APPENDIX B2 –

Finalized Inflow Data Development for the Neuse River Basin

Section 1. Introduction

This report provides a detailed account of the inflow development for the Neuse River Basin. These inflows are used in the Neuse portion of the combined Cape Fear/Neuse OASIS model.

The inflow record runs from January 1930 to September 2011.[1] There are 22 streamflow gages in the basin that are used in this project. These are listed in Table 1. 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 2011. Some of the gages were used just to provide more data for *fillin* (see below) when computing statistics.

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 If water is withdrawn above a gage and returned to the river below the gage, the impairment is the entire withdrawal.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.

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[1] A provisional record extends beyond September 2011, 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.

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 ***inflow_unimpairmen_neuse.xls*** in the 'Inflow Spreadsheets' directory. The unimpaired gage data is summarized in the ***unimpaired_summary_neuse.xls*** file. Impairments in the basin accumulate as each downstream gage is included. For example, the impairments upstream of Falls Lake include the impairments on the Eno River, Flat River, Knap of Reeds Creek, and Little River. 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 discharge and withdrawal data were obtained by Moffatt and Nichol and NC DWR. The reservoir storage data were obtained by NC DWR from the reservoir owner/operator. Records for the largest reservoir, Falls Lake, are available from the Army Corp of Engineers (Corps) since project inception in 1981. Monthly storage data for Durham's Lake Michie, which has been in operation for the entire period of record, was collected when available (1939 to present) by HydroLogics.

Evaporation and precipitation data were collected by HydroLogics. Evaporation data are based on daily measurements from the Chapel Hill station, which is the only long-term station in the basin. When measurements are missing, a monthly pattern based on a study of Lake Michie in Durham is used. Precipitation data are based on daily measurements from the following long-term stations: Butner Filter Plant, Chapel Hill 2W, Clayton WTP, Durham, Neuse 2 NE, RDU Airport, Raleigh 4 SW, NC State Univ Rocky Mount 6 SW, Rougemont, Roxboro 7 ESE, and Wilson 3 SW, as well as data from the Corps for Falls Lake. 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, HydroLogics 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.

HydroLogics unimpaired the streamflow data for ten gages, which are highlighted in bold in Table 1. The other gages are on rivers where impairments are negligible or not quantified.

Table 1. List of Gages

USGS Number	Description	Period of Record	Ref No.	Ref. Name	Drain. Area
02085000	**Eno R. at Hillsborough**	**10/1927-9/1971, 10/1985-present**	**1**	**Hills**	**66**
02085070	**Eno R. nr. Durham**	**09/1963-present**	**2**	**Durha**	**141**
0208521324	Little R. at SR1461 nr. Orange Factory	10/1987-present	3	Litor2	78.2
02085220	Little R. nr. Orange Factory	9/1961-9/1987	4	Litor1	80.4
0208524975	Little R. bl. Little R. Trib. at Fairintosh	10/1995-present	5	Litfa	98.9
02085500	Flat R. at Bahama	7/1925-present	6	Flatb	149
02086500	Flat R. at dam nr. Bahama	9/1927-9/1959, 8/1961-9/1966, 10/1982-9/1990, 10/1992-9/1993, 10/2000-present	7	Flatd	168
02087000	**Neuse R. nr. Northside**	**8/1927-10/1980**	**8**	**North**	**535**
02087183	**Neuse R. nr. Falls**	**7/1970-present**	**9**	**Falls**	**771**
02087500	**Neuse R. nr. Clayton**	**7/1927-present**	**10**	**Clayt**	**1150**
02087580	Swift Ck. nr. Apex	3/2002-present	11	Swift	21
02088000	**Middle Ck. nr. Clayton**	**10/1939-present**	**12**	**Middl**	**83.5**
02088500	**Little R. nr. Princeton**	**2/1930-present**	**13**	**Litpr**	**232**
02089000	**Neuse R. nr. Goldsboro**	**2/1930-present**	**14**	**Golds**	**2399**
0208925200	Bear Ck. at Mays Store	10/1987-present	15	Bearc	57.7
02089500	**Neuse R. at Kinston**	**2/1930-present**	**16**	**Kinst**	**2692**
02090380	Contentnea Ck. nr. Lucama	9/1964-present	17	Lucam	161
02091000	Nahunta Sw. nr. Shine	4/1954-present	18	Nahun	80.4
02091500	**Contentnea Ck. nr. Hookerton**	**12/1928-present**	**19**	**Hooke**	**733**
02091700	Little Contentnea Ck. nr Farmville	10/1956-9/1987	20	Ltcon	93.3
02092000	Swift Ck. nr. Vanceboro	2/1950-10/1989	21	Vance	182
02092500	Trent R. nr. Trenton	1/1951-present	22	Trent	168

