Modeling and Regulatory Support Workgroup Meeting
January 7, 2020

Agenda

- Status updates
  - Results of 3rd party review of processed USGS flow data
  - Development of land use data for recent period
  - Filling missing meteorological data for baseline period
  - Preliminary hydrologic calibration
- Other items
  - DWR grant to expand onsite wastewater simulations
  - Additional SME for statistical modeling
  - Discuss Re-examination MOA with DWR

3rd Party Review of Processed USGS Flow Data

3rd Party Review of Processed USGS Flow Data

- Performed by Nathan Hall at the UNC Collaboratory
- First task was to QAQC the processed USGS flow data into 6-hr increments
  - Ensure accuracy of simulated releases from Lake Michie and Little River Reservoir
  - Ensure flows used to support model calibration are accurate
- Comparison generated similar results, and use of processed flows by BC is sufficient for model development, however
  - Minor differences in baseflow measurements were attributed to computer rounding and deemed negligible
  - A small number of data time stamps are off by 1 hour resulting in different high flow estimates (only affected high flows)
- **Modeling Team corrected time stamps and flow comparisons match well**

Development of Land Use Data for Recent Modeling Period

Status of Land Use Processing and Review - Recent Modeling Period

- Used same approach as baseline period for agricultural land use, DOT-maintained roads, and wildlife impoundments
- Will provide to NC Department of Agriculture and NC DOT for QAQC following January MRSW meeting
- Will distribute to MRSW and PFC for review after approval by NC Department of Agriculture and NC DOT

Urban Land Use Processing for Recent Modeling Period

- NLCD provides data on urban open space and low, medium, and high intensity development
- Falls Lake Watershed has three periods for development to simulate
  - Before the baseline year 2006
    - Existing Development characteristics
  - Before the the New Development Rules were enacted in mid 2012
    - For most jurisdictions, this development has Existing Development characteristics
    - For the City of Durham, other regulations were in place, so an Interim Development category was established for Durham
  - After mid 2012
    - New Development Rules were enacted
    - New development characteristics

Application of NLCD Data

- 2006 NLCD land use data (baseline year)
  - Existing development
- 2011 NLCD data (near the implementation of New Development Rules)
  - Additional development is assumed to have Existing Development characteristics except for the City of Durham
  - City of Durham development is categorized as Interim Development
    - 2007 Neuse Rules: 3.6 N limit lb/ac/yr
    - 2010 Voluntary interim limits: N limit 2.2 lb/ac/yr and P limit 0.5 lb/ac/yr
- 2016 NLCD data (after implementation of New Development Rules
  - Additional development assumed to have New Development characteristics unless otherwise noted (e.g., Town of Hillsborough grandfathered sites)

Checks on Estimated Developed Areas - Butner

- Total and impervious cover areas were provided for development sites since baseline (2006)
- Three of larger developments were spot checked to ensure the change was picked up by NLCD
- NCLD picked up the development, but missed total impervious area at the Ritchie Brothers Auction site
  - 38 acres of imperviousness (parking lot&building).
  - NLCD shows 23 acres of high intensity and 15 acres of medium intensity development
- May increase the percent imperviousness of the low, medium, and high intensity development during model calibration as needed to better represent total impervious area.

2011 NLCD

2016 NLCD

Checks on Estimated Developed Areas - Hillsborough

- Town provided pre and post development land use data to support estimates of Stage I jurisdictional loads
  - Expected the area reported (488 acres) to be picked up in the change in urban land use between NLCD 2006 and NLCD 2011
- Town's data includes sites that were grandfathered under the existing development rules
- Change in NLCD urban land use from 2006 to 2016 for Hillsborough is 424 acres (excludes DOT-maintained roads)
- Reviewed Google Earth historic images
  - Many of the grandfathered projects did not start construction until after the 2011 NLCD data were collected
  - Several larger projects were still under construction in 2016
- Plan to simulate all of the development in Hillsborough picked up through 2016 as existing development – discussed with Town on 12/18

Checks on Estimated Developed Areas - Durham

- City provided reported 3,400 acres for their Stage I jurisdictional load estimates
- Change in NLCD urban land use from 2006 to 2011 for Durham is 811 acres (excludes DOT-maintained roads)
- Reviewed City's site level calculations
  - Site area reported was 3,400 acres but the project area reported was 2,360 acres
  - One quarter of the projects were redevelopment
  - The change in impervious area and managed open space reported in the site data was between 464 acres to 600 acres
  - Thus the NLCD detected change of 811 acres makes sense with the site-level data
- Simulate the types of development in Durham based on the NLCD data (existing, new, interim)

Filling Missing Meteorological Data for Baseline Period

NEXRAD Precipitation Data

- Modelers received and formatted the weather inputs for WARMF using the NLDAS and NEXRAD data
  - 6-hr time steps to run model as approved by the MRSW at the March 2019 meeting
- Complete for the recent modeling period (2015 to 2018) (except for one missing record)
- For the baseline period (2005 to 2007)
  - 115 missing values in 2006
  - 16 missing values in 2007
- Preliminary model development used a single, spatially averaged value based on available observations to fill in the missing values
- The value changed over time, but was applied everywhere in the watershed

Issues with Baseline Period Missing NEXRAD Data

- The baseline period represented a record drought with a few larger storms
- Missing NEXRAD data corresponded to large storm events including Tropical Storm Alberto
- Using one precipitation value across the watershed to fill missing data resulted in poor model calibration
- *Note that the single-value approach was used for model spin up years 2004 and 2014 for which NEXRAD data were not requested*

Developed More Rigorous Filling Routine

- Rather than assume one value across the watershed for each missing record, spatially variable records were generated
- Hourly precipitation was available for 7 stations
  - Precipitation was binned to match the NEXRAD intervals
- Daily precipitation was available for 7 additional stations
  - Precipitation was disaggregated to the 6-hour time steps based on the timing at the hourly stations
- The missing 6-hr records were estimated using spatially explicit, inverse distance weighted interpolation using data from all 14 stations
- *Note that this process uncovered units issues for the Roxboro/Person County Airport data for the baseline period, and these were corrected during filling*

Original Model Development Plan

- Modeling Quality Assurance Project Plan describes the calibration period (2015 to 2016), validation period (2017 to 2018), and historical comparison (2005 to 2007)
- While the historical comparison is not held to the same performance criteria, the original plan was to “calibrate” the model first to the baseline period to ensure that Existing Development was characterized first
- Even with the more rigorous precipitation filling routine, the model fit for the baseline period was not very good
- Note that for the baseline period, some of the USGS gages provided daily average flows, and this also contributed to poor model fit (model is simulating average flows every six hours, which would not have the same magnitude as the daily average)

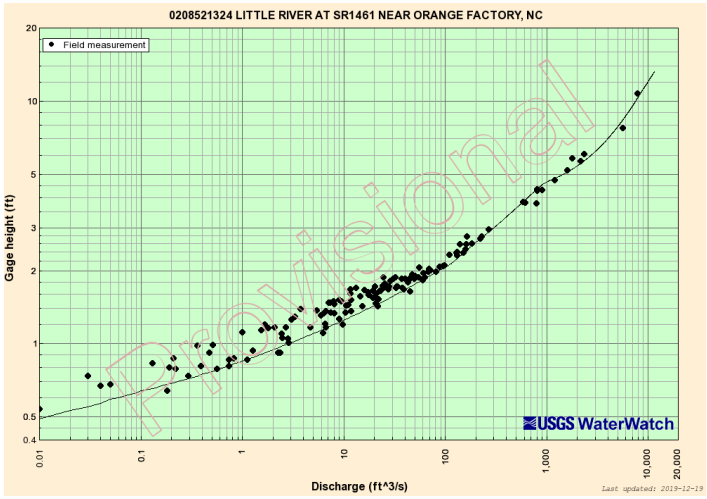
Test the Baseline Model using the Recent Meteorological and Flow Data

- The recent modeling period has higher quality precipitation and flow data than the baseline period
  - Only one missing NEXRAD value
  - All of the USGS gages are subhourly
- Modelers tested the baseline model using the recent meteorological and flow data for gages with little development in the watershed, no upstream impoundments affecting stream flows, and no major wastewater treatment plants
- Model fit improved greatly, even using the older land use data
- Shifted focus to calibrating the recent modeling period, and will use the historic period for comparison as described in the QAPP

Preliminary Hydrologic Calibration – Recent Period

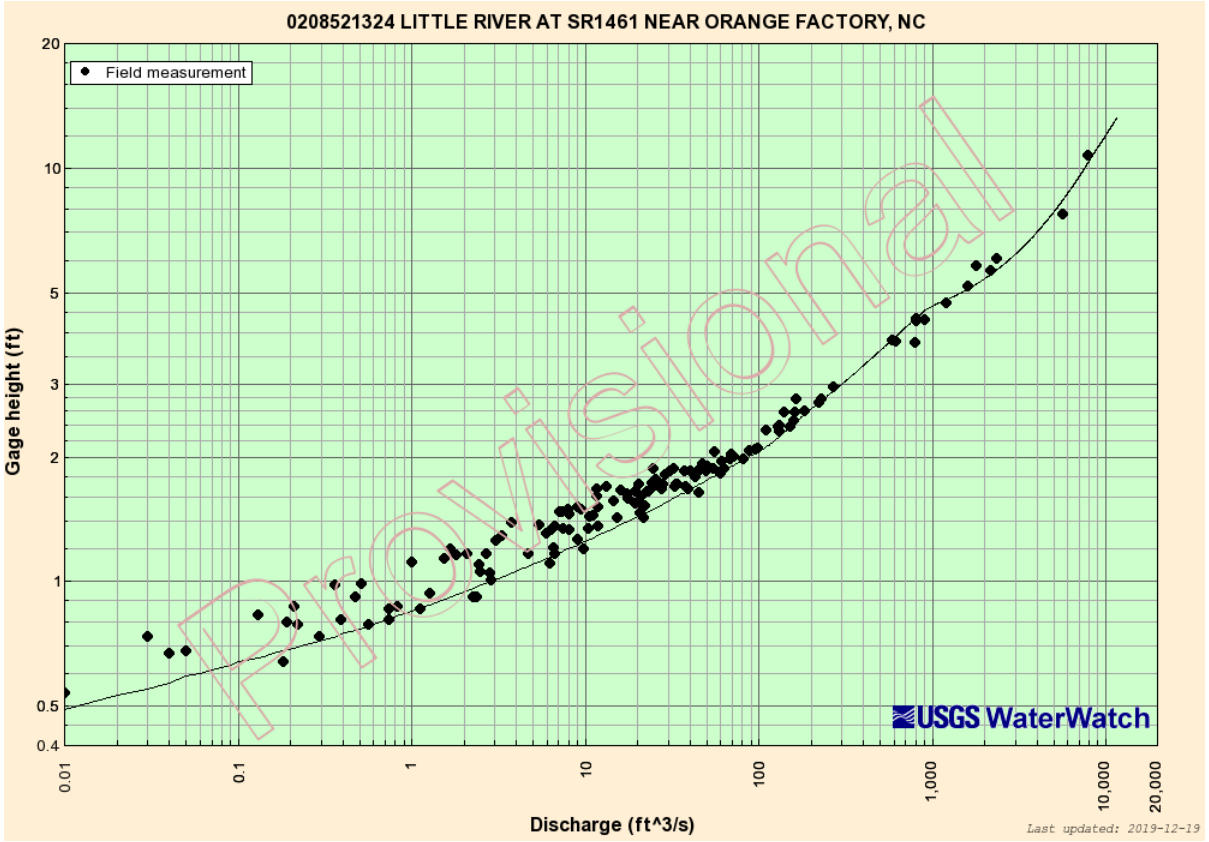
Preliminary Hydrologic Calibration

- Preliminary calibration provided for two gages
  - Flat River upstream of Lake Michie; drainage area = 149 square miles
  - Little River upstream of Little River Reservoir; drainage area = 78 square miles
- “Observed” stream flows are based on measurement of water level and a rating curve based on USGS field measurements to predict flows
- Quality of the rating curve affects model calibration



