Technical Memorandum

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

From: *CDM Smith*

Date: *January 2015*

Subject: *Methodology for Unimpaired Flow Development*
Saluda River Basin, South Carolina (Prepared as part of the South Carolina Surface Water Quantity Modeling Program)

1.0 Background and Objectives for Unimpaired Flows

Unimpaired Flow (UIF) describes the natural hydrology of a river basin. UIFs quantify streamflows throughout a river basin in the absence of human intervention in the river channel, such as storage, withdrawals, discharges, and return flows. From this basis, modeling and decision making can be compared with pristine conditions. This memorandum explains the methods that will be employed to develop UIFs for South Carolina's Saluda River basin. It describes data needs, methods for filling data gaps, and issues specific to the Saluda River basin. Once developed, UIFs will be input to the Simplified Water Allocation Model (SWAM) to evaluate surface water hydrology and operations throughout the basin. The UIFs for the Saluda Basin will extend from 1925-2013.

UIFs will serve two purposes:

- UIFs will be the **fundamental input** to the model at headwater nodes and tributary nodes upstream of historic management activity, representing naturally occurring water in the riverways. Current and future management practices such as storage, withdrawals, and discharges will be superimposed on the UIFs.
- UIFs will provide a **comparative basis** for model results. The impacts of current and future management practices on flow throughout the river network can be compared to the natural conditions represented by the UIFs, and decisions about relative impacts can be well informed.

UIFs are defined as the addition and subtraction of management impacts on measured, impacted flows. UIFs will be calculated on a daily timestep using Equation 1:

Unimpaired Flow *= Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Reservoir Discharge – Return Flow + Reservoir Surface Evaporation – Reservoir Surface Precipitation + Upstream change in Reservoir Storage* **(Equation 1)**

Where reservoirs with large surface areas exist upstream of streamflow gages, UIFs will account for runoff that would have occurred on land that was submerged by reservoirs at the time of streamflow readings. Direct precipitation on the reservoir surface will be replaced by this estimate in Equation 1.

2.0 Overview of the Saluda Basin

The Saluda River basin covers 3,210 square miles, 10 percent of the land area of the State, lying within portions of the Blue Ridge, Piedmont and Coastal Plain physiographic provinces (**Figure 2-1**). The basin's major watercourse, the Saluda River, begins south of the North Carolina state line and flows southeast for 150 miles before joining the Broad River to form the Congaree River near Columbia (**Figure 2-2**). At this location, the 3,800 square mile Broad River basin (South Carolina portion only) empties into the Saluda River basin. Major tributaries to the Saluda River include the Reedy River, Rabon Creek, Little River, Bush River, and Little Saluda River. The Congaree River flows for 40 miles through the upper and middle portions of the Coastal Plain before joining with the Wateree River above Lake Marion in the Santee River Basin. Major tributaries to the Congaree River include Congaree Creek, Gills Creek, Cedar Creek, Big Beaver Creek and Toms Creek.

Eighteen active Unites States Geological Survey (USGS) gaging stations monitor streamflow in the basin, including six on the Saluda River, two on the Congaree, and 10 on tributary streams. The Saluda River station near Columbia (USGS 02169000) offers the longest period of record, beginning in 1925. Average annual streamflow in the Saluda River varies from 623 cubic feet per second (cfs) in the upper reach near Greenville to 2,762 cfs in the lower reach near Columbia. Streamflows in the Blue Ridge portion of the basin are supported by both base flow and relatively high rainfall and runoff. While streamflow in the upper Saluda River is well-sustained throughout the year, it is more variable in the Piedmont region because of hydropower facilities, lower precipitation, and baseflow.

Two small water-supply reservoirs, Table Rock Reservoir and Poinsett (North Saluda) Reservoir have affected streamflow in the upper Saluda River for the entire period of record. Since the 1930s, controlled releases from Lake Murray and Lake Greenwood have influenced lower Saluda River streamflows.

Chapter 5 of The South Carolina State Water Assessment (SCDNR, 2009) describes the basin's surface water and groundwater hydrology and hydrogeology, water development and use, and water quality. A summary is also provided in An Overview of the Eight Major River Basins of South Carolina (SCDNR, 2013).

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Figure 2-1
South Carolina's Saluda River Basin and Other Major River Basins

Figure 2-2
Saluda River Basin

3.0 Water Users and Dischargers in the Saluda Basin

The South Carolina DHEC has provided information and data regarding current (active) and former (inactive) water users and dischargers throughout the state. Currently permitted or registered water users in the Saluda basin are listed in **Table 3-1**. Former users are listed in **Table 3-2**. Withdrawal locations of current and former water users are shown in **Figure 3-1** (municipal water supply, industrial and mining), **Figure 3-2** (thermoelectric power and hydropower), and **Figure 3-3** (golf courses and agriculture). All permitted or registered water users, regardless of their average daily withdrawal amount, are listed in the tables and shown on the figures. Individual withdrawals less than 100,000 gallons per day (gpd) will generally not be included in UIF calculations or in water quantity modeling; however, some aggregation of withdrawals that are less than 100,000 gpd on a particular reach may occur, and the combined amount included. In other instances, withdrawals that average less than 100,000 gpd annually, but are seasonally higher than 100,000 gpd may be included.

Current and former wastewater dischargers are listed in **Tables 3-3 and 3-4**, respectively, based on National Pollution Discharge Elimination System (NPDES) permit information. Discharge locations of current and former discharges are shown in **Figures 3-4 and 3-5**, respectively. Only active discharges that typically average over 100,000 gpd are listed in the tables and shown on Figure 3-4. Discharges that averaged less than 100,000 gpd will generally not be considered when performing UIF calculations, except when the cumulative discharge amount from facilities located on the same tributary or portion of the mainstem are deemed significant.

Table 3-1. Currently Permitted or Registered Water Users in the Saluda Basin

Map ID	User ID	Facility Name
Drinking Water Users (Figure 3-1)		
1	04WS005	BELTON-HONEA PATH WTP
2	23WS002	GREENVILE WATER L.B. STOVALL PLANT*
3	24WS001	WISE WATER TREATMENT PLANT*
4	30WS002	LAURENS WTP*
5	32WS004	CITY OF CAYCE WTP
6	32WS008	WEST COLUMBIA WTP
7	32WS052	CITY OF WEST COLUMBIA
8	36WS001	CITY OF NEWBERRY WTP
9	36WS002	NCWSA - LAKE MURRAY WTP
10	39WS001	EASLEY COMBINED UTILITIES - D.L. MOORE WTP
11	40WS002	CITY OF COLUMBIA - LAKE MURRAY WATER PLANT
12	40WS054	CITY OF COLUMBIA - CANAL WATER PLANT
13	41WS003	SCWSA - RAW WATER INTAKE

Table 3-1 (continued). Currently Permitted or Registered Water Users in the Saluda Basin

Map ID	User ID	Facility Name
Industrial & Mining Users (Figure 3-1)		
14	09IN001	DAK
15	32IN006	SHAW INDUSTRIES GROUP PLANT 8S
16	32IN051	CMC STEEL SOUTH CAROLINA
17	04MI001	VULCAN MATERIALS
18	32MI001	MARTIN MARIETTA MATERIALS - CAYCE QUARRY
Thermoelectric Users (Figure 3-2)		
1	04PT001	DUKE POWER LEE STEAM STATION
2	32PT001	SCE&G - MCMEEKIN STATION
Hydroelectric Users (Figure 3-2)		
3	04PH001	SALUDA RIVER - KENDALL, UPPER HYDRO
4	04PH002	SALUDA RIVER - KENDALL, LOWER HYDRO
5	23PH001	SALUDA RIVER - HOLIDAYS BRIDGE HYDRO
6	24PH001	SALUDA RIVER-BUZZARDS ROOST HYDRO
7	30PH001	SALUDA RIVER
8	32PH001	LAKE MURRAY-SALUDA HYDRO
9	40PH001	COLUMBIA CANAL (BROAD RIVER)
Agricultural Users (Figure 3-3)		
1	02IR011	WATSON JERROLD & SONS
2	04IR001	TWIN OAKS FARM
3	04IR002	STONEYBROOK
4	23IR026	BEECHWOOD FARM
5	32IR005	SEASE CLINTON FARMS*
6	32IR021	SEASE JAMES R FARMS INC*
7	36IR002	OVERBRIDGE FARM
8	36IR004	SATTERWHITE FARMS
9	36IR009	MAYER FARM*
10	36IR035	BUSH RIVER FARMS
11	36IR037	LESLEA FARMS*
12	37IR017	MERRITT BROS INC.*
13	40IR001	WALKER FARM
14	41IR014	TITAN FARMS*

Table 3-1 (continued). Currently Permitted or Registered Water Users in the Saluda Basin

Map ID	User ID	Facility Name
Golf Course Users (Figure 3-3)		
15	23GC004	FURMAN UNIVERSITY GOLF CLUB*
16	23GC013	CLIFFS CLUB AT VALLEY
17	23GC014	THE PRESERVE AT VERDAE
18	32GC004	COUNTRY CLUB OF LEXINGTON
19	32GC007	GOLDEN HILLS GOLF & COUNTRY CLUB
20	32GC010	PONDEROSA COUNTRY CLUB
21	39GC002	ROLLING GREEN GOLF CLUB
22	39GC003	SMITHFIELDS COUNTRY CLUB
23	39GC006	THE ROCK AT JOCASSEE GC
24	40GC002	FOREST LAKE CLUB
25	40GC005	THE MEMBERS CLUB AT WILDEWOOD*

