Modeling the Neuse River Basin Operations with OASIS

Addendum to the
User Manual for OASIS with OCL™

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Prepared for the

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HYDROLOGICS
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Introduction

This report describes how OASIS is used to model the operations of the Neuse River Basin. This application of OASIS, known as the Neuse River Basin Hydrologic Model, extends geographically from the headwaters of the Eno, Flat and Little Rivers to the mouth of the Neuse River.

The model is available for registered users on the Division of Water Resources (DWR) server. The model can be used in two modes: (1) a simulation mode to evaluate system performance for a given set of demands and operating policies over the period of the historical inflow record; and (2) a position analysis mode for managing droughts in real-time.

The model uses an inflow data set that extends from January 1, 1930 through April 30, 2008. This data set was developed using a comprehensive approach that relies on 15 streamflow gages in the basin, accounts explicitly for impairments upstream (from reservoir regulation and net water consumption), and uses statistical techniques to complete missing records for these gages.

Real-time drought management depends upon having current forecasts of inflow. As noted below, the generation of current forecasts is dependent upon having a current inflow data set. Updating the data set requires the collection of impairment data, which can be time intensive. We developed a *provisional* approach for updating inflows so that real-time updates can be made quickly and easily without the need to collect impairment data. It is envisioned that impairment data will be collected and the data set updated every five years. In the interim (e.g., through April 2013), the inflow data (in this case, beginning May 2008) will be based on this provisional inflow technique.

The remainder of this document summarizes the components of the Neuse model and how the model is used for real-time drought management. Appendix A lists the code used in the basecase simulation run. Appendix B describes the comprehensive inflow approach used to establish the finalized inflow data set. Calibration of inflows and operating rules was described in meetings with the Technical Review Committee and formalized in Powerpoint® presentations that were later made available on the DWR server. Appendix C describes the provisional inflow approach and comments on its accuracy. Appendix D describes the weighting setup for nodes and arcs in the model.

It is important to note how the OASIS model should and should not be used. OASIS is a generalized type of mass balance model used for assessing the impacts of different water allocation policies and facilities over the historic record of inflows. It works on a daily timestep and is intended for drought management and capital expansion planning. It is not intended for use in hydraulic routing nor flood management, although it can be linked to other models for those purposes.

