Modeling and Regulatory Support Project
Year Three: Anticipating Stakeholders' Uses for the Modeling Results
Wednesday, October 24, 2018
9:00 AM – 12:30 PM
Butner Town Hall Multi-Purpose Room

Meeting Agenda

9:00 Convene

9:15 Overview of UNRBA Modeling and Regulatory Support Project

9:45 Overview of Project Status

10:45 How Stakeholders Will Use the Modeling Results

11:30 Rapid Report Outs

12:25 Next Steps in Modeling and Regulatory Support

12:30 Adjourn

UNRBA Fall 2018 Stakeholder Meeting

MRS Project
Status Update

October 24, 2018

Brown AND Caldwell

SYSTECH WATER RESOURCES

Dynamic Solutions LLC

Goals of Stakeholder Meeting

Attendees understand UNRBA's Modeling and Regulatory Support project

- Progress made so far
- Current activities
- Future milestones

UNRBA understands how attendees will use the modeling results

- Desired outputs
- Resolution
- Applications

Agenda

Present background information	• Falls Lake Nutrient Management Strategy • Re-examination
Share progress on modeling	• Data collection • Model setup
Hear from stakeholders	• Data sources • Uses of model results

Ground Rules

- Begin and end on time
- One speaker at a time
- Share the time available for speaking
- Stick to the tasks and topics that are on the agenda
- Listen attentively to each other
- It is OK to disagree with each other…
  please do so respectfully

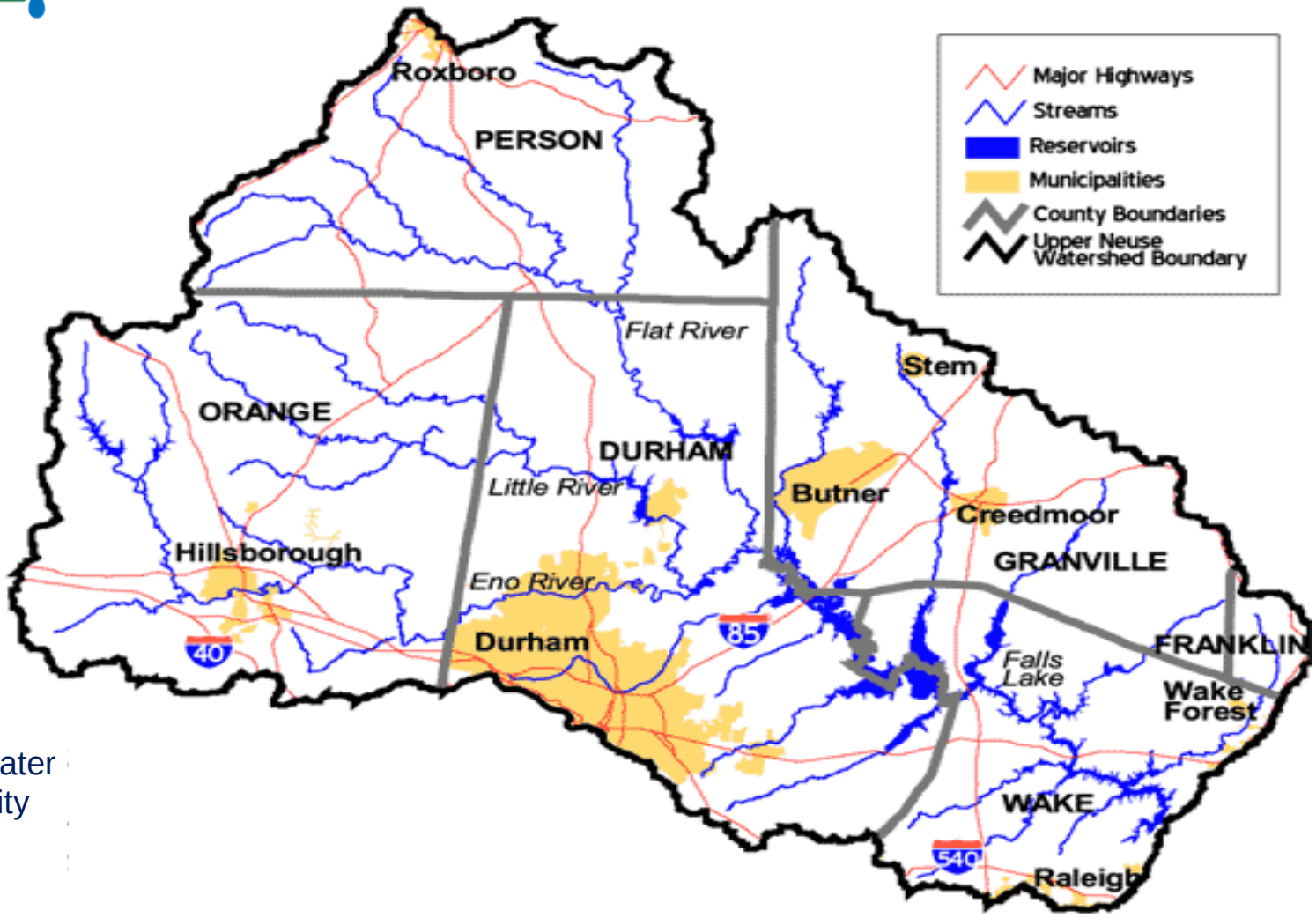
Background Information

Municipalities
Butner
Creedmoor
Durham
Hillsborough
Raleigh
Stem
Wake Forest

Counties
Durham
Franklin
Granville
Orange
Person
Wake

South Granville Water and Sewer Authority (SGWASA)

Soil and Water Conservation Districts (Ex Officio)

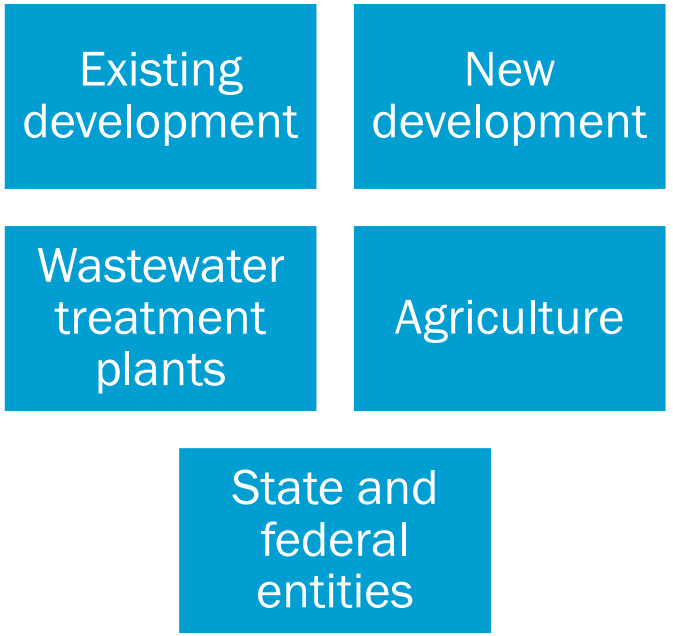


Falls Lake Challenges and the UNRBA

- Falls Lake is a valuable, regional resource
  - Provides drinking water for 550,000 customers
  - Regional recreational facility
  - Provides habitat to aquatic and terrestrial wildlife
  - Protects water quality downstream
- Exceedances of the 40 µg/L chlorophyll a standard resulted in the lake being listed as impaired and development of a nutrient management strategy

Falls Lake Nutrient Management Strategy

- Developed by the Division of Water Resources
- Passed by the Environmental Management Commission in 2010
- Assigns load reduction targets for individual sectors
- Includes the highest nutrient reductions ever passed in NC
- Very expensive to implement



Uncertainties and Questions

- Insufficient time for DWR to collect data and build models
- Baseline year for the rules was during a major drought and affected by a large tropical storm
- Reservoir of nutrients stored in the bottom of Falls Lake and how long it would take to deplete
- Whether not the chlorophyll *a* standard could be met everywhere in the lake
- What would happen if the entire watershed was forested

Falls Lake at I-85 in November 2007
Source: Southeast Regional Climate Center

Consensus Principles

- Consensus Principles were established by UNRBA members
  - Resulted in language in the Rules that allowed for re-examination if certain steps were taken
  - Provided the framework for the UNRBA re-examination process
  - Parties agreed to the protection of Falls Lake as a drinking water supply

Rule Language: Re-examination

- **“Recognizing the uncertainty** associated with model-based load reduction targets…a person may at any time during implementation of the Falls nutrient strategy develop and submit for Commission approval **supplemental nutrient response modeling**” requiring
  - Division review and approval of any **monitoring study plan** and **description of the modeling framework**
  - A minimum of **three years** of lake water quality data
  - Supplemental modeling is conducted in accordance with the **quality assurance requirements** of the Division

UNRBA PLAN FOR THE REEXAMINATION

Coordination with agencies and stakeholders

2010

Falls Lake Strategy is passed ✓

Consensus Principles adopted ✓

2011

UNRBA decides to initiate a reexamination of Stage II ✓

2012-2013

UNRBA contracted work to develop a strategy for the Reexamination process

2013-2014

Developed monitoring plan to support Reexamination and obtain DWR approval ✓

2014-2018

Collected monitoring data for 4 years ✓

2018-2021

Revise watershed and lake models; evaluate nutrient management strategies

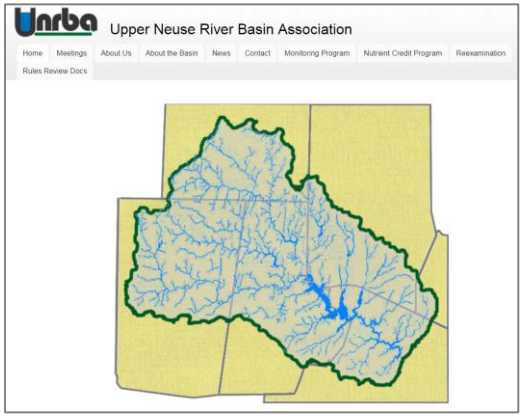
2022-2023

Develop the UNRBA Reexamination package

UNRBA Monitoring Program Website

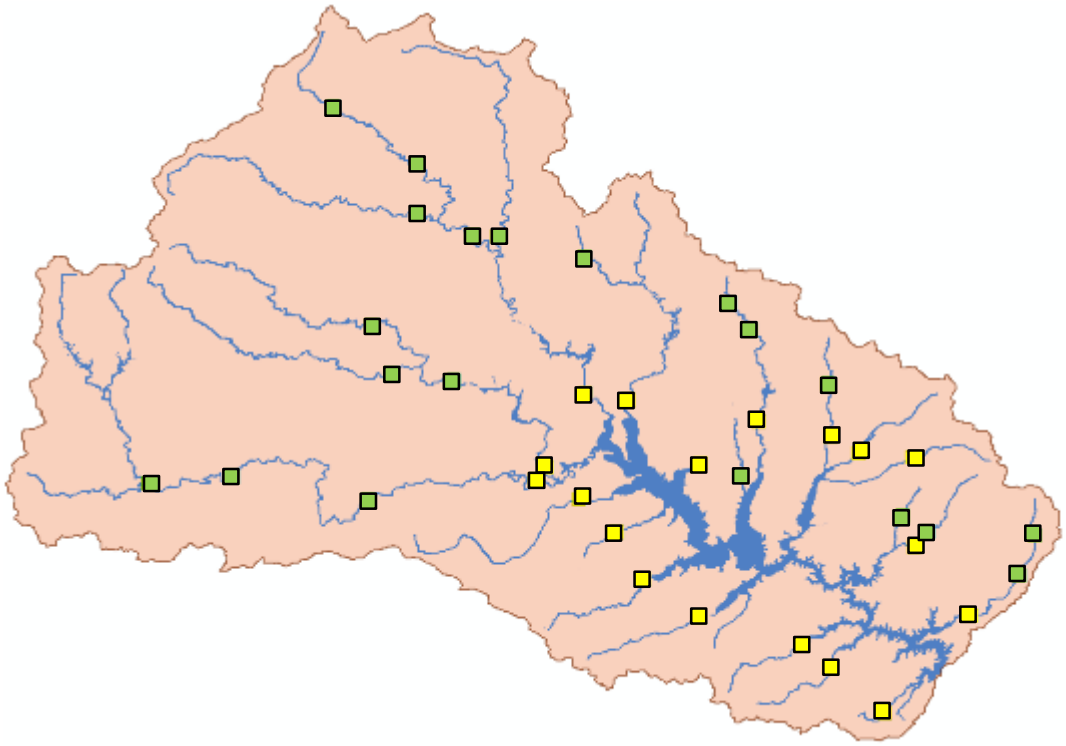
https://www.unrba.org/monitoring-program

- DWR-Approved documents as required by the Falls Lake Rules
  - UNRBA Monitoring Plan
  - UNRBA Monitoring Quality Assurance Project Plan
  - UNRBA Description of the Modeling Framework
- Interim and annual reports that summarize the data collected and provide preliminary analyses
- Link to the UNRBA Monitoring Database and User Documentation
- Study Plans for the Special Studies
- Additional analyses
  - Flow estimation methods
  - Model performance and sensitivity



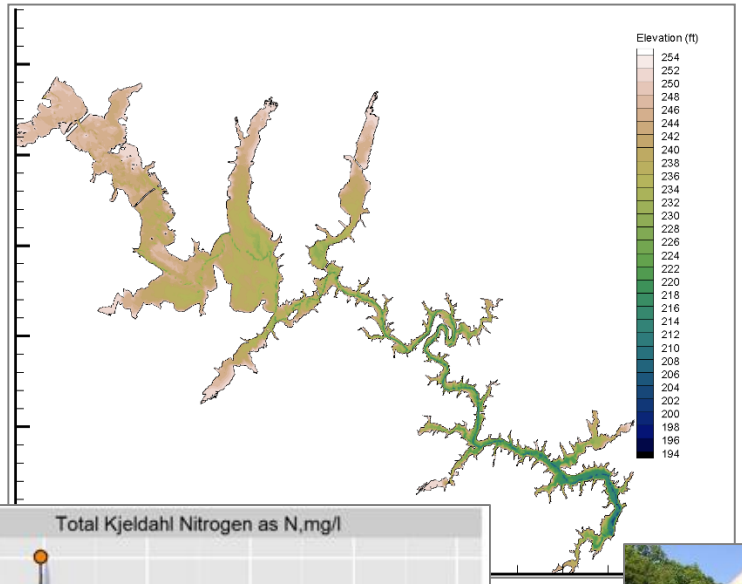
UNRBA Monitoring Program

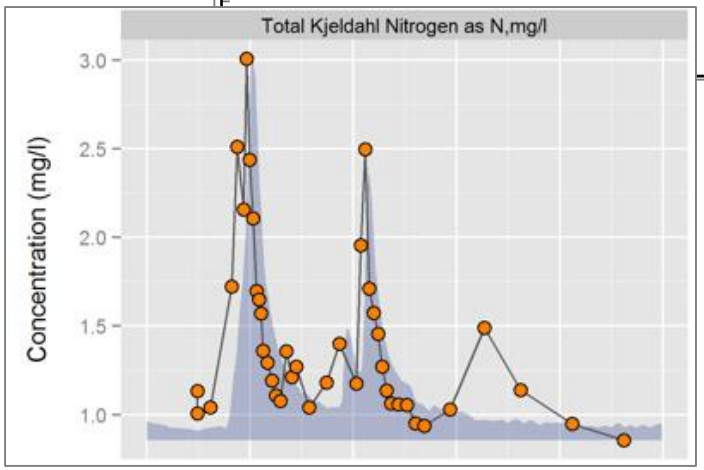
- Developed to support revising the lake and watershed models
- Routine data collection began in August 2014
- 38 watershed stations
- 12 inlake (supplemental data)
- Parameters
  - Field parameters
  - Nutrients
  - Carbon
  - Chlorophyll *a*
- Over 32,500 additional data points as of June 2018



UNRBA Special Studies

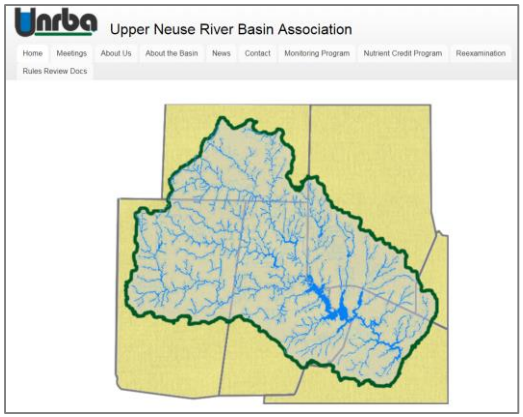
- High flow grab sampling
- Storm event sampling
- Light extinction data
- Lake sediment quality
- Lake bathymetry
- Lake constriction point study
  - Velocity
  - Water Quality





