



Approval of the Tar, Roanoke, and Cape Fear-Neuse Hydrologic River Basin Models

NC Environmental Management Commission

Water Allocation Committee

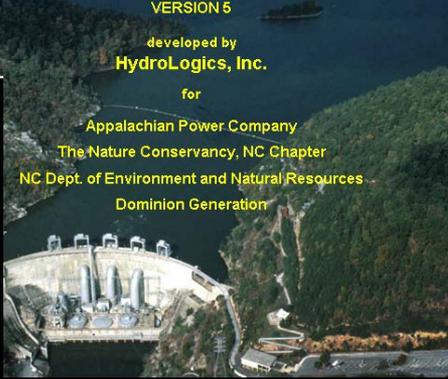
July 9, 2014

ROANOKE RIVER BASIN RESERVOIR OPERATIONS MODEL
VERSION 5

developed by
HydroLogics, Inc.

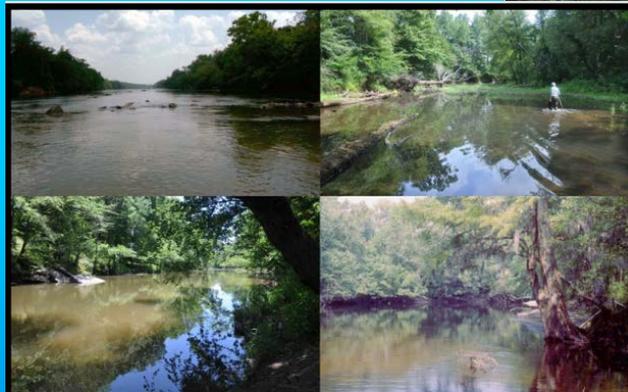
for

Appalachian Power Company
The Nature Conservancy, NC Chapter
NC Dept. of Environment and Natural Resources
Dominion Generation



NUE

An application of OASIS v
covered by US Patent Nos. 6,002,863 and 6,581,027

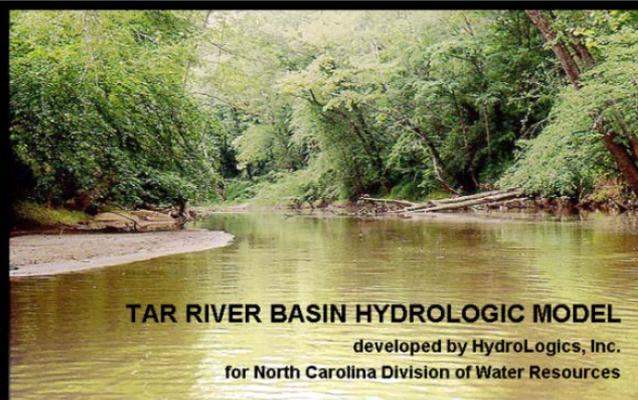


CAPE FEAR / NEUSE RIVER BASIN HYDROLOGIC MODEL

Developed by HydroLogics, Inc.
for North Carolina Division of Water Resources

An application of OASIS with OCL covered by U.S.
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TAR RIVER BASIN HYDROLOGIC MODEL

developed by HydroLogics, Inc.
for North Carolina Division of Water Resources

An application of OASIS with OCL
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EMC's Role

➤ **Model Approval**

- Does the model meet the requirements of SL 2010-143? Approval of a tool to be used for planning.

➤ **Basin Plan Approval**

- The EMC has a separate process to approve basinwide plans. The new basinwide plans will include water supply planning. This is when the EMC has a chance to agree or disagree whether DWR is using the models correctly as part of basin planning.

Improve River Basin Modeling – SL 2010-143

- (3) Model. – Each basinwide hydrologic model shall:
- a. Include surface water resources within the river basin, groundwater resources within the river basin to the extent known by the Department, transfers into and out of the river basin that are required to be registered under G.S. 143-215.22H, other withdrawals, ecological flow, instream flow requirements, projections of future withdrawals, an estimate of return flows within the river basin, inflow data, local water supply plans, and other scientific and technical information the Department deems relevant.
 - b. Be designed to simulate the flows of each surface water resource within the basin that is identified as a source of water for a withdrawal registered under G.S. 143-215.22H in response to different variables, conditions, and scenarios. The model shall specifically be designed to predict the places, times, frequencies, and intervals at which any of the following may occur:
 - 1. Yield may be inadequate to meet all needs.**
 - 2. Yield may be inadequate to meet all essential water uses.**
 - 3. Ecological flow may be adversely affected.**
 - c. Be based solely on data that is of public record and open to public review and comment.

Improve River Basin Modeling – SL 2010-143

- (6) Approval and modification of hydrologic models.
- a. Upon completion of a hydrologic model, the Department shall:
 1. **Submit the model to the Commission for approval.**
 2. Publish in the North Carolina Register notice of its recommendation that the Commission approve the model and of a 60-day period for providing comment on the model.
 3. Provide electronic notice to persons who have requested electronic notice of the notice published in the North Carolina Register.
 - b. Upon receipt of a hydrologic model, the Commission shall:
 1. Receive comment on the model for the **60-day period noticed in the North Carolina Register.**
 2. Act on the model following the 60-day comment period.
 - c. The Department shall submit any significant modification to an approved hydrologic model to the Commission for review and approval under the process used for initial approval of the model.
 - d. **A hydrologic model is not a rule, and Article 2A of Chapter 150B of the General Statutes does not apply to the development of a hydrologic model.**

Is the model good enough to meet the requirements of SL 2010-143?

