APPENDIX D –

Model Weighting Description

Section 1. Introduction

This report provides a detailed account of the weighting of nodes and arcs in the combined Cape Fear / Neuse River Basin model. OASIS uses a linear program solver, which means that it tries to maximize the overall value of allocating water subject to the goals (which have associated weights) and constraints (which must be met). The general strategy with goal-setting is to assign weights to mimic the real-world operating goals. For example, setting a reservoir's storage weight higher than that of an unassociated demand downstream will prevent water from being released from that reservoir to meet the demand. Weighting is also used to properly dictate minimum releases and other flow targets.

In general, positive weights encourage action and negative weights discourage action. Storing water, meeting demand, and meeting flow targets all have positive weights. If pumping can be avoided in favor of gravity flow, the pumping arc will have a negative weight, the gravity flow arc a positive weight. The model solver will gain more points by allocating each increment of flow to the positive-weight arc.

Weighting is mostly relative. If the weight in storage (say 2) is higher than a weight for demand (say 1), the demand will not be met. Minimum flow weights are handled differently at times since they can be additive. If there are multiple minimum flow locations downstream of a reservoir, OASIS will assign value to the minimum releases based on the sum of those weights. So if there are three locations, each having a weight of 1, the model will get 3 points releasing water from an upstream reservoir to meet the minimum flows. If the storage weight is 2, then the reservoir will draw down to meet the minimum flows. Flow exceeding the minimum flow does not get any additional value. The user manual for OASIS provides more description on how model weighting works.

Reservoirs can have up to four zones to which weights can be assigned. The A zone is below dead storage (which is generally non-usable storage). Often this represents the sediment pool, which could be tapped in an emergency situation. The B zone is between dead storage and the lower rule curve. This zone may be usable depending on the purpose. It might be used to maintain minimum releases from the lake, but not used or avoided for water supply because the intake does not extend down to that zone or because the water quality is poor. The C zone is the zone between the lower and upper rules, in which the lakes normally operate. The D zone is above the upper rule curve and below the maximum storage and is usually reserved for flood storage. Note that some reservoirs, including those being modeled as run-of-river, may only need one storage zone. This can simplify the number of weights in larger systems, but is generally not recommended because the model may draw into dead storage, down to the minimum storage in the elevation-storage-area table (even though physically it would not be possible to do), if the storage weight is less than weights for other uses.

Each section of this document describes a portion of the model, broken out by basin and progressing downstream in each basin. The Neuse Basin model weighting is described in detail first. The rationale for the Cape Fear Basin model weighting is similar.

Section 2. Eno River Area – Neuse River Basin

The reservoirs on the Upper Eno are in the headwaters of the basin, and therefore proper weighting must be set up to prevent water being released to meet unrelated needs further downstream.

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Orange Upstream Pond	1010	1050			
WFER (West Fork Eno River)	1050	1000	375	275	-60
Lake Orange	1060	1000	375	275	-60
Corp. Lake	1080	500			
Lake B. Johnston	1100	500			

Other weights in the area include:

Description	**Node/arc Number**	**Weight**
WFER Min. Release	1050.1080	400
Orange Min. Release	1060.1080	400
Or-Alamance Demand	1046	250
WFER_Ag Demand	1052	1050
Or_Pond_Ag Demand	1062	1100
Piedmont Minerals Dem	1080	250
Hillsborough Demand	1106	250
EnoDurha_Ag Demand	1112	240
Hills. Channel Loss (Target)	1110.1107	+1000 -1000

The Orange (Upstream) Pond agricultural demand has the highest weight of 1100. This is higher than the Orange Pond weight to ensure that demand is met first before letting water flow downstream to Orange Pond. Orange Pond only has one zone (which is always assigned to the A-zone), and this weight is set higher than that of Lake Orange to prevent releases to Lake Orange when the pond is below full. The only reason the pond will draw down is net evaporation on the lake surface, which is modeled as a constraint and therefore does not use weights. The B- and C- Zone storage weights on WFER and Lake Orange are lower than the weights for their respective minimum flows, but higher than the downstream demands, since the minimum release is dictated by the amount that can be withdrawn from the lakes to meet demands. Note that the weights for the zones for both reservoirs are the same because their usable storage includes everything from the top of dead storage to the top of the normal pool. For the D zone, weighting is usually negative in order to discourage storing water in this zone,

which is commonly used for flood storage. Water will only be stored if there is a limit on downstream releases during a high inflow event.