Example USGS Rating Curve to Estimate Flow

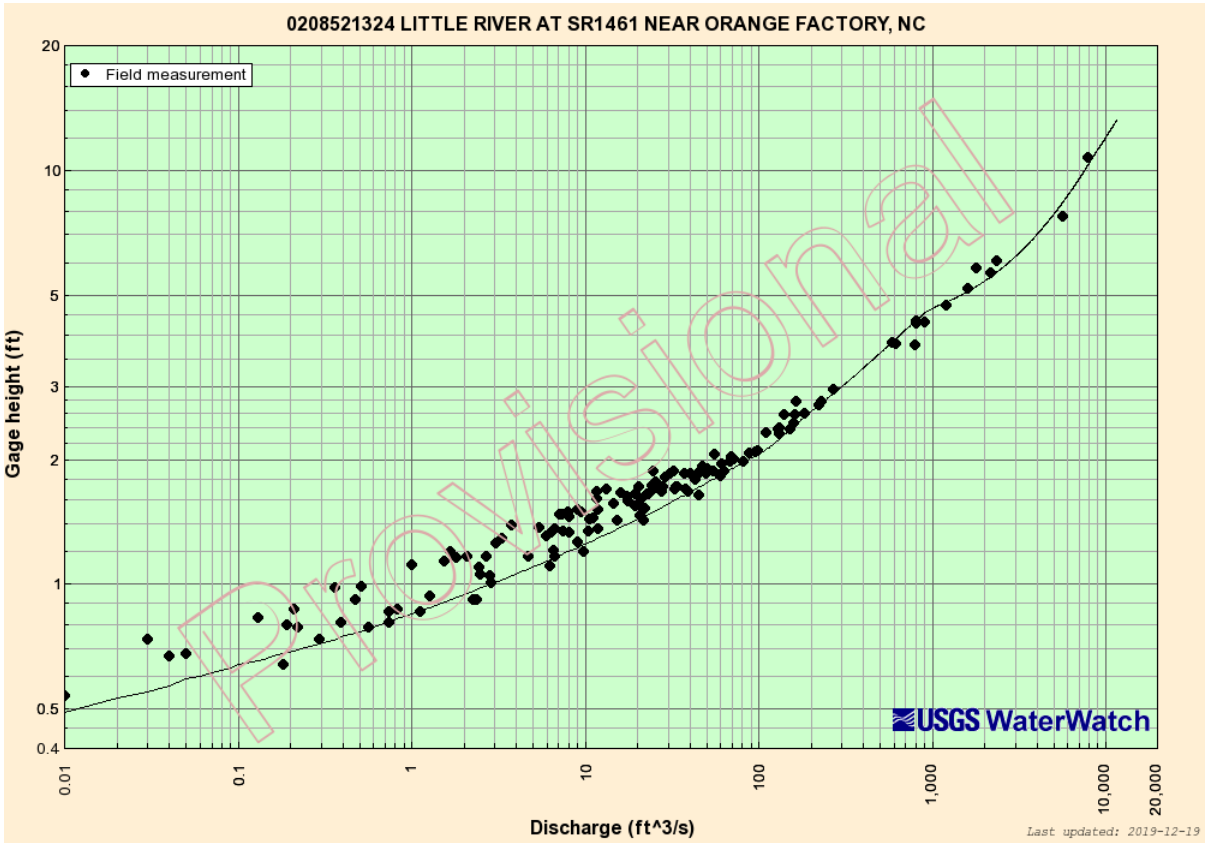
- USGS collects field measurements of gage height and stream flow
- Use field data to create a rating curve to estimate flows on days when measurements were not taken
- Figure to the right displays measurements from the past 20 years which provides good coverage of the estimated flows
- Older data are more uncertain due to channel erosion and change in technique



Example: Field Measurements during Previous 20 Years (black diamonds) and Rating Curve

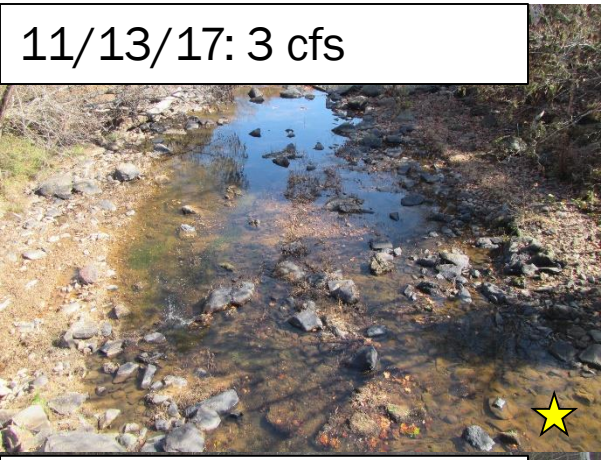
Little River upstream of Little River Reservoir (LRR)

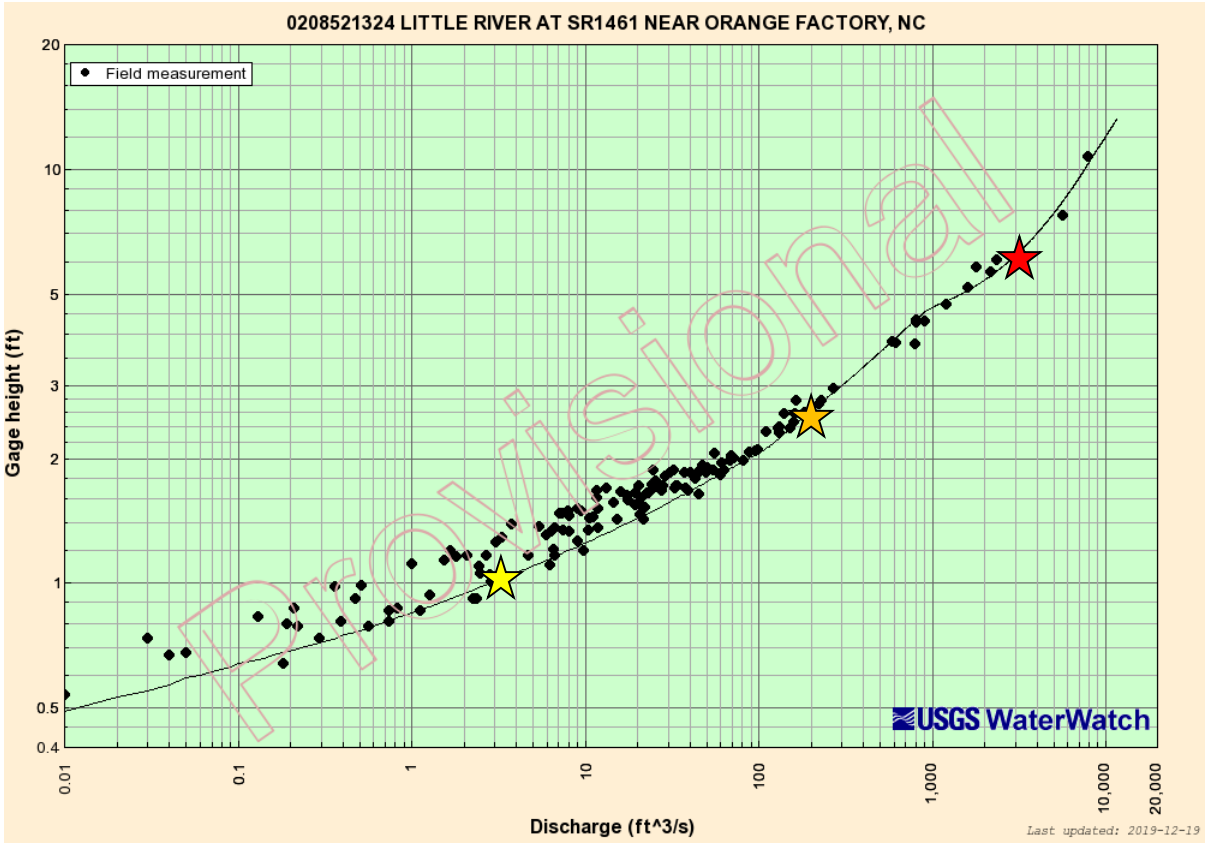
- Field measurements reported from 1987 to 2019
- Figure displays measurements from the past 20 years which provides good coverage of the estimated flows
- Second highest measured flow of 7,880 cfs in 2008 (11 years)
- Highest measured flow of 11,600 cfs in 1996 (23 years old)
- The rating curve is well represented by field measurements collected in the past 20 years



Field Measurements during Previous 20 Years (black diamonds) and Rating Curve for USGS Gage 0208521324

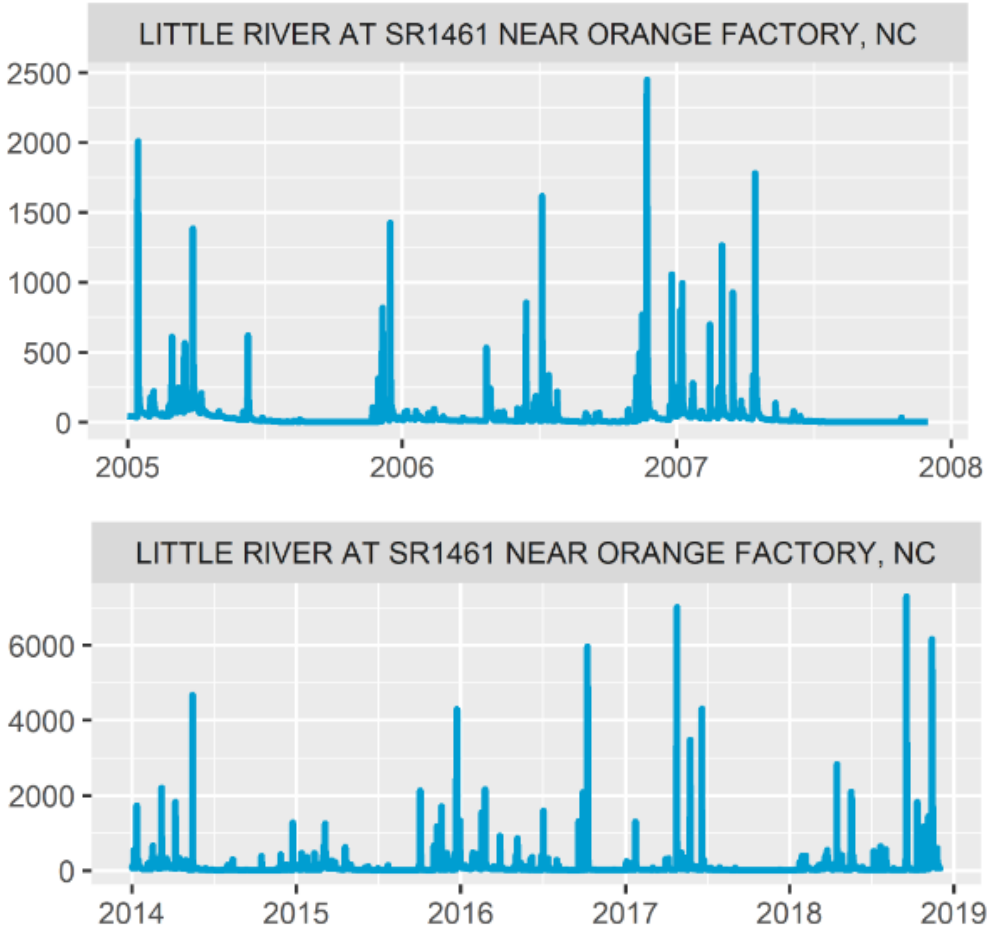
Photos of Different Flows Collected at Little River upstream of Little River Reservoir (LRR)





Field Measurements during Previous 20 Years (black diamonds) and Rating Curve for USGS Gage 0208521324

Little River upstream of LRR:
6-hr Flows, Cubic Feet Per Second,



- The <u>recent modeling period</u> included USGS flow estimates
  - 15-minute flows up to 9,000 cfs
  - 6-hr averaged flows up to 7,300 cfs
- Field measurements in past 20 years were collected at flows up to 7,880 cfs and in past 23 years of 11,600 cfs
- Confidence in the rating curve across a range of flows
- The model performs well during baseflows and high flows at this location.

