Appendix F: Technical Memorandum for OASIS Hydrologic Model of Cape Fear and Neuse River Basins for Interbasin Transfer

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TECHNICAL MEMORANDUM

To:
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Copies:
File

From:
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Date:
August 2025

Subject:
Cape Fear-Neuse Combined River Basin Hydrologic Model (OASIS) Evaluation
Town of Fuquay-Varina Water Supply and Interbasin Transfer Project
Appendix to Environmental Impact Statement

1. Introduction

General Statute § 143-355(o) compels the Division of Water Resources (DWR) to develop hydrologic models for each of the 17 major river basins in North Carolina with approval and modification responsibilities granted to the Environmental Management Commission (EMC). The models must include water uses in the basin and any other withdrawal, ecological flow, instream flow requirements, future withdrawal projections, and local water supply plan (LWSP) data. DWR is the steward of these hydrologic models.

The hydrologic basin models typically use an OASIS hydrologic model platform. OASIS is a computer program designed to simulate surface water flows through a river basin considering watershed runoff (inflows), withdrawals, discharges, and water management protocols. DWR has developed detailed river basin hydrologic models for long-term water supply planning, management, and regulatory decision-making, especially during drought conditions. For this Environmental Impact Statement (EIS), the Cape Fear-Neuse Combined River Basin (CFNCRB) model was used for the evaluation of alternatives.

The original Cape Fear and Neuse River Basin hydrologic models were developed initially in 2004 and 2008 for separate use in the Cape Fear and Neuse River basins. A single combined OASIS model of the Cape Fear and Neuse River basins was developed in 2011 for the purpose of water supply planning, drought management in the Cape Fear and Neuse River basins, and to evaluate the significant interbasin movement of water in the urbanized upper reaches of the basins, particularly in the Research Triangle area (DWR, 2016a). The combined OASIS model, the CFNCRB model, extends geographically from the headwaters of the Deep and Haw Rivers to the mouth of the Cape Fear River and from the headwaters of the Eno, Flat, and Little Rivers to the mouth of the Neuse River. The CFNCRB model has been used to evaluate Jordan Lake water supply allocation requests and the Towns of Cary and Apex interbasin transfer request in 2014.

The CFNCRB model was updated in this EIS to evaluate the impact of the Town of Fuquay-Varina's proposed interbasin transfer. This Technical Memorandum documents the model development, assumptions, and results of the CFNCRB model used to evaluate the water supply alternatives covered in the EIS. This Technical Memorandum will provide basic background on the model, describe the model inputs and assumptions, and the results of the modeled alternatives. Attachments to this Technical Memorandum are as follows:

- Attachment A: Future Climate Scenarios for Town of Fuquay-Varina Interbasin Transfer Study (Tetra Tech, 2020)
- Attachment B: Summary of Withdrawals and Discharges in Cape Fear-Neuse River Combined River Basin Model
- Attachment C: Fayetteville Public Works Commission Water Shortage Response Trigger Flow Mapping
- Attachment D: Cape Fear-Neuse River Combined River Basin Model OCL Code

2. Model Development

The CFNCRB model was used as a foundation for the existing water supply and demands in the Cape Fear and the Neuse River basins. The purpose of the CFNCRB model is to simulate present day or potential future water management operations and assess impacts to streamflow, reservoir storage, water supply reliability, and other metrics of interest. The model was updated with current information from LWSP data. All known, proposed, and approved developments to the water supply to be completed by 2055 (the planning period for this EIS) were added as new information to the model in the form of nodes, junctions, and/or reservoirs.

The model uses a hydrologic and climatic dataset developed from a 90-year historical period. The period of record starts on January 1, 1930 and extends through September 30, 2020. The data set developed for the model used a comprehensive approach, as follows:

1. The model uses data from over 60 United States Geological Survey (USGS) streamflow gages in the Cape Fear and Neuse River basins. The model also uses historical weather station data to develop information on precipitation and evaporation that is applied to reservoirs in the model.
2. The model accounts for direct human-caused flow alterations, or impairments, from reservoir regulation and net water consumption. The model corrects for these influences so that current or future conditions may be simulated using the adjusted historical hydrologic information.
3. Statistical techniques were used to complete missing hydrologic records for the streamflow gages.

2.1 Significant Updates to CFNCRB Model

For this EIS, the CFNCRB model was significantly updated since the last update by DWR in 2014. The most significant changes include the following:

- The Falls Lake Conservation Pool Reallocation was completed in 2019 to expand the water supply pool for Raleigh Water (USACE, 2018). The CFNCRB model reflects the Falls Lake reallocation in both the 2025 and 2055 scenarios.

- It was assumed Johnston County would meet its future supply needs by developing a raw water intake on the lower Neuse River in accordance with the 2009 Environmental Assessment (CH2M Hill, 2009).
- It was assumed the Western Intake Partnership (WIP), comprised of Durham, Pittsboro, OWASA, and Chatham County, could collectively meet their future needs via use of their Jordan Lake allocations. Each member utility owns and operates separate supply systems, which are expected to remain online in the future. The proposed WIP water treatment facility will supplement existing water supply for the WIP members. Except for the City of Durham, the exact nature of WIP member's future participation is somewhat uncertain, as follows:
    - Chatham County's North System demand forecast has been revised downward during the WIP planning process. At present, it is unclear whether Chatham would need to draw on the proposed WIP WTP in the 2055 scenario. All model scenarios are set up such that Chatham County's North System meets its entire need via Jordan Lake. For modeling purposes, it will not matter whether Chatham County's water is treated at their existing WTF or the proposed WIP WTP, since all of this water will be sourced from Jordan Lake.
    - OWASA does not anticipate a shortfall in 2055 even without Jordan Lake as a supply. Therefore, Jordan Lake is not assumed to be a regular supply source for OWASA over the planning horizon.
- Jordan Lake allocations were updated in the model to reflect the final Round 4 allocation approvals per the Environmental Management Commission (EMC) in 2017. The one exception is Raleigh Water. Raleigh Water rescinded their allocation from Jordan Lake in March 2019 as a result of the Falls Lake Reallocation Process for additional storage in the Falls Lake reservoir.
- The model assumes that the City of Durham's Teer Quarry Storage Project is on-line and draws on that storage beginning at the first stage of their Water Shortage Response Plan (WSRP).
- The City of Greensboro's North Buffalo Creek Wastewater Treatment Plant (WWTP) was removed from the model as this facility was decommissioned in 2017.

Several other changes were made to update the CFNCRB model. Minor deficiencies in water supply operations and wastewater discharge locations were corrected. Annual withdrawal and discharge patterns were updated and currently known inter-utility wholesale purchase arrangements were also added to the model. Water shortage response protocols were updated per LWSPs submitted to DWR.

Updated water demand projection data from current LWSPs were used in the model. It was noted that a few communities expressed overly optimistic forecasting of future water needs, which were substantially out of alignment with the Office of State Budget and Management (OSBM) population estimates. Nevertheless, unless noted as follows, the demand forecasts used in the CFNCRB model originated from the 2022 LWSP for each utility. The CFNCRB model updates incorporated recent work with several communities, as follows:

- Water demand projections used for Pittsboro and Chatham County North were from recent work for the Triangle Water Partnership (TWP) (HDR and Hazen, unpublished).
- Water demand projections for Raleigh Water were based on the 25th percentile water demand projection curves from the Integrated Master Plan (HDR, 2021).
- Water demand projections for the Town of Holly springs were from recent work for the TWP (HDR and Hazen, unpublished).
- Projections of water sales were included in the total water demand for any water utility whose sales partner(s) were not already represented in the model.
- Water demand and interbasin transfer projections for the Town of Fuquay-Varina were based on the technical analysis per Section 2 of the EIS.

2.2 Climate Variability

The potential impacts of future climate variability were evaluated in this EIS. Climate variability impacts were applied to Alternatives 1 to 9 for the planning year 2055. Hazen subcontracted with Tetra Tech for a climate variability screening and to produce synthetic hydrology for three selected climate variability scenarios. Tetra Tech's work involved taking outputs from global climate models (GCMs) and running the relevant outputs through a rainfall-runoff model to arrive at basin hydrology that could be incorporated into the CFNCRB model. A detailed report (Tetra Tech, 2020) is provided in Attachment A.

The climate assessment covers a scientifically supported range of future climate variability. As a measure of conservatism, the climate assessment scenarios skew somewhat toward a more severe change (i.e., high emissions scenarios and therefore higher temperatures). Future climate projections remain uncertain, in particular for precipitation (there is less uncertainty for future temperature) and are best used to describe a range of possible future conditions to which adaptation may be needed. To select a set of scenarios that bound the likely range of potential climate futures with respect to water supply, the relative change in mean annual temperature and mean annual precipitation was assessed across a range climate models (over 30 models) paired with two of the more severe but commonly studied greenhouse gas emissions trajectories.

Greenhouse emissions trajectories are standardized by the Intergovernmental Panel on Climate Change (IPCC) and referred to as representative concentration pathways (RCPs) (van Vuuren, 2011). The two RCPs used in this study are RCP 4.5 and RCP 8.5. The number following the RCP (4.5 or 8.5) refers to the climate forcing condition of the emissions trajectory in watts per meter squared (W/m^2) for the year 2100 relative to the pre-industrial year of 1750. The higher the number, the greater the degree of warming expected. A paper published after the scenario screening analysis was conducted suggests that, at present, the most likely warming scenarios are similar to RCP 3.4 (Pielke, 2021). For reference, Table 1 summarizes the currently studied RCPs and the range of global mean temperature increase expected relative to the pre-industrial baseline.

Figure 1 illustrates the relative change in temperature and precipitation predicted by different GCMs and forcing conditions (e.g., RCPs) specific to central North Carolina in a commonly used future climate scenario dataset. Climate variability scenarios likely to predict higher runoff (and therefore water supply) are located in the upper-left quadrant of Figure 1. These scenarios predict a greater increase in mean annual precipitation and a relatively moderate increase in air temperature and associated evapotranspiration compared to their model peers. Conversely, scenarios likely to predict the less runoff are located in the bottom-right quadrant of Figure 1. These scenarios predict a small increase in mean annual precipitation and a relatively large increase in mean annual air temperature. Three climate future scenarios were selected to develop a quantitative climate assessment that covers a scientifically supported range of future climate variability. The three selected scenarios are listed as follows with the model name first followed by the RCP and the purpose for selecting the scenario.

- CNRM-CM5, RCP 4.5 (higher runoff potential)
- MIROC-ESM-CHEM, RCP 8.5 (lower runoff potential)
- GFDL-ESM2M, RCP 8.5 (approximates ensemble mean)

Table 1: Representative Concentration Pathway Scenarios and Temperature Change Projections

Scenario	Range of Global Mean Temperature Increase for Year 2100 relative to Pre-Industrial Baseline
RCP 1.9	1 to 1.5°C
RCP 2.6	1.5 to 2°C
RCP 3.4	2 to 2.4°C
RCP 4.5 [1]	2.5 to 3°C
RCP 6.0	3 to 3.5°C
RCP 7.5	~ 4°C
RCP 8.5 [1]	~ 5°C

[1] *RCPs used in this assessment.*

Timeseries output were then downloaded from the archive for the three selected scenarios. A watershed runoff model, the National Hydrologic Model (NHM) with the Precipitation-Runoff Modeling System (PRMS), was then used to convert GCM output (temperature and precipitation in particular) to a hydrologic runoff timeseries and evaporation timeseries for use in the CFNCRB model. A detailed explanation of the selection and processing of the climate scenario data is included in Attachment A.

Hydrologic timeseries associated with each climate future scenario are compared to a historical “hindcast” model run covering 1950 to 2005. Hindcasting is conducted using the GCM with historical forcing conditions (i.e., past atmospheric greenhouse gas concentrations) to simulate the 1950 to 2005 period and evaluate the GCM’s accuracy in reproducing historical climate conditions. When coupled with a future climate forecast, hindcasting provides an apples-to-apples indication of relative change in any number of climatic factors. The relative change is used to adjust the inputs to the CFNCRB model using a bias-adjustment technique. The bias adjustment accounts for systematic differences that may be present between the PRMS model and historically observed flows. The target future year of 2055 is based upon the assumption of a 30-year IBT certificate issued around 2025. Since a 30-year period is typically used to evaluate statistical climate normals, the climate variability scenarios used outputs from the GCM from 2040 to 2070, the mid-point of which is 2055. The 30-year timeseries for each of the three climate variability scenarios was then inserted into the CFNCRB model for evaluation.

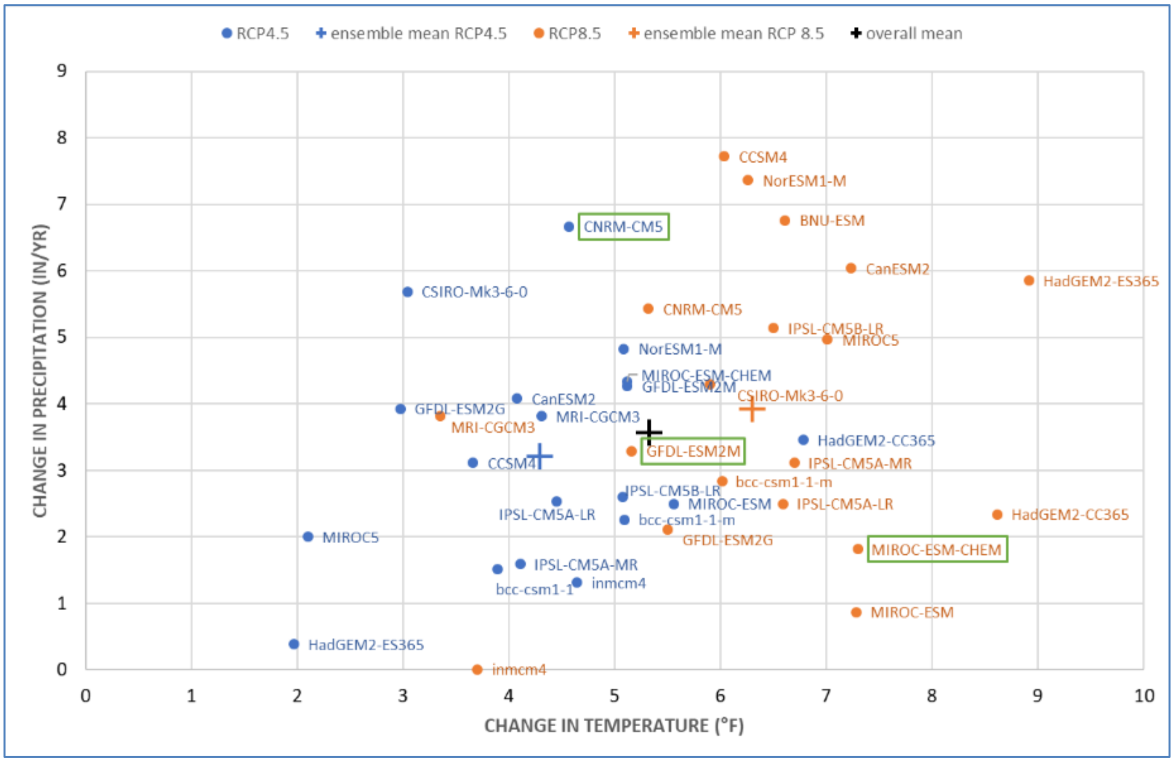

Figure 1: Relative change from historical (1950-2005) for future (2040-2070) average (or mean) annual precipitation and mean annual air temperature for global climate models and greenhouse gas representative concentration pathways (RCP 4.5 and RCP 8.5) for the Central Piedmont Region of North Carolina. Note: Selected scenarios have a green box around the model name (from Attachment A, Tetra Tech 2020).

2.3 Water Supply Alternatives

After completing the model updates required for the 2025 and 2055 baseline conditions, the CFNCRB model was further developed to simulate each of the water supply alternatives considered in the EIS for the year 2055. The models used monthly demand data in the calculations of the deliveries to each demand node. Refer to Section 3 of the EIS for a detailed description and evaluation of alternatives. The CFNCRB model for each alternative was evaluated using the historical hydrologic record contained in the model (1930 to 2020) as well as with each of the three climate variability scenarios (2040 to 2070). A summary of the added CFNCRB model inputs and operational changes to accommodate the alternatives analysis is provided in Table 2. A summary of the withdrawals and discharges in the CFNCRB model are provided in Attachment B. The CFNCRB model inputs and operational changes are described as follows:

- No Action Alternative
  - The demand years of 2025 and 2055 were modeled to show hydrology and supply shortages without any changes to the existing systems, approved or in construction capital improvement projects, or sales contracts.
- Alternative 1 – Surface Water, Purchase Finished Water from Raleigh Water
  - A new reservoir node was created to model Middle Creek Reservoir including storage-area-elevation (SAE) data developed to simulate the manmade

reservoir. The reservoir was sized to meet demand from both Raleigh Water and the Town of Fuquay-Varina. A new connection from the reservoir to the Town of Fuquay-Varina was added.

- Alternative 2 – Surface Water, Purchase Finished Water from Johnston County
  - No new model nodes were added. Water is supplied to the Town of Fuquay-Varina via a new connection from the future Johnston County Quarry Reservoir and WTP.
- Alternative 3 – Surface Water, Town of Fuquay-Varina Independent Water Supply in Neuse River Basin
  - A new reservoir node was created to model Middle Creek Reservoir including SAE data developed to simulate the man-made reservoir. The reservoir was sized to meet demand for the Town of Fuquay-Varina independently. A new connection from the reservoir to the Town of Fuquay-Varina was added. This alternative also assumes a new WTP would be constructed.
- Alternative 4 – Surface Water, Purchase Finished Water from City of Dunn
  - A new connection from the City of Dunn to the Town was added.
- Alternative 5 – Surface Water, Purchase Finished Water from Harnett County
  - The maximum sales from Harnett County was increased to meet the Town of Fuquay-Varina's projected demand.
- Alternative 6 – Surface Water, Raw Water from Jordan Lake (Cary/Apex)
  - A new connection from Jordan Lake to the Town of Fuquay-Varina was added. Alternatives 6 and 7 are identical in simulation. A new WTP would be constructed by the Town of Fuquay-Varina to produce finished water.
- Alternative 7– Surface Water, Raw Water from Jordan Lake (Western Intake Partnership)
  - A new connection from Jordan Lake to the Town of Fuquay-Varina was added. Alternatives 6 and 7 are identical in simulation.
- Alternative 8A – Surface Water, Town of Fuquay-Varina Intake on the Cape Fear with Return of Water to Cape Fear River Basin (Cape Fear River)
  - A new connection from the Cape Fear River at the Lillington gage to the Town of Fuquay-Varina was added and a new connection from the Town of Fuquay-Varina to the Cape Fear River downstream of the Lillington gage for wastewater discharge.
- Alternative 8B – Surface Water, Town of Fuquay-Varina Intake on the Cape Fear with Return of Water to Cape Fear River Basin (Kenneth Creek)
  - A new connection from the Cape Fear River at the Lillington gage to the Town of Fuquay-Varina was added as was a new connection from the Town of Fuquay-Varina to Kenneth Creek for wastewater discharge upstream of the Lillington gage.

- Alternative 9 – Surface Water, Purchase Finished Water from City of Sanford
    - For all sub-alternatives A-D, a new connection to the City of Sanford's water supply was added to the Town of Fuquay-Varina. WTP process loss was factored in for this alternative.
    - The City of Sanford's raw water intake was modeled as a run-of-river intake and does not include storage from the Buckhorn Dam impoundment. Buckhorn Dam is a relatively small impoundment, so the buffering capacity of storage behind the dam is minimal, but the Buckhorn dam impoundment stores approximately one week of withdrawals for the City of Sanford and its partners under the 2055 condition. Therefore, modeling this alternative as a run-of-river withdrawal is conservative.
  - Alternatives 9 A/B – Surface Water, Purchase Finished Water from City of Sanford
    - Wastewater is treated and discharged to the basin used by the Town of Fuquay-Varina's retail customers. Wastewater produced in the Neuse River Basin is assumed to be treated and discharged at the Terrible Creek WWTP. Wastewater produced in the Cape Fear Basin is assumed to be treated and discharged at Harnett County's Regional North Harnett Regional WWTP.
  - Alternative 9C – Surface Water, Purchase Finished Water from City of Sanford with Return of Water to Cape Fear River
    - This alternative has common components with Alternative 9 A/B plus a new connection from the Town of Fuquay-Varina to the Cape Fear River downstream of the Lillington gage for wastewater discharge.
  - Alternative 9D – Surface Water, Purchase Finished Water from City of Sanford with Return of Water to Cape Fear River
    - This alternative has common components with Alternative 9 A/B plus a new connection from the Town of Fuquay-Varina to pump untreated wastewater from the Town's Terrible Creek WWTP service area in the Neuse River basin to the Western Wake WRF.

Table 2: Summary of Modeling Inputs for Cape Fear-Neuse River Hydrologic OASIS Model

	No-action		Raleigh	Johnston County	Independent Reservoir	Dunn	Harnett	Jordan Lake, A	Jordan Lake, B	Fuquay-Varina Intake and Return to Cape Fear River	Fuquay-Varina Intake and Return to Kenneth Creek	Sanford (No Return)	Sanford (With Return)	Sanford (With Return)
Alternative	----		1	2	3	4	5	6	7	8A	8B	9A/B	9C	9D
Model Year	2025	2055	2055	2055	2055	2055	2055	2055	2055	2055	2055	2055	2055	2055
New nodes	N/A	N/A	Middle Creek Reservoir, node 1475, sized for Raleigh and Town use	None	Middle Creek Reservoir, node 1475, sized for Town use only	N/A	N/A	N/A	N/A	N/A	New discharge point	N/A	N/A	N/A
New connections	N/A	N/A	Middle Creek Reservoir to Town, node 1475 to 1706, and Middle Creek to Raleigh, Node 1475 to 1306	Johnston County Quarry Reservoir to Town, node 1648 to 1706	Middle Creek Reservoir to Town, node 1475 to 1706	Dunn Supply to Town, node 662 to 1706	N/A	Jordan Lake to Town, node 0470 to 1706	Jordan Lake to Town, node 0470 to 1706	Cape Fear Lillington Gage to Town, node 0550 to 1706, and Town to downstream of Lillington gage, 1706 to 0650	Cape Fear Lillington Gage to Town, node 0550 to 1706, and Town to Kenneth Creek, 1706 to 0554 (upstream of Lillington)	Sanford Cape Fear withdrawal point to Town, nodes 0489/0492 to 1706 (incorporating process loss)	Sanford Cape Fear withdrawal point to Town, nodes 0489/0492 to 1706, and Town to down-stream of Lillington gage, 1706 to 0650	Sanford Cape Fear withdrawal point to Town, nodes 0489/0492 to 1706, and Town to Western Wake WRF, 1706 to 0930
Operational changes	N/A	N/A	Set Town operations to receive from Raleigh for Neuse demand before exceeding Harnett	Set Town operations to receive from Johnston County for Neuse demand before exceeding	Set Town operations to receive from Middle Creek Res. for Neuse demand before exceeding	Set Town operation to receive from Dunn Water Supply once exceeding Harnett	Set all Town demand to be supplied by Harnett County	Set Town operation to use Jordan Lake once exceeding Harnett contract	Set Town operation to use Jordan Lake once exceeding Harnett contract	Set Town operations to use the Cape Fear, adjust waste-water returns to return to	Set Town operations to use the Cape Fear, adjust waste-water returns to return to	Set Town operations to receive water from Sanford once exceeding Harnett Contract	Set Town operations to receive from Sanford once exceeding Harnett Contract, adjust	Set Town operations to receive from Sanford once exceeding Harnett Contract, adjust

Table 2: Summary of Modeling Inputs for Cape Fear-Neuse River Hydrologic OASIS Model

	No-action		Raleigh	Johnston County	Indep-endent Reservoir	Dunn	Harnett	Jordan Lake, A	Jordan Lake, B	Fuquay-Varina Intake and Return to Cape Fear River	Fuquay-Varina Intake and Return to Kenneth Creek	Sanford (No Return)	Sanford (With Return)	Sanford (With Return)
Alternative	**----**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8A**	**8B**	**9A/B**	**9C**	**9D**
Model Year	**2025**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**	**2055**
			contract	Harnett contract	Harnett contract	contract				Cape Fear	Cape Fear		waste-water returns to Cape Fear	wastewater returns to Cape Fear
Max. Month Sales from Harnett County, mgd	2	2	2	2	2	2	9.9	2	2	2	2	2	2	2
Max. Month Sales from Johnston County, mgd	1.5	0	0	7.9	0	0	0	0	0	0	0	0	0	0
Max. Month Sales from the City of Raleigh, mgd	1.75	0	7.9	0	0	0	0	0	0	0	0	0	0	0
Additional Max. Month Sales, mgd	N/A	N/A	N/A	N/A	N/A	7.9	N/A	7.9, from Cary	N/A	N/A	N/A	7.9, from Sanford	7.9, from Sanford	7.9 from Sanford
Wastewater return routing	Exist-ing	Exist-ing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Discharge 0.5 miles downstre am of proposed intake	Discharge at Kenneth Creek at old plant outflow	Existing	Discharge at Cape Fear River	Discharge to Western Wake WRF (to Cape Fear River)

3. Analysis of CFNCRB Model Simulation Results

The modeling results are summarized with the no-action baseline alternative in 2025 and 2055 in comparison with Alternatives 1 through 9 in the planning year 2055. The modeling results for the historic hydrologic record are presented along with the three selected climate variability scenarios for each alternative, including the no-action alternative. Many of the metrics presented are consistent with the metrics presented in the 2014 Cary-Apex IBT analysis in the Cape Fear. The CFNCRB model results were evaluated using three broad classes of model output, as follows:

1. Municipal water supply reliability.
2. Performance of Jordan Lake and Falls Lake in Meeting Flow Targets and Recreational Criteria.
3. Low-flow discharge in the Cape Fear River and Neuse River:
    a. Potential climate change impact to hydrology.
    b. Cumulative impact related to Cape Fear River basin development (i.e., water demand increase between 2025 and 2055).
    c. Project-related impacts to 7Q10.
    d. Gage accuracy and model precision.

3.1 Municipal Water Supply Reliability

The ability of municipal purveyors to meet water supply needs is a key consideration for long-term planning. This section describes model results related to the ability to achieve this goal. The frequency, in percent of days, for meeting nominal (i.e., unrestricted) water demand for each alternative and climate scenario is summarized in Table 3. The nominal demand does not include reductions produced by conservation measures (i.e., when a water shortage response stage is triggered). For example, a frequency of 100 percent indicates that all of the water demand is met over the entire simulation period and no conservation was triggered for that utility. Frequency values less than 100 percent indicate the nominal demand is not always met. This phenomenon occurs for two reasons: 1) water conservation has been invoked, and/or 2) not enough water is available to meet the demand. For those systems whose triggers can be modeled, water demand is reduced according to the utility's WSRP proscribed conservation schedule when appropriate (i.e., a 10 percent reduction in water use in Stage 1 conservation).

An example is Cary-Apex which meets the conditions for triggering its WSRP at various points in all 2055 scenarios. Per Table 3, simulations using the historic inflow record show 100 percent delivery for Cary-Apex in year 2025 for the No-Action alternative and then decreasing to 93.5 percent in 2055. In 2055, the increased water demand on Jordan Lake prompts activation of Cary-Apex's drought plan on approximately 6.5 percent of the days in the model record (1930 to 2020 hydrology representing 33,000 days). Therefore, delivery of water supply in 2055 would meet Cary-Apex's unrestricted demand on 93.5 percent of days. For the other 6.5 percent of days, the model indicates the reduced demand (i.e., triggering the Cary-Apex's WSRP) would be met 100 percent of the time.

Many of the water systems summarized in Table 3 do not have drought (i.e., WSRP) triggers that are quantifiable in the CFNCRB model. For these systems, water demand is not reduced under water shortage conditions. These systems all follow the statutory requirements for water shortage response; however, the triggers for entering the mandatory stages of the water shortage response are not specific enough to model. A failure to meet the unrestricted demands is due to a shortage of water (i.e., insufficient water on some days in the model to meet the full demand). This unrestricted demand scenario includes the Town of Fuquay-Varina. The model indicated that the Town of Fuquay-Varina would have a 0 percent supply reliability in 2055 in the No-Action alternative, as additional supply is not considered to meet the Town's projected 2055 needs.

Shortages due to absolute insufficiency of supply occur for only two other demand nodes in the model (at a single withdrawal point) and are limited to two of the three climate change scenarios. These shortages due to climate change occur for the Cape Fear Public Utility Authority (CFPUA) and Lower Cape Fear Water and Sewer Authority (LCFWSA) raw water intakes at the downstream end of the Cape Fear River basin. Using historical inflows, the 2055 demands are always met for CFPUA and LCFWSA across every modeled alternative. The frequency of shortages under the two more adverse climate change scenarios is extremely small. The period of record for the climate change runs (2040 to 2070) contains 11,000 days. Therefore, a 0.01 percent result equals approximately 1 day of water supply shortage. These rare instances are highlighted as blue cells in Table 3. All of the modeled shortages for CFPUA and LCFWSA were short, intermittent, infrequent, and did not include mitigation from a WSRP with quantifiable demand reductions by WSRP stage. Additionally, the shortages occurred during significant additional demand-side water stress. The municipal surface water demands for Fayetteville Public Works Commission (PWC), CFPUA and LCFWSA are projected to increase by over 57 mgd between 2025 and 2055 per the respective LWSPs submitted by these utilities, which is a 90 percent increase in water demand at these locations over the 30-year planning horizon. Shortages for CFPUA and LCFWSA are described further in Section 4.

For systems that do have quantifiable WSRP triggers, additional information on the nature of WSRP performance is provided in Table 4A and Table 4B**.** There are four water utilities (Cary-Apex, Raleigh Water, City of Dunn, and Town of Benson) whose WSRPs were activated in the CFNCRB model. In July 2023, PWC adopted changes to their WSRP that included quantifiable shortage response triggers based on water elevation in the Cape Fear River at the PWC raw water intake. The PWC WSRP was adopted after the updates to the CFNCRB model. Drought response operations for PWC were modeled similarly to the operation for the City of Dunn. The City of Dunn's drought response rules are based off Cape Fear River discharges. The PWC WRSP elevation triggers were mapped to the flow output from the CFNCRB simulations using historical stage-discharge data at the Fayetteville NC USGS gage and the state HEC-RAS model for this section of the Cape Fear River, further detail is provided in Attachment C. Tables 4A and 4B provide the percent of years in which the WSRP is activated, the median length of time the WSFPs are active once activated (i.e., the length of water use restrictions), the worst case event length, and the highest (i.e., most restrictive) WSRP stage reached during the entire model run.

When evaluating the results in Tables 4A and 4B, it should be noted that the historical hydrologic record is approximately three times as long as each climate change scenario. When comparing the results for any of these utilities by water supply alternative, there is very little difference between the alternatives. There are differences between the climate scenarios, but the most significant difference is simply due to the cumulative change between 2025 and 2055. Both Raleigh Water and Cary-Apex have WSRP activation frequencies of less than 1 in 3 years for all alternatives and climate outcomes. Using historical hydrology, the median restriction periods extend approximately 2 months for Raleigh Water and about 3.5 months for Cary-Apex. In the most severe historical drought, Cary/Apex spends just over 3 months in Stage 2 of their WSRP and Raleigh Water spends 6 months in Stage 3 of their WSRP. For the City of Dunn and the Town of Benson, the activation frequencies are less than once in ten years and the median restrictions have a one week duration. In the worst case these extend to just under three weeks. For Fayetteville PWC, there is little to no change between the 2025 and 2055 conditions under historical hydrology and the median and maximum event lengths remain the same plus or minus a day across all scenarios within the respective hydrology.

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Table 3: Summary of Frequency of Achieving Nominal (Unrestricted) Demand (% of Days)

			Cape Fear River Basin Model Nodes						Neuse River Basin Model Nodes						
Water Supply Alternative	**Year**	**Inflows**	**Cary-Apex**	**Sanford [1]**	**Harnett County [1]**	**Dunn**	**Fayetteville**	**CFPUA / LCFWSA [1]**	**Raleigh**	**Johnston County [1]**	**Smithfield [1]**	**Fuquay-Varina [1]**	**Benson**	**Goldsboro [1]**	**Neuse-WASA[1]**
No action (baseline)	2025	Historic	100.00%	100.00%	100.00%	99.15%	98.92%	100.00%	100.00%	100.00%	100.00%	100.00%	99.15%	100.00%	100.00%
	2055	Historic	93.53%	100.00%	100.00%	99.83%	98.84%	100.00%	97.72%	100.00%	100.00%	0.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	100.00%	96.68%	100.00%	100.00%	0.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	0.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.35%	96.17%	99.98%	96.90%	100.00%	100.00%	0.00%	99.35%	100.00%	100.00%
Alternative 1	2055	Historic	93.46%	100.00%	100.00%	99.83%	98.88%	100.00%	97.73%	100.00%	100.00%	100.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	99.98%	96.72%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.35%	96.23%	100.00%	96.91%	100.00%	100.00%	100.00%	99.35%	100.00%	100.00%
Alternative 2	2055	Historic	93.56%	100.00%	100.00%	99.83%	98.88%	100.00%	97.72%	100.00%	100.00%	100.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	99.90%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.37%	96.23%	99.86%	96.90%	100.00%	100.00%	100.00%	99.37%	100.00%	100.00%
Alternative 3	2055	Historic	93.46%	100.00%	100.00%	99.83%	98.88%	100.00%	97.72%	100.00%	100.00%	100.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	100.00%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.35%	96.23%	100.00%	96.90%	100.00%	100.00%	100.00%	99.35%	100.00%	100.00%
Alternative 4	2055	Historic	93.48%	100.00%	100.00%	99.83%	98.74%	100.00%	97.72%	100.00%	100.00%	100.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.33%	99.96%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.60%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.35%	95.98%	99.97%	96.90%	100.00%	100.00%	100.00%	99.35%	100.00%	100.00%

Table 3: Summary of Frequency of Achieving Nominal (Unrestricted) Demand (% of Days)

Water Supply Alternative	Year	Inflows	Cape Fear River Basin Model Nodes						Neuse River Basin Model Nodes						
			Cary-Apex	Sanford [1]	Harnett County [1]	Dunn	Fayetteville	CFPUA / LCFWSA [1]	Raleigh	Johnston County [1]	Smithfield [1]	Fuquay-Varina [1]	Benson	Goldsboro [1]	Neuse-WASA[1]
Alternative 5	2055	Historic	93.44%	100.00%	100.00%	99.77%	98.74%	100.00%	97.72%	100.00%	100.00%	100.00%	99.77%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.41%	98.46%	99.89%	96.68%	100.00%	100.00%	100.00%	99.41%	100.00%	100.00%
		GFDL	92.37%	100.00%	100.00%	99.98%	99.66%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.13%	96.23%	99.91%	96.90%	100.00%	100.00%	100.00%	99.13%	100.00%	100.00%
Alternative 6	2055	Historic													
		CNRM	Identical to Alternative 7 (withdrawal from Jordan Lake)												
		GFDL													
		MIROC													
Alternative 7	2055	Historic	93.46%	100.00%	100.00%	99.83%	98.87%	100.00%	97.72%	100.00%	100.00%	100.00%	99.83%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	100.00%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.38%	100.00%	100.00%	99.98%	99.81%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.76%	100.00%	100.00%	99.37%	96.23%	99.94%	96.90%	100.00%	100.00%	100.00%	99.37%	100.00%	100.00%
Alternative 8A	2055	Historic	93.44%	100.00%	100.00%	99.77%	98.92%	100.00%	97.72%	100.00%	100.00%	100.00%	99.77%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.41%	98.54%	99.97%	96.68%	100.00%	100.00%	100.00%	99.41%	100.00%	100.00%
		GFDL	92.37%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.13%	96.28%	99.87%	96.90%	100.00%	100.00%	100.00%	99.13%	100.00%	100.00%
Alternative 8B	2055	Historic	93.46%	100.00%	100.00%	99.78%	98.87%	100.00%	97.72%	100.00%	100.00%	100.00%	99.78%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.55%	99.90%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.66%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.23%	96.23%	99.94%	96.90%	100.00%	100.00%	100.00%	99.23%	100.00%	100.00%

Table 3: Summary of Frequency of Achieving Nominal (Unrestricted) Demand (% of Days)

Water Supply Alternative	Year	Inflows	Cape Fear River Basin Model Nodes						Neuse River Basin Model Nodes						
			Cary-Apex	Sanford [1]	Harnett County [1]	Dunn	Fayetteville	CFPUA / LCFWSA [1]	Raleigh	Johnston County [1]	Smithfield [1]	Fuquay-Varina [1]	Benson	Goldsboro [1]	Neuse-WASA[1]
Alternative 9A/B	2055	Historic	93.44%	100.00%	100.00%	99.77%	98.74%	100.00%	97.72%	100.00%	100.00%	100.00%	99.77%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.41%	98.46%	99.89%	96.68%	100.00%	100.00%	100.00%	99.41%	100.00%	100.00%
		GFDL	92.37%	100.00%	100.00%	99.98%	99.66%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.13%	96.23%	99.91%	96.90%	100.00%	100.00%	100.00%	99.13%	100.00%	100.00%
Alternative 9C	2055	Historic	93.46%	100.00%	100.00%	99.77%	98.91%	100.00%	97.72%	100.00%	100.00%	100.00%	99.77%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.41%	98.54%	99.98%	96.68%	100.00%	100.00%	100.00%	99.41%	100.00%	100.00%
		GFDL	92.37%	100.00%	100.00%	99.98%	99.69%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.11%	96.31%	99.92%	96.90%	100.00%	100.00%	100.00%	99.11%	100.00%	100.00%
Alternative 9D	2055	Historic	93.44%	100.00%	100.00%	99.78%	98.87%	100.00%	97.72%	100.00%	100.00%	100.00%	99.78%	100.00%	100.00%
		CNRM	90.23%	100.00%	100.00%	99.57%	98.52%	99.89%	96.68%	100.00%	100.00%	100.00%	99.57%	100.00%	100.00%
		GFDL	92.41%	100.00%	100.00%	99.98%	99.66%	100.00%	100.00%	100.00%	100.00%	100.00%	99.98%	100.00%	100.00%
		MIROC	87.75%	100.00%	100.00%	99.23%	96.23%	99.93%	96.90%	100.00%	100.00%	100.00%	99.23%	100.00%	100.00%

[1] These systems do not have quantifiable drought triggers that can be modeled in OASIS, so only the unrestricted demand is considered for these systems. Instances when unrestricted demand for these systems cannot be met are highlighted in blue. The only systems subject to this condition, other than Fuquay-Varina in the No-Action alternative, are CFPUA and LCFWSA.

Table 4A: Detailed WSRP Statistics for Cary-Apex, City of Dunn, and Fayetteville PWC

Water Supply Alternative	Year	Inflows [1]	Cape Fear River Basin Model Nodes for Cary-Apex						Cape Fear River Basin Model Nodes for Dunn						Cape Fear River Basin Model Nodes for Fayetteville					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
No action (baseline)	2025	Historic	0	0	0	0	0	0	0	0	0	0	0	0	15.4	13	33	2	1.1	26
	2055	Historic	25.3	102.5	236	2	1.1	96	3.3	7.5	19	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	2	3.2	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	16	37	2	16.1	35
Alternative 1	2055	Historic	25.3	106	236	2	1.1	96	3.3	7.5	19	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	1	12.9	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	16	36	2	12.9	31
Alternative 2	2055	Historic	25.3	106	236	2	1.1	96	3.3	7.5	19	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	1	12.9	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	16	36	2	12.9	31
Alternative 3	2055	Historic	25.3	106	236	2	1.1	96	3.3	7.5	19	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	1	12.9	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	16	36	2	12.9	31

Table 4A: Detailed WSRP Statistics for Cary-Apex, City of Dunn, and Fayetteville PWC

Water Supply Alternative	Year	Inflows [1]	Cape Fear River Basin Model Nodes for Cary-Apex						Cape Fear River Basin Model Nodes for Dunn						Cape Fear River Basin Model Nodes for Fayetteville					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
Alternative 4	2055	Historic	25.3	104.5	236	2	1.1	96	3.3	7.5	19	2	1.1	19	17.6	13	34	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	19.4	9	22	2	3.2	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	17.5	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	17	37	2	16.1	35
Alternative 5	2055	Historic	25.3	106	236	2	1.1	96	5.5	9	20	2	1.1	19	18.7	13	34	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	9.7	10	13	1	9.7	13	12.9	9.5	22	2	6.5	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	9.7	8.5	13	1	9.7	13	32.3	16	36	2	19.4	35
Alternative 6	2055	Historic																		
		CNRM	Identical to Alternative 7 (Jordan Lake Withdrawal)																	
		GFDL																		
		MIROC																		
Alternative 7	2055	Historic	25.3	106	236	2	1.1	96	3.3	7.5	19	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	1	12.9	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	3.2	9	9	1	3.2	9
		MIROC	32.3	144	249	2	19.4	131	6.5	8	13	1	6.5	13	32.3	16	36	2	12.9	31
Alternative 8A	2055	Historic	25.3	106	236	2	1.1	96	5.5	9	20	2	1.1	19	14.3	14.5	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	9.7	10	13	1	9.7	13	12.9	9	22	2	6.5	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	9.7	8.5	13	1	9.7	13	32.3	16	36	2	19.4	35

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Table 4A: Detailed WSRP Statistics for Cary-Apex, City of Dunn, and Fayetteville PWC

Water Supply Alternative	Year	Inflows [1]	Cape Fear River Basin Model Nodes for Cary-Apex						Cape Fear River Basin Model Nodes for Dunn						Cape Fear River Basin Model Nodes for Fayetteville					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
Alternative 8B	2055	Historic	25.3	106	236	2	1.1	96	5.5	8.5	20	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	2	3.2	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8.5	13	1	6.5	13	32.3	16	36	2	16.1	35
Alternative 9A/B	2055	Historic	25.3	106	236	2	1.1	96	5.5	9	20	2	1.1	19	18.7	13	34	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	9.7	10	13	1	9.7	13	12.9	9.5	22	2	6.5	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	9.7	8.5	13	1	9.7	13	32.3	16	36	2	19.4	35
Alternative 9C	2055	Historic	25.3	106	236	2	1.1	96	5.5	9	20	2	1.1	19	14.3	14.5	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	9.7	10	13	1	9.7	13	12.9	9	22	2	6.5	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	9.7	8.5	13	1	9.7	13	32.3	16	36	2	19.4	35
Alternative 9D	2055	Historic	25.3	106	236	2	1.1	96	5.5	8.5	20	2	1.1	19	16.5	13	33	2	1.1	26
		CNRM	22.6	136.5	516	2	9.7	436	6.5	11.5	13	1	6.5	13	12.9	9.5	22	2	3.2	22
		GFDL	29	82	184	1	29	184	0	0	0	0	0	0	6.5	14	19	1	6.5	19
		MIROC	32.3	145	249	2	19.4	131	6.5	8.5	13	1	6.5	13	32.3	16	36	2	16.1	35

[1] *Note that the historical hydrologic record in OASIS spans 91 years whereas the length of record for each of the CNRM-CM5, GFDL-ESM2M, and MIROC-EMS-CHEM hydrologic scenarios is 31 years.*

Table 4B: Detailed WSRP Statistics for Raleigh Water and Town of Benson

Water Supply Alternative	Year	Inflows [1]	Neuse River Basin Model Nodes for Raleigh Water						Neuse River Basin Model Nodes for Benson					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
No action (baseline)	2025	Historic	0	0	0	0	0	0	0	0	0	0	0	0
	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 1	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	385	385	3	3.2	150	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 2	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 3	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 4	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 5	2055	Historic	20.9	67	211	3	2.2	181	5.5	9	20	2	1.1	19
		CNRM	6.5	386	386	3	6.5	174	9.7	10	13	1	9.7	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	9.7	8.5	13	1	9.7	13

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Table 4B: Detailed WSRP Statistics for Raleigh Water and Town of Benson

Water Supply Alternative	Year	Inflows [1]	Neuse River Basin Model Nodes for Raleigh Water						Neuse River Basin Model Nodes for Benson					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
Alternative 6	2055	Historic												
		CNRM [2]	Identical to Alternative 7 (Jordan Lake Withdrawal)											
		GFDL												
		MIROC												
Alternative 7	2055	Historic	20.9	67	211	3	2.2	181	3.3	7.5	19	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8	13	1	6.5	13
Alternative 8A	2055	Historic	20.9	67	211	3	2.2	181	5.5	9	20	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	9.7	10	13	1	9.7	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	9.7	8.5	13	1	9.7	13
Alternative 8B	2055	Historic	20.9	67	211	3	2.2	181	5.5	8.5	20	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8.5	13	1	6.5	13
Alternative 9A/B	2055	Historic	20.9	67	211	3	2.2	181	5.5	9	20	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	9.7	10	13	1	9.7	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	9.7	8.5	13	1	9.7	13
Alternative 9C	2055	Historic	20.9	67	211	3	2.2	181	5.5	9	20	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	9.7	10	13	1	9.7	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	9.7	8.5	13	1	9.7	13

Table 4B: Detailed WSRP Statistics for Raleigh Water and Town of Benson

Water Supply Alternative	Year	Inflows [1]	Neuse River Basin Model Nodes for Raleigh Water						Neuse River Basin Model Nodes for Benson					
			% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)	% of Years with WSRP Events [1]	Median Event Length (days)	Max Event Length (days)	Max Stage	% of Years with Max Stage	Max Event Length of Max Stage (days)
Alternative 9D	2055	Historic	20.9	67	211	3	2.2	181	5.5	8.5	20	2	1.1	19
		CNRM [2]	6.5	386	386	3	6.5	174	6.5	11.5	13	1	6.5	13
		GFDL	0	0	0	0	0	0	0	0	0	0	0	0
		MIROC	29	68	150	2	6.5	77	6.5	8.5	13	1	6.5	13

[1] Note that the historical hydrologic record in OASIS spans 91 years whereas the length of record for each of the CNRM-CM5, GFDL-ESM2M, and MIROC-EMS-CHEM hydrologic scenarios is 31 years.

[2] For each alternative using CNRM-CM5 inflows, Raleigh Water experiences a singular water shortage event that spans two years reaching up to shortage response Stage 3 for 150 to 174 days, thus the mean and median event length are equal.

3.2 Performance of Jordan Lake and Falls Lake in Meeting Flow Targets and Recreational Criteria

The second class of modeling results described in this report pertain to the frequency (in percent of days) that an alternative does not meet storage, lake elevation, or flow metrics at specific locations, as summarized in Table 5. These results generally pertain to the ability of Falls Lake and Jordan Lake to meet their authorized purposes. These metrics are consistent with the metrics presented in the 2014 Cary/Apex IBT analysis in the Cape Fear River. Similar metrics were developed for Falls Lake. The specific metrics used in the analysis include the following:

- Jordan Lake < 210 feet
- Jordan Lake < 210 feet Memorial to Labor Day
- Jordan Lake water quality storage < 80%, < 60%, < 40%, and < 20%
- Jordan Lake water supply storage < 50%
- Lillington gage flow < 550 cfs
- Fayetteville intake flow < 600 cfs
- Falls Lake < 242.5 feet
- Falls Lake < 242.5 feet Memorial to Labor Day
- Jordan Lake water quality storage < 80%, < 60%, < 40%, and < 20%
- Jordan Lake water supply storage < 50%
- Falls Lake gage flow < seasonal target at Falls Lake (April to October at 100 cfs; 60 cfs otherwise).
- Clayton gage flow < seasonal target at Clayton gage (April to October at 254 cfs; 184 cfs otherwise).

The 210 feet pool elevation in Jordan Lake and the 242.5 feet pool elevation in Falls Lake (USACE, 2018) represent lake levels at which boat access (i.e., the recreation purpose authorized for both federal projects) are anticipated to be adversely impacted. The normal pool for Jordan Lake is 216 feet. The normal pool elevation for Falls Lake is 251.5 feet. The following is a summary of the key conclusions:

- Jordan Lake drops to less than 210 feet less than 0.8 percent of the time for nearly all alternatives and climate change scenarios and 0.2 percent or less in the key summer recreational period. The singular exception is for the MIROC climate scenario for Alternatives 6 and 7 where the numbers are 1.2 percent and 0.4 percent, respectively.
- Jordan Lake water quality storage never drops less than 20 percent (i.e., equivalent to the Stage 4 trigger) in any alternative using either historic or climate change inflows. The water quality storage declines to less than 40 percent infrequently (i.e., less than 2.4 percent of the time) for all 2055 scenarios.
- The amount of time the Jordan Lake Water Quality Pool contains less than 80 percent storage (i.e., the Stage 1 drought trigger) ranges from approximately 9 percent of days up to 20 percent of days. The results for the historical hydrology generally indicate approximately 15 percent of days in 2055, which is notably a 40 percent reduction in the

amount of time at or below 80 percent storage as compared to the baseline results for 2025 (i.e., 25 percent in 2025 versus 15 percent in 2055). This owes to the contribution that treated wastewater makes toward meeting the flow target in Lillington in 2055 as compared to projections in 2025.

- The results for Jordan Lake Drought Stage 1 are highly correlated to the amount of time that the full flow target at Lillington (550 cfs) is not met. The discharge at Lillington is less than 550 cfs approximately 14.5 percent of the time for the alternatives using the historical inflow record. The discharge at Lillington is less than 550 cfs approximately 9.3 to 18.8 percent across all the climate change scenarios. The variation across the modeled alternatives is very low with the greatest difference between any two alternatives (and the same hydrology) of only 0.5 percent. The 14.5 percent in 2055 compares to 19.5 percent under 2025 conditions, so there is a relative reduction of over 25 percent of days spent in a Stage 1 event or worse.
- The model demonstrates that approximately 5.5 percent of the days the flow at Fayetteville of 600 cfs would not be met using historical inflows, which is a 50 percent reduction in days with discharge upstream of the PWC intake under 600 cfs as compared to the 2025 baseline. The variation under the climate change inflows is modest except for the MIROC (MIROC-EMS-CHEM) scenario, which produces low runoff periods that increase the percentage from 12 to 12.6 percent. Nevertheless, like the other metrics, the variance across alternatives under this climate scenario is small.
- Falls Lake drops to less than 242.5 feet less than 0.4 percent of the time for all alternatives and climate change scenarios, and never does in the key summer recreational period.
- The Falls Lake water quality storage declines to less than 40 percent infrequently (i.e., less than 2.5 percent of the time and 1.5 percent of the time using historical hydrology). Falls Lake storage almost never declines to less than 20 percent. The lowest modeled storage reached 16.9 percent during one event in the historical hydrology (i.e., in late 2007) and never under the climate change scenarios.
- The Falls Lake minimum release and Clayton gage seasonal flow targets are never impacted.

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Table 5: Frequency (% of Days) Alternatives Do Not Meet Storage and Flow Metrics at Select Locations in Cape Fear and Neuse River Basins

Alternative	Year	Inflows	Jordan Lake < 210 feet	Jordan Lake < 210 feet Memorial to Labor Day	Jordan Lake Water Quality Storage < 80%	Jordan Lake Water Quality Storage < 60%	Jordan Lake Water Quality Storage < 40%	Jordan Lake Water Quality Storage < 20%	Jordan Lake Water Supply Storage < 50%	Lillington Gage Flow < 550 cfs	Fayetteville Intake Flow< 600 cfs	Falls Lake < 242.5 feet	Falls Lake < 242.5 feet Memorial to Labor Day	Falls Lake Water Quality Storage < 80%	Falls Lake Water Quality Storage < 60%	Falls Lake Water Quality Storage < 40%	Falls Lake Water Quality Storage < 20%	Falls Lake Water Supply Storage < 50%	Falls Lake Release < Seasonal target [1]	Clayton Flow < Seasonal target [2]
No action (baseline)	2025	Historic	0.0%	0.0%	25.2%	17.0%	5.7%	0.0%	0.0%	19.0%	11.2%	0.0%	0.0%	13.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	2055	Historic	0.1%	0.0%	15.0%	5.7%	0.6%	0.0%	0.0%	14.2%	5.6%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.2%	7.1%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.3%	1.6%	0.0%	0.0%	0.0%	9.3%	2.9%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.4%	8.5%	1.9%	0.0%	0.0%	18.5%	12.2%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
1	2055	Historic	0.1%	0.0%	15.0%	5.7%	0.6%	0.0%	0.0%	14.2%	5.5%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.2%	7.0%	0.2%	0.0%	14.5%	6.4%	1.5%	0.0%	3.4%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.2%	1.6%	0.0%	0.0%	0.0%	9.3%	2.9%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.3%	8.5%	1.8%	0.0%	0.0%	18.5%	12.0%	0.0%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
2	2055	Historic	0.1%	0.0%	15.0%	5.7%	0.6%	0.0%	0.0%	14.2%	5.5%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.3%	7.0%	0.4%	0.0%	14.6%	6.4%	1.7%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.1%	1.6%	0.0%	0.0%	0.0%	9.3%	2.9%	0.0%	0.0%	11.8%	1.1%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.4%	8.6%	1.9%	0.0%	0.0%	18.5%	12.0%	0.1%	0.0%	23.9%	10.3%	2.5%	0.0%	6.3%	0.0%	0.0%
3	2055	Historic	0.1%	0.0%	15.0%	5.7%	0.6%	0.0%	0.0%	14.2%	5.5%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.2%	7.0%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.1%	1.6%	0.0%	0.0%	0.0%	9.3%	2.9%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.4%	8.6%	2.0%	0.0%	0.0%	18.5%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%

Table 5: Frequency (% of Days) Alternatives Do Not Meet Storage and Flow Metrics at Select Locations in Cape Fear and Neuse River Basins

Alternative	Year	Inflows	Jordan Lake < 210 feet	Jordan Lake < 210 feet Memorial to Labor Day	Jordan Lake Water Quality Storage < 80%	Jordan Lake Water Quality Storage < 60%	Jordan Lake Water Quality Storage < 40%	Jordan Lake Water Quality Storage < 20%	Jordan Lake Water Supply Storage < 50%	Lillington Gage Flow < 550 cfs	Fayetteville Intake Flow< 600 cfs	Falls Lake < 242.5 feet	Falls Lake < 242.5 feet Memorial to Labor Day	Falls Lake Water Quality Storage < 80%	Falls Lake Water Quality Storage < 60%	Falls Lake Water Quality Storage < 40%	Falls Lake Water Quality Storage < 20%	Falls Lake Water Supply Storage < 50%	Falls Lake Release < Seasonal target [1]	Clayton Flow < Seasonal target [2]
4	2055	Historic	0.1%	0.0%	15.0%	5.7%	0.6%	0.0%	0.0%	14.2%	5.9%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.3%	7.3%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.3%	1.6%	0.0%	0.0%	0.0%	9.3%	3.2%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.4%	8.5%	1.9%	0.0%	0.0%	18.5%	12.6%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
5	2055	Historic	0.1%	0.0%	15.7%	6.2%	0.8%	0.0%	0.0%	14.6%	5.7%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.8%	5.7%	1.4%	0.0%	0.0%	12.7%	7.3%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.7%	1.7%	0.0%	0.0%	0.0%	9.8%	3.2%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.8%	0.2%	20.0%	9.1%	2.4%	0.0%	0.0%	18.8%	12.2%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
6	2055	Historic																		
		CNRM	Identical to Alternative 7 (withdrawal from Jordan Lake)																	
		GFDL																		
		MIROC																		
7	2055	Historic	0.2%	0.0%	15.0%	5.8%	0.6%	0.0%	0.0%	14.4%	5.5%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.4%	0.0%	12.4%	5.5%	1.2%	0.0%	0.0%	12.4%	7.0%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.1%	1.4%	0.0%	0.0%	0.0%	9.8%	2.9%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	1.2%	0.4%	19.4%	8.5%	1.9%	0.0%	0.0%	18.7%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%

Table 5: Frequency (% of Days) Alternatives Do Not Meet Storage and Flow Metrics at Select Locations in Cape Fear and Neuse River Basins

Alternative	Year	Inflows	Jordan Lake < 210 feet	Jordan Lake < 210 feet Memorial to Labor Day	Jordan Lake Water Quality Storage < 80%	Jordan Lake Water Quality Storage < 60%	Jordan Lake Water Quality Storage < 40%	Jordan Lake Water Quality Storage < 20%	Jordan Lake Water Supply Storage < 50%	Lillington Gage Flow < 550 cfs	Fayetteville Intake Flow< 600 cfs	Falls Lake < 242.5 feet	Falls Lake < 242.5 feet Memorial to Labor Day	Falls Lake Water Quality Storage < 80%	Falls Lake Water Quality Storage < 60%	Falls Lake Water Quality Storage < 40%	Falls Lake Water Quality Storage < 20%	Falls Lake Water Supply Storage < 50%	Falls Lake Release < Seasonal target [1]	Clayton Flow < Seasonal target [2]
8A	2055	Historic	0.1%	0.0%	15.7%	6.2%	0.8%	0.0%	0.0%	14.7%	5.4%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.9%	5.8%	1.4%	0.0%	0.0%	12.7%	7.0%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.7%	1.7%	0.0%	0.0%	0.0%	9.8%	3.0%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.8%	0.2%	19.9%	9.1%	2.4%	0.0%	0.0%	18.8%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
8B	2055	Historic	0.1%	0.0%	15.2%	5.9%	0.7%	0.0%	0.0%	14.3%	5.6%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.6%	5.5%	1.3%	0.0%	0.0%	12.4%	7.1%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.4%	1.5%	0.0%	0.0%	0.0%	9.6%	3.1%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.5%	8.8%	2.0%	0.0%	0.0%	18.6%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
9A/B	2055	Historic	0.1%	0.0%	15.7%	6.2%	0.8%	0.0%	0.0%	14.6%	5.7%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.8%	5.7%	1.4%	0.0%	0.0%	12.7%	7.3%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.7%	1.7%	0.0%	0.0%	0.0%	9.8%	3.2%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.8%	0.2%	20.0%	9.1%	2.4%	0.0%	0.0%	18.8%	12.2%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%
9C	2055	Historic	0.1%	0.0%	15.7%	6.2%	0.8%	0.0%	0.0%	14.6%	5.4%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.8%	5.7%	1.4%	0.0%	0.0%	12.7%	7.0%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.7%	1.7%	0.0%	0.0%	0.0%	9.8%	3.0%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.8%	0.2%	20.0%	9.1%	2.4%	0.0%	0.0%	18.8%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%

Table 5: Frequency (% of Days) Alternatives Do Not Meet Storage and Flow Metrics at Select Locations in Cape Fear and Neuse River Basins

Alternative	Year	Inflows	Jordan Lake < 210 feet	Jordan Lake < 210 feet Memorial to Labor Day	Jordan Lake Water Quality Storage < 80%	Jordan Lake Water Quality Storage < 60%	Jordan Lake Water Quality Storage < 40%	Jordan Lake Water Quality Storage < 20%	Jordan Lake Water Supply Storage < 50%	Lillington Gage Flow < 550 cfs	Fayetteville Intake Flow< 600 cfs	Falls Lake < 242.5 feet	Falls Lake < 242.5 feet Memorial to Labor Day	Falls Lake Water Quality Storage < 80%	Falls Lake Water Quality Storage < 60%	Falls Lake Water Quality Storage < 40%	Falls Lake Water Quality Storage < 20%	Falls Lake Water Supply Storage < 50%	Falls Lake Release < Seasonal target [1]	Clayton Flow < Seasonal target [2]
9D	2055	Historic	0.1%	0.0%	15.2%	5.9%	0.7%	0.0%	0.0%	14.3%	5.6%	0.3%	0.0%	20.2%	8.3%	1.5%	0.1%	5.2%	0.0%	0.0%
		CNRM	0.3%	0.0%	12.5%	5.5%	1.3%	0.0%	0.0%	12.3%	7.1%	0.4%	0.0%	14.5%	6.4%	1.5%	0.0%	3.7%	0.0%	0.0%
		GFDL	0.0%	0.0%	9.4%	1.5%	0.0%	0.0%	0.0%	9.6%	3.1%	0.0%	0.0%	11.7%	1.0%	0.0%	0.0%	0.2%	0.0%	0.0%
		MIROC	0.7%	0.1%	19.5%	8.8%	2.0%	0.0%	0.0%	18.6%	12.0%	0.1%	0.0%	23.8%	10.2%	2.3%	0.0%	6.3%	0.0%	0.0%

[1] *Falls Lake flow target: April to October, 100 cfs; 60 cfs otherwise.*

[2] *Clayton flow target: April to October, 254 cfs; 184 cfs otherwise.*

3.3 Low-Flow Discharge in the Cape Fear River and Neuse River

The third class of output metrics pertains to low flow conditions at various key locations along the Cape Fear and Neuse Rivers. A statistical summary of streamflow impacts was developed to assess and evaluate the alternatives in the Neuse and Cape Fear River basins, focusing on the 7Q10, which is the lowest 7-day flow that occurs on average once every 10 years.

Table 6 summarizes the 7Q10 flow statistics at various nodes in the CFNCRB model. The evaluated 7Q10 locations are illustrated in Figure 2. The locations where the 7Q10 is reported include the Lillington gage, upstream of Fayetteville PWC's raw water intake in the Cape Fear basin, upstream of the CFPUA/LCFWSA raw water intake in the Cape Fear basin, at the Cayton Gage in the Neuse River basin, the confluence of the Neuse and Little Rivers in the Neuse River basins, and upstream of NRWASA's raw water intake in the Neuse River basin. Alternative 9A/B is the Town of Fuquay-Varina partnering with the City of Sanford for finished water supply. Alternatives 9C and 9D are similar, but also include a return of treated wastewater to the Cape Fear River.

The CFNCRB model provided results for four categories of change that could influence future low flow conditions to include the following:

1. Potential climate change impact to hydrology.
2. Cumulative impact related to Cape Fear River basin development (i.e., water demand increase between 2025 and 2055).
3. Project-related impacts to 7Q10.
4. USGS gage accuracy and CFNCRB model precision.

These impacts can be distinguished by comparing the low flows that result from the array of 45 different model runs and observing how an alternative, climate scenario, or target year demand (2025 vs 2055) affects the 7Q10 compared to other model runs. The magnitude of impacts to low flows were compared across the three aforementioned categories. The model suggests that the impact due to climate change would potentially incur the largest impact followed by cumulative impacts from increased water demand in the basin unrelated to a specific alternative. The selection of a water supply alternative for the Town of Fuquay-Varina resulted in minimal impact.

Figures 3 and 4 illustrate the model run comparisons. The chart for each location begins at the 2025 No Action baseline and progresses to indicate the relative impact of development through 2055, then the range of impacts across all the water supply alternatives (removing the baseline No Action climate effect) and finally shows the cumulative range of impacts due to the three climate scenarios evaluated. Where there is a range shown (water supply alternatives and climate scenarios), the green bar represents the median of the dataset and the whiskers at the top and bottom of the bar represent the entire range for that location.

3.3.1 Potential Climate Change Impact to Hydrology

The climate models selected for use in this EIS are not consistent with respect to the direction of change (increasing or decreasing) to future low flow conditions in central North Carolina. However, the magnitude of the forecasted changes from the climate models are significant. The low flow magnitude of change is 5 to 20 times greater than the change predicted from increased water demand through 2055 or the preferred alternative 9A/B. In the following summaries, the percent value describes the change between the historical hydrology runoff and the indicated climate change scenario for an alternative. Ranges are provided at a fixed location as the magnitude of the impact varies depending on the alternative. For example, the GFDL model suggests the Lillington gage 7Q10 would increase by 23.5 percent in the No-Action alternative but only increase by 18.7 percent for Alternative 9C. Therefore, the range in this scenario is between 19 and 24 percent.

In the Cape Fear River basin, the CNRM and MIROC climate models suggest a decrease in the 7Q10. Both models also suggest the changes are more severe further downstream. This may be a function of more severe hydrologic impacts further south and east in the basin, but it is also a function of how Jordan Lake is managed (refer to Section 4). Compared to the historical hydrology and 2055 water demand, the CFNCRB model 7Q10 results for 2055 are 12 to 20 percent less at Lillington, reduced by 20 percent upstream of PWC's intake, and reduced by 32 to 36 percent at the CFPUA/LCFWSA intake. For the MIROC model the comparative changes are a 35 to 40 percent reduction at Lillington, slightly over a 40 percent reduction at PWC's intake, and a reduction of 60 percent at the CFPUA/LCFWSA intake. The GFDL model suggests the 7Q10 results in the Cape Fear will increase 19 to 24 percent at Lillington, 15 to 18 percent at PWC's intake, and 17 to 19 percent at the CFPUA intake. Ranges are provided as an attempt to characterize the climate impacts broadly across all 12 alternatives.

In the Neuse Reiver basin, all three climate models suggest a decline in the 7Q10. The exception is the GFDL-ESM2M, RCP 8.5 model result at the Clayton gage (+1.5 percent). The MIROC-EMS-CHEM model is the most conservative and resulted in a reduction of 12 percent at Clayton, 19 to 22 percent at the confluence of the Little River and Neuse River, and 24 to 27 percent at the NRWASA intake. The CNRM-CM5, RCP 4.5 model suggests a reduction of 4 percent at Clayton, 1 to 4 percent at the Neuse-Little River confluence, and 2 to 5 percent at the NRWASA intake in Kinston. The GFDL-ESM2M, RCP 8.5 model resulted in a 1.4 percent increase at Clayton, a 5 to 8 percent reduction at the Neuse-Little River confluence, and an 8 to 12 percent reduction at the NRWASA intake. The low flow reductions in the Neuse are more modest than the predicted reductions in in the Cape Fear in part due to the consistency of the flow target at Clayton regardless of the hydrologic scenario.

3.3.2 Cumulative Impact Related to Cape Fear River Basin Development

The cumulative impacts from the increase in water demand between 2025 and 2055 in the Cape Fear basin (excluding the Town of Fuquay-Varina) is forecast to reduce the 7Q10 at the Lillington gage, upstream of PWC's Intake, and upstream of the CFPUA/LCFWSA intake by 4.7 percent, 2.1 percent, and 3.8 percent, respectively. The impact at the Lillington gage is larger and potentially misleading. The Lillington 7Q10 result is reported at the gage location, which is downstream of Harnett County's Regional WTP withdrawal and upstream of the effluent discharge from the North Harnett Regional WWTP. Since Harnett County and partners plan for significant growth between 2025 and 2055, the impact is greater in the one-mile stretch between Harnett County's raw water intake and the effluent discharge than elsewhere along this stretch of the Cape Fear River.