Timeline for Gage Data
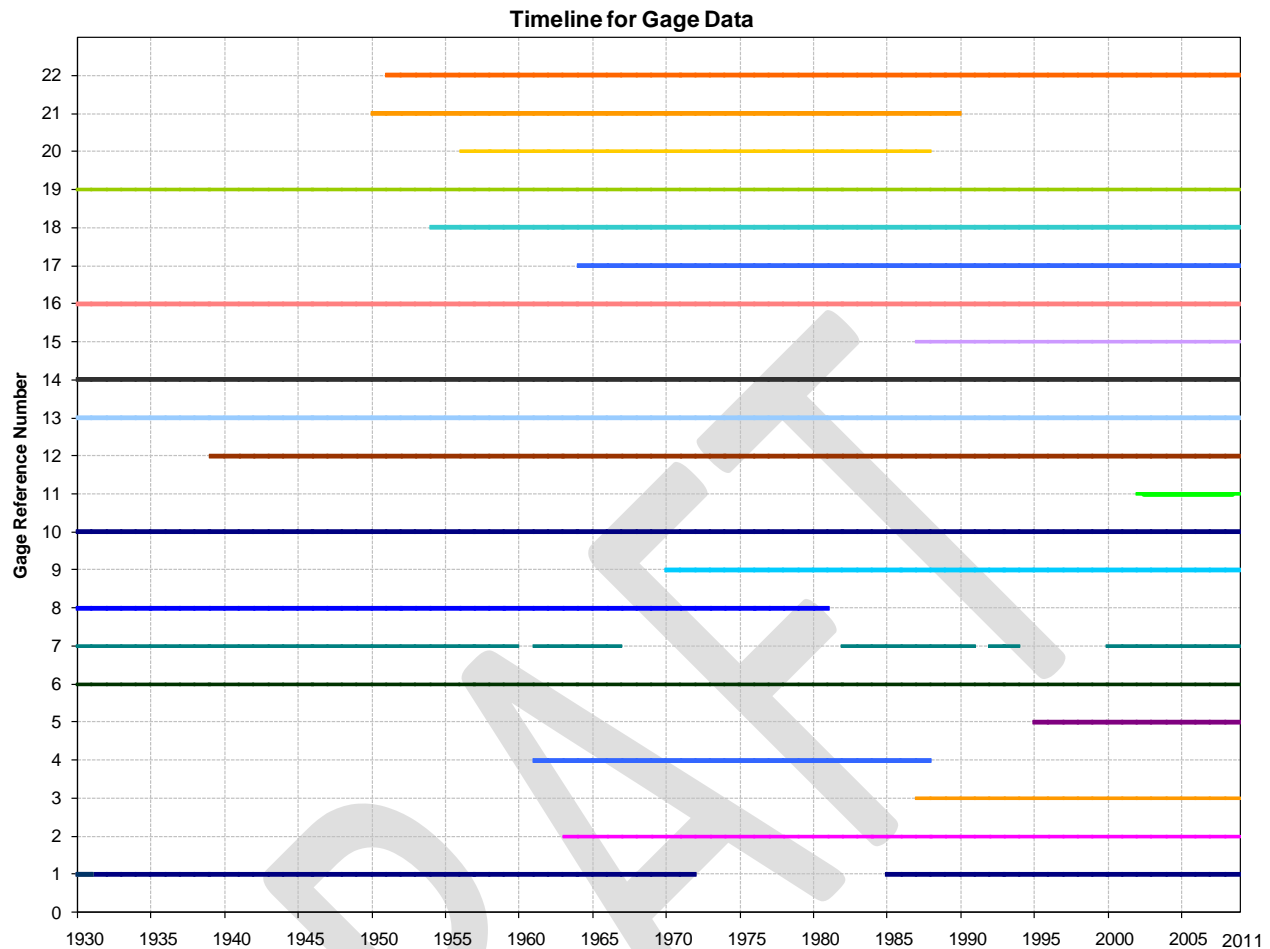
The second step in the inflow development process is to fill in the missing flows and gains for each gage with missing records. This requires assembling a monthly record of unimpaired flows and gains based on the daily unimpaired data computed above. These flows and gains are fed into a program named *fillin* (developed by William Alley and Alan Burns of the USGS[2]). 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 third 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. On the

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

Little River, two gages were combined into one. The gages near Orange Factory (reference Litor1) and SR1461 near Orange Factory (reference Litor2) are adjacent (drainage areas are 80.4 mi^2 and 78.2 mi^2, respectively). Between them, they have a complete but non-overlapping record going back to 1961. We scaled the Litor1 flows by 78.2 / 80.4 and treated the new flows as part of the Litor2 record, thus making one long record at Orange Factory (reference Litor).

