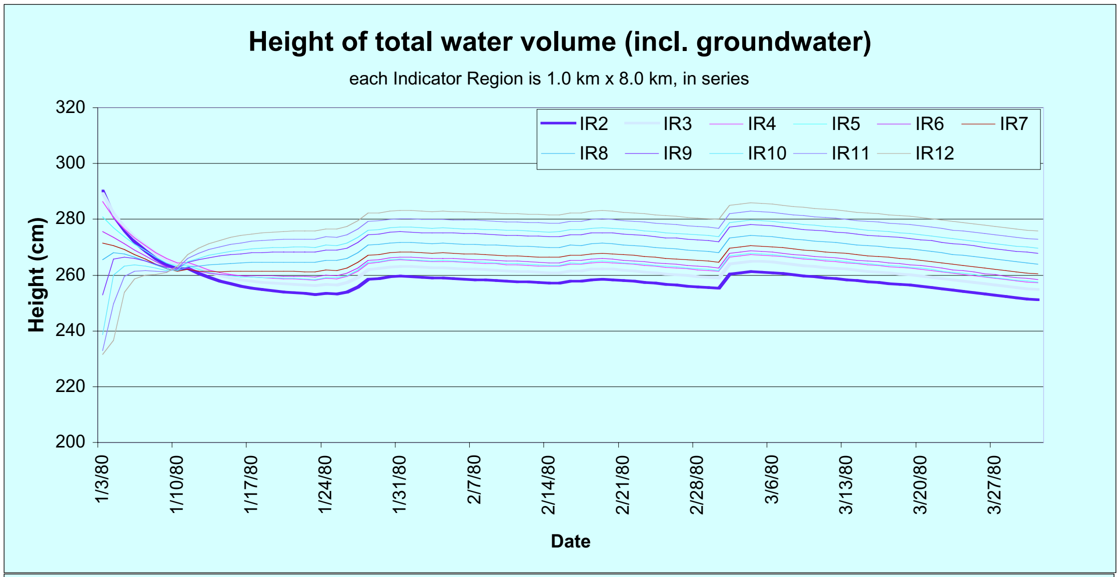
* WaterWall icSfWt==Std. 1/1/1980 Depth in North, zero depth in south
* WaterWall HAB==single 1km^2 cell designated "Typha50" upstream from IndRegions
* WaterWall basins==twelve 8.0km^2 IndRegions placed to respond to innoculation flow
* WaterWall HabParms==SALT_icSfWat conc.=0.001 g/L

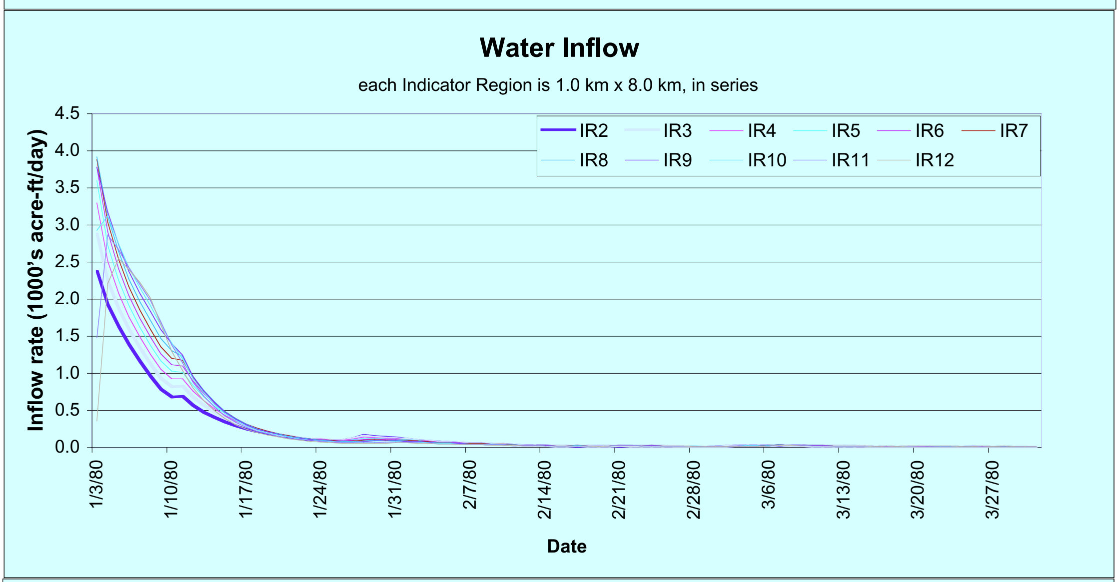
Indicator and tracer-inoculation regions

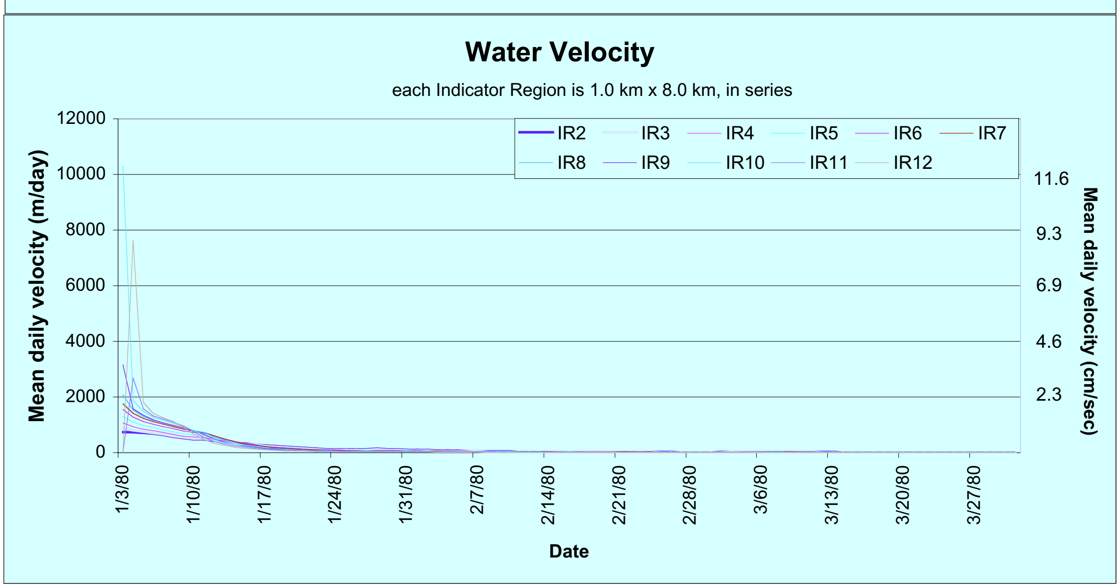


	IR #	km^2	Description
	-99 9	1.0	Innoculation region
	2	8.0	Indicator region2
	3	8.0	Indicator region3
	4	8.0	Indicator region4
	5	8.0	Indicator region 5
	6	8.0	Indicator region 6
	7	8.0	Indicator region 7
	8	8.0	Indicator region 8
	9	8.0	Indicator region 9
	10	8.0	Indicator region 10
	11	8.0	Indicator region 11
	12	8.0	Indicator region 12


Initial depth of ponded surface water
100 m
cell resolution
0.0 cm depth south
of this area
500 m
cell resolution
0.0 cm depth south
of this area
1000 m
cell resolution
0.0 cm depth south
of this area
45
58
72
85
99
Water depth
(cm)
[same at all scales,
but graphics' colors
may appear different]
North
20,000 Metres


Height of total water volume (incl. groundwater)
each Indicator Region is 1.0 km x 8.0 km, in series
Height (cm)
320
300
280
260
240
220
200
IR2 IR3 IR4 IR5 IR6 IR7
IR8 IR9 IR10 IR11 IR12
1/3/80 1/10/80 1/17/80 1/24/80 1/31/80 2/7/80 2/14/80 2/21/80 2/28/80 3/6/80 3/13/80 3/20/80 3/27/80
Date

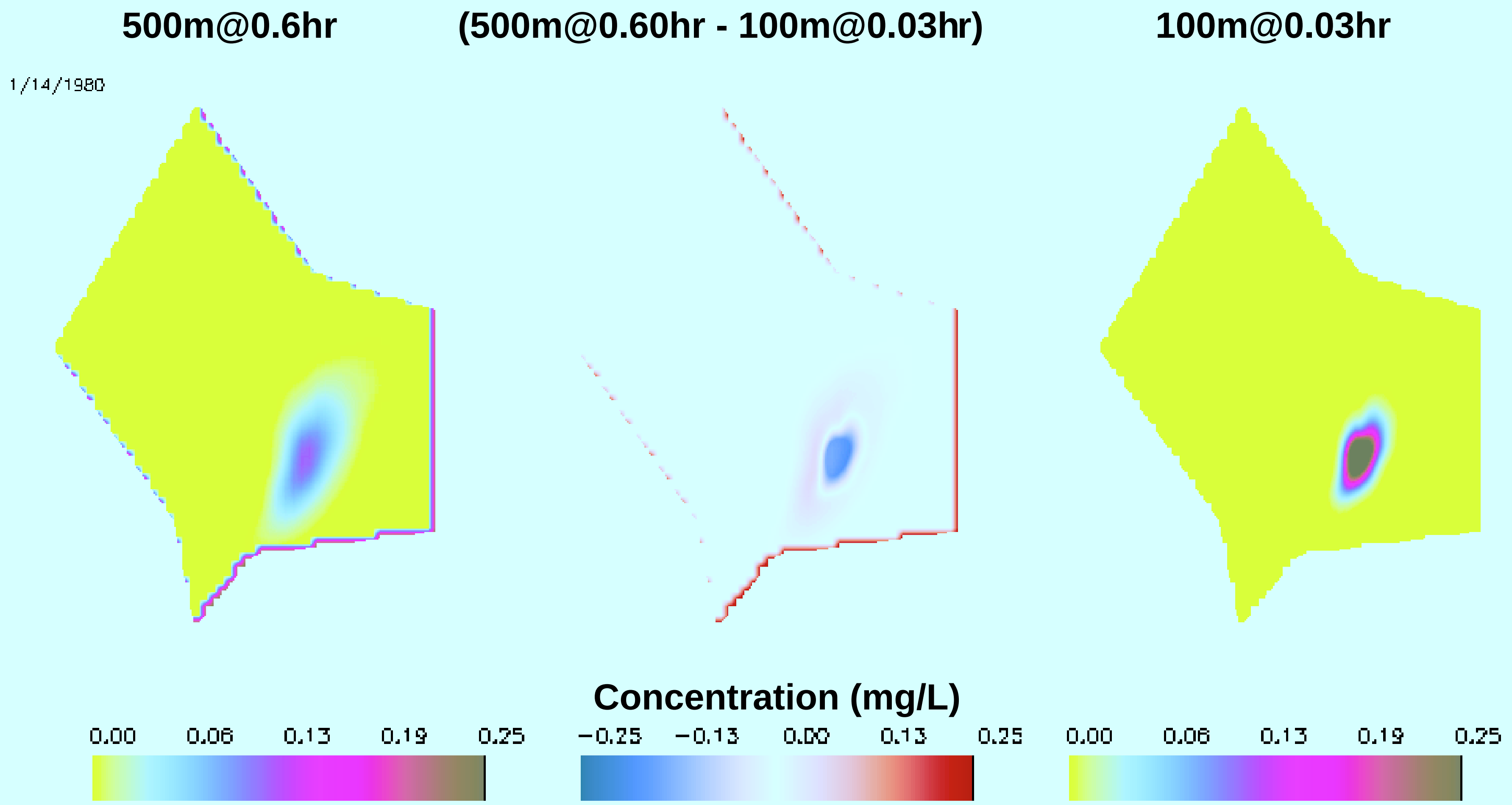

Water Inflow
each Indicator Region is 1.0 km x 8.0 km, in series
Inflow rate (1000's acre-ft/day)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
IR2 IR3 IR4 IR5 IR6 IR7
IR8 IR9 IR10 IR11 IR12
1/3/80 1/10/80 1/17/80 1/24/80 1/31/80 2/7/80 2/14/80 2/21/80 2/28/80 3/6/80 3/13/80 3/20/80 3/27/80
Date


Water Velocity
each Indicator Region is 1.0 km x 8.0 km, in series
Mean daily velocity (m/day)
12000
10000
8000
6000
4000
2000
0
Mean daily velocity (cm/sec)
11.6
9.3
6.9
4.6
2.3
IR2 IR3 IR4 IR5 IR6 IR7
IR8 IR9 IR10 IR11 IR12
1/3/80 1/10/80 1/17/80 1/24/80 1/31/80 2/7/80 2/14/80 2/21/80 2/28/80 3/6/80 3/13/80 3/20/80 3/27/80
Date

Stress test: tracer flow at different scales

Daily tracer concentration differences

Day 14

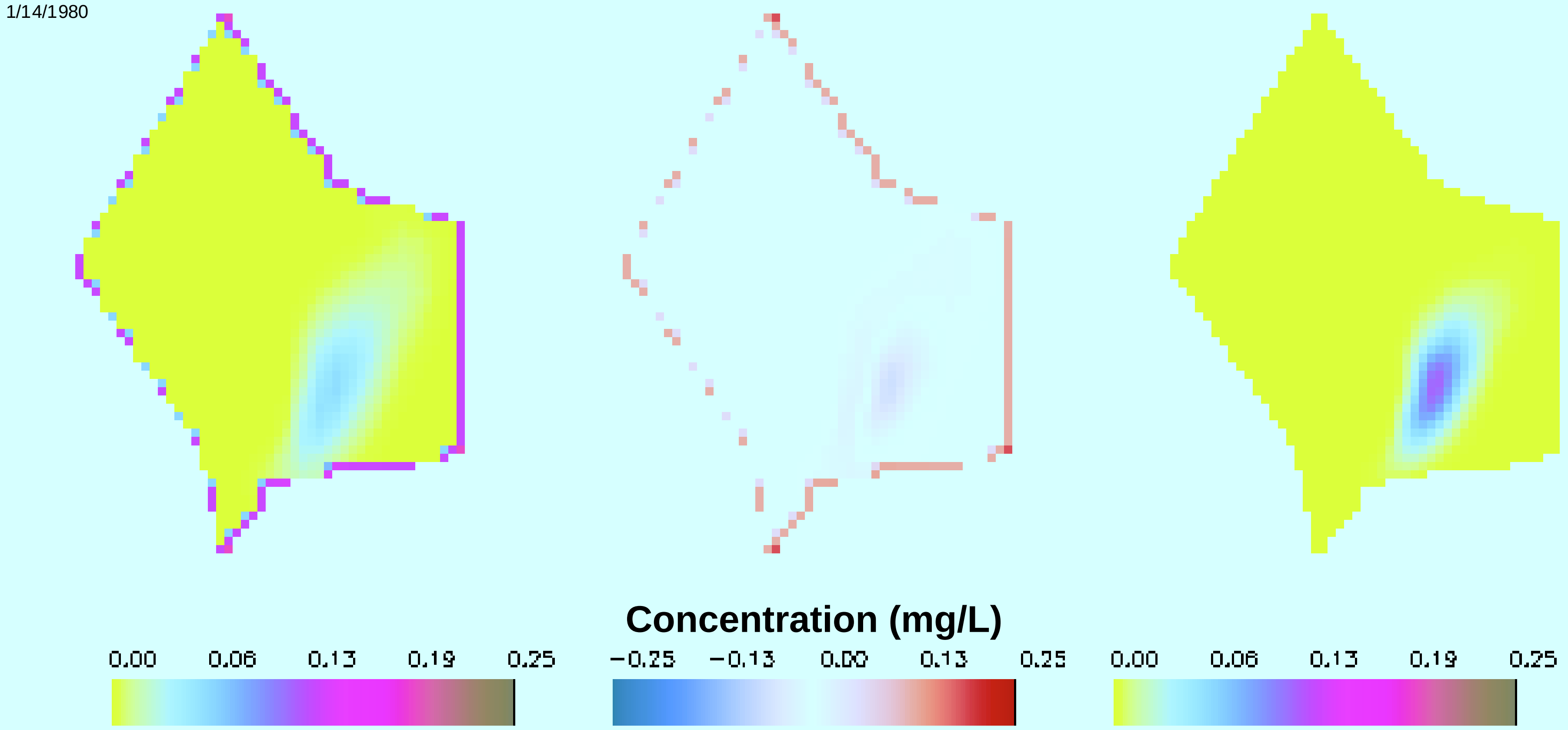


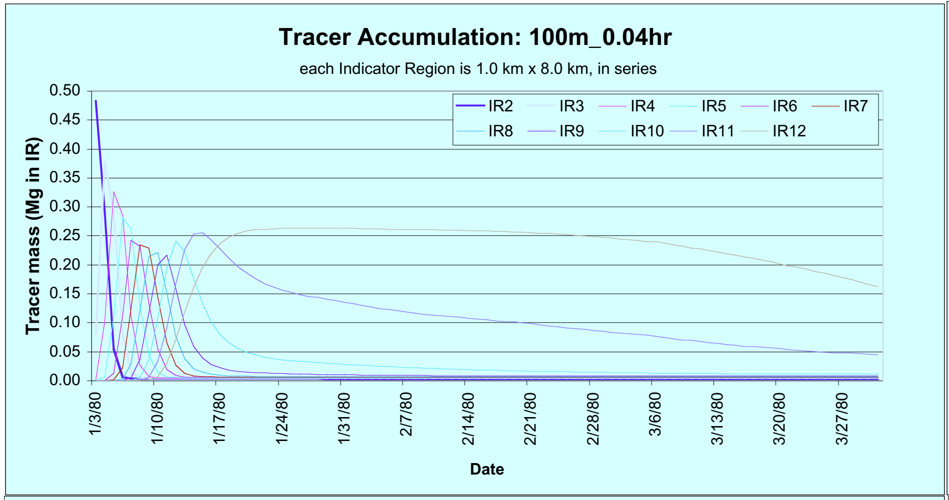
Stress test: tracer flow at different scales