Little River upstream of LRR: Calibration

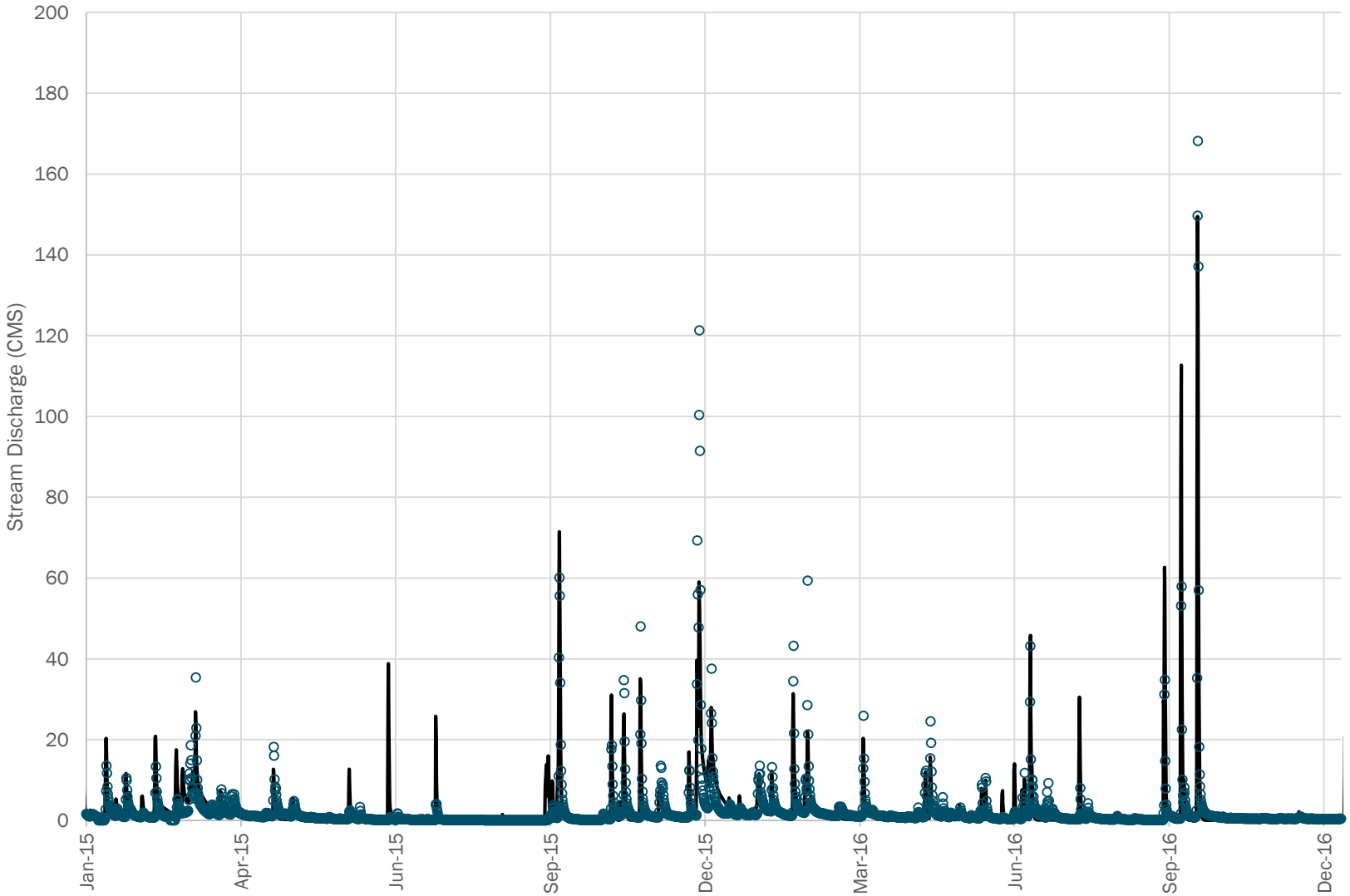


Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Little River upstream of LRR: Calibration

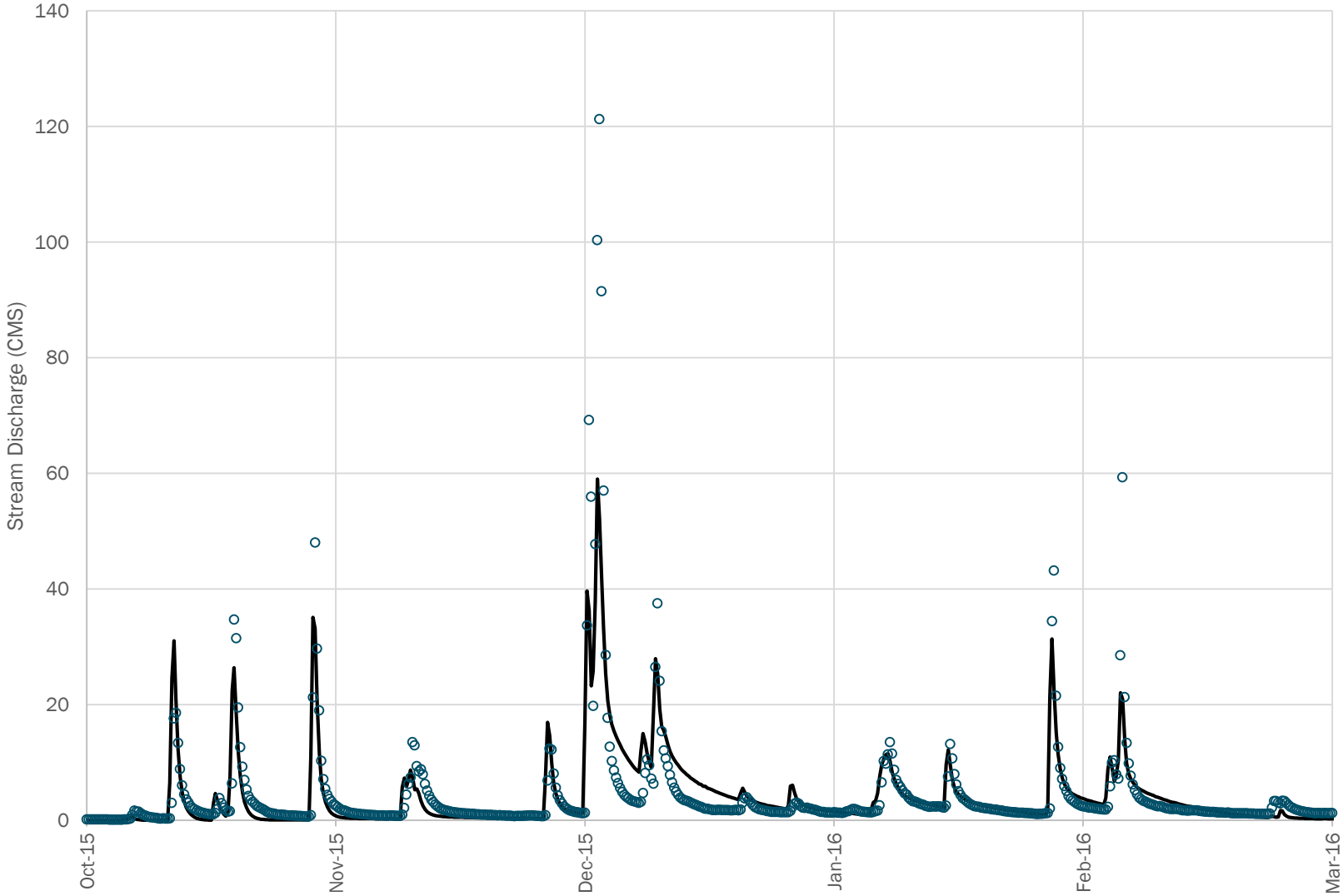
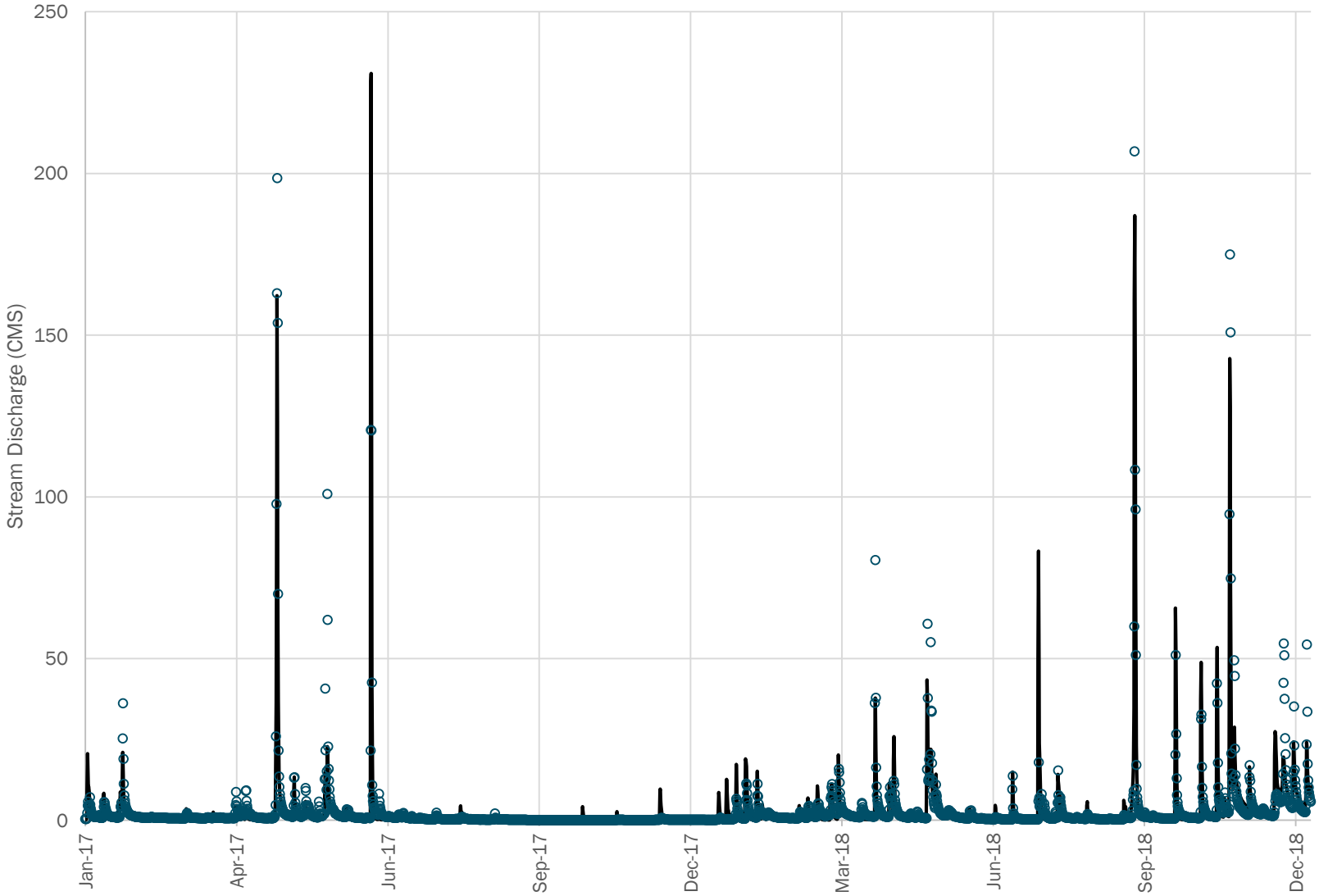


Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Little River upstream of LRR: Validation



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Little River upstream of LRR: Validation