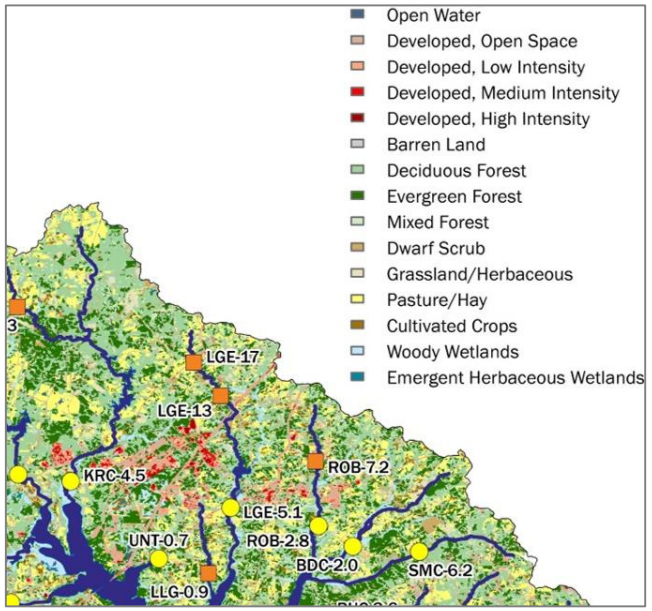
UNRBA Re-examination Program Website

- https://www.unrba.org/reexamination
  - Data Management Plan and Description of the Modeling Process (new)
  - Modeling Quality Assurance Project Plan (Approved by DWR)
  - Stakeholder meeting materials
    - October 2018 (focus on data compilation)
    - October 2017 (focus on watershed modeling)
    - September 2016 (project kickoff/stakeholder concerns)
  - Model selection process
  - Conceptual modeling plan
  - Planning phase of the project (2012 to 2014)
    - Task 1 – Re-examination strategy
    - Task 2 – Review existing data and reports (through 2011)
    - Task 3 – Review methods for estimating nutrient loads
    - Task 4 – Recommend future monitoring and modeling studies ->
      - UNRBA Monitoring Program
      - UNRBA Modeling and Regulatory Support Project

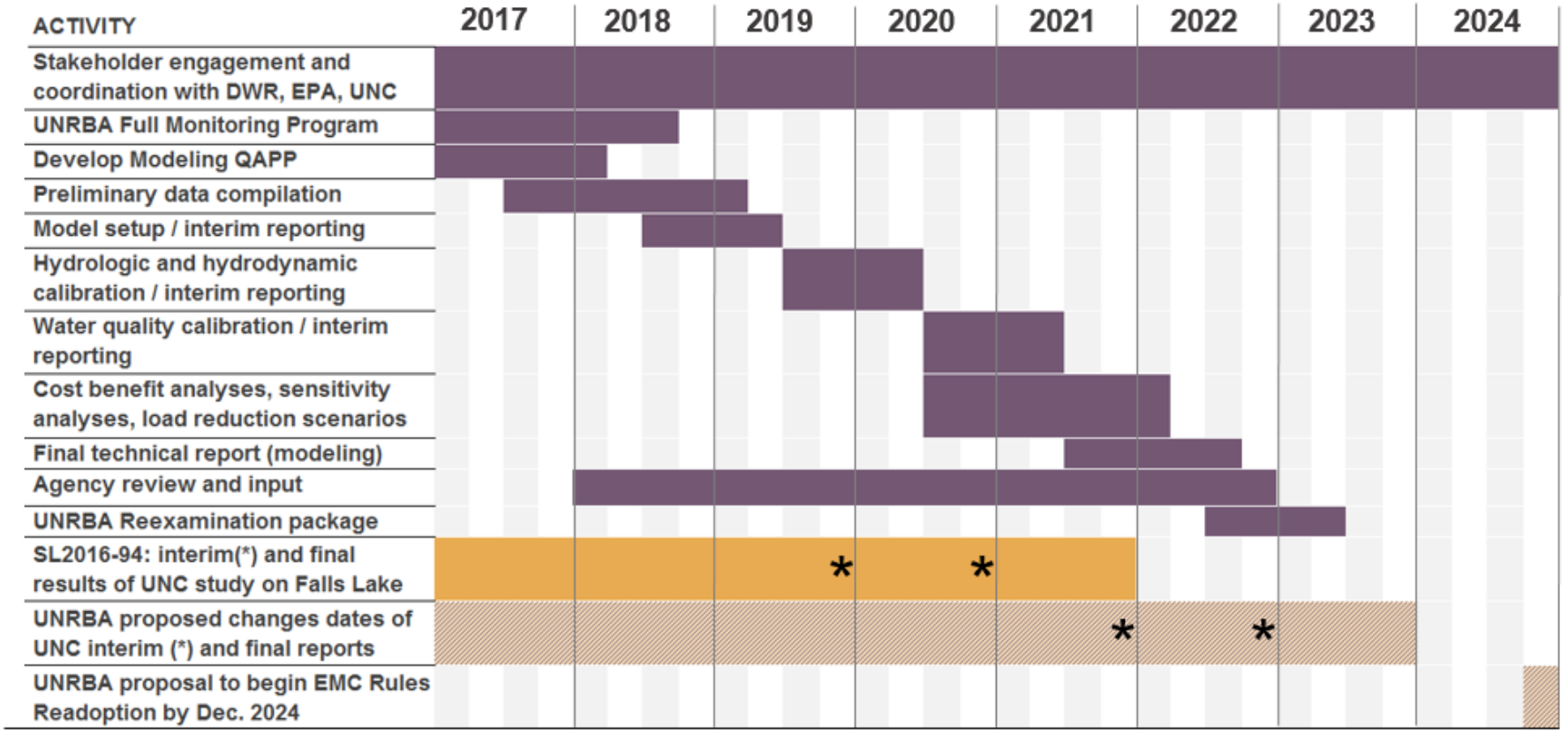


Data Management Plan and Description of the Modeling Process

- Describes the procedures for managing model inputs and outputs
  - Time series
  - Spatial data
- Describes development of the input files
  - WARMF watershed and lake model
  - EFDC lake hydrodynamic/ water quality model
- Describes modeling process



Status of the Project Schedule



Current Focus for the MRS Project

- Set up the models
  - Subwatershed boundaries
  - Lake model grid
- Collect data
- Fill gaps
- Discuss assumptions
- Get stakeholder feedback
- Conduct preliminary model runs

Decisions we make now affect what we can get out of the models later.

Model Overview

Two Model Periods

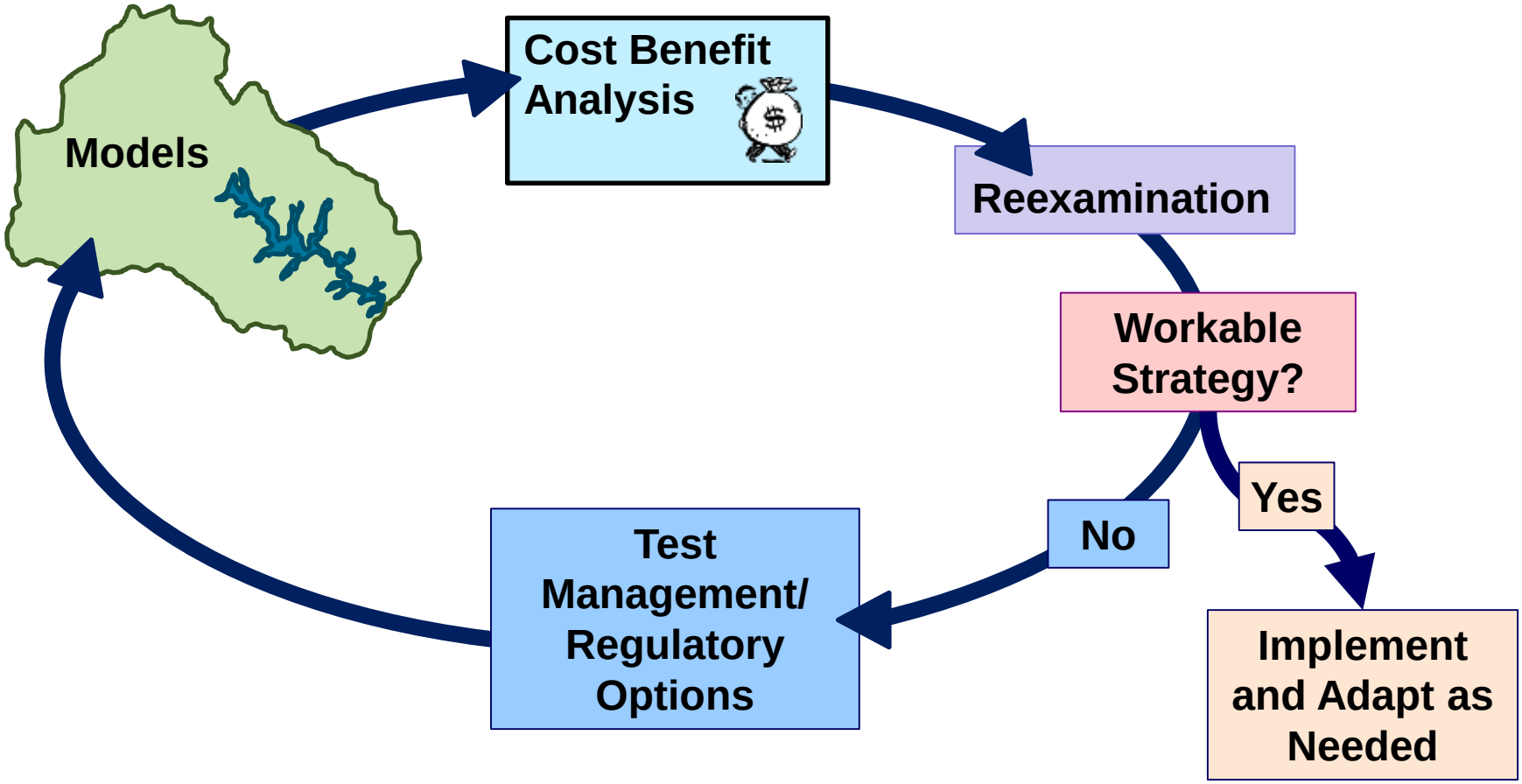
2005 to 2007

- Corresponds to the original modeling period (DWR models)
- Includes the baseline year (2006) that provides the “starting point” for the Stage II load reductions

2014 to 2018

- Corresponds to the UNRBA Monitoring Program
- Incorporates new data and information collected since the original model was developed

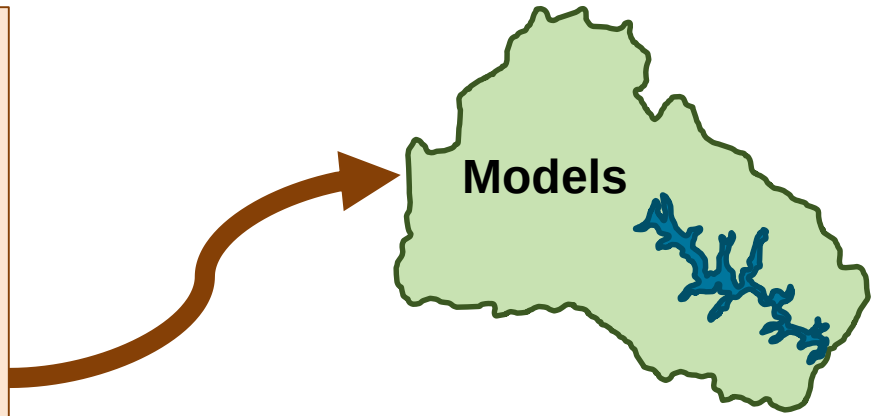
Framework for the Reexamination



Watershed Model

- Watershed Analysis Risk Management Framework (WARMF)
- Uses information about the watershed and weather data to simulate pollutant loading
- Accounts for interactions among land use, soils, and land management
- Develop and calibrate to flow and water quality data collected in the watershed
- Use the calibrated model to predict loading to Falls Lake
- Run scenarios to see how management activities affect loading

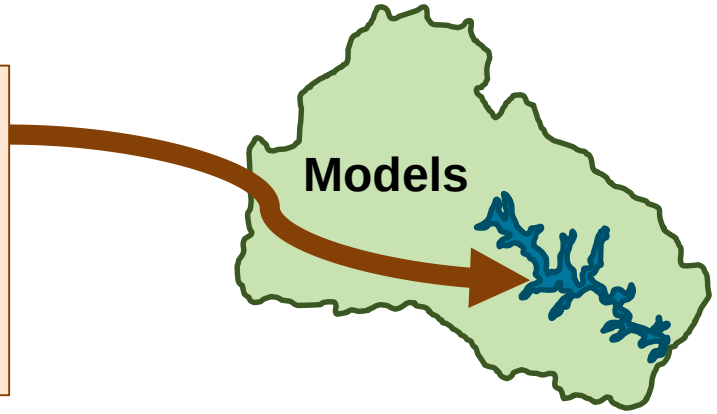
Inputs:
- **Atmosphere/weather**
- **Soils**
- **Land use**
- **Topography**
- **Wastewater**
- **Streams**
- **Lakes**
- **Management practices**



Lake Modeling

- Environmental Fluid Dynamics Code (EFDC), WARMF, and a statistical model (to be discussed at subsequent meeting)
- Simulated flows and pollutant loads from the watershed model become inputs to the lake models
- EFDC and WARMF use similar datasets in terms of weather data and atmospheric deposition to the lake surface
- Develop and calibrate EFDC and WARMF to water levels and water quality observed in the lake
- Use the calibrated model to run scenarios and simulate how management activities affect concentrations in the lake

Inputs:
- **Flows and loading to the lake**
- **Atmosphere/weather**
- **Bathymetry**
- **Management practices**



Cost Benefit Analyses

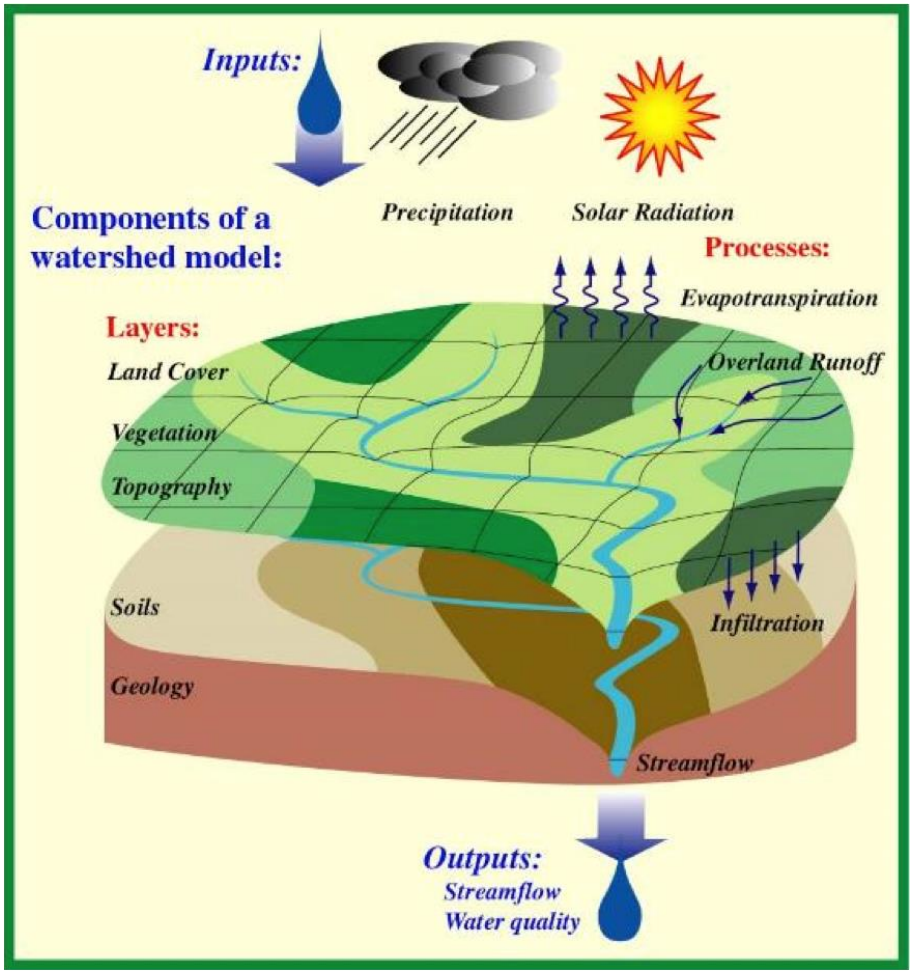
- Use the WARMF and EFDC models to evaluate how management actions affect
  - Nutrient loading to the lake
  - In lake water quality
- Use the statistical model to link water quality to designated uses and evaluate
  - Impacts to recreational use and water treatment costs
  - Risks of hazardous algal blooms, taste and odor problems, and violations of drinking water standards
- Compile data on management costs and constraints to evaluate feasibility
- Weigh the costs, benefits, and likelihood of success associated with potential management options
- Provide transparency for decision making

Cost Benefit Analysis

Meteorological Data

Importance of Accurate Meteorology Data

- Meteorology data is the principal driver of the WARMF model
  - Rainfall -> Runoff or Infiltration -> Pollutant Loading
- Complete time series are required for several parameters
- Data is spatially variable
- Time series for sites distributed across the watershed will be essential

