Surface Water Quantity Models

Progress Meeting Notes

June 6, 2016 - Teleconference

Attendees: **CDM Smith**: John Boyer, Kirk Westphal, Tim Cox, Nina Caraway
SCDNR: Joe Gellici, Andy Wachob, Scott Harder, Alex Pellet, Bill Clendenin
DHEC: Rob Devlin
Clemson: Jeff Allen
Technical Advisory Committee: Eddie Twilley, Ed Bruce, K.C. Price, Heather Nix, Mike Harrelson, Charles Wingard, Eric Kruger, Andy Fairey, Harrison Watson

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1. **Saluda Model and Model Enhancements - DNR Comments and Responses**
   a. Comment Nos. 1 & 2, Daily varying guide curve (see attached)
   - Tim Cox summarized the model enhancements which now provide for daily reservoir targets. The use now has the option to specify "ramping periods" over which the model will calculate through linear interpolation, a daily storage target.
   - Scott Harder questioned whether the model with the recent enhancements was able to recognize the 2-ft deviation from daily lake level targets, which would trigger the Low Inflow Protocol (LIP) for Lake Murray. Tim Cox indicated that the new daily reservoir storage target code would likely require further modification to account for this trigger. CDM Smith will investigate.

   b. Comment No. 9, Lake Murray Verification Exercise
   - Scott Harder said that DNR was still reviewing the updates made to Section 7 of the Saluda Model Report, with regard to the Lake Murray Verification Exercise.

2. **Broad Model - DNR Comments and Responses** (see attached)
   - John Boyer explained that Responses have been provided to DNR comments, and at DNR's direction, a separate call could be set-up to discuss the comments and responses. K.C. Price indicated that he would like to participate in the call.

- Scott Harder, in reference to Comment No. 32, noted that DNR is seeing differences in daily model output, when running the model only for 2002 vs. the full calibration period. Tim Cox indicated that he did not observe any differences in daily model output, but would confirm. *Note: further checking with the latest Broad Model, which includes some code enhancements conducted in May 2016, confirmed that changing the simulation period for the daily model does not result in model output differences. The original version of the Broad model, as provided to DNR, did produce output differences associated with reservoirs, depending on the period of the simulation; however, this was corrected when the code was updated.*

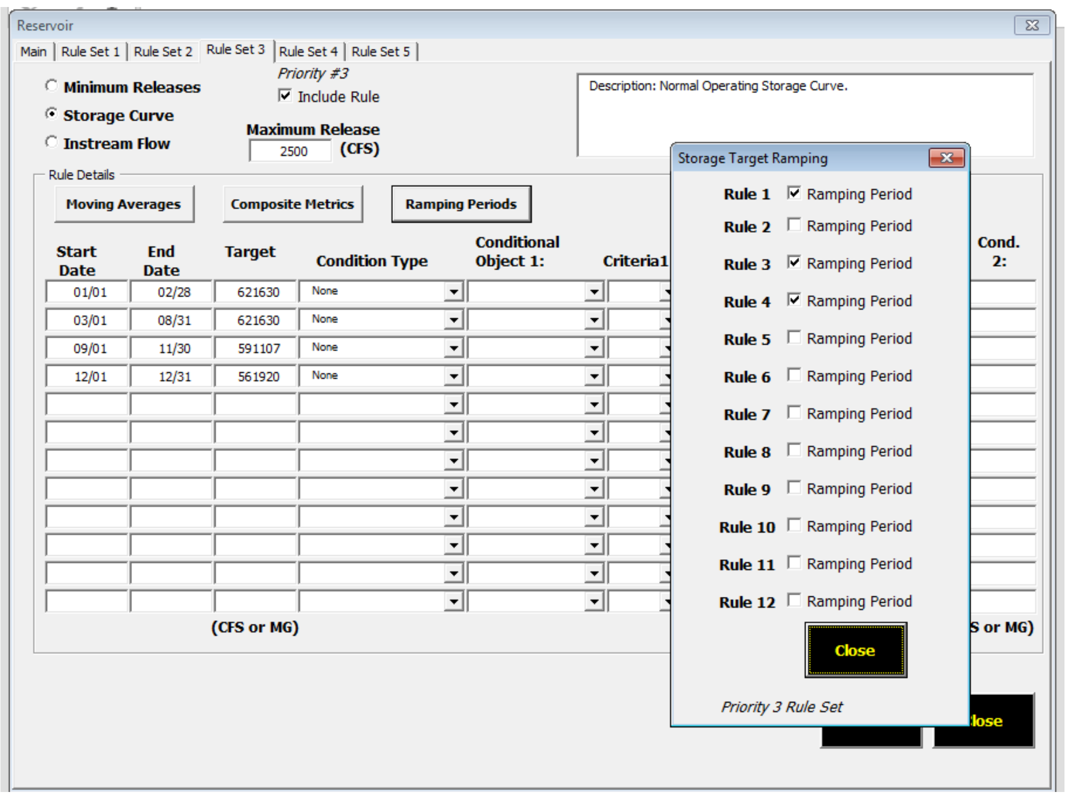
3. **Catawba-Wateree UIFs and Boundary Conditions**
   a. Draft UIF Memorandum submitted to DNR/DHEC
   - John Boyer indicated that the Draft UIF Memorandum for the Catawba-Wateree UIFs was provided to DNR and DHEC for review. TAC members that wish to review the memo and/or dataset should request it from John.
   b. Boundary condition and CHEOPS output for calibration and baseline models
   - John Boyer reviewed several options for establishing model boundary conditions to the Catawba-Wateree SWAM model. One option would to include Lake Wylie, beginning at the confluence of the South Fork Catawba and Catawba River. Under this approach, calculated flows from the existing CHEOPS model would need to be available at this location, as well as along Crowder's Creek (which drains to Lake Wylie) to the east, and Sugar Creek/McAlpine Creek (which to the Catawba River below Lake Wylie) to the west. This approach doesn't include all of Lake Wylie, however, given it extends up to the tailrace of Mountain Island Lake. A second option would be to begin the model just below Mountain Island Lake in North Carolina, and include all of Lake Wylie and its withdrawals and discharges that are in North Carolina. This would also require calculated flows from the existing CHEOPS model for the South Fork Catawba, Crowder's Creek, and Sugar Creek/McAlpine Creek. A third option would include starting with flows just below Lake Wylie. Under this approach, Lake Wylie would not be included in the model. This would represent the simplest approach from a development and user standpoint, since flows are readily available from the CHEOPS model coming out of Lake Wylie. The only other flows that would be needed from the CHEOPS model are for Sugar Creek/McAlpine Creek.
   - Ed Bruce suggested that with the third option, model users could still evaluate changing withdrawals and discharges in Lake Wylie be applying the net