The inflows to Durham's Lake Michie and Little River Reservoirs are based on drainage area adjustments of the upstream Flat River at Bahama and the Little River near Orange Factory gages, respectively, and are given the name Michie and LitRes.

The records of the gages Little River near Princeton, Neuse River near Goldsboro, and Neuse River near Kinston all start in March 1930. We extended the record using *fillin* back to January 1930. These extensions were done prior to any of the work whose description follows.

Table 2. Gages Where Flows and Gains Are Computed

Gage	Flow or Gain	Gain Calculation
Hills	Flow	
Durha	Gain	Durha flow – Hills flow
North	Gain	North flow – Michie flow – LitRes flow – Hills flow
Falls	Gain	Falls flow – North flow
Clayt	Gain	Clayt flow – Falls flow
Middl	Flow	
Golds	Gain	Golds flow – Clayt flow – Middl flow – Litpr flow
Kinst	Gain	Kinst flow – Golds flow
Buckhorn	Flow	
Hooke	Gain	Hooke flow – Buckhorn flow

Note that the gains at Clayton, Goldsboro and Kinston are calculated with consideration made to the time of travel (flow routing) along the Neuse. See Section 6 for more information.

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. These computations are done with the DSSVue script, ***compute_gain.py.*** 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 Hills (reference name for Eno River at Hillsborough gage) and unimpaired gain at North (reference name for Neuse River near Northside gage) from September 1961 to October 1980 when either the impairments at Hills cannot be quantified (and thus the gage cannot be unimpaired) or the Hills gage data are missing. As a result, we have no actual (unimpaired) flow at Hills and no actual gain at North. We extended the gage record at Hills and extended the gain at North using *fillin*. Now we want to adjust those extended values so that the sum of the flows at Hills, Michie, LitRes, and the remaining gain down to North match the unimpaired flow at North. So we say that we maintain the North flow less the inflows to Michie and LitRes by scaling with the sum of the Hills and the North extended gain. The calculation is:

> Scaled North extended gain = (North flow – Michie flow – LitRes flow)* (North
>   extended gain) / (North extended gain + Hills extended flow)

The companion calculation for the flow at Hills is:

> Scaled Hills extended flow = (North flow –Michie flow – LitRes flow)* (Hills extended
>   flow) / (North extended gain + Hills extended flow)

Thus the sum of the actual unimpaired flows (Michie and LitRes) and the scaled flow (Hills) and scaled gain (North) equals the unimpaired gage flow at North, or

> LitRes flow + Michie flow + Hills scaled flow + North scaled gain = North unimpaired
>   gage flow

In 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.

The DSSVue script used to do these calculations is *scale_flow_gain.py*. The output is the file *scale_flow_gain.dss*, which contains monthly flows and gains.

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

Two DSSVue scripts are used to do this step: *convert_month_to_day.py* and *disaggregate.py*. DSSVue cannot work on two records with different time steps, so the first step is to convert the monthly value to daily. For example, the gain at North for January 1930 is 188 cfs; converting the monthly flow to daily gives 156 cfs for each day in the month. The first script converts the monthly flows to daily flows for each location where we need them. The second script computes the daily flows and gains as shown above.

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 remainder of this section shows the details in how the records were extended and disaggregated. This is the short hand used in the remainder of this document:

d/s = downstream
u/s = upstream
DA = drainage area
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

Eno River near Hillsborough FLOW (Hills), 10/28 – 9/71, 10/85 – present

This gage prior to 10/1954 is not influenced by reservoir operations, so it can be unimpaired. After that, reservoir data are only available from 8/1997 to present, meaning it must be filled in from 1955 to 7/1997. Note that we arbitrarily selected 1928 as the starting year, although we standardized the data set later to begin at the start of the 1930 decade.

