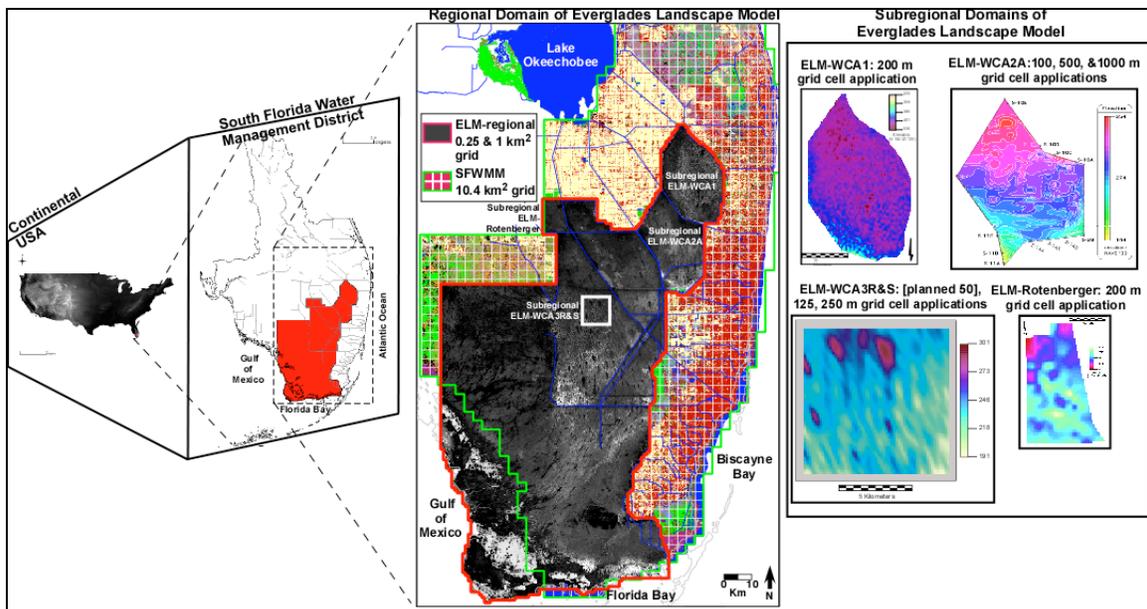
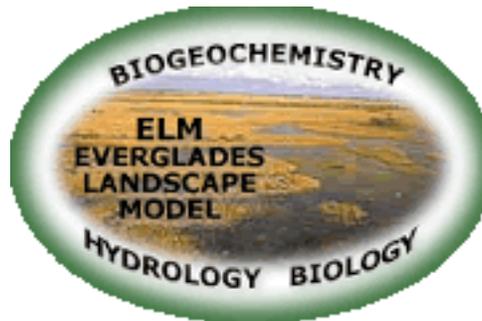


Documentation of the Everglades Landscape Model: ELM v2.8

Overview version of full report



<http://ecolandmod.ifas.ufl.edu>

H. Carl Fitz, Assistant Professor
Soil and Water Science Department
Ft. Lauderdale Research and Education Center
IFAS, University of Florida
3205 College Ave.
Davie, FL 33314
email: cfitz@ufl.edu

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Preface

Documentation purpose

This documentation report provides the information necessary to fully understand the *goals & objectives, supporting data, algorithms, performance, and application* of the Everglades Landscape Model (ELM). This document, the model source code & data, and further supporting information are maintained on the ELM-development web site:

<http://ecolandmod.ifas.ufl.edu>

The primary objective of the documentation is to describe the fine-resolution application of the regional ELM, for use in evaluating ecological responses to alternative management scenarios in the greater Everglades landscape. This is a documentation update, limited to describing changes that were made in model design and data during the transition from ELM v2.5 to ELM v2.8. A number of original ELM v2.5 Documentation Chapters are not included here, as their content remains unchanged; the documentation is available in the above ELM-development web site, and at the ELM-application web site:

<http://my.sfwmd.gov/elm>

The only Chapters included in this ELM v2.8 Documentation Report are those that contain significant new information that is relevant to current application objectives.

Document organization

Each Chapter of this document has its own Table of Contents.

- (see ELM v2.5) Chapter 1: **Introduction** to the Everglades and the model **Goals & Objectives**.*
- (see ELM v2.5) Chapter 2: General overview of **Wetland Ecological Models**.*
- (see ELM v2.5) Chapter 3: Graphical and verbal descriptions of the South Florida and General Ecosystem **Conceptual Models** on which the ELM is based.*
- Chapter 4: Graphical, verbal, and statistical-summary descriptions all of the updates to **Data** that are used in the new model application.
- Chapter 5: Graphical, verbal, and mathematical descriptions of the updates to **Model Structure** and algorithms (including links to source code).
- Chapter 6: Analysis of **Model Performance** relative to the historical period of record in the regional system (1981 - 2000).
- (see ELM v2.5) Chapter 7: Aspects of **Uncertainty** in the model and associated data, including sensitivity analysis, appropriate model expectations, and model complexity.*
- (see ELM v2.5) Chapter 8: Descriptions of **Model Application** in the regional Everglades system.*
- (see ELM v2.5) Chapter 9: Descriptions of past and planned **Model Refinements**, including an overview of its current limitations.*
- Chapter 10: A **User's Guide** that provides the simple steps to installing and running this Open Source model.

