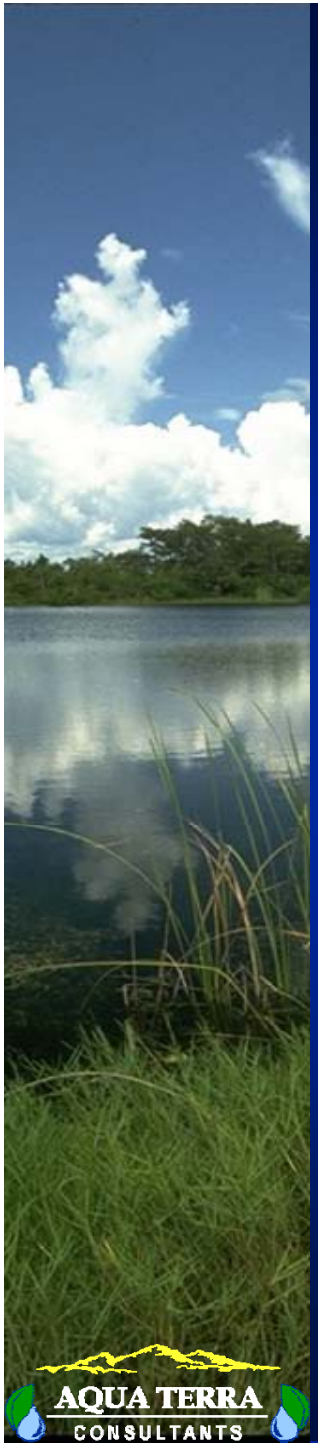

Analyzing The Effects Of Climate, Landuse, and Management Changes in a Chesapeake Bay Watershed

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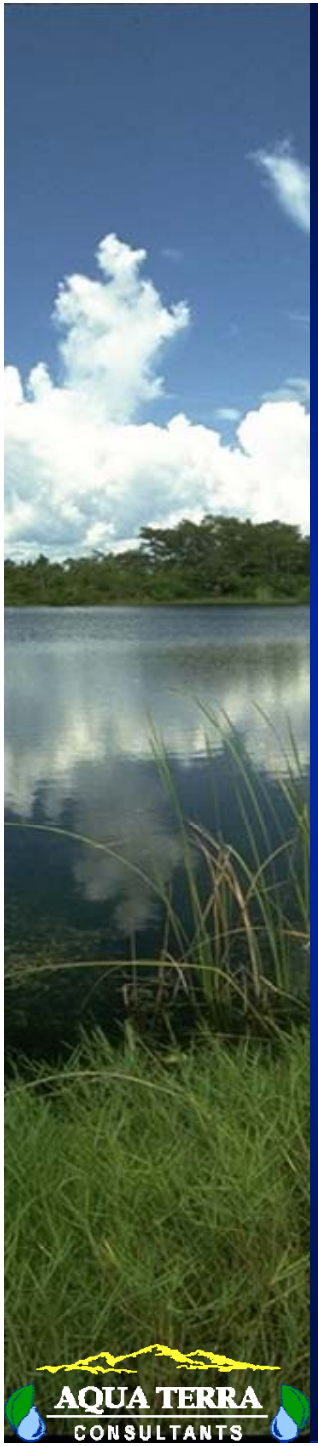
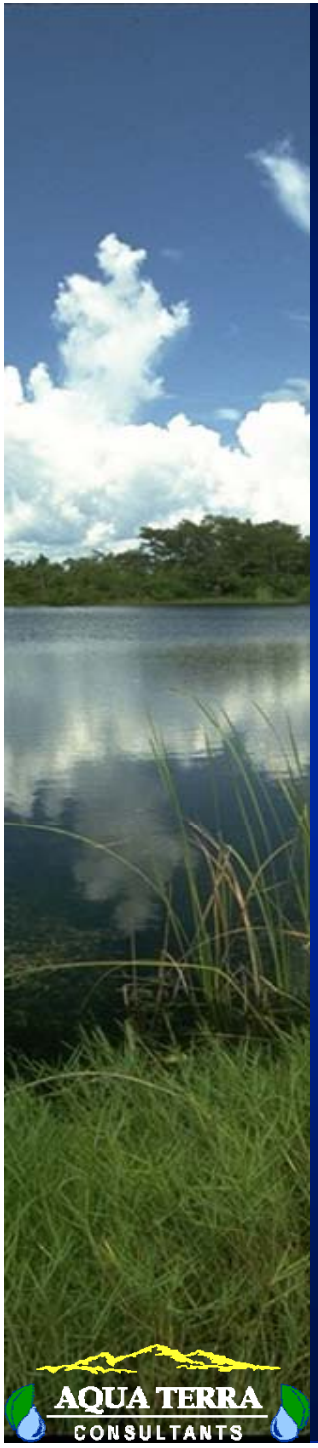
AWRA Specialty Climate Conference May 4-6, 2009
Anchorage, AK