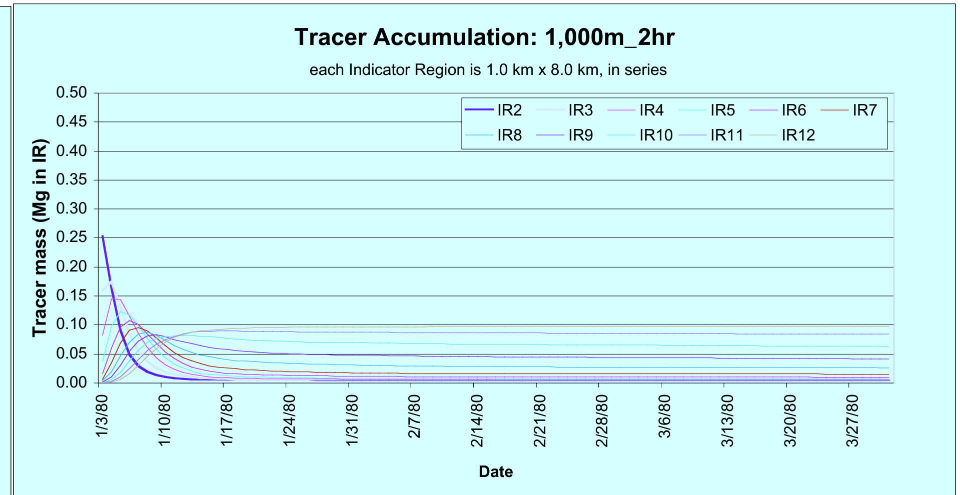
Daily tracer concentration differences

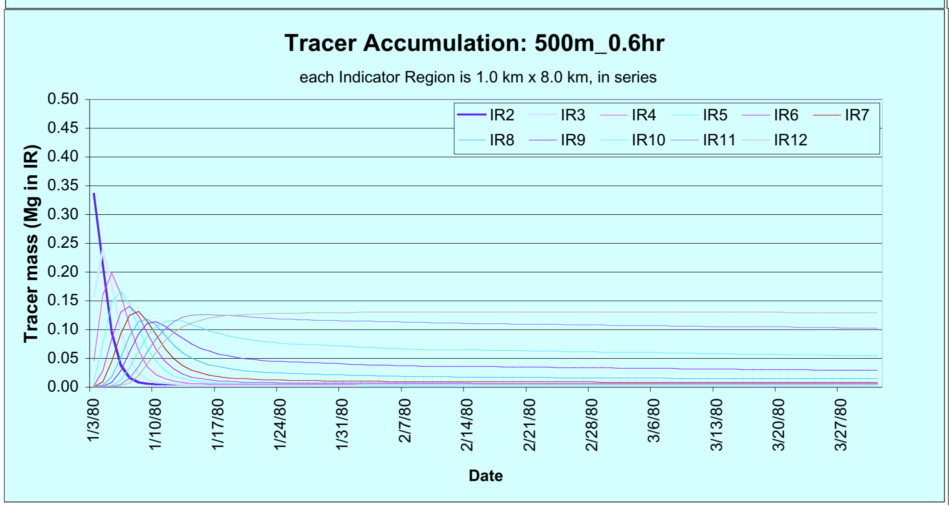
Day 14

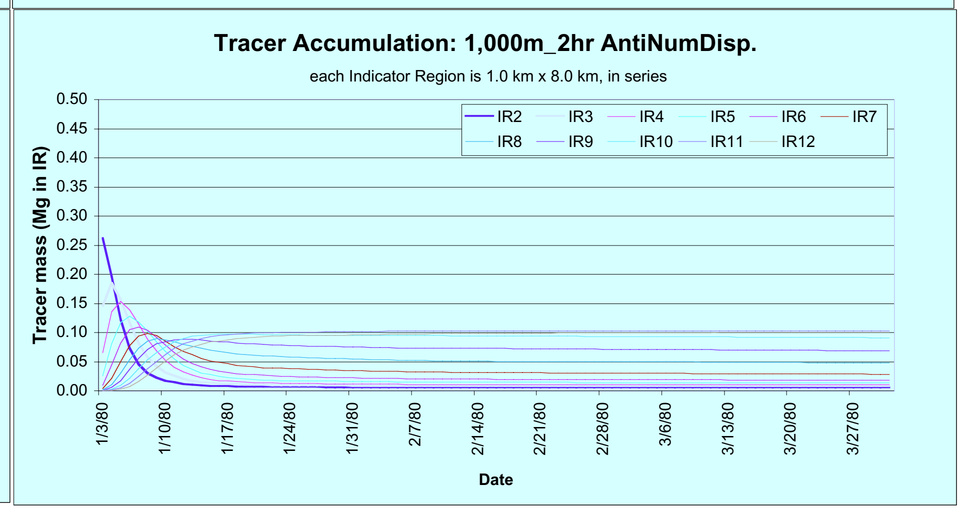
1000m@2.0hr | **(1000m@2.0hr - 500m@0.6hr)** | **500m@0.6hr**

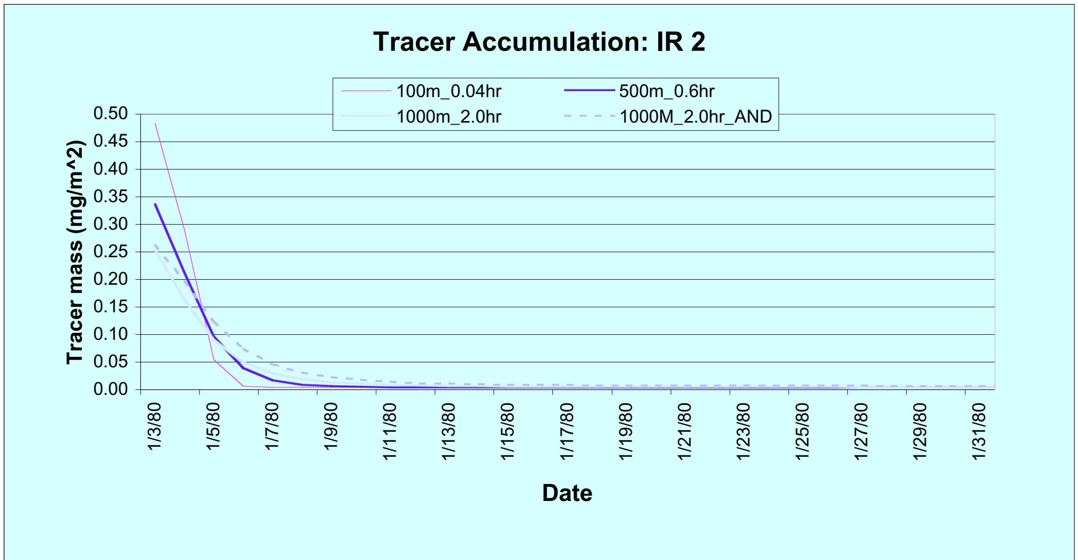


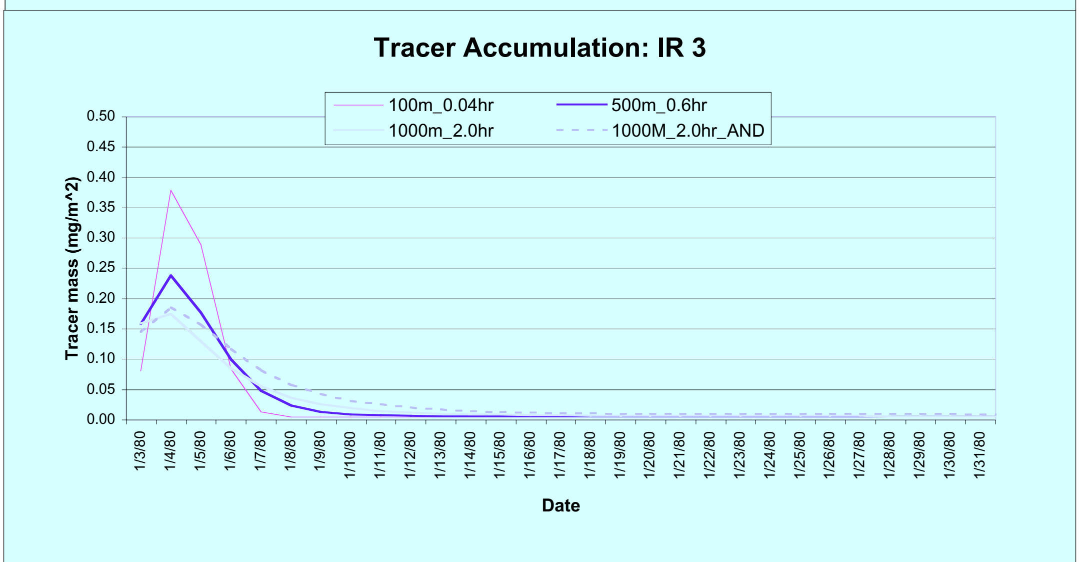

Tracer Accumulation: 100m_0.04hr
each Indicator Region is 1.0 km x 8.0 km, in series
Tracer mass (Mg in IR)
IR2 IR3 IR4 IR5 IR6 IR7 IR8 IR9 IR10 IR11 IR12
Date

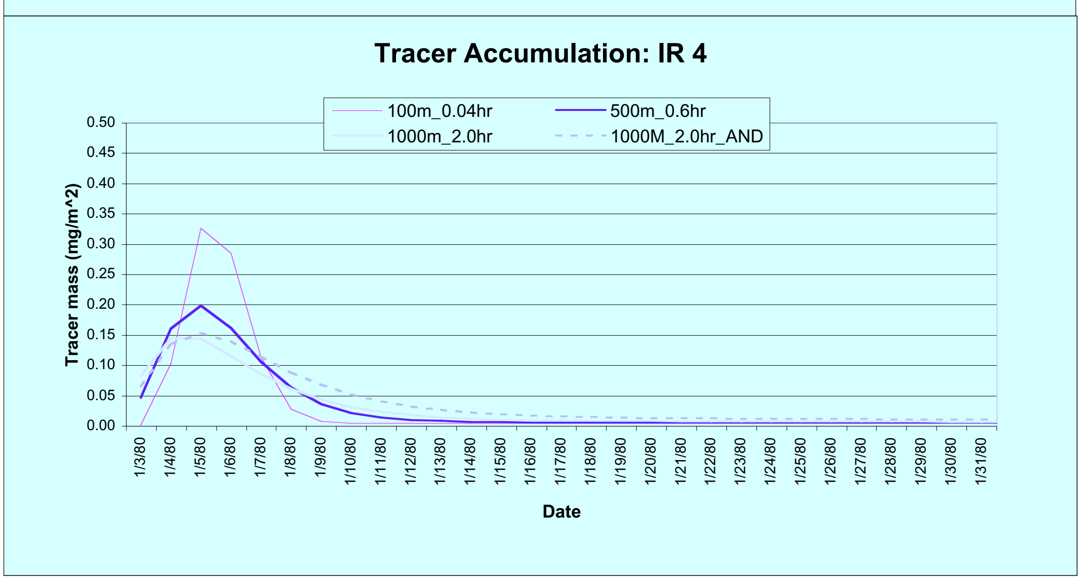

Tracer Accumulation: 1,000m_2hr
each Indicator Region is 1.0 km x 8.0 km, in series
Tracer mass (Mg in IR)
IR2 IR3 IR4 IR5 IR6 IR7 IR8 IR9 IR10 IR11 IR12
Date

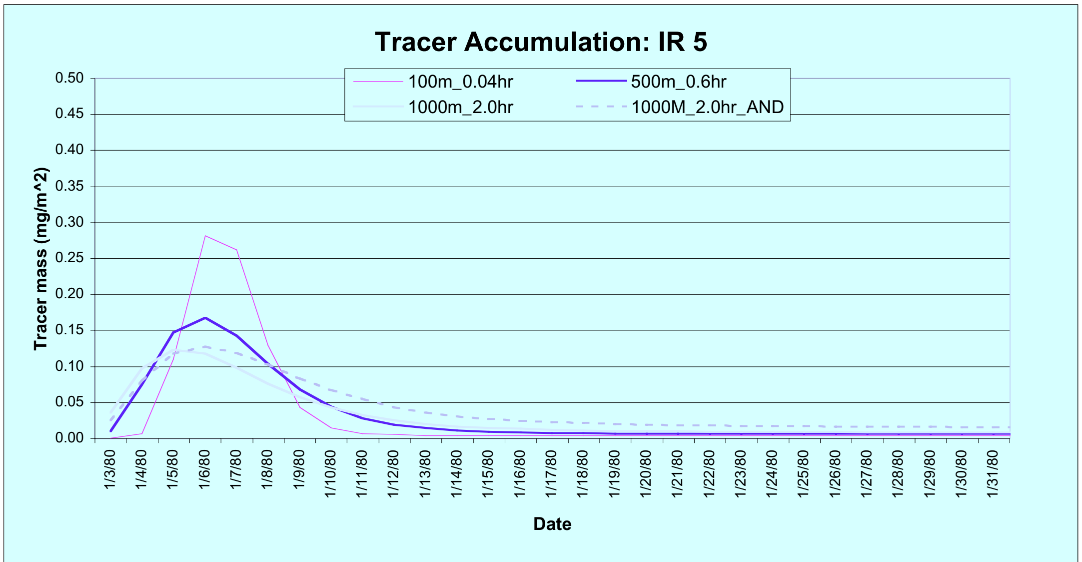

Tracer Accumulation: 500m_0.6hr
each Indicator Region is 1.0 km x 8.0 km, in series
Tracer mass (Mg in IR)
IR2 IR3 IR4 IR5 IR6 IR7 IR8 IR9 IR10 IR11 IR12
Date

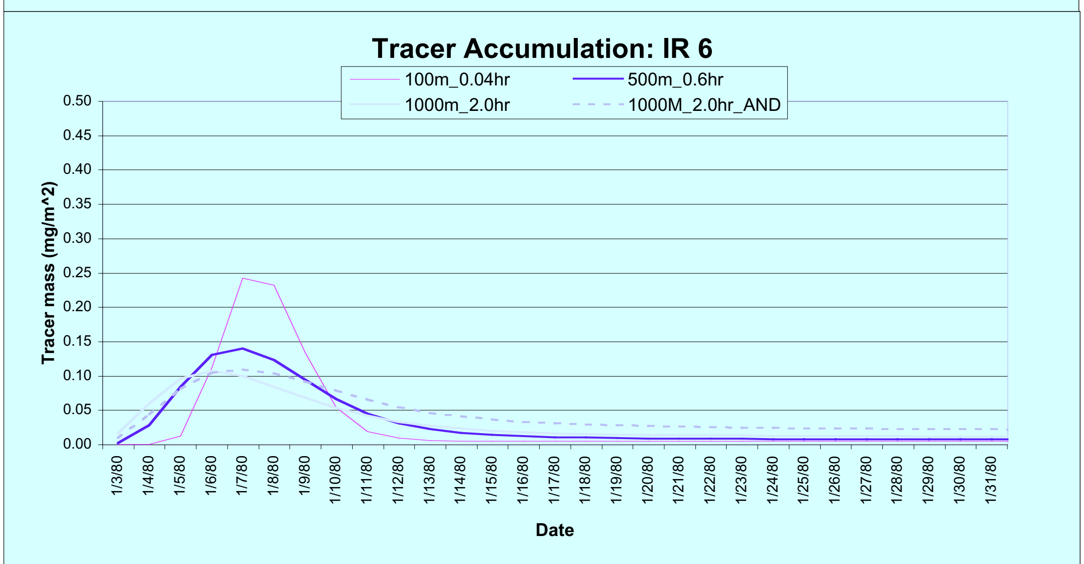

Tracer Accumulation: 1,000m_2hr AntiNumDisp.
each Indicator Region is 1.0 km x 8.0 km, in series
Tracer mass (Mg in IR)
IR2 IR3 IR4 IR5 IR6 IR7 IR8 IR9 IR10 IR11 IR12
Date