* Denotes multiple intake locations

Table 3-2. Formerly Permitted or Registered Water Users in the Saluda Basin

Map ID	User ID	Facility Name
Drinking Water Users (Figure 3-1)		
19	04WS011S01	WILLIAMSTON TOWN OF*
20	24WS001S03	GREENWOOD CPW
21	30WS002S01	LAURENS CPW
22	32WS001S01	LEXINGTON CITY OF
23	32WS004S01	CAYCE WATER PLANT
24	40WS004S01	LAKE MURRAY WATER PLANT
25	41WS003S01	SALUDA COUNTY WATER & SEWER
Industrial & Mining Users (Figure 3-1)		
26	04IN019S01	GERBER CHILDRENSWEAR INC*
27	04IN020S01	SOFT CARE APPAREL*
28	23IN033S01	US FINISHING
29	24IN003S01	GREENWOOD MILLS INC CHALMERS PLANT
30	24IN004S01	GREENWOOD MILLS INC DURST PLANT
31	24IN006S01	GREENWOOD MILLS INC SLOAN PLANT
32	24IN007S01	GREENWOOD MILLS INC ADAMS PLANT
33	24IN009S01	GREENWOOD MILLS INC NINETY SIX PLANT
34	24IN052S01	GREENWOOD MILLS INC HARRIS PLANT
35	32IN001S01	BC COMPONENTS INC
Hydroelectric Users (Figure 3-2)		
10	23PH002	SALUDA RIVER - SALUDA HYDRO
11	04PH004	SALUDA RIVER - PIEDMONT HYDRO

* Denotes multiple intake locations

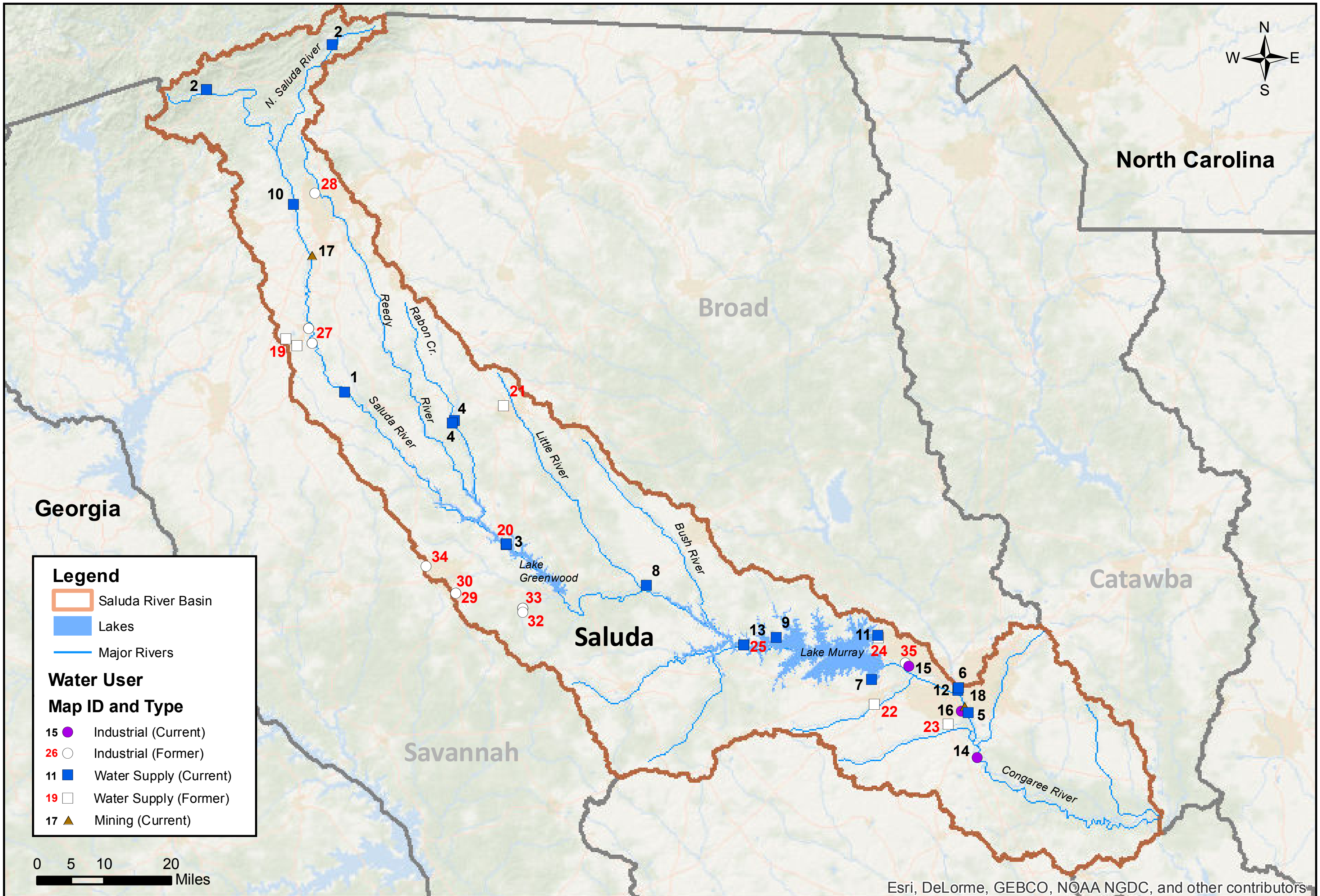

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Figure 3-1
Current and Former Municipal, Industrial, and Mining Surface Water Users

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Figure 3-2
Current and Former Thermoelectric and Hydroelectric Power Surface Water Users

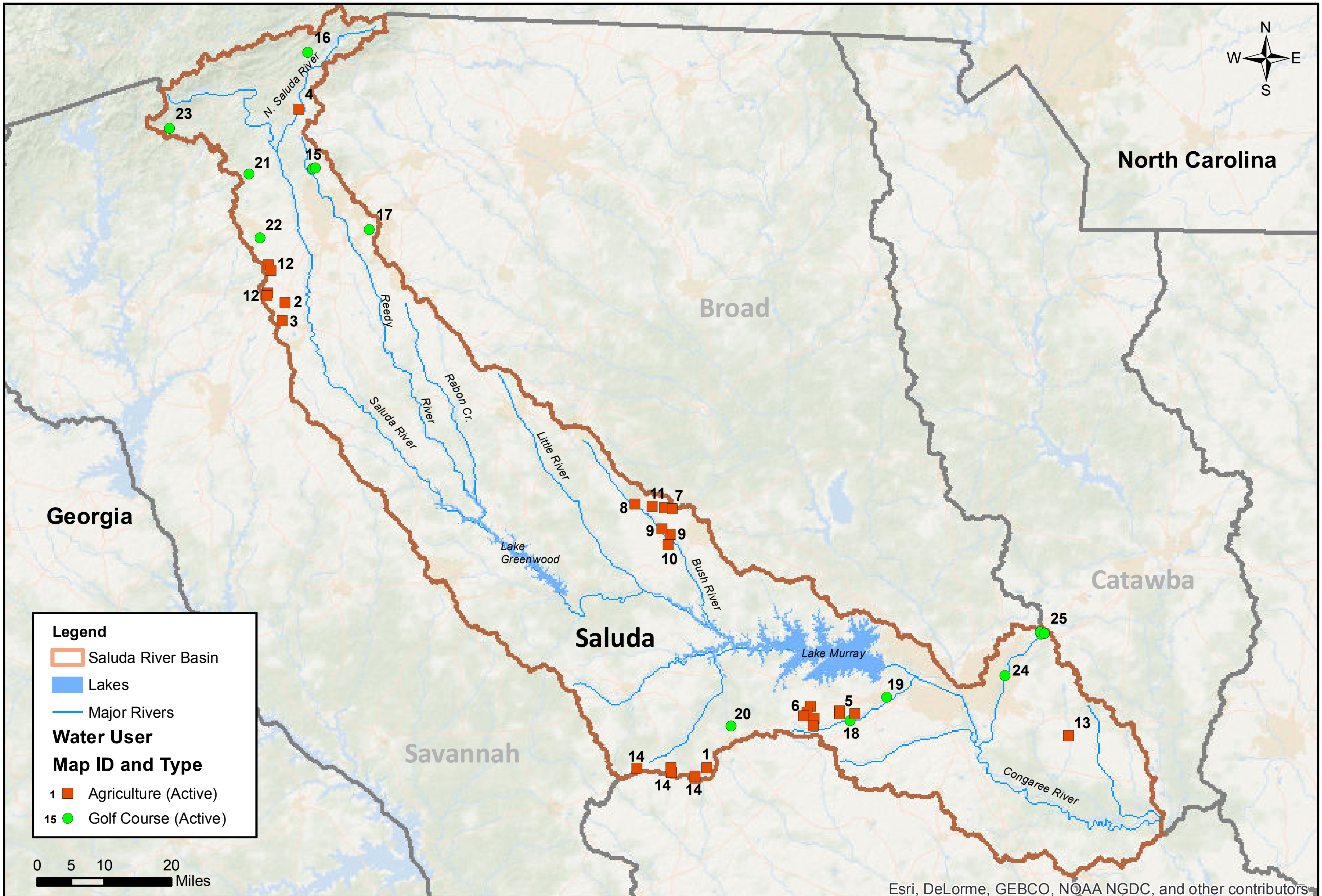

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Figure 3-3
Current Agriculture and Golf Course Surface Water Users

Table 3-3. Currently Permitted NPDES Discharges in the Saluda Basin (Average Discharge ≥100,000 gpd)

NPDES PIPE ID	Facility Name
SC0002046-004	SCE&G/MCMEEKIN STEAM STATION
SC0003191-01A	MILLIKEN/GAYLEY PLANT
SC0003191-T12	MILLIKEN/GAYLEY PLANT
SC0003191-T13	MILLIKEN/GAYLEY PLANT
SC0003191-T14	MILLIKEN/GAYLEY PLANT
SC0003191-T15	MILLIKEN/GAYLEY PLANT
SC0048356-002	CLENDENIN LUMBER COMPANY
SCG730263-000	MARTIN MARIETTA/CAYCE QUARRY
SCG730245-000	VULCAN CONST MAT/LAKESIDE
SC0033367-001	DEVRO INC/CORIA DIVISION
SC0001848-001	WESTINGHOUSE ELEC LLC/COLUMBIA
SC0045110-001	LEXINGTON CO/EDMUND LANDFILL
SC0001333-01D	EASTMAN CHEMICAL/SC OPERATIONS
SC0001333-01A	EASTMAN CHEMICAL/SC OPERATIONS
SC0001333-001	EASTMAN CHEMICAL/SC OPERATIONS
SC0001333-01F	EASTMAN CHEMICAL/SC OPERATIONS
SC0001333-01E	EASTMAN CHEMICAL/SC OPERATIONS
SC0001333-01G	EASTMAN CHEMICAL/SC OPERATIONS
SC0000701-001	SC AIR NATIONAL GUARD/MCENTIRE
SC0038865-001	EAST RICH CO PSD/GILLS CREEK
SC0020940-001	COLUMBIA/METRO PLANT
SC0026735-001	LEXINGTON/COVENTRY WOODS SD
SC0002062-001	COLUMBIA HYDROELECTRIC PROJECT
SC0027162-001	CWS/WATERGATE DEVELOPMENT
SC0022381-001	SALUDA, TOWN OF
SC0032743-001	BUSH RIVER UTILITIES
SC0035564-001	CWS/I-20 REGIONAL
SC0029475-001	WOODLAND HILLS WEST SD
SC0029483-001	ALPINE UTILITIES/STOOP CREEK
SC0003557-001	SHAW INDUSTRIES GROUP/COLUMBIA
SC0003557-003	SHAW INDUSTRIES GROUP/COLUMBIA
SC0003557-002	SHAW INDUSTRIES GROUP/COLUMBIA
SC0036137-001	CWS/FRIARSGATE SD
SC0002046-005	SCE&G/MCMEEKIN STEAM STATION
SC0002046-002	SCE&G/MCMEEKIN STEAM STATION
SC0002046-003	SCE&G/MCMEEKIN STEAM STATION