- Does the model include the required information in Section (3)a & (3)d?
- Can the model answer the 3 questions required in Section (3)b?
 1. Locations the yield may be inadequate to meet all needs.
 2. Locations the yield may be inadequate meet all essential water uses.
 3. Locations ecological flows are adversely impacted.

Does the model produce an adequate flow record to answer the (3)b questions?

DWR's Validation Approach

The inflow datasets are created using gage extension techniques on monthly USGS streamflow data. Since the planning efforts are focused on the larger streams, rivers, and reservoir that can support a 100,000 gpd or larger withdrawal, having a good annual and monthly validation is adequate. DWR includes the daily analyzes to check to be sure there are no outliers that will impact the model results. Analyzes are done at streamflow nodes with good long-term USGS records and existing reservoirs with good operations records.

Overall Goodness-Of-Fit (GOF)

- **Standard Model Goodness-Of-Fit Statistics**
 - **Nash-Sutcliffe efficiency (NSE) – satisfactory $NSE > 0.50$**
 - **Ratio of the root mean square error to the standard deviation of the measured data (RSR) – satisfactory ≤ 0.70**
 - **Percent bias (PBIAS) – satisfactory $PBIAS \leq \pm 25\%$**
 - **Drought Period Analysis based on National Drought Monitor ($\leq \pm 25\%$ Difference) (A special measure included to test the low-flow requirements of S.L. 2010-143.)**
- **Qualitative**
 - **Hydrograph – Annual and Monthly**
 - **Frequency Curve – full range and low-flow ($\leq 30\%$)**
 - **Period-Of-Record daily mass curve analysis**
 - **Low-Flow Log-Pearson III 7-Day and 30-Day**

Tar GOF

Tar Basin Validation Statistical Summary : For Last 5 years Data

Gages	GOF Results			Drought Period Comparison		
	Data Format: Monthly			Data Source	Total, Days	% Difference ≤ ± 25%
	NSE > 0.5	RSR ≤ 0.70	PBIAS ≤ ± 25%			
010 Tar River Gage Flow	0.9999	0.0077	0.7	USGS	527	
	Satisfactory	Satisfactory	Satisfactory	Simbase	509	-3.4%
050 Louisburg Gage Flow	0.9999	0.0102	0.2	USGS	536	
	Satisfactory	Satisfactory	Satisfactory	Simbase	496	-7.5%
070 Cedar Creek near Louisburg Gage Flow	-0.7936	1.3282	-90.1	USGS	617	
	Poor	Poor	Poor	Simbase	1707	176.7%
200 Fishing Creek Near Enfield Gage Flow	1	0.0042	-0.3	USGS	617	
	Satisfactory	Satisfactory	Satisfactory	Simbase	627	1.6%
240 Swift Creek Gage Flow	0.9999	0.0073	-0.4	USGS	532	
	Satisfactory	Satisfactory	Satisfactory	Simbase	536	0.8%
300 Tarboro Gage Flow	0.9995	0.0227	-0.3	USGS	581	
	Satisfactory	Satisfactory	Satisfactory	Simbase	597	2.8%
380 Conetoe Gage Flow	0.9999	0.0114	-1.8	USGS	497	
	Satisfactory	Satisfactory	Satisfactory	Simbase	564	13.5%

NOTE : Cedar Creek statistical correlation is poor partly due to:

