

Watershed Modeling of Haw River Basin using SWAT for Hydrology, Water Quality and Climate Change Study



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Basic Outline

- Climate change and anticipated impacts on North Carolina
- Problem Statement
- SWAT model setup
- Climate variability: Trend analysis of Historical Climate data
- Calibration and Validation results of SWAT model
- Incorporating forecasted climatic scenario from RCM's coupled with GCM's into the SWAT modeling framework
- Expected outcomes

Climate Change and its effect

- Climate changes and its various implications have ever been the driving force for determining a multitude of important factors and essential components in watershed hydrology and its associated water quality
- Observed warming over several decades has been associated with changes in the large-scale hydrological cycle
- Based on the U.S. Global Change Research Program report, *Global Climate Change Impacts in the United States*, there are a number of significant threats projected for North Carolina
- North Carolina particularly have been severely affected by draughts in the recent past.

Importance of Jordan lake and Haw river watershed

- The Lake stretches upon an area of 13940 acres with nearly 200 miles of shoreline.
- At present the Jordan Lake is the source for 100 million gallons of drinking water on a daily basis to the towns of Cary, Apex, Morrisville, northern Chatham County and Wake County portion of Research Triangle Park
- Haw being the largest among the rivers contributes around 70 to 90 percent of the total flow to the lake
- Between 1995 and 2005 6 TMDL's have been conducted for waters draining into the Haw River. Four of them being for the fecal coliform counts and two for TSS.

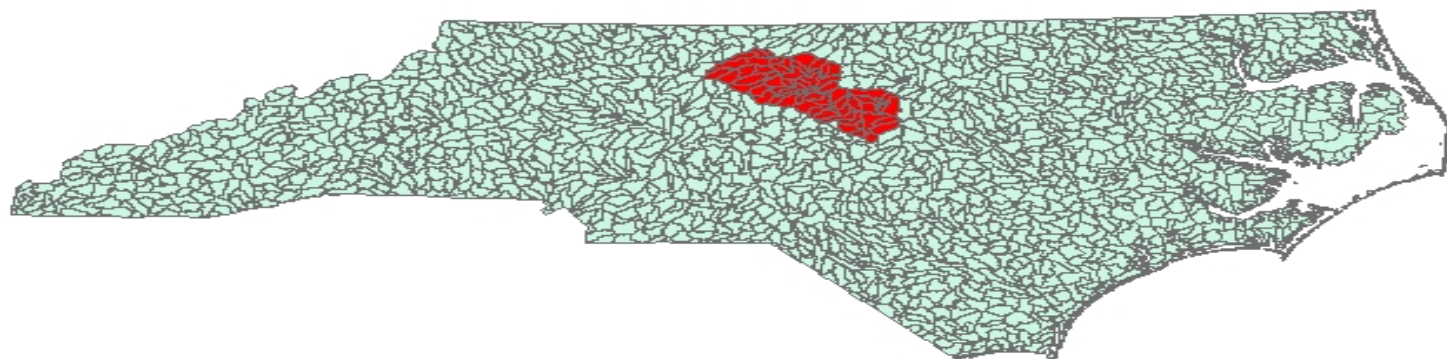
Study Objective

- Establish a hydrologic and water quality modeling framework using Soil and Water Assessment Tool (SWAT)
- Calibrate and validate the SWAT model for watershed hydrology and water quality
- Develop various climate variability and change scenarios using historical observation of climate data as well as projected data of climate models,
- Evaluate the impact of these scenarios on water availability and water quality on spatial and seasonal scales

Watershed Description

- It essentially covers land in ten counties and accounts for the Northern portion of the Cape Fear river basin.
- It drains an area of 1526 square miles
- *Forest Lands: 43% ,Agricultural (crop and pasture):27%,Urban Development: 17.4%,Other: 13%*
- Apart from being the source of freshwater for residential and industrial uses it also serves recreational purposes along with transportation source and irreplaceable wildlife habitat.