Table 3-3 (continued). Currently Permitted NPDES Discharges in the Saluda Basin (Average Discharge ≥100,000 gpd)

NPDES PIPE ID	Facility Name
SC0002071-005	SCE&G/SALUDA HYDRO STATION
SC0002071-008	SCE&G/SALUDA HYDRO STATION
SC0002046-001	SCE&G/MCMEEKIN STEAM STATION
SC0036048-001	NINETY SIX WWTF
SC0021709-001	GREENWOOD/WILSON CREEK WWTF
SC0024490-001	NEWBERRY/BUSH RIVER WWTF
SC0020214-001	WARE SHOALS/DAIRY STREET
SC0020702-001	LAURENS COMM OF PW/LAURENS
SC0048534-001	INGERSOLL RAND/G.W. RECOVERY SYS
SC0045896-002	BELTON/DUCWORTH (SALUDA)
SC0045896-003	BELTON/DUCWORTH (SALUDA)
SC0045896-001	BELTON/DUCWORTH (SALUDA)
SC0002291-001	DUKE ENERGY/LEE STEAM STATION
SC0002291-003	DUKE ENERGY/LEE STEAM STATION
SC0002291-002	DUKE ENERGY/LEE STEAM STATION
SC0002291-004	DUKE ENERGY/LEE STEAM STATION
SC0025194-001	WEST PELZER WWTF
SC0048470-001	WCRSA/PIEDMONT REGIONAL WWTP
SC0039853-001	EASLEY/MIDDLE BRANCH WWTP
SC0041211-001	WCRSA/MAULDIN ROAD
SC0023043-001	EASLEY/GEORGES CREEK LAGOON
SC0026883-001	WCRSA/MARIETTA WWTP
SC0003191-001	MILLIKEN/GAYLEY PLANT
SC0003191-T11	MILLIKEN/GAYLEY PLANT
SC0048356-001	CLENDENIN LUMBER COMPANY
SC0024147-001	CAYCE WWTF
SC0048429-001	AIR PRODUCTS & CHEMICALS, INC

Table 3-4. Formerly Permitted NPDES Discharges in the Saluda Basin (Average Discharge ≥100,000 gpd)

NPDES PIPE ID	Facility Name
SC0001333-01C	EASTMAN CHEMICAL/SC OPERATIONS
SC0041432-001	EASTOVER/SOLOMON STREET WWTP
SC0031402-001	PINEY GROVE UTIL/LLOYDWOOD SD
SC0029122-001	GENTRY'S POULTRY CO, INC
SC0030911-001	STARLITE S/D
SC0023680-001	LEX. CO. JOINT/OLD BARNWELL RD
SC0040789-001	LEX. CO. JOINT/TWO NOTCH RD.
SC0004286-003	SQUARE D COMPANY
SC0040924-001	CAYCE, CITY OF WTP
SC0039225-001	SC FIRE ACADEMY
SC0025585-001	AMICK PROCESSING INC
SC0030945-001	VANARSDALE SD/MIDLANDS UTILITY
SC0043541-001	LEXINGTON/WHITEFORD SD WWTP
SC0003425-001	BC COMPONENTS INC
SC0002071-001	SCE&G/SALUDA HYDRO STATION
SC0002071-003	SCE&G/SALUDA HYDRO STATION
SC0002071-002	SCE&G/SALUDA HYDRO STATION
SC0003425-002	BC COMPONENTS INC
SC0040860-001	NEWBERRY CO W&SA/PLANT #1
SC0022730-001	INTERNATIONAL PAPER/SILVERSTRT
SC0020672-001	HONEA PATH/CHIQUOLA MILL
SC0040827-001	BELTON-HONEA PATH WATER AUTH
SC0020745-001	BELTON/DUCWORTH PLANT
SC0026123-001	EXXON/BELTON PIPELINE TERMINAL
SC0043010-001	SOUTHEASTERN BULK FUEL TERMINA
SC0025976-001	WILLIAMSTON/BIG CREEK EAST
SC0029343-001	SC DEPT CORR/PERRY CORR INST
SC0037460-001	WCRSA/LAKESIDE PLANT
SC0037451-001	WCRSA/PARKER PLANT
SC0034568-001	WCRSA/SALUDA RIVER PLANT

Figure 3-4
Active NPDES Discharges

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Figure 3-5
Inactive NPDES Discharges

4.0 Overview of Methodology

4.1 UIF Process Diagram

Figure 4-1 illustrates the UIF development process. The process involves adding and subtracting known historical management practices from measured streamflow records. In doing so, the impacts of human intervention on the flow in the river can be removed from the historical flow records. Water is added to existing streamflow estimates to account for historic withdrawals and subtracted out to account for historic discharges, and the timing of flows is adjusted to account for impoundment of rivers.

The process can be described in four steps. Each is summarized below and presented in detail in **Section 5.**

Step 1: Data Collection. This step includes collection of available streamflow records, withdrawal records, discharge records, operational records at dams, impoundment features, etc. The duration of the longest available, reliable streamflow record determines the period of record for the basin. Records from other gages are extended to match this duration (described in **Section 5.4**).

Step 2: Unregulated Flow. Unregulated flows represent a progression in the development of UIFs. Unregulated flow refers to flow in which the timing of flow has not been altered by impoundment. The effects of storage differ from those of withdrawals and discharges because impoundment affects not only the volume of water available, but also the timing at which it flows downstream. For this reason, it is useful to compute unregulated flows first, in which just the timing of flow releases downstream is adjusted to what it would have been in an unimpounded state. UIFs can then be computed from these values, as the remainder of the UIF calculation focuses on flow volume. *It may be determined that a more practical approach to disaggregating reservoir impacts includes ALL impacts of the impoundments at once; volume and timing (reservoirs affect the timing of flow by holding water and releasing it according to various schedules, and also the volume of water in the basin, because water evaporates and collects differently on the reservoir surface than it would on a free-flowing stream). In this case, Unregulated Flows would include adjustment for timing of releases and changes in water volume due to the effects of impoundment evaporation, direct precipitation, withdrawals from the impoundment, and discharges to the impoundment. Determination of which method is more effective or reliable will be made during the Saluda basin Pilot Study.*

There is an important difference between the alteration to flow timing associated with impounding a river (corrected with unregulated flows), and the timing of flow due to its traverse through the river channel (hydraulic time lags). Currently, it is not expected that hydraulic time lags (also referred to as "travel time") will be necessary for these UIF data sets for the following reasons:

a. At a monthly timestep, the time lags would be inconsequential.
b. At a daily timestep, for long-term simulation, the key metric is frequency of various flow levels and water availability, which would be preserved over time even if shifted by several days.