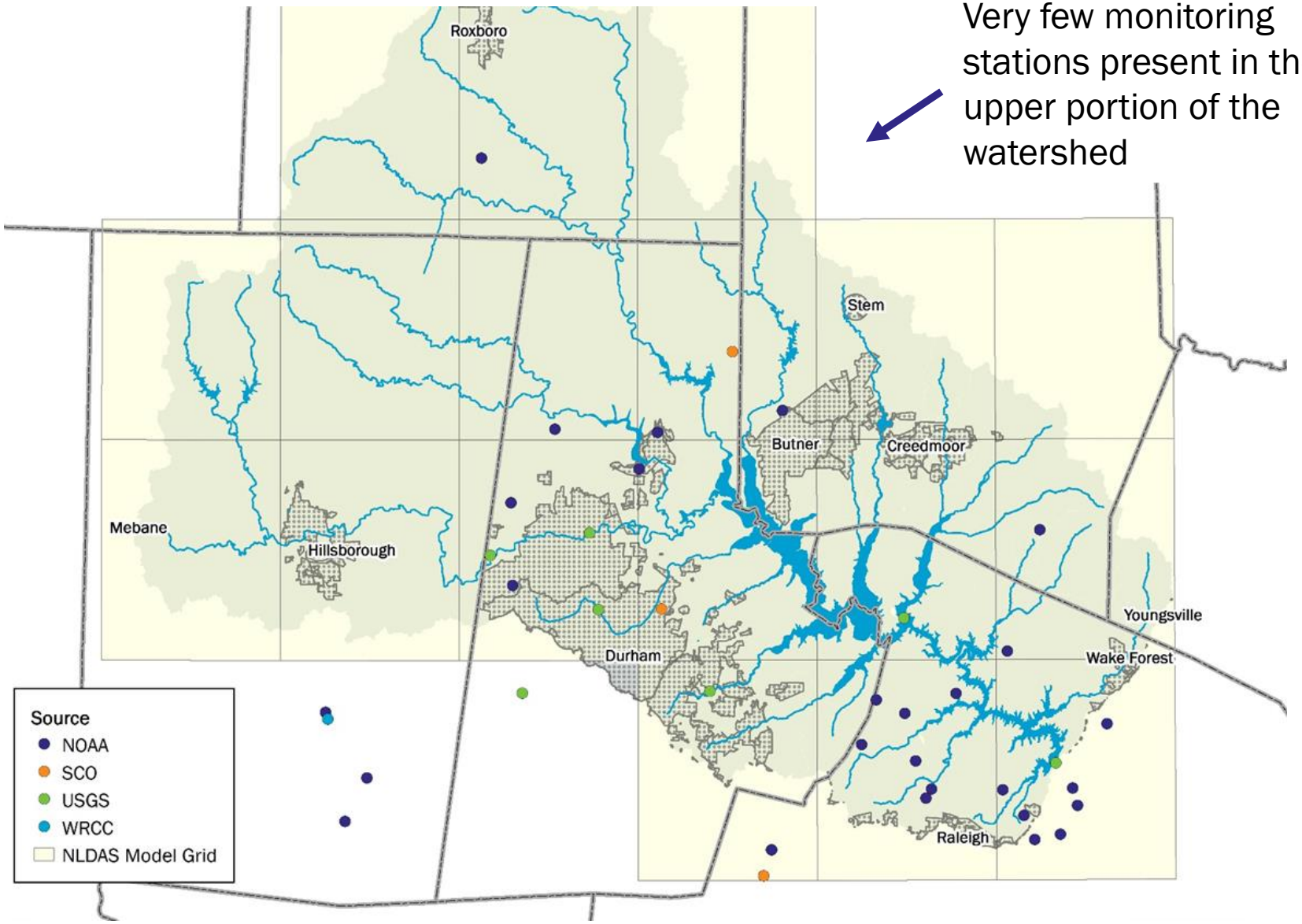


https://scwrs.files.wordpress.com/2016/04/model-components.png

Sources of Meteorology Data for the Modeling

- NC CRONOS/ECONet
  - Database developed by the State Climate Office of North Carolina
- USGS
- Western Regional Climate Center (WRCC)
- National Climatic Data Center (NCDC)
  - Clearinghouse for weather measurements collected by various organizations across the US including NOAA
- North American Land Data Assimilation System (NLDAS)
  - Spatially and temporally consistent, land-surface model (LSM) datasets from the best available observations and model output
  - Higher spatial resolution than other datasets
- NEXRAD Radar Data
  - NOAA data that can be processed to generate precipitation estimates
  - Highest spatial resolution for precipitation data

Locations of Weather Data Sources

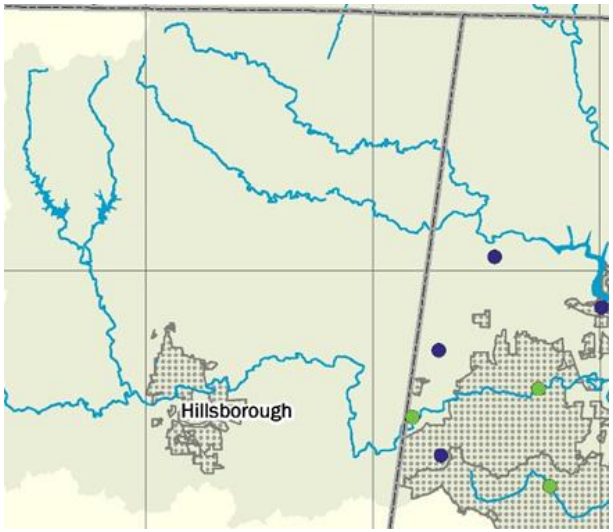


NEXRAD Precipitation Data

- NOAA operates the Next Generation Weather Radar (NEXRAD) system
- Comprised of 160 regional radar sites in the US
- **NC DOT and the State Climate Office have offered to generate time series files for this effort once the watershed modeling units are finalized with the Modeling and Regulatory Support Workgroup**

National Land Data Assimilation System (NLDAS) Data

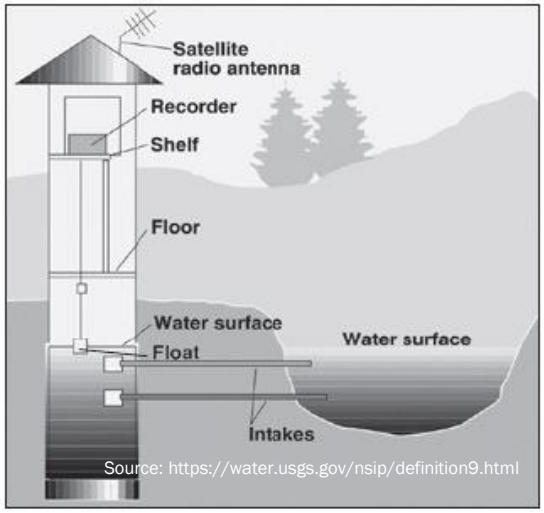
- NLDAS uses remote sensing data to provide meteorology data
- Values are provided for grids cells that are approximately 7 miles by 8.6 miles in area
- Provides data for areas of the watershed that do not have weather monitoring stations
- Provides the parameters needed for the WARMF watershed model
- Modeling team is evaluating these data against measured data for applicability to this modeling effort
  - Accuracy
  - Bias
  - Corrections



USGS Data: Flow and Water Levels

Importance of USGS Data

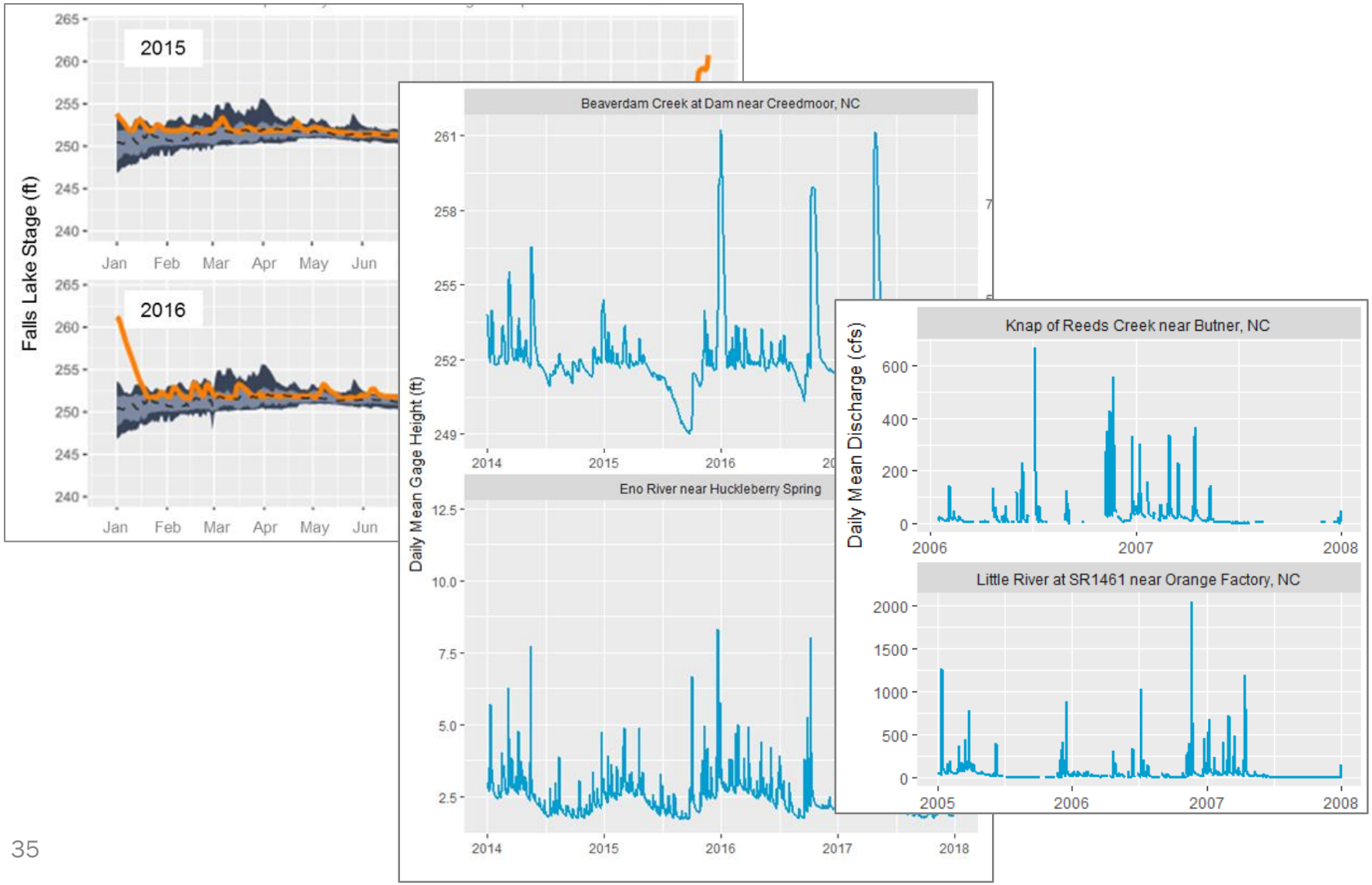
- Provides stream flow, stream elevation, and lake elevation data at different stations in the watershed
- Data will primarily be used to calibrate the watershed model (stream flows in the watershed) and the lake hydrodynamic model (water surface elevation)
- Accurate hydrologic and hydrodynamic calibrations are essential for
  - Estimating flows and nutrient loads to Falls Lake
  - Apportioning loads among sources
  - Simulating lake response in terms of nutrients and algal growth
- Model parameters are adjusted and model output is compared to observations until a good fit is achieved



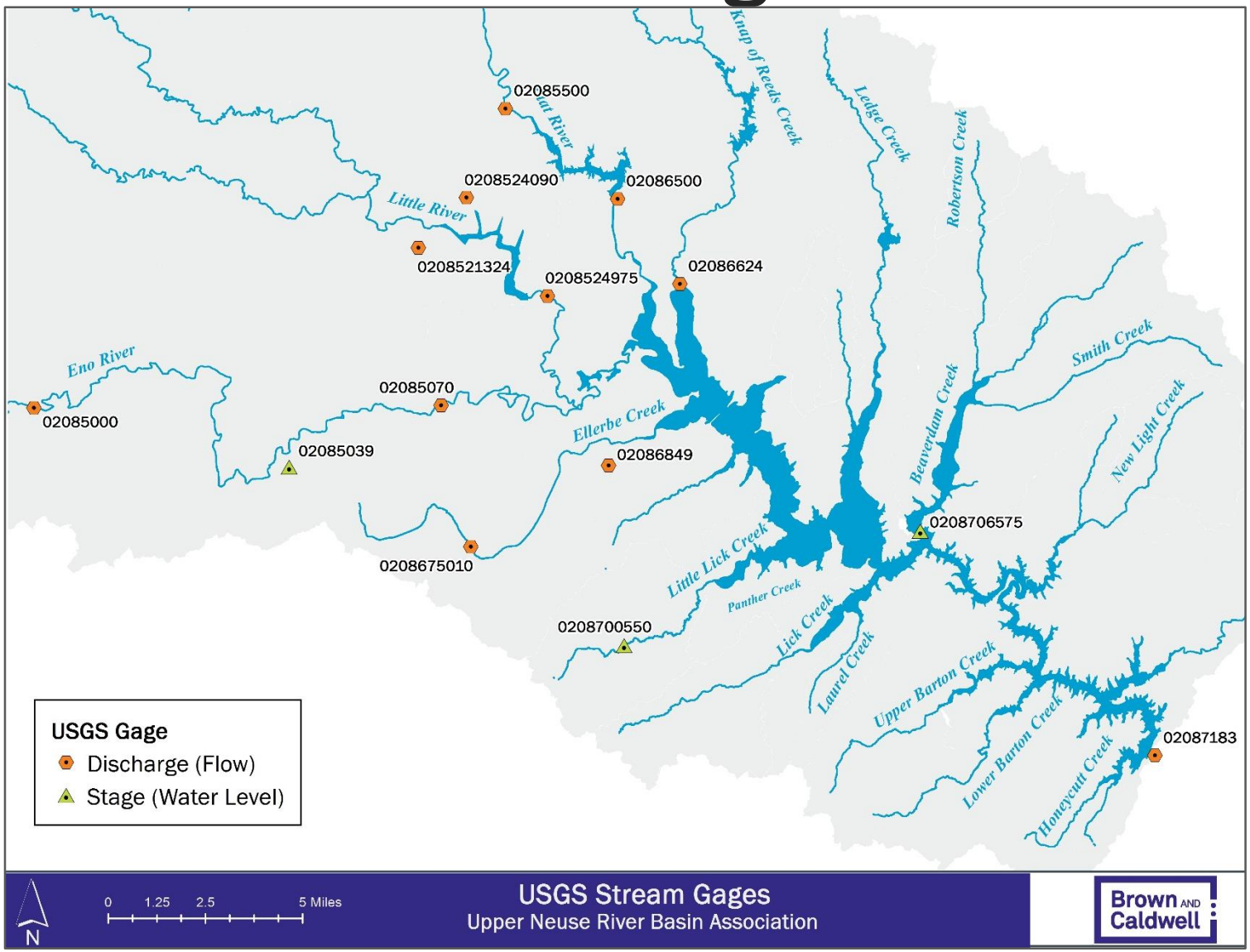
USGS Discharge and Stage Gages

Active USGS Stream Gages							
Gage Number	Waterbody	Drainage Area (mi^2)	Gage Name	Type	Upstream Reservoir	Upstream Major WWTP	Earliest Available Data
02086849	Ellerbe Creek	21.9	Ellerbe Creek near Gorman, NC	Discharge and Stage	No	Yes	1/8/2006
0208675010	Ellerbe Creek	6.01	Ellerbe Creek near Durham, NC	Discharge	No	No	7/24/2008
02085000	Eno River	66	Eno River at Hillsborough, NC	Discharge	Yes	No	10/1/1927
02085070	Eno River	141	Eno River near Durham, NC	Discharge	Yes	Yes	10/1/2004
02086500	Flat River	168	Flat River at Dam near Bahama, NC	Discharge	Yes	No	10/5/2004
02085500	Flat River	149	Flat River at Bahama, NC	Discharge	No	No	10/1/2004
02086624	Knap of Reeds Creek	43	Knap of Reeds Creek near Butner, NC	Discharge	Yes	Yes	1/14/2006
0208521324	Little River	78.2	Little River at SR1461 near Orange Factory, NC	Discharge	No	No	10/1/2014
0208524975	Little River	98.9	Little River at Fairntosh, NC	Discharge	Yes	No	10/24/1995
0208524090	Mountain Creek	7.97	Mountain Creek near Bahama, NC	Discharge	No	No	10/7/1994
02087183	Neuse River	771	Neuse River near Falls, NC	Discharge	Yes	Yes	10/1/2004
0208706575	Beaverdam Creek	52.5	Beaverdam Creek at Dam near Creedmoor, NC	Stage Only	Yes	No	5/3/2006
02085039	Eno River	120.79	Eno River near Huckleberry Spring	Stage Only	Yes	Yes	7/22/2008
0208700550	Little Lick Creek	4.05	Little Lick Creek at NC Hwy 98 at Oak Grove, NC	Stage Only	No	No	7/30/2008