    10/28 – 09/54 use actual daily values
    10/54 – 08/61 $HillsF = (NorthF - MichieF) * HillsXF / (NorthXG + HillsXF + LitResXF)$
    9/61 – 10/80 $HillsF = (NorthF - MichieF - LitResF) * (HillsXF) / (NorthXG + HillsXF)$
    11/80 – 07/97 use values generated by *fillin*
    08/97 – 04/08 use actual daily values
    Disaggregate 10/54 to 7/97 using Flatb.

Eno River near Durham GAIN (Durha), 10/28 – present
Hillsborough gage data are missing from 10/71 to 09/85

    10/28 – 08/63   Hills F * 75 / 66 (drainage area adjustment of Hillsborough flow)
    09/63 – 09/71   Durh F – Hills F + net withdrawal within reach
    10/71 – 09/85   Hills F * 75 / 66 (drainage area adjustment of Hillsborough flow)
    10/85 to present Durh F – Hills F + net withdrawal within reach

Gain included in script files since disaggregation of full record is required. Disaggregate whole record with Flatb.

Little River FLOW (09/61 – present)
    10/28 – 09/54 $LitResF = (NorthF - MichieF - HillsF) * LitResXF / (NorthXG + LitResXF)$, disaggregate with Flatb
    10/54 – 08/61 $LitResF = (NorthF - MichieF) * LitResXF / (NorthXG + LitResXF + HillsXF)$, disaggregate with Flatb
    09/61 – present Use actual daily values.

Neuse River near Northside GAIN (North), 10/1928 – 10/1980
    10/28 – 09/54 $NorthG = (NorthF - MichieF - HillsF) * NorthXG / (NorthXG + LitResXF)$
    10/54 – 08/61 $NorthG = (NorthF - MichieF) * NorthXG / (NorthXG + LitResXF + HillsXF)$
    09/61 – 10/80 $NorthG = (NorthF - MichieF - LitResF) * NorthXG / (NorthXG + HillsXF)$
    11/80 – 04/81 use values generated by *fillin*
    Disaggregate whole record with Flatb

    Beginning May 1981, we no longer need Northside gains since we are using back-calculated inflows from Falls.

Neuse River near Falls GAIN (North), 07/1970 – 06/1976

    Computed gain at Falls is FallsF – NorthF

    10/28 – 06/70 use values generated by *fillin*

    07/70 – 06/76 FallsG = FallsF – NorthF

    7/76 – 04/81   use values generated by *fillin*

    Disaggregate whole record with Flatb

    Flows after this are done with a spreadsheet to compute the daily gain to Falls, which represents the difference between the back-calculated Falls inflow [unimpaired] and upstream inflow [unimpaired]).

Neuse River near Clayton GAIN (Clayt), 10/28 – present

    10/28 – 4/81   ClaytonG = ClaytonF – (NorthF + FallsG)

    5/81 – present Clayton G = ClaytonF (gage flow) – Falls release + local impairments in this
                     reach

    Disaggregate whole record with Litpr.

Neuse River near Goldsboro GAIN (Golds), 03/30 – present (filled in back to 1928)

    Computed gain at Golds is GoldsF – ClaytF – LitprF - MiddlF

    10/28 – 09/39   GoldsG = (GoldsF – ClaytF – LitprF) * (GoldsXG) / (GoldsXG +
                   MiddlXF),

    10/39 – present   GoldsG = GoldsF – ClaytF – LitprF - MiddlF

    Disaggregate whole record with Litpr.

Middle Creek near Clayton FLOW (Middl), 03/30 – present (filled in back to 1928)

    10/28 – 09/39   MiddlF = (GoldsF – ClaytF – LitprF) * (MiddlXF) / (GoldsXG + MiddlXF),
                   disaggregate with Litpr

    10/39 – present Use actual daily values

Neuse River near Kinston GAIN (Kinst), 03/30 – present (filled in back to 1928)

    10/28 – present KinstG = KinstF – GoldsF, disaggregate with Litpr

Buckhorn Reservoir FLOW (Buckhorn), 10/64 – present

Based on the drainage area adjustment of the Lucama gage, whose record does not start until 10/1964 and whose record is impaired by the reservoir operations since 10/1974.

