Surface Water Quantity Models

Progress Meeting Agenda

August 1, 2016 - Teleconference

Attendees: **CDM Smith**: John Boyer, Tim Cox, Nina Caraway
SCDNR: Joe Gellici, Andy Wachob, Alex Pellet, Bill Clendenin
DHEC: Rob Devlin
Clemson: Katie Buckley
Technical Advisory Committee: Ed Bruce, Heather Nix, Andy Fairey, Charles Wingard, Mullen Taylor, Ruth Albright, K.C. Price, William Gaither (guest from Santee Cooper)

---

1. **Upcoming Stakeholder Meetings**
   a. Salkehatchie (Aug 9th) and Savannah (August 10th) Stakeholder Meetings
   - Katie Buckley noted that the venues and times are set for the upcoming stakeholder meetings. For the Salkehatchie meeting, no focus groups are planned given that turnout is expected to be small.
   - John Boyer indicated that CDM Smith will have two demonstration stations, not three.

2. **Broad Model**
   a. Review of updates (see attached slides and comments/responses)
   - John Boyer confirmed that calibration workbooks were posted on the SFT site earlier in the day for K.C. Price's review. The same workbooks and updated calibration model were posted for DNR and DHEC review. A list of model updates was included.
   - Nina Caraway reviewed recent updates to the Broad calibration model, including minor changes that resulted in low flow improvements on the Enoree and Tyger Rivers. Nina also reviewed the results of a separate modeling analysis focusing on the Spartanburg reservoirs. For the analysis, Spartanburg historical withdrawals were separated and represented by multiple user objects so that the exact reported amount was withdrawn from each reservoir. The results

showed modeled reservoir levels that matched well with reported reservoir levels. A similar result was achieved using one object, and setting a preference for withdraws. Based on the results of the analysis, no flow factor or other adjustments were deemed necessary. The analysis confirmed that the allocation of sources currently set within the single Spartanburg Water User object appears to represent the historical withdrawals reasonably well.

3. Salkehatchie Model

a. UIF Response to comments (see attached comments/responses)
- John Boyer reviewed CDM Smith's response to DNR's comments on the Salkehatchie Basin unimpaired flows (UIFs).

b. Calibration and report status
- John noted that the Draft model report and calibration model would be posted for DNR and DHEC review before the end of the day Tuesday, August 2.

4. Status of Other Basins

- John Boyer reviewed the status of other basin models and reports, as summarized below.
  a. Catawba – Draft calibration near completed
  b. Saluda – Congaree UIFs updated; Waiting to finalize Report
  c. Edisto – Finalize Report and Baseline model
  d. Pee Dee – Finalize Report and Baseline model
  e. Santee – UIFs initiated
  f. Savannah – Awaiting additional GA EPD impairment data

Updates to Broad Calibration Model

August 1, 2016

Improvements to Enoree and Tyger River Gages

	Station	Years of Record	Measured Avg (cfs)	Modeled Avg (Orig)	Modeled Avg (Updated)	%Diff Avg (Orig)	%Diff Avg (Updated)
BRD42	TYGER RIVER NEAR DELTA, SC	31	828	771	759	-6.9%	-8.4%
BRD46	ENOREE RIVER AT PELHAM, SC	21	146	150	146	2.6%	0.2%
BRD48	ENOREE RIVER NEAR WOODRUFF, SC	21	343	349	341	1.7%	-0.5%
BRD50	ENOREE RIVER AT WHITMIRE, SC	31	498	514	498	3.3%	0.0%

	Station	Years of Record	Measured 7Q10 (cfs)	Modeled 7Q10 (Orig)	Modeled 7Q10 (Updated)	% Diff 7Q10 (Orig)	% Diff 7Q10 (Updated)
BRD42	TYGER RIVER NEAR DELTA, SC	31	42.9	103.1	94.3	140.6%	119.9%
BRD46	ENOREE RIVER AT PELHAM, SC	21	24.0	13.3	25.4	-44.7%	5.5%
BRD48	ENOREE RIVER NEAR WOODRUFF, SC	21	42.6	27.7	45.7	-34.9%	7.4%
BRD50	ENOREE RIVER AT WHITMIRE, SC	31	52.0	39.2	55.7	-24.6%	7.1%

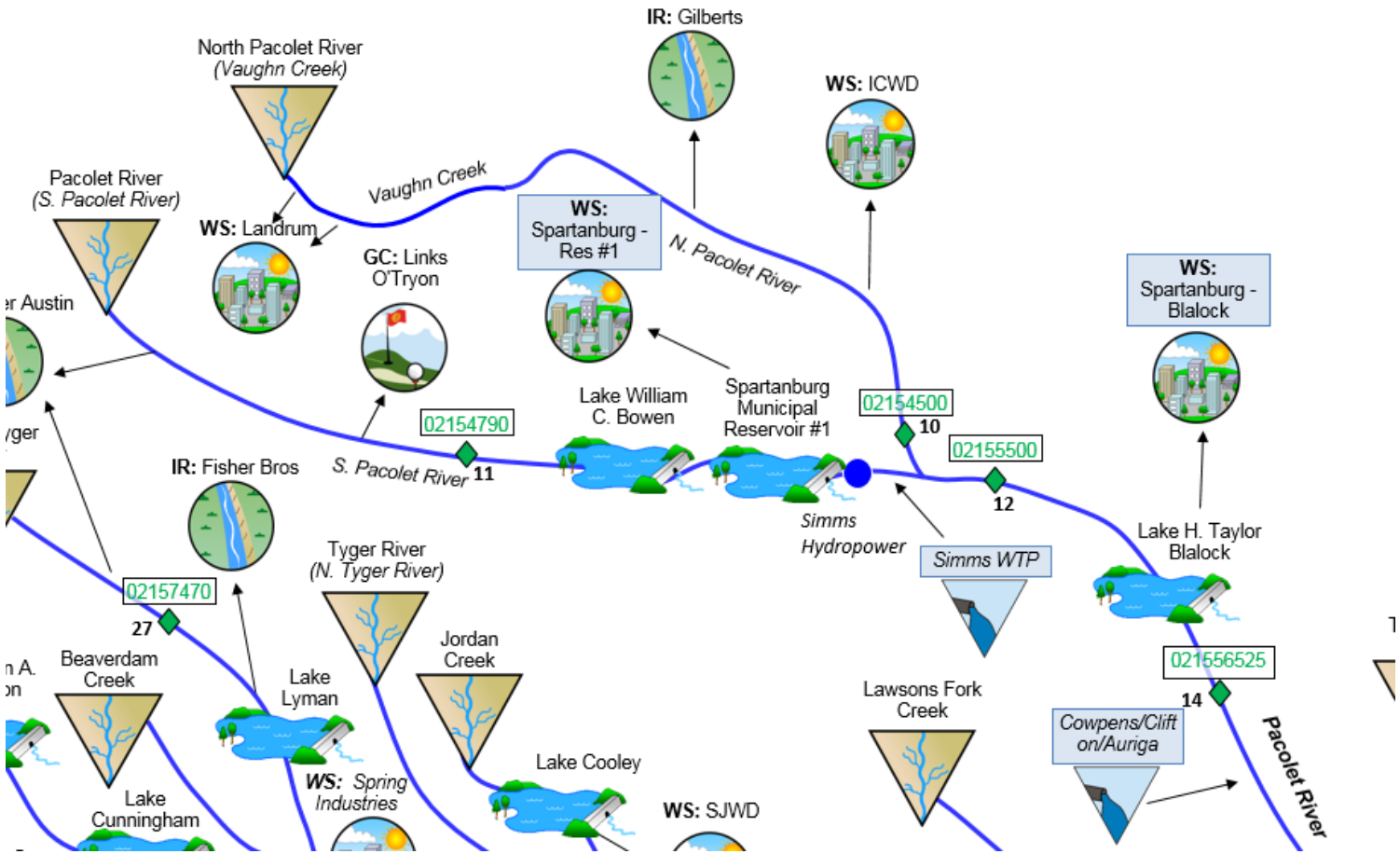
Updated Mainstem Flows 2009-2013 and adjustments to gain/losses

