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Impact of Climate and Landuse Change on the Hydrology and Water Quality of Major River Basins in the United States

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Modeling the impacts of climate and landuse change in some of major river basins in the US

- Minnesota River Basin
- ACF River Basin
- Willamette River Basin
- Trinity River Basin
- Illinois River Basin
- Rio Grande River Basin
- Sacramento River Basin
- Cook Inlet

Model Area	Average annual precipitation total (inches)	Average annual temperature (°F)
ACF River	54.26	63.43
Cook Inlet	28.50	34.16
Illinois River	38.25	49.00
Rio Grande Valley	15.18	44.71
Sacramento River	37.47	57.45
Trinity River	40.65	64.78
Minnesota River	28.26	43.90
Willamette River	58.38	51.19

Objectives

- characterizing the sensitivity of stream flow and water quality
- influence of different techniques for downscaling climate data on the results
- provide a larger-scale watershed context for future

Modeling approach

- Downscaled climate Data from the GCMs (http://www.narccap.ucar.edu)
- Land use change through use of the Integrated Climate and Land Use Scenarios (ICLUS) project
- simulation modeling of 8 large watersheds (~20,000 mi^2) across the U.S. using SWAT
  - calibrated to current (1971-2000) observed conditions.
  - future climate and land use scenarios represent anticipated conditions for 2041-2070 with CO2 fertilization

Matrix of GCMs and downscaling approaches evaluated

Downscaling Method/RCM	GCM			
	CGCM3	HadCM3	GFDL	CCSM
	CRCM (1)	HRM3 (2)	RCM3 (3)	WRFP (6)
	RCM3 (5)		GFDL high res (4)	
	None (7)	None (8)	None (9)	None (10)
	Statistical (11)	Statistical (12)	Statistical (13)	Statistical (14)

Land Use Change data

- NLCD 2001 LULC as the starting point.
- Integrated Climate and Land Use Scenarios (ICLUS) used to estimate change in future residential land use.
- Changes in developed land area were summed.

Other Inputs

- **DEM:** Topography was represented by digital elevation models (DEMs) with a resolution of 30 meters.
- **Watersheds and Reaches:** NHDPlus aggregated into comparable to the HUC10 scale.
- **Landuse**: 2001 NLCD
- **Soil**: STATSGO
- **Reservoirs**: National Inventory of dams (NID).
- **Point sources**: major dischargers, with a design flow greater than 0.5 MGD are included
- **Weather**: BASINS4 Meteorological Database (USEPA 2008)