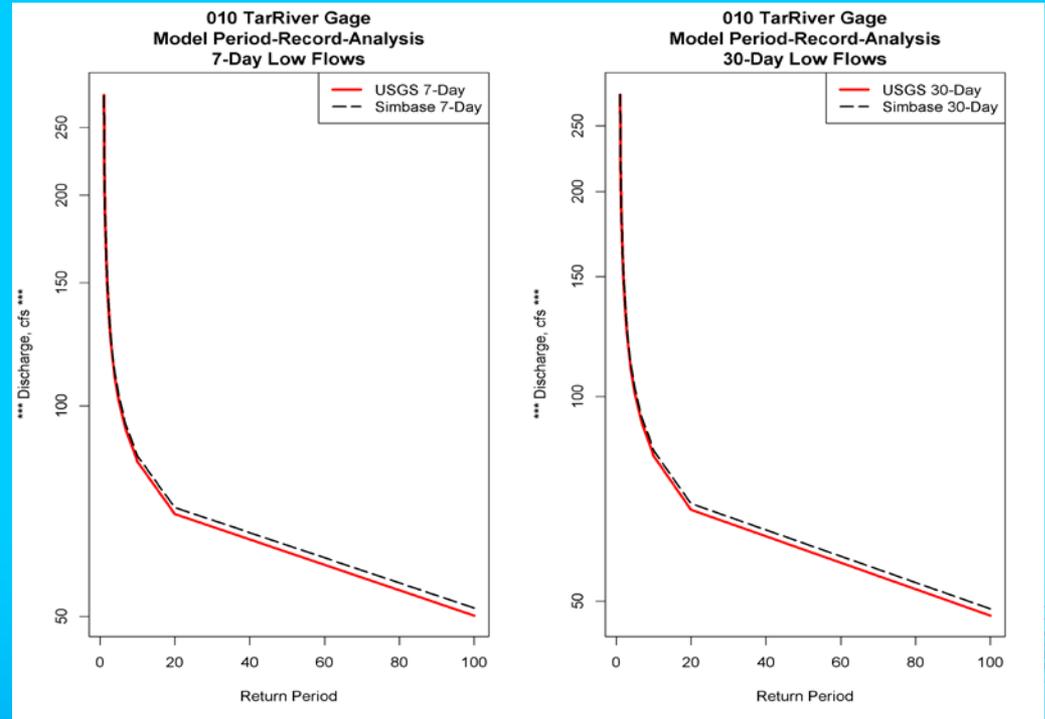
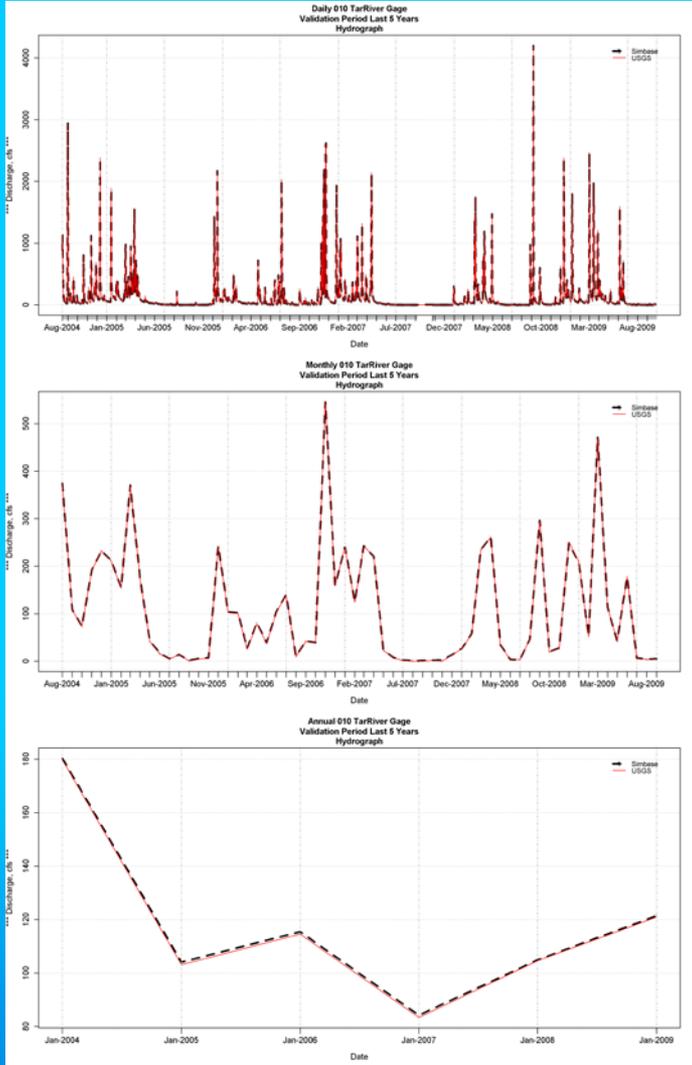
* Cedar Creek gage has only 19 years of flow records; therefore model inflow was generated based on nearby gage flows as synthetic flow data. Other gages have up to 80 years of records.

* Cedar Creek has very small drainage area – only 47.8 sq-miles, and in impaired segment in the headwater part.

* The gage is in a tributary below two very small lakes known as Franklinton reservoirs operated by Franklinton in Franklin County, these two lakes are not modeled as reservoirs with operating rules.

