United States Environmental Protection Agency

Investigating the Sensitivity of U.S. Stream Water Quality to Climate Change: EPA ORD's "20 Watersheds" Project

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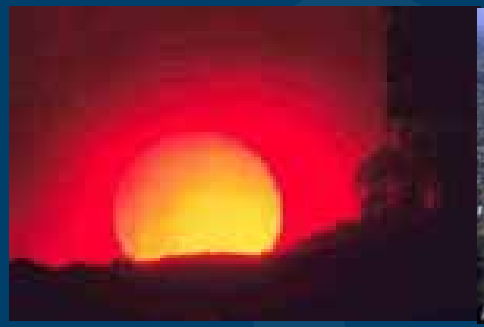
Pilot Utilities Modeling Applications Workshop (PUMA)
San Francisco, CA December 1-3, 2010



Acknowledgement: Project Team

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Background- The Basic Problem

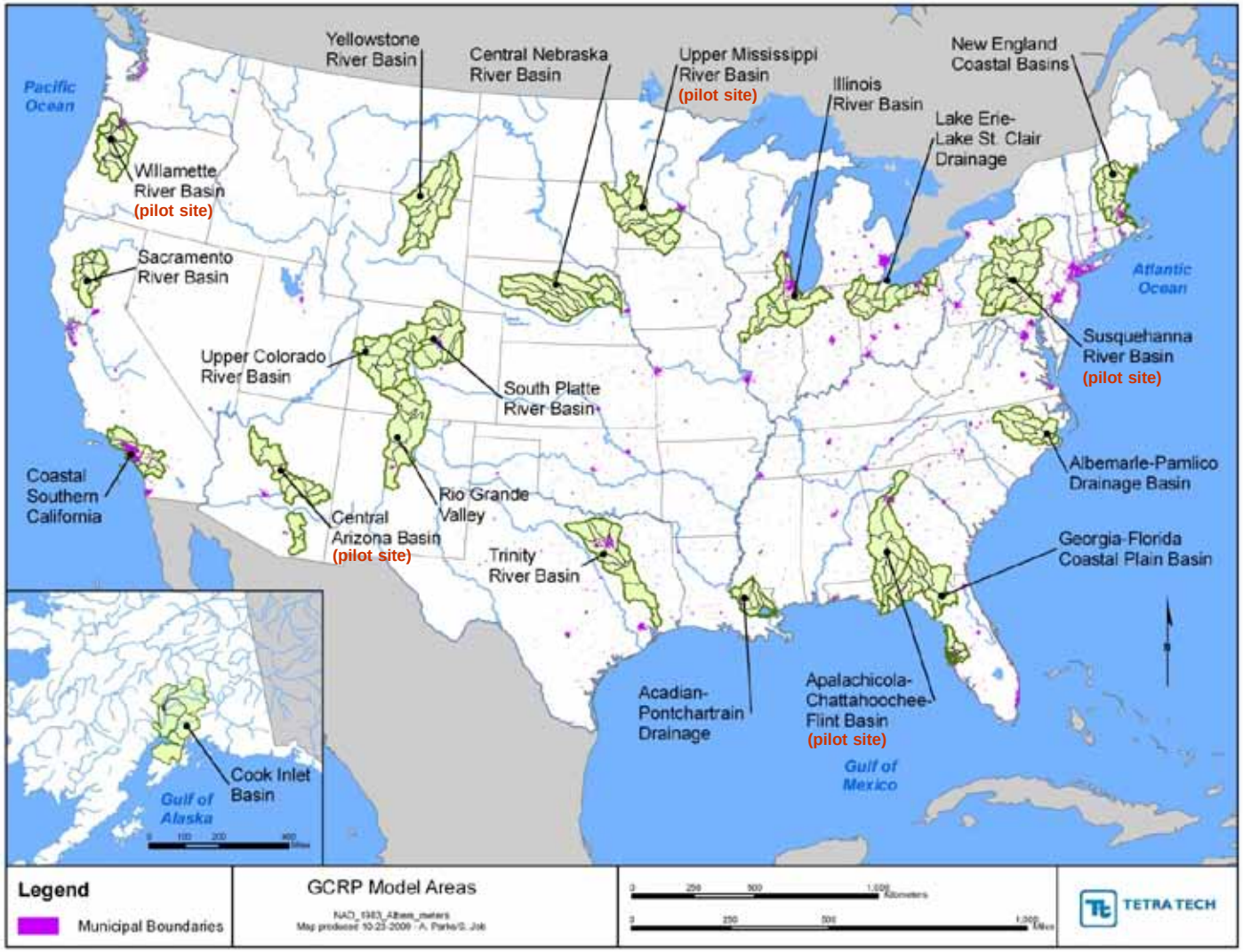
- Managing climate risk will require an understanding of potential impacts and development of adaptive strategies
  - impacts/risk will vary regionally
- Climate change highly uncertain, we don't have accurate multi-decadal forecasts (precip; regional scales)
- Simulation models (e.g., climate, hydrology, ecosystem) useful to systematically explore the implications of different futures, assumptions, and policy choices on management targets (impacts)
- Allows us to identify where the greatest vulnerabilities lie, and to develop response options that are robust across a wide range of plausible climate futures

ORD GCRP 20 Watershed Project

Goal to assess:

- Sensitivity of U.S. streamflow, nutrient, and sediment loading to climate change across a range of plausible mid-21st Century climate futures
- Potential interactions of these climate changes with increasing urbanization in these watersheds
- Methodological challenges associated with integrating existing tools (e.g., climate models, land-use models, watershed models) and datasets to address these scientific questions
- The sensitivity of the results to a range of methodological choices available;
- Ability to scale information from this study up to national scale and down to local, reach scale

20 Watersheds – Study Sites



Site Selection

Sites were selected based on criteria including:

<u>Bio-physical variability</u>
Hydro-climatic variability
Watershed characteristics
Range of ecoregions
Land-uses (urban areas)
Potential issues/vulnerabilities

<u>EPA Programmatic</u>
Overlap with other EPA ORD projects and priority areas
Coverage of all EPA Regions

<u>Practical</u>
Leveraging of existing models
Availability of data for calibration/validation
(streamflow, water quality (NAWQA), meteorological)

Modeling Approach

Focus on streamflow, N, P, sediment

Daily simulations for 30-year historical (1970-2000) and 30-year future (2040-2070) periods

Maximum spatial resolution about HUC8 (~ 1000-2000 sq. miles)

<u>In 5 pilot watersheds:</u>
- Use 2 watershed models, HSPF and SWAT
    - 6 dynamically downscaled climate change scenarios (NARCCAP)
    - 2 land-use scenarios, current and future (EPA ICLUS)
- Effects of climate change, land-use change, coupled C-L change
- Sensitivity studies to assess influence of different methods of downscaling

<u>In 15 non-pilot watersheds:</u>
- Use 1 watershed model, SWAT
    - 6 dynamically downscaled climate change scenarios (NARCCAP)
    - 2 land-use scenarios, current and future (EPA ICLUS)
- Effects of climate change, land-use change, coupled C-L change