    10/28 – 09/64   BuckhornF = HookeF * (BuckhornXF) / (HookeXG + BuckhornXF),
                   disaggregate with Litpr

    10/64 – 09/74   Use actual daily values

    10/74 – present   BuckhornF = HookeF * (BuckhornXF) / (HookeXG +BuckhornXF),
                   disaggregate with Litpr

Contentnea Creek near Hookerton GAIN (Hooke), 12/28 - present

    Computed gain at Hooke is HookeF – BuckhornF

    10/28 – 09/64   HookeG = HookeF * (HookeXG) / (HookeXG + LucamXF)

10/64 – 09/74   HookeG = HookeF - BuckhornF
10/74 – present   HookeG = HookeF * (HookeXG) / (HookeXG + LucamXF)
Disaggregate whole record using Litpr

The result of the computations in this section is a set of monthly and daily flows and gains at each of the locations shown in Table 2.

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

This section describes the computation of inflows at OASIS nodes from flows and gains at gages described above. The computations are done "on the fly" during an OASIS run called "Compute_Inflows" using ratios of drainage area (total or incremental) as shown in Table 3 below. The computations are included in an OCL file called *set_inflows.ocl* and are listed below.

Node 1010 (u/s Orange pond)   Hills Flow * 7.1 / 66
Node 1050 (WFER)   Hills Flow * 9.4 / 66
Node 1060 (Lk Orange)   Hills Flow * 1.8 / 66
Node 1080 (Corporation Lk)   Hills Flow * 22.9 / 66

Node 1100 (Lk Ben Johnston)   Hills Flow * 19.2 / 66
Node 1110 (Hills gage)   Hills Flow * 5.6 / 66
Node 1115 (Durha gage)   Durha Gain
Node 1140 (Lk Michie)   Michie Flow
Node 1200 (Little River Res)   LitRes Flow
Node 1250 (Lk Holt)   Inflow1200 * 30 / 97.7
Node 1270 (Lk Rogers)   Inflow1200 * 17.4 / 97.7
Node 1230 (Beaverdam Lk)   (North Gain + Falls Gain – Inflow1115 –Inflow1250 –
                                     Inflow1270) * 0.05 prior to 5/1981

                                     [The Corps assumes 5% of the total inflows to Falls and
                                     Beaverdam are allocated to Beaverdam, even though the
                                     proportion would be a bit different on a drainage area basis.
                                     The remaining 95% is allocated to Falls.]

                                     See below for 5/1981 to present

Node 1290 (Wake Forest Lk)   Middl Flow * 3 / 83.5

Node 1300 (Falls Lk)   (North Gain + Falls Gain – Inflow1115 – Inflow1250 –
                                     Inflow1270)) * 0.95 prior to 5/1981

                                     See below for 5/1981 to present

Node 1400 (Lk Crabtree)   Middl Flow * 93.7 / 83.5
Node 1420 (Lk Wheeler)   Middl Flow * 35.8 / 83.5 prior to 03/2002;
                                     Swift Flow * 35.8 / 21 from 03/2002 – present

Node 1440 (Lk Benson)   Middl Flow * 30.5/ 83.5 prior to 03/2002;
                                     Swift Flow * 30.5 / 21 from 03/2002 – present

Node 1445 (Lk Johnson)	Middl Flow * 7.1 / 83.5
Node 1450 (Lk Raleigh)	Middl Flow * 5.2 / 83.5
Node 1480 (Middl gage)	Middl Flow
Node 1500 (Buckhorn Res)	Buckhorn Flow
Node 1560 (Hookerton gage)	Hooke Flow - Buckhorn Flow
Node 1630 (Clayton gage)	Clayt Gain – Inflow1290 – Inflow1400 – Inflow1445 – Inflow1450
Node 1740 (Little River Res)	Litpr Flow * 51.8 / 232
Node 1750 (Litpr gage)	Litpr Flow * 179 / 232
Node 1780 (Goldsboro gage)	Golds Gain – Inflow1420 – Inflow1440
Node 1800 (Kinst gage)	Kinst Flow – Golds Flow
Node 1900 (Weyerhauser)	Weighted average cfsm based on Kinst Flow and Contentnea Creek * Incremental drainage area

Node 1230 (Beaverdam) and Node 1300 (Falls Lake) inflows require extra computations once the dam was built. Post-project, the gain at Falls is computed by back-calculating the inflows from the Falls release and the change in storage, with the net evaporation added back. Since the Corps inflows include Beaverdam storage only when Falls is at or above 249 ft, we need to increase these inflows for those periods when Beaverdam was below 249 ft. We proportion 5% of the total Falls inflow to Beaverdam, so we divide the Falls/Beaverdam inflow by 0.95 to achieve this. The back-calculated inflows are impaired due to upstream impairments, so we need to take these into account. To get agreement with the total unimpaired flow at Clayton, we must account for the same impairments.