Corporation Lake and Lake Ben Johnston only have one storage zone. The weights are higher than weights on uses immediately downstream because they are run of river reservoirs and should remain full. The weighting on the C-zones on the upstream WFER and Lake Orange facilities is lower to ensure that water is withdrawn from this usable storage zone (excluding the A-zone for these reservoirs, which in this case represents dead storage) to keep Corporation Lake and Lake Ben Johnston full.

Weighting in OASIS can also be done with target commands, in which case a penalty is assigned for being above or below the target. A target is applied to the Eno River channel loss. Every unit of water in excess (+) of the computed target for channel loss is penalized a 1000 points and every unit of water below (-) the target is penalized a 1000 points. Since the penalty for going above or below is the same, the model will meet the computed channel loss exactly. Furthermore, because the overall value is higher than any other in the system, the computed channel loss will always be met before other "goals".

All of the storage weights for this reach are higher than downstream weights (see following sections) to ensure that releases are not made to meet downstream needs (e.g., Falls Lake).

Section 3. Upstream of Falls Lake – Neuse River Basin

As with the Eno, these reservoirs are in the headwaters of the basin, and therefore proper weighting must be set up to prevent water being released to meet unrelated needs further downstream.

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Lake Michie	1140	1000	350	250	-60
Little River Res.	1200	1000	350	250	-60
Lake Holt	1250	1000	350	250	-60
Lake Rogers	1270	5000	350	250	-60

Other weights in the area include:

Description	**Node/arc Number**	**Weight**
Durham Demand	1162	300
SGWASA Demand	1256	300
Creedmor Demand	1060	300
Michie_Ag Demand	1142	550
LitRes_Ag Demand	1202	550
Little River min. release	1200.1205	450
Durham Res. Balance (Target)	1140, 1200	2

The C- zone storage weights on reservoirs are all set lower than their associated withdrawals, which allow withdrawals to be made. For reservoirs with a minimum release, the B- zone weight is lower than the weight on the release arc. It is assumed that the minimum release from the Little River Reservoir has priority over water supply withdrawals from the reservoir. Agricultural demands are weighted higher than lake withdrawals and B- and C- zone storage since they represent upstream irrigation withdrawals. For Durham's two reservoirs, a balancing target with a low weight attempts to bring down the reservoirs proportionally, after other higher weight requirements have been met.

All of the storage weights for this reach are higher than downstream weights (see following sections) to ensure that releases are not made to meet downstream needs (e.g., Falls Lake).

Section 4. Falls and Beaverdam Lakes – Neuse River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Falls, Beaverdam	1300, 1230	200	200	50	-5

Other weights in the area include:

Description	Node/arc Number	Weight
Raleigh Demand	1306	100
Falls_Ag Demand	1302	230
Falls min. release	1300.1310	100
Clayton min. flow	1630.1640	125
Falls flood operation rules (target)	1300	+50 -50
Downstream flood control (targets)	1630.1640, 1780.1790, 1800.1850	+10 -0
Beaverdam elevation (target)	1230	+10000 -10000
Beaverdam release (targets)	1230	+1000 -1000

The weights for Raleigh demand and demands between Falls and Clayton (see tables below) are higher than the C zone weight for Falls to ensure these demands are met. The Corps implicitly accounts for withdrawals between Falls and Clayton when determining what releases need to be made from Falls to meet the Clayton minimum flow. Since the water quality storage is used for making minimum releases, and this storage is represented by zone C, the minimum release weight is higher than the C-zone weight. Zone B in Falls Lake is not used for meeting minimum release, hence its higher storage weight relative to the minimum release weight. Raleigh's demand can also be met from Lake Benson, which is dictated by OCL as shown in Appendix A. Note that there is also a constraint on Raleigh's demand, where the delivery will be zero from Falls Lake if the Falls water supply account is empty. A similar constraint is imposed on the minimum release if the Falls water quality account is empty.