USGS Discharge and Stage Gages

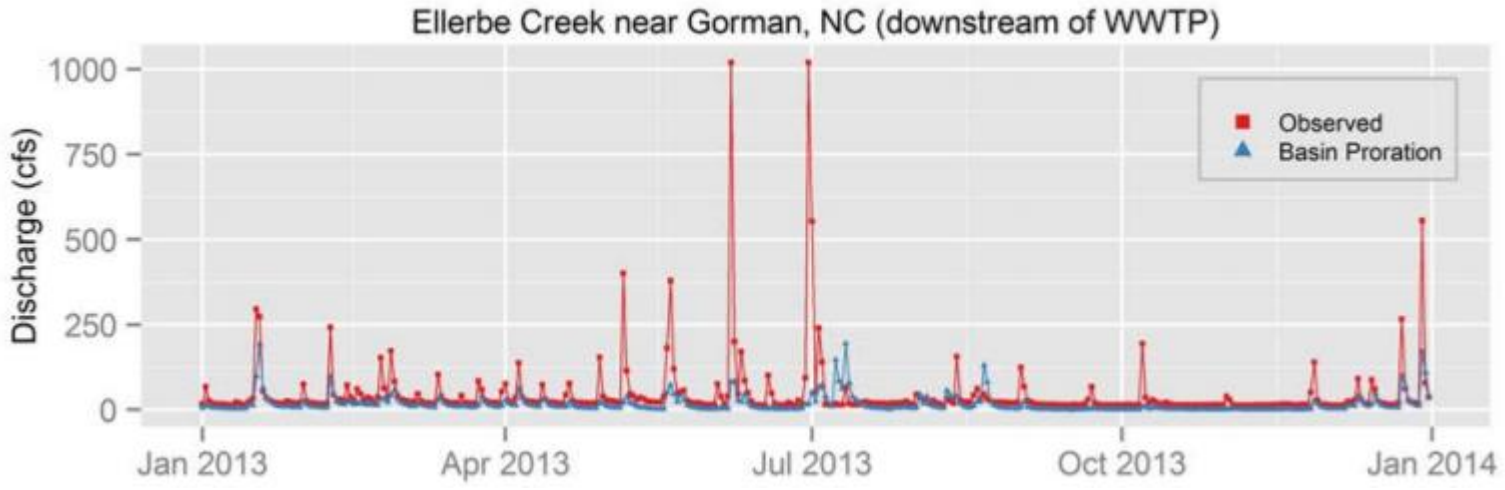


Location of USGS Gages



Flow Estimation at Ungaged Locations

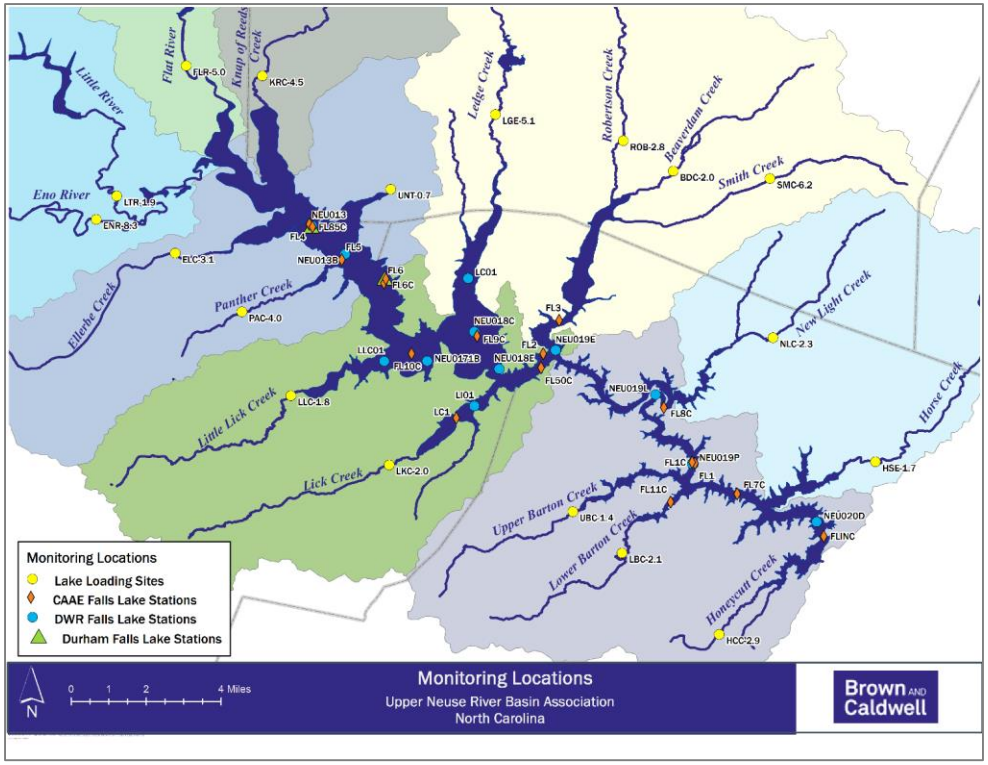
- Provides estimates of stream flow at ungaged locations
- Approach is documented in the Comparison of Flow Estimation Methods TM on the UNRBA Monitoring Page
- Will not be used for formal calibration but provides estimates of flow for loading analyses and model “gut checking”



Water Quality Observations

Sources of Water Quality Data for the Modeling

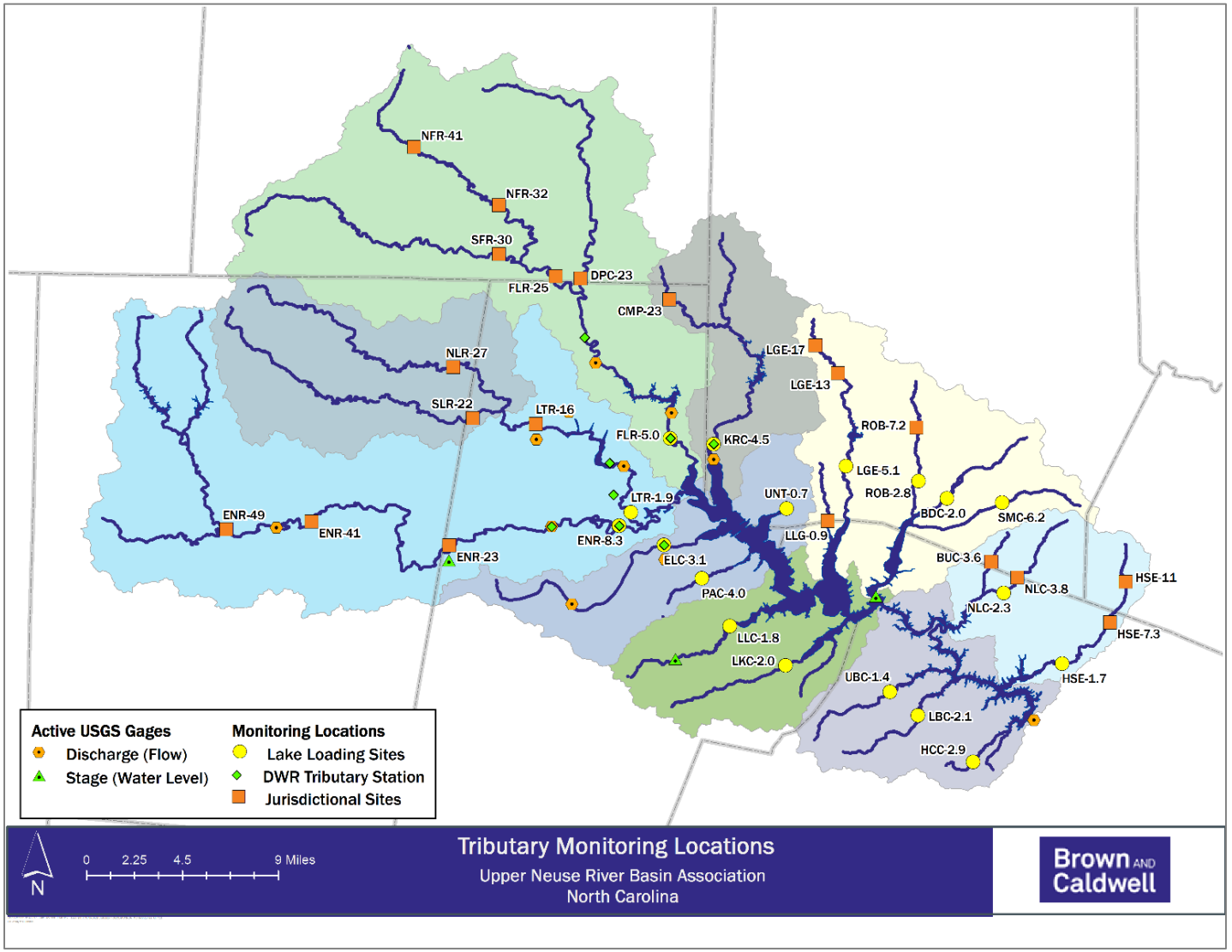
- UNRBA Monitoring Program
  - Routine monitoring and special studies
- NC DEQ
  - Ambient watershed and lake monitoring
- Local governments
  - Ambient watershed and lake monitoring
- Universities/researchers
  - Ambient lake monitoring
  - Special studies



Importance of Water Quality Data

- Provides measurements of parameters at different stations in the watershed and the lake
- Data will primarily be used to calibrate the models
  - Water quality in the streams and rivers
  - Water quality in the lake
- Accurate water quality calibrations are essential for
  - Estimating nutrient loads to Falls Lake
  - Apportioning loads among sources
  - Simulating lake response (nutrients and chlorophyll a)
- Model parameters are adjusted and model output is compared to observations until a good fit is achieved

Location of Water Quality Monitoring Stations



Major and Minor Wastewater Facilities

Importance of Accounting for Major and Minor Wastewater Facilities

- Wastewater facilities can alter in-stream water quality and stream flows
- Accurate accounting of discharges is essential for accurate model development and calibration to observations
  - In stream flows (USGS)
  - Water quality (UNRBA, DEQ, UNRBA members, etc.)
- Revised nutrient management strategy will need to address
  - Reductions achieved to date
  - Cost and benefits of additional technologies
  - Roll of wastewater treatment plants in the revised nutrient management strategy

Differences Between Major and Minor Wastewater Facilities

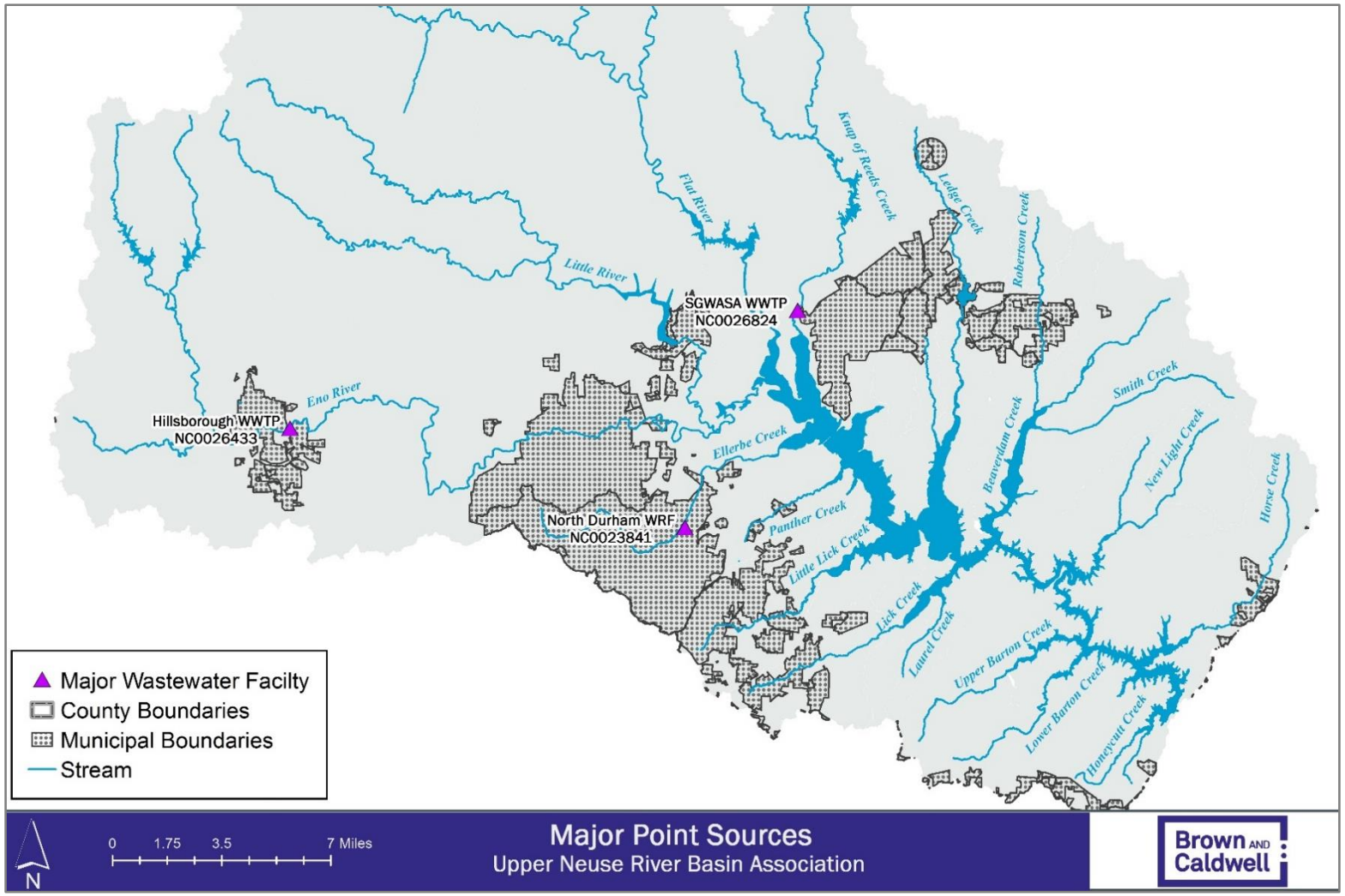
- Wastewater facilities are designated as minor/major based on the permitted daily discharge
- Major facilities generally have advanced (secondary or tertiary) treatment technologies to reduce the concentrations of pollutants in their effluent
- Minor facilities discharge small quantities of water, compared to major facilities
- Minor facilities typically employ less sophisticated water treatment procedures than major facilities, resulting in higher pollutant concentrations in their effluent
- While discharge flowrate from minor facilities may be low, pollutant load may be high depending on the characteristics of the receiving stream

Major Wastewater Facilities

- Three major wastewater treatment facilities in the watershed (discharging more than 1 million gallons per day of treated effluent)

Major Wastewater Treatment Facilities in the Watershed		
NPDES Permit Number	Facility Name	Receiving Water
NC0023841	North Durham WRF	Ellerbe Creek
NC0026433	Hillsborough WWTP	Eno River
NC0026824	SGWASA	Knap of Reeds Creek

Location of Major Wastewater Facilities



Summary of Effluent Data Provided by the Three Major Facilities in the Watershed							
Owner:	SGWASA			NDWRF	Hillsborough		
Permit Number:	NC0026824			NC0023841	NC0026433		
	Jan-Mar 2006, Sep-Dec 2007	Apr 2006-Aug 2007	2014-2017	2014-2018	2006-2010	Jan 2011-Aug 2013	Sept 2013-Dec 2017
Flow (MGD)	D	D	D	D	D	D	D
Temperature (°C)	5/W	D	5/W		5/W	5/W	5/W
pH	5/W	D	5/W		5/W	5/W	5/W
Dissolved Oxygen (mg/l)	5/W	D	5/W		5/W	5/W	5/W
Conductivity (UMHOS/cm)	3/W	3/W	5/W				
BOD_5 (20°C) (mg/l)	5/W	5/W	5/W		5/W	5/W	2/W
Total Suspended Residue (mg/l)	5/W	D	5/W		5/W	5/W	2/W
Ammonia Nitrogen (mg/l)	5/W	5/W	5/W		5/W	5/W	2/W
Nitrate plus nitrite (mg/l)	W	W	W		W	W	W
Total Kjeldahl Nitrogen (mg/l)	W	W	W	W	W	W	W
Total Nitrogen (mg/l)	W	W	W	W	W	W	W
Total Phosphorus (mg/l)	W	W	W	W	2/W	W	W

D: daily, /W: per week, W: weekly

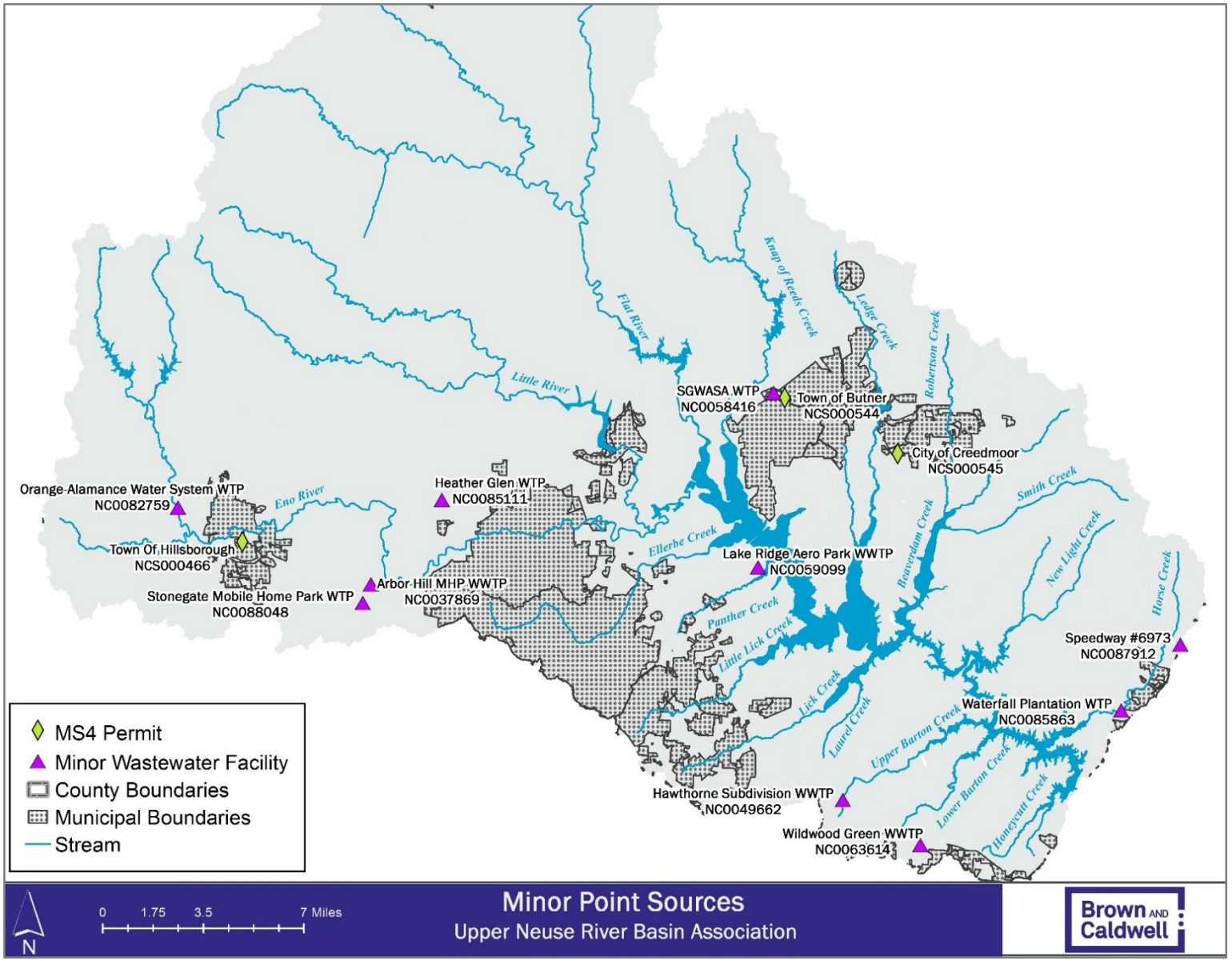
Minor Facilities

- Several minor water or wastewater treatment facilities are located in the watershed
- DEQ provided information on discharge flow rate and concentrations