Introduction

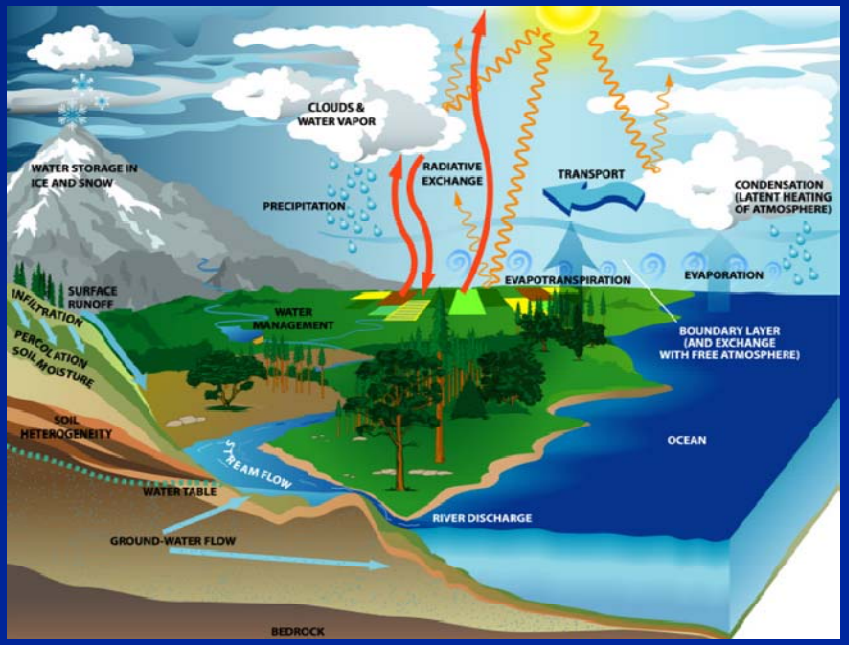
- **Why** was this study done?
- **How** was it implemented?
- **What** was learned?



Climate and Water Resources Management Issues

Watersheds are highly climate sensitive, indicating likely impacts on:

- **Frequency and magnitude of floods and droughts**
- **Water quality**
- **Infrastructure design**
- **Ecosystems**



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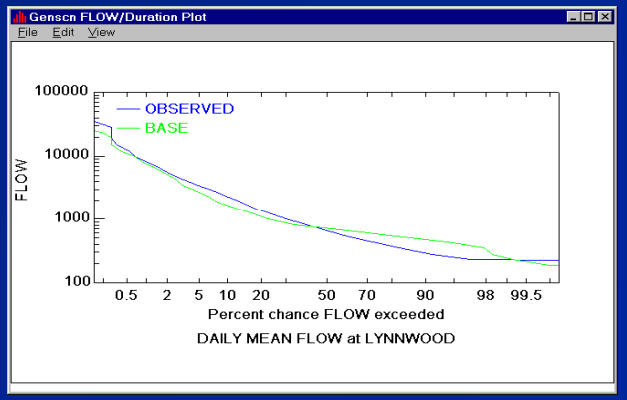
Climate and Water Resources Management Issues (cont.)

- **Assessing risk associated with climate variability is central to water management**
- **Past typically assumed a guide to the future**
- **Management traditionally based on statistical analysis of historical record (e.g., 100-year flood, 7Q10)**



- **Long-term climatic trends may lead to unprecedented conditions and events that challenge this assumption**

"Stationarity is Dead"

(Milly et al, Science, Feb. 2008)