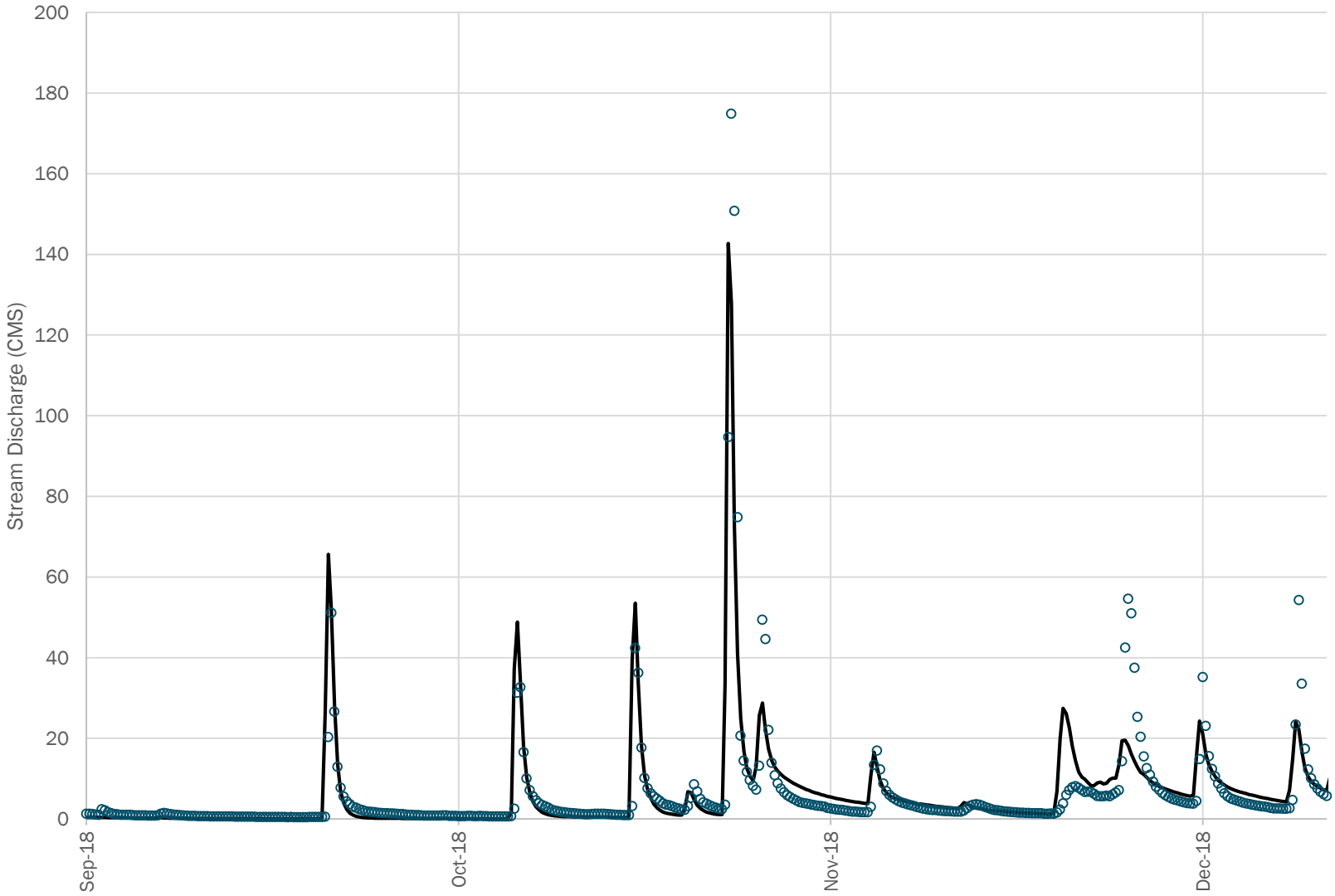


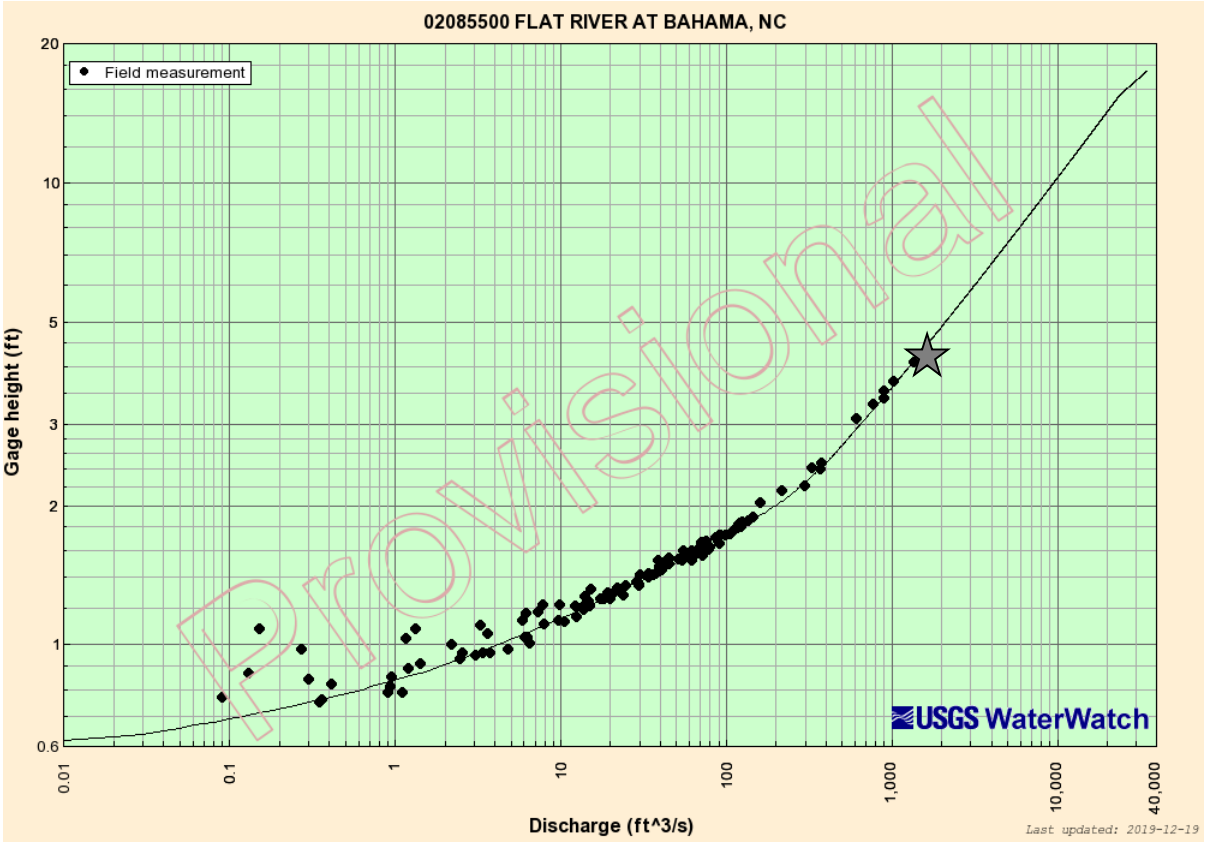
Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Little River upstream of LRR: Performance Criteria from Modeling QAPP

	Time Period					
	Calibration (2015-2016)		Validation (2017-2018)		Complete (2015-2018)	
	Statistic	Interpretation (QAPP)	Statistic	Interpretation (QAPP)	Statistic	Interpretation (QAPP)
Observed Median Discharge	0.933		0.741		0.811	
Observed 90th Percentile Discharge	4.149		4.461		4.355	
Simulation Error:						
Total Volume	0.3%	Very Good	-4.7%	Very Good	-2.4%	Very Good
Peak Flow	-8.6%	Very Good	-2.2%	Very Good	-4.7%	Very Good
High Flow	-0.6%	Very Good	-4.2%	Very Good	-2.5%	Very Good
Low Flow	10.3%	Good	-11.8%	Good	-0.9%	Very Good
Winter	12.7%	Very Good	2.6%	Very Good	8.6%	Very Good
Spring	-30.3%	Fair	-26.3%	Good	-27.7%	Good
Summer	12.4%	Very Good	20.6%	Good	17.3%	Good
Fall	5.0%	Very Good	8.3%	Very Good	6.8%	Very Good

Flat River upstream of Lake Michie

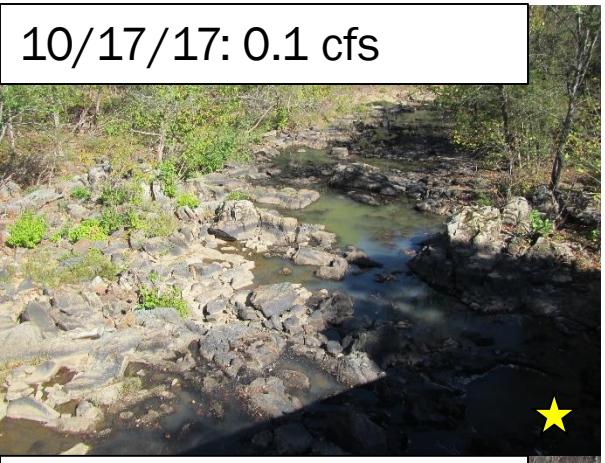
- Field measurements reported back to 1925
- Figure displays measurements from the past 20 years
- In the past 20 years, the highest field measurement was 1,360 cfs in 2016
- Highest flow of 33,800 cfs measured in 1996 (rated poor); three times higher than any other recorded
- Second highest flow of 13,000 cfs measured in 1929
- A lot of uncertainty in the rating curve for flows over 1,360 cfs



Field Measurements during Previous 20 Years (black diamonds) and Rating Curve for USGS Gage 02085500

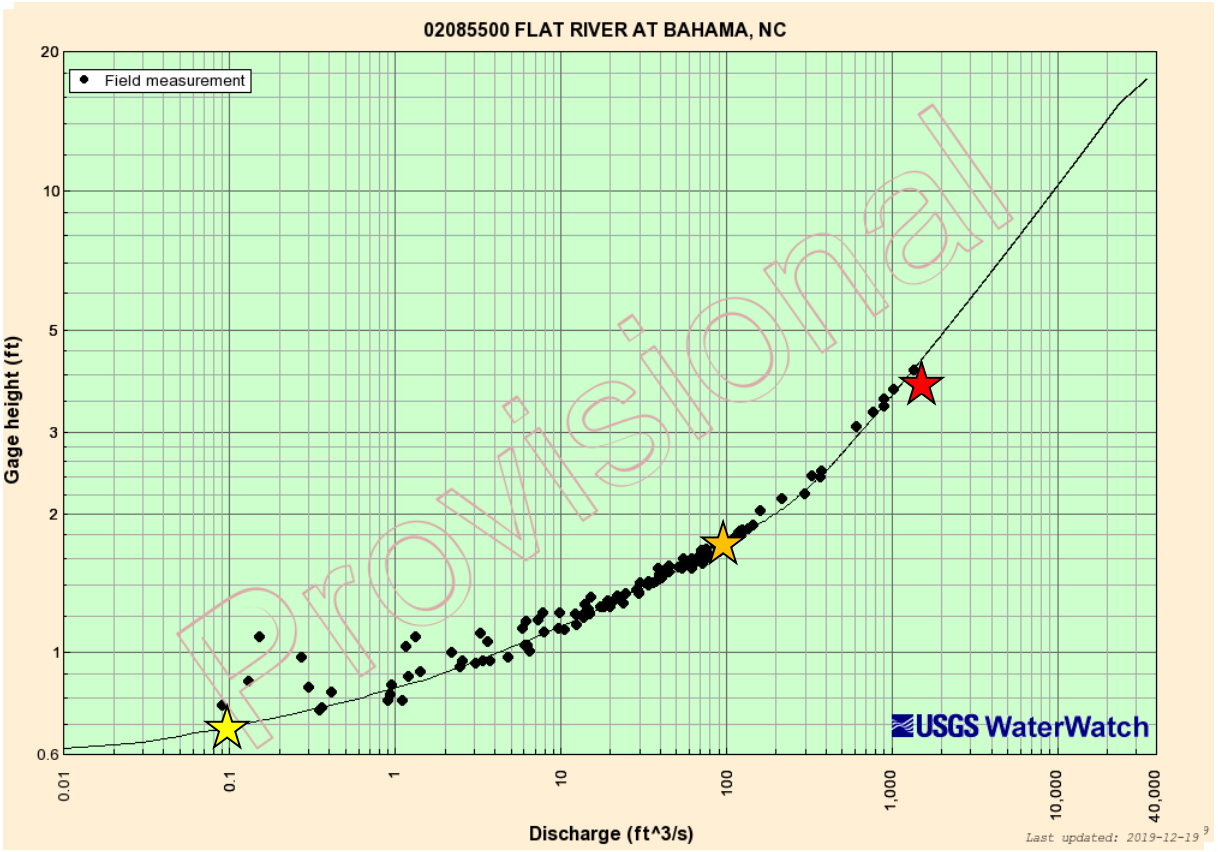
Photos of Different Flows Collected at Flat River upstream of Lake Michie