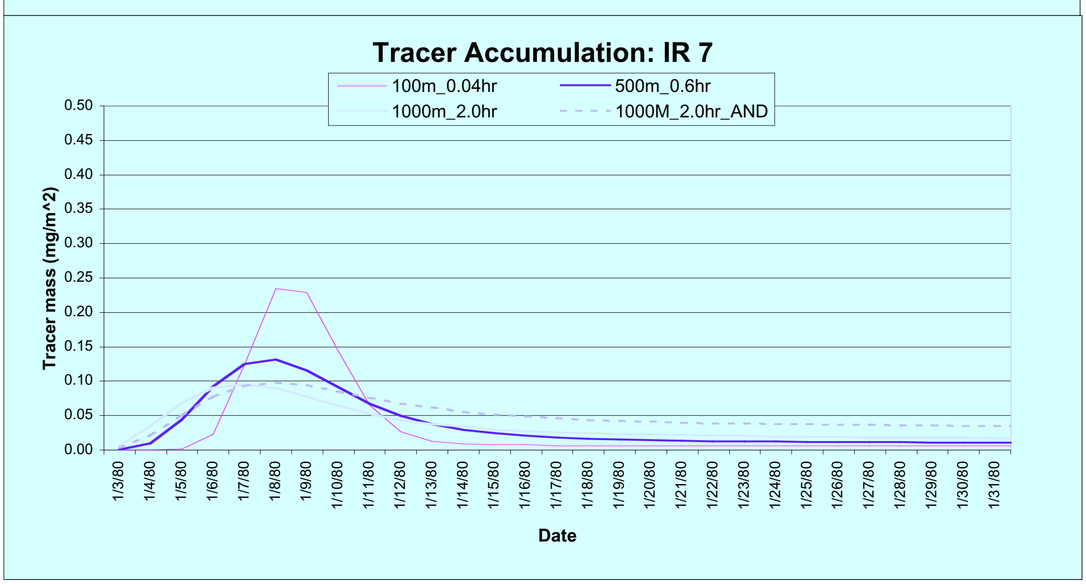

Tracer Accumulation: IR 2
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
Date


Tracer Accumulation: IR 3
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
Date

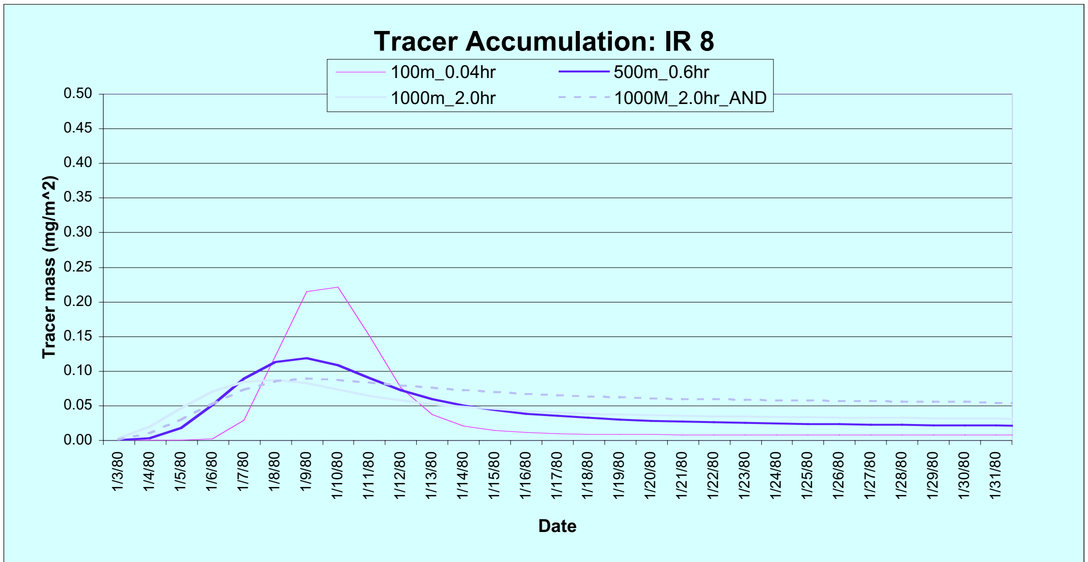

Tracer Accumulation: IR 4
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
Date

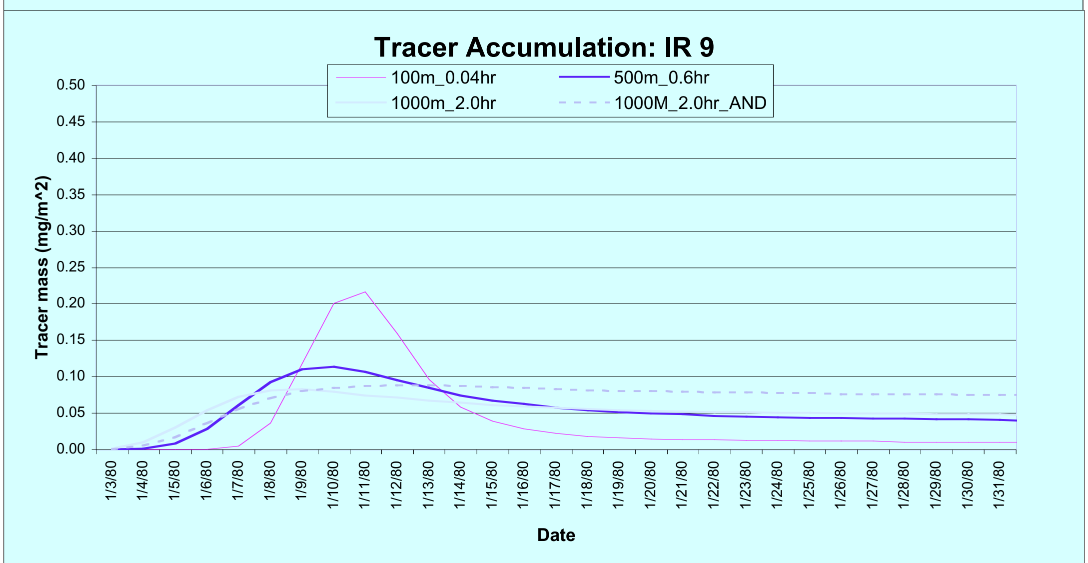

Tracer Accumulation: IR 5
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date

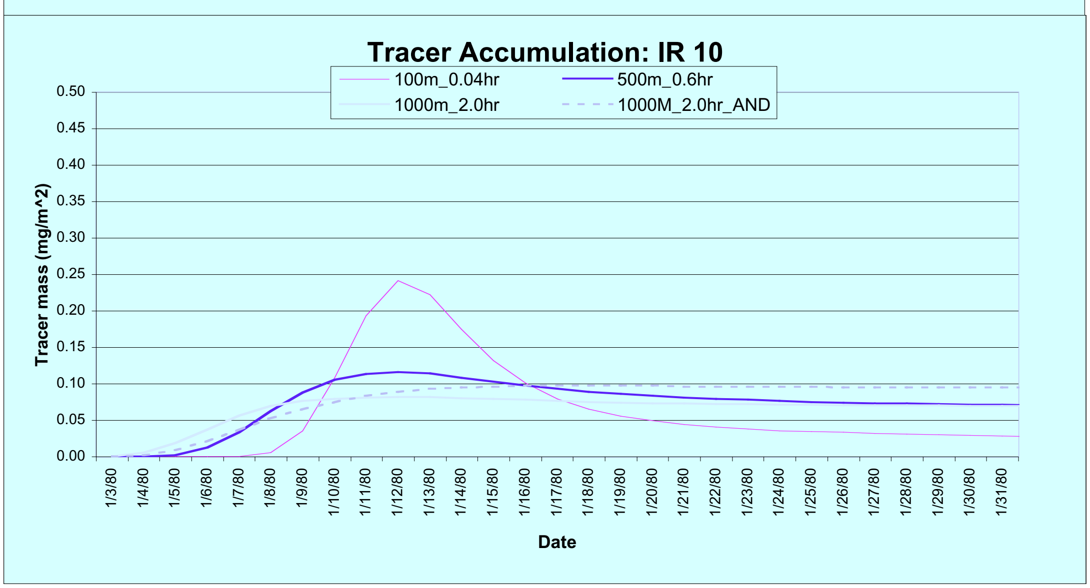

Tracer Accumulation: IR 6
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date


Tracer Accumulation: IR 7
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date

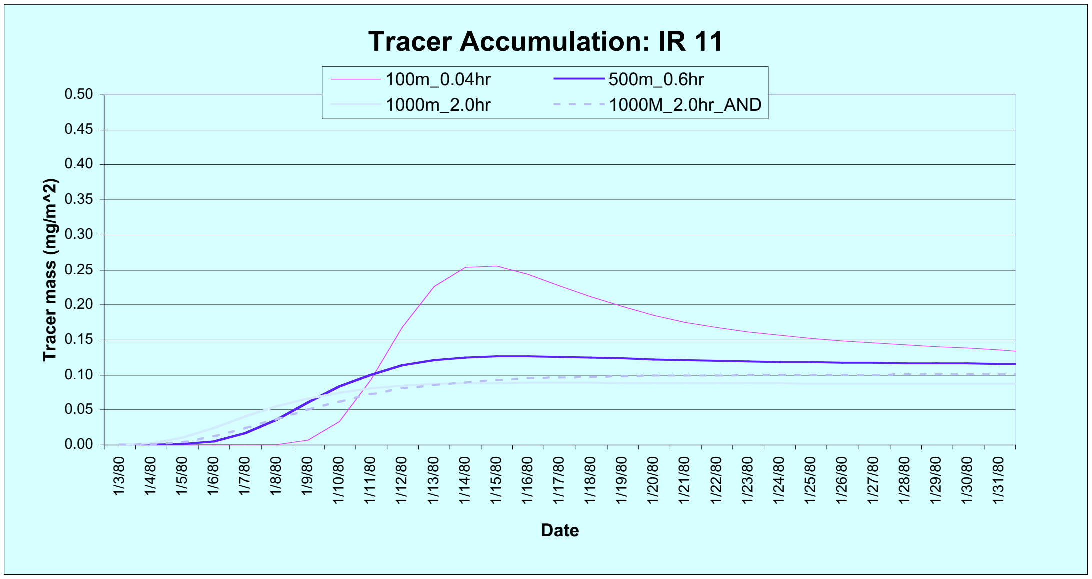
13c


Tracer Accumulation: IR 8
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date


Tracer Accumulation: IR 9
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date


Tracer Accumulation: IR 10
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date

13d


Tracer Accumulation: IR 11
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
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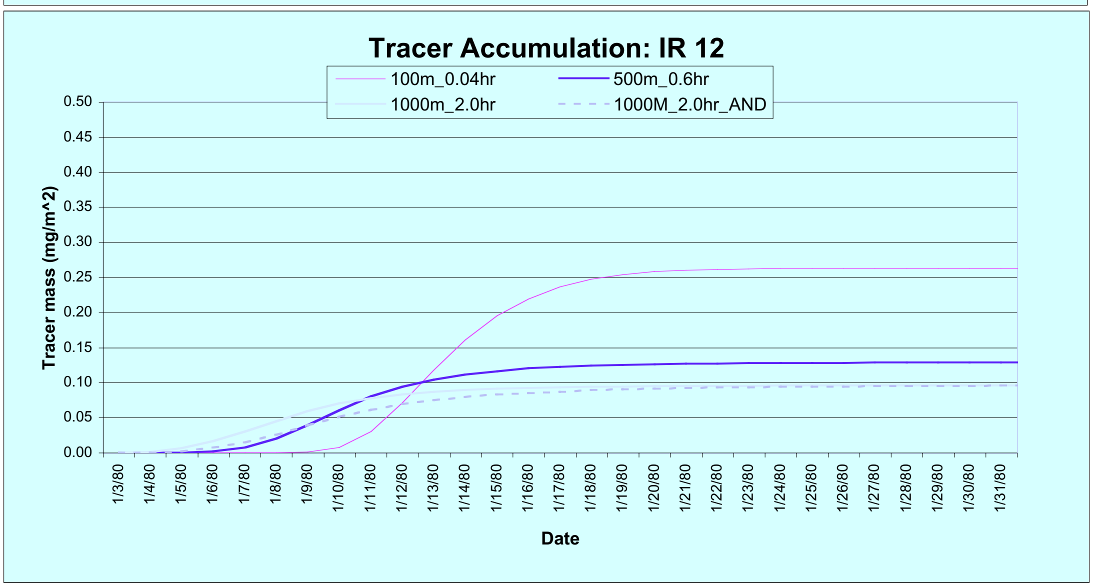
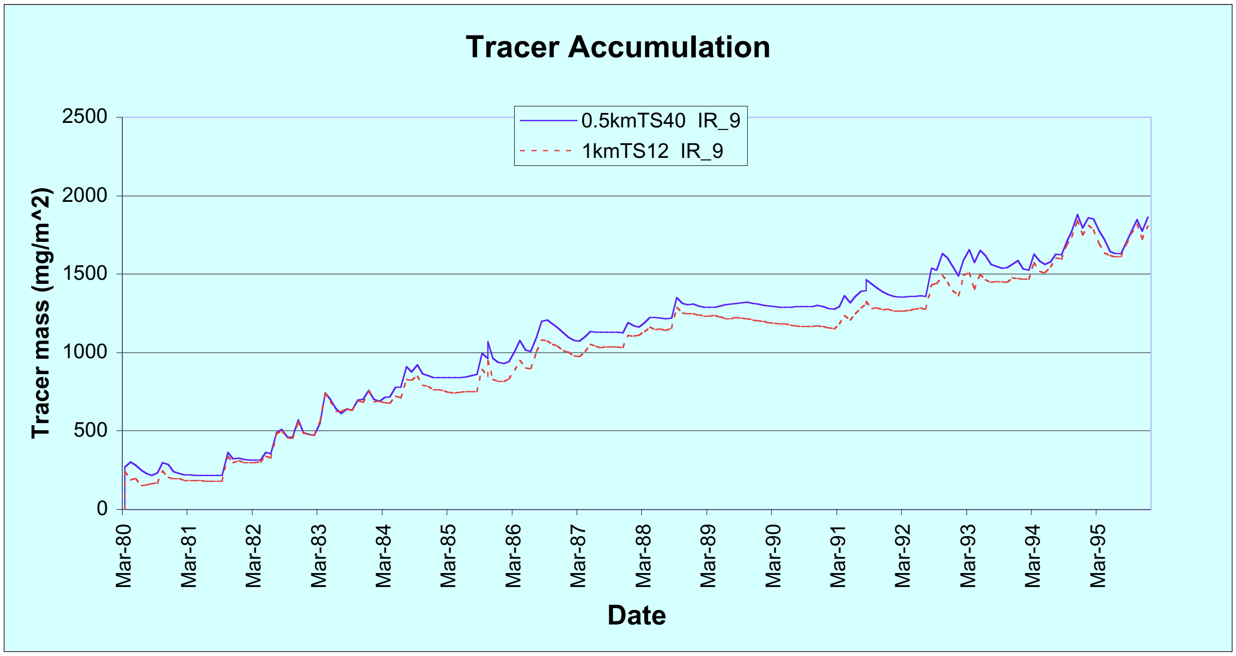
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date

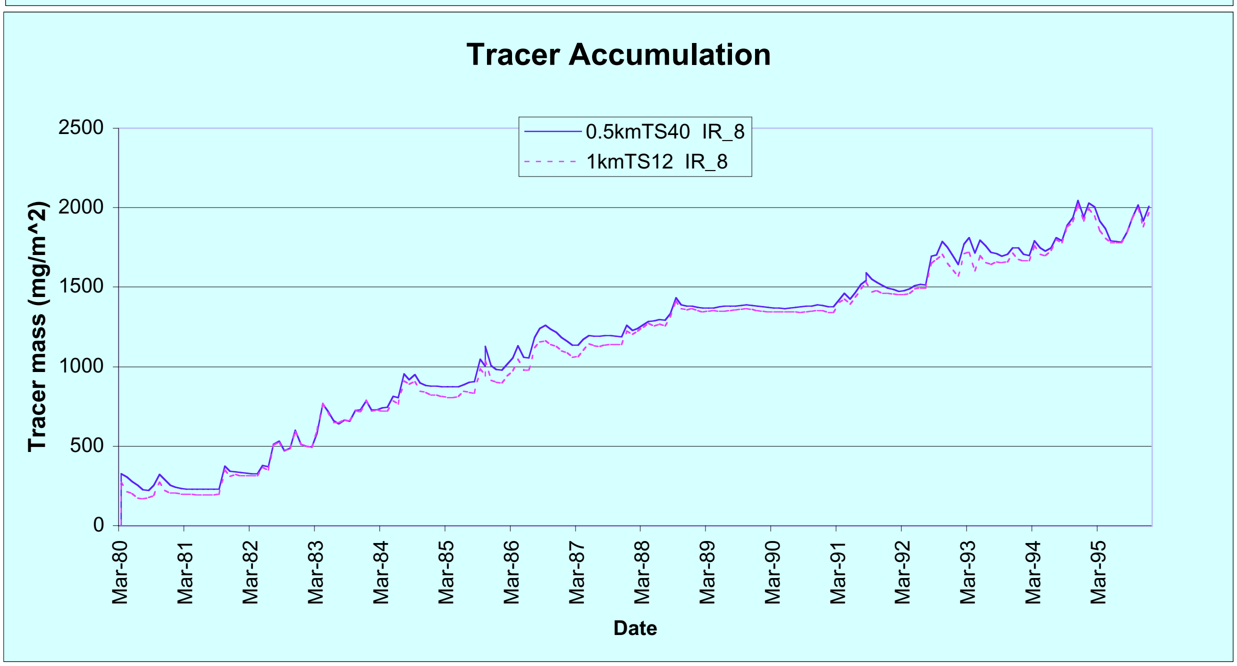

Tracer Accumulation: IR 12
100m_0.04hr
500m_0.6hr
1000m_2.0hr
1000M_2.0hr_AND
Tracer mass (mg/m^2)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/3/80
1/4/80
1/5/80
1/6/80
1/7/80
1/8/80
1/9/80
1/10/80
1/11/80
1/12/80
1/13/80
1/14/80
1/15/80
1/16/80
1/17/80
1/18/80
1/19/80
1/20/80
1/21/80
1/22/80
1/23/80
1/24/80
1/25/80
1/26/80
1/27/80
1/28/80
1/29/80
1/30/80
1/31/80
Date