<u>05/1981 – present</u>
If Beaverdam elev < 249
(Corps net inflow + net evap) / 0.95 – Hills Flow – Inflow1115 – Inflow1140 – Inflow1200 – Inflow1250 – Inflow1270 + total impairment from net withdrawals and reservoirs upstream of Falls Lake (including those on the Eno and from Durham's reservoirs).

If Beaverdam elev >= 249
(Corps net inflow + net evap) – Hills Flow – Inflow1115 – Inflow1140 – Inflow1200 – Inflow1250 – Inflow1270 + total impairment from net withdrawals and reservoirs upstream of Falls Lake (including those on the Eno and from Durham's reservoirs).

The final inflow to Node 1300 (Falls) is 95% of the above calculations, after proportioning 5% to Beaverdam (Node 1230).

Additional Inflow Nodes

In addition to the inflow nodes listed above, a number of natural inflows/gains have been added to the model, to improve the resolution at points of interest such as withdrawals, discharges, or locations of environmental interest. These inflows are allocated within the model run; the code for the allocation can be found in the OCL file *filter_inflows.ocl* (see Appendix A).

Table 3. List of Drainage Areas (in square miles)

Reservoirs			Gages		
Description	**Total Drainage Area**	**Incremental Drainage Area**	**Description**	**Total Drainage Area**	**Incremental Drainage Area**
Orange Impoundment	7.1	7.1	Eno River at Hillsborough	66	5.6
West Fork Eno Reservoir	9.4	9.4	Eno River nr Durham	141	75
Lake Orange	8.9	1.8	Neuse River at Clayton	1150	380
Corp. Lake	41.2	22.9	Little River nr Princeton	232	179
Lake Ben Johnston	60.4	19.2	Neuse River at Goldsboro	2399	933.5
Lake Michie	167	167	Contentnea Cr at Hookerton	733	578
Little River Reservoir	97.7	97.7	Neuse River at Kinston	2692	293
Lake Holt_Butner	30	30	Middle Creek near Clayton	83.5	83.5
Lake Rogers	17.4	17.4	Swift Creek near Apex	21.0	21.0
Beaverdam Lake	50	50			
Falls Lake	770 (751)	316.9 (297.9)			
Wake Forest Lake	3	3			
Lake Crabtree	93.7	93.7			
Lake Wheeler	35.8	35.8			
Lake Benson	66.3	30.5			
Lake Johnson	7.1	7.1			
Lake Raleigh	12.3	5.2			
Buckhorn Reservoir	155	155			
Little River Reservoir (Raleigh proposed)	50.8	50.8			
Weyerhaeuser	4103	678			

* Value in parentheses is net of surface area of lake at full pond

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.

- For this work, the changes are tracked in the file *hand_mods_neuse.xls*.

No daily adjustments were made for the Neuse basin. Monthly flows were adjusted in the "monthly" sheet of *hand_mods.xls*. Revisions were done for North, Hills, Durha and Middl flows and Golds and Kinst gains in the *unimpaired.dss* file, and for Hills and Middl flows and Durha, North, Clayt, Golds and Kinst gains in file *scale_flow_gain.dss*.

An example of a negative monthly gain occurred on April 1978 at Golds; a large inflow at the end of the month upstream did not travel down to Golds until the beginning of the next month:

	04/1978	05/1978
ClaytF	2395 cfs	3840 cfs
MidllF	256 cfs	167 cfs
LitPrF	598 cfs	457 cfs
GoldsF	3070 cfs	8821 cfs

This leads to values of -179 cfs and 4357 cfs for the Golds gain in April and May, respectively. A manual adjustment was then made by adding 200 cfs to the Golds flow in April, and subtracting 200 cfs from the Golds flow in May, which eliminates the negative gain in April and maintains the total volume over the two month period.

To prevent model infeasibility from provisional inflows (see Appendix C), unrealistic releases from upstream reservoirs, or unrealistic water supply shortages, 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.

The main exception are Falls and Beaverdam inflows, which rely on back-calculations as described earlier and result in occasional negative values. There is enough storage to handle the negative inflows, so no filtering is needed.