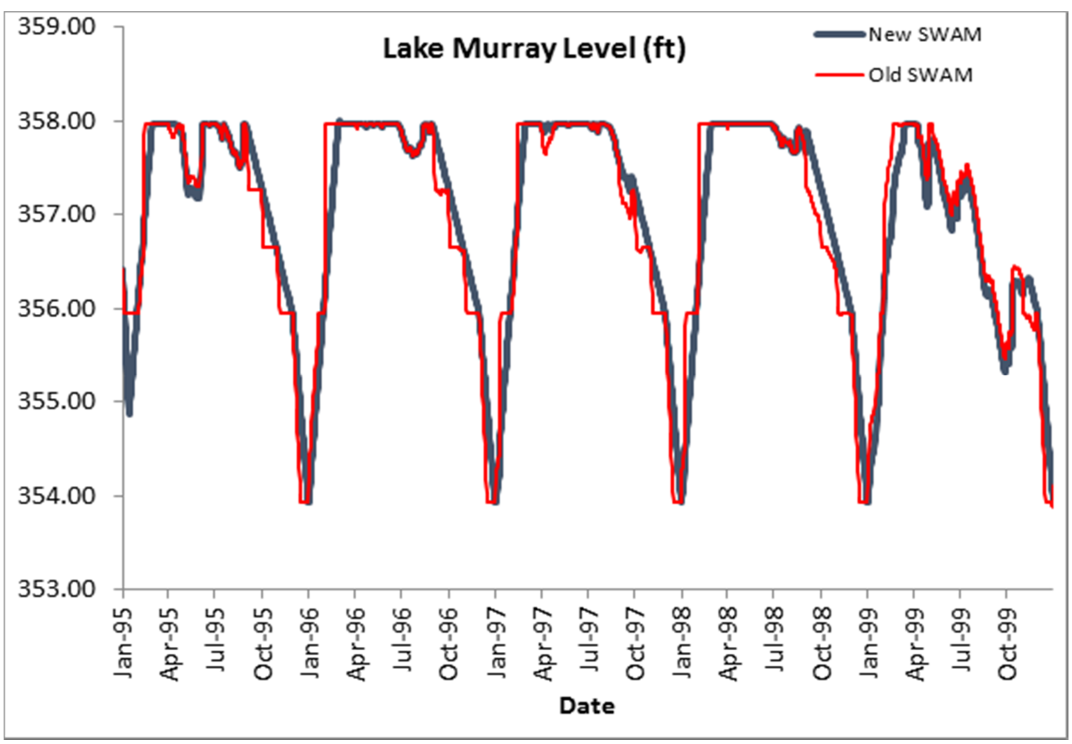
consumptive use to just below Lake Wylie, assuming outflow from Lake Wylie was above the FERC-required minimum release.
- Rob Devlin indicated that not including Lake Wylie was not a problem from a permitting standpoint since DHEC defers to Duke Energy for determining whether additional withdrawals can be supported from their lakes.
- Bill Clendenin suggested the third option, which starts the model below Lake Wylie made the most sense.
- John Boyer noted that a decision did not need to be made now, and that CDM Smith would further evaluate the options and propose a recommended option for DNR, DHEC and the TAC to consider.

4. **Salkehatchie Draft Model Framework** (see attached)
- John Boyer explained that the Salkehatchie River Basin model representation will be limited due to the existence of only two active USGS streamflow gages with records dating back to 1951, and three gages inactive gages. The only withdrawals which are not on small streams that drain directly to the coast, include just over 20 agricultural withdrawals on the Coosawhatchie, Salkehatchie and Little Salkehatchie rivers, or small tributaries to them.
- John noted that the UIF dataset will be developed back to 1951, which coincides with the earliest USGS streamflow records within the basin. Alternatively, they could be extended, using a gage in the Edisto, to the 1920's. Joe Gellici and Scott Harder indicated their preference to begin the UIF dataset in 1951.

5. **Upcoming Meetings**
   a. July Progress Meeting – moving to Tuesday, July 5th
   b. Salkehatchie and Savannah Stakeholder Meetings #1 – end of July
   - John Boyer noted that the next two progress meetings were being targeted for the end of July.
   - Rob Devlin noted that he would be out the last week of July, and those dates may need to be adjusted.
   - John Boyer asked if DNR had put further thought into whether the Savannah River Basin model should begin below Lake Thurmond, or include all of the Lakes in the Upper Savannah Basin. Joe responded that CDM Smith should proceed as originally planned, and include the entire basin.

Attachment for Agenda Item 1a – Daily varying guide curve enhancement





Memorandum

To: John Boyer, CDM Smith

From: SCDNR Hydrology Team

Date: 6/2/16; **CDM Smith Responses in red, 6/6/2016**

Re: Comments on the Draft Broad Basin Calibration Model

Typographical

1. On page 5-1, bottom paragraph: the "d" was left off of "included".
2. On page 6-8, Section 6.2.3
    a. First paragraph: "pool" was left off the end of the third sentence.
    b. We recommend rewriting the last sentence of the bottom paragraph for clarity.

    Several instances throughout where withdrawal (noun) should be withdraw (verb).
3. On page 8-1, the heading should be "User Guidelines" not "Use Guidelines".
4. On page 5-1: "Current demands were estimated by averaging water use data over the past ten years (2005 – 2014) for most users, on a monthly basis." But then on Page 6-19: "For all municipal and industrial water users, consumptive use was calculated from DHEC-reported withdrawals and discharges over the baseline period (2004 through 2013)." We assume 2005-2014 was a typo, but please clarify and update appropriately.
5. Figure 7-1: USGS 02156370 Pacolet River near Sarratt, SC is listed as "current". Please clarify in the report that it is no longer operating (operating dates are 8/2012 through 6/2015).
6. P 7-7: "The two sites where average modeled vs. measured flows exceeded 10% were Lawsons Fork Creek at Spartanburg (BRD18) and Turkey Creek near Lowrys (BRD20). Both gages had few years of records (4 and 9) and average flows below 40 cfs." Should this be 9 and 4 years respectively, and not 4 and 9?
7. Parr Hydroelectric Project consists of Parr Shoals Development and Fairfield Pumped Storage Development. Parr Shoals Development consists of Parr Dam (or Parr Shoals Dam) and Parr Reservoir. Note that the reservoir is not called Parr Shoals Reservoir (P 6-9 and 6-10).
8. P 4-1: Principle #3, second sentence should read "These include the most primary tributaries...", not "This includes most primary tributaries".
9. P 4-1: Principle #4, first sentence should read "these tributaries are embedded" not "these tributaries is embedded".
10. P 4-5: 4th sentence under 4.4, withdrawal (noun) should be withdraw (verb).
11. P 6-6: Under section 6.2.1, remove the word "for" in the next to last sentence.

Modeling Report

12. Calibration period for some subbasins (Pacolet, for example), may require shortening the calibration period. For the Pacolet basin, calibration focus may need to be on 2007-2013.
    CDM Smith Response: We agree that this would be appropriate for Lake Blalock and downstream for the Pacolet River. However, the use of the 1983-2004 period for Lake Bowen and Municipal Reservoir #1 is also important for capturing historic water supply patterns and reservoir drawdowns.

We will review the other subbasins to determine if there is reason to shorten the period of record presented in the calibration graphs for select gages.

13. Page 7-2 under section 7.1, we agree that there is error in USGS gage data, but if you are going to highlights upwards of 20% for some gages, should you not determine (the USGS could probably offer some information on this) which one's in the basin may be 20% or more and let that inform the success or lack thereof of the calibration process?
CDM Smith Response: According to the USGS… *the gage data characterized as "Excellent" indicates that about 95 percent of the daily discharges are within 5 percent of the true value; "good" within 10 percent; and "fair," within 15 percent. "Poor" indicates that daily discharges have less than "fair" accuracy. Different accuracies may be attributed to different parts of a given record.* CDM Smith will revise the text to indicate which specific stations, and over which parts of a given record, contain records that are characterized as "poor", and thus may have errors of upwards of 20%.