Results

- Climate Change Impacts
- Landuse Change Impacts
- Combined impacts

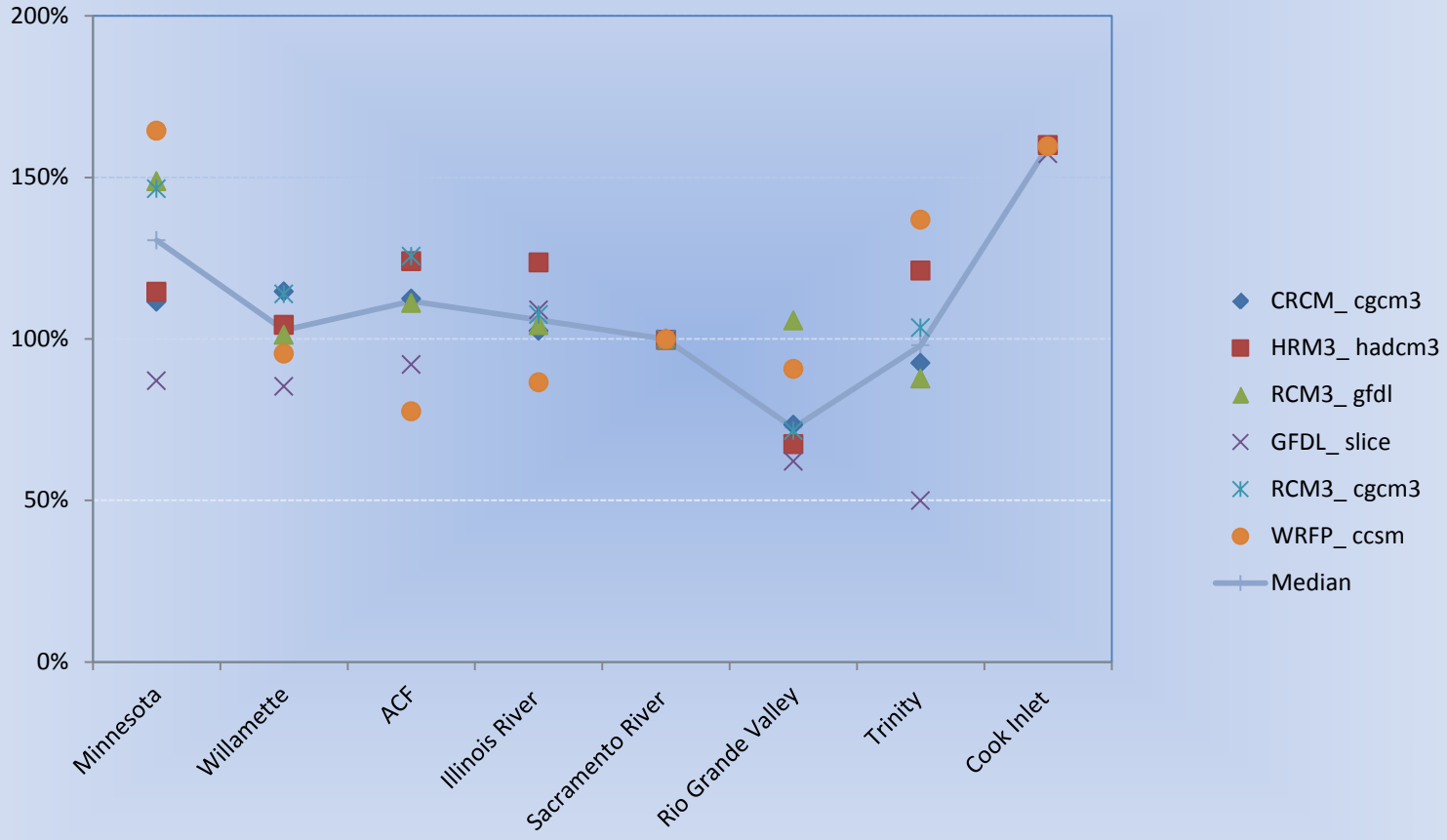
Endpoints for Change Analysis

- **Hydrologic Endpoints**
  - flow volumes
- **Water Quality Endpoints**
  - annual loads of sediment, phosphorus, and nitrogen

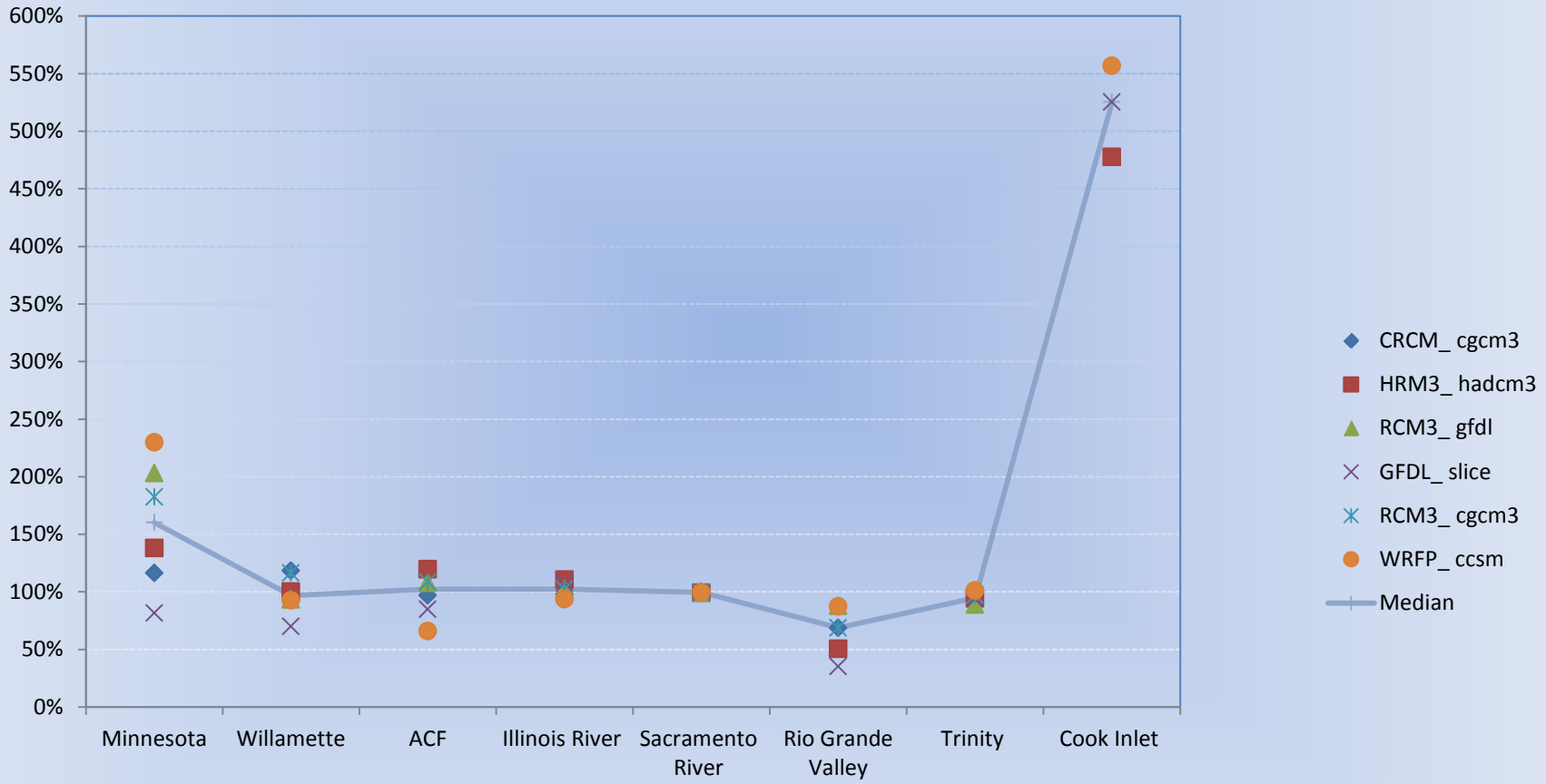
Climate Change Impacts (Percent Relative to Current Conditions)

