**3.B. RESPONSES TO CRITICAL QUESTIONS for HSPF**

**(Answers to Task D.2 Questions #1A-D, #2A-F, and #3A-G for HSPF)**

**1. Model Documentation Provided by WMD’s:**

**A. Does the documentation provide a clear and appropriate description of the NFSEG groundwater flow model and supporting HSPF surface-water models?**

**Yes**, the HSPF model documentation provides a clear and appropriate description of the model’s approach, conceptual model, and development, i.e., the input data development and construction of the model inputs. It also includes sufficient documentation of the model calibration results. The areas that are lacking are: 1) the presentation of the calibrated model parameters and 2) calibrated model water balances. HSPF models should include documentation of the key hydrologic parameters that are used to calibrate a model. The NFSEG HSPF model is quite complex due to the large geographic area and the large number of unique HSPF models that are included. In order for a reviewer to determine whether the various parameters are within reasonable/valid ranges, the documentation should include an appendix that summarizes the parameter values with tables and maps.

**B. Are the purposes and scope of the documentation clearly stated and sufficient to document the models? Is the content of the documentation consistent with the stated purpose and scope of the document?**

**Yes**, the purposes and scope of the HSPF documentation are to present the model conceptualization, input datasets, implementation/construction of the model, calibration approach, and calibration results for the HSPF models. The documentation is consistent with these purposes and scope with a couple of caveats that are described in the responses to some of the other questions. The conceptualization, input data, implementation, and calibration approach sections are mostly complete and clear. The calibration approach should include discussion of the effects of calibration of flows affected by tides and significant man-made influences on the predicted recharge. The calibration results (shown in the 55 watershed-specific appendix sections) should include a brief discussion of man-made influences and other causes of poor calibration for poorly calibrated gauges. The calibration section should also include documentation of the key hydrologic parameter values obtained or reproduced from a nearby watershed during calibration **(see question #1D**), and also the simulated water balance summaries described under **question #3G.**

**C. Is the documentation readable? Are the figures clear? Does the format of the documentation need to be modified or expanded?**

**Yes**, the HSPF documentation is readable, and the figures are clear. The format of the documentation is good, with the exceptions noted above in **Question 1A.**

**D. After reading the documentation, are the purposes, scope, strengths/weaknesses, intended use, and limitations of the NFSEG [HSPF] model understandable?**

**Yes**, the purpose, scope, strengths/weaknesses, intended use, and limitations of the NFSEG HSPF model are generally understandable. The calibration of watersheds with tidal and man-made influences on measured flows should be discussed in the calibration approach, and the possible effects on computed recharge should be evaluated. Since PEST is used for the automated calibration, the effects of specific objective function components on calibration should be discussed in this section.

**2. Model Implementation:**

**A. Is the conceptual model appropriate for the intended use of the model? For example,**

**are critical physical and hydrologic processes represented appropriately?**

**Yes,** the conceptual model is appropriate for the intended use of the model. The HSPF model provides recharge and maximum saturated ET for use in the MODFLOW model that includes the critical physical and hydrologic processes that are required for estimating those quantities. HSPF models the hydrologic cycle for the unsaturated zone plus the groundwater that contributes to surface water bodies. The key processes resulting from rainfall, i.e., evapotranspiration, surface runoff, infiltration, recharge to the saturated zone, and streamflow are well represented, and the model can be segmented adequately to provide recharge results at the resolution of the groundwater model. There are limitations to use of HSPF or any similar model in flat areas such as Florida, where groundwater levels are often above the land surface.

Most aspects of the HSPF approach used for the NFSEG model are appropriate, and in several cases innovative. These aspects include:

* the use of NLDAS rainfall data;
* use of NLDAS PET, adjusted by USGS PET-derived monthly factors to represent the appropriate PET quantity;
* use of Special Actions to model closed basins by collecting the watershed runoff and directing it to a virtual sink with an appropriate flow rate;
* use of a subsurface reach to collect recharge in springsheds and calibrate the recharge to the observed spring flows;
* use of PEST in an automated environment to consistently calibrate more than 50 watersheds to USGS stream flow using a comprehensive set of metrics in the PEST objective function; and
* inclusion of calibration of total actual ET (by land cover) to literature-derived expected annual amounts to constrain this key component in the water balance to a consistent and appropriate value.