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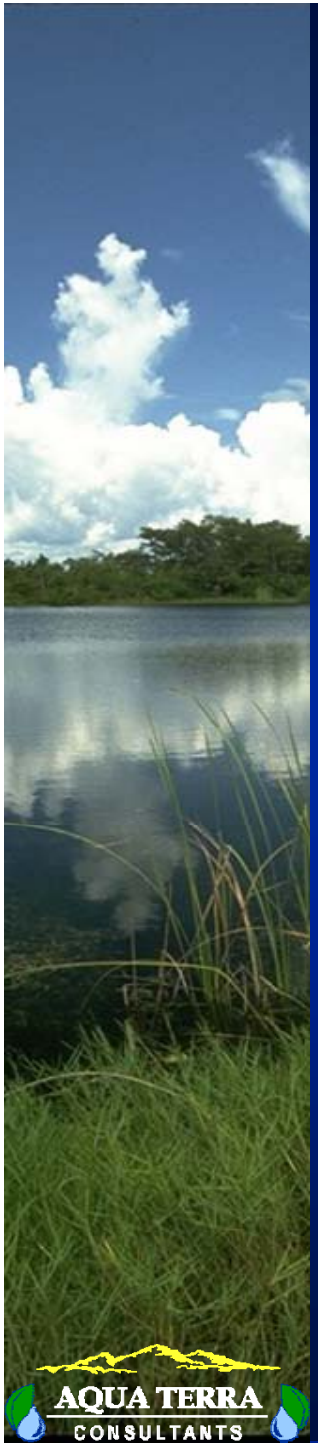
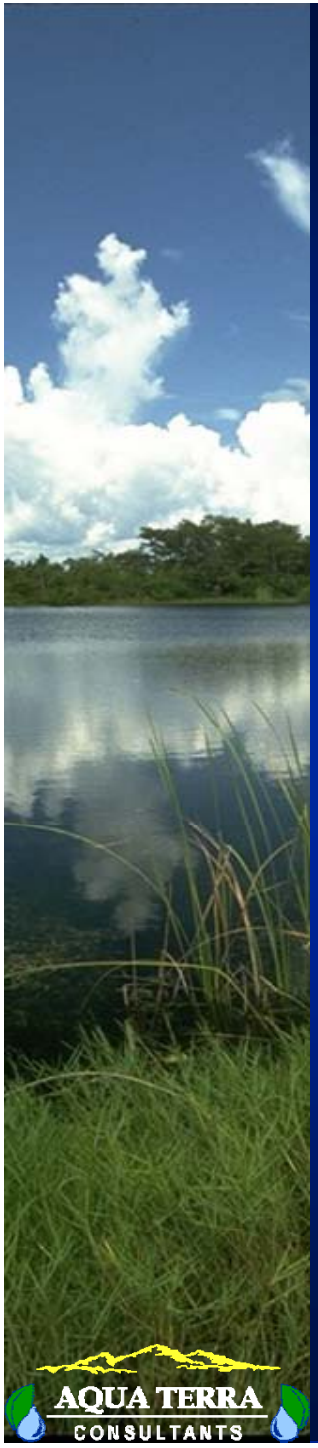


Fundamental Needs

- **Evaluate potential impacts of climate change on endpoints used to make watershed planning decisions.**
- **Represent climate change scenarios on the watershed scale at which most planning decisions are made.**
- **Enable expression of seasonal climate change in terms of precipitation amount/form and other significant meteorological drivers (air temperature, evapotranspiration)**



Fundamental Needs (cont.)

- **Climate scenarios should be used to drive a dynamic and mechanistic watershed model.**

Dynamic Stressors → **Dynamic Endpoint Responses** → **Adaptive Management**

- **Climate change is most effectively evaluated in parallel with other dynamic stressors affecting watersheds (e.g. land use, BMP).**

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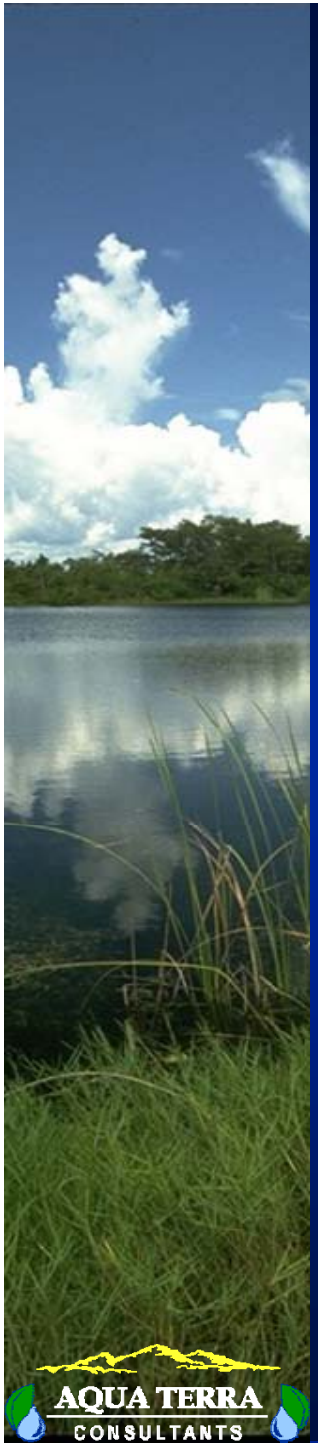
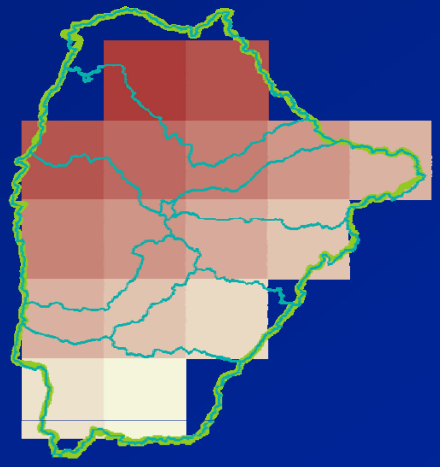