The cumulative impacts due to growth in water demand between 2025 and 2055 in the Neuse Basin are mixed depending on location. At the Clayton gage, the 7Q10 is forecast to rise by nearly 20 percent due to increased use and discharge at Raleigh's Neuse Regional Resource Recovery Facility (NRRRF) and the Town of Clayton's Sam's Branch WRF. Further downstream at the confluence of the Neuse and Little River in Goldsboro, the models predict a reduction of 2.8 percent in the future 7Q10 and 1.3 percent at NRWASA's raw water intake. The confluence of the Neuse and Little Rivers is downstream of Goldsboro's raw water intake and upstream of the City of Goldsboro's wastewater discharge, so approximately one-half of the impact at this location (between no change and -2.8 percent) is due to the increase in the City of Goldsboro's water demand over the planning horizon.

The CFNCRB model suggests the upstream increase in 7Q10 at Clayton may be counteracted further downstream by growth in Johnston County combined with conservative model assumptions about Johnston County's wastewater return to water demand ratio. The wastewater return to water demand ratio for Johnston County will increase with urbanization similar to other urbanizing areas across the state. The wastewater return to water demand ratio is increasing in urban areas but has not been subject to extensive research and therefore is difficult to forecast. The CFNCRB model reflects the present day wastewater to water demand ratio in the 2055 demand scenario.

3.3.3 Project-related Impacts to 7Q10

The following 7Q10 comparative statistics apply to the historical basin runoff (e.g., hydrology) using the 2055 water demand scenario:

- The 7Q10 difference between the No-Action alternative in 2055 and Alternative 9A/B (no return of wastewater to the Cape Fear River basin) is a reduction of 4.6 cfs (-1.1 percent) for Alternative 9A/B at the PWC raw water intake and 3.1 cfs (-0.8 percent) at the CFPUA raw water intake. In the No-Action alternative, the majority of the Town of Fuquay-Varina's demand is unmet as additional supply options are not considered. In Alternative 9A/B, the Town of Fuquay-Varina's water demand is met with a withdrawal from the Cape Fear River near Sanford, which results in an approximate 1 percent reduction in the 7Q10 downstream of Sanford's intake.
- The 7Q10 difference between the 2055 No-Action alternative and Alternative 9C (return of water to Cape Fear) is an increase of 3.4 cfs (+0.8 percent) at PWC's raw water intake and 4.6 cfs (+1.2 percent) at the CFPUA raw water intake. The difference between the No-Action alternative and Alternative 9D (i.e., Western Wake WRF) is an increase of 0.8 cfs and 0.5 cfs at the same respective downstream locations. The smaller change with Alternative 9D is due to the fact the wastewater is returned upstream of the Lillington gage and the releases from Jordan Lake are adjusted accordingly in the model.
- The difference between Alternatives 9A/B (i.e., no return of water) and 9C (i.e., return of water) is an increase of 8 cfs (+2 percent) at PWC's raw water intake and 7.9 cfs (+2 percent) at the CFPUA raw water intake.
- The difference between Alternatives 9A/B and 9D is an increase of 5.4 cfs (+1.3 percent) at PWC's raw water intake and an increase of 3.9 cfs (+1 percent) at the CFPUA raw water intake.
- The model predicts small differences in 7Q10 downstream of the confluence of Middle Creek and the Neuse River depending on the source of the Town of Fuquay-Varina's future water supply and the location of the Town's discharged wastewater (i.e., Terrible

Creek in the Neuse River basin or returned to the Cape Fear River). The impact to the 7Q10 reported at the confluence of the Neuse and Little Rivers and at the NRWASA intake can be reduced by approximately 7 cfs for Alternative 1 over the 2055 No Action alternative or supplemented by up to nearly 6 cfs for Alternatives 4, 5, 6, 7, and 9A/B. For either Alternatives 9C or 9D, the impact at both locations is a very small reduction of 1.6 cfs compared to the 2055 No Action Alternative.

3.3.4 USGS Gage Accuracy and CFNCRB Model Precision

Models allow a high precision comparison of scenario outputs and relative changes as a result of modifying model variables. Modifying a model variable allows a relational cause and effect to be identified. The CFNCRB model has produced accurate and precise output results for the comparison of alternatives in this EIS. However, the ability to discern marginal changes in the field is a separate issue. The USGS gages used to measure streamflow are not nearly as precise in consistency and reproducibility as results from a mathematical model.

The USGS provides ratings for all installed stream gages. An assessment of gage accuracy is found in the “Remarks” Section in the station description (USGS, 2023). A gage station with an “Excellent" rating indicates that approximately 95 percent of the daily flow records are within 5 percent of the true value. A “Good” rating indicates that flow records are within 10 percent of the true flow value and a “Fair” rating indicates that the daily flow record is within 15 percent of the daily flow value. Stations with a “Poor” rating have daily discharge records of less than “Fair” accuracy. Per USGS, the gage station at Lillington has a “Good” rating, the gage station at Fayetteville has a “Poor” rating, and the gage station at Cape Fear Lock 1 NR Kelly has a “Good” rating. At the Lillington gage, a “Good” rating in the low-flow range of 250 to 600 cfs translates to a margin of error of +/- 25 to 60 cfs.

The modeled 7Q10 differences between any two alternatives using the historical hydrology are less than 10 cfs at Lillington and at the other gage sites reported in Table 6. The difference in the 7Q10 flow values between the evaluated water supply alternatives are substantially less than the station margin of error (i.e., accuracy) for daily discharge for all three gaging stations in the Cape Fear River. Since a 7Q10 event is statistically an event that lasts seven days, it is possible that the gage margins of error are reduced over this longer time period versus an instantaneous flow event. However, even with the potential for a lower margin of error, the CFNCRB model predict differences in streamflow that will most likely not be captured at the USGS gage stations.

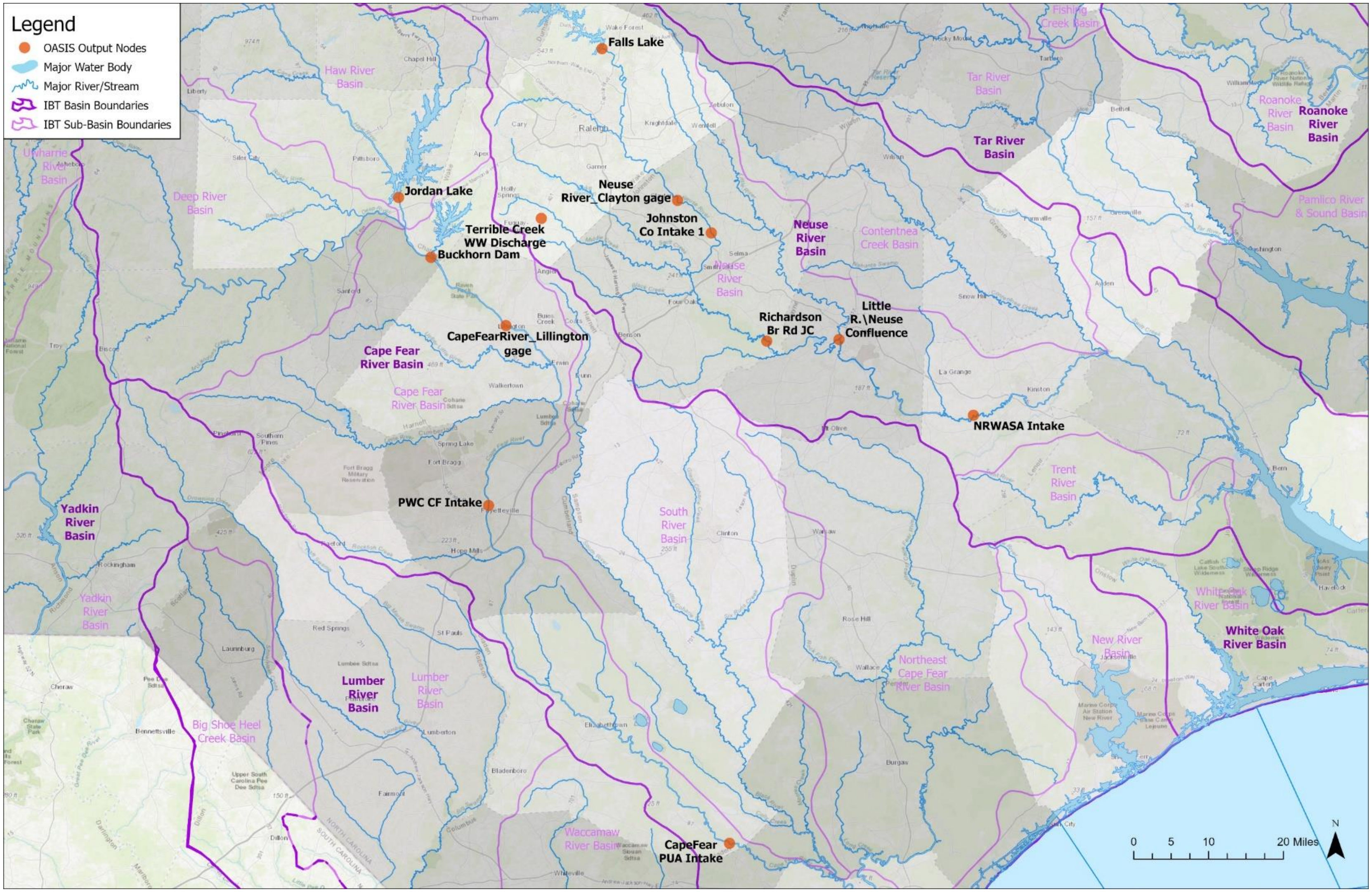


Figure 2: Model Nodes Used for Hydrologic Analysis

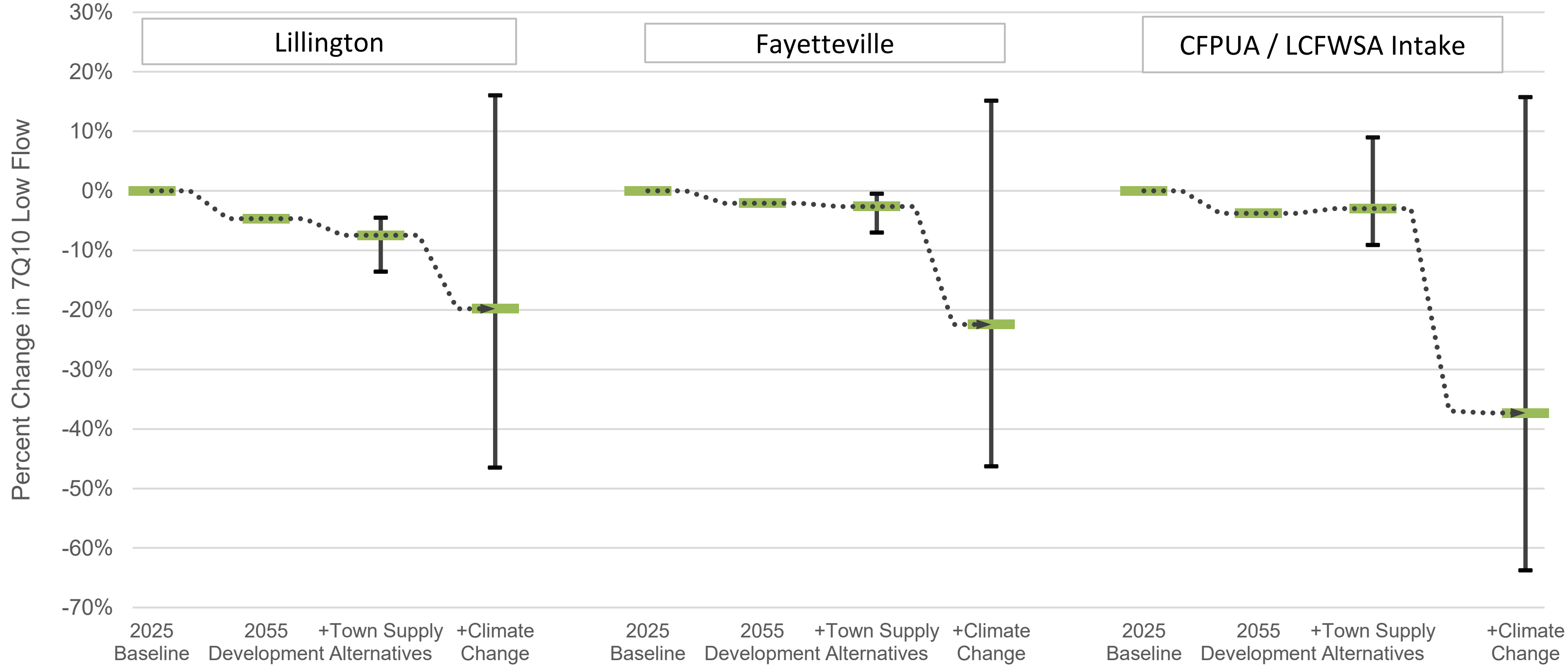


Figure 3: Comparison of Low Flow Impacts at Select Points in the Cape Fear River

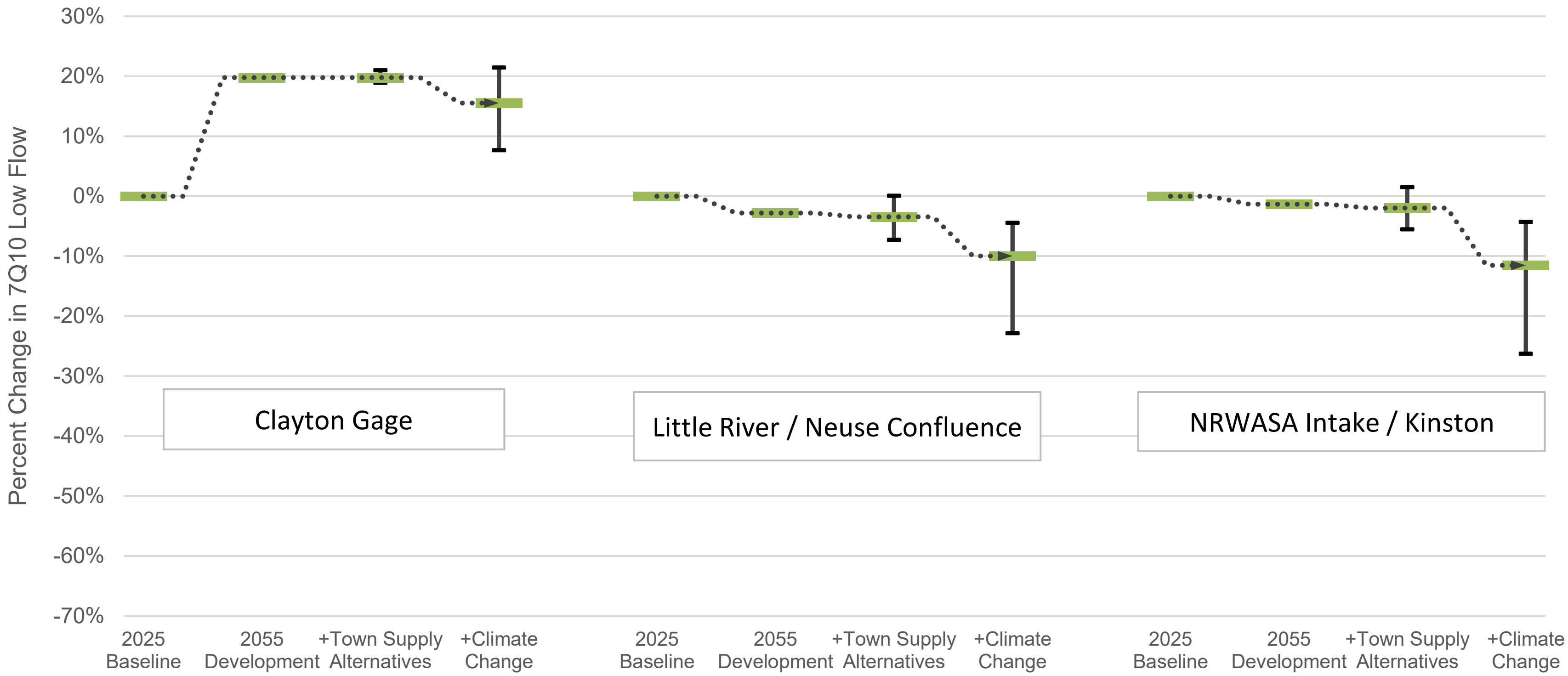


Figure 4: Comparison of Low Flow Impacts at Select Points in the Neuse River

Table 6: Summary of 7Q10 Flow Statistics at Select Nodes in the Neuse and Cape Fear River Basins

Water Supply Alternative	Demand Year	Inflows	Lillington Flow, cfs	Fayetteville Intake, cfs	Cape Fear PUA Intake, cfs	Clayton Flow, cfs	Neuse River / Little River Confluence, cfs	Neuse River WASA Intake, cfs
No-Action (baseline)	2025	Historic	278.9	415.2	407.2	198.8	224.7	244.9
	2055	Historic	265.8	406.5	391.9	238.1	218.4	241.6
		CNRM	233.8	326.7	248.6	228	216.1	236.1
		GFDL	328.2	477.5	462.8	241.4	204.2	218.6
		MIROC	170.7	238.1	164.4	209.8	176.8	183.6
Alternative 1	2055	Historic	266.3	410.3	395.8	238.1	211.2	234.3
		CNRM	233.8	330.5	272.1	230.8	207.3	226.5
		GFDL	319.2	475	466.4	241.4	195.1	209.5
		MIROC	170.9	241.8	169.7	209.8	172.4	181.5
Alternative 2	2055	Historic	266	410.3	396	236.6	217.4	240.7
		CNRM	233.8	330.5	260.7	226.6	215.1	235.1
		GFDL	319.2	474.9	466.2	240.6	205.5	220.5
		MIROC	170.7	241.7	165.4	208	176.3	183.6
Alternative 3	2055	Historic	266.3	410.4	395.8	238.1	212.3	235.3
		CNRM	233.9	330.6	280.2	228	209.5	228.5
		GFDL	319.2	475	466.4	241.4	195.6	210
		MIROC	170.9	241.8	167.8	209.8	173.2	180.1
Alternative 4	2055	Historic	265.8	399.2	384.1	238.1	224.3	247.5
		CNRM	233.8	318.1	273.3	228	220.2	240.7
		GFDL	328.2	470.1	455	241.4	210.1	224.6
		MIROC	170.7	230.8	160.8	209.8	181.5	188.8

Table 6: Summary of 7Q10 Flow Statistics at Select Nodes in the Neuse and Cape Fear River Basins

Water Supply Alternative	Demand Year	Inflows	Lillington Flow, cfs	Fayetteville Intake, cfs	Cape Fear PUA Intake, cfs	Clayton Flow, cfs	Neuse River / Little River Confluence, cfs	Neuse River WASA Intake, cfs
Alternative 5	2055	Historic	258	401.9	388.7	238.1	224.3	247.5
		CNRM	213	313.7	251.2	228	220.8	241.2
		GFDL	315.7	469	461.4	241.4	210.1	224.6
		MIROC	157.3	226.4	158.4	209.8	181.5	188.8
Alternative 6/7	2055	Historic	265.9	409.6	395	238.1	224.3	247.5
		CNRM	233.9	330.6	255	228	220.2	240.7
		GFDL	328.2	481.2	466.4	241.4	210.1	224.6
		MIROC	170.9	241.9	167	209.8	181.5	188.8
Alternative 8A	2055	Historic	258	412.3	399.9	238.1	216.8	240
		CNRM	213	322	269.8	228	214.7	234.5
		GFDL	315.7	476.6	468.8	241.4	202.6	217.1
		MIROC	157.2	234	158	209.8	175	181.9
Alternative 8B	2055	Historic	263.9	407.5	392.9	238.1	216.8	240
		CNRM	230.9	326.7	257.1	228	214.7	234.5
		GFDL	316.6	470.7	463	241.4	202.6	217.1
		MIROC	163.7	234.1	163.4	209.8	175	181.9
Alternative 9A/B	2055	Historic	258	401.9	388.7	238.1	224.3	247.5
		CNRM	213	313.7	251.2	228	220.8	241.2
		GFDL	315.7	469	461.4	241.4	210.1	224.6
		MIROC	157.3	226.4	158.4	209.8	181.5	188.8

Table 6: Summary of 7Q10 Flow Statistics at Select Nodes in the Neuse and Cape Fear River Basins

Water Supply Alternative	Demand Year	Inflows	Lillington Flow, cfs	Fayetteville Intake, cfs	Cape Fear PUA Intake, cfs	Clayton Flow, cfs	Neuse River / Little River Confluence, cfs	Neuse River WASA Intake, cfs
Alternative 9C	2055	Historic	258	409.9	396.6	238.1	216.8	240
		CNRM	213	322	267.9	228	214.7	234.5
		GFDL	315.7	476.6	468.8	241.4	202.6	217.1
		MIROC	157.3	234	155.6	209.8	175	181.9
Alternative 9D	2055	Historic	263.9	407.3	392.6	238.1	216.8	240
		CNRM	230.9	326.7	257.1	228	214.7	234.5
		GFDL	316.5	470.7	463	241.4	202.6	217.1
		MIROC	163.8	234.2	165.1	209.8	174.8	181.8

4. Interpretation of Future Climate Simulation Results

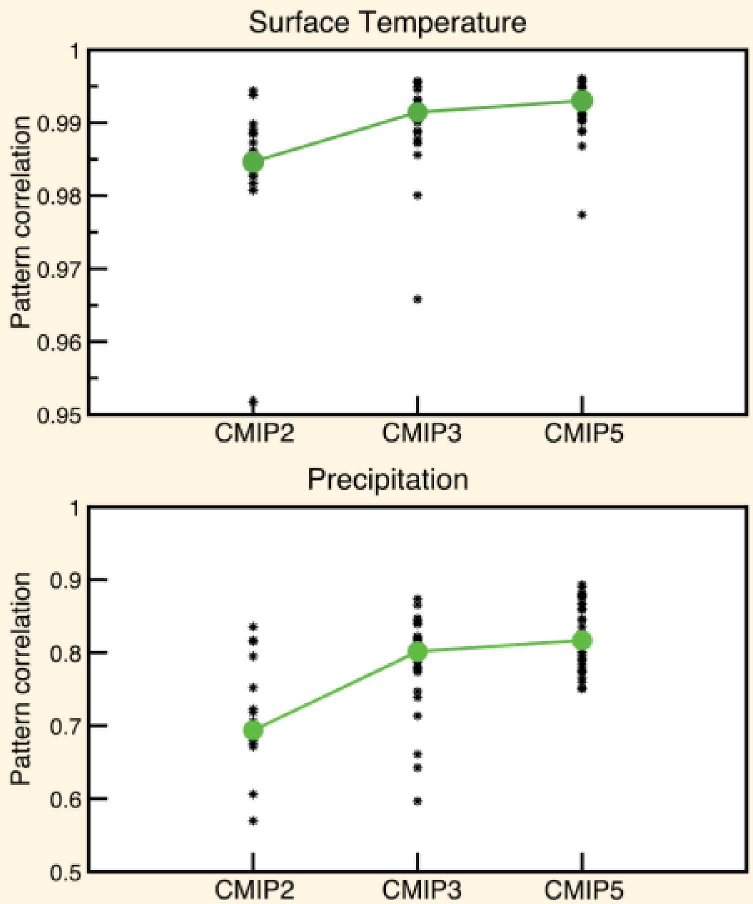
The climate variability scenarios results need to be interpreted with caution as discussed in Section 2.2. Climate models are typically run for hundreds of years to collect statistics on the frequency and intensity of weather events. One variable is changed and the model simulations are re-run to assess the global change in the statistics (Lerner, 2022). When climate models are used to predict the average future surface temperature for a given greenhouse gas emissions scenario, the majority of the models tend to agree (i.e., the models converge). The climate models do not converge as well for precipitation scenarios and struggle particularly with predicting the magnitude and frequency of extreme weather events.

Figure 5 illustrates the improvement of climate models over the course of several generations and also indicates the weaker capability of these models to reproduce precipitation patterns (Flato, 2013). The models used in this evaluation come from the CMIP5 archive. The improvement in skill of CMIP5 models over prior iterations (i.e., CMIP2 and CMIP3) to predict temperature and precipitation is shown in Figure 5. The lesser ability of these models to predict precipitation magnitude and timing will have implications for the hydrologic conditions assumed for these scenarios. Preparing for future climate variability is widely recognized as an important planning consideration for water supply infrastructure and therefore merits attention in this EIS despite continued uncertainty in the timing, magnitude, and patterns.

Shifts in the overall hydrologic productivity and timing of runoff for the three climate scenarios were evaluated with respect to the future water supply reliability in the Cape Fear and Neuse River basins. Table 7 summarizes the median unit runoff for four broad geographic areas in the Cape Fear and Neuse River basins. The median unit runoff provides additional quantitative context on the overall impact to the region's hydrology. The four geographical areas are as follows:

1. Neuse basin upstream of Falls Lake Dam
2. Neuse basin downstream of Falls Lake Dam
3. Cape Fear basin upstream of Jordan Lake Dam
4. Cape Fear basin downstream of Jordan Lake Dam (includes Rocky/Deep River watersheds)

Unit runoff results are presented for both 2010 to 2040 and 2040 to 2070 for the three climate variability scenarios even though the former period was not modeled in the CFNCRB model. The unit runoff results between 2010 and 2040 provide context for how the climate scenarios unfold over the next decades. Both historical observations and climate variability scenarios demonstrate greater unit runoff for the downstream portions of each basin as compared to the upstream portions. Runoff originating in the upper portions of the basins flowing into the lower basins was not included in the runoff statistics for the lower basins. The unit runoff in the Cape Fear basin is marginally higher than for the Neuse River basin. It is also notable that the unit runoff for the MIROC-ESM-CHEM model between 2040 and 2070 indicates a marked reduction compared to the historical runoff and runoff from the other two climate scenarios. The suitability of any of these scenarios is difficult to assess; however, one indication that there are challenges in plausibility of the MIROC-ESM-CHEM model is that the model has a known warm temperature bias at mid-latitudes, including the southeastern United States (Watanabe, 2011). Nevertheless, the MIROC-ESM-CHEM model was selected as a worst-case bounding condition despite this model flaw.



FAQ 9.1, Figure 1 | Model capability in simulating annual mean temperature and precipitation patterns as illustrated by results of three recent phases of the Coupled Model Intercomparison Project (CMIP2, models from about year 2000; CMIP3, models from about 2005; and CMIP5, the current generation of models). The figure shows the correlation (a measure of pattern similarity) between observed and modelled temperature (upper panel) and precipitation (lower panel). Larger values indicate better correspondence between modelled and observed spatial patterns. The black symbols indicate correlation coefficient for individual models, and the large green symbols indicate the median value (i.e., half of the model results lie above and the other half below this value). Improvement in model performance is evident by the increase in correlation for successive model generations.

Figure 5: Generalized comparison of GCM accuracy for temperature and precipitation outputs over the course of 3 generations of the CMIP project (models used for this EIS analysis are from CMIP5).

Table 7: Median Unit Runoff by Inflow Scenario in the Neuse and Cape Fear Upstream and Downstream of Major Basin Reservoir Nodes

Time Period	Climate Change Scenario	Neuse Upstream Falls Lake, cfs/mi^2	Neuse Downstream Falls Lake, cfs/mi^2	Cape Fear Upstream Jordan Lake, cfs/mi^2	Cape Fear Downstream Jordan Lake, cfs/mi^2
Historic (1930 to 2020)	N/A	0.35	0.63	0.47	0.69
2010 to 2040	MIROC-ESM-CHEM	0.36	0.63	0.48	0.70
	GFDL-ESM2M	0.34	0.61	0.45	0.78
	CNRM-CM5	0.40	0.74	0.51	0.80
2040 to 2070	MIROC-ESM-CHEM	0.24	0.44	0.35	0.48
	GFDL-ESM2M	0.30	0.57	0.40	0.66
	CNRM-CM5	0.34	0.64	0.44	0.74

The hydrologic changes modeled in MIROC-ESM-CHEM and CNRM-CM5 produce rare shortages for a single major municipal water supply withdrawal, CFPUA and LCFWSA, at the last freshwater withdrawal point on the Cape Fear River. Per the aforementioned discussion, climate models have difficulty reproducing precipitation patterns under historical conditions, so similar challenges should be anticipated for future predictions. There are six events in the MIROC scenario and three events in the CNRM scenario that produce supply shortages at the CFPUA/LCFWSA intake over a 30-year hydrologic period. These events are typically a single day in length; however, the longest duration event is 11 days.

Table 8 summarizes key system conditions during the months of water supply shortages for CFPUA and LCWSA. In each case, there are several factors or opportunities that would either naturally mitigate these events or could be leveraged to prevent the water supply shortages from occurring. The following are factors and opportunities that will mitigate these shortages:

The monthly average discharge at the intake is well in excess of the raw water need.

The average monthly discharge in the Cape Fear River at the point of withdrawal, even in a severe drought, is well in excess of the magnitude of the water supply withdrawal needed to satisfy CFPUA and LCFWSA demands. This result is demonstrated by comparing the column "Monthly Mean River Discharge at Intake" with the adjacent column, "Monthly Mean Water Withdrawal" in Table 8. The data suggests that the river discharge may not decline to the low daily discharges observed in the CFNCRB model to cause the observed shortages. In reality the runoff (and consequently flow) in the Lower Cape Fear may be more stable than the daily fluctuations in these climate scenarios suggest.

The storage behind Lock and Dam #1 is not part of the OASIS model.

The CFNRBM model assumes the CFPUA /LCFWSA intake points are "run-of-river" and that there is no storage in the Cape Fear River. However, backwater from Lock & Dam 1 runs upstream to Lock and Dam 2 (Palmer, 2024), a distance of 32 miles. Combined with an average river width between 200 and 300 feet and a navigation channel of 8 feet deep, over a billion gallons is stored in this reach of the Cape Fear River. Each inch of backwater storage is equivalent to 20 to 30 million gallons. This storage may be sufficient to mitigate the longest modeled shortage timeframe of 11 days. This storage could be a mitigating factor for an actual sustained shortage, should a shortage occur, particularly when combined with other management factors to help alleviate and buffer low flow events.

CFPUA/LCFWSA do not have target demand reductions in WSRPs or a quantifiable source water trigger condition.

Neither CFPUA nor LCFWSA have WSRPs with quantifiable triggers and target demand reductions in the CFNCRB model. Demand curtailment would undoubtedly accompany the response to drought events of this magnitude. However, the CFNCRB model assumes no water demand reduction for CFPUA nor LCFWSA unlike several other utilities in the Cape Fear River basin.

Modified management of Jordan Lake.

Modified or improved management of Jordan Lake could eliminate the rare shortages observed at the CFPUA/LCFWSA intake with or without consideration of the three aforementioned mentioned mitigation opportunities. The management of Jordan Lake under the current Drought Contingency Plan (DCP) in the CFNCRB model plays a role in causing these rare shortages. In each shortage provided in Table 8, there is sufficient storage in Jordan Lake to mitigate downstream shortages with releases from the Water Quality Pool.

Jordan Lake operations are not explicitly managed to meet needs downstream of Lillington. The release protocol for Jordan Lake was established to help meet downstream water quality needs while maintaining water supply storage in the reservoir. The drought plans for Jordan Lake allow for reductions in this minimum flow target at Lillington. In the Stage 3 and Stage 4 drought protocol, there is no flow target at Lillington but there is a specified maximum release from Jordan Lake. The CFNCRB model uses these operating conditions by limiting the maximum Jordan Lake release to 200 cfs. For example, when a Jordan Lake Stage 3 drought is invoked, there is far less protection remaining for downstream uses. It is only under Stage 3 conditions (Stage 4 is never reached in any scenario) when the CFPUA/LCFWSA shortages occur. Historically, the runoff downstream of Jordan Lake has been sufficient to meet water demands and have not required flow augmentation from Jordan Lake during low-flow periods. However, if water demand growth in the lower portions of the Cape Fear River basin is achieved as forecasted by LWSPs and climate change is severe, there will be a need to change the Jordan Lake operational approach.

Using the Jordan Lake Water Quality Pool to consider water supply needs in the Cape Fear River downstream of Lillington appears to be a viable means of ensuring water supply reliability per the CFNCRB model results. For reference, Jordan Lake drought Stages 1 through 4 are triggered when the Water Quality Pool storage drops below 80 percent, 60 percent, 40 percent, and 20 percent, respectively. The USACE operates Jordan Lake to meet the following flow targets:

- Drought level 0: Flow target at Lillington remains at 600 +/- 50 cfs
- Drought level 1: Flow target at Lillington ranges from 450 to 600 +/- 50 cfs
- Drought level 2: Flow target at Lillington ranges from 300 to 450 +/- 50 cfs
- Drought level 3: No flow target set at Lillington. A maximum release rate of 200 cfs from Jordan Lake, plus any required water supply releases downstream to Lillington.

- Drought level 4: No flow target set at Lillington. A maximum release rate of 100 to 200 cfs from Jordan Lake plus any required water supply releases downstream to Lillington.

The 2008 Jordan Lake DCP indicates the USACE may engage in a range of flow targets at Lillington during drought Stages 1 and 2. The target flow in Stages 1 and 2 is establish via collaboration and coordination on a variety of parameters such as stakeholder input, short and long-term weather outlook, gate status, influences on stream flows downstream, and local inflows to both Jordan Lake and reaches downstream of the dam. When Jordan Lake is in drought Stages 3 and 4, the DCP does not specify how far downstream water supply needs should be fulfilled. Flexibility in adjusting dam releases has some limits under the DCP. When Jordan Lake contains water in the conservation pool (as has always been the case), Jordan Lake will be operated to meet water supply requirements and water quality low flow releases. Utilities using Jordan Lake as a water supply will be unaffected by this change in DCP operating protocol.

The few shortages for the CFPUA/LCFWSA, which only occur in two of the climate variability scenarios, are due to extremely low inflows projected for this downstream portion of the Cape Fear River. The aggregate water supply need for utilities downstream of Lillington are not satisfied by the modest release from Jordan Lake because the shortages occur under significant additional water demand stress. The municipal surface water demands for PWC, CFPUA and LCFWSA are projected to increase by over 57 mgd between 2025 and 2055 per the respective LWSPs submitted by these systems, which is approximately a 90 percent increase in water demand at these locations over the 30-year planning period. The water supply shortages for CFPUA/LCFWSA disappear when the climate models are rerun with a modification to the Jordan Lake Stage 3 minimum release to mimic a Stage 2 release. Adjusting the Jordan Lake releases from the water quality pool to consider downstream water supply needs will require coordination between the State and USACE as specified in the Jordan Lake DCP. The authority to modify releases appears to be vested in the State under the current DCP as described on pages 6-9 of the Jordan Lake DCP.

Given the various mitigation options, it seems reasonable to conclude that if climate impacts of the magnitude suggested by the CNRM and MIROC scenarios occur, there are available options to mitigate the emergency. Per the discussion in Section 3, it is clear that the selection of a water supply alternative for the Town of Fuquay-Varina does not significantly exacerbate the water supply shortages in the Cape Fear River basin nor does the Town of Fuquay-Varina’s preferred water supply alternative prevent mitigation strategies from being implemented.

Table 8: Key System Conditions During Months with Shortages for CFPUA and LCWSA

Alternative	Climate Scenario	Month and Year	Jordan Lake		CFPUA / LCFWSA			
			Minimum Water Quality Storage, MG (%)	Average Release (mgd)	Monthly Mean River Discharge at Intake (mgd)	Monthly Mean Water Withdrawal (mgd)	Days with Shortage [1]	Average Shortage (mgd) [1]
No Action	MIROC-ESM-CHEM	August, 2043	12,036 (39%)	129	304	68.5	----	----
		September, 2043	9,804 (32%)	119	347	61.3	----	----
		October, 2050	10,631 (34%)	92	352	54.0	1	16.4
		August, 2051	12,056 (39%)	195	218	66.9	----	----
		September, 2056	10,051 (33%)	140	153	60.5	1	30.2
		September, 2063	10,620 (34%)	143	269	58.7	4	16.2
	CNRM-CM5	September, 2057	8,930 (29%)	124	121	61.3	----	----
		August, 2058	10,671 (35%)	141	306	59.7	9	34.3
		September, 2058	11,676 (38%)	136	1,862	61.3	1	7.5
9A/B	MIROC-ESM-CHEM	August, 2043	12,034 (39%)	129	304	62.7	1	0.4
		September, 2043	9,741 (32%)	119	348	60.3	----	----
		October, 2050	10,631 (34%)	92	357	54.6	2	12.6
		August, 2051	12,055 (39%)	195	224	67.6	1	51.2
		September, 2056	10,053 (33%)	140	158	61.1	1	26.2
		September, 2063	10,620 (34%)	143	270	57.2	4	19.8
	CNRM-CM5	September, 2057	8,930 (29%)	124	124	59.8	----	----
		August, 2058	10,671 (35%)	141	317	67.7	11	24.8
		September, 2058	11,676 (38%)	136	1,866	60.4	----	----
9C	MIROC-ESM-CHEM	August, 2043	12,312 (40%)	130	310	68.5	7	26
		September, 2043	10,023 (33%)	119	349	61.3	5	6.5
		October, 2050	10,808 (35%)	92	357	54.6	1	4.9
		August, 2051	12,238 (40%)	196	224	66.7	1	27.7
		September, 2056	10,225 (33%)	141	159	61.1	1	5.8
		September, 2063	11,070 (36%)	147	272	57.1	5	24.7

Table 8: Key System Conditions During Months with Shortages for CFPUA and LCWSA

Alternative	Climate Scenario	Month and Year	Jordan Lake		CFPUA / LCFWSA			
			Minimum Water Quality Storage, MG (%)	Average Release (mgd)	Monthly Mean River Discharge at Intake (mgd)	Monthly Mean Water Withdrawal (mgd)	Days with Shortage [1]	Average Shortage (mgd) [1]
	CNRM-CM5	September, 2057	9,088 (29%)	124	123	59.8	1	44.9
		August, 2058	10,907 (35%)	147	316	61.7	2	13.4
		September, 2058	11,918 (39%)	133	1,863	60.5	1	29.1
9D	MIROC-ESM-CHEM	August, 2043	12,443 (40%)	152	321	68.5	1	0.4
		September, 2043	9,400 (30%)	122	355	61.3	----	----
		October, 2050	10,973 (36%)	92	356	54.3	1	4.9
		August, 2051	12,325 (40%)	205	230	68.5	2	29.1
		September, 2056	10,196 (33%)	145	162	60.3	1	8.2
		September, 2063	11,254 (37%)	146	272	59.2	5	25.2
	CNRM-CM5	September, 2057	9,280 (30%)	124	125	61.3	1	45.4
		August, 2058	11,010 (36%)	145	312	58.6	9	23.6
		September, 2058	11,981 (39%)	131	1,862	61.1	1	26.2

[1] The number of days and average shortage quantities are for both CFPUA and LCFWSA as they share a common intake location in the model.

[2] One of the two shortage days averaged was 26.3 mgd for CFPUA, the demand for this node on this day was 33.0 mgd.

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Hazen

ATTACHMENT A

Future Climate Scenarios for Town of Fuquay-Varina Interbasin Transfer Study (Tetra Tech, 2020)

Future Climate Scenarios for Town of Fuquay-Varina Interbasin Transfer Study

November 30, 2020

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1.0 Introduction

Hazen & Sawyer ("Hazen") is supporting the Town of Fuquay-Varina ("Town") in developing an Environmental Impact Statement (EIS) in support of an Inter-basin Transfer (IBT) application. The proposed IBT will transfer water from the Cape Fear River basin to the Neuse River basin. Impacts of the proposed IBT will be evaluated using the OASIS Cape Fear - Neuse Combined Hydrologic Model. The potential impact of climate change on the hydrologic status of the Cape Fear and Neuse River basins as a result of the proposed transfer must be evaluated in the EIS. This technical evaluation requires estimating how natural hydrologic inputs to both basins may change over time.

Hazen has subcontracted with Tetra Tech to assess climate variability via the development of quantitative daily timestep hydrology for the Neuse River Cape Fear River basins. Specifically, runoff for all areas upstream of New Bern, NC in the Neuse River Basin, and all areas upstream of Lock and Dam #1 in the Cape Fear River basin were requested. The required estimates are natural flows (i.e., without consideration of dams) at the subbasin scale. The influence of dams, discharges, and flow withdrawals in the basins will be simulated within the OASIS model.

To develop the analysis covering these two large drainage basins and still retain sufficient spatial resolution, the USGS National Hydrology Model (NHM) was used. The NHM Model incorporates a calibrated Precipitation Runoff Modeling System (PRMS) rainfall runoff model (Regan et al., 2018). The NHM and PRMS hydrologic modeling tools are described in Section 2.0.

To provide an assessment that covers a scientifically supported range of future climate variability, timeseries output (statistically downscaled to local conditions) was selected from three global climate models (GCMs) that represent the spectrum of future conditions. Selection and processing of the climate model data is described in Section 3.2. A watershed runoff model (NHM/PRMS) is then used to convert weather to runoff timeseries. Section 4.0 describes the application of the watershed model, including examination of the performance of the model relative to historic streamflow.

Results of the modeling are provided for a 30-year future climate run centered at 2055 (i.e., 2041 – 2070). Flow timeseries associated with each GCM are compared to a historical "hindcast"[1] model run spanning 1950 to 2005 (as recommended by Abatzoglou and Brown [2012], the developers of the downscaled climate dataset). Hindcasting provides an "apples to apples" indication of relative change that is used to adjust the observed inputs to OASIS using a bias-adjustment technique described in Section 4.4. The bias adjustment accounts for systematic differences that may be present between the PRMS model and observed flows.

The workflow for creating future climate-adjusted runoff timeseries is summarized in Figure 1

The results of the modeling are provided in an electronic database compatible with OASIS model inputs and summarized in Section 5.0.

[1] A hindcast is a model produced estimate of all outputs (e.g. runoff, PET, etc.) using historical input conditions (e.g. temperature and precipitation), which can be used to evaluate model performance.

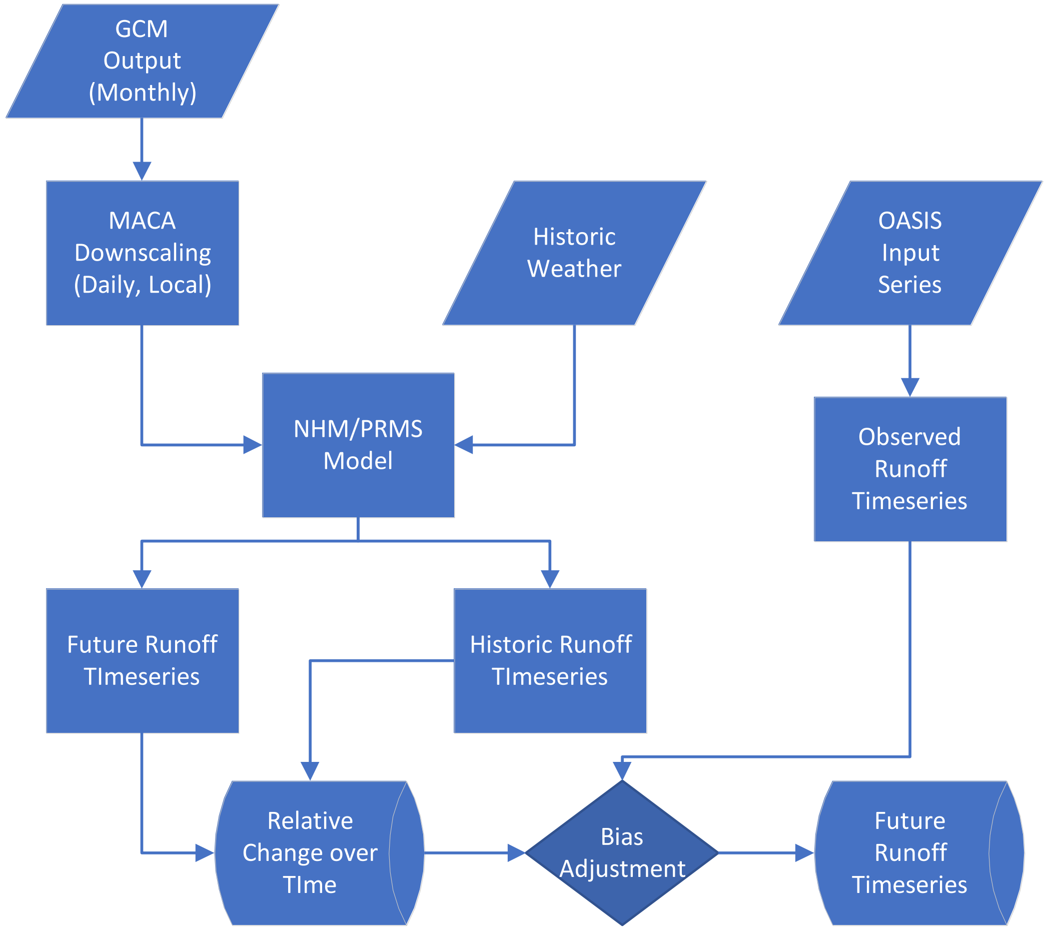

Figure 1. Workflow for creating future runoff timeseries

2.0 Rainfall-Runoff Model

2.1 NHM/PRMS Model

The USGS National Hydrologic Model (NHM) infrastructure supports the efficient construction of local-, regional-, and national-scale hydrologic models. The NHM infrastructure consists of 1) an underlying geospatial fabric of modeling units with an associated parameter database, 2) a model input data archive, and 3) a repository of the physical model simulation code bases. The PRMS model is the rainfall-runoff component of the NHM. Adaptation of PRMS for use in the NHM is described in Regan et al. (2018).

The National Geospatial Fabric for the NHM is based on the National Land Cover Database (NLCD) for 2001. This land use representation is used for simulation of both historic and future conditions and no attempt has been made to simulate future changes in land use. Approximately 10,000 square miles (mi^2) of drainage area in the source and receiving basins are included in the model. Areas with significant recent growth are mostly confined to the Triangle, Triad, and Fayetteville urban areas and represent a small fraction of the source and receiving basin drainage area. It is not anticipated that changes to the small fraction of urbanization in the source and receiving basins will significantly change the findings of the hydrologic analysis. Assuming a constant land cover will allow the model to discern the direction and relative magnitude of hydrologic impacts from climate variability, which are then applied to the OASIS input timeseries calculated from observed gage records. Further, the analysis required for the IBT primarily considers the impacts to the source and receiving basins during low-flow periods. Therefore, use of the 2001 baseline was determined to be adequate for the purpose of this task to evaluate *relative* changes to hydrology that may occur as a result of climate change.

2.2 Model Development and Hydrologic Response Units (HRUs)

Subwatersheds in the NHM (referred to as hydrologic response units or “HRUs” by the model developers) are similar in scale to HUC10 boundaries, but do not follow the HUC10 breakpoints exactly. The geospatial fabric is based on an aggregation of the spatial features associated with NHDPlus version 1. The more than two million catchments in the U.S. in the NHDPlus version 1 dataset were aggregated to approximately 110,000 HRUs. The NHM subwatersheds or HRUs for the Cape Fear and Neuse are displayed in Figure 2 and range in size from 0.02 to 242 square miles with a median of 9.4 and average of 18.6 square miles. These subwatersheds were reviewed with Hazen and determined to be sufficient for providing input to the OASIS model. Aggregated local flows (not including flows from upstream subwatersheds) as well as evaporation rates are provided for each subwatershed. The OASIS model is responsible for aggregating the flows from each HRU along tributaries and the main stems of both river systems as well as simulating operations.

The PRMS model for the Cape Fear consists of 296 HRUs and 168 stream segments while the Neuse model is comprised of 228 HRUs and 127 stream segments. A description of the NHM PRMS modeling system including a discussion of the modules and parameterization is provided in Regan et al. (2018). The parameters in the Cape Fear and Neuse PRMS models (described in Appendix I of Regan et al., 2018) have not been changed from the USGS-provided values for this study.

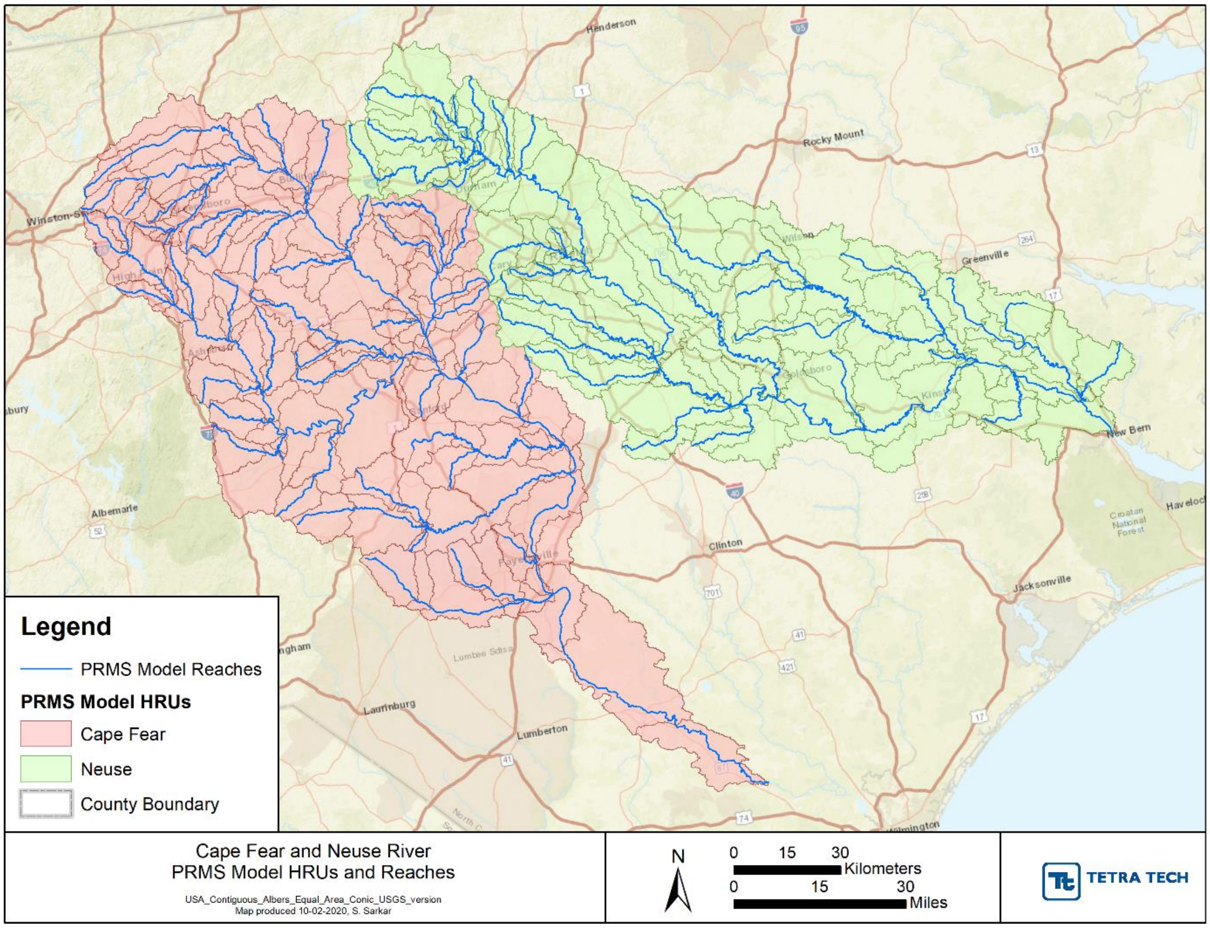

Figure 2. PRMS model HRUs and reaches for the Cape Fear and Neuse River

3.0 Weather and Climate

Estimation of runoff under historic conditions requires daily time step weather series. Prediction of potential future conditions is based on re-estimation of daily weather time series consistent with the projected changes in climate in accordance with climate modeling efforts.

3.1 PRMS Meteorology

The NHM PRMS models require daily precipitation, potential evapotranspiration (PET), and daily maximum and minimum air temperature as meteorological forcing. PET may be supplied as an external time series; however, the PRMS model also has provisions for calculating PET internally using the Jensen-Haise, Hamon, Hargreaves-Samani, Priestley-Taylor, or Penman-Monteith methods. Several of these PET methods require additional meteorological inputs, including solar radiation, relative humidity, and wind travel (total wind movement per unit time independent of direction). For the national NHM PRMS models, USGS estimated PET using the Jensen-Haise method, which uses air temperature and solar radiation as inputs and the calibrated runoff parameters are conditional on this choice for PET. Section 4.1 includes a comparison of model performance using the Penman-Monteith energy balance method for PET that demonstrates that a switch to the Penman-Monteith method degrades model performance and is not advisable.

The meteorological forcing in the national PRMS models is obtained from Daymet, gridMET and other gridded climate datasets. In this study the meteorological inputs are replaced by gridded data from downscaled hindcast and forecast runs of climate models to evaluate expected changes in runoff in the future.

3.2 Selection of Climate Scenarios

Global average air temperatures are rising due to human activities and GCM projections are in general agreement that temperature increases will continue throughout the 21st century. GCM predictions regarding future precipitation patterns are less certain and more variable. Effective water resources planning needs to consider the risks associated with these potential changes to help ensure reliability and resiliency of the water sector.

Assuming that the future will resemble the past is insufficient in the presence of a changing climate, and decisions made today can exacerbate or mitigate a community's vulnerability to change. The risks and impacts of future climate on water resources will vary by location and sector and will depend on complex interactions between precipitation frequency, precipitation intensity, and increases in evaporation associated with warmer temperatures.

Potential climate-related impacts and risks to the Southeast region of the U.S. are summarized as part of the Fourth National Climate Assessment Report (USGCRP, 2018). Daytime and nighttime temperatures in the Southeast for the present decade (2010-present) have been warmer than previous decades on record, extending the freeze-free season length by about 1.5 weeks compared to the early 1900s, and nearly three-quarters of precipitation monitoring locations have recorded more frequent extreme precipitation events (> 3 inches). GCM simulations predict warmer air temperatures and more extreme precipitation events for the Southeast over the 21st century. These changes are predicted across Representative Concentration Pathway (RCP) trajectories that represent anticipated greenhouse gas concentrations and radiative forcing based on different levels of anthropogenic emissions and greenhouse gas accumulation in the atmosphere produced as part of the Intergovernmental Panel on Climate Change (IPCC) Coupled Model Intercomparison Project, round 5 (CMIP5), completed in 2014 in support of the most recent IPCC Fifth Assessment Report. RCP 4.5 and RCP 8.5 represent lower and higher levels of end-of-century radiative forcing (4.5 and 8.5 W/m^2, respectively), and are believed to bound the likely trajectories that may occur as a result of human economic, political, and climate mitigation activities. Increases in global temperatures are predicted to be more severe for the higher radiative forcing (8.5 W/m^2) scenario. Recent trends in fossil fuel consumption and carbon emissions have been more in line with the trajectory of the higher radiative forcing scenario (RCP 8.5), although both are examined to support planning efforts. Temperature predictions from the two RCPs are not expected to deviate strongly until after the middle of the 21st century, while rainfall predictions vary more between different GCMs than between different RCPs.

If realized, rising air temperatures are anticipated to lengthen the freeze-free growing season in the Southeast by more than a month by the late 21st century as compared to the late 20th century. Daytime high and nighttime low temperatures are expected to increase. Central and Eastern North Carolina are assessed as having a particularly high future heat wave risk. Increasing water demands in urban centers and prolonged dry periods that limit supply replenishment and enhance watershed and reservoir evapotranspiration may stress water supplies. Nevertheless, conservation practices among water users and the increased efficiency of water-using devices have been counteracting these risks in many areas over the past two decades. Changes in ecosystem composition are also expected, potentially including the loss and replacement of local plant species, and such changes may alter the hydrology of water supply watersheds and, ultimately, water availability. Droughts are a primary concern for water supply planning, but increased flooding from extreme rainstorms and hurricanes will put communities simultaneously at risk for inland flooding, infrastructure damage (e.g., water supply reservoir dams), and potentially loss of life.

Results for a large number of GCMs and greenhouse gas scenarios are available from CMIP5. No one climate scenario is predictive of the future because the models have uncertainties and the greenhouse gas emission scenarios that drive these scenarios depend on assumptions about future economic activity and political decisions, all of which are uncertain. To define the range of futures to which adaptation may be needed at a reasonable level of effort, it is appropriate to define a set of bounding scenarios that encompass the likely range of future conditions.

In previous work conducted in the Piedmont region of the Neuse River basin, Tetra Tech identified a set of reasonable bounding climate scenarios for analysis of future impacts on water supply. The future climate conditions assessed for this project are generally applicable throughout the Piedmont region and inland Coastal Plain of North Carolina; therefore, the same set of scenarios were selected for evaluating potential impacts to the broader areas of the Cape Fear and Neuse River basins relevant to the proposed IBT. The reasonableness of this selection is verified in the following paragraphs.

Future climate projections are uncertain and are best used to describe a probability envelope of potential future conditions (an "ensemble of opportunity"; Mote et al., 2011) to which adaptation may be needed. To select a set of GCMs that bound the likely range of potential climate futures with respect to water supply, predicted relative change in mean annual temperature and mean annual precipitation was assessed using USEPA's LASSO (Locating and Selecting Scenarios On-line) tool (http://lasso.epa.gov). The tool performs automated annual and seasonal summaries of monthly-level spatially downscaled (4 km) GCM output from the Multivariate Constructed Analogs (MACA v2) CMIP5 archive (http://maca.northwestknowledge.net/).

GCMs predict future climate as a function of large-scale forcing, not date-specific weather series. Climate is defined as weather at a place averaged over a long period of time, generally multiple decades, and GCM output must similarly be analyzed over a multi-decadal period. The bi-plot produced by LASSO, represents the future climate as the change in mean annual air temperature and mean annual precipitation for the future-cast period of 2050 to 2080 (centered at 2065) relative to the hind-cast period (1950-2005). The results of the case study in the Neuse are shown in Figure 3. The different model-RCP scenario pairs show a wide range of changes in average annual precipitation for the watershed containing the water supply reservoirs, although all but one predicts some increase. All scenarios also predict an increase in average annual temperature of between 2 and 9° F, which will increase evapotranspiration rates.

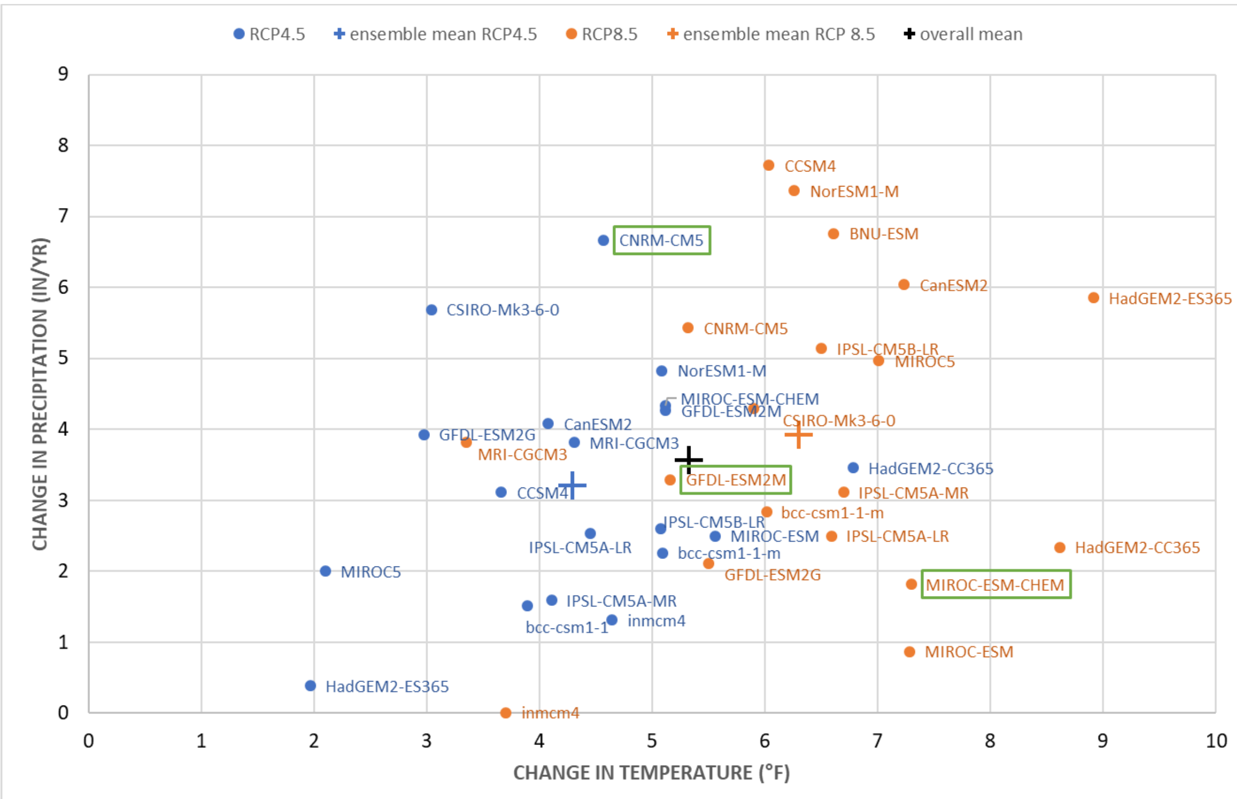

Figure 3. Relative change in hindcast (1950-2005) and future (2050-2080) average annual precipitation and mean annual air temperature for global climate models and greenhouse gas representative concentration pathways (RCP 4.5 and RCP 8.5) for Neuse River Case Study, NC.

Note: Green boxes Identify selected scenarios

Scenarios that are likely to predict the maximum runoff (and therefore water supply) are in the upper-left quadrant – these scenarios predict a greater increase in mean annual precipitation and a relatively moderate increase in air temperature and associated evapotranspiration. Conversely, scenarios that are likely to predict the minimum runoff are in the bottom-right quadrant. These scenarios predict a small increase in mean annual precipitation and a relatively large increase in mean annual air temperature. While both temperature and precipitation changes play a role in future water supply, the changes in precipitation are likely to have the greater impact.

To evaluate the risk associated with possible futures, it is advisable to look at scenarios that span the general range of climate change. However, some GCMs that produce outlying results may not be realistic for this region. Accordingly, scenarios were selected that approximate the mean, 10th percentile, and 90th percentile results of available CMIP5 GCMs across both RCPs for further analysis. Specifically, the GCM CNRM-CM5 under RCP 4.5 was selected as a plausible high runoff potential scenario (e.g., large increase in precipitation with moderate increase in air temperature) and MIROC-ESM-CHEM RCP 8.5 is applied as a plausible low runoff potential scenario (e.g., low increase in precipitation with large increase in air temperature). The CNRM-CM5 model was also ranked highest for its ability to reproduce observed historical climate for the Southeast U.S. (Rupp, 2016), although there is no guarantee that accurately predicting past climate will mean that the model will best predict future climate. The full ensemble average, which combines both the RCP 4.5 and RCP 8.5 scenarios across all GCMs, is designated in the plot by a black cross. The scenario that aligns closest to the ensemble average is GFDL-ESM2M, RCP 8.5, and it is applied as the moderate climate scenario.

To summarize, the following three scenarios were selected for the climate assessment screening based on the aforementioned analysis:

- CNRM-CM5, RCP 4.5 (higher runoff potential)
- MIROC-EMS-CHEM, RCP 8.5 (lower runoff potential)
- GFDL-ESM2M, RCP 8.5 (approximates ensemble mean)

Average annual statistics for the three selected scenarios for the Neuse River basin case study are summarized in Table 1. Note that the results for the case study are centered at 2065, whereas the requested output for this proposed IBT is centered at 2055; however, little change in relative ranking is expected between 2065 and 2055.

Table 1. Precipitation percentiles (in/month) and annual average totals for historic (1981-2010) and future (2050-2074) climate for Neuse River Basin case study

Period	Precipitation Percentile (in/month)					Annual Average (in/yr)
	10%	25%	50%	75%	90%	
MIROC-ESM-CHEM (RCP 8.5)						
1981-2010	1.7	2.5	3.6	4.8	6.6	46.3
2050-2080	1.6	2.5	3.7	5.0	6.4	46.8
Relative Change	-5.4%	2.3%	2.1%	3.2%	-2.6%	1.1%
GFDL-ESM2M (RCP 8.5)						
1981-2010	1.6	2.4	3.6	4.9	6.3	46.2
2050-2080	1.8	2.6	3.8	5.3	7.0	50.5
Relative Change	12.8%	7.0%	4.1%	8.0%	10.4%	8.4%
CNRM-CM5 (RCP 4.5)						

1981-2010	1.7	2.5	3.6	4.8	6.5	46.2
2050-2080	1.8	2.6	3.7	5.2	7.1	50.9
Relative Change	6.0%	3.3%	1.6%	8.7%	7.5%	9.1%

To confirm that the GCMs selected for the Neuse River basin case study remain reasonable for the entire Cape Fear and Neuse River basins when applied to a slightly earlier future time period (2041-2070 instead of 2050-2080), the LASSO tool was re-run for those conditions (Figure 4). While there are some small changes in the relative positioning of the GCM scenarios, the three selected scenarios remain appropriate, representing a median scenario, a hotter and drier scenario, and a wet scenario with moderate temperature increase.