Table 3-3. Minor Wastewater Treatment Facilities

Permit Number	Facility Name	Type	Permitted Flow (MGD)	Receiving Stream
NC0037869	Arbor Hills MHP WWTP	Discharging 100% Domestic < 1MGD	0.0060	Stony Creek
NC0049662	Hawthorne Subdivision WWTP	Discharging 100% Domestic < 1MGD	0.2500	Upper Barton Creek
NC0082759	Orange-Alamance Water System WTP	Water Plants and Water Conditioning Discharge	0.3000	Eno River
NC0059099	Lake Ridge Aero Park WWTP	Discharging 100% Domestic < 1MGD	0.016	Panther Creek
NC0063614	Wildwood Green WWTP	Discharging 100% Domestic < 1MGD	0.1	Lower Barton Creek
NC0085111	Heather Glen WTP	Water Plants and Water Conditioning Discharge	not limited	Sevenmile Creek
NC0085863	Waterfall Plantation WTP	Water Plants and Water Conditioning Discharge	0.0050	Horse Creek

Location of Minor Facilities



Summary of data from minors

Table 3-4. Summary of Effluent Data Provided by Minor Facilities in the Watershed														
Facility:	Arbor Hills MHP		Hawthorne Subdivision		Lake Ridge Aero Park		Wildwood Green		Orange-Alamance Water System		Heather Glen		Waterfall Plantation	
Permit number:	NC0037869		NC0049662		NC0059099		NC0063614		NC0082759		NC0085111		NC0085863	
	Apr '05– Dec '07	Jan '14 – Jun '18	Apr '05 – Dec '07	Jan '14 – Jun '18	Jan '05 – Dec '07	Jan '14 – Jun '18	Jan '05 – Dec '07	Jan '14 – Jun '18	May '05 – Dec '07	Jan '14 – Jun '18	Apr '05 – Dec '07	Jan '14 – Jun '18	Apr '05 – Dec '07	Jan '14 – Jun '18
Flow (MGD)	W	W	D	D	D	D	D	D	D	D	10 obs.	No data available[2]	2-3/W	D
Total Flow (MGD)						M		M						M
Temperature (°C)	5/W	5/W	5/W	5/W	5/W	5/W - W	5/W	5/W		3/W				
Dissolved Oxygen (mg/l)	W	W	W	3/W	5/W	W	5/W - W	W						
Total Nitrogen (mg/l)	W	alt-W/M	M	D/Alt-W	M	D - Alt-W/M	M	Alt-W	M- 3/W	2/W	7 obs.		6 obs.	42 obs.
Ammonia Nitrogen (mg/l)	W	W	W	W	W	W	W	W		2/W				
Total Kjeldahl Nitrogen (mg/l)	W	Alt-W/M	Alt-W/M	Alt-W	M		Alt-W/M	Alt-W	M- 3/W	2/W	7 obs.		6 obs.	
Nitrate plus nitrite (mg/l)	W	Alt-W/M	Alt-W/M	Alt-W	M		M	Alt-W	M- 3/W	2/W	7obs.		6 obs.	
Total Phosphorus (mg/l)	Alt-W	Alt-W/M	W	Alt-W	W	M	W	W	M- 3/W	2-3/W	7 obs.		6 obs.	68 obs.
Total Nitrogen (calculated) (lb/yr)		M		M				M						
Total Nitrogen (calculated) (lb/month)		Alt-W/M		Alt-W/M				Alt-W/M						12 obs.

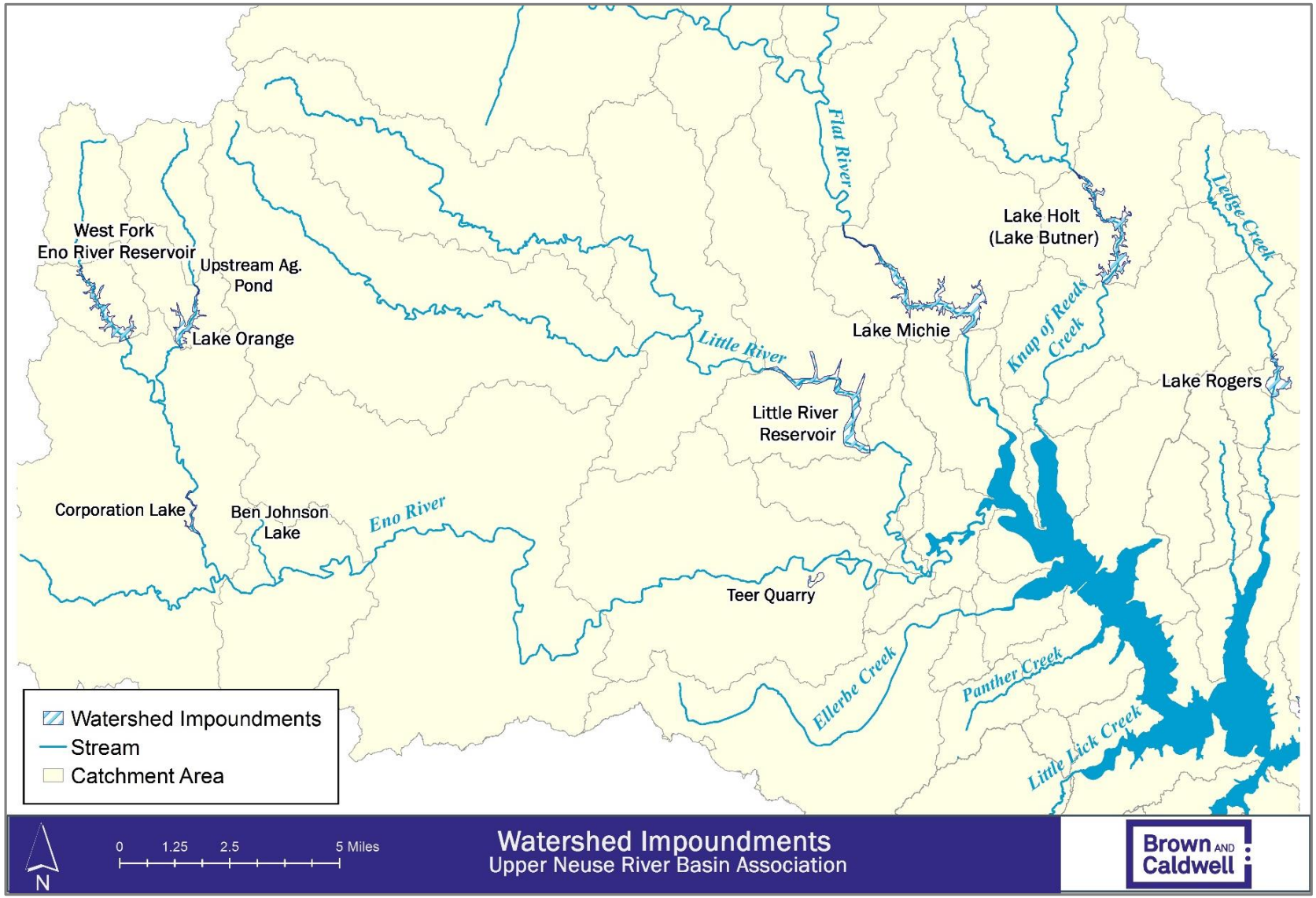
D: daily, /W: per week, W: weekly

Watershed Impoundments

Importance of Accounting for Impoundments in the Watershed

- Impoundments in the watershed can have significant effects on the storage and release of water and resulting impacts on water quality
- WARMF requires time series information to simulate impoundments that are managed (e.g., water withdrawals, reservoir releases, etc.)
- Accurate hydrology simulation can only be achieved if time series for each actively managed water body are available
- There are a significant number of small, unmanaged impoundments in the watershed
  - Unmanaged impoundments reduce overland flow, and increase evaporative water loss
  - These processes will be accounted for during hydrology calibration

Significant Impoundments



Sources of Water Withdrawal Data

Impoundment	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information
Lake Butner	SGWASA (2005 to 2007 and 2014 to 2018)	Daily withdrawal rates for both modeling periods	DEQ WARMF files and OASIS modeling files for 2005 to 2007
Lake Michie	City of Durham (2014 to 2018) City of Durham revised WARMF model (2005 to 2007)	Daily withdrawal rates for both modeling periods	DEQ WARMF files and OASIS modeling files for 2005 to 2007
Little River Reservoir	City of Durham (2014 to 2018) City of Durham revised WARMF model (2005 to 2007)	Daily withdrawal rates for both modeling periods	DEQ WARMF files and OASIS modeling files for 2005 to 2007
Teer Quarry	Not available (emergency supply)	Not applicable	Not applicable
Lake Orange	Not applicable	Not applicable	Not applicable
Compton's Pond	Not applicable	Not applicable	Not applicable
West Fork Eno River Res.	Not applicable	Not applicable	Not applicable
Corporation Lake	DEQ (2005 to 2017)	Daily withdrawals	OASIS (2005 to 2007)
Lake Ben Johnson	Town of Hillsborough (2005 to 2007 and 2014 to 2018)	Daily withdrawal rates for both modeling periods	OASIS modeling files for 2005 to 2007
Lake Rogers	Population based estimates (2005 to 2007) No water supply withdrawals from 2014 to 2018	Monthly estimates based on historic withdrawals (1997) and census data.	Not applicable

Sources of Release Data

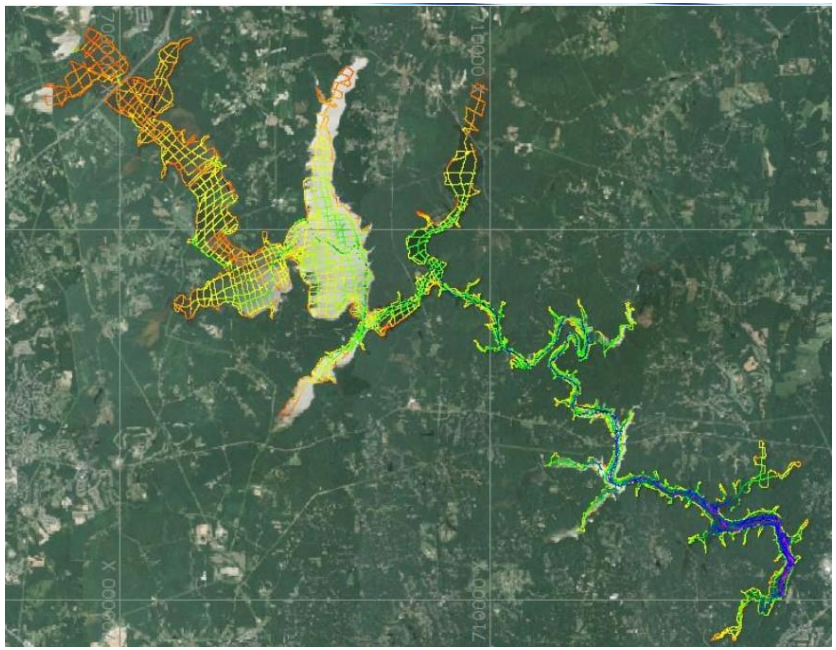
Impoundment	Primary Sources of Information	Secondary Sources of Information
Lake Butner	WARMF Stage-Release curves	OASIS model (2005 to 2007 time series of releases)* OASIS stage-storage data
Lake Michie	Flows observed at USGS Gage 02086500 just downstream (both periods)	City of Durham revised WARMF model (2005 to 2007) WARMF Stage-Release curves
Little River Reservoir	Flows observed at USGS Gage 0208524975 just downstream (both periods)	City of Durham revised WARMF model (2005 to 2007) WARMF Stage-Release curves
Lake Orange	OASIS time series of releases (2005 to 2007) Orange County time series of releases (2014 to 2017)	WARMF Stage-Release curves
Compton's Pond	Simulate as a river reach consistent based on analysis of OASIS model output	Not applicable
West Fork Eno River	Town of Hillsborough (both periods)	WARMF Stage-Release curves
Lake Ben Johnson	Simulate as a river reach consistent based on analysis of OASIS model output	OASIS model (2005 to 2007) OASIS stage-storage data (2014 to 2018)*
Lake Rogers	Simulate as a river reach consistent based on analysis of OASIS model output	OASIS model (2005 to 2007) OASIS stage-storage data (2014 to 2018)*
Corporation Lake	Simulate as a river reach consistent based on analysis of OASIS model output	OASIS model (2005 to 2007) OASIS stage-storage data (2014 to 2018)*
Teer Quarry	Does not release water downstream	Not applicable: provides offline emergency storage

*DWR may update the OASIS Model which would provide release data for 2014-2018.

Lake Model Grid Development

Purpose of Lake Grid Development

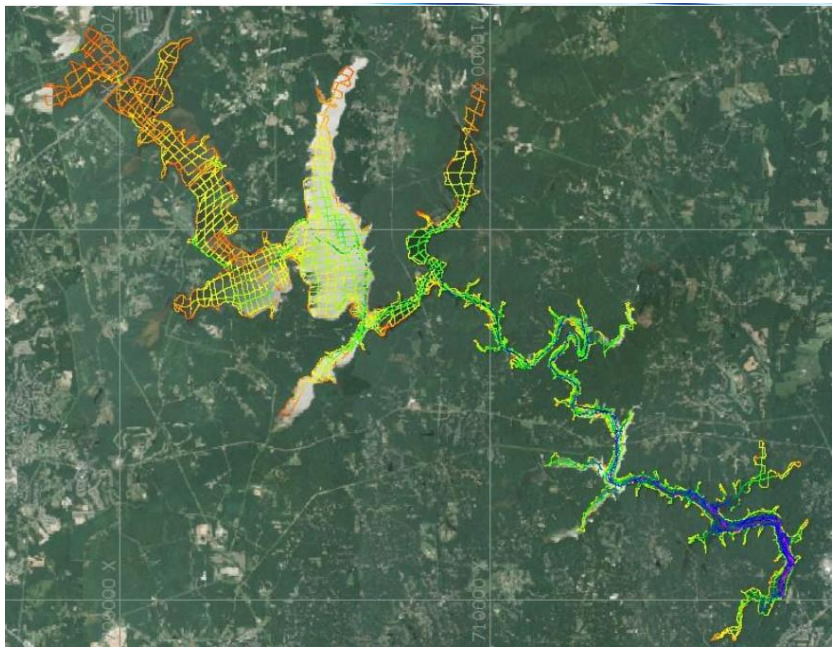
- The lake grid divides the lake into small modeling units
- The grid is divided into layers to simulate stratification, settling, etc.
- Hydrodynamic and water quality calculations are performed on each grid cell
- More grid cells lead to a more refined simulation
- Selected resolution balances
  - Available information
  - Improvements in calculations
  - Model run times



UNRBA transects for the bathymetry study

Status of Lake Grid Development

- Lake modelers developed a model grid for the EFDC model
- Uses data collected by the UNRBA (Lake Bathymetry Study)
- Established 804 grid cells
  - 454 cells in lower lake
    - Smaller cells are required to capturing meandering section of the lake
  - 350 cells in upper lake
    - Lake bathymetry varies gradually, so larger cells are sufficient to capture changes in water quality

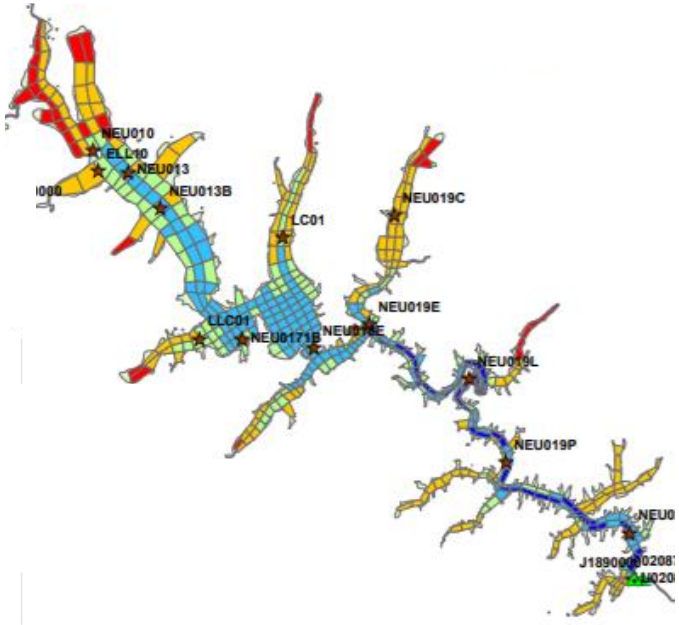


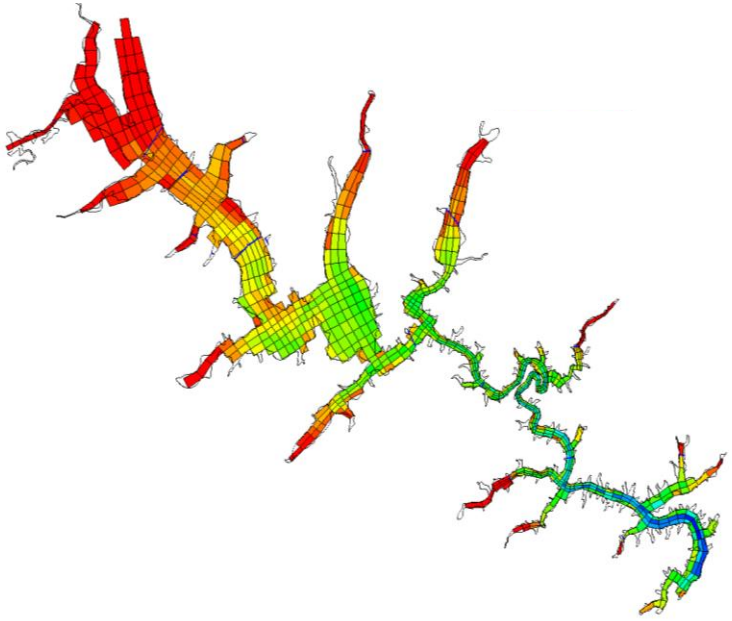
UNRBA transects for the bathymetry study

Comparison of DWR and UNRBA EFDC Model Grids

The DWR model grid had 519 grid cells. It was developed using 17 transects measured across Falls Lake.