Location of Haw River Watershed

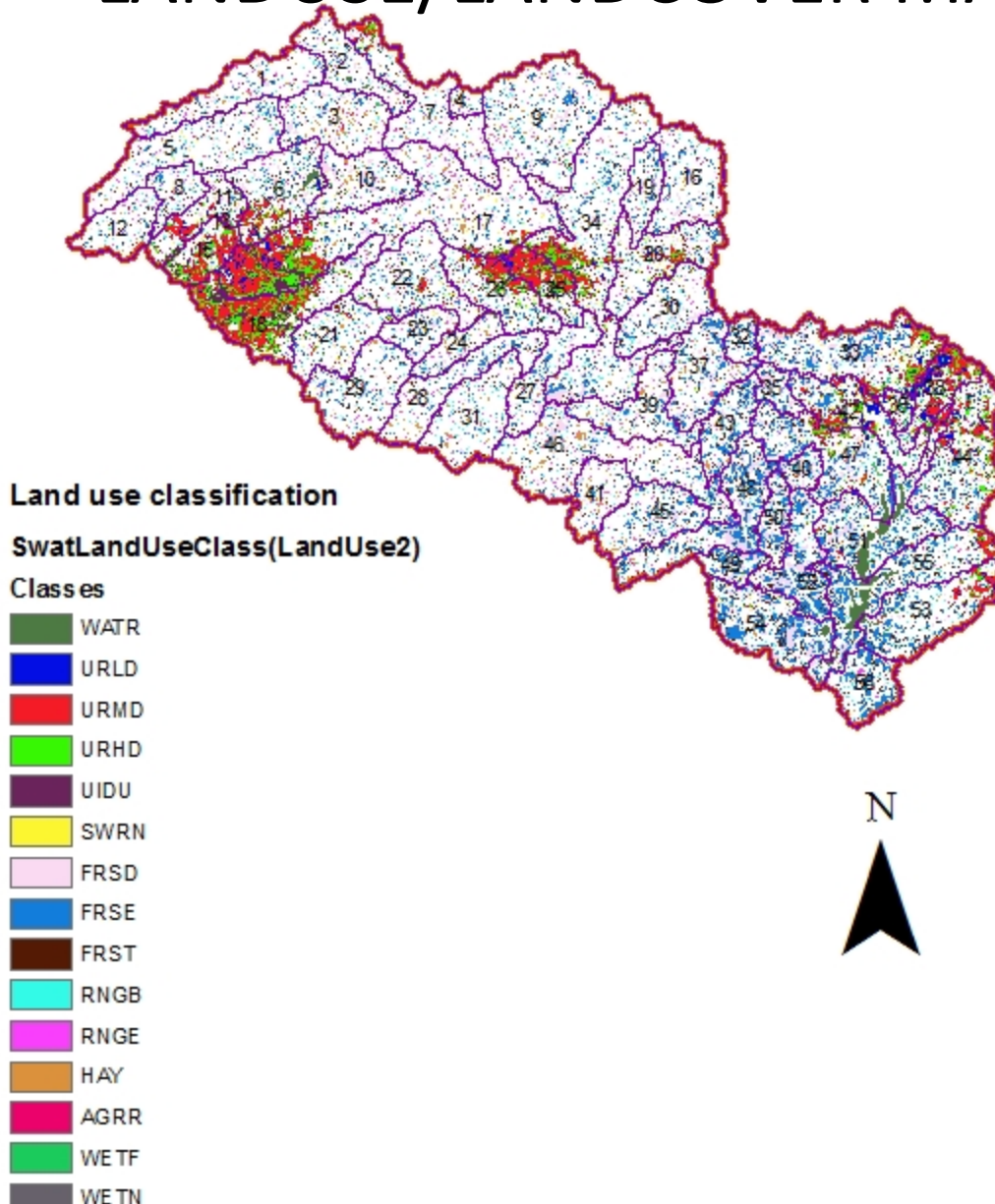


Legend

-  NC 12 digit HUC
-  HAW_12



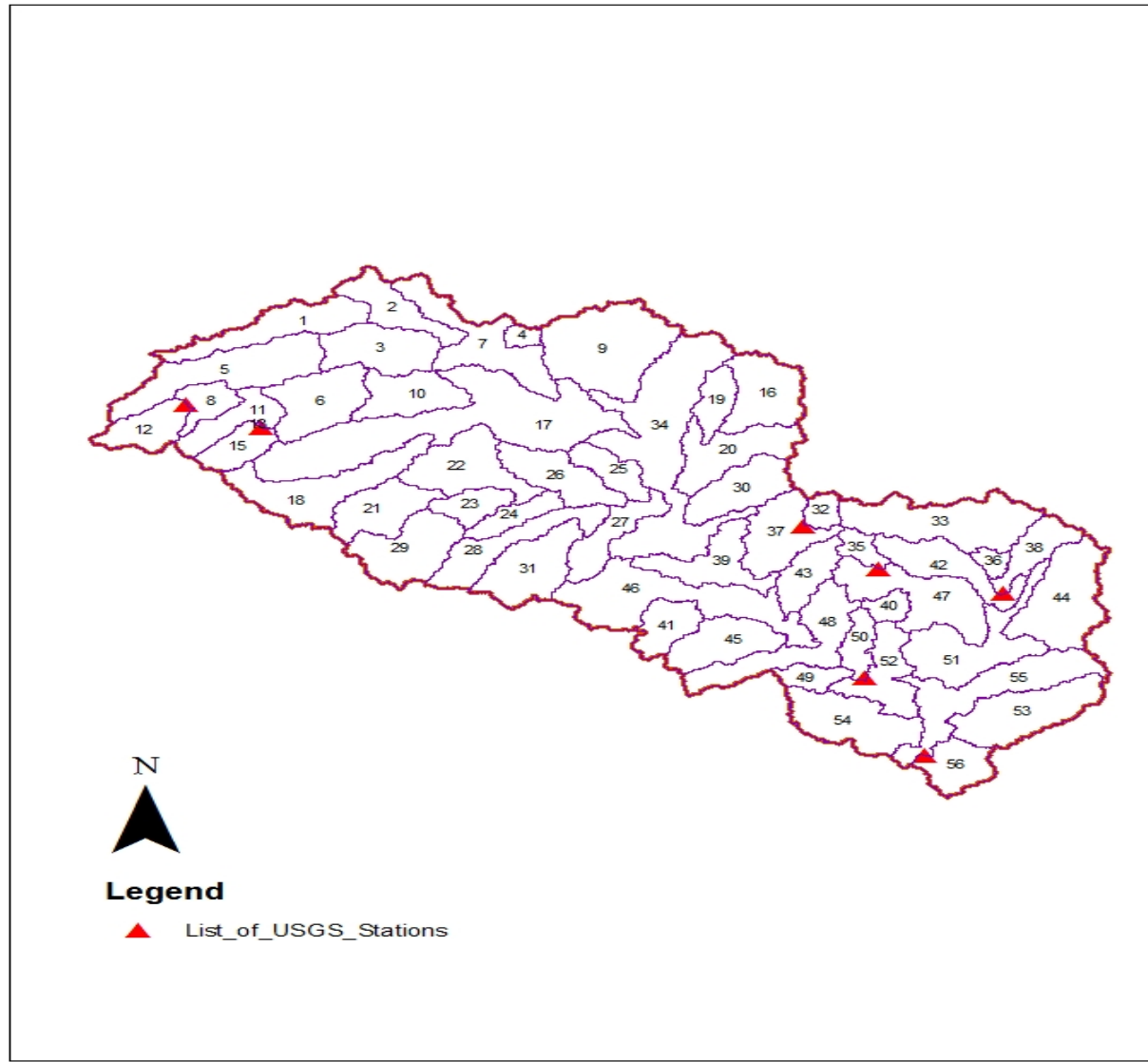
LANDUSE/LANDCOVER MAP



SWAT : The modeling framework

- Soil and Water Assessment Tool (SWAT) is a hydrologic and water quality model developed by the USDA Agricultural Research Service (USDA-ARS).
- It is a long-term, continuous, watershed-scale simulation model that operates on a daily time step and is designed to assess the impact of different management practices on water, sediment, and agricultural chemical yields.
- SWAT has already been applied across the U.S. and in other regions of the world for a multitude of applications including hydrologic, sediment and pollutant loss, and climate change studies.

Haw river watershed with USGS Sites



Data layers and model setup

- Topography, Weather, Land use, Soil, and Management data
- Elevation data: (30m DEM) 1/3 Arc-second downloaded from National Seamless Data Server
- Soil Data STATSGO was used
- Landuse data NLCD 2006 data from National Seamless Data Server
- Delineation was performed in such a way that the boundary of the subwatersheds match with the 12 digit Hydrologic Unit Code (HUC's)
- 456 HRU's were created by ArcSWAT for the 57 subwatersheds

Data layers and model setup

- Daily precipitation and temperature data : USDA ARS website for 12 weather stations in and around watershed
- Other significant input options that were used for the study included the modified CN method to calculate partitioning of surface runoff versus infiltration, the Muskingum method for simulating the channel routing process, and the Hargreaves method for estimating potential evapotranspiration
- SWAT was simulated for a period of 21 years (1988-2009) as a baseline scenario with the first 2 years as a warm-up period