Climate change scenarios

Climate Change Scenarios Evaluated

Scenario #	Climate Model(s)
NARCCAP scenarios	
1	CRCM_CGCM3
2	HRM3_HadCM3
3	RCM3_GFDL
4	GFDL high res_GFDL
5	RCM3_CGCM3
6	WRFP_CCSM
Driving GCMs of the NARCCAP scenarios (i.e., no downscaling)	
7	CGCM3
8	HADCM3
9	GFDL
10	CCSM
Bureau of Reclamation BCSD statistically downscaled scenarios	
11	CGCM3
12	HADCM3
13	GFDL
14	CCSM

<u>Representation of climate scenarios:</u>

- GCM/RCM projections interpolated to NCDC weather stations

- “delta change” method to create hydro model inputs

- PET calculated using Penman-Monteith

NARCCAP Climate Change Data

Regionally downscaled climate change scenarios from NCAR North American Regional Climate Change Assessment Program (NARCCAP)
http://www.narccap.ucar.edu/

- Includes14 combinations of 4 IPCC GCMs downscaled to the U.S. with 6 different RCMs
    - EPA modeling will evaluate only 6 NARCCAP scenarios that are currently available

- Climate scenarios based on the IPCC A2 greenhouse gas storyline (a relatively “pessimistic” scenario)

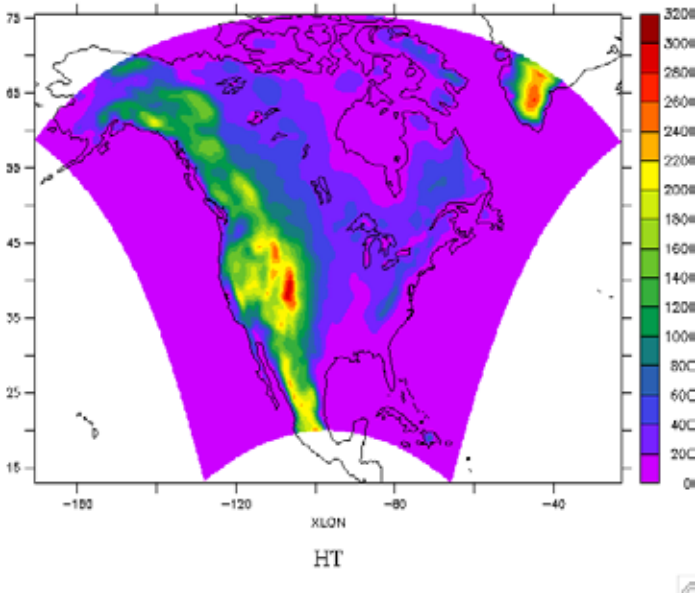
- Coverage for the conterminous U.S.

- Spatial Resolution 50-km horizontal grid

- Temporal Coverage: 1970-2000 and 2040-2070

- Temporal Resolution: 3-hourly data, usually averaged to monthly

- Example variables: Surface and atmospheric temperature, humidity, and winds, precipitation, cloudiness, surface energy and moisture budget quantities, etc.



Land-use change scenarios

<u>Representation of land-use change scenarios:</u>

- current land-use is from 2001 NLCD

- future land-use based on ICLUS 2050, A2 projected changes in housing density (same as climate scenarios)

- a “business as usual” growth scenario

ICLUS: ORD GCRP's Integrated Climate and Land-use Change Project Scenarios

- Includes 5 unique scenarios , one based on the U.S. Census "middle" scenario and 4 modifications consistent with the different assumptions underlying the A1, A2, B1, B2 IPCC greenhouse gas storylines.
    - EPA modeling will use the A2 ICLUS land-use change scenario for 2050 (to be consistent with climate change scenarios)

- Coverage for the conterminous U.S.

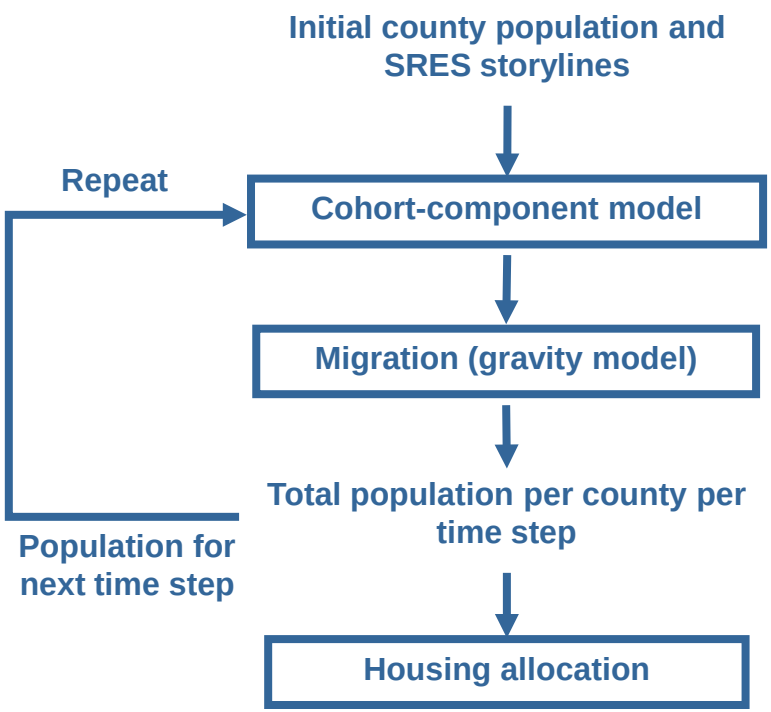
- Spatial Resolution is 100 m grid cells for allocation of population to housing density; population processes resolved at county scale

- Temporal coverage is 2000 – 2100

- Temporal resolution is decadal for spatial allocation and every 5 years for demographics

- Variables are population, housing density, impervious surface

- Developed using the SERGoM* allocation model with a gravity migration model

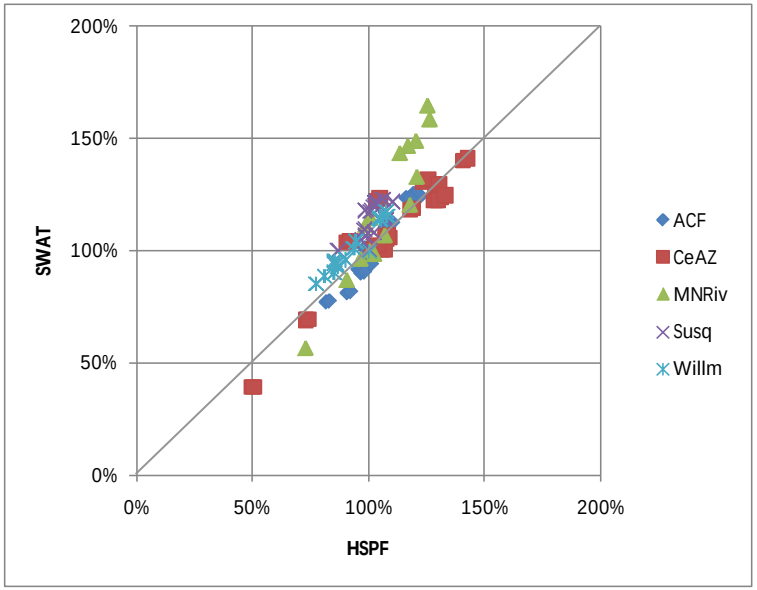


* Spatially Explicit Regional Growth Model, Natural Resources Ecology Laboratory, Colorado State University