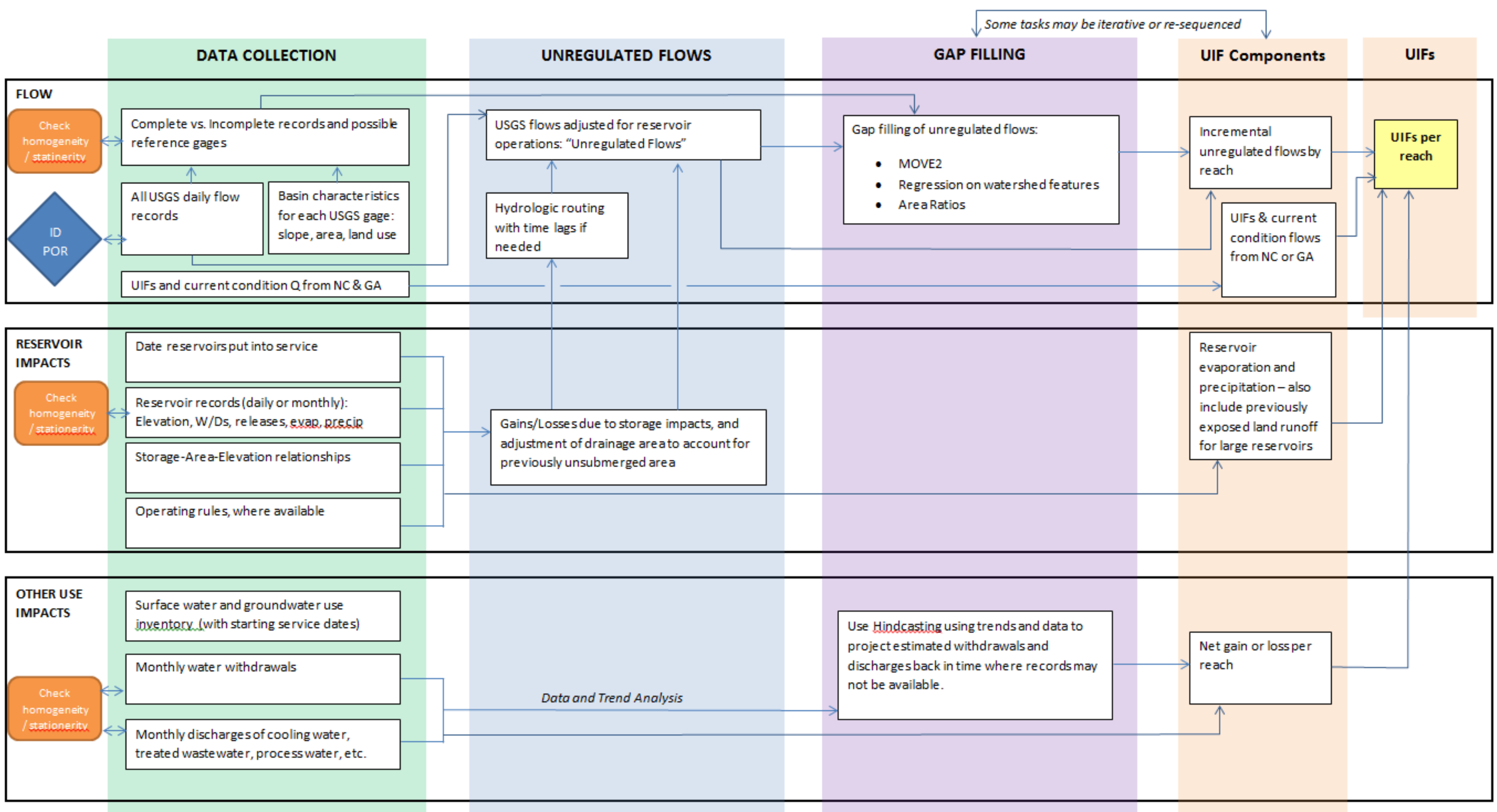

Figure 4-1. Unimpaired Flow Process Diagram

c. Accurate prediction of hydraulic time lags requires channel bathymetry and iterative hydraulic routing equations (HEC-RAS, for example).
d. For UIFs, the observed lags (albeit for impaired flows) are already resident within the USGS streamflow records, so the UIFs will have some of the lag already built in.

If special circumstances warrant rough estimation of hydraulic time lags, flow-based lag equations from USGS could be considered. Note that time lags associated specifically with return flows, e.g. via groundwater, are able to be simulated in SWAM.

*Steps 3 and 4 are presented sequentially in **Figure 4-1**, but may be conducted in either order, and possibly with iteration. It may be preferable to compute UIFs to the greatest extent possible and then fill data gaps using trends observed in documentable UIFs, or it may be preferable to first fill gaps in historic data and then compute uninterrupted UIFs. These decisions will be made on a case-by-case basis, and will likely depend primarily on data availability (see additional detail in **Step 3: Gap Filling**, below).*

Step 3: Gap Filling. As stated under Step 1, the period of record for the basin will begin with the first date that any USGS gage began recording streamflow. All other records will be synthetically extended back to this date if measurements are not available. Likewise, measurement gaps will be filled in synthetically. Two types of synthetic data will be developed: unregulated flow (or in certain cases as noted above, UIFs themselves if these are computed first and then extended/filled), and historic withdrawals and discharges. Hydrologic flows, either unregulated or unimpaired, will be computed using one of a variety of alternative statistical approaches described in **Section 5.4**. Historical management practices, such as withdrawals and discharges, will be filled in to the greatest extent possible with anecdotal information from relevant utilities, supplemented with statistical hindcasting based largely on population.

Where practical, gap filling of the hydrologic flow should occur after UIFs are developed as fully as they can be. This will help preserve the statistical integrity of natural hydrologic relationships. However, the approach is illustrated as flexible for two reasons:

- **Regional Consistency:** It appears that Georgia may have applied some level of gap filling on unregulated flows prior to developing unimpaired flows (see Figure 4-1 of *REVIEW DRAFT: Synopsis of Surface Water Availability Assessment, Georgia Statewide Water Management Plan, Section 4, March 2010*), and we will be using those data sets for the Savannah River Basin.

- **Case-by-Case Decisions:** For basins in which UIFs will be newly developed as part of this study, some flexibility may be important because the timing of when gap filling can be most effective may depend on the type of data sets being filled.

Unregulated flows correct flow measurements for the *timing* of flow, as affected by impoundment and scheduled releases of water downstream. As such, there may be needs to fill in gaps in these datasets prior to fully developing the UIFs, which add the impacts of *volume* to water management (withdrawals, discharges, evaporation, etc.).

Also, there may be some operational flows that require hind-casting to characterize their impacts over time. It may be beneficial to do this prior to developing the UIFs. In other cases, it may simply be advantageous to extend USGS records synthetically if they can be shown to correlate well with other data so that UIFs can be developed from data sets that are as comprehensive as possible. Not all of the reasons for these decisions are foreseeable at this time, and some will be case-by-case decisions made in collaboration with DNR/DHEC.

For the pure hydrologic timeseries, however, the project team will endeavor to compute UIFs to the greatest extent possible and then fill in gaps *in the UIFs* using statistical techniques. The flexible approach outlined above facilitates the filling in of some operational gaps and gaps in unregulated flows along the way if the project team (collectively with DNR/DHEC) deems it to be necessary or advantageous to create the most comprehensive datasets with which to compute the UIFs.

Step 4 – Unimpaired Flow Calculation: UIFs will be computed following Equation 1. Additionally, where reservoirs with large surface areas exist upstream of streamflow gages, UIFs will account for runoff that would have occurred on land that was submerged by reservoirs at the time of streamflow readings. Direct precipitation on the reservoir surface will be replaced by this estimate in Equation 1.

4.2 Locations of UIFs

UIFs will be computed at two types of locations throughout the basin:

- Any site where a USGS gage station has recorded streamflow measurements will have calculated UIFs (See **Figure 4-2**). This is because the USGS records provide a necessary "footing" with which to begin the calculation per Equation 1. It will allow model development to proceed with UIFs at upstream sites as input, and at downstream sites for comparative use, or as input of incremental hydrologic flows:
    - Where a gage is located upstream of historical management activity, it will be included in the model as direct input.
    - Where a gage is located on a tributary downstream of a management activity, the management activity will be removed in the calculations and, if necessary, the record can be scaled according to drainage area to estimate an upstream boundary condition UIF for that tributary.
    - Where a gage is located downstream of a management activity on a river mainstem, it will available for comparative purposes, and also used to calibrate reach gains and losses (see Section 4.3 below) or explicit incremental unimpaired flows. Simulated flow at these locations will be computed by the model itself based on upstream UIFs and subsequent river management.

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Figure 4-2
Active and Inactive USGS Streamflow Gaging Stations

- Any tributary that will be explicitly included in the model will require input of unimpaired headwater boundary flow (Sections 4 and 8 of the November 2014 South Carolina Surface Water Quantity Models Modeling Plan discuss explicit and implicit tributaries). If USGS gage data is unavailable for an explicitly modeled tributary, a synthetic UIF will be developed using reference gages and statistical methods discussed in **Section 5.4**.

4.3 Gains and Losses Between UIF Nodes

UIFs will be computed for each USGS streamgage in the basin but, as discussed, not all UIFs will be used for model input. UIFs will be used for model inputs at headwater locations, and available in the river network to compare against computed flows as they are affected by storage, withdrawals, and discharges, and to use for model calibration.

During the subsequent model development and calibration process (after the UIFs are input into the model as headwater inputs), there will be reaches in which hydrologic gains or losses are computed. Gains or losses can be simulated in SWAM in one of two ways. As a first option, the gain/loss function available in SWAM for each tributary object could be used and parameterized according to user-specified percent increases (or decreases) per unit length of stream reach. Alternatively, a timeseries calculated in a similar way to the UIFs themselves (using the difference between two UIFs, and simulated as an inflow or withdrawal) could be specified in SWAM using separate tributary or user objects. Note that for losing streams, the modeled losses would not return elsewhere in the model network, and would be assumed to be lost from the river system.

While it is not expected that losing streams are prevalent in the Saluda Basin, it is understood that they are present elsewhere in the state (the Edisto Basin, for example), and so a general methodology for losses is discussed here. If a downstream gage indicates lower flow than an upstream gage (both unimpaired), this would indicate that the reach in between loses water to the ground, and the REACH GAIN/LOSS function in SWAM would be calibrated accordingly. Alternatively, the difference between the daily flows could be added as a withdrawal from the river using a user object (and not returned elsewhere).

Another possibility that may arise is that an upstream flood may not result in downstream flow immediately (due to travel time). In a normally gaining river, simply subtracting the higher upstream flow from the lower downstream flow that hasn't received the flood waters yet could result in negative values. This is unlikely in the Saluda Basin because it is well populated with USGS gages, so the distance between UIF data sets will not be so significant that a localized flood would not be observed until the next day at the downstream gage. However, if this is observed, we will apply discretionary correction factors or time shifts to reduce the impact of the perceived time lag and help ensure that the reach does not lose water simply because of the hydraulic routing of floods.

5.0 Unimpaired Flow Methodology

The UIF methodology follows the diagram previously shown in Figure 4-1. In addition to discussion of the period of record, each block (from left to right) is discussed in detail below.

5.1 Period of Record

While UIF estimates will begin in 1925, many local streamgages began operation in the 1980s and 1990s. The records for all gages that started tracking flow after 1925 will be extended using gap filling techniques. Although much of the UIFs will thus be based on estimated flows, the value of a lengthy record, even if approximate, is that DNR, DHEC, and other users can evaluate results over a large range of hydrologic and climate conditions. **Figure 5-1** depicts the length and timing of records available for all USGS gages in the Saluda basin. **Table 5-1** lists each gage.

