APPENDIX B –

Finalized Inflow Data Development

Section 1. Introduction

This report provides a detailed account of the inflow development for the Yadkin Pee-Dee and Lumber River (YPDL) Basins. The inflow record runs from October 1929 to September 2019.[a] There are 47 streamflow gages in the basin that are used in this project. These are listed in Table 1, and the key ones used as inflow locations are mapped in Figures 1a & 1b. These gages have at least 10 years of daily data with which to make valid statistical comparisons with other gages. Most of the gages have incomplete records; they either started after 1930 or ended before 2019. 38 of the gages are used as inflow locations in the model, while the rest (as well as some others outside the basin) were used just to provide more data for *fillin* (see below) when computing statistics. Additionally, the USACE's net inflow record (computed by adding the change in storage to the release) for Kerr Scott Reservoir was used as an inflow timeseries for this model and is treated as a "gage" in the inflow methodology described in this report.

The inflow dataset is based on "unimpaired" gage flows. Gages only show the actual flow in the stream; they have no information about what the flow would have been without human intervention. "Impairments" are modifications of the natural flows due to change in reservoir storage (including evaporation and precipitation on the reservoir surface) and consumptive withdrawals of water (municipal, industrial, or agricultural). If water is withdrawn above a gage and returned to the river below the gage, the impairment is the entire withdrawal.

The next section describes the process used to compute daily flows and gains. Because of the noise in the data, it is important to look at the data at each step to find unrealistic values. These are noted later.

The summary of the inflow development process was provided to the Technical Review Committee as a slide deck (**Inflow Development_TRC Meeting 2.pptx**, Oct. 2020). All inflow development files are provided in the "Inflow Files" directory and are referenced in the subsequent sections.

[a] A provisional record extends beyond September 2019, but this does not account for most of the actual impairments. Future updates will require impairment data for the inflow dataset to be considered finalized.

Table 1. List of Gages used in the YPDL Model Inflow Development

Site Number	Site Name	# Years	Drainage Area (sq. mi.)	Basin	Subbasin
02111000	YADKIN RIVER AT PATTERSON, NC	79	28.8	Yadkin-Pee Dee	Kerr Scott
02111180	ELK CREEK AT ELKVILLE, NC	53	50.9	Yadkin-Pee Dee	Kerr Scott
02111500	REDDIES RIVER AT NORTH WILKESBORO, NC	79	89.2	Yadkin-Pee Dee	High Rock
02112000	YADKIN RIVER AT WILKESBORO, NC	89	504	Yadkin-Pee Dee	High Rock
02112120	ROARING RIVER NEAR ROARING RIVER, NC	51	128	Yadkin-Pee Dee	High Rock
02112360	YADKIN RIVER AT ELKIN, NC	55	866	Yadkin-Pee Dee	High Rock
02112250	MITCHELL RIVER NEAR STATE ROAD, NC	50	78.8	Yadkin-Pee Dee	High Rock
02113000	FISHER RIVER NEAR COPELAND, NC	79	128	Yadkin-Pee Dee	High Rock
02113850	ARARAT RIVER AT ARARAT, NC	55	231	Yadkin-Pee Dee	High Rock
02114450	LITTLE YADKIN RIVER AT DALTON, NC	58	42.8	Yadkin-Pee Dee	High Rock
02115360	YADKIN RIVER AT ENON, NC	55	1694	Yadkin-Pee Dee	High Rock
02115500	FORBUSH CREEK NEAR YADKINVILLE, NC	32	22.1	Yadkin-Pee Dee	High Rock
02115860	MUDDY CREEK NEAR MUDDY CREEK, NC	22	186	Yadkin-Pee Dee	High Rock
02115900	SOUTH FORK MUDDY CREEK NR CLEMMONS, NC	19	42.9	Yadkin-Pee Dee	High Rock
02116500	YADKIN RIVER AT YADKIN COLLEGE, NC	89	2280	Yadkin-Pee Dee	High Rock
02117030	HUMPY CREEK NEAR FORK, NC	15	1.05	Yadkin-Pee Dee	High Rock
02117500	ROCKY CREEK AT TURNERSBURG, NC	32	101	Yadkin-Pee Dee	High Rock
02118000	SOUTH YADKIN RIVER NEAR MOCKSVILLE, NC	80	306	Yadkin-Pee Dee	High Rock
02118500	HUNTING CREEK NEAR HARMONY, NC	68	155	Yadkin-Pee Dee	High Rock
02119000	SOUTH YADKIN RIVER AT COOLEEMEE, NC	36	569	Yadkin-Pee Dee	High Rock
02120500	THIRD CREEK AT CLEVELAND, NC	31	87.4	Yadkin-Pee Dee	High Rock
02120780	SECOND CREEK NEAR BARBER, NC	40	118	Yadkin-Pee Dee	High Rock
02121500	ABBOTTS CREEK AT LEXINGTON, NC	30	174	Yadkin-Pee Dee	High Rock
02122500	YADKIN RIVER AT HIGH ROCK, NC	20	4000	Yadkin-Pee Dee	High Rock
02123500	UWHARRIE RIVER NEAR ELDORADO, NC	33	342	Yadkin-Pee Dee	Tillery
02123567	DUTCHMANS CREEK NR UWHARRIE, NC	21	3.44	Yadkin-Pee Dee	Tillery
0212393300	W. BR ROCKY R B MTH OF S PRONG R NR CORNELIUS, NC	14	20.8	Yadkin-Pee Dee	Blewett Falls
02124080	CLARKE CREEK NEAR HARRISBURG, NC	15	21.9	Yadkin-Pee Dee	Blewett Falls
0212414900	MALLARD CR BL STONY CR NR HARRISBURG, NC	24	34.6	Yadkin-Pee Dee	Blewett Falls
0212419274	CODDLE CR AT SR 1612 NEAR DAVIDSON, NC	16	22.7	Yadkin-Pee Dee	Blewett Falls
0212427947	REEDY CREEK AT SR 2803 NR CHARLOTTE, NC	11	2.5	Yadkin-Pee Dee	Blewett Falls
0212433550	ROCKY R AB IRISH BUFFALO CR NR ROCKY RIVER, NC	17	278	Yadkin-Pee Dee	Blewett Falls
02125000	BIG BEAR CR NR RICHFIELD, NC	56	55.6	Yadkin-Pee Dee	Blewett Falls
02126000	ROCKY RIVER NEAR NORWOOD, NC	89	1372	Yadkin-Pee Dee	Blewett Falls