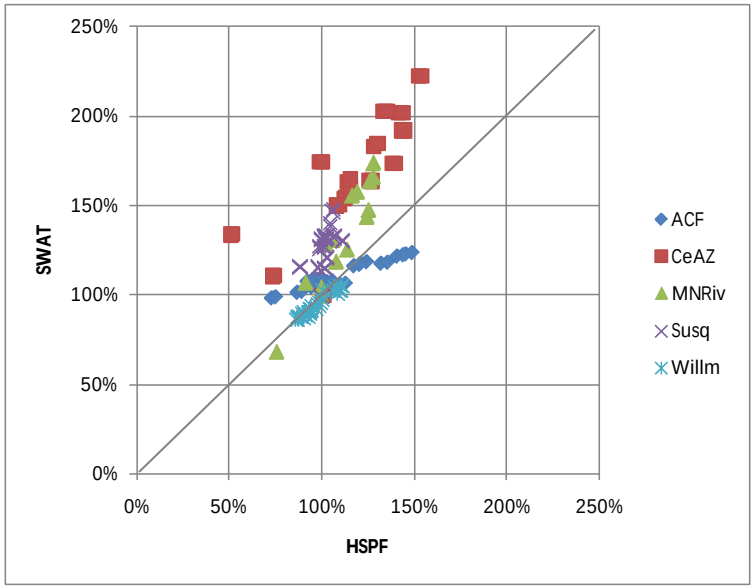
Nash Sutcliffe Coefficient of Model Fit Efficiency (E) for Daily Flow Predictions: 10-year Calibration and Validation Periods

Study Area	Model	Target Site Calibration	Target Site Validation	Downstream Calibration
ACF	HSPF	0.71	0.65	0.72
	SWAT	0.62	0.58	0.65
Central Arizona (CeAZ)	HSPF	0.48	0.45	0.53
	SWAT	0.03	-1.00	0.22
Minnesota River (Minn)	HSPF	0.75	0.78	0.92
	SWAT	0.79	0.74	0.63
Susquehanna (Susq)	HSPF	0.70	0.55	0.77
	SWAT	0.29	0.42	0.45
Willamette (Willm)	HSPF	0.80	0.81	0.88
	SWAT	0.49	0.47	0.67

Comparison of HSPF- and SWAT-simulated changes relative to existing conditions (5 pilot basins; all 28 scenarios)

