Regional Simulation Model (RSM)

Implementation Report

SFWMD Response to Final Panel Report

Peer Review of the Natural System Regional Simulation Model v2.0

July 2007

sfwmd.gov

Executive Summary

The South Florida Water Management District (SFWMD) initiated a multi-part peer review of the Regional Simulation Model (RSM) in 2005 to improve the overall quality of the model and to provide an important quality control step in RSM development. Part I (completed) involved the review of the RSM theory and the model's computational engine by a panel of experts. Part II: Natural System Regional Simulation Model (NSRSM) Implementation review, the subject of this document, is currently underway and is expected to conclude by August 2007. The purpose of this document is to respond to the *Scientific Peer Review of the NSRSM Draft Final Report v1.1* received during the peer review process.

The Peer Review Panel was provided extensive documentation and access to a website with additional references. The initial feedback from the panel was used to formulate a two day workshop that addressed topics that required further explanation through a series of presentations. The information disseminated during the workshop was included in the review. Communication between the panelists was done through a public web board.

As requested, the Peer Review Panel Draft Final Report provided a balanced presentation of strengths, weaknesses, and potential enhancements of the NSRSM implementation. The effort is much appreciated by the District and the public.

The District believes that the NSRSM, as presented through the extensive documentation provided to the Review Panel, comprehensive responses to their questions, and presentation of the NSRSM at a workshop, has adequately demonstrated that the NSRSM implementation is scientifically sound and suitable to represent south Florida's pre-drainage conditions.

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1.0 Introduction

This document provides the official response of the SFWMD to the NSRSM implementation peer review panel's draft final report. It also summarizes the peer review work done to date, and provides discussion to clarify some issues brought forth by the Review Panel. The Peer Review Panel Final Report document together with the Final Response document will reflect the status of the NSRSM implementation at the end of Part II of the RSM peer review.

The NSRSM was implemented by the SFWMD as a Regional Simulation Model (RSM) designed to simulate south Florida hydrology prior to drainage (ca. 1880). Its predecessor, the Natural System Model (NSM [2x2]) was developed to establish "… a tool which mimics natural and, eventually, pre-drainage hydrology, with the limitations of recorded history… to provide insight in evaluating alternatives for future restoration initiatives" (Davis and Ogden, 1994[1]). Intensive application of this tool during the Central & Southern Florida Project Restudy, CERP, and several Water Supply Planning efforts has made it a significant component of the planning process.

The NSRSM includes estimated topographic and land cover input data that represent natural conditions prior to drainage activities. Overland flow is the dominant water-transport mechanism in the natural system. In addition to overland flow, processes included in the NSRSM are rainfall, evapotranspiration, surface water infiltration, groundwater flow, and stream flow. NSRSM flows are simulated in an integrated system using "watermovers" that control fluxes between "waterbodies"—an RSM concept particularly suited to natural system application.

1.1 NSRSM Development and Implementation Challenges

Because modern hydrologic data from pre-drainage south Florida does not exist for comparison of model results, NSRSM calibration was non-traditional. A "soft" calibration/verification was conducted using prior modeling experience, and the best available sources of surveyed and estimated historical hydrologic data to compare with model results.

The NSRSM v2.0 Implementation Report was provided to the panel as a draft document for review in conjunction with workshop presentations and teleconference discussions. Simultaneous execution of model data development, data testing, implementation, evaluation and documentation did not allow for final document preparation and it was assumed that the status of the draft document was adequate for a comprehensive panel feedback prior to its completion. District staff made it clear that known formatting and content issues existed in the draft NSRSM v2.0 Implementation Report. Panel comments providing recommendations for improved organization and content were constructive and will be considered during documentation revision.

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[1] Davis, S.M. and J.C. Ogden. 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie Press, Delray Beach, FL.

1.2 Scope of Work

This review of the implementation of the Natural System Regional Simulation Model is Part II of the RSM peer review. A scientific panel of experts examined model conceptualization, evaluated model performance and performance measures, and reviewed model documentation. The purpose of this work was to identify opportunities to improve NSRSM conceptual formulation, simulation, and performance measurement. The selected panelists are listed below.