Challenges

- **Conflicting scales - climate change analysis versus watershed analysis**
- **Climate model limitations**
- **Differences in climate model predictions**
- **Data intensive analyses – better use a modeling system**



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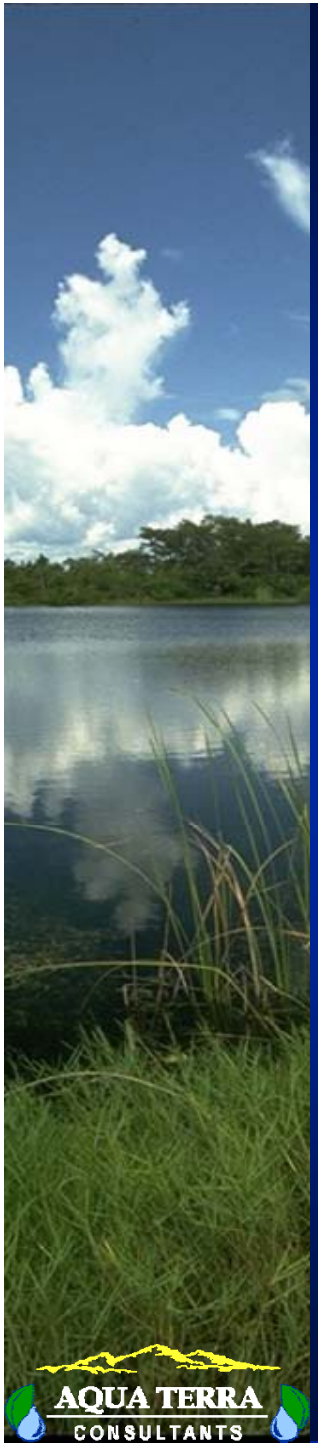
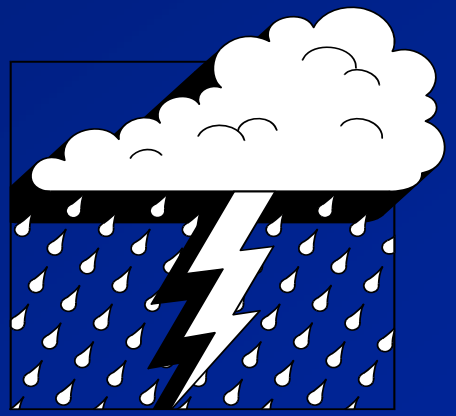


Climate Assessment Tool (CAT)

- **Implemented as a component of BASINS 4.0**
- **Generate weather time series for input to BASINS models (HSPF, SWAT)**
- **Create and run new meteorological time series by modifying historical data**
- **Perform sensitivity analyses and predictive assessments**

CAT Weather Timeseries Modifications



- **Apply arithmetic operators over any increment of time**
- **Apply changes seasonally**
- **Apply uniform increases or decreases to event, or**
- **Selectively apply increases or decreases to events above or below a threshold value, or**
- **Add events (more frequent storms, design storms, paleo-extreme events)**

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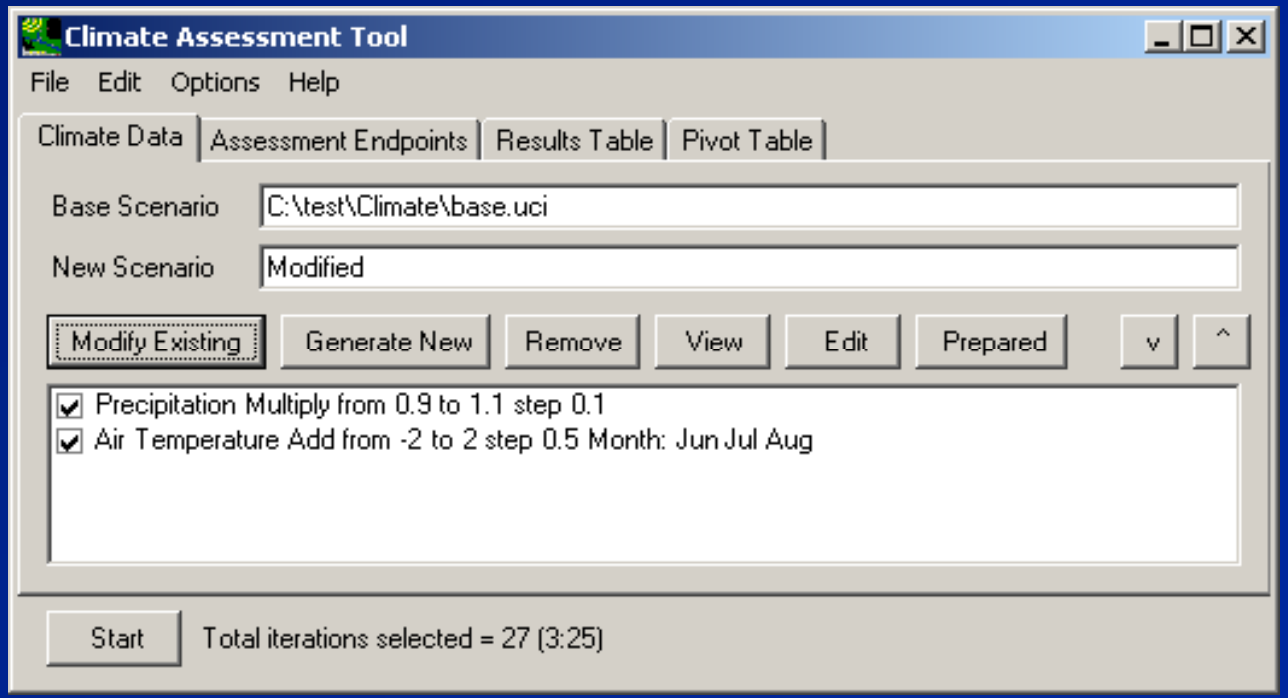
CAT Capabilities