	Station	Years of Record	Measured Avg (cfs)	Modeled Avg (Orig)	Modeled Avg (Updated)	%Diff Avg (Orig)	%Diff Avg (Updated)
BRD01	BROAD RIVER NEAR BLACKSBURG, SC	17	1681	1734	1702	3.1%	1.2%
BRD02	BROAD RIVER NEAR GAFFNEY, SC	9	2050	2087	2034	1.8%	-0.8%
BRD03	BROAD RIVER BELOW NINETYNINE ISLAND RESERVOIR,SC	16	1776	1863	1828	4.9%	2.9%
BRD06	BROAD R NR HICKORY GROVE, SC	3	2091	2093	2093	0.1%	0.1%
BRD21	BROAD RIVER NEAR LOCKHART, SC	6	2551	2648	2634	3.8%	3.3%
BRD22	BROAD RIVER BELOW NEAL SHOALS RES. NR CARLISLE,SC	2	3103	3301	3168	6.4%	2.1%
BRD24	BROAD RIVER NEAR CARLISLE, SC	31	3325	3355	3200	0.9%	-3.8%
BRD54	BROAD RIVER AT ALSTON, SC	31	5226	5617	4847	7.5%	-7.3%

	Station	Years of Record	Measured 7Q10 (cfs)	Modeled 7Q10 (Orig)	Modeled 7Q10 (Updated)	% Diff 7Q10 (Orig)	% Diff 7Q10 (Updated)
BRD01	BROAD RIVER NEAR BLACKSBURG, SC	17	208	222	222	6.5%	6.5%
BRD03	BROAD RIVER BELOW NINETYNINE ISLAND RESERVOIR,SC	16	214	242	242	13.1%	13.1%
BRD24	BROAD RIVER NEAR CARLISLE, SC	31	386	522	386	35.0%	30.6%
BRD54	BROAD RIVER AT ALSTON, SC	31	435	693	435	59.2%	58.4%

Spartanburg Calibration Test (Separate Model)

- Disaggregated total demand into historic withdrawals from Municipal Res #1 and Lake Blalock
- Separated Pacolet River discharges into discharge objects (versus being within a water user object)

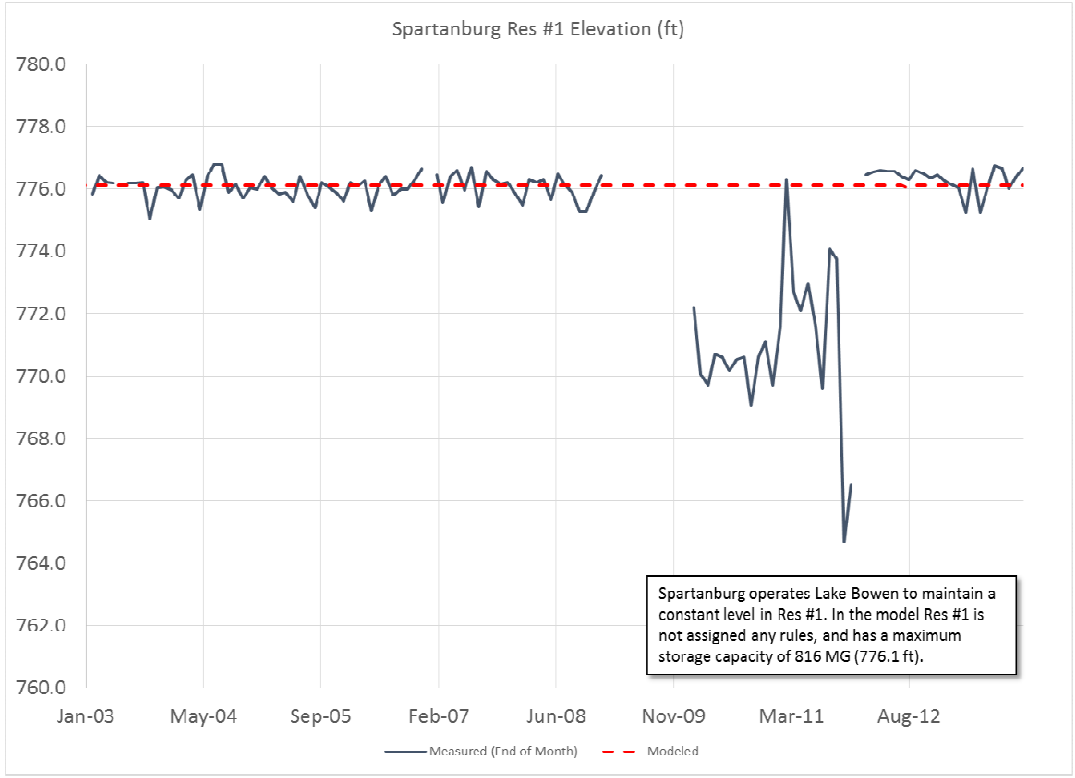


Overall Change (monthly simulation)