**Questions B and C are applicable to the MODFLOW model.**

**B. Is the [MODFLOW] model code appropriate, given the intended use of the model?**

**C. Was the [MODFLOW] numerical model constructed in a manner that is consistent with the underlying conceptual model, using appropriate data and methods of analysis?**

**D. Was the [HSPF] hydrologic model code selected appropriate for its intended use? And:**

**E. Was the use of HSPF as a method to develop recharge and maximum saturated ET that is assigned to the MODFLOW groundwater flow model a valid and defensible method?**

**Yes**, the use of HSPF to develop recharge (and maximum saturated ET) that is input to groundwater flow models is definitely a common and defensible method. The most prominent example is the Integrated Hydrologic Model ([IHM](https://integratedhydrologicmodel.org/)), which was developed initially for Tampa Bay Water and the Southwest Florida Water Management District (Geurink and Basso, 2013). It should be noted that the IHM contains a dynamic coupling of HSPF with the MODFLOW groundwater model, which is more complex than the one-way coupling used for NFSEG.

**F. Responses specific to HSPF Model:**

**a. The version of HSPF utilized for the hydrologic models is a non-standard version of HSPF that is not publically available. Is the version of HSPF utilized appropriate and defensible?**

**Yes,** the version of HSPF used is defensible and appropriate, based primarily on personal communications regarding this issue with the SJRWMD staff in past years. However, this could be backed up more clearly in the documentation, including a description of the feature(s) that are non-standard, and citation of a document that confirms the District’s prior validation of the non-standard version. The primary feature that is not in the publicly-available version is an optional method for computing surface runoff from a standard pervious land area (PERLND). This feature is utilized to improve the simulation of surface runoff from the land areas categorized as wetlands and water in the NFSEG model.

**b. Was the best available information utilized to develop the HSPF hydrologic models?**

**Yes**, in summary, the data and other information used to develop the hydrologic models is the best available, given the limitations imposed by the scale of the model (i.e., the large area and number of sub-watersheds modeled). Input rainfall and potential evapotranspiration data, which are the primary driving forces of the model, utilize the best available, consistent data source (NLDAS) that covers the entire model area. The analysis and decisions related to the various rainfall data sources (gauges, radar, NLDAS) is impressive, and the source that exhibited the best combination of accuracy, consistency and geographical resolution was selected. The NLDAS PET data were adjusted (tensioned) using a consistent PET dataset for Florida developed by USGS to represent the correct quantity required by HSPF, i.e., lake evaporation.

The primary data used for calibration, i.e., the measured streamflows, are the best/only available data for this purpose. As documented, the quality of these data is quite variable, and many of the streamflow gauges are rated as poor quality. This is one of the primary sources of error in the NFSEG HSPF model.

Another data source consists of literature-derived estimates of the expected total ET from the various pervious land cover categories. These data are used to calibrate the actual/simulated ET so that this major component of the water balance is reasonable and consistent across the model domain. It is appears that the literature data are reasonable, and most of the data are obtained from Florida.

The model area was segmented (delineated) into watersheds based on the USGS HUC8 watersheds, with sub-watersheds based on elevation (DEM) data. The hydrology of separate land covers/uses is appropriately represented by segmenting the sub-watersheds into individual hydrology computational units (pervious and impervious land segments) using primarily NLCD 2001 coverages.

The effects of irrigation are represented using standard methodologies. The agricultural quantities are estimated using an appropriate model of specific plant needs, soil moisture and available rainfall, and the amounts are consistent with known records of local pumping and withdrawal data. The urban irrigation is based on utility records of usage, where available, and golf course irrigation is based on permitted/measure data, where available. The implementation of the irrigation water input to the soil, and removals from surface water bodies appear to be correct.

**c. Unique aspects of these systems were represented with Special Actions or with other features of HSPF and are these conceptually sound and implemented appropriately:**

**1. RCHRES representation of Inactive Groundwater Storage to represent spring discharges?**

**2. Closed basins?**

**3. Drainage wells and swallets?**

**4. Implementation of water use:**

**a. Agricultural irrigation?**

**b. Urban:**

**i. Septic?**

**ii. Irrigation?**

**c. Golf courses?**

**d. Reuse spray fields?**

**Yes,** items listed above in items 1-4d are conceptually sound and implemented appropriately. The HSPF model includes an innovative spring representation that uses a RCHRES to collect the inactive groundwater inflow (IGWI) within a designated springshed, and then routes this “reach” to the surface reach where the actual spring is located. This simulated spring outflow was calibrated to measured spring flows, which is very innovative. However, this aspect of the spring feature does not seem to be included in the documentation.

The closed basin flow into sinks/drainage wells is represented using Special Actions. Review of a HSPF model input file with a closed basin indicates that it is implemented correctly; however, the values of the reach-specific parameters used to represent the invert, the maximum flow and depth above invert where maximum flow begins could not be verified as part of this peer review. The use of this feature is impressive, since it allows more reasonable parameter values to be used from an adjacent calibrated watershed. This avoids the extreme parameter values that would sometimes result from forcing the runoff flows to near zero.