Site Number	Site Name	# Years	Drainage Area (sq. mi.)	Basin	Subbasin
02127000	BROWN CREEK NEAR POLKTON, NC	34	110	Yadkin-Pee Dee	Blewett Falls
02128000	LITTLE RIVER NEAR STAR, NC	65	106	Yadkin-Pee Dee	Blewett Falls
02129000	PEE DEE R NR ROCKINGHAM, NC	89	6863	Yadkin-Pee Dee	D/S of Blewett Falls
02131000	PEE DEE RIVER AT PEEDEE, SC	89	8830	Yadkin-Pee Dee	D/S (South Carolina)
02132320	BIG SHOE HEEL CREEK NR LAURINBURG, NC	32	83.3	Lumber	Little Pee Dee
02133500	DROWNING CREEK NEAR HOFFMAN, NC	79	183	Lumber	Lumber
02133624	LUMBER RIVER NEAR MAXTON, NC	32	365	Lumber	Lumber
02134170	LUMBER RIVER AT LUMBERTON, NC	18	708	Lumber	Lumber
02134480	BIG SWAMP NR TAR HEEL, NC	33	229	Lumber	Lumber
02134500	LUMBER RIVER AT BOARDMAN, NC	89	1228	Lumber	Lumber
02135000	LITTLE PEE DEE R. AT GALIVANTS FERRY, SC	77	2790	Lumber	D/S (South Carolina)
02109500	WACCAMAW RIVER AT FREELAND, NC	79	680	Lumber	Waccamaw
02110500	WACCAMAW RIVER NEAR LONGS, SC	59	1110	Lumber	D/S (South Carolina)