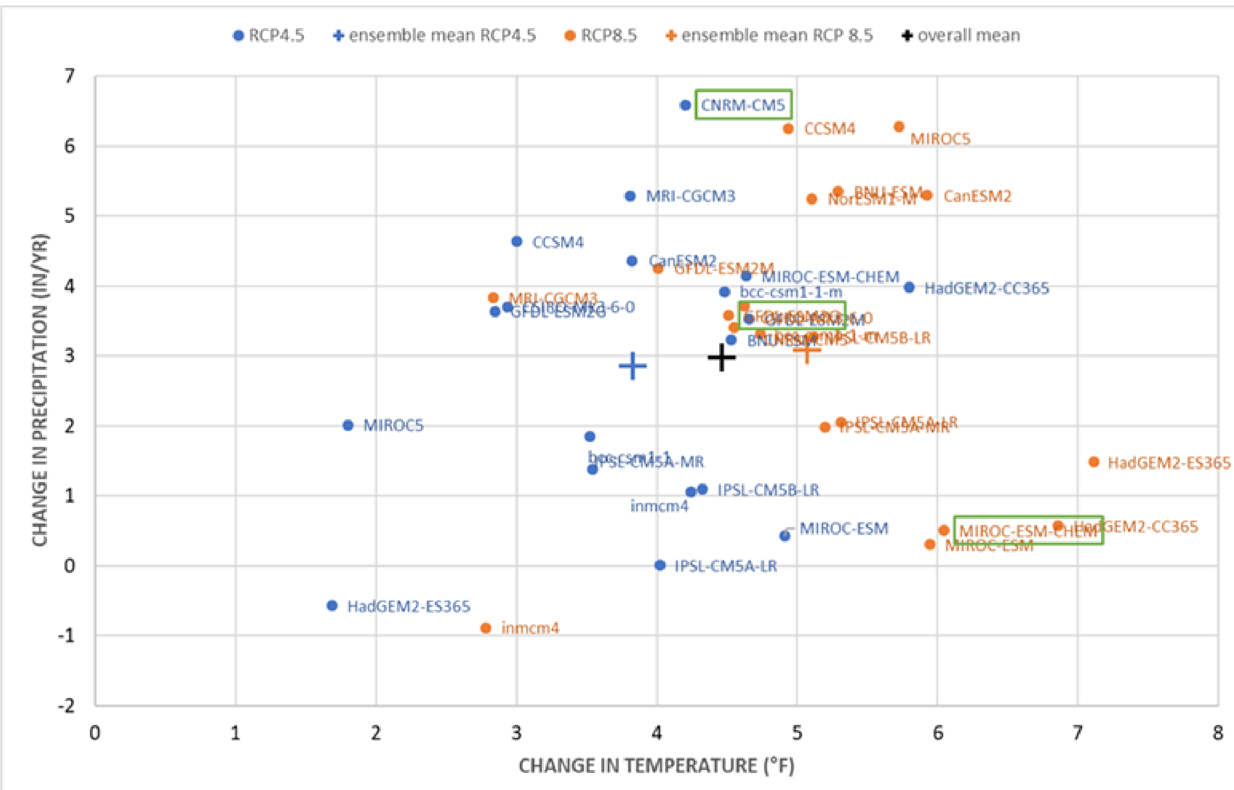

Figure 4. Relative Change in hindcast (1950-2005) and future (2041-2070) Mean Annual Precipitation and Mean Annual Air Temperature for Global Climate Models and Representative Concentration Pathways (RCP 4.5 and RCP 8.5) for the Cape Fear and Neuse River Basins

Note: Green boxes Identify selected scenarios.

3.3 Climate Scenario Processing

Hindcast and forecast downscaled GCM output were obtained from the MACAv2-Metdata archive. A Python script was developed to transform the gridded MACA data to meteorological forcing time-series for the PRMS model. The sequential processes implemented within the Python script include -

1) Generate a reference grid to determine grid cells that intersect each of the PRMS model HRUs.
2) Extract time-series data for grid cells that intersect the PRMS model HRUs from the MACA files for required meteorological parameters (daily precipitation, maximum air temperature, and minimum air temperature).
3) Spatially aggregate gridded climate data to the PRMS model HRUs scale using an area-weighting approach.
4) Generate meteorological forcing files formatted for the PRMS model from the HRU-scale time-series data. Unique time-series for each HRU are supplied to PRMS via the “climate-by-HRU” (CBH) files for each meteorological variable.

4.0 NHM/PRMS Application

The NHM PRMS model is calibrated nationally and comes with a parameter database. The assumption for this project is that the model can be used "as is." However, it is also desirable to document and corroborate model performance.

Such corroboration is challenging because the model is being applied here to generate natural, unregulated flows. Many of the stream gages in the region are strongly affected by water supply reservoirs and dams (most notably Falls Lake and Jordan Lake, but also including many smaller impoundments), water withdrawals, and major and minor wastewater discharges. Even for watersheds that do not have major impoundments, the model does not explicitly represent factors such as well withdrawals, onsite wastewater disposal via septic systems, and irrigation, which together can have a strong effect on baseflow. However, the NHM PRMS model output is an intermediate product that will be used, in conjunction with the OASIS model, to estimate relative changes between historic and future flow. The OASIS model can and will account for withdrawals, discharges, and impoundments and therefore the disregard for these influences at this stage of the analysis is considered acceptable.

4.1 Model Corroboration

The existing NHM PRMS models are configured to simulate watershed hydrology from water year 1981 to 2016. Qualitative corroboration of the Cape Fear and Neuse PRMS models for historic hydrology was done by evaluating components of the water balance against peer-reviewed literature and comparing simulated streamflow against USGS measurements at multiple locations on the mainstems and tributaries. The USGS streamflow monitoring locations used for the corroboration of the Cape Fear and Neuse models are shown in Figure 5.

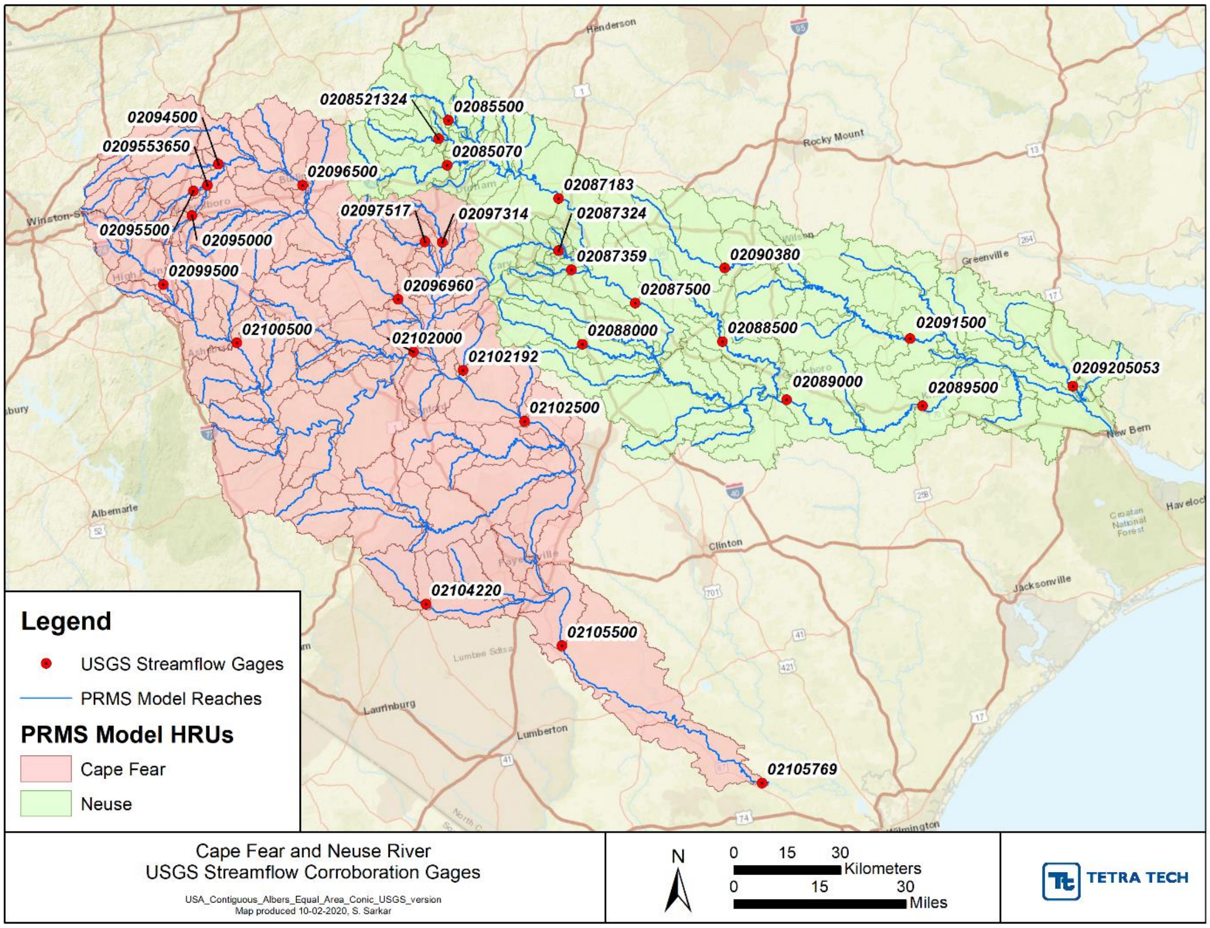

Figure 5. PRMS model HRUs and USGS stream gages for the Neuse and Cape Fear basins

The simulated water budget for the Cape Fear PRMS model (Figure 6) is consistent with the generalized water budgets for the Cape Fear River Basin reported by the North Carolina Department of Natural Resources (NCDENR) in the Cape Fear River Basin Plan (NCDENR, 2009). The simulated water budget for the Neuse PRMS model (Figure 7) is similar to the Cape Fear model and comparable to the water budget for the Piedmont region for the Cape Fear River Basin reported by NCDENR. Note that the groundwater outflow for the PRMS models shown in the water budgets include interflow (i.e., lateral flow through unsaturated soil zones). The changes in storage (not shown in the water budget summaries) simulated for the Cape Fear and Neuse models are negligible, approximately 0.1% of the average annual precipitation.

The ratio of average annual simulated evapotranspiration to precipitation for the Cape Fear and Neuse PRMS models are 0.65 and 0.67, respectively. These ratios are consistent with the range of 0.60 to 0.69 reported by Sanford and Selnick (2012) for this region.

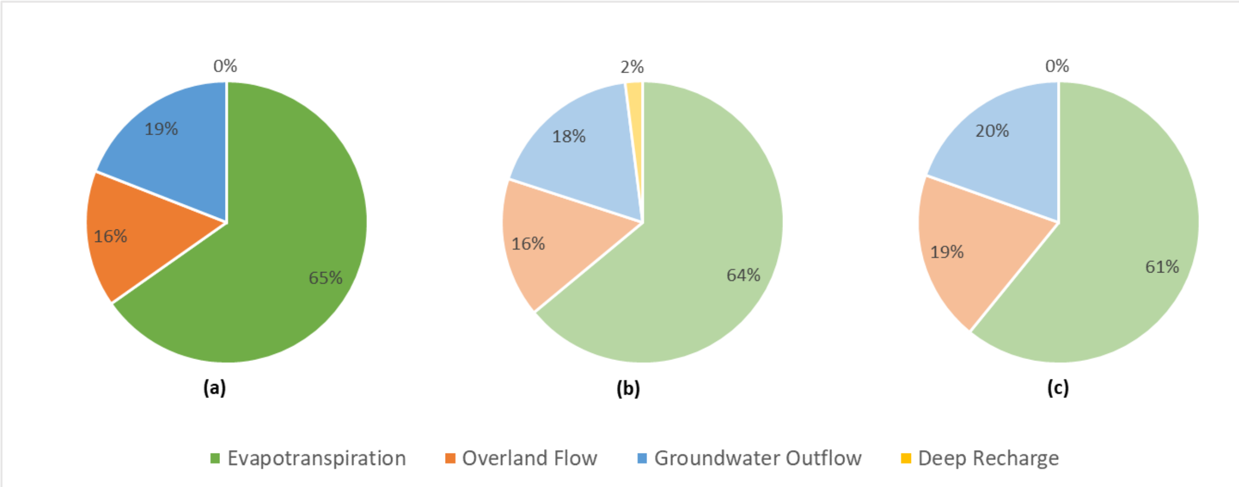

Figure 6. Simulated long-term water budget for the (a) Cape Fear PRMS model compared to the generalized water budgets for the (b) Coastal Plain and (c) Piedmont regions of the Cape Fear River Basin

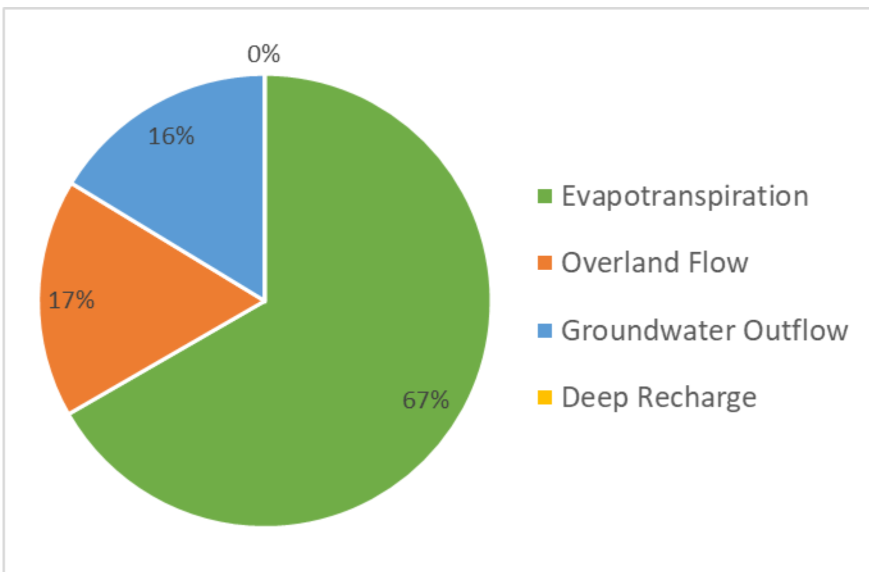

Figure 7. Simulated long-term water budget for the Neuse PRMS model

Comparison of streamflow predicted by PRMS to USGS gages along the Cape Fear River and major tributaries such as the Deep and Haw Rivers, suggest that streamflow is generally over-predicted by the PRMS model relative to gaged flows (Table 2). Much of the over-prediction occurs during low flow periods. On the main-stem Cape Fear, peak flows are generally over-predicted in addition to the low flows.

The majority of these discrepancies are believed to be due to the influence of dams and associated water withdrawals (including Jordan Lake on the Cape Fear, Randleman Lake and the former Carbonton Dam (removed in 2006) on the Deep River, and various smaller dams in the Haw drainage.)

At many gages, including some not strongly influenced by dams, the PRMS model appears to over-predict summer low flows. This suggested possible issues with the calculation of PET. As noted earlier, the NHM PRMS models use a modified version of the Jensen-Haise PET method. The influence of this method choice was checked through comparison to alternative simulations undertaken with the Penman-Monteith energy balance method. This required estimates of daily relative humidity and wind speed time-series, which were obtained from the National Land Data Assimilation System (NLDAS) version 2 forcing data (https://ldas.gsfc.nasa.gov/nldas/nldas-2-forcing-data). As implemented in PRMS, the Penman-Monteith method yields much higher estimates of PET that result in a large under-estimation of runoff when compared to gaged streamflow. As PRMS parameters were regionally calibrated using Jensen-Haise PET, it appears that a switch to Penman-Monteith PET is not advisable as it would require significant additional effort for detailed recalibration of the NHM PRMS model. Instead, a bias correction approach, described in Section 4.4, is used to compensate for uncertainties present in the PRMS model.

For the Cape Fear basin, the monthly Nash-Sutcliffe coefficients of model fit efficiency (NSEs) at the larger-scale USGS gages are generally between 0.6 and 0.7, which falls within the category rated as "Satisfactory" to "Good" as recommended by Moriasi et al. (2007) despite the influence of many dams. A poorer match was found at some of the smaller area gages. Nevertheless, the model performance is believed to be sufficient for the intended purpose of evaluating relative change in local runoff between historic changes and potential future climate.

The match between gaged streamflow and PRMS predictions for Neuse basin is generally better than for the Cape Fear (Table 3). Like the Cape Fear model, the Neuse model also systematically over-predicts of low flows and baseflow, but the comparisons are affected by numerous dams and water withdrawals. The low-flow statistics at the USGS gages for streams not impacted by major water withdrawals or impoundments such as Contentnea Creek and Little River are better than for the main-stem Neuse. Evaluation of incremental flows for Neuse River downstream of Falls Lake to the Goldsboro and Kinston gages demonstrates better agreement for low flow periods, strengthening the hypothesis that the influence of water withdrawals and impoundments is negatively affecting the PRMS to USGS gage comparison at low flows. However, the OASIS model will account for these influences. Based on the magnitude of streamflow error and monthly NSE, the performance of the Neuse PRMS model is rated as "Good" for major USGS streamflow gage locations.

Table 2. Comparison of gaged flow to the Cape Fear River PRMS model

USGS Gage Name	South Buffalo Creek near Greensboro, NC		Buffalo Creek near Greensboro, NC		Buffalo Creek at SR2819 near McLeansville, NC		Reedy Fork near Gibbonsville, NC		Haw River near Haw River, NC		Morgan Creek near Chapel Hill, NC		New Hope Creek near Blands, NC		Deep River near Randleman, NC	
USGS Gage Id	02095000		02095500		0206553650		02094500		02096500		02097517		02097314		02099500	
Drainage Area	34.0		37.1		88.5		131.0		606.0		41.0		75.9		125.0	
Analysis Period	8/1/1998 to 9/30/2016		10/1/1981 to 9/30/2016		8/1/1998 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		11/1/1982 to 9/30/2016		10/1/1982 to 9/30/2016		10/1/1981 to 9/30/2016	
Constituent	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**
Total flow	19.8	-27.6	17.6	-28.4	23.7	-28.2	9.4	140.9	14.0	33.9	13.5	17.2	17.0	12.3	15.2	37.2
Total lowest 50% flows	1.3	33.0	3.2	-43.1	4.6	-43.0	0.5	680.9	1.8	91.4	2.2	-60.6	1.7	-10.5	1.6	41.8
Total highest 10% flows	13.7	-54.0	8.5	-37.8	11.6	-43.3	6.3	44.8	7.0	-1.2	6.8	30.3	9.3	5.6	8.4	13.3
Summer flow volume (months 7-9)	5.2	-23.5	4.0	-20.1	5.8	-22.6	1.3	232.6	2.3	61.8	2.1	23.9	2.5	29.8	2.5	63.4
Fall flow volume (months 10-12)	4.7	-38.6	4.2	-42.1	5.6	-38.3	1.8	149.9	2.9	22.4	2.7	-5.2	3.4	-9.3	2.9	22.7
Winter flow volume (months 1-3)	5.3	-32.5	5.1	-33.0	6.5	-32.5	3.9	92.5	5.3	14.2	5.6	17.8	7.1	8.4	6.0	19.9
Spring flow volume (months 4-6)	4.7	-15.7	4.4	-17.6	5.8	-19.0	2.4	162.5	3.4	55.8	3.1	31.2	4.0	26.2	3.8	58.8
Monthly NSE		0.49		0.38		0.45		-0.88		0.61		0.63		0.67		0.54

USGS Gage Name	Deep River at Ramseur, NC		Haw River near Bynum, NC		Deep River at Moncure, NC		Buckhorn Creek near Corinth, NC		Cape Fear River at Lillington, NC		Rockfish Creek at Raeford, NC		Cape Fear River at Wilmington, NC		Cape Fear River at Lock #1, NC	
USGS Gage Id	02100500		02096960		02102000		02102192		02102500		02104220		02105500		02105769	
Drainage Area	349.0		1275.0		1434.0		76.3		3464.0		93.1		4852.0		5255.0	
Analysis Period	10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		7/1/1988 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016	
Constituent	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**
Total flow	13.2	40.4	12.6	34.1	12.3	39.2	8.6	102.1	12.1	40.5	15.9	-28.0	12.6	32.7	13.1	27.1
Total lowest 50% flows	1.4	82.6	1.4	108.2	1.0	190.7	0.2	759.4	1.4	115.0	4.7	-73.5	1.8	77.1	1.9	76.9
Total highest 10% flows	7.2	-0.5	6.4	-3.6	7.1	-11.8	4.9	81.1	5.4	12.3	3.9	44.8	5.1	11.0	4.9	11.1
Summer flow volume (months 7-9)	1.8	91.2	1.8	90.5	1.5	116.3	1.1	196.3	1.7	99.2	3.6	-45.7	1.9	73.4	2.0	66.5
Fall flow volume (months 10-12)	2.8	24.3	2.6	22.0	2.5	18.6	1.2	111.0	2.3	28.5	4.0	-27.3	2.4	16.5	2.5	9.8
Winter flow volume (months 1-3)	5.4	19.3	5.2	9.6	5.7	11.6	4.0	68.7	5.3	14.9	4.7	-0.7	5.3	11.2	5.4	6.3
Spring flow volume (months 4-6)	3.2	62.0	3.1	52.7	2.8	72.7	2.3	112.8	2.9	62.9	3.6	-46.8	2.9	58.0	3.1	51.7
Monthly NSE		0.53		0.63		0.61		0.11		0.63		-0.87		0.65		0.68

Notes: "Obs" represents the gaged flow, converted to inches per year. "Err" is percentage difference between PRMS and the gaged flow. A positive value of Err indicates over-prediction.

Table 3. Comparison of gaged flow to the Neuse River PRMS model

USGS Gage Name	Flat River at Bahama, NC		Eno River near Durham NC		Little River at SR1461 near Orange Factory, NC		Neuse River near Falls, NC		Crabtree Creek at US1 at Raleigh, NC		Walnut Creek at Sunnybrook Drive near Raleigh, NC		Contentnea Creek near Lucama, NC		Neuse River near Clayton, NC		Neuse River near Clayton, NC (incremental)		Middle Creek near Clayton		Little River near Princeton, NC		Neuse River near Goldsboro, NC		Neuse River near Goldsboro, NC (incremental)		Contentnea Creek at Hookerton, NC		Neuse River at Kinston, NC		Neuse River at Kinston, NC (incremental)		Swift Creek at Hwy 43 near Streets Ferry, NC	
USGS Gage Id	02085500		02085070		020852134		02087183		02087324		02087359		02090380		02087500		02087500		02088000		02088500		02089000		02089000		02091500		02089500		02089500		0209205053	
Drainage Area	149.0		141.0		78.2		771.0		121.0		29.8		161.0		1150.0		1150.0		83.5		232.0		2399.0		2399.0		733		2692.0		2692.0		269.0	
Analysis Period	10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1987 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1990 to 9/30/2016		10/1/1996 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1981 to 9/30/2016		10/1/1996 to 9/30/2007	
Constituent	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**	**Obs (in)**	**Err (%)**
Total flow	12.5	23.5	11.9	68.4	11.9	45.7	10.7	60.4	16.9	17.9	16.6	0.5	13.0	34.1	12.4	39.9	13.8	28.4	14.9	30.7	13.9	30.6	13.5	23.9	14.4	15.5	14.6	14.1	13.8	21.5	14.5	15.2	16.6	-40.3
Total lowest 50% flows	0.8	61.2	0.9	149.1	0.7	98.2	1.1	123.9	2.2	37.2	1.9	10.4	1.1	217.1	1.9	52.2	2.5	2.7	1.7	24.2	1.2	73.7	1.9	53.1	2.1	31.4	1.8	75.8	2.2	38.6	2.3	18.3	2.0	-62.9
Total highest 10% flows	7.8	-1.0	6.9	34.3	7.3	15.8	5.6	21.9	8.3	4.5	9.5	-29.6	6.8	1.2	5.0	30.2	5.7	24.0	7.4	22.1	6.8	18.9	4.9	18.6	5.3	13.2	5.9	6.4	4.8	19.7	5.0	19.5	8.0	-28.0
Summer flow volume (months 7-9)	1.5	98.9	1.5	151.7	1.5	103.0	1.4	127.0	4.0	2.2	4.2	-11.1	2.2	67.7	2.1	63.1	2.9	27.2	2.6	46.8	2.4	57.1	2.3	45.6	2.58	32.5	2.7	34.7	2.4	40.3	2.7	29.9	4.5	-41.3
Fall flow volume (months 10-12)	2.4	4.0	2.2	58.1	2.4	21.1	1.8	58.8	3.8	7.4	3.8	-8.6	2.2	50.2	2.3	30.5	2.8	11.0	2.9	1.8	2.5	22.5	2.5	10.2	2.7	1.1	2.7	14.4	2.6	6.1	2.7	-0.9	4.0	-50.2
Winter flow volume (months 1-3)	5.6	-2.9	5.3	41.8	5.2	24.6	4.6	34.4	5.5	33.1	4.8	14.0	5.8	7.3	4.9	29.1	4.8	30.1	6.0	27.2	6.0	14.6	5.4	11.9	5.7	5.3	5.8	-3.7	5.4	12.0	5.5	7.5	4.8	-35.1
Spring flow volume (months 4-6)	3.0	52.0	3.0	81.9	2.8	74.9	2.8	70.5	3.6	23.0	3.9	5.2	2.8	50.2	3.2	48.3	3.3	41.7	3.4	49.2	3.0	48.1	3.3	39.1	3.4	31.6	3.4	28.0	3.4	35.1	3.5	29.0	3.3	-34.7
Monthly NSE		0.69		0.20		0.57		0.42		0.68		0.72		0.71		0.53		0.25		0.54		0.75		0.77		0.80		0.82		0.77		0.78		0.62

Notes: "Obs" represents the gaged flow, converted to inches per year. "Err" is percentage difference between PRMS and the gaged flow. A positive value of Err indicates over-prediction. "Incremental" flows for the USGS gages near Clayton, Goldsboro and Kinston are obtained by subtracting the gaged records at Neuse River near Falls, NC.

4.2 Application to Future Climate Scenarios

The NHM PRMS models for the Cape Fear and Neuse were simulated from 1/1/1950 through 12/31/2070 using HRU level daily precipitation, and maximum and minimum air temperature time-series data developed for the MACA-downscaled output from the following climate models and RCPs.

- CNRM-CM5 (RCP 4.5)
- GFDL-ESM2M (RCP 8.5)
- MIROC-ESM-CHEM (RCP 8.5)

Meteorological time-series development for the climate scenario simulations is discussed in 3.3. The only changes made to the PRMS models for the climate scenario simulations are the meteorological forcing time-series (precipitation and air temperature) and the simulation time-period. The PRMS runoff outputs for the climate scenarios simulations were compared against the USGS National Climate Change Viewer (NCCV) estimates, discussed in the following sections. The water budgets and average monthly total runoff and actual evapotranspiration for the historic (1950-2005) and target future period (2041-2070) are summarized in the subsequent sections.

4.3 Comparison of PRMS and NCCV for Future Climate

Model performance for future climate cannot, of course, be checked against observations. However, a general check for consistency was performed by comparing the PRMS output to predictions obtained from the USGS National Climate Change Viewer (NCCV; Alder and Hostettler, 2013). The NCCV uses a different statistical downscaling method and computes runoff based on a simplified monthly water balance calculation. The results for a given GCM are thus not expected to match PRMS but should show strong correlation.

Annual runoff simulated by the Cape Fear and Neuse PRMS models for the CNRM-CM5 (RCP 4.5), GFDL-ESM2M (RCP 8.5) and MIROC-ESM-CHEM (RCP 8.5) climate scenarios from 1951 to 2099 were compared against estimates of runoff reported by the USGS NCCV. The annual runoff time-series simulated by the PRMS model shows good agreement with the NCCV estimates, as shown in Figure 8 and Figure 9 for the Neuse and Cape Fear rivers. Interestingly, this comparison also suggests that PRMS may be biased high during low flow periods.

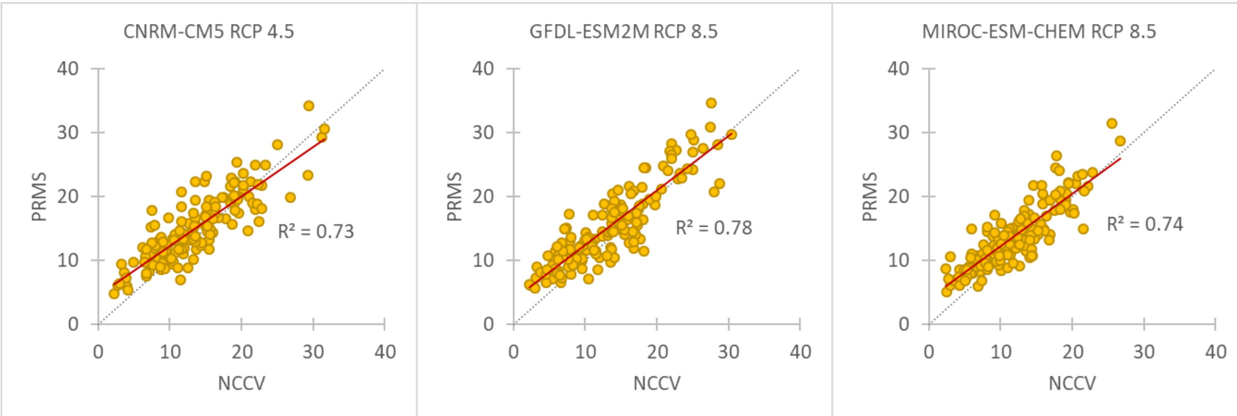

Figure 8. Annual runoff (in/yr) simulated by PRMS vs. NCCV estimates from 1951 to 2099 for the Cape Fear River basin

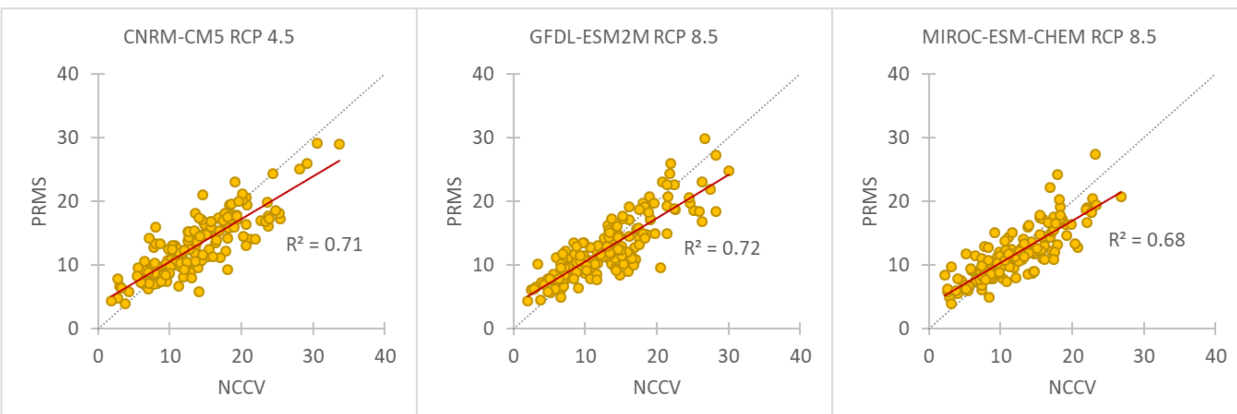

Figure 9. Annual runoff (in/yr) simulated by PRMS vs. NCCV estimates from 1951 to 2099 for the Neuse River basin

4.4 Bias Correction for Flow

The PRMS model provides an imperfect match to gaged flows, including for gages that are not affected by major dams, withdrawals, or discharges. This suggests the presence of some biases in the PRMS output. Comparison of statistics for the incremental inflow timeseries specified for the historical period in OASIS to PRMS output for the same period also reveals differences, typically on the order of 10-20%. These differences suggest that a bias correction step is needed before using PRMS to predict the future water balance in OASIS. Specifically, rather than using the PRMS output directly in OASIS it is preferable to modify the existing OASIS input timeseries based on the difference in runoff distributions between the historical and future time windows in PRMS.

The bias correction for the future incremental inflow timeseries is accomplished using the method of empirical quantile mapping (eQM). The eQM approach (Amengual et al., 2012) is a method developed and frequently used for adjusting biases in climate model precipitation series. However, it makes no assumption of a specific parametric form of statistical distribution and is applicable to bias adjustment of any time series. Given a model output timeseries for the historical training period (*H*), a model output timeseries for a future prediction period (*F*), and a timeseries of local observations for the historical period (*O*), the approach locates the quantile of the prediction *F* within the cumulative distribution function of the training data *H*, then transfers this position to the same quantile within the cumulative distribution function of the local observations, *O*, thus creating a prediction (*P*) that is bias-corrected to the local observations. In our application, *O* is the historical timeseries of incremental inflows currently used in OASIS, while *H* and *F* are the historic and future periods, respectively, in the PRMS output for the same drainage area. The general method developed by Amengual et al. expresses the quantile adjustment or shift as $P_i = O_i + g\,\bar{\Delta} + f\,\Delta_i$, where $\bar{\Delta}$ is the mean regime shift and Δ_i, is the difference between the future and historic *i*th quantile. The parameters *g* and *f* allow for adjustments that weight the influence between the overall regime shift and the shift in individual quantiles. Typical applications of eQM where a parametric form of the cumulative distribution function is not specified use *g* = *f* = 1, in which case the equation for P_i is equivalent to applying the quantile shift directly.

A Python implementation of this method is available in bias_correction.py (https://svn.oss.deltares.nl/repos/openearthtools/trunk/python/applications/hydrotools/hydrotools/statistics/bias_correction.py), in turn based on the R package downscaleR, (https://github.com/SantanderMetGroup/downscaleR/wiki/Bias-Correction-and-Model-Output-Statistics-(MOS)). The method is highly efficient and automatable.

For application to the OASIS inflow timeseries an initial approach evaluated applying the bias correction on a regional basis for efficiency (e.g., Neuse Basin, Piedmont geographic province); however, this causes problems because many of the drainage areas intersect the Piedmont and Coastal Plain areas and does not consider specific local variations in runoff conditions. Therefore, the eQM method was applied individually to each of the 61 locations with OASIS inflow timeseries in the Neuse and Cape Fear study areas. The calculations were also done by individual month to account for any seasonal effects. The eQM application used 1,000 bins to characterize the historical cumulative distribution functions, which is near the maximum feasible for a 56-year training data set. Using a large number of bins is desirable to ensure that the high and low tails of the distribution are adequately covered. The large number of bins means that there will be a small number of observations in each bin (average of a little less than 2) and that many bins will be empty. However, the method relies on comparing the cumulative distribution functions, so the presence of empty bins does not cause problems. A large number of bins (even sparsely populated) just gives a more refined step-function approximation of the underlying continuous cumulative distribution.

One modification was made to the bias correction code to address the situation where a future predicted flow falls outside of the range of bins in the historic training data. (This is a rare event with 1,000 bins in use). The original Python and R codes provide two options when this occurs. One is to use the constant value associated with the largest (or smallest) bin of the observed data; the other is to apply the difference between the largest (or smallest) bin in the observed data and the training data. The original R code indicates that the developers also considered a linear extrapolation, but that this was rejected "due to lack of robustness."

Neither of these approaches is satisfactory for extrapolation of extreme high flow events. Accordingly, the tails of the distribution are addressed by re-introducing a linear extrapolation in which the simulated result is multiplied by the ratio of the highest bins in the training and observed data. This appears to provide reasonable results and avoids an implausible flattening out of the extreme upper end of the cumulative distribution function.

An example of the resulting shifts in the cumulative distribution function are shown for July for OASIS input node 0820 (downstream end of the Cape Fear River) in Figure 10. This shows a large increase in the biggest runoff events associated with summer convective storm activity. (Less change is predicted for winter months.) Figure 11 shows the same points plotted on a logit scale (LN[p/(1-p)]), which expands the tails of the distribution.

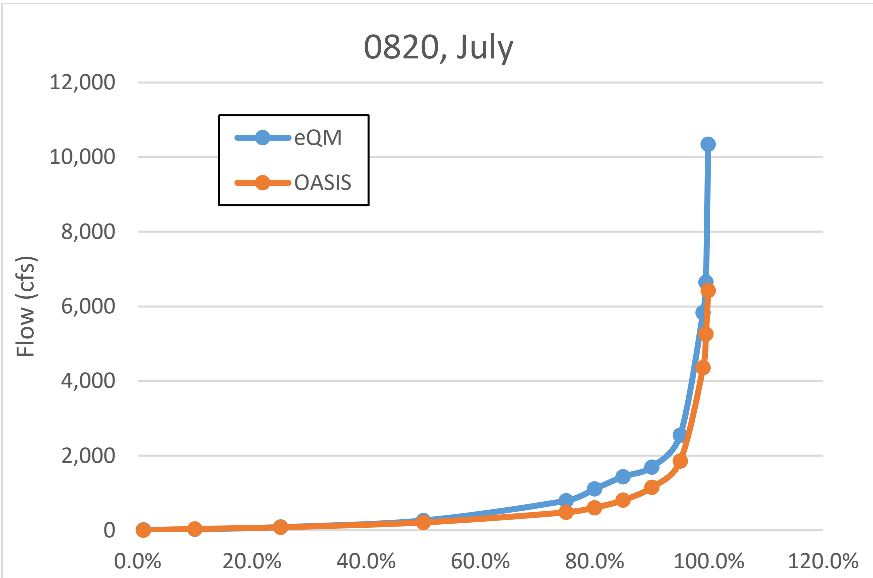

Figure 10. Cumulative distribution functions for node 0820, July, for OASIS historical data and bias-corrected CNRM-CM5 (RCP 4.5) model output centered at 2055

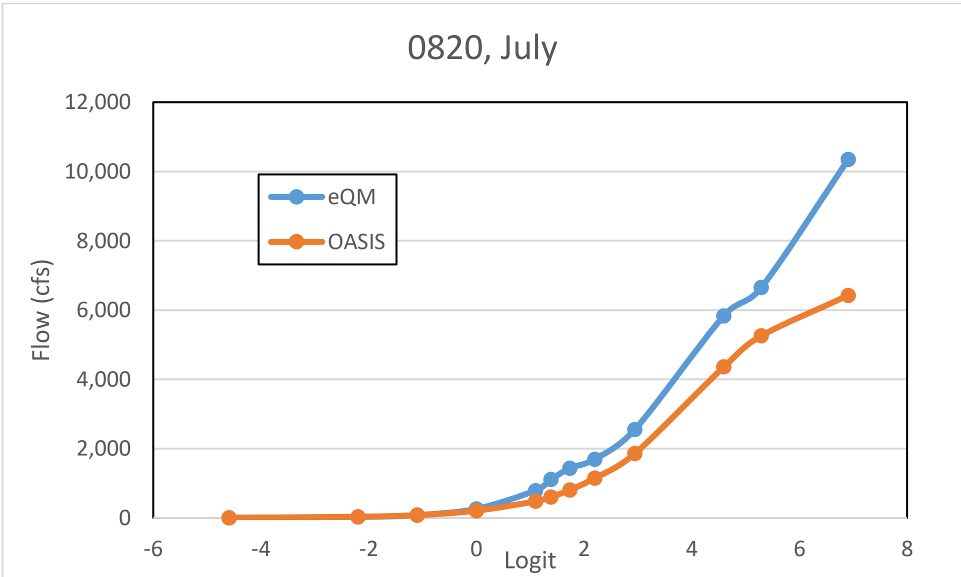

Figure 11. Cumulative distribution functions for node 0820, July, for OASIS historical data and bias-corrected CNRM-CM5 (RCP 4.5) model output centered at 2055, replotted on logit scale

5.0 Results

5.1 Water Budget Summary and Average Monthly Output

The simulated water budgets for historic and future conditions for the Cape Fear PRMS model for the three climate scenarios are summarized in Table 4 and shown in Figure 12. The simulations suggest that the proportions of the components of the overall water budget will not change dramatically between the historic and future (ca. 2055) conditions due to predictions of increased precipitation being balanced by increased evapotranspiration (Figure 17 to Figure 19).

The simulated water budgets for historic and future conditions for the Neuse PRMS model for the three climate scenarios are summarized in Table 5 and shown in Figure 16. The simulation results for the Neuse are similar to the Cape Fear. The proportions of the components of the overall water balance for the future and historic conditions do not show significant difference. Higher evapotranspiration is simulated for the spring and summer months while runoff is higher for the winter months for future compared to the historic time-period (Figure 17 to Figure 19).

Table 4. Simulated water budgets for Cape Fear PRMS model for the historic and future (ca. 2055) conditions for the selected climate scenarios

Constituent	Average Annual Values (inches/year)					
	CNRM-CM5, RCP 4.5		GFDL-ESM2M, RCP 8.5		MIROC-ESM-CHEM, RCP 8.5	
	Historic	Future	Historic	Future	Historic	Future
Precipitation	45.4	50.0	45.4	49.8	45.6	46.9
Evapotranspiration	30.9	33.5	30.6	33.8	31.2	34.0
Runoff	7.0	8.0	7.1	7.8	7.0	6.9
Interflow	2.0	2.5	2.0	2.6	1.9	1.6
Groundwater Outflow	5.6	5.8	5.7	5.8	5.5	4.5

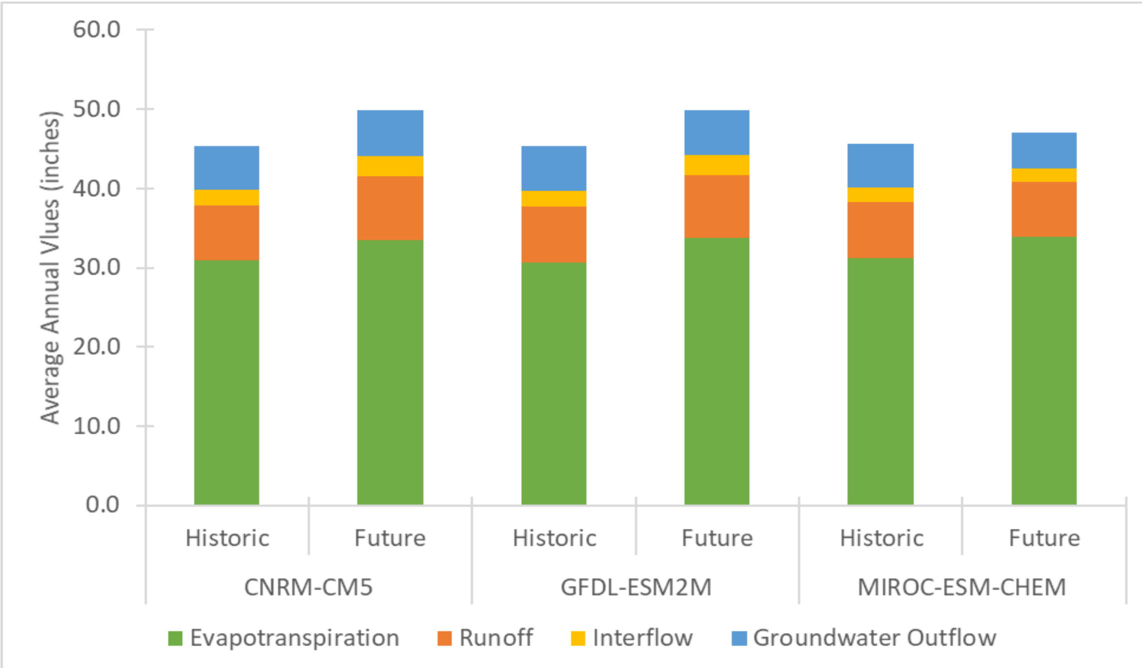

Figure 12. Simulated water budgets for Cape Fear PRMS model for the historic (1951-2005) and future (2041-2070) conditions for the selected climate scenarios

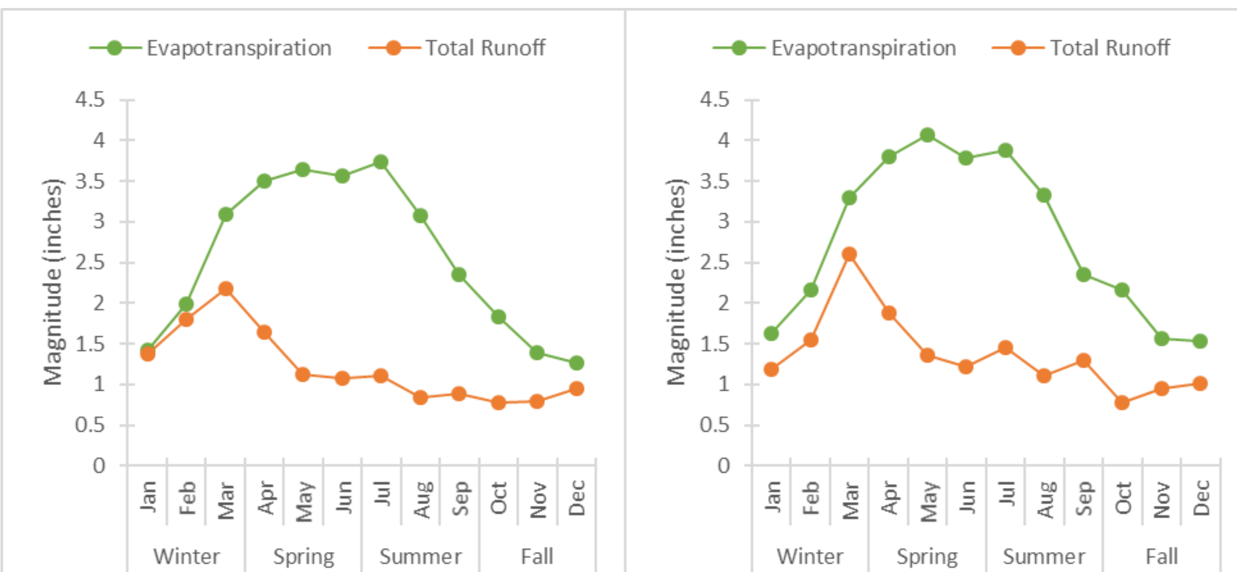

Figure 13. Average monthly simulated evapotranspiration and total runoff for the Cape Fear PRMS model for CNRM-CM5, RCP 4.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

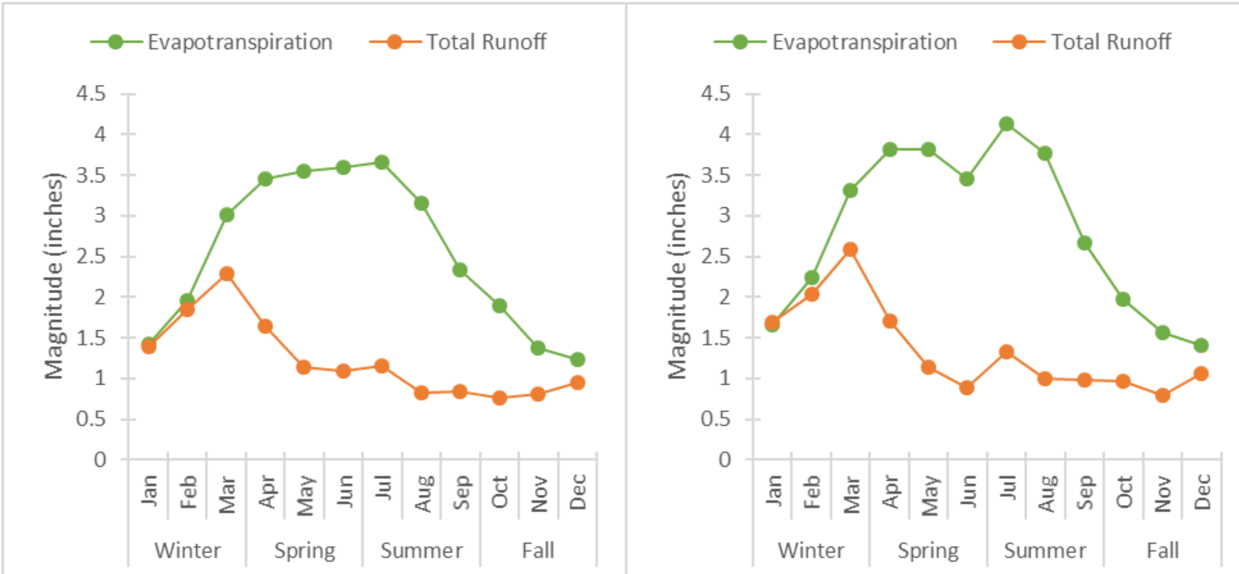

Figure 14. Average monthly simulated evapotranspiration and total runoff for the Cape Fear PRMS model for GFDL-ESM2M RCP 8.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

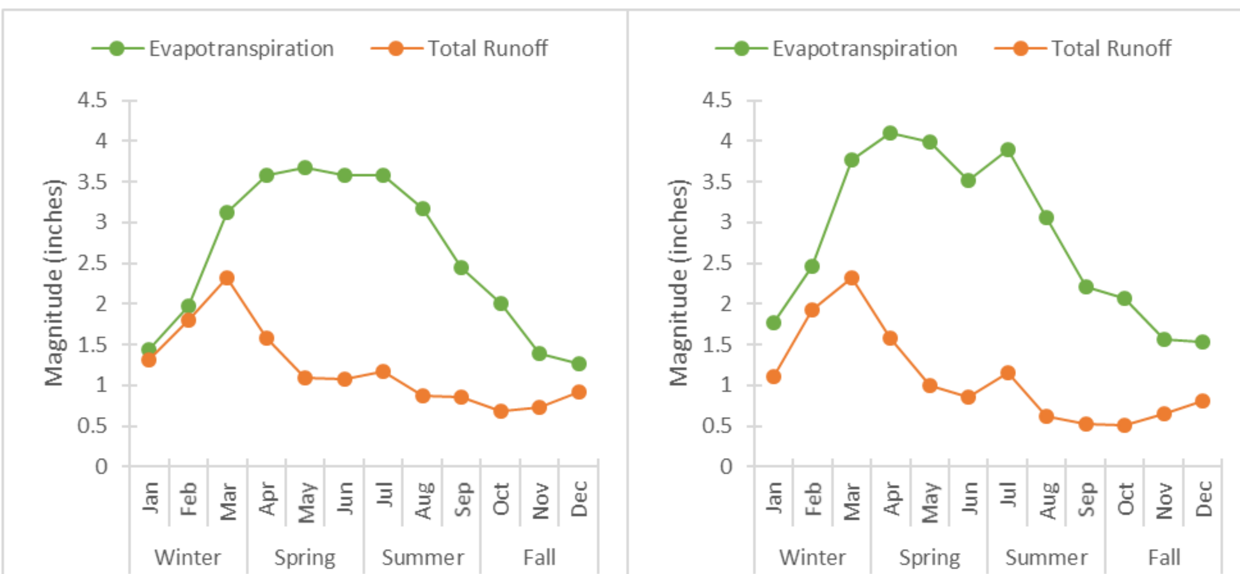

Figure 15. Average monthly simulated evapotranspiration and total runoff for the Cape Fear PRMS model for MIROC-ESM-CHEM RCP 8.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

Table 5. Simulated water budgets for Neuse PRMS model for the historic and future (ca. 2055) conditions for the selected climate scenarios

Constituent	Average Annual Values (inches/year)					
	CNRM-CM5, RCP 4.5		GFDL-ESM2M, RCP 8.5		MIROC-ESM-CHEM, RCP 8.5	
	Historic	Future	Historic	Future	Historic	Future
Precipitation	42.8	47.5	42.9	46.5	43.1	43.7
Evapotranspiration	30.0	32.6	29.9	32.5	30.2	32.3
Runoff	6.8	8.1	6.8	7.6	6.9	6.3
Interflow	1.7	2.2	1.7	2.1	1.6	1.5
Groundwater Outflow	4.3	4.6	4.4	4.5	4.3	3.6

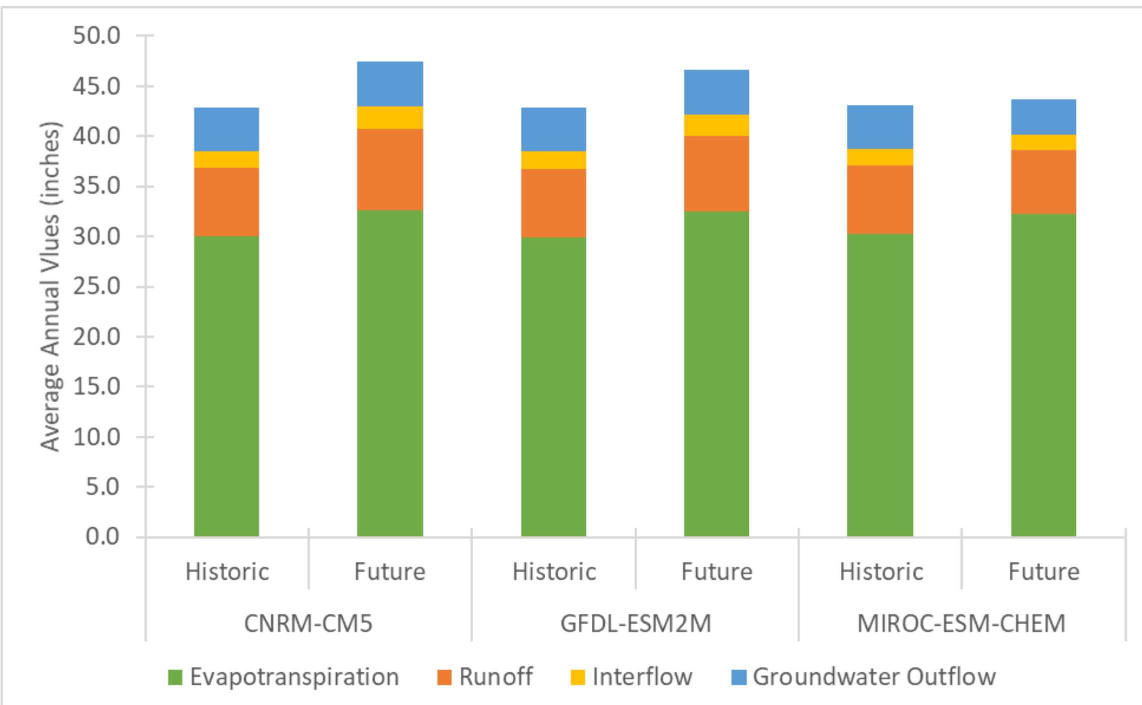

Figure 16. Simulated water budgets for Neuse PRMS model for the historic (1951-2005) and future (2041-2070) conditions for the selected climate scenarios

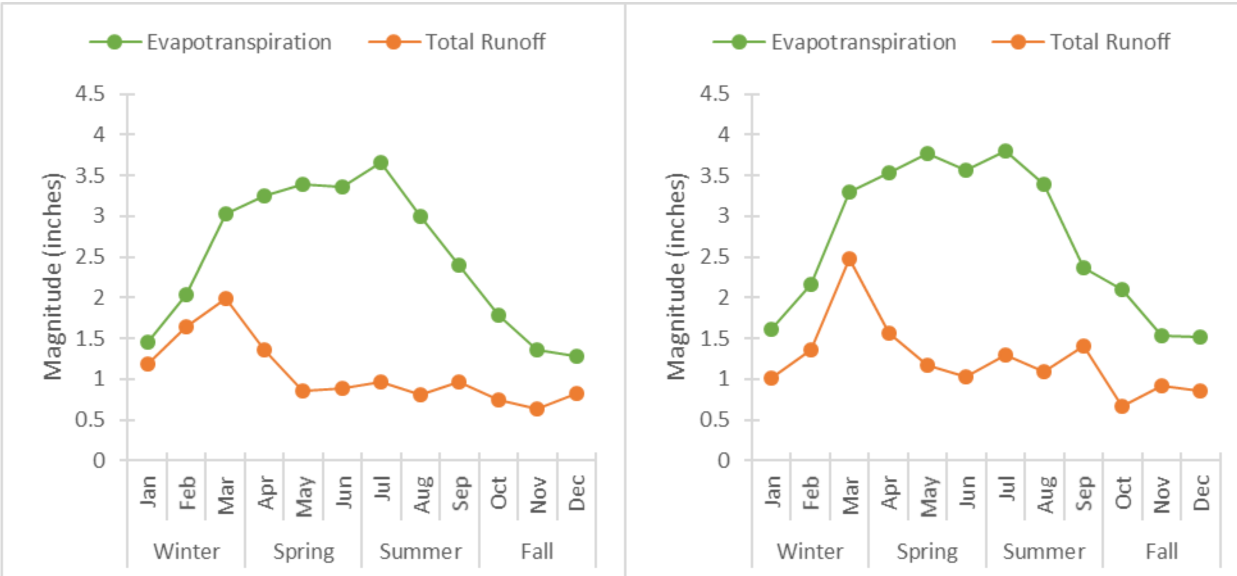

Figure 17. Average monthly simulated evapotranspiration and total runoff for the Neuse PRMS model for CNRM-CM5 RCP 4.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

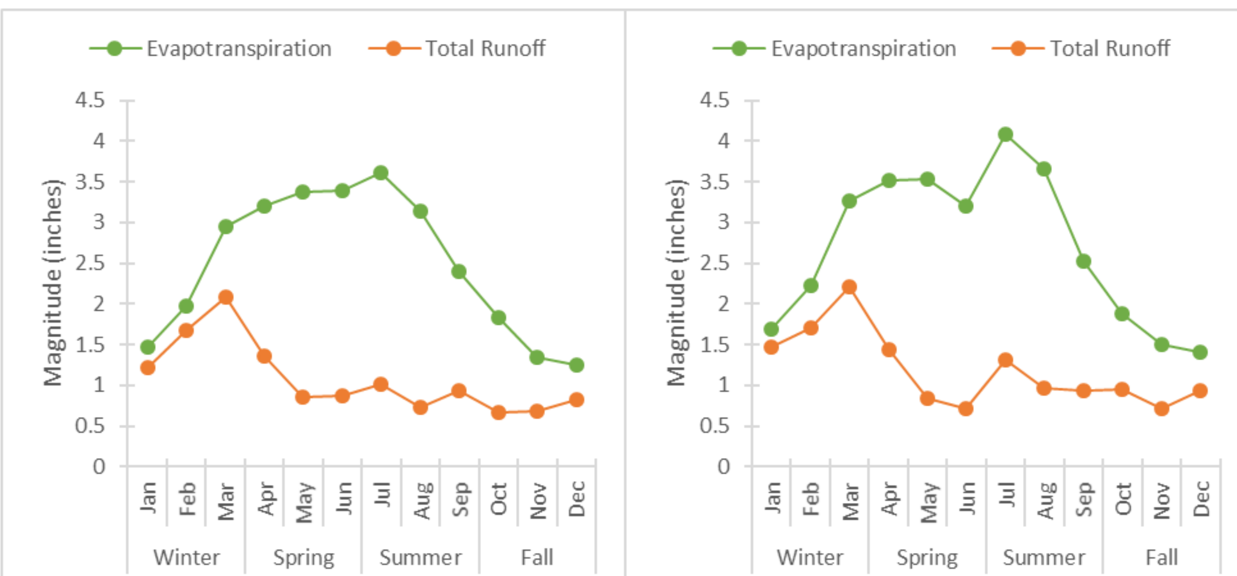

Figure 18. Average monthly simulated evapotranspiration and total runoff for the Neuse PRMS model for GFDL-ESM2M RCP 8.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

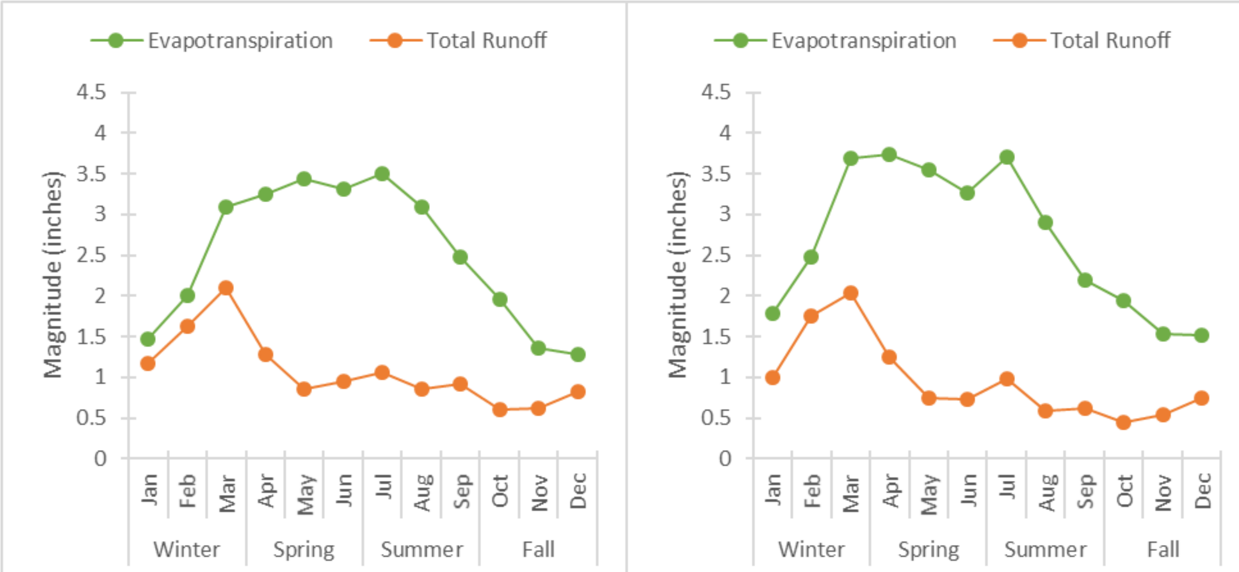

Figure 19. Average monthly simulated evapotranspiration and total runoff for the Neuse PRMS model for MIROC-ESM-CHEM RCP 8.5, for historic (1951-2005; left) and future (2041-2070; right) conditions

5.2 Lake Evaporation Timeseries

The OASIS model estimates lake evaporation rates by applying pan coefficients to continuous measurements of pan evaporation recorded by the Orange Water and Sewer Authority (OWASA) in Carrboro, NC. For application to future climate, lake evaporation could be estimated in OASIS directly from the PET estimates from the Jensen-Haise method used by the PRMS model; however, there is no guarantee that the resulting estimates would be fully consistent with the approach currently used in OASIS. In addition, the PRMS estimates of PET differ across the watersheds. Therefore, an alternative approach to adjust lake evaporation for future climate was adopted.

Adjusted lake evaporation timeseries were calculated using a bias correction method similar to that described for future runoff timeseries in Section 4.4. Specifically, the eQM method was applied to map the relative changes from historic to future conditions in the Jensen-Haise PET estimates at each lake onto the cumulative distribution function of the historic estimate of lake evaporation rates. As with the runoff timeseries, the eQM quantile mapping approach adjusts for systematic differences that are present between observed pan evaporation and Jensen-Haise PET. The revised lake evaporation timeseries were then converted to the net evaporation timeseries (the difference between evaporation and precipitation on the lake surface) used by OASIS, preserving the temporal match between evaporation and precipitation.

5.3 Database

The historic and future, bias-corrected daily simulated runoff and evapotranspiration time-series for each of the HRUs in the Cape Fear and Neuse NHM PRMS models are provided for use in the respective OASIS models to evaluate the impacts on future water supply. The climate-adjusted estimates of lake evaporation rates along with net evaporation adjusted for precipitation (Section 5.2) are also included in separate files.

The OASIS model requires time-series data in the U.S. Army Corps of Engineers Data Storage System-(DSS) format. A Python script was developed that uses the "pyhecdss" module (https://github.com/CADWRDeltaModeling/pyhecdss) to write the PRMS time-series outputs to the HEC-DSS format. DSS files are provided for each climate scenario and model combination (total of 6) for the historic (1/1/1951 to 12/31/2005) and future (1/1/2041 to 12/31/2070) time-periods.

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6.0 References

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Hazen

ATTACHMENT B

Summary of Withdrawals and Discharges in Cape Fear-Neuse River Combined River Basin Model

General Note: Table values are annual averages and vary seasonally. WTP Process Water (PW) is not included in the withdrawal value when the PW discharge location is sufficiently close to the withdrawal location.

A – Values in millions of gallons per day (mgd) and include purchases from other utilities; excludes sales to other utilities with an OASIS node

B - Values in mgd and include wastewater discharges to other utilities; excludes wastewater discharges from other utilities

				2025 Conditions		2055 Conditions	
OASIS Node	Name of Water Utility (or Company)	PWSID(s)	Ownership	Withdrawals and Purchases[A]	Discharges[B]	Withdrawals and Purchases[A]	Discharges[B]
0031	Reidsville	02-79-020	Municipal	3.93	2.29	4.37	2.45
0075	Haw River	02-01-020	Municipal	0.19	0.16	0.27	0.22
0123	Greensboro	02-41-010	Municipal	35.84	35.67	46.58	46.21
0223	High Point	02-41-020	Municipal	11.22	11.99	13.18	14.08
0261	City of Randleman	02-76-015	Municipal	0.84	0.84	0.94	0.94
0301	Ramseur	02-76-020	Municipal	0.62	0.21	0.82	0.28
0321	Graham & Mebane	02-01-015 & 02-01-018	Municipal	4.18	3.19	7.10	5.42
0327	Siler City	03-19-010	Municipal	2.03	1.84	2.67	2.42
0341	Burlington	02-01-010	Municipal	12.92	11.12	16.13	13.88
0401	Pittsboro	03-19-015	Municipal	1.41	0.81	4.65	3.2
0431	OWASA	03-68-010	Authority	7.17	6.8	10.62	10.07
0471	Cary-Apex (includes RTP and Morrisville)	03-92-020 & 03-92-045	Municipal	24.52	22.39	38.24	34.91
0473	Chatham Co. North System	03-19-126	County	2.84	0.39	3.35	0.46
0476	Chatham Co. Asbury System	40-19-010	Municipal	1.04	0	2.05	0
0483	Performance Fibers / Allied Signal Demand	NA	Industrial	0.20	0.2	0.20	0.2
0491	Sanford	05-53-010	Municipal	6.31	5.51	9.15	5.62
0521	Progress Harris	NA	Industrial	20.00	0	20.00	0
0551	Harnett County	03-43-045	County	16.24	9.28	21.56	12.32
0601	Pilgrims Pride	NA	Industrial	0.97	0.06	0.97	0.06
0605	Goldston-Gulf	03-19-025	District	0.08	0.02	0.07	0.02
0654	Angier	03-43-015	Municipal	0.58	0.51	1.31	1.15
0663	Dunn	03-43-010	Municipal	3.55	2.44	3.48	2.39
0674	Carolina Trace	03-53-101	Industry	0.20	0.2	0.22	0.22
0701	Carthage	03-63-025	Municipal	0.37	0	0.55	0
0719	Spring Lake	03-26-020	Municipal	0.90	0.9	0.91	0.91
0721	Old North Utility Services, Inc.	50-26-019	Business	3.49	3.58	4.13	4.23
0733	Fayetteville	03-26-010	Municipal	26.65	26.54	55.27	55.04
0735	Hoke County	03-47-025	Municipal	0.91	0.88	1.11	1.08
0781	Dupont	NA	Industrial	11.17	11.91	11.17	11.91
0785	LCFWSA Bladen Bluff	50-09-012	Authority	4.04	0	4.04	0
0823	Cape Fear PUA-Wilmington	04-65-010	Authority	15.22	0	24.48	0

OASIS Node	Name of Water Utility (or Company)	PWSID(s)	Ownership	2025 Conditions Withdrawals and Purchases[A]	2025 Conditions Discharges[B]	2055 Conditions Withdrawals and Purchases[A]	2055 Conditions Discharges[B]
0825	LCFWSA Kings Bluff	50-09-013	Authority	21.69	0	40.86	0
0903	Jamestown	02-41-030	Municipal	0.57	0	0.87	0
0904	Archdale	02-76-030	Municipal	0.86	0.83	0.98	0.94
0923	Holly Springs	03-92-050	Municipal	3.68	3.58	9.50	9.25
0940	Broadway	03-53-015	Municipal	0.10	0.06	0.14	0.09
1046	Orange-Alamance	03-68-020	Non-Profit	0.62	0.06	0.70	0.07
1106	Hillsborough	03-68-015	Municipal	1.42	0.91	1.89	1.21
1162	Durham	03-32-010	Municipal	32.93	27.03	38.17	31.33
1256	SGWASA	02-39-107	Authority	1.79	1.1	1.84	1.14
1306	Raleigh	03-92-010	Municipal	59.75	52.4	92.40	81.03
1506	Wilson	04-98-010	Municipal	6.69	5.72	6.59	5.63
1646	Johnston County	03-51-070	County	17.08	8.98	41.59	21.88
1666	Smithfield	03-51-010	Municipal	1.62	1.22	1.69	1.27
1706	Fuquay-Varina	03-92-055	Municipal	3.58	3.27	8.37	7.66
1756	Benson	03-51-025	Municipal	0.86	0.3	1.03	0.36
1766	Progress Lee Steam Plant	NA	Industrial	8.91	0	8.91	0
1786	Goldsboro	04-96-010	Municipal	7.05	9.81	8.82	12.27
1806	Neuse Regional WASA	60-54-001	Authority	8.25	7.07	8.39	7.19
1906	Weyerhauser	NA	Industrial	14.47	14.09	14.47	14.09

Hazen

ATTACHMENT C

Fayetteville Public Works Commission Water Shortage Response Trigger Flow Mapping

Effective July 12, 2023, the Fayetteville PWC adopted changes to their WSRP including the addition of water shortage triggers based off the elevation at their Cape Fear River water supply intake. The CFNCRB model used for hydrological analysis in this EIS is a water accounting model and does not quantify water elevations at specific stream sites. Therefore, to include PWC's updated WSRP triggers in the CFNCRB model analysis, each elevation trigger was mapped to a flow value. No USGS data at the Cape Fear River at Fayetteville gauge exists for gauge heights as low as the proposed PWC WSRP triggers.