The UNRBA model grid has 804 grid cells. It was developed using sonar data measured along many transects across Falls Lake.

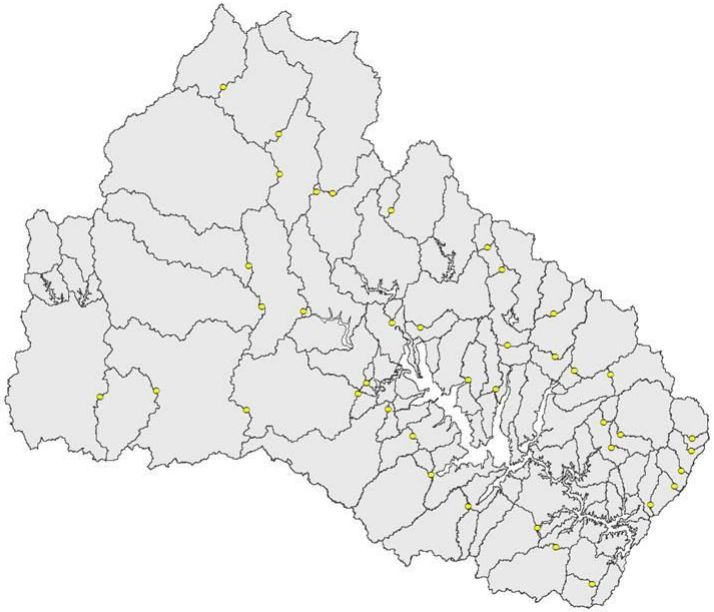




Catchment Delineation

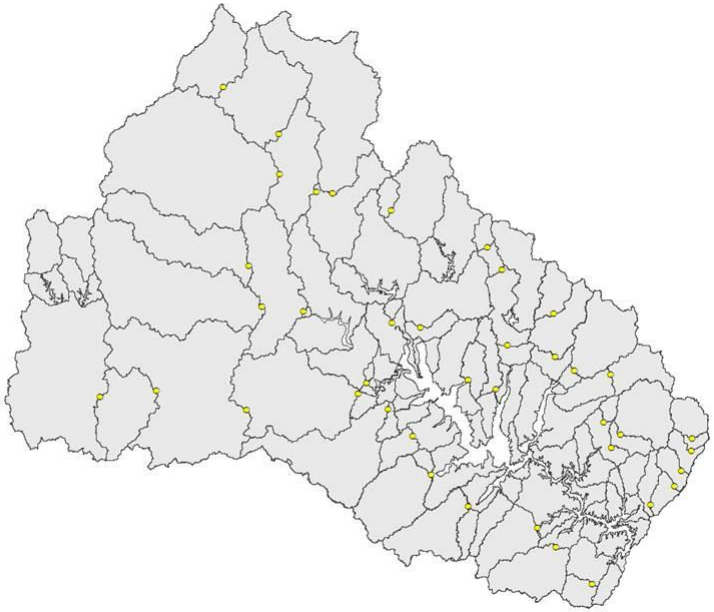
Purpose of Catchment Delineation

- Divides the watershed into smaller units to support modeling
- Input and output are “lumped” to the resolution of the catchment
- Increasing the number of catchments = increasing resolution
- Important for calibration and output interpretation



Status Catchment Delineation

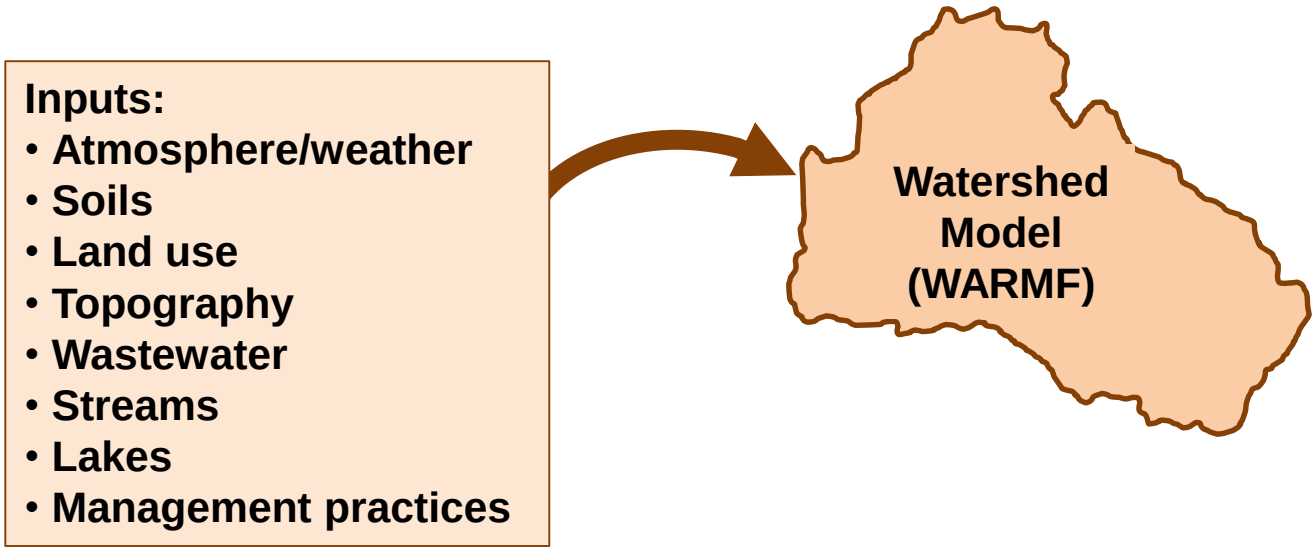
- Watershed modelers have delineated preliminary catchments for the watershed model
- Boundaries are based on topography, with outlets located at the UNRBA watershed monitoring stations
- Created using the USGS StreamStats Tool
- One goal of modeling is to assign jurisdictional loading
- Potential need for further delineations
- Input from today's meeting will help determine additional delineations to ensure modeling can generate useful output



Future Meeting Topics and Data Summaries

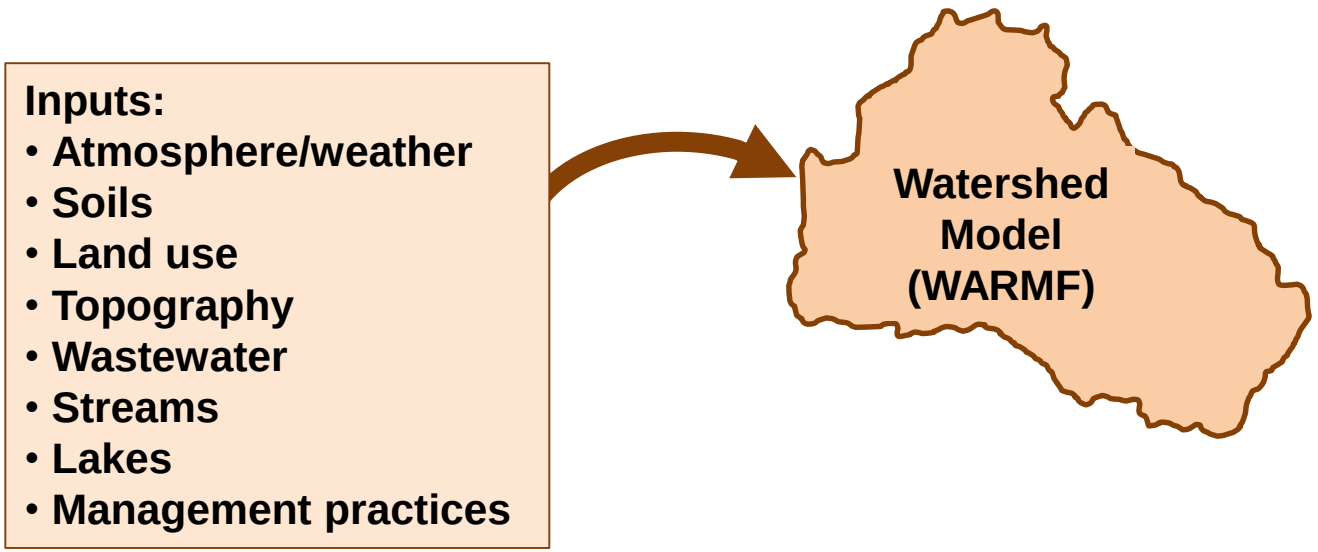
Continued Data Collection

- Received approximately 75 percent of the data expected from UNRBA members and agricultural representatives
- Continue to compile and summarize data for the watershed
- Process USGS NLCD data when released in December 2018
  - Year 2016 release
  - Years 2001, 2006, 2011 - reharmonized



Data Topics Planned for Subsequent Meetings

- Soils
- Land use and land cover
- Nutrient application rates
- Onsite wastewater treatment
- Air quality and deposition
- Best management practices



Breakout Discussions

Do you have any input on the data sets that were described today?

- Additional sources of information?
- Input on assumptions?
- Is there anything that we should know about these data sets as we develop the models?

Please provide information on the data sets to Alix Matos (amatos@brwncald.com) and Forrest Westall (forrest.westall@unrba.org)

What do you want to get out of the watershed model? Rank top 3. Examples below: [11 minutes]

- Concentrations
- Loads
- Timing with respect to storms
- Sources of loading
  - Jurisdiction
  - Land use
  - Activities
- Impacts of management options
- Answer “what if” questions
- Other

How would you prefer information from the watershed model be summarized and provided to you? [11 minutes]

- Spatially (pick 1)
  - Jurisdiction (15)
  - Perennial stream subwatersheds (~30)
  - UNRBA Monitoring Stations (38)
  - Modeling units (over 100)
  - Other
- Temporally (pick 1)
  - Hourly
  - Daily
  - Monthly
  - Seasonally
  - Annually

What do you want to get out of the lake models? Rank top 3. Examples below: [11 minutes]

- Nutrient loading/concentration relationships
- Sources of loading to the lake (internal/external)
- Differences in water quality at different locations
- Evaluation of a range of weather conditions
- Evaluation of seasonal loading and flow patterns
- Evaluation of lake management/operations
- Evaluation of watershed management options
- Answer “what if” questions
- Other

How would you prefer information from the lake models be summarized and provided to you? [11 minutes]

- Spatially (pick 1)
  - Whole lake (1)
  - Upper versus lower lake (2)
  - Each DWR monitoring station (12)
  - Separate lake arms and lake segments (~20)
  - Other
- Temporally (pick 1)
  - Daily
  - Monthly
  - Seasonally
  - Annually

Thank you for Participating

Pre-Meeting Materials for the Fall 2018 UNRBA Stakeholder Meeting

Year Three: Anticipating Stakeholders' Uses for the Modeling Results

October 24, 2018, Butner Town Hall, 9:00 AM to 12:30 PM

The Upper Neuse River Basin Association (UNRBA) is hosting its twice-yearly stakeholder meeting for the Modeling and Regulatory Support Project. The "Year Three: Anticipating Stakeholders' Uses for the Modeling Results" meeting will be held at the Butner Town Hall from 9:00 to 12:30 on October 24th, 2018.

This pre-meeting material is being provided to the stakeholders prior to the meeting. The intent is to provide background information about the UNRBA's re-examination project. A primer for the stakeholder feedback part of the meeting is also provided, as well as sources of additional information.

Please review the materials in advance of the meeting as limited time will be available for each of the four questions posed during the feedback session. Some of these questions ask that you rank your preferences. Reviewing in advance of the meeting will provide more time to consider these questions.

Contents of Pre-Meeting Materials:

Thank you for your interest and participation.

Re-examination Background Information

Why is the re-examination needed?

The Falls Lake Nutrient Management Strategy was developed by the NC Division of Water Resources (DWR). At the time, limited information was available to develop the models that were used to establish the rules. Because of the uncertainty associated with the modeling, the Falls Lake Nutrient Management Strategy allows for a re-examination of the second phase of nutrient load reduction requirements (Stage II). The Falls Lake Nutrient Management Strategy listed the requirements that any person or group must follow to perform a re-examination. The UNRBA has been working since 2012 to fulfill these requirements and produce an improved set of models and tools.

What is a model? How are models being used to support the re-examination?

A model is a representation of a system (like Falls Lake or the Falls Lake watershed) that uses a series of mathematical formulas to explain or predict how the system behaves. These formulas may be based on patterns and mathematical relationships within measured parameters (statistical model) or may use more complex equations to represent the actual physical, chemical and biological processes that occur in the system (mechanistic model). The UNRBA is using both types of model to support their re-examination of Stage II of the Falls Lake Nutrient Management Strategy because using multiple modeling tools is expected to yield more robust and reliable conclusions than relying on a single model.

The UNRBA is developing these models to represent two periods. The first period (2005 to 2007) is consistent with the years simulated by DWR in their modeling effort. Year 2006 was ultimately used by DWR to establish the baseline period for the Falls Lake Nutrient Management Strategy. The second period (2014 to 2018) corresponds with the data collection effort undertaken by the UNRBA.

Once the models are developed, they can be used to test management scenarios and inform decision making. This information will be used to identify cost effective solutions to maintain and improve water quality conditions in Falls Lake.

Where is the UNRBA in the re-examination process?

The current focus of the project is development of watershed and lake models. Over the past four years, the UNRBA has been collecting water quality observations in the lake and watershed that will support development of the models. Data from other organizations, including NC Department of Environmental Quality, has been gathered and analyzed to support this process. To develop the models, several types of data are needed in addition to these observations.

Where can I learn more about the UNRBA re-examination?

The UNRBA website catalogues the information obtained or evaluated to support the re-examination. Two main tabs house the information related to the Monitoring Program and the Modeling and Regulatory Support (i.e., the Re-examination). Please refer to the following links for additional information:

https://www.unrba.org/monitoring-program

- DWR-Approved documents as required by the Falls Lake Rules
    - UNRBA Monitoring Plan
    - UNRBA Monitoring Quality Assurance Project Plan
    - UNRBA Description of the Modeling Framework
- Interim and annual reports that summarize the data collected with preliminary analyses
- Link to the UNRBA Monitoring Database (open to the public) and User Documentation
- Study plans for the special studies
- Additional analyses
    - Flow estimation methods
    - Model performance and sensitivity

https://www.unrba.org/reexamination

- Data Management Plan and Description of the Modeling Process (posted recently)
- Modeling Quality Assurance Project Plan (Approved by DWR)
- Stakeholder meeting materials including presentations
    - October 2018 (focus on data compilation)
    - October 2017 (focus on watershed modeling); to download a version of this presentation with audio, please use the following link: https://www.dropbox.com/s/4tqlhyi3la3xmc8/Year%202%20Kickoff%20Presentation.mp4?dl=0
    - September 2016 (project kickoff/stakeholder concerns)
- Model selection process and evaluation criteria
- Conceptual modeling plan (how the models will be used together)
- Earlier planning phase of the project (2012 to 2014)
    - Task 1 – Re-examination strategy
    - Task 2 – Review existing data and reports (through 2011)
    - Task 3 – Review methods for estimating nutrient loads
    - Task 4 – Recommend future monitoring and modeling studies
        - UNRBA Monitoring Program
        - UNRBA Modeling and Regulatory Support Project

Meeting Overview and Questions for Stakeholders

The first part of the Fall 2018 stakeholder meeting will review the status of the modeling work and discuss some of the types of data that have been compiled to support this effort. The modeling team will describe the sources of data and summarize the amount of data compiled. Table 1 lists the data and sources that will be discussed at the meeting. Other data sets will be described at subsequent stakeholder meetings.

The modeling team will also describe how the watershed and the lake have been divided into smaller units. The units allow the models to represent conditions in distinct parts of the lake or watershed, based on measurements, observations, or predictions of the chemical, physical and biological factors affecting nutrient loading from the watershed and water quality in the lake.

The second part of the meeting will provide the stakeholders an opportunity to share their perspective on how they will use, or want to use, the model results. This information will help the modeling team and the UNRBA's Modeling and Regulatory Support Workgroup and Path Forward Committee make informed decisions about how the models should be set up.

Decisions made early in the modeling process affect the types of information that can be generated by the models.