All of the storage weights are higher than weights for demands downstream of Clayton (see following sections) to ensure that releases are not made for these demands.

The flood control targets are weighted such that the Corps' recommended flood control operations are followed. The goal is to store water in the lake to avoid causing flooding downstream. The downstream flood control targets are weighted lower, which means they have less priority than the elevation-based flood operating rules. However, the combined minimum

release and Clayton minimum flow target weight is set high enough to ensure that those flows are always met.

The target for Beaverdam elevation applies when Falls Lake is at or above 249 feet. At this elevation, Beaverdam and Falls become one pool, and the weight ensures that that the elevations for both track the same at or above 249. The Beaverdam target for releases relate to the drought release protocol for transfers of water from Beaverdam into Falls.

Section 5. Middle Basin – Neuse River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Wake Forest Lake	1290	500	250	250	-10
Crabtree impoundments	1400 – 1418, 1422	250			
Lake Wheeler	1420	500	50	50	-10
Lake Benson	1440	500	60	40	-10
Lake Johnson	1445	250			
Lake Raleigh	1450	200			
Johnston Co. Active Quarry	1647	20			
Johnston Co. Aband Quarry	1648	20			

Other weights in the area include:

Description	**Node/arc Number**	**Weight**
Swift Min. release	1440.1700	100
Burlington Ind. Demand	1318	75
Clayton_Ag Demand	1632	75
Middl_Ag Demand	1480	30
Johnston Co. Demand	1646	25
Johnston Co. Intake 1	1650.1654	50
Smithfield Demand	1666	25

The reservoirs all have weights higher than downstream demands. B- and C- zone Wheeler/Benson storage is weighted lower than the required minimum release. The storage weights in Benson and Wheeler are set up to allow, if the Raleigh withdrawal from this system is activated, drawdown of 2 feet from Benson first, subsequent release from Wheeler, and then draw down the rest of Benson. This is done to minimize spill and maximize yield. Lakes Raleigh and Johnson are not being used for water supply in the basecase (year 2010 demand) scenario and therefore only have one storage zone.

Johnston County has two quarries available for offline storage. The operations for filling the quarries are controlled by OCL. The storage weights for the quarries allow withdrawals to be made when needed. The weight on Johnston County's Intake 1 arc is used to set a target withdrawal from that intake.

Section 6. Lower Basin – Neuse River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Buckhorn Reservoir	1500	1000	350	250	-10
Little River Reservoir (Raleigh Proposed)	1740	250			

Other weights in the area include:

Description	Node/arc Number	Weight
Buckhorn Min. release	1500.1520	400
Buckhorn_Ag Demand	1502	550
Wilson Demand	1506	275
Litpr_Ag Demand	1752	30
Progress E. Demand	1766	25
Golds_Ag Demand	1782	30
Goldsboro Demand	1786	25
Kinst_Ag demand	1802	30
NRWASA Demand	1806	25
Weyer_Ag Demand	1802	30
Weyer. Demand	906	25

On Contentnea Creek, Buckhorn's B- and C- Zone storage weights are lower than the minimum release requirement, and the C- zone weight is lower than the downstream Wilson demand weight, which allows the reservoir to be used for those purposes. The Buckhorn agricultural demand is weighted higher since it represents upstream irrigation withdrawals. Raleigh's proposed Little River Reservoir, which is included in the model for planning purposes, only has one storage zone because it is not active in the basecase scenario. The other demands in this area are set lower to prevent any releases from upstream storage to meet demand.