14. On page 5-1, bottom paragraph: It is stated that "In certain instances, future rules that are not yet in effect, were include[d] (and can be toggled on or off in the model)". Please denote where this occurs and consider describing in more detail in the report.
CDM Smith Response: This will be updated such that the language indicates the possibility of including future rules.

15. We may have already covered this in a previous comment memorandum but for the Pacolet and Tyger subbasins and corresponding reservoirs, was the Clemson Station the most suitable temperature station? Are there other weather stations closer to these reservoirs that could be used?
CDM Smith Response: Clemson was selected because of its long period of record, the gage elevation (251 m) is very close to Bowen/Blalock Reservoir elevations (220-250 m), and there exists Purvis values for the gage (which we used to develop pan factors to convert pan evaporation to free surface evaporation). Other nearby HCN stations considered were: Hendersonville, which is in another state and had larger elevation differences; Grnvl Spart International, which lacks Purvis values; Newberry, which has an 8 year gap in data; and Ridgeville, Sandhill, Union and Winthrop, all which lack Purvis values and have other issues precluding their use.

16. Additional information on Lake Blalock's release rules and stage-storage relationship has been submitted (the lake is not run-of-river). Dam construction was completed in 2006 and water levels reached full pool sometime the same year (reports states that dam completion and repairs were ongoing to 2010, we believe this is incorrect). Please update the model and report and add a calibration review for the Spartanburg reservoir system from 2007 to 2013.
CDM Smith Response: These updates are being completed.

17. Parr and Monticello reservoirs:
    a. Since these reservoirs have target "ranges" instead of specific targets and complex hydro-plant operations, modeling the historic operations is probably not possible. However, the Broad River at Alston gage is a very important calibration site and we want to be sure that the uncertainty in recreating historic operations does not skew the calibration at this gage.

b. Should Monticello be modelled as an offline reservoir? The model has it denoted an online reservoir.
   CDM Smith Response: Keeping Monticello online ensures it can receive inflows, which in this instance is how the reservoir receives precipitation and local inflow, otherwise it would only be filled via the pumped storage.
c. We recommend having discussion with SCE&G representatives to determine how these reservoirs should be represented in the baseline model.
   CDM Smith Response: Agreed.

18. The report states on page 7-7 to 7-8 that "The reservoirs in the Broad River are simulated in a way that caps the reservoir capacity at the spillway elevation, and any excess water is assumed to spill in one timestep. If downstream flows are found to be overly skewed because of this simplification, it can be adjusted to meter flood water out in accordance with estimated rating curves, but to date, this has not appeared to be necessary." If these adjustments are warranted at some point, can this be handled by the existing model (would this be the 'Flood Control Outflow' table in the Reservoir Object) or would this require further SWAM enhancements?
    CDM Smith Response: Yes, this can be handled by increasing capacity and adding the requisite volumes and flows to the flood control table.

19. As noted on page 7-7 in section 7.3, the Tyger River near Delta (BRD42) and the Broad River near Alston (BRD54) gages had higher error than most other calibration sites. We recommend further investigation into the differences between observed and modeled flows to reduce this error. Some additional comments and observations for these sites:
    a. The calibration results show that flows are generally being over estimated for the last 8-10 years throughout the mainstem. Is the Alston gage showing the accumulated effect of these overestimations on the mainstem upstream or are they related to Tyger and Enoree modeled flows?
    b. BRD01: cumulative flows begin diverging notably in 2006 and worsens after 2010. Is this partly related to how the "managed flows" were calculated from NC? This may be worth investigating.
    c. BRD42, Tyger River near Delta: Peak flows are greatly underestimated and the calibration process, we assume, tried to match these peaks at the expense of larger deviations in low flows.
    d. Daily BRD25 plots are missing in Appendix B. Monthly low flows are not being modeled well for some years – is this a Lake Cooley influence?
    e. 7Q10s (and low flows in general) are being significantly overestimated on the mainstem and at the Tyger River near Delta.

    CDM Smith Response: These will be investigated. For BRD01, this may be a result of North Carolina OASIS model flows only being available until 2009 and managed flows after being estimated from flows at the Boiling Springs gage (02151500).

20. For precipitation and evaporation:
    a. We do not understand why a net evaporation is not always used even when precipitation exceeds evaporation. Though errors *might* be small, it seems straightforward to always include a net evaporation and there would be no confusion or question about it.
    b. Please reconsider whether Bowen or Blalock should be have direct precipitation included along with local inflow (as done with large reservoirs).

    CDM Smith Response: Direct precipitation, if deemed significant, has always been handled in SWAM by including as part of the larger catchment "Local Inflow" tributary object. Negative net evaporation rates are not allowed as SWAM input. There are multiple reasons for this, but one of them is that linking direct precipitation with reservoir surface area (as is done with evaporation rates) is not strictly correct. As an example, even if the reservoir area is close to 0 (dry lake), precipitation is still falling on the catchment "footprint" of the lake. Some of this water, at least, becomes part of the reservoir and local catchment hydrologic regime. A model that simulated this dynamic with a direct precipitation rate (inches) would not include any of this water in the water budget (since there would be no lake area). SWAM circumvents this issue by requiring the user to include local precipitation inputs as part of the larger local catchment inflow.

21. Please include the table of %Errors between mean modeled and observed results from the stakeholder meeting presentation in the model report. Please also note:
    a. Turkey Creek gage has missing data that is skewing gaged averages, which is why this error may be large.
    b. Please double checking the modeled average flow for the period of record for Lawson's Fork Creek (BRD18). The graphical comparisons suggest that the error (-72.4% as listed in the table) is not correct, but likely smaller.

    CDM Smith Response: These will be checked.

22. In the comment box for the Bullock Creek Tributary Object, it says that the tributary "accounts for Clarks Fork drainage" (similar comments may be in other tributary objects). Please provide clarification on what this comment means (Clarks Fork is modeled separately in the model).
    CDM Smith Response: This pertains to initial estimates of subbasin flow factors for tributaries, which are defined as the ratio of the initial headwater drainage to final confluence area. If a tributary drains into another tributary, such as Clarks Fork into Bullock Creek, the accumulation of flow in the Clarks Fork is already accounted for in its own object and therefore its drainage area would be double-counted if not removed from Bullock Creek subbasin flow factors.

23. BRD12 – There are some data gaps where annual flows shouldn't be computed for the measured or gaged flows and shouldn't be plotted on annual plots (see 2007 for example, but there are two other significant gaps).
    CDM Smith Response: Agree and will update.

24. Gages with less than 10 years of data shouldn't have a 7Q10 estimated. Plot 7 day average low flows, but don't compute 7Q10 for those gages with less than 10 years of record.
    CDM Smith Response: Agree and will update.

25. Modeled low flows for Enoree are consistently and notably less than measured. We recommend double check the calibration to see if this can be improved.
CDM Smith Response: We will investigate further to see if any improvements can be made.

Model functionality (perhaps some of these were resolved with the new upgrades done and discussed previously with the Saluda):

26. Gaston Shoals – The distribution of flow between "regulated release" and "outflow" is sometimes incorrect (see June 2008, for example).
CDM Smith Response: In some cases, the differences between these two output parameters are subtle. In all cases, the total sum of these two outflows is more important than the distribution between the two. For Gaston Shoals, the regulated releases are much lower than the prescribed minimum releases; but the total of the two parameters satisfies the rule to the extent possible. In the model, regulated releases are releases directly from starting storage (start of timestep). If starting storage contents are not enough to satisfy a release requirement, then the remainder is included as "Additional Outflow". Storage capacity of Gaston Shoals is very low relative to the release requirements, thus the majority of the minimum release requirement shows up under "Additional Outflow".