14

(A)



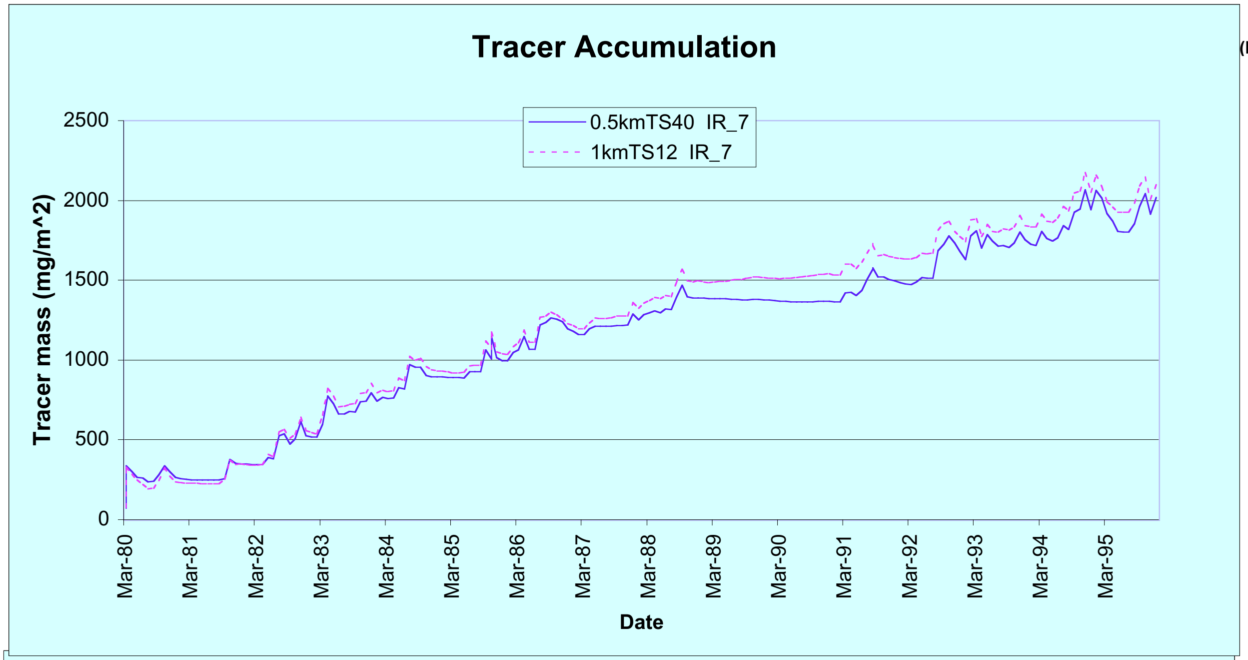
Tracer Accumulation
0.5kmTS40 IR_9
1kmTS12 IR_9
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date

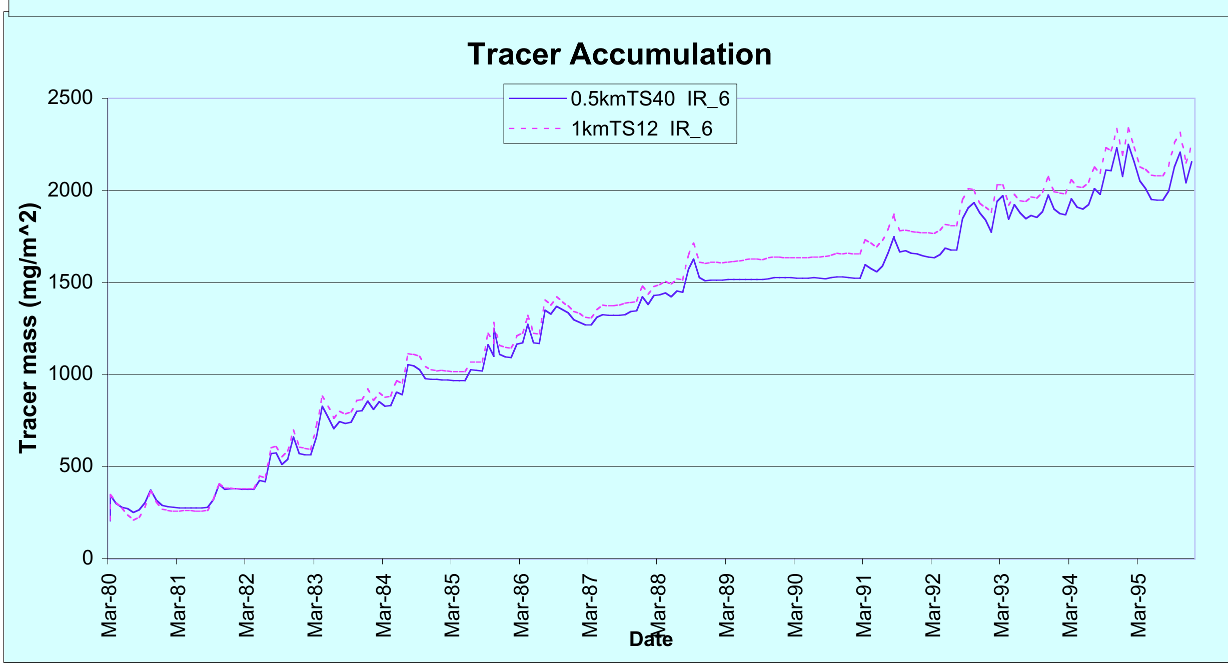


Tracer Accumulation
0.5kmTS40 IR_8
1kmTS12 IR_8
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date

14

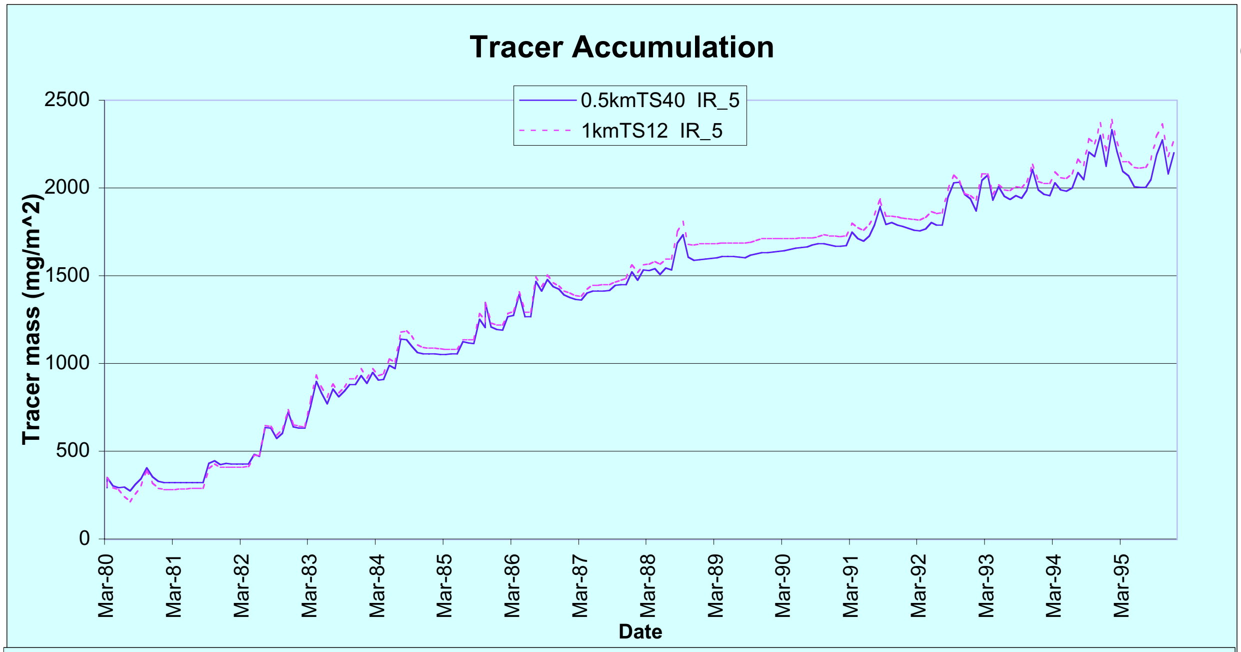
(B)

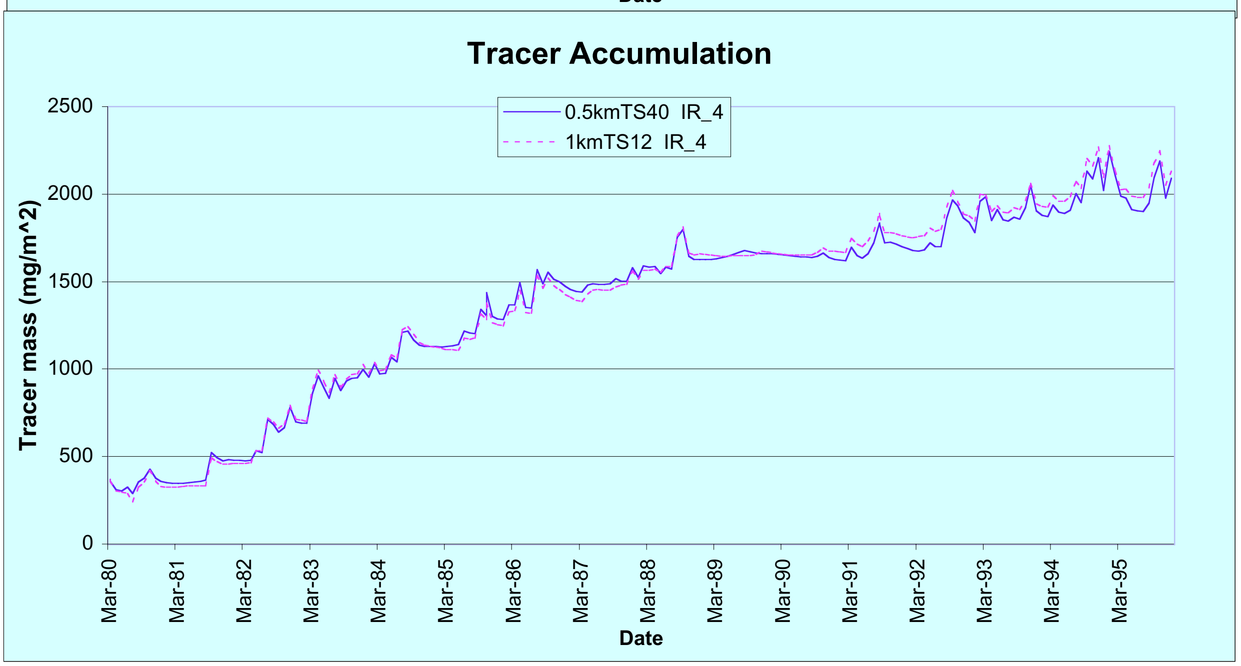

Tracer Accumulation
0.5kmTS40 IR_7
1kmTS12 IR_7
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date

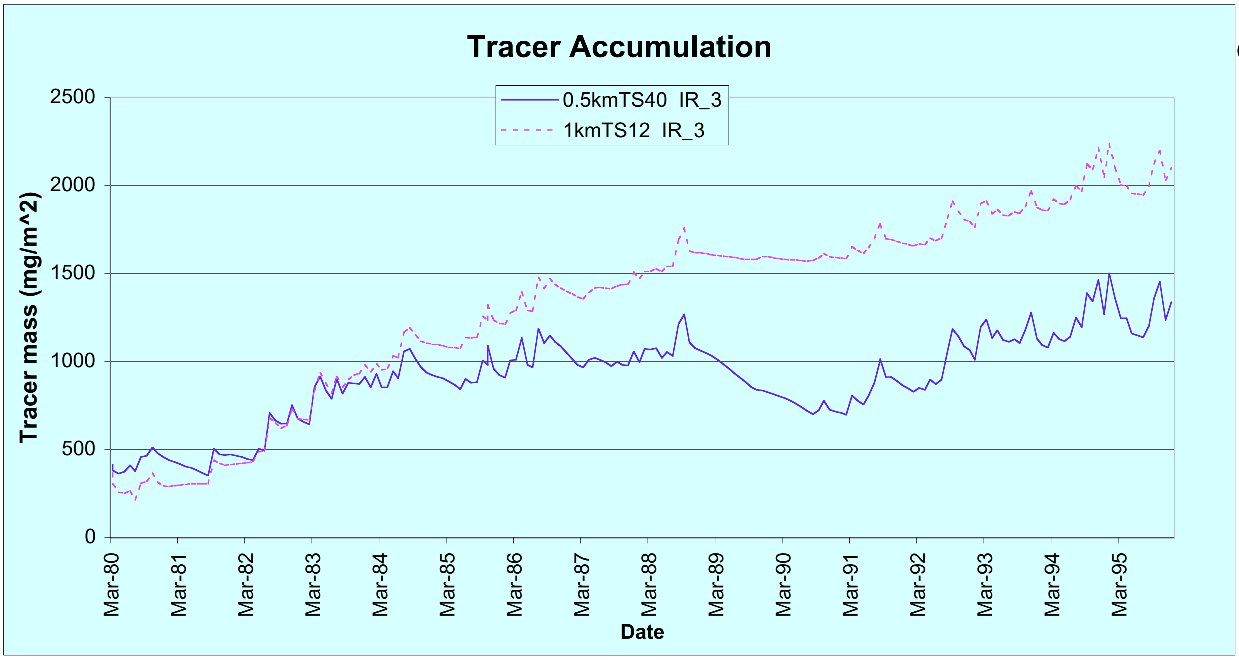

Tracer Accumulation
0.5kmTS40 IR_6
1kmTS12 IR_6
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date

14

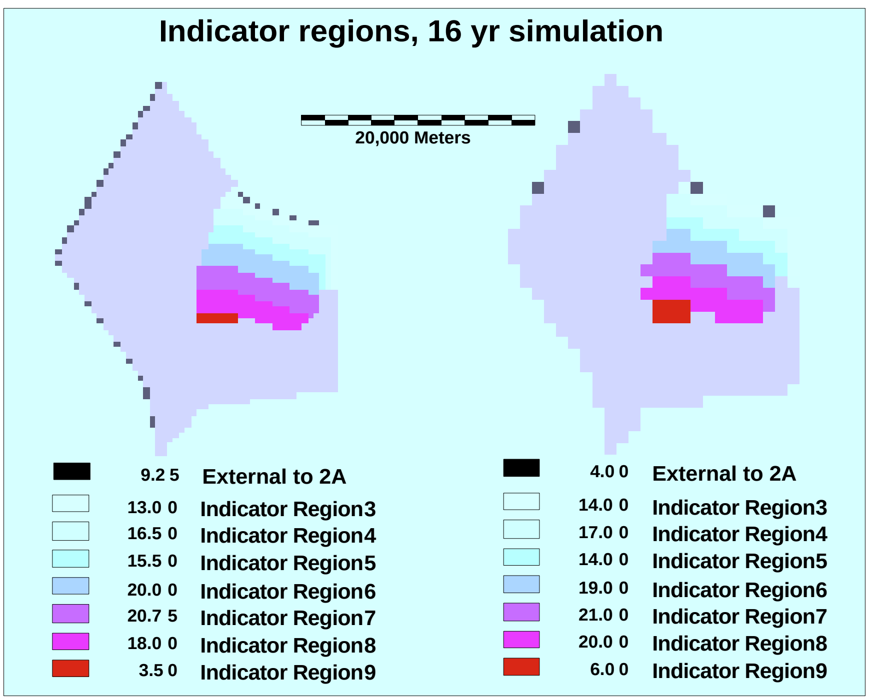
(C)


Tracer Accumulation
0.5kmTS40 IR_5
1kmTS12 IR_5
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date


Tracer Accumulation
0.5kmTS40 IR_4
1kmTS12 IR_4
Tracer mass (mg/m^2)
2500
2000
1500
1000
500
0
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Mar-93
Mar-94
Mar-95
Date



(D)



The significant difference in the Indicator Region immediately adjacent to the canal/inflow structures was due to the hasty rescaling of the 500 m resolution Indicator Regions to 1000 m,which did not accomodate the different extents of canal-cell interaction geometries and thus the two scales of implementation had different areas of exchange with the inflow canal/structures.