To test that all flows, gains, and drainage areas have been properly accounted for, we check that the "reconstituted," unimpaired gage flows match the actual unimpaired gage flows. In this case, reconstituted means that the flow at a given gage is computed by summing the appropriate upstream flows and gains. File *gage_comp_neuse.xls* compares the actual monthly unimpaired gage flows with the computed values from *flows_gains_month.dss*. To test that all the drainage areas have been properly accounted for, file *model_comp_neuse.xls* compares the same actual unimpaired gage flows to the gage flows reconstituted from the computed OASIS inflows.

Section 6. Time of Travel / Flow Routing

To account for time of travel between points along the main stem of the Neuse River, flow routing has been incorporated into both the development of inflows, and the handling of flows within the model. The time of travel or lag coefficients were furnished by the Corp of Engineers. The time of travel reaches consist of the Falls dam to the Clayton gage, the Clayton gage to the Goldsboro gage, and the Goldsboro gage to the Kinston gage. Flow routing for the development of inflows is handled in the HEC-DSSVue script called ***routing.py***. Flow routing within the model is handled in the OCL file ***routing.ocl***. The routing equations used for each gain are as follows:

Routed Falls release = 0.5*yesterday's release + 0.5*today's release
Clayton gain = Clayton flow - 2 day average of Falls releases

Routed Clayton Flow = [flow(-4 days) + flow(-3 days) + flow(-2 days) + flow(-1 day)] / 4
Goldsboro gain = Goldsboro flow - previous four day average of Clayton flows

Routed Goldsboro Flow = [flow(-2 days) + flow(-1 day)] / 2
Kinston gain = Kinston flow - previous two day average of Goldsboro flows

Note that the computation of gains may include subtracting the flows from tributaries in the reach (see Section 3), which are not routed.

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.

Section 7. Extending the Record Beyond September 2011

As mentioned earlier, the finalized inflow record ends on September 30, 2011. This section describes how to finalize updates to the record when new records (including impairments) become available. This is not to be confused with *provisional* updates used to facilitate real-time forecasting, which are done directly from the model interface using the Update Record tab. Let us assume that we are adding data from October 1, 2011 to September 30, 2012. Note that we are only <u>adding</u> to the record. We are not changing any of the values prior to October 2011.

1. Assemble the new data for the gage records in Table 4 below and place in the files *gage_day.dss* and *gage_month.dss*. Note that the Flatb and Litor gage flows need to be adjusted by drainage area to the Lake Michie and Little River Reservoir drainage areas, respectively, before being entered into *gage_day.dss* and *gage_month.dss* under the appropriate reservoir names.

   Note that the local upstream impairments for the Clayton gage need to go into the *gage_day.dss* and *gage_month.dss* files.

2. Compute the impairments at each gage and add them to the gage flows. This has been done in the unimpairment spreadsheets described earlier (called *inflow_unimpairment_neuse.xls)*. Next put the daily unimpaired flows into the spreadsheet *unimpaired_summary.xls* to compute the monthly unimpaired flows using a spreadsheet pivot table.

3. Append the new unimpaired flows to the *unimpaired.dss* file (monthly averages) and to the *unimpaired_daily.dss* file (daily data) where appropriate. Note that the unimpaired Little River at Princeton gage needs to be appended into the *gage_day.dss* and *gage_month.dss* files, and the daily unimpaired Eno River at Hillsborough and Middle Creek nr Clayton gage flows need to go into the *gage_day.dss* file (with "Unimpaired" in the F-part) in addition to the monthly flows going into the *unimpaired.dss* file.

4. Copy the following files into the folder *c:\Program Files\HecDssVue* (assuming the DSSVue has been installed in the default location). Update the fillin.cf so the ending year is 2012.

   > *fillin.cf*
   > *fillin.exe*
   > *gage_day.dss*
   > *gage_month.dss*
   > *path_list.dat*
   > *unimpaired.dss*
   > *unimpaired_daily.dss*

5. Copy the following files in folder of *c:\Program Files\HEC\HecDssVue\HecDssVue\scripts.* If extending the record to a year beyond 2011, be sure to change the ending years in the script

from either '11 or 2011 to the appropriate year. Use the script files from the folder "scripts_2012", in which this change has already been made.

> *routing.py*
> *compute_gain.py*
> *convert_day_to_month.py*
> *convert_month_to_day.py*
> *disaggregate.py*
> *scale_flow_gain.py*

6. Execute the script *01_routing.py.* This reads from file *unimpaired_daily.dss*, creates routed time-series where necessary (see Section 6), and writes monthly routed flows to *unimpaired.dss* and *extend_flow_gain.dss*.