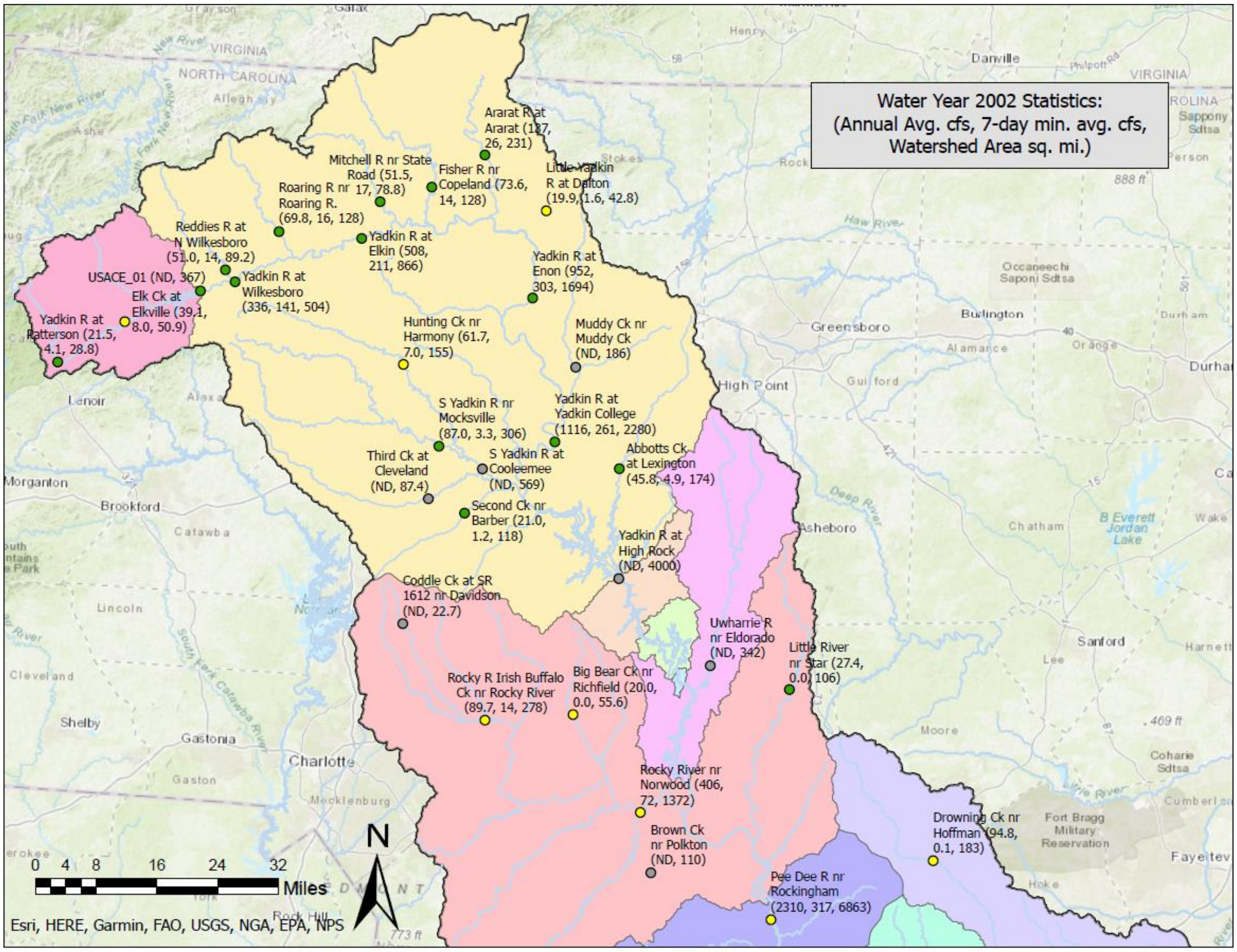

Figure 1a. Map of gages used as inflow nodes in the Yadkin/Pee Dee River Basin

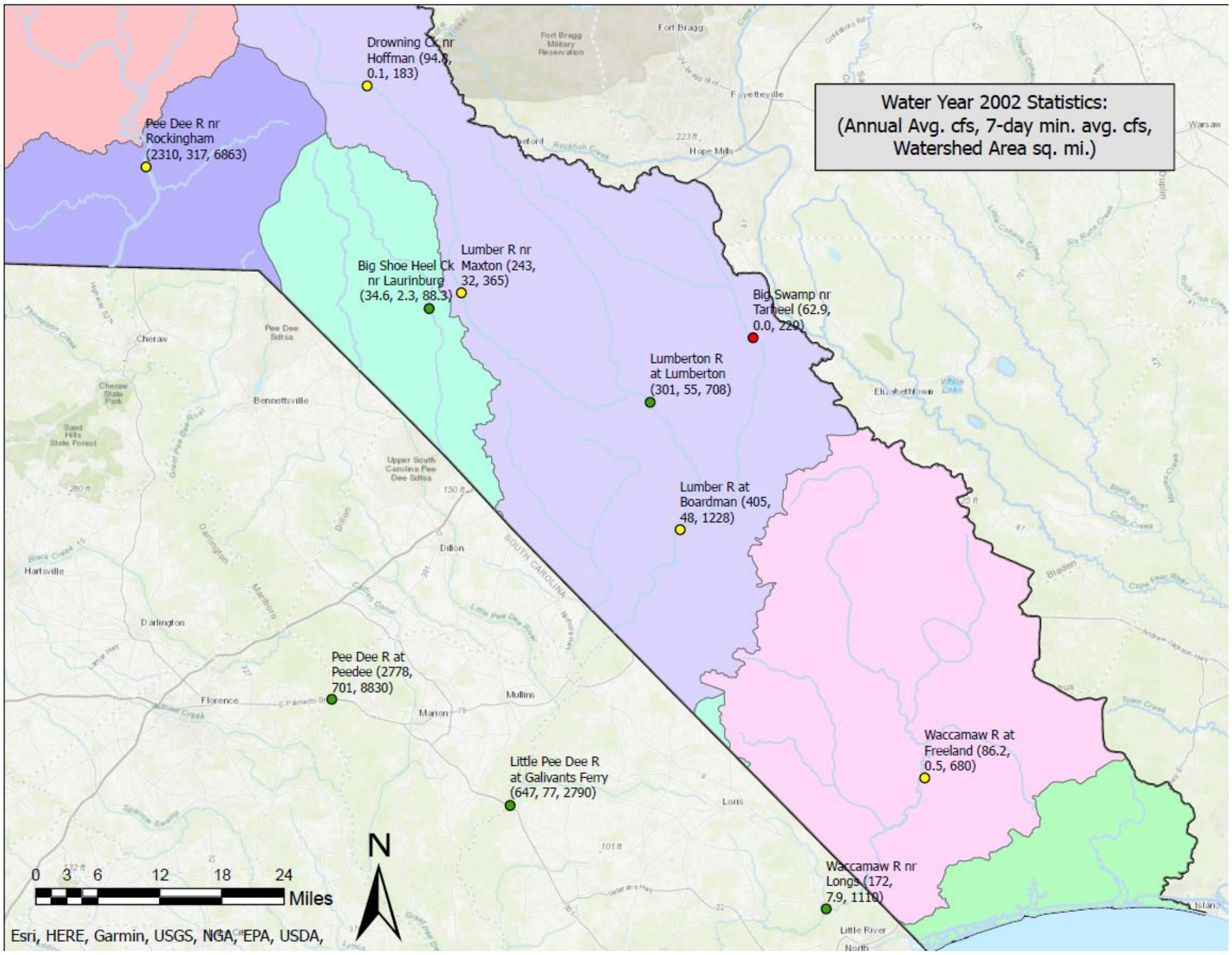

Figure 1b. Map of gages used as inflow nodes in the Lumber and Waccamaw River Basins

Section 2. Data and General Procedure

The first step in building the record is to compute the unimpaired gage flows. These computations are contained in the spreadsheet ***Unimpairments_By_Gage_Consistent_Columns_with_Routing_ StartStop_Dates.xlsx*** in the '01a_UIFs directory. The unimpared gage flows are extracted from the unimpairment spreadsheet using the Python script ***Extract_UIF_Col_from_UIF_SS.ipynb*** in the 01_UIFs sub-directory and the extracted data is summarized in the ***UIFs_Output_daily.xlsx and UIFs_Output_monthly.xlsx*** files. Impairments in the basin accumulate as each downstream gage is included. For example, the impairments upstream of the Yadkin College gage include the impairments on the mainstem Yadkin and the tributaries upstream. The unimpairment of a gage is calculated as follows:

Unimpaired gage flow = gage flow + upstream water withdrawal (by agricultural, municipal, and industrial users) – upstream discharge (water or wastewater from municipal or industrial users, including power plants) + upstream change in reservoir storage + upstream evaporation on the reservoir surface - upstream precipitation on the reservoir surface.

The impairment data collection effort was led by Hazen and is described in a companion data collection report. Hazen collected withdrawal and discharge data from databases and stakeholders.

Evaporation and precipitation data were also collected by Hazen. Evaporation data are based on based on a USGS study of Lake Michie in Durham, NC. This has the advantage of being measured at the surface of the lake rather than in a pan, avoiding the need for a monthly adjustment factor for converting from pan to surface. Precipitation data are based on daily measurements from the long-term stations shown in Figure 2.

Data from the station closest to a reservoir are used to estimate the precipitation at the reservoir. When these data are missing, data from the next nearest station are used, and so on. For each reservoir, Hazen calculated a daily timeseries of net evaporation (or the difference between evaporation and precipitation) for the hydrologic record. These data are contained in spreadsheets in the "Evap-Precip" folder. These data are used to (1) estimate the historic change in reservoir storage due to net evaporation and (2) estimate net evaporation on the reservoir surface during OASIS model simulation.

