Surface Water Quantity Models

Progress Meeting Notes

October 3, 2016

Attendees: **CDM Smith**: John Boyer, Tim Cox, Nina Caraway
SCDNR: Joe Gellici, Scott Harder, Andy Wachob, Alex Pellet, Ken Rentiers
DHEC: Rob Devlin, Leigh Anne Monroe
Clemson: Jeff Allen
Technical Advisory Committee: Ed Bruce, Heather Nix, Eddie Twilley, Eric Krueger, Andy Fairey, Harrison Watson, K.C. Price

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1. **Broad Basin Model**
    a. Response to DNR Comments (attached)
    - Nina Caraway explained that minor subbasin flow factor adjustments were necessary after implementing DNR's recommendation to use BRD42 as a reference gage for Fairforest Creek. No other comments or responses were discussed.
    b. Reservoir forecasting algorithm enhancements (see attached slides)
    - Tim Cox reviewed updates to SWAM's reservoir forecasting formula. As opposed to the original formula, the new formula uses the current timestep's known releases to improve the forecast. Tim reviewed an example of the calculations for Lake Blalock.
    - Scott Harder note that, in the example provided, other days (before and after the example day) also had different release values using the new formula, and questioned whether that should be the case. Tim Cox responded that yes, the change in the formula would be expected to result in different calculated releases for other days shown on the table as well.

2. **Catawba-Wateree Basin Draft Model Report** (attached)
   - John Boyer explained that the Draft Catawba-Wateree model was distributed to DNR and DHEC the previous week. The Draft Report has now been distributed to DNR, DHEC and the TAC.
   - Scott Harder questioned whether Duke Energy was following the Low Inflow Protocol (LIP) in 2007-2008. Ed Bruce responded that yes, to the extent they could, they were following it. He noted that the ability to meet certain recreational flow releases was (and still is) being implemented via infrastructure improvements.
   - Scott Harder noted that each basin has its own unique challenges, and in the Catawba-Wateree, the challenge is using output from another model in a basin where flow is heavily regulated. Scott questioned whether it was valid to establish mainstem gains and losses using outflow from Lake Wylie, which is heavily regulated.
   - Scott harder asked if the LIP rules were incorporated into the calibration model. John Boyer noted that, except for a few limited instances, the model-calculated releases at the four reservoirs in the SWAM model exceeded the LIP-specified minimum releases. As such, the LIP rules were not included in calibration. John noted that this was not expected to have any effect on calibration; however, now that the rules have been programmed into the baseline model, they could also be included in the calibration to confirm this assumption.
   - K.C. Price asked at what point the TAC will get to work with the models and if additional training would be offered for the TAC.
   - John Boyer noted that model access has been limited to DNR and DHEC staff up to now. No additional discussions have occurred regarding allowing TAC access until the models are released to the public in 2017 (via a cloud-based server). However, John indicated that, if DNR and DHEC are OK with CDM Smith providing “evaluation” versions of the baseline models to the TAC, it should not be a problem. John indicated that he would follow-up with DNR and DHEC to discuss.
   - John noted that training was a topic he intended to discuss, but erroneously left it off of the agenda. John asked if DNR and DHEC had a preference for training dates, and offered mid-November and late December as options. John indicated that he would follow-up with DNR and DHEC to discuss specific dates and whether to offer additional training to the TAC.

3. **Remaining Basin Updates**
    a. Santee
    b. Savannah

- John Boyer noted that work is progressing on both the Santee and Savannah UIFs, and that portions of the Santee calibration and baseline model have been built.

4. **Upcoming Stakeholder Meetings**
    a. Catawba 2nd Meeting, late-October (after SCWRC)
    - Jeff Allen suggested that the City of Rock Hill Operations Center could be used again. Clemson will check on availability during late October and early November.
    b. Santee 2nd Meeting, early November
    - Jeff Allen suggested that the Santee Cooper Auditorium could be used again. Clemson will check on availability during early November.