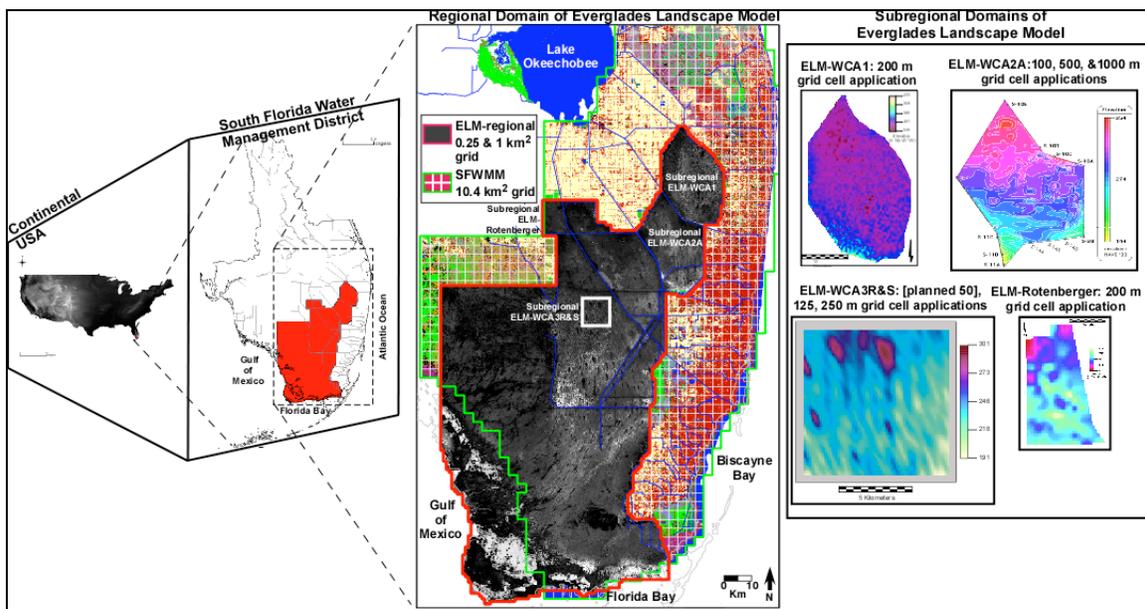
Acknowledgments

Funding for this ELM application came primarily from the U.S. Geological Survey, Priority Ecosystem Science Program, within the auspices of the Joint Ecosystem Modeling partnership. L. Brandt and R. Best provided management and direction for the model refinements described in this documentation update. See the ELM v2.5 Documentation Report for descriptions of other collaborations that were part of the overall ELM development.

Executive Summary

Today's Everglades are significantly different from the landscape that existed a century ago. Humans compartmentalized a once-continuous watershed, altering the distribution and timing of water flows, and increasing the quantity of nutrients that move into the Everglades. The result is a degraded mosaic of ecosystems in a region that is highly controlled by water management infrastructure. However, plans are being developed and implemented to restore parts of this system towards their earlier state.

To support scientific evaluations of restoration plans, computer simulation models can be used to predict the relative benefits of one alternative plan over another. One such tool is the Everglades Landscape Model (ELM). The ELM is designed to improve understanding of the ecology of the Everglades landscape, and can be applied at a range of spatial and temporal scales depending on the project requirements. This model integrates, or dynamically combines, the hydrology, water quality, and biology of the mosaic of habitats in the Everglades landscape. It is a state-of-the-art *model that is capable of evaluating long-term benefits of alternative project plans with respect to hydrology, water quality and other ecological Performance Measures.*



Existing regional and subregional applications of the ELM, including the 500 m grid resolution application developed for the regional Everglades system.

Because the ELM was designed to be explicitly scalable, it is relatively simple to adapt (spatial input map) data to accommodate the scientific objectives that may call for a particular scale of grid resolution or extent. There are a variety of ecological models (i.e., ATLSS (<http://atlss.org>)) that operate at a 500 m grid resolution, which is 4x finer resolution than that of the regional ELM v2.5. The finer scale was chosen by the model developers to capture more of the variability of animal community responses than possible with 1 km or larger grids. The hydrologic data used to drive these models is output from the South Florida Water Management Model (SFWMM), with 2x2 mile (~10 km²) grid resolution. While there exist several innovative methods to obtain 500 m

resolution hydrologic data from the SFWMM output and fine scale land elevation data, there was interest in obtaining finer scale hydrology from the regional ELM.

At the request of the Joint Ecosystem Modeling¹ group, and with funding from the USGS Priority Ecosystem Science program, we developed the 500 m resolution regional ELM v2.8² in order to provide another alternative for “driving” the other ecological models with fine scale hydrologic data. Moreover, this finer scale regional ELM application is available for evaluating other hydro-ecological responses of the Everglades landscape to alternative scenarios of water and nutrient management. This ELM v2.8 Documentation Report includes the information necessary for scientists and planners to understand this application of ELM, including *a) the ELM objectives, b) how it works, c) how well it works, and d) how to interpret its results.*

The fine spatial scale and very good performance of the resulting model may be useful in a variety of projects involving Everglades synthesis and management. The model “skill” in predicting stage and flow was improved over earlier ELM versions, and continued to be consistent with the SFWMM output. Of particular interest with respect to “driving” fine scale ecological models, this scale of ELM hydrologic output exhibited detailed spatial patterns of flow, with improved connectivity among and within habitats (such as sloughs) relative to the 4x (ELM v2.5) or ~40x (SFWMM v5.4) coarser-scale resolution hydrologic models previously available for the greater Everglades region. In particular for the JEM partnership, making use of a model with a “native” (original) resolution of 0.25 km² may likely lead to improved realism in modeling animal communities which respond to hydrologic patterns at these relatively fine scales.

¹ JEM, a partnership among several US Dept. of Interior agencies, several universities, and government and non-government organizations

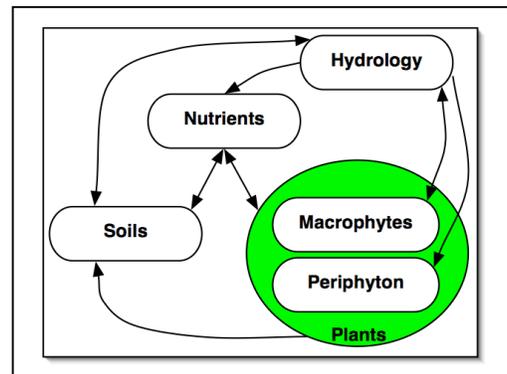
² The tertiary subversion designation of this v2.8 application release is v2.8.3.