27. Operating rules for 99 Island Reservoir regarding target releases for a given month appear incorrect or incomplete:
    a. Is priority rule that reservoir can't go below 98 ft? This is what output indicates.
    b. For July-Nov, what is release if storage is below 561 MG?
    CDM Smith Response: For (a) and (b), documentation supplied by Duke indicates a minimum releases subject to maximum drawdown of 98' or 99' depending on month, and if below that drawdown, then allow a minimum drought contingency flow. No contingency flows were indicated for July-Nov. See table below.

	Max Drawdown	**Min Release Flow**	**Drought contingency flow if inflow < Min**
	ft (100 local datum)	cfs	cfs
Jan	98	966	483
Feb	98	966	483
Mar	99	966	483
Apr	99	966	483
May	99	725	483
Jun	98	725	483
Jul	98	483	
Aug	98	483	
Sep	98	483	
Oct	98	483	
Nov	98	483	
Dec	98	725	483

    c. See August, 2002: storage is greater than 561 MG for some days and model indicates release should be 483 cfs (312 MGD), but model output has total outflow of much less.
    CDM Smith Response: In the monthly model, August 2002 outflow is equal to the total

inflow. This is correct per the Priority 1 Rule. This is the case for neighboring timesteps as well, although the model does not always forecast the inflow exactly correct (within 2% at quick glance).

28. For Gaston Shoals and 99 Island Reservoirs (and others?), the inflow = outflow rules appear to be represented as output = input – evaporation? Is this defined in the FERC licenses? This may not be a huge impact on these smaller reservoirs, but we want to make sure we are consistent on how inflow and outflow are interpreted in licenses on small and large reservoirs. Evaporation should be subtracted from the inflow only if FERC license or other agreement explicitly states this.
CDM Smith Response: No, this is not correct. The rule, as represented in the model, is outflow = inflow. This is confirmed by looking at the August 2002 output for 99 Islands (as described above). However, note that the model forecasting algorithm does not always get the inflow exactly correct and you may see instances where outflow is slightly less or slightly more than the inflow. As described previously, the forecasting algorithm performs better for the daily timestep.

29. Neal's Shoals reservoir: Output results indicate that this reservoir is modeled exactly as a run of river and that operating rules in model are not modifying the inflow at all. Is modeling this reservoir as "advanced" necessary?
CDM Smith Response: The reservoir rules, including the storage target, were included based on information contained in the *Broad River CHEOPS model Operations Report*. Note that flood control outflow was also specified for this reservoir, based on information contained in the *Operations Report,* and the reservoir storage was set at 515 MG. Since the reservoir is operated to maintain 484.4 MG, then without the rule curve, which is specified in the "advanced" reservoir options, the reservoir storage would revert to 515 MG.

30. Instream flow target below Lake Cooley on the N. Tyger (Tyger) is 5 cfs at BRD25. The instream flow target below Lake Lyman is 10 cfs at BRD30 on the Middle Tyger. According to the output these targets are not being met even when there is available reservoir storage to provide the water. This indicates that the reservoir operating rule is not working properly or perhaps we are misinterpreting the rule.
CDM Smith Response: Given this is a riparian simulation, the model must make *a priori* estimates for downstream targets. For these two flow targets, the priority is ensuring SJWD has enough flow for supply, not necessarily having a precise flow amount in the river. However, if there are actual rules followed by operators, this should be investigated further.

31. Flow Gage Output sheet: statistics in rows 4-6 do not update to include the total number of days for a given period of record that was run on the daily time step.
CDM Smith Response: This has been corrected.

32. It appears that changing the period of simulation in SWAM can have unexpected results on model outputs. We noticed this with storage at Lake Lyman when we ran the full calibration period, 1983-2013 and just the 2002 period. Storage in winter/spring was the same between the different periods (full pool), but outputs began to deviate in summer and fall of some years. This does not appear to be related to initial conditions for each period. Please investigate.

CDM Smith Response: Regulated releases are different for the two simulation periods. This is due to the fact that, for the monthly model, the forecasted "impairment", used to evaluate various conditions or downstream flow targets, is based on the impairment during the same calendar month of the *previous* year. So it needs at least 2 years of simulation to accurately execute this forecasting and thus your single year simulation is less accurate with respect to reservoir operations. This is not an issue with the daily timestep model, which uses information from the previous day in its forecasting algorithm. We recommend at least 2 years of simulation for any monthly timestep simulation involving complex reservoir operational rules. This is also a good idea to ensure that initial conditions are not playing a role.

Additional Discussion Questions

1. Perhaps a discussion question for the agencies to decide upon: Should ET estimates in the baseline be based on a historic time series or monthly averages? If monthly averages, then should they be based on the last few decades as opposed to a 70-80 year record, since temperatures and potentially ET may generally be higher in the 21st century than in the 20th century?
2. Further discussion is warranted on the efforts to model some of the run-of-river reservoirs/hydropower plants on the mainstem and which one's should be explicitly included in the baseline model. Or perhaps have two versions of baseline, one with run or river reservoirs and one without them.
3. Ed Bruce at Duke Energy has expressed an interest in including the Cherokee Falls hydropower plant explicitly. The plant has the capability to reinstall flashboards (and may be required to under existing FERC rules) that could increase the storage of the reservoir. Further discussion is warranted.
4. We have had some additional, internal discussion on modeling error and how it should be quantified. We agree that graphical analysis is a very useful tool for evaluating model performance. We also agree with the suggestion that "reliance on specific statistical metrics can result in skewed and/or shortsighted assessments on model performance". However, we recommend providing additional, quantifiable, error estimates for the monthly and annual results to supplement the graphical analyses. We recommend discussing model error in a future meeting.

Memorandum

To: *South Carolina Department of Natural Resources (DNR)*
South Carolina Department of Health and Environmental Control (DHEC)

From: *CDM Smith*

Date: *June 3, 2016*

Subject: *Salkehatchie River Basin SWAM Model Framework*

This memorandum presents the Simplified Water Allocation Model (SWAM) framework for the Salkehatchie River Basin. Several tables and figures are provided to help understand how the tributaries, water users, and discharges are being represented in the SWAM modeling environment. The tables and figures include:

Table 1 **Permitted and registered water users included in the Salkehatchie River Basin model framework.**

Table 2 **NPDES discharges included in the Salkehatchie Basin model framework.**

Table 3 **Interbasin transfers in the Salkehatchie Basin.**

Figure 1 **Overview Map**
This map consolidates and presents all active permitted and registered water users; significant discharge locations; USGS stream gage locations; and tributaries (the "higher order tributaries" are not represented explicitly in the model, but their contributions to flow are included in the flows of larger, modeled tributaries). Significant discharge locations generally include NPDES discharges that average over 3 million gallons per month (Mg/m).

Figure 2 **Model Tributaries and USGS Streamflow Gages**
This map presents the Salkehatchie River Basin hydrography. Also represented are major branches, primary tributaries and several secondary tributaries. The contributions of many of the secondary and higher order tributaries are accounted for in the aggregate flow in the larger tributaries that are modeled explicitly. Both active and inactive USGS streamflow gages are displayed as are tidally and non-tidally influenced gages. Not all streams which have a former USGS streamflow gage

will be explicitly included in the model due to the influence of tides on the gage records.