- Total Flow Volume Results
- 7-day Low Flow Results
- Total Suspended Solids Load Results
- Total Phosphorus Load Results
- Total Nitrogen Load Results

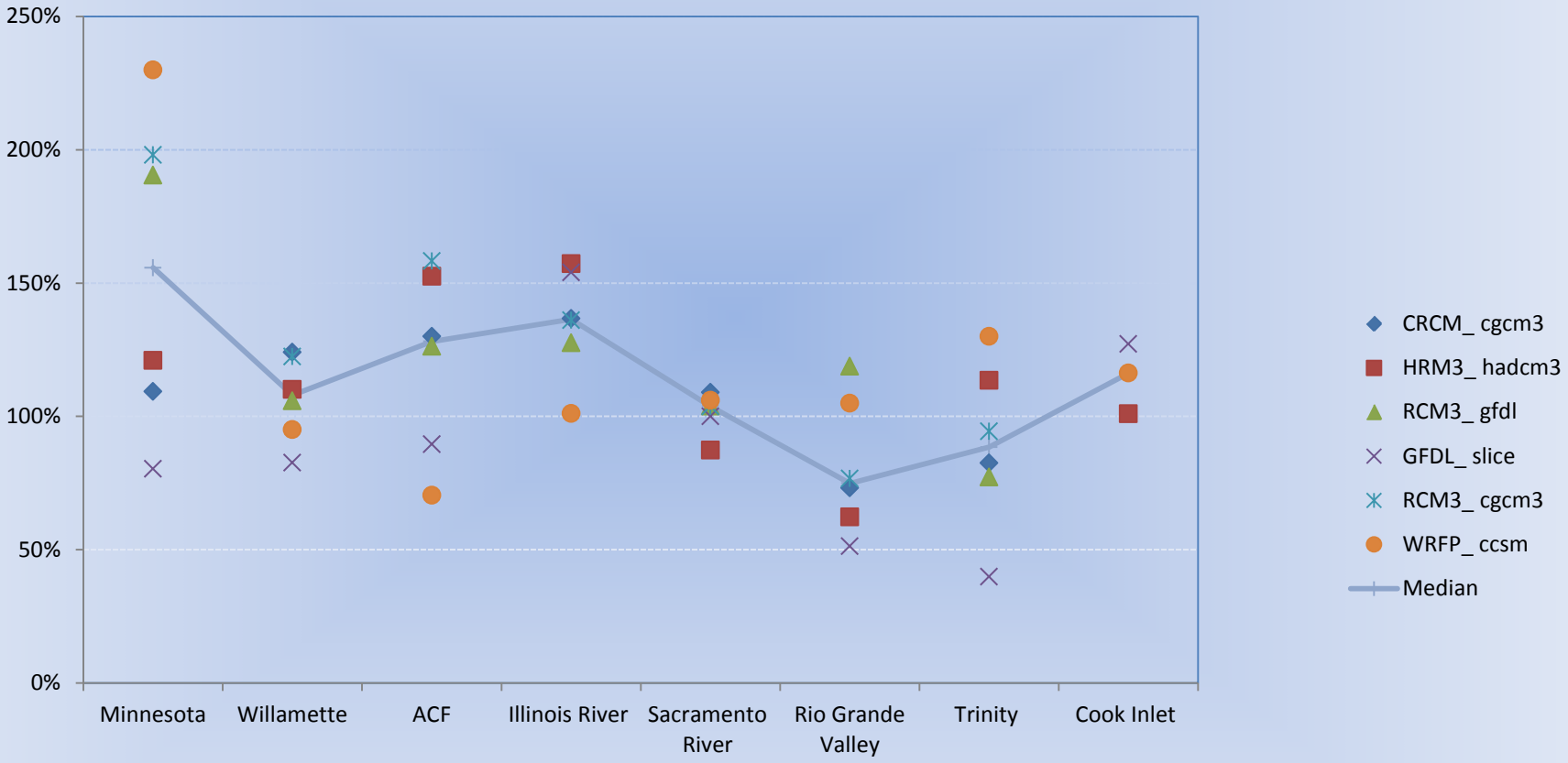
Total Flow Volume Results



7-day Low Flow Results

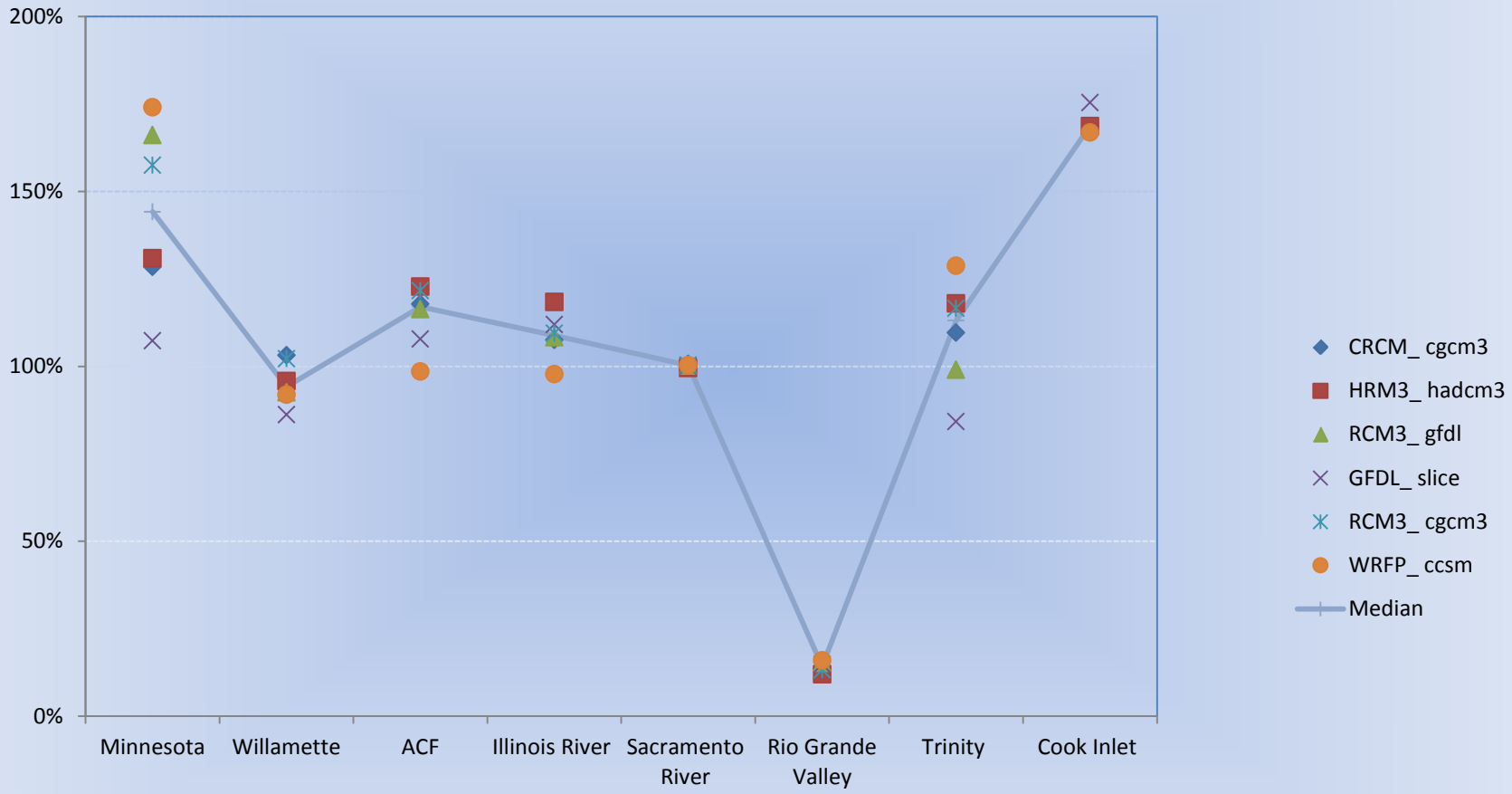


Total Suspended Solids Load Results