Goals

- Develop a simulation modeling tool for integrated ecological assessment of water management scenarios for Everglades restoration
 - Integrate hydrology, biology, and nutrient cycling in spatially explicit, dynamic simulations
 - Synthesize these interacting hydro-ecological processes at scales appropriate for regional assessments,
 - **Understand and predict the relative responses of the landscape to different water and nutrient management scenarios**
 - Provide a conceptual and quantitative framework for collaborative field research and other modeling efforts

Design

- Can be applied at multiple spatial or temporal scales, for regional or subregional evaluations
 - Regional application at fine resolution (40x finer than SFWMM³)
 - Multi-decadal (36-yr) simulation period
- Combine physics, chemistry, biology – *interactions*
 - *Hydrology*: overland, groundwater, canal flows
 - *Nutrients*: phosphorus cycling and transport
 - *Periphyton*: response to nutrients and water
 - *Macrophytes*: response to nutrients and water
 - *Soils*: response to nutrients and water
- Combine ecological research with modeling
 - research advances led to model refinements
 - model output aided research designs



Reliability

- Excellent performance (1981 - 2000 history-matching)
 - *Hydrology*: the offset (median bias) of predicted and observed values of water stage elevations in the marsh was 0 cm
 - *Water quality*: the offset (median bias) of predicted and observed values of phosphorus in the marsh was 0 ug L⁻¹; chloride was 6 mg L⁻¹.
- Tested computer code
 - evaluated model response to wide range of conditions (sensitivity analyses)
 - years of experience in testing and refining code
 - applied at different scales for regional and sub-regional evaluations
- Uses best available data
 - comprehensive, unique summary of Everglades ecology
 - thorough QA/QC of input data
 - continuous interactions with other Everglades scientists and engineers

³ South Florida Water Management Model, the widely-accepted simulation tool used for regional evaluations of water management alternatives

Model Reviews

- Open Source
 - All ELM data and computer source code freely available on web site
 - Requires only Open Source (free) supporting software
- Publications
 - 1996-2008: Peer-reviewed scientific journals and book chapters
 - 1993-2006: Technical reports published by SFWMD
- CERP⁴ Model Refinement Team
 - 2003: Recommended independent peer review
- Independent Panel of Experts
 - 2006: Peer review of ELM by an independent panel of experts
- CERP Interagency Modeling Center
 - 2007: Review of ELM for CERP applications

Application

- Specific **model objectives** (Performance Measures)
 - For Joint Ecosystem Modeling partnership, provide fine-scale hydrologic output for use in “driving” other ecological models
 - ELM v2.5 – 2.8: Relative predictions of phosphorus 1) concentrations and 2) net load along spatial gradients in the greater Everglades, over decadal time scales
 - Other ecological Performance Measures proposed, pending model/data updates
- Appropriate applications
 - Relative comparisons of the above Performance Measures under scenarios of alternative water management plans
- Recent applications
 - ELM v2.8.2 application to subregional domain of Water Conservation Area 1, 200 m grid resolution; evaluated hydrologic and water quality responses to simple management scenarios

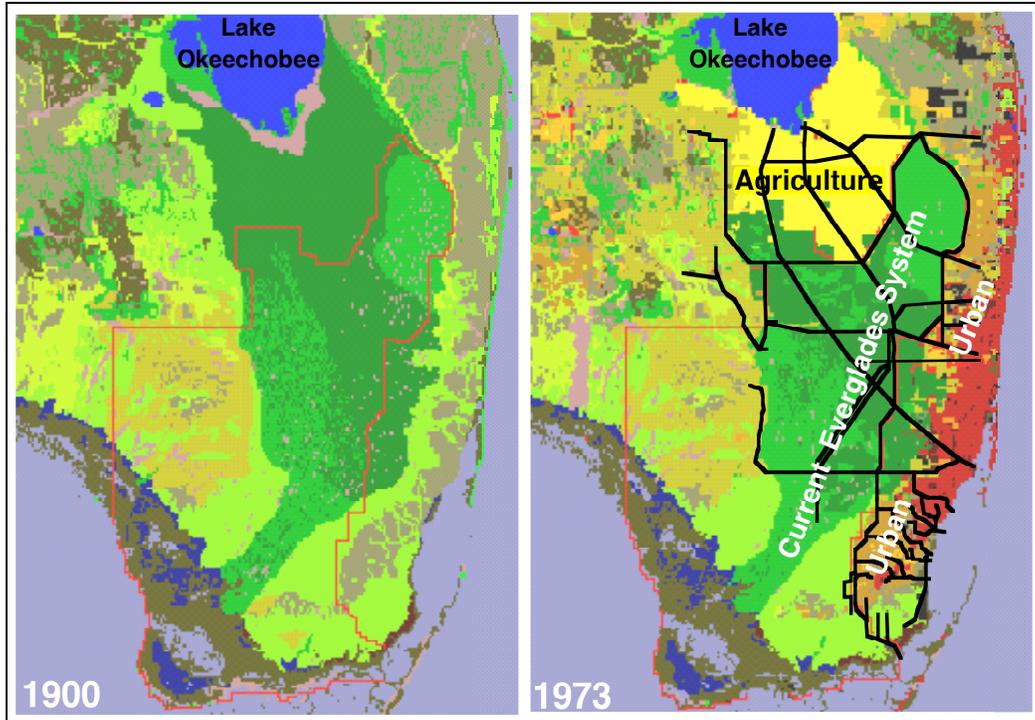
⁴ Comprehensive Everglades Restoration Plan

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Overviews of Chapters in ELM Documentation

This document is a greatly abbreviated version of the full documentation report on the Everglades Landscape Model (ELM). (Page numbers in the preceding Table of Contents refer to the full version of the documentation report). The following sections provide a high-level overview of the contents of each Chapter in the full report. Summaries in **red font** are unchanged chapters from the ELM v2.5 Documentation.

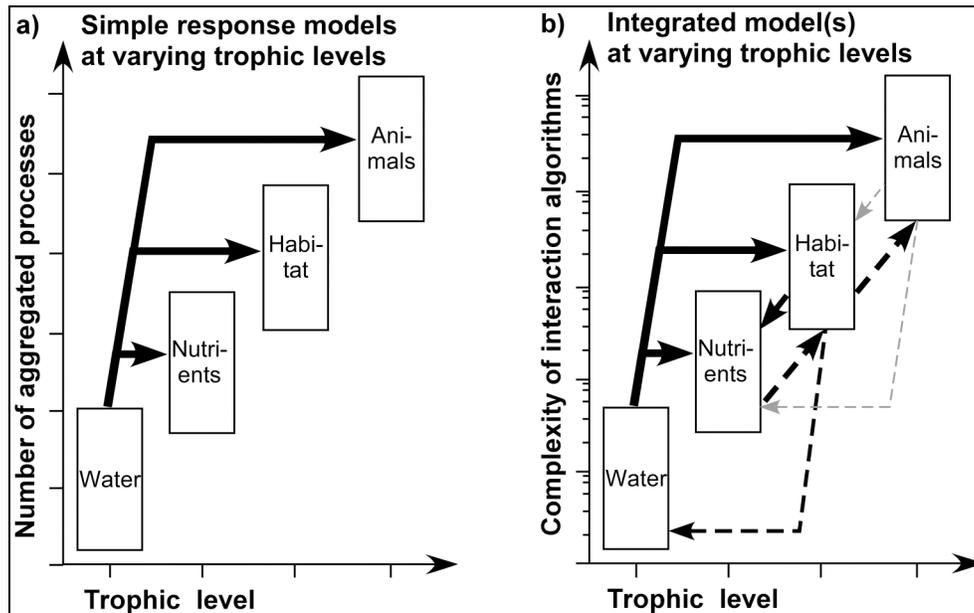
Chapter 1: **[v2.5] Introduction, Goals & Objectives Overview**