Memorandum

To: John Boyer, CDM Smith

From: SCDNR Hydrology Team

Date: 9/7/16 **CDM Smith Response of 9/30/16 in red**

Re: Additional Comments on the Draft Broad Basin Calibration Model

Recommendations for Calibration (We focused on a calibration period of 1997-2013):

1. Tyger Basin
    a. Use BRD42 for the reference gage for the Headwater flows on the Tyger River (North Tyger River), but still use the original references gages for the Middle and South Tyger tributaries. For our tests, we settled on using the following flow factors (though these should be reviewed and adjusted as deemed appropriate):
    End Mile: 2.2 10.5 22.2 50.6 68.7
    Factor: 1.4 2.6 3.9 7 10
    CDM Smith Response: Updated headwater references and added these flow factors. No additional changes were made.

    b. Use BRD42 as a reference for the Fairforest Creek headwater flows. BRD40 in the upper part of the Fairforest basin, in our assessment, does not appear to be representative of flow dynamics for much of the lower basin and may lead to an over estimation of flows into the Tyger mainstem. Improvement in the calibration results at BRD42 appear significant enough to make this change.
    CDM Smith Response: This also requires adjusting Fairforest Creek flow factors, else the calibration at BRD40 is poor (bias of -18.3%). Since this tributary is segmented, raising the first subbasin flow factor to 10.2 only affects BRD40 calibration and does not affect flows elsewhere.

2. Enoree Basin:
    a. Use BRD48 as a reference gage for the headwater flows. Though this causes more apparent uncertainty in the upper part of the basin, our assessment shows that flows at BRD46, BRD 48, and BRD50 as a whole are generally improved. Flow factors are (though again, these should be reviewed and possibly fine-tuned):
    End Mile: 0.8 9.2 33 73.1 92.7
    Factor: 1 2 3 5 7.4
    CDM Smith Response: Updated reference gage and flow factors. First flow factor needed adjusting to correct bias of -36.8% at BRD43; final value was adjusted to 1.55.

3. Please also consider lowering flow factors for the last flow factor segments on the Tyger and Enoree (the reaches between the most downstream gage and the confluence with the Broad) to improve low flow periods on the mainstem Broad. Lowering flow factors further may cause too much of a water imbalance in these subbasins (deviations between cumulative modeled and gaged flows would become greater, but since there are no gages near the confluence this is

difficult to assess); however, we would like CDM Smith to consider lowering flow factors and provide feedback.
CDM Smith Response: With these changes, the overall bias at BRD42 stands at -9.3% and -10.2% at BRD50. As it stands, continually lowering the subbasin flow factors yields marginal improvements in low flows.

It must also be taken into consideration multiple discharges have been simplified by being folded in water user objects and expressed in terms of consumptive use calculated from monthly averages. If every single discharger in the basin were represented by a prescriptive discharge object, low flows may improve given that actual discharges, and not generalized averages, would be returned via the tributaries objects. Additionally, discharges were originally monthly values and applied as a flat rate in a daily simulation. This would have an effect on representing historic 7Q10s.

Other comments/Questions

1. Lake Blalock's full pool elevation is computed as 710.5 ft in the daily calibration model. Full pool elevations should be 710.0 ft. Lake Bowen also has a shift of 0.12 ft (815.12 versus 815.00). Is this because for calibration purposes, you are trying to match a full pool elevation that appears to have historically occurred, which may have been 710.5 instead of 710? An appropriate full pool level for the baseline model will need to be discussed.
   CDM Smith Response: According to specs documents supplied to us by Spartanburg, "normal full pool" for Blalock is 710.0 ft and spillway elevation is 710.5 ft. Since historic elevations frequently exceeded 710.0 ft by a small margin, the top of the spillway was used to set the capacity.

2. A reminder – please do not compute 7Q10s for sites with less than 10 years of gaged data, though still include annual 7-day low flows in the table.
   CDM Smith Response: This is reflected in the current calibration workbooks, but we will be sure to update the report and only show 7Q10s for sites with greater than 10 years of gaged data.

3. Minimum modeled flow for BRD14 is 1 cfs in August, 2008 (refer to daily timestep). I do not think this is allowed for in Blalock's operating rules, unless elevation is below 705 (where outflow = inflow if inflow is less than 61 cfs) and inflow is 1 cfs; however inflow was never close to 1 cfs. This anomaly may skew modeled versus observed 7Q10 comparisons. Please investigate.
   CDM Smith Response: This was a result of the reservoir forecasting that the model must perform. Additional testing was completed and the forecasting algorithm has been improved (Tim Cox will discuss this further during the Monthly Progress Call).

4. Why was the period 2007-2013 chosen for review to evaluate the Tyger River?
   CDM Smith Response: 2007 was a pivotal year with regards to the interconnections of users and discharge facilities on the Tyger River system. For example, Greer started sending a portion of their wastewater to the Pelham WWTP in the Enoree while simultaneously taking more wastewater from SJWD, which had just started withdrawing from Lake Cooley. 2007-2013 was examined to determine if the calibration results changed significantly. From 2007-2013, the

annual average error is -9.3%; if using 1983-2013 this error becomes -15.8%. For 7Q10s, 2007-2013 (modeled 61.4 cfs, measured 24.8 cfs, though this is less than 10 years) is 150% and 74.0% (modeled 74.6 cfs, measured 42.8 cfs) for the full period.