To estimate what flows may be observed in the Cape Fear River at Fayetteville for the PWC triggers levels, a relationship was developed based on existing USGS data and HEC-RAS river bathymetry information. Based on comparisons to existing USGS data, the HEC-RAS model overpredicted streamflow at the gauge for low stream flows, so these results could not be used directly. Instead, the shape of HEC-RAS relationship between stage and discharge was mapped onto the USGS data used to develop an equation to project flows between the lowest USGS records and a gauge height of 0 feet.

Table C.1: Fayetteville PWC WSRP Triggers as Flows

PWC Drought Stage	PWC Trigger - River Stage at Fayetteville (feet)	Projected River Flow for Trigger Height (cfs)
1	9.45	527
2	8.9	319
3	8.4	202
4	7.66	103

Hazen

ATTACHMENT D

Cape Fear-Neuse River Combined River Basin Model OCL Code

_SafeYield_Constants.ocl

```
/* '_SafeYield_Constants.ocl'
   This file is automatically generated by the OASIS GUI.
   Any changes you make to this file will be overwritten by the program. */

:substitute: [SafeYield_IterNum] = 06   /* Iteration number in the safe-yield procedure */

```

Agric_Allocation.ocl

```
/*  File is Agric_Allocation.ocl. */

/* This file allocates the agricultural demands by the assumed distribution of
demand within each county */

/*  The county demand is represented by "dem__" that varies by number.  These
numbers are established in the agricultural input dialog box, with 01 set for Alamance, 02 for
Bladen, and so on.  */

// For counties in the the Cape Fear Basin

/*  Note that for Alamance, Chatham, Cumberland, Randolph, and Moore, M&N changed the
distribution to reflect demand patterns since 1998 */

Set  Demand_Alamance_35Pct :    demand0371    {    value     :  dem01 * 0.35 }
Set  Demand_Alamance_30Pct    :  demand0361    {    value     :  dem01 * 0.30 }
Set  Demand_Alamance_35Pct :    demand0081    {    value     :  demand0371 }

Set  Demand_Bladen_60Pct   :  demand0811   { value :  dem02 *  0.60  }
Set  Demand_Bladen_20Pct :  demand0801     { value :  dem02 *  0.20}
Set  Demand_Bladen_20Pct :  demand0821     { value :  dem02 *  0.20 }

Set  Demand_Caswell_100% :   demand0083  { value :  dem03 * 1.0  }

Set  Demand_Chatham_10Pct  :   demand0403  {     value     :  dem04 *  0.10      }
Set  Demand_Chatham_85Pct  :   demand0621  {     value     :  dem04 *  0.85  }
Set  Demand_Chatham_5Pct   :   demand0481  {     value     :  dem04 *  0.05   }

Set  Demand_Cumberland_50Pct :  demand0741  {     value     :  dem05 *  0.50  }
Set  Demand_Cumberland_10Pct :  demand0775  {     value     :  dem05 *  0.10  }
Set  Demand_Cumberland_40Pct :  demand0783  {     value     :  dem05 *  0.40  }

Set  Demand_Durham_3Pct  :   demand0461  { value :  dem06 * 0.03  }

Set  Demand_Forsyth_50Pct :  demand0111   { value :  dem07  }
Set  Demand_Forsyth_50Pct :  demand0211   { value :  demand0111  }

Set  Demand_Guilford_20Pct :  demand0051   { value :  dem08 * 0.20 }
Set  Demand_Guilford_15Pct :  demand0331   { value :  dem08 * 0.15 }
Set  Demand_Guilford_40Pct :  demand0161   { value :  dem08 * 0.40 }
Set  Demand_Guilford_13Pct :  demand0043   { value :  dem08 * 0.13 }
Set  Demand_Guilford_12Pct :  demand0231   { value :  dem08 * 0.12 }


Set  Demand_Harnett_15Pct :  demand0691   { value :  dem09     * 0.15 }
Set  Demand_Harnett_35Pct :  demand0553   { value :  dem09     * 0.35 }
Set  Demand_Harnett_50Pct :  demand0681   { value :  dem09     * 0.50 }
```

```
Set  Demand_Hoke_100%  :   demand0773  { value :  dem10 * 1.0  }

Set  Demand_Lee_7Pct :   demand0623   { value :  dem11 * 0.07  }
Set  Demand_Lee_55Pct :  demand0671   { value :  dem11 * 0.55  }
Set  Demand_Lee_38Pct :  demand0511   { value :  dem11 * 0.38  }

Set  Demand_Montgomery_100%  :   demand0593  { value :  dem12 * 1.0  }

Set  Demand_Moore_40Pct :  demand0603 {    value     :  dem13 *  0.40  }
Set  Demand_Moore_30Pct :  demand0713 {    value     :  dem13 *  0.30  }
Set  Demand_Moore_30Pct :  demand0595 {    value     :  dem13 *  0.30  }

// Orange Co. - for CF as a percentage of the acerage (48%) in the basin
Set  Demand_Orange_36Pct :  demand0441   { value :  dem14 * 0.36 * 0.48  }
Set  Demand_Orange_24Pct :  demand0381   { value :  dem14 * 0.24 * 0.48  }
Set  Demand_Orange_40Pct :  demand0311   { value :  dem14 * 0.40 * 0.48  }

Set  Demand_Randolph_50Pct :  demand0581  {  value     :  dem15 *  0.50  }
Set  Demand_Randolph_30Pct :  demand0281  {  value     :  dem15 *  0.30  }
Set  Demand_Randolph_20Pct :  demand0263  {  value     :  dem15 * 0.20  }

Set  Demand_Rockingham_40Pct :  demand0021   { value :  dem16 * 0.40  }
Set  Demand_Rockingham_60Pct :  demand0041   { value :  dem16 * 0.60  }

// Wake Co. - for CF as a percentage of the acerage (13%) in the basin
Set  Demand_Wake_5Pct :   demand0541   { value :  dem17 *  0.05 * 0.13 }
Set  Demand_Wake_75Pct :  demand0411   { value :  dem17 *  0.75 * 0.13 }
Set  Demand_Wake_20Pct :  demand0531   { value :  dem17 * 0.20 * 0.13 }



// For counties in the the Neuse Basin

Set  Demand_Or_Pond_Ag   : demand1062 { value: dem14 * 0.095 }
Set  Demand_WFER_Ag   : demand1052 { value: dem14 * 0.095 }
Set  Demand_EnoDurha_Ag : demand1112 { value: dem14 * 0.16 + dem06 * 0.137 }
Set  Demand_Michie_Ag   : demand1142 { value: dem06 * 0.078 + dem25 * 0.31 }
Set  Demand_LitRes_Ag   : demand1202 { value: dem14 * 0.03 + dem06 * 0.097 + dem14 * 0.14 }
Set  Demand_Falls_Ag   : demand1302 { value: dem06 * 0.076 + dem20 * 0.02 + dem06 * 0.488 + dem25 * 0.01 + dem20 * 0.07
                                             + dem06 * 0.094 + dem17 * 0.05 + dem19 * 0.02 + dem20 * 0.15 }
Set  Demand_Clayt_Ag   : demand1632 { value:  dem22 * 0.04 +  dem17 * 0.20 + dem19 * 0.01 + dem17 * 0.035 }
Set  Demand_Middl_Ag   : demand1482 { value:  dem22 * 0.01 +  dem17 * 0.158 }
Set  Demand_Litpr_Ag   : demand1752 { value:  dem28 * 0.02 +  dem22 * 0.18 + dem17 * 0.158 + dem19 * 0.03 }
Set  Demand_Golds_Ag   : demand1782 { value:  dem22 * 0.10 + dem17 * 0.053 + dem22 * 0.08 + dem27 * 0.42 + dem22 * 0.39
          + dem22 * 0.13 }
Set  Demand_Kinst_Ag   : demand1802 { value:  dem23 * 0.35 + dem21 * 0.05 }
```

```
Set  Demand_Buckhorn_Ag  : demand1502 { value:  dem28 * 0.05 + dem22 * 0.04 + dem24 * 0.13 + dem17 * 0.035 + dem19 * 0.05 }
Set  Demand_Hooke_Ag   : demand1562 { value:  dem27 * 0.23 + dem21 * 0.57 + dem28 * 0.70 + dem24 * 0.07 + dem22 * 0.01 }
Set  Demand_Weyer_Ag   : demand1902 { value:  dem18 * 0.04 + dem23 * 0.39 + dem23 * 0.09 + dem21 * 0.39 + dem26 * 0.17
            + dem28 * 0.04 + dem26 * 0.23 }

/* Adjust Little River Ag Demands to distribute them across the proposed Reservoir's sub-basin*/
Set Demand_LitR_sub_Ag   : demand1738 { value: demand1752 * 52.6/232 }
Set  Demand_Litpr_Ag     : demand1752 { value: demand1752 - demand1738}
```

Agric_Calculation.ocl

```
/*  File is Agric_Calculation.ocl. */

/*  Note the precip data is contained in the basedata file and for simplicity uses Jordan Lake for the Cape Fear
    and Falls Lake for the Neuse.   */

// The first 17 counties are for the Cape Fear Basin.   The next 11 are for the Neuse.  Three counties are in both basins (Wake, Durham, and Orange).
// For the combined model, the more recent acreages (from the Neuse model) for these counties are used.

// First compute agricultural water demand for Cape Fear counties based on Jordan Lake precip. The counties are
// labeled in the Edit Agricultural Data dialog box in the GUI.  Note - counties in both basins (Durham, Orange, Wake) use the CF precip.
:For:
{   [cty] = {01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15, 16, 17}
}

    RUN_MODULE: AgricDem
    {
      Input:  { [cty],                    // County number
                timesers(CFear/precip),      // Precip for Jordan Lake in inches

                pattern(IrrCoef_Tobacco),    // Water Use Coefficients for Tobacco, etc.
                pattern(IrrCoef_Turf),
                pattern(IrrCoef_Golf),
                pattern(IrrCoef_ContNurs),
                pattern(IrrCoef_FieldNurs),
                pattern(IrrCoef_Cotton),
                pattern(IrrCoef_EarlySoy),
                pattern(IrrCoef_LateSoy),
                pattern(IrrCoef_Corn),
                pattern(IrrCoef_Veg),
                pattern(IrrCoef_PastHay),
                pattern(IrrCoef_Peanut),
                pattern(IrrCoef_Blueberry),
                pattern(IrrCoef_Strawberry),
                pattern(IrrCoef_Fruit),
                pattern(IrrCoef_Beef),
                pattern(IrrCoef_Dairy),
                pattern(IrrCoef_Horse),
                pattern(IrrCoef_Pig),
                pattern(IrrCoef_Chicken),
                pattern(IrrCoef_Turkey),
                pattern(IrrCoef_OtherAnimal)
              }

      Output: { dem[cty] }
    }
:Next:
```

```
/* Then compute agricultural demand for the Neuse counties based on Falls Lake precip.
 Note - counties in both basins (Durham, Orange, Wake) use the CF precip.*/
:For:
{   [cty] = {18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28}
}

    RUN_MODULE: AgricDem
    {
      Input:  { [cty],                  // County number
                timesers(Neuse/precip),      // Precip for Falls Lake in inches

                pattern(IrrCoef_Tobacco),    // Water Use Coefficients for Tobacco, etc.
                pattern(IrrCoef_Turf),
                pattern(IrrCoef_Golf),
                pattern(IrrCoef_ContNurs),
                pattern(IrrCoef_FieldNurs),
                pattern(IrrCoef_Cotton),
                pattern(IrrCoef_EarlySoy),
                pattern(IrrCoef_LateSoy),
                pattern(IrrCoef_Corn),
                pattern(IrrCoef_Veg),
                pattern(IrrCoef_PastHay),
                pattern(IrrCoef_Peanut),
                pattern(IrrCoef_Blueberry),
                pattern(IrrCoef_Strawberry),
                pattern(IrrCoef_Fruit),
                pattern(IrrCoef_Beef),
                pattern(IrrCoef_Dairy),
                pattern(IrrCoef_Horse),
                pattern(IrrCoef_Pig),
                pattern(IrrCoef_Chicken),
                pattern(IrrCoef_Turkey),
                pattern(IrrCoef_OtherAnimal)
              }

      Output: { dem[cty] }
    }
:Next:


/*  The results are in mgd.  Now convert these to acre feet for use in the
agric_allocation.ocl file  */

// For the Cape Fear
Set  :  dem01  {  value  :  convert_units {dem01, mgd, af }  }
Set  :  dem02  {  value  :  convert_units {dem02, mgd, af }  }
Set  :  dem03  {  value  :  convert_units {dem03, mgd, af }  }
```

```
Set : dem04 { value : convert_units {dem04, mgd, af } }
Set : dem05 { value : convert_units {dem05, mgd, af } }
Set : dem06 { value : convert_units {dem06, mgd, af } }
Set : dem07 { value : convert_units {dem07, mgd, af } }
Set : dem08 { value : convert_units {dem08, mgd, af } }
Set : dem09 { value : convert_units {dem09, mgd, af } }
Set : dem10 { value : convert_units {dem10, mgd, af } }
Set : dem11 { value : convert_units {dem11, mgd, af } }
Set : dem12 { value : convert_units {dem12, mgd, af } }
Set : dem13 { value : convert_units {dem13, mgd, af } }
Set : dem14 { value : convert_units {dem14, mgd, af } }
Set : dem15 { value : convert_units {dem15, mgd, af } }
Set : dem16 { value : convert_units {dem16, mgd, af } }
Set : dem17 { value : convert_units {dem17, mgd, af } }

// For the Neuse
Set : dem18 { value : convert_units {dem18, mgd, af } }
Set : dem19 { value : convert_units {dem19, mgd, af } }
Set : dem20 { value : convert_units {dem20, mgd, af } }
Set : dem21 { value : convert_units {dem21, mgd, af } }
Set : dem22 { value : convert_units {dem22, mgd, af } }
Set : dem23 { value : convert_units {dem23, mgd, af } }
Set : dem24 { value : convert_units {dem24, mgd, af } }
Set : dem25 { value : convert_units {dem25, mgd, af } }
Set : dem26 { value : convert_units {dem26, mgd, af } }
Set : dem27 { value : convert_units {dem27, mgd, af } }
Set : dem28 { value : convert_units {dem28, mgd, af } }
```

Benson_ops.ocl

```
/* BENSON_OPS.OCL  */

/*  Operational policy for Bensons's system */

// Set targets to dictate deliveries from Dunn and Johnston Cos.
Target Dunn_Del : dflow0662.1756
{   condition : default
    priority  : 1
    penalty+  : 75
    penalty-  : 75
    Value     : 0.96 * min{_Benson_Consvn_1_Demand, _Benson_Consvn_2_Demand,
       _Benson_Consvn_3_Demand, _Benson_Consvn_4_Demand,
       _Benson_Consvn_5_Demand, _Benson_Consvn_6_Demand,
       demand1756}  // 96% from Dunn, the rest will be from Johnston Co. (arc 1656.1756)
}

Target JC_Del : dflow1656.1756
{   condition : default
    priority  : 1
    penalty+  : 75
    penalty-  : 75
    Value     : 0.04 * min{_Benson_Consvn_1_Demand, _Benson_Consvn_2_Demand,
       _Benson_Consvn_3_Demand, _Benson_Consvn_4_Demand,
       _Benson_Consvn_5_Demand, _Benson_Consvn_6_Demand,
       demand1756} // 4% from  Johnston Co. (arc 1656.1756)
}
```

buckhorn_Wilson_ops.ocl

```
/*  BUCKHORN_Wilson_OPS.OCL  */

/*  Minimum release policy for Wilson's Buckhorn Lake - based on storage remaining.
Modified by R. Palmer - minimum release needs to be made below the
City of Wilson withdrawal point - Wiggon's Mill Lake, not Buckhorn Dam - will add the arc downstream accordingly*/

Set :  min_flow1520.1560
{   condition : storage1500 / max_stor1500 < 0.5
    Value     : convert_units { 1.4 , cfs , af }

    condition : storage1500 / max_stor1500 < 0.7
    Value     : convert_units { 5.3 , cfs , af }

    condition : default
    Value     : convert_units { 7.6 , cfs , af }
}
```

constants.ocl

```
/* 'constants.ocl'
   This file is automatically generated by the OASIS GUI.
   Any changes you make to this file will be overwritten by the program.
   To edit the Constants table, do not edit this file.  Instead, go to
   the 'OCL' tab of the GUI and edit the 'OCL Constants' table.  */

:substitute: [ClaytonTarget_Override] = 0         /* 0 = Normal Clayton target; 1 = Override target when Falls WQ < threshold */
:substitute: [ClaytonTarget_SafeFact] = 0         /* Pct. safety factor for Clayton minimum target */
:substitute:       [Demand_FV_Neuse] = 0.62       /* Fraction of Fuquay Varina Demand in the Neuse River Basin */
:substitute:      [Demand_Multiplier] = 1         /* Multiplication factor used to adjust all demands in the system */
:substitute:       [Drought_Plans_On] = 1         /* 1 = Use drought plans, 0 = do not use drought plans */
:substitute:      [FLakeMin_SafeFact] = 0         /* Pct. safety factor for Falls minimum releases */
:substitute:      [FV_Harnett_Supply] = 2         /* Supply contract from Harnett County to Fuquay Varina */
:substitute:     [FV_Johnston_Supply] = 0         /* Supply contract from Johnston County to Fuquay Varina */
:substitute:          [FV_Ral_Supply] = 0         /* Supply contract from Raleigh to Fuquay Varina */
:substitute:      [FV_Sanford_Supply] = 0         /* Supply contract from Sanford to Fuquay Varina */
:substitute:  [Use_Demand_Multiplier] = 0         /* Flag tells whether to adjust all demands in the system with a mult. factor */
```

constants_removed.ocl

```
/* this file was created to contain constants removed from constants table to simplify run
evaluated in beginning of main.ocl so all files can reference values as needed */

//Raleigh constants
:SUBSTITUTE: [Total_Max_WQ_Storage]  = 44022  /*Raleigh total max water quality storage, af */
:SUBSTITUTE: [Total_Max_WS_Storage]  = 62300  /* Raleigh total max water supply storage, af*/
:SUBSTITUTE: [NR_DS_intake]    = 0   /*Neuse River raleigh intake benton mgd*/
:SUBSTITUTE: [DE_Benton_WTP_Capacity]  = 40   /*DE Benton WTP Capacity, mgd*/
// Falls Lake
:SUBSTITUTE: [Falls_upper_rule]   = 251.5  /*Falls Lake upper rule, ft */
:SUBSTITUTE: [Falls_lower_rule]   = 236.5  /*Falls Lake lower rule, ft*/
:SUBSTITUTE: [FLake_WQ_Threshold]   = 20   /*Falls Lake water quality threshold, % */
:SUBSTITUTE: [FLake_WQ_Stor]    = 42110  /*Falls Lake water quality storage, af */
:SUBSTITUTE: [FLake_WS_Stor]    = 59595  /*Falls Lake Water Supply Storage, af */
// Beaverdam Lake
:SUBSTITUTE: [Bdam_WQ_Stor]    = 1912   /*Beaverdam water quality storage, af */
:SUBSTITUTE: [Bdam_WS_Stor]    = 2705   /* Beaverdam water supply storage, af*/
:SUBSTITUTE: [Bdam_WQ_WS_Stor]    = 4617   /*Beaverdam total water quality and water supply storage, af  */

//Jordan Lake constantss
:SUBSTITUTE: [Max_WQ_Storage]    = 94600  /* Jordan max water quality storage, af */
:SUBSTITUTE: [Lillington_Target_Normal] = 600   /* cape Fear Lillington Gage Target, cfs*/
:SUBSTITUTE: [Max_WS_Storage]    = 45800  /* Jordan max ater supply storage, af */
:SUBSTITUTE: [Max_WQ_WS_Storage]   = 140400  /* Jordan lake max total storage, af*/
// allocation fractions
:SUBSTITUTE: [WS_CaryAp_Fraction]   = 0.392  /* Available water supply storage for Cary Apex (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Chatham_Fraction]  = 0.13   /* Available water supply storage for Chatham Co. (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Durham_Fraction]   = 0.165  /* Available water supply storage for Durham (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Holly_Fraction]   = 0.02   /* Available water supply storage for Holly Springs (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Morris_Fraction]   = 0.035  /* Available water supply storage for Morrisville(as a fraction of the total pool) */
:SUBSTITUTE: [WS_Orange_Fraction]   = 0.015  /* Available water supply storage for Orange Co. (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Other_Fraction]   = 0.088  /* Available water supply storage for unallocated (as a fraction of the total pool) */
:SUBSTITUTE: [WS_OWASA_Fraction]   = 0.05   /* Available water supply storage for OWASA (as a fraction of the total pool) */
:SUBSTITUTE: [WS_RTP_Fraction]    = 0.035  /* Available water supply storage for RTP (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Pitt_Fraction]   = 0.06   /* Available water supply storage for Pittsboro (as a fraction of the total pool) */
:SUBSTITUTE: [WS_Hillsb_Fraction]   = 0.01   /* Available water supply storage for Hillsborough (as a fraction of the total pool) */

//Durham constants
:SUBSTITUTE: [TQ_Max_LM_Refill_Rate]   = 20   /* Teer Quarry max Lake Michie refill, mgd*/
:SUBSTITUTE: [Max_Quarry_refill_rate]  = 0   /* Maximum Raleigh quarry refill rate, mgd*/
```

Crabtree_ops.ocl

```
/* CRABTREE.OCL */

/* Set the Crabtree Creek inflows and net evap for the individual flood control impoundments
 Instead of having 11 inflow and evap records in the basedata file, base all of them
 the inflow1400/evap1400 from the main basedata.dss */


/* Variables for the incremental DA into each reservoir */
:Substitute: [1400] = 2.1
:Substitute: [1402] = 1.4
:Substitute: [1404] = 2.3
:Substitute: [1406] = 8.9
:Substitute: [1408] = 5.2
:Substitute: [1410] = 8.2
:Substitute: [1412] = 2.5
:Substitute: [1414] = 11.5
:Substitute: [1416] = 3.7
:Substitute: [1418] = 23.1
:Substitute: [1422] = 24.8
:Substitute: [CrabtreeTotal] = 93.7

/* Filter the total inflow (in case there are any negative provisional inflows) */
Set : _TempInfCrabtree { Value : timesers(1400/inflow) }
Set : _TotInfCrabtree  { Value : max{0, _TempInfCrabtree - _InfDeficitCrabtree(-1) } }
Set : _InfDeficitCrabtree { Value : max{0, _InfDeficitCrabtree(-1) - _TempInfCrabtree } }

/* Set the inflows - proportion by drainage area the total inflow to Crabtree Creek */
Set : inflow1400  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1400]  }
Set : inflow1402  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1402]  }
Set : inflow1404  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1404]  }
Set : inflow1406  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1406]  }
Set : inflow1408  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1408]  }
Set : inflow1410  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1410]  }
Set : inflow1412  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1412]  }
Set : inflow1414  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1414]  }
Set : inflow1416  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1416]  }
Set : inflow1418  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1418]  }
Set : inflow1422  { value :  _TotInfCrabtree / [CrabtreeTotal] * [1422]  }

/* Set the evap for all nodes */
:For:
{   [node] = { 1400, 1402, 1404, 1406, 1408, 1410, 1412, 1414, 1416, 1418, 1422 }
}
    Set : evap[node]  { value : stor_to_area { [node], storage[node] } * timesers(1400/evap) / 11 }

:Next:

```

```
/* Set the spillway rating curves for the Crabtree Creek impoundments.  Prevent releases from drawing pond below spill elevation  */
Target 1400_release: dflow1400.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1400Outflow, elevation1400 }, cfs, af}, storage1400 - elev_to_stor {1400, 305} }
}

Target 1402_release: dflow1402.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1402Outflow, elevation1402 }, cfs, af}, storage1402 - elev_to_stor {1402, 326} }
}

Target 1404_release: dflow1404.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1404Outflow, elevation1404 }, cfs, af}, storage1404 - elev_to_stor {1404, 342.5} }
}

Target 1406_release: dflow1406.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1406Outflow, elevation1406 }, cfs, af}, storage1406 - elev_to_stor {1406, 306.5} }
}

Target 1408_release: dflow1408.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1408Outflow, elevation1408 }, cfs, af}, storage1408 - elev_to_stor {1408, 313} }
}

Target 1410_release: dflow1410.1412
{  Condition  : default
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : min {convert_units { Lookup{ 1410Outflow, elevation1410 }, cfs, af}, storage1410 - elev_to_stor {1410, 306.5} }
```

```
}

Target 1412_release: dflow1412.1416
{   Condition  : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : min {convert_units { Lookup{ 1412Outflow, elevation1412 }, cfs, af}, storage1412 - elev_to_stor {1412, 276} }
}

Target 1414_release: dflow1414.1416
{  Condition  : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : min {convert_units { Lookup{ 1414Outflow, elevation1414 }, cfs, af}, storage1414 - elev_to_stor {1414, 301 } }
}

Target 1416_release: dflow1416.1424
{  Condition  : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : min {convert_units { Lookup{ 1416Outflow, elevation1416 }, cfs, af}, storage1416 - elev_to_stor {1416, 230} }
}

Target 1418_release: dflow1418.1424
{  Condition  : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : min {convert_units { Lookup{ 1418Outflow, elevation1418 }, cfs, af}, storage1418 - elev_to_stor {1418, 335} }
}

Target 1422_release: dflow1422.1424
{  Condition  : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : min {convert_units { Lookup{ 1422Outflow, elevation1422 }, cfs, af}, storage1422 - elev_to_stor {1422, 252} }
}
```

drought_plan_durham.ocl

```
/* durham_drought_plan.ocl
   Forecast-based triggers and demand reductions based on Durham's Water Shortage Response Plan */

:If: {[Drought_Plans_On] = 1} // First check if drought plan variable is on

/* Compute Durham's usable storage */

Set : _Durham_usable_stor { Value : (storage1140 - lower_rule1140) + (storage1200 - lower_rule1200) }

Set : _Max_Durham_usable_stor { Value : (upper_rule1140 - lower_rule1140) + (upper_rule1200 - lower_rule1200) }

Set : _Durham_usable_pct { Value : 100 * (_Durham_usable_stor / _Max_Durham_usable_stor) }


/*  This section computes the projected demand, inflow, and net evap for each forecast horizon.
 The forecast horizon # is the forecast used to help establish when level # (same number) restrictions are imposed.
 The min flow requirement is small compared to the demand, so ignore; plus min flow is lowest when forecasts are likely to show
 any triggering */


    /* First Trigger Horizon */
Set : _Proj_1_Demand
{   Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand1162, 0, +[Forecast_1_Horizon_Days] }

    Condition : default
    Value     : _Proj_1_Demand(-1)
}

Set : _Proj_1_Evap
{   condition  :  weekday{year, month, day} <= 1
 value :  stor_to_area { 1140 , storage1140 } * 7 * (timesers(1140/Evap_[ForcCode_1]) / 12 )
   + stor_to_area { 1200 , storage1200 } * 7 * (timesers(1200/Evap_[ForcCode_1]) / 12 )

 Condition : default
    Value     : _Proj_1_Evap(-1)
}

/* Since timestep is daily and forecasts in dss file are weekly, the forecast must be multiplied by 7 */

Set :  _Proj_1_Inflow
{  value :  7 * (timesers(1140/[ForcCode_1]) ) + 7 * (timesers(1200/[ForcCode_1]) )
}


    /* Second Trigger Horizon */
Set : _Proj_2_Demand
```

```
{   Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand1162, 0, +[Forecast_2_Horizon_Days] }  * ( 1 -  pattern(Stage_1_Dem_Red)  )
    // Note:  demand reductions in each stage are cumulative!

    Condition : default
    Value     : _Proj_2_Demand(-1)
}


Set : _Proj_2_Evap
{   condition  :  weekday{year, month, day} <= 1
 value :  stor_to_area { 1140 , storage1140 } * 7 * (timesers(1140/Evap_[ForcCode_2]) / 12 )
   + stor_to_area { 1200 , storage1200 } * 7 * (timesers(1200/Evap_[ForcCode_2]) / 12 )

 Condition : default
    Value     : _Proj_2_Evap(-1)
}

Set :  _Proj_2_Inflow
{  value :  7 * (timesers(1140/[ForcCode_2]) ) + 7 * (timesers(1200/[ForcCode_2]) )
}

    /* Third Trigger Horizon */
Set : _Proj_3_Demand
{   Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand1162, 0, +[Forecast_3_Horizon_Days] }  * ( 1 -  pattern(Stage_2_Dem_Red)  )

    Condition : default
    Value     : _Proj_3_Demand(-1)
}


Set : _Proj_3_Evap
{   condition  :  weekday{year, month, day} <= 1
 value :  stor_to_area { 1140 , storage1140 } * 7 * (timesers(1140/Evap_[ForcCode_3]) / 12 )
   + stor_to_area { 1200 , storage1200 } * 7 * (timesers(1200/Evap_[ForcCode_3]) / 12 )

 Condition : default
    Value     : _Proj_3_Evap(-1)
}


Set :  _Proj_3_Inflow
{  value :  7 * (timesers(1140/[ForcCode_3]) ) + 7 * (timesers(1200/[ForcCode_3]) )
}
```

```
    /* Fourth Trigger Horizon */
Set : _Proj_4_Demand
{   Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand1162, 0, +[Forecast_4_Horizon_Days] }  * ( 1 -  pattern(Stage_3_Dem_Red)  )

    Condition : default
    Value     : _Proj_4_Demand(-1)
}


Set : _Proj_4_Evap
{   condition  :  weekday{year, month, day} <= 1
 value :  stor_to_area { 1140 , storage1140 } * 7 * (timesers(1140/Evap_[ForcCode_4]) / 12 )
   + stor_to_area { 1200 , storage1200 } * 7 * (timesers(1200/Evap_[ForcCode_4]) / 12 )

 Condition : default
    Value     : _Proj_4_Evap(-1)
}


Set :  _Proj_4_Inflow
{  value :  7 * (timesers(1140/[ForcCode_4]) ) + 7 * (timesers(1200/[ForcCode_4]) )
}


// Use this for the refill calculation later on.
Set :  _Proj_5_Inflow
{  value :  7 * (timesers(1140/[ForcCode_5]) ) + 7 * (timesers(1200/[ForcCode_5]) )
}



/*  This section computes the projected water supply storage based on the the demand, inflow, and net
 evaporation for the forecast horizon. Note these udefs are volumetric */

Set : _Proj_1_WSPool
{   Condition : weekday{year, month, day} <= 1
    Value     : min{_Durham_usable_stor(-1) + _Proj_1_Inflow -
                _Proj_1_Evap - _Proj_1_Demand, _Max_Durham_usable_stor}

    Condition : default
    Value     : _Proj_1_WSPool(-1)
}

Set : _Proj_2_WSPool
{   Condition : weekday{year, month, day} <= 1
    Value     : min{_Durham_usable_stor(-1) + _Proj_2_Inflow -
```

```
            _Proj_2_Evap - _Proj_2_Demand, _Max_Durham_usable_stor}

   Condition : default
   Value     : _Proj_2_WSPool(-1)
}


Set : _Proj_3_WSPool
{   Condition : weekday{year, month, day} <= 1
   Value     : min{_Durham_usable_stor(-1) + _Proj_3_Inflow -
            _Proj_3_Evap - _Proj_3_Demand, _Max_Durham_usable_stor}

   Condition : default
   Value     : _Proj_3_WSPool(-1)
}


Set : _Proj_4_WSPool
{   Condition : weekday{year, month, day} <= 1
   Value     : min{_Durham_usable_stor(-1) + _Proj_4_Inflow -
            _Proj_4_Evap - _Proj_4_Demand, _Max_Durham_usable_stor}

   Condition : default
   Value     : _Proj_4_WSPool(-1)
}

/* USE JUST ONE REFILL TRIGGER (PROJ_REFILL) AND ASSUME ALL RESTRICTIONS STAY ON UNTIL TRIGGER IS MET OR
 USABLE STORAGE HITS 95%.  USE INFLOW ASSOCIATED WITH TRIG 5 PARAMETERS.
 USE FULL UNRESTRICTED DEMAND TO BE CONSERVATIVE.  */
Set : _Proj_WSPool_Refill
{   Condition : weekday{year, month, day} <= 1
   Value     : min{_Durham_usable_stor(-1) + _Proj_5_Inflow - _Proj_4_Evap - _Proj_1_Demand, _Max_Durham_usable_stor}

   Condition : default
   Value     : _Proj_WSPool_Refill(-1)
}



/*Set : _Proj_3_WSPool_Refill
{   Condition : weekday{year, month, day} <= 1
   Value     : min{_Durham_usable_stor(-1) + _Proj_4_Inflow - _Proj_3_Evap - _Proj_1_Demand, _Max_Durham_usable_stor}

   Condition : default
   Value     : _Proj_3_WSPool_Refill(-1)
}

```

```

Set : _Proj_2_WSPool_Refill
{   Condition : weekday{year, month, day} <= 1
    Value     : min{_Durham_usable_stor(-1) + _Proj_4_Inflow - _Proj_3_Evap - _Proj_1_Demand, _Max_Durham_usable_stor}

    Condition : default
    Value     : _Proj_2_WSPool_Refill(-1)
}

Set :  _Proj_1_WSPool_Refill
{   Condition : weekday{year, month, day} <= 1
    Value     : min{_Durham_usable_stor(-1) + _Proj_4_Inflow - _Proj_3_Evap - _Proj_1_Demand, _Max_Durham_usable_stor}

    Condition : default
    Value     : _Proj_1_WSPool_Refill(-1)
}
*/


/*  This section evaluates whether the two triggers were on during the
    last time step.  If so, it checks to see whether the water supply pool has refilled,
 in which case the triggers are released.  If the trigger was not on in the last timestep,
 it compares the projected storage with the threshold to determine whether it should be turned on.


    Use 28 day waiting period between restrictions */




Set : _Durham_Trigger_4_On
{
    Condition : _Durham_Trigger_4_On(-1) = 1
    {
        Condition : _Proj_WSPool_Refill >= [Trigger_5_Stor] / 100 * _Max_Durham_usable_stor or _Durham_usable_pct >= 95
        Value     : 0

        Condition : default
        Value     : _Durham_Trigger_4_On(-1)
    }

 Condition : _Durham_Stage_3_Counter(-1) >= 28
  {    Condition : weekday{year, month, day} <= 1
       {
           Condition : _Proj_4_WSPool <= [Trigger_4_Stor] / 100 * _Max_Durham_usable_stor
           Value     : 1
    }
```

```

  Condition : default
     Value     : _Durham_Trigger_4_On(-1)
    }

   Condition : default
   Value     : _Durham_Trigger_4_On(-1)
}



Set : _Durham_Trigger_3_On
{
   Condition : _Durham_Trigger_3_On(-1) = 1
   {
      Condition : _Proj_WSPool_Refill >= [Trigger_5_Stor] / 100 * _Max_Durham_usable_stor or _Durham_usable_pct >= 95
      Value     : 0

      Condition : default
      Value     : _Durham_Trigger_3_On(-1)
   }

 Condition : _Durham_Stage_2_Counter(-1) >= 28
  {    Condition : weekday{year, month, day} <= 1
       {
          Condition : _Proj_3_WSPool <= [Trigger_3_Stor] / 100 * _Max_Durham_usable_stor
          Value     : 1
   }

  Condition : default
     Value     : _Durham_Trigger_3_On(-1)
    }

   Condition : default
   Value     : _Durham_Trigger_3_On(-1)
}





Set : _Durham_Trigger_2_On
{
   Condition : _Durham_Trigger_2_On(-1) = 1
   {
      Condition : _Proj_WSPool_Refill >= [Trigger_5_Stor] / 100 * _Max_Durham_usable_stor or _Durham_usable_pct >= 95
      Value     : 0
```

```

        Condition : default
        Value     : _Durham_Trigger_2_On(-1)
    }

 Condition : _Durham_Stage_1_Counter(-1) >= 28
  {    Condition : weekday{year, month, day} <= 1
        {
           Condition : _Proj_2_WSPool <= [Trigger_2_Stor] / 100 * _Max_Durham_usable_stor
           Value     : 1
    }

   Condition : default
     Value     : _Durham_Trigger_2_On(-1)
     }

    Condition : default
    Value     : _Durham_Trigger_2_On(-1)
}


Set : _Durham_Trigger_1_On
{
    Condition : _Durham_Trigger_1_On(-1) = 1
    {
        Condition : _Proj_WSPool_Refill >= [Trigger_5_Stor] / 100 * _Max_Durham_usable_stor or _Durham_usable_pct >= 95
        Value     : 0

        Condition : default
        Value     : _Durham_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {
        Condition : _Proj_1_WSPool <= [Trigger_1_Stor] / 100 * _Max_Durham_usable_stor or  _Durham_usable_pct < 40
        Value     : 1
    }

    Condition : default
    Value     : _Durham_Trigger_1_On(-1)
}


:FOR:
{   [num] = { 1, 2, 3, 4 }
}

```

```
Set : _Durham_Stage_[num]_Counter
{
   Condition : _Durham_Trigger_[num]_On = 1
   Value     : _Durham_Stage_[num]_Counter(-1) + 1


   Condition : default
   Value     : 0
}

/* When Teer Quarry is active (assumed to be the case in this 2055 run), it is assumed that if in stage 1 drought phase, there would
  be no demand reductions. Teer Quarry supply would allow us to avoid that. */

Set : _Durham_Consvn_[num]_Demand
{
   Condition : _Durham_Trigger_2_On = 1 or _Durham_Trigger_3_On = 1 or _Durham_Trigger_4_On = 1
   Value     : demand1162 * ( 1 -  pattern(Stage_[num]_Dem_Red) )

   Condition : default
   Value     : demand1162
}


Constraint   Durham_Demand_Limit_Consvn_[num] :
          {   Condition  :  _Durham_Trigger_[num]_On = 1
              Expression :  ddelivery1162 <= _Durham_Consvn_[num]_Demand }


Set : _Durham_Ph_[num]_event_counter
{   Condition : _Durham_Stage_[num]_Counter = 5 and _Durham_Stage_[num]_Counter(-1) = 4
   Value     : _Durham_Ph_[num]_event_counter(-1) + 1

   Condition : default
   Value      : _Durham_Ph_[num]_event_counter(-1)
}

:NEXT:

Set :  _Trig_Level_Durham
{  condition  :  _Durham_Trigger_4_On = 1
  value      :  4

  condition  :  _Durham_Trigger_3_On = 1
  value      :  3

  condition  :  _Durham_Trigger_2_On = 1
  value      :  2
```

```

   condition  :  _Durham_Trigger_1_On = 1
   value      :  1

   condition  :  default
   value      :  0
}

:else:

// Otherwise, set the triggers to zero and trig level to 0.  The quarry operations refer to the triggers. This will allow the trig level to be plotted to
// confirm plan was off.


:For: {   [trig] = {1, 2, 3, 4}}

Set : _Durham_Trigger_[trig]_On  {  value  :  0   }

:Next:


Set :  _Trig_Level_Durham   {  value :  0  }


:endif:

```

drought_plans_cf.ocl

```
/* File is drought_plans_cf.ocl.  Computes trigger levels and demand reductions. */

:If: {[Drought_Plans_On] = 1} // First check if drought plan variable is on

:Include: ocl\OWASA_wsrp.ocl // OWASA's forecast-based plan is in a separate OCL file

/* Burlington */
Set : _Burl_Max_Usable_Stor { Value: (upper_rule0070 - lower_rule0070) + (upper_rule0340 - lower_rule0340) }
Set : _Burl_Usable_Stor { Value : min { _Burl_Max_Usable_Stor, storage0070 - lower_rule0070 + storage0340 - lower_rule0340 } }
Set : _Burl_Usable_Stor_Pct { Value : 100 * _Burl_Usable_Stor / _Burl_Max_Usable_Stor }

Set : _Burl_Trigger_6_On { Value : 0 }

Set : _Burl_Trigger_5_On
{   Condition : _Burl_Trigger_5_On(-1) = 1
    {   Condition : _Burl_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Burl_Trigger_5_On(-1)
    }

    Condition : _Burl_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Burl_Usable_Stor_Pct <= 15
              Value     : 1
        }
        Condition : default
        Value     : _Burl_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Burl_Trigger_5_On(-1)
}

Set : _Burl_Trigger_4_On
{   Condition : _Burl_Trigger_4_On(-1) = 1
    {   Condition : _Burl_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Burl_Trigger_4_On(-1)
    }

    Condition : _Burl_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Burl_Usable_Stor_Pct < 30
              Value     : 1
```

```
        }
        Condition : default
        Value     : _Burl_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Burl_Trigger_4_On(-1)
}

Set : _Burl_Trigger_3_On
{   Condition : _Burl_Trigger_3_On(-1) = 1
    {   Condition : _Burl_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Burl_Trigger_3_On(-1)
    }

    Condition : _Burl_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Burl_Usable_Stor_Pct < 45
              Value     : 1
        }
        Condition : default
        Value     : _Burl_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Burl_Trigger_3_On(-1)
}


Set : _Burl_Trigger_2_On
{   Condition : _Burl_Trigger_2_On(-1) = 1
    {   Condition : _Burl_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Burl_Trigger_2_On(-1)
    }

    Condition : _Burl_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Burl_Usable_Stor_Pct < 60
            Value     : 1
        }
        Condition : default
        Value     : _Burl_Trigger_2_On(-1)
    }
```

```
    Condition : default
    Value     : _Burl_Trigger_2_On(-1)
}


Set : _Burl_Trigger_1_On
{   Condition : _Burl_Trigger_1_On(-1) = 1
    {   Condition : _Burl_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Burl_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _Burl_Usable_Stor_Pct < 75
        Value     : 1

        Condition : default
        Value     : _Burl_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Burl_Trigger_1_On(-1)
}

/* Grensboro */
Set : _Gree_Max_Usable_Stor { Value: (upper_rule0120 - lower_rule0120) + (upper_rule0140 - lower_rule0140) }
Set : _Gree_Usable_Stor { Value : min { _Gree_Max_Usable_Stor, (storage0120 - lower_rule0120) + (storage0140 - lower_rule0140) } }
Set : _Gree_Usable_Stor_Pct { Value : 100 * _Gree_Usable_Stor / _Gree_Max_Usable_Stor }
Set : _Gree_DSR { Value :_Gree_Usable_Stor / demand0123 }

Set : _Gree_Trigger_6_On { Value : 0 }

Set : _Gree_Trigger_5_On
{   Condition : _Gree_Trigger_5_On(-1) = 1
    {   Condition : _Gree_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Gree_Trigger_5_On(-1)
    }

    Condition : _Gree_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Gree_DSR <= 75
              Value     : 1
        }
```

```
        Condition : default
        Value     : _Gree_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Gree_Trigger_5_On(-1)
}

Set : _Gree_Trigger_4_On
{   Condition : _Gree_Trigger_4_On(-1) = 1
    {   Condition : _Gree_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Gree_Trigger_4_On(-1)
    }

    Condition : _Gree_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Gree_DSR <= 100
              Value     : 1
        }
        Condition : default
        Value     : _Gree_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Gree_Trigger_4_On(-1)
}

Set : _Gree_Trigger_3_On
{   Condition : _Gree_Trigger_3_On(-1) = 1
    {   Condition : _Gree_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Gree_Trigger_3_On(-1)
    }

    Condition : _Gree_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Gree_DSR <= 125
              Value     : 1
        }
        Condition : default
        Value     : _Gree_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Gree_Trigger_3_On(-1)
```

```
}


Set : _Gree_Trigger_2_On
{   Condition : _Gree_Trigger_2_On(-1) = 1
    {   Condition : _Gree_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Gree_Trigger_2_On(-1)
    }

    Condition : _Gree_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Gree_DSR <= 150
            Value     : 1
        }
        Condition : default
        Value     : _Gree_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Gree_Trigger_2_On(-1)
}


Set : _Gree_Trigger_1_On
{   Condition : _Gree_Trigger_1_On(-1) = 1
    {   Condition : _Gree_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Gree_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _Gree_DSR <= 200 // Note - Drought plan only references 'water levels ... do not conform to
          //seasonal expectation' - subbed in 200 DSR so trigger would activate
        Value     : 1

        Condition : default
        Value     : _Gree_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Gree_Trigger_1_On(-1)
}

/* High Point */
```

```
Set : _High_Max_Usable_Stor { Value: (upper_rule0220- lower_rule0220) }
Set : _High_Usable_Stor { Value : min { _High_Max_Usable_Stor, storage0220 - lower_rule0220  } }
Set : _High_Usable_Stor_Pct { Value : 100 * _High_Usable_Stor / _High_Max_Usable_Stor }

Set : _High_Trigger_6_On  { Value : 0 }

Set : _High_Trigger_5_On  { Value : 0 }

Set : _High_Trigger_4_On
{   Condition : _High_Trigger_4_On(-1) = 1
    {   Condition : _High_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _High_Trigger_4_On(-1)
    }

    Condition : _High_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _High_Usable_Stor_Pct < 40
              Value     : 1
        }
        Condition : default
        Value     : _High_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _High_Trigger_4_On(-1)
}

Set : _High_Trigger_3_On
{   Condition : _High_Trigger_3_On(-1) = 1
    {   Condition : _High_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _High_Trigger_3_On(-1)
    }

    Condition : _High_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _High_Usable_Stor_Pct < 50
              Value     : 1
        }
        Condition : default
        Value     : _High_Trigger_3_On(-1)
    }
    Condition : default
```

```
    Value     : _High_Trigger_3_On(-1)
}


Set : _High_Trigger_2_On
{   Condition : _High_Trigger_2_On(-1) = 1
    {   Condition : _High_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _High_Trigger_2_On(-1)
    }

    Condition : _High_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _High_Usable_Stor_Pct < 60
            Value     : 1
        }
        Condition : default
        Value     : _High_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _High_Trigger_2_On(-1)
}


Set : _High_Trigger_1_On
{   Condition : _High_Trigger_1_On(-1) = 1
    {   Condition : _High_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _High_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _High_Usable_Stor_Pct < 80
        Value     : 1

        Condition : default
        Value     : _High_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _High_Trigger_1_On(-1)
}

/* Reidsville */
```

```
Set : _Reid_Max_Usable_Stor { Value : upper_rule0030 - lower_rule0030 }
Set : _Reid_Usable_Stor { Value : min { _Reid_Max_Usable_Stor, storage0030 - lower_rule0030 } }
Set : _Reid_Usable_Stor_Pct { Value : 100 * _Reid_Usable_Stor / _Reid_Max_Usable_Stor }
Set : _Reid_DSR { Value :_Reid_Usable_Stor / (demand0031) }

Set : _Reid_Trigger_6_On { Value : 0 }

Set : _Reid_Trigger_5_On
{   Condition : _Reid_Trigger_5_On(-1) = 1
    {   Condition : _Reid_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Reid_Trigger_5_On(-1)
    }

    Condition : _Reid_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Reid_DSR <= 50
              Value     : 1
        }
        Condition : default
        Value     : _Reid_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Reid_Trigger_5_On(-1)
}

Set : _Reid_Trigger_4_On
{   Condition : _Reid_Trigger_4_On(-1) = 1
    {   Condition : _Reid_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Reid_Trigger_4_On(-1)
    }

    Condition : _Reid_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Reid_DSR <= 75
              Value     : 1
        }
        Condition : default
        Value     : _Reid_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Reid_Trigger_4_On(-1)
```

```
}

Set : _Reid_Trigger_3_On
{   Condition : _Reid_Trigger_3_On(-1) = 1
    {   Condition : _Reid_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Reid_Trigger_3_On(-1)
    }

    Condition : _Reid_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Reid_DSR <= 100
              Value     : 1
        }
        Condition : default
        Value     : _Reid_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Reid_Trigger_3_On(-1)
}


Set : _Reid_Trigger_2_On
{   Condition : _Reid_Trigger_2_On(-1) = 1
    {   Condition : _Reid_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Reid_Trigger_2_On(-1)
    }

    Condition : _Reid_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Reid_DSR <= 125
            Value     : 1
        }
        Condition : default
        Value     : _Reid_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Reid_Trigger_2_On(-1)
}


Set : _Reid_Trigger_1_On
```

```
{   Condition : _Reid_Trigger_1_On(-1) = 1
    {   Condition : _Reid_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Reid_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _Reid_DSR <= 150
        Value     : 1

        Condition : default
        Value     : _Reid_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Reid_Trigger_1_On(-1)
}

/* Ramseur */
Set : _Rams_Max_Usable_Stor { Value : upper_rule0300- lower_rule0300 }
Set : _Rams_Usable_Stor { Value : min { _Rams_Max_Usable_Stor, storage0300- lower_rule0300 } }
Set : _Rams_Usable_Stor_Pct { Value : 100 * _Rams_Usable_Stor / _Rams_Max_Usable_Stor }

Set : _Rams_Trigger_6_On {Value : 0 }

Set : _Rams_Trigger_5_On
{   Condition : _Rams_Trigger_5_On(-1) = 1
    {   Condition : _Rams_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Rams_Trigger_5_On(-1)
    }

    Condition : _Rams_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Rams_Usable_Stor_Pct <= 0
              Value     : 1
        }
        Condition : default
        Value     : _Rams_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Rams_Trigger_5_On(-1)
}
```

```
Set : _Rams_Trigger_4_On
{   Condition : _Rams_Trigger_4_On(-1) = 1
    {   Condition : _Rams_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Rams_Trigger_4_On(-1)
    }

    Condition : _Rams_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Rams_Usable_Stor_Pct < 67
              Value     : 1
        }
        Condition : default
        Value     : _Rams_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Rams_Trigger_4_On(-1)
}

Set : _Rams_Trigger_3_On
{   Condition : _Rams_Trigger_3_On(-1) = 1
    {   Condition : _Rams_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Rams_Trigger_3_On(-1)
    }

    Condition : _Rams_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Rams_Usable_Stor_Pct < 75
              Value     : 1
        }
        Condition : default
        Value     : _Rams_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Rams_Trigger_3_On(-1)
}


Set : _Rams_Trigger_2_On
{   Condition : _Rams_Trigger_2_On(-1) = 1
    {   Condition : _Rams_Usable_Stor_Pct >= 100
        Value     : 0
```

```

        Condition : default
        Value     : _Rams_Trigger_2_On(-1)
    }

    Condition : _Rams_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Rams_Usable_Stor_Pct < 83
            Value     : 1
        }
        Condition : default
        Value     : _Rams_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Rams_Trigger_2_On(-1)
}


Set : _Rams_Trigger_1_On
{   Condition : _Rams_Trigger_1_On(-1) = 1
    {   Condition : _Rams_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _Rams_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _Rams_Usable_Stor_Pct < 91
        Value     : 1

        Condition : default
        Value     : _Rams_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Rams_Trigger_1_On(-1)
}

/* Graham-Mebane */
Set : _GramMeb_Max_Usable_Stor { Value : upper_rule0320 - lower_rule0320 }
Set : _GramMeb_Usable_Stor { Value : min { _GramMeb_Max_Usable_Stor, storage0320 - lower_rule0320 } }
Set : _GramMeb_Usable_Stor_Pct { Value : 100 * _GramMeb_Usable_Stor / _GramMeb_Max_Usable_Stor }
Set : _GramMeb_DSR { Value :_GramMeb_Usable_Stor / (demand0321) }

Set : _GramMeb_Trigger_6_On { Value : 0 }

Set : _GramMeb_Trigger_5_On
```

```
{   Condition : _GramMeb_Trigger_5_On(-1) = 1
    {   Condition : _GramMeb_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _GramMeb_Trigger_5_On(-1)
    }

    Condition : _GramMeb_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _GramMeb_DSR <= 30
              Value     : 1
        }
        Condition : default
        Value     : _GramMeb_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _GramMeb_Trigger_5_On(-1)
}

Set : _GramMeb_Trigger_4_On
{   Condition : _GramMeb_Trigger_4_On(-1) = 1
    {   Condition : _GramMeb_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _GramMeb_Trigger_4_On(-1)
    }

    Condition : _GramMeb_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _GramMeb_DSR <= 60
              Value     : 1
        }
        Condition : default
        Value     : _GramMeb_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _GramMeb_Trigger_4_On(-1)
}

Set : _GramMeb_Trigger_3_On
{   Condition : _GramMeb_Trigger_3_On(-1) = 1
    {   Condition : _GramMeb_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
```

```
        Value     : _GramMeb_Trigger_3_On(-1)
    }

    Condition : _GramMeb_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _GramMeb_DSR <= 90
              Value     : 1
        }
        Condition : default
        Value     : _GramMeb_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _GramMeb_Trigger_3_On(-1)
}


Set : _GramMeb_Trigger_2_On
{   Condition : _GramMeb_Trigger_2_On(-1) = 1
    {   Condition : _GramMeb_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _GramMeb_Trigger_2_On(-1)
    }

    Condition : _GramMeb_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _GramMeb_DSR <= 120
            Value     : 1
        }
        Condition : default
        Value     : _GramMeb_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _GramMeb_Trigger_2_On(-1)
}


Set : _GramMeb_Trigger_1_On
{   Condition : _GramMeb_Trigger_1_On(-1) = 1
    {   Condition : _GramMeb_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _GramMeb_Trigger_1_On(-1)
    }

```

```
    Condition : weekday{year, month, day} <= 1
    {   Condition : _GramMeb_DSR <= 150
        Value     : 1

        Condition : default
        Value     : _GramMeb_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _GramMeb_Trigger_1_On(-1)
}

/* Siler City */

Set : _Siler_Trigger_6_On  { Value : 0 }
Set : _Siler_Trigger_5_On  { Value : 0 }

Set : _Siler_Trigger_4_On
{   Condition : _Siler_Trigger_4_On(-1) = 1
    {   Condition : _SilerCity_UsableStorPct >= 100
        Value     : 0

        Condition : default
        Value     : _Siler_Trigger_4_On(-1)
    }

    Condition : _Siler_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _SilerCity_UsableStorPct < 10
              Value     : 1
        }
        Condition : default
        Value     : _Siler_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Siler_Trigger_4_On(-1)
}

Set : _Siler_Trigger_3_On
{   Condition : _Siler_Trigger_3_On(-1) = 1
    {   Condition : _SilerCity_UsableStorPct >= 100
        Value     : 0

        Condition : default
        Value     : _Siler_Trigger_3_On(-1)
    }

    Condition : _Siler_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
```

```
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _SilerCity_UsableStorPct < 20
              Value     : 1
        }
        Condition : default
        Value     : _Siler_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Siler_Trigger_3_On(-1)
}


Set : _Siler_Trigger_2_On
{   Condition : _Siler_Trigger_2_On(-1) = 1
    {   Condition : _SilerCity_UsableStorPct >= 100
        Value     : 0

        Condition : default
        Value     : _Siler_Trigger_2_On(-1)
    }

    Condition : _Siler_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _SilerCity_UsableStorPct < 40
            Value     : 1
        }
        Condition : default
        Value     : _Siler_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Siler_Trigger_2_On(-1)
}


Set : _Siler_Trigger_1_On
{   Condition : _Siler_Trigger_1_On(-1) = 1
    {   Condition : _SilerCity_UsableStorPct >= 100
        Value     : 0

        Condition : default
        Value     : _Siler_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _SilerCity_UsableStorPct < 70
        Value     : 1

```

```
        Condition : default
        Value     : _Siler_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Siler_Trigger_1_On(-1)
}

/* Pittsboro - based on intake pool elevation, cannot model without more information */

/* Cary-Apex */
Set : _Cary_DSR
{   Condition : abs_period <= 2
    Value     : ([Starting_Storage_CaryAp] + [Starting_Storage_RTP] + [Starting_Storage_Morris]) / (demand0471 + demand0474 + demand0477)

    Condition : default
    Value     : (_Storage_CaryAp(-1) + _Storage_RTP(-1) + _Storage_Morris(-1))
    / ( ( accumulate {demand0471, -30,-1} + accumulate{demand0474, -30, -1} + accumulate {demand0477, -30, -1} ) / 30 )
}

Set : _Cary_Trigger_6_On  { Value : 0 }
Set : _Cary_Trigger_5_On  { Value : 0 }

Set : _Cary_Trigger_4_On
{   Condition : _Cary_Trigger_4_On(-1) = 1
    {   // condition needs to be met for 14 consecutive days
  Condition : _Cary_DSR(-14) >= 60 and _Cary_DSR(-13) >= 60 and _Cary_DSR(-12) >= 60  and _Cary_DSR(-11) >= 60
     and _Cary_DSR(-10) >= 60  and _Cary_DSR(-9) >= 60 and _Cary_DSR(-8) >= 60 and _Cary_DSR(-7) >= 60
     and _Cary_DSR(-6) >= 60  and _Cary_DSR(-5) >= 60  and _Cary_DSR(-4) >= 60   and _Cary_DSR(-3) >= 60
     and _Cary_DSR(-2) >= 60 and _Cary_DSR(-1) >= 60
        Value     : 0

        Condition : default
        Value     : _Cary_Trigger_4_On(-1)
    }

    Condition : _Cary_Stage_3_Counter(-1) >= 1   // No waiting period required for stage 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Cary_DSR <= 30
              Value     : 1
        }
        Condition : default
        Value     : _Cary_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Cary_Trigger_4_On(-1)
}