Agricultural (yellow) and urban (orange/red) land use expanded dramatically in south Florida during the 20th century. Black lines denote some of the major canals & levees that were constructed as part of the C&SF Project. The red polygon is the domain of the ELM.

This Chapter provides the background for the Everglades Landscape Model (ELM) documentation. We review how and why the Everglades region has changed, and how the ELM is intended to be applied towards understanding and better managing the system. The Everglades landscape is “inside” a highly engineered system of interconnected water basins, with altered water flows and nutrient additions that have caused ecological impacts during multiple decades of management. A variety of projects are underway that will attempt to restore as much of the existing Everglades as possible. While field observations and expert judgments are integral to this goal, computer modeling tools such as the ELM are part of the process of better understanding the landscape, and refining plans for its restoration. This Chapter introduces the ELM as a model that is designed to evaluate the long-term, regional benefits of alternative project plans with respect to water quality and other ecological Performance Measures.

Chapter 2: [v2.5] Ecological Models: Wetlands Overview

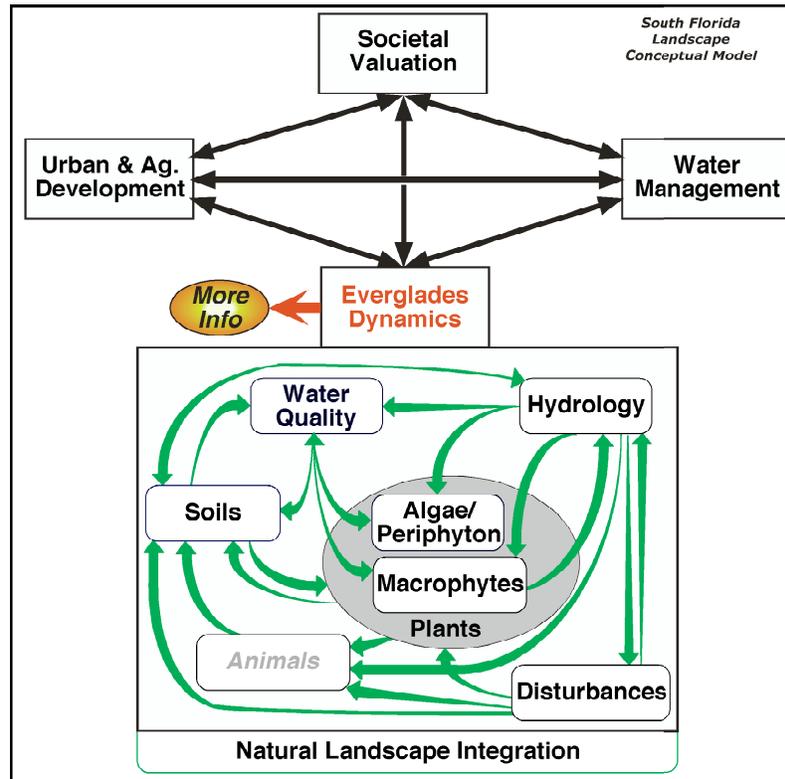


Trophic level and aggregation of different models. a) As simple (Nutrient, or Habitat, or Animal) models of ecological responses to hydrology incorporate higher trophic levels, the number of (implicit) aggregated processes increases. b) With increased explicit integration among trophic levels, the complexity of interacting equations may increase geometrically.

This Chapter provides a generalized overview of the objectives and design of ecological models of wetland systems. The intent is to broadly introduce the reader to the important wetland characteristics that are typically the focus of ecological models, without delving into any specifics of the Everglades or of the Everglades Landscape Model.

While wetlands have a wide range of characteristics, ecological models of these systems share at least one general goal: to understand the ecological responses to varying magnitudes and frequencies of flooding. Regardless of the specific objectives and the level of model complexity, a principal driver of wetland models is flooding and associated surficial sediment saturation. These wetland physics influence the selection of the implicit or explicit ecological processes to be considered in model development. The hydrology is thus an important consideration in the spatial and temporal scales of the model. Horizontal and vertical transport processes establish the basis for biogeochemical transformations of nutrients in shallow surface waters and the upper sediment layers. Sediment accumulation and loss combine with vegetative and algal dynamics to lead to varying trajectories of habitat type in space and time. Animal trophic dynamics respond to these physical and biological processes as wetlands evolve over time. Integrated models across this spectrum of ecological process complexity are usually limited by our state of knowledge, particularly over long time scales. In combination with directed research and monitoring, the diversity of ecological modeling in wetlands is leading to improved understanding of wetland dynamics. In an era of increased management of wetlands, judicious application of this model-based knowledge should aid in more informed decisions regarding the fate of wetlands.

