

A Statistical Analysis of the Effects of River Flow on Downstream Water Quality in the Lower Roanoke River, North Carolina



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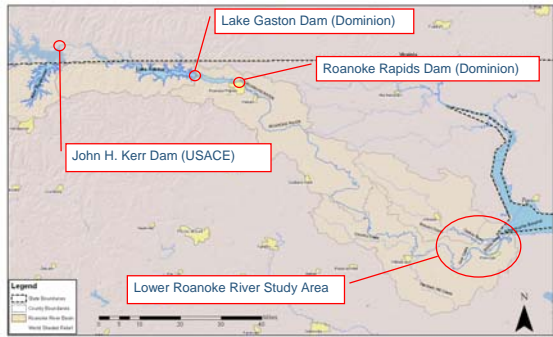
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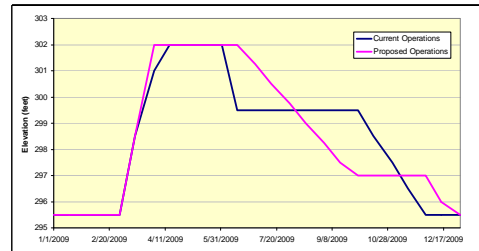
Study Overview

- Roanoke River Basin
 - Originates in the Blue Ridge Mountains, Northwestern Virginia and empties into Albemarle Sound, North Carolina
 - Also includes the Dan River and its tributaries
 - Watershed Area – 10,000 mi²
 - Lower Roanoke – tidal, Class C waters, SW designation
- 11 Reservoirs / Dams; Lower Roanoke most affected by operations at
 - John H. Kerr Dam
 - Lake Gaston Dam
 - Roanoke Rapids Dam
- Dam release impacts on the Lower Roanoke River
 - Dissolved Oxygen (DO) - downstream DO deficits
 - Salt Wedge incursion - migration recorded up to 10 miles upstream of Albemarle Sound
- ENSR identified flow thresholds

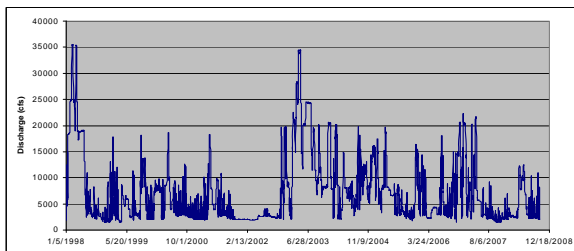
Roanoke River Study Area



John H. Kerr Dam Guide Curve



Roanoke Rapids Dam Discharge (1998 – 2008)



Average Discharge: 7,187 cfs
Median Discharge: 4,480 cfs
Discharge Range: 1,480 – 35,500 cfs

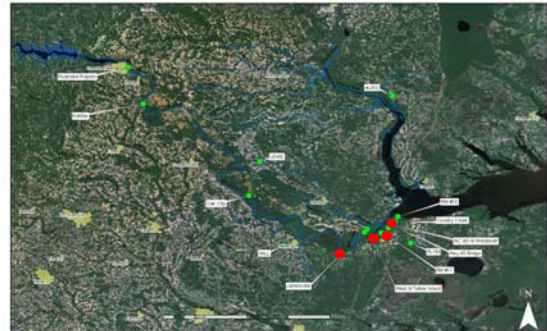
25th percentile: 2,610 cfs
75th percentile: 8,610 cfs

Dissolved Oxygen

Dissolved Oxygen Data Analysis

- ENSR incorporated data from the following sources:
 - Discharge: USGS streamflow gage at Roanoke Rapids
 - Continuous chemical/physical data: USGS monitoring gages at Roanoke Rapids, Halifax, Scotland Neck, Oak City, Hamilton, Williamston, Jamesville, Westover
 - Meteorological data: Lewiston (LEWS), Tidewater (PLYM), Pamlico (AURO), and Highway Patrol (WILL)
- ENSR conducted a series of statistical analyses to assess DO variability
 - Decision tree analysis/recursive partitioning used to identify parameters
 - Multiple regression – to confirm decision tree analysis
 - Frequency analysis conducted to further identify flow thresholds

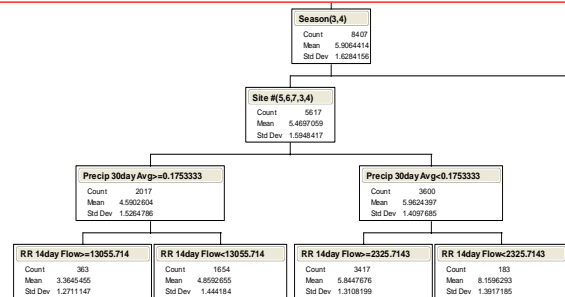
Roanoke River Study Area



Decision Tree Analysis/Recursive Partitioning

- Identification of significant predictor variables by means of splitting, or 'partitioning' variables into subsets using a binary splitting function
- The algorithm used in recursive partitioning selects variables to split that will optimize the explanatory value of a response variable
- Created several decision trees