```

```
Set : _Cary_Trigger_3_On
{   Condition : _Cary_Trigger_3_On(-1) = 1
    { // condition needs to be met for 14 consecutive days
  Condition : _Cary_DSR(-14) >= 90 and _Cary_DSR(-13) >= 90 and _Cary_DSR(-12) >= 90  and _Cary_DSR(-11) >= 90
     and _Cary_DSR(-10) >= 90  and _Cary_DSR(-9) >= 90 and _Cary_DSR(-8) >= 90 and _Cary_DSR(-7) >= 90
     and _Cary_DSR(-6) >= 90  and _Cary_DSR(-5) >= 90  and _Cary_DSR(-4) >= 90   and _Cary_DSR(-3) >= 90
     and _Cary_DSR(-2) >= 90 and _Cary_DSR(-1) >= 90
        Value     : 0


        Condition : default
        Value     : _Cary_Trigger_3_On(-1)
    }

    Condition : _Cary_Stage_2_Counter(-1) >= 1   // No waiting period required for stage 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Cary_DSR <= 60
              Value     : 1
        }
        Condition : default
        Value     : _Cary_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Cary_Trigger_3_On(-1)
}


Set : _Cary_Trigger_2_On
{   Condition : _Cary_Trigger_2_On(-1) = 1
    {   // condition needs to be met for 14 consecutive days
  Condition : _Cary_DSR(-14) >= 120 and _Cary_DSR(-13) >= 120 and _Cary_DSR(-12) >= 120  and _Cary_DSR(-11) >= 120
     and _Cary_DSR(-10) >= 120 and _Cary_DSR(-9) >= 120 and _Cary_DSR(-8) >= 120 and _Cary_DSR(-7) >= 120
     and _Cary_DSR(-6) >= 120  and _Cary_DSR(-5) >= 120 and _Cary_DSR(-4) >= 120   and _Cary_DSR(-3) >= 120
     and _Cary_DSR(-2) >= 120 and _Cary_DSR(-1) >= 120
        Value     : 0

        Condition : default
        Value     : _Cary_Trigger_2_On(-1)
    }

    Condition : _Cary_Stage_1_Counter(-1) >= 28   // Require a 28 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _Cary_DSR <= 90
            Value     : 1
        }
        Condition : default
        Value     : _Cary_Trigger_2_On(-1)
```

```
    }
    Condition : default
    Value     : _Cary_Trigger_2_On(-1)
}


Set : _Cary_Trigger_1_On
{   Condition : _Cary_Trigger_1_On(-1) = 1
    {   /* condition needs to be met for 14 consecutive days.  WSRP refers to "Jordan Lake Water Supply allocation has been 100% full"
   -  assume that is each of the three accounts that go into the calculation of DSR.*/
  Condition : (_Stor_Final_Pct_CaryAp(-14) >= 100  and _Stor_Final_Pct_CaryAp(-13) >= 100 and _Stor_Final_Pct_CaryAp(-12) >= 100
      and _Stor_Final_Pct_CaryAp(-11) >= 100 and _Stor_Final_Pct_CaryAp(-10) >= 100 and  _Stor_Final_Pct_CaryAp(-9) >= 100
      and _Stor_Final_Pct_CaryAp(-8) >= 100  and _Stor_Final_Pct_CaryAp(-7) >= 100  and _Stor_Final_Pct_CaryAp(-6) >= 100
      and _Stor_Final_Pct_CaryAp(-5) >= 100  and _Stor_Final_Pct_CaryAp(-4) >= 100  and _Stor_Final_Pct_CaryAp(-3) >= 100
      and _Stor_Final_Pct_CaryAp(-2) >= 100  and _Stor_Final_Pct_CaryAp(-1) >= 100 )
     and (_Stor_Final_Pct_RTP(-14) >= 100  and _Stor_Final_Pct_RTP(-13) >= 100 and _Stor_Final_Pct_RTP(-12) >= 100
      and _Stor_Final_Pct_RTP(-11) >= 100 and _Stor_Final_Pct_RTP(-10) >= 100 and _Stor_Final_Pct_RTP(-9) >= 100
      and _Stor_Final_Pct_RTP(-8) >= 100  and _Stor_Final_Pct_RTP(-7) >= 100  and _Stor_Final_Pct_RTP(-6) >= 100
      and _Stor_Final_Pct_RTP(-5) >= 100  and _Stor_Final_Pct_RTP(-4) >= 100   and _Stor_Final_Pct_RTP(-3) >= 100
      and _Stor_Final_Pct_RTP(-2) >= 100  and _Stor_Final_Pct_RTP(-1) >= 100 )
     and (_Stor_Final_Pct_Morris(-14) >= 100  and _Stor_Final_Pct_Morris(-13) >= 100 and _Stor_Final_Pct_Morris(-12) >= 100
      and _Stor_Final_Pct_Morris(-11) >= 100 and _Stor_Final_Pct_Morris(-10) >= 100 and _Stor_Final_Pct_Morris(-9) >= 100
      and _Stor_Final_Pct_Morris(-8) >= 100  and _Stor_Final_Pct_Morris(-7) >= 100  and _Stor_Final_Pct_Morris(-6) >= 100
      and _Stor_Final_Pct_Morris(-5) >= 100  and _Stor_Final_Pct_Morris(-4) >= 100   and _Stor_Final_Pct_Morris(-3) >= 100
      and _Stor_Final_Pct_Morris(-2) >= 100  and _Stor_Final_Pct_Morris(-1) >= 100 )
        Value     : 0

        Condition : default
        Value     : _Cary_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   /* the plan calls for turning on trigger 1 if DSR <= 120 days.  However, for the 2055 demand year, the demands are high enough
   to cause the trigger to be met even if the storage account is full.So add in a condition that trigger can only turn on if
   the DSR condition is met and storage in the Cary account is <= 80%.  */
  Condition : _Cary_DSR <= 120 and _Stor_Final_Pct_CaryAp(-1) < 80
        Value     : 1

        Condition : default
        Value     : _Cary_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Cary_Trigger_1_On(-1)
}

/* Chatham North */
Set : _ChatNo_Usable_Stor_Pct
```

```
{   Condition : abs_period <= 1
    Value     : 100

    Condition : default
    Value     : _Stor_Final_Pct_Chatham(-1)
}

Set : _ChatNo_Trigger_6_On  {Value : 0 }

Set : _ChatNo_Trigger_5_On
{   Condition : _ChatNo_Trigger_5_On(-1) = 1
    {   Condition : _ChatNo_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _ChatNo_Trigger_5_On(-1)
    }

    Condition : _ChatNo_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _ChatNo_Usable_Stor_Pct < 0
              Value     : 1
        }
        Condition : default
        Value     : _ChatNo_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _ChatNo_Trigger_5_On(-1)
}

Set : _ChatNo_Trigger_4_On
{   Condition : _ChatNo_Trigger_4_On(-1) = 1
    {   Condition : _ChatNo_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _ChatNo_Trigger_4_On(-1)
    }

    Condition : _ChatNo_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _ChatNo_Usable_Stor_Pct < 30
              Value     : 1
        }
        Condition : default
        Value     : _ChatNo_Trigger_4_On(-1)
    }
```

```
    Condition : default
    Value     : _ChatNo_Trigger_4_On(-1)
}

Set : _ChatNo_Trigger_3_On
{   Condition : _ChatNo_Trigger_3_On(-1) = 1
    {   Condition : _ChatNo_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _ChatNo_Trigger_3_On(-1)
    }

    Condition : _ChatNo_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _ChatNo_Usable_Stor_Pct < 50
              Value     : 1
        }
        Condition : default
        Value     : _ChatNo_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _ChatNo_Trigger_3_On(-1)
}


Set : _ChatNo_Trigger_2_On
{   Condition : _ChatNo_Trigger_2_On(-1) = 1
    {   Condition : _ChatNo_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _ChatNo_Trigger_2_On(-1)
    }

    Condition : _ChatNo_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _ChatNo_Usable_Stor_Pct < 65
            Value     : 1
        }
        Condition : default
        Value     : _ChatNo_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _ChatNo_Trigger_2_On(-1)
}
```

```

Set : _ChatNo_Trigger_1_On
{   Condition : _ChatNo_Trigger_1_On(-1) = 1
    {   Condition : _ChatNo_Usable_Stor_Pct >= 100
        Value     : 0

        Condition : default
        Value     : _ChatNo_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _ChatNo_Usable_Stor_Pct < 75
        Value     : 1

        Condition : default
        Value     : _ChatNo_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _ChatNo_Trigger_1_On(-1)
}

/* Sanford - demand/production based - not modeled */

/* Harnett Co. - mostly demand based - not modeled */


/* Dunn */

Set : _Dunn_Trigger_6_On
{   Condition : _Dunn_Trigger_5_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 100, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_6_On(-1)
    }

    Condition : _Dunn_Stage_5_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0555.0650 < convert_units { 100, cfs, af } and flow0555.0650(-1) < convert_units { 100, cfs, af } and
                          flow0555.0650(-2) < convert_units { 100, cfs, af } and flow0555.0650(-3) < convert_units { 100, cfs, af } and
                          flow0555.0650(-4) < convert_units { 100, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Dunn_Trigger_6_On(-1)
    }
```

```
    Condition : default
    Value     : _Dunn_Trigger_6_On(-1)
}

Set : _Dunn_Trigger_5_On
{   Condition : _Dunn_Trigger_5_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 125, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_5_On(-1)
    }

    Condition : _Dunn_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0555.0650 < convert_units { 125, cfs, af } and flow0555.0650(-1) < convert_units { 125, cfs, af } and
                          flow0555.0650(-2) < convert_units { 125, cfs, af } and flow0555.0650(-3) < convert_units { 125, cfs, af } and
                          flow0555.0650(-4) < convert_units { 125, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Dunn_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Dunn_Trigger_5_On(-1)
}

Set : _Dunn_Trigger_4_On
{   Condition : _Dunn_Trigger_4_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 150, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_4_On(-1)
    }

    Condition : _Dunn_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0555.0650 < convert_units { 150, cfs, af } and flow0555.0650(-1) < convert_units { 150, cfs, af } and
                          flow0555.0650(-2) < convert_units { 150, cfs, af } and flow0555.0650(-3) < convert_units { 150, cfs, af } and
                          flow0555.0650(-4) < convert_units { 150, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Dunn_Trigger_4_On(-1)
    }
    Condition : default
```

```
    Value     : _Dunn_Trigger_4_On(-1)
}

Set : _Dunn_Trigger_3_On
{   Condition : _Dunn_Trigger_3_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 175, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_3_On(-1)
    }

    Condition : _Dunn_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0555.0650 < convert_units { 175, cfs, af } and flow0555.0650(-1) < convert_units { 175, cfs, af } and
                          flow0555.0650(-2) < convert_units { 175, cfs, af } and flow0555.0650(-3) < convert_units { 175, cfs, af } and
                          flow0555.0650(-4) < convert_units { 175, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Dunn_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Dunn_Trigger_3_On(-1)
}


Set : _Dunn_Trigger_2_On
{   Condition : _Dunn_Trigger_2_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 200, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_2_On(-1)
    }

    Condition : _Dunn_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0555.0650 < convert_units { 200, cfs, af } and flow0555.0650(-1) < convert_units { 200, cfs, af } and
                          flow0555.0650(-2) < convert_units { 200, cfs, af } and flow0555.0650(-3) < convert_units { 200, cfs, af } and
                          flow0555.0650(-4) < convert_units { 200, cfs, af }
            Value     : 1
        }
        Condition : default
        Value     : _Dunn_Trigger_2_On(-1)
    }
    Condition : default
```

```
    Value     : _Dunn_Trigger_2_On(-1)
}


Set : _Dunn_Trigger_1_On
{   Condition : _Dunn_Trigger_1_On(-1) = 1
    {   Condition : flow0555.0650 > convert_units { 225, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Dunn_Trigger_1_On(-1)
    }

    // Assume no waiting period since Dunn_Trigger 1 only drought alert
    Condition : weekday{year, month, day} <= 1
    {   Condition : flow0555.0650 < convert_units { 225, cfs, af } and flow0555.0650(-1) < convert_units { 225, cfs, af } and
                    flow0555.0650(-2) < convert_units { 225, cfs, af } and flow0555.0650(-3) < convert_units { 225, cfs, af } and
                    flow0555.0650(-4) < convert_units { 225, cfs, af }
        Value     : 1

        Condition : default
        Value     : _Dunn_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Dunn_Trigger_1_On(-1)
}

/* Benson - triggers follow those of Dunn - their main supplier */

Set : _Benson_Trigger_6_On
{       Condition : default
        Value     : _Dunn_Trigger_6_On
}

Set : _Benson_Trigger_5_On
{       Condition : default
        Value     : _Dunn_Trigger_5_On
}

Set : _Benson_Trigger_4_On
{       Condition : default
        Value     : _Dunn_Trigger_4_On
}

Set : _Benson_Trigger_3_On
{       Condition : default
        Value     : _Dunn_Trigger_3_On
```

```
}

Set : _Benson_Trigger_2_On
{       Condition : default
        Value     : _Dunn_Trigger_2_On
}

Set : _Benson_Trigger_1_On
{       Condition : default
        Value     : _Dunn_Trigger_1_On
}





/* Carthage - Trigger based on Nicks Creek - using arc 700.710 Little River_Linden gage in model since that is where their WD is from */
Set : _Carth_Trigger_6_On  {Value : 0}
Set : _Carth_Trigger_5_On  {Value : 0}

Set : _Carth_Trigger_4_On
{   Condition : _Carth_Trigger_4_On(-1) = 1
    {   Condition : flow0700.0710 > convert_units { 0.50, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Carth_Trigger_4_On(-1)
    }

    Condition : _Carth_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0700.0710 < convert_units { 0.50, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Carth_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Carth_Trigger_4_On(-1)
}

Set : _Carth_Trigger_3_On
{   Condition : _Carth_Trigger_3_On(-1) = 1
    {   Condition : flow0700.0710 > convert_units { 1.50, cfs, af }
        Value     : 0

        Condition : default
```

```
        Value     : _Carth_Trigger_3_On(-1)
    }

    Condition : _Carth_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0700.0710 < convert_units { 1.50, cfs, af } and flow0700.0710(-1) < convert_units { 1.50, cfs, af } and
                          flow0700.0710(-2) < convert_units { 1.50, cfs, af }
              Value     : 1
        }
        Condition : default
        Value     : _Carth_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Carth_Trigger_3_On(-1)
}


Set : _Carth_Trigger_2_On
{   Condition : _Carth_Trigger_2_On(-1) = 1
    {   Condition : flow0700.0710 > convert_units { 2.40, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Carth_Trigger_2_On(-1)
    }

    Condition : _Carth_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : flow0700.0710 < convert_units { 2.40, cfs, af } and flow0700.0710(-1) < convert_units { 2.40, cfs, af } and
                          flow0700.0710(-2) < convert_units { 2.40, cfs, af }
            Value     : 1
        }
        Condition : default
        Value     : _Carth_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Carth_Trigger_2_On(-1)
}


Set : _Carth_Trigger_1_On
{   Condition : _Carth_Trigger_1_On(-1) = 1
    {   Condition : flow0700.0710 > convert_units { 3, cfs, af }
        Value     : 0

        Condition : default
        Value     : _Carth_Trigger_1_On(-1)
```

```
    }

    // Assume no waiting period since Carth_Trigger 1 only drought alert
    Condition : weekday{year, month, day} <= 1
    {   Condition : flow0700.0710 < convert_units { 3, cfs, af } and flow0700.0710(-1) < convert_units { 3, cfs, af } and
                    flow0700.0710(-2) < convert_units { 3, cfs, af } and flow0700.0710(-3) < convert_units { 3, cfs, af } and
                    flow0700.0710(-4) < convert_units { 3, cfs, af } and flow0700.0710(-5) < convert_units { 3, cfs, af } and
                    flow0700.0710(-6) < convert_units { 3, cfs, af }
        Value     : 1

        Condition : default
        Value     : _Carth_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Carth_Trigger_1_On(-1)
}

/* Fayetteville - mostly demand based (w/ one Lillington trigger), so leaving out for now */



/*  This section sets/resets the counters used to maintain the proper spacing of conservation stages */

:For:
{ [Util] = { Burl, Gree, High, Reid, Rams, GramMeb, Siler, Cary, ChatNo, Dunn, Carth, Benson }
}

:For:
{   [trig] = {1, 2, 3, 4, 5, 6}
}

Set : _[Util]_Stage_[trig]_Counter
{   Condition : _[Util]_Stage_[trig]_Counter(-1) > 0 and _[Util]_Trigger_[trig]_On = 0
    Value     : 0

    Condition : _[Util]_Trigger_[trig]_On = 1
    Value     : _[Util]_Stage_[trig]_Counter(-1) + 1

    Condition : default
    Value     : _[Util]_Stage_[trig]_Counter(-1)
}

/*  Count all trigger events lasting at least 7 days */

Set : _[Util]_Ph_[trig]_event_counter
{   Condition : _[Util]_Stage_[trig]_Counter = 7 and _[Util]_Stage_[trig]_Counter(-1) = 6
    Value     : _[Util]_Ph_[trig]_event_counter(-1) + 1
```

```

   Condition : default
   Value      : _[Util]_Ph_[trig]_event_counter(-1)
}

:Next:

:Next:


// Set conservation demand and delivery constraints for each trigger level in effect.

// Set demand reduction factors
:SUBSTITUTE: [Dem_1_Red_Factor] = 5
:SUBSTITUTE: [Dem_2_Red_Factor] = 10
:SUBSTITUTE: [Dem_3_Red_Factor] = 20
:SUBSTITUTE: [Dem_4_Red_Factor] = 25
:SUBSTITUTE: [Dem_5_Red_Factor] = 35
:SUBSTITUTE: [Dem_6_Red_Factor] = 50

:For:
{   [trig] = {1, 2, 3, 4, 5, 6}
}



// Burlington
Set : _Burl2_Consvn_[trig]_Demand
{   Condition : _Burl_Trigger_[trig]_On = 1
    Value     : Demand0341 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0341
}

Constraint   Burl2_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _Burl_Trigger_[trig]_On = 1
                Expression :  dflow0071.0341 <= _Burl2_Consvn_[trig]_Demand }

// Greensboro
Set : _Gree2_Consvn_[trig]_Demand
{   Condition : _Gree_Trigger_[trig]_On = 1
    Value     : Demand0123 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0123
}
```

```

Constraint   Gree2_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _Gree_Trigger_[trig]_On = 1
                Expression :  dflow0121.0123 <= _Gree2_Consvn_[trig]_Demand }

// High Point
Set : _High_Consvn_[trig]_Demand
{   Condition : _High_Trigger_[trig]_On = 1
    Value     : Demand0223 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0223
}

Constraint   High_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _High_Trigger_[trig]_On = 1
                Expression :  dflow0220.0221 <= _High_Consvn_[trig]_Demand }

// Reidsville
Set : _Reid_Consvn_[trig]_Demand
{   Condition : _Reid_Trigger_[trig]_On = 1
    Value     : Demand0031 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0031
}

Constraint   Reid_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _Reid_Trigger_[trig]_On = 1
                Expression :  dflow0029.0031 <= _Reid_Consvn_[trig]_Demand }

// Ramseur
Set : _Rams_Consvn_[trig]_Demand
{   Condition : _Rams_Trigger_[trig]_On = 1
    Value     : Demand0301 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0301
}

Constraint   Rams_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _Rams_Trigger_[trig]_On = 1
                Expression :  dflow0300.0301 <= _Rams_Consvn_[trig]_Demand }

// Graham-Mebane
Set : _GramMeb_Consvn_[trig]_Demand
{   Condition : _GramMeb_Trigger_[trig]_On = 1
```

```
   Value    : Demand0321 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

   Condition : default
   Value    : Demand0321
}

Constraint   GramMeb_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _GramMeb_Trigger_[trig]_On = 1
              Expression :  dflow0319.0321 <= _GramMeb_Consvn_[trig]_Demand }

// Siler City
Set : _Siler_Consvn_[trig]_Demand
{   Condition : _Siler_Trigger_[trig]_On = 1
   Value    : Demand0327 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

   Condition : default
   Value    : Demand0327
}

Constraint   Siler_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _Siler_Trigger_[trig]_On = 1
              Expression :  dflow0325.0327 <= _Siler_Consvn_[trig]_Demand }

// Chatham-North
Set : _ChatNo_Consvn_[trig]_Demand
{   Condition : _ChatNo_Trigger_[trig]_On = 1
   Value    : Demand0473 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

   Condition : default
   Value    : Demand0473
}

Constraint   ChatNo_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _ChatNo_Trigger_[trig]_On = 1
              Expression :  dflow0470.0473 <= _ChatNo_Consvn_[trig]_Demand }

// Dunn
Set : _Dunn_Consvn_[trig]_Demand
{   Condition : _Dunn_Trigger_[trig]_On = 1
   Value    : Demand0663 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

   Condition : default
   Value    : Demand0663
}

Constraint   Dunn_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _Dunn_Trigger_[trig]_On = 1
```

```
            Expression :  dflow0662.0663 <= _Dunn_Consvn_[trig]_Demand }

//Benson
Set : _Benson_Consvn_[trig]_Demand
{   Condition : _Benson_Trigger_[trig]_On = 1
    Value     : Demand1756 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand1756
}

Constraint   Benson_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _Benson_Trigger_[trig]_On = 1
              Expression :  dflow0662.1756 <= _Benson_Consvn_[trig]_Demand }

// Carthage
Set : _Carth_Consvn_[trig]_Demand
{   Condition : _Carth_Trigger_[trig]_On = 1
    Value     : Demand0701 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand0701
}

Constraint   Carth_Demand_Limit_Consvn_[trig] :
          {   Condition  :  _Carth_Trigger_[trig]_On = 1
              Expression :  dflow0700.0701 <= _Carth_Consvn_[trig]_Demand }


:Next:

// Set Cary's Consv Demand - differs seasonally

Set : _Cary_Consvn_1_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_1_On = 1
    Value     : Demand0471 * ( 1 - 13 / 100 )

    Condition : _Cary_Trigger_1_On = 1
    Value     : Demand0471 * ( 1 - 6 / 100 )

    Condition : default
    Value     : Demand0471
}

Set : _Cary_Consvn_2_Demand
{
```

```
    Condition : month > 4 and month < 11 and _Cary_Trigger_2_On = 1
    Value     : Demand0471 * ( 1 - 32 / 100 )

    Condition : _Cary_Trigger_2_On = 1
    Value     : Demand0471 * ( 1 - 10 / 100 )

    Condition : default
    Value     : Demand0471
}

Set : _Cary_Consvn_3_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_3_On = 1
    Value     : Demand0471 * ( 1 - 38 / 100 )

    Condition : _Cary_Trigger_3_On = 1
    Value     : Demand0471 * ( 1 - 17 / 100 )

    Condition : default
    Value     : Demand0471
}

Set : _Cary_Consvn_4_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_4_On = 1
    Value     : Demand0471 * ( 1 - 46 / 100 )

    Condition : _Cary_Trigger_4_On = 1
    Value     : Demand0471 * ( 1 - 29 / 100 )

    Condition : default
    Value     : Demand0471
}

:For:
{   [trig] = {1, 2, 3, 4}
}

Constraint   Cary_Demand_Limit_Consvn_[trig] :
{   Condition  :  _Cary_Trigger_[trig]_On = 1
    Expression :  dflow0479.0471 <= _Cary_Consvn_[trig]_Demand }

:Next:

// Includes Morrisville & RTP

Set : _RTP_Consvn_1_Demand
```

```
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_1_On = 1
    Value     : Demand0474 * ( 1 - 13 / 100 )

    Condition : _Cary_Trigger_1_On = 1
    Value     : Demand0474 * ( 1 - 6 / 100 )

    Condition : default
    Value     : Demand0474
}

Set : _RTP_Consvn_2_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_2_On = 1
    Value     : Demand0474 * ( 1 - 32 / 100 )

    Condition : _Cary_Trigger_2_On = 1
    Value     : Demand0474 * ( 1 - 10 / 100 )

    Condition : default
    Value     : Demand0474
}

Set : _RTP_Consvn_3_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_3_On = 1
    Value     : Demand0474 * ( 1 - 38 / 100 )

    Condition : _Cary_Trigger_3_On = 1
    Value     : Demand0471 * ( 1 - 17 / 100 )

    Condition : default
    Value     : Demand0474
}

Set : _RTP_Consvn_4_Demand
{
    Condition : month > 4 and month < 11 and _Cary_Trigger_4_On = 1
    Value     : Demand0474 * ( 1 - 46 / 100 )

    Condition : _Cary_Trigger_4_On = 1
    Value     : Demand0474 * ( 1 - 29 / 100 )

    Condition : default
    Value     : Demand0474
}
```

```
:For:
{   [trig] = {1, 2, 3, 4}
}

Constraint   RTP_Demand_Limit_Consvn_[trig] :
{   Condition  :  _Cary_Trigger_[trig]_On = 1
    Expression :  dflow0479.0474 <= _RTP_Consvn_[trig]_Demand }

:Next:

Set : _Morris_Consvn_1_Demand
{
    Condition : month > 4 and month < 11 and  _Cary_Trigger_1_On = 1
    Value     : Demand0477 * ( 1 - 13 / 100 )

    Condition :  _Cary_Trigger_1_On = 1
    Value     : Demand0477 * ( 1 - 6 / 100 )

    Condition : default
    Value     : Demand0471
}

Set : _Morris_Consvn_2_Demand
{
    Condition : month > 4 and month < 11 and  _Cary_Trigger_2_On = 1
    Value     : Demand0477 * ( 1 - 32 / 100 )

    Condition :  _Cary_Trigger_2_On = 1
    Value     : Demand0477 * ( 1 - 10 / 100 )

    Condition : default
    Value     : Demand0477
}

Set : _Morris_Consvn_3_Demand
{
    Condition : month > 4 and month < 11 and  _Cary_Trigger_3_On = 1
    Value     : Demand0477 * ( 1 - 38 / 100 )

    Condition :  _Cary_Trigger_3_On = 1
    Value     : Demand0477 * ( 1 - 17 / 100 )

    Condition : default
    Value     : Demand0477
}

Set : _Morris_Consvn_4_Demand
```

```
{
    Condition : month > 4 and month < 11 and  _Cary_Trigger_4_On = 1
    Value     : Demand0477 * ( 1 - 46 / 100 )

    Condition :  _Cary_Trigger_4_On = 1
    Value     : Demand0477 * ( 1 - 29 / 100 )

    Condition : default
    Value     : Demand0477
}

:For:
{   [trig] = {1, 2, 3, 4}
}

Constraint   Morris_Demand_Limit_Consvn_[trig] :
{   Condition  :   _Cary_Trigger_[trig]_On = 1
    Expression :  dflow0479.0477 <= _Morris_Consvn_[trig]_Demand }

:Next:




:else:
// Do nothing if not using drought plans
:endif:
```

drought_plans_neuse.ocl

```
/* File is drought_plans_neuse.ocl.  Computes trigger levels and demand reductions. */

:If: {[Drought_Plans_On] = 1} // First check if drought plan variable is on

//Note - Hillsborough and Orange-Alamance drought restrictions are handled in upper_eno_ops.ocl




// Raleigh -Turn triggers on based on monthly curves. Triggers are lifted when storage is above the trigger storage + 20% */
Set : _Ral_Trigger_1_On
{
   Condition : _Ral_Trigger_1_On(-1) = 1
   {
      Condition : _Total_WS_Stor(-1) >= min { (lookup{ Ral_Trig1, month } + 20) / 100 *  [Total_Max_WS_Storage], [Total_Max_WS_Storage] }
      Value    : 0

      Condition : default
      Value    : _Ral_Trigger_1_On(-1)
   }

   Condition : weekday{year, month, day} <= 1
   {
      Condition : _Total_WS_Stor(-1)  <= lookup{ Ral_Trig1, month } / 100 *  [Total_Max_WS_Storage]
      Value    : 1
   }

   Condition : default
   Value    : _Ral_Trigger_1_On(-1)
}

Set : _Ral_Trigger_2_On
{
   Condition : _Ral_Trigger_2_On(-1) = 1
   {
      Condition : _Total_WS_Stor(-1) >= (lookup{ Ral_Trig2, month } + 20) / 100 *  [Total_Max_WS_Storage] //Total max ws storage
      Value    : 0

      Condition : default
      Value    : _Ral_Trigger_2_On(-1)
   }

 Condition : _Ral_Stage_1_Counter(-1) >= 30
  {    Condition : weekday{year, month, day} <= 1
      {
         Condition : _Total_WS_Stor(-1) <= lookup{ Ral_Trig2, month } / 100 *  [Total_Max_WS_Storage]
         Value    : 1
```

```
    }

   Condition : default
      Value     : _Ral_Trigger_2_On(-1)
     }

    Condition : default
    Value     : _Ral_Trigger_2_On(-1)
}

Set : _Ral_Trigger_3_On
{
    Condition : _Ral_Trigger_3_On(-1) = 1
    {
        Condition : _Total_WS_Stor(-1) >= (lookup{ Ral_Trig3, month } + 20) / 100 *  [Total_Max_WS_Storage]
        Value     : 0

        Condition : default
        Value     : _Ral_Trigger_3_On(-1)
    }

 Condition : _Ral_Stage_2_Counter(-1) >= 30
  {    Condition : weekday{year, month, day} <= 1
       {
           Condition : _Total_WS_Stor(-1) <= lookup{ Ral_Trig3, month } / 100 *  [Total_Max_WS_Storage]
           Value     : 1
    }

   Condition : default
      Value     : _Ral_Trigger_3_On(-1)
     }

    Condition : default
    Value     : _Ral_Trigger_3_On(-1)
}

/*  This section sets/resets the counters used to maintain the proper spacing
    of conservation stages */

Set : _Ral_Stage_1_Counter
{
    Condition : _Ral_Stage_1_Counter(-1) > 0
    {
        Condition : _Total_WS_Stor(-1) >= min { (lookup{ Ral_Trig1, month } + 20) / 100 *  [Total_Max_WS_Storage], [Total_Max_WS_Storage] }
        Value     : 0
    }

```

```
   Condition : _Ral_Trigger_1_On = 1
   Value     : _Ral_Stage_1_Counter(-1) + 1


   Condition : default
   Value     : _Ral_Stage_1_Counter(-1)
}


Set : _Ral_Stage_2_Counter
{
   Condition : _Ral_Stage_2_Counter(-1) > 0
   {
      Condition : _Total_WS_Stor(-1) >= (lookup{ Ral_Trig2, month } + 20) / 100 *  [Total_Max_WS_Storage]
      Value     : 0
   }

   Condition : _Ral_Trigger_2_On = 1
   Value     : _Ral_Stage_2_Counter(-1) + 1


   Condition : default
   Value     : _Ral_Stage_2_Counter(-1)
}

Set : _Ral_Stage_3_Counter
{
   Condition : _Ral_Stage_3_Counter(-1) > 0
   {
      Condition : _Total_WS_Stor(-1) >= (lookup{ Ral_Trig3, month } + 20) / 100 *  [Total_Max_WS_Storage]
      Value     : 0
   }

   Condition : _Ral_Trigger_3_On = 1
   Value     : _Ral_Stage_3_Counter(-1) + 1


   Condition : default
   Value     : _Ral_Stage_3_Counter(-1)
}



/*  This section determines the demand depending upon which level of conservation
   is in place. */

Set : _Ral_Consvn_1_Demand
```

```
{
   Condition : _Ral_Trigger_1_On = 1
   Value     : Demand1306 * ( 1 - ( lookup { Raleigh_Stage1_Red, month } ) / 100 )

   Condition : default
   Value     : Demand1306
}

Set : _Ral_Consvn_2_Demand
{
 Condition : _Ral_Trigger_2_On = 1
   Value     : Demand1306 * ( 1 - ( lookup { Raleigh_Stage1_Red, month } + lookup { Raleigh_Stage2_Red, month } ) / 100 )

   Condition : default
   Value     : Demand1306
}

Set : _Ral_Consvn_3_Demand
{
 Condition : _Ral_Trigger_3_On = 1
   Value     : Demand1306 * ( 1 - ( lookup { Raleigh_Stage1_Red, month } + lookup { Raleigh_Stage2_Red, month }
   + lookup { Raleigh_Stage3_Red, month } ) / 100 )

   Condition : default
   Value     : Demand1306
}

/* Constrain the water supply withdrawal to implement the desired conservation */

Constraint   Demand_Limit_Consvn_1 :
          {   Condition  :  _Ral_Trigger_1_On = 1
              Expression :  ddelivery1306 <= _Ral_Consvn_1_Demand }

Constraint   Demand_Limit_Consvn_2 :
          {   Condition  :  _Ral_Trigger_2_On = 1
              Expression :  ddelivery1306 <= _Ral_Consvn_2_Demand }

Constraint   Demand_Limit_Consvn_3 :
          {   Condition  :  _Ral_Trigger_3_On = 1
              Expression :  ddelivery1306 <= _Ral_Consvn_3_Demand }


/*  Turn on event counter whenever duration exceeds 4 days */

Set : _Ral_Ph_1_event_counter
{   Condition : _Ral_Stage_1_Counter = 5 and _Ral_Stage_1_Counter(-1) = 4
   Value     : _Ral_Ph_1_event_counter(-1) + 1
```

```

    Condition : default
    Value      : _Ral_Ph_1_event_counter(-1)
}

Set : _Ral_Ph_2_event_counter
{   Condition : _Ral_Stage_2_Counter = 5  and _Ral_Stage_2_Counter(-1) = 4
    Value     : _Ral_Ph_2_event_counter(-1) + 1

    Condition : default
    Value      : _Ral_Ph_2_event_counter(-1)
}

Set : _Ral_Ph_3_event_counter
{   Condition : _Ral_Stage_3_Counter = 5  and _Ral_Stage_3_Counter(-1) = 4
    Value     : _Ral_Ph_3_event_counter(-1) + 1

    Condition : default
    Value      : _Ral_Ph_3_event_counter(-1)
}

// SGWASA

Set : _SGWASA_Trigger_5_On
{   Condition : _SGWASA_Trigger_5_On(-1) = 1
    {   Condition : elevation1250 >= 356
        Value     : 0

        Condition : default
        Value     : _SGWASA_Trigger_5_On(-1)
    }

    Condition : _SGWASA_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1250<= 320
              Value     : 1
        }
        Condition : default
        Value     : _SGWASA_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _SGWASA_Trigger_5_On(-1)
}

Set : _SGWASA_Trigger_4_On
{   Condition : _SGWASA_Trigger_4_On(-1) = 1
    {   Condition : elevation1250 >= 356
```

```
        Value     : 0

        Condition : default
        Value     : _SGWASA_Trigger_4_On(-1)
    }

    Condition : _SGWASA_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1250< 340.5
              Value     : 1
        }
        Condition : default
        Value     : _SGWASA_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _SGWASA_Trigger_4_On(-1)
}

Set : _SGWASA_Trigger_3_On
{   Condition : _SGWASA_Trigger_3_On(-1) = 1
    {   Condition : elevation1250 >= 356
        Value     : 0

        Condition : default
        Value     : _SGWASA_Trigger_3_On(-1)
    }

    Condition : _SGWASA_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1250< 343.08
              Value     : 1
        }
        Condition : default
        Value     : _SGWASA_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _SGWASA_Trigger_3_On(-1)
}


Set : _SGWASA_Trigger_2_On
{   Condition : _SGWASA_Trigger_2_On(-1) = 1
    {   Condition : elevation1250 >= 356
        Value     : 0

        Condition : default
        Value     : _SGWASA_Trigger_2_On(-1)
```

```
    }

    Condition : _SGWASA_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1250< 345.25
         Value     : 1
        }
        Condition : default
        Value     : _SGWASA_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _SGWASA_Trigger_2_On(-1)
}


Set : _SGWASA_Trigger_1_On
{   Condition : _SGWASA_Trigger_1_On(-1) = 1
    {   Condition : elevation1250 >= 356
        Value     : 0

        Condition : default
        Value     : _SGWASA_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : elevation1250< 349.67
        Value     : 1

        Condition : default
        Value     : _SGWASA_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _SGWASA_Trigger_1_On(-1)
}

// Wilson

Set : _Wilson_Trigger_5_On
{   Condition : _Wilson_Trigger_5_On(-1) = 1
    {   Condition : elevation1500 >= 148
        Value     : 0

        Condition : default
        Value     : _Wilson_Trigger_5_On(-1)
    }

    Condition : _Wilson_Stage_4_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 5
```

```
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1500<= 135
              Value     : 1
        }
        Condition : default
        Value     : _Wilson_Trigger_5_On(-1)
    }
    Condition : default
    Value     : _Wilson_Trigger_5_On(-1)
}

Set : _Wilson_Trigger_4_On
{   Condition : _Wilson_Trigger_4_On(-1) = 1
    {   Condition : elevation1500 >= 148
        Value     : 0

        Condition : default
        Value     : _Wilson_Trigger_4_On(-1)
    }

    Condition : _Wilson_Stage_3_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 4
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1500< 138
              Value     : 1
        }
        Condition : default
        Value     : _Wilson_Trigger_4_On(-1)
    }
    Condition : default
    Value     : _Wilson_Trigger_4_On(-1)
}

Set : _Wilson_Trigger_3_On
{   Condition : _Wilson_Trigger_3_On(-1) = 1
    {   Condition : elevation1500 >= 148
        Value     : 0

        Condition : default
        Value     : _Wilson_Trigger_3_On(-1)
    }

    Condition : _Wilson_Stage_2_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1500< 140
     Value     : 1
        }
        Condition : default
```

```
        Value     : _Wilson_Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Wilson_Trigger_3_On(-1)
}


Set : _Wilson_Trigger_2_On
{   Condition : _Wilson_Trigger_2_On(-1) = 1
    {   Condition : elevation1500 >= 148
        Value     : 0

        Condition : default
        Value     : _Wilson_Trigger_2_On(-1)
    }

    Condition : _Wilson_Stage_1_Counter(-1) >= 14   // Require a 14 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : elevation1500< 142
     Value     : 1
        }
        Condition : default
        Value     : _Wilson_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _Wilson_Trigger_2_On(-1)
}


Set : _Wilson_Trigger_1_On
{   Condition : _Wilson_Trigger_1_On(-1) = 1
    {   Condition : elevation1500 >= 148
        Value     : 0

        Condition : default
        Value     : _Wilson_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : elevation1500< 144
        Value     : 1

        Condition : default
        Value     : _Wilson_Trigger_1_On(-1)
    }
    Condition : default
    Value     : _Wilson_Trigger_1_On(-1)
```

```
}

/*  This section sets/resets the counters used to maintain the proper spacing of conservation stages */

:For:
{ [Util] = { SGWASA, Wilson }
}

:For:
{   [trig] = {1, 2, 3, 4, 5}
}

Set : _[Util]_Stage_[trig]_Counter
{   Condition : _[Util]_Stage_[trig]_Counter(-1) > 0 and _[Util]_Trigger_[trig]_On = 0
    Value     : 0

    Condition : _[Util]_Trigger_[trig]_On = 1
    Value     : _[Util]_Stage_[trig]_Counter(-1) + 1

    Condition : default
    Value     : _[Util]_Stage_[trig]_Counter(-1)
}

/*  Count all trigger events lasting at least 7 days */

Set : _[Util]_Ph_[trig]_event_counter
{   Condition : _[Util]_Stage_[trig]_Counter = 7 and _[Util]_Stage_[trig]_Counter(-1) = 6
    Value     : _[Util]_Ph_[trig]_event_counter(-1) + 1

    Condition : default
    Value      : _[Util]_Ph_[trig]_event_counter(-1)
}

:Next:

:Next:


// Set conservation demand and delivery constraints for each trigger level in effect.

// Set demand reduction factors
:SUBSTITUTE: [Dem_1_Red_Factor] = 5
:SUBSTITUTE: [Dem_2_Red_Factor] = 10
:SUBSTITUTE: [Dem_3_Red_Factor] = 20
:SUBSTITUTE: [Dem_4_Red_Factor] = 25
:SUBSTITUTE: [Dem_5_Red_Factor] = 35
:SUBSTITUTE: [Dem_6_Red_Factor] = 50
```

```

:For:
{   [trig] = {1, 2, 3, 4, 5}
}



// SGWASA
Set : _SGWASA_Consvn_[trig]_Demand
{   Condition : _SGWASA_Trigger_[trig]_On = 1
    Value     : Demand1256 *  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand1256
}

Constraint   SGWASA_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _SGWASA_Trigger_[trig]_On = 1
                Expression :  dflow1250.1256 <= _SGWASA_Consvn_[trig]_Demand }

//Wilson
Set : _Wilson_Consvn_[trig]_Demand
{   Condition : _Wilson_Trigger_[trig]_On = 1
    Value     : Demand1506*  ( 1 - [Dem_[trig]_Red_Factor] / 100 )

    Condition : default
    Value     : Demand1506
}

Constraint   Wilson_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _Wilson_Trigger_[trig]_On = 1
                Expression :  dflow1520.1505 <= _Wilson_Consvn_[trig]_Demand }

:Next:

:else:
// Do nothing if not using drought plans
:endif:
```

drought_protocol_Jordan.ocl

```
// Drought protocol

:SUBSTITUTE: [WQ_Pct_Remaining_Stage_1] = 80
:SUBSTITUTE: [WQ_Pct_Remaining_Stage_2] = 60
:SUBSTITUTE: [WQ_Pct_Remaining_Stage_3] = 40
:SUBSTITUTE: [WQ_Pct_Remaining_Stage_4] = 20
:SUBSTITUTE: [Jordan_Minimum_Release_Normal] = 40
:SUBSTITUTE: [Jordan_Minimum_Release_Stage_1] = 40
:SUBSTITUTE: [Jordan_Minimum_Release_Stage_2] = 40
:SUBSTITUTE: [Jordan_Minimum_Release_Stage_3] = 200
:SUBSTITUTE: [Jordan_Minimum_Release_Stage_4] = 100

:SUBSTITUTE: [Level_Change_Time_Interval] = 7



// Determine average inflow to WQ account over the last 14 days
Set :  _Avg_JLake_Inflow
{    condition  :  abs_period = 1
  value      :  inflow0470

  condition  :  abs_period <= 14
     value :       _JLake_WQ_Inf(-1)

     condition  :  default
     value      :  accumulate{ _JLake_WQ_Inf(-1) , -14, -1 } / 14
}


/* Determine which zone of the WQ pool the lake is in.  In the udef list, initialize the WQ storage to the starting storage as defined
   in the constants table.*/
Set :  _WQZone
{    condition   : _WQ_Storage(-1) / [Max_WQ_Storage] * 100  <= [WQ_Pct_Remaining_Stage_4] /* WQ Zone 4  */
     value       : 4

     condition   : _WQ_Storage(-1) / [Max_WQ_Storage] * 100  <= [WQ_Pct_Remaining_Stage_3] /* WQ Zone 3  */
     value       : 3

     condition   : _WQ_Storage(-1) / [Max_WQ_Storage] * 100  <= [WQ_Pct_Remaining_Stage_2] /* WQ Zone 2  */
     value       : 2

     condition   : _WQ_Storage(-1) / [Max_WQ_Storage] * 100  <= [WQ_Pct_Remaining_Stage_1] /* WQ Zone 1 */
     value       : 1

     condition   : default                                    /* WQ Zone 0 (Normal Operations) [right now, 80% and above) */
     value       : 0
}
```

```
/*  This is to set the triggers.  In all cases, the triggers and associated level counters are reset to zero when the elevation reaches 216 feet.

For the first trigger, activate it when the water quality zone reaches 1.
The triggers for other levels activate whenever the pond hits that water quality zone (or lower) and a specified number of days in the prior level
has elapsed. The specified number of days (specified in the OCL constants) is the minimum interval between levels. In other words, the trigger will
stay in place for at least a specified number of days (even if the zone drops below that level) at which time the next trigger goes on.

Each level # is associated with the water quality zone.

Note that on refill, no skipping of levels is allowed.  The WQ Zone must improve two levels before turning off the next level trigger.   */

Set : _Trigger_1_On
{   //  For first day of simulation, set to the initial value in the udef list as defined in the constants table.  User may wish to simulate conditions
 //  starting with a certain trigger condition.  Setting the WQ zone would not be adequate since there is generally a waiting period between triggers.
 //  The trigger condition is important since it sets the minimum release from Jordan and target flow at Lillington.
 condition  :  abs_period = 1
 value      :  _Trigger_1_On(-1)

 // Turning off trigger
 condition  :  _Count_Trigger_1(-1) > 0 and elevation0470 < 216
  {   condition  :  _Trigger_2_On(-1) = 1   // during drawdown
   value      :  0

   condition  :  default                // during refill, trigger will stay on as long as pond has not refilled to 216 feet
   value      :  _Trigger_1_On(-1)
  }

 // Turning on trigger

  // The first condition is during drawdown.  WQ zone could drop to zones 2 through 4, but those triggers cannot go on until passing through the
  // first trigger. Once we've gotten to the second and higher triggers, the 1st trigger will turn off, as there is no waiting period.
     condition  : _WQZone >= 1 and elevation0470 < 216 and _Trigger_2_On(-1) = 0 and _Trigger_3_On(-1) = 0 and _Trigger_4_On(-1) = 0
     Value      : 1

  //  for turning on trigger during refill. It cannot turn on again if pond has refilled to 216 feet.
  condition  :  _Trigger_2_On(-1) = 1 and _WQZone = 0 and elevation0470 < 216
     Value      : 1

 // Otherwise, trigger is off
 Condition : default
    Value     : 0
}

// Logic is similar for the other triggers.
Set : _Trigger_2_On
{   condition  :  abs_period = 1
```

```
value      :  _Trigger_2_On(-1)
// Turning off trigger
condition  :  _Count_Trigger_2(-1) > 0 and elevation0470 < 216
 {   condition  :  _Trigger_3_On(-1) = 1   // during drawdown
  value      :  0
  condition  :  _WQZone <= 0  // during refill.
  value      :  0
  condition  :  default
  value      :  _Trigger_2_On(-1)
 }
// Turning on trigger
 // The first condition is during drawdown
 condition  :  _Count_Trigger_1(-1) >= [Level_Change_Time_Interval] and _WQZone >= 2 and elevation0470 < 216
    Value      : 1
 // The second condition is during refill. It cannot turn on again unless WQ zone is two zones higher than yesterday.
 condition  : _Trigger_3_On(-1) = 1 and _WQZone <= 1  and elevation0470 < 216
 value      :  1
// Otherwise, trigger is off
Condition : default
   Value     : 0
}
Set : _Trigger_3_On
{   condition  :  abs_period = 1
value      :  _Trigger_3_On(-1)
// Turning off trigger
condition  :  _Count_Trigger_3(-1) > 0 and elevation0470 < 216
 {   condition  :  _Trigger_4_On(-1) > 0   // during drawdown
  value      :  0
  condition  :  _WQZone <= 1  // during refill
  value      :  0
  condition  :  default
  value      :  _Trigger_3_On(-1)
 }
// Turning on trigger
```

```

  // The first condition is during drawdown
  condition  :  _Count_Trigger_2(-1) >= [Level_Change_Time_Interval] and _WQZone >= 3 and elevation0470 < 216
     Value      : 1

  // The second condition is during refill.
  condition  : _Trigger_4_On(-1) = 1 and _WQZone <= 2  and elevation0470 < 216
  value      :  1

 // Otherwise, trigger is off
 Condition : default
    Value     : 0
}

Set : _Trigger_4_On
{   condition  :  abs_period = 1
 value      :  _Trigger_4_On(-1)

 // Turning off trigger
 condition  :  _Count_Trigger_4(-1) > 0 and elevation0470 < 216
  {   condition  :  _WQZone <= 2  // during refill.
   value      :  0

   condition  :  default
   value      :  _Trigger_4_On(-1)
  }

 // Turning on trigger

  // During drawdown
  condition  :  _Count_Trigger_3(-1) >= [Level_Change_Time_Interval] and _WQZone >= 4 and elevation0470 < 216
     Value      : 1

    // Otherwise, trigger is off
 Condition : default
    Value     : 0
}




/*  The following lines set the drought stage according to which triggers are on and for how long.*/
Set :  _Drought_Stage
{   condition : _Trigger_4_On = 1
    value     : 4

    condition : _Trigger_3_On = 1
```

```
    value    : 3

    condition : _Trigger_2_On = 1
    value    : 2

    condition : _Trigger_1_On = 1
    value    : 1

    condition : _Trigger_1_On(-1) = 1 or _Trigger_2_On(-1) = 1 or _Trigger_3_On(-1) = 1 or _Trigger_4_On(-1) = 1
    value    : _WQZone

    condition : default
    value    : 0
}


// This is for determining whether the lake is drawing down based on changing WQ zones (rather than just day to day change in WQ storage
// while in that zone). Turn the index off only if the WQ zone increases during refill.
Set :  _Level_Drawdown
{    condition  :  _Level_Drawdown(-1) = 1
       {  condition  :  _Drought_Stage < _Drought_Stage(-1)
          value      :  0

          condition  :  default
          value      :  _Level_Drawdown(-1)
       }

     condition  :  _Drought_Stage > _Drought_Stage(-1)
     value      :  1

     condition  :  default
     value      :  0
}


//  These are the counters associated with each trigger

// Do FOR:NEXT loop since the counters are the same for all Jordan Lake trigger levels.  Here, DWR has chosen
// to end a trigger level when the next has been reached rather than keeping it on for the entire drought.

:FOR:
{  [Level] = { 1, 2, 3, 4}  }

 // Number of days in which counter is on and the number of days in each drought stage
 Set : _Count_Trigger_[Level]
 {
    Condition : _Count_Trigger_[Level](-1) >= 1
```

```
    {
        Condition : _Trigger_[Level]_On = 0
        Value     : 0

        Condition : default
        Value     : _Count_Trigger_[Level](-1) + 1
    }

    Condition : _Trigger_[Level]_On = 1
    Value     : 1

    Condition : default
    Value     : 0
}

//  DWR included this counter for determining total # of days at each level over the simulation period.  Here the
// trigger stays on and is counted even if another trigger has been reached.
Set :  _Total_Count_Trigger_[Level]
{   Condition :  _Count_Trigger_[Level] > 0
      Value     :  _Total_Count_Trigger_[Level](-1) + 1

      Condition : default
      Value     : 0
}


// Establish a day counter which resets after _ days have elapsed as defined by the user for the [Level Change Time Interval].
// This will be used to determine adjustments to the Lillington target after the day counter reaches the time interval
Set :  _CumDayWithinInt_[Level]
{   condition  :   _CumDayWithinInt_[Level](-1) = [Level_Change_Time_Interval]
 {   condition :  _Trigger_[Level]_On = 1
     value      :  1

  condition  :  default
  value      :  0
 }

 condition  :  _Trigger_[Level]_On = 1
 value      :  _CumDayWithinInt_[Level](-1) + 1

 condition  :  default
 value      :  0
}


:NEXT:
```

```
/*  These are counters to track the number of times (events) in the record each trigger level would have activated.  This is not the same as tracking
as how often a zone is reached due to the criteria for switching levels (which include a waiting period).  Events are arbitrarily selected to last
at least 5 days. In other words, the phase 1 counter will solve to 2 if in 2 drought years, trigger 1 is activated twice, each time lasting at least 5 days.
If the trigger is reactivated during refill, and if it lasts for 5 days, the phase event will be counted here.  To get a better representation of the actual
number of drought events, not the drawdown and refill events, may need to adjust this code.  */

:FOR:
{  [Level] = { 1, 2, 3, 4 }  }

 Set : _Ph_[Level]_event_count
 {   Condition : _Count_Trigger_[level]  = 5 and _Count_Trigger_[level](-1) = 4
     Value     : _Ph_[Level]_event_count(-1) + 1

     Condition : default
     Value      : _Ph_[Level]_event_count(-1)
 }

:NEXT:


/* The following lines determine the Lillington target according to the drought level and the number of days at that drought level.
   The target at Lillington steps down (on drawdown) or up (on refill) by a specified amount every specified number of
 days (Level_Change_Time_Interval).*/
:substitute:    [Lillington_Increment_Stage_1] = 50             /* In cfs */
:substitute:    [Lillington_Increment_Stage_2] = 50             /* In cfs */
:substitute:    [Lillington_Increment_Stage_3] = 0              /* In cfs */
:substitute:    [Lillington_Increment_Stage_4] = 0              /* In cfs */
:substitute: [Lillington_Lower_Target_Stage_1] = 450            /* In cfs */
:substitute: [Lillington_Lower_Target_Stage_2] = 300            /* In cfs */
:substitute: [Lillington_Lower_Target_Stage_3] = 0              /* In cfs */
:substitute: [Lillington_Lower_Target_Stage_4] = 0              /* In cfs */
:substitute: [Lillington_Upper_Target_Stage_1] = 600            /* In cfs */
:substitute: [Lillington_Upper_Target_Stage_2] = 450            /* In cfs */
:substitute: [Lillington_Upper_Target_Stage_3] = 0              /* In cfs */
:substitute: [Lillington_Upper_Target_Stage_4] = 0              /* In cfs */


:FOR:
{  [Level] = { 1, 2, 3, 4 }  }

 Set :   _Lill_Target_[Level]
 {   /* for moving into more restrictive drought phases (based on trigger conditions) during drawdown.  On the first day of entering
   the more restrictive trigger, set the target to the upper end of the target range associated with that trigger.  Do not do
   this if in the previous phase (as expressed by yesterday's Lillington target value, or min_flow0550.0555(-1)), the target
   was at the lower end of the lower phase.  In this case, drop down by the user-defined increment right away.  */
        condition  :  _Drought_Stage > _Drought_Stage(-1)
            {   condition  :  min_flow0550.0555(-1) = convert_units {[Lillington_Upper_Target_Stage_[Level]], cfs, af}
```

```
          value      :  convert_units {[Lillington_Upper_Target_Stage_[Level]] - [Lillington_Increment_Stage_[Level]], cfs, af}

              condition  :  default
              value      :  convert_units {[Lillington_Upper_Target_Stage_[Level]], cfs, af}
            }

  /* For moving into less restrictive drought phases during refill.  Only apply the lower end of the target range to be conservative.
   For example, if the range is 450 to 600 cfs, keep the target at 450 cfs throughout that period (even if longer than 7 days).  */
  condition  :  _Drought_Stage < _Drought_Stage(-1)
      value      :  convert_units {[Lillington_Lower_Target_Stage_[Level]], cfs, af}

  // if drawdown is continuing, but the drought phase has not changed
      condition  :  _Level_Drawdown = 1
   {   // reduce target by user-defined increments, but only when the user-defined time interval has been reached.  The lowest value it
    // can reach is the lower range of the target.  The target will be reduced even if WQ storage is increasing while in this drought
    // level, again to be conservative.
    condition  :  _CumDayWithinInt_[Level] =  [Level_Change_Time_Interval]
      value      :  max { convert_units {[Lillington_Lower_Target_Stage_[Level]], cfs, af},
        _Lill_Target_[Level](-1) -  convert_units { [Lillington_Increment_Stage_[Level]], cfs, af} }

    condition  :  default
    value      :  _Lill_Target_[Level](-1)
   }

  // if refill is occuring, but the drought phase has not changed.  Set to the lower end of the target range throughout that particular drought phase.
  condition  :  _Level_Drawdown = 0
      value      :  _Lill_Target_[Level](-1)

    // default condition is to set the target to its upper level
  condition  :   default
  value      :   convert_units {[Lillington_Upper_Target_Stage_[Level]], cfs, af}
 }

:NEXT:

// Now set the min flow at Lillington based on the computed target
Set : min_flow0550.0555
{   condition  :  _Trigger_4_On = 1
 value      :  _Lill_Target_4

 condition  :  _Trigger_3_On = 1
 value      :  _Lill_Target_3

 condition  :  _Trigger_2_On = 1
 value      :  _Lill_Target_2

 condition  :  _Trigger_1_On = 1
```

```
 value      :  _Lill_Target_1

   condition  :  _Trigger_1_On(-1) = 1 or _Trigger_2_On(-1) = 1 or _Trigger_3_On(-1) = 1 or _Trigger_4_On(-1) = 1
   value      :  min_flow0550.0555(-1)

 condition  :  default  // which will apply if the lake refills
 value      :  convert_units {[Lillington_Target_Normal], cfs, af}
}

//  Adjust the min release from Jordan depending on drought trigger condition.

Set  :  min_flow0470.0480
{   /* For trigger 3 and 4 conditions, reduce the minimum release if there is enough local inflow to provide a minimum
  of 300 cfs at Lillington.The net withdrawal in this reach (between Deep River Moncure gage, Jordan Lake, and
  Lillington gage) can be approximated using the largest withdrawals (Sanford and Harnett County) and WW returns
  (Western Wake) using yesterday's flows.   Factor this in to meet the 300 cfs minimum; Releases will be higher to
  meet local net withdrawals down to Lillington due to weighting.  Never release less than 40 cfs. */
   condition  :  _Trigger_4_On = 1
   value      :  max { convert_units{40, cfs, af},
                    min {convert_units{ [Jordan_Minimum_Release_Stage_4], cfs, af},  convert_units {300, cfs, af}
       + flow0550.0549 + flow0490.0489 - flow0930.0510
                          - (inflow0550 + inflow0490 + flow0527.0510 + flow0640.0480 ) } }

   condition  :  _Trigger_3_On = 1
   value      :  max { convert_units{40, cfs, af},
                    min {convert_units{ [Jordan_Minimum_Release_Stage_3], cfs, af},  convert_units {300, cfs, af}
       + flow0550.0549 + flow0490.0489 - flow0930.0510
                         - (inflow0550 + inflow0490 + flow0527.0510 + flow0640.0480 ) } }

   condition  :  _Trigger_2_On = 1
   value      :  convert_units{ [Jordan_Minimum_Release_Stage_2], cfs, af}

   condition  :  _Trigger_1_On = 1
   value      :  convert_units{ [Jordan_Minimum_Release_Stage_1], cfs, af}

   condition  :  _Trigger_1_On(-1) = 1 or _Trigger_2_On(-1) = 1 or _Trigger_3_On(-1) = 1 or _Trigger_4_On(-1) = 1
   value      :  min_flow0470.0480(-1)

   condition  :  default
   value      :  convert_units{ [Jordan_Minimum_Release_Normal], cfs, af}
}
```

Durham_ops.ocl

```
/*  DURHAM_OPS.OCL  */

/*  Operational policy for Durham's system */

Set: _Durham_Tot_Use_Stor { value: max_stor1140 + max_stor1200 - (lower_rule1140 + lower_rule1200)}
Set: _Durham_Stor { value: storage1140 + storage1200}
Set: _Durham_Use_Stor { value: _Durham_Stor - (lower_rule1140 + lower_rule1200)}
Set: _Durham_Pct_Use_Stor { value: 100 * _Durham_Use_Stor/_Durham_Tot_Use_Stor }
Set: _Durham_TQ_Pct_Use_Stor { value: ( storage1120 - lower_rule1120 ) / (max_stor1120 - lower_rule1120 ) * 100 }


/*  Sets the Little River Reservoir (Durham) minimum release - based on usable storage (per SEPA/NEPA [EIS] process) and time of year.
Lake Michie min release also is tied to usable storage.  Note reference is to dead_stor since that defines the bottom of the usable
storage and will change with sedimentation associated with demand year.  It is not tied to lower rule since the lower rule embeds
a reserve in the calculation and would artificially reduce the usable storage for making the min release.      */

Set LittleRiverRelease : min_flow1200.1205
{   condition : ( storage1200 - dead_stor1200) / (max_stor1200 - dead_stor1200) < 0.7
    value     : convert_units {0.64,cfs,af}

    condition : month > 5 and month < 12
    value     : convert_units {2.0,cfs,af}

    condition : default
    value     : convert_units {6.0,cfs,af}
}


// For this 2055 year scenario, no planned use of the Eno to refill Teer Quarry, so shut off.  Quarry would be refilled from Lake Michie.

Set Teer_Quarry_Eno_River_Refill : max_flow1115.1120   {  value  :  0   }

Set: _Durham_estim_spill  // Used to determine Lake Michie min release and refill of Teer Quarry
{
    condition :  default
    value      :  max { 0,
      (storage1140 + inflow1140 - evap1140 - demand1142)
       + (storage1200 + inflow1200 - evap1200 - min_flow1200.1205 - demand1202)
       - demand1162 - (max_stor1140 + max_stor1200),
      (storage1140 + inflow1140 - evap1140 - demand1142 - demand1162 - max_stor1140) }
      // This last term anticipates when LM will spill unavoidably when LRR is not yet near full
}

// For refill of quarry from Michie, contain same transfer provisions on the deadband and the Falls upper rule 1-inch allowance.
Set Teer_Quarry_Lake_Michie_Refill : max_flow1140.1120
{
    condition : convert_units{_Durham_estim_spill, af, cfs} >= 11.75
```

```
    and (storage1120 + 10) < max_stor1120
    and elevation1300 >= ( [Falls_upper_rule] - 0.083 )
   value     : convert_units{ [TQ_Max_LM_Refill_Rate] , mgd , af }

   condition : default
   value     : 0

}

// Assume no supply from Little River to the quarry
Constraint : {dFlow1200.1120 = 0 }


Set TeerQuarrySupply: max_flow1120.1151
{
   condition : (_Durham_Trigger_2_On(-1) = 1 or _Durham_Trigger_3_On(-1) = 1 or _Durham_Trigger_4_On(-1) = 1)
    and storage1120 > lower_rule1120
    and _Durham_TQ_Pct_Use_Stor > _Durham_Pct_Use_Stor //After reaching Stage 2
   value     : convert_units {20, mgd, af}

 condition : _Durham_Trigger_1_On(-1) = 1 and storage1120 > lower_rule1120
    and _Durham_TQ_Pct_Use_Stor > _Durham_Pct_Use_Stor
    and (Month >10 or Month <4)
   value     : convert_units {5, mgd, af}

 condition : _Durham_Trigger_1_On(-1) = 1 and storage1120 > lower_rule1120
    and _Durham_TQ_Pct_Use_Stor > _Durham_Pct_Use_Stor
    and (Month >3 or Month <11)
   value     : convert_units {10, mgd, af}

   condition : default
   value     : 0
}


// Set the new minimum release for Lake Michie.
Set LakeMichie_min_release : min_flow1140.1205
{   // One of the conditions for pumping from Michie to the quarry is a minimum flowby of 11.75 cfs below the dam.
 condition : convert_units{_Durham_estim_spill, af, cfs} > 11.75
    and (storage1120 + 10) < max_stor1120 and elevation1300 >= ([Falls_upper_rule] - 0.083)
 value     : convert_units {11.75 ,cfs,af}

 // when below 40% storage (assume usable storage)
 condition :  (storage1140 - dead_stor1140) / ( upper_rule1140 - dead_stor1140) <= 0.4
   value     :   convert_units {0.61,cfs,af}

 // 40% - 70% storage release tier
```

```
    condition : (storage1140 - dead_stor1140) / ( upper_rule1140 - dead_stor1140) <= 0.7
    value     :  convert_units {1.2,cfs,af}

    condition : default
    value     : convert_units {1.75,cfs,af}
}


// Assume baseloading from the WIP of 16.5 mgd assuming sufficient storage in Durham and OWASA Jordan Lake accounts.
Target Jordan_Lake_usage  :  dFlow0468.1151
{   condition :default
    priority  : 1
    penalty+  : 500
    penalty-  : 500
    Value     : min { demand1162, convert_units {16.5,  mgd, af}, _Storage_Durham(-1) + _Storage_OWASA(-1)}
}



/*  Turn off interconnects from Durham for base case - transfers can be simulated
    with an operating policy in alternative scenarios */
Constraint : {dFlow0479.1151 = 0} //After WIP WTP is on-line, Durham would only buy water from Cary in an emergency
/*Constraint : {dFlow1151.0431 = 0}  Durham-OWASA Interconnect */
Constraint : {dFlow1151.0471 = 0}  /* Durham-Cary Interconnect */
Constraint : {dFlow1151.1106 = 0} /* Durham-Hillsborough Interconnect */
Constraint : {dFlow1151.1305 = 0}  /* Durham-Raleigh Interconnect */


/*  RESERVOIR BALANCING -- Durham
    With a very low penalty in Priority 1, balance the water (usable stor pct) between the
    reservoirs. This will draw Michie and Little River Res. down proportionally.
    This can be replaced with a more comprehensive operating policy from Durham
    in alternative scenarios */

Constraint Balance1200 : { d_StorRatio > ( Dstorage1200 - lower_rule1200 ) / (upper_rule1200 - lower_rule1200 ) }

Constraint Balance1140 : { d_StorRatio > ( Dstorage1140 - lower_rule1140 ) / (upper_rule1140 - lower_rule1140 ) }

Minimax : d_StorRatio
{   priority  : 1
    penalty   : 2
    tolerance : .02
}
```

falls_bdam_ops.ocl

```
/*  FALLS_BDAM_OPS.OCL  */
/* Operational policies for Falls and Beaverdam */

//Set the Seasonal increase in Falls Lake Normal Pool

set Falls_Lake_upper_rule : upper_rule1300
{
    Condition  :   default
    value      :   elev_to_stor{1300, [Falls_upper_rule]}
}

set Falls_Lake_lower_rule : lower_rule1300
{    Condition  :   Default
    value      :   elev_to_stor{1300,[Falls_lower_rule]}
}

set Beaver_Dam_upper_rule : upper_rule1230
{
    Condition  :   default
    value      :   elev_to_stor{1230, [Falls_upper_rule]}
}

set Beaver_Dam_lower_rule : lower_rule1230
{
    Condition  :   default
    value      :   elev_to_stor{1230, [Falls_lower_rule]}
}

/*  Sets the Falls minimum release - seasonal pattern (100/60 cfs) with user-defined safety factor (only when using service gates)
   The safety factor can be set in the ocl constants table. */
Set FallsRelease : min_flow1300.1304
{   condition : month > 3 and month < 11
   value     : convert_units { 100, cfs, af } * ( 1 + [FLakeMin_SafeFact] / 100 )

   condition : default
   /*  Winter min. release based on amount from Piggyback gates, which is approx. 60 cfs depending on stage. */
   value     : convert_units { lookup { PiggybackGate, elevation1300 }, cfs, af }
}

/*  Sets the Clayton minimum flow target - seasonal pattern (254/184 cfs) with user-defined safety factor
   Also can be overridden if user chooses, when WQ storage drops below 20%; this can be truned on in the ocl constants table. */
Set Clayt_Target: min_flow1630.1640
{   condition : [ClaytonTarget_Override] = 1 and ( _Total_WQ_Pct(-1) < [FLake_WQ_Threshold] or elevation1300 <= 245 )
   value     : 0

   condition : month > 3 and month < 11
   value     : convert_units { 254, cfs, af } * ( 1 + [ClaytonTarget_SafeFact] / 100 )
```

```

   condition : default
   value     : convert_units { 184, cfs, af } * ( 1 + [ClaytonTarget_SafeFact] / 100 )
}

/*  Beaverdam elevation = projected Falls elevation if at or above 249 ft.  */
Target Bdam_elevation : dstorage1230
{   condition : elevation1300 >= 249.0
 priority  : 1
   penalty+  : 10000
   penalty-  : 10000
   Value     : elev_to_stor {1230, elevation1300}
}

/*Beaverdam drought release policy*/

Target Beaverdam_release : dflow1230.1300

{   /* If Falls is between 237 and 240, and Beaverdam is above [Falls_lower_rule], draw down Beaverdam maximum of 1-ft (down to a minimum
  of [Falls_lower_rule]); next drawdown can occur after 5 days */
   condition :  elevation1230(-5) - elevation1230 < 5 and elevation1300 < 240
    and elevation1230 > elevation1300 and elevation1230> [Falls_lower_rule]
   priority  :  1
   penalty+  :  1000
   penalty-  :  1000
   Value     :  min { elev_to_stor { 1230, elevation1230 } - elev_to_stor { 1230, elevation1230 - 1 },
      elev_to_stor { 1230, elevation1230 } - elev_to_stor { 1230, [Falls_lower_rule] } }

   /* If Falls is below 249 ft, make sure Beaverdam is not above 249 ft */
   condition : elevation1230 > 249 and elevation1300 < 249
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : elev_to_stor { 1230, elevation1230 } - elev_to_stor { 1230, 249 }

  /*  To ensure accurate accounting of water supply and quality pools, when stressed, release some contents from Beaverdam if either
 yesterday's water supply or water quality account for Falls was less than 5% full; do not draw down more than 1 ft per day
 THIS IS NOT PART OF TERRY'S SPREADSHEET (sn) */
   condition :  _FLake_WS_Pct(-1) < 5 or _FLake_WQ_Pct(-1) < 5 and elevation1230 > elevation1300 + 0.9
    and elevation1230(-5) - elevation1230 < 5
   priority  : 1
   penalty+  : 1000
   penalty-  : 1000
   Value     : max {0, min {elev_to_stor { 1230, elevation1230 } - elev_to_stor { 1230, elevation1230 - 1 } ,
     ( _Bdam_WS_Stor(-1) + _Bdam_WQ_Stor(-1) + inflow1230 - evap1230 )} }

   condition : default
```

```
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : 0
}


/*  Constrain the delivery for Raleigh from Falls based on amount in the total (Falls+Bdam) water supply storage account.
    Demand will not be fulfilled if the account has gone empty and there is not enough inflow to the water supply account (for the previous day).
    Similarly, constrain the water quality release from Falls (arc 1300.1310) based on amount in the water quality storage account.

    Since we refer to yesterday's storage estimates, for the first day of the run, constrain deliveries and releases to the initialized volumes for
    each account (for simplicity, ignore inflows) so that deliveries and releases are made. */


Constraint   Deliv_Lim_Raleigh :
 {  condition  :  abs_period = 1
    expression :  dflow1300.1305 <= [FLake_WS_Stor] + [Bdam_WS_Stor]
 }

Constraint   Deliv_Lim_Raleigh :
 {  condition  :  abs_period > 1
    expression :  dflow1300.1305 <= _Total_WS_Stor(-1)
 }

Constraint   Release_Limit_Falls :
 {  condition  :  abs_period = 1
    expression :  dflow1300.1304 <= [FLake_WQ_Stor] + [Bdam_WQ_Stor]
 }

Constraint   Release_Limit_Falls :
 {  condition  :  abs_period > 1
    expression :  dflow1300.1304 <= _Total_WQ_Stor(-1)
 }
```

Falls_Bdam_WQ_WS_Accounts.ocl

```
/*  Falls_Bdam_WQ_WS_Accounts.ocl */


/*  Beaverdam Accounting */

Set  :  _Bdam_Inf  {  value :  inflow1230 - evap1230(0) }  /* Base it on net inflow for Beaverdam.
                 Evap (0) since this file is included after the solve statement and we want today's evap, not tomorrow's */

Set  :  _Bdam_Inf_WS   {  value :  _Pct_Max_WS_Storage / 100 * _Bdam_Inf }

Set  :  _Bdam_WS_Rel /* Calculate the WS outflow to Falls from Beaverdam.  Assume that the WS amount is simply based on
      the percent of water supply to total account storage in Beaverdam */
{     condition  :  elevation1230 < 249 /* WS Outflow only if Beaverdam is less than 249ft (spillage is accounted for in Falls) */
      value      :  flow1230.1300 * _Pct_Max_WS_Storage / 100

      condition  :  default
      value      :  0
}

Set  :  _Bdam_WS_Stor_Init /* Calculate the initial Beaverdam WS storage (before computing spill to WQ and back*/
{     condition  :  elevation1230 >= 249 or _Bdam_WS_Stor(-1) + _Bdam_Inf_WS - _Bdam_WS_Rel >= _Bdam_Max_WS_Storage
      value      :  _Bdam_Max_WS_Storage

/*    Prevent the water supply account from going negative */
      condition  :  default
      value      :  max {  0, _Bdam_WS_Stor(-1) + _Bdam_Inf_WS - _Bdam_WS_Rel }
}

Set  :  _Bdam_WStoWQ_Spill /* Calculate the spillover from WS to WQ*/
{     condition  :  _Bdam_WS_Stor(-1) + _Bdam_Inf_WS - _Bdam_WS_Rel > _Bdam_Max_WS_Storage /* Spillover only if projected WS storage
                          is more than 100% */
      value      :  _Bdam_WS_Stor(-1) + _Bdam_Inf_WS - _Bdam_WS_Rel - _Bdam_Max_WS_Storage

      condition  :  default
      value      :  0
}

Set  :  _Bdam_Inf_WQ   {  value  :  _Pct_Max_WQ_Storage / 100 * _Bdam_Inf }

Set  :  _Bdam_WQ_Rel /* Calculate the WQ outflow to Falls from Beaverdam */
{     condition  :  elevation1230 < 249 /* WQ Outflow only if Beaverdam is less than 249ft (spillage is accounted for in Falls) */
      value      :  flow1230.1300 * _Pct_Max_WQ_Storage / 100

      condition  :  default
      value      :  0
}