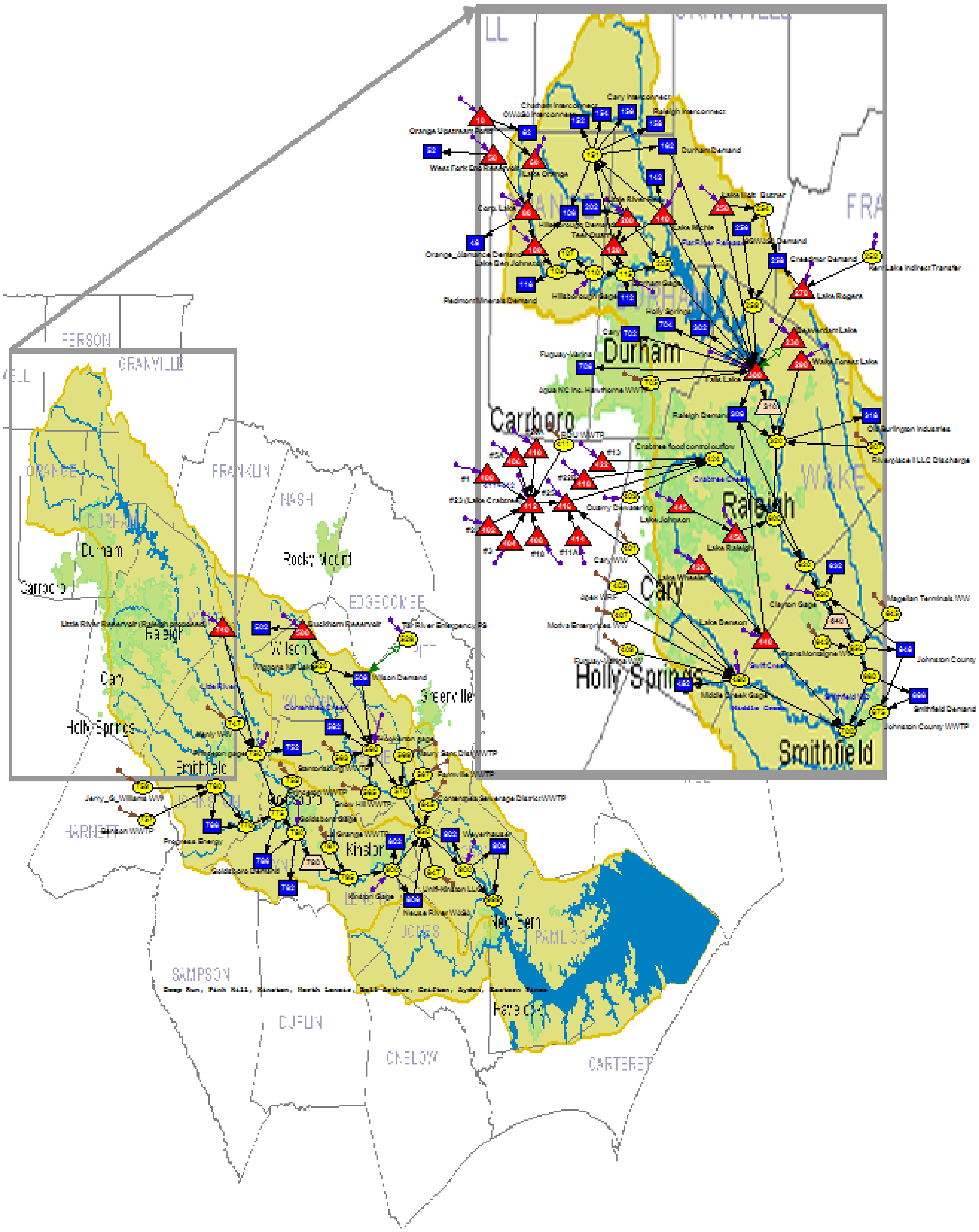
In addition, since modeling results are largely influenced by the accuracy of the inflows, the user must be cautioned about the inflows. HydroLogics spent considerable effort in developing the inflow data. The methodology ensures that the monthly naturalized flows at the gage locations match, which assumes that any measurement error is embedded in the impairments and not the streamflow data. DWR agreed to this method, which, although imperfect, is the most reasonable given the available data. Further, it is important to note that we are not trying to replicate history in computing the OASIS inflows; rather, we are trying to build a data set of daily flows whose variation is *representative* of history while preserving monthly gaged flows as “ground truth”.

Due partly to the inaccuracy of some of the impairment data and to time of travel, negative inflows may occur. These can lead to potential model infeasibility. The model code filters out negative inflows, particularly large ones, but preserves the total inflow volume over a short period by debiting those negative inflows from subsequent positive inflows. For example, if a rainstorm hits the upstream part of the reach but not the downstream part, the gaged flow data may indicate a large negative inflow (gain) between the upstream and downstream ends. When the flow attenuates upstream and peaks downstream, the inflow becomes positive, and the negative gain from the day(s) before is debited from the positive inflows the day(s) after to ensure that the average inflow over that period is preserved. The occurrence of negative inflows was reduced in the main-stem of the Neuse downstream of Falls Lake by incorporating time-of-travel equations recommended by the Corps of Engineers.

Model Components

The model uses a map-based schematic that includes nodes for withdrawals (agricultural, municipal, and industrial), discharges (municipal and industrial), reservoirs, and inflows. The model schematic is shown on the following page and is sized to show the full system. To make it more legible, the user is encouraged to adjust the schematic size from the model's graphical user interface (GUI) rather than from here.