10/17/17: 0.1 cfs



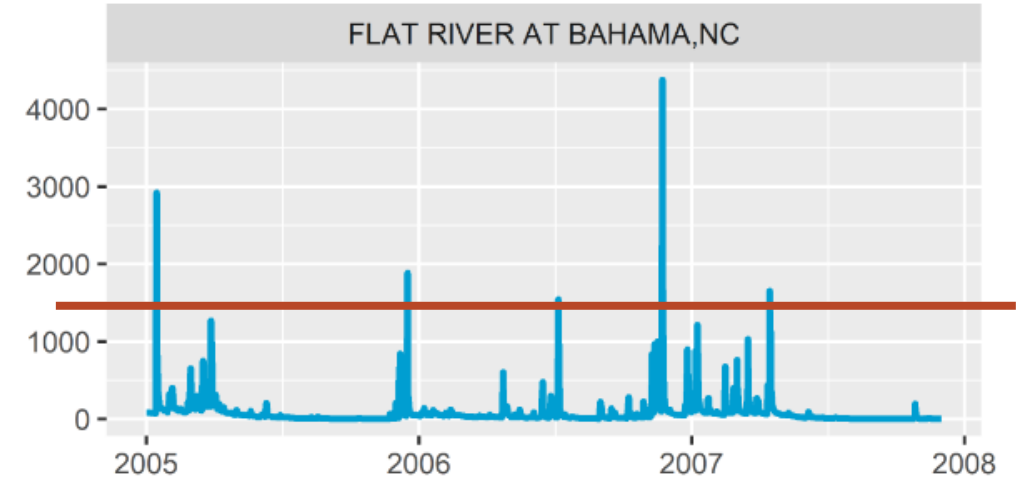
12/9/15: 100 cfs

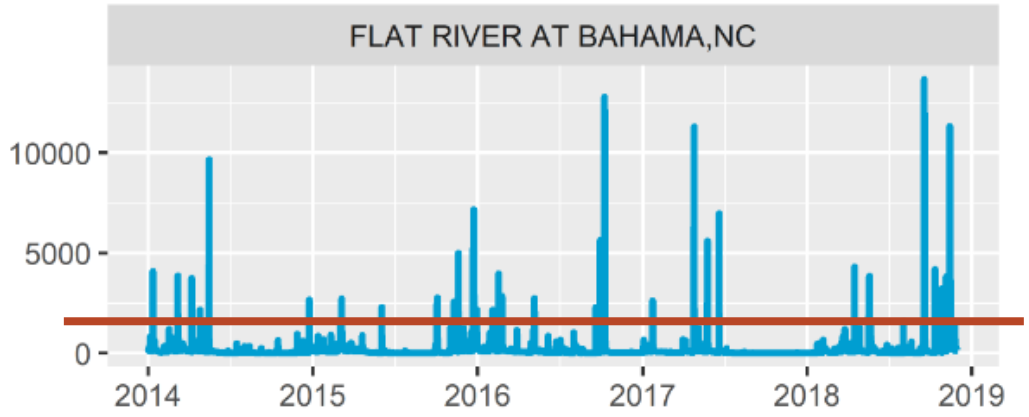
04/25/15: 500-1500 cfs



Field Measurements during Previous 20 Years (black diamonds) and Rating Curve for USGS Gage 02085500

Flat River upstream of Lake Michie: 6-hr Flows, Cubic Feet Per Second,





- The recent modeling period included USGS flow estimates
  - 15-minute flows up to 14,600 cfs
  - 6-hr averaged flows up to 13,700 cfs
- Beyond approximately 1,360 cfs, flows at Flat River at Bahama are extrapolated beyond the recent field measurement data.
- **The model does not simulate flows that match the flow estimates, even if the watershed is simulated as 100 percent impervious (i.e., all pavement)**
- For model calibration, recorded flows above 1,400 cfs were omitted

Flat River upstream of Lake Michie: Calibration

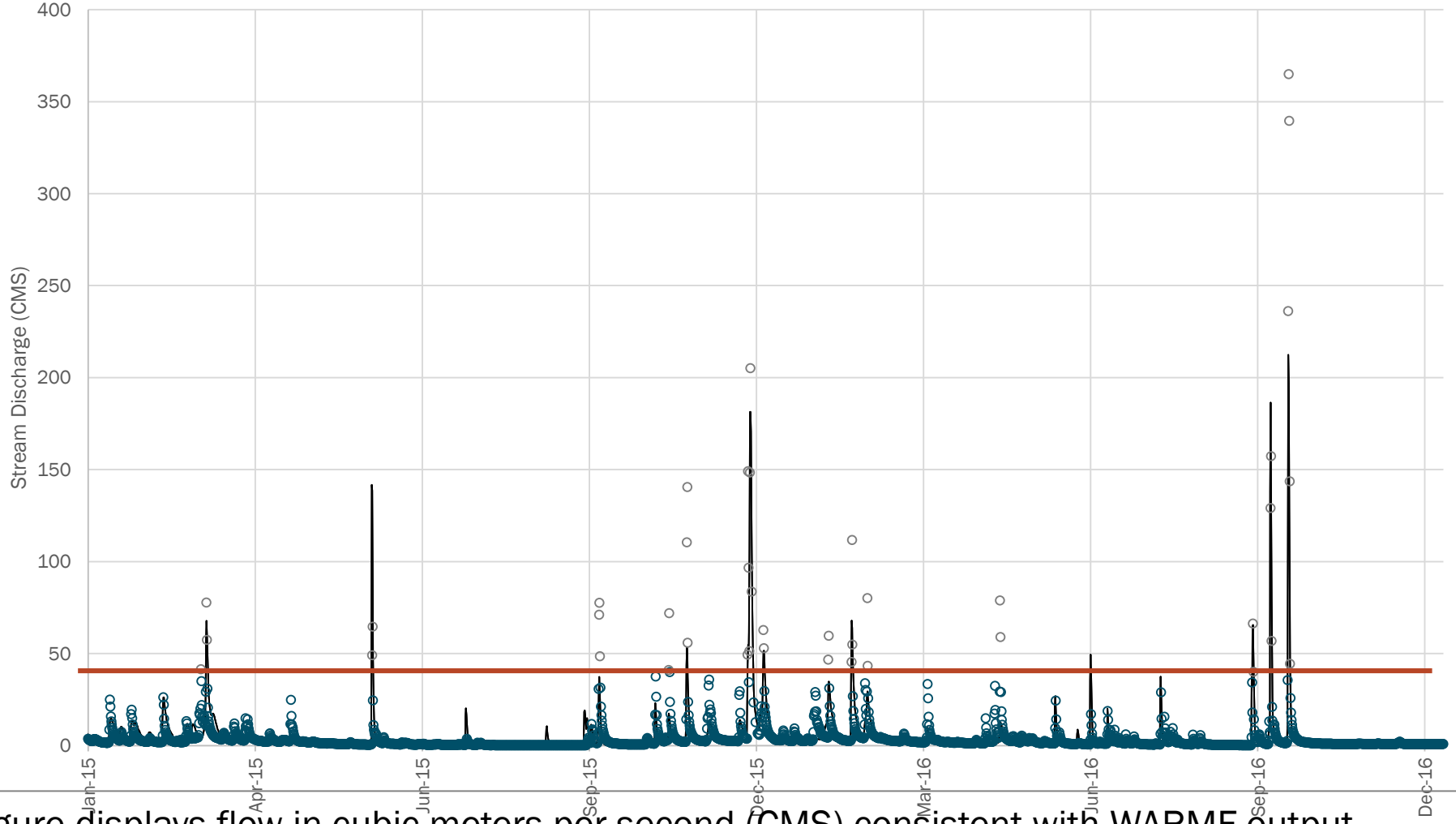


Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Flat River upstream of Lake Michie: Calibration

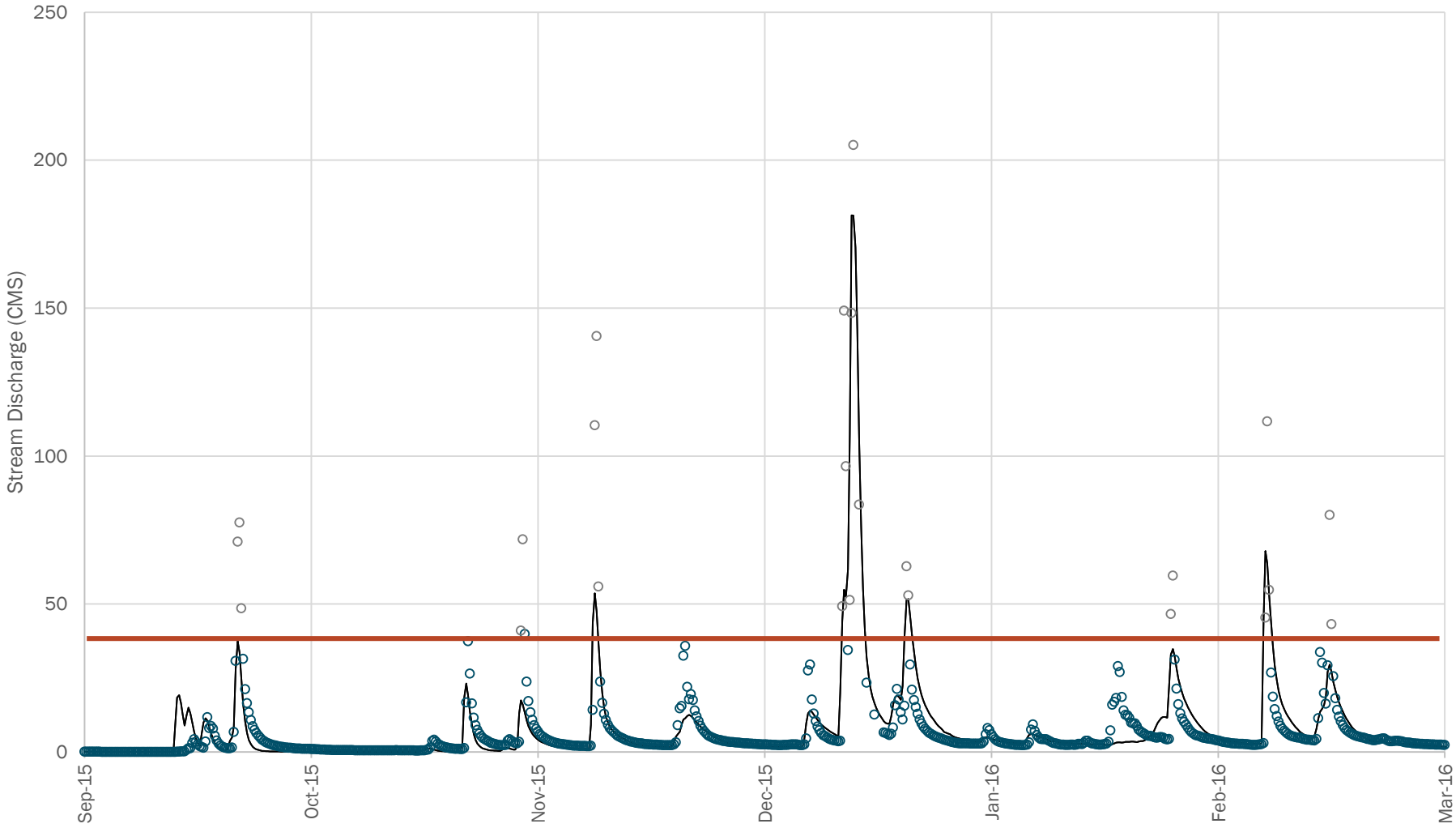
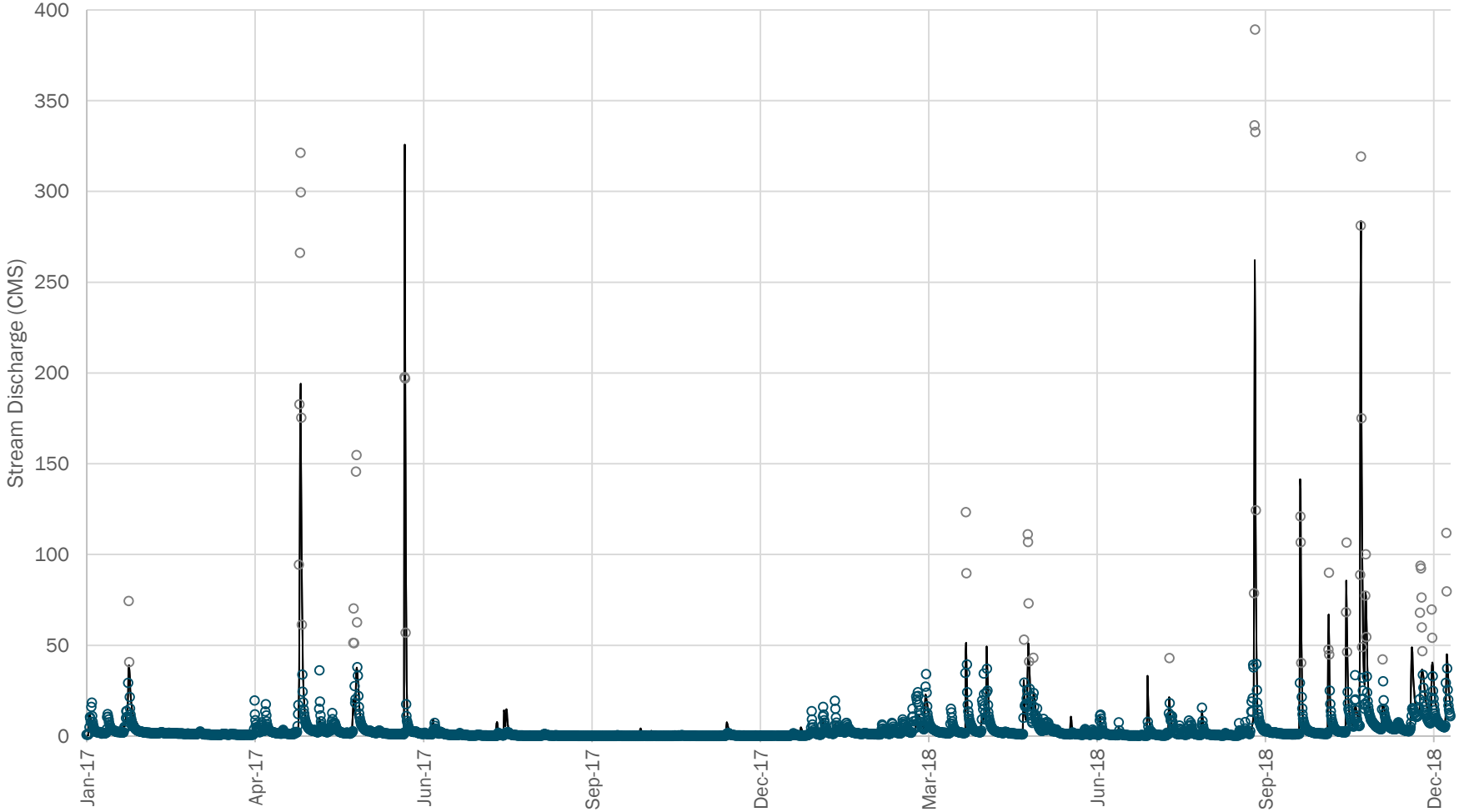


Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Flat River upstream of Lake Michie: Validation



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Flat River upstream of Lake Michie: Validation

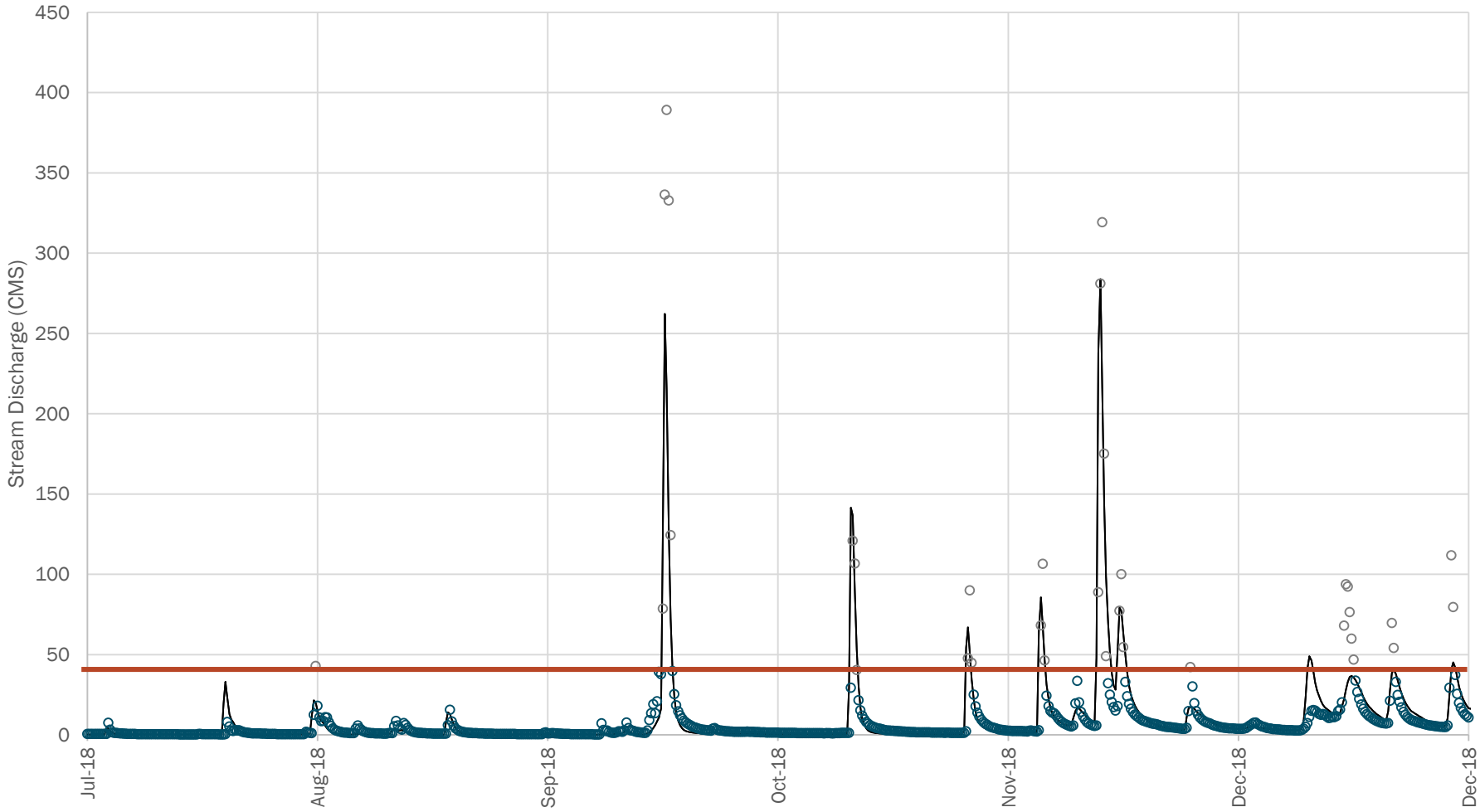


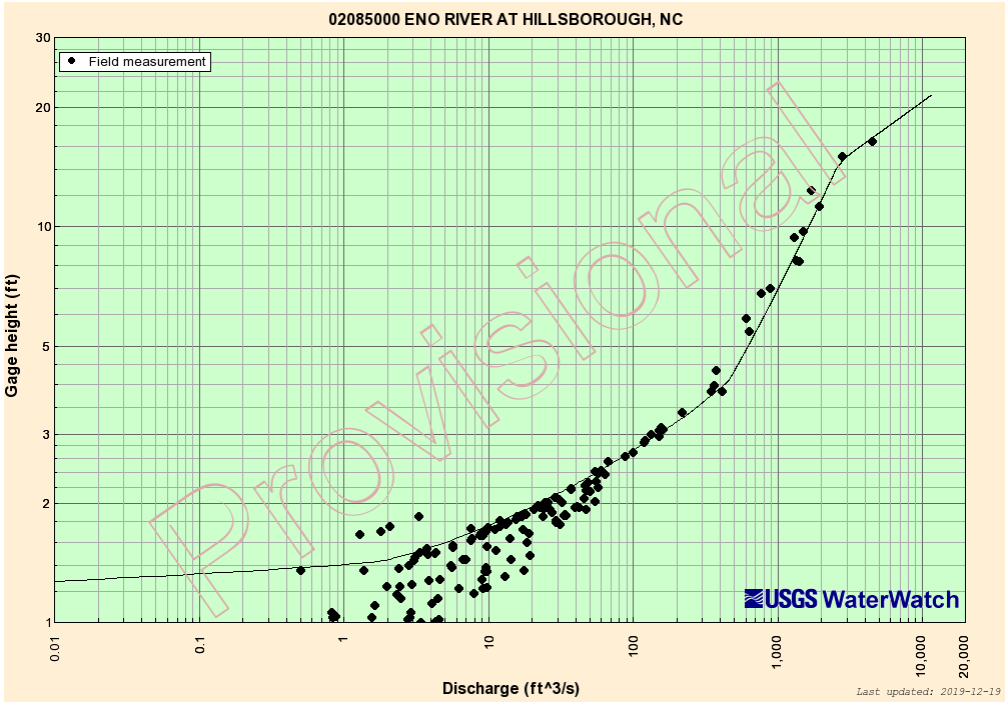
Figure displays flow in cubic meters per second (CMS) consistent with WARMF output

Flat River upstream of Lake Michie: Performance Criteria

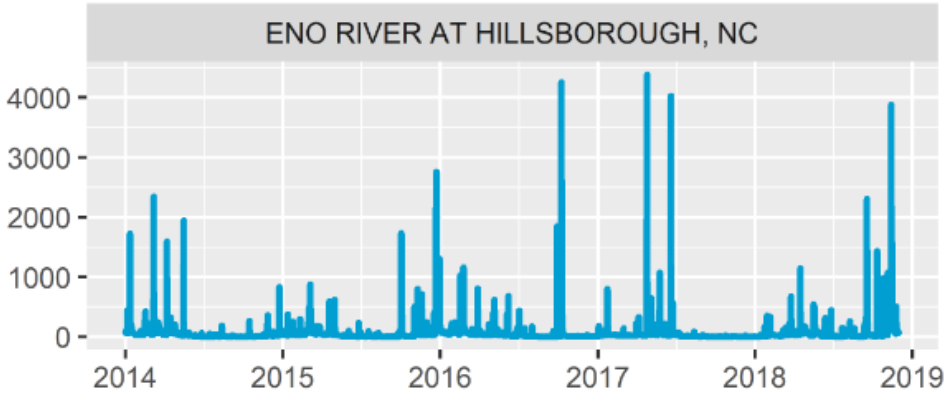
	Time Period					
	Calibration (2015-2016)		Validation (2017-2018)		Complete (2015-2018)	
	Statistic	Interpretation (QAPP)	Statistic	Interpretation (QAPP)	Statistic	Interpretation (QAPP)
Observed Median Discharge	1.730		1.340		1.485	
Observed 90th Percentile Discharge	6.493		7.782		7.226	
Simulation Error:						
Total Volume	3.8%	Very Good	3.2%	Very Good	3.5%	Very Good
Peak Flow	-5.5%	Very Good	7.1%	Very Good	0.7%	Very Good
High Flow	4.3%	Very Good	4.1%	Very Good	4.1%	Very Good
Low Flow	-0.1%	Very Good	-6.2%	Very Good	-1.4%	Very Good
Winter	30.9%	Fair	21.5%	Good	27.0%	Good
Spring	-28.3%	Good	-17.0%	Good	-21.9%	Good
Summer	6.6%	Very Good	20.0%	Good	13.2%	Very Good
Fall	-2.8%	Very Good	7.1%	Very Good	2.4%	Very Good

Rating Curves for Other Gages Used for Model Calibration

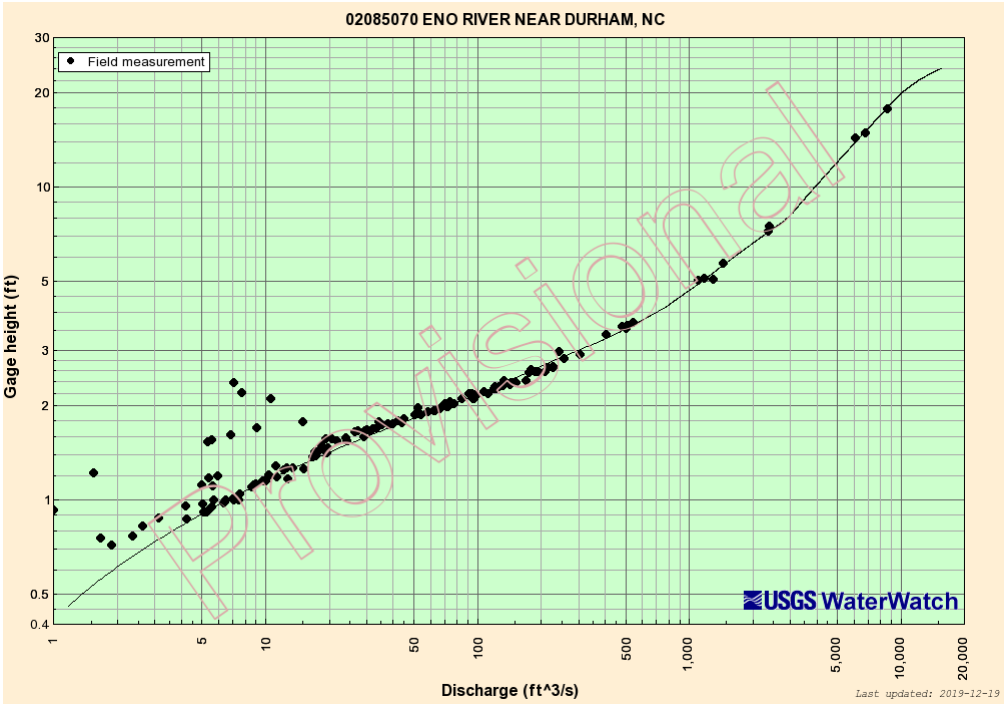
Rating Curve for Eno River at Hillsborough



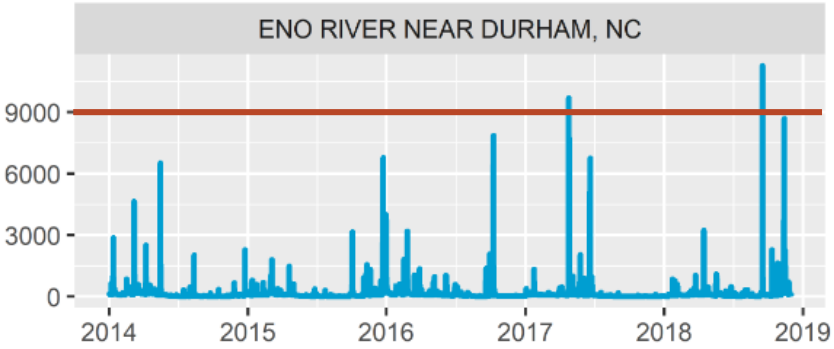
- At Hillsborough, estimated flows up to 4,500 cfs are well represented by field measurements collected in the past 20 years.
- This generally covers flows observed during the recent modeling period.