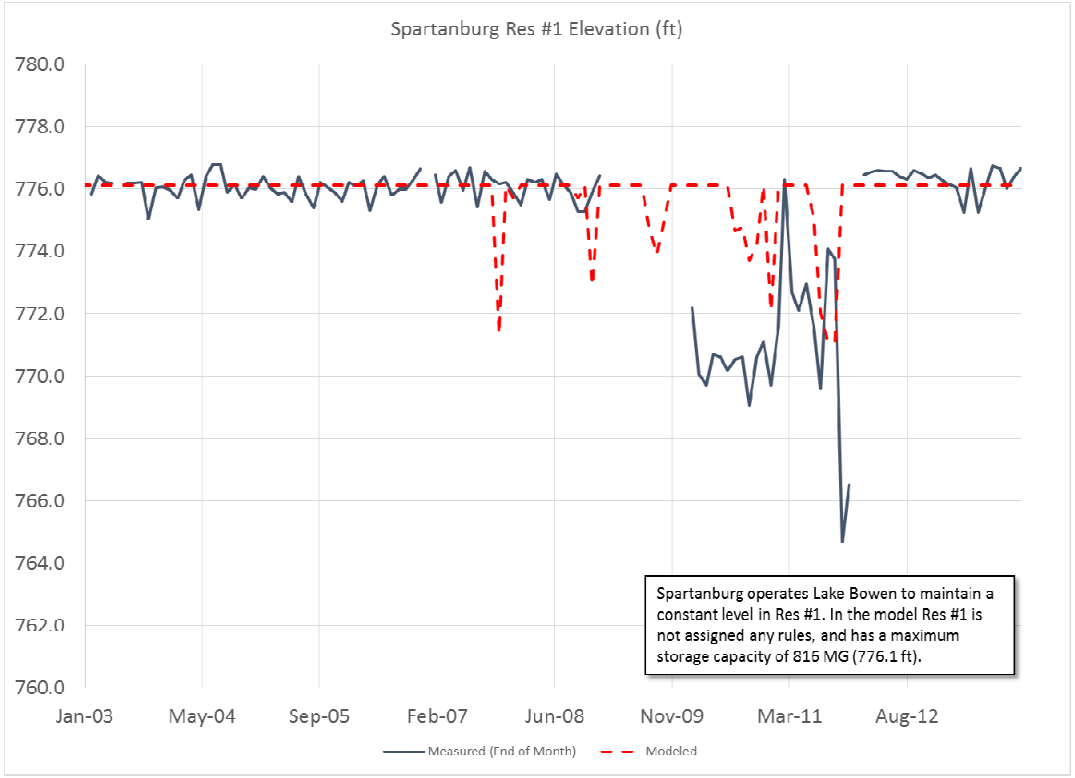
	Station	Years of Record	Measured Avg (cfs)	Modeled Avg (Orig)	Modeled Avg (Updated)	%Diff Avg (Orig)	%Diff Avg (Updated)
BRD12	PACOLET RIVER NEAR FINGERVILLE, SC	31	283.0	291.0	283.8	2.8%	0.3%
BRD14	PACOLET RIVER BELOW LAKE BLALOCK NEAR COWPENS, SC	21	320.2	321.8	312.9	0.5%	-2.3%
BRD19	PACOLET RIVER NEAR SARATT,SC	2	621.7	628.6	604.9	1.1%	-2.7%

Tiered releases in Lake Bowen upstream were created such that Res #1 stayed full. These same rules cause periodic draw down in the updated scenario.