Total Phosphorus Load Results

Total Nitrogen Load Results



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Landuse Change impact

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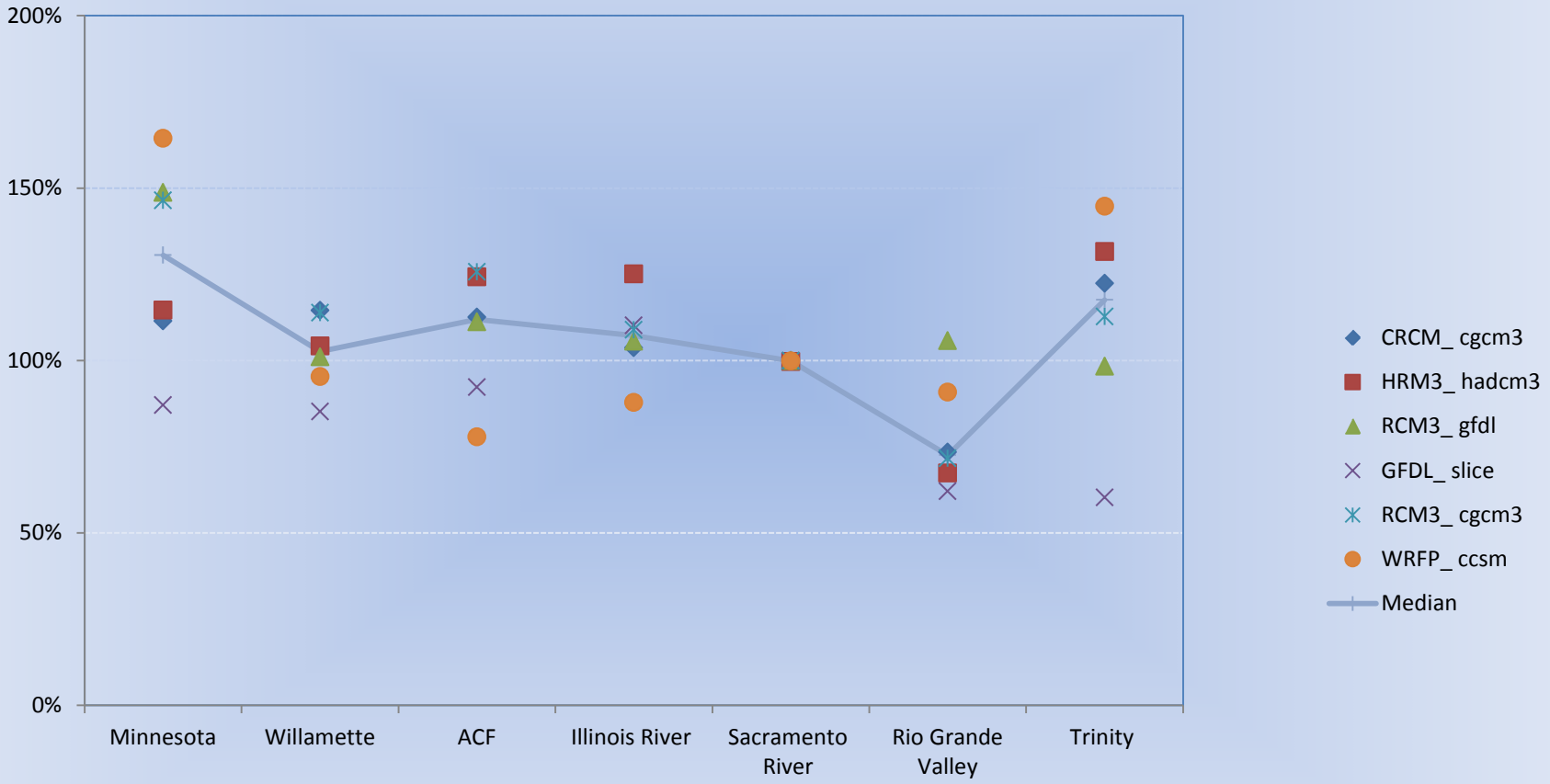
Station	Total Flow	7-day low flow	TSS load	TP load	TN load
Minnesota River	100.19%	100.34%	98.03%	99.31%	99.53%
Willamette River	99.89%	100.05%	99.70%	99.91%	102.45%
ACF River	100.30%	101.05%	100.37%	101.19%	100.47%
Illinois River	101.80%	101.75%	96.83%	99.65%	98.63%
Sacramento River	100.00%	99.99%	98.95%	100.78%	100.41%
Rio Grande River	100.08%	100.02%	100.56%	98.46%	99.61%
Trinity River	108.58%	108.08%	76.45%	102.56%	100.40%