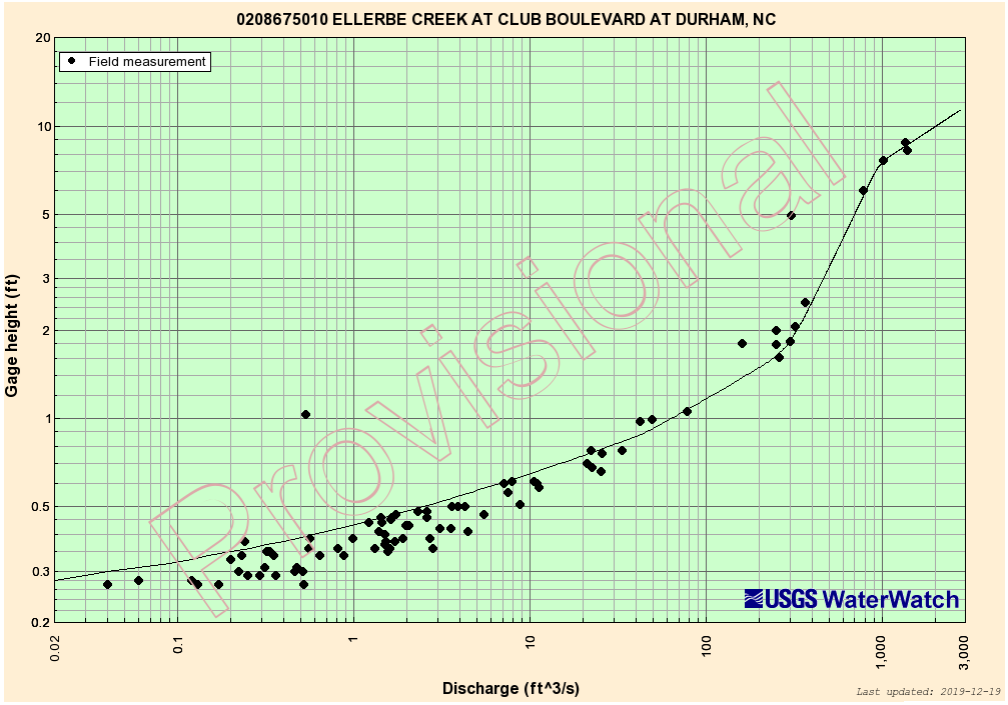
Rating Curve for Eno River Near Durham



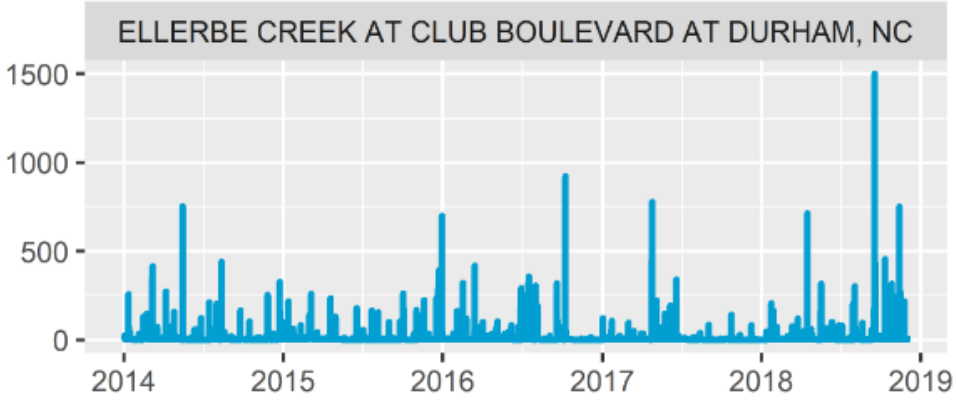
- Near Durham, estimated flows up to 9,000 cfs are well represented by field measurements collected in the past 20 years.
- This generally covers flows observed during the recent modeling period though there are some exceedances.



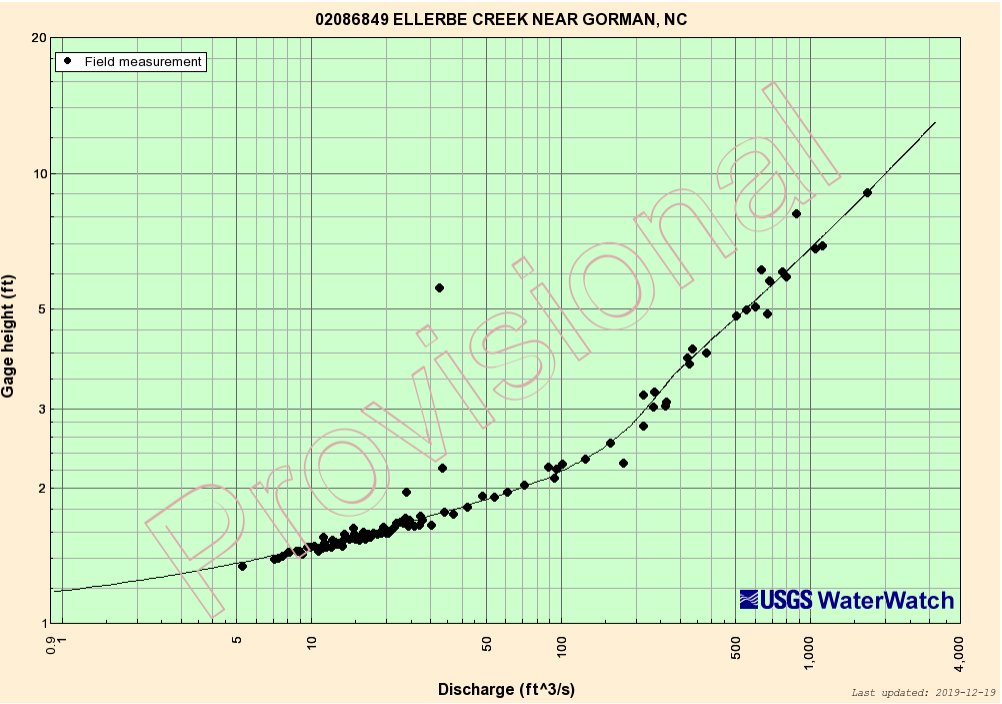
Rating Curve for Ellerbe Creek at Durham



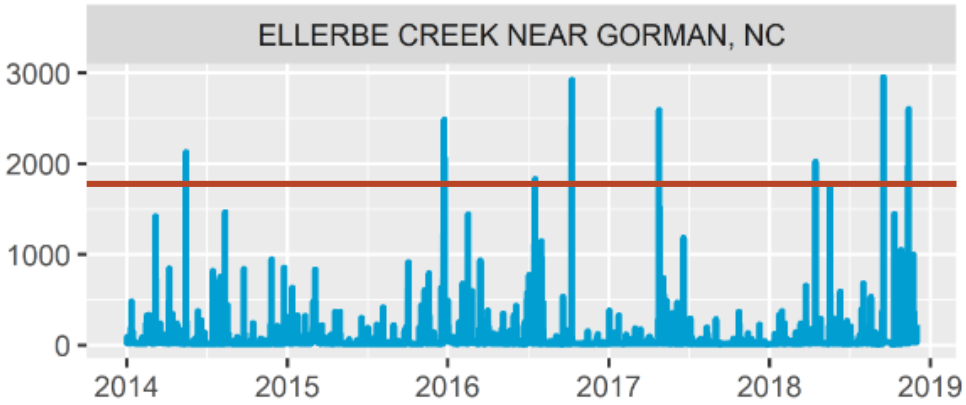
- Estimated flows up to 1,500 cfs are represented by field measurements collected in the past 20 years.
- This covers the range of 6-hr flows observed during the recent modeling period.



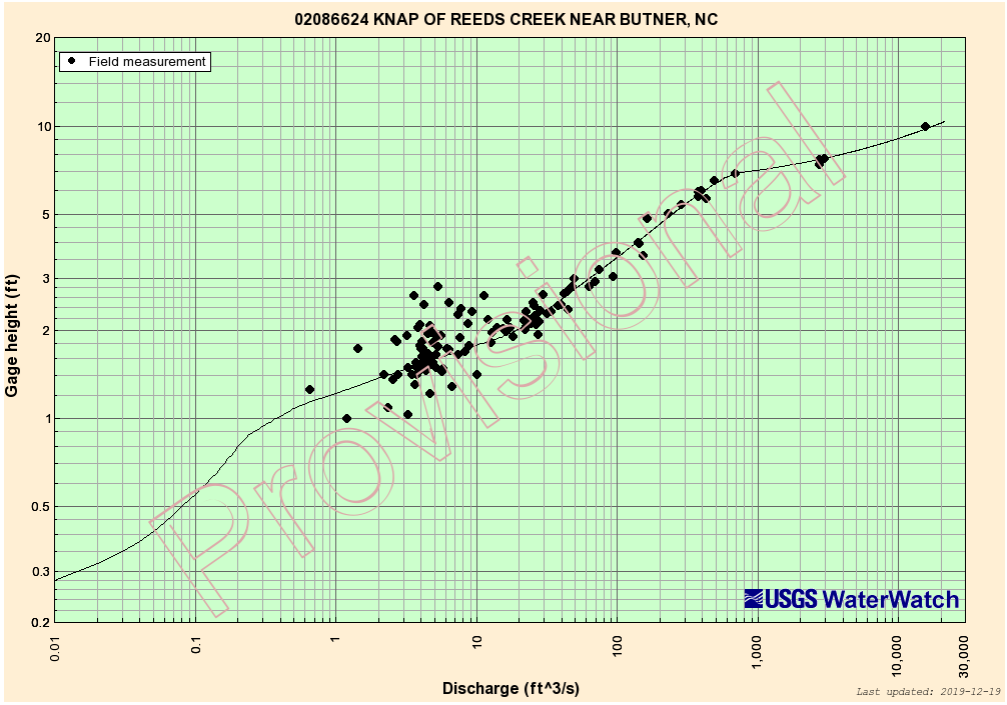
Rating Curve for Ellerbe Creek Near Gorman

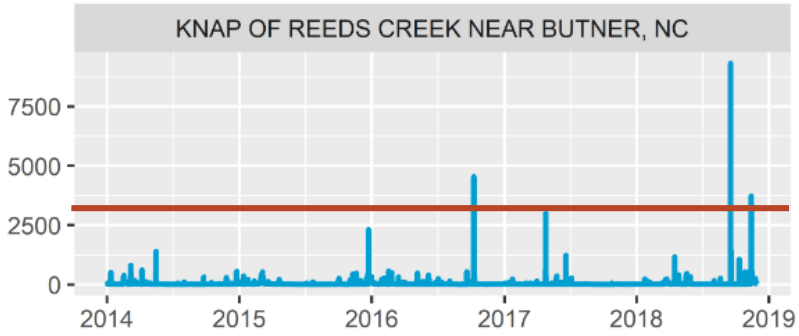


- Estimated flows up to 1,700 cfs are represented by field measurements collected in the past 20 years.
- There are several exceedances of 6-hr flows observed during the recent modeling period.
- Flows above 1,700 cfs may be omitted for the purposes of calibration (in progress).