Compared to most other South Carolina basins, streamflow data in the Salkehatchie basin are limited both spatially and temporally. There are only two active, non-tidally influenced USGS streamflow gages with daily flow records. These are supplemented by three inactive, non-tidally influenced gages. The active and inactive gages are located on the Coosawhatchie River, the Salkehatchie River, the Combahee River, and Savannah Creek. The earliest daily flow records date to February 1951.

Figure 3 Permitted Surface Water Users and Registered Agriculture
This map presents the location of permitted surface water users and registered agricultural surface water users.

Figure 4 Dischargers
This map presents the location of all significant NPDES discharge locations, including several discharges that originate from withdrawals in the Savannah Basin. Significant discharge locations generally include NPDES discharges that average over 3 Mg/m; however, certain discharges that average less than 3 Mg/m, but with some months greater than 3 Mg/m are also included.

Figure 5 Salkehatchie Basin SWAM Model Framework
This figure represents the proposed SWAM model schematic, including tributaries, water users, and dischargers. Note that the permitted surface water withdrawals (golf courses) and one agricultural withdrawal that are near the coast are not included. This is because they are located on small streams that are tidally influenced and drain directly to the ocean. These small streams are not included in the model. The only other surface water withdrawals in the basin are registered agricultural withdrawals – most of which are located in the headwaters of the basin.

The Ashepoo River is not included in the model due to the lack of USGS flow records (i.e., no active or inactive gages) and the fact that there are no permitted or registered withdrawals.

The SWAM schematic includes a stretch of the Coosawhatchie River below the inactive USGS gage (0217**6517**) near Early Branch, up to the formation of the Broad River. Streamflow in this section can only be estimated, given the lack of a downstream gage to support calibration. Similarly, the schematic also extends the Combahee River beyond the inactive USGS gage (0217**6000**); however, streamflow estimates in this stretch cannot be confirmed through calibration.

Similar to the other basins already completed or in development, the guiding principles in determining what elements of the Salkehatchie River Basin to simulate explicitly were:

1. Begin with a simple representation, with the understanding that it is easier to add additional details in the future than to remove unnecessary detail to make the model more efficient.

2. Most tributaries with current uses (permitted or registered withdrawals or significant discharge) will be represented explicitly. In the Salkehatchie Basin, there are several exceptions to this. Many of the agricultural withdrawals are located on small tributaries to the Salkehatchie, Little Salkehatchie and Combahee rivers. Since these are very minor tributaries, the withdrawal location is typically close to the major river that they drain to, and there is a lack of available streamflow data to characterize flows in these minor tributaries with much precision, the withdrawal locations will be assigned to the adjacent major river. While this approach is limiting in that it may suggest that there is more water available to the user than is actually present, it still accounts for the withdrawal, and the impact on flow downstream.

3. Generally, tributaries that are unused are not included explicitly, but the hydrologic contributions from these tributaries is embedded in the unimpaired flows (or reach gains) in downstream locations. As UIFs are developed throughout the Salkehatchie, some additional tributaries may be added explicitly if warranted as candidates to support future use (or these can be easily added at any time in the future as permit applications are received).

The proposed framework is submitted with the understanding that it is malleable – that is, we may find that additional tributaries are warranted as explicit model objects (to support simulation of future withdrawals or discharges) rather than implicit flow additions, or that further simplifications are possible without compromising model utility.

The proposed model framework is a starting point based on discussions with DNR and DHEC, and on CDM Smith's initial estimate of an appropriate framework for planning and permitting in South Carolina. Feedback from water users, environmental organizations, and other stakeholders within the Salkehatchie River Basin will be important in refining the representation of the river system. The framework will be presented at the first planned stakeholder meeting for the Salkehatchie River Basin, and feedback will be used to refine the framework as appropriate.

Table 1. Permitted and registered surface water users included in the Salkehatchie Basin model

ID	Type	Facility Name	Withdrawal Tributary	Model Object ID
03IR002S02	IR	Chappell Farms	Coosawhatchie River	IR: Chappell Farms
03IR004S01	IR	Coosaw Farms	Coosawhatchie River	IR: Coosaw Farms
03IR006S01	IR	Sharp & Sharp Certified Seed	Coosawhatchie River	IR: Sharp Seed
03IR006S02	IR	Sharp & Sharp Certified Seed	Coosawhatchie River	IR: Sharp Seed
03IR006S03	IR	Sharp & Sharp Certified Seed	Coosawhatchie River	IR: Sharp Seed
03IR010S01	IR	JCO Farms	Coosawhatchie River	IR: JCO Farms
03IR011S01	IR	Connelly Farms	Salkehatchie River	IR: Connelly Farms
03IR011S02	IR	Connelly Farms	Miller Swamp	IR: Connelly Farms
03IR011S03	IR	Connelly Farms	Jackson Branch	IR: Connelly Farms
05IR007S01	IR	Brubaker Farms Inc	Salkehatchie River	IR: Brubaker Farms
05IR011S01	IR	Anilorac Farm	Little Salkehatchie River	IR: Anilorac Farm
05IR023S01	IR	Gary Hege Farm	Salkehatchie River	IR: Gary Hege Farm
05IR023S02	IR	Gary Hege Farm	Little Salkehatchie River	IR: Gary Hege Farm
05IR042S01	IR	Diem Aden Farm	Little Salkehatchie River	IR: Diem Aden Farm
06IR007S01	IR	Danny Hege Farm Barnwell	Salkehatchie River	IR: Danny Hege Farm
07GC012S04	GC	Dataw Island Club	Coast*	*NA*
07GC026S01	GC	Spring Island Club	Coast*	*NA*
07GC031S01	GC	Belfair Plantation LLC	Coast*	*NA*
07GC031S02	GC	Belfair Plantation LLC	Coast*	*NA*
07GC036S01	GC	Eagles Pointe Golf Club	Coast*	*NA*
07GC037S01	GC	Crescent Pointe Golf Club	Coast*	*NA*
07GC039S01	GC	Chechessee Creek Club	Coast*	*NA*
07IR054S01	IR	Kuzzens Inc Lobeco	Coast*	*NA*
15IR002S01	IR	Breland Farm	Little Salkehatchie River	IR: Breland Farm
15IR012S01	IR	Williams Farms Partnership	Little Salkehatchie River	IR: Williams Farms
15IR012S02	IR	Williams Farms Partnership	Willow Swamp	IR: Williams Farms
15IR012S03	IR	Williams Farms Partnership	Willow Swamp	IR: Williams Farms
15IR012S04	IR	Williams Farms Partnership	Willow Swamp	IR: Williams Farms
15IR012S05	IR	Williams Farms Partnership	Willow Swamp	IR: Williams Farms
25IR059S01	IR	Coosaw Land LLC	Coosawhatchie River	IR: Coosaw Land

Blue and gray shading identifies water users with multiple permitted withdrawal locations. These are represented by one model object.

** Will not be included in the model due to withdrawal location near the coast or non-modeled river*

NA = Not appplicable (no model object necessary)

Table 2. NPDES discharges included in the Salkehatchie Basin model framework.