7. Transfer the monthly flows from *unimpaired.dss* to *hand_mods_neuse.xls*. Here perform necessary modifications to remove negative gains from the records, following the examples of previous modifications. Then paste the modified flows and routed flows back into **unimpaired.dss** and *extend_flow_gain.dss.*

8. Execute the script *02_compute_gain.py.* This reads from file *unimpaired.dss*, computes all the gains, and writes to the files *extend_flow_gain.dss***,** *scale_flow_gain.dss***, and** *fillin_input.dss.*

9. Close DSSVUE, and execute *fillin* by double-clicking it. This updates the file *extend_flow_gain.dss* with filled-in flows. Thus, this file is a combination of the actual unimpaired values and extended values.

10. Open up DSSVue again, execute the script *03_scale_flow_gain.py*, which does the calculations described in Section 3. This reads from file *extend_flow_gain.dss* and updates file *scale_flow_gain.dss*.

11. Import the appropriate flows and gains from *scale_flow_gain.dss* into *hand_mods_neuse.xls* and perform hand modifications to remove negative flows and gains. Paste modified flows/gains back into *scale_flow_gain.dss*.

12. Execute the script *04_convert_month_to_day.py*. This reads from files *gage_month.dss* and *scale_flow_gain.dss* to generate a daily record from the monthly records. The daily records are used to disaggregate the flows, as shown in Section 3. File *month_day.dss* is written.

13. Execute the script *05_disaggregate.py* to convert the monthly flows and gains at the gages to daily. File *flow_gain.dss* is produced; this file has the data that are read by OASIS.

14. Execute the script *06_convert_day_to_month.py* to convert the daily flows and gains at the gages into monthly values. The purpose of this step is to import the monthly flows and gains into *gage_comp.xls* to ensure that all the accounting has been properly done.

15. Execute the OASIS run called "Compute_Inflows", beginning October 1, 2011 and ending September 30, 2012. This run contains a file called "set_inflows.ocl" that assigns inflows to the OASIS nodes.

    Then go to the run folder, open the *output.dss* file, click View → Refresh Catalog. Select all of the inflow nodes (i.e, those which have a pathname labeled inflow) and convert from acre feet (af) to cubic feet per second (cfs) by doing the following: click Utilities → Math Functions. On the Arithmetic tab, select Divide from the pull down menu, click the Data Set radio button, and highlight all of the inflow records, click the Constant radio button and enter 1.9835 into the field, and then press the Compute button at the bottom of the window. Once the computation has completed, close the Math Functions window and click Yes when prompted to save the changes. Now select all of the inflow records and click Edit → Tabular Edit, and change all of the units to cfs, and all of the units Type to PER-AVER. Close the editing window and save your changes.

    Next select all of the records, and copy and append to the *basedata.dss* file in the basedata folder. The basedata file will now contain this finalized data from October 1, 2011 to September 30, 2012. This basedata file will be used for all future runs.

Table 4. Gages Used to Extend the Record Beyond September 2011

USGS Number	Description	Period of Record	Ref. Name	Drainage Area
02085000	Eno R. at Hillsborough	10/1927-9/1971, 10/1985-present	Hills	66
02085070	Eno R. nr. Durham	09/1963-present	Durha	141
0208521324	Little R. at SR1461 nr. Orange Factory	10/1987-present	Litor2	78.2
02085500	Flat R. at Bahama	7/1925-present	Flatb	149
02087000	Neuse R. nr. Northside	8/1927-10/1980	North	535
02087183	Neuse R. nr. Falls	7/1970-present	Falls	771
02087500	Neuse R. nr. Clayton	7/1927-present	Clayt	1150
02087580	Swift Ck. nr. Apex	3/2002-present	Swift	21
02088000	Middle Ck. nr. Clayton	10/1939-present	Middl	83.5
02088500	Little R. nr. Princeton	2/1930-present	Litpr	232
02089000	Neuse R. nr. Goldsboro	2/1930-present	Golds	2399
0208925200	Bear Ck. at Mays Store	10/1987-present	Bearc	57.7
02089500	Neuse R. at Kinston	2/1930-present	Kinst	2692
02091000	Nahunta Sw. nr. Shine	4/1954-present	Nahun	80.4
02091500	Contentnea Ck. nr. Hookerton	12/1928-present	Hooke	733
02091700	Little Contentnea Ck. nr Farmville	10/1956-9/1987	Ltcon	93.3