



Memorandum

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

From: CDM Smith

Date: April 2018

*Subject: Summary of Updates to the Saluda River Basin Unimpaired Flow Dataset,
Calibration Model and Baseline Model*

The purpose of this memo is to document updates made between February and April 2018 to the Saluda River Basin unimpaired flows (UIF), the calibration model and the baseline model. The updates consist of the following, which are detailed in subsequent sections of this memorandum.

- UIF and Headwater Flow Updates
- Calibration Model Updates
 - Adjustments to select Water User objects
 - Adjustments to select sub-basin flow factors and mainstem gains/losses
- Baseline Model Updates
 - Adjustments to select Water User objects
 - Adjustments to select sub-basin flow factors and mainstem gains/losses
 - Adjustment to Lake Greenwood and Lake Murray Reservoir Operating Rules
- SWAM Software Code and Interface Enhancements

UIF and Headwater Flow Updates

UIF calculations made on reaches with upstream agricultural irrigation were discovered to contain a unit conversion error, necessitating minor corrections to UIF calculations. Specifically, UIF calculations were updated due to an error in converting the irrigation water use from million gallons per month (mgm) to acre-feet per day. The irrigation timeseries consists of estimated values from 1950 to 2001, and DHEC-reported values from 2002 to 2013.

These minor corrections had a cascading, although numerically minimal effect, on basin UIFs, as the most upstream change affected SLD04 (02162500 Saluda River near Greenville). UIFs on the Saluda River and Congaree River downstream were affected, along with any tributaries also containing irrigation. Additionally, these corrected UIFs in turn affected other UIFs in the extension process.

Table 1 lists which UIFs received calculation corrections and/or which were subsequently affected in the extension process. Ultimately, all extended UIFs were updated except three: SLD28 (02169550 Congaree Creek at Cayce, SC), SLD29 (02169570 Gills Creek at Columbia, SC), and SLD31 (02169630 Big Beaver Creek near St. Matthews, SC). The actual numeric changes to the UIFs were insignificant, except in the case of very low flows.

Tables 2 and 3 (from Tables 6-1 and 6-2 of the Saluda River Basin Model Report) list the explicit and implicit model tributaries respectively, which had headwater inputs that were updated as a result of the UIF updates. The headwater inputs listed in **bold** were *not* affected by changes to their headwater flows.

Table 1. Summary of Updated UIFs

UIF ID	Change	UIF ID	Change
SLD01	Extended by corrected UIF	SLD20	Corrected UIF & extended by corrected UIF
SLD02	Extended by corrected UIF	SLD21	Corrected UIF & extended by corrected UIF
SLD03	Extended by corrected UIF	SLD22	Corrected UIF & extended by corrected UIF
SLD04	Corrected UIF	SLD23	Corrected UIF & extended by corrected UIF
SLD04	Extended by corrected UIF	SLD25	Corrected UIF
SLD05	Extended by corrected UIF	SLD26	Corrected UIF
SLD06	Corrected UIF & extended by corrected UIF	SLD27	Corrected UIF
SLD07	Corrected UIF & extended by corrected UIF	SLD30	Corrected UIF
SLD08	Extended by corrected UIF	SLD32	Corrected UIF
SLD09	Corrected UIF	SLD33	Extended by corrected UIF
SLD10	Extended by corrected UIF	SLD34	Extended by corrected UIF
SLD11	Extended by corrected UIF		
SLD12	Extended by corrected UIF		
SLD13	Extended by corrected UIF		
SLD14	Extended by corrected UIF		
SLD15	Extended by corrected UIF		
SLD16	Corrected UIF & extended by corrected UIF		
SLD17	Extended by corrected UIF		
SLD18	Corrected UIF		
SLD19	Extended by corrected UIF		

Table 2. Gages and Reference Gages Used for Headwater Flows on Explicit Tributaries