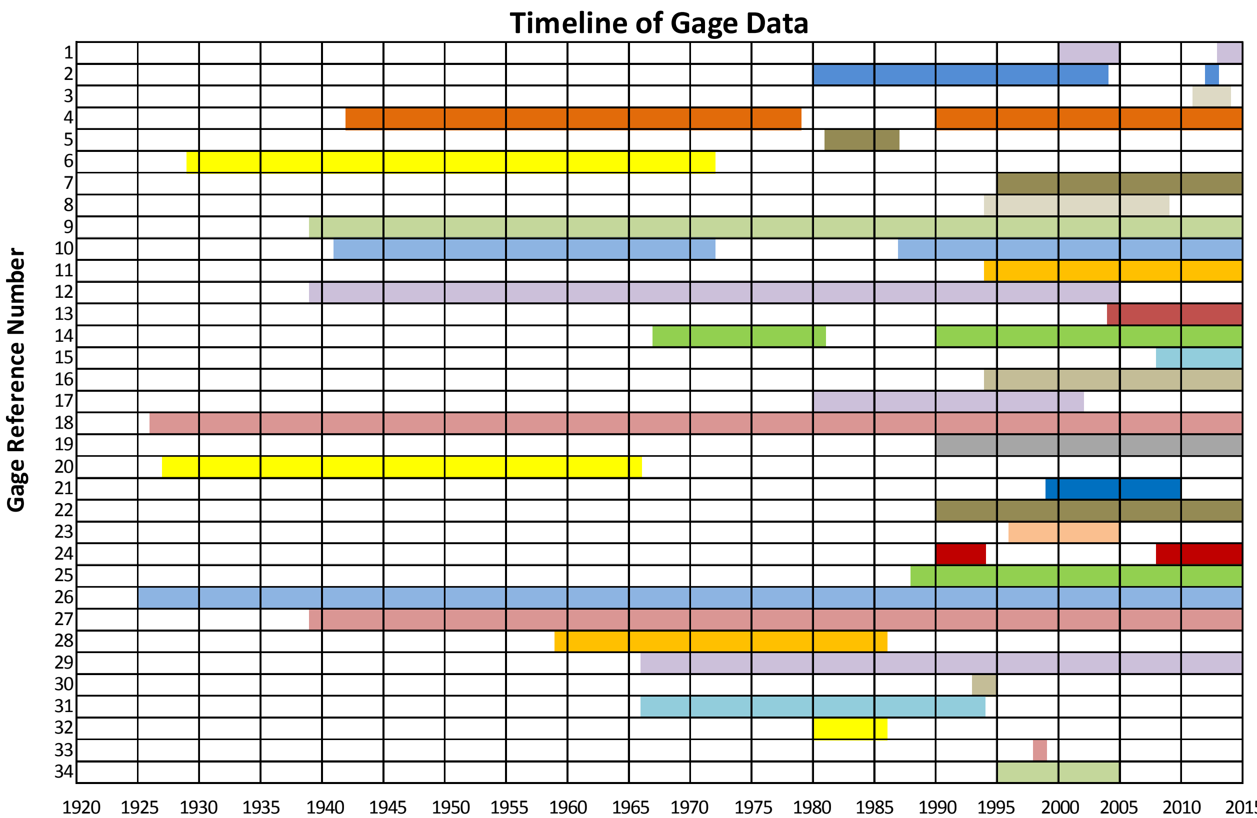

Figure 5-1. Period of record for USGS gages in the Saluda Basin

Table 5-1. USGS gages in the Saluda Basin

USGS Number	Description	Period of Record						Gage ID
		From:	To:	From:	To:	From:	To:	
02162290	SOUTH SALUDA RIVER NEAR CLEVELAND	Feb-2000	Sep-2005	Nov-2013	Jan-2014			1
02162350	MIDDLE SALUDA RIVER NEAR CLEVELAND	Oct-1980	Sep-2003	Jul-2012	Oct-2013			2
021623975	NORTH SALUDA RIVER ABOVE SLATER	Jan-2011	Jan-2013					3
02162500	SALUDA RIVER NEAR GREENVILLE	Jan-1942	Sep-1978	Feb-1990	Aug-2014			4
02162525	HAMILTON CREEK (RD 135) NR EASLEY	Jan-1981	Sep-1986					5
02163000	SALUDA RIVER NEAR PELZER	Oct-1929	Sep-1971					6
02163001	SALUDA RIVER NEAR WILLIAMSTON	Apr-1995	Aug-2014					7
021630967	GROVE CREEK NEAR PIEDMONT	Jul-1994	Nov-2008					8
02163500	SALUDA RIVER NEAR WARE SHOALS	Mar-1939	Aug-2014					9
02164000	REEDY RIVER NEAR GREENVILLE	Nov-1941	Sep-1971	Jun-1987	Aug-2014			10
02164110	REEDY RIVER ABOVE FORK SHOALS	Sep-1993	Aug-2014					11
02165000	REEDY RIVER NEAR WARE SHOALS	Apr-1939	Sep-2004					12
021650905	REEDY RIVER NEAR WATERLOO	Nov-2004	Aug-2014					13
02165200	SOUTH RABON CREEK NEAR GRAY COURT	Jan-1967	Sep-1981	May-1990	Aug-2014			14
021652801	NORTH RABON CREEK NEAR HICKORY TAVERN	Aug-2008	Aug-2014					15
02166501	LAKE GREENWOOD TAILRACE NR CHAPPELLS	Nov-1994	Apr-1995	Oct-1996	Aug-2014			16
02166970	NINETY-SIX CREEK NR NINETY-SIX	Oct-1980	Sep-2001					17
02167000	SALUDA RIVER AT CHAPPELLS	Oct-1926	Aug-2014					18
02167450	LITTLE RIVER NR SILVERSTREET	Mar-1990	Aug-2014					19
02167500	SALUDA RIVER NEAR SILVERSTREET	Jan-1927	Sep-1965					20
02167563	BUSH RIVER AT NEWBERRY	Mar-1999	Jun-2009					21
02167582	BUSH RIVER NR PROSPERITY	Feb-1990	Aug-2014					22
021677037	LITTLE SALUDA RIVER AT SALUDA	Oct-1996	Sep-2001	Nov-2001	May-2002	Oct-2002	Sep-2004	23
02167705	LITTLE SALUDA RIVER NEAR SALUDA	Mar-1990	Jul-1993	Jul-2008	Jan-2009	Apr-2009	Aug-2014	24
02168504	SALUDA RIVER BELOW LK MURRAY DAM NR COLUMBIA	Oct-1988	Aug-2014					25

USGS Number	Description	Period of Record						Gage ID
		From:	To:	From:	To:	From:	To:	
02169000	SALUDA RIVER NEAR COLUMBIA	Aug-1925	Aug-2014					26
02169500	CONGAREE RIVER AT COLUMBIA	Oct-1939	Aug-2014					27
02169550	CONGAREE CREEK AT CAYCE	Oct-1959	Sep-1980					28
02169570	GILLS CREEK AT COLUMBIA	Oct-1966	Aug-2014					29
02169625	CONGAREE RIVER AT CONGAREE NP NEAR GADSDEN	May-1993	Sep-1994					30
02169630	BIG BEAVER CREEK NEAR ST. MATTHEWS	Jul-1966	Sep-1993					31
02169670	CEDAR CREEK BELOW MYERS CREEK NR HOPKINS	Nov-1980	Sep-1985					32
02162700	MIDDLE BRANCH NEAR EASLEY	May-1998	Sep-1998					33
02167557	BUSH RIVER AT JOANNA	June-1995	Sep-2005					34

5.2 Data Needs and Collection

Data needs, discussion of how the data will be used, and potential sources of the data are presented in **Table 5-2**. The majority of data needed are historic records. The categories of data needed include flow, reservoir impacts, and other use impacts. These categories partially overlap. Additional information that needs to be collected as part of developing the SWAM model may also be used to assist with gap filling. Each main category is briefly discussed below.

<u>Flow</u>: All available records of streamflow in the basin need to be gathered, whether they are complete or not. Incomplete records will be filled using the gap filling techniques discussed in **Section 5.4**. The gap filling technique includes correlation with other stream gage records, precipitation data, and evaporation data, which may include gages from outside the basin. As UIF estimates are being prepared across South Carolina, flow data will be gathered from stations statewide to determine the nearest gages from which to correlate flows.

<u>Reservoir Impacts</u>: Reservoir levels and/or discharges are needed to estimate unregulated flows. A mass balance is performed to convert changes in reservoir storage to an unregulated flow in the stream. This calculation is discussed in **Section 5.3**. Reservoir operating rules and records may be used to assist with gap filling.

<u>Other Use Impacts:</u> Other impacts include water users, water dischargers, and groundwater withdrawals. Current and historical water users and dischargers are listed in **Section 3**. While daily withdrawal and discharge data would be ideal, such data is unlikely to be available in most cases. Monthly data should be available for most, but the period of record for such data is limited as such data was not required to be maintained before 2000. Water users and dischargers will be contacted

Table 5-2. Data Needs

Data Category	Data	Use(s)	Potential Sources	Comments
Flow	USGS Stream gage Records	UIFs for every available gage	USGS	Provides opportunity to calculate incremental flows between gages.
	Unimpaired Flow Estimates, Broad River	Direct UIF input	CDM Smith	Broad River is tributary to Saluda basin
	North Carolina Unimpaired Flow Estimates		North Carolina	For Broad River basin. USGS gage records near the state line should capture current managed flow conditions from NC. Records may require updating through 2013.
	Slope, contributing area, and land use for each USGS gage	Correlation for flow estimation	USGS, GIS	USGS provides contributing area, GIS tools and data used to determine slope and land use.
Flow and Reservoir Impacts	Historic Precipitation (Daily)	Reservoir surface precipitation, correlation for flow estimation	US Historical Climatology Network (USHCN)	30 South Carolina sites
	Historic Pan Evaporation (Monthly)	Reservoir surface evaporation, correlation for flow estimation	DNR	13 sites with data from 1948
Reservoir Impacts	Historic Air Temperature (Daily or Monthly)	Extend evaporation records using temperature as independent variable	National Climatic Data Center (NCDC)	
	Reservoir Operations and Levels	Compute change in volume to develop unregulated flows	Dam operators, Federal Energy Regulatory Commission (FERC) Licenses, USACE, etc.	Includes date reservoir put in service
	Reservoir Storage-Area-Elevation Curves	Compute area for direct rainfall and evaporation and convert changes in reservoir level to volume		
	Spillway Rating Curves	Compute volume spilled to develop unregulated flows		
	Reservoir Operating Rules	Compute undocumented historic releases or other changes in reservoir storage		Includes FERC licenses for hydroelectric dams
Other Use Impacts	Historical M&I Water Withdrawals	Compute net gain or loss per reach	DHEC databases, Records and anecdotal information from individual users/ permittees	Overlap with UIF data collection and development, but useful in confirming models' ability to recreate historic flows as measured by USGS stream gages.
	Historic Ag Water Withdrawals			
	Historic Industrial / Energy Water Withdrawals			
	Historic Discharges			
	Historic Groundwater Use			
	Historic Interbasin Transfers		DNR/DHEC	
	Historic Population	Estimate historical withdrawals absent data	US Census	Surrogate for actual withdrawal data

Data Category	Data	Use(s)	Potential Sources	Comments
Potential Use for Gap Filling	Instream Flow Requirements	Estimate historical reservoir releases	DNR/DHEC	All data gathered as part of model development, but may be utilized for gap filling of UIFs
	Drought Management Requirements	Estimate changes in water user withdrawals given hydrologic conditions		
	Contingency Plan Requirements			
	Spatially distributed acreage of crop types	Estimate historical agricultural water demand and return flows		

by phone to collect additional information on historic usage/discharge patterns to extend the records. Details on the information that will be requested are presented in **Attachment A**.