Chapter 3: [v2.5] Conceptual Model Overview

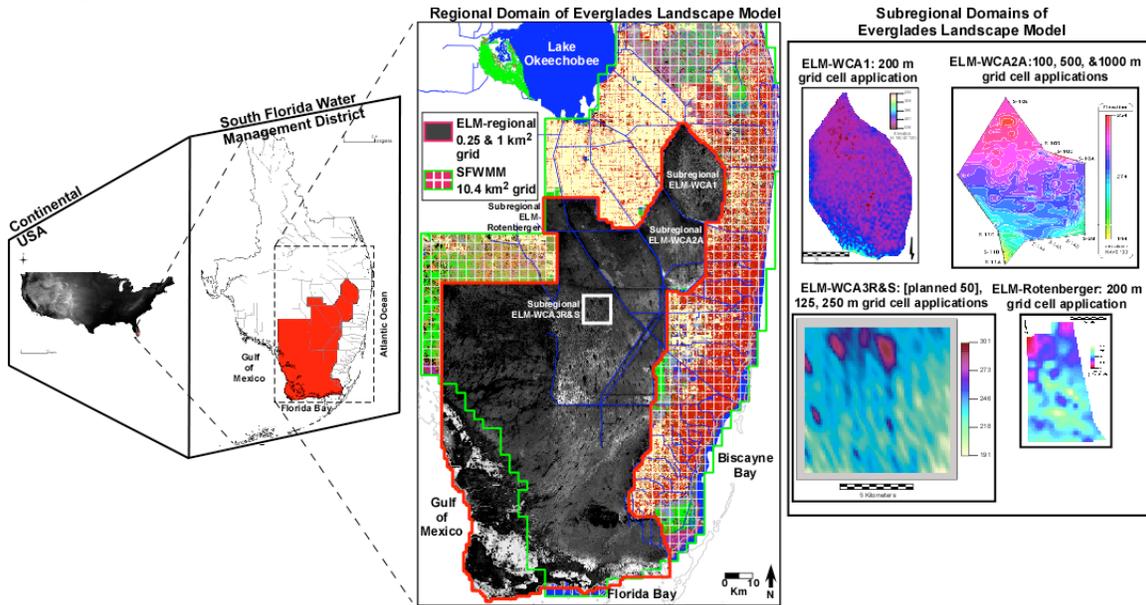


As E.P. Odum (one of the "fathers" of ecology) put it, an ecosystem is more than the sum of its parts. The ecosystem feedbacks, or interactions, among the physical, chemical, and biological components of the Everglades landscape are fundamental to the dynamics of this complex system. Using a simple framework, we believe that insights into the basic interactive processes aid in better understanding the system behavior as a whole.

The fundamental linkages among the natural and human-based environments are described in this chapter, using the South Florida Conceptual Model. This establishes the context of the "natural" Everglades landscape as it is integrated into the issues of the south Florida region. The General Ecosystem Conceptual Model for the "natural" area is then described, summarizing the ecological interactions among the primary physical, chemical, and biological processes that drive the ecosystem(s). Natural systems integrate these processes in a dynamic landscape. This is the basis of the concepts that were used in designing the Everglades Landscape Model, which is summarized in a subsequent Chapter on the Model Structure.

We recommend viewing this Conceptual Model via the hyper-linked version on the ELM web site (<http://ecolandmod.ifas.ufl.edu/background/sfcm.html>).

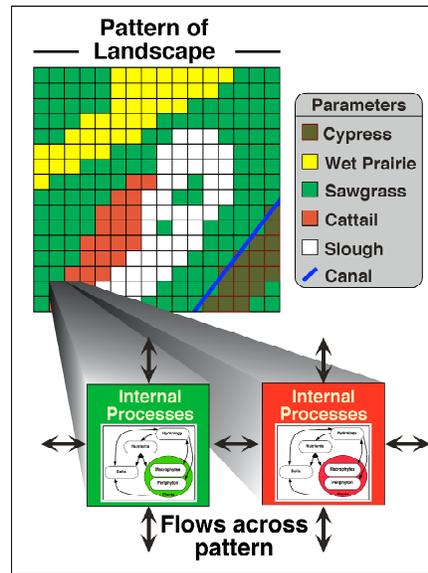
Chapter 4: Data Overview



Data are summarized for the regional domain(s) of the ELM, shown relative to the South Florida Water Management Model. At the right are subregional applications of ELM at different scales.

The focus of this Chapter is the description of changes to data used in the 500 m resolution regional ELM v2.8 application, relative to those documented for the 1 km resolution regional ELM v2.5. The new fine resolution regional model encompasses the identical domain of 10,394 km², but with 42,576 active grid cells (four times the 10,394 grid cells in the 1 km resolution version). For this ELM v2.8 regional application, most of the data remain the same as those used for the ELM v2.5 regional application. In parallel with the 500 m application, we continue to update/maintain the 1 km application (but which is not specifically covered in this document). The principal changes involved “resampling” data from the 1 km resolution map inputs, and generating new spatial interpolations of the updated land surface elevation data at the 500 m resolution. This ELM v2.8 Data Chapter thus makes extensive reference to the regional ELM v2.5 Documentation Report’s Data Chapter.

Chapter 5: Model Structure Overview



The conceptualization of how the “unit” model of general ecosystem dynamics is applied across the heterogeneous spatial grid of different habitat types.

The Everglades Landscape Model (ELM) is a spatially distributed simulation using integrated hydro-ecological process modules. With a structured programming approach, the hydrologic, biogeochemical, and biological processes (such as evapotranspiration, soil oxidation, and plant growth) are contained in code modules that are activated by the user at runtime. Being “data-driven”, the model relies on databases to modify scenarios of water management, while computer source code remains constant.

This Chapter on Model Structure for ELM v2.8 serves to update the Model Structure Chapter 5 of the complete ELM v2.5 Documentation Report. Therefore, this is not a “stand-alone” document on the model structure, but simply updates any algorithm which has changed to meet the objectives of different projects.

The major change from ELM v2.5 to ELM v2.8 was the restructuring and refinement of algorithms that defined schedule-based managed flows through water control structures. Integral with the goals and objectives of new modeling projects for evaluating local management alternatives, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the landscape.

This Chapter also includes an Appendix on the numerical dispersion attributes of the code, with results. That document was created during the 2006 Independent Peer Review of ELM v2.5, and is included verbatim for this ELM v2.8 update.

A separate User’s Guide Chapter includes information on the required computing environment¹ and the basic steps needed to install and use an ELM project.