SWAT- Calibration and Validation

- Daily streamflow and water quality data including suspended sediment, nitrate, organic N, organic P for the 2 USGS sites i.e. a)02096500 b)02096960 were downloaded from the USGS website.
- Daily data were aggregated into monthly and annual basis and were used to calibrate and validate the model
- Web Based Hydrograph Analysis Tool (WHAT) a web-based application which uses the automated digital filter technique (Arnold and Allen, 1999) was used to separate the streamflow into two contributing components i.e. surface runoff and baseflow

Calibration continued...

- Overall water balance was corrected to make sure the individual components of streamflow were correctly resembled
- Calibration period was chosen as 2000-2009 and validation period was 1990-1999

Overall water balance

- Precipitation 1132.64 mm
- ET-721.80 mm
- Surface Runoff-165.93 mm
- Baseflow-143.04 mm
- Water Yield-332.59 mm

i_SWAT in manual calibration

- i_SWAT is an interactive software package which was actually constructed to manage the input and output data for the UMRB SWAT simulations and execution of the model for each simulations (Gassman et al 2003).
- It stores SWAT input data in an Access database, feeds that data to SWAT, runs SWAT, and reads and stores the results.

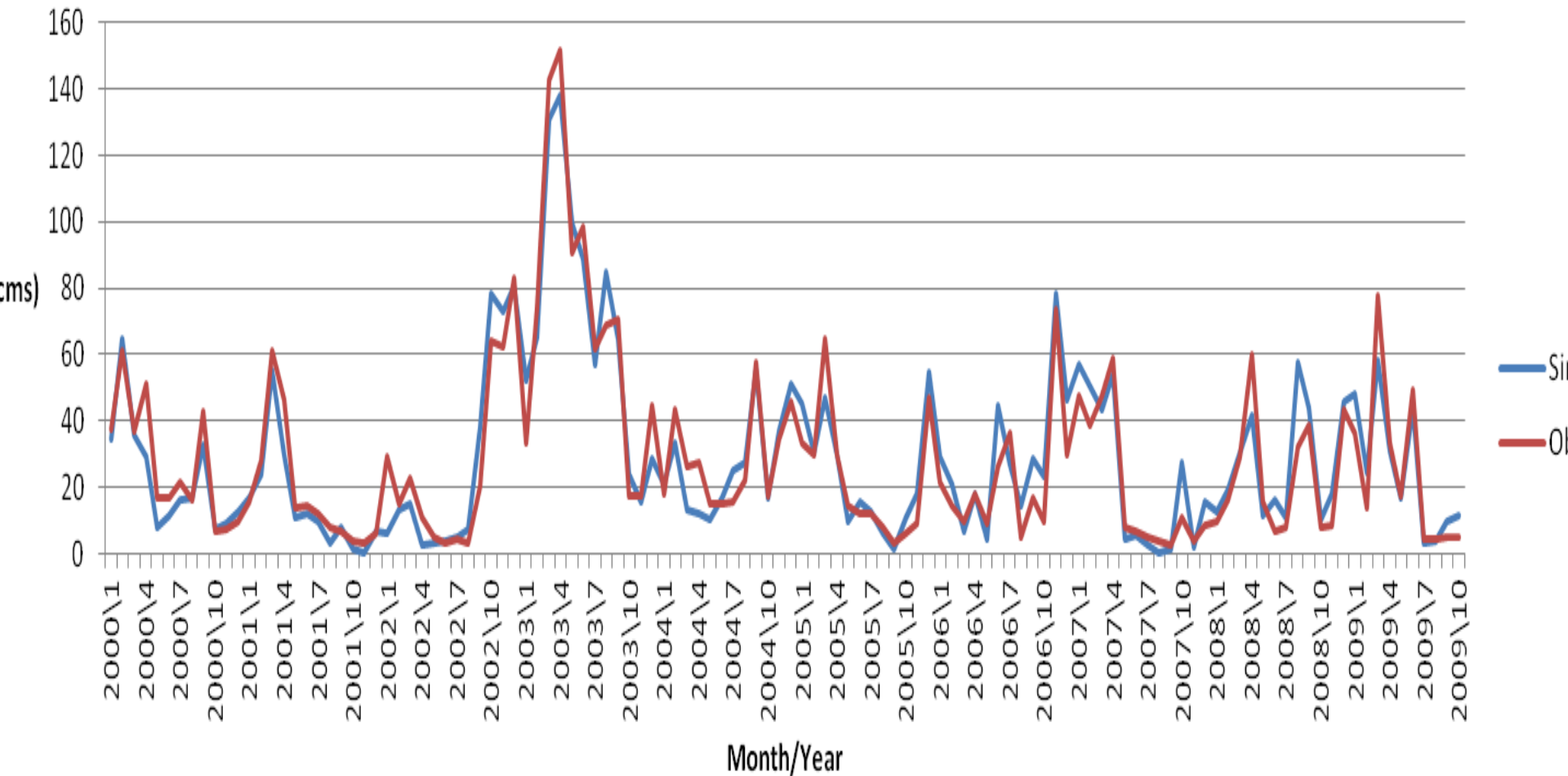
Parameter and their Final values

Parameter	Default value	Final Calibrated Value
CN	30-98	-10%
ESCO	0-1	0.88
EPCO	0-1	0.05
ALPHA_BF	0.048	0.3
GW_DELAY	0	50
Rchrg_DP	0-1	0.18
REVAP	0-500	0.17
SOL_AWC		0.04
GWQMN	0-5000	5

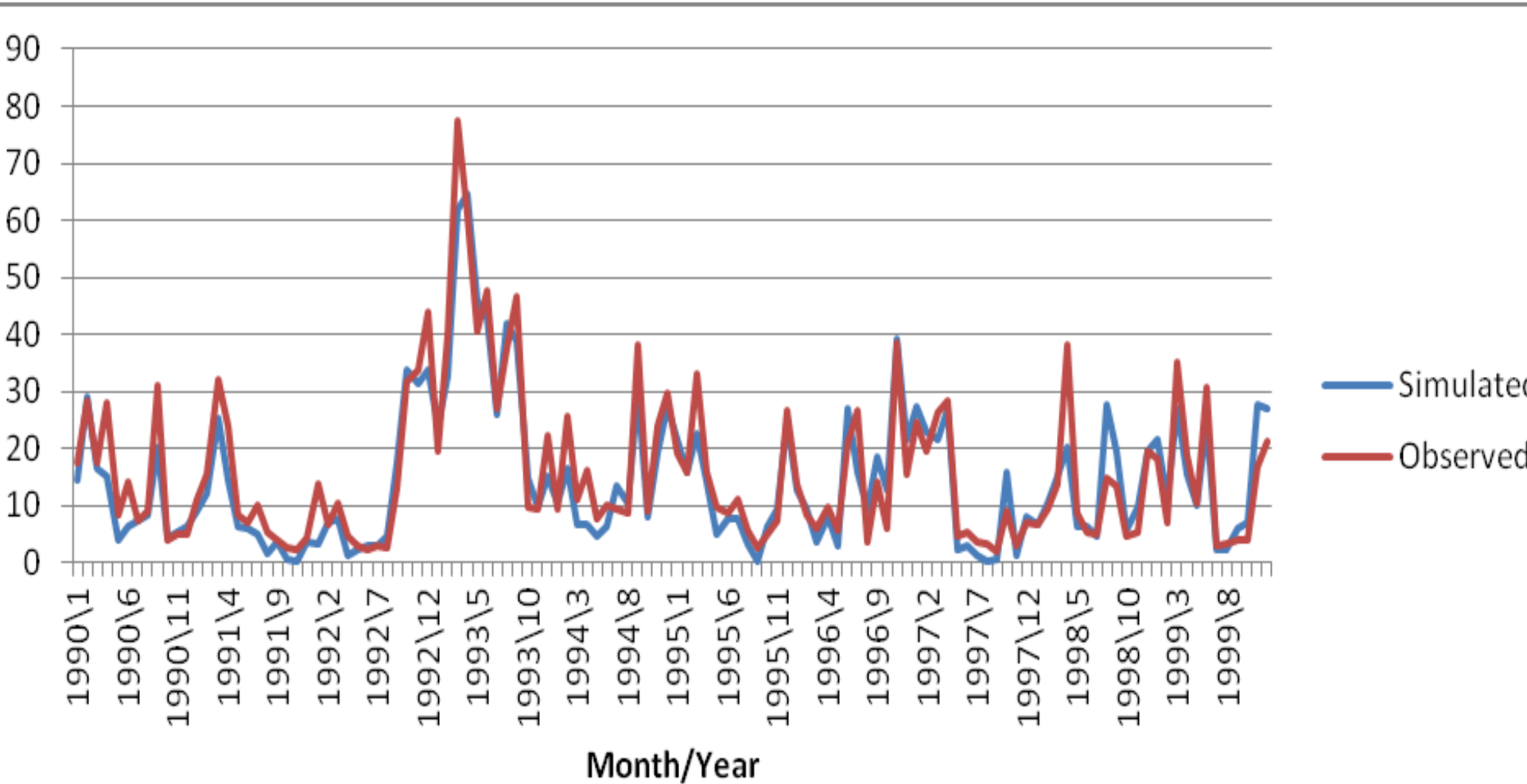
Statistical measures of Calibration and validation