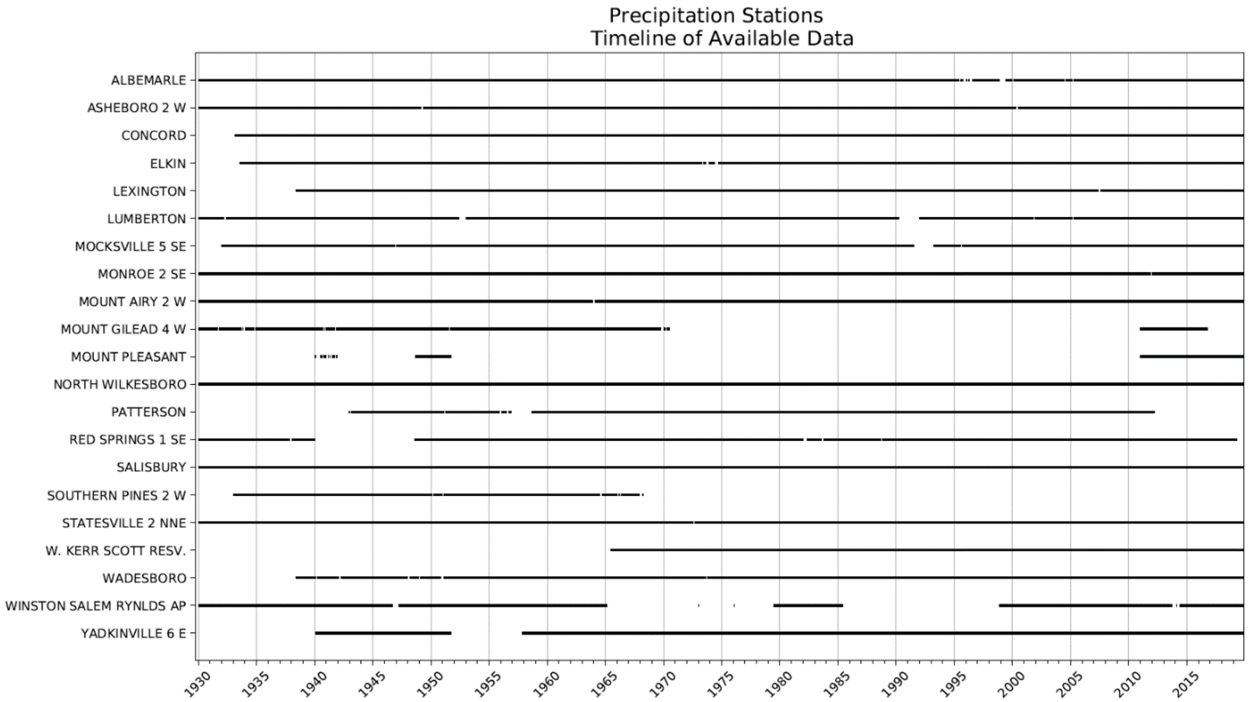

Figure 2. Precipitation stations used to develop net evaporation timeseries data

The streamflow data for 29 gages was unimpaired (plus the USACE's net inflow for Kerr Scott Reservoir) for use as inflow locations in the model, mapped in Figures 1a (for the Yadkin-Pee Dee) and 1b (for the Lumber). The 18 other gages are on rivers where impairments are negligible or not quantified, or not required for the inflow methodology. A timeline showing the period of record of the gages used for inflow development is shown in Figure 3.