5.3 Unregulated Flow Estimation

Unregulated flows are flows with the timing impacts from reservoirs removed. Unregulated flows are estimated by computing stream flow from changes in reservoir storage. All components affecting change in storage in a reservoir considered in this study are shown as a mass balance in **Figure 5-2**. The components that represent regulated flow are indicated in orange while other components that represent volume components of the reservoir mass balance are shown in gray. Other losses from a reservoir not shown in Figure 5-2 include dam seepage and ground infiltration. While these data may not be available for the reservoirs in the Saluda basin, available rate estimates can be included in the mass balance.

Equation 2 derives the change in storage from the mass balance of only the regulated flow components in **Figure 5-2**:

$$\text{Change in Storage} = \text{Stream Inflow} - \text{Spills or Releases} \qquad \textbf{(Equation 2)}$$

The change in reservoir storage will be derived from historic reservoir level records as shown below:

$$\text{Change in Storage} = (\text{Reservoir Level}_{(n)} - \text{Reservoir Level}_{(n-1)}) * \text{Reservoir Area} \qquad \textbf{(Equation 3)}$$

where n represents the time step. Reservoir area will be derived from reservoir level records using Storage-Area-Elevation relationship curves. Using the two above equations to solve for stream inflow (i.e. unregulated flow) produces the following equation:

$$\text{Stream Inflow} = (\text{Reservoir Level}_{(n)} - \text{Reservoir Level}_{(n-1)})\ \text{Reservoir Area} +$$

$$\text{Spills or Releases} = \text{Unregulated Flow} \qquad \textbf{(Equation 4)}$$

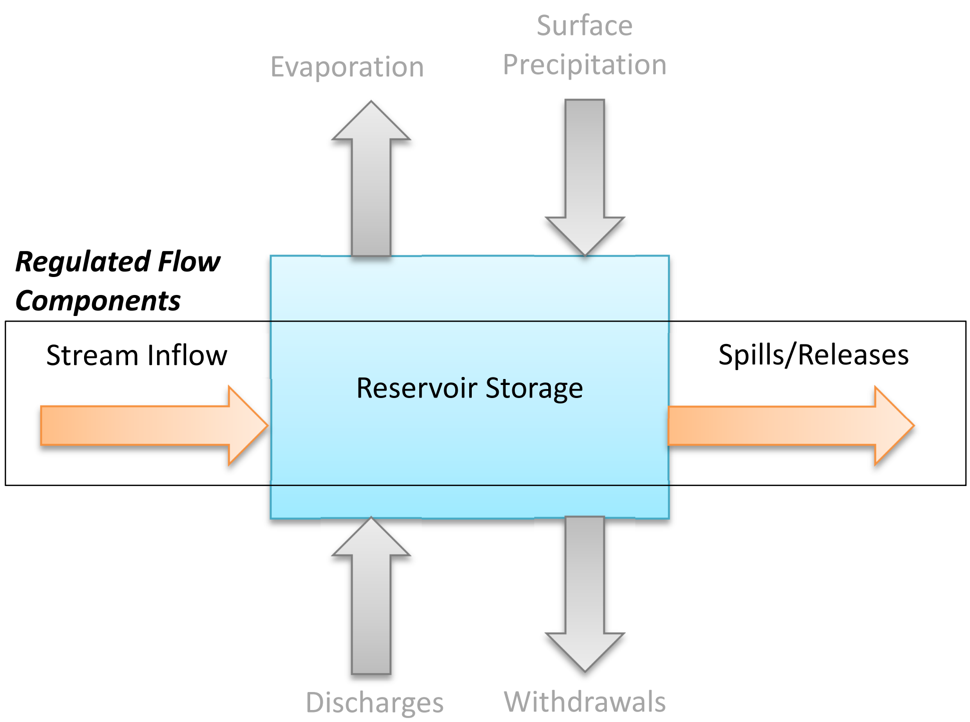

Figure 5-2. Reservoir Mass Balance

It may be determined that a more practical approach to disaggregating reservoir impacts includes ALL impacts of the reservoir impoundments at once; volume and timing. In this case, the Unregulated Flows would include adjustment for the timing of releases and the changes in water volume due to the effects of impoundment evaporation, direct precipitation, withdrawals from the impoundment, and discharges to the impoundment. Determination of which method is more effective or reliable will be made during the Saluda basin Pilot Study.

5.4 Gap Filling Techniques

As stated in **Section 4**, the period of record for the basin will begin with the first date that any USGS gage began recording streamflow. Hydrologic records will be extended, filled, or created for sites in the model that meet one or more of the following criteria:

- Sites with USGS gages that began recording after the earliest start date in the basin
- Sites with USGS gages that have gaps in their records
- Ungaged tributaries that will be modeled explicitly in SWAM (Sections 4 and 8 of the November 2014 *South Carolina Surface Water Quantity Models Modeling Plan* discuss explicit and implicit tributaries)

As noted, some of the gap filling and record extension techniques may be applied to Unregulated Flows, and in other cases these may be applied to Unimpaired Flows. Decisions will be largely driven by available data, and efforts to avoid accumulation of uncertainty if possible. Additionally, management practices that have been recorded (withdrawals, discharges, etc.) will likely require record extension using hindcasting approaches. The various techniques to fill in data gaps are described below in **Sections 5.4.1** through **5.4.5**. Decisions on which method to use will be made on a case-by-case basis, based on available data, confidence in the data, and the nature of the incomplete data. In some cases, it may be best to combine methods, or apply more than one for validation purposes.

5.4.1 Streamflow Transposition by Area Ratios *(For extension, gap filling, or full synthesis of historical flows in ungaged or partially gaged basins)*

Where good correlation exists between overlapping periods of streamflow records, or where hydrologic and physical features (drainage area, land use, slope) of an ungaged or incompletely gaged basin correlate well with a nearby gaged reference basin, the correlated reference gage will be used to generate a new synthetic timeseries of flows, or to fill gaps in an existing dataset. Basin area ratios will be applied, and possibly adjusted by correction factors from empirical observations of overlapping periods of record, or literature values related to the magnitude of difference in the area (which may have more of an influence on daily flows than on monthly flows). Reference gages will selected based on proximity to the ungaged or incompletely gaged basin, as well as similarities (to the greatest extent practical based on data availability) in drainage basin land use, size, and slope.

5.4.2 MOVE.2 Technique *(For basins with partial streamflow records)*

Periods of missing streamflow data can be filled based on flow in nearby measured streams using the Maintenance of Variance Extension (MOVE.2) technique (Hirsch, 1982)[1] MOVE.2 is a statistical flow record extension technique that fills missing data in a streamflow record (y) based on flow in a nearby reference stream gage (x) while preserving the statistics in basin *y*. The method has been employed in other U.S. statewide water plans, such as for the Oklahoma Comprehensive Water Plan 2011 Update. The technique shown in the equation below uses the mean (m) and standard deviation (s) of the two streams (the index 'i' is the daily timestep).

$$y_i = m_y + \frac{s_y}{s_x} \cdot (x_i - m_x) \qquad \textbf{(Equation 5)}$$

The selection of an appropriate reference gage will be an important aspect of applying MOVE.2. It is preferred that only nearby reference gages be used for any given basin. Additionally, reference basins will be selected so that basin size, land use, and slope match the characteristics of the basin whose record is to be extended as closely and as practically as possible, based in large part on data

[1] R.M. Hirsch, 1982: *A Comparison of Four Streamflow Record Extension Techniques.* Water Resources Research, Volume 18, Issue 4, pages 1081–1088, August 1982.

availability. Any overlapping data will be checked for reasonable correlation before final selection of reference gages.

Also, if statistics for the reference basin differ substantially between the periods for which the basin with data gaps has data and is missing data, a determination will be made as to whether to apply statistics for the entire record or just periods over which the statistics are relatively stable, and which include the gaps to fill.

5.4.3 Regression on Overlapping Flow Periods, Precipitation, Temperature, and Watershed Features *(for basins with partial records)*

In some cases, area transposition is not robust enough to cover the full range of hydrologic conditions in a basin, especially on a daily basis. In these cases, regression equations can be developed based on overlapping periods of streamflow record with a longer reference gage, provided there is good correlation between the two. Features such as basin size, level of development, and basin slope may be useful as additional predictive variables for streamflow. It is unlikely that precipitation or temperature will be highly correlated with streamflow on a daily basis, but these records can also be checked for correlation and included in multivariate regression analysis if statistically valid correlation can be demonstrated.

5.4.4 Historical Operating Logs: (For basins with substantial monthly operating logs at reservoirs)

Where sufficient operational data are available at reservoirs, water balance calculations can provide reliable estimates of net hydrologic flow into or out of a reservoir. Required data include monthly spills, releases/withdrawals, and changes in water surface elevation or storage. If those data are available, the water balance equation for each timestep (Equation 6) can be solved for net hydrologic inflow (Equation 7).