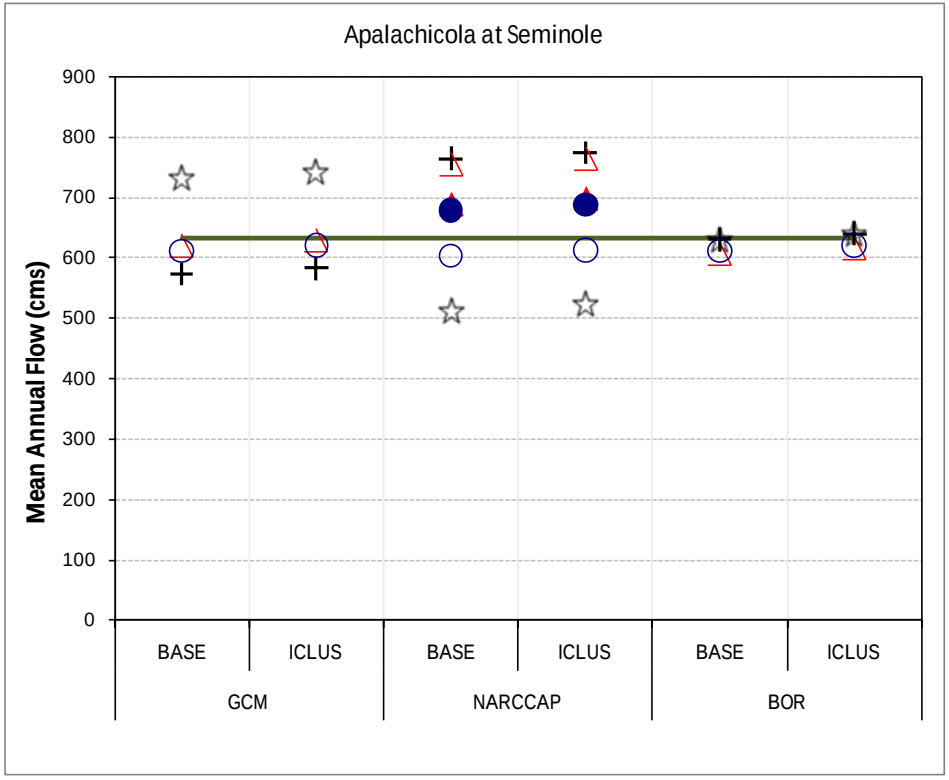


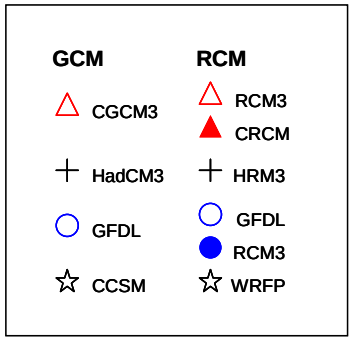
Total Streamflow



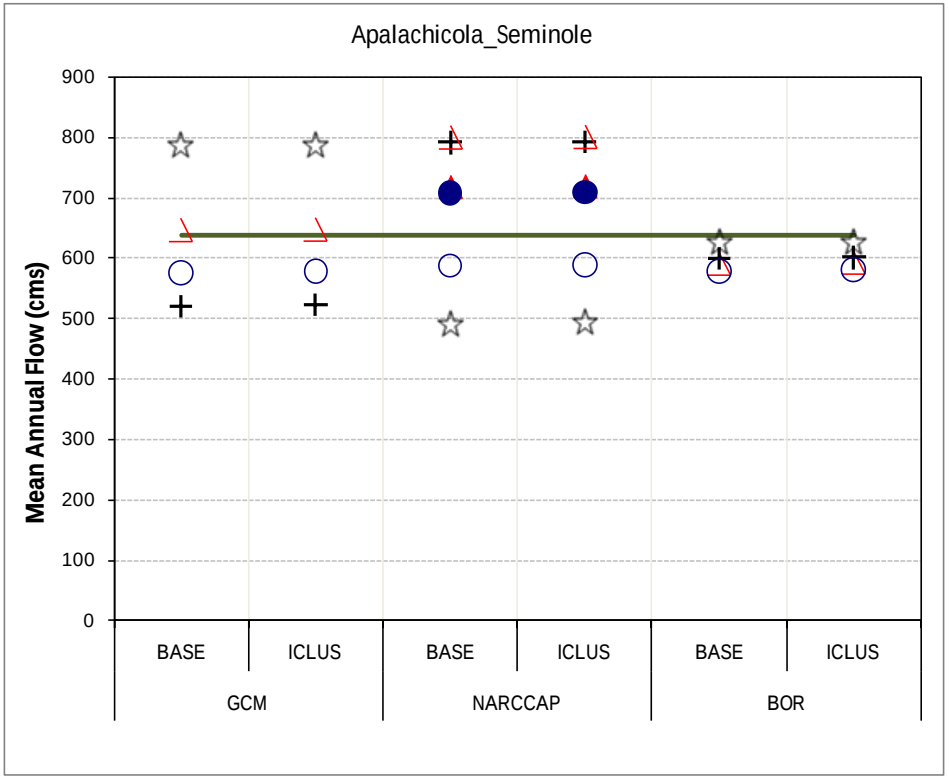
Total Nitrogen

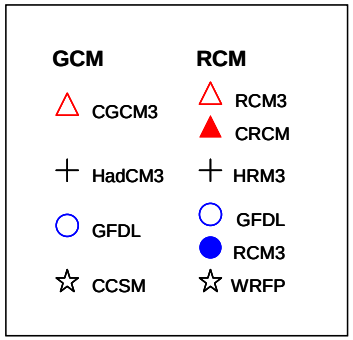
Mean Annual Flow (cms)
Apalachicola River at Seminole (HSPF)



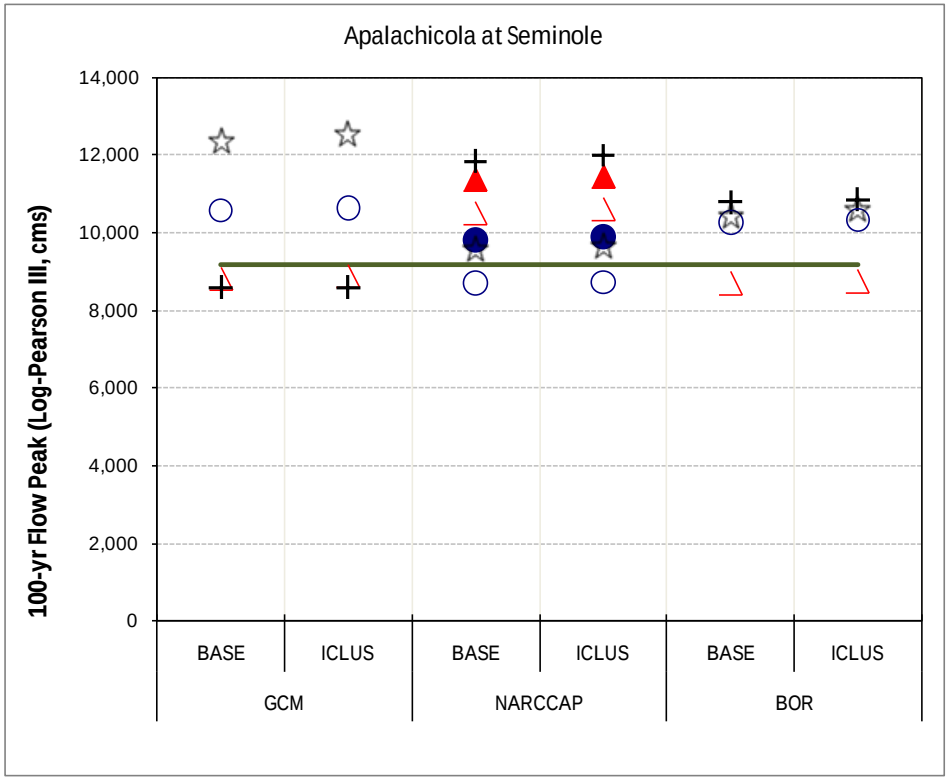


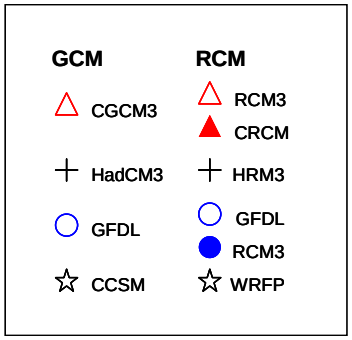
Mean Annual Flow (cms)
Apalachicola River at Seminole (SWAT)



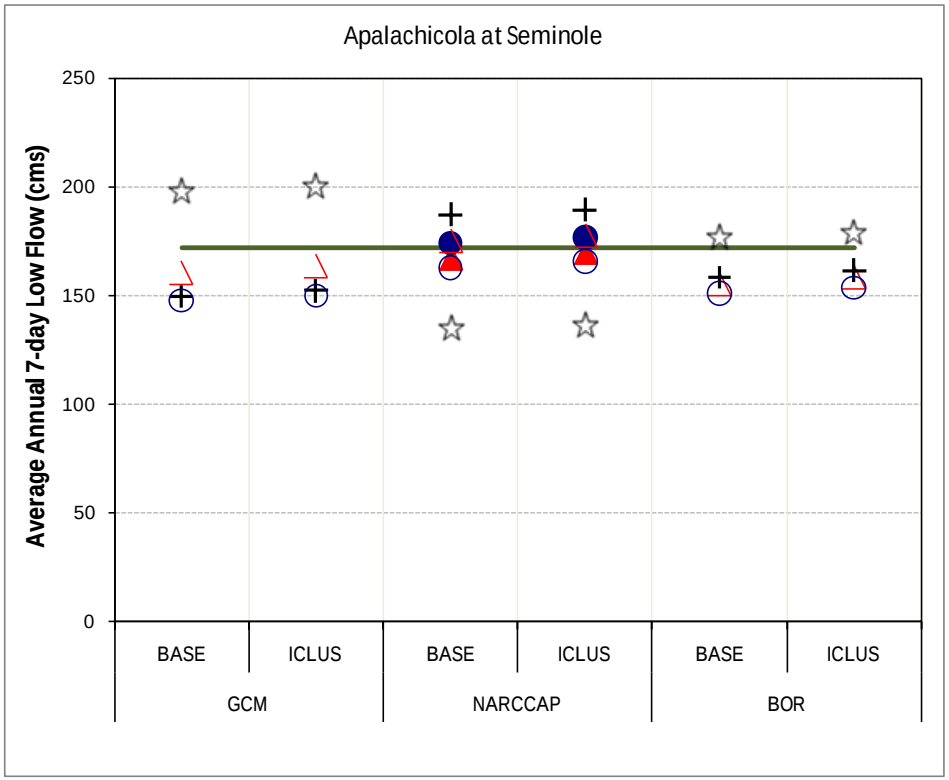


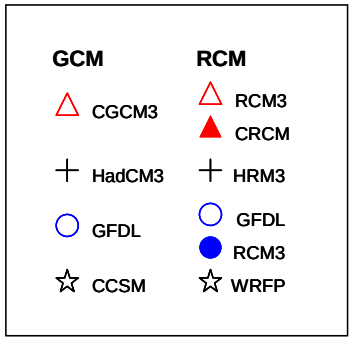
100-yr Flow Peak (Log-Pearson III, cms)
Apalachicola River at Seminole (HSPF)