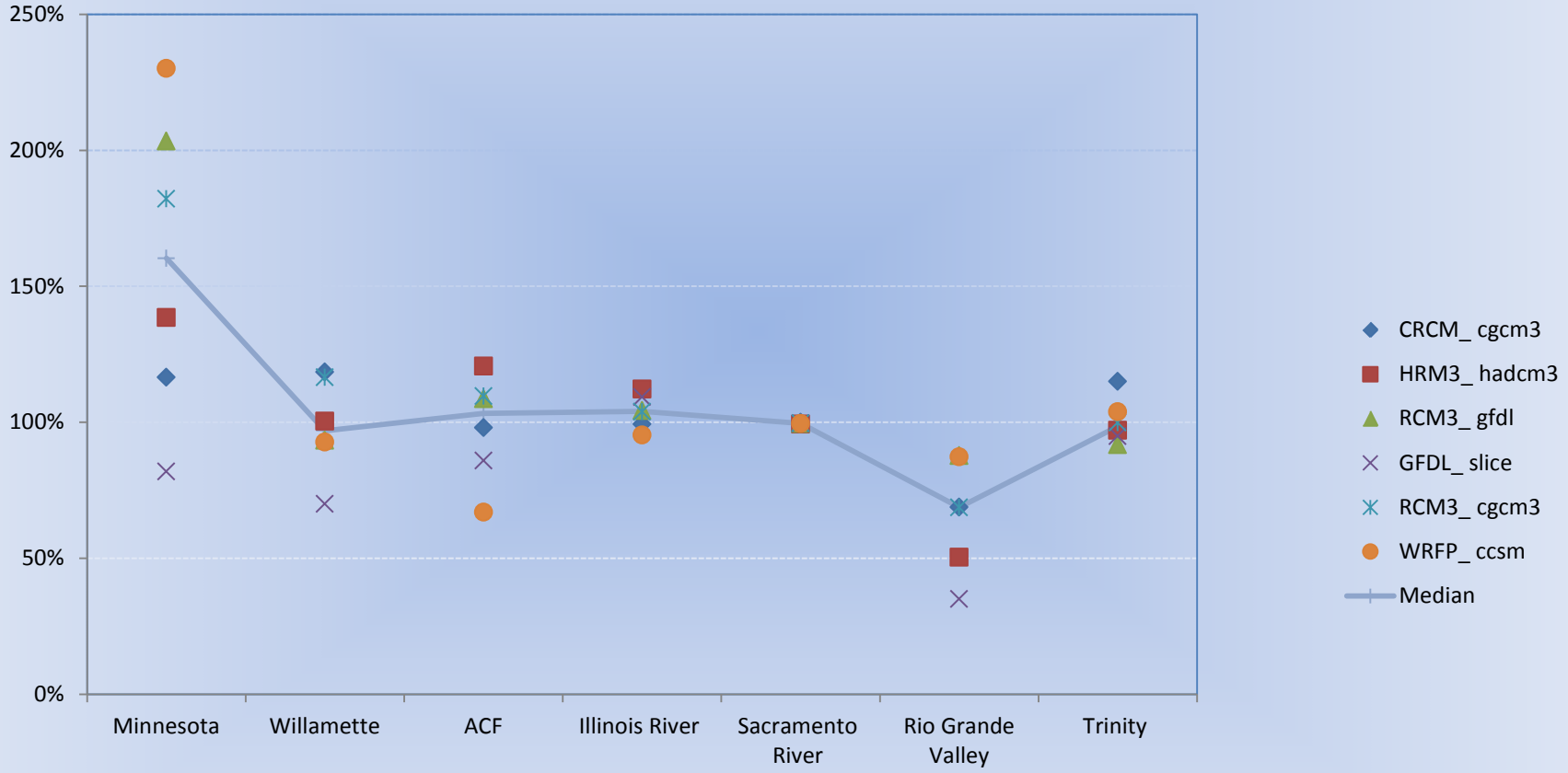
Combined Change Impacts
(Percent Relative to Current Conditions)