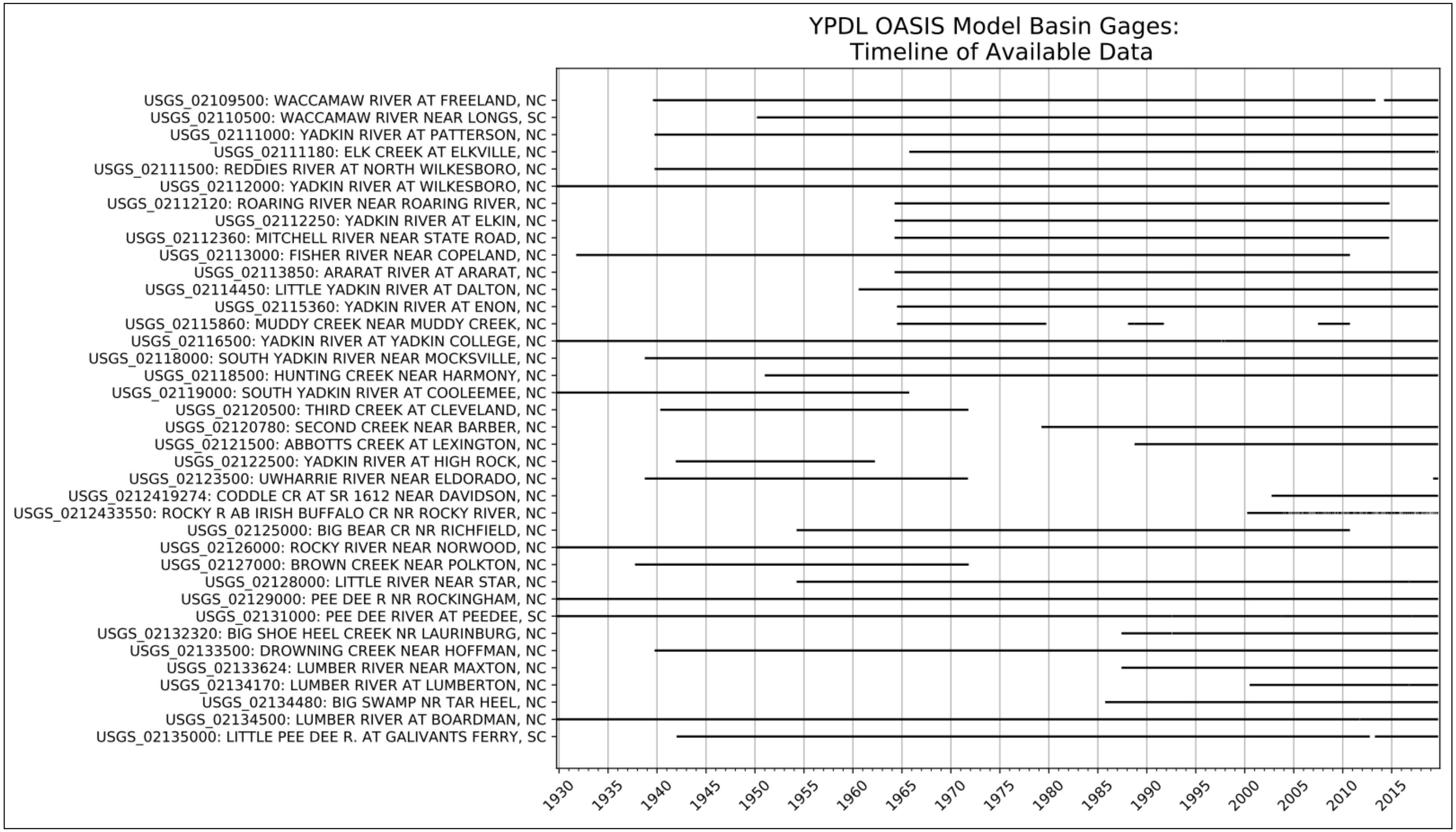

Figure 3. Timeline of YPDL gages used for inflow development

The second step in inflow development is to compute the gains – i.e. the local inflow between two gages. This is done by subtracting the upstream gage flow(s) from the next downstream gage flow. The downstream gages where gains are calculated are shown in Figure 4. The gains calculations are contained in the sub-directory "02_Gains" using the ***Gains_Calc_FINAL.ipynb*** Pyton script, with the results stored in ***Gain_Output_monthly_cfs.xlsx***.

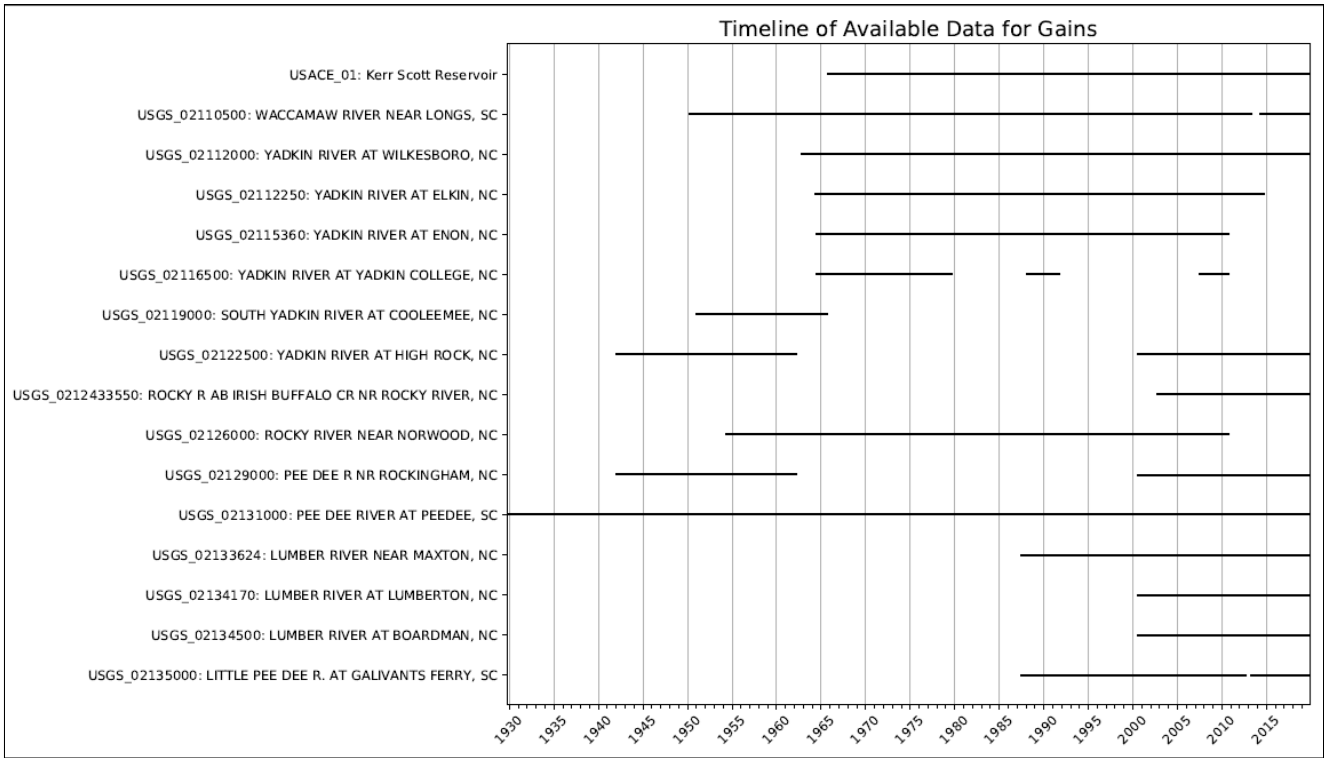

Figure 4. Timeline of gains used for YPDL inflow development

The third step in the inflow development process is to fill in the missing flows and gains for each gage with missing records. This requires assembling a monthly record of unimpaired flows and gains based on the daily unimpaired data computed above. These flows and gains are fed into a program named *fillin* (developed by William Alley and Alan Burns of the USGS[b]). We will refer to these as "extended" flows and gains. This is done on a monthly basis because *fillin* only works with monthly data. The gages associated with the flows and gains used in the remainder of this document are shown in Table 2. The inputs and outputs of *fillin* are contained in the "04_Fillin" directory.