Section 7. Upstream of Jordan Lake – Cape Fear River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Reidsville Dam	0030	1000	350	250	-20
Old Stony Creek Res.	0070	1000	350	250	-20
Lake Higgins	0112	2000	400	300	-20
Brandt Res.	0120	1500	350	250	-20
Greensboro/Townsend Res.	0140	1000	325	200	-20
Graham Mebane Res.	0320	1000	350	250	-20
Mackintosh Res.	0340	1000	350	250	-20
Cane Creek Res.	0390	1000	350	250	-20
Stone Quarry	0395	1000	375	275	-20
University Lake	0430	1000	350	250	-20

Other weights in the area include:

Description	**Node/arc Number**	**Weight**
Reidsville min release	0030.0040	400
Brandt min release	0120.0140	400
Greensboro/Townsend min release	0140.0145	375
Graham Mebane min release	0320.0100	400
Cane Creek min release	0390.0370	400
Rockingham_40%	0021	550
Reidsville Demand	0031	300
Rockingham_60%	0041	100
Guilford_13%	0043	100
Guilford_20%	0051	100
Alamance_35%	0081	100
Caswell_100%	0083	100
Forsyth_50%	0111	550
Greensboro Total Demand	0123	350
Burlington to Greensboro Transfer	0071.0121	100
Greensboro Townsend withdrawal	0140.0121	100
Guilford_40%	0161	100
Orange_40%	0311	300
Graham Mebane Demand	0321	300
Guildford_15%	0331	300
Burlington Demand	0341	300
Alamance_Other_35%	0361	100
Alamance_30%	0371	100
Orange_24%	0381	550
Pittsboro water supply	0401	100
Chatham_50%	0403	100
Wake_75%	0411	100

Description	Node/arc Number	Weight
OWASA Demand	0431	300
Orange_36%	0441	100
Durham_100%	0461	100

The reservoirs all have weights higher than downstream demands. B- and C- zone storage for reservoirs with minimum release requirements are weighted lower than the associated minimum release arcs. Reservoir demands are set higher than C- zone weights, but lower than B- zone weights. Agricultural demand weights are set higher than B- and C- zone storage. To simplify the handling of agricultural withdrawals, agricultural demand is often modeled as a withdrawal from a reservoir even though it would actually occur upstream. It is assumed these withdrawals would occur except under very dry conditions, thus effectively lowering inflow to the reservoir, so we allow the model to provide for these withdrawals from the reservoir except in extreme conditions when the reservoir has reached dead storage. All weights in the upper portion of the basin are set high enough to prevent operations downstream (at Jordan Lake, etc.) from impacting upstream operations.

Weighting for OWASA's system is set up to mimic their standard operating policy. The specific operating rules are set in OCL, but the weighting dictates that Stone Quarry will be used after the primary sources, Cane Creek Reservoir and University Lake.

Greensboro has additional weights on certain arcs to control the flow of water from their reservoirs and from outside sources. The operations are set in OCL.

Section 8. Jordan Lake – Cape Fear River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Jordan Lake	0470	200	200	5	-5

Other weights in the area include:

Description	Node/arc Number	Weight
Jordan Release	0470.0480	25
Jordan Flood Targets	0470.0480	10
Downstream Flood Targets (Lillington, Fayetteville)	0550.0555, 0740.0770	7, 7
Cary Apex water supply	0471	100
Chatham water supply	0473	100
RTP Demand	0474	100
Jordan Make Up Demand	0475	100
Morrisville demand	0477	100
Orange Co Demand Jordan	0921	100

Demand and minimum release weights on Jordan Lake are higher than the C- Zone storage weights. The weighting rationale is similar to Falls Lake, which also has water supply and water quality storage zones and associated minimum releases downstream. The complex operations for Jordan water supply and water quality accounting, downstream releases (including setting the Lillington target), and flood operations are modeled using OCL (see Appendix A).