The description of the water use components implemented in the model appears to be complete. These include computation of irrigation for agricultural and urban areas based on plant needs and rainfall/ET (agriculture), urban water use (urban), and typical usage (golf courses). The incorporation of the water timeseries in the model as additions to the various soil compartments in HSPF is correct based on review of the document.

**3. Model Calibration and Application**

**A. Is the parameterization scheme used in the PEST calibration [for HSPF] appropriate?**

**Generally yes,** based experience with PEST that is limited to an understanding of its general usage and theory with HSPF calibration and not a full calibration. The main complaint that some have with using automated calibration with HSPF is the tendency to arrive at a calibration endpoint with parameter values that vary from the ranges that are valid with respect to the specific hydrologic process algorithms in HSPF. If the automated process can be constrained to vary parameters within those limits, and if the calibration can be monitored and adjusted by modelers who are familiar with these limitations, then that issue can be mitigated. Based on the documentation, the HSPF parameters optimized in the PEST calibration are the appropriate set. Furthermore, the establishment of relative values of four key parameters (LZSN, UZSN, INFILT, LZETP) to land use/cover categories is appropriate, and the assignment of AGWRC and DEEPFR on a watershed basis rather than by land cover is definitely standard usage for many modelers.

**B. Were the types of observations and their implementation in the PEST calibration**

**[of HSPF] appropriate, given the intended use of the model?**

**Yes,** in general, the observations used in the PEST calibration are appropriate, even with using such a large number of observations, including a series of baseflow-related measures, minimum flows, and flow reversal measures. The calibration of total actual ET measures by land cover is critical to constraining the ET to reasonable and consistent values, and thereby achieving consistent recharge results over the domain. Because PEST is not yet in common usage by HSPF modelers, it is recommended that the objective function components be more completely described, especially the effects of adjusting the relative weights.

**C. Have the differences between observations and their simulated equivalents (model**

**residuals) been described sufficiently? For example, have an appropriate set of summary statistics, plots, and maps been presented that allow for evaluation of model limitations, (such as model bias and uncertainty) in a manner that meets or exceeds existing professional practices?**

**Yes.** The appendix (appendices) described at the end of the Calibration section for HSPF contain separate documents for each of the 51 HUC8 watersheds that were calibrated. Each document contains detailed statistics and three graphs for each calibrated gauge location. They also provide maps showing the gauge locations, land cover, and subwatershed delineation. There is also a graphic that depicts the flow gauges in the HUC 8 watershed, including 1) location/USGS ID number, 2) period of record, 3) whether the gauge was used for calibration, and 4) mean flow in cfs. These appendices provide sufficient information to evaluate calibration errors. The main recommendation is to include a very brief discussion of the modelers’ conclusions and evaluation of the reasons for poor agreement in the calibration results **at gauges that are poorly calibrated**. These reasons can be a combination of poor observed data, tidal effects, man-made influences in the watershed, unmodeled groundwater gains/losses, and uncertainty in a key input.

**D. Have the values of calibrated parameters been described appropriately, using (for**

**example) maps illustrating the range and spatial distribution of parameter values?**

**No,** the HSPF documentation does not include appropriate description of the primary hydrologic parameter values obtained during calibration. (Refer to Question #1A.) The minimum set of calibrated parameters that should be documented in an appendix (tables and maps) are listed below:

AGWRC - Base groundwater recession

BASETP - Fraction of remaining ET from baseflow

CEPSC - Interception storage capacity

DEEPFR - Fraction of groundwater inflow to deep recharge

INFILT - Index to infiltration capacity

INTFW - Interflow inflow parameter (omit due to low value)

IRC - Interflow recession parameter (omit due to low value of INTFW)

KVARY - Variable groundwater recession

LZETP - Lower zone ET parameter

LZSN - Lower zone nominal soil moisture storage

UZSN - Upper zone nominal soil moisture

The main purposes of this recommendation are to: 1) ensure that the parameters have reasonable values, i.e., they are within valid ranges for the respective process formulations and for the specific land cover and climate; and 2) ensure that the variation over the model domain and within specific watersheds is reasonable. The standard requirement for any HSPF model documentation includes summaries of the key calibrated (and assumed) hydrologic parameters listed above.

**E. Does the final version of the model appear to be adequately calibrated given the available data for calibration and the state of knowledge (and lack thereof) of the hydrologic system prior to development of the [HSPF] model?**

**Yes,** the final version of the model appears to be adequately calibrated, based on reviewing the Calibration Results section and Table 17 in the main HSPF document and the more detailed calibration statistics/graphics for all gauges in the Appendix. The automated calibration appears to use appropriate criteria, based on the Parameter Estimation with PEST section of the document and the use of percent bias and Nash-Sutcliffe coefficients as key criteria for determination of calibration performance.