- **Climate scenario definition**
- **Watershed endpoints selection**
- **Results and statistics**
- **Pivot table production**



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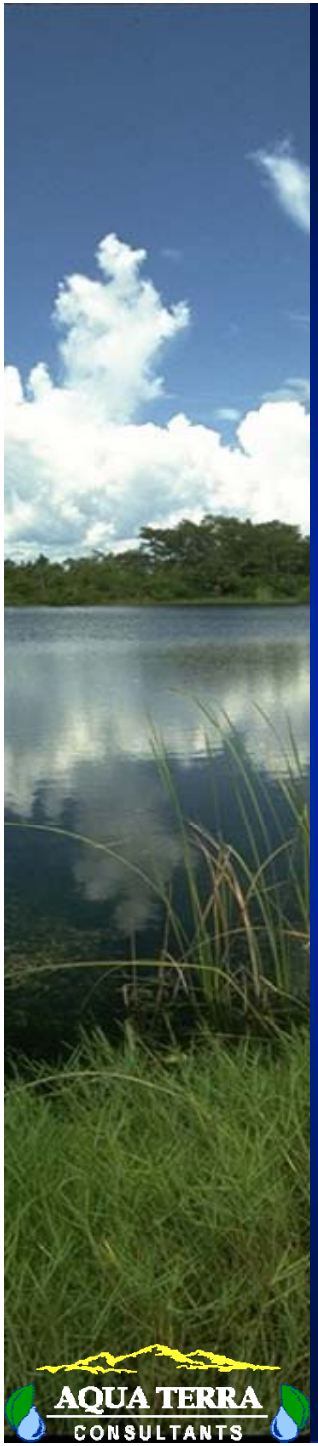

HSPF: Hydrological Simulation Program - FORTRAN

- **Continuous, mechanistic simulation model**
- **Natural and developed watersheds and water systems**
- **Land surface and subsurface hydrology and quality processes**
- **Stream/lake hydraulics and water quality processes**

Core watershed model in EPA BASINS, U.S. Army Corps WMS, and Chesapeake Bay Program's Phase V Bay Model….development and maintenance activities sponsored by U.S. EPA and U.S. Geological Survey

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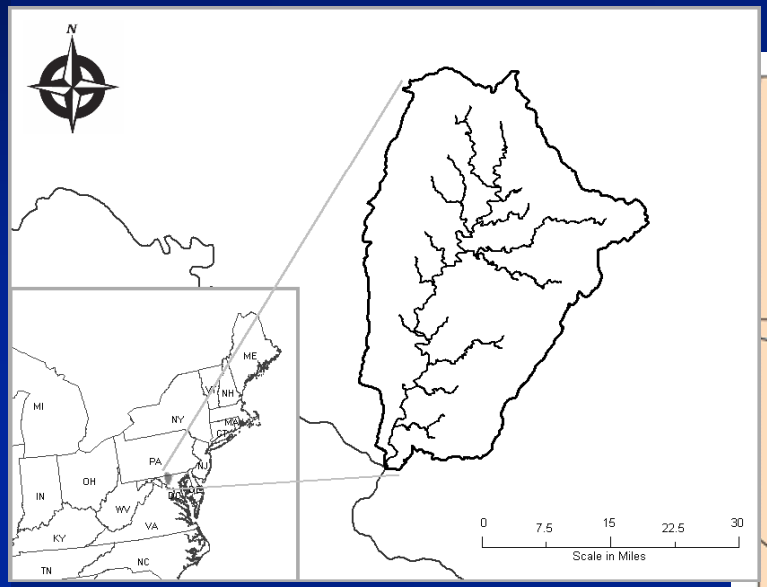
Monocacy River Watershed Case Study