The flood control targets are weighted such that the Corps' recommended flood control operations are followed. The goal is to store water in the lake to avoid causing flooding downstream; in Jordan Lake this is accomplished by increasing the release compared to the previous day by a maximum amount during a flood event. The downstream flood control targets are weighted lower, which means they have less priority than the elevation-based flood operating rules. However, the combined minimum release and Lillington minimum flow target weight is set high enough to ensure that those flows are always met.

All of the storage weights are set to allow for releases to meet the demands and minimum flow targets downstream to Lillington, but not for releases for needs further downstream, reflecting how the Corps of Engineers operates Jordan Lake .

Section 9. Cape Fear River downstream of Jordan – Cape Fear River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
Harris Lake	0520	500	3	3	-5
Harris Aux. Res.	0528	275	0	0	0
Glenville Res	0760	500	5	2	-5

Other weights in the area include:

Description	Node/arc Number	Weight
CF Lillington target	0550.0650	25
Chatham_5%	0481	100
Allied Signal water Demand	0483	100
Progress Cape Fear water supply	0487	100
Sanford Water Supply	0491	100
Lee_38%	0511	100
Progress Harris Demand	0521	300
Wake_20%	0531	300
Wake_5%	0541	100
Harnett County water supply	0551	100
Holly Springs Demand	0923	100
Harnett_35%	0553	100
Dunn Demand	0663	2
Lee_55%	0671	2
Harnett_Other_50%	0681	2
Harnett_15%	0691	2
Carthage Demand	0701	2
Moore_35%	0713	2
Ft. Bragg Demand	0721	2
Fayetteville Demand	0733	4
Cumberland_45%	0741	2
Monsanto water supply	0771	2
Hoke_100%	0773	2
Cumberland_40%	0775	2
Dupont WS	0781	2
Cumberland_15%	0783	2
LCFWSA Bladen Bluff Demand	0785	2
Bladen_20%	0801	2
Bladen_60%	0811	2
Bladen_Other_20%	0821	2
Wilmington Demand	0823	2
Lower Cape Fear WSA Demand	0825	2

Note weighting on demands downstream of Lillington is less than weighting on reservoir storage upstream, namely Jordan Lake, meaning reservoir releases will not be made to meet these demands.

Weighting of Harris Lake is set up to allow for a power plant withdrawal, but not to release water downstream for Lillington

Section 10. Deep River – Cape Fear River Basin

The reservoir storage weights in this area are:

		Storage Zone Weights			
Reservoir	**Node Number**	**A**	**B**	**C**	**D**
High Pt	0220	1500	400	250	-20
Randleman	0270	1000	350	250	-20
Ramseur	0300	1000	350	250	-20
Siler City Upper Res.	0324	1000	240	240	-20
Siler City Lower Res.	0325	900	250	230	-20

Other weights in the area include:

Description	**Node/arc Number**	**Weight**
High Pt min release	0220.0230	425
Randleman min release	0270.0280	375
Siler City Release	0325.0328	325
Forsyth_Other_50%	0211	550
High Point Service Area Demand	0223	300
Guildford_12%	0231	100
City of Randleman Demand	0261	100
Randolph_Other_36%	0263	100
Randolph_28%	0281	100
Ramseur Demand	0301	300
Siler City demand	0327	300
Randolph_36%	0581	100
Robbins Demand	0591	100
Montgomery_100%	0593	100
Moore_25%	0595	100
Pilgrims Pride WTP	0601	100
Moore_40%	0603	100
Goldston Gulf water supply	0605	100
Chatham_45%	0621	100
Lee_7%	0623	100
Jamestown Demand	0903	300
Archdale Demand	0904	300
Randolph Co Demand	0906	300

Weighting of Siler City's reservoirs is set up to simulate their operating policy of using the upper reservoir to keep the lower reservoir one foot below full until the upper reservoir is empty, and to allow for a minimum release from the lower reservoir. See Appendix A for the detailed OCL that dictates operations.