Headwater Input				USGS Reference Gage (Unimpaired)		
Project ID	Type	USGS Number	SWAM Tributary	Project Gage ID	USGS Number	Stream
SLD201	Ungaged	-	South Saluda River	SLD01	02162290	South Saluda River
SLD200	Ungaged	-	North Saluda River	SLD03	021623975	North Saluda River
SLD203	Ungaged	-	Oolenoy River	SLD04	02162500	Mainstem (Saluda River)
SLD204	Ungaged	-	Doddies Creek			
SLD206	Ungaged	-	Georges Creek	SLD06	02163000	Mainstem (Saluda River)
SLD210	Ungaged	-	Hurricane Creek			
SLD211	Ungaged	-	Big Creek	SLD09	02163500	Mainstem (Saluda River)
SLD213	Ungaged	-	Broad Mouth Creek			
SLD212	Ungaged	-	Laurel Creek	SLD11	02164110	Reedy River
SLD205	Ungaged	-	Reedy River	SLD13	021650905	Reedy River
SLD215	Ungaged	-	Wilson Creek	SLD18	02167000	Mainstem (Saluda River)
SLD129	Ungaged	-	Little Saluda River	SLD19	02167450	Mainstem (Saluda River)
SLD216	Ungaged	-	Little River			
SLD221	Ungaged	-	Clouds Creek			
SLD218	Ungaged	-	Big Beaverdam Creek	SLD21	02167563	Bush River
SLD222	Ungaged	-	West Creek	SLD25	02168504	Mainstem (Saluda River)
SLD223	Ungaged	-	Twelvemile Creek	SLD26	02169000	Mainstem (Saluda River)
SLD139	Ungaged	-	Congaree Creek	SLD28	02169550	Congaree Creek
SLD226	Ungaged	-	Jackson Creek	SLD29	02169570	Gills Creek
SLD227	Ungaged	-	Gills Creek			
SLD225	Ungaged	-	Cedar Creek	SLD32	02169670	Cedar Creek
SLD207	Ungaged	-	Brushy Creek	SLD33	02162700	Middle Branch
SLD02	Gaged	02162350	Mainstem (Middle Saluda Riv.)	-	-	-
SLD05	Gaged	02162525	Hamilton Creek	-	-	-
SLD08	Gaged	021630967	Grove Creek	-	-	-
SLD14	Gaged	02165200	Rabon Creek (South Rabon Cr.)	-	-	-
SLD15	Gaged	021652801	North Rabon Creek	-	-	-
SLD17	Gaged	02166970	Ninety-Six Creek	-	-	-
SLD31	Gaged	02169630	Big Beaver Creek	-	-	-
SLD34	Gaged	02167557	Bush River	-	-	-
Headwater inputs listed in bold were not affected by changes to their headwater flows.						

Table 3. Reference Gages Used for Headwater Flows on Implicit Tributaries

	Ungaged Basin	USGS Reference Gage (Unimpaired)		
Project ID	SWAM Tributary	Project Gage ID	USGS Number	Stream
SLD115	Turkey Creek	SLD16	02166501	Saluda River
SLD161	Halfway Swamp Creek	SLD17	02166970	Ninety-Six Creek
SLD163	Terrapin Creek			
SLD301	Lake Greenwood Inflow	SLD19	02167450	Little River
SLD160	Cane Creek			
SLD302	Lake Murray Inflow			
SLD162	Beaverdam Creek	SLD21	02167563	Bush River
SLD167	Buckhead Creek	SLD31	02169630	Big Beaver Creek
SLD164	Sandy Run	SLD32	02169670	Cedar Creek
SLD165	Mill Creek			
SLD166	Toms Creek			
Headwater inputs listed in bold were not affected by changes to their headwater flows.				

Calibration Model Updates

With input from SCDNR, two adjustments to Water User objects were incorporated into the calibration model, as described below.