- ☐ Dr. Rafael Bras, panel chair, Dept. Director, MIT Civil & Environmental Engineering
- ☐ Dr. Wendy Graham, Director, University of Florida Water Institute
- ☐ Peter Stone, Bureau of Water, South Carolina
- ☐ Dr. Lance Gunderson, Emory University, Dept. of Environmental Studies
- ☐ Dr. Jerad Bales, USGS, Raleigh, NC

Specific goals were given to the Peer Review Panel, again with the focus on finding strengths, weaknesses, and possible limitations. The goals identified in the Statement of Work were:

- ☐ Determine if proper and sound scientific approaches were used in the implementation of the NSRSM.
- ☐ Identify weaknesses and potential enhancements in the conceptual framework of the model and determine if the model contains all of the important hydrologic processes necessary to perform regional scale natural system modeling in south Florida.
- ☐ Determine if the model is suitable to simulate south Florida pre-drainage conditions, including specifying if there are any fatal flaws apparent in its implementation.
- ☐ Recommend improvements in performance metrics.

1.3 Information Provided to the Review Panel

Panelists were given paper copies of materials to read and were granted access to additional references via a website[2]. A tour of south Florida by helicopter was offered to the panelists to acquaint them with the landscapes being modeled. Feedback to an initial set of comments was also presented on the website[3]. Handouts and presentations were provided during a District-sponsored two-day peer review workshop held in West Palm Beach on March 1-2, 2007.

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[2] Part II: NSRSM v2.0 Peer Review website at: https://my.sfwmd.gov/portal/page?_pageid=1314,2555966,1314_2608149:1314_2564292&_dad=portal&_schema=PORTAL

[3] District response to initial comments at: https://my.sfwmd.gov/pls/portal/url/ITEM/2D361EDF5A843AEBE040E88D4952462D

The "required reading" mailed to the panelists at the onset of the peer review included **NSRSM v2.0 Implementation Report** and its appendices. [4]

1.4 Review Process

The peer review was conducted in accordance with the Florida Sunshine Law with limited interaction between the panel members and District staff. A facilitator (Kent Loftin of SynInt, Incorporated) was selected to serve as a liaison between the Peer Review Panel and the District. Aside from the tour and two-day workshop, all communication was captured on a public web board[5] and advertised on the SFWMD external website.

A major task given to the Peer Review Panel was to review the "required reading" materials and provide an initial set of comments before the on-site workshop. These comments[6], along with District responses, are available online.

At the workshop, panel members posed numerous questions. All issues brought forth by the panelists were captured in the workshop minutes, which are available online[7].

After the workshop, the panel members communicated through teleconferences and disseminated their findings via the web board as they processed the provided information and assembled their report. Communications will be archived electronically upon completion of the peer review.

1.5 Format of this Response

The Peer Review Panel had the difficult task of evaluating an enormous amount of material to gain a basic comprehension of the NSRSM and its implementation. The panel remained diligent throughout the review and offered numerous constructive comments along the way. The remainder of this report responds to the findings of the Review Panel, organized by the structure of the panel report.

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[4] For NSRSM v2.0 Implementation Report files, see "Required Reading" section of the web site at https://my.sfwmd.gov/portal/page?_pageid=1314,2555966,1314_2608149:1314_2564292&_dad=portal&_schema=PORTAL

[5] Public web board at: http://webboard.sfwmd.gov/default.asp?action=10&boardid=2&fid=382

[6] Initial Panel comments at: https://my.sfwmd.gov/pls/portal/url/ITEM/29EA2A4998DE1A82E040E88D49527D8E

[7] Workshop minutes at: https://my.sfwmd.gov/pls/portal/url/ITEM/2CD0EDD7E618625CE040E88D485268D1

2.0 Suggestions from the Peer Review Panel

The Peer Review Panel generated a report that summarized their assessment of the NSRSM implementation and made recommendations[8]. The District has responded to the panel's major findings in this section, point by point, in a summary form.

2.1 The Conceptual Model

One of the major items of discussion amongst the Peer Review Panel was the natural system conceptual model. The panel defines a conceptual model as "a theoretical construct that represents some process or processes, with a set of variables and a set of logical and quantitative relations among the variables." An important aspect of the conceptual model is the catalog of assumptions involved in its development, because differences between the modeler's assumptions and those of the end user can result in the misapplication of the model.