NPDES Pipe ID	Facility Name	Discharge Tributary	Associated Surface Water Permit	Associated Groundwater Withdrawal ID	Model Object ID
SC0001830-001	Nevamar Company LLC	Coosawhatchie River	None	25IN001G	IN: Nevamar
SC0021318-001	Hampton, Town of	Coosawhatchie River	None	25WS001G	WS: Hampton
SC0025950-001	Yemassee, Town of	Combahee River	None	25WS004G	WS: Yemassee
SC0040215-001	Denmark, City of	Little Salkehatchie River	None	05WS002G	WS: Denmark
SC0040215-002	Denmark, City of	Little Salkehatchie River	None	05WS002G	WS: Denmark
SC0040436-001	Walterboro City of WWTP	Ashepoo River*	None	15WS001G	*NA*
SC0047872-001	Barnwell, City of WWTF (New)	Salkehatchie River	None	06WS003G	WS: Barnwell
SC0046191-001	Hilton Head No 1 PSD WWTP	Coast*	None	07WS017G	*NA*
SC0046191-002	Hilton Head No 1 PSD WWTP	Coast*	None	07WS017G	*NA*
SC0046191-003	Hilton Head No 1 PSD WWTP	Coast*	None	07WS017G	*NA*
SC0002577-003	US Marines/Parris Island Depot	Coast*	None	None	*NA*

Blue shading identifies dischargers that have a public water supply permit or registration to withdraw groundwater, but no surface water permit, and are represented by a Water User object.

Gray shading identifies dischargers that do not have a public water supply permit or active registration to withdrawal groundwater.

** Will not be included in the model due to discharge location near the coast or non-modeled river*

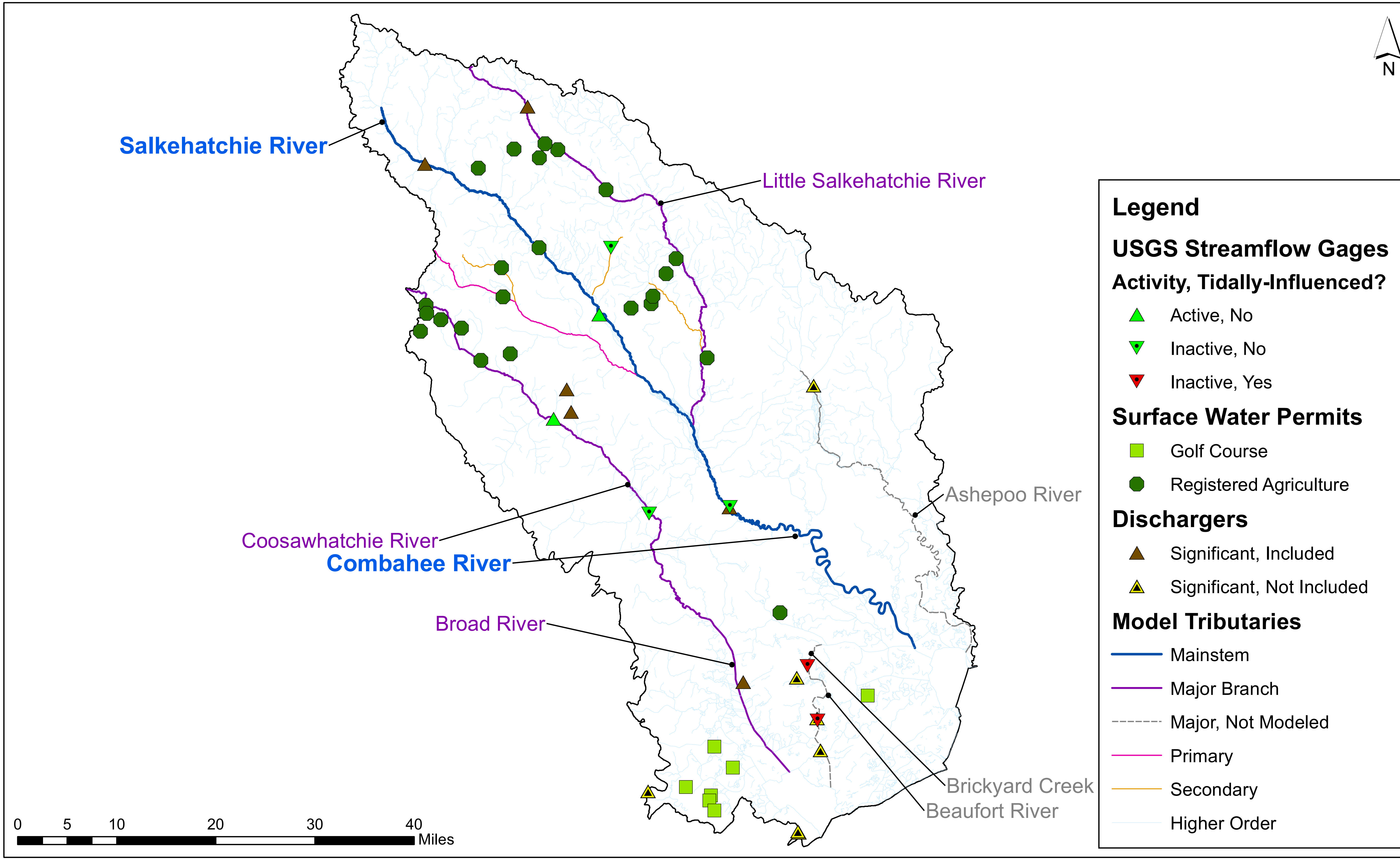
NA = Not appplicable (no model object necessary)

Table 3. Interbasin transfers in the Salkehatchie Basin.

NPDES Pipe ID	NPDES Facility Name	Associated Water Permit	Associated Water Permit Facility	Intake Basin	Discharge Basin	Location of Discharge in Salkehatchie	Model Object ID
SC0047279-003	BJW&SA/Cherry Point WWWTP	07WS005	Beaufort Jasper Water & Sewer Authority	Savannah	Salkehatchie	Coast*	*NA*
SC0048348-001	BJW&SA/Port Royal WTR Recl Fac	07WS005	Beaufort Jasper Water & Sewer Authority	Savannah	Salkehatchie	Beaufort River*	*NA*
SC0000825-001	US Marine Corps Air Station	07WS005	Beaufort Jasper Water & Sewer Authority	Savannah	Salkehatchie	Beaufort River*	*NA*
SC0000825-002	US Marine Corps Air Station	07WS005	Beaufort Jasper Water & Sewer Authority	Savannah	Salkehatchie	Broad River*	*NA*

** Will not be included in the model due to discharge location near the coast or non-modeled river*

NA = Not appplicable (no model object necessary)