Change in Storage = ***Stream Inflow*** *–Withdrawals – Spills – Releases – Evaporation + Surface Precipitation* **(Equation 6)**

Stream Inflow = *Change in Storage +Withdrawals + Spills + Releases + Evaporation - Surface Precipitation* **(Equation 7)**

5.4.5 Hindcasting Historical Operations *(For basins with undocumented operations that affect streamflow)*

This method refers to the operational components of UIFs, as opposed to the hydrologic components discussed above. Currently, the project team is contacting water users throughout the Saluda basin to augment historical information on operating practices (withdrawals, discharges, impoundment management, etc.) that may not be recorded in databases extending back as far as the USGS gage records. Based on information collected (some of which is likely to be anecdotal), historical undocumented operations can be estimated using start dates, trend analysis for hindcasting, relationships to population, etc. These synthetic operating records can then be used in UIF calculation.

5.5 Unimpaired Flow Calculations

Once unregulated flows are developed and data gaps are filled, UIFs can be developed by removing the impacts of changes in volume. This includes evaporation and precipitation impacts due to reservoirs and withdrawals and/or discharges from water users along a river reach along a reservoir. Evaporation is a loss from the reservoir that will become a gain to the calculated UIF while precipitation that falls directly over the reservoir is a gain that will become a loss to the UIF. These two components may be combined as net evaporation. For larger reservoirs it will also be necessary to account for runoff that would have occurred on land that is now submerged as a gain to the UIFs. Discharges and withdrawals come from one or more of the water users and dischargers listed in **Section 3**.

Using unregulated flow as a variable, UIFs will be computed using the following general equation:

UIF = Measured Gage Flow + River Withdrawals - River Discharges - Irrigation Return Flow – Septic/Other Return Flow + Unregulated Flow + (Reservoir Evaporation - Reservoir Surface Precipitation) × Reservoir Area + Reservoir Withdrawals + Submerged Surface Runoff

(**Equation 8)**

Note that reservoir area will be derived from the reservoir level records using the reservoir Storage-Area-Elevation relationship curves.

UIFs will be developed for every stream gage and every major tributary and/or tributary that has managed flows. These particular tributaries will be modeled explicitly. If gage data is not available for such tributaries, synthetic UIFs will be developed to represent these reaches. Smaller tributaries without a gage and without managed flows will be modeled implicitly and do not require development of synthetic UIFs.

Rather than compute UIFs for individual additive reaches from upstream to downstream (a process by which error can accumulate), CDM Smith will compute UIFs for the entire upstream area of each gage, and subtract upstream UIFs to determine incremental UIFs between gages. This avoids accumulation or error or uncertainty by adding calculated UIFs together into a network.

UIFs for basins that originate in North Carolina (Broad, Catawba, and Pee Dee) have already been developed, or will be developed as part of ongoing surface water modeling studies in North Carolina. CDM Smith will obtain these calculations as boundary condition inputs for the relevant South Carolina models. However, while this will provide a basis for comparing managed flows to natural flows, it may be more practical for future planning to also include managed flows from North Carolina as optional model boundary conditions. The reason is because flows entering South Carolina are based on operating practices regulated by North Carolina, and/or by interstate agreements, neither of which can be controlled by South Carolina. It is recommended that the managed flows from North Carolina be established as the default boundary conditions.

Similarly, for the Savannah River Basin which is shared with Georgia, UIFs have already been developed for the entire basin as part of statewide planning work in Georgia. CDM Smith will obtain the UIFs for both the Georgia and South Carolina portions of the basin as model input (Georgia is currently updating these to 2013). Additionally, CDM Smith will include managed flows from the Georgia tributaries for the same reasons that the calculations will include managed flows from North Carolina. South Carolina may not have influence over these flows, and for future planning, it will be important to combine natural flows in South Carolina with managed flows originating in Georgia.

A subsequent report will be issued with the completed UIF datasets to help explain how they were computed, and what assumptions were made. This report will include:

- Data sources
- Specific gap filling measures and where they were applied (and why)
- Examples of each step in the process of computing different types of UIFs, including direct computations from data, operational gap filling, and hydrologic record extension/filling techniques.

6.0 Issues Specific to the Saluda Basin

6.1 Historic Hydropower Operations

There are two hydroelectric power stations in the Saluda basin that no longer operate; Saluda Hydro on the Saluda River (User ID 23PH002), and Piedmont Hydro on the Saluda River (User ID 04PH004). For the inactive Saluda Hydro site, records exist from 1983-1997. For the inactive Piedmont Hydro site, records exist from 1984-1996, but between 1984 and 1992, reported values do not indicate any flow volume. Collecting or developing missing data from these stations for development of UIFs may be difficult, and may require judgment and collaboration with DNR and DHEC.

6.2 Need for Broad River UIFs

Figure 2-1 shows that the Broad River is a major tributary of the Saluda River, as delineated by DHEC. At the confluence, these two rivers join to form the Congaree River in Columbia, and the Congaree is included in the delineation of the Saluda basin. Therefore, UIFs for Broad River will also be needed to complete Saluda UIFs.

UIFs for Broad River include UIFs and managed flows from the portion of the basin in North Carolina, which will be collected as part of the data collection exercise for the Saluda basin. UIFs for the Broad River will be based on managed flows in North Carolina, representing a boundary condition at the state line over which South Carolina has limited influence, but which most faithfully represents the water available within the South Carolina borders. As necessary, the flow dataset will be updated to 2013.

In South Carolina, UIFs for the Broad River were developed for Duke Energy by DTA in 2007. The methodology is described in *Broad River Basin Hydrology Report* by DTA, 2007. The flow dataset extends through 2006, and as part of the UIF development for South Carolina, it will be updated through 2013.

6.3 Groundwater

Registered and permitted (both active and inactive) groundwater withdrawal locations are shown in **Figure 6-1**. Between 2002 and 2013, total reported groundwater withdrawals for municipal, industrial, mining, golf course, and agricultural purposes in the Saluda basin averaged between 7 and 12.8 mgd. The majority of the groundwater withdrawals occur south of the Fall Line, in the Upper Coastal Plain.

Groundwater withdrawals may lower streamflow to a point that they potentially influence UIF estimates in a significant manner if the following conditions are met:

- The withdrawal occurs in an aquifer that contributes baseflow to a stream via direct groundwater discharge.
- The withdrawals are greater than 100,000 gpd.
- A significant portion of the withdrawal is not returned to the stream as a wastewater discharge or to the surficial aquifer via onsite wastewater treatment systems (septic tanks). For example, groundwater withdrawals for irrigation of golf courses or agriculture are expected to be mostly lost to evapotranspiration. Very little is returned to the stream via direct or indirect runoff.

In most instances within the Saluda basin, registered and permitted groundwater withdrawals will likely not meet these conditions, and can therefore be ignored when calculating UIFs; however, each groundwater withdrawal will be reviewed for consideration.

The combined net amount of groundwater withdrawals from private wells (individual wells not permitted or registered) that is not returned to the surficial aquifer system via onsite wastewater systems is not expected to significantly lower stream baseflow in any area of the basin, such that consideration of these withdrawals is necessary in calculating UIFs.

6.4 Agriculture

Registered agriculture surface withdrawal locations in the Saluda basin were shown in **Figure 3-3.** Of the 14 registered agricultural surface water users, only 5 had total reported water withdrawals greater than 100,000 gpd over the last 5 years (2009-2013). As seen on the figure, the agricultural

CDM Smith

Figure 6-1
Active and Inactive Groundwater Withdrawal Locations

withdrawals mostly concentrated in four areas. Although the individual withdrawals are below 100,000 gpd, the combined amount of these concentrated withdrawals may merit inclusion in calculating UIFs.

7.0 Validation of UIFs

Independent checks on final calculated unimpaired flows will occur as part of the surface water model calibration and validation task. Basin-specific surface water allocation models constructed using SWAM will include all the same major withdrawals, return flows, storage reservoirs, and tributaries used to calculate the UIFs described above. In contrast to the UIF calculations, however, SWAM will include spatially continuous flow balance calculations that originate with UIF inputs upstream and incorporate the impacts of reach gains/losses and management activity, rather than calculations for specific downstream nodes.

Flow regimes are constructed in the model from the top of a simulated reach to the bottom based on headwater flows, tributary inputs, and calibrated reach gains or losses. Unimpaired flows are used directly in the models in upstream headwater locations, or areas that are not affected by upstream management activity. However, as the stream network develops and management activity is simulated, UIFs at downstream nodes are *not* used directly as inputs to the models, but will be available for comparative purposes to managed flows. Downstream gaged flows, which include existing development and flow impairment, will be used as calibration targets in the modeling.

Reach gains or losses and ungaged tributary flows will serve as the primary calibration parameters. Following calibration, UIFs at downstream nodes can be easily extracted from SWAM by "turning off" upstream water uses and storage and simulating historical periods. The resulting modeled downstream flows essentially represent simulated unimpaired flows for the given historical period. These downstream flows, calculated by removing upstream water users and storage in the model, can be used to confirm and validate the previously calculated UIFs – That is, we will check the comparability between a UIF at a downstream node (calculated per the procedures outlined in previous sections) and the simulated Unimpaired Flow at that location by removing the management objects from the calibrated model. When upstream management activity is removed from the model, the resulting flow at a given node *should* match the calculated UIF for that node. The model and downstream UIF calculations, therefore, can corroborate each other.

It is likely that the SWAM calibration period will not extend as far as the UIF calculation period. The SWAM models will be calibrated using only periods well supported by data and where there is high confidence in the model input data. These periods may or may not exactly coincide with the full UIF calculation periods. Model development (programming and data entry) and calibration are two separate tasks, and it is not possible to predetermine the model calibration periods until all available data has been collected and reviewed. However, once calibrated, "baseline" historical models will be constructed with simulation periods that match the UIF periods (1925-2013).

ATTACHMENT A

Telephone Questionnaires for Water Users
To Supplement Information on Historical Flow Management

Script for <u>Water Supply (WS)</u> Water User

Contact the water user, following the suggested script below.

Hello, my name is __________ with CDM Smith. As you may be aware, South Carolina DNR and DHEC have begun a two-year project to conduct surface water availability assessment modeling for each of the State's eight major river basins. CDM Smith has partnered with DNR and DHEC to assist with this process.

One of our first responsibilities is to characterize the natural hydrologic conditions in each basin, and we'll do this by blending historic streamflow measurements with historic records of water usage. I'm calling you today to solicit your help in confirming our understanding of the history of your water source(s) and operation, and to collect additional data that may be useful to characterize and quantify your utility's historical water use. You may have recently received a letter from DHEC indicating that we would be contacting you. This should only take about 5 to 10 minutes of your time.