Tar GOF

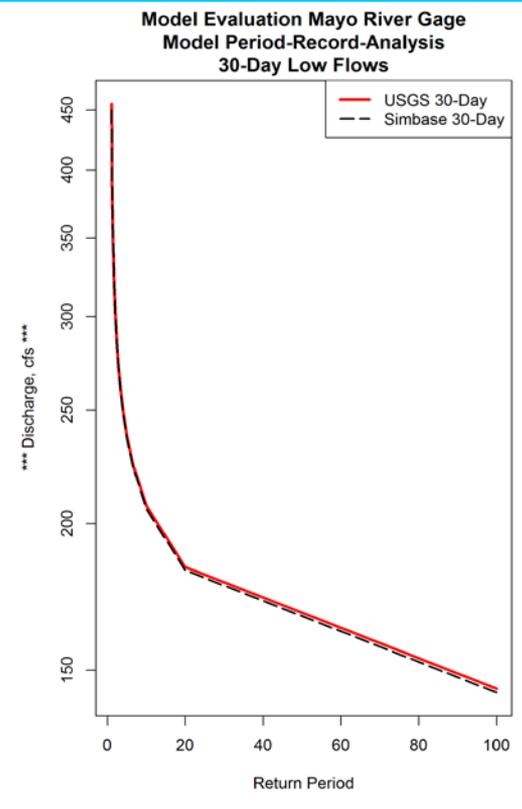
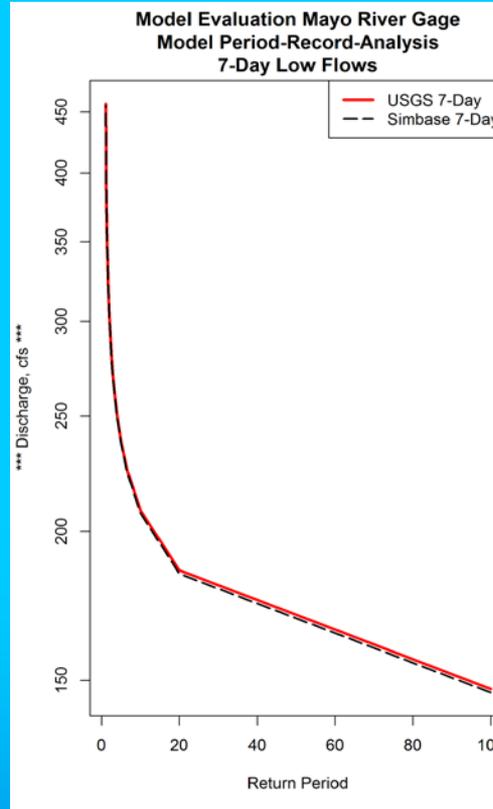
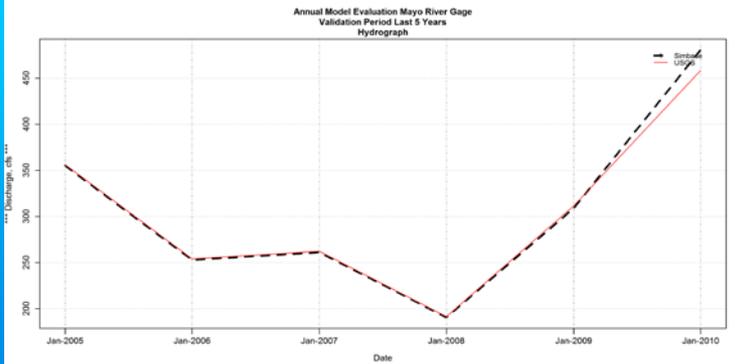
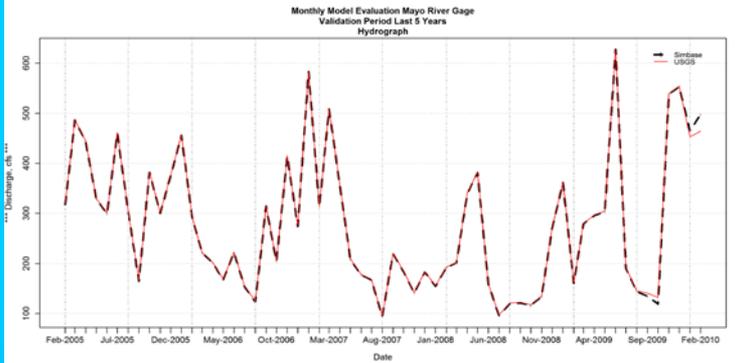
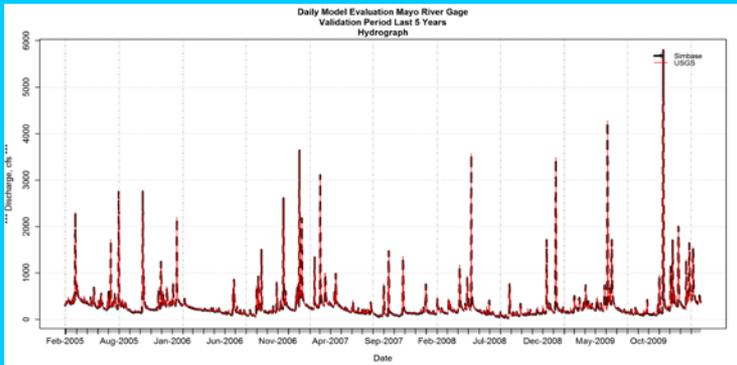
Tar River Gage



Roanoke GOF

Statistical Validation Summary for Roanoke Basin Hydrologic Model Gage Flow						
Gages / GOF Results	Last 5 Years Data			Drought Period Comparison		
	Monthly			Data Source	Total, Days	% Difference $\leq \pm 25\%$
	NSE > 0.5	RSR ≤ 0.70	PBIAS $\leq \pm 25\%$			
220 Alta Vista Gage	0.9584	0.2024	-6.1	USGS	307	
	Satisfactory	Satisfactory	Satisfactory	Simbase	366	19
240 Brook Neal Gage	0.9743	0.159	-3.1	USGS	555	
	Satisfactory	Satisfactory	Satisfactory	Simbase	620	12
306 Dan River, Francisco Gage	0.9831	0.1289	0	USGS	730	
	Satisfactory	Satisfactory	Satisfactory	Simbase	698	-4
320 Mayo Gage at Mayo River	0.9986	0.0369	-0.2	USGS	512	
	Satisfactory	Satisfactory	Satisfactory	Simbase	518	1
340 Eden Gage at Smith River	0.9285	0.2653	3.5	USGS	332	
	Satisfactory	Satisfactory	Satisfactory	Simbase	319	-4
349 Dan River at Paces Gage	0.9862	0.1165	1.7	USGS	549	
	Satisfactory	Satisfactory	Satisfactory	Simbase	518	-6
720 Roanoke River at Roanoke Rapids Gage	0.8862	0.3346	-12.3	USGS	564	
	Satisfactory	Satisfactory	Satisfactory	Simbase	248	-56