- PT: SCE&G – This Water User object, representing the McMeekin Plant on Lake Murray, was adjusted to return 99.8% of its total return flow back to Lake Murray. The remaining 0.2% of the return flow is returned just below the Lake Murray Dam, on the Saluda River. Additionally, the overall consumptive use percentage for this user was changed from 26% to 0.5%. These changes were based on recent correspondence between Ray Ammarell of SCE&G and SCDNR.
- WS: West Columbia – This Water User object includes two sources – the first on Lake Murray and the second on the Saluda River. To achieve a more accurate representation of the relative distribution of these two sources, permit limits were modified to force the model to draw from the sources in a pattern that agrees with reported usage patterns. A highest preference source water account was constructed for the water user to withdraw water from the lake according to typical monthly patterns. Monthly “dummy” permit limits were set for this source water account, equal to reported average monthly values calculated since 2010. The second source water account (direct river, downstream of the Lake) was left unchanged. A third source water account was added to represent the residual permit capacity on the Lake

Murray withdrawal. This account would only ever be utilized in the model if demands exceeded the total permit capacity of the first two accounts. This approach of manipulating permit limits across source water accounts, to achieve a more accurate distribution of source water withdrawals, is consistent with the approach taken elsewhere. Output analysis reveals that the resulting modeled withdrawal distribution agrees well with reported data.

The UIF and headwater flow updates, as well as the minor changes to the two Water User objects required a re-examination of the calibration results. As a result, minor adjustments were made to select tributary sub-basin flow factors and one mainstem gains/loss factor. The changes are noted in the final column of **Table 4** (from Table 6-3 of the Saluda River Basin Model Report). Note that several sub-basin flow factors had been changed previously, following completion of the Saluda River Basin Model Report.

Table 4. Model Tributary Inputs

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Confluence Drainage Area (ac)	Headwater ID	End Mile	Drainage Area Ratio	Original Subbasin Flow Factor (unitless)	Updated Subbasin Flow Factor (unitless)
Mainstem	Explicit	none	none	2,055,737	SLD02	32	NA	0.07*	
						56		0.01*	
						82		0.02*	
						117		0*	
						500		0.05*	0.09*
Big Beaver Creek	Explicit	Mainstem	204	29,047	SLD31	9	4.6	4.6	
Big Beaverdam Creek	Explicit	Bush River	16	7,766	SLD218	4	3.8	3.8	
Big Creek	Explicit	Mainstem	60	12,452	SLD211	11	17.1	17.1	
Broad Mouth Creek	Explicit	Mainstem	74	21,733	SLD213	14	8.3	8.3	
Brushy Creek	Explicit	Mainstem	46	23,341	SLD207	11	18.2	18.2	
Bush River	Explicit	Mainstem	139	77,215	SLD34	19	7.0	1.25	1.4
						26		2.53	2.6
						32		5	
Cedar Creek	Explicit	Mainstem	221	103,061	SLD225	9	4.4	2.4	2.6
						24		4.4	
Clouds Creek	Explicit	Mainstem	143	71,743	SLD221	1	46.0	4	
						28		50	
Congaree Creek	Explicit	Mainstem	185	99,229	SLD139	17	4.4	4.4	
Doddies Creek	Explicit	Mainstem	23	7,207	SLD204	4	7.0	7	
Georges Creek	Explicit	Mainstem	35	21,123	SLD206	9	9.3	9.3	
Gills Creek	Explicit	Mainstem	186	47,111	SLD227	7	2.8	1.2	
						15		2.8	
Grove Creek	Explicit	Mainstem	57	22,217	SLD08	8	1.8	1.8	
Hamilton Creek	Explicit	Georges Creek	6	2,581	SLD05	2	2.5	2.5	
Hurricane Creek	Explicit	Mainstem	50	9,585	SLD210	6	15.0	15	
Jackson Creek	Explicit	Gills Creek	3	12,291	SLD226	8	23.4	23.4	
Laurel Creek	Explicit	Reedy River	15	7,449	SLD212	4	3.8	3.8	

Table 4. Model Tributary Inputs (continued)