Using an Open Source² philosophy, we hope to encourage collaboration in the modeling community. Towards that end, all source code (and data) necessary for an ELM project

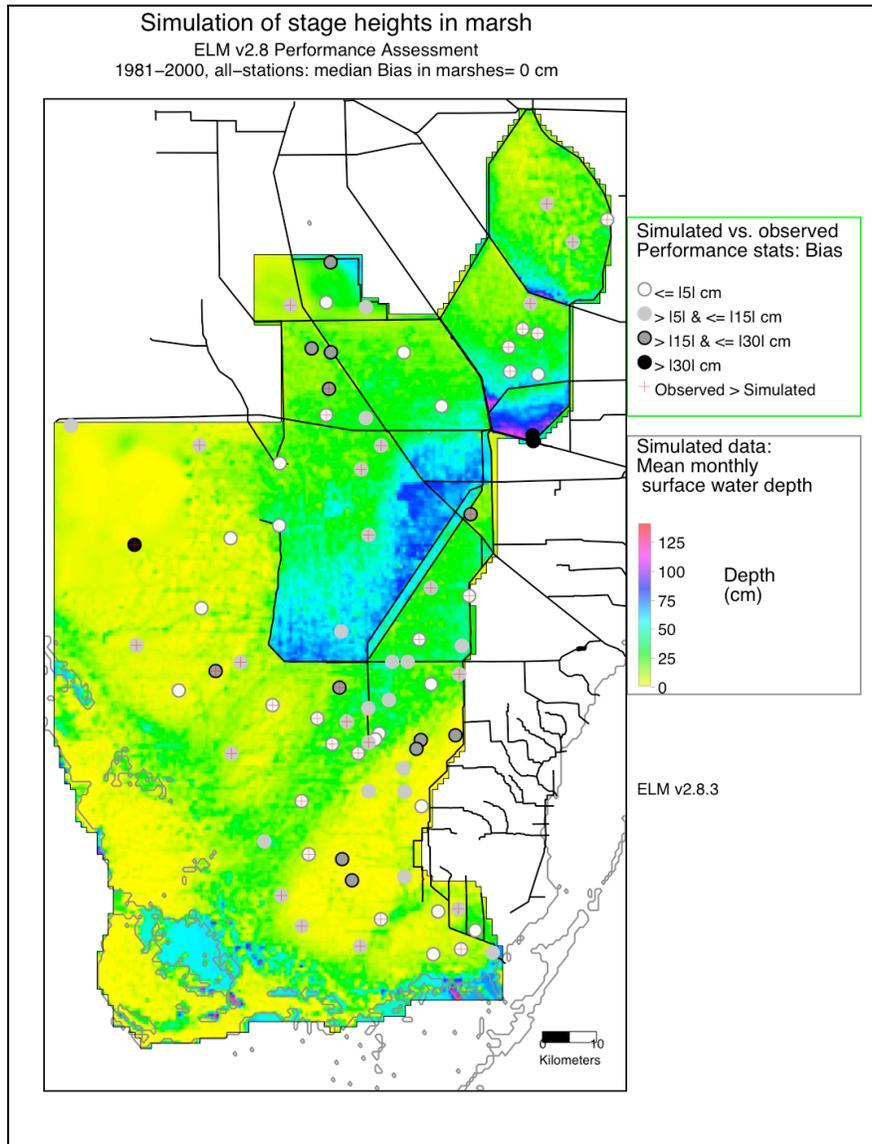
¹ Unix operating system (Linux, Darwin, or Solaris) using Open Source software.

² <http://www.opensource.org/>

is available for download on the ELM web site, and all code in the ELM project is documented in detail using the automated “Doxygen” documentation system. This online, source-code level documentation extends beyond the scientific algorithms described in this Chapter, including details of all of the functions that are compiled in the (ANSI C) code project.

We recommend viewing the hyper-linked version of the algorithm interactions and equations at this location on the ELM development web site (http://ecolandmod.ifas.ufl.edu/models/algorithms_ELM/MainControllerModule.html).

Chapter 6: Model Performance Overview



Simulated long term pattern of ponded surface water depths, indicating the low bias in predictions at specific monitoring locations.

As described in the Introduction Chapter 1 of the ELM v2.5 Documentation, an overarching Goal of the ELM is to understand and predict ecological dynamics across the greater Everglades landscape. For the current ELM v2.8, the primary goal was to provide fine scale (500 m grid resolution) hydrologic output for use in driving other ecological models (see the Executive Summary of this documentation report). For this specific project under the auspices of Joint Ecosystem Modeling partnership, the ecological performance measures were of secondary importance. For future water quality/ecological applications, specific Objectives involve Performance Measures of the “water quality” and other ecological aspects of ecosystem dynamics across the landscape.

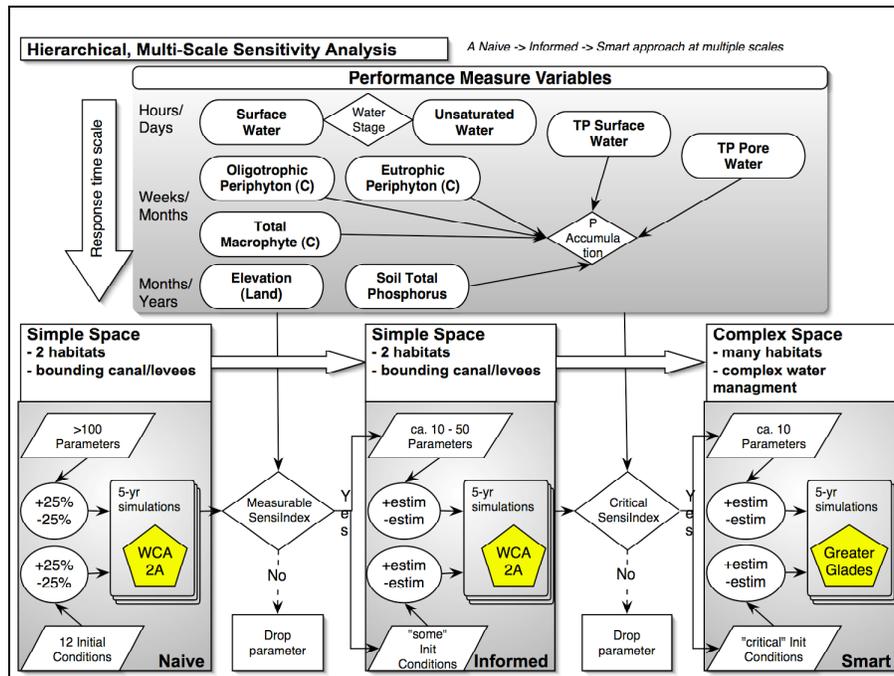
The overall approach of (developing and) calibrating the ELM was described in Chapter 6 of the ELM v2.5 Documentation Report. In this update to ELM v2.8, the only

parameter changes involved the segmentation of the canal reach vectors; there was relatively little effort involved in “tweaking” the calibration/validation performance. However, a number of code changes (Chapter 5 of this document) and initial condition data (primarily land elevation, Chapter 4 of this document) were made for this update to ELM v2.8.