Original

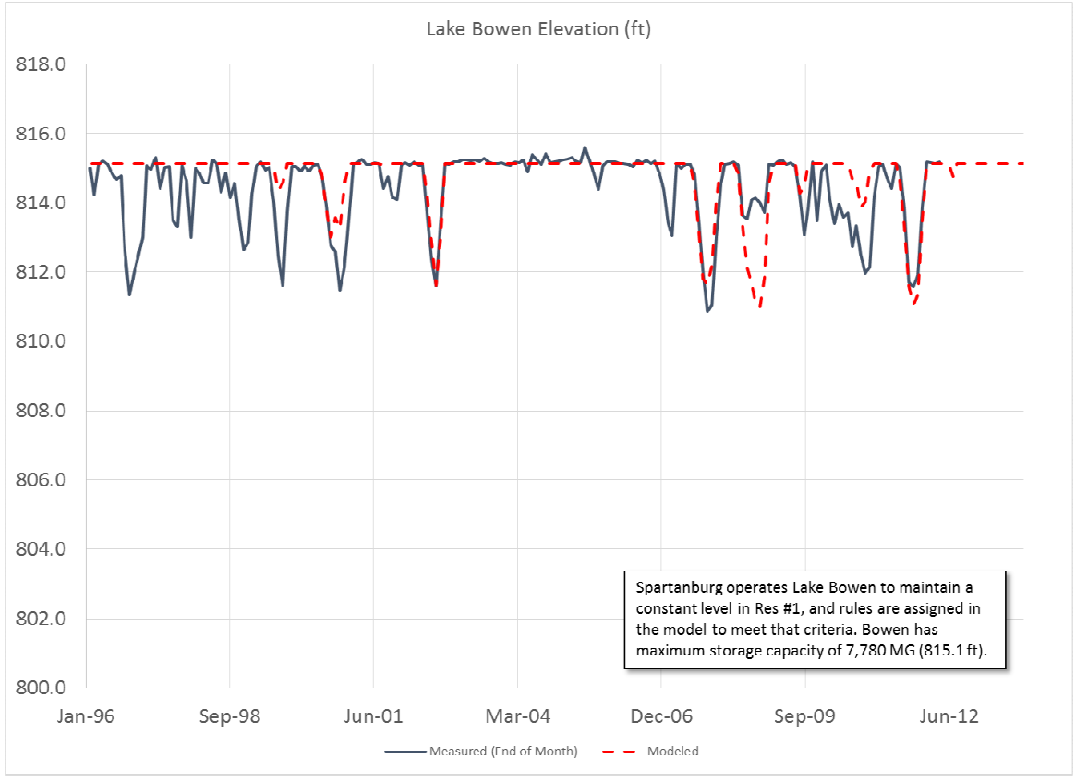


Updated

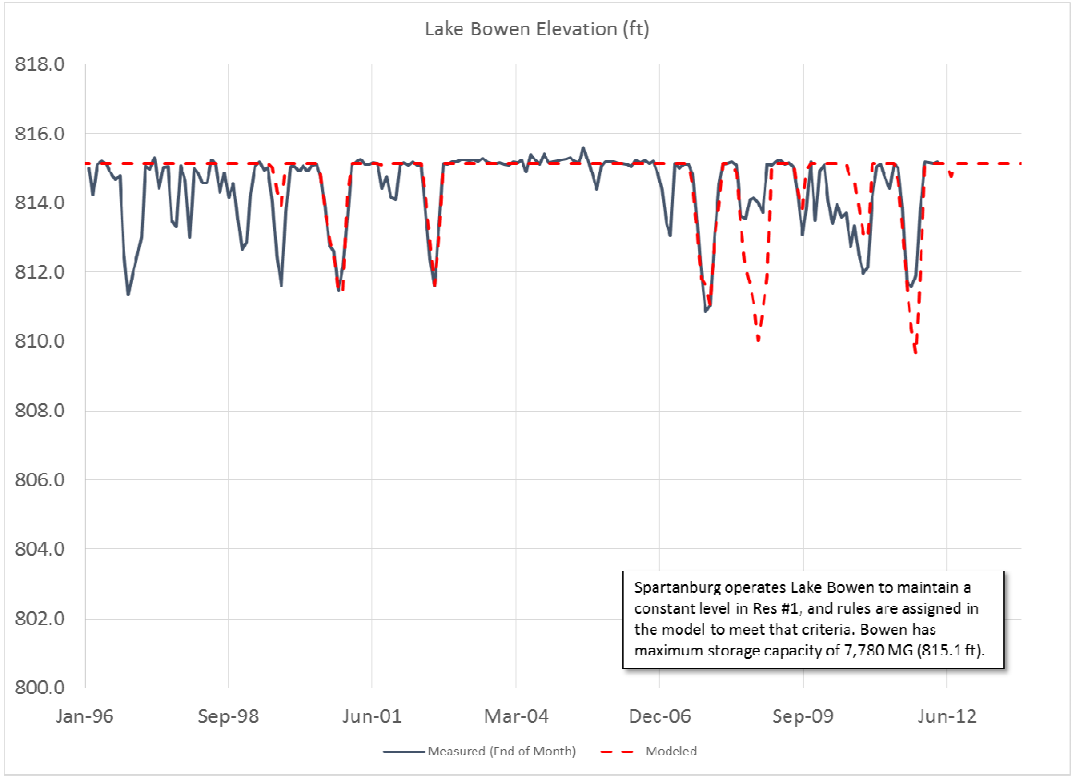


For Lake Bowen, slight changes in drawdown magnitude, but similar occurrences.