- ~ 750 mi^2
- ~ 50% Ag, 34% Forest, 16% Urban
- MD Wild and Scenic River
- High nonpoint loads

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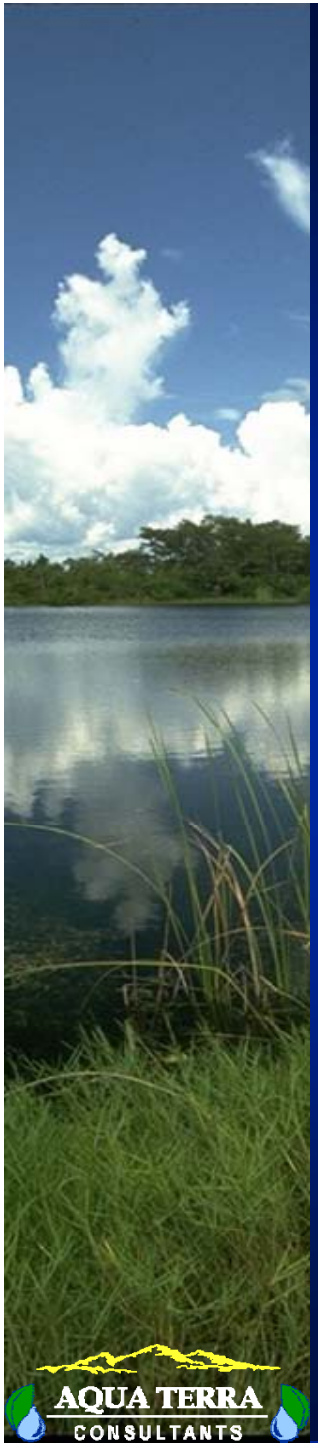

Scenario Development
Climate

Penn State's Consortium of Atlantic Regional Assessments (CARA) projections:

- **Spatial grids of projected change in Air Temp (°C) and Precipitation (%); base period 1971-2000**
- **Future periods 2010-2039, 2040-2069, 2070-2099**
- **7 GCMs from IPCC 3rd Assessment Report**
- **2 IPCC greenhouse gas emission storylines (A2, B2)**

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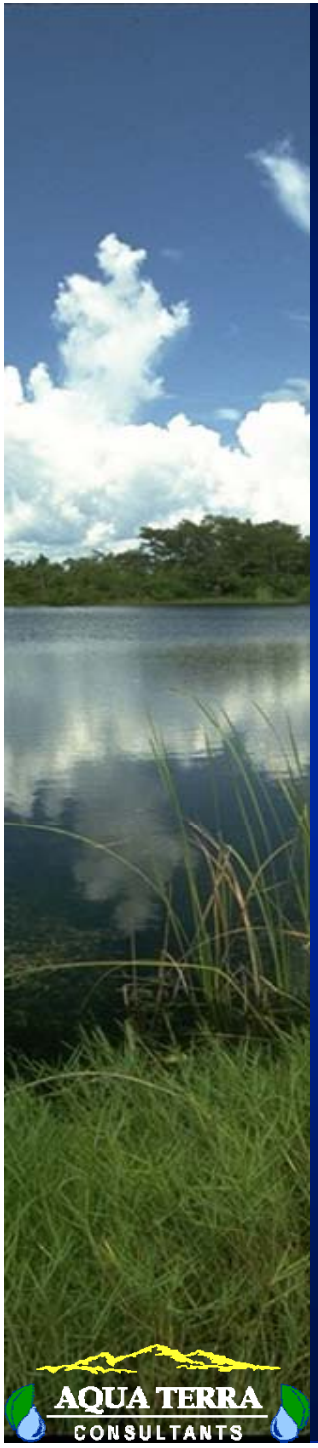

Scenario Development Climate

GCMs available from CARA:

Model	Description
CCCM	Canadian Centre for Climate Modeling and Analysis
CSIR	Australia's Commonwealth Scientific and Industrial Research Organisation
ECHM	German High Performance Computing Centre for Climate and Earth System Research
GFDL	Geophysical fluid Dynamics Laboratory
HDCM	Hadley Center for Atmospheric Research
NCAR	National Center for Atmospheric Research
CCSR	Univ. of Tokyo, Center for Climate System Research/National Institute for Environmental Studies