```

```
Set  :  _Bdam_WQ_Stor /* Calculate the Beaverdam WQ storage */
{     condition  :  elevation1230 >= 249 or _Bdam_WQ_Stor(-1) +
     ( _Bdam_WStoWQ_Spill + _Bdam_Inf_WQ - _Bdam_WQ_Rel ) >= _Bdam_Max_WQ_Storage
      value      :  _Bdam_Max_WQ_Storage

/*    Prevent the water quality account from going negative */
      condition  :  default
      value      :  max { 0, _Bdam_WQ_Stor(-1) + ( _Bdam_WStoWQ_Spill + _Bdam_Inf_WQ - _Bdam_WQ_Rel ) }
}

Set  :  _Bdam_WQtoWS_Spill /* Calculate the spillover from WQ to WS */
{     condition  :  _Bdam_WQ_Stor(-1) +
     ( _Bdam_WStoWQ_Spill + _Bdam_Inf_WQ - _Bdam_WQ_Rel ) > _Bdam_Max_WQ_Storage   /* Spillover only if
                         projected WS storage more than 100% */
      value      :  _Bdam_WQ_Stor(-1) + ( _Bdam_WStoWQ_Spill + _Bdam_Inf_WQ - _Bdam_WQ_Rel ) - _Bdam_Max_WQ_Storage

      condition  :  default
      value      :  0
}

Set  :  _Bdam_WS_Stor /* Calculate the final Beaverdam WS storage (after computing spillage) */
{     condition  :  _Bdam_WS_Stor_Init + _Bdam_WQtoWS_Spill >= _Bdam_Max_WS_Storage  /* Set at 100% if at or above full */
      value      :  _Bdam_Max_WS_Storage

      condition  :  default
      value      :  _Bdam_WS_Stor_Init + _Bdam_WQtoWS_Spill
}


/*  Falls Accounting  */

/* Falls Lake inflow is Falls gain + upstream flows into Falls*/
Set  :  _FLake_Inf
{   /* When Beaverdam is full, inflow to Falls account from Beaverdam will simply be the Beaverdam surplus above 249 (= net inflow).
  Note for the general accounting (i.e, not the WS/WQ accounting), storage will accumulate in Beaverdam (and Falls) until the
  upper rule of [Falls_upper_rule] is reached. The point of this is to mirror what historic elevations have been */
 condition  :   elevation1230 >= 249 and elevation1230(0) >= 249 // second statement added by Reed
 value      :   inflow1300 + flow1163.1300 + flow1205.1300 + flow1250.1300 + flow1256.1300 +
     flow1270.1300 + flow1705.1300 - delivery1302 - evap1300(0) + _Bdam_Inf

// the next two statements added by Reed to improve performance of reservoir balancing
 condition :  elevation1230 >= 249 and elevation1230(0) < 249 and elevation1300 < 249
 value      :  inflow1300 + flow1163.1300 + flow1205.1300 + flow1250.1300 + flow1256.1300 +
     flow1270.1300 + flow1705.1300 - delivery1302 - evap1300(0) + _Bdam_Inf - (storage1230 - storage1230(0))

 condition  :  elevation1230 >= 249 and elevation1230(0) < 249 and elevation1300 >= 249
 value      :  inflow1300 + flow1163.1300 + flow1205.1300 + flow1250.1300 + flow1256.1300 +
```

```
    flow1270.1300 + flow1705.1300 - delivery1302 - evap1300(0) + _Bdam_Inf - (elev_to_stor{1230,249} - storage1230(0))

/* Otherwise, inflow to Falls account from Beaverdam is simply the Beaverdam release defined in the main.ocl
 (associated with drought operations).  This will be today's release since
   this accounting file is included after the solve statement in the main.ocl file */
 condition  :   default
 value      :   inflow1300 + flow1163.1300 + flow1205.1300 + flow1250.1300 + flow1256.1300 +
    flow1270.1300 + flow1705.1300 - delivery1302 - evap1300(0) + flow1230.1300
}

Set  :  _FLake_Inf_WS  {  value  : _Pct_Max_WS_Storage / 100 * _FLake_Inf  }  /* Calculate WS portion of Falls inflow */

/*  The water supply release from Falls = the delivery to Raleigh.  The delivery is constrained in the main.ocl file
 to the amount in the water supply storage pool plus the inflow to that account.  This way, the delivery will not
 be made if the account has emptied */
Set  :  _Flake_WS_Rel  {  value  :  flow1300.1305  }

Set  :  _FLake_WS_Stor_Init /* Calculate the initial Falls WS storage (before computing spill to WQ and back) */
{     condition  : elevation1300 >= [Falls_upper_rule] or _FLake_WS_Stor(-1)
    + ( _FLake_Inf_WS -  _Flake_WS_Rel ) >= _FLake_Max_WS_Storage     /* Set at 100% if at or above full */
     value      :  _FLake_Max_WS_Storage

   /*  Sets the water supply storage floor as zero minus the storage in Beaverdam */
     condition  :  default
     value      :  max {  0 - _Bdam_WS_Stor, _FLake_WS_Stor(-1) + ( _FLake_Inf_WS -  _Flake_WS_Rel ) }
}

Set  :  _FLake_WStoWQ_Spill /* Calculate the spillover from WS to WQ */
{     condition  :  _FLake_WS_Stor(-1) + ( _FLake_Inf_WS - _Flake_WS_Rel ) > _FLake_Max_WS_Storage  /* Spillover only if
                          projected WS storage is
                          more than 100%  */
     value      :  _FLake_WS_Stor(-1) + ( _FLake_Inf_WS - _Flake_WS_Rel ) - _FLake_Max_WS_Storage

     condition  :  default
     value      :  0
}

Set  :  _FLake_Inf_WQ  {  value  : _Pct_Max_WQ_Storage / 100  * _FLake_Inf  }  /* Calculate WQ portion of Falls inflow */

/*  The water quality release from Falls = outflow from Falls.  The release is constrained in the main.ocl file to the amount in the water
 quality storage pool plus the inflow to that account.  This way, the release will not be made if the account has emptied. Note the outflow may
 include releasing surplus water above the rule curve, which technically would be more than the water quality release.  But since the account
 is reset to full above the rule curve, it makes no difference.  However, to make it more realistic, set the WQ release to the minimum flow from Falls
 (for simplicity) when the elevation is at [Falls_upper_rule] or above.  */
Set  :  _Flake_WQ_Rel
{     condition  :  elevation1300 >= [Falls_upper_rule]
   value      :  min_flow1300.1304
```

```

   condition  :  default
   value      :  flow1300.1304
}

Set  :  _FLake_WQ_Stor /* Calculate the Falls WQ storage */
{     condition  : elevation1300 >= [Falls_upper_rule] and elevation1230 < [Falls_upper_rule]
      value      : _FLake_Max_WQ_Storage - ( max { 0, elev_to_stor{ 1230, [Falls_upper_rule] } - storage1230 } ) * _Pct_Max_WQ_Storage/100

      condition  :  elevation1300 >= [Falls_upper_rule] or _FLake_WQ_Stor(-1)
     + ( _FLake_WStoWQ_Spill + _FLake_Inf_WQ -_Flake_WQ_Rel ) >= _FLake_Max_WQ_Storage
      value      :  _FLake_Max_WQ_Storage

/*    Fix WS WQ accounting error on first day of drought. */
      condition  : elevation1300(0) >= [Falls_upper_rule] and elevation1300 < [Falls_upper_rule]
      value      :  _FLake_Max_WQ_Storage - ( elev_to_stor{ 1300, [Falls_upper_rule] } - storage1300 ) * _Pct_Max_WQ_Storage/100

   /*  Sets the water supply storage floor as zero minus the storage in Beaverdam */
      condition  :  default
      value      :  max { 0 - _Bdam_WQ_Stor, _FLake_WQ_Stor(-1)
       + ( _FLake_WStoWQ_Spill + _FLake_Inf_WQ -_Flake_WQ_Rel ) } /* Appears to be counted twice in
                        terry's spreadsheet, but we are not here.*/
}

Set  :  _FLake_WQtoWS_Spill /* Calculate the spillover from WQ to WS */
{     condition  :   _FLake_WQ_Stor(-1)
     + ( _FLake_WStoWQ_Spill + _FLake_Inf_WQ - _Flake_WQ_Rel ) > _FLake_Max_WQ_Storage   /* Spillover only if
                            projected WS storage
                            more than 100% */
      value      :   _FLake_WQ_Stor(-1) + ( _FLake_WStoWQ_Spill + _FLake_Inf_WQ - _Flake_WQ_Rel ) - _FLake_Max_WQ_Storage

      condition  :  default
      value      :  0
}

Set  :  _FLake_WS_Stor /* Calculate the final Falls WS storage (after computing spillage) */
{     condition  : elevation1300 >= [Falls_upper_rule] and elevation1230 < [Falls_upper_rule] // modified by R.Palmer
      value      : _FLake_Max_WS_Storage - ( max { 0, elev_to_stor{ 1230, [Falls_upper_rule] } - storage1230 } ) * _Pct_Max_WS_Storage/100

      // Following two conditions added by R. Palmer to improve accurate accounting under cross-over conditions
      condition  :  _FLake_WS_Stor_Init + _FLake_WQtoWS_Spill >= _FLake_Max_WS_Storage /* Set to 100% if more than full */
      value      :  _FLake_Max_WS_Storage

/*    Fix WS WQ accounting error on first day of drought. */
      condition  : elevation1300(0) >= [Falls_upper_rule] and elevation1300 < [Falls_upper_rule]
      value      : _FLake_Max_WS_Storage - ( elev_to_stor{ 1300, [Falls_upper_rule] } - storage1300 ) * _Pct_Max_WS_Storage/100

```

```
   condition  :  default
      value      :  _FLake_WS_Stor_Init + _FLake_WQtoWS_Spill
}

Set  :  _Total_WS_Stor  {  value  :  _FLake_WS_Stor + _Bdam_WS_Stor  } /* Sum the total WS storage for Falls + Beaverdam */


Set  :  _Total_WQ_Stor  {  value  :  _FLake_WQ_Stor + _Bdam_WQ_Stor  } /* Sum the total WQ storage for Falls + Beaverdam */


/*  Calculate the percent of full for the WS and WQ accounts */

Set  :  _Bdam_WS_Pct  {  value  :  100 * _Bdam_WS_Stor  / _Bdam_Max_WS_Storage  }
Set  :  _Bdam_WQ_Pct  {  value  :  100 * _Bdam_WQ_Stor  / _Bdam_Max_WQ_Storage  }
Set  :  _FLake_WS_Pct {  value  :  100 * _FLake_WS_Stor / _FLake_Max_WS_Storage }
Set  :  _FLake_WQ_Pct {  value  :  100 * _FLake_WQ_Stor / _FLake_Max_WQ_Storage }
Set  :  _Total_WS_Pct {  value  :  100 * _Total_WS_Stor / [Total_Max_WS_Storage]}
Set  :  _Total_WQ_Pct {  value  :  100 * _Total_WQ_Stor / [Total_Max_WQ_Storage] }
```

Falls_flood_ops.ocl

```
/*  FALLS_FLOOD_OPS.OCL  */

/* Flood release policy for Falls Lake */

/*  Calculate estimated local inflow to Clayton, which is used in determing Falls flood releases */
Set : _ClaytLocal
{        Value : inflow1290 + inflow1445 + inflow1450 + inflow1630 +
        /*  To increase accuracy, estimate Crabtree outflows by using starting elevation and spillway curve */
        min {convert_units { Lookup{ 1416Outflow, elevation1416 }, cfs, af}, storage1416 - elev_to_stor {1416, 230} } +

        min {convert_units { Lookup{ 1418Outflow, elevation1418 }, cfs, af}, storage1418 - elev_to_stor {1418, 335} } +

        min {convert_units { Lookup{ 1422Outflow, elevation1422 }, cfs, af}, storage1422 - elev_to_stor {1422, 252} }
}


/*  Falls flood operations per recommendations in Terry Brown's email 02/26/2009 */
Target Falls_release  :  dflow1300.1304
{   /*  Release only the minimum release if elevation is less than 255 and est. Clayton inflows >= 7000 cfs */
   condition : elevation1300 >= [Falls_upper_rule] and elevation1300 <= 255 and _ClaytLocal >= convert_units { 7000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : min_flow1300.1304

   /*  If elev. < 255 and est. Clayton inflow < 7000 cfs, release the lesser of 4000 cfs or (7000 - the Clayt inflow).
       Also added provision to only drop Falls to the guide curve, but not less than the minimum release */
   condition : elevation1300 >= [Falls_upper_rule] and elevation1300 <= 255 and _ClaytLocal < convert_units { 7000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 0  // Set to 0 for underage to improve release performance - RP
   Value     : max { min_flow1300.1304, min { convert_units { 4000, cfs, af }, convert_units { 7000, cfs, af }
    - _ClaytLocal, storage1300 - elev_to_stor { 1300, [Falls_upper_rule] } } }

   /*  Release only the minimum release if elevation is less than 255 - 258 and est. Clayton inflows >= 7000 cfs */
   condition : elevation1300 > 255 and elevation1300 <= 258 and _ClaytLocal >= convert_units { 7000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : min_flow1300.1304

   /*  If elev. is 255 - 258 and est. Clayton inflow < 7000 cfs, release 7000 - the Clayt inflow. */
   condition : elevation1300 > 255 and elevation1300 <= 258 and _ClaytLocal < convert_units { 7000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : convert_units { 7000, cfs, af } - _ClaytLocal
```

```
   /*  Release only the minimum release if elevation is 258 - 264.8 and est. Clayton inflows >= 8000 cfs */
   condition : elevation1300 > 258 and elevation1300 <= 264.8 and _ClaytLocal >= convert_units { 8000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : min_flow1300.1304

   /*   If elev. is 258 - 264.8 and est. Clayton inflow < 8000 cfs, release 8000 - the Clayt inflow. */
   condition : elevation1300 > 258 and elevation1300 <= 264.8 and _ClaytLocal < convert_units { 8000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : convert_units { 8000, cfs, af } - _ClaytLocal

   /*  If elev. is 264.8 - 268 and est. Clayton inflow >= 8000 cfs, release only the computed spillway amount */
   condition : elevation1300 > 264.8 and elevation1300 <= 268 and _ClaytLocal >= convert_units { 8000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : convert_units { lookup { FallsSpillway, elevation1300 }, cfs, af }

   /*  If elev. is 264.8 - 268 and est. Clayton inflow < 8000 cfs, release [(8000 cfs + the computed spillway amount) - the Clayt inflow]. */
   condition : elevation1300 > 264.8 and elevation1300 <= 268 and _ClaytLocal < convert_units { 8000, cfs, af}
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : convert_units {  8000 + lookup { FallsSpillway, elevation1300 }, cfs, af } - _ClaytLocal

   /*  If elev. is > 268, release the full amounts possible from the service gates and the spillway. */
   condition : elevation1300 > 268
   priority  : 1
   penalty+  : 50
   penalty-  : 50
   Value     : convert_units { lookup { FallsSvcGate, elevation1300 } + lookup { FallsSpillway, elevation1300 }, cfs, af }
}

/*  Set targets based on flood stages at downstream gages; note that the above release policy takes priorty over these targets */

/*  Clayton flood control target */
Target Clayton_max  :  dflow1630.1640
{   condition : default
   priority  : 1
   penalty+  : 10
   penalty-  : 0
   Value     : convert_units{ 5332, cfs, af }
}
```

```
/*  Goldsboro flood control target  */
Target Goldsboro_max  :  dflow1780.1790
{   condition : default
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : convert_units{ 6003, cfs, af }
}

/*  Kinston flood control target */
Target Kinston_max  :  dflow1800.1850
{   condition : default
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : convert_units{ 7168, cfs, af }
}
```

Fayetteville_ops.ocl

```
/*  Fayetteville_ops.ocl  */
/*  Operational policies for Fayetteville */


// Switch to river intake only when Glenville < 212.2 ft
Target Glenville_WD : dflow0760.0731
{   condition : storage0760 < lower_rule0760
    priority  : 1
    penalty+  : 50
    penalty-  : 50
    Value     : 0

// Otherwise WD 4.5 mgd (per conversation with Chris Smith at Fayetteville). 4.5 mgd is also set as the max flow pattern
    condition : default
    priority  : 1
    penalty+  : 50
    penalty-  : 50
    Value     : convert_units { 4.5, mgd, af }
}
```

filter_inflows.ocl

```
/*  FILTER_INFLOWS.OCL  */

/* Sets the inflows for nodes that need to be filtered. The finalized inflows (through Sept 2011)
   were already filtered; however, the provisional inflows from the update record routine can be
   negative due to time of travel or imperfect impairment estimations, and therefore are filtered
   here to prevent model infeasibility or unrealistic reservoir releases and/or demand shortages.
   All Neuse inflows are filtered except Falls/Bdam, which can have negatives due to the use of
   back-calculated inflows; and Michie/LRR in Durham, which are based on already unimpaired gages
   that will not be negative.  The inflows to the Crabtree Creek system are set and filtered
   separately in Crabtree.ocl. Negative back-calculated inflows for Falls/Bdam are not physically
   possible since we've adjusted for net evap and net withdrawals; however, reservoir storage can
   handle these negatives.  The negatives are not used in developing regressions to fill in other
   gages, so we do not need to adjust the negatives.
*/

// The Cape Fear inflow nodes could be expanded
:For:
{   [node] = { 0020, 0040, 0070, 0090, 0300, 0310, 0324, 0325, 0590, 0760, 0140, 0145, 0170, 0210, 0220, 0260,
    0270, 0280, 0340, 0380, 0400, 0430, 0450, 0470, 0490, 0520, 0527, 0550, 0700, 1010, 1050, 1060,
    1080, 1100, 1110, 1115, 1250, 1270, 1290, 1420, 1440, 1445, 1450, 1500, 1560, 1630, 1740 }
}
    Set : _TempInf[node] { Value : timesers([node]/inflow) }
    Set : inflow[node] { Value : max{0, _TempInf[node] - _InfDeficit[node](-1) } }
    Set : _InfDeficit[node] { Value : max{0, _InfDeficit[node](-1) - _TempInf[node] } }

:Next:

// In addition to filtering, this also sets inflows to points of interest
// that are not contained in the basedata file, and adjusts existing inflows accordingly

// New inflows for CF

// Greensboro Haw intake
Set : _TempInf0044 { Value : timesers(0090/inflow)*(14/174.6) }
Set : inflow0044 { Value : max{0, _TempInf0044 - _InfDeficit0044(-1) } }
Set : _InfDeficit0044 { Value : max{0, _InfDeficit0044(-1) - _TempInf0044 } }

// Adj Haw gage
Set : _TempInf0090 { Value : timesers(0090/inflow)*(160.6/174.6) }
Set : inflow0090 { Value : max{0, _TempInf0090 - _InfDeficit0090(-1) } }
Set : _InfDeficit0090 { Value : max{0, _InfDeficit0090(-1) - _TempInf0090 } }

// Since the timeseries for Oakrdige includes the gain to Brandt, need to separate out that gain
Set : _Gibso_Gain { value : 110.4 *timesers(0140/inflow) / 35 }

// Lake Higgins - 11 sq mi of the gain from Oakridge to Brandt
Set : _TempInf0112 { Value : (11 / 49.4) * _Gibso_Gain * 49.4 / 110.4  } // Higgins is
```

```
Set : inflow0112 { Value : max{0, _TempInf0112 - _InfDeficit0112(-1) } }
Set : _InfDeficit0112 { Value : max{0, _InfDeficit0112(-1) - _TempInf0112 } }

// Brandt Reservoir - the remaining 38.4 sq mi of the gain from Oakridge to Brandt
Set : _TempInf0120 { Value : (38.4 / 49.4) * _Gibso_Gain * 49.4 / 110.4  }
Set : inflow0120 { Value : max{0, _TempInf0120 - _InfDeficit0120(-1) } }
Set : _InfDeficit0120 { Value : max{0, _InfDeficit0120(-1) - _TempInf0120 } }

// Adj Oakridge Inflow - now just the Oakridge gage portion of the 110 inflow timeseries
Set : _TempInf0110 { Value : timesers(0110/inflow) - inflow0112 - inflow0120 }
Set : inflow0110 { Value : max{0, _TempInf0110 - _InfDeficit0110(-1) } }
Set : _InfDeficit0110 { Value : max{0, _InfDeficit0110(-1) - _TempInf0110 } }

// Rocky River Discharge
Set : _TempInf0328 { Value : (timesers(0324/inflow)+timesers(0325/inflow))*(22.8/55) }
Set : inflow0328 { Value : max{0, _TempInf0328 - _InfDeficit0328(-1) } }
Set : _InfDeficit0328 { Value : max{0, _InfDeficit0328(-1) - _TempInf0328 } }

// Ramseur Discharge
Set : _TempInf0570 { Value : timesers(0300/inflow)*(6/355) }
Set : inflow0570 { Value : max{0, _TempInf0570 - _InfDeficit0570(-1) } }
Set : _InfDeficit0570 { Value : max{0, _InfDeficit0570(-1) - _TempInf0570 } }

// Adj 590 for Robbins intake
Set : _TempInf0590 { Value : timesers(0590/inflow)*(268/400) }
Set : inflow0590 { Value : max{0, _TempInf0590 - _InfDeficit0590(-1) } }
Set : _InfDeficit0590 { Value : max{0, _InfDeficit0590(-1) - _TempInf0590 } }

// Robbins intake
Set : _TempInf0580 { Value : timesers(0590/inflow)*(132/400) }
Set : inflow0580 { Value : max{0, _TempInf0580 - _InfDeficit0580(-1) } }
Set : _InfDeficit0580 { Value : max{0, _InfDeficit0580(-1) - _TempInf0580 } }

// Pilgrims Pride intake
Set : _TempInf0600 { Value : timesers(0640/inflow)*(371/630) }
Set : inflow0600 { Value : max{0, _TempInf0600 - _InfDeficit0600(-1) } }
Set : _InfDeficit0600 { Value : max{0, _InfDeficit0600(-1) - _TempInf0600 } }

// Node 610
Set : _TempInf0610 { Value : timesers(0640/inflow)*(40/630) }
Set : inflow0610 { Value : max{0, _TempInf0610 - _InfDeficit0610(-1) } }
Set : _InfDeficit0610 { Value : max{0, _InfDeficit0610(-1) - _TempInf0610 } }

// Adj Deep Moncure Gage
Set : _TempInf0640 { Value : timesers(0640/inflow)*(219/630) - inflow0328 - inflow0570}
Set : inflow0640 { Value : max{0, _TempInf0640 - _InfDeficit0640(-1) } }
Set : _InfDeficit0640 { Value : max{0, _InfDeficit0640(-1) - _TempInf0640 } }
```

```
// Node 660
Set : _TempInf0660 { Value : timesers(0780/inflow)*(286/919.6) }
Set : inflow0660 { Value : max{0, _TempInf0660 - _InfDeficit0660(-1) } }
Set : _InfDeficit0660 { Value : max{0, _InfDeficit0660(-1) - _TempInf0660 } }

// Node 680
Set : _TempInf0680 { Value : timesers(0780/inflow)*(20/919.6) }
Set : inflow0680 { Value : max{0, _TempInf0680 - _InfDeficit0680(-1) } }
Set : _InfDeficit0680 { Value : max{0, _InfDeficit0680(-1) - _TempInf0680 } }

// Node 700 - Carthage WS WD upstream on Little River.
// Note that 700/inflow timeseries is the full Little R. Linden gage flow
Set : _TempInf0700 { Value : timesers(0700/inflow)*(200/459) }
Set : inflow0700 { Value : max{0, _TempInf0700 - _InfDeficit0700(-1) } }
Set : _InfDeficit0700 { Value : max{0, _InfDeficit0700(-1) - _TempInf0700 } }

// Node 720 - Set as the remainder of the Little River Linden Gage flow
Set : _TempInf0720 { Value : timesers(0700/inflow)*(259/459) }
Set : inflow0720 { Value : max{0, _TempInf0720 - _InfDeficit0720(-1) } }
Set : _InfDeficit0720 { Value : max{0, _InfDeficit0720(-1) - _TempInf0720 } }

// Fayetteville PWC Intake
Set : _TempInf0730 { Value : timesers(0780/inflow)*(131/919.6) }
Set : inflow0730 { Value : max{0, _TempInf0730 - _InfDeficit0730(-1) } }
Set : _InfDeficit0730 { Value : max{0, _InfDeficit0730(-1) - _TempInf0730 } }

// Monsanto WS Intake
Set : _TempInf0770 { Value : timesers(0780/inflow)*(420.6/919.6) }
Set : inflow0770 { Value : max{0, _TempInf0770 - _InfDeficit0770(-1) } }
Set : _InfDeficit0770 { Value : max{0, _InfDeficit0770(-1) - _TempInf0770 } }

// Adj CF Tarheel Gage
Set : _TempInf0780 { Value : timesers(0780/inflow)*(62/919.6) }
Set : inflow0780 { Value : max{0, _TempInf0780 - _InfDeficit0780(-1) } }
Set : _InfDeficit0780 { Value : max{0, _InfDeficit0780(-1) - _TempInf0780 } }

// L&D #2 / Elizabethtown WWTP
Set : _TempInf0790 { Value : timesers(0820/inflow)*(168/403) }
Set : inflow0790 { Value : max{0, _TempInf0790 - _InfDeficit0790(-1) } }
Set : _InfDeficit0790 { Value : max{0, _InfDeficit0790(-1) - _TempInf0790 } }

// Adj of CF Kelly Gage
Set : _TempInf0820 { Value : timesers(0820/inflow)*(235/403) }
Set : inflow0820 { Value : max{0, _TempInf0820 - _InfDeficit0820(-1) } }
Set : _InfDeficit0820 { Value : max{0, _InfDeficit0820(-1) - _TempInf0820 } }
```

```

// New inflows for Neuse

// 205 - Little R @ Eno R
Set : _TempInf1205 { Value : timesers(1115/inflow)*(105/75) }
Set : inflow1205 { Value : max{0, _TempInf1205 - _InfDeficit1205(-1) } }
Set : _InfDeficit1205 { Value : max{0, _InfDeficit1205(-1) - _TempInf1205 } }

// Adj Falls inflow (not filtered)
Set : inflow1300 { Value : timesers(1300/inflow) - inflow1205 }

// Apex WW Discharge
Set : _TempInf1405 { Value : timesers(1480/inflow)*(0.9/83.5) }
Set : inflow1405 { Value : max{0, _TempInf1405 - _InfDeficit1405(-1) } }
Set : _InfDeficit1405 { Value : max{0, _InfDeficit1405(-1) - _TempInf1405 } }

// Fuquay-Varina WW Discharge
Set : _TempInf1409 { Value : timesers(1480/inflow)*(7.6/83.5) }
Set : inflow1409 { Value : max{0, _TempInf1409 - _InfDeficit1409(-1) } }
Set : _InfDeficit1409 { Value : max{0, _InfDeficit1409(-1) - _TempInf1409 } }

// Cary SWRF Discharge
Set : _TempInf1471 { Value : timesers(1480/inflow)*(21.5/83.5) }
Set : inflow1471 { Value : max{0, _TempInf1471 - _InfDeficit1471(-1) } }
Set : _InfDeficit1471 { Value : max{0, _InfDeficit1471(-1) - _TempInf1471 } }

// Adj Middle Ck Gage
Set : _TempInf1480 { Value : timesers(1480/inflow)*(53.5/83.5) }
Set : inflow1480 { Value : max{0, _TempInf1480 - _InfDeficit1480(-1) } }
Set : _InfDeficit1480 { Value : max{0, _InfDeficit1480(-1) - _TempInf1480 } }

// Wiggons Mill Lake
Set : _TempInf1520 { Value : timesers(1560/inflow)*(77/575) }
Set : inflow1520 { Value : max{0, _TempInf1520 - _InfDeficit1520(-1) } }
Set : _InfDeficit1520 { Value : max{0, _InfDeficit1520(-1) - _TempInf1520 } }

// Adj Contentnea Hookerton Gage
Set : _TempInf1560 { Value : timesers(1560/inflow)*(498/575) }
Set : inflow1560 { Value : max{0, _TempInf1560 - _InfDeficit1560(-1) } }
Set : _InfDeficit1560 { Value : max{0, _InfDeficit1560(-1) - _TempInf1560 } }

// Smith Confluence -
Set : _TempInf1320 { Value : timesers(1630/inflow)*(20/271) }
Set : inflow1320 { Value : max{0, _TempInf1320 - _InfDeficit1320(-1) } }
Set : _InfDeficit1320 { Value : max{0, _InfDeficit1320(-1) - _TempInf1320 } }

// Crabtree Ck Confluence
```

```
Set : _TempInf1600 { Value : timesers(1630/inflow)*(90/271) }
Set : inflow1600 { Value : max{0, _TempInf1600 - _InfDeficit1600(-1) } }
Set : _InfDeficit1600 { Value : max{0, _InfDeficit1600(-1) - _TempInf1600 } }

// Walnut Ck Confluence -
Set : _TempInf1620 { Value : timesers(1630/inflow)*(41/271) }
Set : inflow1620 { Value : max{0, _TempInf1620 - _InfDeficit1620(-1) } }
Set : _InfDeficit1620 { Value : max{0, _InfDeficit1620(-1) - _TempInf1620 } }

// NRWWTP - Natural inflow between Walnut Creek and Neuse River WWTP - node added in 2014
Set : _TempInf1625 { Value : timesers(1630/inflow)*(62/271) }
Set : inflow1625 { Value : max{0, _TempInf1625 - _InfDeficit1625(-1) } }
Set : _InfDeficit1625 { Value : max{0, _InfDeficit1625(-1) - _TempInf1625 } }

// Adj Neuse Clayton Gage (increased to 58 sq. miles from 11 sq. mi.based on drainage between NRWWTP and Clayton Gage)
Set : _TempInf1630 { Value : timesers(1630/inflow)*(58/271) }
Set : inflow1630 { Value : max{0, _TempInf1630 - _InfDeficit1630(-1) } }
Set : _InfDeficit1630 { Value : max{0, _InfDeficit1630(-1) - _TempInf1630 } }

// Kenly WW
Set : _TempInf1747 { Value : timesers(1750/inflow)*(165.2/181.2) }
Set : inflow1747 { Value : max{0, _TempInf1747 - _InfDeficit1747(-1) } }
Set : _InfDeficit1747 { Value : max{0, _InfDeficit1747(-1) - _TempInf1747 } }

// Adj Little R Princeton Gage
Set : _TempInf1750 { Value : timesers(1750/inflow)*(16/181.2) }
Set : inflow1750 { Value : max{0, _TempInf1750 - _InfDeficit1750(-1) } }
Set : _InfDeficit1750 { Value : max{0, _InfDeficit1750(-1) - _TempInf1750 } }

// Johnston County Intake
Set : _TempInf1650 { Value : timesers(1780/inflow)*(30/867.2) }
Set : inflow1650 { Value : max{0, _TempInf1650 - _InfDeficit1650(-1) } }
Set : _InfDeficit1650 { Value : max{0, _InfDeficit1650(-1) - _TempInf1650 } }

// Neuse Smithfield
Set : _TempInf1660 { Value : timesers(1780/inflow)*(26/867.2) }
Set : inflow1660 { Value : max{0, _TempInf1660 - _InfDeficit1660(-1) } }
Set : _InfDeficit1660 { Value : max{0, _InfDeficit1660(-1) - _TempInf1660 } }

// Swift Ck Confluence - changed from 4 to 144.2 based on total DA at Swift/Middle/Neuse confluence of 1500.0
// sq. mi (per USGS streamstats) - 1206 @ Smithfield  - 83.5@ Middle Creek - 66.3 @ L. Benson  = 144.2
Set : _TempInf1700 { Value : timesers(1780/inflow)*(144.2/867.2) }
Set : inflow1700 { Value : max{0, _TempInf1700 - _InfDeficit1700(-1) } }
Set : _InfDeficit1700 { Value : max{0, _InfDeficit1700(-1) - _TempInf1700 } }

// Richardson Bridge Rd crossing of Neuse - potential JC Intake #2 site. Total DA is 1677 sq mi. per CH2M Hill 2013 SY Addendum
Set : _TempInf1730 { Value : timesers(1780/inflow)*(177/867.2) }
```

```
Set : inflow1730 { Value : max{0, _TempInf1730 - _InfDeficit1730(-1) } }
Set : _InfDeficit1730 { Value : max{0, _InfDeficit1730(-1) - _TempInf1730 } }

// Alternative site for Johnston County lower Neuse Intake below the confluence with Mill Creek - total DA is 1889 sq. mi
// per CH2M Hill 2013 SY Addendum
Set : _TempInf1735 { Value : timesers(1780/inflow)*(212/867.2) }
Set : inflow1735 { Value : max{0, _TempInf1735 - _InfDeficit1735(-1) } }
Set : _InfDeficit1735 { Value : max{0, _InfDeficit1735(-1) - _TempInf1735 } }

// Princeton WWTP
Set : _TempInf1755 { Value : timesers(1780/inflow)*(32/867.2) }
Set : inflow1755 { Value : max{0, _TempInf1755 - _InfDeficit1755(-1) } }
Set : _InfDeficit1755 { Value : max{0, _InfDeficit1755(-1) - _TempInf1755 } }

// Progress Energy Intake - reduced to 161 based on multiple adjustments above Swift Ck confluence adjustment above
Set : _TempInf1760 { Value : timesers(1780/inflow)*(161/867.2) }
Set : inflow1760 { Value : max{0, _TempInf1760 - _InfDeficit1760(-1) } }
Set : _InfDeficit1760 { Value : max{0, _InfDeficit1760(-1) - _TempInf1760 } }

// Little R Confluence
Set : _TempInf1775 { Value : timesers(1780/inflow)*(62/867.2) }
Set : inflow1775 { Value : max{0, _TempInf1775 - _InfDeficit1775(-1) } }
Set : _InfDeficit1775 { Value : max{0, _InfDeficit1775(-1) - _TempInf1775 } }

// Adj Neuse Goldsboro Gage
Set : _TempInf1780 { Value : timesers(1780/inflow)*(23/867.2) }
Set : inflow1780 { Value : max{0, _TempInf1780 - _InfDeficit1780(-1) } }
Set : _InfDeficit1780 { Value : max{0, _InfDeficit1780(-1) - _TempInf1780 } }

// NRWASA Intake
Set : _TempInf1795 { Value : timesers(1800/inflow)*(211/293) }
Set : inflow1795 { Value : max{0, _TempInf1795 - _InfDeficit1795(-1) } }
Set : _InfDeficit1795 { Value : max{0, _InfDeficit1795(-1) - _TempInf1795 } }

// Adj Neuse Kinston Gage
Set : _TempInf1800 { Value : timesers(1800/inflow)*(82/293) }
Set : inflow1800 { Value : max{0, _TempInf1800 - _InfDeficit1800(-1) } }
Set : _InfDeficit1800 { Value : max{0, _InfDeficit1800(-1) - _TempInf1800 } }

// Little Contentnea Confluence
Set : _TempInf1570 { Value : timesers(1900/inflow)*(62/625) }
Set : inflow1570 { Value : max{0, _TempInf1570 - _InfDeficit1570(-1) } }
Set : _InfDeficit1570 { Value : max{0, _InfDeficit1570(-1) - _TempInf1570 } }

// Contentnea Confluence
Set : _TempInf1850 { Value : timesers(1900/inflow)*(208/625) }
Set : inflow1850 { Value : max{0, _TempInf1850 - _InfDeficit1850(-1) } }
```

```
Set : _InfDeficit1850 { Value : max{0, _InfDeficit1850(-1) - _TempInf1850 } }

// Adj Weyerhauser Gain
Set : _TempInf1900 { Value : timesers(1900/inflow)*(355/625) }
Set : inflow1900 { Value : max{0, _TempInf1900 - _InfDeficit1900(-1) } }
Set : _InfDeficit1900 { Value : max{0, _InfDeficit1900(-1) - _TempInf1900 } }

// New Bern
Set : _TempInf1999 { Value : timesers(1900/inflow)*(10/625) }
Set : inflow1999 { Value : max{0, _TempInf1999 - _InfDeficit1999(-1) } }
Set : _InfDeficit1999 { Value : max{0, _InfDeficit1999(-1) - _TempInf1999 } }
```

Forecast_Horizon_Days.ocl

```
/* This file converts the forecast horizon in weeks to days (less one, for the accumulate function)
   for use in the projections in the user_def_ops.ocl file  */



/* Start with the forecast horizon 1 */
:if: {[Forecast_1_Horizon] = 24 }
  :Substitute: [Forecast_1_Horizon_Days] = 167
:endif:

:if: {[Forecast_1_Horizon] = 23 }
  :Substitute: [Forecast_1_Horizon_Days] = 160
:endif:

:if: {[Forecast_1_Horizon] = 22 }
  :Substitute: [Forecast_1_Horizon_Days] = 153
:endif:

:if: {[Forecast_1_Horizon] = 21 }
  :Substitute: [Forecast_1_Horizon_Days] = 146
:endif:

:if: {[Forecast_1_Horizon] = 20 }
  :Substitute: [Forecast_1_Horizon_Days] = 139
:endif:

:if: {[Forecast_1_Horizon] = 19 }
  :Substitute: [Forecast_1_Horizon_Days] = 132
:endif:

:if: {[Forecast_1_Horizon] = 18 }
  :Substitute: [Forecast_1_Horizon_Days] = 125
:endif:

:if: {[Forecast_1_Horizon] = 17 }
  :Substitute: [Forecast_1_Horizon_Days] = 118
:endif:

:if: {[Forecast_1_Horizon] = 16 }
  :Substitute: [Forecast_1_Horizon_Days] = 111
:endif:

:if: {[Forecast_1_Horizon] = 15 }
  :Substitute: [Forecast_1_Horizon_Days] = 104
:endif:

:if: {[Forecast_1_Horizon] = 14 }
```

```
  :Substitute: [Forecast_1_Horizon_Days] = 97
:endif:

:if: {[Forecast_1_Horizon] = 13 }
  :Substitute: [Forecast_1_Horizon_Days] = 90
:endif:

:if: {[Forecast_1_Horizon] = 12 }
  :Substitute: [Forecast_1_Horizon_Days] = 83
:endif:

:if: {[Forecast_1_Horizon] = 11 }
  :Substitute: [Forecast_1_Horizon_Days] = 76
:endif:

:if: {[Forecast_1_Horizon] = 10 }
  :Substitute: [Forecast_1_Horizon_Days] = 69
:endif:

:if: {[Forecast_1_Horizon] = 9 }
  :Substitute: [Forecast_1_Horizon_Days] = 62
:endif:

:if: {[Forecast_1_Horizon] = 8}
  :Substitute: [Forecast_1_Horizon_Days] = 55
:endif:

:if: {[Forecast_1_Horizon] = 7 }
  :Substitute: [Forecast_1_Horizon_Days] = 48
:endif:

:if: {[Forecast_1_Horizon] = 6 }
  :Substitute: [Forecast_1_Horizon_Days] = 41
:endif:

:if: {[Forecast_1_Horizon] = 5 }
  :Substitute: [Forecast_1_Horizon_Days] = 34
:endif:

:if: {[Forecast_1_Horizon] = 4 }
  :Substitute: [Forecast_1_Horizon_Days] = 27
:endif:

:if: {[Forecast_1_Horizon] = 3 }
  :Substitute: [Forecast_1_Horizon_Days] = 20
:endif:
```

```
:if: {[Forecast_1_Horizon] = 2 }
  :Substitute: [Forecast_1_Horizon_Days] = 13
:endif:

:if: {[Forecast_1_Horizon] = 1 }
  :Substitute: [Forecast_1_Horizon_Days] = 6
:endif:


/* Repeat for forecast horizon 2 */

:if: {[Forecast_2_Horizon] = 24 }
  :Substitute: [Forecast_2_Horizon_Days] = 167
:endif:

:if: {[Forecast_2_Horizon] = 23 }
  :Substitute: [Forecast_2_Horizon_Days] = 160
:endif:

:if: {[Forecast_2_Horizon] = 22 }
  :Substitute: [Forecast_2_Horizon_Days] = 153
:endif:

:if: {[Forecast_2_Horizon] = 21 }
  :Substitute: [Forecast_2_Horizon_Days] = 146
:endif:

:if: {[Forecast_2_Horizon] = 20 }
  :Substitute: [Forecast_2_Horizon_Days] = 139
:endif:

:if: {[Forecast_2_Horizon] = 19 }
  :Substitute: [Forecast_2_Horizon_Days] = 132
:endif:

:if: {[Forecast_2_Horizon] = 18 }
  :Substitute: [Forecast_2_Horizon_Days] = 125
:endif:

:if: {[Forecast_2_Horizon] = 17 }
  :Substitute: [Forecast_2_Horizon_Days] = 118
:endif:

:if: {[Forecast_2_Horizon] = 16 }
  :Substitute: [Forecast_2_Horizon_Days] = 111
:endif:
```

```
:if: {[Forecast_2_Horizon] = 15 }
  :Substitute: [Forecast_2_Horizon_Days] = 104
:endif:

:if: {[Forecast_2_Horizon] = 14 }
  :Substitute: [Forecast_2_Horizon_Days] = 97
:endif:

:if: {[Forecast_2_Horizon] = 13 }
  :Substitute: [Forecast_2_Horizon_Days] = 90
:endif:

:if: {[Forecast_2_Horizon] = 12 }
  :Substitute: [Forecast_2_Horizon_Days] = 83
:endif:

:if: {[Forecast_2_Horizon] = 11 }
  :Substitute: [Forecast_2_Horizon_Days] = 76
:endif:

:if: {[Forecast_2_Horizon] = 10 }
  :Substitute: [Forecast_2_Horizon_Days] = 69
:endif:

:if: {[Forecast_2_Horizon] = 9 }
  :Substitute: [Forecast_2_Horizon_Days] = 62
:endif:

:if: {[Forecast_2_Horizon] = 8}
  :Substitute: [Forecast_2_Horizon_Days] = 55
:endif:

:if: {[Forecast_2_Horizon] = 7 }
  :Substitute: [Forecast_2_Horizon_Days] = 48
:endif:

:if: {[Forecast_2_Horizon] = 6 }
  :Substitute: [Forecast_2_Horizon_Days] = 41
:endif:

:if: {[Forecast_2_Horizon] = 5 }
  :Substitute: [Forecast_2_Horizon_Days] = 34
:endif:

:if: {[Forecast_2_Horizon] = 4 }
  :Substitute: [Forecast_2_Horizon_Days] = 27
:endif:
```

```

:if: {[Forecast_2_Horizon] = 3 }
  :Substitute: [Forecast_2_Horizon_Days] = 20
:endif:

:if: {[Forecast_2_Horizon] = 2 }
  :Substitute: [Forecast_2_Horizon_Days] = 13
:endif:

:if: {[Forecast_2_Horizon] = 1 }
  :Substitute: [Forecast_2_Horizon_Days] = 6
:endif:


/* Repeat for forecast horizon 3 */

:if: {[Forecast_3_Horizon] = 24 }
  :Substitute: [Forecast_3_Horizon_Days] = 167
:endif:

:if: {[Forecast_3_Horizon] = 23 }
  :Substitute: [Forecast_3_Horizon_Days] = 160
:endif:

:if: {[Forecast_3_Horizon] = 22 }
  :Substitute: [Forecast_3_Horizon_Days] = 153
:endif:

:if: {[Forecast_3_Horizon] = 21 }
  :Substitute: [Forecast_3_Horizon_Days] = 146
:endif:

:if: {[Forecast_3_Horizon] = 20 }
  :Substitute: [Forecast_3_Horizon_Days] = 139
:endif:

:if: {[Forecast_3_Horizon] = 19 }
  :Substitute: [Forecast_3_Horizon_Days] = 132
:endif:

:if: {[Forecast_3_Horizon] = 18 }
  :Substitute: [Forecast_3_Horizon_Days] = 125
:endif:

:if: {[Forecast_3_Horizon] = 17 }
  :Substitute: [Forecast_3_Horizon_Days] = 118
:endif:
```

```

:if: {[Forecast_3_Horizon] = 16 }
  :Substitute: [Forecast_3_Horizon_Days] = 111
:endif:

:if: {[Forecast_3_Horizon] = 15 }
  :Substitute: [Forecast_3_Horizon_Days] = 104
:endif:

:if: {[Forecast_3_Horizon] = 14 }
  :Substitute: [Forecast_3_Horizon_Days] = 97
:endif:

:if: {[Forecast_3_Horizon] = 13 }
  :Substitute: [Forecast_3_Horizon_Days] = 90
:endif:

:if: {[Forecast_3_Horizon] = 12 }
  :Substitute: [Forecast_3_Horizon_Days] = 83
:endif:

:if: {[Forecast_3_Horizon] = 11 }
  :Substitute: [Forecast_3_Horizon_Days] = 76
:endif:

:if: {[Forecast_3_Horizon] = 10 }
  :Substitute: [Forecast_3_Horizon_Days] = 69
:endif:

:if: {[Forecast_3_Horizon] = 9 }
  :Substitute: [Forecast_3_Horizon_Days] = 62
:endif:

:if: {[Forecast_3_Horizon] = 8}
  :Substitute: [Forecast_3_Horizon_Days] = 55
:endif:

:if: {[Forecast_3_Horizon] = 7 }
  :Substitute: [Forecast_3_Horizon_Days] = 48
:endif:

:if: {[Forecast_3_Horizon] = 6 }
  :Substitute: [Forecast_3_Horizon_Days] = 41
:endif:

:if: {[Forecast_3_Horizon] = 5 }
  :Substitute: [Forecast_3_Horizon_Days] = 34
```

```
:endif:

:if: {[Forecast_3_Horizon] = 4 }
  :Substitute: [Forecast_3_Horizon_Days] = 27
:endif:

:if: {[Forecast_3_Horizon] = 3 }
  :Substitute: [Forecast_3_Horizon_Days] = 20
:endif:

:if: {[Forecast_3_Horizon] = 2 }
  :Substitute: [Forecast_3_Horizon_Days] = 13
:endif:

:if: {[Forecast_3_Horizon] = 1 }
  :Substitute: [Forecast_3_Horizon_Days] = 6
:endif:


/* Repeat for forecast horizon 4 */

:if: {[Forecast_4_Horizon] = 24 }
  :Substitute: [Forecast_4_Horizon_Days] = 167
:endif:

:if: {[Forecast_4_Horizon] = 23 }
  :Substitute: [Forecast_4_Horizon_Days] = 160
:endif:

:if: {[Forecast_4_Horizon] = 22 }
  :Substitute: [Forecast_4_Horizon_Days] = 153
:endif:

:if: {[Forecast_4_Horizon] = 21 }
  :Substitute: [Forecast_4_Horizon_Days] = 146
:endif:

:if: {[Forecast_4_Horizon] = 20 }
  :Substitute: [Forecast_4_Horizon_Days] = 139
:endif:

:if: {[Forecast_4_Horizon] = 19 }
  :Substitute: [Forecast_4_Horizon_Days] = 132
:endif:

:if: {[Forecast_4_Horizon] = 18 }
  :Substitute: [Forecast_4_Horizon_Days] = 125
```

```
:endif:

:if: {[Forecast_4_Horizon] = 17 }
  :Substitute: [Forecast_4_Horizon_Days] = 118
:endif:

:if: {[Forecast_4_Horizon] = 16 }
  :Substitute: [Forecast_4_Horizon_Days] = 111
:endif:

:if: {[Forecast_4_Horizon] = 15 }
  :Substitute: [Forecast_4_Horizon_Days] = 104
:endif:

:if: {[Forecast_4_Horizon] = 14 }
  :Substitute: [Forecast_4_Horizon_Days] = 97
:endif:

:if: {[Forecast_4_Horizon] = 13 }
  :Substitute: [Forecast_4_Horizon_Days] = 90
:endif:

:if: {[Forecast_4_Horizon] = 12 }
  :Substitute: [Forecast_4_Horizon_Days] = 83
:endif:

:if: {[Forecast_4_Horizon] = 11 }
  :Substitute: [Forecast_4_Horizon_Days] = 76
:endif:

:if: {[Forecast_4_Horizon] = 10 }
  :Substitute: [Forecast_4_Horizon_Days] = 69
:endif:

:if: {[Forecast_4_Horizon] = 9 }
  :Substitute: [Forecast_4_Horizon_Days] = 62
:endif:

:if: {[Forecast_4_Horizon] = 8}
  :Substitute: [Forecast_4_Horizon_Days] = 55
:endif:

:if: {[Forecast_4_Horizon] = 7 }
  :Substitute: [Forecast_4_Horizon_Days] = 48
:endif:

:if: {[Forecast_4_Horizon] = 6 }
```

```
  :Substitute: [Forecast_4_Horizon_Days] = 41
:endif:

:if: {[Forecast_4_Horizon] = 5 }
  :Substitute: [Forecast_4_Horizon_Days] = 34
:endif:

:if: {[Forecast_4_Horizon] = 4 }
  :Substitute: [Forecast_4_Horizon_Days] = 27
:endif:

:if: {[Forecast_4_Horizon] = 3 }
  :Substitute: [Forecast_4_Horizon_Days] = 20
:endif:

:if: {[Forecast_4_Horizon] = 2 }
  :Substitute: [Forecast_4_Horizon_Days] = 13
:endif:

:if: {[Forecast_4_Horizon] = 1 }
  :Substitute: [Forecast_4_Horizon_Days] = 6
:endif:


/* Repeat for forecast horizon 5 */

:if: {[Forecast_5_Horizon] = 24 }
  :Substitute: [Forecast_5_Horizon_Days] = 167
:endif:

:if: {[Forecast_5_Horizon] = 23 }
  :Substitute: [Forecast_5_Horizon_Days] = 160
:endif:

:if: {[Forecast_5_Horizon] = 22 }
  :Substitute: [Forecast_5_Horizon_Days] = 153
:endif:

:if: {[Forecast_5_Horizon] = 21 }
  :Substitute: [Forecast_5_Horizon_Days] = 146
:endif:

:if: {[Forecast_5_Horizon] = 20 }
  :Substitute: [Forecast_5_Horizon_Days] = 139
:endif:

:if: {[Forecast_5_Horizon] = 19 }
```

```
  :Substitute: [Forecast_5_Horizon_Days] = 132
:endif:

:if: {[Forecast_5_Horizon] = 18 }
  :Substitute: [Forecast_5_Horizon_Days] = 125
:endif:

:if: {[Forecast_5_Horizon] = 17 }
  :Substitute: [Forecast_5_Horizon_Days] = 118
:endif:

:if: {[Forecast_5_Horizon] = 16 }
  :Substitute: [Forecast_5_Horizon_Days] = 111
:endif:

:if: {[Forecast_5_Horizon] = 15 }
  :Substitute: [Forecast_5_Horizon_Days] = 104
:endif:

:if: {[Forecast_5_Horizon] = 14 }
  :Substitute: [Forecast_5_Horizon_Days] = 97
:endif:

:if: {[Forecast_5_Horizon] = 13 }
  :Substitute: [Forecast_5_Horizon_Days] = 90
:endif:

:if: {[Forecast_5_Horizon] = 12 }
  :Substitute: [Forecast_5_Horizon_Days] = 83
:endif:

:if: {[Forecast_5_Horizon] = 11 }
  :Substitute: [Forecast_5_Horizon_Days] = 76
:endif:

:if: {[Forecast_5_Horizon] = 10 }
  :Substitute: [Forecast_5_Horizon_Days] = 69
:endif:

:if: {[Forecast_5_Horizon] = 9 }
  :Substitute: [Forecast_5_Horizon_Days] = 62
:endif:

:if: {[Forecast_5_Horizon] = 8}
  :Substitute: [Forecast_5_Horizon_Days] = 55
:endif:
```

```
:if: {[Forecast_5_Horizon] = 7 }
  :Substitute: [Forecast_5_Horizon_Days] = 48
:endif:

:if: {[Forecast_5_Horizon] = 6 }
  :Substitute: [Forecast_5_Horizon_Days] = 41
:endif:

:if: {[Forecast_5_Horizon] = 5 }
  :Substitute: [Forecast_5_Horizon_Days] = 34
:endif:

:if: {[Forecast_5_Horizon] = 4 }
  :Substitute: [Forecast_5_Horizon_Days] = 27
:endif:

:if: {[Forecast_5_Horizon] = 3 }
  :Substitute: [Forecast_5_Horizon_Days] = 20
:endif:

:if: {[Forecast_5_Horizon] = 2 }
  :Substitute: [Forecast_5_Horizon_Days] = 13
:endif:

:if: {[Forecast_5_Horizon] = 1 }
  :Substitute: [Forecast_5_Horizon_Days] = 6
:endif:





/* Repeat for forecast horizon 6 */

:if: {[Forecast_6_Horizon] = 24 }
  :Substitute: [Forecast_6_Horizon_Days] = 167
:endif:

:if: {[Forecast_6_Horizon] = 23 }
  :Substitute: [Forecast_6_Horizon_Days] = 160
:endif:

:if: {[Forecast_6_Horizon] = 22 }
  :Substitute: [Forecast_6_Horizon_Days] = 153
:endif:

:if: {[Forecast_6_Horizon] = 21 }
```

```
  :Substitute: [Forecast_6_Horizon_Days] = 146
:endif:

:if: {[Forecast_6_Horizon] = 20 }
  :Substitute: [Forecast_6_Horizon_Days] = 139
:endif:

:if: {[Forecast_6_Horizon] = 19 }
  :Substitute: [Forecast_6_Horizon_Days] = 132
:endif:

:if: {[Forecast_6_Horizon] = 18 }
  :Substitute: [Forecast_6_Horizon_Days] = 125
:endif:

:if: {[Forecast_6_Horizon] = 17 }
  :Substitute: [Forecast_6_Horizon_Days] = 118
:endif:

:if: {[Forecast_6_Horizon] = 16 }
  :Substitute: [Forecast_6_Horizon_Days] = 111
:endif:

:if: {[Forecast_6_Horizon] = 15 }
  :Substitute: [Forecast_6_Horizon_Days] = 104
:endif:

:if: {[Forecast_6_Horizon] = 14 }
  :Substitute: [Forecast_6_Horizon_Days] = 97
:endif:

:if: {[Forecast_6_Horizon] = 13 }
  :Substitute: [Forecast_6_Horizon_Days] = 90
:endif:

:if: {[Forecast_6_Horizon] = 12 }
  :Substitute: [Forecast_6_Horizon_Days] = 83
:endif:

:if: {[Forecast_6_Horizon] = 11 }
  :Substitute: [Forecast_6_Horizon_Days] = 76
:endif:

:if: {[Forecast_6_Horizon] = 10 }
  :Substitute: [Forecast_6_Horizon_Days] = 69
:endif:
```

```
:if: {[Forecast_6_Horizon] = 9 }
  :Substitute: [Forecast_6_Horizon_Days] = 62
:endif:

:if: {[Forecast_6_Horizon] = 8}
  :Substitute: [Forecast_6_Horizon_Days] = 55
:endif:

:if: {[Forecast_6_Horizon] = 7 }
  :Substitute: [Forecast_6_Horizon_Days] = 48
:endif:

:if: {[Forecast_6_Horizon] = 6 }
  :Substitute: [Forecast_6_Horizon_Days] = 41
:endif:

:if: {[Forecast_6_Horizon] = 5 }
  :Substitute: [Forecast_6_Horizon_Days] = 34
:endif:

:if: {[Forecast_6_Horizon] = 4 }
  :Substitute: [Forecast_6_Horizon_Days] = 27
:endif:

:if: {[Forecast_6_Horizon] = 3 }
  :Substitute: [Forecast_6_Horizon_Days] = 20
:endif:

:if: {[Forecast_6_Horizon] = 2 }
  :Substitute: [Forecast_6_Horizon_Days] = 13
:endif:

:if: {[Forecast_6_Horizon] = 1 }
  :Substitute: [Forecast_6_Horizon_Days] = 6
:endif:




/* Repeat for forecast horizon 7 */

:if: {[Forecast_7_Horizon] = 24 }
  :Substitute: [Forecast_7_Horizon_Days] = 167
:endif:

:if: {[Forecast_7_Horizon] = 23 }
  :Substitute: [Forecast_7_Horizon_Days] = 160
```

```
:endif:

:if: {[Forecast_7_Horizon] = 22 }
  :Substitute: [Forecast_7_Horizon_Days] = 153
:endif:

:if: {[Forecast_7_Horizon] = 21 }
  :Substitute: [Forecast_7_Horizon_Days] = 146
:endif:

:if: {[Forecast_7_Horizon] = 20 }
  :Substitute: [Forecast_7_Horizon_Days] = 139
:endif:

:if: {[Forecast_7_Horizon] = 19 }
  :Substitute: [Forecast_7_Horizon_Days] = 132
:endif:

:if: {[Forecast_7_Horizon] = 18 }
  :Substitute: [Forecast_7_Horizon_Days] = 125
:endif:

:if: {[Forecast_7_Horizon] = 17 }
  :Substitute: [Forecast_7_Horizon_Days] = 118
:endif:

:if: {[Forecast_7_Horizon] = 16 }
  :Substitute: [Forecast_7_Horizon_Days] = 111
:endif:

:if: {[Forecast_7_Horizon] = 15 }
  :Substitute: [Forecast_7_Horizon_Days] = 104
:endif:

:if: {[Forecast_7_Horizon] = 14 }
  :Substitute: [Forecast_7_Horizon_Days] = 97
:endif:

:if: {[Forecast_7_Horizon] = 13 }
  :Substitute: [Forecast_7_Horizon_Days] = 90
:endif:

:if: {[Forecast_7_Horizon] = 12 }
  :Substitute: [Forecast_7_Horizon_Days] = 83
:endif:

:if: {[Forecast_7_Horizon] = 11 }
```

```
  :Substitute: [Forecast_7_Horizon_Days] = 76
:endif:

:if: {[Forecast_7_Horizon] = 10 }
  :Substitute: [Forecast_7_Horizon_Days] = 69
:endif:

:if: {[Forecast_7_Horizon] = 9 }
  :Substitute: [Forecast_7_Horizon_Days] = 62
:endif:

:if: {[Forecast_7_Horizon] = 8}
  :Substitute: [Forecast_7_Horizon_Days] = 55
:endif:

:if: {[Forecast_7_Horizon] = 7 }
  :Substitute: [Forecast_7_Horizon_Days] = 48
:endif:

:if: {[Forecast_7_Horizon] = 6 }
  :Substitute: [Forecast_7_Horizon_Days] = 41
:endif:

:if: {[Forecast_7_Horizon] = 5 }
  :Substitute: [Forecast_7_Horizon_Days] = 34
:endif:

:if: {[Forecast_7_Horizon] = 4 }
  :Substitute: [Forecast_7_Horizon_Days] = 27
:endif:

:if: {[Forecast_7_Horizon] = 3 }
  :Substitute: [Forecast_7_Horizon_Days] = 20
:endif:

:if: {[Forecast_7_Horizon] = 2 }
  :Substitute: [Forecast_7_Horizon_Days] = 13
:endif:

:if: {[Forecast_7_Horizon] = 1 }
  :Substitute: [Forecast_7_Horizon_Days] = 6
:endif:
```

Forecast-Trigger_Parms.ocl

```
// This file is automatically generated by the OASIS GUI
// Any changes you make in this file may be automatically overwritten

// This file contains parameter values that define the forecasting-and-trigger scenario

:SUBSTITUTE: [UseForecast] = 1
:SUBSTITUTE: [ForecastData] = cond


// The values below vary by trigger level

:SUBSTITUTE: [ForcCode_1] = R30W12
:SUBSTITUTE: [ForcCode_2] = R20W10
:SUBSTITUTE: [ForcCode_3] = R10W08
:SUBSTITUTE: [ForcCode_4] = R05W04
:SUBSTITUTE: [ForcCode_5] = R05W10

:SUBSTITUTE: [Risk_1_Factor_0] = 30
:SUBSTITUTE: [Risk_2_Factor_0] = 20
:SUBSTITUTE: [Risk_3_Factor_0] = 10
:SUBSTITUTE: [Risk_4_Factor_0] = 05
:SUBSTITUTE: [Risk_5_Factor_0] = 05

:SUBSTITUTE: [Forecast_1_Horizon_0] = 12
:SUBSTITUTE: [Forecast_2_Horizon_0] = 10
:SUBSTITUTE: [Forecast_3_Horizon_0] = 08
:SUBSTITUTE: [Forecast_4_Horizon_0] = 04
:SUBSTITUTE: [Forecast_5_Horizon_0] = 10

:SUBSTITUTE: [Risk_1_Factor] = 30
:SUBSTITUTE: [Risk_2_Factor] = 20
:SUBSTITUTE: [Risk_3_Factor] = 10
:SUBSTITUTE: [Risk_4_Factor] = 5
:SUBSTITUTE: [Risk_5_Factor] = 5

:SUBSTITUTE: [Forecast_1_Horizon] = 12
:SUBSTITUTE: [Forecast_2_Horizon] = 10
:SUBSTITUTE: [Forecast_3_Horizon] = 8
:SUBSTITUTE: [Forecast_4_Horizon] = 4
:SUBSTITUTE: [Forecast_5_Horizon] = 10

:SUBSTITUTE: [Trigger_1_Stor] = 45
:SUBSTITUTE: [Trigger_2_Stor] = 35
:SUBSTITUTE: [Trigger_3_Stor] = 25
:SUBSTITUTE: [Trigger_4_Stor] = 15
:SUBSTITUTE: [Trigger_5_Stor] = 90
```

```
:SUBSTITUTE: [Dem_1_Red_Factor] = 0
:SUBSTITUTE: [Dem_2_Red_Factor] = 0
:SUBSTITUTE: [Dem_3_Red_Factor] = 0
:SUBSTITUTE: [Dem_4_Red_Factor] = 0
:SUBSTITUTE: [Dem_5_Red_Factor] = 0

:SUBSTITUTE: [MinFlow_1_Red_Factor] = 0
:SUBSTITUTE: [MinFlow_2_Red_Factor] = 0
:SUBSTITUTE: [MinFlow_3_Red_Factor] = 0
:SUBSTITUTE: [MinFlow_4_Red_Factor] = 0
:SUBSTITUTE: [MinFlow_5_Red_Factor] = 0
```

FtBragg_ops.ocl

```
/*FTBRAGG_OPS.OCL  */

/*  Operational policy for Ft. Bragg */

// Set targets to dictate WDs between
Constraint : {dFlow0662.0721 = 0}  // none from Dunn


// Set the fraction coming from Harnett w/ a substitute

:Substitute: [FtBraggWS_Harnett] = 0.5

Target Harnett_WD : dflow0549.0721
{   condition : default
    priority  : 1
    penalty+  : 90
    penalty-  : 90
    Value     : [FtBraggWS_Harnett] * demand0721 // The rest will be from Fayettville
}
```

Fuquay_ops.ocl

```
/* FUQUAY_OPS.OCL  */

/*  Operational policy for Fuquay-Varina's system.  Set as maximum flows to limit deliveries to supply contracts, with OASIS reducing deliveries
 if needed so that the nominal F-V demand is not exceeded.  Weighting on delivery arcs reflects priority of delivery using supply contracts with
 local entities. First, for the Neuse portion of the F-V demand (= demand 1706 x [Demand_FV_Neuse], meet first from Raleigh, then Johnston
 County, so no IBT since they are both in the Neuse. Assume any additional supply needed to meet the Neuse portion of demand would be part
 of the alternative that is being evaluated assuming it is in the Neuse (thus minimizing the IBT).

 Any unmet portion of this demand then comes from Sanford, then Harnett County. IBT would be from Cape Fear (since Sanford and HC are in the
 Cape Fear) to the Neuse to meet the Neuse portion of the demand. Should that not be enough, if the alternative supply is in the Cape Fear, this
 is assumed to provide the remaining amount to meet the Neuse portion of the demand.

 For the remaining portion of the F-V demand, in the Cape Fear, first meet from Sanford, then Harnett County, then Johnston County, ensuring the
 contracts are maxed out.  [Although for alternative supplies that rely on new WTP for F-V, F-V would probably prioritize the alternative supply
 since it would be cheaper].  This approach provides consistency across all alternatives.

 IBT would be from Neuse to Cape Fear (since Johnston County is in the Neuse) to meet the Cape Fear portion of the demand.  Raleigh supply since
 it is relatively small would only be used on the Neuse portion of the F-V demand. Assume any additional supply needed to meet the Cape Fear
 portion of the demand would be part of the alternative that is being evaluated.   */

// First pull from Raleigh to meet the Neuse portion of the F-V demand.
Set FV_Ral_Max : max_flow1305.1706  { value  : min { demand1706 * [Demand_FV_Neuse], convert_units{[FV_Ral_Supply], mgd, af} } }

// Pull from JC for the remaining Neuse portion of this demand.
Set FV_Johnston_Prelim :  _Prelim_Max_JC_Neuse
{  value  : min { demand1706 * [Demand_FV_Neuse] - max_flow1305.1706, convert_units{[FV_Johnston_Supply], mgd, af } } }

// ***
// Pull from the alternative being evaluated (if in the Neuse) for the remaining Neuse portion of this demand.  Set to 0 if not evaluating an alternative,
// or evaluating an alternative that pulls only from the Cape Fear.
Set FV_Alt_Prelim :  _Prelim_Max_Alt_Neuse
{  value  : 0 }  // demand1706 * [Demand_FV_Neuse] - max_flow1305.1706 -  _Prelim_Max_JC_Neuse }

// Pull from Sanford for the remaining Neuse portion of this demand.
Set FV_Sanford_Prelim :  _Prelim_Max_Sanford_Neuse
{  value  : min { demand1706 * [Demand_FV_Neuse] - max_flow1305.1706 - _Prelim_Max_JC_Neuse
    -_Prelim_Max_Alt_Neuse, convert_units{[FV_Sanford_Supply], mgd, af } } }

// Pull from Harnett County for the remaining Neuse portion of this demand.
Set FV_HC_Prelim :  _Prelim_Max_HC_Neuse
{  value  : min { demand1706 * [Demand_FV_Neuse] - max_flow1305.1706 -  _Prelim_Max_JC_Neuse
    - _Prelim_Max_Alt_Neuse - _Prelim_Max_Sanford_Neuse, convert_units{[FV_Harnett_Supply], mgd, af } } }

// ***
// Pull from the alternative being evaluated (if in the Cape Fear) for the remaining Neuse portion of this demand.  Set to 0 if not evaluating an
// alternative, or if the alternative pulls only from the Neuse.
Set FV_Alt_Prelim :  _Prelim_Max_Alt_CF_to_Neuse
```

```
{  value  : 0  }
// demand1706 * [Demand_FV_Neuse] - max_flow1305.1706 -  _Prelim_Max_JC_Neuse - _Prelim_Max_Sanford_Neuse - _Prelim_Max_HC_Neuse }

// Set the IBTs based on this.  For the Cape Fear to Neuse, it would be Sanford and HC and alternative supply (if any) deliveries to the Neuse portion
// of the F-V demand since they are in the Cape Fear.
Set :  _IBT_CF_to_Neuse {  value  :  _Prelim_Max_Sanford_Neuse + _Prelim_Max_HC_Neuse + _Prelim_Max_Alt_CF_to_Neuse }

// The above assumes the Neuse portion of the demand is fully met (check output to confirm this). Reset production for Sanford, HC, and JC
// based on the total system demand less the contributions above toward the Neuse portion of the demand.

// Now for the Cape Fear portion of the demand.  To be met first from Sanford, then Harnett County (so no IBT), then Johnston County (so an IBT),
// then the alternative being evaluated (Whether in the Neuse or Cape Fear).
Set FV_Sanford_Max : max_flow0489.1706
{  value  : min { demand1706 - max_flow1305.1706 - _Prelim_Max_JC_Neuse - _Prelim_Max_Alt_Neuse
    - _IBT_CF_to_Neuse, convert_units{[FV_Sanford_Supply], mgd, af } } }
Set FV_Harnett_Max : max_flow0549.1706
{  value  : min { demand1706 - max_flow1305.1706 - _Prelim_Max_JC_Neuse - _Prelim_Max_Alt_Neuse
    - _IBT_CF_to_Neuse - max_flow0489.1706, convert_units{[FV_Harnett_Supply], mgd, af } } }

// Reset Johnston County delivery depending on whether there is still a demand deficit for F-V Cape Fear portion to be met.  Do not include
// the alternative supply that comes only from the Cape Fear since that comes later..
Set  Johnston_County_Final :  max_flow1656.1706
{  value :  min {demand1706 - max_flow1305.1706 - _Prelim_Max_Alt_Neuse -  max_flow0489.1706 - max_flow0549.1706,
    convert_units{[FV_Johnston_Supply], mgd, af } } }

// ***
// Set alternative to 0 if not being evaluated.  Otherwise, it is the amount to meet the remaining system demand.
Set :  _Final_Max_Flow_Alt  { value  :  0  }// demand1706 - max_flow1305.1706 - max_flow0489.1706 - max_flow0549.1706 - max_flow1656.1706}

// Comment out if not evaluating an alternative.  Otherwise, the max flow is on the alternative supply arc.
// Set :  max_flow0490.1706   {  value :  _Final_Max_Flow_Alt }


// Set the IBT from the Neuse to the Cape Fear to meet the Cape Fear portion of F-V demand.  Again, assume Raleigh supply is only
// enough to help meet the Neuse portion of demand.
Set :  _IBT_Neuse_to_CF
/* This will be zero if either Sanford or HC supplies water to the Neuse portion of the demand (since the alternative supply if from the Neuse
   would be used first).  If Raleigh and JC supply were high enough to meet the Neuse portion of the demand, this condition may not be met,
   but this scenario would not occur based on expected contract amounts. */
{   condition  :  _Prelim_Max_Sanford_Neuse > 0 or _Prelim_Max_HC_Neuse > 0
 value     :  0

/* This will be the amount from JC in excess of what it supplies to the Neuse portion of the demand, plus the amount of the
 alternative supply in excess of what is supplied to the Neuse portion of the demand.  */
   condition  :  default
 value    :   ( max_flow1656.1706 - _Prelim_Max_JC_Neuse )  + ( _Final_Max_Flow_Alt - _Prelim_Max_Alt_Neuse )
}
```