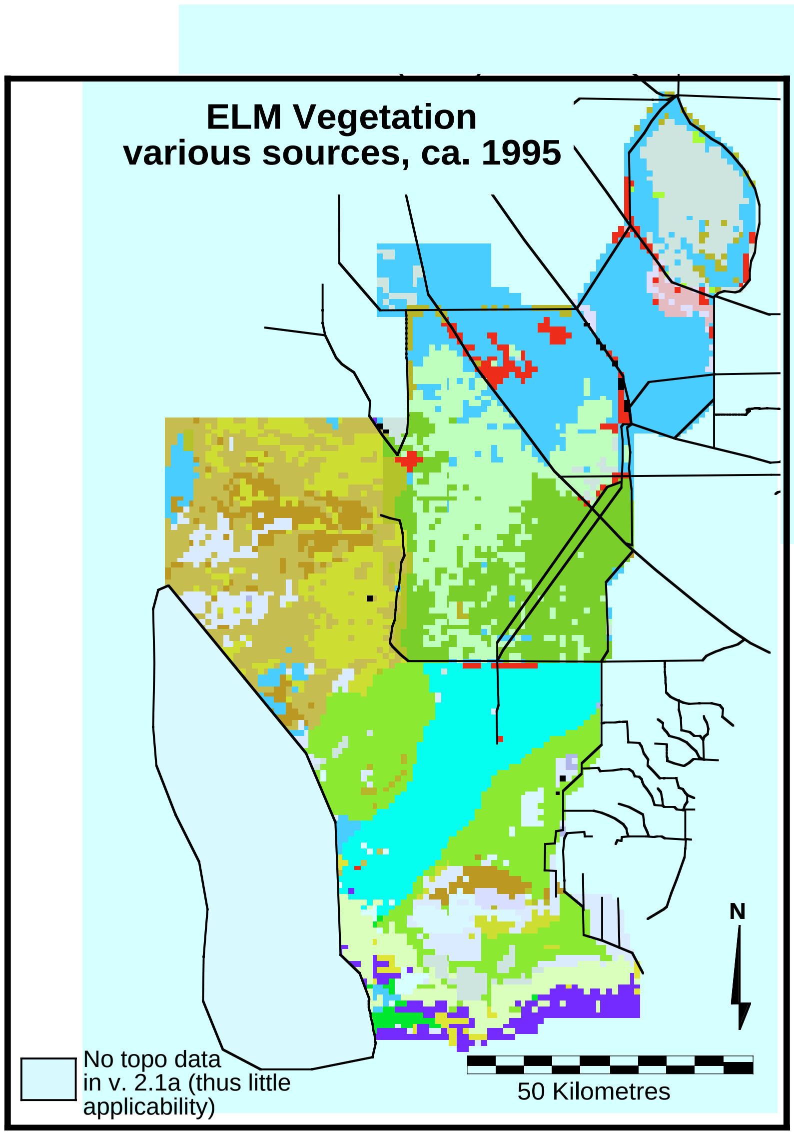
Global parameters used in ELM

Modifications to the "Chosen" numeric values may be made in this Worksheet;
those values and the brief supporting documentation column are mirrored in the GlobalParms Worksheet,
with the GlobalParms worksheet exported as tab-delimited text for ELM

ALL RANKINGS AND EXTENDED DOCUMENTATION ARE DRAFT (GENERAL ESTIMATES) FOR PRELIMINARY EVALUATION BY ELM REVIEWERS

Rank	Group	Grp#	Parameter name	ChosenValue	Units	efaultValue	∆Def&Chosen	Brief documentation	Extended documentation
5	1	1	SOLOMEGA=	0.03259	dimless	0.03259		***empirical constant used in solar radiation, don't change from 0.03259	fixed published value
5	1	2	ALTIT=	1.0	m	1.0		***regional altitude	pertinent only to moving model to other region
5	1	3	LATDEG=	26.00	deg.min	26.00		***regional latitude (degrees.minutes, don't convert min to decimal deg)	pertinent only to moving model to other region
5	1	4	DATUM_DISTANCE=	6.0	m	6.0		***distance (m below NGVD'29) to base datum	not simulating deep aquifer; non-critical parameter
5	1	5	HYD_IC_SFWAT=	0.0	m	0.0		***surf water depth added to ICwater depth map (+-m)	only used in exploratory model experiments
5	1	6	HYD_IC_UNSATZ=	0.0	m	0.0		***depth of unsat zone added to ICunsat depth map (+-m)	only used in exploratory model experiments
5	1	7	HYD_RCRECHG=	0.0	m/d	0		***Rate of recharging of the aquifer below the base datum (loss from model system).	not implemented
5	1	8	HYD_PAN_K=	1.0	dimless	1		***Pan evaporatioin coeficient.	Potential global calibration parameter for surface water evap, and a component of the plant transpiration. NOT used in calibration (fix at 1.0)
4	1	9	HYD_ICUNSATMOIST=	1.0	dimless	1		***Initial condition of the moisture proportion in the unsaturated zone.	limited spatial data; non-critical initial condition
3	1	10	DetentZ=	0.01	m	0.01		***detention depth	scale-dependent relative to topographic heterogeneity
5	1	11	MinCheck=	0.0001	m	0.0001		***small threshold number, generally for error-checking	only used in constraining fluxes at extremely mimimal conditions
	1								
5	2	1	ALG_IC_MULT=	1.0	dimless	1.0		***algal init-cond multiplier	only used in exploratory model experiments
5	2	2	alg_uptake_coef=	3	dimless	3		***parameter for exp function	only used to define (fixed) function behavior
2	2	3	ALG_SHADE_FACTOR=	1.0	dimless	1.0		***calibration parm to modify LAI in shading fcn	regulate magnitude of macrophyte shading; CALIBRATE to achieve observed periphyton biomass in dense/moderate vegetation
5	2	4	ALG_NC=	0.15	dimless	0.15		***Initial nitrogen:carbon ratio in all algae/periphyton (not implemented)	NA
2	2	5	algMortDepth=	0.05	m	0.05		***depth of unsat zone, below which the "dry" alg mort occurs	limited field observations
2	2	6	ALG_RC_MORT_DRY=	0.005	1/d	0.005		***Mortality rate of benthic algae in dry conditions.	limited field observations; preliminary lab experiments
2	2	7	ALG_RC_MORT=	0.001	1/d	0.001		***Specific rate of algal mortality. Note that this is in the presence of water.	liimited field observations relating to biomass changes
2	2	8	ALG_RC_PROD=	0.5	1/d	0.5		***Maximum specific rate of algal gross primary production.	field experiments (and O2->Carbon conversion); CALIBRATE to achieve observed periphyton production rates
2	2	9	ALG_RC_RESP=	0.0005	1/d	0.0005		***Max specific rate of algal respiration.	field experiments (and O2->Carbon conversion)
2	2	10	alg_R_accel=	1.0	dimless	1.0		***acceleration of rate of respiration of oligotrophic community under high P conditions	due to uncertainty of mechanism for mat loss, increase respiration loss at elevated P concentrations; CALIBRATE to achieve biomass observations
2	2	11	AlgComp=	2.0	dimless	2.0		***algal density-dep competition	best professional judgement; CALIBRATE to achieve relative biomass estimates of the two communities under low nutrient conditions
4	2	12	ALG_REF_MULT=	0.01	dimless	0.01		***algal refuge level multiplier	proxy for maintaining senescent stocks under severe drydown conditions
2	2	13	NC_ALG_KS_P=	0.10	mg/L	0.10		***half-saturation conc of avail P, non-calc periph	Lab study; CALIBRATE to achieve plant growth rates along nutrient gradients
4	2	14	alg_alkP_min=	0.1	dimless	0.1		***minimum P availablity (0-1) control on P limitation, indicative of alkaline phosphotase activity increasing bioavailability	indicative of observed continued (low) uptake and growth at very low ambient P concentrations
2	2	15	C_ALG_KS_P=	0.05	mg/L	0.05		***half-saturation conc of avail P, calcareous periph	Lab study; CALIBRATE to achieve plant growth rates along nutrient gradients
4	2	16	ALG_TEMP_OPT=	33	deg C	33		***Optimal temperature for algal primary production (degrees C). Also used in respiration control.	General literature estimates relative to plant type/family
2	2	17	C_ALG_threshTP=	0.02	mg/L	0.02		***TP conc above which calcareous periph have elevated respiration	due to uncertainty of mechanism for mat loss, increase respiration loss at elevated P concentrations; CALIBRATE to achieve biomass observations
4	2	18	ALG_C_TO_OM=	0.48	dimless	0.48		***Mass ratio of organic carbon to total organic material in algae (ash free dry weight).	multiple glades field and lab observations
3	2	19	alg_light_ext_coef=	0.005	dimless	0.005		***light extinction parameter, currently used to fully define (statically) extinction	fixed extinction coef for clear water
3	2	20	ALG_LIGHT_SAT=	550	cal/cm/d	550		***Saturating light intensity for algal photosyn (langley/d = cal/cm^2 per day)	assume max normal radiation is saturation
3	2	21	ALG_PC=	0.003	dimless	0.003		***Initial phophorus:carbon ratio in all algae/periphyton	multiple glades field and lab observations
	2								
1	3	1	DOM_RCDECOMP=	0.001	1/d	0.001		***Maximum observed specific rate of organic matter decomposition (w/o limitations); used in Floc and DOM.	field and lab studies, glades peat-systems
1	3	2	DOM_DECOMPRED=	0.3	dimless	0.3		*** anaerobic conditions, reduce the max rate of aerobic decomposition by this proportion.	glades lab experiments
5	3	3	DOM_decomp_coef=	3	dimless	3		***parameter for exp function	only used to define (fixed) function behavior
2	3	4	DOM_DECOMP_POPT=	0.35	mg/L	0.35		***Optimal phosphorus water concentration for maximum rate of decomposition.	glades lab experiments
4	3	5	DOM_DECOMP_TOPT=	33	deg C	33		***Optimal temperature for maximum rate of decomposition of organic material; used in Floc and DOM.	assume max normal temperature is optimum
3	3	6	DOM_C_OM_OPT=	0.15	dimless	0.15		***optimal C:OM substrate quality for decomposition	glades lab experiment; general literature
3	3	7	sorbToTP=	0.01	dimless	0.01		***init cond. only, the ratio of sorbed P to TP in soil	generalization of soilTP conc initial condition
	3							***	
5	4	1	MAC_IC_MULT=	0.5	dimless	0.5		***macrophyte init-cond multiplier	assume one-half of max biomass
5	4	2	MAC_LITTERSEAS=	1.0	NI	1.0		***not implemented	NA
4	4	3	MAC_REFUG_MULT=	0.01	dimless	0.01		***macrophyte refuge level multiplier	proxy for maintaining seed source
4	4	4	mac_uptake_coef=	3	dimless	3		***parameter for exp function	only used to define (fixed) function behavior
3	4	5	mann_height_coef=	0.15	dimless	0.15		***proportion of height at which macrophyte starts to bend over	estimate from field observations
	4								
3	5	1	Floc_BD=	20	mg/cm3	20		***bulk density of floc layer (mg/cm3 == kg/m3)	generalized from multiple soil cores
3	5	2	FlocMax=	0.1	m	0.1		***max floc depth	generalized from multiple soil cores
3	5	3	TP_P_OM=	0.012	gP/gOM	0.012		***P:OM of particulate phosphorus	standard redfield ratios
3	5	4	Floc_rcSoil=	0.01	1/d	0.01		***rate of incorporation of floc layer into flooded soil	CALIBRATE to achieve spatial and temporal distribution in floc depth
	5								
4	6	1	STDET_IC_MULT=	0.05	dimless	0.05		***standing detritus init-cond multiplier	assume low initial density relative to habitat specific max

5	6	2	STDET_REF_MULT=	0.01	dimless	0.01		***standing detritus refuge level multiplier	parameter that should be removed due to lack of need
4	6	3	StDetLos=	0.05	1/d	0.05		***standing detritus base loss rate	generalized loss rate; CALIBRATE to intermediate levels (StDetritus not well calibrated, not critical to model dynammics
	6								
4	7	1	TP_DIFFCOEF=	0.0000088	cm^2/sec	0.0000088		***Phosphorus molecular (surface-soil) diffusion coefficient.	general literature value
4	7	2	TP_K_INTER=	40	mg/L	40		***intercept for Freundlich sorption eqn	lab study
4	7	3	TP_K_SLOPE=	-300	dimless	-300		***slope for Freundlich sorption eqn	lab study
5	7	4	WQMthresh=	0.01	m	0.15	diff	***EWQM implement: water depth threshold below which settling stops (EWQM used 0.15m)	ONLY used to emulate Everglades Water Quallity Model
4	7	5	PO4toTP=	0.54	dimless	0.54		***slope of regression of predicting PO4 from TP	synoptic (northern) glades monitoring
3	7	6	TP_IN_RAIN=	0.02	mg/L	0.02		***TP concentration in rainfall (switching to 0.010 for ELMv2.2)	glades literature estimates; to incorporate recent reviews of data
4	7	7	PO4toTPint=	-0.003	mg/l	-0.003		***intercept of regression of predicting PO4 from TP	synoptic (northern) glades monitoring
4	7	8	TP_ICSFWAT=	0.01	mg/L	0.01		***initial TP concentration, surface water	conservatively low, global estimate
4	7	9	TP_ICSEDWAT=	0.001	mg/L	0.001		***initial TP concentration, soil pore water	conservatively low, global estimate
3	7	10	TPpart_thresh=	0.1	mg/L	0.1		***TP conc used for predicting particulate P for settling	generalized estimate from (relatively limited) POC and TP observations
2	7	11	TP_DIFFDEPTH=	0.1	m	0.1		***depth of surface-soil water diffusion zone	large depth due to poorly defined soil-water interface (w/ floc)
2	7	12	settlVel=	0.4	m/d	0.4		***ELM (NOT EWQM emulation) mean settling velocity of particulate P	Black-box to incorporate particulate settling and microbial uptake at high concentrations/particulate levels
	7								
5	8	1	DIN_DIFFCOEF=	0.0000198	NI		diff	***not implemented	NA
5	8	2	DIN_DIFFDEPTH=	0.01	NI		diff	***not implemented	NA
5	8	3	DIN_IN_RAIN=	0.45	NI		diff	***not implemented	NA
5	8	4	DIN_ICSFWAT=	0.1	NI		diff	***not implemented	NA
5	8	5	DIN_ICSEDWAT=	0.1	NI		diff	***not implemented	NA
5	8	6	DIN_K_OF_NH4=	0.75	NI		diff	***not implemented	NA
5	8	7	DIN_RCDENIT=	0.03	NI		diff	***not implemented	NA
	8								
5	9	1	FIRE_HEAT_FOR_IGNIT=	2	NI		diff	***not implemented	NA
5	9	2	FIRE_PROP_THRESH=	1	NI		diff	***not implemented	NA
	9								
5	10	1	CONS_IC_MULT=	0	NI			***not implemented	NA
5	10	2	CONS_ASSIM=	0.25	NI		diff	***not implemented	NA
5	10	3	CONS_C_TO_OM=	0.35	NI		diff	***not implemented	NA
5	10	4	CONS_MAX=	2	NI		diff	***not implemented	NA
5	10	5	CONS_NC=	0.01	NI		diff	***not implemented	NA
5	10	6	CONS_PC=	0.005	NI		diff	***not implemented	NA
5	10	7	CONS_RC_INGEST=	0	NI			***not implemented	NA
5	10	8	CONS_RC_MORT=	0	NI			***not implemented	NA
5	10	9	CONS_RC_RESP=	0	NI			***not implemented	NA
5	10	10	CONS_T_OPT=	33	NI		diff	***not implemented	NA



Habitat Code	Area (km^2)	Description
1	556	Open Water
2	1705	Sawgrass plain
3	802	Sawgrass ridge
4	834	Sawgrass slough deep
5	848	Sawgrass slough shallow
6	982	Sawgrass marl prairie
7	518	Gramminoid mix
8	475	Wet prairie
9	9	Slough w/ gramminoids
10	26	Slough w/ non-gramminoids
11	157	Cattail (high density)
12	43	Cattail (med density)
13	35	Cattail (low density)
14	90	Muhly grass
15	58	Salt marsh
16	25	Hardwood-mixed
17	861	Swamp forest
18	477	Mangrove forest
19	99	Buttonwood forest
20	290	Pineland savannah
21	594	Cypress savanna
22	89	Brush
23	95	Hardwood Scrub
24	59	Cypress scrub
25	489	Mangrove Scrub
26	121	ButtonWood Scrub
27	35	Brazilian Pepper
28	9	Melaleuca
29	13	Human Influence

Habitat Code	Full domain area (km^2)	Effective domain area (km^2)	% of effective domain
1	556	229	2.6
2	1705	1627	18.2
3	802	802	9.0
4	834	823	9.2
5	848	848	9.5
6	982	956	10.7
7	518	425	4.8
8	475	457	5.1
9	9	9	0.1
10	26	26	0.3
11	157	156	1.7
12	43	43	0.5
13	35	35	0.4
14	90	90	1.0
15	58	6	0.1
16	25	18	0.2
17	861	833	9.3
18	477	54	0.6
19	99	51	0.6
20	290	292	3.3
21	594	575	6.4
22	89	87	1.0
23	95	28	0.3
24	59	59	0.7
25	489	300	3.4
26	121	41	0.5
27	35	28	0.3
28	9	9	0.1
29	13	13	0.1
Total:	10394	8920	100.0