- Total Flow Volume Results
- 7-day Low Flow Results
- Total Suspended Solids Load Results
- Total Phosphorus Load Results
- Total Nitrogen Load Results

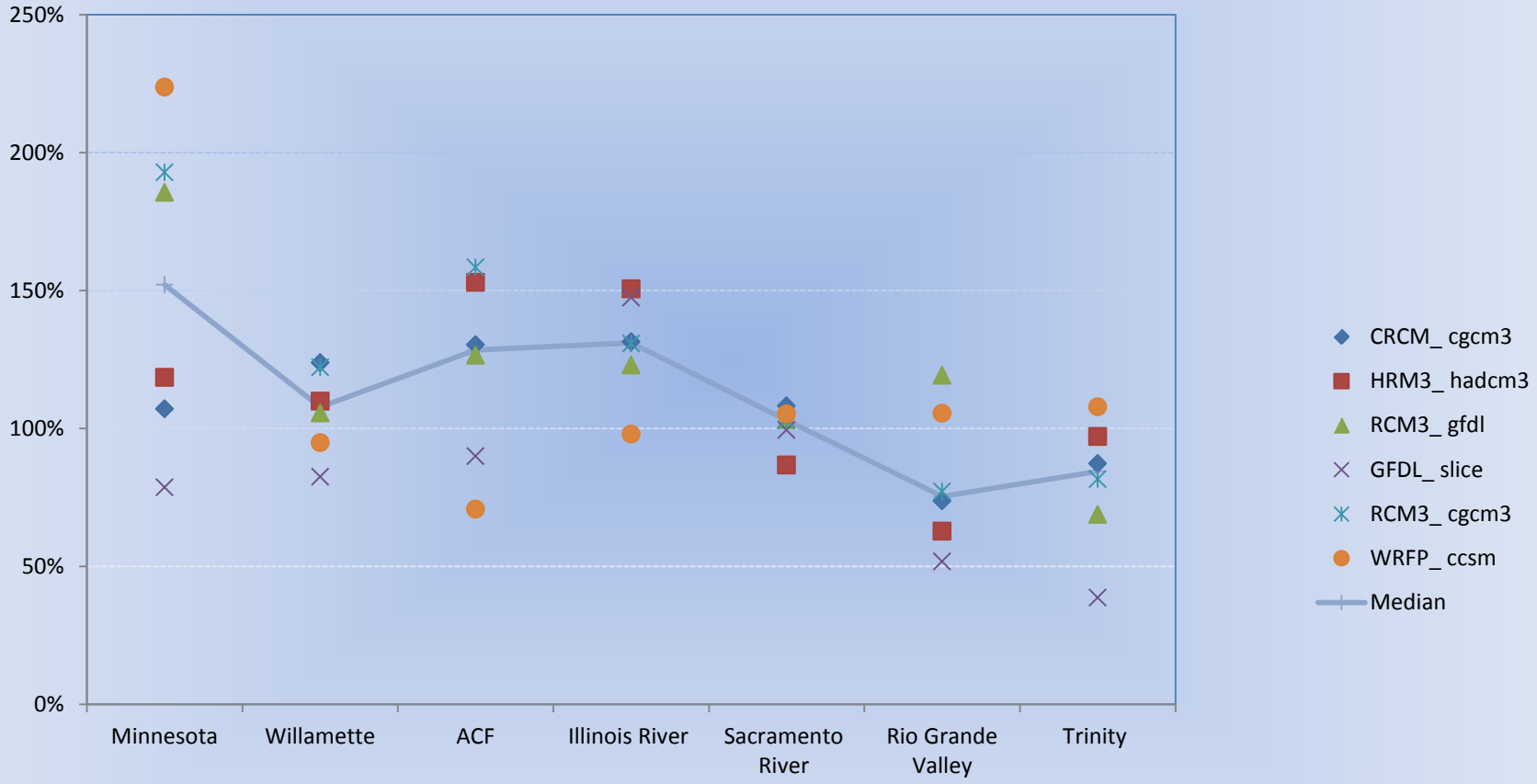
Total Flow Volume Results



7-day Low Flow Results



Total Suspended Solids Load Results



Total Phosphorus Load Results

Total Nitrogen Load Results

Regional Variability
(Median of NARCCAP Climate Scenarios with Land Use Change)