Gravity_Refill.ocl

```
/* This file contains the commands for estimating one day's spill from a reservoir.
   The file is included once for each reservoir where detailed spill estimates are
   required.  A set of substitutes must be properly set before the :include:
   statement of this file.  The substitutes are:

   //updated from Spill_Curve.ocl

     [sp_us_node]     = The reservoir node to which the spillway flows //1120
     [sp_spill_node]  = The junction node at which we compute spill //1115
     [sp_ds_node]     = The downstream node that represents gatehouse flow from the reservoir, or 'NONE'
     [sp_spill_node2] = The node to which the second spillway flows, or 'NONE'.
                        If there are two spillways, then this must be the lower of the two.
     [sp_lookup2]     = The name of the OCL lookup function for the second spillway, or 'NONE'


   The calculations are performed at a small time step for better accuracy.  The
   small time step is now 1 hour, but the file is easily modified for another
   small-time-step size.  The assumed 'total inflow' and 'total outflow' for the
   reservoir node are assumed steady over the day.  Within each small time step,
   the spillway flow is assumed steady based on the WSE at the beginning of the
   small time step.
*/


// The number of steps must correspond with the number of iterations
// in the :FOR: loop below

:substitute: [sp_num_steps] = 24

// Repeat the calculations once for every small time step for calculating
// spillway flow.  The number of iterations in the :FOR: loop must match
// [sp_num_steps] above.  The first [sp_step_num] must be 01, and the last
// must be the same as [sp_num_steps].

:FOR:
{ [sp_step_num] =
    { 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14,15, 16, 17, 18, 19, 20, 21, 22, 23, 24 }
}

   :if: { [sp_step_num]=01 }
      // In the first small time step, use zero spillway flow for the day
      :substitute: [i_sp_flow]  = 0
   :else:
      // In the subsequent small time step, accumulate spillway flow in this variable
      :substitute: [i_sp_flow]  = sp_flow
   :endif:

```

```
   // Compute storage in Teer that results from flow (from Eno) of the current small time step
   SET sp_stor_[sp_us_node].[sp_spill_node]_[sp_step_num]: sp_stor
   {
       value:   storage[sp_us_node]+ [i_sp_flow]

   }

//Calculates head differential between Eno River and Teer Quarry to determine flow through pumping station,
//calc doesn't consider quarry elevation below 254


 Set : Head_Differential_Teer_Hourly
{
 condition 1 : stor_to_elev{[sp_us_node],sp_stor} >= 254
 value     : Eno_River_Stage-stor_to_elev{[sp_us_node],sp_stor}

 condition 2 : default
 value       : Eno_River_Stage - 254
}



 SET : Max_Gravity_Refill_Eno_Hourly
 {
  value  : min{Lookup{48inConduit, Head_Differential_Teer_Hourly}, Max_Weir_Flow} //will be in cfs

 }

   // Compute Flow from Eno that results from the storage level at the beginning
   // of the current small time step.
   SET sp_flow_[sp_us_node].[sp_spill_node]_[sp_step_num]: sp_flow
   {
       value:   [i_sp_flow]
              + convert_units { Max_Gravity_Refill_Eno_Hourly , cfs , af }
                     / [sp_num_steps]

   }



:NEXT:


// Apply the spill to the model using the min_flow variable.  The weights in
// the weights table apply a very large penalty to exceeding this min flow.
// A negative weight on the D zone of the reservoir forces the water out
// of the reservoir.
```

Gravity_Refill.ocl

```
SET: Max_Gravity_Refill_Eno_Hourly_1
{
    value: sp_flow
}
```

Greensboro_ops.ocl

```
/*GREENSBORO_OPS.OCL  */

/*  Operational policy for Greensboro's system */

/*  Set interconnects unused in basecase to zero */
Constraint : {dFlow0044.0140 = 0 } // Emer Intake

//Constraint : {dFlow0271.0121 = 0 } // PTRA - currently in use, not 0
//Constraint : {dFlow0122.0224 = 0 } // High Pt WW
//Constraint : {dFlow0121.0903 = 0 } // Jamestown



//  Current Townsend Min. Release
//Set TownsendRelease : min_flow0140.0145 { value :  convert_units { 3.0, cfs, af } }

//  Future scenario Townsend minimum release - based on stage
Set TownsendRelease : min_flow0140.0145
{   condition : elevation0140 < 709.7
    value     : convert_units { 2.0, cfs, af }

    condition : elevation0140 < 714.5
    value     : convert_units { 3.5, cfs, af }

    condition : default
    value     : convert_units { 7.0, cfs, af }
}

// Set the transfer (1 MGD constant) from Reidsville
Target Reids_GB_Transfer : dflow0029.0121
{   condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  :  275
    Value     : convert_units { 5, mgd, af } // new contract value
}

// Set the transfer (2 MGD constant) from Burlington
Target Burl_GB_Transfer : dflow0071.0121
{   condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 275
    Value     : convert_units { 5, mgd, af } //new contract value
}

//Set the transfer from PTRA
```

```
Target PTRA_GB_Transfer: dflow0271.0121
{ condition : default
 priority  : 1
 penalty+  : 100
 penalty-  : 1000
 Value     : convert_units{15.31, mgd,af} // must purchase 53.1% of increase in allocation
}

Set PTRA_GB_Max: max_flow0271.0121
{ condition: default
 Value: convert_units{24.03,mgd,af} // max contract in 2055
}

// Set targets to dictate WDs between reservoirs
Target Townsend_WD : dflow0140.0121
{   condition : default
    priority  : 1
    penalty+  : 100
    penalty-  : 100
    Value     : 0.67 * (demand0123 - flow0071.0121 - flow0029.0121 - flow0271.0121) // 67% (previously 50%, changed by KES based off of
                    // LWSP) (less the Burlington/Reidsville/PTRA
                    // transfers) from Townsend, the rest will be from Brandt
}
```

Harris_ops.ocl

```
/*  Harris_Ops.ocl  */
/*  Operational policies for Harris Lake */

// Spill rating curve for Harris.

// The D zone weight is -25, so if in the spill zone, the computed spill will occur because 25 points will otherwise be lost.
// However, spill will not exceed the computed amount because 100 points will be lost, or a net loss of 100 -25, or 75 points.
// We don't want spill to occur above the computed amount in order to meet shortages downstream on the main stem. Also, we don't
// want the spill to be curtailed for a Fayetteville max flow downstream of 20,000 cfs, which is the Corps operating target.  Jordan
// will curtail releases (but not below the minimum release), but Harris will not, so the D zone penalty is higher than the weight
// at Fayetteville.

// If reservoir elevation is below the spill zone starting at 220 feet, only the min release (if any is set) will be met since that arc gets a weight
// of gets a weight of 10.  The spill arc gets a weight of -10.    Note releases will not exceed the minimum when below the spill zone since
// a weight of -100 is placed on the B zone of the arc.  Normally this is not needed but with the interplay with Jordan Lake, the weights in the
// reservoir zones are such that we need additional confirmation that Harris won't release more than the minimum in this arc.

// Set a udef for the projected end of day elevation will be used to determine spill from the rating curve.
Set :  _Proj_Harris_Storage  {  value :  min {max_stor0520, storage0520 + inflow0520 - ( timesers(0520/evap)
            / 12 * stor_to_area{0520,storage0520} )
            - delivery0531 - delivery0521 - flow0521.0520 - flow0520.0528 - flow0520.0525 } }
Set :  _Proj_Harris_Elev     {  value :  stor_to_elev {0520, _Proj_Harris_Storage}  }


Target Harris_spill: dflow0520.0526
{   Condition : default
    priority  : 1
    penalty+  : 100
    penalty-  : 0
    Value     : convert_units { Lookup{ Harris_Spill, _Proj_Harris_Elev }, cfs, af}
}
```

HawR_Or_Almnc.ocl

```
/*  Northeast Har River Basin Ops  */
// Orange- Alamance
// Haw River 02-01-020
// Graham-Mebane - to be used later


// Set the transfer from Haw River to Orange-Alamance

Set : inflow1041 { Value : convert_units { 0.05, mgd, af } } // Looking at sum of well usage from LWSP and days of use

Target Burl_HR_OA : dflow0074.1046
{   condition : default
    priority  : 1
    penalty+  : 500
    penalty-  : 20
    Value     : min {convert_units { 0.8, mgd, af }, demand1046 - _Max_OrAl_WD } // contract value is 0.8 mgd max
}
```

Johnston_ops.ocl

```
/*  Johnston_OPS.OCL  */

/*  Operational policy for Johnston County's facilities */

:substitute: [Tim_Broome_Permit] = 17 //mgd, DWR permitted withdrawal includes return (assumed 10% in the WW_returns.ocl file) -- sn comment

// Existing intake
Set: max_flow1650.1654   {  value : Convert_Units {[Tim_Broome_Permit], mgd, af } }


//Purchases //Setting these first to be used in flow by calcs for lower intake -KS

Set: max_flow1660.1656 //Smithfield sales
{  condition : default
 value  : convert_units{3.0, mgd, af}
}

Set: max_flow1505.1656 //Wilson sales, set at less than 2 mgd IBT trigger amount
{  condition : default
 value  : convert_units{1.99, mgd, af}
}

Set: max_flow0549.1656 //Harnett sales, set at less than 2 mgd IBT-trigger amount
{  condition : default
 value  : convert_units{1.99, mgd, af}
}






// This is for intake 2 operations with the quarries.  Use simplified estimate of flow upstream of intake 2 using yesterday's flow + local inflow.
// Set to min flow for day 1 x d.a. adjustment to get a reasonable estimate for day 1.

Set: Exp_RBrdgeRd_Upstream
{   condition  :  abs_period = 1
 value      :  min_flow1630.1640 * 1677 / 1150

 condition  : default
 value      : flow1700.1730 + inflow1730
}


/* This assumes JC Intake#2 on Neuse is at Richardson Bridge Rd, not below the confluence with Mill Creek (node 1735).
 WD amounts per the revised guidance from Reed (no longer using the 2009 EA/FONSI).

```

```
 So pumped flows are as follows:  none below 198 cfs (as estimated upstream).  Up to 29.2 mgd (20% of the updated 7Q10)
 for flows below 903 cfs (which is the median annual flow). with pumping limited to ensure flow does not drop below 198 cfs.
 Above 903 cfs, pump 20% of the estimated flow (or the amount above 903 cfs, whichever is less) or the maximum amount set
 for the alternative (in lookup table). There may be a quick bump in pumping from 29.2 to the maximum pumping level above
 903 cfs depending on what the maximum pumping level is used. Here it is 30 mgd.   */

Set: max_flow1730.1652
{   condition  :  convert_units{Exp_RBrdgeRd_Upstream, af, cfs} > 903
 value      :  min {
      max { convert_units {lookup {JohnstonCFlow, 903}, mgd, af},
        min {0.2 * Exp_RBrdgeRd_Upstream, Exp_RBrdgeRd_Upstream - convert_units {903, cfs, af} } }  ,
      convert_Units {lookup {JohnstonCFlow, convert_units{Exp_RBrdgeRd_Upstream, af, cfs}}, mgd, af}
        }

 condition  :  default
 value      :  min {convert_Units {lookup {JohnstonCFlow, convert_units{Exp_RBrdgeRd_Upstream, af, cfs}}, mgd, af},
        max {Exp_RBrdgeRd_Upstream - convert_units {198, cfs, af}, 0} }
}

/* Assume abandoned quarry is being used. Water is assumed here to go directly to the demand, even though it would go technically
 through the WTP node of 1652.  Can do this here since it is assumed there would be no WTP process loss with the new plant.
 Water only pumped to quarry if below full (could do with weighting of course).  Put a negative weight on delivery arc to
 prioritize water from intake node/WTP.   */
Set : max_flow1653.1648
{   condition  :  storage1648 < max_stor1648
 value      :  1000   // Set high limit as not to be constraining

 condition  :  default
 value      :  0
}

// Do not consider any use of the active quarry, so set supply to the quarry to 0.
Set : max_flow1653.1647   {  value  :  0  }
```

Jordan_ops.ocl

```
/*  Jordan_Ops.ocl  */
/*  Operational policies for Jordan Lake */

// Limit the increase in flood releases from previous day (per Terry Brown's suggestion) when Jordan is above normal pool
Target JordanFloodRelease : dflow0470.0480
{  // Above 240 ft just release uncontrolled spill
    condition : elevation0470 >= 240
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : convert_units { lookup { JordanSpillway, elevation0470 }, cfs, af }

    // When Jordan is on the way back down (defined by decreasing inflows) limit the decrease in releases for a 'soft landing',
  // making sure not to drop it below the normal pool.
    condition : elevation0470 >= 216 and inflow0470 < inflow0470(-1) and inflow0470(-1) < inflow0470(-2) and inflow0470(-2) < inflow0470(-3)
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : min  {flow0470.0480(-1) - convert_units {4000, cfs, af }, storage0470 - elev_to_stor { 0470, 216 } }

    // Above 220 ft release no more than the previous days' release + 5500 cfs
    condition : elevation0470 >= 220
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : flow0470.0480(-1) + convert_units {5500, cfs, af }

    // Above 216 ft release no more than the previous days' release + 4000 cfs, making sure not to drop it below the normal pool.
    condition : elevation0470 >= 216
    priority  : 1
    penalty+  : 10
    penalty-  : 0
    Value     : min { flow0470.0480(-1) + convert_units {4000, cfs, af }, storage0470 - elev_to_stor { 0470, 216 } }
}

// Set a flood target of 18,000 cfs at Lillington
Target LillingtonMaxFlow : dflow0550.0555
{   condition :  default
    priority  : 1
    penalty+  : 12
    penalty-  : 0
    Value     : convert_units {18000, cfs, af }
}

// Set a flood control target at Fayetteville of 20,000 cfs, meaning Jordan will store water to minimize chance of having flow downstream
// exceed this target.  Local inflows between Jordan and Fayetteville could cause flows to exceed this target.  However, Jordan will not curtail
// the minimum release, nor the release to meet local demands.  So the penalty for going above the 20000 cfs flow is less than the minimum release
```

```
// weight from Jordan (but is more than the D zone weight for Jordan).
Target FayettevilleMaxFlow : dflow0740.0749
{   condition :  default
    priority  : 1
    penalty+  : 12
    penalty-  : 0
    Value     : convert_units {20000, cfs, af }
}


/*  The Jordan water quality and supply accounting file is evaluated after the solve statement, mainly to establish the water quality
 release based on computation of the decision variable for outflow from Jordan.  This determination is made based on weights and min
 flow targets from Jordan andat Lillington (and points in between).  The min flow from Jordan depends on the drought protocol.
 When the Lillington target applies, the model will release enough water to exactly meet the target after accounting for today's
 inflows (namely on the Deep River) and demands between Jordan and Lillington (the intent of which is to mimic how the Corps would
 operate).  Extra water will not be released above the target based on how the weighting is done.

 Set delivery for the water supply users based on amount in the their accounts.  Demand will not be fulfilled if the account has gone
 empty and there is not enough inflow to the water supply account (for simplicity, use yesterday's inflow as factored into yesterday's
 storage).The water supply account is not allowed to go negative (see the Jordan_WQ_WS_Accounts.ocl file). Similarly, set the water
 quality release from Jordan (arc 470.480) based on amount in the water quality storage account, again forbidding the account to go negative.

 Since we refer to yesterday's storage estimates, for the first day of the run, constrain deliveries and releases to the initialized
 volumes for each account so that deliveries and releases are made */


//  Water supply releases
Constraint   Deliv_Lim_CaryAp :
 {  condition  :  abs_period = 1
    expression :  ddelivery0471 <= [WS_CaryAp_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_CaryAp :
 {  condition  :  abs_period > 1
    expression :  ddelivery0471 <= _Stor_Final_CaryAp(-1)
 }

Constraint   Deliv_Lim_Chatham :
 {  condition  :  abs_period = 1
    expression :  ddelivery0473 <= [WS_Chatham_Fraction] * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Chatham :
 {  condition  :  abs_period > 1
    expression :  ddelivery0473 <= _Stor_Final_Chatham(-1)
 }

```

```
Constraint   Deliv_Lim_Pittsboro :
 {  condition  :  abs_period = 1
    expression :  dflow0468.0401 <= [WS_Pitt_Fraction] * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Pittsboro :
 {  condition  :  abs_period > 1
    expression :  dflow0468.0401 <= _Stor_Final_Pitt(-1) // + 0.7 * _Stor_Final_Chatham(-1)  // RNP SWAG that Chatham and
                   // Pittsboro work something out
                   // on their JL allocations
 }

Constraint   Deliv_Lim_RTP :
 {  condition  :  abs_period = 1
    expression :  ddelivery0474 <= [WS_RTP_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_RTP :
 {  condition  :  abs_period > 1
    expression :  ddelivery0474 <= _Stor_Final_RTP(-1)
 }

Constraint   Deliv_Lim_Other :
 {  condition  :  abs_period = 1
    expression :  ddelivery0475 <= [WS_Other_Fraction]   * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Other :
 {  condition  :  abs_period > 1
    expression :  ddelivery0475 <= _Stor_Final_Other(-1)
 }

Constraint   Deliv_Lim_Durham&OWASA :
 {  condition  :  abs_period = 1
    expression :  dflow0468.1151 <= [WS_Durham_Fraction]  * [Max_WS_Storage] + [WS_OWASA_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Durham&OWASA :
 {  condition  :  abs_period > 1
    expression :  dflow0468.1151 <= _Stor_Final_Durham(-1) + _Stor_Final_OWASA(-1)
 }

Constraint   Deliv_Lim_Durham&OWASA_alt :
 {  condition  :  abs_period = 1
    expression :  dflow0479.1151 <= [WS_Durham_Fraction]  * [Max_WS_Storage] + [WS_OWASA_Fraction]  * [Max_WS_Storage]
 }

```

```
Constraint   Deliv_Lim_Durham&OWASA_alt :
 {  condition  :  abs_period > 1
    expression :  dflow0479.1151 <= _Stor_Final_Durham(-1) + _Stor_Final_OWASA(-1)
 }

Constraint   Deliv_Lim_Morris :
 {  condition  :  abs_period = 1
    expression :  ddelivery0477 <= [WS_Morris_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Morris :
 {  condition  :  abs_period > 1
    expression :  ddelivery0477 <= _Stor_Final_Morris(-1)
 }

Constraint   Deliv_Lim_Orange :
 {  condition  :  abs_period = 1
    expression :  ddelivery0921 <= [WS_Orange_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Orange:
 {  condition  :  abs_period > 1
    expression :  ddelivery0921 <= _Stor_Final_Orange(-1)
 }

Constraint   Deliv_Lim_Holly :
 {  condition  :  abs_period = 1
    expression :  dflow0479.0923 <= [WS_Holly_Fraction]  * [Max_WS_Storage]
 }

Constraint   Deliv_Lim_Holly :
 {  condition  :  abs_period > 1
    expression :  dflow0479.0923 <= _Stor_Final_Holly(-1)
 }

Constraint Deliv_Lim_Hillsb :
 {   condition  : abs_period = 1
  expression : dflow1151.1106 <= [WS_Hillsb_Fraction] * [Max_WS_Storage]
 }

Constraint Deliv_Lim_Hillsb :
 {   condition  : abs_period > 1
  expression : dflow1151.1106 <= _Stor_Final_Hillsb(-1)
 }


// Water quality release
```

```
Constraint   Release_Limit_Jordan :
 {  condition  :  abs_period = 1
    expression :  dflow0470.0480 <= [Max_WQ_Storage]
 }

Constraint   Release_Limit_Jordan :
 {  condition  :  abs_period > 1
    expression :  dflow0470.0480 <= _WQ_Storage(-1)
 }


// Compute Jordan hydro production (total kW)
Set : _Jordan_Hydropower { Value : lookup { JordanHydro, convert_units { flow0470.0480, af, cfs } } }
```

Jordan_WQ_WS_Accounts.ocl

```
/*  Jordan_WQ_WS_Accounts.ocl */

// Note this file is included after the solve statement in the main.ocl file, so references to decision variables like flow and delivery
// have already been solved.


/* The conservation storage between elevation 202 and 216 feet consists of the water supply storage for up to six users and the
 water quality storage.

Fraction of conservation storage and inflow :
WQ = 67.38% allocated (94,600 acft.)
WS = 32.62% allocated (45,800 acft.), which is broken down by user:

The accounts are numbered as follows:

    Cary-Apex (node 471)
    Chatham County (node 473)
 Wake (RTP South) (node 474)
  Durham (arc1151)
 Morrisville  (node 477)
    Orange County (node 921)
 OWASA (arc 1151.431, via 479.1151)  - now via arc 0468.1151
 Holly Springs (arc 479.923)
 Pittsboro (no path to access yet defined) - now 0468.0401
 Hillsborough (arc 1151.1106, via arc 0471.1151)

 To this we add an allocation to a "dummy" account to track the unallocated water or to increase
 demands on the water supply storage without changing other allocations

 Other (node 475)

The allocations for each account are defined below (formerly in constants table for DWR model) */


/*  INFLOW DISTRIBUTION BY WATER SUPPLY ACCOUNT */

/* Start with Leila's spreadsheet calculating the water supply inflow distribution */

// Evap (0) since this file is included after the solve statement and we want today's evap, not tomorrow's */

Set  :  _JLakeInf     {  value :  flow0410.0470 + inflow0470 - evap0470(0) }  /* Base it on net inflow */
Set  :  _JLake_WQ_Inf {  value :  _JLakeInf * [Max_WQ_Storage] /  [Max_WQ_WS_Storage] }
Set  :  _JLake_WS_Inf {  value :  _JLakeInf * [Max_WS_Storage]/  [Max_WQ_WS_Storage]  }
/*  Calculate total inflow available to pool to include any spillover from the water quality account. */
Set  :  _Inf_avail_to_WS_pool   {  value  :  _WQ_Pool_Excess(-1) + _JLake_WS_Inf  }

/*  Calculate the total water supply demand and delivery for all accounts */
```

```
Set  :  _WS_Total_Demand   {  value  :  demand0471 + demand0473 + demand0474 + demand0475
        + flow0470.0468 + demand0477 + demand0921 + 0 + 0 }  // Since OWASA & Durham, and HIllsborough
                        // are arcs and not demand nodes, sub in
                        // zero, can be changed if a Jordan transfer
                        // is used. No Holly Springs either.
Set  :  _WS_Total_Deliv    {  value  :  delivery0471 + delivery0473 + delivery0474 + delivery0475
           + flow0479.1151  + delivery0477 + delivery0921 + flow0479.0923 + flow0470.0468 }

// Reset water supply account to 100% if elevation reaches 216 or projected water supply is full.
// For the first day of simulation, use the starting storage based on the individual accounts
// as defined in the constants table.
Set  :  _Total_WS_Storage
{   condition  :  abs_period = 1
 value      :  [Starting_Storage_CaryAp]  + [Starting_Storage_Chatham] + [Starting_Storage_RTP]       + [Starting_Storage_Other]
     + [Starting_Storage_Durham] + [Starting_Storage_Morris]   + [Starting_Storage_Orange]  + [Starting_Storage_OWASA]
     + [Starting_Storage_Holly] + [Starting_Storage_Pitt] + [Starting_Storage_Hillsb]

 condition  :  elevation0470 >= 216.0 or (_Total_WS_Storage(-1) + _Inf_avail_to_WS_pool - _WS_Total_Deliv ) >= [Max_WS_Storage]
    value      :  [Max_WS_Storage]

    condition  :  default
    value      :  _Total_WS_Storage(-1) + _Inf_avail_to_WS_pool - _WS_Total_Deliv
}

Set :   _Total_WS_Storage_Pct {  value  :  100 * _Total_WS_Storage / [Max_WS_Storage] }

Set  :  _Req_Refill_WS_Pool   {  value  :  [Max_WS_Storage] - _Total_WS_Storage + _WS_Total_Deliv }
Set  :  _WS_Pool_Excess       {  value  :  max { 0, _JLake_WS_Inf - _Req_Refill_WS_Pool  } }
Set  :  _Inf_used_for_WS_pool {  value  :  min { _Inf_avail_to_WS_pool,  _Req_Refill_WS_Pool } }


/*  --------------- */

// Determine required refill for each account.

Set  : _Req_Refill_CaryAp
{ condition  :  abs_period = 1
 value      :  delivery0471

 condition  :  default
 value     :  [WS_CaryAp_Fraction] * [Max_WS_Storage] - _Stor_Final_CaryAp(-1) +  delivery0471
}

Set  : _Req_Refill_Chatham
{ condition  :  abs_period = 1
 value      :  delivery0473

```

```
 condition : default
 value    : [WS_Chatham_Fraction]  * [Max_WS_Storage] - _Stor_Final_Chatham(-1) +  delivery0473
}

Set : _Req_Refill_RTP
{ condition : abs_period = 1
 value    : delivery0474

 condition : default
 value    : [WS_RTP_Fraction] * [Max_WS_Storage] - _Stor_Final_RTP(-1) +  delivery0474
}

Set : _Req_Refill_Other
{ condition : abs_period = 1
 value    : delivery0475

 condition : default
 value    : [WS_Other_Fraction] * [Max_WS_Storage] - _Stor_Final_Other(-1) +  delivery0475
}

Set : _Req_Refill_Durham
{ condition : abs_period = 1
 value    : flow0468.1151 - flow1151.0431

 condition : default
 value    : [WS_Durham_Fraction] * [Max_WS_Storage] - _Stor_Final_Durham(-1) +  flow0468.1151 - flow1151.0431
}

Set : _Req_Refill_Morris
{ condition : abs_period = 1
 value    : delivery0477

 condition : default
 value    : [WS_Morris_Fraction] * [Max_WS_Storage] - _Stor_Final_Morris(-1) +  delivery0477
}

Set : _Req_Refill_Orange
{ condition : abs_period = 1
 value    : delivery0921

 condition : default
 value    : [WS_Orange_Fraction] * [Max_WS_Storage] - _Stor_Final_Orange(-1) +  delivery0921
}

Set : _Req_Refill_OWASA
{ condition : abs_period = 1
 value    : flow1151.0431
```

```

 condition : default
 value    : [WS_OWASA_Fraction] * [Max_WS_Storage] - _Stor_Final_OWASA(-1) +  flow1151.0431
}

Set : _Req_Refill_Holly
{ condition : abs_period = 1
 value     : flow0479.0923

 condition : default
 value    : [WS_Holly_Fraction] * [Max_WS_Storage] - _Stor_Final_Holly(-1) +  flow0479.0923
}

Set : _Req_Refill_Pitt
{ condition : abs_period = 1
 value     : 0

 condition : default
 value    : [WS_Pitt_Fraction] * [Max_WS_Storage] - _Stor_Final_Pitt(-1) + flow0468.0401 // Pittsboro 6% Rnd 4 JLA
}

Set : _Req_Refill_Hillsb
{ condition : abs_period = 1
 value     : flow1151.1106

 condition : default
 value    : [WS_Hillsb_Fraction] * [Max_WS_Storage] - _Stor_Final_Hillsb(-1) +  flow1151.1106 // Hillsborough 1% Rnd 4 JLA
}


/*  Establish initial inflow to the accounts */

// Determine initial inflow to each account
Set : _Inf_CaryAp  { value : min { [WS_CaryAp_Fraction]  * _Inf_avail_to_WS_pool, _Req_Refill_CaryAp  } }
Set : _Inf_Chatham {  value : min { [WS_Chatham_Fraction] * _Inf_avail_to_WS_pool, _Req_Refill_Chatham } }
Set : _Inf_RTP     { value : min { [WS_RTP_Fraction]     * _Inf_avail_to_WS_pool, _Req_Refill_RTP     } }
Set : _Inf_Other   { value : min { [WS_Other_Fraction]   * _Inf_avail_to_WS_pool, _Req_Refill_Other   } }
Set : _Inf_Durham  {  value : min { [WS_Durham_Fraction]  * _Inf_avail_to_WS_pool, _Req_Refill_Durham  } }
Set : _Inf_Morris  {  value : min { [WS_Morris_Fraction]  * _Inf_avail_to_WS_pool, _Req_Refill_Morris  } }
Set : _Inf_Orange  {  value : min { [WS_Orange_Fraction]  * _Inf_avail_to_WS_pool, _Req_Refill_Orange  } }
Set : _Inf_OWASA   {  value : min { [WS_OWASA_Fraction]   * _Inf_avail_to_WS_pool, _Req_Refill_OWASA   } }
Set : _Inf_Holly   {  value : min { [WS_Holly_Fraction]   * _Inf_avail_to_WS_pool, _Req_Refill_Holly   } }
Set : _Inf_Pitt    {  value : min { [WS_Pitt_Fraction]    * _Inf_avail_to_WS_pool, _Req_Refill_Pitt    } } // new for JLA Round 4 6%
Set : _Inf_Hillsb  {  value : min { [WS_Hillsb_Fraction]  * _Inf_avail_to_WS_pool, _Req_Refill_Hillsb  } } //new for JLA Round 4 1%

/*  Determine remaining inflow to be distributed */
Set : _Inf_Rem_WS   { value :  _Inf_used_for_WS_pool - (_Inf_CaryAp +  _Inf_Chatham + _Inf_Durham + _Inf_Other + _Inf_RTP
```

```
              + _Inf_Morris +_Inf_Orange + _Inf_OWASA + _Inf_Holly + _Inf_Pitt
              + _Inf_Hillsb ) }

/*  Determine remaining deficit by account */

:FOR:
{  [Account] = { CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb }  }

 Set  :  _Rem_def_[Account]   {  value  :  _Req_Refill_[Account] - _Inf_[Account]  }

:NEXT:

Set  :  _Rem_def_Total    {  value  :  _Rem_def_CaryAp +  _Rem_def_Chatham + _Rem_def_Durham  + _Rem_def_Other + _Rem_def_RTP
         +  _Rem_def_Morris+ _Rem_def_Orange + _Rem_def_OWASA + _Rem_Def_Holly + _Rem_Def_Pitt
         + _Rem_Def_Hillsb }

:FOR:
{  [Account] = { CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb }  }

 //  Distribute remaining inflow proportional to remaining deficit
 Set  :  _Rem_Inf_[Account]
  {   condition  :  _Rem_def_total > 0
        value      :  min { _Rem_def_[Account], _Inf_Rem_WS * _Rem_def_[Account] / _Rem_def_total }

        condition  :  default
        value      :  0
  }

 //  Compute total inflow to each pool
 Set :  _Inf_Total_[Account]  {  value  :  _Inf_[Account] + _Rem_Inf_[Account] }

:NEXT:


// Determine water supply storage in each account.  For initialization in the udef list, set equal to the starting storage defined in the constants table.
// Set the storage to account for starting storage less the delivery plus the total inflow. If that exceeds the max storage for that account, reset
// the account to full.  The accounts are not allowed to go negative.

Set  : _Storage_CaryAp  {  value :  max { 0, min { [WS_CaryAp_Fraction]  * [Max_WS_Storage] ,
            _Stor_Final_CaryAp(-1)  + _Inf_Total_CaryAp  - delivery0471 } } }
Set  : _Storage_Chatham {  value :  max { 0, min { [WS_Chatham_Fraction] * [Max_WS_Storage] ,
            _Stor_Final_Chatham(-1) + _Inf_Total_Chatham - delivery0473 } } }
Set  : _Storage_RTP  {  value :  max { 0, min { [WS_RTP_Fraction]     * [Max_WS_Storage] ,
            _Stor_Final_RTP(-1)     + _Inf_Total_RTP     - delivery0474 } } }
Set  : _Storage_Other  {  value :  max { 0, min { [WS_Other_Fraction]   * [Max_WS_Storage] ,
            _Stor_Final_Other(-1)   + _Inf_Total_Other   - delivery0475 } } }
Set  : _Storage_Durham  {  value :  max { 0, min { [WS_Durham_Fraction]  * [Max_WS_Storage] ,
```

```
           _Stor_Final_Durham(-1)  + _Inf_Total_Durham  - flow0468.1151 - flow1151.0431 } } }
Set  : _Storage_Morris  {  value :  max { 0, min { [WS_Morris_Fraction]  * [Max_WS_Storage] ,
           _Stor_Final_Morris(-1)  + _Inf_Total_Morris  - delivery0477 } } }
Set  : _Storage_Orange  {  value :  max { 0, min { [WS_Orange_Fraction]  * [Max_WS_Storage] ,
           _Stor_Final_Orange(-1)  + _Inf_Total_Orange  - delivery0921 } } }
Set  : _Storage_OWASA  {  value :  max { 0, min { [WS_OWASA_Fraction]   * [Max_WS_Storage] ,
           _Stor_Final_OWASA(-1)   + _Inf_Total_OWASA   - flow1151.0431 } } }
Set  : _Storage_Holly  {  value :  max { 0, min { [WS_Holly_Fraction]   * [Max_WS_Storage] ,
           _Stor_Final_Holly(-1)   + _Inf_Total_Holly   - flow0479.0923 } } }
Set  : _Storage_Pitt  {  value :  max { 0, min { [WS_Pitt_Fraction]    * [Max_WS_Storage] , _Stor_Final_Pitt(-1)
          + _Inf_Total_Pitt    - flow0468.0401 } } }//new for JLA Round 4 JLA
Set  : _Storage_Hillsb {  value :  max { 0, min { [WS_Hillsb_Fraction]  * [Max_WS_Storage] ,
         _Stor_Final_Hillsb(-1)  + _Inf_Total_Hillsb  - flow1151.1106 } } }//new for JLA Round 4 JLA
// Assume pools are automatically reset to full if the total water supply storage account has refilled (do this by overwriting initial calculation).
// Account is refilled automatically when Jordan elevation reaches 216 feet.

:FOR:
{  [Account] = { CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb }  }

 Set :  _Stor_Final_[Account]
  {  condition  :  _Total_WS_Storage >= [Max_WS_Storage] //
     value      :  [WS_[Account]_Fraction]  * [Max_WS_Storage] //

     condition  :  default
     value      :  _Storage_[Account]
        }

:NEXT:

// Calculate pool volume as percent of max storage

:FOR:
{  [Account] = { CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb }  }

 Set :  _Stor_Final_Pct_[Account]
  {
  condition : [WS_[Account]_Fraction] = 0
   value  : 0

  condition : default
   value  : _Stor_Final_[Account] / ( [WS_[Account]_Fraction]  * [Max_WS_Storage] )  * 100  } //
:NEXT:


/*  WQ ACCOUNTING */

/*  The _WQ_Release is the amount of water required to be released from Jordan Lake to meet the Lillington flow target for days
```

```
 when the lake is not full.  This variable's value should be the same as the model's computed Jordan release when the lake
 is not full. It is done by setting the WQ Release to the model's computed Jordan releases at the dam.  When the lake is full,
 we set the WQ Release to the value that would have been required to meet the Lillington target were the lake not full.
 So it is the Lillington target minus the Moncure flow minus the Harris Lake release plus demands between the
    dam at Jordan Lake and Lillington minus the discharges between the dam and Lillington. */


/*  The water quality release from Jordan = outflow from Jordan.  The release is constrained in the main.ocl file to the amount
 in the water quality storage pool plus the inflow to that account.  This way, the release will not be made if the account
 has emptied. Note the outflow may include releasing surplus water above the rule curve, which technically would be more than
 the water quality release.  But since the account is reset to full above the rule curve, it makes no difference.  However,
 to make it more realistic, set the WQ release to the minimum flow from Jordan when the elevation is at 216 or above.  */
Set  :  _WQ_Release
{     condition  :  elevation0470 >= 216
   value      :  min_flow0470.0480

   condition  :  default
   value      :  flow0470.0480
}


// Initial value set in the udef list based on starting WQ storage reported in the constants table
Set  :  _WQ_Storage
 {  condition  : elevation0470 >= 216.0
        value      : [Max_WQ_Storage]

  // the WQ storage is not allowed to go negative
  condition  :  default
        value      :  max { 0, min { [Max_WQ_Storage], _WQ_Storage(-1) + _JLake_WQ_Inf + _WS_Pool_Excess - _WQ_Release } }
 }

Set  :  _WQ_Storage_Pct  {  value  :  _WQ_Storage /  [Max_WQ_Storage] * 100     }
Set  :  _Req_Refill_WQ   {  value  :  [Max_WQ_Storage] - _WQ_Storage + _WQ_Release }

Set  :  _WQ_Pool_Excess
{      condition  :  _Req_Refill_WS_Pool > _JLake_WS_Inf
       value      :  max { 0, _JLake_WQ_Inf -  _Req_Refill_WQ  }

       condition  :  default
       value      :  0
}
```

main.ocl

```
/*  MAIN.OCL  */

:INCLUDE: OCL\constants.ocl
:INCLUDE: OCL\constants_removed.ocl
:INCLUDE: OCL\Forecast-Trigger_Parms.ocl
:INCLUDE: OCL\Forecast_Horizon_Days.ocl
:Static: statdata.mdb
:Time:   [HomeDir]\basedata\basedata.dss

:if: {[UseForecast]=1}
   :if: {[ForecastData]=cond}
      :Time:   [HomeDir]\basedata\forecasts_sim_cond_durham.dss
   :Time:   [HomeDir]\basedata\forecasts_cond.dss
   :else:
      :Time:   [HomeDir]\basedata\forecasts_sim_noncond_durham.dss
   :Time:   [HomeDir]\basedata\forecasts_non_cond.dss
   :endif:
:endif:

:if: {[Drought_Plans_On] = 1}
   :Time:   [HomeDir]\basedata\forecasts_non_cond.dss
:endif:

:MODULE: DLL  AgricDem = modules\AgricDem.DLL

:Include: ocl\udef_list.ocl

:Commands:

// For both basins

:Include: ocl\Agric_Calculation.ocl
:Include: ocl\Agric_Allocation.ocl
:Include: ocl\filter_inflows.ocl

// For the Cape Fear

/* :Include: ocl\user_def_ops.ocl */

:Include: ocl\routing_cf.ocl
:Include: ocl\Harris_ops.ocl
:Include: ocl\drought_protocol_jordan.ocl
:Include: ocl\Greensboro_ops.ocl
:Include: ocl\owasa_ops.ocl
:Include: ocl\Jordan_ops.ocl
:Include: ocl\Pitt_Chatham_ops.ocl
:Include: ocl\Randleman_ops.ocl
```

```
:Include: ocl\SilerCity_ops.ocl
:Include: ocl\Fayetteville_ops.ocl
:Include: ocl\FtBragg_ops.ocl
:Include: ocl\SpringLake_ops.ocl
:Include: ocl\drought_plans_cf.ocl
:Include: ocl\WW_Returns.ocl

// For the Neuse

:Include: ocl\routing_neuse.ocl
:Include: ocl\crabtree_ops.ocl
:Include: ocl\upper_eno_ops.ocl
:Include: ocl\HawR_Or_Almnc.ocl
:Include: ocl\durham_ops.ocl
:Include: ocl\falls_bdam_ops.ocl
:Include: ocl\falls_flood_ops.ocl
:Include: ocl\raleigh_ops.ocl
:Include: ocl\Fuquay_ops.ocl
:Include: ocl\Johnston_ops.ocl
:Include: ocl\buckhorn_Wilson_ops.ocl
:Include: ocl\Raleigh_Quarry_ops.ocl
:Include: ocl\NRWWTP_intake.ocl
:Include: ocl\drought_plans_neuse.ocl
:Include: ocl\drought_plan_durham.ocl
:Include: ocl\Benson_ops.ocl


// For both basins, this captures miscellaneous operations
:Include: ocl\misc_ops.ocl


// Solve model

Solve : {Priority : 1}

//Compute actual shortages based on drought plans
:Include: ocl\Shortages.ocl //added during Fuquay IBT study to calculate shortages based on cosnvn demands

//  Compute the Falls/Beaverdam and Jordan water quality and supply accounting after the SOLVE statement

:Include:   ocl\Falls_Bdam_WQ_WS_accounts.ocl
:Include:   ocl\Jordan_WQ_WS_Accounts.ocl


:End:

```

Misc_Ops.ocl

```
/*  Misc_Ops  */



// Misc. Cape Fear Ops.

// Set Cape Fear Arcs/Interconnects not used in basecase to zero
Constraint : {dFlow0319.0077 = 0}  // Green Level Gr-Meb WS
Constraint : {dFlow0479.0923 = 0}  // JL Holly Springs
Constraint : {dFlow0920.0319 = 0}  // Orange Co. Gr-Meb
Constraint : {dFlow0920.1106 = 0}  // Orange Co. Hills
Constraint : {dFlow0920.1162 = 0}  // Orange Co. Durham

// Add arc from Sanford to Pittsboro. Limit the current supply to Pittsboro
// from the Haw River to 2 mgd; the rest will come from Sanford.
Constraint : {dFlow0400.0401 = convert_units {2, mgd, af} }  // Haw River supply to Pittsboro

// Add arc from Sanford to Holly Springs with baseload supply of 4 mgd.  Use a constraint.
// Rest of Holly Springs demand will be met from the supply from Harnett County.
Constraint : {dFlow0489.0923 = convert_units {4, mgd, af} }  // Sanford to Holly Springs


// Let's add the corrected min release for Graham-Mebane Lake.  Since drought triggers are tied
// to usable storage (days of supply remaining), base min release adjustment on usable storage.
// The WTP process return (about 5% of the demand, applied to arc 319.100) can be used to help meet the min release

Set :  min_flow0320.0100
{   condition  :  (storage0320 - lower_rule0320) / (upper_rule0320 - lower_rule0320) <  0.4
 value      :  convert_units {3, cfs, af} - flow0319.0100

 condition  :  default
 value      :  convert_units {5, cfs, af} - flow0319.0100
}


// Misc. Neuse Ops.

/*  Set demands not used in basecase run to zero */
Set :  demand1318  {  value :  0 } /* Old Burlington Industries */

/*  Set interconnects not used in basecase run to zero */
Constraint : {dFlow1300.0471 = 0}  /* Raleigh-Cary Interconnect */
Constraint : {dFlow1300.0923 = 0}  /* Raleigh-Holly Springs Interconnect */

/*  Set inflows not used in basecase run to zero*/
Set : inflow1252  {  value :  0 } /* Kerr Lake indirect transfer*/
Set : inflow1403  {  value :  0 } /* Quarry dewatering */
```

```
Set : inflow1528  {  value :  0 } /* Tar River transfer - Wilson */
```

NRWWTP_intake.ocl

```
/* NRWWTP_Intake.OCL */

/* This subroutine dictates the operation of the NRWWTP intake alternative G2. */

Set Neuse_intake : max_flow1620.1305 {value: convert_units {[NR_DS_intake], mgd, af}}

Target Deliv_NRintake_to_Raleigh : dflow1620.1305
{   condition : abs_period<=1
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : 0

 // This code is being written so that the sum of withdrawals from Lake Benson and NR Intake
 // equals whatever we set the Benton WTP capacity.  This would only serve for Operational
 // yield tests as reality would dictate running at lower than max plant capacity
    condition : abs_period > 1
    priority  : 1
    penalty+  : 500
    penalty-  : 500
    Value     : convert_units {[DE_Benton_WTP_Capacity], mgd, af}-max_flow1440.1305

    condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 0
    value     : 0
}

Set Total_Intake_Pumping: _tot_intake_pump
{   condition : flow1620.1305 > 0
    value     : _tot_intake_pump(-1) + flow1620.1305

    condition : default
    value     : 0
}
```

OWASA_ops.ocl

```
// Operations policy for OWASA's system

// Set the Stone Quarry inflow - area adjustment of the Univ. Lake inflow
// Quarry = 1.2 sq. mi., Univ. Lake = 28.7 sq. mi.

Set : inflow0395 { value : 1.2 * inflow0430 / 28.7 }


//Set to refill Stone Quarry w/ spill from Cane Ck Res.
Target CaneCk_SQ_Trans : dflow0390.0395
{   condition : storage0390 >= upper_rule0390
    priority  : 1
    penalty+  : 350
    penalty-  : 300
    Value     : max { 0, min { upper_rule0395 - storage0390 - inflow0395 + evap0395 * stor_to_area { 0395, storage0395 } / 12 ,
                inflow0390 - evap0390 * stor_to_area { 0390, storage0390 } / 12 - min_flow0390.0370 - upper_rule0390 } }

    condition : default
    priority  : 1
    penalty+  : 350
    penalty-  : 350
    Value     : 0
}


// Anticipated OPERATING POLICY
//This is only necessary becuase dFlow can't be used in RHS of equation below in the
//next two targets - particularly the second one
Set  : _OWASA_JL_Use_Targ
{ // Use JL when in WSRP stages 1-3
 condition : (_OWASA_Trigger_3_On(-1) + _OWASA_Trigger_2_On(-1) + _OWASA_Trigger_1_On(-1) ) >=1
     and _Storage_OWASA(-1) > convert_units { 4, mg , af } //if any trigger is on, and there is
                    // water intheir JL Account, then buy
                    // water from WIP WTP
    Value     : convert_units { 4, mg , af }

    // No regular JL use if not in WSRP
    condition : default
    Value     : 0
}

Target JL_Access : dFlow1151.0431  // Access JL supply if WSRP stage >=1
{
    condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
```

```
   Value     : _OWASA_JL_Use_Targ
}

// EXISTING OPERATING POLICY
// Set the WD from Cane Creek Reservoir, depending on reservoir levels
// Stone Quarry will be utilized last.

Target CaneCkWD : dflow0390.0431
{   // If Univ. Lake full and CCR is below full, make all WDs from Univ. Lake
   condition : storage0430 >= upper_rule0430 - 0.1 and storage0390 < upper_rule0390
   priority  : 1
   penalty+  : 310
   penalty-  : 310
   Value     : 0

   // If both reservoirs are full split the WD
   condition : storage0430 >= upper_rule0430 and storage0390 >= upper_rule0390
   priority  : 1
   penalty+  : 310
   penalty-  : 310
   Value     : min { 0.5 * demand0431, max_flow0390.0431 }


   // Split WDs for the first 100 MG of drawdown (50 MG from Univ Lake)
   condition :  upper_rule0430 - storage0430 <= convert_units { 50, mg, af}
   priority  : 1
   penalty+  : 310
   penalty-  : 310
   Value     : min { 0.5 * demand0431, max_flow0390.0431 }

   // After that withdraw the majority, less 1 mgd, from Cane Creek
   condition : upper_rule0430 - storage0430 > convert_units { 50, mg, af}
   priority  : 1
   penalty+  : 310
   penalty-  : 310
   Value     : min { demand0431 - convert_units { 1, mgd, af } - _OWASA_JL_Use_Targ, max_flow0390.0431 }

   // Then draw down Cane Creek completely if Univ Lake is depleted
   condition : default
   priority  : 1
   penalty+  : 310
   penalty-  : 310
   Value     : min { demand0431 - _OWASA_JL_Use_Targ, max_flow0390.0431 }
}

```

OWASA_wsrp.ocl

```
/* OWASA's Drought Plan - based on the risk that usable storage will drop below 20% over the next year */

Set : _OWASA_Max_Usable_Stor { Value: (upper_rule0390 - lower_rule0390) + (upper_rule0395 - lower_rule0395)
        + (upper_rule0430 - lower_rule0430) }
Set : _OWASA_Usable_Stor { Value : min { _OWASA_Max_Usable_Stor,
                                (storage0390 - lower_rule0390) + (storage0395 - lower_rule0395)
        + (storage0430 - lower_rule0430) } }
Set : _OWASA_Usable_Stor_Pct { Value : 100 * _OWASA_Usable_Stor / _OWASA_Max_Usable_Stor }

// Compute the projected total inflows, demand, min. flow and evap at various forecast horizons over the next 52 weeks
:For:
{   [hrz] = {08, 12, 16, 20, 24, 52}
    [lag] = {56, 84, 112, 140, 168, 364}
}

// Trigger 1 horizon.
Set : _OWASA_ProjInflow1_[hrz]
{   condition : weekday{year, month, day} <= 1
    value     : 7 * ( timesers(0380/R02W[hrz]) + (1.2 / 28.7) * timesers(0430/R02W[hrz]) + timesers(0430/R02W[hrz]) )

    condition :  default
    value     :  _OWASA_ProjInflow1_[hrz](-1)
}


Set : _OWASA_ProjDemand1_[hrz]
{   condition : weekday{year, month, day} <= 1
    value     : accumulate { demand0431 , 0 , +[lag] }

    condition :  default
    value     :  _OWASA_ProjDemand1_[hrz](-1)
}


Set : _OWASA_ProjMinFlow1_[hrz]
{   condition : weekday{year, month, day} <= 1
    value     : accumulate { min_flow0390.0370 , 0 , +[lag]}

    condition :  default
    value     :  _OWASA_ProjMinFlow1_[hrz](-1)
}


Set : _OWASA_ProjEvap1_[hrz]
{   condition : weekday{year, month, day} <= 1
    value     : (stor_to_area { 0390 , storage0390 } * 7 * timesers(0390/EVAP_R02W[hrz]) / 12) +
              (stor_to_area { 0395 , storage0395 } * 7 * timesers(0395/EVAP_R02W[hrz]) / 12) +
```

```
            (stor_to_area { 0430 , storage0390 } * 7 * timesers(0430/EVAP_R02W[hrz]) / 12)
    condition :  default
    value     :  _OWASA_ProjEvap1_[hrz](-1)
}

// Trigger 2 horizon.
Set : _OWASA_ProjInflow2_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : 7 * ( timesers(0380/R10W[hrz]) + (1.2 / 28.7) * timesers(0430/R10W[hrz]) + timesers(0430/R10W[hrz]) )

    condition :  default
    value     :  _OWASA_ProjInflow1_[hrz](-1)
}


Set : _OWASA_ProjDemand2_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : accumulate { demand0431 , 0 , +[lag] }  * 0.9

    condition :  default
    value     :  _OWASA_ProjDemand1_[hrz](-1)
}


Set : _OWASA_ProjMinFlow2_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : accumulate { min_flow0390.0370 , 0 , +[lag]}

    condition :  default
    value     :  _OWASA_ProjMinFlow1_[hrz](-1)
}


Set : _OWASA_ProjEvap2_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : (stor_to_area { 0390 , storage0390 } * 7 * timesers(0390/EVAP_R10W[hrz]) / 12) +
            (stor_to_area { 0395 , storage0395 } * 7 * timesers(0395/EVAP_R10W[hrz]) / 12) +
            (stor_to_area { 0430 , storage0390 } * 7 * timesers(0430/EVAP_R10W[hrz]) / 12)
    condition :  default
    value     :  _OWASA_ProjEvap1_[hrz](-1)
}

// Trigger 3 horizon.
Set : _OWASA_ProjInflow3_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : 7 * ( timesers(0380/R20W[hrz]) + (1.2 / 28.7) * timesers(0430/R20W[hrz]) + timesers(0430/R20W[hrz]) )

```

```
    condition :  default
    value     :  _OWASA_ProjInflow1_[hrz](-1)
}


Set : _OWASA_ProjDemand3_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : accumulate { demand0431 , 0 , +[lag] }  * 0.85

    condition :  default
    value     :  _OWASA_ProjDemand1_[hrz](-1)
}


Set : _OWASA_ProjMinFlow3_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : accumulate { min_flow0390.0370 , 0 , +[lag]}

    condition :  default
    value     :  _OWASA_ProjMinFlow1_[hrz](-1)
}


Set : _OWASA_ProjEvap3_[hrz]
{    condition : weekday{year, month, day} <= 1
    value     : (stor_to_area { 0390 , storage0390 } * 7 * timesers(0390/EVAP_R20W[hrz]) / 12) +
              (stor_to_area { 0395 , storage0395 } * 7 * timesers(0395/EVAP_R20W[hrz]) / 12) +
              (stor_to_area { 0430 , storage0390 } * 7 * timesers(0430/EVAP_R20W[hrz]) / 12)
    condition :  default
    value     :  _OWASA_ProjEvap1_[hrz](-1)
}


 // Compute projected storage for the entire system for each trigger.  Projected storage will not exceed the max usable storage

 :For:
 {   [trig] = {1, 2, 3}
 }

 Set : _OWASA_ProjStorage[trig]_[hrz]
 {   Condition : weekday{year, month, day} <= 1
  Value     : min{_OWASA_Usable_Stor + _OWASA_ProjInflow[trig]_[hrz] - _OWASA_ProjDemand[trig]_[hrz]
      - _OWASA_ProjEvap[trig]_[hrz] - _OWASA_ProjMinFlow[trig]_[hrz] ,
    _OWASA_Max_Usable_Stor}

  Condition : default
  Value     : _OWASA_ProjStorage[trig]_[hrz](-1)
```

```
 }

 Set : _OWASA_ProjStorage_Pct[trig]_[hrz]
 {   Condition : weekday{year, month, day} <= 1
  Value     : 100 * _OWASA_ProjStorage[trig]_[hrz] / _OWASA_Max_Usable_Stor

  Condition : default
  Value     : _OWASA_ProjStorage_Pct[trig]_[hrz](-1)
 }

 :Next:
:Next:

/*  This section evaluates whether any of the three triggers were on during the
    last time step.  If so, it checks to see whether the reservoir has re-filled
    to the release storage, in which case the triggers are released.
    If the trigger was not on in the last timestep, it compares the projected stage with
    the threshold to determine whether it should be turned on.

    Note the projected storage is calculated only at beginning of week, so determination of triggers
    is kept to the beginning of the week.  That provides some delay in enactment of triggers and duplicates
    to some extent the waiting period requirement below.
*/

// Enact only if trigger storage is met and put in some waiting period as shown below.
// Triggers 2 and 3 can only turn on in sequence after trigger 1 has turned on.

Set : _OWASA_Trigger_3_On
{   Condition : _OWASA_Trigger_3_On(-1) = 1
    {   Condition : _OWASA_Usable_Stor >= _OWASA_Max_Usable_Stor
        Value     : 0

        Condition : default
        Value     : _OWASA_Trigger_3_On(-1)
    }

    Condition : _OWASA_Stage_2_Counter(-1) >= 7   // Require a 7 day waiting period before going into phase 3
    {   Condition : weekday{year, month, day} <= 1
        {     Condition : _OWASA_ProjStorage_Pct3_08 <= 20 or _OWASA_ProjStorage_Pct3_12 <= 20
       or _OWASA_ProjStorage_Pct3_16 <= 20 or _OWASA_ProjStorage_Pct3_20 <= 20
       or _OWASA_ProjStorage_Pct3_24 <= 20 or _OWASA_ProjStorage_Pct3_52 <= 20
              Value     : 1
        }
        Condition : default
        Value     : _OWASA_Trigger_3_On(-1)
    }
    Condition : default
```

```
  Value     : _OWASA_Trigger_3_On(-1)
}


Set : _OWASA_Trigger_2_On
{   Condition : _OWASA_Trigger_2_On(-1) = 1
    {   Condition : _OWASA_Usable_Stor >= _OWASA_Max_Usable_Stor
        Value     : 0

        Condition : default
        Value     : _OWASA_Trigger_2_On(-1)
    }

    Condition : _OWASA_Stage_1_Counter(-1) >= 7   // Require a 7 day waiting period before going into phase 2
    {   Condition : weekday{year, month, day} <= 1
        {   Condition : _OWASA_ProjStorage_Pct2_08 <= 20 or _OWASA_ProjStorage_Pct2_12 <= 20
       or _OWASA_ProjStorage_Pct2_16 <= 20 or _OWASA_ProjStorage_Pct2_20 <= 20
       or _OWASA_ProjStorage_Pct2_24 <= 20 or _OWASA_ProjStorage_Pct2_52 <= 20
            Value     : 1
        }
        Condition : default
        Value     : _OWASA_Trigger_2_On(-1)
    }
    Condition : default
    Value     : _OWASA_Trigger_2_On(-1)
}


Set : _OWASA_Trigger_1_On
{   Condition : _OWASA_Trigger_1_On(-1) = 1
    {   Condition : _OWASA_Usable_Stor >= _OWASA_Max_Usable_Stor
        Value     : 0

        Condition : default
        Value     : _OWASA_Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {   Condition : _OWASA_ProjStorage_Pct1_08 <= 20 or _OWASA_ProjStorage_Pct1_12 <= 20
      or _OWASA_ProjStorage_Pct1_16 <= 20 or _OWASA_ProjStorage_Pct1_20 <= 20
      or _OWASA_ProjStorage_Pct1_24 <= 20 or _OWASA_ProjStorage_Pct1_52 <= 20
        Value     : 1

        Condition : default
        Value     : _OWASA_Trigger_1_On(-1)
    }
    Condition : default
```

```
   Value     : _OWASA_Trigger_1_On(-1)
}

:For:
{   [trig] = {1, 2, 3}
}

Set : _OWASA_Stage_[trig]_Counter
{   Condition : _OWASA_Stage_[trig]_Counter(-1) > 0 and _OWASA_Trigger_[trig]_On = 0
    Value     : 0

    Condition : _OWASA_Trigger_[trig]_On = 1
    Value     : _OWASA_Stage_[trig]_Counter(-1) + 1

    Condition : default
    Value     : _OWASA_Stage_[trig]_Counter(-1)
}

/*  Count all trigger events lasting at least 7 days */

Set : _OWASA_Ph_[trig]_event_counter
{   Condition : _OWASA_Stage_[trig]_Counter = 7 and _OWASA_Stage_[trig]_Counter(-1) = 6
    Value     : _OWASA_Ph_[trig]_event_counter(-1) + 1

    Condition : default
    Value      : _OWASA_Ph_[trig]_event_counter(-1)
}

:Next:

/*  This section determines the demand depending upon which level of conservation
    is in place. */

Set : _OWASA_Consvn_1_Demand
{
    Condition : _OWASA_Trigger_1_On = 1
    Value     : Demand0431 * ( 1 - ( 10/ 100 ))

    Condition : default
    Value     : Demand0431
}

Set : _OWASA_Consvn_2_Demand
{
 Condition : _OWASA_Trigger_2_On = 1
    Value     : Demand0431 * ( 1 - ( 15 / 100 ))

```

```
    Condition : default
    Value     : Demand0431
}

Set : _OWASA_Consvn_3_Demand
{
 Condition : _OWASA_Trigger_3_On = 1
    Value     : Demand0431 * ( 1 - ( 20 / 100 ))

    Condition : default
    Value     : Demand0431
}

:For:
{   [trig] = {1, 2, 3}
}

Constraint   OWASA_Demand_Limit_Consvn_[trig] :
            {   Condition  :  _OWASA_Trigger_[trig]_On = 1
                Expression :  ddelivery0431<= _OWASA_Consvn_[trig]_Demand }

:Next:

```

Pitt_Chatham_ops.ocl

```
/*  Pittsboro_Ops.ocl  */
/*  Operational policies for Town of Pittsboro */

// Since supply from Jordan Lake WIP to Pittsboro may not occcur, set the flow to 0 in this arc.  Ignore the rest below.
Constraint : {dFlow0468.0401 = convert_units {0, mgd, af} }  // JLake supply to Pittsboro

/*

// Balance use of the two water sources for Pittsboro in accordance with rough guidance from J. Hennessy in fall of 2021
Target Pittsboro_WIP_usage : dflow0468.0401
{
   condition : _Storage_Pitt(-1) > demand0401  //Sufficient storage in JL is available
   priority  : 1
   penalty+  : 20
   penalty-  : 20
   Value     : 0.75 * demand0401

   condition : default
   priority  : 1
   penalty+  : 5
   penalty-  : 5
   Value     : min {_Storage_Pitt(-1), 0.5 * demand0401}

}

*/

Constraint : {dFlow0468.0473 = 0}   // WIP to Chatham - for calculation simplicity, not what will actually happen.
          // This way Chatham gets all it water directly from the 0470.0473 arc

// Ignore the rest below.

// Balance use of the two water sources for Chatham Co. in accordance with rough guidance from J. Hennessy
// in fall of 2021 that Chatham will supply it's North zone/region from the WIP facility
// Data on usage from WIP demands.xlsx

/*Target Chatham_WIP_usage : dflow0468.0473
{
   condition : default
   priority  : 1
   penalty+  : 10
   penalty-  : 10
   Value     : 0.64 * demand0473

}*/
```

Raleigh_ops.ocl

```
/*  RALEIGH_OPS.OCL  */

/*  Set flow from Falls Lake to Raleigh demand to zero when performing anaysis on the Swift Creek system in isolation. */
//Constraint : {dFlow1300.1305 = 0 }

/* This code block was moved from Falls_Bdam_WQ_WS_Accounts.ocl in order that the variable _Raleigh_Sys_Stor_Pct
 (see end of file) can be appropriately calculated here. These variables will mostly be used in
 Falls_Bdam_WQ_WS_Accounts.ocl*/

/* The Falls conservation storage zone is divided into water quality and water storage accounts
Fraction of conservation storage and inflow :
WQ = 57.7% allocated (61,322 acft.)
WS = 42.3% allocated (45,000 acft.)

Beaverdam is also included in the WQ/WS accounting, the proportion to each is the same as Falls. */
/*  WQ and WS accounts by lake */

set :  _FLake_Max_WQ_WS_Storage
{    condition  :   Default
     value      :   101705 // removed algorithm that allows adjustment to Falls Conservation Pool - RNP
}

set :  _FLake_Max_WS_Storage
{    condition  :   Default
     value      :   _FLake_Max_WQ_WS_Storage - [FLake_WQ_Stor] // This latter number should be the volume of the reallocated
                    // WQ Poolin Falls only (w/o Beaver Dam portion)

}

set :  _FLake_Max_WQ_Storage
{    condition  :   Default
     value      :   _FLake_Max_WQ_WS_Storage - _FLake_Max_WS_Storage

}


Set :  _Pct_Max_WS_Storage
{  value  :  ( _FLake_Max_WS_Storage  /  _FLake_Max_WQ_WS_Storage  ) * 100  } // removed algortihm allowing
                        //easy adjusment to pool percentage - RNP 1/25/21
Set :  _Pct_Max_WQ_Storage  {  value  :   100 - _Pct_Max_WS_Storage }

set :   _Total_Max_WQ_WS_Storage {value: _FLake_Max_WQ_WS_Storage + [Bdam_WQ_WS_Stor]  }
set :   _Total_Max_WS_Storage  { value : _FLake_Max_WS_Storage + [Bdam_WQ_WS_Stor]  * _Pct_Max_WS_Storage / 100  }
set :   _Total_Max_WQ_Storage { value : _Total_Max_WQ_WS_Storage  -  _Total_Max_WS_Storage}

Set :  _Bdam_Max_WQ_Storage  {  value  : [Bdam_WQ_WS_Stor]  * _Pct_Max_WQ_Storage / 100 }
Set :  _Bdam_Max_WS_Storage  {  value  : [Bdam_WQ_WS_Stor]  * _Pct_Max_WS_Storage / 100 } //  add this when Beaver Dam Sediment
```

```
                    // Storage is to be included in Alt
                    // A3:  + (elev_to_stor{230, [Falls_lower_rule]} - lower_rule230)


/* Set inflow and evaporation on farm ponds in Little River Sub-basin */
Set : evap1739 { value :0.40 * evap1740}
:Substitute: [farm_inflow_fraction] = 0.46 // I believe this was a GIS estimate of the fraction of the LRR watershed
          // that passes through an upstream pond before reaching the LRR
Set : inflow1739 { value : [farm_inflow_fraction] * inflow1740}
Set : inflow1740 { value : inflow1740 - inflow1739}

// Set operational policy for Swift Creek system

Set : Swift_Sys_WS_Stor_Pct
{ value: ((storage1420 - dead_stor1420 + storage1440 -  dead_stor1440)
  / (max_stor1420 - dead_stor1420 + max_stor1440 - dead_stor1440)) *100 }

/*  Set the minimum release for Benson/Wheeler - based on useable storage */
Set :  min_flow1440.1700
{   condition : Swift_Sys_WS_Stor_Pct < 30
    Value     : convert_units { 1 , cfs , af }

    condition : Swift_Sys_WS_Stor_Pct < 60
    Value     : convert_units { 2 , cfs , af }

    condition : default
    Value     : convert_units { 3 , cfs , af }
}



/*  Operational policy for withdrawals from Benson/Wheeler */


/* Set the maximum delivery from Raleigh WTP's (change the capacities using the substitutes below) */

:Substitute: [EMJ_WTP_capacity] = 120 //MGD - Reed changed from 86 to 120 since this run is used for long-term planning out beyond 2040

Set :  max_flow1440.1305 //Set max WTP flows based on Final EA for D.E. Benton WTP
{

 condition : (Swift_Sys_WS_Stor_Pct + 10) < _Total_WS_Pct(-1) // adjusted margin to +10% and low Benton production to 6 mgd
    Value     : convert_units {6, mgd, af}

    condition : Swift_Sys_WS_Stor_Pct < 30
    Value     : convert_units { 11.2, mgd, af }