Our goal with this part of the meeting is to gather information before the modeling is conducted to ensure we will be able to answer key questions. The following questions will be asked during the meeting:

Do you have any input on the data sets that were described today? (See Table 1 below - additional data sets will be covered at future stakeholder meetings.)

- Additional sources of information?
- Input on assumptions?
- Is there anything that we should know about these data sets as we develop the models?

Please provide information on the data sets to
Alix Matos (amatos@brwncald.com) and
Forrest Westall (forrest.westall@unrba.org)

What do you want to get out of the watershed model? Rank your top 3 items. [11 minutes]

- Simulate nutrient concentrations and loading at specific locations (e.g., monitoring stations)
- Understand the relationship between nutrient concentrations and nutrient loads in the watershed.
- Understand how certain storm events affect concentrations and loading
  _____small storms, _____typical storms, _____large storms/hurricanes
- Understand where nutrient loading is highest
  ____by tributary, _____by jurisdiction, _____by soil type
- Understand which land uses or activities contribute to the highest nutrient loads
- Predict the effects of implementing various Best Management Practices on nutrient loading to the lake
- Understand how onsite wastewater treatment systems impact nutrient loading to Falls Lake
- Understand how adjacent wetlands affect water quality in Falls Lake
- Estimate jurisdictional loads (City, County, Utility) as total pounds per unit time
- Compare nutrient loading across jurisdictions (total pounds and pounds per acre)
- Produce nutrient, TSS, and carbon loads at an appropriate time step to provide input to the lake model. Time frame preferred:
  _____ daily, _____ four times per day or every 6 hours, _____ hourly.
- Identify areas needing further exploration because the loads are not well explained by the models.
- Understand the role atmospheric deposition plays in nutrient loads from the landscape.
- Identify unmanageable and manageable sources of nutrient loading for Falls Lake (i.e., what loading is controllable?) and rank them in terms of contribution.
- Ask "What if" questions such as _____
- Ask "What if" questions such as _____
- Other _____
- Other _____

How would you prefer information from the watershed model be summarized and provided to you? [11 minutes]

Pick 1 for Spatial and Temporal Scales

Spatial scale (see Figure 1 through Figure 4)

- At the jurisdictional/utility level
- At the perennial stream level
- At the UNRBA monitoring station level
- At the modeling unit level
- At the locations where streams enter Falls Lake
- Other_____
- Other _____

Temporal scale

- Hourly
- Daily
- Monthly
- Seasonal
- Annual

What do you want to get out of the lake models? (rank top 3) **[11 minutes]**

- Quantify all of the in-lake sources of nutrients (e.g., nitrogen fixation from the atmosphere, bottom sediment nutrient releases, decomposition of detritus)
- Quantify all of the external sources of nutrients to the lake (e.g., atmospheric deposition, watershed loading)
- Understand the relationship between nutrient loading to the lake and nutrient concentration in the lake, and how each relates to chlorophyll a concentrations
- Quantify the reservoir of nutrients in the Falls Lake sediments and understand how long it will take for those stores to deplete
- Predict differences in water quality in different portions of the lake (e.g., upper lake vs lower lake, tributary arms vs. main stem)
- Predict water quality at beaches and docks
- Predict water quality at the water supply intake
- Predict water quality released to the Neuse River at the dam
- Evaluate a range of weather conditions and long-term response to management
- Understand how seasonal loading and flow patterns affect water quality in the lake
- Understand the variability in water quality from year-to-year
- Understand how rainfall patterns, residence time, and causeways affect water quality
- Understand how lake management/operations affect water quality
- Understand how watershed management affects levels of nutrients, chlorophyll, and carbon in the lake
- Ask "What if" questions such as _____
- Ask "What if" questions such as _____
- Other _____
- Other _____
- Other _____

How would you prefer information from the lake model be summarized and provided to you? **[11 minutes]**

Lake model, spatial scale (pick 1) (see Figure 2 on the next page)

- For the whole lake (1 summary unit)
- For the upper and lower lake (divided at Hwy 50) (2 summary units)
- For each DWR monitoring station (12 stations)
- For each lake arm and incremental segment (approximately 20 summary units)
- Many locations to demonstrate how much water quality varies across the lake, whilst still maintaining all of the designated uses of the lake
- Other_____

Lake model, temporal scale (pick 1)

- Daily
- Monthly
- Seasonal
- Annual
- Other_____

Table 1. Summary of Data, Sources, and Assumptions to be Discussed at the October 24th Meeting; Additional Data Types to Discussed at Subsequent Meetings

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
Meteorological Data				
Rainfall	NOAA NEXRAD radar data	Radar data covers the watershed and is available for both modeling periods at hourly increments	NC CRONOS/ ECONet Database (developed by the State Climate Office of North Carolina), USGS, NOAA NCDC, and the Western Regional Climate Center (WRCC) weather stations.	The State Climate Office through a collaboration with the NC DOT has offered to provide these data in a processed format. More information will be provided as it is available. The UNRBA would like to express their appreciation to both organizations for offering to compile and process this very large dataset. A description of the NEXRAD data is available at https://www.ncdc.noaa.gov/data-access/radar-data/nexrad.
Air temperature, atmospheric pressure, dew point, wind speed, cloud cover	National Land Data Assimilation System (NLDAS)	1/8th-degree grid (approximately 60 square mile grid cells) that covers the watershed; provides hourly data for both modeling periods	NC CRONOS/ ECONet Database (developed by the State Climate Office of North Carolina), USGS, NOAA NCDC, and the Western Regional Climate Center (WRCC) weather stations.	Predicted air temperature estimates generated by the NLDAS are being compared to observations at select NOAA NCDC weather monitoring stations. The benefit of using NLDAS is that it provides better spatial coverage than the individual weather monitoring stations. The modeling team is evaluating additional weather parameters to confirm NLDAS will provide accurate inputs for the modeling. More information about NLDAS is available at https://ldas.gsfc.nasa.gov/nldas/.
Hydrologic data				
Stream Flow and Water Level Data	US Geological Survey (USGS)	Approximately every 15 minutes at monitoring gages	For ungaged locations, flows may be estimated using basin proration with a map correlation modification.	The basin proration with a map correlation modification was evaluated and documented in The Comparison of Flow Estimation Methods TM. This method may be used to approximate flows at ungaged stations for interpretation of model results but will not be used directly for model calibration.

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
Water Quality Observations				
In the watershed	UNRBA Monitoring Program (2014 – 2018) NC DEQ and local governments (2005 – 2007)	At least monthly with more frequent sampling during high flows during the years 2014 – 2018	NC DEQ, local governments, USGS, researchers	Most of the data collected from 2014 to 2018 in the watershed has been collected by the UNRBA. This data may be accessed by the public at the UNRBA website: https://www.unrba.org/monitoring-program For the historic period, multiple sources of data are available. Raw data access is available through the respective organizations. A summary of this data is available on the UNRBA website in the Task 2 TM.
In Falls Lake	NC DEQ	Monthly with twice monthly sampling in 2005 to 2007	UNRBA, local governments, USGS, researchers	The UNRBA analyzes some parameters in Falls Lake, and this data is housed in the UNRBA database (see row above). DEQ data are available through STORET. The UNRBA Monitoring Program Annual Reports summarize data collected in Falls Lake by multiple organizations. These reports are available at https://www.unrba.org/monitoring-program
Wastewater Treatment Plant Effluent Discharges				
Major facilities (discharging more than 1 million gallons per day)	Operators	Daily to weekly measurements depending on the parameter	Not applicable	Days with missing values will be filled in using either a step function (model default) or linear interpolation following discussion with the Modeling and Regulatory Support Workgroup.
Minor facilities (discharging less than 1 million gallons per day)	DEQ	Daily to weekly measurements depending on the parameter	Not applicable	Days with missing values will be filled in using either a step function (model default) or linear interpolation following discussion with the Modeling and Regulatory Support Workgroup.

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
Watershed Impoundments – Water Withdrawals for Water Supply				
Lake Butner	SGWASA (2005 to 2007 and 2014 to 2018)	Daily withdrawal rates for both modeling periods	DEQ WARMF files and OASIS modeling files for 2005 to 2007	Primary source of daily withdrawal rates will be used to develop the model inputs.
Lake Michie	City of Durham (2014 to 2018) City of Durham revised WARMF model (2005 to 2007)	Daily withdrawal rates for both modeling periods	OASIS modeling files for 2005 to 2007	Primary source of daily withdrawal rates will be used to develop the model inputs.
Little River Reservoir	City of Durham (2014 to 2018) City of Durham revised WARMF model (2005 to 2007)	Daily withdrawal rates for both modeling periods	OASIS modeling files for 2005 to 2007	Primary source of daily withdrawal rates will be used to develop the model inputs.
Lake Orange	Not applicable	Not applicable	Not applicable	Water is not withdrawn from Lake Orange for water supply. Rather, releases from this lake flow to Corporation Lake and Lake Ben Johnson where OAWS and the Town of Hillsborough withdraw water.
Compton's Pond	Not applicable	Not applicable	Not applicable	Water is not withdrawn from Compton's Pond for water supply.
West Fork Eno River Reservoir	Not applicable	Not applicable	Not applicable	Water is not withdrawn from West Fork Eno River Reservoir for water supply. Rather, releases from this lake flow to Corporation Lake and Lake Ben Johnson where OAWS and the Town of Hillsborough withdraw water.

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
Lake Ben Johnson	Town of Hillsborough (2005 to 2007 and 2014 to 2018)	Daily withdrawal rates for both modeling periods	WARMF modeling files or OASIS modeling files for 2005 to 2007	Primary source of daily withdrawal rates will be used to develop the model inputs.
Lake Rogers	Population based estimates (2005 to 2007) No water supply withdrawals from 2014 to 2018	Monthly estimates based on historic withdrawals (1997) and census data.	Not applicable	The 2003 Water Supply Plan for Lake Rogers includes monthly withdrawals for 1997. These values will be scaled by population to estimate monthly withdrawals for 2005, 2006, and 2007 assuming linear population growth between the 2000 and 2010 census data. Lake Rogers ceased use as a water supply in 2012 when SGWASA began to provide water to Creedmoor (Plewah and Richardson 2018). .
Corporation Lake	DEQ (2005 to 2017)	Daily withdrawals	OASIS (2005 to 2007)	Primary source of daily withdrawal rates will be used to develop the model inputs. Days with blank values are assumed zero (confirmed with DEQ staff that withdrawals do not occur every day from this impoundment).
Teer Quarry	Not available	Not applicable	Not applicable	Teer Quarry is used as a source of water supply during emergency droughts. The quarry was used over a 59-d period during the 2007 to 2008 drought, but specific dates and volumes withdrawn are not available (AECOM 2018).
Watershed Impoundments – Releases to Downstream Waters				
Lake Butner (storage capacity of 6,331 ac-ft based on OASIS model files)	DEQ WARMF Stage-Release curves	Simulated	OASIS model files (2005 to 2007 time series of releases) OASIS model may be updated by DWR to include forecasts for	Use previously developed DEQ WARMF model stage-release curves to simulate outflows.

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
			2014-2018 modeling period.	
Lake Michie (storage capacity of 11,584 ac-ft based on OASIS model files)	Flows observed at USGS Gage 02086500 just downstream of the impoundment (2005 to 2007 and 2014 to 2018)	15 minute	City of Durham revised WARMF model (2005 to 2007) WARMF Stage-Release curves	Use primary sources of data to develop model input files.
Little River Reservoir (storage capacity of 15,164 ac-ft based on OASIS model files)	Flows observed at USGS Gage 0208524975 just downstream of the impoundment (2005 to 2007 and 2014 to 2018)	15 minute	City of Durham revised WARMF model (2005 to 2007) WARMF Stage-Release curves	Use primary sources of data to develop model input files.
Lake Orange (storage capacity of 3,560 ac-ft based on OASIS model files)	OASIS time series of releases (2005 to 2007) Orange County time series of releases (2014 to 2017)	Daily	WARMF Stage-Release curves	Use primary sources of data to develop model input files.
Compton's Pond (storage capacity of 414 ac-ft based on	This pond is just upstream of Lake Orange. The release data from Lake Orange will	Outflow equals inflow	Not applicable	Rely on the release data from Lake Orange to account for the effects of Compton's Pond. Based on analysis of the OASIS modeling, simulate this pond as a river reach (inflow equals outflow).

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
OASIS model files)	account for storage in this pond. OASIS modeling indicates inflows closely match outflows for this pond.			
West Fork Eno River (storage capacity of 2,821 ac-ft based on OASIS model files)	Town of Hillsborough (2005 to 2007 and 2014 to 2018)	Daily	WARMF Stage-Release curves	Use primary sources of data to develop model input files.
Lake Ben Johnson (storage capacity of 150 ac-ft based on OASIS model files)	Simulate as a river reach based on analysis of OASIS model output (inflow closely matches outflow)	Outflow equals inflow	OASIS time series of releases (2005 to 2007) OASIS model may be updated by DWR to include forecasts for 2014-2018 modeling period.	This lake is a run-of-river impoundment with a low head dam. OASIS model output indicates that outflow is similar to inflow for this impoundment.
Lake Rogers (storage capacity of 661 ac-ft based on OASIS model files)	Simulate as a river reach based on analysis of OASIS model output (inflow closely matches outflow)	Outflow equals inflow	OASIS time series of releases (2005 to 2007) OASIS model may be updated by DWR to include forecasts for 2014-2018 modeling period.	OASIS model output indicates that outflow is similar to inflow for this impoundment.

Data Type	Primary Sources of Information	Resolution of Primary Data Source	Secondary Sources of Information	Key Assumptions or Ongoing Evaluations
Corporation Lake (storage capacity of 645 ac-ft based on OASIS model files)	Simulate as a river reach based on analysis of OASIS model output (inflow closely matches outflow)	Outflow equals inflow	OASIS time series of releases (2005 to 2007) OASIS model may be updated by DWR to include forecasts for 2014-2018 modeling period.	This lake is a run-of-river impoundment with a low head dam. OASIS model output indicates that outflow is similar to inflow for this impoundment.
Teer Quarry (storage 7,530 ac-ft based on OASIS model files)	Does not release water downstream; provides offline emergency storage	Not applicable	Not applicable	Teer Quarry is used to store emergency water supply water but does not discharge to downstream waters.

References to Table 1 that do not have hyperlinks:

AECOM. 2018. Eno River WARMF Update and Calibration. May 2018. Eno River Watershed Improvement Plan, Durham, North Carolina. Prepared for the City of Durham, Stormwater and GIS Services Division Public Works Department.

Plewa, M.J. and S.D. Richardson. 2018. Analysis of Elevated Health Risks for South Granville Water and Sewer Authority System and Potential Association with Drinking Water Disinfection By-Products.

The Wooten Company. 2003. Lake Rogers Lake Management Plan Revised September 2003.