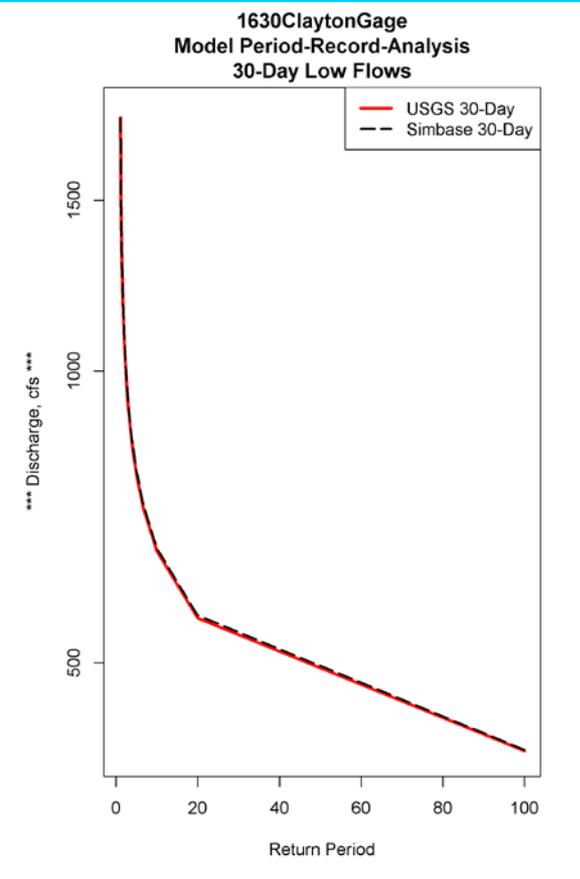
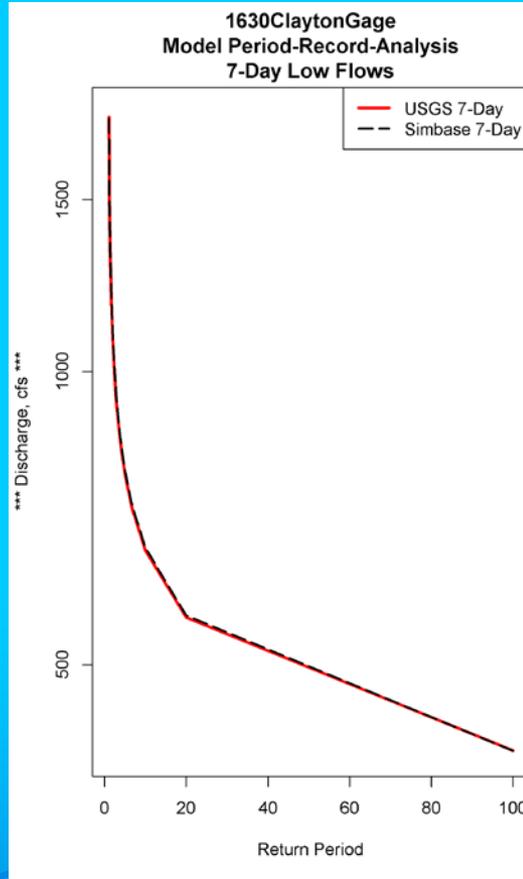
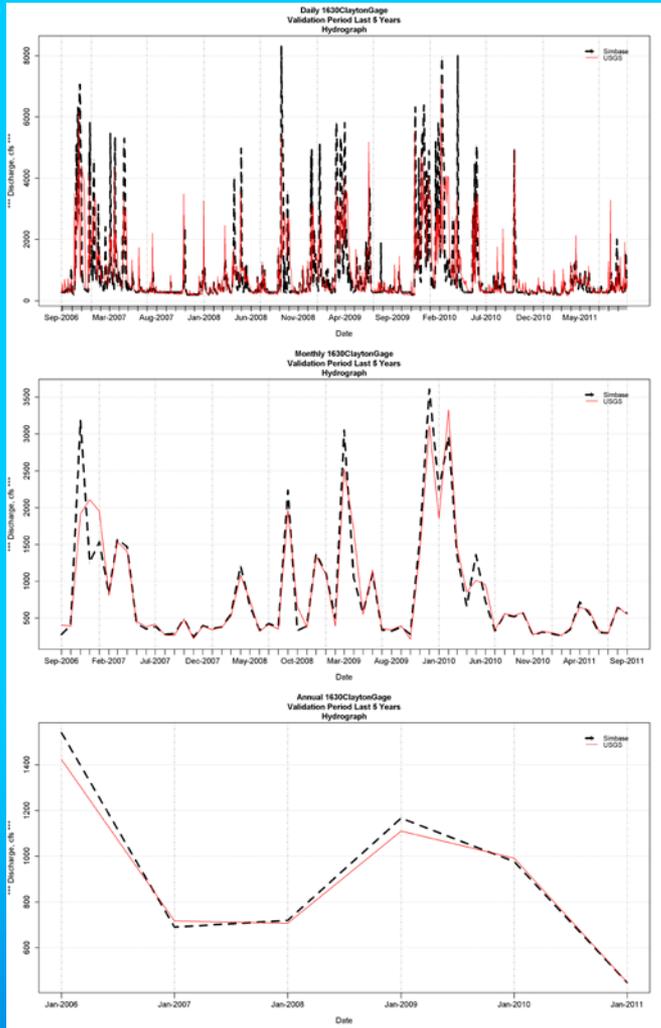
Roanoke GOF Mayo River Gage