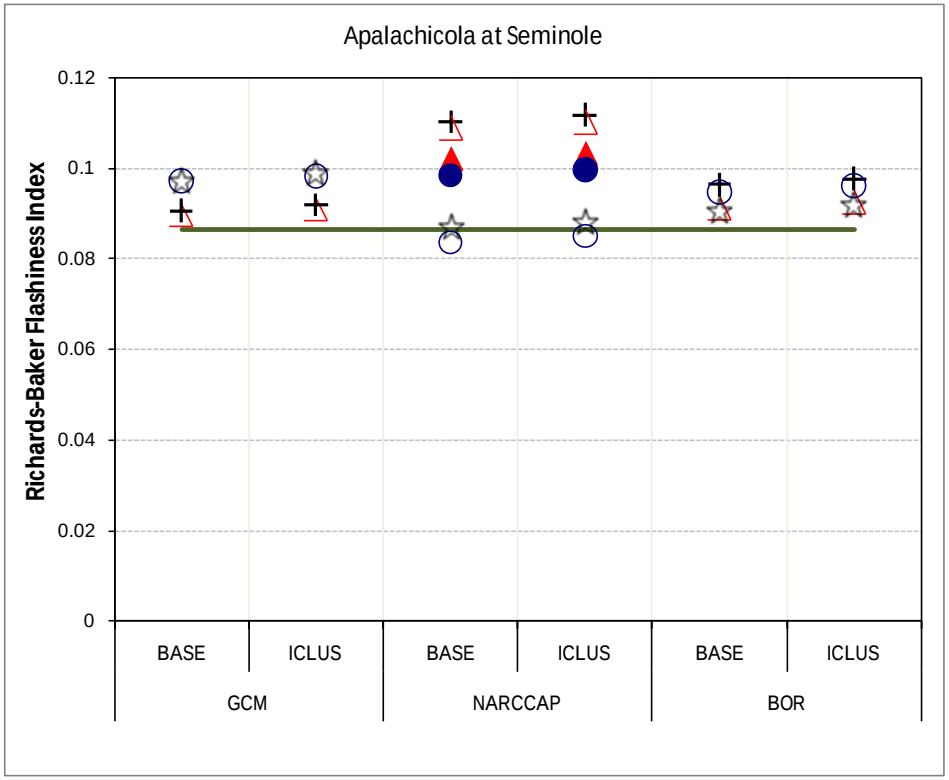


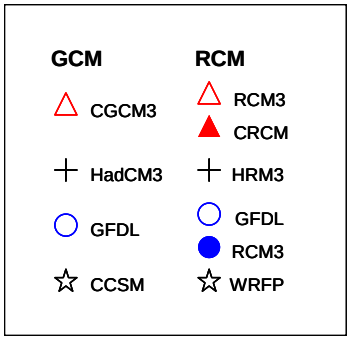
Average Annual 7-day Low Flow (cms)
Apalachicola River at Seminole (HSPF)



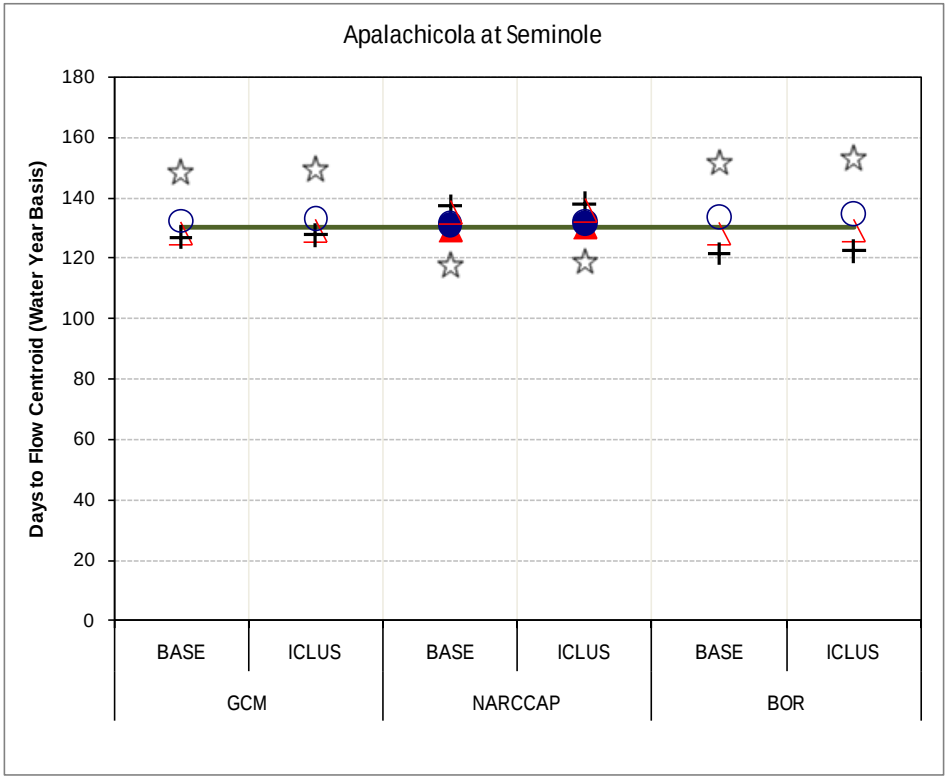


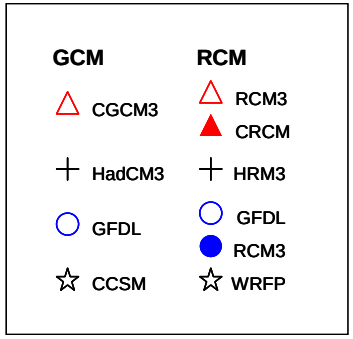
Richards-Baker Flashiness Index
Apalachicola River at Seminole (HSPF)



