NFSEG v1.1 Phase 2
Task C1 Meeting

July 26, 2017
Outline

- Introduction/Meeting Objectives
- Status of Peer Review Comments to Date
- Baseflow Review
- Sensitivity and Uncertainty Analysis
- 2010 Verification Simulation
- Peer Review Panel Discussion
- Technical Stakeholder Input
- Next Steps
  - NFSEG Case 005 Simulation
  - August 24 Meeting
- Public Comments
Introduction / Meeting Objective

- Update activities currently underway and/or complete
- Refine path forward
Status of Peer Review Comments and Responses to Date

- Update on panel/tech team comments
  - Matrix of Comments and Responses, Including:
    - HSPF
    - APT/Modeled Transmissivity Scatter Plot
    - Hydrostratigraphic Cross Section
Investigation of NFSEG Baseflow Estimates
Summary of Results for 14 Gages
Approach

- Create baseflow hydrographs using hydrograph-separation routines implemented in USGS *Groundwater Toolbox* (i.e., BFI Modified, BFI Standard, HYSEP Fixed Interval, HYSEP Local Minimum, HYSEP Sliding Interval, PART);
- Inspect resulting baseflow hydrographs;
- Select approaches that appear applicable to rivers/streams of the area.

**In addition:**
- Include results of a 120-day low-pass filter method by Perry (1995; i.e. “the USF Method”), per suggestion of Ron Basso.
- Include the exceedance-curve approach per suggestion of Dann Yobbi, also implemented in *Groundwater Toolbox*. 
Approach (Cont.)

- In the final analysis, average annual estimates for 2001 and 2009 resulting from the following methods were obtained and averaged to provide 2001 and 2009 estimates at fourteen gages:
  - HYSEP Local Minimum hydrograph-separation method;
  - BFI Standard hydrograph-separation method;
  - BFI Modified hydrograph-separation method;
  - USF hydrograph-separation method;
  - Exceedance-curve method at 70-percent exceedance
Gage-Selection Criteria

• 14 gages selected;
• Confined, semiconfined, and unconfined conditions;
• Six different rivers/streams (Suwannee, Alapaha, Withlacoochee, Santa Fe, and St Marys Rivers, and Black Creek).

These are as follows:
## List of Evaluated Gages

<table>
<thead>
<tr>
<th>USGS Gage ID</th>
<th>Name</th>
<th>Dominant Contributing Aquifer</th>
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<tr>
<td>02318500</td>
<td>WITHLACOOCHEE RIVER AT US 84, NEAR QUITMAN, GA</td>
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<td>ALAPAHA RIVER AT STATENVILLE, GA</td>
<td>SAS</td>
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<td>02314500</td>
<td>SUWANNEE RIVER AT US 441, AT FARGO, GA</td>
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<tr>
<td>02315500</td>
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<td>FAS</td>
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<td>ECONFINA RIVER NEAR PERRY, FLA.</td>
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<td>02231000</td>
<td>ST. MARYS RIVER NEAR MACCLENNY, FL</td>
<td>SAS</td>
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<tr>
<td>02245500</td>
<td>SOUTH FORK BLACK CREEK NEAR PENNEY FARMS, FL</td>
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Locations of Selected Gages
Example Hydrographs/Exceedance Curves for St. Marys River near Macclenny (02231000) for all Available Methods in GWToolbox and USF Method, 2001 and 2009
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, BFI Modified
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, BFI Standard
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Fixed Interval

FLOW, IN CUBIC FEET PER SECOND

Daily Observed Streamflow
Daily Estimated by Fixed Baseflow

Daily at 02231000
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Local Minimum.
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Sliding Interval
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, PART
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, USF Method
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, BFI Modified
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, HYSEP Fixed Interval
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, HYSEP Local Minimum
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, HYSEP Sliding Interval
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, PART
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, USF Method
Exceedance Plot for St. Marys near Macclenny (02231000), 2009
Summary of Estimated Baseflows by Method for St. Marys near Macclenny (0223100)
Final Proposed Estimates

• Final proposed method is an average of annual averages derived from the following methods:
  - HYSEP Local Minimum
  - BFI Standard
  - BFI Modified
  - USF
  - Exceedance curves at 70-percent exceedance
• Other separation techniques implemented in *Groundwater Toolbox* were judged to be consistently too peaky
Additional Noteworthy Results

• The HYSEP Local Minimum, BFI Standard, and BFI Modified approaches provide similar results that are almost always higher than corresponding estimates resulting from the USF and exceedance-curve approaches.

• The USF and exceedance-curve approaches also provide similar results.
## Results of Selected Methods, All Gages

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<td>472</td>
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<td>408</td>
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<td>3,814</td>
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<td>3,800</td>
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## Table of Proposed Estimates

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<td>PART</td>
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<td>HSPF Ratio</td>
<td>HSPF Ratio</td>
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</table>
Summary of Proposed Method/Recommendation

• Final proposed method is to determine an average of annual averages derived from the following methods:
  • HYSEP Local Minimum
  • BFI Standard
  • BFI Modified
  • USF
  • Exceedance curves at 70-percent exceedance
  • Exclude the following methods due to excessive peakiness of resulting baseflow hydrographs: HYSEP Fixed Interval, HYSEP Sliding Interval, PART

• Apply the proposed method to all other gages used in the model calibration.
NFSEG Uncertainty Analysis: Previous and Planned Work

July 26, 2017
Outline

- Background info
- Review of NFSEG v1.0 analyses
  - Parameter uncertainty
  - Predictive uncertainty
- Discussion of planned analyses/products for NFSEG v1.1
Background