NEUSE RIVER BASIN SCHEMATIC



The user can click on any node or connecting arc to access specific information, like reservoir stage-storage-area data or minimum streamflow requirements. These data are also contained in tables contained on other tabs of the model.

Municipal and industrial demand nodes use an annual average demand subject to a monthly pattern, and an associated wastewater discharge. Wastewater discharges not associated with demand nodes are modeled using an annual average return subject to a monthly pattern. In total, the model has approximately 115 nodes and a similar number of connecting arcs. There are approximately 30 reservoir nodes (11 of which are Crabtree Creek flood impoundments), 15 irrigation nodes, 20 municipal and industrial demand nodes, 20 independent discharge nodes, 40 natural inflow nodes (including the reservoir nodes), and other miscellaneous nodes to account for minimum flow requirements, junctions, etc. To limit the length of this document, the tables containing the nodes and arcs shown later reflect only the most important information. The rest can be viewed from the model interface.

Run times increase as nodes are added. It is recommended that the balance sheet, which provides the water accounting summary for all nodes and arcs, as well as other diagnostic files be turned off when executing simulation runs in order to speed run times. The switch to turn these files on or off is found on the Misc (miscellaneous) tab of the model interface under Output Options. For the nearly 80 year inflow record, the run time in simulation mode (on a daily timestep) is no more than a few minutes. In position analysis mode, diagnostics are not an option, so run time cannot be changed. Run time in position analysis mode is approximately five minutes.

Agricultural water use is broken out by county and depends on livestock count, crop usage, livestock and crop water consumption, and rainfall. The water use can be easily adjusted from the model interface by opening the Edit Irrigation Data dialog box on the Setup tab. An algorithm provided by the sub-consultant is used to convert the input data on crop acreage and livestock count into water use values. The agricultural demand nodes are a summation of the agricultural water usage in a particular reach of interest. The demand for these reaches is computed by summing the usage in the upstream sub-basins, which are based on a percentage of the county's agricultural demand.

The timeseries data are stored in a basedata HEC-DSS file, which contains all the inflow and net evaporation (evaporation less precipitation) data. The sources for these data are provided in Appendix B along with a more detailed description of how the inflows were developed. As noted, updating the timeseries data can be done in two ways: (1) using the comprehensive approach described in Appendix B; or (2) using the provisional approach for facilitating real-time drought management described in Appendix C. The provisional approach relies on streamflow data from fifteen gages throughout the basin as well as precipitation data and operational data for select points. The provisional updates can be done directly from the interface by selecting the Update Record tab, inputting the data, and clicking on the Update Record button. The update record algorithm will calculate the inflows to all the OASIS inflow nodes and net evaporation for all the reservoir nodes and write them to the basedata.dss file automatically.

In simulation mode, on the Setup tab, the user can select from three radio buttons: No Forecasts, Conditional Forecasts, and Non-conditional Forecasts. The latter two enable the user to evaluate forecast-based operating policies, with forecasts generated each week in the historical inflow record. Conditional forecasts account for antecedent flow conditions while non-conditional forecasts are made independent of how wet or dry the basin is. The forecasts for the simulation mode are generated outside the GUI and stored in the basedata folder. The current forecast file is developed from the basedata.dss file that extends through April 2008. The forecast file should only be updated in conjunction with the comprehensive inflow updates (anticipated every five years with the first update in 2013).

In position analysis mode, the user can select from Conditional or Non-conditional Forecasts on the Setup tab. By executing a run, the model will produce a forecast for up to the next 365 days. A forecast can be made on any date in the historic inflow record or no more than one day after the end of the inflow record. Typically it will be used starting the day after the last update of the inflow record. For example, if the inflow record ends April 30, 2008, the user can run a forecast for May 1, 2008. If a month has passed, and the user wants to run a forecast for June 1, 2008, the user would update the inflows and net evaporation for May using the Update Record tab and then start the position analysis run on June 1. Note the forecasts are tied to the starting elevation and water quality/supply storage accounts of Falls Lake, which is the controlling reservoir for the Neuse River basin. On the OCL tab, the user inputs the starting account storage values in the Constants table, and then on the Setup tab, the user simply inputs the starting elevation (or storage), the starting date of the run (forecast), and clicks Run.