CDM Smith

Figure 1: Overview Map

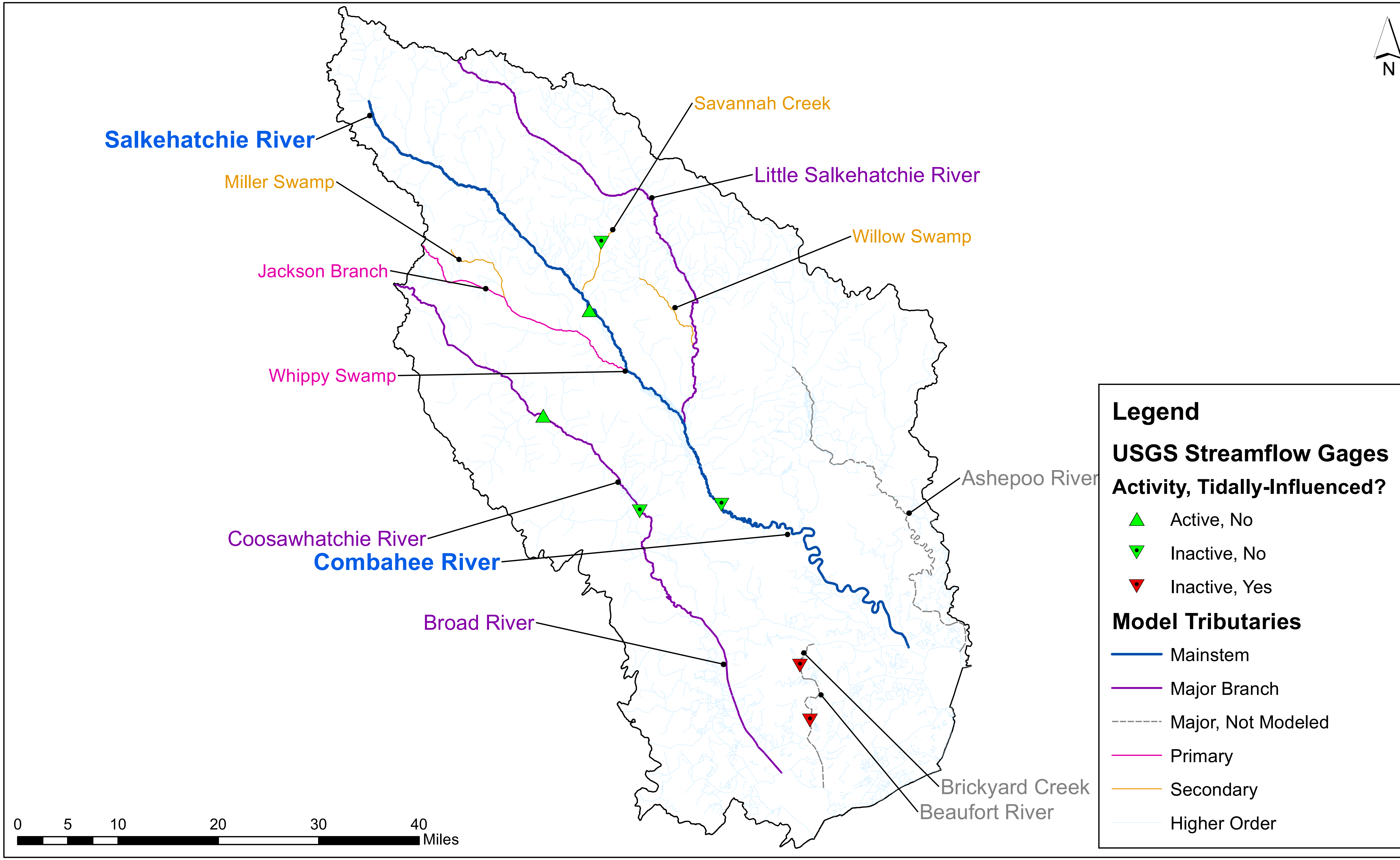


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Figure 2: Model Tributaries and USGS Streamflow Gages