15c

Parameter summary of HabParms.fmp database (of habitat-specific parameters)

ALL RANKINGS AND DESCRIPTIONS OF DATA SOURCES ARE DRAFT (BEST ESTIMATES) FOR PRELIMINARY EVALUATION BY ELM REVIEWERS

Parameter	Description of parameter	Sensitivity Rank	Description of data sources
Periphyton			
alg_max	Maximum attainable (observed) algal carbon biomass density.	2	Glades synoptic monitoring; isolated field experiments; quasi-regional
Dep. Organic Matter			
DOM_MaxDepth	Maximum depth of biologically active zone of soil.	3	Glades synoptic monitoring; isolated field experiments; quasi-regional
DOM_NPhBioProp	Proportion (0-1) of NonPhotobio mortality allocated to DOM;complement goes to Standing detritus.	4	Field researcher-professional judgement
DOM_PhBioProp	Proportion (0-1) of Photobio mortality allocated to Floc (was DOM);complement goes to Standing detritus.	4	Field researcher-professional judgement
DOM_AerobThin	Depth of thin aerobic zone in a flooded wetland.	4	General literature estimates; isolated glades field experiments
bulk_density	Bulk density of upper soil profile; not dbase-habitat parameter	2	Spatial map; fine-grain in WCAs; moderate grain in ENP/BCNP
ash_proportion	Proportion inorganic matter in upper soil profile; not dbase-habitat parameter	2	Spatial map; fine-grain in WCAs; moderate grain in ENP/BCNP
ic_soil_TP	Initial concentration of phosphorus in upper soil profile; not dbase-habitat parameter	2	Spatial map; fine-grain in WCAs; moderate grain in ENP/BCNP
Nitrogen			
DIN_conc_grad	UNUSED	5	NA
Phosphorus			
TP_conc_grad	Porewater P concentration gradient, the ratio of P in the inactive DOM zone to that in the active DOM zone	3	Glades synoptic monitoring; isolated field experiments; quasi-regional
Salt			
SALT_icSedWat	Initial concentration of tracer ("salt") in porewater	4	Dependent on application; Glades synoptic monitoring; isolated field experiments; quasi-regional
SALT_icSfWat	Initial concentration of tracer ("salt") in surface water	4	Dependent on application; Glades synoptic monitoring; isolated field experiments; quasi-regional
Macrophytes			
PhBio_max	Maximum attainable (observed) macrophyte photosynthetic carbon biomass density.	2	Isolated glades field experiments/synoptic measurements; only require "global" maximum
NPhBio_max	Maximum attainable (observed) macrophyte non-photosynthetic carbon biomass density.	2	Isolated glades field experiments/synoptic measurements; only require "global" maximum
NPhBio_AbvBel	UNUSED	5	NA
mac_MaxHt	Maximum height of mature plant associated with a unit plant density at maturity.	3	Isolated glades field experiments/synoptic measurements; only require "global" maximum
NPhBio_RootDepth	Constant depth of roots below the sediment/soil surface (positive value).	4	Isolated glades field experiments/synoptic measurements; only require "global" maximum
mac_MaxRough	The maximum Manning's n roughness associated with present vegetation when fully inundated by water.	2	Isolated glades field experiments; other wetland measurements; CALIBRATE to achieve stage heights and limited gradient observations
mac_MinRough	The minimum Manning's n roughness for minimal/no vegetation.	4	General literature estimates; isolated glades field experiments
mac_MaxLAI	Maximum Leaf Area Index for a mature community	2	Isolated field experiments; glades literature relation to biomass; extrapolation to subregion
mac_MaxCanopCond	Maximum canopy conductance for plant that is NOT water stressed; most related to forest canopies.	3	Isolated field experiments; extrapolation to subregion
mac_CanopDecoupl	Canopy couple/decoupling (0-1), describing how closely the saturation deficit at the canopy is linked to that in lower Boundary Layer.	4	General literature estimates relative to canopy type
mac_TempOpt	Optimal temperature for maximum primary production.	4	General literature estimates relative to plant type/family
mac_LightSat	Optimal solar radiation for maximum primary production.	4	General literature estimates relative to plant type/family
mac_KsP	Half saturation concentration of P for uptake kinetics.	1	Glades lab experiments; CALIBRATE to achieve plant growth rates along nutrient gradients

PhBio_rcNPP	Maximum attainable (observed) specific rate of net primary production.	1	Glades field and lab experiments, limited synoptic monitoring; CALIBRATE to achieve observed net growth rate under range of conditions
mac_spr_gr	Julian month (1-12) that has spring growth of shoots, period of translocation of carbohydrates from nonphoto to photobiomass.	4	Glades field observations
PhBio_rcMort	Maximum specific rate of photobiomass mortality.	1	Limited glades field experiments and synoptic monitoring; CALIBRATE to achieve observed soil accretion and plant biomass
mac_watToler	Depth of ponded surface water above which plant growth becomes restricted.	2	Glades observations of plant distributions under varying water depths; early results from glades lab experiments
mac_water_avail_cf	Constraint on primary production; not dbase parameter, but (0-1) control function dependent on time-varying water presence in root zone (NPhBio_RootDepth)	3	Glades observations of plant distributions under varying water depths; early results from glades lab experiments
mac_salin_thresh	Salinity threshold, above which plant growth decreases linearly with increasing salinity.	5	Current model version does not simulate salinity distributions in southern glades, salinity constraint not operative; however, limited field/lab experiments are available for some habitats
PhBio_CtoOM	(Constant) mass ratio of organic carbon to total organic material in PhotoBiomass (ash free dry weight).	4	Glades field measurements; generalized to fixed value
NPhBio_CtoOM	(Constant) mass ratio of organic carbon to total organic material in Non-PhotoBiomass (ash free dry weight).	4	Glades field measurements; generalized to fixed value
PhBio_PC	Initial phosphorus:carbon ratio, PhotoBiomass	3	Glades synoptic monitoring; isolated field experiments; quasi-regional
NPhBio_PC	Initial phosphorus:carbon ratio, Non-PhotoBiomass	3	Glades synoptic monitoring; isolated field experiments; quasi-regional
PhBio_NC	UNUSED	5	NA
NPhBio_NC	UNUSED	5	NA
mac_KsN	UNUSED	5	NA
mac_transl_rc	Carbon translocation rate constant; simple, limited algorithm	4	Inferences from limited glades observations of temporal changes carbon allocation
ic_habitat	Initial habitat type; not dbase-habitat parameter	2	Spatial map based on ca. 1990-95 habitat classification from photos and satellite remote sensing

Hydrology

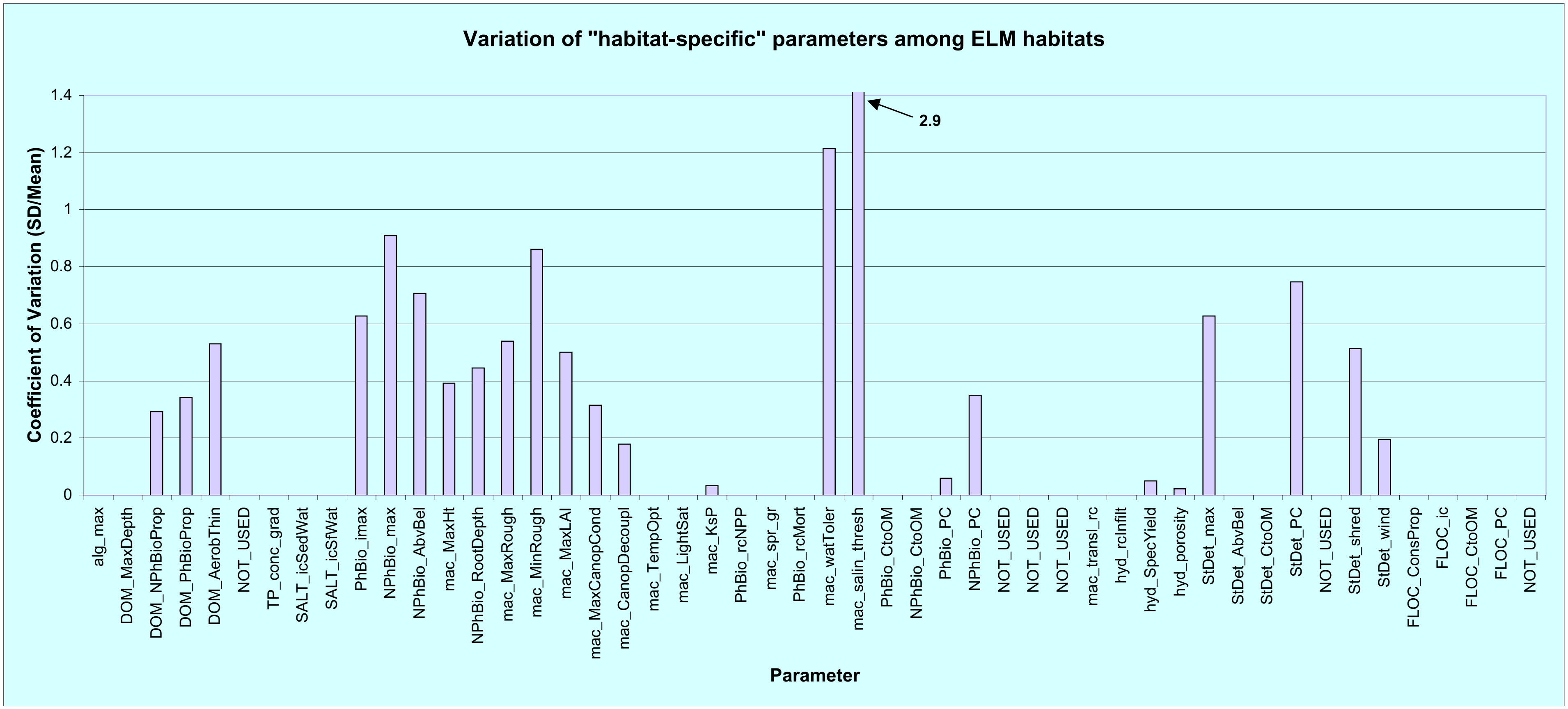
hyd_rcInfilt	Infiltration rate from ponded to unsaturated zone.	3	Limited glades spatial data
hyd_SpecYield	Proportion of total soil volume that represents water able to be drained by gravity.	3	Limited glades spatial data
hyd_porosity	Porosity of the aquifer, average from the sediment to base datum.	3	Limited glades spatial data
hydr_conductivity	Surficial aquifer hydraulic conductivity; not dbase-habitat parameter	2	Spatial map; SFWMM data interpolated to 1km
ic_surf_water	Initial depth of ponded water; not dbase-habitat parameter	2	Spatial map; SFWMM data interpolated to 1km
ic_unsat_water	Initial depth of unsaturated zone; not dbase-habitat parameter	2	Spatial map; SFWMM data interpolated to 1km

Standing detritus

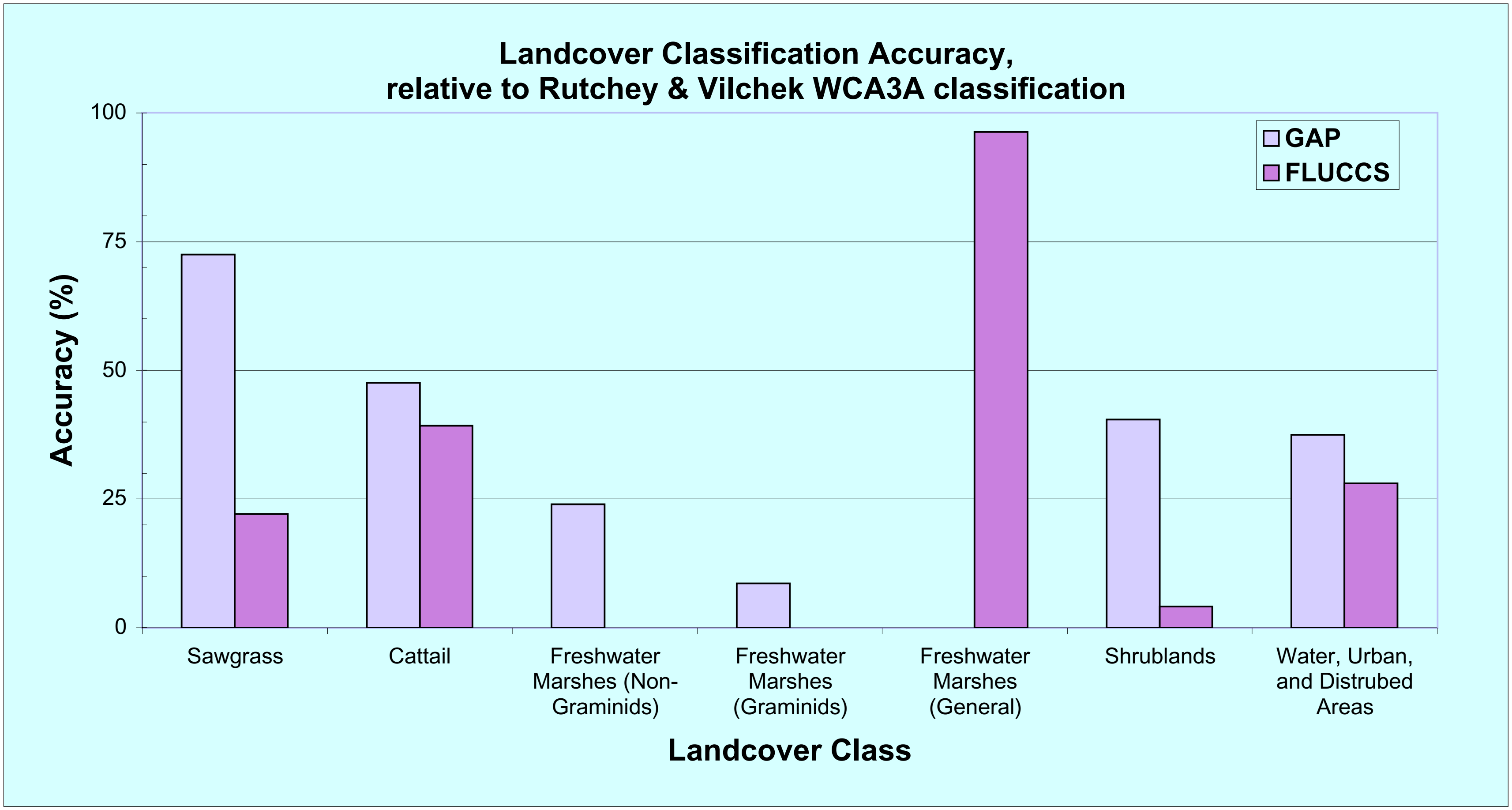
StDet_max	Maximum carbon biomass density of standing detritus.	4	Isolated glades field experiments/synoptic measurements; only require "global" maximum
StDet_AbvBel	Proportion of standing detritus biomass that is above the sediment relative to below sediment; FIRE USE ONLY.	5	NA; not implementing fire losses
StDet_CtoOM	(Constant) mass ratio of organic carbon to total organic material (ash free dry weight).	4	Glades field measurements; generalized to fixed value
StDet_PC	Initial phosphorus:carbon ratio	4	Isolated glades observations
StDet_NC	UNUSED	5	NA
StDet_shred	UNUSED	5	NA
StDet_wind	Wind speed threshold at which wind damage and breakup of standing detritus is initiated; ineffective (non-critical) implementation.	5	Professional judgement

Floc

FLOC_ConsProp	UNUSED	5	NA
FLOC_ic	Initial carbon biomass of floc.	4	Generalized to initial moderate levels relative to spatial data on soil cores
FLOC_CtoOM	(Constant) mass ratio of organic carbon to total organic material (ash free dry weight).	4	Glades field measurements; generalized to fixed value
FLOC_PC	Initial phosphorus:carbon ratio		Generalized to initial low levels relative to spatial data on soil cores
FLOC_NC	UNUSED	5	NA


Variation of "habitat-specific" parameters among ELM habitats
Coefficient of Variation (SD/Mean)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2.9
alg_max
DOM_MaxDepth
DOM_NPhBioProp
DOM_PhBioProp
DOM_AerobThin
NOT_USED
TP_conc_grad
SALT_icSedWat
SALT_icSfWat
PhBio_imax
NPhBio_max
NPhBio_AbvBel
mac_MaxHt
NPhBio_RootDepth
mac_MaxRough
mac_MinRough
mac_MaxLAI
mac_MaxCanopCond
mac_CanopDecoupl
mac_TempOpt
mac_LightSat
mac_KsP
PhBio_rcNPP
mac_spr_gr
PhBio_rcMort
mac_watToler
mac_salin_thresh
PhBio_CtoOM
NPhBio_CtoOM
PhBio_PC
NPhBio_PC
NOT_USED
NOT_USED
NOT_USED
mac_transl_rc
hyd_rcInfilt
hyd_SpecYield
hyd_porosity
StDet_max
StDet_AbvBel
StDet_CtoOM
StDet_PC
NOT_USED
StDet_shred
StDet_wind
FLOC_ConsProp
FLOC_ic
FLOC_CtoOM
FLOC_PC
NOT_USED
Parameter

16



Landcover Classification Accuracy,
relative to Rutchey & Vilchek WCA3A classification
Accuracy (%)
100
75
50
25
0
GAP
FLUCCS
Sawgrass
Cattail
Freshwater Marshes (Non-Graminids)
Freshwater Marshes (Graminids)
Freshwater Marshes (General)
Shrublands
Water, Urban, and Distrubed Areas
Landcover Class

Appendix: reviewers' full comments

Tom Armentano {TA}; DOI, NPS

Following are questions pertaining to the MRT review of ELM which are offered as discussion topics for the Oct 2 meeting per the message from Monica Legner:

1. ELM has been shown to simulate the strong P gradients and dominant vegetation types in WCA2A, (i.e. Cladium vs Typha) but P, periphyton and macrophyte patterns are much more complex in the relatively unaltered Everglades. How will you achieve reliable simulations given data limitations on variables such as macrophyte and periphyton distribution and biomass ? Twenty-nine vegetation cover types are presented in a legend. How will you parameterize the key components of each of these for modeling purposes?