Decision Tree Analysis



Decision Tree Analysis/Recursive Partitioning

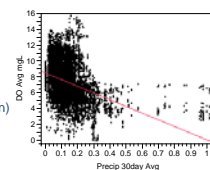
- 14-day Average Flow: > 13,000 cfs and > 8,000 cfs
- Other parameters of interest
 - Site: Jamesville, Tallow Island, River Marker 17, and Highway 45
 - Season: Fall and Summer
 - Month: June – September
 - Temperature: > 15.6°C
 - 30-day Average Precipitation: > 0.133, > 0.18 inches
- Seasonality, month, temperature are related to oxygen saturation and kinetics
- Precipitation and high flow benchmarks potentially result in nonpoint source BOD loading from riparian lowlands

Multiple Regression

- Regression analysis predicts a linear response (y) based on a single predictor (x)

Example:
 x = 30-day Precipitation Average
 y = DO

$$DO \text{ (mg/L)} = 8.56 - 8.54(30\text{-day Precipitation})$$



- Multiple regression predicts a response based on a *linear combination* of several predictors from a dataset

Multiple Regression

- A series of multiple regressions was conducted
 - Used 'Season' as an explanatory variable
 - Used 'Month' as explanatory variable
- Focused on Jamesville and Tallow Island
- River Marker 17 and Highway 45 are further downstream – greater tidal influence (note that Albemarle Sound has a relatively small tidal range)

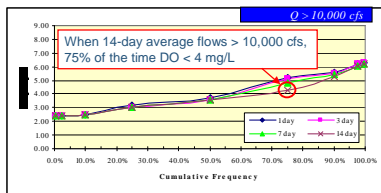
Multiple Regression – Jamesville

- Four multiple regressions conducted for each season using 'Temperature', '14-day Average Flow', and '30-day Average Precipitation'
 - Winter $R^2 = 0.60$
 - Spring $R^2 = 0.75$
 - Summer $R^2 = 0.68$
 - Fall $R^2 = 0.73$
- R^2 results – moderately high, but suggest that other existing factors influence DO during winter
- Results confirmed flow, precipitation, temperature, and season as important variables to DO

Frequency Analysis

- Derivation of the relationship between the magnitude and frequency of a parameter of concern – in this case, DO
- ENSR used sub-groups for flow and month