Table 2. Gages locations used to compute flows and gains

Upstream Gage	Downstream Gage
USGS_02111000: YADKIN RIVER AT PATTERSON, NC	USACE_01: Kerr Scott Reservoir
USGS_02111180: ELK CREEK AT ELKVILLE, NC	USACE_01: Kerr Scott Reservoir
USACE_01: Kerr Scott Reservoir	USGS_02112000: YADKIN RIVER AT WILKESBORO, NC
USGS_02111500: REDDIES RIVER AT NORTH WILKESBORO, NC	USGS_02112000: YADKIN RIVER AT WILKESBORO, NC
USGS_02112120: ROARING RIVER NEAR ROARING RIVER, NC	USGS_02112250: YADKIN RIVER AT ELKIN, NC
USGS_02112000: YADKIN RIVER AT WILKESBORO, NC	USGS_02112250: YADKIN RIVER AT ELKIN, NC
USGS_02112250: YADKIN RIVER AT ELKIN, NC	USGS_02115360: YADKIN RIVER AT ENON, NC
USGS_02112360: MITCHELL RIVER NEAR STATE ROAD, NC	USGS_02115360: YADKIN RIVER AT ENON, NC
USGS_02113000: FISHER RIVER NEAR COPELAND, NC	USGS_02115360: YADKIN RIVER AT ENON, NC
USGS_02113850: ARARAT RIVER AT ARARAT, NC	USGS_02115360: YADKIN RIVER AT ENON, NC
USGS_02114450: LITTLE YADKIN RIVER AT DALTON, NC	USGS_02115360: YADKIN RIVER AT ENON, NC
USGS_02115360: YADKIN RIVER AT ENON, NC	USGS_02116500: YADKIN RIVER AT YADKIN COLLEGE, NC
USGS_02116500: YADKIN RIVER AT YADKIN COLLEGE, NC	USGS_02122500: YADKIN RIVER AT HIGH ROCK, NC
USGS_02118000: SOUTH YADKIN RIVER NEAR MOCKSVILLE, NC	USGS_02119000: SOUTH YADKIN RIVER AT COOLEEMEE, NC
USGS_02122500: YADKIN RIVER AT HIGH ROCK, NC	USGS_02129000: PEE DEE R NR ROCKINGHAM, NC
USGS_02125000: BIG BEAR CR NR RICHFIELD, NC	USGS_02126000: ROCKY RIVER NEAR NORWOOD, NC
USGS_02126000: ROCKY RIVER NEAR NORWOOD, NC	USGS_02129000: PEE DEE R NR ROCKINGHAM, NC
USGS_02129000: PEE DEE R NR ROCKINGHAM, NC	USGS_02131000: PEE DEE RIVER AT PEEDEE, SC
USGS_02133500: DROWNING CREEK NEAR HOFFMAN, NC	USGS_02133624: LUMBER RIVER NEAR MAXTON, NC
USGS_02133624: LUMBER RIVER NEAR MAXTON, NC	USGS_02134170: LUMBER RIVER AT LUMBERTON, NC
USGS_02134170: LUMBER RIVER AT LUMBERTON, NC	USGS_02134500: LUMBER RIVER AT BOARDMAN, NC
USGS_02134480: BIG SWAMP NR TAR HEEL, NC	USGS_02134500: LUMBER RIVER AT BOARDMAN, NC
USGS_02134500: LUMBER RIVER AT BOARDMAN, NC	USGS_02135000: LITTLE PEE DEE R. AT GALIVANTS FERRY, SC
USGS_02132320: BIG SHOE HEEL CREEK NR LAURINBURG, NC	USGS_02135000: LITTLE PEE DEE R. AT GALIVANTS FERRY, SC
USGS_02109500: WACCAMAW RIVER AT FREELAND, NC	USGS_02110500: WACCAMAW RIVER NEAR LONGS, SC

[b] "Mixed-Station Extension of Monthly Streamflow Records," *Journal of Hydraulic Engineering*, ASCE, Vol. 109, No. 10, October 1983.

Fillin completes the missing record of flows and gains by selecting the mostly highly correlated gages. A sample of the correlations for overlapping flows at Kerr Scott and other gaged locations is shown in Figure 5. In this case, to complete the missing record of Kerr Scott inflows (pre-1962 before the dam existed), *fillin* would rely mostly on the Reddies River gage (assuming it was available) to estimate the monthly flow for Kerr Scott.

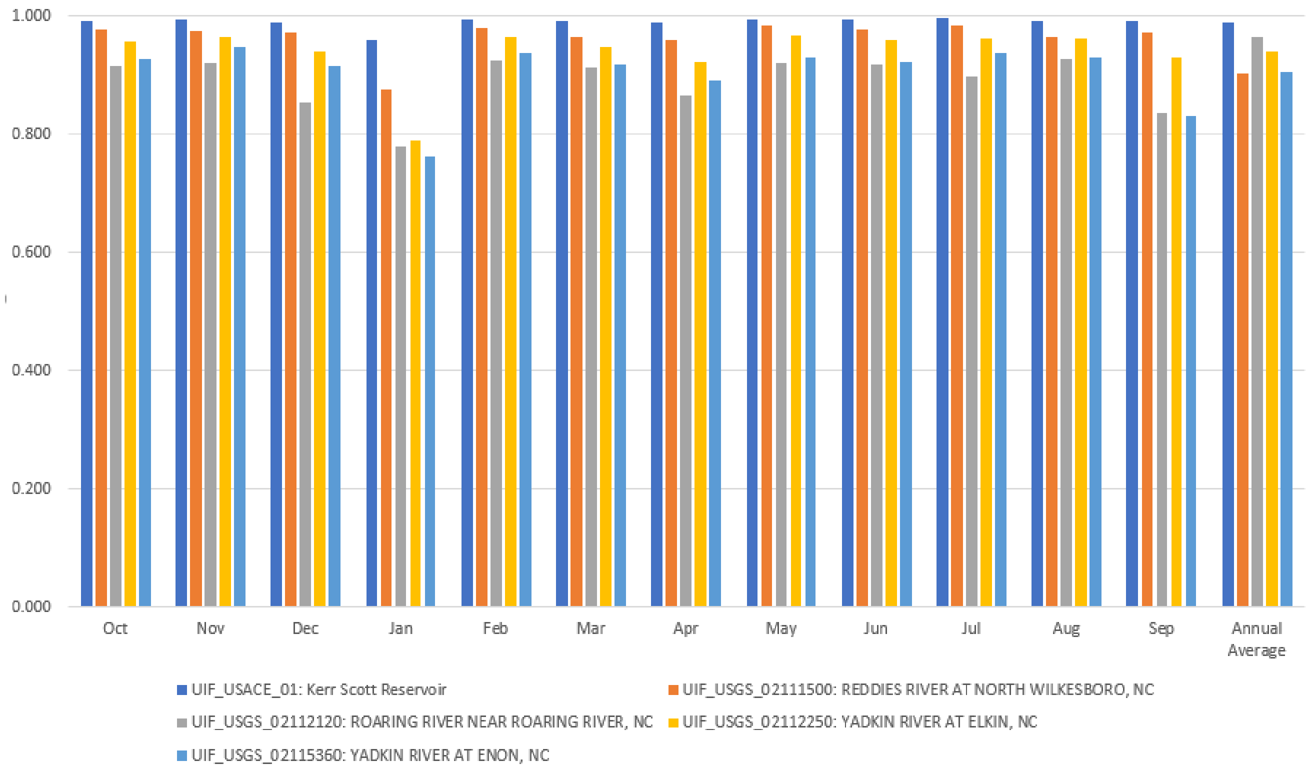

Figure 5. Sample *Fillin* Correlations Plot for Kerr Scott (USACE_01)

The fourth step is to apportion the extended flows and gains to make sure that their volumes match downstream unimpaired gage flows. The monthly flows and gains are then disaggregated into daily values using local, unimpaired gages. These steps are described in detail in Section 3.