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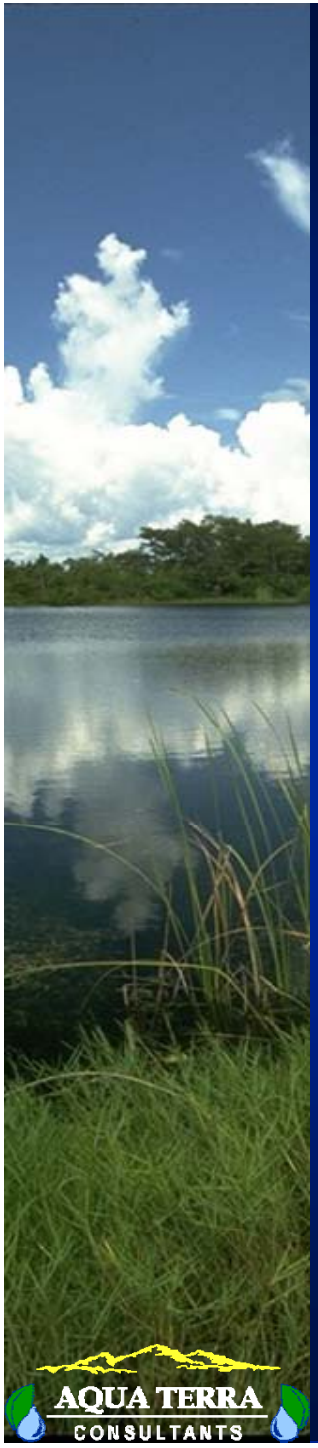

Scenario Development Climate

IPCC emissions storylines:

Scenario Category	A2	B2
Geo-scope	Regional	Local
Economic development	Moderate	Moderate
Population	Increase at high rate	Increase at slow rate
Energy	High consumption	Less consumption
Natural resources	Becoming scarce	More available
Technological change	More fragmented, slower	More diverse

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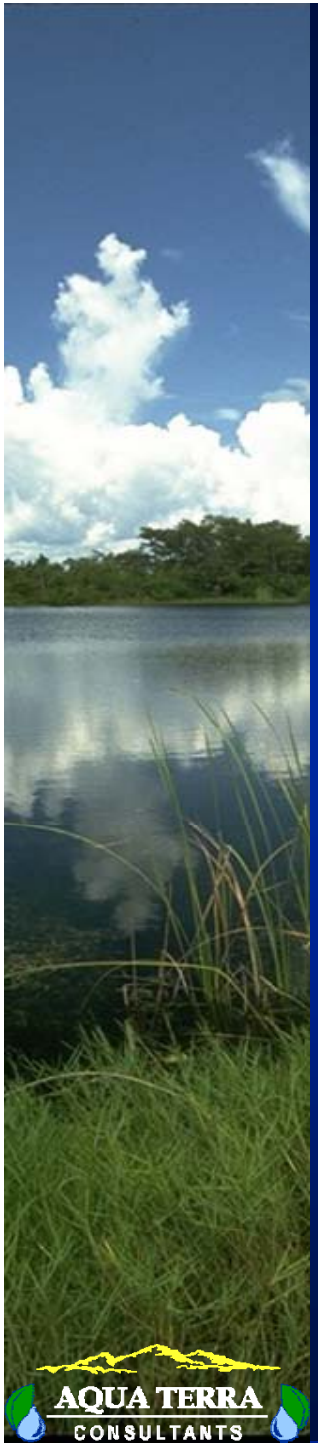

Scenario Development
Climate

- **Along with CARA data, 3 precipitation intensity adjustments were applied – all, top 30%, top 10%**
- **Revised PET data estimated based on revised air temperature using Hamon method**
- **2 time points (2030, 2090)**
- **42 climate scenarios generated for each time point (7 GCMs, 2 emission storylines, 3 precip intensities)**