The District's conceptual model is based on peer reviewed assumptions synthesized from historical documentation. Most of the available historical information is descriptive and without numerical measurements, thus the conceptual model and its results should be viewed from the qualitative perspective. A better integration of Appendix A into the main body of the implementation report will help define the conceptual model and better demonstrate the relationships among various components of the model. Illustrations showing how water moves through the system will also be generated to aid in the understanding of the conceptual model and to better align it with the panel's definition.

2.2 Evaluation of Hydrologic Processes

The Peer Review Panel stated that all significant processes of the regional hydrology of pre-development south Florida are represented in the model and suggested a more rigorous discussion of the level of complexity chosen for each process. They believe the model provides a reasonable estimate of pre-drainage topography and recommend the model be exercised to reveal sensitivity of key performance indicators to alternative topographic and land cover representations. SFWMD staff concurs and have initiated this effort through the uncertainty analysis tasks.

Topography and Land Cover

Modelers observed the effects of changing topography in the model through the many iterations performed in the development process. The District acknowledges the need to further explore and document the model's sensitivity to topography. District staff agrees that the inclusion of dynamic landscape in the NSRSM will allow for simulation of the effects of changing land cover on flows and hydroperiods at strategic locations. At this stage of NSRSM development, the District wishes to establish a reasonable representation of the historic landscape before

[8] Panel Draft Report at: https://my.sfwmd.gov/pls/portal/url/ITEM/311558958D5CB2E7E040E88D48527D19

introducing the dynamics of droughts, floods, and fires on vegetation and topography. The dynamic relationship between hydrology and vegetation has been considered for future inclusion in the natural system model. District staff recognizes the lack of prior studies on uncertainty/sensitivity analysis of multi-dimensional models such as NSRSM and have embarked on developing methodologies for investigating topographic uncertainties. The Peer Review Panel suggested that the methodologies used to merge and match the different topography datasets need to be described more clearly. The software specific algorithms and acronyms are meaningless to those unfamiliar with geographic information systems. Therefore, the District will make an effort to reduce jargon and offer a more thorough explanation of the process in the next revision of the NSRSM v2.0 Implementation Report.

Rainfall

The rainfall presented at the workshop and in the NSRSM v2.0 Implementation Report was based on historical measured rainfall from 1965 to 2000. The Peer Review Panel suggested that the choice of input periods needs further analysis, justification and discussion. It is obvious from the Peer Review Panel's report that the inclusion of PRISM precipitation data to show the variability causes by wet and dry time periods was not clearly understood. The District will address this by adding discussion to the NSRSM v2.0 Implementation Report and abbreviating the PRISM frequency analysis in Appendix C to its relevant points.

Reference Evapotranspiration

District staff is pleased with their effort to generate Penman-Monteith Reference ET over the NSRSM domain and appreciates the panel's acknowledgment of the innovative yet defensible approach. The Review Panel suggested that the District investigate alternative interpolation schemes to bring the 32 km NARR grid onto the higher spatial resolution NSRSM grid; this recommendation will be considered. District staff agrees with the panel recommendation that RefET patterns need more explanation. While the patterns in the basic variables used for PET estimation (relative humidity, solar radiation, wind speed, temperature, etc.) appear reasonable based on historical data, input from local climate experts may be necessary to assist in explanation of Reference ET patterns.

Actual Evapotranspiration (ET)

The District admits that information provided on the workings of Hydrologic Process Modules (HPMs) that process rainfall and ET for each cell need to be clarified. The difference between the two methodologies (layer1nsm and unsat) and their coefficients (e.g., Kc, Kveg, Kw, Rd, Xd) require better explanations. The RSM allows for exceedingly complicated HPM implementations compared to the NSRSM HPM implementation which is very simple; (net rainfall-ET) is applied to the individual cells as a boundary condition, and ET is a function of PET and a crop coefficient. The District will address these issues in the documentation. The panel raised the issue of allowing adaptation of vegetation in response to hydrology, which would change the ET with time. This aspect is beyond the scope of the current NSRSM efforts and will be addressed in future model development.

Another question regarding actual ET is why the rate of ET from a lake should depend on depth, and how the cutoff between "deep areas" and "shallow areas" was determined. This methodology was developed for the South Florida Water Management Model where ET rates from dry, littoral and deep water areas need to be different. Under natural conditions, this method would consider the entire lake to be deep water, and only deep water ET rates would be simulated.