Overall, the calibration of large areas of the model domain is very good for an automated procedure, considering that the measured flows at many gauges are: 1) affected by man-made influences that are not included in the models, 2) subject to tidal effects, and 3) poor quality due to difficulty with measuring flows in flat terrain and areas where groundwater effects are large. It is noted that at several gauges, there are large, virtually constant differences between the simulated and observed flows that are caused by either an error in the model or a significant man-made influence. These should have been investigated and either documented, if it is man-made; or corrected, if a model error was the cause. Examples are gauges 02197500 and 02198500, both in the Savannah River. It is assumed in these cases that the calibration criteria used by PEST were affected by objective function components other than the total flow, (e.g., total actual ET). Otherwise, the automated calibration might have improved the total flow agreement. The discussion and graphics (Figures 27 and 28) correlating poor calibration performance with poor flow measurement are useful. In reviewing many individual gauge results, it was observed that this correlation is quite apparent.

The main questions or concerns with the calibration are related to the effects on recharge of calibration to observed flows that are affected by tidal and (especially) man-made influences. The discussion should include an analysis of this impact. Possibly, the effect is small for the same reason that the calibration did not adjust the simulated flow to match observed in the examples of large, constant differences in the two Savannah River gauges noted above. It is assumed that other criteria in the objective function prevented the large changes that would be needed to bring the flows into better agreement.

**F. Is the final version of the [HSPF] model appropriate for the intended planning and regulatory uses in the SRWMD and SJRWMD areas of the model domain? [Is the NFSEGv1.1 groundwater flow model a sufficient tool for evaluating individual CUP’s and compliance with individual spring MFL’s?]**

**Yes.** While the HSPF model results are not intended to be used directly for regulatory decisions, the use of the NFSEG HSPF results as recharge input to the groundwater model is appropriate based on the model conceptualization, implementation, and calibration.

**G. Has the complete model water balance, accounting for all water sources and sinks,**

**been assessed and found reasonable?**

**Not completely.** This question seems to be addressed primarily to the MODFLOW model. However, it is also applicable to the HSPF model. The Districts should generate and document (in an appendix) summaries of the average annual HSPF water balance results for the individual land areas (PERLND and IMPLND). This water balance provides a summary of the: 1) inputs (rainfall, irrigation), 2) evapotranspiration losses, 3) runoff losses to streams (by soil layer), and 4) groundwater recharge. Weighted average summaries can be generated for each land cover in a watershed in addition to averages over all land covers. The primary purpose for this output is to determine the reasonableness of the amounts. It allows the modeler to identify errors in the input data such as rainfall, PET, and irrigation; and unreasonable water balance quantities caused by the automated calibration. In addition, the calibration of total actual ET to expected annual amounts can be verified.

Based on a review of preliminary water balance data that the District recently produced for individual years (2001, 2009, and 2010), it is recommended that the water balance should be computed for the full period of calibration instead of individual years, and it should be included in an appendix so that model reviewers can compare the results with input data (rainfall, irrigation, etc.) and the calibrated of total ET, in addition to verifying that the other components are reasonable.

**Questions #3H-J are specific to MODFLOW.**

**H.** **Have the uncertainty of key model parameters and predictions been assessed using**

**methods that are appropriate and that meet or exceed typical practice for developing groundwater flow models? Has a detailed statistical assessment of uncertainty in modeled groundwater level and spring flow estimates been provided?**

**I. Have the limitations of the final version of the NFSEG groundwater flow model been**

**J. Have the Measures of Success for NFSEG Charter Objectives 2, 5, and 6 been met?**

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| **Objective** | **Measure of Success** |
| **2. The model output helps to answer all regional-scale model questions in Appendix A of the NFSEG Charter.** | **A reasonable groundwater modeling technical expert would judge the model output useful in answering the questions in Appendix A.** |
| **5. The model is calibrated to industry standards.** | **The model calibration statistics meet industry standards in ASTM Standard Guide for Calibrating a Ground-Water Flow Model Application, Designation D 5981-96 (2008).** |
| **6. The model is accepted as a useful tool.** | **Success would be (1) a reasonable, independent groundwater modeling technical expert judging the model developed by this project to be acceptable by the standards of the profession for helping to answer the modeling questions that have been asked; and (2) a clear understanding by all involved parties of the uncertainties and limitations of the model for answering the modeling questions in Appendix A.** |

Geurink, J.S. and Basso, R. (2013). “Development, calibration, and evaluation of the Integrated Northern Tampa Bay Hydrologic Model.” Prepared for Tampa Bay Water and the Southwest Florida Water Management District, Clearwater, FL.