The model allows the user to customize output files (tables or plots) and save them for routine use. Alternatively, the user can click on any node or arc in the schematic or go to the Setup tab and select Quick View to access and save tabular or plotted output.

Two other output options are available with this model. One is the ability to create USGS plots from the Setup tab that show model output (e.g., flows) in any given year relative to the historic percentiles or recurrence intervals on a 1-day or 7-day basis. This information is set to display in a spreadsheet. In addition, the model is capable of automatically determining the safe yield. The safe yield can be determined for each year in the historic inflow record (annual safe yield analysis) or for the entire period of record. The user inputs the adjustment criteria by selecting the Run Safe Yield Analysis button on the Setup tab.

The operations control language (OCL) contains the code unique to the Neuse Model. These files are accessible from the model interface. The OCL files associated with the basecase simulation run that uses year 2004 demands are included in the appendix. The demands can be adjusted from the model interface. The key OCL files include *main.ocl*, which initializes the run and refers to all the other OCL files that control inflows and operational policies, as agreed to by the Technical Review Committee.

Static Data Tables

Table 1 – Model Nodes

Node Number	Type	Inflow	Name
010	Reservoir	OCL	Orange Upstream Pond
046	Demand	None	Orange_Alamance Demand
050	Reservoir	OCL	West Fork Eno Reservoir
052	Demand	None	WFER Ag
060	Reservoir	OCL	Lake Orange
062	Demand	None	Or_Pond_Ag
080	Reservoir	OCL	Corp. Lake
100	Reservoir	OCL	Lake Ben Johnston
105	Junction	None	Piedmont Minerals
106	Demand	None	Hillsborough Demand
107	Junction	None	Channel Loss
110	Junction	OCL	Hillsborough Gage
112	Demand	None	EnoDurha_Ag
115	Junction	OCL	Durham Gage
116	Demand	None	Piedmont Minerals Demand
120	Reservoir	None	Teer Quarry
140	Reservoir	Time Series	Lake Michie
142	Demand	None	Michie_Ag
151	Junction	None	Durham System Demand
152	Demand	None	OWASA Interconnect
154	Demand	None	Chatham Interconnect
156	Demand	None	Cary Interconnect
158	Demand	None	Raleigh Interconnect
162	Demand	None	Durham Demand
200	Reservoir	Time Series	Little River Res.
202	Demand	None	LitRes_Ag
205	Junction	None	Node 205
230	Reservoir	Time Series	Beaverdam Lake
250	Reservoir	OCL	Lake Holt_Butner
252	Junction	OCL	Kerr Lake Indirect Transfer
254	Junction	None	Holt Withdrawal
256	Demand	None	SGWASA Demand
258	Demand	None	Creedmor Demand
259	Junction	None	SGWASA Total WW Ret
270	Reservoir	OCL	Lake Rogers
290	Reservoir	OCL	Wake Forest Lake
300	Reservoir	Time Series	Falls Lake
302	Demand	None	Falls_Ag
306	Demand	None	Raleigh Demand
307	Junction	Pattern	Riverplace II LLC Discharge