Overland Flow and Groundwater Flow

The Peer Review Panel identified five issues of potential concern related to the integrated overland and groundwater flow: significant differences in system response time between surface and subsurface flows, extreme differences in flow resistance in groundwater and surface water regimes, the model's inability to predict actual flow paths, possible problems where water is ponded in a cell but not in an adjacent cell, and the lack of anisotropy in the model where surface water may flow in a different direction than groundwater. These concerns/issues will be forwarded to District's Hydrologic Simulation Engine development team for clarification and further investigation, if necessary.

The District accepts the recommendation to investigate the incorporation of anisotropic flow resistance terms. NSRSM does use Kadlec's formulation for flow resistance which includes water depth and vegetation impacts on flow. Incorporation of anisotropy requires a major theoretical development and will be considered in the future.

The Peer Review Panel suggested a flux coupling term between the overland water store and the groundwater store to produce more realistic interactions between the overland and the groundwater domains. This option will be considered by the District. The recommendation that the term "transmissivity" be avoided is well taken and different terms will be used to describe this integrated flow resistance.

The District understands that the Peer Review Panel was unable to evaluate the interaction of Hydrologic Process Modules (HPMs) with the overland / groundwater flow system. Improving documentation on the HPMs will be a focal point of the revised NSRSM v2.0 Implementation Report, as a better explanation is clearly needed.

The Review Panel expressed concern over the methodology used to convert stage to volume in the ridge and slough system. The stage-volume relationship is used in many models. The NSRSM implementation team requests that Panel members recommend a way to test the stage/volume relationship to address their concerns or suggest and alternative methodology to handle microtopography.

The final concern regarding surface / subsurface interactions is how river seepage into groundwater occurs, as the equation used to represent this interaction assumes a low conductivity layer exists. We agree with the concern and we are currently investigating the sediment conductance to reflect properties of the connecting aquifer. The rivers that will have a higher conductivity between the sides and bottom of the river aquifer reside within the Biscayne aquifer. A USGS report confirms that a direct hydraulic connection exists between canals and the Biscayne aquifer. Peer-reviewed published manuscripts documenting results of HSE/RSM

comparisons against analytical solutions are available. Based on RSM Peer Review Part I recommendations that additional verification tests be conducted, the District is currently conducting HSE verification tests to assist in documentation of HSE/RSM formulation. Three of these tests are focused on canal segment interaction, in which a comparison will be made between model predictions and analytical solution.

Mathematical Representation of Processes

The Peer Review Panel praised the efficient and innovative numerical solution to the representation of the hydrologic process. However, the panel did identify two issues: the need of a physical argument for the assumption that a single hydraulic head is valid, and the need for a better discussion of numerical errors and computational constraints.

These issues will be addressed in the final documentation.

2.3 Calibration, Verification, Performance and Metrics

Calibration and Verification

The Peer Review Panel's main concern with the calibration was the lack of discussion of how it was performed. The panel accepted and understood the necessity for a "soft" calibration and verification due to the lack of historical measurements throughout the system. They did see a need to include other reasonable alternative interpretations of history and the resulting ranges of variables and their impact on calibration.

The District realizes that the scientific process of calibration requires additional experimentation and documentation. Much iteration is necessary to refine the parameters and it is difficult to document the means in their entirety. In-depth discussion of the derivation of model parameters will be added to the NSRSM v2.0 Implementation Report. The method of interpreting historical information to create parameters that best reproduce the behavior of the system will be better defined in the revised report. Future refinement of the model will include the panel's suggested testing of the individual processes to show that the best possible representation has been attained.

Model Performance and Performance Indicators

The Peer Review Panel acknowledged that quantitative performance measures are not applicable to the NSRSM due to the lack of pre-drainage data. The panel stated that model performance should be evaluated with more of a qualitative approach that addresses the acceptability of the conceptual model and its assumptions, as well as the validity of the input datasets. The Peer Review Panel did have three issues with the District's model performance evaluation: time frames, indicator cells, and the 35-year climate window.

The District concurs with the panel's conclusion that the NSRSM should be evaluated in a qualitative manner. The assessment of the model's performance is largely based on interpretation of historical information. The District believes that performance indicators are ways to look at the model and if the evidence is there, they become performance measures.