Cape Fear- Neuse GOF

1. Statistical Summary Table - CF-Neuse River Basin Gage Flow						
Gages/Location	GOF Results			Drought Period, Days		
	Monthly			Data	Total	% Difference $\leq \pm 25\%$
	NSE > 0.5	RSR ≤ 0.70	PBIAS $\leq \pm 25\%$			
0090 Haw River at Haw River Gage	0.9905	0.0968	1.8	USGS	557	
	Satisfactory	Satisfactory	Satisfactory	Simbase	633	13.64%
0110 RFork Oak Ridge Gage	0.9917	0.0903	-3.6	USGS	724	
	Satisfactory	Satisfactory	Satisfactory	Simbase	761	5.11%
0145 R Fork at Gibsonville Gage	0.925	0.2715	-6.3	USGS	995	
	Satisfactory	Satisfactory	Satisfactory	Simbase	777	-21.91%
0170 North Buffalo Creek Gage	0.9416	0.2396	8.7	USGS	870	
	Satisfactory	Satisfactory	Satisfactory	Simbase	0	-100.00%
0280 Deep River at Ramseur Gage	0.9942	0.0755	-3.2	USGS	422	
	Satisfactory	Satisfactory	Satisfactory	Simbase	606	43.60%
0400 Haw Eiver at Bynum Gage	0.9946	0.073	4.4	USGS	595	
	Satisfactory	Satisfactory	Satisfactory	Simbase	521	-12.44%
0527 Buckhom Creek Gage	0.5603	0.6576	-23.7	USGS	777	
	Satisfactory	Satisfactory	Satisfactory	Simbase	754	-2.96%
0550 Cape Fear at Lilington Gage	0.9693	0.1738	-1.2	USGS	631	
	Satisfactory	Satisfactory	Satisfactory	Simbase	944	49.60%
0640 Deep River at Moncure Gage	0.9995	0.0216	-1.5	USGS	606	
	Satisfactory	Satisfactory	Satisfactory	Simbase	578	-4.62%
0780 Cape Fear at Tarheel Gage	0.8542	0.3787	-4.7	USGS	728	
	Satisfactory	Satisfactory	Satisfactory	Simbase	728	0.00%
1110 Eno Hillsborough Gage	0.9898	0.1	-0.7	USGS	756	
	Satisfactory	Satisfactory	Satisfactory	Simbase	512	-32.28%
1115 Eno Durham Gage	0.9978	0.0466	-0.7	USGS	600	
	Satisfactory	Satisfactory	Satisfactory	Simbase	536	-10.67%
1480 Middle Creek Gage	0.9984	0.0399	-0.3	USGS	392	
	Satisfactory	Satisfactory	Satisfactory	Simbase	425	8.42%
1560 Hookerton Gage	0.9749	0.157	11.1	USGS	603	
	Satisfactory	Satisfactory	Satisfactory	Simbase	582	-3.48%
1630 Neuse R Clayton Gage	0.8635	0.3664	1.4	USGS	459	
	Satisfactory	Satisfactory	Satisfactory	Simbase	158	-65.58%
1660 Neuse R Smithfield Gage	0.9254	0.2709	-13	USGS	200	
	Satisfactory	Satisfactory	Satisfactory	Simbase	159	-20.50%
1750 Neuse R Princeton Gage	0.9972	0.0525	0.3	USGS	670	
	Satisfactory	Satisfactory	Satisfactory	Simbase	661	-1.34%
1780 Neuse R Goldsboro Gage	0.9824	0.1317	-0.7	USGS	532	
	Satisfactory	Satisfactory	Satisfactory	Simbase	559	5.08%
1800 Neuse R Kinston Gage	0.9805	0.1386	-1.2	USGS	492	
	Satisfactory	Satisfactory	Satisfactory	Simbase	574	16.67%

Cape Fear- Neuse GOF Clayton Gage



Tar Comments

1. City of Raleigh

- Will review in detail in later slides.



Roanoke Comments

1. Virginia Canals & Navigations Society

- Use the river mileage system in the *The Roanoke/Staunton River Atlas*.
- *DWR response, the Division planners are geo-referencing the model as a GIS layer.*

2. Duke Energy

- Provided updated projections for their steam stations.
- *DWR response, the updated withdrawals will be included.*

Cape Fear-Neuse Comments

1. Town of Cary

- Cary appreciated the time and effort taken to develop the models, and being included as stakeholders in the model development.
- *DWR response, comment noted.*

2. CH2M Hill

- We have reviewed the current iteration of the Cape Fear – Neuse model and believe that it will be a useful tool for water resources planning. The previous models were useful as planning tools and the revised model is an improvement over the previous Cape Fear and Neuse models.
- *DWR response, comment noted.*

3. City of Raleigh

- Will review in detail in later slides.



DWR's responses to the City of Raleigh's Comments on the Tar (March 28, 2014) and Cape Fear-Neuse (April 16, 2014) models.