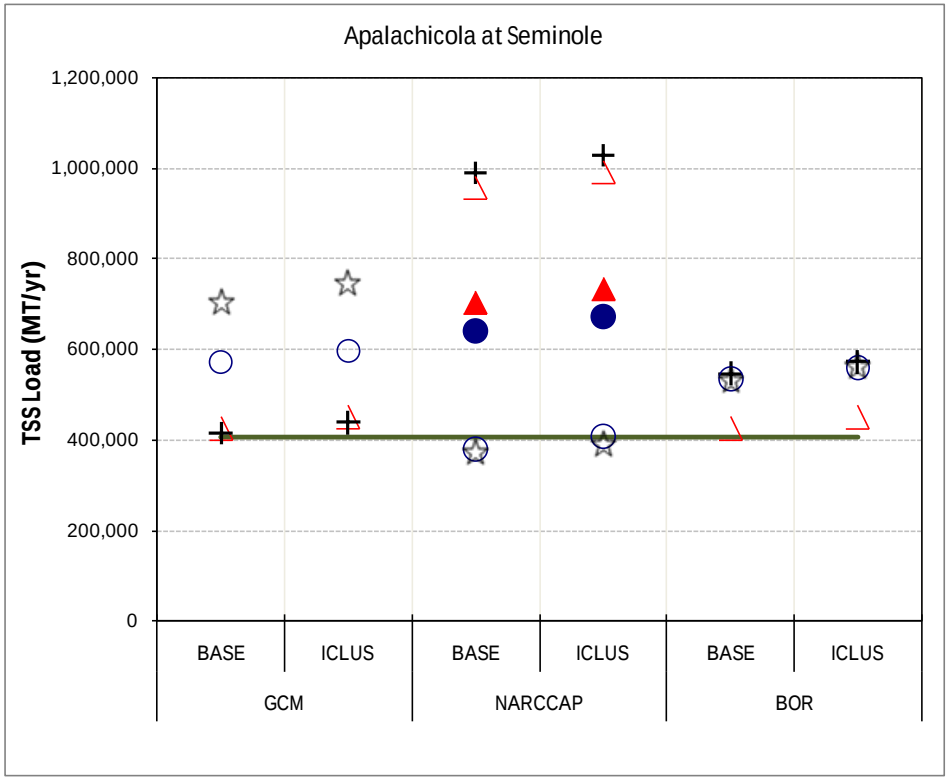


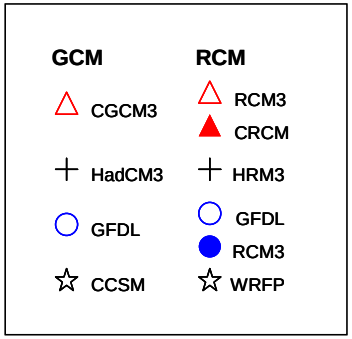
Days to Flow Centroid (Water Year Basis)
Apalachicola River at Seminole (HSPF)



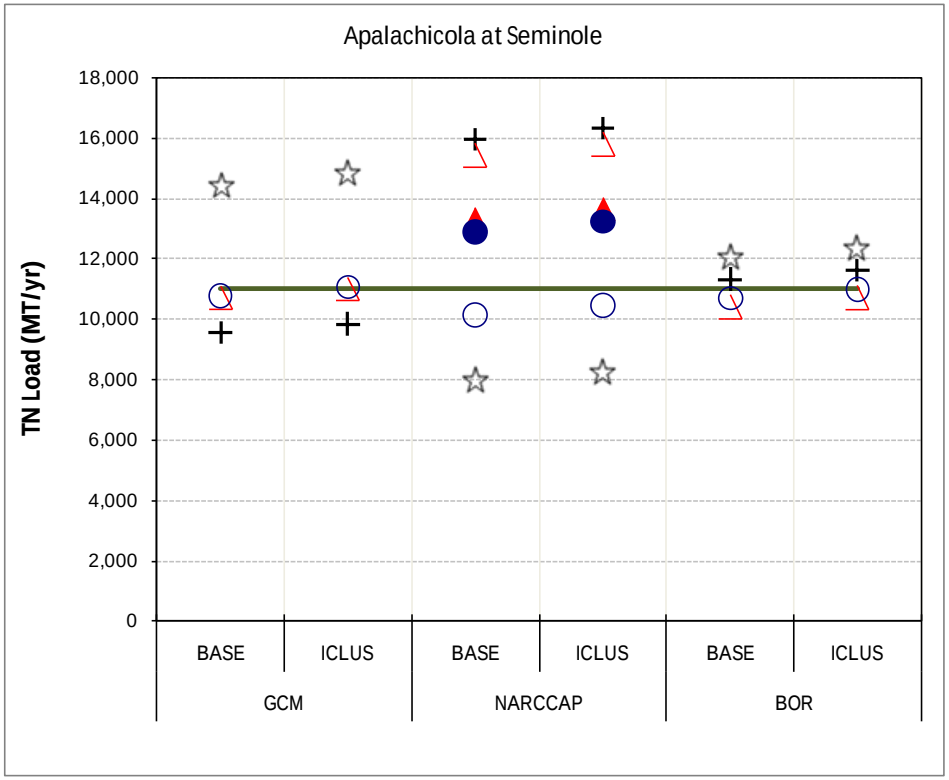


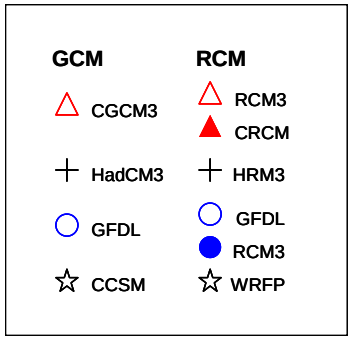
TSS Load (MT/yr)
Apalachicola River at Seminole (HSPF)



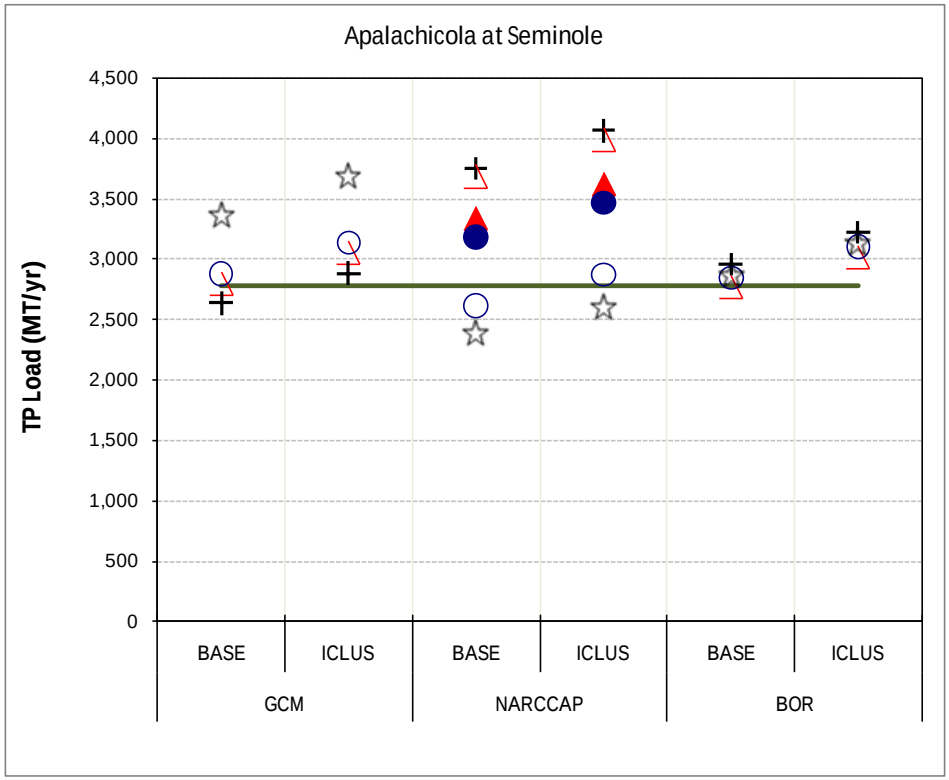


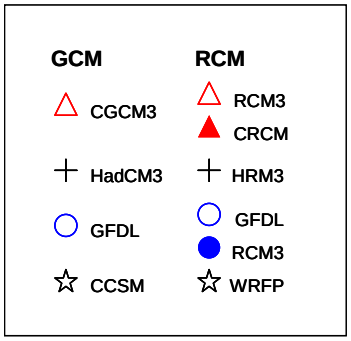
TN Load (MT/yr)
Apalachicola River at Seminole (HSPF)