2. A closely related question- vegetation maps have limited vreliability in areas where herbaceous-graminoid marsh types of several kinds occur at varying scales. How will you accurately delineate the marsh community level differences that, despite being difficult to handle via mapping, are ecologically important?

3. There is some evidence that Everglades vegetation types are more dynamic than some have thought, depending on fluctuations in key hydrological variables and stochastic events like fire. In long-term simulations (e.g., 31 years) how will ELM handle vegetation shifts (not to mention the accompanying changes in properties such as flow resistance, evapotranspiration and nutrient uptake) that may occur one or more times within the simulation period?

4. What is the explanation for the pattern of soil P depicted in your regional map- i.e., an area of elevated P extending south of western Shark SLough down to the area west of Long Pine Key and then eastward to Taylor Slough? Is there a model artifact or were assumptions made in the absence of field data?

5. Will you do any sensitivity analysis relative to the choices made as to the variables and parameters selected for vegetation modeling in the southern and central Everglades areas? What independent data sets will you use for sensitivity analysis and model calibration and verification?
6. At the 1 km2 scale, how are tree islands and sawgrass strands handled? How do you deal with their roles in flow and in nutrient distribution?
7. How is peat accretion and its effects upon nutrients vegetaion type and hydrology handled in the model?

Gwen Burzycki {GB}; Miami-Dade DERM

Miami-Dade DERM Comments
RECOVER - MRT Review of ELM
August 2002

Questions

Land Use.

Are there definitions available for the vegetation types in the 1995 ELM land use map? We may have suggestions for land use changes in some areas, depending on the vegetation definitions. (minor issue: "graminoid" is the correct spelling)

We are concerned about the use of the Welch et al. information for land use within ENP because we have repeatedly heard that there are errors in the mapping, although we do not have good information about either the extent or magnitude of the errors. Was the use of this source of information supported by ENP staff?

Several land use maps over time are presented on the Web site. They have different classification systems. How are these used in the modeling? The documentation implies that a static land use map is used.

Vegetation Succession.

Does the model predict any other vegetation succession patterns other than cattail?

Does the model predict cattail succession throughout the ELM model domain, or only in the more detailed CALM domain?

Concerns

Static vs. Dynamic Boundary Conditions. The model is of limited utility at present without the ability to accept changing boundary conditions.

Model Extent. There are critical needs for water quality evaluation throughout the natural area of the Everglades system, yet ELM only covers a subset of this area.

Fire. ELM does not currently include fire effects, and the model is considered insensitive to fire (reference: statements made at the August 7 presentation). This does not make sense from an ecological viewpoint, given how important fire has been and continues to be in the Everglades system. Fire has an immediate and dramatic effect on when and whether nutrients locked up in vegetative material (and soil) are released, either as ash on the ground or as smoke that transports nutrients elsewhere. It also has dramatic and sometimes catastrophic effects on standing plant biomass, soil characteristics, and elevation. The time frame for effects to be noticeable may vary, depending on the season and severity of the fire. It seems unlikely that soil and nutrient interactions in a water quality model would fully calibrate (especially over a 30+ year period of record) until and unless fire effects are taken into account.

Output in Coastal Areas. Recent information from SICS model development indicates
that density transport functions are very important to critical for calibration in salt intruded areas. ELM does not have this function, yet its model domain extends well into salt intruded areas.
Static Land Use. If land use is static (see question above), the model's effectiveness in predicting vegetation response to changing hydrology and water quality parameters is suspect.

Model Limitations

No comments at this time.

Appropriate Use of the Model

No comments at this time.

Critical Recommendations

Static vs. Dynamic Boundary Conditions. Every effort should be made to update the model so it can accept dynamic boundary conditions.
Model Extent. If there is consensus that this model will be useful for water quality evaluation, every effort should be made to expand the model extent to cover all natural areas in the Everglades system.
Period of Record. The model needs to be updated with the '96-'00 water years in order to match the SFWMM period of record.

Non-Critical Recommendations

Fire. A fire module should be added.
Vegetation Succession. If land use is currently static, the model should be expanded to include a vegetation succession module that covers not just cattail invasion but vegetation responses to changing hydrology, as well.

Michael Choate {MC}; USCOE
CESAJ-DR-R 4 Sept. 2002

To: MRT Model Review Group: Carl and Mike Waldon

SUBJECT: Review Comments Everglades Landscape Model 2.1a

Questions:

1) Globally the hydraulic stage results are within the confidence limits expected and the model understandably mimics results from the SFWMM 2x2. Due to the lack of calibration data, flow rates and volumes do not similarly enjoy such close confidence limits. Is it possible to generally attribute the errors in phosphorus prediction to the lack of reliable volume estimates? Have volume sensitivity tests been done?
   2) Algorithms appear to be reasonably responsive to stimulus from boundary loadings. I'm assuming that a large percentage of missed phosphorus predictions are a result of poor boundary condition estimates. Have the algorithms been calibrated at sites that have controlled boundary conditions?

Concerns:

Model results are limited by field data availability and reliable boundary conditions.

Appropriate Use of the Model and Model Limitations:

Model appears to work well to predict regional and sub-regional trends and as a means of comparing alternative project features. In some areas the model fails to predict high phosphorus peaks, which may be explained by poor boundary information.

Critical Recommendations:

None – This model has a tough job to do.

Non-Critical Recommendations:

Must get better boundary data if results are to improve.

Comment: Excellent on-line documentation.

Reviewer: Michael Choate 904-899-5031

Don DeAngelis {DD}; USGS, BRD

<u>Review Comments on the Everglades Landscape Model Relevant to August 7, 2002 Presentation of ELM</u>

[Note: I wrote up my comments before I received a format for the review. While the format is a good one and I would have preferred to use it as a basis for my comments if I had time, I am going away for two weeks starting tomorrow, so I will not have a chance to re-organize them into the desired form. DLD - August 21.]

Comments of Don DeAngelis

I have read through the basic reports on ELM v1.0, plus most of the material provided for the current review. I have not read any source code. The model is described by the authors as being primarily intended to provide an understanding of the ecosystem dynamics across the Everglades landscape, including water flow, movement of main nutrients, and vegetation biomass. In addition, it is also designed to provide the basis for projections of different water regulation scenarios and for management.

At its heart is a mechanistic process based Unit Model (or General Ecosystem Model) which is scalable, but is most typically used for a 1 km^2 unit cell. It is adjusted to different ecosystems (or habitat types) within the Everglades through different parameterizations. In addition, there is transport between cells due to water movement. My expertise is largely with the Unit Model, so I have read through the documentation on that carefully

Overall comments:

The Everglades Landscape Model (ELM) is an indispensable tool for understanding the main ecological processes of production, decomposition, and material flows that occur in the Everglades. The model, being mechanistic and process-oriented, is the right type of model for its task. Only the careful accounting of mass balances and incorporation of the causal mechanisms in a model framework can provide the basis for understanding the system and the possibility for making predictions concerning the consequences of external perturbations. The other major type possible type of model for this application, an empirical regression model or set of models, would be of limited usefulness.

The mechanistic nature of the model also, however, accounts for some of the difficulties in getting the model properly calibrated and validated. No model of a complex ecosystem can take into account all of the processes that occur, or all of the spatial heterogeneity. There is much that is unknown, difficult to quantify, or too complex to represent. Therefore, approximations and, in some cases, guesses, have to be made. It appears that the authors of ELM have done a highly professional job of making a model that contains the right level of detail. Despite many legitimate difficulties, they are succeeding in calibrating and validating the model over a substantial area.

Specifics about the Unit Model:

The components and mechanisms built into the Unit Model are in accord with the best understanding of what the major processes are in a typical wetland ecosystem. The model also is consistent with other models of the same level of detail developed for wetland or shallow aquatic system. A lot of decisions had to be made concerning the level of detail to use, and I think that good judgment was used in all decisions. The Unit Model is parameterized differently in different ecosystems within the Everglades. But the components and processes are the same everywhere. To briefly outline the main biotic parts of the Unit Model:

- The most important two biotic compartments are algae (lumped benthic periphyton and phytoplankton) and macrophytes. Both are reasonably modeled as having growth limited by light, nutrient (nitrogen or phosphorus, whichever is most limiting), and temperature. Carrying capacity seems to result through light limitation, which is in part through self-shading. It was difficult to tell from the documentation if there is an interaction between macrophytes and algae (though from "Development and Application of the Everglades Landscape Model", page 8, it seems that macrophytes are modeled to have a negative effect on periphyton). The macrophyte biomass is composed of photosynthetic and non-photosynthetic biomass (which appears to be both structural carbon and labile carbon). The amount of non-photosynthetic biomass has some control on the growth of new shoots. Macrophytes have a feedback effect on Manning coefficient.

- Mortality of plant goes into three compartments, standing dead detritus (SDD), suspended organic matter (SOM) and deposited organic matter (DOM). The SDD is exposed to aerobic decomposition and to SOM. The flux between DOM and SOM is driven by shear stress. Decomposition is aerobic for SOM. Only part of the DOM is subjected to aerobic decomposition (thin zone at surface of sediments or depth of unsaturated zone).

- Consumers are aggregated into one compartment, which feeds on all other carbon stocks. Fire is also simulated in the Unit Model.

Comments on the Unit Model:

The Unit Model seems reasonable to me, as a component of a landscape model that will mainly be focused on projecting the movement of nutrients through the Everglades, and taking into account the key feedback loops, such as changes in vegetation biomass, leading to changes in Manning's coefficient, leading to changes in water flow, etc. I believe that the processes included, plus rigorous accounting for the flows of energy and cycling of nutrients, allow ELM to provide a good understanding of the Everglades at the ecosystem level, as well as making reliable projections possible.

I have some slight concerns. The documentation is (by necessity) not absolutely complete and doesn't account for every detail that is probably in the model. In particular, I wasn't able to ascertain whether all nutrients were strictly conserved (in the processes of consumption and decomposition/remineralization). I assume this is done, but it is hard to tell. Also details of nutrient cycling, such as the nitrogen cycle, are vastly simplified. Simplification of the N cycle may not make too much difference, but it would help to describe in the documentation the modeling of the P cycle in more detail, especially the possible complexing with calcium.

There does appear to be competitive action of macrophytes on periphyton and macrophytes, through a shading effect of macrophytes on periphyton. It might be useful to see if there are data for the reverse (e.g., periphyton smothering young macrophytes).

Suggestions concerning the Unit Model:

ELM is an evolving model. It will certainly change and improve as new information becomes available. There are also some ways in which the usefulness of ELM might be extended.

Inclusion of more than one algal type, especially taking into account changes in the algal composition as a function of P concentration (e.g., periphyton model of Quan Dong et al. 2002).

Possible elaboration of the consumers, at least into a few functional types. Quan Dong's lower trophic level model may provide some help. But there could be some inclusion of changes in consumer guilds according to P-availability also (e.g., calanoid copepods vs. cladocerans), since zooplankton community type might be an indicator of P. These are only vague suggestions. The complexity of dealing with detailed consumer components across all of the Everglades may be too difficult.

ELM should eventually migrate towards being able to describe vegetation succession in as mechanistic a way as possible.

Model calibration and testing:

Model calibration and testing of a model of this type can be exceedingly difficult. Having been a reviewer of other major models (e.g., EPA's AQUATOX, NPS's Rocky Mountain National Park Elk-vegetation model), I find the methods used here to compare favorably with these other models. In fact, although it's difficult to compare models that have different objectives, I think that the care in systematic calibration and testing in ELM go beyond what I have seen for other models. My overall impression is that the uncertainties in ELM for key variables are smaller than those in AQUATOX.

A simpler form of the model (CALM) was calibrated and tested in WCA-2A with respect to predictions of water stage, surface- and pore-water P, peat accumulation, and macrophyte and periphyton succession. The model results follow empirical data on spatial trends very well. ELM Version 2.1 has been calibrated for hydrology and surface water quality at 40 monitoring locations across the Everglades.

Testing and improvements on ELM should certainly continue. However, I think there is no doubt that ELM at this stage is ready for application to scenario evaluation. As with any model, output needs to be viewed as a possible projection of what may happen in the future, subject to uncertainty, not as an absolute prediction. Active application of the model will accelerate ELM's comparisons with data and continued improvement.

Matthew Harwell {MH}; DOI, USFWS

MRT's ELM Review

General Comments on review process:

Thank you for the opportunity to examine and provide comments on the potential use of the ELM for CERP/RECOVER activities. After attending the Aug. 7th review workshop (and the USGS Landscape Modeling Workshop on May 9th), I believe that there are some concerns about the readiness of the ELM to be used for water column P performance measures. Examples of comments/questions that raise this concern are provided below, although the time frame for providing comments did not allow this to be comprehensive.

While MRT has developed a 2+ month process for model review/evaluation that RLG is happy with, it should be noted that RECOVER participants who are not part of MRT (or present at the ELM review on August 7th) were, for all practical purposes provided only 2+ weeks to provide comments given the delay in the preparation of the template MRT developed to categorize comments. MRT should be aware that this might not provide enough time for other RECOVER participants to contribute extensive comments on ELM.

One aspect of the ground rules remains unclear to non-MRT RECOVER people. To use the classification terminology for the review of ELM and SFWMM, how many "Concerns" or "Non-Critical Recommendations" need to be identified for any given model such that, when taken as a whole, they become "Critical Recommendations" and potentially "fatal" such that no applications can be recommended? This is an issue that MRT should tackle.

Respectfully submitted,

Matthew C. Harwell

ELM Comments:

Question: The ELM results web page presented only Calib/Verif Data, although it listed future links to specific case studies. Have any of these been initiated (and available for examination), or is this review limited to examining calib/verif results for consideration?

Question: Atmospheric P deposition is modeled at a uniform level across the whole system, correct? {inferred from 31-yr Phosphorus Accumulation figure {slide 41 from 060802_mrt_elm_status.ppt)}. There are significant differences in rainfall among regions (which is why rainfall was imported directly from the WMM at its 2x2 mi scale), potentially leading to different levels of P input from atmospheric deposition as a whole. Are any other sources of atmospheric deposition are being modeled? Also, why is the global parameter for TP concentration in rainfall being changed from 0.02 mg/L to 0.10 mg/L in Version 2.2? Where do these values come from, and why a 5-fold increase in a global parameter?

Question: One of the major revisions of the ELM to Version 2.1 was the addition of a floc layer. Where did the max floc depth of 0.1 m come from? My understanding is that floc depths, while they can vary extensively, can be up to ~ 0.20 m.

Question: Particulate P settling velocity is defined as a global parameter at 0.4 m/d. Where did this value come from? The pseudo-code {Phosphorus (in water) Module, p. 4-5} only describes particulate settling as a function of water depth. Is this correct? Particulate settling velocity is probably not only a function of water depth, but velocity and the presence/type of vegetative structures providing resistance to flow.

Question/Concern: At the ELM presentation on Aug 7th the P outflow from the STAs were described as being modeled as 50ppb outflow and static (though I can't find information on this on the web site). Has ELM incorporated any of the existing time-series data (or a stochastic component) on actual outflow concentrations? If not, this is clearly a "model limitation" that would necessitate a "critical recommendation" before its widespread application.

Concern/Question: Would like to see a calibration figure for water column P on the F-transect in WCA-2A that was presented for Version 1.0 (in the book chapter for the new Costanza and Voinov text). This nutrient transect is one of the most studied transects for water column phosphorus, with significant recent emphasis on its contribution to threshold criteria determination. Version 1.0 had a poor calibration for this, not capturing the high levels (and variability) seen close to the canal. The Version 2.1 calibration data for S10ACD vs. Reach 19 showed a number of segments of time with a poor match, often with ELM (Reach 19) results lower than measured at S10ACD for periods of time ranging from 6-18 months in duration. How much of this is attributed to the ELM using an equal partition of flow to calculate Reach 19 levels? How might this translate into P levels in the water column in the marsh long those 2A transects? While ELM 2.1 may be at "3" and approaching "2" in calibration on water quality as a whole, calibration may need to be at a higher resolution for locations such as this in order to have confidence in using ELM for specific projects.