Both sets of comments have the same 3 basic objections:

- The models do not contain information or processes sufficient to analyze adverse impacts to ecological flows.**
- The models failed to include set-asides for ecological flows.**
- The flow-by approach is a rule and therefore violates State law.**

The Cape Fear-Neuse model contains an additional section on specific objections to the Cape Fear-Neuse model.

Specific objections to the Cape Fear-Neuse model.

- The comments and concerns are based on the Neuse model. We have no information to show that they have done any analyzes or worked with the Cape Fear-Neuse model.
- There is a model oscillation of the daily flows at a proposed Neuse River alternative withdrawal location.
 - *DWR has discussed the oscillation concern with our contractor and we have a technical fix for the concern.*
- A reduction in yield for the proposed Little River reservoir.
 - *The reduction in reservoir yield is a misrepresentation of the purpose of the flow-by approach. Using an 85% flow-by approach is only for the purposes of having a planning trigger as to when addition planning studies may be needed, NOT a minimum release from a reservoir. We will base minimum release requirements on site specific information. DWR and others have been working with Raleigh for a number of years on the Little River Reservoir site. This new flow-by approach will not impact the ongoing work, so the reduced yield based on flow-by approach has no basis for concern.*



Common Issue - The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.

This concern includes several issues: the methodology does not take into account prevailing ecological conditions nor the anthropogenic water uses; not basin specific, based on generic scientific conditions; does not allow for temporary flow disruptions when needed to install new withdrawal projects; cannot analyze the impacts of new withdrawals; and the methodology is not provided in the Model.

Common Issue - The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.

The methodology does not take into account prevailing ecological conditions nor the anthropogenic water uses.

The flow-by approach does take into account prevailing ecological conditions and anthropogenic water uses. Since the session law was passed in 2010, DWR decided to define prevailing conditions as 2010 operations. We've developed a model scenario that is representative of 2010 operational conditions for the model period of record to use as the ecological flow baseline.

Common Issue - *The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.*

Not basin specific, based on generic scientific conditions.

DWR disagrees with the conclusion that a flow-by approach is not basin specific. This analysis is based on stream flow conditions unique to each node of the model. The City's comments reference 7Q10 water quality flow standard. Flow-by and 7Q10 are similar in that both are a streamflow statistic calculated at specific location. This approach does meet the requirement to predict the places, times, frequencies, and intervals that ecological flow maybe adversely affected.

Common Issue - *The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.*

Does not allow for temporary flow disruptions when needed to install new withdrawal projects.

Raleigh has misinterpreted the meaning of temporary flow disruptions. In a modeling context you do not want to include streamflow records that are temporary anomalies caused by construction. When the model inflow records are created these time periods have been adjusted appropriately.

Common Issue - *The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.*

Cannot analyze the impacts of new withdrawals.

It is not clear why Raleigh's comments included the concern the model cannot analyze the impacts of new withdrawals. The approach to analyze impacts of either new or a change in operations is to develop a new model scenario and compare the results a baseline scenario. This is the approach Raleigh and others having been using for years. To assist users, DWR's modeling and planning staffs develop and make available current and future scenarios, based on local water supply plans, in 10 year intervals out to a 50-year planning horizon.

Common Issue - The model does not contain information or processes sufficient to analyze adverse impacts to ecological flows.

The methodology is not provided in the Model.

It is not clear what Raleigh means by the methodology is not provided in the Model. It appears that this comment assumes a model is not adequate if the analysis cannot be done within the model's interface. The model interface does not include a direct link to an ecological flow analysis. However, the statute does not require this direct link. It only requires the model to be designed to simulate flows and to predict the times, frequencies, and intervals ecological flows maybe adversely affected. DWR has demonstrated the models do a good job of simulating flows and has developed tools to analyze ecological flows based on the models' simulated flows.

Common Issue - *The models fail to include set-asides for ecological flows.*

The concerns in this section include: DWR failed to include presumptive set-asides for ecological flows in the model; changing the standard of retaining 80% of the 7Q10 to protect water quality and aquatic life; and based on natural, unaltered flows.

Common Issue - *The models fail to include set-asides for ecological flows.*

DWR failed to include presumptive set-asides for ecological flows in the model.

Raleigh is correct DWR does not include presumptive set-asides for ecological flows in the model. The statute does not require ecological flows to be included only the ability to predict adverse affected, which we can do. DWR only includes ecological flows that are part of a permit requirement or operational plan of a federal project.