The last step in the process is to compute the OASIS nodal inflows based on the flows and gains computed above. This step is described in detail in Section 4.

Before undertaking these steps, we made some simplifications to certain gage records.

Net inflow data from Cube Hydro was available for High Rock Reservoir from 2000 – 2019. This record was used to append the gage 02122500 Yadkin River at High Rock, which was in place from 1941 – 1962.

To capture flows crossing from North Carolina to South Carolina, the OASIS model incorporates an inflow node in South Carolina at the Pee Dee gage (02131000), which has a continuous daily record starting in October 1938. The Bennettsville gage was not included as a node because the gage data were deemed by USGS, South Carolina officials to be unreliable.

Up through 1939, the National Weather Service collected daily stage measurements at Mars Bluff immediately downstream of the Pee Dee gage. These were converted to daily flow estimates using a rating curve provided by USGS. Overlapping records from 1938 to 1939 show, as expected, almost identical flows at Pee Dee and Mars Bluff. For simplicity, the Pee Dee flows prior to 1938 are assumed to be equivalent to the Mars Bluff flow estimates. Due to the complete flow record, use of *fillin* was not required for this gage.

Additionally, due to limited overlapping records, some gages, listed below, were excluded from gain calculations and added back in after filling in and scaling, to extend the available period of known gains.

- USGS_02115860: MUDDY CREEK NEAR MUDDY CREEK, NC
- USGS_02121500: ABBOTTS CREEK AT LEXINGTON, NC
- USGS_02118500: HUNTING CREEK NEAR HARMONY, NC
- USGS_02119000: SOUTH YADKIN RIVER AT COOLEEMEE, NC
- USGS_02120500: THIRD CREEK AT CLEVELAND, NC
- USGS_02120780: SECOND CREEK NEAR BARBER, NC
- USGS_0212419274: CODDLE CR AT SR 1612 NEAR DAVIDSON, NC
- USGS_0212433550: ROCKY R AB IRISH BUFFALO CR NR ROCKY RIVER, NC
- USGS_02127000: BROWN CREEK NEAR POLKTON, NC
- USGS_02128000: LITTLE RIVER NEAR STAR, NC
- USGS_02123500: UWHARRIE RIVER NEAR ELDORADO, NC

Section 3. Computation of Extended Gage Flows and Reach Gains

All the computations outlined in this section are done on monthly data, which reduces noise and is required for statistical hydrology programs like *fillin*. Noisy data occurs when time of travel differences occur or when the impairment data create artificial variation in the flows.

First, the actual gains are determined from the unimpaired gage flows as described previously. Next, *fillin* is run to compute the extended flows and gains for the gages with missing records. Note that *fillin* preserves the actual flows and gains where they exist. These extended flows and gains are then "scaled." The objective of scaling is to ensure that the sum of filled-in flows upstream of a gage with an actual record equals the actual unimpaired flow at that gage. The *fillin* program does not ensure this for two reasons. First, it utilizes only a single correlated record for each value generated, thus ignoring sums, and second, it works with log transforms, and not actual flows.

Here is an example. We want to compute the unimpaired flow at Roaring River and unimpaired gain at Elkin from 2015 to present when the Roaring River gage data are missing. As a result, we have no actual (unimpaired) flow at Roaring River and no actual gain at Elkin.

So we extend the gage record at Roaring River and extend the gain at Elkin using *fillin*. Now we want to adjust those extended values so that the sum of the flows at Roaring River, Wilkesboro, and the remaining gain down to Elkin match the unimpaired flow at Elkin. So we maintain the Elkin flow less the flow at Wilkesboro by scaling with the sum of the Roaring River and the Elkin extended gain.

The calculation is:

> Scaled Elkin extended gain = (Elkin flow – Wilkesboro flow)* (Elkin extended gain) / (Elkin extended gain + Roaring River extended flow)
>
> The companion calculation for the flow at Roaring River is:
>
> Scaled Roaring River extended flow = (Elkin flow –Wilkesboro flow)* (Roaring River extended flow) / (Elkin extended gain + Roaring River extended flow)

Thus the sum of the actual unimpaired flow (Wilkesboro) and the scaled flow (Roaring River)) and scaled gain (Elkin) equals the unimpaired gage flow at Elkin.

This way, we ensure that the total volume of all the flows and gains, be they actual or extended, upstream from a given gage match the unimpaired flow at the gage, preserving the unimpaired gaged flows.

These computations are done in the "06_Scale" directory with a series of Matlab scripts contained in the "MATLAB_Script" sub-directory. The scripts automatically identify which flows/gains need to be scaled for each month using the knowledge from the ***Topology.xlsx*** input spreadsheet (which matches each gage to the next downstream gage) and the timeseries of the filled in flows/gains from the previous step. The output from the scaling scripts are stored is the file ***Scale_Gain_Results.xlsx***, which contains monthly flows and gains. The file ***Scaling_SQ_QC.xlsx*** compares the output of the scaling script to the known unimpaired flows to ensure that the flows are matching.