• Motivation:
  • More informative calibration diagnostics
  • Uncertainty estimates (confidence intervals for parameters and predictions)
  • Framework for improved decision-making and future model development
• Uncertainty analysis theory is well established, and has been implemented in modeling studies around the world
• NFSEG v1.0 work one of the few examples of parameter and prediction uncertainty analysis in Florida
Linear Uncertainty Analysis

Source: Doherty, J.D., 2010, Methodologies and software for PEST-based model predictive uncertainty analysis
Uncertainty Analysis

- Parameter uncertainty
- Predictive uncertainty
- Uncertainty analysis includes sensitivity analysis
- Recognizes that parameters can’t be estimated uniquely – quantifies consequences of parameter insensitivity and correlation
NFSEG v1.0 Uncertainty Analysis

- Documented in Appendix J of NFSEG v1.0 Draft Report (Watermark Numerical Computing, 2016)
- Based on highly-parameterized history match:
  - Some parameters are insensitive from a history-match/calibration perspective, but ...
  - ... might be important with respect to making certain types of predictions
NFSEG v1.0 Uncertainty Analysis Components

- Parameter uncertainty
  - Linear analysis
- Predictive uncertainty
  - Linear analysis
  - Semi-linear analysis
NFSEG v1.0 Uncertainty Analysis: Parameter Uncertainty

- Relative parameter uncertainty variance reduction ($r_i$):

$$r_i = \frac{\text{reduction in uncertainty from calibration}}{\text{precalibration uncertainty}}$$

- A value of 0 indicates no reduction in uncertainty through calibration.
- A value of 1 indicates that the parameter is known with absolute certainty after calibration.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
Relative uncertainty variance reduction

Figure 4.3b Relative parameter uncertainty variance reduction of k3x parameters together with observation wells in layer 3; see figure 4.3a for colour scale.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
Relative uncertainty variance reduction of recharge multiplier parameters together with observation wells in layer 3.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
NFSEG v1.0 Uncertainty Analysis: Predictive Uncertainty

- GW levels and GW discharge to rivers and springs (predictive absolutes)
- Changes in levels and flows (predictive differences)
- Predictions at 23 key locations:
  - GW levels in Keystone Heights
  - Flows in SRWMD
NFSEG v1.0 Linear Analysis of Uncertainty: Predictive Absolutes
Assessing parameter contributions to predictive uncertainty

Figure 5.1 Contributions made by different parameter groups to the uncertainty variance of prediction qspring09_s12161002. Pre- and post-calibration predictive variances are 23.87 (ft³/day)² and 0.257 (ft³/day)², respectively.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
Assessing the information content of various observation groups

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
NFSEG v1.0 Linear Analysis of Uncertainty:

Based on results from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
NFSEG v1.0 Linear Analysis of Uncertainty:

Based on results from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

Note that results for qspring09_s101429027 are not shown because the predicted change and uncertainty were less than or equal to 0.0001
### NFSEG v1.0 Semi-linear Analysis of Uncertainty: Predictive Differences

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<th>Prediction</th>
<th>Value of predicted change from 2009 to 2035, calculated using $k$</th>
<th>Linear analysis, postcalibration uncertainty standard deviation of predicted change from 2009 to 2035</th>
<th>Semi-linear, postcalibration uncertainty standard deviation of predicted change from 2009 to 2035</th>
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<td>34.51</td>
<td>0.72</td>
</tr>
</tbody>
</table>

1. Values are in feet. Positive predictive changes mean drawdown.
2. Values are in cubic feet per second. Negative predictive changes mean reduction in flows.
3. Postcalibration uncertainty estimates from semi-linear analysis were estimated as half of the difference between the predicted change values that were calculated using $k \pm \delta k$.

Adapted from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
Explicit framework for quantifying uncertainty
Like the underlying parameter and prediction estimates, estimates of uncertainty will always be approximations
Informative ancillary results
Identification of issues:
  • Solver convergence can affect results of important predictions
  • Linear analysis probably overstates uncertainty in some cases
  • Semi-linear analysis probably understates uncertainty in some cases
  • Nonlinear analysis logical next step
At a minimum, another linear and semi-linear analysis ....

Plan to carry out nonlinear analysis if possible:
- Generate a set of random parameter-field ‘realizations’
- Compute parameter uncertainty as the variance of individual parameters from the above set of parameter realizations
- Compute prediction uncertainty by running the model once for each of the above random-parameter-field realizations

- Generate a few hundred parameter fields (about 200)
- Additional prediction locations (compared to NFSEG v1.0)
2010 Verification Simulation
2010 Verification Simulation

- 2010 was selected based on input from SJRWMD Water Supply Planning staff early on in model development.
- Subsequently built input datasets to compile the 2010 simulation, including:
  - Recharge and applied irrigation
  - Water Use
  - Observation Datasets:
    - Groundwater levels, lake levels, spring flows, gaged river/stream flows
Peer Review Panel Discussion
Next Steps
Case 005 Updates

- Updated water use – 2001/2009
- Recharge updates
- Updated baseflow targets/ranges
- Upper and lower bound adjustments
  - Bubble high east
- Review and update observations as needed
- VHDs
  - Add synthetic targets: Layer 1-3, Layer 3-5
- Drainage improvements
- Re-weighting
- Covariance matrices pilot point regularization
- Temporal differences/test with consideration of eliminating them
August 24 Meeting

- Case 5 results
Public Comments