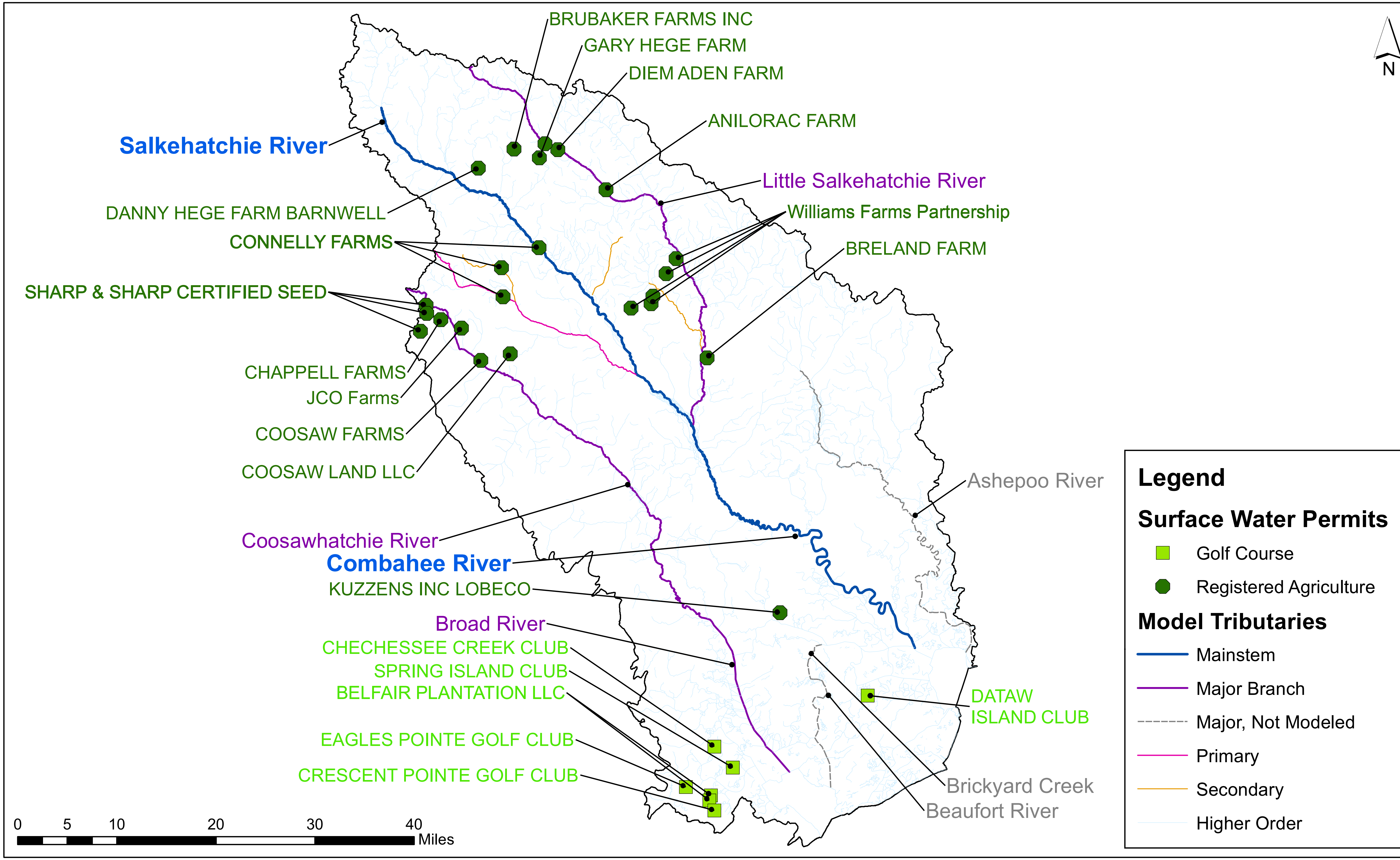

Figure 3: Permitted Surface Water Users and Registered Agriculture

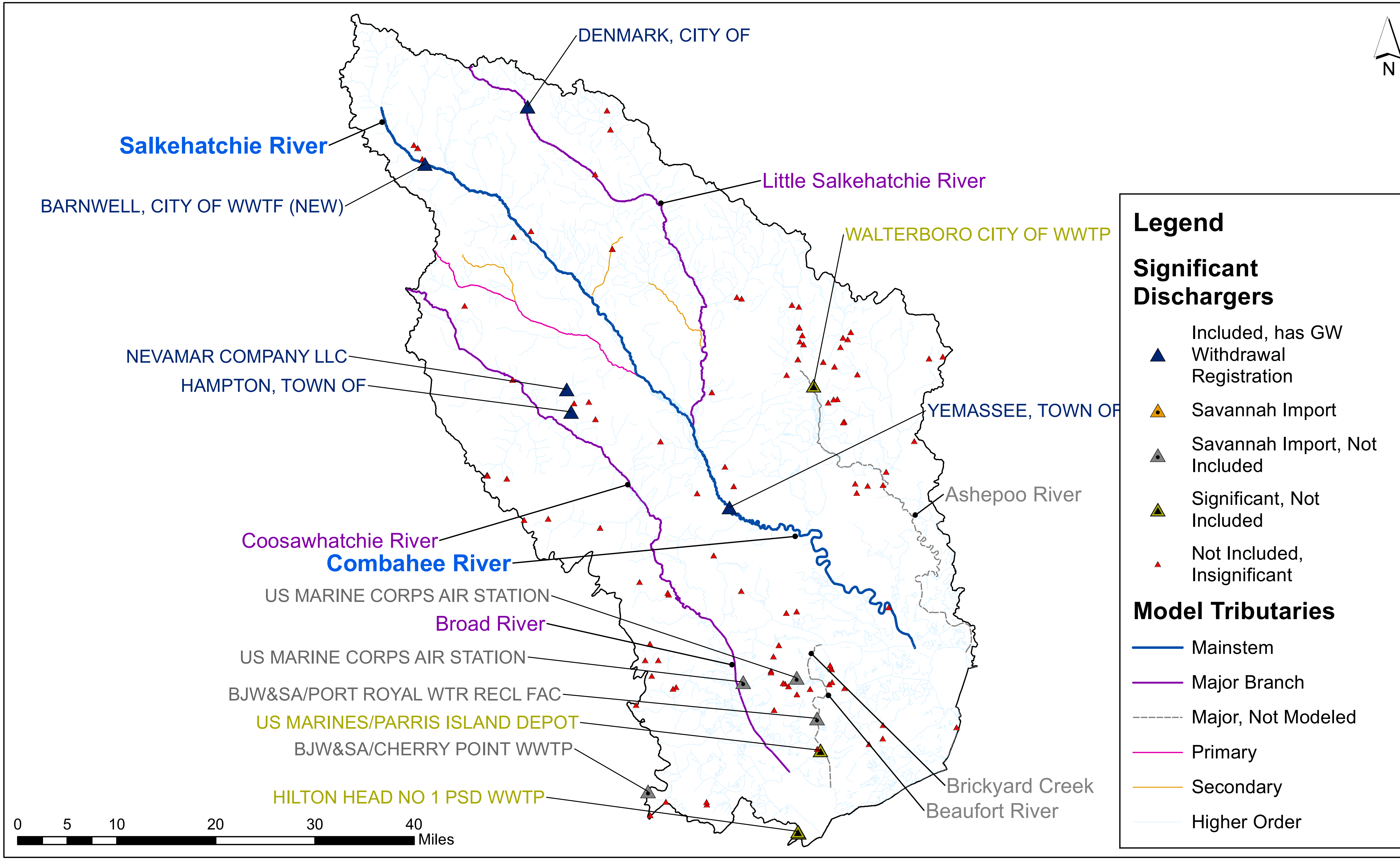

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Figure 4: Dischargers

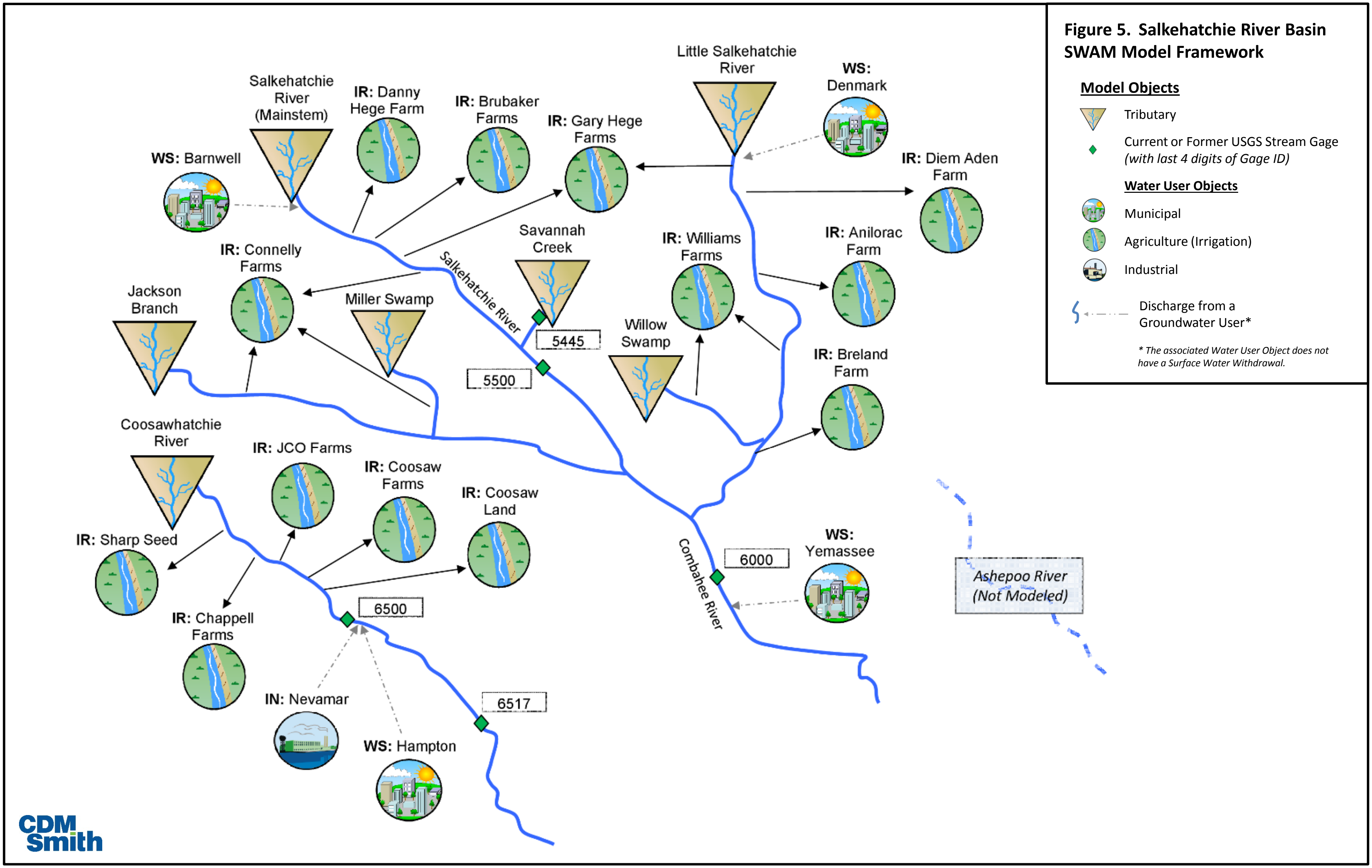

Figure 5. Salkehatchie River Basin SWAM Model Framework