Original

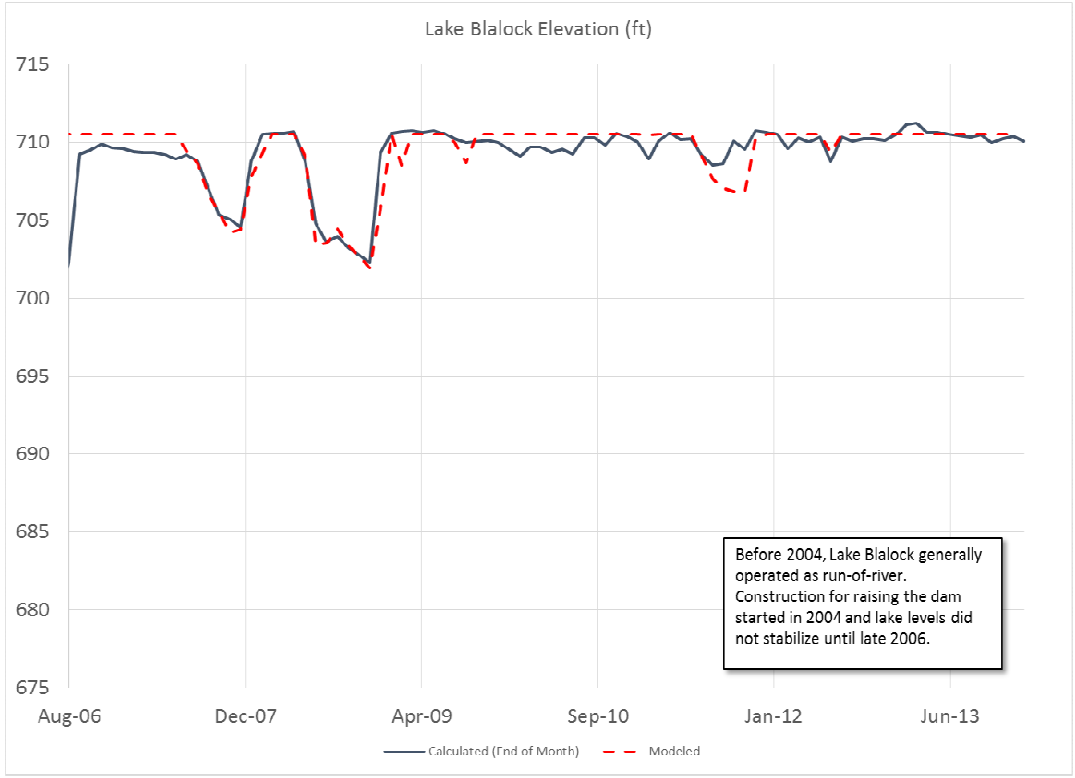


Updated

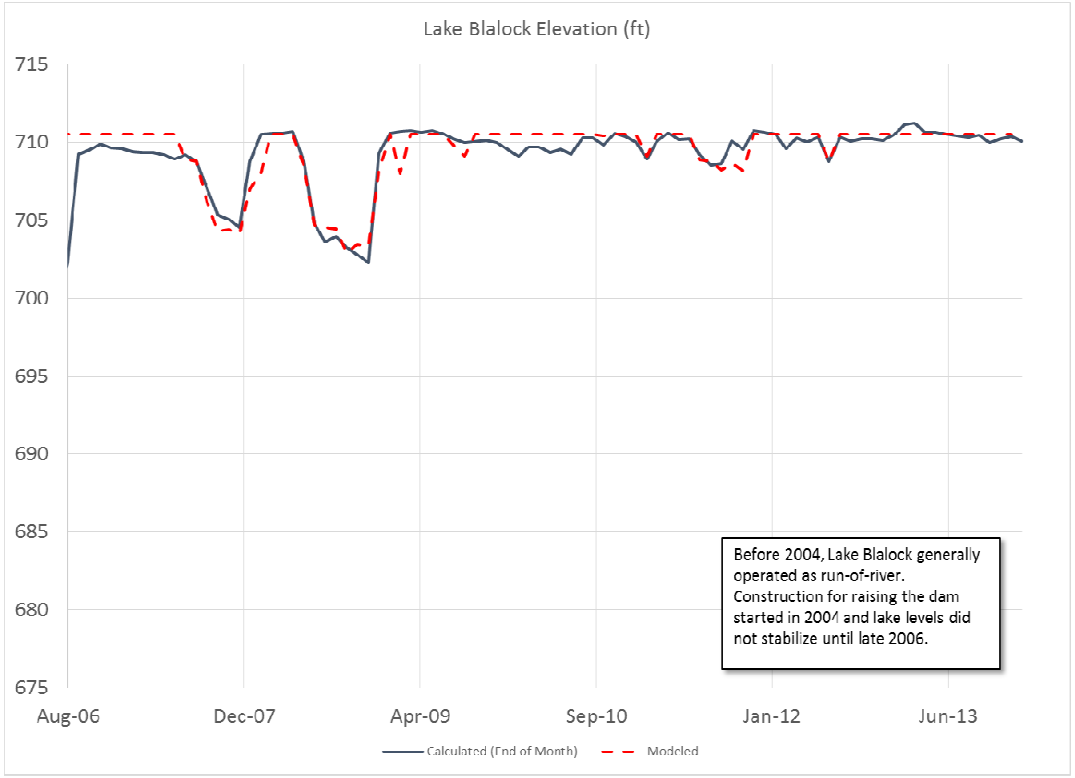


For Lake Blalock, slight changes in drawdown magnitude, but similar occurrences.

Original



Updated



Low-flow Statistics

	Station	Years of Record	Measured 7Q10 (cfs)	Modeled 7Q10 (Orig)	Modeled 7Q10 (Updated)	% Diff 7Q10 (Orig)	% Diff 7Q10 (Updated)
BRD12	PACOLET RIVER NEAR FINGERVILLE, SC	31	40.9	40.3	34.1	-1.6%	-16.6%
BRD14	PACOLET RIVER BELOW LAKE BLALOCK NEAR COWPENS, SC	21	32.9	51.2	33.2	55.6%	0.9%

Changes listed on June 23, 2016

Changes in Calibration Workbooks:

- Added summary of USGS streamflow gage record qualities (will be added as appendix in report).
- Fixed formula typo for BRD18 overall average error.
- For BRD20 and BRD12, removed monthly gaged values if 10 or more daily values were missing.
    - Additionally, for BRD12, removed 1997, 2007, and 2010 from annual average calculations.
- Updated plots for Lake Blalock.

Changes in Calibration Model:

- Added Caldwell Lake to improve calibration of Turkey Creek while still meeting WS: York demands
- Added tiered release rules for Lake Blalock.
- Updated Parr Shoals reservoir rules based on feedback from SCE&G.
- Lowered dead pool for 99 Islands Reservoir to be lower than maximum drawdown storage.
- Removed instream flow target rules for Lake Cooley and Lake Lyman and changed SJWD withdrawals directly from lakes.
- Adjusted calibration on Brushy Creek to improve low flows along Enoree River.
- Reservoir enhancements as added to Saluda model since first draft of Broad calibration model.

Changes listed July 1, 2016

Changes to Calibration workbook:

- In monthly workbook, fixed cell reference error for Lake Blalock. Mismatched years were being compared with one another. No fix needed for daily version.

Changes in Calibration Model:

- Updated 99 Islands to ensure it passes inflow during low flows, all months of year.
- Lowered Gaston Shoals dead pool to help fulfill minimum releases.
- Updated Monticello release rules to ensure it releases a minimum amount such that Parr Shoals can meet its own minimum releases.

- *Note: Tim Cox demonstrated no issue with 99 Islands releases in his comment #27 response on June 28, but DNR noted they saw different results in their model version. Tim is traveling, so we were not able to confirm the model version that he used to generate the response to comment; however, we believe it was one which had a different dead pool designation. Regardless, please refer to the latest model and results.*

Changes listed August 1, 2016

Changes to Calibration workbooks:

- Statistics for BRD42 (Tyger River near Delta, SC) now focus on years 2007-2013.

Changes in Calibration model:

- Modified Tier 4 release threshold from 67.8 cfs to 61 cfs.
- Previously Monticello local inflow only had monthly flows. Now has daily as well.
- Removed increased evaporative effects from V.C. Summer thermal plume from Monticello reservoir object. Now expressed as consumptive use in V.C Summer water user object.
- Removed consumptive use estimates based on DHEC discharge data given uncertainty (overall change of ~90 MGD now not being lost from the system).
- Turned off monthly median targets for Parr Shoals and Monticello. Now have year-round target at middle of operating range (261' and 422.75', respectively).
- Revisited and modified subbasin flow factors for Lawson Fork Creek, Enoree River, Fairforest Creek, Middle and South Tyger Rivers, and Tyger River.
- Modified flow control outflow table for Parr Shoals.
- Updated mainstem flows. As OASIS flows stop at Oct 2009, flows from that point were estimated using a linear regression of gage flows at the Boiling Springs gage in NC. This regression has been updated based on log-transformed flows.
- Small decrease to mainstem gain/loss factor between BRD24 and BRD54.
- Removed effect of implicit tributaries between BRD24 and BRD54.

Spartanburg test (separate model):

- Disaggregated withdrawals from Municipal Reservoir #1 and Lake Blalock into two separate water user objects.
- Separated Pacolet River discharges into discharge object (previously represented as consumptive use in water user object).

Memorandum

To: John Boyer, CDM Smith

From: SCDNR Hydrology Team

Date: 7/14/16

Re: Additional Comments on the Draft Broad Basin Calibration Model

CDM Smith Responses in red 7/29/16; Calibration model and workbook changes noted below in blue

Changes to Calibration workbooks:

- Statistics for BRD42 (Tyger River near Delta, SC) now focus on years 2007-2013.