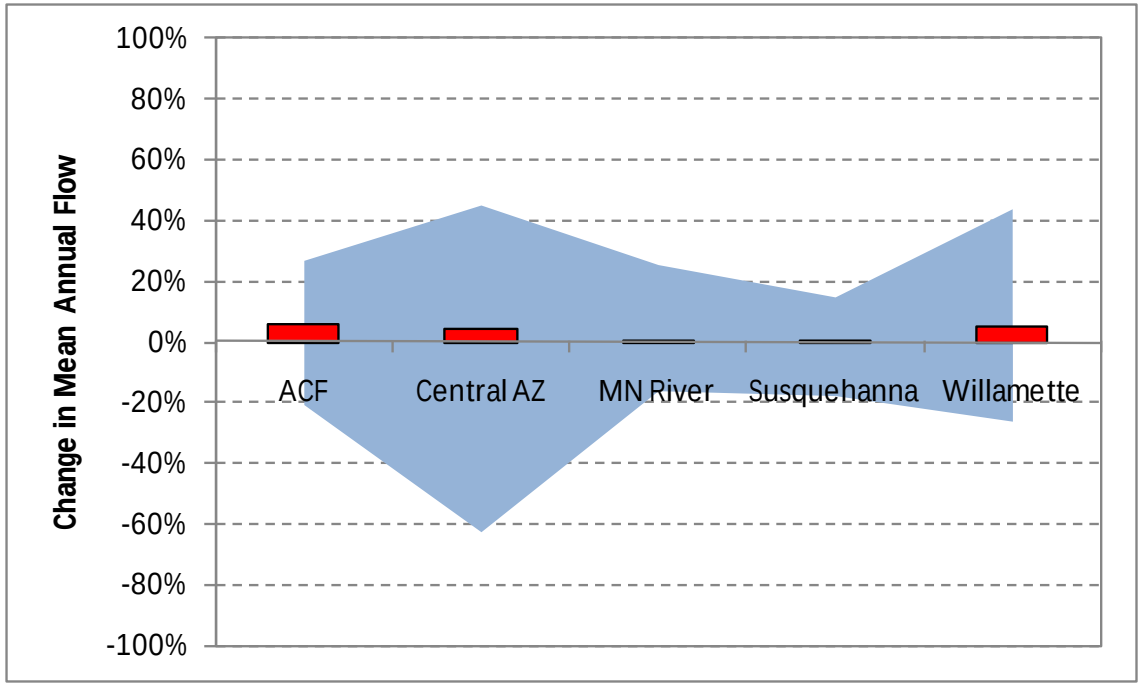


TP Load (MT/yr)
Apalachicola River at Seminole (HSPF)