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Confluence Drainage Area (ac)	Headwater ID	End Mile	Drainage Area Ratio	Original Subbasin Flow Factor (unitless)	Updated Subbasin Flow Factor (unitless)
Little River	Explicit	Mainstem	128	147,256	SLD216	30	8.7	8.5	
						41		8.7	
Little Saluda River	Explicit	Mainstem	142	141,298	SLD129	27	12.2	12.2	15
Ninety-Six Creek	Explicit	Mainstem	110	91,523	SLD17	9	6.7	3.7	1
North Rabon Creek	Explicit	Rabon Creek	3	32,931	SLD15	4	1.4	1.4	
North Saluda River	Explicit	Mainstem	19	48,294	SLD200	3	13.1	3	
						23		13.1	
Oolenoy River	Explicit	South Saluda River	18	31,454	SLD203	12	11.8	11.8	
Rabon Creek	Explicit	Reedy River	65	81,324	SLD14	4	2.5	1	
						18		2.5	
Reedy River	Explicit	Mainstem	95	257,031	SLD205	27.5	28.0	13	
						59		24	
						69		26	24
South Saluda	Explicit	Mainstem	12	66,442	SLD201	2	6.7	2	3
						21		6.7	
Twelvemile Creek	Explicit	Mainstem	174	30,029	SLD223	18	11.1	11.1	
West Creek	Explicit	Clouds Creek	19	15,019	SLD222	8	3.8	3.8	
Wilson Creek	Explicit	Ninety-Six Creek	7	49,512	SLD215	11	1.5	1.5	0.7
Beaverdam Creek	Implicit	Mainstem	135	18,157	SLD162	0	1	1	
Broad River	Implicit	Mainstem	176	3,412,232	NA	10	1	0.75	0.78
Buckhead Creek	Implicit	Mainstem	227	12,559	SLD167	0	1	1	
Cane Creek	Implicit	Mainstem	99	20,426	SLD160	0	1	1	
Greenwood Local Inflow	Implicit	Mainstem	100	59,014	SLD301	1	1	0.1	0.85
Halfway Swamp Creek	Implicit	Mainstem	113	22,496	SLD161	0	1	1	
Mill Creek	Implicit	Mainstem	197	27,263	SLD165	0	1	1	
Murray Local Inflow	Implicit	Mainstem	149	153,221	SLD302	1	1	0.75	0.77
Sandy Run	Implicit	Mainstem	195	25,537	SLD164	0	1	1	
Terrapin Creek	Implicit	Mainstem	124	6,700	SLD163	0	1	1	
Toms Creek	Implicit	Cedar Creek	22	32,183	SLD166	0	1	1	
Turkey Creek	Implicit	Mainstem	88	28,989	SLD115	0	1	1	

* On the Mainstem, these are referred to as "gain/loss factors", not "subbasin flow factors".

The updated daily and monthly calibration results workbooks have been provided separately to SCDNR. Overall, a slight improvement was observed with the updated calibration, especially in cumulative flows just below Lake Greenwood and Lake Murray.

Baseline Model Updates

The adjusted sub-basin flow factors and mainstem gains/losses of the calibration model were incorporated into the baseline model. The same updates to the PT: SCE&G and West Columbia Water User objects were also incorporated into the baseline model.

SCDNR completed a review of the reservoir operating rules for both Lake Greenwood and Lake Murray. Based on this review, several adjustments to the representation of various rules were proposed. These adjustments were documented in the SCDNR memoranda dated February 23, 2018 (for Lake Murray) and March 23, 2018 (for Lake Greenwood). CDM Smith reviewed the proposed adjustments and agreed to their incorporation into the baseline model.

SWAM Code Enhancements

Several enhancements to the SWAM code have been made since the original Saluda and other basin models were completed. These enhancements have been included in the latest versions of the Saluda calibration and baseline models. They include:

- Expansion of sub-basin flow factors and mainstem gains/losses from a possible of 5 to 10 segments. Note that for the Saluda Basin, no more than 5 segments are currently being used.
- Ability to include temporally variable sub-basin flow factors. Note that for the Saluda Basin, this feature is not currently being used.
- The addition of demands summary tables that allow for a comprehensive tabular viewing of all demands, and permit limits, in the model and easy adjustments of input values for predictive simulations. These tables are accessible from the “Demands Table” and “Demands Multiplier” buttons on the main screen.
- New outputting options, including (1) the ability to turn on shortage alerts which provide a shortage warning immediately after each run, and (2) a node output summary table. These features may be turned on or off from a “Output Specs” button on the main screen.
- The ability to include conditional rules for flow targets within Instream Flow objects. This feature is included, but not likely to be used for South Carolina SWAM models.
- Code revisions which corrected minor bugs in the implementation of reservoir rules and their corresponding calculations.