Changes in Calibration model:

- Modified Tier 4 release threshold from 67.8 cfs to 61 cfs.
- Previously Monticello local inflow only had monthly flows. Now has daily as well.
- Removed increased evaporative effects from V.C. Summer thermal plume from Monticello reservoir object. Now expressed as consumptive use in V.C Summer water user object.
- Removed consumptive use estimates based on DHEC discharge data given uncertainty (overall change of ~90 MGD now not being lost from the system).
- Turned off monthly median targets for Parr Shoals and Monticello. Now have year-round target at middle of operating range (261' and 422.75', respectively).
- Revisited and modified subbasin flow factors for Lawson Fork Creek, Enoree River, Fairforest Creek, Middle and South Tyger Rivers, and Tyger River.
- Modified flow control outflow table for Parr Shoals.
- Updated mainstem flows. As OASIS flows stop at Oct 2009, flows from that point were estimated using a linear regression of gage flows at the Boiling Springs gage in NC. This regression has been updated to be on log-transformed flows.
- Small decrease to mainstem gain/loss factors between BRD22 and BRD54.

Spartanburg test (separate model):

- Disaggregated withdrawals from Municipal Reservoir #1 and Lake Blalock into two separate water user objects.
- Separated Pacolet River discharges into discharge object (previously represented as consumptive use in water user object).

1. Lake Blalock operating rules:
    a. This is more of a question on the SWAM enhancements to modeling rules. In rule set 1, each row as you go down the list will supercede the row above in terms of rule priority, correct? Also, another way to illustrate the release rules for Blalock would be to use two conditional storage objects, correct (in other words when storage is greater than 6246 MG but less than 7534 MG, for Jan through Apr, then release 122 cfs)? Would this be a more simple way to set up the rules?
    CDM Smith Response: Yes correct, if two rules are provided that are mutually exclusive within the same "Rule Set" then the lower row rule will supersede the rule above it. Regarding Blalock releases (Rule Set 1), agreed that it might be clearer to include the upper and lower bounds in the rules rather than rely on the superseding order of calculations. It will still require the same number of rules but might be clearer to the new user. We will make that change.

    b. In rule set 3, the part that corresponds to Tier 4 is unclear. Where does 67.8 cfs come from? Is this factoring in evaporation part of the release in this tier?
    CDM Smith Response: The target was reset to 61 cfs.

2. Bowen-Blalock calibration:
    a. We strongly recommend separating out the Spartanburg water use object for the calibration model. The way their system is set up in the model is likely not how they operated historically and using the exact reported withdrawals from each individual withdrawal will allow for a much better calibration analysis for each individual reservoir. Another option would be to keep Spartanburg as one water use object and look at the gross or total storage of the system as a whole instead of individually. However, we prefer the first option of separating out.
    CDM Smith Response: A separate model was created to test disaggregating the Spartanburg water user object. See attached slides for results. While there were some small improvements to reservoir drawdown and small changes to gage statistics, the results of the exercise confirmed that the calibration parameters were appropriately set.

    b. We need to decide along with Spartanburg how their system should be modeled in the Baseline version. Does Spartanburg have an idea or plan for how much water gets taken from each reservoir and if so, can it be incorporated into the model (the existing rules in the calibration model may approximate this, but we are not sure)
    CDM Smith Response: We have set Lake Blalock to be more of an auxiliary supply. The results of the calibration suggest that this is appropriate; however, Spartanburg will need to let us know what they prefer.

3. The Monticello Local Inflow has not headwater data for calibration period – is this a mistake or should the local inflow object simply be removed?
    CDM Smith Response: The local inflow object contained monthly flows but not daily. The daily flows have now been added.

4. VC Summer:
    a. The consumptive use is generally too high, way too high. Communication from SCE&G suggests that total evaporating losses (excluding ambient) from the nuclear plant is on average 13-18 cfs. We suspect there may be an error in the reporting of withdrawals or returns that DHEC have on record. Withdrawals in model are somewhat different at times than what we see from the DHEC water use database as well. We don't think these differences explain all the consumptive use percentage errors however.
    b. Another indication of error in the reported values is that consumptive use percentages vary unrealistically from month to month.
    c. Consumptive use percentages are also sometimes zero even though withdrawal data suggests the plant was in operation.
    d. Return flow is to local inflow object. Comments say there is a lag time of 1 month, but no lag time is listed in return flows box.

       CDM Smith Response: As discussed in e-mail correspondence on 7-27-16, we agreed to make the following changes:

       - We currently have ambient evaporation and additional evaporation from VCS lumped together in the Monticello evaporation time series. We will revise that to only include the ambient evaporation estimates, as provided by SCE&G. That way, if the model user wants to run the model with VCS off-line, they won't need to revise the evaporation time series.

       - We will account for the additional evaporation (23 cfs, but ranges by month from 20 to 26 cfs) in the consumptive use estimate for VC Summer. We will assume that the 23 cfs also accounts for the small amount (~5 cfs) of lost process water. So, if the plant withdrawals 845 cfs, we will return all but 23 cfs (2.7% CU).

       - Lag time was in the monthly model, but not daily. This has been updated.

5. Parr-Monticello operating rules (It has been challenging to follow/understand all the rules of this system and some of the comments below may reflect just misunderstanding the rules in the model):
    a. We have doubts about the approach of using a median monthly storage target on these reservoirs. This creates the potential to skew Parr releases and hence flows estimated at BRD54 downstream making it difficult to make a meaningful assessment of calibration. This was my concern expressed in 17a of my original comments.

       CDM Smith Response: This approach was taken due to the lack of better information about how these reservoirs are operating during "normal" conditions. The model has been updated to include a year-around target that falls halfway through the operating range for both Parr Shoals and Monticello.
    b. Why does BRD52 exceed physically available flow for Parr Reservoir (see July 2002 for examples)? Shouldn't physically available flow always be equal to or greater than BRD52?

       CDM Smith Response: This is due to Fairfield Pumped Storage withdrawals. In the model, Fairfield PS withdraws from the mainstem (direct river) just upstream of the reservoir. This decreases the physical availability of flow into the reservoir itself.

c. If BRD52 is greater than 800 cfs (517 MGD) and storage is less than target, shouldn't outflow be just 800 cfs, with the excess, if any, going into storage (and also accounting for evaporation)? This does not appear to be the case – see July, 2002 for examples.
CDM Smith Response: The releases are also a function of the prescribed storage targets. If the model can satisfy both the minimum release rule and the storage target in a given month, then it does so. This is the case for the July 2002 example. The minimum release requirement is satisfied (remember – it is a *minimum* release requirement) and the storage target (5214 MG) are both achieved by the modeled release.

d. When inflow is less than 800 cfs, but greater than 150 cfs, then outflow should be inflow – evaporation (ambient evaporation only?). However, in August 2002, there are days that meets these conditions (of course, based on BRD52), but the outflow is much less than expected even when taking into account evaporation. There are also days when outflow is greater inflow, though the storage is well below guide curve, so how can this be?
CDM Smith Response: In the monthly model, Aug 2002 shows the same behavior as above. The release is slightly above the minimum in order to hit the prescribed storage target. Both targets are achieved. In the daily model, the higher releases are due to the flood control pool (spills). This is actually more accurately simulated than the monthly model. The monthly model doesn't have the resolution to handle the high spills, so they effectively get lost in the numerics. For the daily model, we see high spills occurring regularly. The spillway table has been updated such that it does not start spilling within a target storage range.

e. Monticello's rule #1 has release rule related to Parr releases – not sure we understand this part of the system's operating rules.
CDM Smith Response: Parr Shoals looks to flows at BRD52 to define its releases. However, the Fairfield pumping occurs downstream of BRD52. Therefore Monticello has rules mirroring Parr's such that it will release the necessary amount for Parr to meet its targets.

f. The modeling report needs to provide a more detailed description of how this system is being modeled.
CDM Smith Response: This will updated in the final report.