The District accepts the suggestion to provide output statistics that reflect both long-term dynamics (decadal) and short-term (monthly) scales. The system operates at multiple time frames and should be measured as such. Annual statistics have been the standard method of analysis for data comparisons.

The Peer Review Panel believes that the use of indicator cells is problematic and such comparisons are erroneous. They suggested that comparisons should only be made over regions using averages of large spaces. This advice was given early in the Peer Review and was immediately implemented into the latest reporting of model results to the panel. The District agrees that results from individual cells can be extreme and that the "regional performance" approach is reasonable for evaluation.

The Peer Review Panel asked if a better validation of the NSRSM implementation could be obtained by using artificial rainfall input that is more representative of the long-term average. This was instigated by the NSRSM v2.0 Implementation Report stating that the base simulation is "representative of a drier than average decadal climate oscillation" as an explanation for lower reference values. Historic measurements were not taken at all locations simultaneously, thus it is difficult to generate reference values at specific locations and times. The District will take this suggestion into consideration as it continues to study and better understand rainfall variability. A 35-year average rainfall dataset is possible once there is a consensus on historical rainfall cycles.

Comments on Performance

In April 2007, the District provided the final version of "NSRSM v2.0 Results and Evaluation" to the Peer Review Panel[9]. This chapter was re-done in an effort to incorporate the panel's comments from the workshop and offer a more meaningful presentation of results. The NSRSM is performing well within expectations, as acknowledge by the Peer Review Panel, however, there were some issues and recommendations in the panel's report.

The Peer Review Panel stated the weaknesses of the results chapter was the lack of discussion and critical analyses. They recommended that a significant amount of time and effort be given to the evaluation and discussion of the meaning of the results. Several items were suggested for inclusion in this chapter. The peer review schedule precluded comprehensive analysis and discussion of the results. The need to expand this section is obvious -- many of the panel's suggestions will be incorporated into the revised Implementation Report.

2.4 Uncertainties and Model Use

The Peer Review Panel stated that the uncertainty analysis should be the tool to identify model elements and parameters that require attention in order to reduce uncertainties. Resources should be prioritized based on the areas of most uncertainty. The panel agreed with the methodology defined by the Interra Report and suggested that it be extended and integrated into the revised NSRSM v2.0 Implementation Report. The Peer Review Panel also recommended discussion on

[9] NSRSM v2.0 results and discussion at:
https://my.sfwmd.gov/pls/portal/url/ITEM/24FD7D9E98649028E040E88D485275A8

how uncertainty will be used to direct future calibration and refinement efforts of the system representation. The District will expand their discussion of uncertainty in the next version of the NSRSM v2.0 Implementation Report.

The Peer Review Panel asked for the expected accuracy of the model results based on the current understanding of the pre-drainage system and the sensitivity testing. This will take time and effort by the District to provide. The District has had several workshops on sensitivity and uncertainty analyses in the past and is well aware of their importance. Additional study and comparison of results will allow the District to establish guidance on the accuracy of the NSRSM for future users.

The NSRSM v2.0 Implementation Report includes an analysis of sensitivity and uncertainty analysis techniques considered by the Peer Review Panel to provide "very good methodology to do uncertainty analysis. The panel read and heard a proof-of-concept to generate quantitative measures of uncertainty". District technical guidance contributed to the success of this analysis, and District staff will continue to improve the understanding of the model uncertainty.

The District agrees with the Review Panel's understanding that the NSRSM "is most appropriately applied as a tool to examine the effects of perturbations to the natural system hydrology." The NSRSM allows the user to observe how changes in parameters would alter the natural system.

The Review Panel recommended that output from the NSRSM not be used to set targets or any other such prescriptions for restoration because of uncertainty in model results and because aspects of the ecology have been altered between pre-drainage and current conditions. They recommended that the NSRSM be used to indicate relative changes in hydrology between pre-drainage and current conditions. Another recommended use would be in the adaptive management framework to help guide management experiments. The District will carefully consider the panel's recommendations with respect to the use of the model output.