Concern/Model Limitations: There might be instances where uncertainty in the hydrodynamics aspect of the model plus uncertainty in the phosphorus dynamics of the model (sensu the Modeling Uncertainty Workshop Report) could translate into inability to use the model output to examine water quality goals. For example, while there is a general agreement between ELM results and measured water depths, there appear to be a handful of events in which ELM under-predicts water depth at the three interior stages of Loxahatchee NWR. These stations are used to determine whether individual water quality sampling dates can be used to examine deviation from whatever P threshold standard is set. As an ELM forecasting exercise, these under-predictions of water levels (below 4.7 m) by ELM would be classified as too shallow to include the corresponding P data for determination of compliance.

Appropriate use of Model: Would like to see a more comprehensive list of projects that ELM is being considered for use than those listed on the Calib/Verif web page (ECP; Modwaters/CSOP; CERP – RECOVER; CERP – Decomp; CERP – L31 Pilot; CERP – C111 Spreader). Would like to know if PDT leaders, etc., involved with specific projects that have targeted ELM as relevant tool attended the Aug. 7^{th} review and are providing comments to MRT. This would be an appropriate important step for a given project to determine if ELM is an appropriate tool for its use.

Critical Recommendation: A formal sensitivity analysis needs to be conducted for Version 2.1 to at least the same extent as that for the earlier version (analysis published in 1995) following the recommendation of the Modeling Uncertainty Workshop Report (p. 32-33) and C. Fitz's comments from the Aug. 7^{th} presentation. Of interest would be an examination of the degree of sensitivity of P response as it relates to the level of "sensitivity" needed to make decision among project alternatives in examining and comparing potential P levels.

Robert Kadlec {RK}; consultant to DOI

MEMORANDUM

COMMENTS ON EVERGLADES LANDSCAPE MODEL

September 4, 2002
R. H. Kadlec

INTRODUCTION

The large and comprehensive set of works planned or under way in south Florida require a sound, state-of-the-art model that can deal with hydrology, water quality, and to some degree the flora and possibly fauna in that region.

The Everglades Landscape Model (ELM) represents a huge undertaking involving many scientists over almost a decade. It exists in some degree of competition with other Everglades models that deal with hydrology, phosphorus, soils and vegetation. I have been a reviewer (in detail) or a co-developer of most of these models, including STADM, DMSTA, EPGM, WWQM, EWQM, PSTA Forecast, PMSAV, CALM and ELM.

The recent (August 6, 2002) release of significant amounts of detail concerning ELM has made possible the beginnings of critical scientific review. The RECOVER Model Refinement Team has initiated an MRT/agency review of the South Florida Water Management Model (SFWMM) and the Everglades Landscape Model (ELM). Information about both models was presented at the August 6-7 MRT workshops. This memorandum is in response to the MRT request to provide technical review comments on the ELM.

The information basis for this review consists of several historical ELM development reports from the University of Maryland project (such as et al, 1992abc), the ELM website (http://www.sfwmd.gov/org/wrp/elm/index.html), and published papers (et al, 1996 & 1999). I participated in workshops at SFWMD during the development phase of the University of Maryland project. There have also been two recent extended presentations with question/answer sessions conducted by H. C. Fitz.

SUMMARY OF OPINION

a) ELM is in no condition to be trusted for forecasting for conditions outside the calibration envelope - which I think is all the future potential uses.

b) The current version of ELM is probably the preferred starting point for development of a trustworthy model. There are many features that are very good for the intended purposes; probably more so than any of the existing competitor models.

c) ELM needs a lot of work to be useable. Modern south Florida research results need to be woven in as replacements for archaic and inappropriate "place-holder" pieces put in place during previous development.

d) Rather than continuing to "review" ELM, it would be preferable to immediately embark on the necessary fixes. The ingredients would logically include one or more workshops on upgrades, trim-downs, and validation. Commitments of manpower are needed, above and beyond any plans I have heard for the near future.

OVERVIEW COMMENTS

Consistency with South Florida Water Management Model (SFWMM)

It is my understanding that ELM takes flows and stages for all structures from SFWMM. In SFWMM, outflows are computed from inflows, together with rainfall, ET, infiltration and overland flow resistances. If ELM borrows all the inflows and outflows, but uses different ET, infiltration and overland flow resistances, the ELM water budget contains inconsistencies.

Calibration Parameters

There are far too many - over a thousand. These occur at no less than five levels of identification:

a) Listed global parameters, identified on the web site (GlobalParms2.1a.pdf). Some of these are critical, such as the single value for the settling rate of particulate P.

b) Listed habitat-specific parameters. There are over 800 of these identified on the web site (e.g., HabParms2.1a_mac_list1.pdf). There is a great lack of data to support the selection of this plethora of numbers.

c) Identified, unlisted fudge factors buried in the code. For example, "beta2" and "beta3."

d) Hard-wired coefficients. As one example, the 10 arbitrary coefficients associated with evaporation computed from the Christiansen (1968) model. There are many, many more of these. Some are more critical to the movement of phosphorus than others. For another example, an arbitrary 90% recycle from the floc layer to porewater is hard-wired into the code (Where does that come from? How is it justified?)

e) Coefficients that do not even appear in the code. As an example, the foliar absorption coefficient has been chosen to be unity, and therefore does not appear in the code. However, it varies from 0.3 to 1.3 for most plant canopies (Nobel, 1999).

Calibration

The assertion is made that for "reasonable" choices of the exceedingly numerous parameters, a "pretty good" fit of hydrology and water column phosphorus can be made. No one can doubt this, given the huge number of adjustable parameters. There are certainly many other choices of parameters that would give good fits to that same dataset as well. However, this begs the question of whether the complicated ELM structure, together with that calibration, can be trusted to provide "reasonable" forecasts for other sets of driving forces. Future conditions will involve large changes in flows and phosphorus that drive the system. Calibration is simply not enough; validation and verification are needed.

The current calibration set ended several years ago. There now exists a subsequent dataset of adequate duration (5+ years) to provide validation. In particular, this newer period contains significant changes in driving forces - such as the P reductions achieved by BMPs and the STAs.

Until such validation there is no way ELM and its current calibration can be trusted to provide forecasts of even the water column P concentration. Further, there will be no good test of the biological transition features.

It is extremely doubtful that ELM and its current calibration can be trusted to predict current or future conditions in the southern Everglades. The marl prairies and rocky glades do not fit the assumptions made for soils in the northern system. The differences in soil physics and chemistry argue strongly against transferability.

SPECIFIC COMMENTS

Time does not permit an in-depth investigation of the internal details of ELM. Therefore, I looked at a few specifics to obtain some sense of the structure and function of the model.

Evapotranspiration

The Christiansen (1968) model is identified as the predictive model for evaporation. The model equations and coefficients in ELM do not match those in Christiansen (1968). It was calibrated for northern Utah, and predicts Class A Pan evaporation, not evaporation. An arbitrary pan factor and a beta2 factor are inserted to adjust evaporation. Net radiation (R) at the ground drives the Christiansen (1968) model. ELM uses a predictive model for

R, which itself uses many arbitrary coefficients (Nikolov and Zeller, 1992) - rather than the data from south Florida.

Transpiration is computed from vapor pressure deficit (energy balance technique) coupled to a stomatal resistance component. The first part is essentially an alternate and duplicative computation with evaporation. The second part is questionable, since south Florida stomatal data show transpiration in excess of evapotranspiration (see Koch and Rawlik, 1993).

This shaky combined approach is in need of re-examination, and probably replacement. It would be wise to bring all the south Florida ET research to bear on these issues - the extensive SFWMD and USGS results across many community types (German, 2000; Abtew, 1996).

Overland Flow Resistance

ELM uses Manning's coefficient to parameterize overland flow. Although widely used for water flows in wetlands, the turbulent Manning's formulation is inappropriate for the slow, laminar flows that often occur.

Nonetheless it can be forced to work if the "n" value is appropriately selected as a function of depth and flow. ELM is parameterized to a depth relation based on work by Petryk and Bosmajian (1975) for agricultural crops (e.g. sorghum) in Oklahoma. That relationship is seriously at odds with data from south Florida, reported over the past twenty years (Shih & Rahi, 1982; Rosendahl, 1981; MacVicar, 1985; Mierau & Trimble, 1988). Unpublished USGS data may also be available for some of the vegetation types.

This archaic approach is in need of re-examination, and probably replacement. It would be wise to bring all the south Florida ET research to bear on these issues - again, the extensive SFWMD and USGS results across many community types.

Dispersion

ELM uses a rectangular finite difference grid and fixed time steps. This formulation is notorious for producing numerical dispersion. However, ELM adds no dispersion, as have other models, such as the EWHM.

Two dimensional vertically averaged finite difference models have been used to predict tracer movement in south Florida field situations (Moustafa and Hamrick, 2002; Lee & Guardo, unpublished). Subsequently, these wetlands have been tracer tested. Unfortunately, the finite difference model predictions are quite different from the field test data (DB Environmental, 2002). In particular, Moustafa and Hamrick (2002) were quite satisfied that their model was successfully calibrate to depth data. But their tracer transport predictions are now known to be badly in error.

Thus, although ELM has the capability to provide animated cartoons of tracer movement through south Florida, it is unlikely that these represent reality.

Closure on Specifics

The three examples above clearly illustrate the patchwork, non-Floridian character of some of the ELM internals. I see no fatal flaw in any of the three cases, but all three need some serious reconsideration and revision. And I have no faith in current results produced from these faulty structures.

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Shawn Komlos {SK}; USEPA

Mike and Carl,

Are anisotropical factors assigned to the roughness coefficients for various land cover classes (e.g., water management model type I ridge and slough versus type V ridge and slough, predominant alignment of drainage ditches, etc.)? If not, has consideration been given to assigning an anisotropical factor to the resistance coefficients? For example, the depth-dependent resistance formulae for each vegetation class could be based on the azimuth of the predominant vegetation alignment and/or; or two separate depth-dependent resistance formulae could be developed and assigned weights for each cell based on the predominant alignment vegetation alignment and the depths of adjacent cells for the preceding time-step.

Has consideration been given to allowing simulated structures internal to the model domain (i.e., points at which flows from the water management model are imported) to operate based on head-water and tail-water conditions? Given that vegetation coverage is constant/static for the duration of a water management model period of simulation, and the ELM is anticipated to allow for dynamic vegetation coverage over the period of a simulation (potentially the same period of simulation), how sensitive are stages and/or flows predicted by the ELM to imported flows (i.e., from the water management model)? For example, if over the duration of an ELM simulation, vegetation types/densities downstream of one or more structures (e.g., the S-10s, and/or potentially new structures associated with the CERP C-111 spreader canal project) are predicted to change, would the flows predicted by the water management model for those structures be any different if the predicted change in vegetation were fed back into the water management model?

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Mike Waldon {MW}; DOI, USFWS

ELM Review Comment and Questions
Mike Waldon, USFWS/DOI EPT
September 6, 2002

Questions

Do you follow procedures for model self-documentation (commenting)? Is there a prescribed style for commenting procedures?

Is model input self-documented? Is there a standard procedure used for input data documentation?

Do you maintain a list of known bugs?

Concerns

As with any model that is used by a large number of individuals, the ELM model needs to have comprehensive documentyation including a user's manual and a programmer's manual. In addition to specifying input and output file requirements and formats, the user's manual should document the theory of the model, document the equations used in the model, and provide citations to supporting literature. The programmer's manual should describe the program structure in sufficient detail to support future modifications and improvements in the program. An adequate peer review of the model or its applications will not be possible until acceptable documentation is available. Model developers should anticipate that roughly 30% of their team efforts need to be directed to documentation.

Water velocities and discharges between cells is not directly calibrated. I am concerned that modeled velocities may be unrealistic. A simple way to greatly improve the credibility of the model is to demonstrate that it can simulate concentration of a conservative solute. Several candidates for calibration are chloride concentration, TDS, conductivity (as a surogate for TDS). Without this demonstration, we should give little credibility to modeled transport and velocities.

Is aerial deposition simulated as an equivalent rain water concentration? If yes, this may significantly distort seasonal patterns of P deposition. I believe wet and dry deposition should be modeled separately. Dry deposition in the dry-season may be much more important because depths are more shallow and dilution flows are reduced.

Model Limitations

Appropriate Use of the Model

Critical Recommendations

ELM is an ecological model that was developed to simulate landscape scale plant community changes. Although some aspects of water quality are currently simulated or planned for the model, ELM is not a traditional water quality model. There are major features that typically are included in water quality models that are not a part of ELM, and ELM includes features that are not generally included in water quality models. These additional ELM features complicate calibration and raise calibration issues that would not normally be addressed in water quality modeling. These combined facts may reduce peer acceptance of ELM as an adequate tool for water quality planning and management. The decision, perhaps by default, by the state and federal CERP partners to not pursue development a more traditional regional water quality model may have severe consequences on the validity of CERP decisions, future adaptive management, and on our ability to defend CERP decisions to stakeholders and taxpayers.

I am not saying here that development and calibration of an Everglades water quality model would be easy. Indeed, I do not know of an off-the-shelf model that would fulfill CERP needs, but, selecting ELM as our regional water quality model requires a level of commitment (money and manpower) beyond that which would have been required if a more traditional water quality model were selected. I do believe that ELM could serve many of the water quality modeling needs of CERP, and might prove itself capable other valuable analyses that would not be provided by traditional water quality modeling. A major commitment is needed to build ELM into a useable tool for water quality decision support.

The ELM is far more complex and ambitious in its scope than the SFWMD's Water Management Model (WMM or 2x2 model), but staffing levels supporting the WMM are far greater than those allocated to ELM. Current and planned effort levels allocated to ELM development are inadequate. I conservatively estimate that the completion of a well developed and documented model including calibration and verification of the model will require 10 additional man-years of effort beyond current staffing levels. With these resources available, ELM might be ready for credible project evaluations in as little as 18 months from the start of this enhanced development effort.

I submit that there are three alternatives for developing regional water quality model support for CERP:

f) Maintain the current level of effort on ELM and initiate no other regional water quality modeling effort. This will leave CERP with no quantitative regional water quality model for at least the next 5 years.

g) Maintain the current level of effort on ELM and initiate a new regional water quality modeling effort. As with any new modeling project, there is a real possibility that this new regional water quality model would fail to produce a model that is adequate to meet CERP needs.

h) Provide model development resources to build ELM into an adequate, peer-accepted water quality model.

If alternative 1 is selected, I believe that it will be difficult to provide adequate regional water quality evaluations of CERP impacts. In my opinion, alternative 1 is unacceptable. From the present perspective, alternatives 2 and 3 likely would require similar investments of human resources. At this time, I would support either alternative 2 or 3. An advantage of alternative 2 is that the new modeling effort could be integrated with the new HSE program recently developed by the SFWMD. An advantage of alternative 3 is that it builds on the current investment in ELM and would support extension of the landscape modeling capabilities of ELM.

After the ELM (or alternative water quality model) is fully developed, as described above, it will then be necessary to estimate the level of modeling effort that will be required to support CERP decision making and project design. We need to have a list of all applications, by project, that will be requiring ELM modeling support. Some effort at this may already be available, but I am unaware of this. I request that the review responce include a list of all CERP and non-CERP applications that are currently anticipated. As a part of this list, I also request that total effort (e.g. man-months) be listed for each anticipated modeling effort.

I am vitally concerned that there are not adequate resources being provided to support the level of modeling effort that will be required to support CERP decision making and project design. We need to have a list of all applications, by project, that will be requiring ELM modeling support. Some effort at this may already be available, but I am unaware of this. I propose the following table as an starting point for project resource needs evaluation.

Progress has been made on quantifying the calibration of ELM. I believe that ELM should use quantitative calibration measures similar to those now used by the WMM. The WMM reports bias, RMSE, efficiency, and r^2. ELM needs to report these calibration and verification error measures not only for concentration, but also for proposed CERP performance measures.

In most surface water systems that I have modeled, horizontal dispersion has been a significant mechanism. Because of the explicit finite difference approach used in ELM (and many other models) integration error roughly approximates dispersion. In some systems, this “numerical dispersion” is insignificant when compared with estimated levels of dispersion. In others, an adequate simulation is not possible because numerical dispersion is much greater than the ambient dispersion level. Numerical dispersion depends on both spatial and temporal step-size, and can not be eliminated by simply reducing the time step to a very small value. One estimate of numerical dispersion in a one-dimensional stream is:

$$E_{num} = 0.5 U (L - U \_t)$$

where U is velocity, L is cell length, and _t is the time step size. Is there any evidence that ignoring dispersion of dissolved and suspended material transport is acceptable? Is numerical dispersion generally larger than typical surface water dispersion levels?

Model instability can also result from numerical integration in space and time. To maintain stability, it is generally required that the mass advected for each constituent in each cell be less than the resident mass. Does ELM check for stability this or similar conditions within each cell and canal segment?

Non-Critical Recommendations

Much effort has been expended in calibration of the DMSTA model. Is there any way to compare parameter values between ELM and DMSTA? For example, is there an analog to c* in ELM? Can you calculate the fraction of P in accreted plant material permanently lost to peat accretion?

Are there plans to make the ELM compatible with the HSE model? This is complicated by the difference in spatial grid structure. How difficult is it to transform ELM to a random triangular grid structure?

How are locations specified in model input? By cell number or by some geographic location? The latter is preferred because it simplifies tests using alternative cell dimensions.

Are there plans to add a sulfur cycle, mercury cycle, and DO concentration to the model? These may all be needed for CERP project evaluations and regional impact assessment.