6. Broad River at Alston calibration:
    a. Calibration is not very good – low flows are overestimated compared to gage flows. This warrants more attention.
    b. Two potential causes for this include:
        i. Operating rules incorrectly defined or not working properly or
        ii. BRD52 flows, the flows used to designate outflows, are overestimated (overestimation at the Tyger near Delta gage contributes to this).
    c. Refer also to 5a above – is the calibration being affected by the limitations of modeling the Parr/Monticello system accurately or is it an overestimation of inflows? We think that it could be both. We need to think hard about if there is a better way to model the system for calibration purposes.

CDM Smith Response: Flows at the Tyger River near Delta are lower given recalibration focus on 2007-2013. Flows have also improved from Enoree River system.

7. Tyger River at Delta:
    a. Calibration is poor, however, may not be much the model can do about this.
    b. Using an alternative headwater flow helps a little, but then accuracy of low flows in the upper basin are sacrificed somewhat.

CDM Smith Response: Yes, as previously discussed, we have made the decision to focus on achieving a good match of flows in the upper part of the basin. Various alternative headwater flows were tested, but no improvement was noted at the Delta gage, without sacrificing the good match of flows in the upper part of the basin.

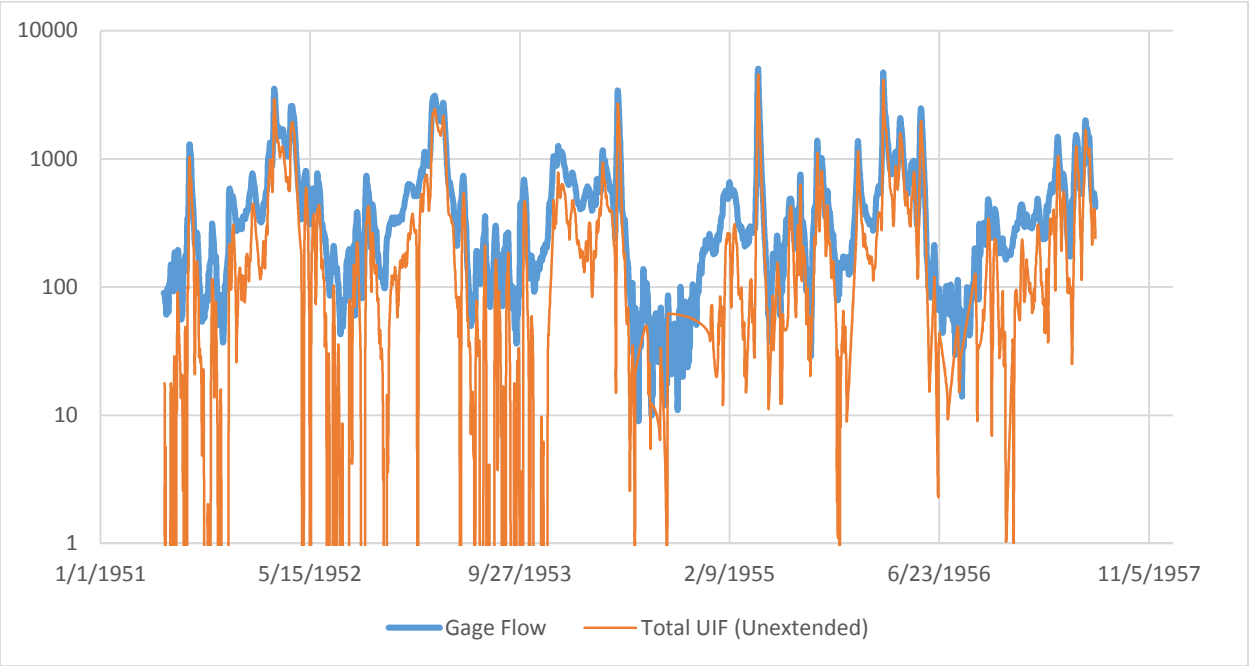
Comments on Draft Salkehatchie UIF Results

By: SCDNR Hydrology Section

Date: 7/6/2016

CDM Smith Responses in red, 7/29/16

The UIF Comp worksheet for SLK04 has many negative flows in column N. This appears to be a mistake – upstream gage data (SLK02) was subtracted from SLK04 gage data, but the upstream UIF was apparently not added back in this worksheet. This led to many very low flows, visible in the graph below of SLK04 gage versus UIF (from the Unextend UIF worksheet of the SLK04 UIF workbook). In graphs of the SLK04 flow duration curve from the UIF report, these low flows do not appear to be present.



CDM Smith Response: Clarified that links must be turned on when opening worksheet for columns and plots to calculate correctly.