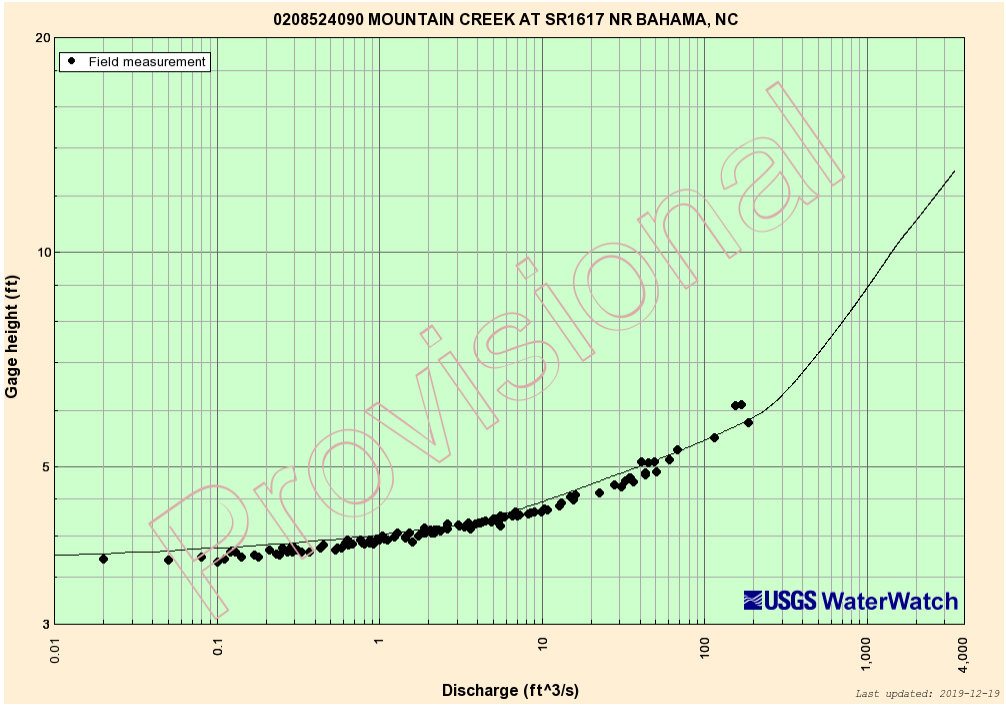
Rating Curves at Knap of Reeds Creek Gage

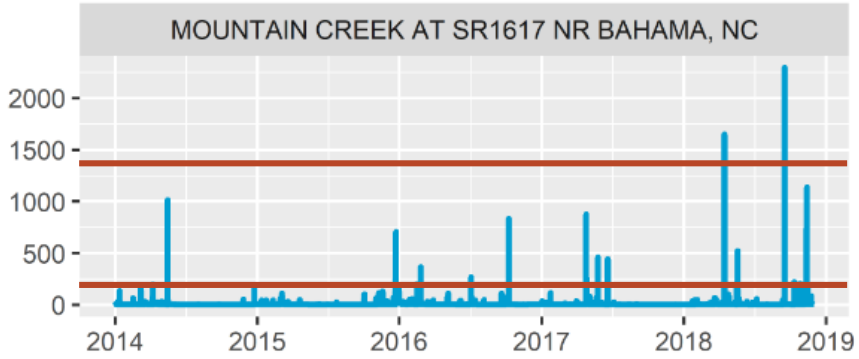




- Estimated flows up to 15,500 cfs are represented by field measurements collected in the past 20 years (this gage is downstream of the SGWASA WWTP).
- Highest flow measurement (15,500 cfs) was collected in 2018 and rated poor.
- The next highest was 3,300 cfs; also rated poor.
- The highest flow measurement rated fair was 2,950 cfs collected in 2018.
- Flows above 3,000 cfs may be omitted for the purpose of model calibration (in progress).

Rating Curve at Mountain Creek Gage

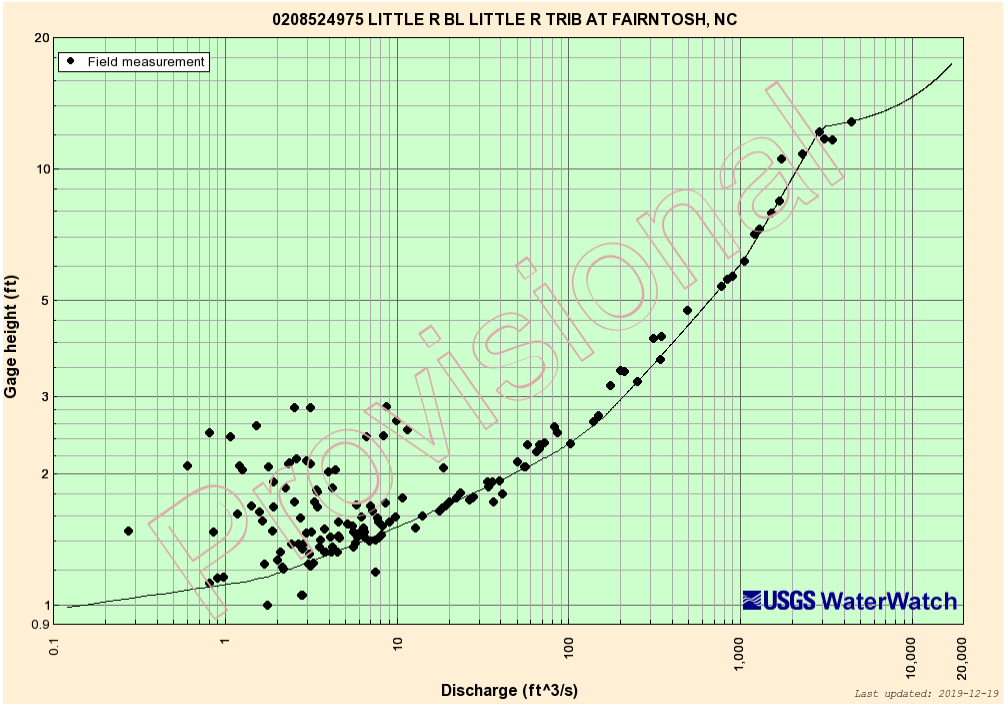


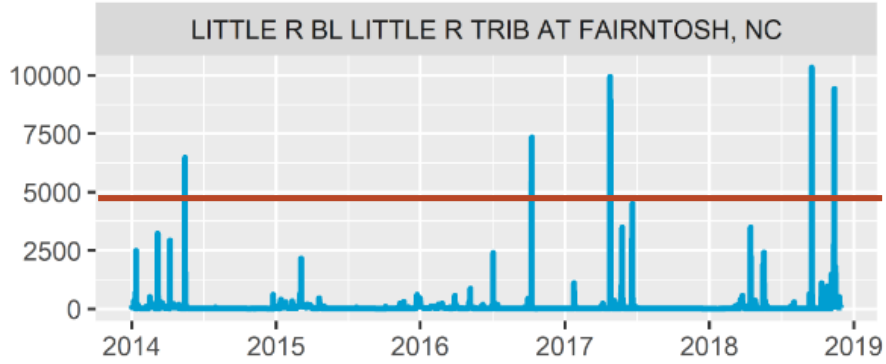


- Estimated flows up to 185 cfs are represented by field measurements collected in the past 20 years.
- Measurement up to 1,880 cfs was recorded in 1996, but the rating for the measurement was poor
- A measurement in 1995 of 1,430 cfs was recorded and rated fair.
- The third highest measurement was 185 cfs in 2017.
- Model calibration may omit flows greater than 200 cfs (or 1,430 cfs) for the comparison of simulated to observed flows (in progress).

Rating Curves for Gages Used to Estimate Releases from Impoundments

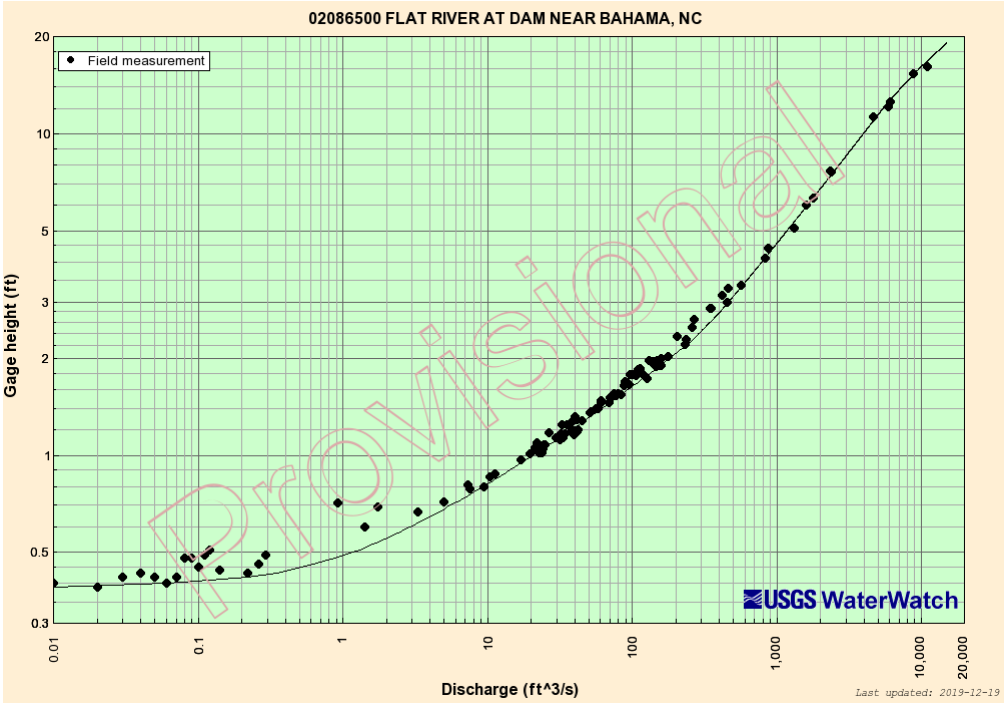
Rating Curve at Little River Below LRR



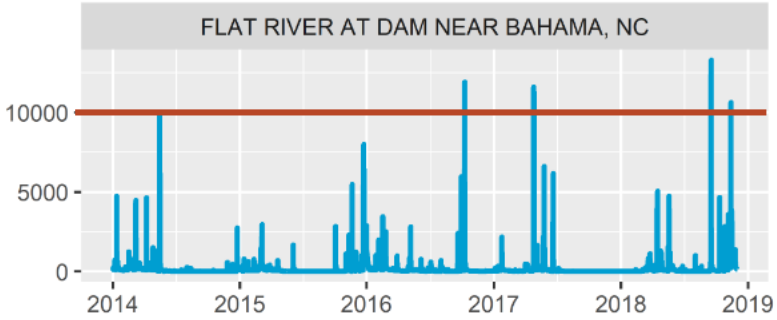


- Estimated flows greater than 4,440 cfs are not represented by field measurements collected in the past 20 years.
- Flows of 10,900 cfs and 16,600 cfs were collected in 1998 and 1996 respectively with ratings of fair.
- Flows above 4,500 cfs may be omitted (gage is used to estimate releases from LRR).

Rating Curves for Flat River below Lake Michie



- Estimated flows up to 10,000 cfs are represented by field measurements collected in the past 20 years.
- 6-hr average flows exceed this level in the recent modeling period.
- Flows above 10,000 cfs may be omitted (gage is used to estimate releases from Lake Michie).



Other Items

319 Grant Application Process for Custom Model Code Development

- Modeling Team sent a description of the scope of work and budget to DWR to begin the EPA pre-approval process
  - Initial draft provided December 10, 2019
  - Revised draft provided December 20, 2019
- DWR submit the pre-application to EPA on December 20, 2019
- If successful, the formal application will be submitted for $23,500 grant
- Application requires a minimum 40 percent match
  - Task 321 (Modeling Linkages and Testing) of the UNRBA Modeling and Regulatory Support Contract with Brown and Caldwell could be used as the match for this project. The fee associated with Task 321 is $43,584
  - Board would need to authorize use of this task for the match; UNRBA would need to ensure these funds were not used for other matches

Additional SME for Statistical Modeling

- Ken Reckhow has requested technical support for the statistical modeling from Dr. Ashton Drew
- Per the contract between the UNRBA and Brown and Caldwell, the Executive Director must approve any changes to the Project Team
  - Approval of expanded statistical modeling team by the Executive Director in December 2019

Core Competencies:

- Integrate data, knowledge, and values in data visualizations and statistical models with R
- Design adaptive management and monitoring solutions for complex and complicated systems
- Model systems to identify optimal management decisions given available resources and uncertainty

Education:

Beloit College, WI	Environmental Biology	BA 1995
Dalhousie University, NS	Marine Management	MMM 1996
North Carolina State University, NC	Marine Biology	PhD 2006
North Carolina State University, NC	Landscape Ecology	Post-doc 2006-11

Re-examination MOA with DWR

- Authorizing Legislation: Session Law 2010-155
- UNRBA is drafting definitions for the draft MOA for submittal to DEQ
- Additional items to consider
  - Agency review time (DWR/EPA), point of contact, milestones
  - Upper versus lower – potential silos
  - Expectations for DWR to provide comments throughout the process, not just formal submissions
  - Third party reviewers
  - Education of the EMC / UNRBA presentation of re-examination findings to the EMC
  - Conflict resolution, agency level

Closing Comments
Additional Discussion