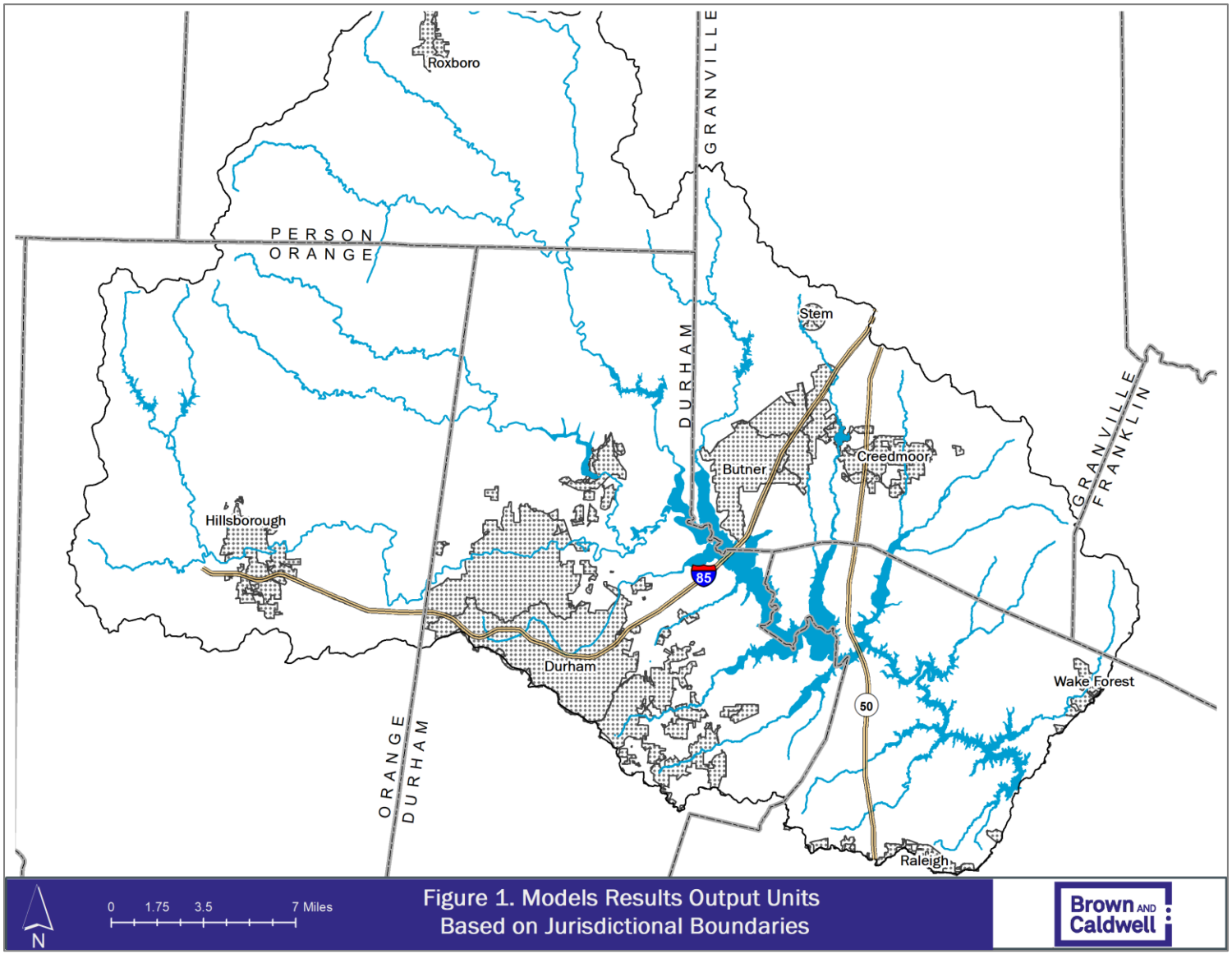
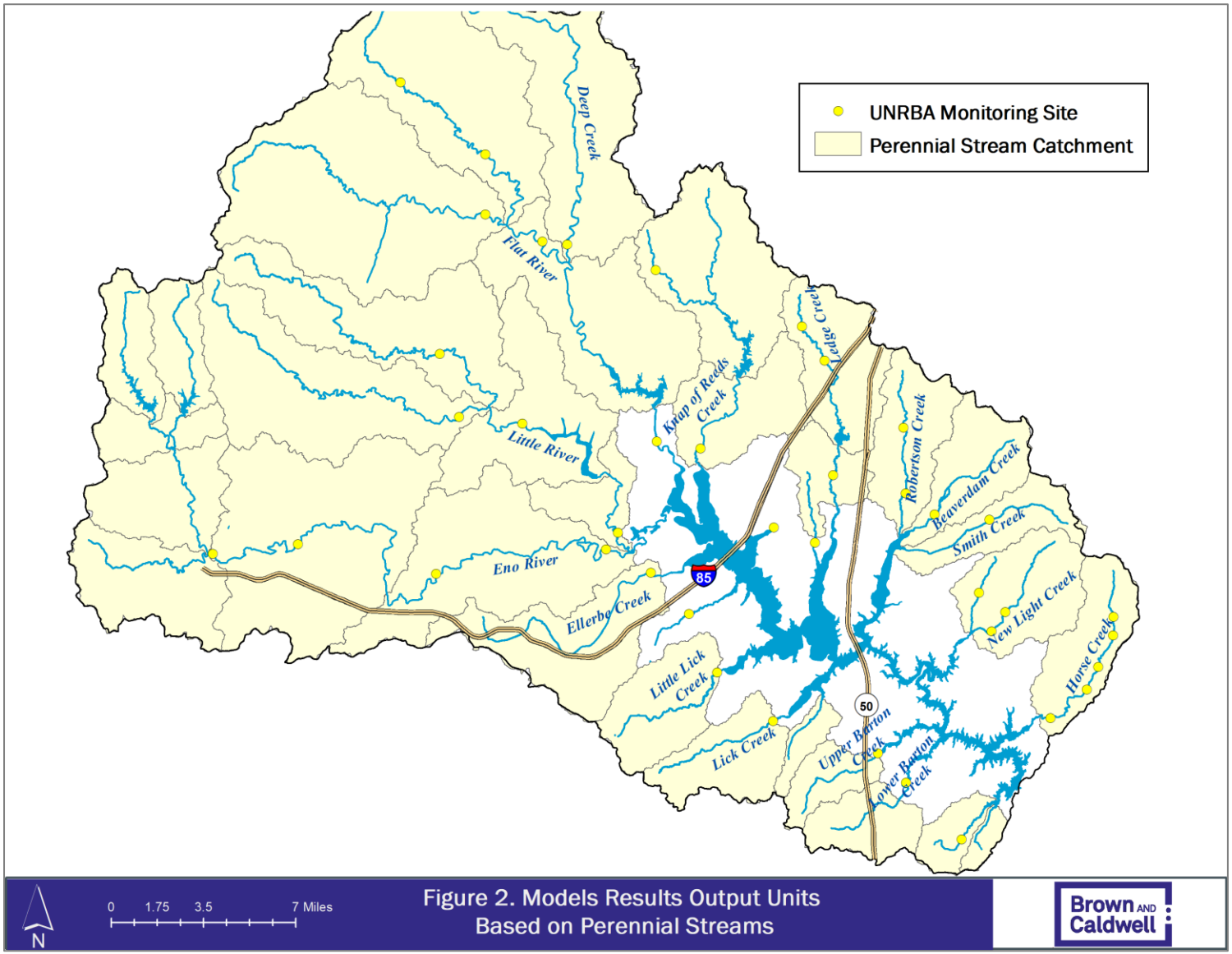
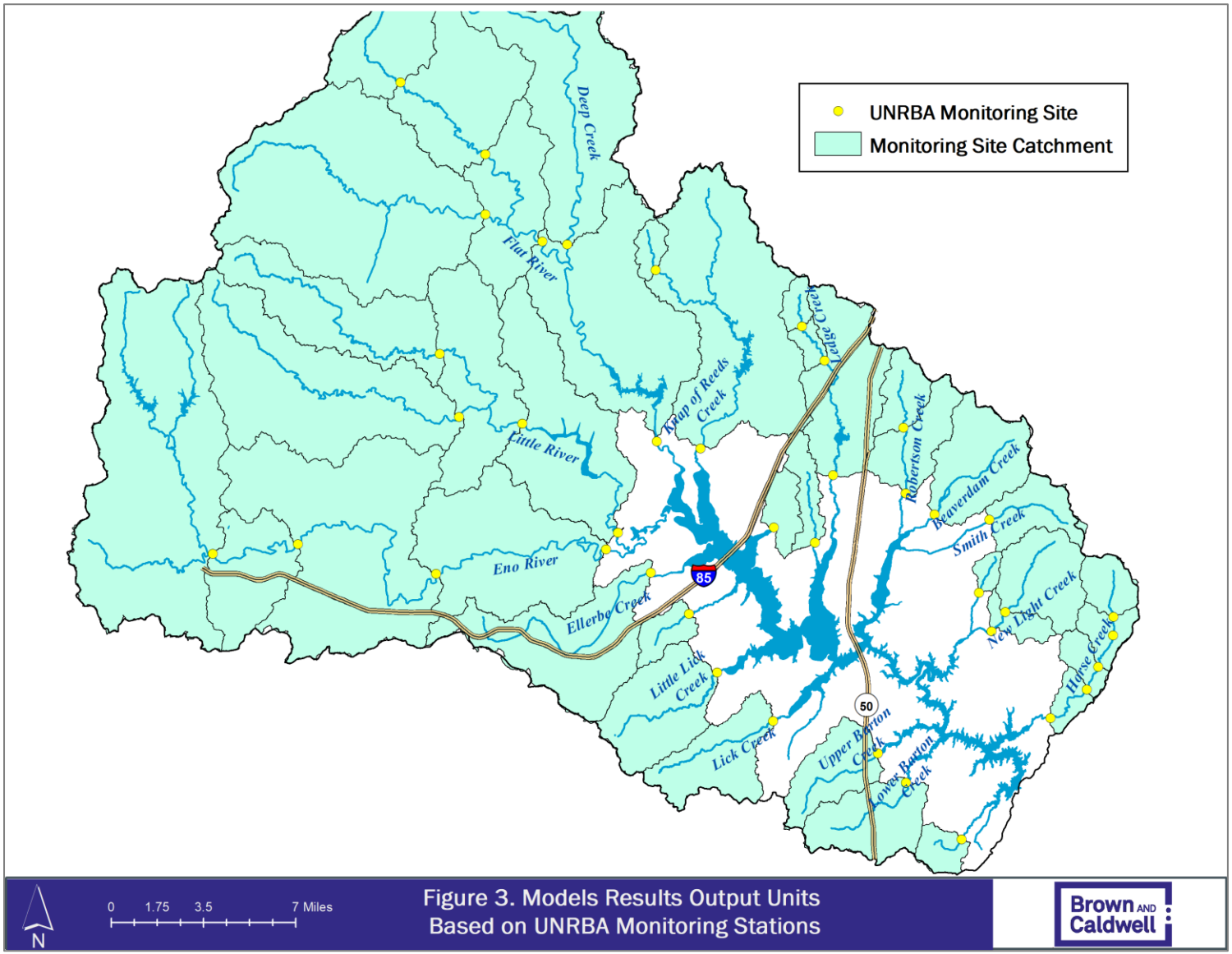
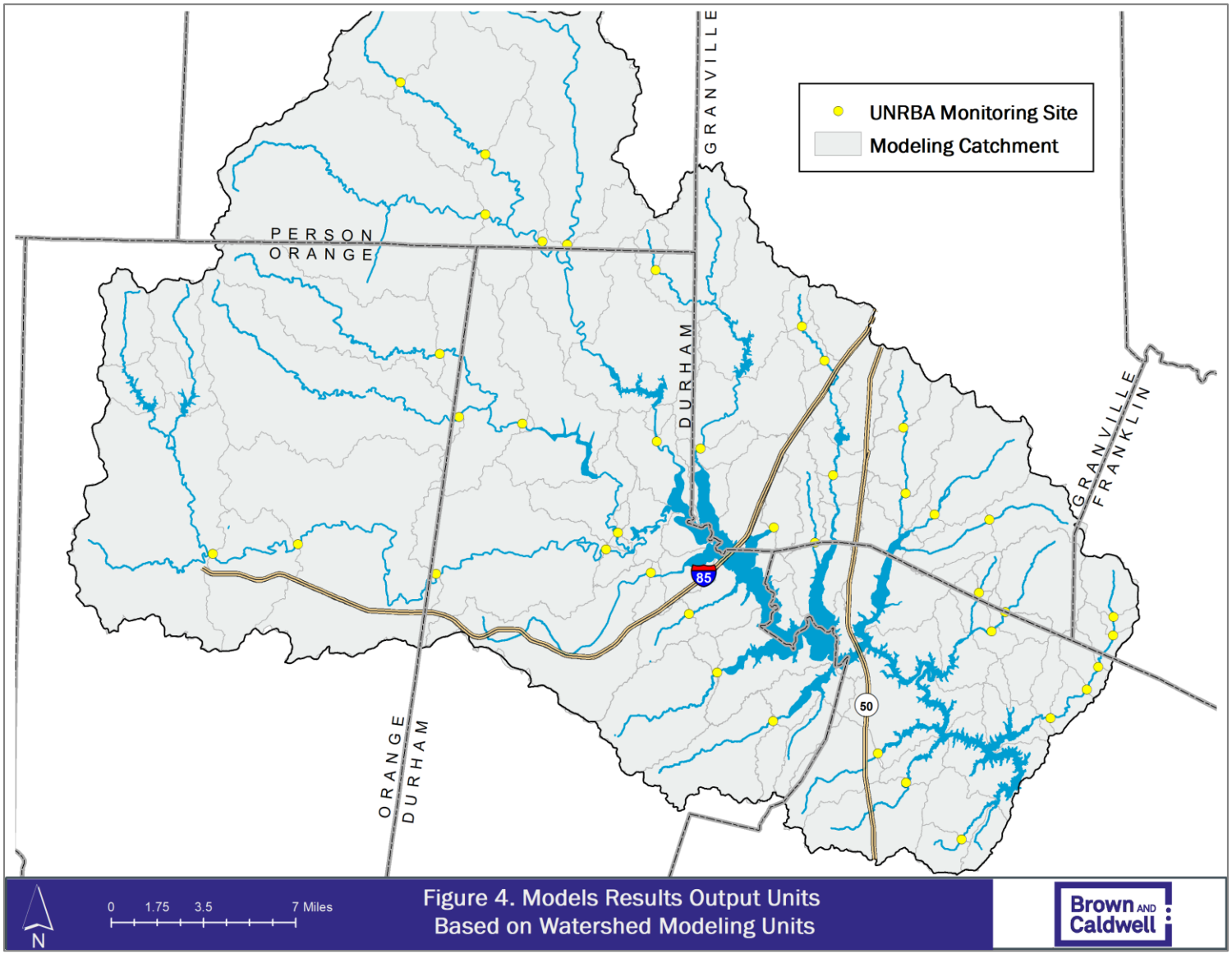
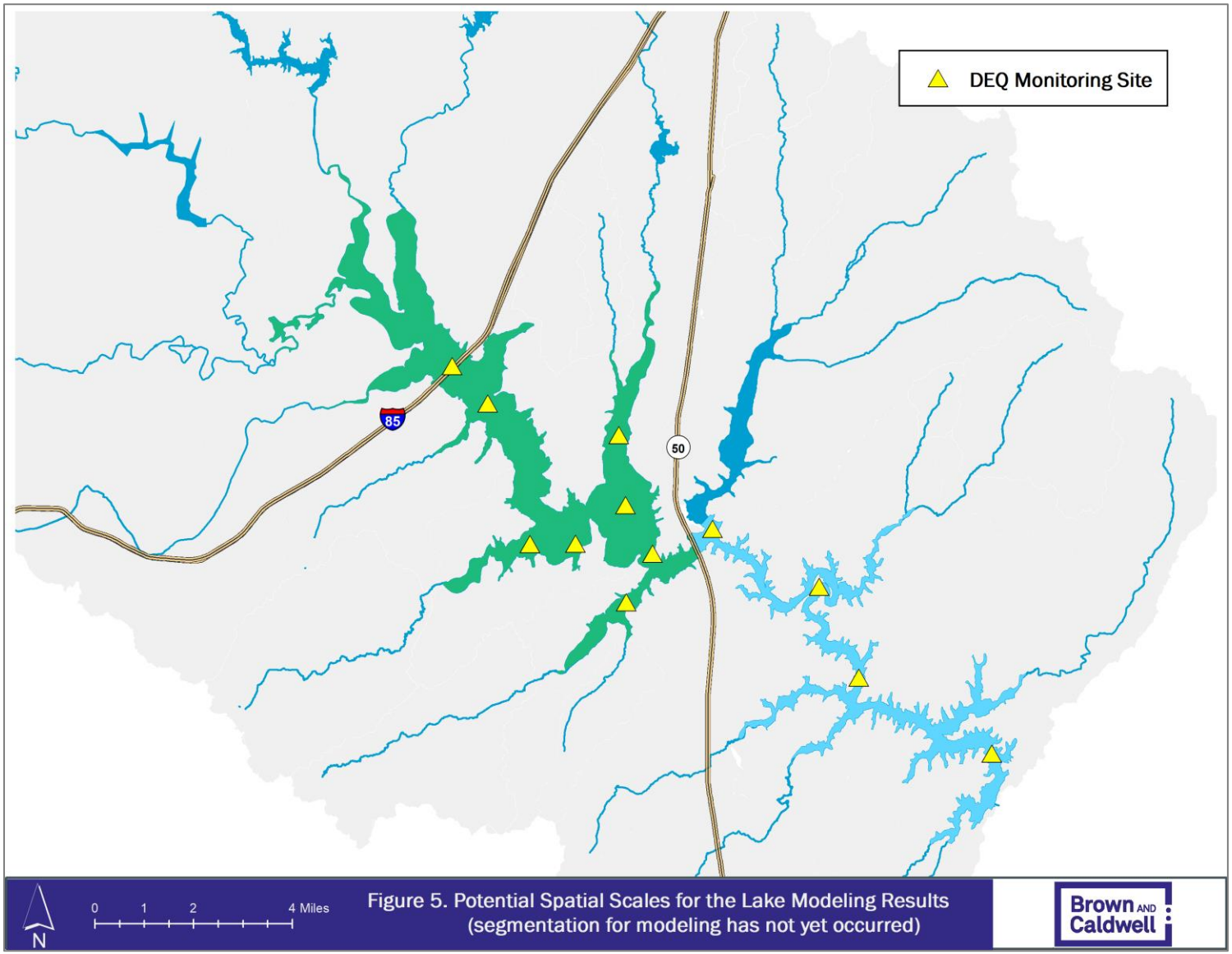


Figure 1. Models Results Output Units Based on Jurisdictional Boundaries


UNRBA Monitoring Site
Perennial Stream Catchment
Deep Creek
Flat River
Little River
Knap of Reeds Creek
Ledge Creek
Robertson Creek
Beaverdam Creek
Smith Creek
New Light Creek
Horse Creek
Eno River
Ellerbe Creek
Little Lick Creek
Lick Creek
Upper Barton Creek
Lower Barton Creek
85
50
N
0 1.75 3.5 7 Miles
Figure 2. Models Results Output Units
Based on Perennial Streams
Brown AND Caldwell


UNRBA Monitoring Site
Monitoring Site Catchment
Deep Creek
Flat River
Little River
Eno River
Ellerbe Creek
Little Lick Creek
Lick Creek
Upper Barton Creek
Lower Barton Creek
Knap of Reeds Creek
Lake Creek
Robertson Creek
Beaverdam Creek
Smith Creek
New Light Creek
Horse Creek
85
50
N
0 1.75 3.5 7 Miles
Figure 3. Models Results Output Units
Based on UNRBA Monitoring Stations
Brown AND Caldwell


UNRBA Monitoring Site
Modeling Catchment
PERSON
ORANGE
GRANVILLE
DURHAM
GRANVILLE
FRANKLIN
ORANGE
DURHAM
85
50
N
0 1.75 3.5 7 Miles
Figure 4. Models Results Output Units
Based on Watershed Modeling Units
Brown AND Caldwell


DEQ Monitoring Site
85
50
N
0 1 2 4 Miles
Figure 5. Potential Spatial Scales for the Lake Modeling Results
(segmentation for modeling has not yet occurred)
Brown AND Caldwell