Example:
Jamesville
July – September
Flow > 10,000 cfs



Frequency Analysis – Tallow Island

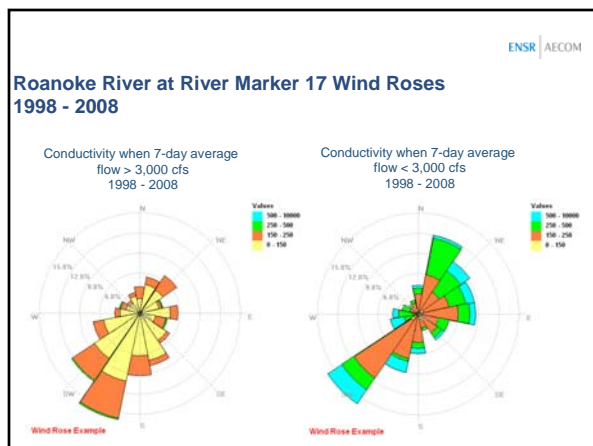
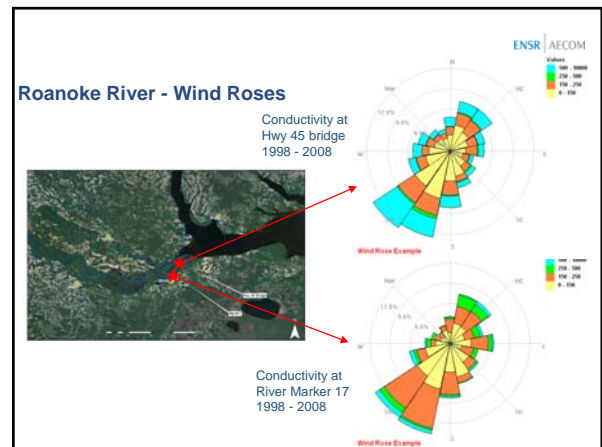
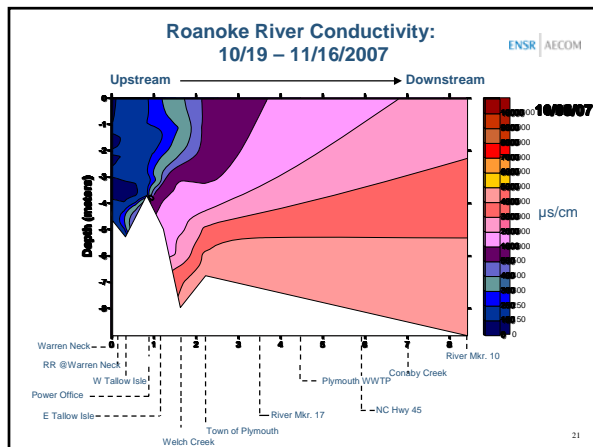
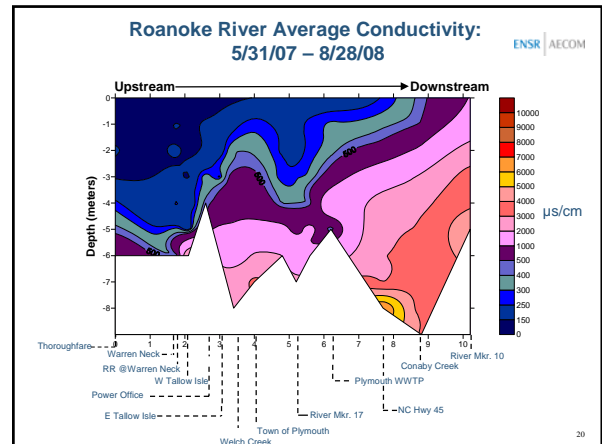
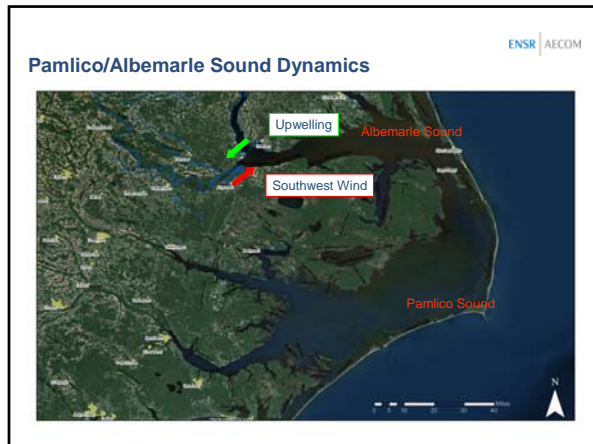
- Identified 3-day, 7-day, and 14-day average flows as significant variables
- Identified July – September, September – October as time periods with the potential for DO < 5 mg/L
- Identified flow breakpoints
 - 7,000 – 10,000 cfs (< 5 mg/L 50% of the time)
 - >10,000 cfs (< 5 mg/L 50% – 75% of the time)

Synopsis of All Statistical Analyses

- Four variables of significance
 - Time of year
 - June - November
 - Water temperature
 - > 15.6°C (60°F)
 - 30-day Average Precipitation
 - > 0.133 - 0.177 inches
 - 14-day average flow at Roanoke Rapids
 - 7,000 – 8,000 cfs associated with low DO
 - > 10,000 cfs associated with greater DO deficit

Water Quality Management – Salt Wedge Migration

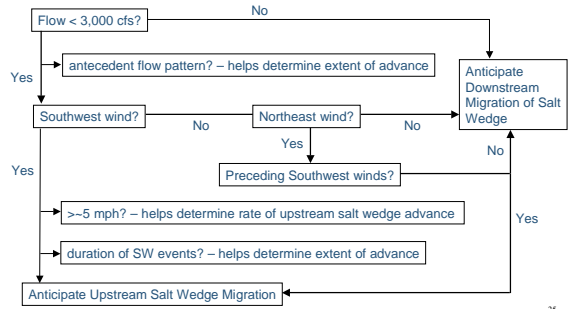




Sustained Water Quality Effects – Significant Observations

- Southwest winds and low flow are the primary driving forces behind the salt wedge movement upstream of Highway 45
 - Statistical analyses yield a minimum SW wind speed of ~5 mph
 - Several persistent days of SW winds are necessary to move the salt wedge up to River Marker 17
 - Conditions of flow < 3,000 cfs
- 7-day average flows greater than ~3,000 cfs tend to push the salt wedge downstream regardless of wind direction and speed
- While wind directions along the axis of the river are capable of moving salt up to Highway 45 under conditions of low flow, upstream movement to River Marker 17 appears to require southwest winds

Summary Worksheet – Decision Analysis Tree



Questions?