Node Number	Type	Inflow	Name
310	Reservoir	None	Lag Falls Release
318	Demand	None	Old Burlington Industries
320	Junction	None	Smith Confluence
400	Reservoir	OCL	#1
401	Junction	Pattern	Cary WW
402	Reservoir	OCL	#2
403	Junction	OCL	Quarry Dewatering
404	Reservoir	OCL	#3
405	Junction	Pattern	Apex WRF
406	Reservoir	OCL	#5A
407	Junction	Pattern	Motiva Enterprises WW
408	Reservoir	OCL	#18
409	Junction	Pattern	Fuquay-Varina WW
410	Reservoir	OCL	#20A
411	Junction	Pattern	RDU WWTP
412	Reservoir	OCL	#23 (Lake Crabtree)
414	Reservoir	OCL	#11A
416	Reservoir	OCL	#25
418	Reservoir	OCL	#22B
420	Reservoir	OCL	Lake Wheeler
422	Reservoir	OCL	#13
424	Junction	None	Crabtree flood control outflow
440	Reservoir	OCL	Lake Benson
445	Reservoir	OCL	Lake Johnson
450	Reservoir	OCL	Lake Raleigh
480	Junction	OCL	Middle Creek Gage
482	Demand	None	Middl_Ag
500	Reservoir	OCL	Buckhorn Reservoir
502	Demand	None	Buckhorn_Ag
506	Demand	None	Wilson Demand
520	Junction	None	Wiggons Mill Lake
528	Junction	OCL	Tar River Emergency PS
560	Junction	OCL	Hookerton gage
562	Demand	None	Hooke_Ag
563	Junction	Pattern	Stantonsburg WWTP
565	Junction	Pattern	Snow Hill WWTP
567	Junction	Pattern	Farmville WWTP
569	Junction	Pattern	Maury Sant. Dist WWTP
570	Junction	None	Little Contentnea Confluence
600	Junction	None	Confluence_Crabtree
620	Junction	None	Walnut Creek Confluence
630	Junction	OCL	Clayton Gage
632	Demand	None	Clayt_Ag
640	Reservoir	None	Lag Clayton Gage
643	Junction	Pattern	TransMontaigne WW

Node Number	Type	Inflow	Name
645	Junction	Pattern	Magellan Terminals WW
646	Demand	None	J. County Demand
650	Junction	None	Johnston County
660	Junction	None	Neuse River at Smithfield
666	Demand	None	Smithfield Demand
675	Junction	None	Johnston County WWTP
700	Junction	None	Confluence_Swift Creek
702	Demand	None	Cary
704	Demand	None	Holly Springs
705	Junction	Pattern	Aqua NC Inc. Hawthorne WWTP
706	Demand	None	Fuquay-Varina
740	Reservoir	OCL	Little River Reservoir (Raleigh proposed)
747	Junction	Pattern	Kenly WW
750	Junction	OCL	Princeton gage
752	Demand	None	Litpr_Ag
753	Junction	Pattern	Princeton WWTP
757	Junction	Pattern	Benson WWTP
759	Junction	Pattern	Jerry_G_Williams WW
760	Junction	None	Progress Energy
766	Demand	None	Progress Demand
770	Junction	None	Node 770
775	Junction	None	Confluence Little River
780	Junction	OCL	Goldsboro Gage
782	Demand	None	Golds_Ag
786	Demand	None	Goldsboro Demand
787	Junction	Pattern	La Grange WWTP
790	Reservoir	None	Lag Goldsboro Gage
795	Junction	None	Node 795
800	Junction	OCL	Kinston Gage
802	Demand	None	Kinst_Ag
806	Demand	None	Neuse River WASA
845	Junction	Pattern	Contentnea Sewerage District WWTP
847	Junction	Pattern	Unifi-Kinston LLC
850	Junction	None	Contentea Crk Confluence
900	Junction	OCL	Weyerhauser
902	Demand	None	Weyer_Ag
906	Demand	None	Weyerhauser Demand
999	Junction	None	Terminal_New Bern