You will hear more about the project in the coming months. DNR is in the process of procuring a facilitator to help engage stakeholders in each basin. The facilitator will be organizing meetings to provide additional information regarding the water quantity modeling and subsequent phases of the state water planning effort.

Do you mind if I ask you a few questions about your utilities water withdrawals, both current and historical, or is there someone else that I should speak with?

As I mentioned, one of the first steps in the process is the development of naturalized flows, which are basically estimates of past river flows without any man-made influences such as withdrawals discharges, and dams. These are based in-part on historical records of withdrawal and discharges.

You have provided DHEC with monthly withdrawal data dating from _________ to ____________.

- *Did your utility withdraw surface water prior to ________?*
- **[if Yes]** *Do you have data quantifying the withdrawal amounts prior to ___________, or if not, can you provide estimated average monthly or annual water use prior to ___________?*
- *Has your water source(s) ever changed?*
- *Have multiple sources ever been used?*
- **[Only if multiple sources are used]** *What are your priorities/rules for withdrawing water if multiple sources are used?*

- *Do you have offline storage reservoirs (*not tanks*)? If yes, is storage/area/elevation data available?*

- *Do you have interconnections with other systems?*

- *Do you purchase water from or sell water to other utilities? Have you historically purchased or sold water (but no longer do so)?*

- **[Only if they do not have a Drought Contingency Plan]** *Have you prepared a Drought Contingency Plan and have you used it?*

- **[If they have a Drought Contingency Plan]** *Have you had to use your Drought Contingency Plan in the past?*

- **[If they have an NPDES permit]** *We have your reported NPDES discharge amounts for your utility dating from _________ to _________. Do you have any records of discharge prior to __________?* **[May not need to ask this depending on the situation. Also, we may need to contact some on the wastewater side of their utility, instead].**

- **[For some utilities which also operate WWTPs, their wastewater is stored in holding ponds when the stream's flow and assimilative capacity are low. Water may be withdrawn from the stream but not returned as wastewater while instream flow remains low. This is a "controlled discharge". Ask them the following question:]** *Does your WWTP ever use controlled discharges?*

- **[Only if they have an interbasin transfer permit]** *Can you describe your interbasin transfer* (e.g. is it a constant transfer, or used only in emergency such as through an interconnection to another utility?*) Do you have records quantifying your historical interbasin transfers?*

Thank you very much for your time. To follow-up, I am going to e-mail to you a memorandum documenting my understanding of the information we have discussed today and listing any additional data needs. If you could review the letter, provide corrections or clarifications, and include any additional withdrawal or other data we discussed within the next 30 days, I would appreciate it. I can be reached by phone at _________________ or e-mail at _________________________.

I have your e-mail address as _____________________________. **[Or if we don't have their e-mail address, ask for it]**

Thanks again for your time.

Script for <u>Golf Course (GC)</u> Water User

Contact the water user, following the suggested script below.

Hello, my name is __________ with CDM Smith. As you may be aware, South Carolina DNR and DHEC have begun a two-year project to conduct surface water availability assessment modeling for each of the State's eight major river basins. CDM Smith has partnered with DNR and DHEC to assist with this process.

One of our first responsibilities is to characterize the natural hydrologic conditions in each basin, and we'll do this by blending historic streamflow measurements with historic records of water usage. I'm calling you today to solicit your help in confirming our understanding of the history of your water source(s) and operation, and to collect additional data that may be useful to characterize and quantify your utility's historical water use. You may have recently received a letter from DHEC indicating that we would be contacting you. This should only take about 5 to 10 minutes of your time.

You will hear more about the project in the coming months. DNR is in the process of procuring a facilitator to help engage stakeholders in each basin. The facilitator will be organizing meetings to provide additional information regarding the water quantity modeling and subsequent phases of the state water planning effort.

Do you mind if I ask you a few questions about your water withdrawals, both current and historical, or is there someone else that I should speak with?

As I mentioned, one of the first steps in the process is the development of naturalized flows, which are basically estimates of past river flows without any man-made influences such as withdrawals discharges, and dams. These are based in-part on historical records of withdrawal and discharges.

You have provided DHEC with monthly withdrawal data dating from _________ to _____________.

- *Did your golf course withdraw <u>surface water</u> prior to ________?*
- **[if Yes]** *Do you have data quantifying the withdrawal amounts prior to ____________, or if not, can you provide estimated average monthly water use prior to ___________?* **[Many golf courses may only irrigate April-October]**
- *Has your water source(s) ever changed?* **[Make sure you develop an understanding of groundwater use vs. surface water use, if both have been used. Often, they may pump groundwater to a pond, then withdraw from the pond to irrigate – which is not considered surface water use.**
- *Have multiple surface water sources ever been used?* **[Not likely]**

Thank you very much for your time. To follow-up, I am going to e-mail to you a memorandum documenting my understanding of the information we have discussed today and listing any additional data needs. If you could review the letter, provide corrections or clarifications, and *include any additional withdrawal or other data we discussed within the next 30 days, I would appreciate it. I can be reached by phone at ________________ or e-mail at ________________________.*

I have your e-mail address as ___________________________. **[Or if we don't have their e-mail address, ask for it]**

Thanks again for your time.

Script for Industrial (IN) and Mining (MI) Water User

Contact the water user, following the suggested script below.

Hello, my name is __________ with CDM Smith. As you may be aware, South Carolina DNR and DHEC have begun a two-year project to conduct surface water availability assessment modeling for each of the State's eight major river basins. CDM Smith has partnered with DNR and DHEC to assist with this process.

One of our first responsibilities is to characterize the natural hydrologic conditions in each basin, and we'll do this by blending historic streamflow measurements with historic records of water usage. I'm calling you today to solicit your help in confirming our understanding of the history of your water source(s) and operation, and to collect additional data that may be useful to characterize and quantify your utility's historical water use. You may have recently received a letter from DHEC indicating that we would be contacting you. This should only take about 5 to 10 minutes of your time.

You will hear more about the project in the coming months. DNR is in the process of procuring a facilitator to help engage stakeholders in each basin. The facilitator will be organizing meetings to provide additional information regarding the water quantity modeling and subsequent phases of the state water planning effort.

Do you mind if I ask you a few questions about your utilities water withdrawals, both current and historical, or is there someone else that I should speak with?

As I mentioned, one of the first steps in the process is the development of naturalized flows, which are basically estimates of past river flows without any man-made influences such as withdrawals discharges, and dams. These are based in-part on historical records of withdrawal and discharges.

You have provided DHEC with monthly withdrawal data dating from _________ to _____________.

- *Did your plant withdraw surface water prior to ________?*
- **[if Yes]** *Do you have data quantifying the withdrawal amounts prior to ____________, or if not, can you provide estimated average monthly or annual water use prior to ___________?*
- *Has your water source(s) ever changed?*
- *Have multiple sources ever been used?*
- *Do you have offline storage reservoirs (*not tanks*)? If yes, is storage/area/elevation data available?*
- *Do you have interconnections with other systems?*

- *Do you also purchase water from a nearby utility? Have you historically purchased or water (but no longer do so)?*

- **[If they have an NPDES permit]** *We have your reported NPDES discharge amounts for your utility dating from _________ to __________. Do you have any records of discharge prior to ___________?* **[May not need to ask this depending on the situation.]**

- **[Only if they have an interbasin transfer permit]** *Can you describe your interbasin transfer* (e.g. is it a constant transfer, or used only in emergency such as through an interconnection a utility?*) Do you have records quantifying your historical interbasin transfers?*

Thank you very much for your time. To follow-up, I am going to e-mail to you a memorandum documenting my understanding of the information we have discussed today and listing any additional data needs. If you could review the letter, provide corrections or clarifications, and include any additional withdrawal or other data we discussed within the next 30 days, I would appreciate it. I can be reached by phone at _________________ or e-mail at _________________________.

I have your e-mail address as _____________________________. **[Or if we don't have their e-mail address, ask for it]**

Thanks again for your time.

Script for Power/Thermal (PT) and Nuclear (PN) Water User

Hello, my name is __________ with CDM Smith. As you may be aware, South Carolina DNR and DHEC have begun a two-year project to conduct surface water availability assessment modeling for each of the State's eight major river basins. CDM Smith has partnered with DNR and DHEC to assist with this process.

One of our first responsibilities is to characterize the natural hydrologic conditions in each basin, and we'll do this by blending historic streamflow measurements with historic records of water usage. I'm calling you today to solicit your help in confirming our understanding of the history of your water source(s) and operation, and to collect additional data that may be useful to characterize and quantify your utility's historical water use. You may have recently received a letter from DHEC indicating that we would be contacting you. This should only take about 5 to 10 minutes of your time.

You will hear more about the project in the coming months. DNR is in the process of procuring a facilitator to help engage stakeholders in each basin. The facilitator will be organizing meetings to provide additional information regarding the water quantity modeling and subsequent phases of the state water planning effort. Do you mind if I ask you a few questions about your facilities water withdrawals, both current and historical, or is there someone else that I should speak with?

As I mentioned, one of the first steps in the process is the development of naturalized flows, which are basically estimates of past river flows without any man-made influences such as withdrawals discharges, and dams. These are based in-part on historical records of withdrawal and discharges.

You have provided DHEC with monthly withdrawal data dating from _________ to _____________.

- *Did your facility withdraw surface water prior to ________?*
- **[if Yes]** *Do you have data quantifying the withdrawal amounts prior to ___________, or if not, can you provide estimated average monthly or annual water use prior to ___________?*
- *We have your reported NPDES discharge amounts for your utility dating from _________ to _________. Do you have any records of discharge prior to ___________?*

Thank you very much for your time. To follow-up, I am going to e-mail to you a memorandum documenting my understanding of the information we have discussed today and listing any additional data needs. If you could review the letter, provide corrections or clarifications, and include any additional withdrawal or other data we discussed within the next 30 days, I would appreciate it. I can be reached by phone at _________________ or e-mail at _________________________.

I have your e-mail address as _____________________________. **[Or if we don't have their e-mail address, ask for it]**

Thanks again for your time.