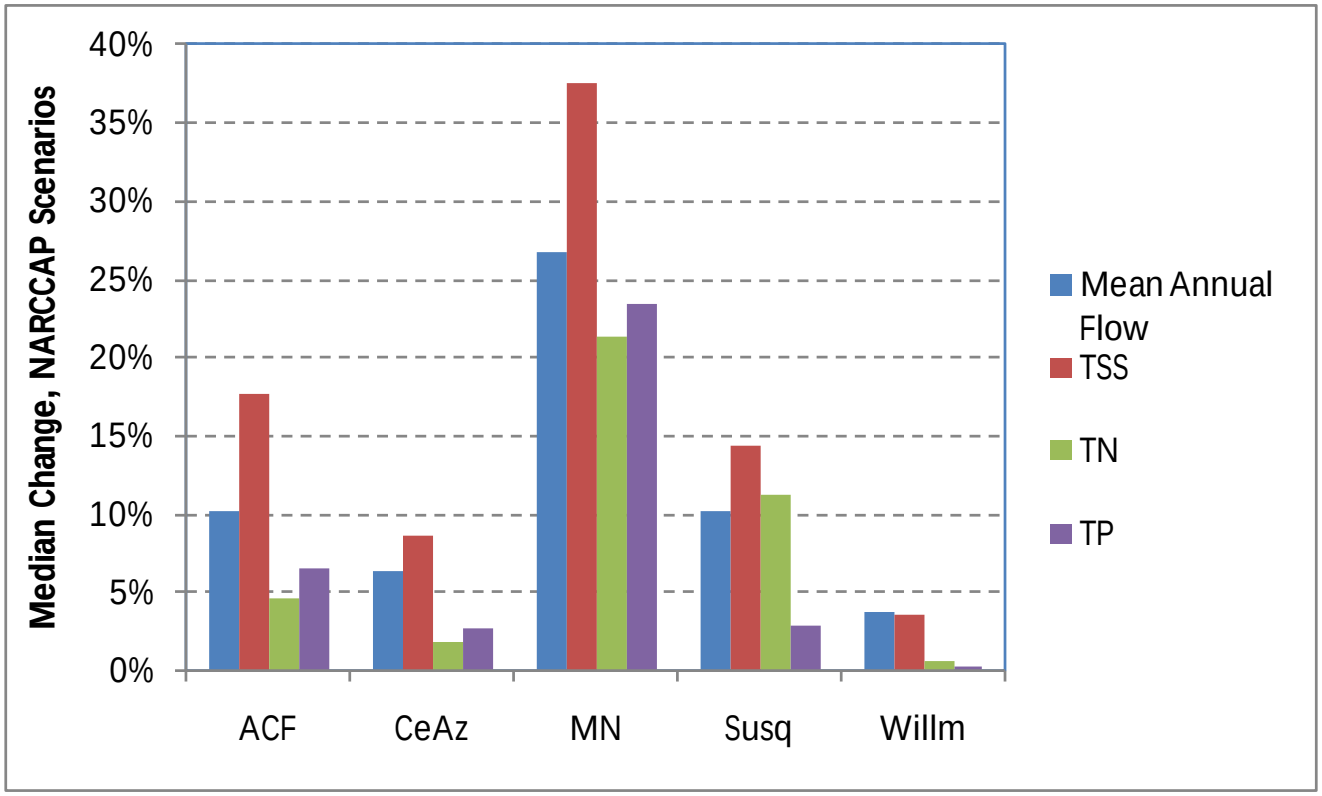


Comparison of Responses to Land Use and Climate Change: HSPF Model



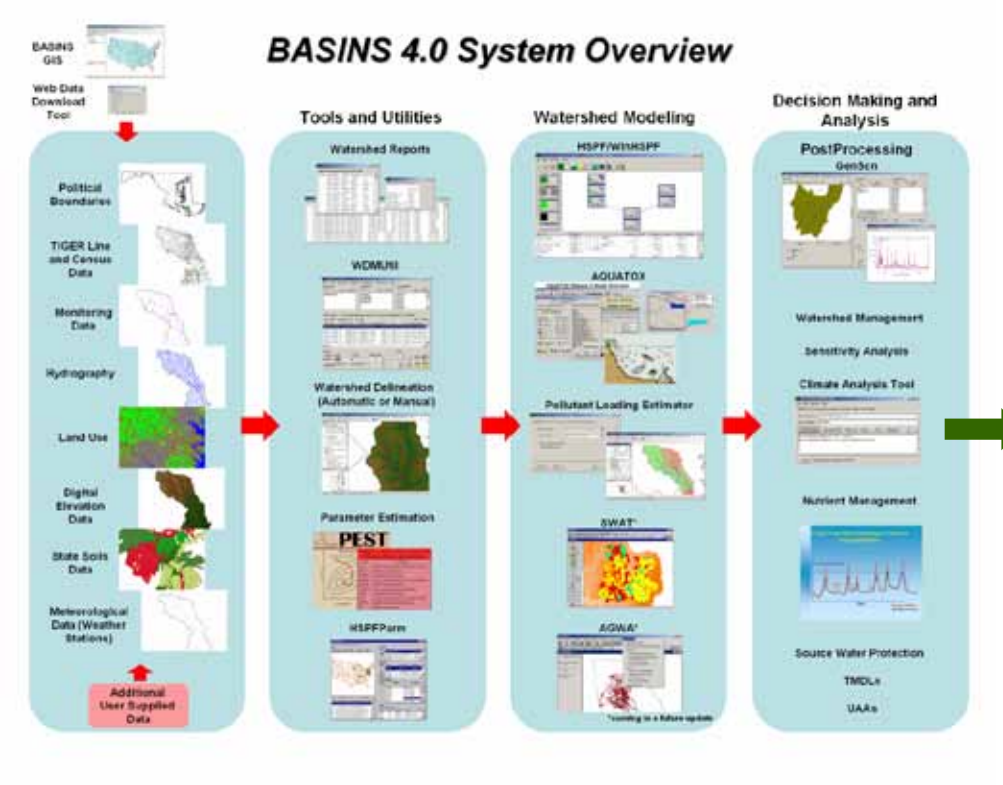
The blue area represents the range of responses to the six NARCCAP RCM-downscaled 2050 climate scenarios across the different reporting sites (with no change in land use). The red bars represent the maximum response to land use change among the reporting sites (with no change in climate).

Percent Change from Incorporating CO2 Fertilization into SWAT Model



BASINS Climate Assessment Tool (CAT)

Available within EPA's BASINS version 4 modeling system:
http://www.epa.gov/waterscience/basins/b3webdwn.htm

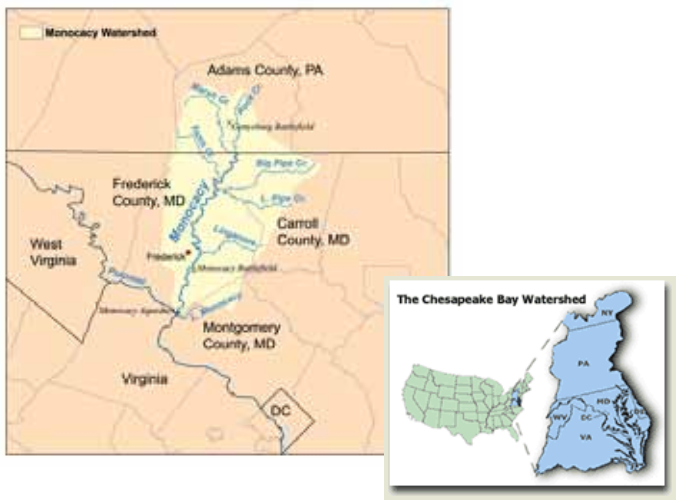


- *pre-processing* capability to modify historical temperature and precipitation time series to create scenarios (user-determined)

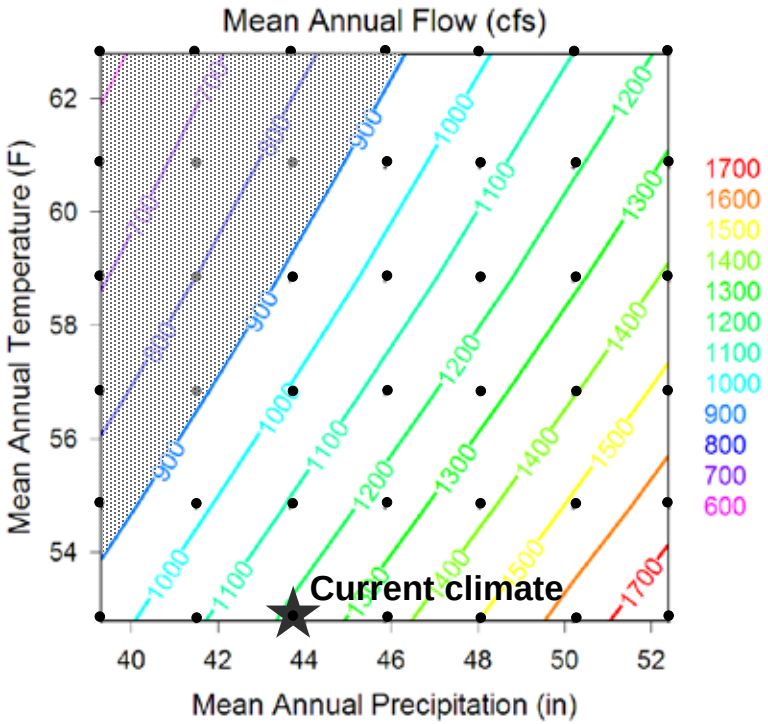
- *post-processing* capability to calculate hydrologic and water quality endpoints (e.g. mean flow, 100 yr flood, annual N loading)

- manages/automates input to BASINS model *(HSPF, SWAT, SWMM)*

A case study in the Monocacy River watershed



~ 750 mi^2 drainage area
~ 60% ag, 33% forest, 7% urban



Closing comments

- Key project goal:
  - evaluate watershed sensitivity to changes in different regions
  - identify a plausible ranges of potential future change
  - influence of methodological choices on variability of outcomes

- Modeling is at a fairly coarse spatial scale (HUC8), for period ~2050

- Timeline for completion
  - Initial simulations completed, early 2011
  - Reports and datasets, mid- to late 2011 (?)

Thanks!

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