Table 2 - Reservoirs

Reservoir	Node Number	Dead Storage	Dead Stor Units	Lower Rule	Upper Rule	Max Storage	Max Stor Units
Orange Upstream Pond	010	635.0	FT	None	None	643.0	FT
West Fork Eno Reservoir	050	603.0	FT	Pattern	Pattern	633.0	FT
Lake Orange	060	601.7	FT	Pattern	Pattern	615.0	FT
Corp. Lake	080	528.0	FT	None	None	538.0	FT
Lake Ben Johnston	100	501.0	FT	None	None	515.0	FT
Teer Quarry	120	154.0	FT	None	None	300.0	FT
Lake Michie	140	312.5	FT	Pattern	Pattern	341.0	FT
Little River Res.	200	326.0	FT	Pattern	Pattern	355.0	FT
Beaverdam Lake	230	230.0	FT	Pattern	Pattern	289.2	FT
Lake Holt_Butner	250	320.0	FT	Pattern	Pattern	356.0	FT
Lake Rogers	270	274.0	FT	Pattern	Pattern	281.0	FT
Wake Forest Lake	290	279.0	FT	Pattern	Pattern	296.8	FT
Falls Lake	300	200.0	FT	Pattern	Pattern	289.2	FT
#1	400	289.0	FT	None	None	321.5	FT
#2	402	307.5	FT	None	None	341.5	FT
#3	404	323.5	FT	None	None	358.5	FT
#5A	406	286.5	FT	None	None	329.0	FT
#18	408	300.0	FT	None	None	334.0	FT
#20A	410	286.0	FT	None	None	328.7	FT
#23 (Lake Crabtree)	412	256.0	FT	None	None	298.0	FT
#11A	414	277.4	FT	None	None	331.5	FT
#25	416	215.5	FT	None	None	274.1	FT
#22B	418	315.0	FT	None	None	354.0	FT
Lake Wheeler	420	275.0	FT	Pattern	Pattern	285.0	FT
#13	422	234.0	FT	None	None	285.0	FT
Lake Benson	440	228.0	FT	Pattern	Pattern	234.0	FT
Lake Johnson	445	312.0	FT	None	None	343.3	FT
Lake Raleigh	450	264.0	FT	None	None	288.0	FT
Buckhorn Reservoir	500	120.0	FT	Pattern	Pattern	148.0	FT
Little River Reservoir (Raleigh proposed)	740	236.0	FT	None	None	260.0	FT
Orange Upstream Pond	010	635.0	FT	None	None	643.0	FT
West Fork Eno Reservoir	050	603.0	FT	Pattern	Pattern	633.0	FT

Table 3 – Reservoir Upper and Lower Rules

Reservoir	Node Number	Units	Month	Day	Upper Rule	Lower Rule
West Fork Eno Reservoir	050	FT	1	1	633.00	603.00
West Fork Eno Reservoir	050	FT	12	31	633.00	603.00
Lake Orange	060	FT	1	1	615.00	601.70
Lake Orange	060	FT	12	31	615.00	601.70
Lake Michie	140	FT	1	1	341.00	312.50
Lake Michie	140	FT	12	31	341.00	312.50
Little River Res.	200	FT	1	1	355.00	326.00
Little River Res.	200	FT	12	31	355.00	326.00
Beaverdam Lake	230	FT	1	1	251.50	236.50
Beaverdam Lake	230	FT	12	31	251.50	236.50
Lake Holt_Butner	250	FT	1	1	356.00	320.00
Lake Holt_Butner	250	FT	12	31	356.00	320.00
Lake Rogers	270	FT	1	1	281.00	274.00
Lake Rogers	270	FT	12	31	281.00	274.00
Wake Forest Lake	290	FT	1	1	296.80	279.00
Wake Forest Lake	290	FT	12	31	296.80	279.00
Falls Lake	300	FT	1	1	251.50	236.50
Falls Lake	300	FT	12	31	251.50	236.50
Lake Wheeler	420	FT	1	1	285.00	285.00
Lake Wheeler	420	FT	12	31	285.00	285.00
Lake Benson	440	FT	1	1	234.00	232.00
Lake Benson	440	FT	12	31	234.00	232.00
Buckhorn Reservoir	500	FT	1	1	148.00	120.00
Buckhorn Reservoir	500	FT	12	31	148.00	120.00

* Note: All other reservoirs in the basin are modeled using the dead storage zone and the maximum storage, with one zone in between.