SFWMD RECOVER Division Review of Response to NSRSM v2.0 Peer Review

by Andrew Gottlieb

SFWMD RECOVER Division staff evaluated the peer review comments of the Natural System Regional Simulation Model (NSRSM) v2.0, as well as the SFWMD response to comments. Overall, the peer review panel was very supportive of the NSRSM and related efforts. The peer review panel identified both general and specific concerns and potential next steps for the model developers. The SFWMD response to comments identifies areas where the developers will address comments and in some cases identifies specific (responses in) future development tracks.

Organizational structure of the NSRSM documentation was one of the key shortcomings identified by the review panel. The panel felt the majority of information was available to them in some format, but the information was not easily accessible in a single, unified document. SFWMD RECOVER realizes that model development is an iterative process and that integrating methods documentation is not an easy task for such a large model effort. SFWMD RECOVER feels it is in the best interest of developers and potential clients to clearly link the model documentation into a unified, logical/stepwise Implementation Report. This is particularly important when it comes to model assumptions, documentation of parameter estimates, and model uncertainty. By clearly illustrating model assumptions, developers can limit the misapplication of the model. Documentation of parameter estimates will help with (guide/prioritize) intermediate to long-term updates to the model as well as help with future sensitivity and uncertainty analysis.

SFWMD RECOVER recognizes the large investment in resources needed for future development and refinement of the NSRSM. Because not all tasks can be accomplished immediately, SFWMD RECOVER recommends identification of short-term, intermediate and long-term tasks. Initial tasks should address model development, testing, and documentation issues. Later tasks should investigate applied work addressing performance measure (PM) coding (transfer of existing PMs from the SFWMM) and development, as well as PM target exploration. Intermediate tasks should also include continued development of an extended climate record. This will provide a more robust utility to investigate changes in system performance relative to increased climatological variability.

Future efforts, given sufficient resources, would focus on feedback loops including succession and climate issues. Current understanding points to a dynamic system partially driven by extreme conditions (very wet vs very dry). It is during these extremes (and the period following) that changes in the landscape structure and function can be expected. Extreme dry periods are associated with intense fires that can alter vegetation and soil structure and composition. These changes may result in a shift in vegetation and landscape pattern thereby directly impacting system biology (alligator and wading bird nesting), chemistry (species specific nutrient uptake rates) and wetland hydrology (resistance to flow). Succession processes not only affect within marsh functionality but may also impact regional weather patterns thereby changing system hydrology even further. Although long-term steps for NSRSM development, feedback loops and succession will make the NSRSM a more relevant tool to be applied to system operations and

management. The SFWMD RECOVER Division is supportive of the developers' consideration to incorporate the dynamic relationship between hydrology and vegetation into the NSRSM.

The NSRSM peer review was very favorable. The SFWMD RECOVER Division supports the continued development and potential future application of NSRSM. The increased spatial resolution of the model will provide enhanced support to project delivery teams during project modeling. Additionally, the resolution of the model is at a scale that is more comparable to the varying habitats, features, and potential ecological interactions within the Everglades system. NSRSM will help future exploration of performance targets and will be extremely useful for hypothesis testing, including the effects of single variable/parameter manipulation on system performance (which can then be compared to field observations made under the Monitoring and Assessment Plan (MAP)). In order for developers to effectively design NSRSM to help answer relevant applied and theoretical questions, continued interaction with SFWMD RECOVER staff is suggested/recommended (where resources permit). SFWMD RECOVER will continue dialogue with NSRSM developers' to provide recommendations on needed tools and related functionality to be applied to system-wide evaluation, planning and operations.

Areas of focus and ongoing questions:

Uncertainty and uncertainty propagation (confidence estimates of PM output)

Increased model performance around boundaries (Southern estuaries) and better understanding of groundwater-surface water interactions at these boundaries

Is there a threshold scale at which model output should be more readily acceptable or meaningful? (Not at the cell level, how big does an indicator region need to be, multiple IRs, landscape types)?

Linkages between real world and model world performance/

Use of parameter estimate arrays to better understand ranges in alternative performance

(Use the model to test hypothesis and to test sensitivity of metrics to individual parameter estimates and compare to real world scenarios and experimental output).

PM output- loss of spatial and temporal scale through averaging (explore relevant aggregation scales)

PM targets- model should be used to explore targets and related performance, but targets should be set based on sound biological, hydrologic, and ecological justification. The model should be used in an AM framework to help guide experiments addressing hydrologic and ecological uncertainty.

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