- **Geographic Distribution of Total Future Flow Volume Relative to Current Conditions**
- **Geographic Distribution of Change in Days to Flow Centroid**
- **Geographic Distribution of Estimated 100-year Peak Flows Relative to Current Conditions**

Geographic Distribution of Total Future Flow Volume Relative to Current Conditions

Geographic Distribution of Change in Days to Flow Centroid

Geographic Distribution of Estimated 100-year Peak Flows Relative to Current Conditions

Discussion

- **Climate Change Scenarios**
- Total average annual flow volume, ranges from 60% to 164% of current average flows.
- 7-day low flows: max in Cook Inlet because warmer temperatures alter the snow/ice melt regime
- Negative shifts, for estimated change in days to flow centroid relative to the start of the water year. This indicates earlier snowmelt resulting in an earlier center of flow mass. In contrast, several stations show positive shifts due to increased summer precipitation.
- The patterns of predicted changes in pollutant loads (TSS, TP, TN) are generally similar to changes in flow. Increases in pollutant loads are predicted for many watersheds, but there are also basins where loads decline, mostly due to reduced flows.

Discussion

- **Land Use Change Scenarios**
  - Effects of land use change is relatively small
    - predicted new development ranges from 0 percent to 11.72 percent of the total area.
  - Significant effects may occur in smaller watersheds
  - Increase in developed land is a more certain prediction than the specific magnitude of changes in precipitation.
  - The largest response is for the Trinity River in Texas, where total flow increased 8 percent, but peak flow and days to flow centroid decreased.

Discussion

- **Combination Climate Change with Land Use Change Scenarios**
- Given the relatively small response to predicted land use change by 2050, results of the model scenarios that combine climate change and land use change are fairly consistent with those for the climate scenarios.
- Work demonstrates the feasibility of evaluating watershed response to climate and land use change using large scale simulation models.

Limitations

- Do not evaluate the uncertainty in the A2 storyline.
- Calibration introduces modeler choice and potential biases
- Watershed model projections do not consider feedback from other large scale adaptations or natural adjustments.

Acknowledgements

- Thomas E. Johnson and Christopher Weaver at U.S. EPA's Global Change Research Program for sponsoring this work
- The authors also acknowledge and thank for their hard work the entire project team at Tetra Tech (Tt), Stratus Consulting, and FTN Associates

Thank You!!

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Utility of this study:

- resource management decisions;
- informed discussion of climate variability and change issues;
- support adaptive management and planning
- support climate change policymaking

Climate Change Data

- 6 downscaled scenarios from NARCCAP (based on four GCMs, two of which have been downscaled by a pair of RCMs)
- A2 storyline
- Downscaled to a 50 km x 50 km grid by NARCCAP
- Meteorological time series for input created using a “change factor” or “delta change” method.

Specific 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

- Temperature increases consistently (on the order of 2 to 3 °C),
- Systematic differences between the scenarios (for example, W3 – GFDL downscaled with RCM3 – typically provides the coolest predicted future).
- Precipitation differ widely,
- Dynamically downscaled results differ from the statistically downscaled results from the same GCM,
- Results vary when the same GCM is downscaled with a different RCM (e.g., compare W1 and W5 for CGCM3, also W3 and W4 for the GFDL).

Land Use Change data

- Derived from the Integrated Climate and Land Use Scenarios (ICLUS) project.
- Compatible with the assumptions of population growth and migration for IPCC storylines.
- estimate future population through 2100 for each county in the conterminous U.S
- final spatial dataset provides decadal projections of housing density and impervious surface cover for the period 2000 through 2100

The overall approach to implementing the ICLUS changes was as follows:

- NLCD 2001 LULC as the starting point.
- ICLUS used to estimate change in future residential land use.
- Changes in developed land area were summed.
- Land area was removed from each undeveloped NLCD class (excluding water and wetlands) according to their relative ratios in each subwatershed to account for increases in developed area.
- If the undeveloped land area was not sufficient to accommodate the projected growth, development on wetlands was allowed.