- USGS Site 02096960
Calibration(2000-2009) $R^2 = 0.896$, $E = 0.896$
Validation(1990-1999) $R^2 = 0.89$, $E = 0.88$
- USGS Site 02096500
Calibration(2000-2009) $R^2 = 0.87$, $E = 0.86$
Validation(1990-1999) $R^2 = 0.86$, $E = 0.76$

Calibration comparison chart



Validation comparison chart

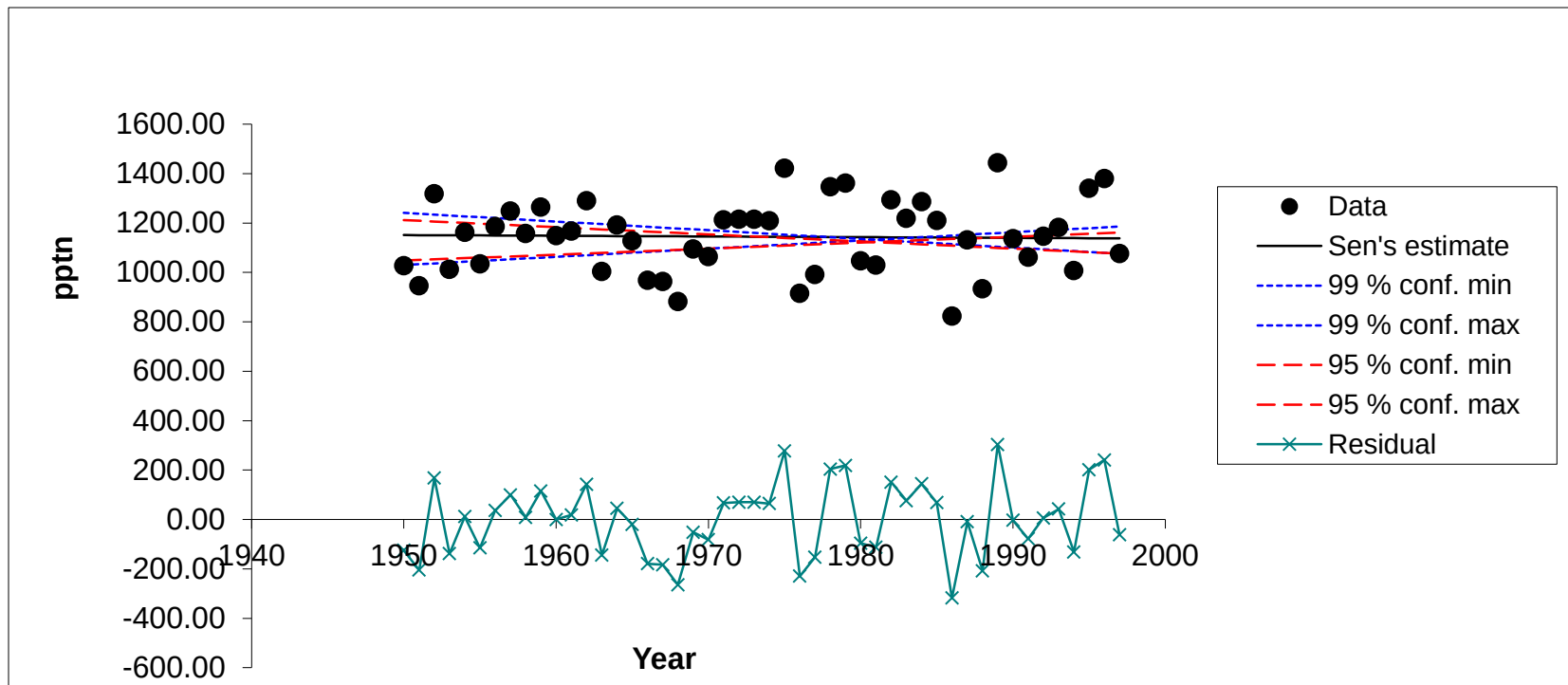


Trend Analysis and Regime shift detection

- Daily precipitation and temperature data for 59 years (1950-2009) for the watershed were obtained from the USDA-ARS website (<http://www.ars.usda.gov/Research/docs.htm?docid=19390>) which were later aggregated into monthly and annual basis
- Mann-Kendall test was performed on the annual precipitation data to detect the trends in the time series
- The test was based upon the null hypothesis of no trend, *H₀*, i.e. the observations are randomly ordered in time, against the alternative hypothesis, *H₁*, where there is an increasing or decreasing monotonic trend

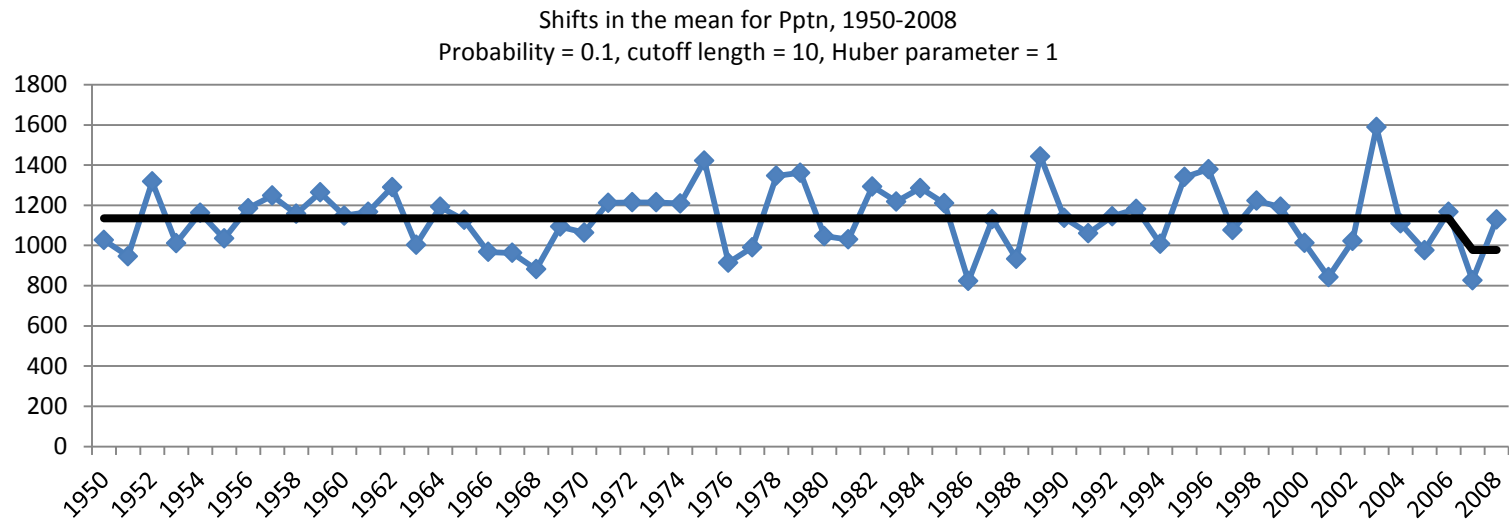
Continued..

- Precipitation showed a monotonic decreasing trend throughout the watershed for 59 years



Regime shift detection

- Historical annual precipitation data were analyzed for presence of any significant regime. There was a change in regime in 2007 which was a drought year in North Carolina



Ongoing work

- Incorporate future climatic scenario from the RCM's and GCM's guided by the latest IPCC scenario's
- Climate outputs from a number of RCM's have already been downloaded from NARCCAP and currently the processing of the data which is in netcdf format is being done
- Calibrate the SWAT model for the water quality
- Examine the effects and impacts of Extreme Climatic events on water availability and quality

Expected outcomes

- SWAT model would be effective in predicting the hydrology and water quality under the anticipated climate change
- Study results would be helpful for water resource planners, manager and stakeholders in addressing serious issues regarding the sustainability, water quality and infrastructure of Jordan Lake

THANK YOU 😊

- Questions