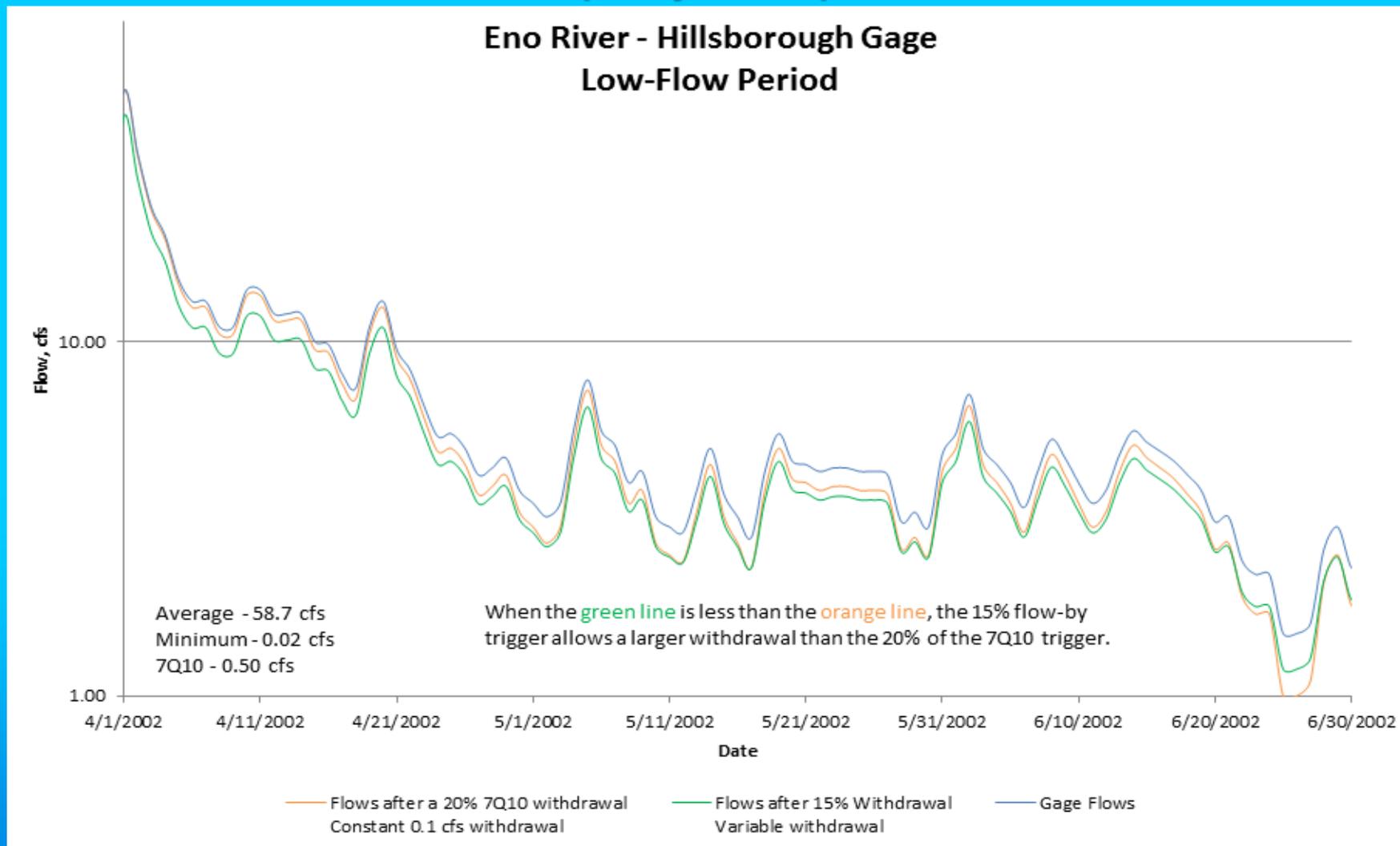
Common Issue - *The models fail to include set-asides for ecological flows.*

DWR is changing the standard of retaining 80% of the 7Q10 to protect water quality and aquatic life.

Raleigh has misrepresented the meaning of requiring an environmental assessment for proposed withdrawals greater than 20% of the 7Q10. **20% of the 7Q10 is a trigger for requiring additional site specific studies.** This requirement does not mean retaining 80% of the 7Q10 protects water quality and aquatic life. The 20% of the 7Q10 applies to low and high flows just like the proposed flow-by requirement does. Using the flow-by approach provides more flexibility to account for stream size and flow variations. In contrast, the 20% of the 7Q10 is constant for the full flow range from low to high flows.

Common Issue - *The models fail to include set-asides for ecological flows.*

DWR is changing the standard of retaining 80% of the 7Q10 to protect water quality and aquatic life.



Common Issue - *The models fail to include set-asides for ecological flows.*
Is based on natural, unaltered flows.

As stated in an earlier slide, the flow-by approach does take into account prevailing ecological conditions and anthropogenic water uses. Since the session law was passed in 2010, DWR decided to define prevailing conditions as 2010 operations. We've developed a model scenario that is representative of 2010 operational conditions for the model period of record to use as the ecological flow baseline.

Common Issue - *The flow-by approach is a rule and therefore violates State law*

Raleigh states the flow-by approach is not a science based criteria unique to each basin therefore the APA would define the approach as a rule. The flow-by approach is based on flow data specific to each river basin; therefore the approach is unique to each basin.

In G.S. 143-355(o)(6)d clearly states hydrologic models are not a rule and G.S. 143-355(o)(8) states nothing in this subsection will change or impose no new regulatory requirements.

DWR disagrees, we are not violating state law because the statute exempts models from the APA.

Questions?



EMC's Role

➤ **Model Approval**

- Does the model meet the requirements of SL 2010-143?
Approval of a tool to be used for planning.

➤ **Basin Plan Approval**

- The EMC has a separate process to approve basinwide plans. The new basinwide plans will include water supply planning. Each river basin is unique and the ecological flow analyzed will probably need to be fine tuned basin by basin. So the basin plans are the appropriate time for the EMC to agree or disagree whether DWR is using the models correctly as part of basin planning.





Common Issue - *The models fail to include set-asides for ecological flows.*

DWR is changing the standard of retaining 80% of the 7Q10 to protect water quality and aquatic life.