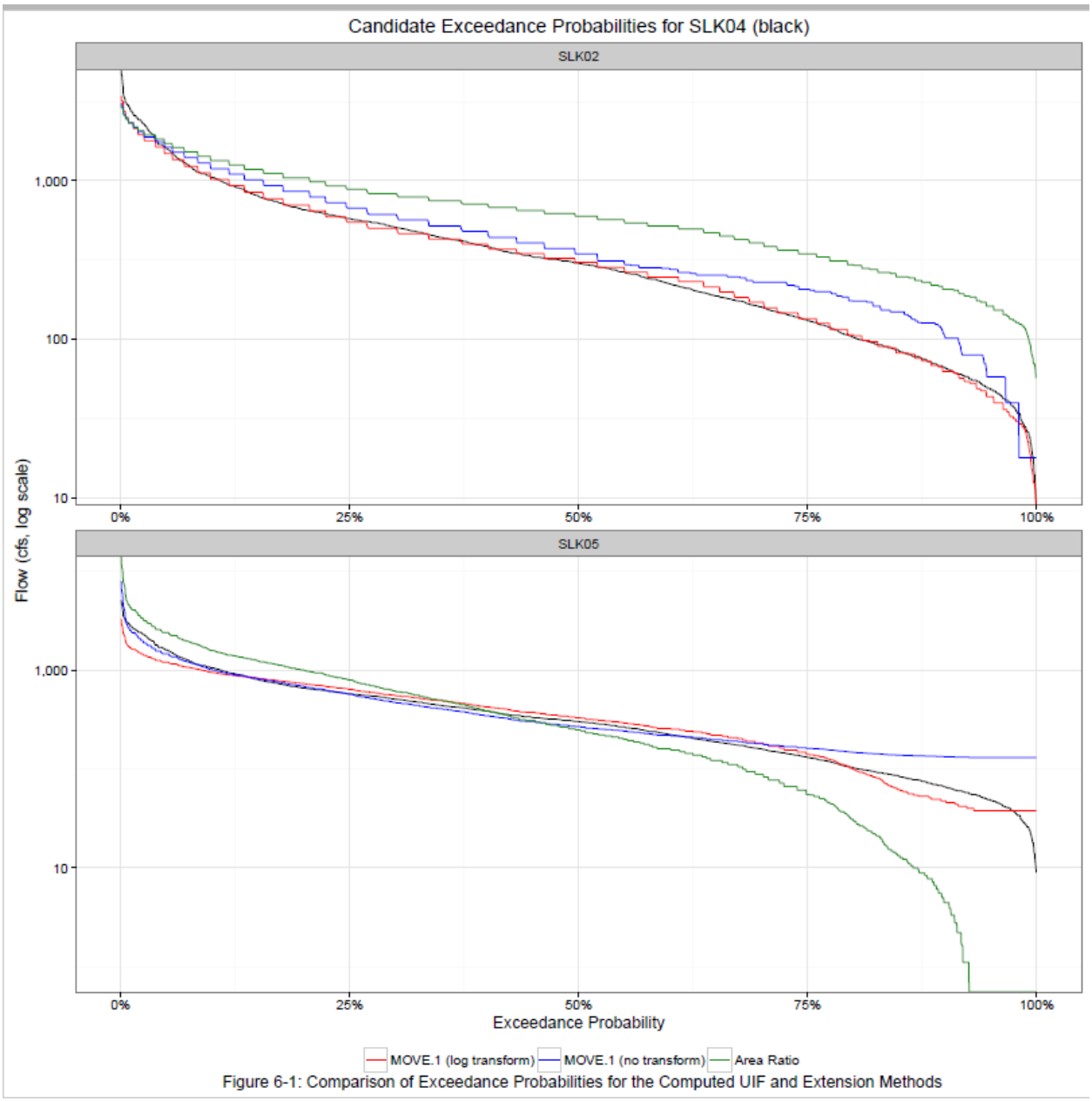


Figure 6-1: Comparison of Exceedance Probabilities for the Computed UIF and Extension Methods

Figure 6-1 demonstrates the variable flow durations among gages in the Salkehatchie basin, even when corrected for drainage area. SLK04 – the Combahee River at Yemassee is represented by the black curve in both the upper and the lower graphs. SLK02 – the Salkehatchie River at Miley, which is upstream of SLK04 with about 1/3 of the drainage area is represented by the green curve in the upper graph. The low flows at SLK02 – Miley are about double the low flows at SLK04 – Yemassee, on a per square mile basis.

SLK05 – the Coosawhatchie River at Hampton is represented by the green line in the lower graph. It has a drainage area of under 200 square miles. Its low flows are far lower than SLK04 – Yemassee, on a per square mile basis.

Table 7-1. UIFs in Ungaged Basins (Area Ratio Method Only)

	Ungaged Basin				USGS Reference Gage				
Project ID	**SWAM Usage**	**Stream**	**Basin Area (mi²)**	**% Developed / % Forest**	**Project Gage ID**	**USGS Number**	**Stream**	**Basin Area (mi²)**	**% Developed / % Forest**
SLK10	Headwater Flow	Salkehatchie River	105	8 / 49	SLK02	02175500	Salkehatchie River	342	5 / 52
SLK11	Headwater Flow	Miller Swamp	6	6 / 34	SLK04	02176000	Combahee River	1087	5 / 57
SLK12	Headwater Flow	Jackson Branch	26	6 / 37					
SLK13	Headwater Flow	Little Salkehatchie River	27	5 / 52					
SLK14	Headwater Flow	Willow Swamp	19	5 / 45					
SLK15	Headwater Flow	Coosawhatchie River	4	2 / 55	SLK05	02176500	Coosawhatchie River	196	7 / 51

Table 7-1 shows that flows at 4 small headwaters (<30 sqmi drainage area) will be represented by flow records from the Combahee River at Yemassee, which has a drainage area of over 1,000 sqmi. The Yemassee records will be transformed using Area Ratio to represent these small headwaters. The previous graphs indicate that Area Ratio transformation is not appropriate from Combahee at Yemassee (SLK04 - 1,087 sqmi) to Salkehatchie at Miley (SLK02 – 342 sqmi) or Coosawhatchie at Hampton (SLK05 - 196 sqmi). Notwithstanding those results, Area Ratio will be used to transform Yemassee records to headwaters of less than 30 sqmi.

I am uncertain how or whether the methods CDM Smith has employed in previous basins will accurately reflect the variable flow durations throughout this basin. It appears that many tributaries will be modelled inaccurately, and that could improve performance on the main stem.

CDM Smith Response: Since SLK11 – SLK14 are ungaged basins, area ratio is the only method available to develop flows. As noted, the differences in basin area size between SLK04 and the ungaged UIF points on the small tributaries makes it less than ideal as a reference gage. Furthermore, SLK04 only has records available from 1951-1957, and thus was extended (MOVE.1 log transform) using SLK02.

The headwater flows for SLK11 – SLK14 were recalculated using SLK02 (basin area 342 mi^2) as the reference gage. A second option was tested using SLK02 as the reference gage for SLK13 and SLK14, and SLK05 (basin area 196 mi^2) for SLK11 and SLK12. As noted in the comment, neither are ideal given the differences in the exceedance probability graphs; however, there are no other potential reference gages in the basin, or in nearby basins, that appear suitable. During calibration, the second option mentioned above appears to provide the best match of observed vs. modeled flows at the downstream gage location, SLK04; however, the gage only has records available from 1951-1957 to compare.