The next step is to disaggregate the monthly flows into daily flows. This is done using flows for a daily, unimpaired gage that is local or has similar drainage area (call it a “reference gage”) along with our monthly flows. We multiply the monthly value by the ratio of that day’s flow to that month’s flow at the reference gage. The disaggregation formula is:

daily ratio = daily reference value / monthly reference value
daily computed value = monthly computed value * daily ratio

The disaggregation calculations are done in the “07_Dissagregate” directory using the Python script ***disaggregation_script.ipynb***. The output from the script is stored in the file ***daily_disagg_final_output_clean.xlsx***. The daily ratios used by the script are shown in the ***daily_ratios.xlsx*** spreadsheet. The final daily disaggregated flows, averaged back to monthly, are compared to the original known unimpaired flows in the spreadsheet ***daily_disagg_final_output_clean_QAQC.xlsx*** to ensure the flows match.

It is important to note that we are not trying to replicate history in computing the OASIS inflows; rather, we are trying to build daily flows whose variation is *representative* of history while preserving unimpaired gaged flows as “ground truth”.

Note that actual daily values of unimpaired gage *flows* are often maintained in the script files. Actual daily *gains* between gages are generally not maintained due to their “noise”, so the script files aggregate them monthly and then disaggregate them back to daily values using a locally unimpaired gage. Therefore, actual flows and gains on a monthly basis are maintained, but generally the former will only be maintained on a daily basis.

The following is an example of a scaling equation for the Yadkin River at Wilkesboro gain for different time periods. In this example, all gages upstream of Wilkesboro need to be filled in and scaled prior to 1939. In October 1939 the Reddies River gage is in place and it no longer needs to be scaled. Then in October 1962 W Kerr Scott comes online, and none of the records in the Wilkesboro reach need to be scaled.

The scaling output spreadsheet referenced above contains full details on which gages were scaled for which months for the entire basin.

Yadkin River at Wilkesboro Gain

10/29 – 09/39 Wilkes F = (Wilkes F) * Wilkes XG / (Patterson XF + Elk XF + Kerr Scott XG + Reddies XF + Wilkes XF)

10/39 – 09/62 Wilkes F = (Wilkes F – Reddies F) * Wilkes XG / (Patterson XF + Elk XF + Kerr Scott XG + Wilkes XF)

10/62 – 09/19 Wilkes F = (Wilkes F – Reddies F – Kerr Scott F) [no scaling]

F = actual or scaled flow at a gage

XF = "extended" flow at a gage as computed by *fillin* when actual flows do not exist

G = actual or scaled gain, or inflow, between two locations, which is the difference of u/s gage F and d/s gage F

XG = extended gain between two locations as computed by *fillin* when actual gains do not exist

Section 4. Computing Inflows at OASIS Nodes from the Flows and Gains

To assign inflows to points in the modelbetween USGS gages (i.e. reservoirs, intakes, and other points of interest), the final disaggregated unimpaired gage flow dataset is apportioned by drainage area to those points. The drainage areas for non-gage locations were provided by NCDWR. The computations are done "on the fly" using an OASIS run that invokes the OCL file called ***set_inflows.ocl***. The comments of that OCL file (provided in appendix A) show in detail the calculations being made.

Section 5. Error Checking and Inflow Filtering

As noted in Section 1, because of the noisy data, a lot of error checking is necessary. These are some of the errors that can occur. Often the available impairment data is only available on a monthly average basis, which can cause issues when applying to daily gage flows.

- Negative unimpaired gage flow. These are physically impossible and should be corrected unless the value is small, say between 0 and -10 cfs, because the impact is negligible.

- Negative gains. These are sometimes legitimate. However, there are times when a flood hits a gage at the very end of the month, while not arriving at the gage downstream until the beginning of the next month. This can cause a highly negative gain in the first month and a highly positive gain the next month. These should be corrected.

- There are pathological cases where the scaling can cause one gage to have a large positive flow, while the adjacent gage has a large negative flow. This can occur when the two extended values are similar in magnitude but opposite in sign. These need to be adjusted.

- Negative corrections are made at various steps in the inflow development process: after unimpairing the flows, after computing gains, after filling in the flows/gains, and after scaling the flows/gains. Negatives corrections are tracked in the following directories:

    - 01b_UIF_Negative_Correction
    - 03_Correct_Gains_Negatives
    - 05a_Correct_Negatives_UIF_Filled
    - 06b_scaling_Negative_Correction

Initial negative corrections are computed using the R script called ***inflow-adjustment.r***, and additional corrections are made in the spreadsheets ending in ***"_Corrected***" in each of the directories mentioned above.

To prevent model infeasibility from provisional inflows (see Appendix C), we added code in the OCL to filter remaining daily negative inflows. The negative inflow is "stored" until there is a sufficiently positive inflow to release the accumulated negative flows, thereby preserving mass over a multi-day period. Since the negative inflows are generally very small and infrequent, the filtering has negligible impact on being able to match the monthly unimpaired gage flow.

Section 6. Time of Travel / Flow Routing

To account for time of travel between points along the main stem of the Yadkin and Pee Dee river, flow routing has been incorporated in both the development of inflows and the handling of flows within the model. The locations and lag coefficients were agreed to by the Technical Review Committee. The time of travel reaches consist of the Kerr Scott Reservoir release down to the Yadkin College Gage, and the Pee Dee River Rockingham gage down to the Pee Dee River at Pee Dee gage. Flow routing for the development of inflows is handled in the inflow unimpairment spreadsheet and the gains calculations. Flow routing within the model is handled in the OCL file ***routing.ocl***. The routing equations used for each gain are as follows:

Routed Kerr Scott release to Yadkin College = 1 day lag
Routed Rockingham Gage to Pee Dee Gage = 2 day lag

Note that the computation of gains may include subtracting the flows from tributaries in the reach (see Section 3), which are not routed. Given the extensive network of gages in the basin, mostly on tributaries, routing is generally not needed for this model.

The daily routed timeseries are averaged monthly; the monthly flows are used to compute gains for the above-mentioned reaches by subtracting from the monthly downstream un-routed flow. No routing is necessary when disaggregating to daily flows since gains are disaggregated using a representative local unimpaired gage flow.

For inflow development, upstream flows are routed before being subtracted from the downstream flow to compute a gain. In the model runs, routing is handled using a routing reservoir, which holds back upstream flows for the appropriate amount of time before releasing downstream.