In its regional (~10,000 km²) application at 0.25 km² grid resolution, the current ELM version 2.8 is available to assess relative differences in hydro-ecological performance of Everglades water management plans - at decadal time scales. Hydrologic performance of the ELM improved over that of ELM v2.5, with a median Nash- Sutcliffe Efficiency statistic was 0.61 and median bias of 0 cm, comparable to the South Florida Water Management Model (SFWMM) within the Everglades. The chloride tracer is an indicator of how well flows were simulated relative to observed data: the median seasonal relative bias of all stations was 10% in the marshes, and 11% in canals (and the bias was 6 mg L⁻¹ in the marsh and 13 mg L⁻¹ in canals), again showing improvement over the ELM v2.5. While not a focus of this project, the simulated and observed phosphorus concentrations were very closely related, with a bias of 0 ppb in the marsh and canal locations (which again was an improvement over that of ELM v2.5).

Thus, the model “skill” in predicting stage and flow was improved over earlier ELM versions, and continued to be consistent with the SFWMM output. Of particular interest with respect to “driving” fine scale ecological models, this scale of ELM hydrologic output exhibited detailed spatial patterns of flow, with improved connectivity among and within habitats (such as sloughs) relative to the 4x (ELM v2.5) or ~40x (SFWMM v5.4) coarser-scale resolution hydrologic models previously available for the greater Everglades region. Making use of a model with a “native” (original) resolution of 0.25 km² may likely lead to improved realism in modeling animal communities which respond to hydrologic patterns at these relatively fine scales.

Chapter 7: [v2.5] Uncertainty Overview



The conceptual model of our approach to analyzing the sensitivity of complex system simulations.

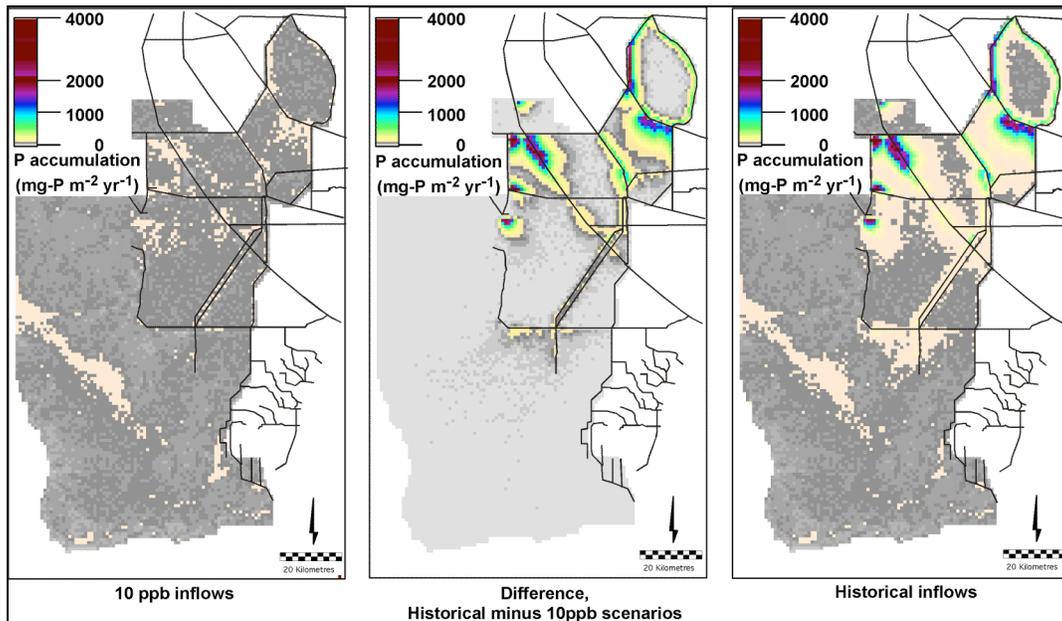
As we noted in the Introduction, Goals & Objectives Chapter, models are simple abstractions of reality, and may be used to guide our thinking. Towards this end, it is vital that modelers and model users acknowledge and understand the uncertainties inherent in any model. The topic of "Uncertainty" is broad, and a thorough treatment of it is well-beyond the scope of this documentation. Instead, we refer the reader to the report of the "Comprehensive Everglades Restoration Plan's Model Uncertainty Workshop" held in January 2002.

In the Uncertainty Workshop technical report, the authors specifically recommended that the Everglades Landscape Model (ELM) developers repeat the methods of prior sensitivity analyses on the current ELM version. In this chapter, we report on those results, and discuss their implications relative to model complexity.

Hydrology and water quality are primary drivers of the Everglades ecology, and are likewise an important component of the ELM ecological dynamics. Beyond the analysis of model sensitivity to parameter choices, we quantify the statistical expectations of the water quality performance metrics, which are highly dependent on the forces that drive the "boundaries" of the model. Another important concern in water quality modeling is that of "numerical dispersion", which is explicitly simulated in ELM (see Model Structure Chapter), and discussed here relative to model and data uncertainty.

Finally, we touch upon another common topic in modeling: what is validation, and can modelers truly validate the model output? The basic answer is "No". However, these model abstractions of reality have served useful purposes in better understanding system dynamics, and will continue to be important tools in aiding our decision-making process for uncertain topics such as understanding and restoring the Everglades.