5. In the final report, please include a description on the North Carolina inflow dataset from OASIS that reflects that these flows represent current water use and management and not historical water use and management.
   CDM Smith Response: This will be added to the final report.

Future Calibration Considerations by SCDNR:

There were additional calibration tests performed by SCDNR hydrologists; however, these are still in an exploratory phase and we did not want to commit to these changes at this time. SCDNR hydrologists may incorporate some of these changes in the next 6-12 months. Any changes will be well documented and an addendum to CDM Smith's Modeling Report will be formally prepared describing any changes. The addendum will be the responsibility of the SCDNR. For your information, other considerations for calibrating the Broad model include, but are not limited to:

1. Evaluating the role and/or value of using implicit tributaries in the calibration process.
2. Reducing the calibration period to 1997-2013.
3. Evaluating how to incorporate inflows from North Carolina in light of the fact that OASIS outputs reflect current water use and management and not historical use and management.
4. Adjusting or fine tuning mainstem and tributary flow factors.

(Excerpt from previous presentation)

- *Note: hydrologic conditions for conservation triggers are assessed at the start of each timestep (daily or monthly)*

- *Conditions are forecast for that timestep based on a combination of known and unknown variables*
  - *Forecasting not 100% perfect (similar to reality).*

Forecasting Concepts

- What is *known* at start of timestep?
  - Current timestep unimpaired flow throughout the basin
  - Current timestep evaporation
  - Start of timestep reservoir storage
  - Previous patterns of water use and operations

- What is *unknown* at start of timestep?
  - Current timestep water use and return flows
  - Current timestep reservoir operations (*unless already calculated*)

Forecasting Concepts

Flow forecasting equations:

<u>Old Formula:</u>

$Q(t) = Q_{base}(t) - Q_{impairment}(t-1)$

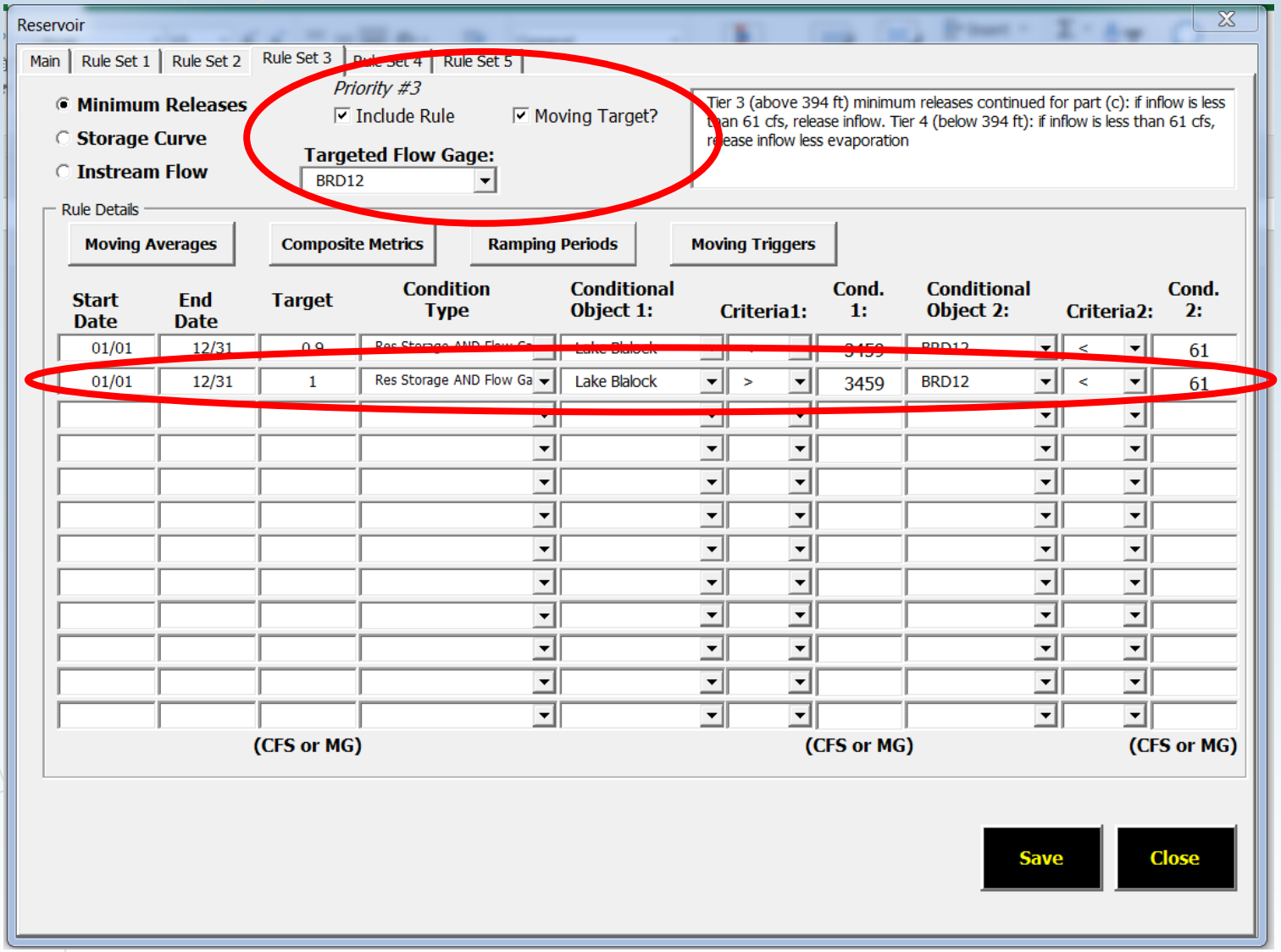
$Q_{impairment} = \sum$upstream CU + res ops – transbasin inflow