```

```
    condition : Swift_Sys_WS_Stor_Pct < 60
    Value     : convert_units { 12.6, mgd, af }

    condition : default
    Value     : convert_units { 14 , mgd , af }
}


Set :  max_flow1300.1305
{   condition  :  default
 Value      :  convert_units { [EMJ_WTP_capacity], mgd , af }

}

// Don't allow Falls/EMJ WD to drop below 36 MGD
Target Falls_WTP_Min_production  :  dflow1300.1305
{   condition : default
    priority  : 1
    penalty+  : 0
    penalty-  : 200
    Value     : convert_units{ 36, mgd, af }
}

/* Set delivery target for DE Benton WTP  */
Target Benton_WTP_Min_production  :  dflow1440.1305
{   condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 10
    Value     : max_flow1440.1305
}


/*  RESERVOIR BALANCING -- Raleigh - Attempt to draw down the Falls/Bdam WS account and the usable storage
    in Benson/Wheeler proportionally. */

Constraint Balance1300 : { d_StorRatio2 > (( Dstorage1300 + Dstorage1230 - elev_to_stor { 1300 , [Falls_lower_rule] }
          - elev_to_stor { 1230, [Falls_lower_rule] } - _Total_WQ_Stor(-1))
                                       / ( (elev_to_stor { 1300 , [Falls_upper_rule] } - elev_to_stor { 1300 , [Falls_lower_rule] }) +
                                         (elev_to_stor { 1230 , [Falls_upper_rule] } - elev_to_stor { 1230 , [Falls_lower_rule] })
          - _Total_Max_WQ_Storage )) }

Constraint Balance1440 : { d_StorRatio2 > (( Dstorage1440 + Dstorage1420 - dead_stor1440 - dead_stor1420 )
         / (max_stor1440 + max_stor1420 - dead_stor1440 - dead_stor1420)) }
```

```

// Assume Little River Reservoir is not operational in the 2055 scenario since its projected demand can
// be met from the existing supply sources.

/*
Target LRR_WTP_Min_production  :  dflow1740.1305
{   condition : abs_period > 1 and ((storage1740 - dead_stor1740)/(max_stor1740 - dead_stor1740) + 0.07) < _Total_WS_Pct(-1)/100
    priority  : 1
    penalty+  : 30
    penalty-  : 30
    Value     : convert_units{ 6, mgd, af }

    condition : abs_period > 1 and ((storage1740 - dead_stor1740)/(max_stor1740 - dead_stor1740)) - 0.07 > _Total_WS_Pct(-1)/100
    priority  : 1
    penalty+  : 50
    penalty-  : 30
    Value     : convert_units{ 20, mgd, af }

    condition : default
    priority  : 1
    penalty+  : 0
    penalty-  : 30
    Value     : convert_units{ 7.5, mgd, af }
}
*/

// Set delivery to Raleigh to 0.
Set :  max_flow1740.1305
{   condition  :  default
 Value      :  convert_units { 0, mgd , af }
}


// Set the minimum release.  Set to 0 since reservoir is not active for the 2055 scenario.

Set :  min_flow1740.1747
{   /*condition : (storage1740 - dead_stor1740) / (max_stor1740 - dead_stor1740) < 0.5
    Value     : convert_units { 0.48 , cfs , af }

    condition : (storage1740 - dead_stor1740) / (max_stor1740 - dead_stor1740) < 0.7
    Value     : convert_units { 2.31 , cfs , af }
 */

    condition : default
    Value     : convert_units { 0 , cfs , af }
}

```

```

// More reservoir balancing -- include Little River.  Shut off for the 2055 scenario since it is not active.

/*
Constraint Balance1740 : { d_StorRatio2 > (( Dstorage1740 - dead_stor1740) / (max_stor1740 - dead_stor1740)) }

Minimax : d_StorRatio2

{  priority  : 1
   penalty   : 50
   tolerance : .02
}

*/


/* System Storage for Raleigh - including Little River Reservoir should it be evaluated.
Little River set to 0 storage since not used for this scenario.   */

Set : _Raleigh_Sys_Stor_Pct
{  value      :   (_Total_WS_Stor(-1) + storage1420 - dead_stor1420 + storage1440 -  dead_stor1440 + storage1740 - dead_stor1740 ) /
                  ( _Total_Max_WS_Storage + max_stor1420 - dead_stor1420 + max_stor1440 - dead_stor1440 + max_stor1740 - dead_stor1740)

}
```

Raleigh_Quarry_ops.ocl

```
/*  Raleigh_Quarry_ops.OCL  */

/* This subroutine dictates the operation of the Raleigh Quarry WS concept. */



// Ensure that the minimum release obligation from Falls is also met below the Quarry and Lag node
Constraint FallsDownstreamFlow1 :
{   condition : month > 3 and month < 11
    expression: dflow1310.1320 >= convert_units { 100, cfs, af } * ( 1 + [FLakeMin_SafeFact] / 100 )
}

Constraint FallsDownstreamFlow2 :
{   condition : month<=3 or month>=11
    expression: dflow1310.1320 >= convert_units { lookup { PiggybackGate, elevation1300 }, cfs, af }
}


Set :  Expected_Durham_Spill
{
    value : max {0, inflow1140 + inflow1200 + storage1140 + storage1200 - evap1140 - evap1200 - demand1162 - max_stor1140 - max_stor1200}
}

Set : Expected_Falls_Spill
{               // Spill is expected
    condition : (inflow1300 + flow1163.1300(-1) + inflow1080 + inflow1100 + inflow1110 + inflow1115 + flow1256.1300(-1)
     + inflow1270 + inflow1230  + Expected_Durham_Spill - delivery1302 - evap1300 - evap1230 - demand1306
     - min_flow1300.1304 + storage1300 + storage1230 - elev_to_stor{1300, [Falls_upper_rule]}
     - elev_to_stor{1230, elevation1300}) > 0

    value     :  inflow1300 + flow1163.1300(-1) + inflow1080 + inflow1100 + inflow1110 + inflow1115 + flow1256.1300(-1)
     + inflow1270 + inflow1230  + Expected_Durham_Spill - delivery1302 - evap1300 - evap1230 - demand1306
     - min_flow1300.1304 + storage1300 + storage1230 - elev_to_stor{1300,[Falls_upper_rule]}
     - elev_to_stor{1230, elevation1300}
                // No spill expected
    condition : default
    value     : 0
}



Set Raleigh_Quarry_Refill : max_flow1304.1340 // Fill conditions
{
    condition : Expected_Falls_Spill > 0 and storage1340 < max_stor1340
    value     : max {0, min{ convert_units { [Max_Quarry_refill_rate] , mgd , af }, max_stor1340
        - storage1340, Expected_Falls_Spill}}

```

```
    condition : default
    value     : 0
}





//Quarry release rule
Target Raleigh_Quarry_Outflow  :  dflow1340.1305
{   condition : elevation1300 < [Falls_upper_rule] - 0.5
    priority  : 1
    penalty+  : 1000
    penalty-  : 50
    Value     : convert_units { [Max_Quarry_refill_rate]  , mgd , af }


    condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 0
    Value     : 0
}

//Quarry refill target
Target Raleigh_Quarry_Refill  :  dflow1304.1340
{   condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 50
    Value     : max_flow1304.1340



}
```

Randleman_ops.ocl

```
/*  Randleman_Ops.ocl  */
/*  Operational policies for Randleman Lake */


Set MinReleaseRandleman :  min_flow0270.0280
{    condition  :  storage0270 / max_stor0270 <= 0.30
     value      :  convert_units {10, cfs, af }

     condition  :  storage0270 / max_stor0270 <= 0.60
     value      :  convert_units {20, cfs, af }

     condition  :  default
     value      :  convert_units {30, cfs, af }
}

```

routing_cf.ocl

```
/*  File is ROUTING_CF.OCL, which has the coding to handle the Jordan - Lillington,
    and Lillington to Fayetteville routing, daily time step only. */

/*  Jordan-to-Lillington.
        Jordan Release seen at Lill.
        = .5 * yesterday's release + .5 * today's release.

    Lillington-to-Fayetteville.
        Lillington flow seen at Fayetteville
        = Average flow of previous day

    Nodes 555 and 749 are reservoirs used for channel storage.
    The flow into these three nodes is unrouted; the release from them is routed.
    The storage in the nodes makes up the difference.

    Note that for the first day of the simulation the routed flows need to be
    estimated; the current values set the routed flows equal to the flow
    for that day when the simulation is started on 01/01/1930; they may need to be
    adjusted if the run is started on a different date. */

Target JordanRout : dflow0555.0650 - 0.5 * dflow0550.0555
{   Condition : abs_period <= 1
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : convert_units { 3711, cfs, af }

    Condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000

    value     : 0.5 * flow0550.0555(-1)
}

Target LillRout : dflow0749.0770
{   Condition : abs_period <= 1
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : convert_units { 4381, cfs, af }


    Condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
```

```
    value     : flow0740.0749(-1)
}
```

routing_neuse.ocl

```
/*  File is ROUTING_NEUSE.OCL, which has the coding to handle the Falls - Clayton,
    Clayton - Goldsboro and Goldsboro - Kinston routing, daily time step only. */

/*  Falls-to-Clayton.
        Falls Release seen at Clayton
        = .5 * yesterday's release + .5 * today's release.

    Clayton-to-Goldsboro.
        Clayton flow seen at Goldsboro
        = Average flow of previous four days

    Goldsboro-to-Kinston.
        Goldsboro flow seen at Kinston
        = Average flow of previous two days

    Nodes 310, 640 and 790 are reservoirs used for channel storage.
    The flow into these three nodes is unrouted; the release from them is routed.
    The storage in the nodes makes up the difference.

    Note that for the first day of the simulation the routed flows need to be
    estimated; the current values set the routed flows equal to the upstream flow
    for that day when the simulation is started on 01/01/1929; they may need to be
    adjusted if the run is started on a different date. */

Target FallsRout : dflow1310.1320 - .5 * dflow1300.1304
{   Condition : abs_period <= 1
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : convert_units { 49.25, cfs, af }

    Condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : .5 * flow1304.1310(-1)
}
Target ClaytRout : dflow1640.1650
{   Condition : abs_period <= 1
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : convert_units { 353.6, cfs, af }

    Condition : abs_period = 2
    priority  : 1
    penalty+  : 10000
```

```
    penalty-  : 10000
    value     : flow1630.1640(-1)

    Condition : abs_period = 3
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : ( flow1630.1640(-2) + flow1630.1640(-1) ) / 2

    Condition : abs_period = 4
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : ( flow1630.1640(-3) + flow1630.1640(-2) + flow1630.1640(-1) ) / 3

    Condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : ( flow1630.1640(-4) + flow1630.1640(-3) + flow1630.1640(-2) + flow1630.1640(-1) ) / 4
}
Target GoldsRout : dflow1790.1795
{   Condition : abs_period <= 1
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : convert_units { 1047.6, cfs, af }

    Condition : abs_period = 2
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : flow1780.1790(-1)

    Condition : default
    priority  : 1
    penalty+  : 10000
    penalty-  : 10000
    value     : ( flow1780.1790(-2) + flow1780.1790(-1) ) / 2
}
```

Shortages.ocl

```
//Shortages.ocl
//Calculates shortages using conservation demands from drought plans to determine actual shortages

//Neuse drought demands


set:_Durham_Shortage_Calc
{ condition  : default
 value   : demand1162 - delivery1162
}

:For:
{   [trig] = {1,2,3,4}
}
set:_Durham_Shortage_Calc
{ condition  : _Durham_Trigger_[trig]_On = 1
 value   : _Durham_Consvn_[trig]_Demand-delivery1162
}
:Next:


set:_Ral_Shortage_Calc
{ condition  : default
 value   : demand1306 - delivery1306
}

:For:
{   [trig] = {1,2,3}
}
set:_Ral_Shortage_Calc
{ condition  : _Ral_Trigger_[trig]_On = 1
 value   : _Ral_Consvn_[trig]_Demand-delivery1306
}
:Next:

set:_SGWASA_Shortage_Calc
{ condition  : default
 value   : demand1256 - delivery1256
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_SGWASA_Shortage_Calc
{ condition  : _SGWASA_Trigger_[trig]_On = 1
 value   : _SGWASA_Consvn_[trig]_Demand-delivery1256
}
```

```
:Next:

set:_Wilson_Shortage_Calc
{ condition  : default
 value   : demand1506 - delivery1506
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_Wilson_Shortage_Calc
{ condition  : _Wilson_Trigger_[trig]_On = 1
 value   : _Wilson_Consvn_[trig]_Demand-delivery1506
}
:Next:


set:_Benson_Shortage_Calc
{ condition  : default
 value   : demand1756 - delivery1756
}

:For:
{   [trig] = {1,2,3,4,5,6}
}
set:_Benson_Shortage_Calc
{ condition  : _Benson_Trigger_[trig]_On = 1
 value   : _Benson_Consvn_[trig]_Demand-delivery1756
}
:Next:


////Cape Fear drought demands
//

set:_OWASA_Shortage_Calc
{ condition  : default
 value   : demand0431 - delivery0431
}

:For:
{   [trig] = {1,2,3}
}
set:_OWASA_Shortage_Calc
{ condition  : _OWASA_Trigger_[trig]_On = 1
 value   : _OWASA_Consvn_[trig]_Demand-delivery0431
}
```

```
:Next:

set:_Burl_Shortage_Calc
{ condition  : default
 value   : demand0341 - delivery0341
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_Burl_Shortage_Calc
{ condition  : _Burl_Trigger_[trig]_On = 1
 value   : _Burl2_Consvn_[trig]_Demand-delivery0341
}
:Next:

set:_Gree_Shortage_Calc
{ condition  : default
 value   : demand0123 - delivery0123
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_Gree_Shortage_Calc
{ condition  : _Gree_Trigger_[trig]_On = 1
 value   : _Gree2_Consvn_[trig]_Demand-delivery0123
}
:Next:

set:_High_Shortage_Calc
{ condition  : default
 value   : demand0223 - delivery0223
}

:For:
{   [trig] = {1,2,3,4}
}
set:_High_Shortage_Calc
{ condition  : _High_Trigger_[trig]_On = 1
 value   : _High_Consvn_[trig]_Demand-delivery0223
}
:Next:

set:_Reid_Shortage_Calc
{ condition  : default
 value   : demand0031 - delivery0031
```

```
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_Reid_Shortage_Calc
{ condition  : _Reid_Trigger_[trig]_On = 1
  value   : _Reid_Consvn_[trig]_Demand-delivery0031
}
:Next:

set:_Rams_Shortage_Calc
{ condition  : default
  value   : demand0301 - delivery0301
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_Rams_Shortage_Calc
{ condition  : _Rams_Trigger_[trig]_On = 1
  value   : _Rams_Consvn_[trig]_Demand-delivery0301
}
:Next:

set:_GramMeb_Shortage_Calc
{ condition  : default
  value   : demand0321 - delivery0321
}

:For:
{   [trig] = {1,2,3,4,5}
}
set:_GramMeb_Shortage_Calc
{ condition  : _GramMeb_Trigger_[trig]_On = 1
  value   : _GramMeb_Consvn_[trig]_Demand-delivery0321
}
:Next:


set:_Cary_Shortage_Calc
{ condition  : default
  value   : demand0471 - delivery0471
}

:For:
{   [trig] = {1,2,3,4}
```

```
}
set:_Cary_Shortage_Calc
{ condition  : _Cary_Trigger_[trig]_On = 1
 value   : _Cary_Consvn_[trig]_Demand-delivery0471
}
:Next:


set:_Dunn_Shortage_Calc
{ condition  : default
 value   : demand0663 - delivery0663
}

:For:
{   [trig] = {1,2,3,4,5,6}
}
set:_Dunn_Shortage_Calc
{ condition  : _Dunn_Trigger_[trig]_On = 1
 value   : _Dunn_Consvn_[trig]_Demand-delivery0663
}
:Next:
```

SilerCity_ops.ocl

```
/*  SilerCity_Ops.OCL  */

/*  Minimum release policy for Siler City's Charles Turner Reservoir on the Rocky River - based on combined usable
    storage remaining in the reservoirs. */

Set : _SilerCity_UsableStor     { Value : max { 0,
             min { (max_stor0324 - dead_stor0324 + max_stor0325 - dead_stor0325),
               (storage0324 - dead_stor0324 + storage0325 - dead_stor0325)  } } }
Set : _SilerCity_UsableStorPct { Value : 100 * _SilerCity_UsableStor
           / (max_stor0324 - dead_stor0324 + max_stor0325 - dead_stor0325) }


// Trigger when reaching tier 2
Set :  _SilerCityTrig2
{   condition :  _SilerCity_UsableStorPct < 70
    value     :  1

    condition :  default
    value     :  0
}


// Trigger when reaching tier 3
Set :  _SilerCityTrig3
{   condition :  _SilerCity_UsableStorPct < 40
    value     :  1

    condition :  default
    value     :  0
}


Set :  _Tier_MinRelease
{   // Tier 3
    condition : _SilerCityTrig3 = 1
    Value     : convert_units {pattern(Tier3_RockyRiver),cfs,af}

    // Tier 2
    condition : _SilerCityTrig2 = 1
    Value     : convert_units {pattern(Tier2_RockyRiver),cfs,af}

    // Tier 1
    condition : default
    Value     : convert_units {pattern(Tier1_RockyRiver),cfs,af}
}

// Also provide pulsing to simulate storm events (if those do not occur) of 20 cfs for 12 hours, or 20 acre feet per day, once per month,
```

```
// whenever combined usable storage exceeds 40%.  401 Water Quality Certificate says pulses only required when no natural events of similar
// magnitude are observed.  Assume we will provide this at the beginning of each month regardless of natural flows.

// Set min flow
Set :  min_flow0325.0328
{    condition  :  day = 1 and _SilerCity_UsableStorPct > 0.4
     value      :  max{_Tier_MinRelease, 20}

     condition  :  default
     value      :  _Tier_MinRelease
}
```

SpringLake_ops.ocl

```
/*SPRINGLAKE_OPS.OCL  */

/*  Operational policy for Spring Lake */

// Set the fraction coming from Harnett w/ a substitute

:Substitute: [SpringLakeWS_Harnett] = .28//0.21 old value


// Set targets to dictate WDs between sources
Target Harnett_WD : dflow0549.0719
{   condition : default
    priority  : 1
    penalty+  : 100
    penalty-  : 100
    Value     : [SpringLakeWS_Harnett] * demand0719 // 72% from Fayettville from 2019 LWSP  rest will be from Harnett
}
```

udef_list.ocl

```
/* File is udefs_list.ocl */

:Udef:

// ---------------------------


/* Udefs for inflow filtering */
:For:
{   [node] = { 0020, 0040, 0070, 0090, 0300, 0310, 0324, 0325, 0590, 0760, 0110, 0140, 0145, 0170, 0210, 0220, 0260, 0270, 0280, 0340,
    0380, 0400, 0430, 0450, 0470, 0490, 0520, 0527, 0550, 0640, 0700, 0780, 0820, 1010, 1050, 1060, 1080, 1100, 1110, 1115,
    1250, 1270, 1290, 1420, 1440, 1445, 1450, 1480, 1500, 1560, 1630, 1740, 1780, 1800, 1900, 0044, 0112, 0120, 0328, 0570,
    0580, 0600, 0610, 0660, 0680, 0720, 0730, 0770, 0790, 1205, 1320, 1405, 1409, 1471, 1520, 1600, 1620, 1625, 1650, 1660,
    1700, 1730, 1735, 1747, 1750, 1755, 1760, 1775, 1795, 1570, 1850, 1999 }
}
    Udef : _TempInf[node]
    Udef : _InfDeficit[node]  init{0}
:Next:

/* Udefs for Crabtree inflow filtering */
Udef : _TempInfCrabtree
Udef : _TotInfCrabtree
Udef : _InfDeficitCrabtree  init{0}

// Gibson gain - required for allocating inflows to Higgins & Brandt
Udef : _Gibso_Gain

// For Harris Ops
Udef :  _Proj_Harris_Storage
Udef :  _Proj_Harris_Elev

// For Siler City operations
Udef : _SilerCity_UsableStor init {5348.79}
Udef : _SilerCity_UsableStorPct init {1}
Udef : _SilerCityTrig2
Udef : _SilerCityTrig3
Udef : _Tier_MinRelease

// Use for the Jordan Lake drought protocol

Udef :  _JLake_Inflow    init {0}
Udef :  _Avg_JLake_Inflow
Udef :  _WQZone
Udef :  _Drought_Stage
Udef :  _Level_Drawdown

// FOR:NEXT loop to declare udefs
```

```
:FOR: { [level_num] = { 1, 2, 3, 4 } }

 Udef :  _Trigger_[level_num]_On         init {0}
 Udef :  _Count_Trigger_[level_num]     init {0}
 Udef :  _Total_Count_Trigger_[level_num] init {0}
 Udef :  _CumDayWithinInt_[level_num]   init {0}
 Udef :  _Lill_Target_[level_num]   init {0}
 Udef :  _Ph_[level_num]_event_count   init {0}

:NEXT:

// Jordan hydropower generation
Udef : _Jordan_hydropower

// ------------------

/*  For the agricultural demand computations */

// FOR:NEXT loop to declare udefs
:FOR: { [county] = { 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21,
            22, 23, 24, 25, 26, 27, 28, 29, 30, 31  } }

 Udef : dem[county]

:NEXT:

// -----------------------

/*  Udefs for the Jordan Lake pool allocation */

Udef :  _JLakeInf
Udef :  _JLake_WQ_Inf
Udef :  _JLake_WS_Inf
Udef :  _Inf_avail_to_WS_pool
Udef :  _Inf_used_for_WS_pool
Udef :  _WS_Total_Demand
Udef :  _WS_Total_Deliv


// FOR:NEXT loop to declare udefs

:substitute:        [Starting_Storage_CaryAp] = 17953.6          /* Initial condition for the CaryApex account (in acre feet) */
:substitute:        [Starting_Storage_Chatham] = 5954            /* Initial condition for the Chatham account (in acre feet) */
:substitute:        [Starting_Storage_Durham] = 7557             /* Initial condition for the Durham account (in acre feet) */
:substitute:         [Starting_Storage_Holly] = 916              /* Initial condition for the Holly Springs account (in acre feet) */
:substitute:        [Starting_Storage_Morris] = 1603             /* Initial condition for the Morrisville account (in acre feet) */
:substitute:        [Starting_Storage_Orange] = 687              /* Initial condition for the Orange Co. account (in acre feet) */
```

```
:substitute:        [Starting_Storage_Other] = 4030.4          /* Initial condition for the unallocated account (in acre feet) */
:substitute:        [Starting_Storage_OWASA] = 2290            /* Initial condition for the OWASA account (in acre feet) */
:substitute:          [Starting_Storage_RTP] = 1603            /* Initial condition for the RTP account (in acre feet) */
:substitute:           [Starting_Storage_Pitt] =  2748         /* Initial condition for the Pittsboro account (in acre feet) */
:substitute:          [Starting_Storage_Hillsb] =  458         /* Initial condition for the Hillsborough account (in acre feet) */
:substitute:           [Starting_WQ_Storage] = 94600           /* Initial Jordan Lake WQ storage (in acre feet) */



 :FOR: {  [accounts] = {CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb }  }

  Udef :  _Req_Refill_[Accounts]
  Udef :  _Inf_[Accounts]
  Udef :  _Rem_def_[Accounts]
  Udef :  _Rem_Inf_[Accounts]
  Udef :  _Inf_Total_[Accounts]
  Udef :  _Storage_[Accounts]     init{ [Starting_Storage_[Accounts]] }
  Udef :  _Stor_Final_[Accounts]
  Udef :  _Stor_Final_Pct_[Accounts]

 :NEXT:

Udef :  _Inf_Rem_WS
Udef :  _Rem_def_Total

Udef :  _Total_WS_Storage
Udef :  _Total_WS_Storage_Pct
Udef :  _Req_Refill_WS_Pool
Udef :  _WS_Pool_Excess
Udef :  _WQ_Release
Udef :  _WQ_Storage   init {[Starting_WQ_Storage]}
Udef :  _WQ_Storage_Pct
Udef :  _Req_Refill_WQ
Udef :  _WQ_Pool_Excess


// FOR THE NEUSE
//
//

/*  Udefs for cumulative tracking variables */
Udef :  _CumWSupplyDemand   init {0}
Udef :  _CumWSupplyDelivery init {0}
Udef :  _CumWWReturn        init {0}
Udef :  _CumWSupplyWWReturn init {0}

/*  Udefs for Eno operations */
```

```
Udef :  _Orange_streamflow  init {3.376} /* Initially set to 1.1 mgd*/
Udef :  _Eno_Channel_Loss   init {0}
Udef :  _Max_Hills_WD       init {4.634} /* Initially set to 1.51 mgd */
Udef :  _Max_OrAl_WD        init {2.157} /* Initially set to 0.82 mgd */
Udef :  _Max_Pied_WD        init {1.320} /* Initially set to 0.43 mgd */
Udef :  _WFER_Tier          init {1}

/*  For proportional drawdown for Durham*/
Udef : _StorRatio   Decision { 0 , unbounded }
Udef : _StorRatio2  Decision { 0 , unbounded }

/*  Udef for Local Clayton Inflow for Falls Flood control */
Udef : _ClaytLocal init {0}

/*  Udefs for Falls/Clayton minimum flow */
Udef : ClaytonTarget_Override
Udef : ClaytonTarget_SafeFact
Udef : FLake_WQ_Threshold
Udef : FLakeMin_SafeFact

/* Udefs for Raleigh Quarry and Neuse River Intake operations*/
Udef : _tot_intake_pump      init{0}
Udef :  Expected_Falls_Spill
Udef :  Expected_Durham_Spill

/*  Udefs for Raleigh system storage pct. - only used when Swift
    Creek WD being used. */
UDef : _Raleigh_Sys_Stor_Pct
Udef : Swift_Sys_WS_Stor_Pct


/* Udefs for operating Johnston County's water supply system*/
Udef : Clayton_gage_expected
Udef : Expected_JC_WTP_flowby
Udef : Middle&Swift_Expected_Discharge
Udef : Exp_RBrdgeRd_Upstream

/*  Udefs for the Falls and Beaverdam pool allocation */
Udef :  _Pct_Max_WQ_Storage
Udef :  _Pct_Max_WS_Storage
Udef :  _FLake_Max_WQ_Storage
Udef :  _FLake_Max_WS_Storage
Udef :  _Bdam_Max_WQ_Storage
Udef :  _Bdam_Max_WS_Storage
Udef :  _Total_Max_WQ_Storage
Udef :  _Total_Max_WS_Storage
Udef :  _Total_Max_WQ_WS_Storage
```

```
Udef :  _FLake_Max_WQ_WS_Storage
Udef :  _WQ_Stor_fraction
Udef :  _WS_Stor_fraction
Udef :  _Bdam_Inf
Udef :  _Bdam_Inf_WS
Udef :  _Bdam_WS_Rel
Udef :  _Bdam_WS_Stor_Init
Udef :  _Bdam_WStoWQ_Spill
Udef :  _Bdam_Inf_WQ
Udef :  _Bdam_WQ_Rel
Udef :  _Bdam_WQ_Stor       init {[Bdam_WQ_Stor]}
Udef :  _Bdam_WQtoWS_Spill
Udef :  _Bdam_WS_Stor       init {[Bdam_WS_Stor]}
Udef :  _FLake_Inf
Udef :  _FLake_Inf_WS
Udef :  _Flake_WS_Rel
Udef :  _FLake_WS_Stor_Init
Udef :  _FLake_WStoWQ_Spill
Udef :  _FLake_Inf_WQ
Udef :  _Flake_WQ_Rel
Udef :  _FLake_WQ_Stor      init {[FLake_WQ_Stor]}
Udef :  _Total_WQ_Stor
Udef :  _FLake_WQtoWS_Spill
Udef :  _FLake_WS_Stor      init {[FLake_WS_Stor]}
Udef :  _Total_WS_Stor
Udef :  _Bdam_WS_Pct
Udef :  _Bdam_WQ_Pct
Udef :  _FLake_WS_Pct
Udef :  _FLake_WQ_Pct
Udef :  _Total_WS_Pct
Udef :  _Total_WQ_Pct


Udef :  _WtAvgRunoff

// Set usable storage & DSR udefs for drought plans
Udef : _OWASA_Max_Usable_Stor
Udef : _OWASA_Usable_Stor
Udef : _OWASA_Usable_Stor_Pct init {100}
Udef : _OWASA_JL_Use_Targ


Udef : _Burl_Max_Usable_Stor
Udef : _Burl_Usable_Stor
Udef : _Burl_Usable_Stor_Pct init {100}

Udef : _Gree_Max_Usable_Stor
```

```
Udef : _Gree_Usable_Stor
Udef : _Gree_Usable_Stor_Pct init {100}
Udef : _Gree_DSR

Udef : _High_Max_Usable_Stor
Udef : _High_Usable_Stor
Udef : _High_Usable_Stor_Pct init {100}

Udef : _Reid_Max_Usable_Stor
Udef : _Reid_Usable_Stor
Udef : _Reid_Usable_Stor_Pct init {100}
Udef : _Reid_DSR

Udef : _Rams_Max_Usable_Stor
Udef : _Rams_Usable_Stor
Udef : _Rams_Usable_Stor_Pct init {100}

Udef : _GramMeb_Max_Usable_Stor
Udef : _GramMeb_Usable_Stor
Udef : _GramMeb_Usable_Stor_Pct init {100}
Udef : _GramMeb_DSR

Udef : _Siler_Max_Usable_Stor
Udef : _Siler_Usable_Stor
Udef : _Siler_Usable_Stor_Pct init {100}

Udef : _Cary_DSR

Udef : _ChatNo_Usable_Stor_Pct init {100}

Udef : _Durham_add_sources init {0}
Udef : _Durham_usable_stor
Udef : _Max_Durham_usable_stor
Udef : _Durham_usable_pct
// Udefs below straight from Neuse mode run name "Scenario_2" from 2012 Durham modeling per Reed
Udef : _Durham_Tot_Use_Stor
Udef : _Durham_Stor
Udef : _Durham_Use_Stor
Udef : _Durham_Pct_Use_Stor
Udef : _Durham_TQ_Pct_Use_Stor

/* Udefs for Forecasts - ported from Durham model */
Udef : Release_storage
//Udef : _Trigger_1_On       init{0}
Udef : _Consvn_1_Demand
Udef : _Proj_1_Demand
Udef : _Proj_1_Evap
```

```
Udef : _Proj_1_Inflow
Udef : _Proj_1_WSPool init{19588} // all these values would need to be updated for 2035 sedimentation to be correct for the first week of a run
Udef : _Stage_1_Counter    init{0}
Udef : _Proj_1_WSPool_Refill init{19588}
//Udef : _Trigger_2_On       init{0}
Udef : _Consvn_2_Demand
Udef : _Proj_2_Demand
Udef : _Proj_2_Evap
Udef : _Proj_2_Inflow
Udef : _Proj_2_WSPool init{19588}
Udef : _Stage_2_Counter    init{0}
Udef : _Proj_2_WSPool_Refill init{19588}
//Udef : _Trigger_3_On       init{0}
Udef : _Consvn_3_Demand
Udef : _Proj_3_Demand
Udef : _Proj_3_Evap
Udef : _Proj_3_Inflow
Udef : _Proj_3_WSPool init{19588}
Udef : _Stage_3_Counter    init{0}
Udef : _Proj_3_WSPool_Refill init{19588}
//Udef : _Trigger_4_On       init{0}
Udef : _Consvn_4_Demand
Udef : _Proj_4_Demand
Udef : _Proj_4_Evap
Udef : _Proj_4_Inflow
Udef : _Proj_4_WSPool init{19588}
Udef : _Stage_4_Counter    init{0}
Udef : _Proj_4_WSPool_Refill init{19588}
Udef : _Proj_WSPool_Refill init{19588}
Udef : _Proj_5_Inflow
// Udefs for drought plan triggers
:FOR: { [Util] = { Burl, Burl1, Burl2, Gree, Gree1, Gree2, High, Reid, Rams, GramMeb, Siler, Cary,
    RTP, Morris, ChatNo, Dunn, Benson, Carth, Ral, Durham, SGWASA, Wilson } }
:FOR: { [level_num] = { 1, 2, 3, 4, 5, 6 } }
   Udef :  _[Util]_Consvn_[level_num]_Demand
   Udef :  _[Util]_Trigger_[level_num]_On          init {0}
```

```
 Udef :  _[Util]_Stage_[level_num]_counter     init {0}
 Udef :  _[Util]_Ph_[level_num]_event_counter    init {0}

:NEXT:

:NEXT:

// Setting Durham's drought trigger level
Udef :  _Trig_Level_Durham


Udef : _CaryApex_WW_Consvn init{1}

:FOR: { [level_num] = { 1, 2, 3 } }

 :For: { [hrz] = {08, 12, 16, 20, 24, 52} }

    Udef :  _OWASA_ProjInflow[level_num]_[hrz]
    Udef :  _OWASA_ProjDemand[level_num]_[hrz]
    Udef :  _OWASA_ProjMinFlow[level_num]_[hrz]
    Udef :  _OWASA_ProjEvap[level_num]_[hrz]
    Udef :  _OWASA_ProjStorage[level_num]_[hrz]
    Udef :  _OWASA_ProjStorage_Pct[level_num]_[hrz]

 :Next:

    Udef :  _OWASA_Consvn_[level_num]_Demand

    Udef :  _OWASA_Trigger_[level_num]_On          init {0}
 Udef :  _OWASA_Stage_[level_num]_counter     init {0}
 Udef :  _OWASA_Ph_[level_num]_event_counter    init {0}

:NEXT:

// Udefs for the Cary/Apex WW system
Udef : _CaryApexWW
Udef : _RTPWW
Udef : _MorrisWW
Udef : _CarySystemWW

// Allocate the total to the various discharge points, assigning monthly patterns and conservation factors (if any)
Udef : _CaryNorthWW
Udef : _CarySouthWW
Udef : _ApexWW
Udef : _CaryDTCWWTP
Udef : _CaryWestWakeWWTP
```

```
// For Fuquay IBT

Udef :  _Prelim_Max_JC_Neuse
Udef :  _Prelim_Max_Alt_Neuse
Udef :  _Prelim_Max_Sanford_Neuse
Udef :  _Prelim_Max_HC_Neuse
Udef :  _Prelim_Max_Alt_CF_to_Neuse
Udef :  _IBT_CF_to_Neuse
Udef :  _Final_Max_Flow_Alt
Udef :  _IBT_Neuse_to_CF


//For calculating actual shortages based on conservation plans
Udef : _Durham_Shortage_Calc    init{0}
Udef : _Ral_Shortage_Calc       init{0}
Udef : _SGWASA_Shortage_Calc    init{0}
Udef : _Wilson_Shortage_Calc    init{0}

Udef : _OWASA_Shortage_Calc     init{0}
Udef : _Burl_Shortage_Calc      init{0}
Udef : _Gree_Shortage_Calc      init{0}
Udef : _High_Shortage_Calc      init{0}
Udef : _Reid_Shortage_Calc      init{0}
Udef : _Rams_Shortage_Calc      init{0}
Udef : _GramMeb_Shortage_Calc   init{0}
Udef : _Siler_Shortage_Calc     init{0}
Udef : _Cary_Shortage_Calc      init{0}
Udef : _ChatNo_Shortage_Calc    init{0}
Udef : _Dunn_Shortage_Calc      init{0}
Udef : _Benson_Shortage_Calc    init{0}
Udef : _Carth_Shortage_Calc     init{0}
Udef : _RTP_Shortage_Calc       init{0}
Udef : _Morris_Shortage_Calc    init{0}




// ---------------------------------

// For use in output tables
:substitute: [accounts] = "CaryAp, Chatham, RTP, Other, Durham, Morris, Orange, OWASA, Holly, Pitt, Hillsb" // for WQ_WS accounting
                            // for Jordan Lake
:substitute: [level_num] = "1, 2, 3, 4"  // for drought trigger and level determination for Jordan Lake drought protocol

```

```
// Natural inflows in both basins
:substitute: [InflowNd_CFear] =   "0020, 0040, 0044, 0070, 0090, 0110, 0112, 0120, 0140, 0145, 0170, 0210, 0220, 0260, 0270, 0280, 0300,
          0310, 0324, 0325, 0328, 0340, 0380, 0395, 0400, 0430, 0450, 0470, 0495, 0520, 0527, 0550, 0570, 0580,
          0590, 0600, 0610, 0640, 0660, 0680, 0700, 0720, 0730, 0760, 0770, 0777, 0780, 0790, 0820"

:substitute: [InflowNd_Neuse] =   "1010, 1050, 1060, 1080, 1100, 1110, 1115, 1140, 1200, 1205, 1230, 1250, 1270, 1290, 1300, 1320, 1400,
          1402, 1404, 1405, 1406, 1408, 1409, 1410, 1412, 1414, 1416, 1418, 1420, 1422, 1440, 1445, 1450, 1471,
          1480, 1500, 1520, 1560, 1570, 1600, 1620, 1630, 1650, 1660, 1700, 1740, 1747, 1750, 1755, 1760, 1775,
          1780, 1795, 1800, 1850, 1900, 1999"


// Reservoir nodes
:substitute: [ResNd_CFear] = "0030,  0070,  0112,  0120,  0140,  0220,  0270,  0300,  0320,  0324,  0325,  0340,  0390,  0395,
         0430,  0470,  0520,  0528,  0760,  0777,  0790"
:substitute: [ResNd_Neuse] = "1010,  1050,  1060,  1080,  1100,  1120,  1140,  1200,  1230,  1250,  1270,  1290,  1300,  1420,
         1440,  1445,  1450,  1500,  1647,  1648,  1740"

:substitute: [CrabtreeNd] = "1400, 1402, 1404, 1406, 1408, 1410, 1412, 1414, 1416, 1418, 1422"  // For Crabtree impoundments

// for reservoirs that are being modeled with rule curves.  for some of the Neuse reservoirs, we are not modeling with a
// "rule curve" - see reservoir rules table on GUI
:substitute: [ResNd_RCurves_CFear] = "0030,  0070,   0120,  0140,  0220,  0270,  0300,  0320,  0324,  0325,  0340,  0390,
           0395,  0430,  0470,  0520,  0760"
:substitute: [ResNd_RCurves_Neuse] = "1050, 1060, 1140, 1200, 1230, 1250, 1290, 1300, 1420, 1440, 1500"


// For municipal and industrial demands
:substitute: [DemandNd_CFear] = "0031,  0123,  0223,  0261,  0301,  0321,  0327,  0341,  0401,  0431,  0471,  0473,  0474,  0475,
          0477,  0483,  0487,  0491,  0521,  0551,  0601,  0605,  0663,  0701,  0719,  0721,  0733,  0771,
          0781,  0785,  0823,  0825,  0903,  0904,  0906,  0921,  0923"

:substitute: [DemandNd_Neuse] = "1046,  1106,  1116,  1162,  1256,  1258,  1306,  1506,  1646,  1666,  1706,  1766,  1786,  1806,
         1906"

//  For WW returns linked to demands
:substitute: [LinkedWWRetArc_CFear] = "0031.0040,  0341.0072,  0072.0100,  0072.0350,  0341.0350,  0121.0140,  0122.0170,  0122.0180,
            0223.0222, 0261.0280,  0904.0224,  0301.0570,  0321.0100,  0401.0410,  0431.0440,  0473.0470,
            1162.0453,  1162.0463,  0483.0480,  0487.0490,  0491.0490,  0491.0610,  0521.0520,  0554.0686,
            0554.0664,  0554.0550,  0554.0556,  0601.0610,  0327.0328,  0663.0680,  0663.0690,  0733.0740,
            0733.0770,  0771.0770,  0781.0790,  0785.0790,  0923.0520, 0471.0472,  0474.0472,  0477.0472,
            0472.0453,  0472.0930,  0479.0470"

:substitute: [LinkedWWRetArc_Neuse] = "1046.1100,  1106.1109,  1162.1163,  1259.1300,  1306.1620,  1306.1500,  1306.1320,  1646.1630,
            1646.1675,  1666.1675,  0663.1756,  1756.1757,  1766.1770,  1675.1747,  1786.1780,  1806.1795,
            1806.1850,  1806.1845, 1506.1560,  1906.1999,  1706.1409,  1706.0554, 0472.1401,  0472.1471,
            0472.1405"
```

```

// For independent WW returns
:substitute: [IndepWWRetNd_CFear] = "0148, 0192, 0227, 0282, 0464, 0591, 0592, 0772, 0774, 0910, 0960, 0962"

:substitute: [IndepWWRetNd_Neuse] = "1307, 1407, 1563, 1565, 1567, 1569, 1643, 1645, 1705, 1753, 1759, 1787, 1847"


// For agricultural demand
:substitute: [AgricNd_CFear] = "0021, 0041, 0043, 0051, 0075, 0077, 0081, 0083, 0111, 0161, 0211, 0231, 0263, 0281, 0311,
        0331, 0361, 0371, 0381, 0403, 0411, 0441, 0461, 0481, 0511, 0531, 0541, 0553, 0581, 0593,
        0595, 0603, 0621, 0623, 0671, 0674, 0681, 0691, 0713, 0741, 0773, 0775, 0783, 0801, 0811,
        0821, 0940"

:substitute: [AgricNd_Neuse] = "1052, 1062, 1112, 1142, 1202, 1302, 1318, 1482, 1502, 1562, 1632, 1752, 1756, 1782, 1802,
        1902"

//all added for task b1+b2 for Durham
UDef : _Durham_estim_spill
```

Upper_Eno_Ops.ocl

```
/*  UPPER_ENO_OPS.OCL  */
/* Operation policy the Upper Eno, based on the Capacity Use Plan */

/*  Compute channel loss factor, which is used in the Lake Orange and WFER min release computations,
    and to calculate channel loss at the Hillsborough Gage.  Based on the values in the WFER dam safety permit.  */
Set  :  _Eno_Channel_Loss
{   condition : flow1110.1115 < convert_units{4,cfs,af}
    Value     : 0.2

    condition : flow1110.1115 <= convert_units{12,cfs,af}
    Value     : 0.1

    condition : default
    Value     : 0
}

/*  Determine the maximum release from Lake Orange for Hillsborough demand; based on stage. */
Set :  _Max_Hills_WD
{      /* For Dead Storage */
       Condition : storage1060 / max_stor1060 <= 0.1365
       Value     : 0

       /* Stages 6 */
       condition : storage1060 / max_stor1060 <= 0.3
       Value     : convert_units { 0.68, mgd, af }

       /* Stages 5 */
       condition : storage1060 / max_stor1060 <= 0.4
       Value     : convert_units { 1.13, mgd, af }

       /* Stages 3 & 4 */
       condition : storage1060 / max_stor1060  <= 0.6
       Value     : convert_units { 1.28, mgd, af }

       /* Stage 2 */
       condition : storage1060 / max_stor1060 <= 0.8
       Value     : convert_units { 1.36, mgd, af }
       /* Stage 1 */
       condition : default
       Value     : convert_units { 1.51, mgd, af }
}

/*  Determine the maximum release from Lake Orange for Orange-Alamance demand; based on stage. */
Set :  _Max_OrAl_WD
{      /* For Dead Storage */
       Condition : storage1060 / max_stor1060 <= 0.1365
       Value     : 0
```

```

    /* Stages 6 */
    condition : storage1060 / max_stor1060 <= 0.3
    Value     : convert_units { 0.37, mgd, af }

    /* Stages 5 */
    condition : storage1060 / max_stor1060 <= 0.4
    Value     : convert_units { 0.62, mgd, af }

    /* Stages 3 & 4 */
    condition : storage1060 / max_stor1060  <= 0.6
    Value     : convert_units { 0.70, mgd, af }

    /* Stage 2 */
    condition : storage1060 / max_stor1060 <= 0.8
    Value     : convert_units { 0.74, mgd, af }
    /* Stage 1 */
    condition : default
    Value     : convert_units { 0.82, mgd, af }
}

/*  Determine the maximum release from Lake Orange for Piedmont Minerals demand; based on stage. */
Set :  _Max_Pied_WD
{     /* Stages 6 */
    condition : storage1060 / max_stor1060 <= 0.3
    Value     : convert_units { 0.00, mgd, af }

    /* Stages 5 */
    condition : storage1060 / max_stor1060 <= 0.4
    Value     : convert_units { 0.19, mgd, af }

    /* Stages 4 */
    condition : storage1060 / max_stor1060  <= 0.5
    Value     : convert_units { 0.32, mgd, af }

    /* Stages 3 */
    condition : storage1060 / max_stor1060  <= 0.6
    Value     : convert_units { 0.36, mgd, af }

    /* Stage 2 */
    condition : storage1060 / max_stor1060 <= 0.8
    Value     : convert_units { 0.38, mgd, af }
    /* Stage 1 */
    condition : default
    Value     : convert_units { 0.43, mgd, af }
}

```

```
/*  Determine the Lake Orange required streamflow augmentation; based on stage. */
Set :  _Orange_streamflow
{      /* Stages 6 */
      condition : storage1060 / max_stor1060 <= 0.3
      Value     : 0

      /* Stages 5 */
      condition : storage1060 / max_stor1060 <= 0.4
      Value     : 0

      /* Stages 3 & 4 */
      condition : storage1060 / max_stor1060  <= 0.6
      Value     : convert_units { 0.45, mgd, af }

      /* Stage 2 */
      condition : storage1060 / max_stor1060 <= 0.8
      Value     : convert_units { 0.65, mgd, af }
      /* Stage 1 */
      condition : default
      Value     : convert_units { 1.10, mgd, af }
}

/*  Lake Orange minimum release, based on Eno Capacity Use plan.  Includes a streamflow augmentation release plus
   a release for downstream demands.  The release for Hillsborough, Or-Al and Pied. Minerals' demand is only up to
   the maximum specified in the plan. A multiplier for channel loss, the same as for WFER, is also included.  */
Set :  min_flow1060.1080
{      /* All stage-dependant streamflow augmentation and max. WDs have been determined above  */
      condition : default
      Value     : (1 + _Eno_Channel_Loss) * (_Orange_streamflow + min { demand1046, _Max_OrAl_WD }
     + min { demand1106, _Max_Hills_WD } + min { demand1116, _Max_Pied_WD })
}

/*  Determine which Phase WFER is in.  Set to Tier 3 if elevation < 624.  Set to Tier 2 if elevation is between 624 and 628 ft.
 Otherwise set to Tier 1 */

Set : _WFER_Tier
{    Condition : elevation1050 < 624
     Value     : 3

  Condition : elevation1050 < 628
     Value     : 2

     Condition : default
     Value     : 1
}

/*  WFER Minimm release - depends on storage tier, and remaining Hillsborough demand that cannot be met by Lake Orange.
```

```
   From Eno Capacity Use pland and WFER dam safety permit; either enough to meet downstream requirements, or the specified
   seasonal pattern, whichever is greater  */
Set :  min_flow1050.1080
{    /* If in Tier1 */
     condition : _WFER_Tier = 1
     Value     : max { (1 + _Eno_Channel_Loss) * (convert_units{1.0,cfs,af}
       + max { 0, demand1106 - _Max_Hills_WD }) ,
      convert_units{pattern(Tier1),cfs,af} }

     /* If in Tier2 */
     condition : _WFER_Tier = 2
     Value     : max { (1 + _Eno_Channel_Loss) * (convert_units{1.0,cfs,af}
       + max { 0, demand1106 - _Max_Hills_WD }) ,
      convert_units{pattern(Tier2),cfs,af} }

     /* If in Tier3 */
     condition : _WFER_Tier = 3
     Value     : max { (1 + _Eno_Channel_Loss) * (convert_units{1.0,cfs,af}
       + max { 0, demand1106 - _Max_Hills_WD }) ,
      convert_units{pattern(Tier3),cfs,af} }
}

/*  Compute channel loss at Hills. Gage (computed) */
Target Channel_Loss  :  dflow1110.1107
{   condition : default
    priority  : 1
    penalty+  : 1000
    penalty-  : 1000
    Value     : max { 0, _Eno_Channel_Loss * (flow1105.1110 + inflow1110) }
}
```

WW_Returns.ocl

```
/*  File is WW_Returns.ocl. */

// Note that WW only returns are handled as inflows (see inflow pattern under the Node tab for the monthly patterns).


/* Set inflow fractions for WW returns associated with demands  */

// Cape Fear River Basin discharges

Constraint ReidsvilleWW_nc0024881_WTP_WW_nc0046345 : {dFlow0031.0040 = lookup {ReidsvilleWWTP_NC0024881, month}
        * dDelivery0031 + lookup {ReidsvilleWTP_WW_nc0046345, month} * dDelivery0031}
Constraint BurlingtonTotalWW              : {dFlow0341.0072 = lookup {BurlingtonTotalWWRF, month} * dDelivery0341}
Constraint BurlingtonEastWW_nc0023868           : {dFlow0072.0100 = lookup {BurlingtonTotalWWRF, month} * (dDelivery0341
        + dDelivery0075) * 0.41} // Eastside is 41% of total
Constraint BurlingtonSouthsideWW_NC0023876      : {dFlow0072.0350 = lookup {BurlingtonTotalWWRF, month} * dDelivery0341
        * 0.59} // Southside is 59% of total
Constraint HawRiverWW_to_Burlington     : {dflow0075.0072 = lookup {BurlingtonTotalWWRF, month} * dDelivery0075}
Constraint BurlingtonMackintoshWW_NC0023828    : {dFlow0341.0350 = lookup {BurlingtonMackintoshWW_NC0023828, month}
        * dDelivery0341}
Constraint GreensboroLakeTownsendWW_NCG590017   : {dFlow0123.0140 = lookup {GBTownsendWTPNCG590017, month} * dDelivery0123}
Constraint GreensboroMitchellWTPNC0081426         : {dFlow0122.0170 = lookup {GBMitchellWTPNC0081426, month} * dDelivery0123}
Constraint GBOzborneWWNC0047384               : {dFlow0122.0180 = lookup {GBOzborneWWNC0047384, month} * dDelivery0123}
Constraint GBHighPointWW        : {dFlow0122.0224 = lookup {GBHighPointWW, month} * dDelivery0123}
Constraint HighPointWW_nc0081256_nc0024210        : {dFlow0223.0222 = lookup {HighPointWW, month} * dDelivery0223}
Constraint RandlemanWW_nc0025445                : {dFlow0261.0280 = lookup {RandlemanWW_nc0025445, month} * dDelivery0261}
Constraint ArchdaleWW                   : {dFlow0904.0224 = lookup {ArchdaleWW, month} * dDelivery0904}
Constraint RamseurWW_nc0026565                  : {dFlow0301.0570 = lookup {RamseurWW_nc0026565, month} * dDelivery0301}

/* For Graham Mebane, we had all WW returns lumped together.  Graham's asre permits 0045292 to Haw River (WW, with avg.day
 = 1.8 mgd in 2020) and 0021211 to Back Creek (WTP process, with avg day = 0.3 mgd); and Mebane's is 0021474 to Moadam's
 Creek (avg day = 1.5 mgd).  Separate the WTP process return since that can be counted toward the min release.
 Monthly pattern can be left as is.  */
Constraint GrahamMebaneTotWW_nc0045292_nc0021474 : {dFlow0321.0100 = lookup {GrMebTotWW_nc0045292, month} * dDelivery0321}
// Assume 5% based on historical data (0.28 mgd vs. raw water WD from G-M lake of 4.5 mgd).  Transfer included from Orange County,
// but this may be finished water, not raw water, which means it would be plumbed to the demand node itself.  However, an
// emergency interconnection that hasn't been used in recent years.
Constraint GrahamMebane_WTP_Process_Return : {dFlow0319.0100 = 0.05 *  (dflow0320.0319 + dflow0920.0319) }

Constraint PittsboroWW_nc0020354           : {dFlow0401.0410 = lookup {PittsboroWW_nc0020354, month} * dDelivery0401}
Constraint OWASA_WW_nc0025241               : {dFlow0431.0440 = lookup {OWASA_WW_nc0025241, month} * dDelivery0431}
Constraint NorthChathamWWWTP_nc0084093      : {dFlow0473.0470 = lookup {NorthChathamWTP_nc0084093, month} * dDelivery0473}
Constraint DurhamCtyTriangleWW_nc0026051    : {dFlow1162.0453 = lookup {DurhamCtyTriangleWW_nc0026051, month} * dDelivery1162}
Constraint DurhamReclamationWW_nc0047967    : {dFlow1162.0463 = lookup {DurhamReclamationW_nc0047597, month} * dDelivery1162}
Constraint AlliedSignalWW_NC0001899        : {dFlow0483.0480 = lookup {AlliedSignalWW_NC0001899, month} * dDelivery0483}

// Multiple demands met from Sanford; must use the flow to the junction node since that represents the total withdrawal on which the process
// loss is calculated.  Otherwise, we'd be undercounting process loss since it would be calculated on deliveries to the demand node3,
```

```
// which represent finished water.
Constraint SanfordPW_WTP_nc0002861    : {dFlow0489.0490 = lookup {Sanford_WTP_dis_nc0002861, month} * dflow0490.0489 }
Constraint Sanford_WWTP_nc0024147     : {dFlow0491.0610 = lookup {Sanford_WWTP_nc0024147, month} * dDelivery0491}
Constraint GoldstonGulf_nc0024147  : {dFlow0605.0610 = lookup {GoldstonGolfWW_nc0024147, month} * dDelivery0605}
Constraint BroadwayWW_nc0059242       : {dFlow0940.0540 = lookup { BroadwayWW_nc0059242, month} * dDelivery0940}
Constraint CarolinaTraceWW_nc0038831  : {dFlow0674.0660 = lookup { CarolinaTraceWW_nc0038831, month} * dDelivery0674}
Constraint ProgressHarrisWW_nc0039586 : {dFlow0521.0520 = 0 * dDelivery0521}  // Accounted for in the consumptive use
                    // represented by the demand value
Constraint AngierWW_HarnettCo         : {dFlow0654.0664 = lookup { AngierWW_to_HarnettCo, month} * dDelivery0654}
:Substitute: [HarnettWTP_process] = 0.066  //placeholder based on 2019&2020 LWSP data process/total demand [internal + sales]
Constraint North_Harnett_WWTP         : {dFlow0551.0664 = lookup {HarnettWW_North, month} * dDelivery0551 }
// Same logic for Sanford above applies to the Harnett County WTP process water; tie it to total withdrawal.
Constraint HarnettWTP_process             : {dFlow0549.0550 = dflow0550.0549  * [HarnettWTP_process] }
Constraint SouthHarnettRegionalWWTP         : {dFlow0551.0556 = lookup {HarnettWW_South, month} * dDelivery0551 }
Constraint PilgrimsPride_nc0083852              : {dFlow0601.0610 = lookup {PilgrimsPride_nc0083852, month} * dDelivery0601}
Constraint SilerCityWW_nc0026441                : {dFlow0327.0328 = lookup {SilerCityWW_nc0026441, month} * dDelivery0327}
Constraint DunnWTP_nc0078955                    : {dFlow0663.0680 = lookup {DunnWW_nc0078955, month} * dDelivery0663}
Constraint DunnWWTP_nc0043176                   : {dFlow0663.0690 = lookup {DunnWWTP_nc0043176, month} * dDelivery0663}
Constraint FtBraggWW_NC0003964                  : {dFlow0721.0722 = lookup {FtBraggWW_NC0003964, month} * dDelivery0721}
Constraint FayettevilleCrossWWTP_nc0023957    : {dFlow0733.0740 = lookup {FayCrossWW_NC0023957, month} * dDelivery0733}
Constraint FayettevilleRockfishCreekWWTP_nc0050105 : {dFlow0733.0770 = lookup {FayRockfishCkWW_NC0050105, month}
                * dDelivery0733}
Constraint HokeRockfishCreekWTP_nc0089176    : {dFlow0735.0770 = lookup {HokeRockfishCkWW_NC0089176, month} *dDelivery0735}
Constraint MonsantoWW                        : {dFlow0771.0770 = lookup {MonsantoWW_NC0003719, month} * dDelivery0771}
Constraint DupontWW                          : {dFlow0781.0790 = lookup {DupontWW_nc0003573, month} * dDelivery0781}
Constraint LCFWSA-BladenBluffsWW_nc0078344          : {dFlow0785.0790 = 0 * dDelivery0785} // No return in 2010 scenario
Constraint HollySpringsWW_nc0063098                 : {dFlow0923.0520 = lookup {HollySpringsWW_nc0063098, month}
                * dDelivery0923}  // Capped at 1.0 to ignore I and I.
// Neuse River Basin discharges
Constraint OrAlaReturn_nc0082759        : {dFlow1046.1100 = lookup {OrAlaReturn_nc0082759, month} * dDelivery1046}
Constraint Hillsborough_nc0026433        : {dFlow1106.1109 = lookup {HillsReturn_nc0026433, month} * dDelivery1106}
Constraint Durham_nc0023841              : {dFlow1162.1163 = lookup {DurhamReturn_nc0023841, month} * dDelivery1162}
Constraint SGWASA_nc0026824     : {dFlow1256.1300 = lookup {SGWASAReturn_nc0026824, month}
             * dDelivery1256} // Creedmoor now part of SGWASA
Constraint Raleigh_NeuseWWTP_nc0029033    : {dFlow1306.1625 = lookup {RaleighReturn_nc0029033, month} * dDelivery1306}
Constraint Raleigh_LittleCreek_nc0079316 : {dFlow1306.1500 = lookup {RalLitCrReturn_nc0079316, month} * dDelivery1306 }
Constraint Raleigh_SmithCreek_nc0030759   : {dFlow1306.1320 = lookup {RalSmithCrReturn_nc0030759, month} * 0.05 * dDelivery1306}
Constraint ClaytonWW_nc0064564&nc0025453 : {dFlow1646.1630 = lookup {ClaytReturn_nc0064564&nc0025453, month}
```

```
            * dDelivery1646} // Clayton demand is included in Johnst Co.
Constraint JohnstReturn_nc0030716   : {dFlow1646.1675 = lookup {JohnstReturn_nc0030716, month} * (dDelivery1646)}
Constraint JohnstReturn_Benson    : {dFlow1646.1757 = 0.015 * (dDelivery1646)}
Constraint JohnstonCoWTP_Retur    : {dFlow1655.1650 = 0.1 * (dflow1650.1654)} // This is the 10% process water return to the river
Constraint SfieldReturn      : {dFlow1666.1675 = lookup {SfieldReturn, month} * (dDelivery1666)}
Constraint BensonWW_nc0020389            : {dFlow1756.1757 = lookup {BensonWW_nc0020389, month} * dDelivery1756}
Constraint ProgressEnergy                 : {dFlow1766.1770 = 0.0 * dDelivery1766}
Constraint KenlyWW_nc0064891             : {dFlow1675.1747 = lookup {KenlyReturn_nc0064891, month} * dDelivery1646}
Constraint GoldsboroWW_nc0023949   : {dFlow1786.1780 = lookup {GoldsReturn_nc0023949, month} * dDelivery1786}
Constraint NRWASA_nc0088111              : {dFlow1806.1795 = lookup {NRWASAReturnWTP_nc0088111, month} * dDelivery1806}
Constraint KinstonWW_nc0024236           : {dFlow1806.1850 = lookup {KinstonWW_nc0024236, month} * dDelivery1806}
Constraint AydenGriftonWW                : {dFlow1806.1845 = lookup {AydenGriftonWW, month} * dDelivery1806}
Constraint WilsonWW_nc0023906            : {dFlow1506.1560 = lookup {WilsonReturn_nc0023906, month} * dDelivery1506}
Constraint Weyerhauser_nc0003191         : {dFlow1906.1999 = lookup {WeyerReturn_nc0003191, month} * dDelivery1906}

/* Note:  in the past, F-V WW return was a function of the total demand x the lookup fractions.  For the updates, it is a function
 of how much demand is in the Neuse and Cape Fear. WW from the Neuse service area is returned to the Terrible Creek plant
 (in the Neuse); the WW from the Cape Fear service area is returned to North Harnett County plant (in the Cape Fear). Adjust
 the monthly WW return fractions in the lookup table for FuquayWW_nc00516&nc0066150 above.  The return fraction is capped at
 100% of the respective demand (i.e., I and I is ignored).*/

Constraint   Terrible_Creek_WW_Return : {dflow1706.1409 = lookup {FuquayReturn_nc0066516&nc0066150, month}
            * dDelivery1706  * [Demand_FV_Neuse] }
Constraint   Harnett_County_WW_Return : {dflow1706.0664 = lookup {FuquayReturn_nc0066516&nc0066150, month}
            * dDelivery1706 * (1 - [Demand_FV_Neuse])  }


// Compute Cary/Apex system separately
// First compute the amount of reductions to WW discharges expected if the drought plan is active (stages 3-4 only)

:If: {[Drought_Plans_On] = 1} // First check if drought plan variable is on

Set : _CaryApex_WW_Consvn
{ Condition : _Cary_Trigger_4_On
  {
  Condition : month > 4 and month < 11
  Value     : 1 - 14 / 100 // 14% reduction for Stg. 4, May-Oct

  Condition : default
  Value     : 1 - 19 / 100 // 19% reduction for Stg. 4, Nov-Apr
  }

 Condition : _Cary_Trigger_3_On
  {
  Condition : month > 4 and month < 11
  Value     : 1 - 6 / 100 // 6% reduction for Stg. 3, May-Oct

```

```
  Condition : default
  Value     : 1 - 7 / 100 // 7% reduction for Stg. 4, Nov-Apr
  }

    Condition : default
    Value     : 1
}

:else:

Set : _CaryApex_WW_Consvn
{ Condition : default
    Value     : 1
}

:EndIf:


// Now compute various WW flows and discharges as Udefs, since they'll be used in multiple constraints

//Total WW for Cary/Apex, RTP and Morrisville
Set : _CaryApexWW { Value : lookup {CaryApexReturn, month} * demand0471 * _CaryApex_WW_Consvn }
Set : _RTPWW  { Value : lookup {RTPReturn, month} * demand0474 * _CaryApex_WW_Consvn }
Set : _MorrisWW  { Value : lookup {MorrisReturn, month} * demand0477 * _CaryApex_WW_Consvn }
Set : _CarySystemWW { value : _CaryApexWW + _RTPWW + _MorrisWW }

// Allocate the total to the various discharge points, assigning monthly patterns and conservation factors (if any)
Set : _CaryNorthWW  { Value : _CarySystemWW * 0.29 * lookup{CaryNWRFReturn, month}}
Set : _CarySouthWW  { Value : _CarySystemWW * 0.24 * lookup{CarySWRFReturn, month}}
Set : _ApexWW   { Value : _CarySystemWW * 0.07 * lookup{ApexWRFReturn, month}}
Set : _CaryDTCWWTP  { Value : _CarySystemWW * 0.00 }

/* For Western Wake WRF, put in an adjustment factor of 1.4 since our computed returns to Western Wake WRF relative to 2022
 data are about 40% too low.  Also computed system WW relative to finished water demand was only about 80%; this adjustment
 factor raises that to almost 90%, which is more consistent with 2022 data. This adjustment is important since IBT
 compliance (described below) is dependent on it.  */
Set : _CaryWestWakeWWTP { Value : _CarySystemWW * 0.40 * lookup{WestWakeWRFReturn, month} * 1.4 }

// Next set the constraints that will force the flows to match the udefs
Constraint CaryApexTotalWW  : {dflow0471.0472 = (_CaryApexWW / _CarySystemWW)
          * (_CaryNorthWW + _CarySouthWW + _ApexWW + _CaryDTCWWTP + _CaryWestWakeWWTP) }
Constraint RTPWW      : {dFlow0474.0472 = (_RTPWW / _CarySystemWW)
          * (_CaryNorthWW + _CarySouthWW + _ApexWW + _CaryDTCWWTP + _CaryWestWakeWWTP) }
Constraint MorrisvilleWW  : {dFlow0477.0472 = (_MorrisWW / _CarySystemWW)
          * (_CaryNorthWW + _CarySouthWW + _ApexWW + _CaryDTCWWTP + _CaryWestWakeWWTP) }
```

```
Constraint CaryNorthWW  : {dFlow0472.1401 = _CaryNorthWW}
Constraint CarySouthWW  : {dFlow0472.1471 = _CarySouthWW}
Constraint ApexWW   : {dFlow0472.1405 = _ApexWW}
Constraint CaryDTCWWTP  : {dFlow0472.0453 = _CaryDTCWWTP}
Constraint CaryWestWakeWWTP : {dFlow0472.0930 = _CaryWestWakeWWTP}

// Finally,compute the WTF discharge back into Jordan based on the raw water withdrawal from the lake.
// Do not use delivery since that represents finished water based on the plumbing.
Constraint CaryApexWTFWW : {dflow0479.0470 = lookup {CaryApexWTFReturn, month} * (dflow0470.0479)}

/* The 2015 IBT certificate for Cary-Apex allows for a 33 mgd WD from the Haw River basin to the Neuse (31 mgd) and Cape Fear
 basins (2 mgd).  A consent order was later issued requiring that WW be returned to the Cape Fear basin = Neuse demand
 (finished water including non-revenue water) - 9.756 mgd.  In 2022, Cary finished water use was 20.82 (raw) -
 3.08 (process loss) = 17.7 mgd, with 96% going to the Neuse, or 17.0 mgd.  Apex used 5.6 - 0.84 = 4.8 mgd, with 29%
 going to the Neuse, or 1.4 mgd.  So total Neuse finished water use was 18.4 mgd.  So required discharge back to the
 Cape Fear would be 18.4 - 9.8 = 8.6.  Process water (from the Cary-Apex WTP on the east side of Jordan Lake) can be
 included in the discharge since it goes into Jordan Lake and amounted to 3.1 + 0.8 mgd (listed above), or 3.9 mgd.
 So required remaining discharge (through the Western Wake WRF) would be 8.6 - 3.9, or 4.7 mgd.  In 2022, the facility
 discharged 6.5 mgd from Cary and 3.7 mgd from Apex, for a total of 10.2 mgd.  All compliance is based on 3-year running
 annual average daily amounts.

 The model is not imposing any restrictions; to view whether the return requirements are met, the user can track the
 returns with user-defined output tables.  Also note that CaryApex demand (demand473) lumps CaryApex, RTP, and Morrisville
 demands (demands for RTP [node 474] and Morrisville [node 477] are set to 0).  Also, when calculating the return amount,
 since Apex demand is a reasonable amount of the CaryApex  demand (based on 2022 data above), assume the Neuse demand
 (finished) = 85% of the CaryApex demand (finished).  This should be a conservative estimate of the required return amount.
 Assume the same in the Neuse for future year planning runs.  Note if the percentage were 95% or higher, then there might be
 a deficit in terms of meeting the required IBT return.

 Need to add constraints on the WW returns for High Point, IBT and Spring Lake.  Weren't in there before.  For now, set to 0
 for the first -- meaning WW return from upstream nodes will now go back to the Deep River in full.  For Spring Lake,
 assumed 100% of the delivery.  Delivery is insignificant.   */

Constraint HighPt     : {dflow0222.0225 = 0 }
Constraint SpringLake   : {dflow0719.0720 = 1.0 * ddelivery0719 }


// There is another WW transfer out of basin in the model, but in this case water is not diverted here since there is no
// benefit to doing so.  WW returns instead to the Cape Fear.  However, a constraint is always safe to impose, in this
// case assume 0 flow in the IBT.

Constraint HokeCounty       : {dflow0735.0737 = 0 }
```