Chapter 8: [v2.5] Model Application Overview



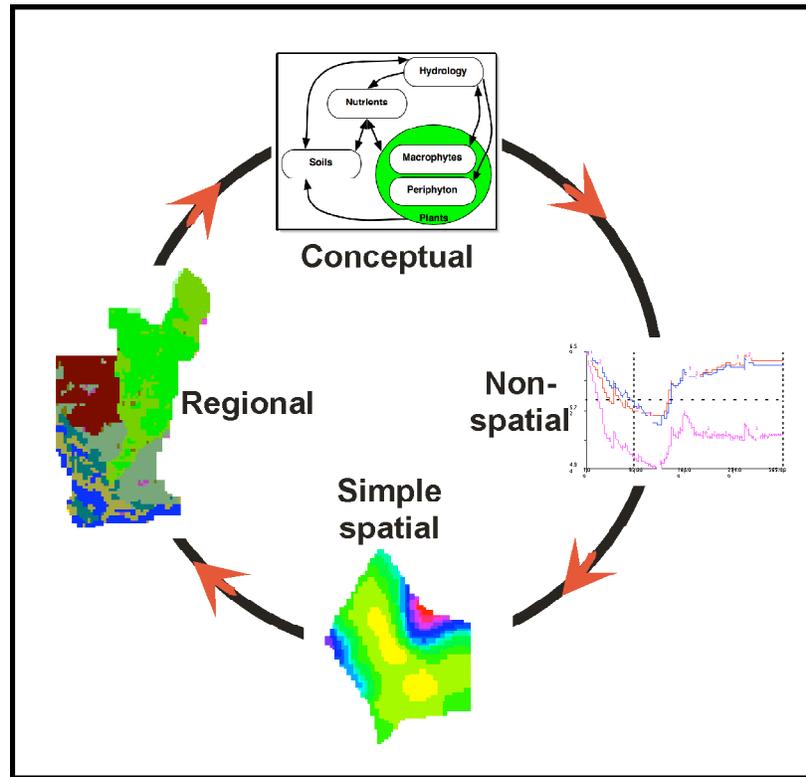
(ELM v2.5.0 output, current version is v2.5.2)

Phosphorus (P) accumulation rates during two scenarios of (10 ppb, and higher historical) phosphorus inflows to the greater Everglades during 1981 - 2000.

The Model Performance chapter of the ELM documentation provides strong evidence of model skill in predicting eutrophication trends across these scales that are of interest in Everglades landscape analysis. In its regional ($\sim 10,000 \text{ km}^2$) application at 1 km^2 grid resolution, the current ELM version 2.5 is available to assess relative differences in ecological performance of Everglades water management plans. Two water quality-oriented model Performance Measures may be used in this interim model version: phosphorus (P) concentration in the surface water, and P accumulation (net load) in the ecosystem. The latter is the more sensitive metric for evaluating ecosystem nutrient status. Consistent with the goals of water management planning for the regional system, the temporal scales of these Performance Measures are multi-decadal with seasonal or annual resolution. Likewise, the spatial scales capture multi-kilometer gradients at a 1-kilometer resolution, within a regional landscape of thousands of square kilometers.

Examples of application of the ELM to scenarios of alternative water management are shown. One example is from recent peer reviewed publication, while the other demonstrates a hypothetical scenario of reduced historical phosphorus inflows. In comparing relative benefits of different alternatives, graphs of trends along gradients and maps of regional differences are presented as examples of model application for planning purposes. Other applications of ELM include the ongoing use of the model in Everglades research programs, wherein the model can help identify information needs. Importantly, models such as ELM can be used to extrapolate and synthesize fine-scaled research results to the larger regional scales of the greater Everglades, across decadal time scales.

Chapter 9: [v2.5] Model Refinement Overview

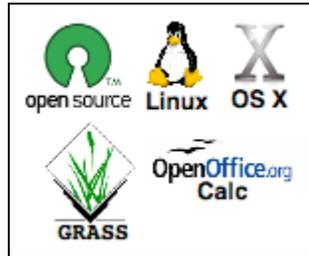


Model refinement is a continuous process, from conceptualization to implementation at different scales.

The Everglades Landscape Model (ELM) has been under continuous development and refinement since the inception of the project in the early 1990's. In this Chapter, we provide a high-level summary of the major developments in the timeline of the ELM project. These developments are documented in technical reports and/or peer-reviewed manuscripts, which are available (where possible) on the ELM web site under the Publications button.

All models have uncertainties (see Uncertainty Chapter) and associated limitations. Those limitations, and plans to reduce such limitations if applicable, are outlined in this Chapter. In particular, we hope that our Open Source philosophy will stimulate further collaborations towards continued refinement of this model - for enhanced understanding of the greater Everglades and its restoration.

Chapter 10: User's Guide Overview



The ELM is designed for ease of use, emphasizing collaboration with an Open Source philosophy.

The ELM is a freely available, “Open Source” project that we hope will be used and modified by others in the scientific community in a collaborative spirit. Other Chapters of the Everglades Landscape Model (ELM) documentation describe the input data, scientific algorithms & source code, model performance, and other material. This Chapter is intended to instruct users on the steps needed to install and apply the ELM in historical (e.g., calibration) simulations.

To use the ELM, one starts with a computer running some “flavor” of the unix operating system (such as Linux). Basic familiarity with unix is required, but advanced expertise is not absolutely necessary. The ELM is installed from a single script that extracts data and code from two compressed file archives. The executable is then built (compiled & linked) from a script, and the model is ready to go.

In the most common/simple application of ELM, a single script is run to verify what output is desired, execute a model run, and archive the results. The user is guided through the several fundamental checks of model output to verify that the model indeed performed as expected. The outputs are described, covering a range of spatial and temporal scales of the landscape. Their interpretation is dependent on an understanding of the science of ELM covered in the other Chapters of this documentation.

As should be apparent from this and other Chapters of the model documentation, the ELM was designed to be applied by modifying databases, not the model source code. “User-friendly” supporting databases are available to select different outputs, change parameters, or explore/edit aspects of the supporting data. However, those databases need not be immediately opened/modified, depending on the user’s initial interest.

A few of the more advanced applications of ELM are covered in brief, but are generally beyond the scope of this User’s Guide. These topics include the automated sensitivity analysis of the model, the creation of new subregional applications, and evaluating scenarios of future restoration alternatives. While these applications of the model are all data-driven and relatively straightforward, the details of changes to data and requisite quality assurance are left to a subsequent extension of this guide.

UPDATES to this Chapter, v2.5 to v2.8:

1. numerous edits for clarification; updated installation script and documentation
2. documented use of new netCDF and floating point generic binary map output

3. added scripts and documentation for use of OpenDX for visualizations (Appendix)
4. added details on extracting SFWMM water control structure output for input to ELM future-scenario applications (Appendix)
5. added the “Unix & ELM Cheat Sheet” Appendix, for novice unix users