<u>New Formula:</u>

$Q(t) = Q_{base}(t) - Q_{impairment}(t-1) + \mathbf{(\sum Q_{release}(t) - \sum Q_{release}(t-1))}$

new formula uses current timestep known releases to improve forecast

Lake Blalock Example: Aug 18, 2008



Lake Blalock Example: Aug 18, 2008

Date		Lake Blalock Storage (MG)	Total Inflow (MGD)	8066 Total Withdrawal (MGD)	28 Regulated Release (MGD)	Additional Outflow (MGD)	Evap (MG
Min		6,199	23	0	0	0	0
Max		8,066	5,176	23	105	5,123	6
Avg		7,851	185	1	73	108	2
8/13/08		6,199	32	5	39	0	0
8/14/08		6,203	38	5	29	0	0
8/15/08		6,207	34	5	25	0	0
8/16/08		6,205	32	6	24	0	4
8/17/08		6,225	60	0	39	0	0
8/18/08		6,262	44	3	0	0	4
8/19/08		6,250	36	5	39	0	4
8/20/08		6,233	32	6	39	0	4
8/21/08		6,234	29	6	18	0	4
8/22/08		6,233	28	7	19	0	4
8/23/08		6,227	28	7	23	0	4
8/24/08		6,224	28	7	21	0	4
8/25/08		6,212	35	5	39	0	3

Calculations: Flow Gage Forecast (BRD 12)

Old Formula:

$Q(t) = Q_{base}(t) - Q_{impairment}(t-1)$

$Q(t) = 100 - 100 = 0$ cfs

- During the previous day, an upstream reservoir was filling; resulting in a forecast of 0 flow at the target flow gage
- As a consequence, Lake Blalock release = 0 (based on rule)

Calculations: Flow Gage Forecast (BRD 12)

New Formula:

$$Q(t) = Q_{base}(t) - Q_{impairment}(t-1) + \mathbf{(\sum Q_{release}(t) - \sum Q_{release}(t-1))}$$

$$Q(t) = 100 - 100 \mathbf{+ 60} = 60 \text{ cfs}$$

- Lake Blaylock release = 60 cfs

Lake Blalock Example: Aug 18, 2008

Date		*Lake Blalock* Storage (MG)	Total Inflow (MGD)	*8066* Total Withdrawal (MGD)	*28* Regulated Release (MGD)	Additional Outflow (MGD)	Evap (MGD)
Min		6,059	23	0	39	0	0
Max		8,066	5,176	17	105	5,123	6
Avg		7,844	185	1	74	108	2
8/10/08		6,272	24	8	39	0	5
8/11/08		6,243	24	8	39	0	5
8/12/08		6,215	23	8	39	0	4
8/13/08		6,202	32	5	39	0	0
8/14/08		6,195	38	5	39	0	0
8/15/08		6,184	34	5	39	0	0
8/16/08		6,167	32	6	39	0	4
8/17/08		6,187	60	0	39	0	0
8/18/08		6,185	44	3	39	0	4
8/19/08		6,173	36	5	39	0	4
8/20/08		6,156	32	6	39	0	3
8/21/08		6,136	29	6	39	0	4
8/22/08		6,114	28	7	39	0	4
8/23/08		6,093	28	7	39	0	4
8/24/08		6,071	28	7	39	0	3