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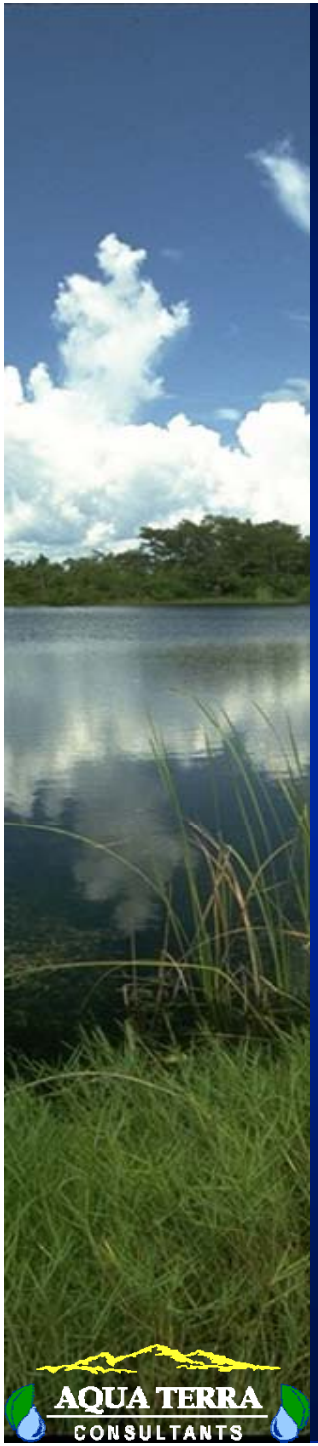
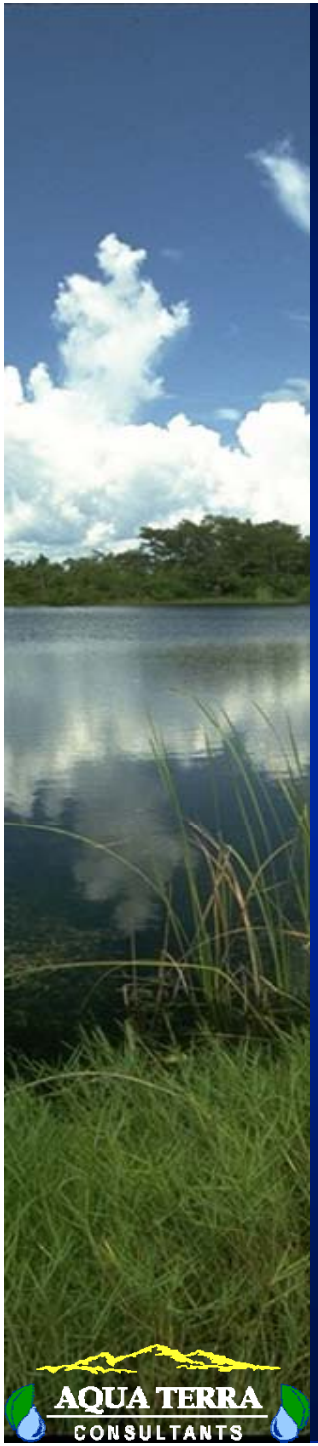


Scenario Development
Land Use

- **Integrated Climate and Landuse Scenarios (ICLUS) dataset developed by EPA's Global Change Research Program (GCRP)**
- **Compatible with IPCC emissions storylines (A2, B2)**
- **Decadal projections from 2000 - 2100**
- **Use same time points as climate scenarios (2030, 2090)**
- **Method developed to map ICLUS scale and categories to those used by CBP Phase V model**



Scenario Development
BMP

- **Simplified approach to assess watershed sensitivity to BMPs in conjunction with climate and land use change**
- **Goals and efficiencies extracted from various CBP resources**
- **Aggregate BMPs developed and applied either by removal factor (model parameter) or land use change (e.g. hi-till → lo-till)**

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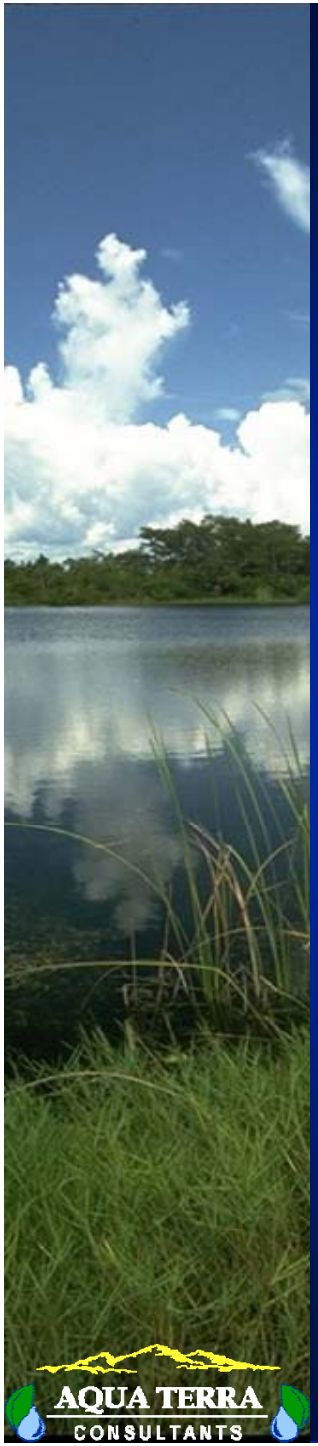

Model Setup

- **Baseline conditions from CBP Phase V model; historical met data from 1984 – 2000 at 7 gages**
- **Model run for each unique scenario combination**
- **Total Scenarios:**
  - **7 GCMs X**
  - **2 Emission storylines (A2, B2) X**
  - **3 Precipitation intensities (all, 30%, 10%) X**
  - **2 Land use projections (current, future) X**
  - **2 Time points (2030, 2090)**
  - **2 BMP options (Y, N)**
  - **336 Scenarios**

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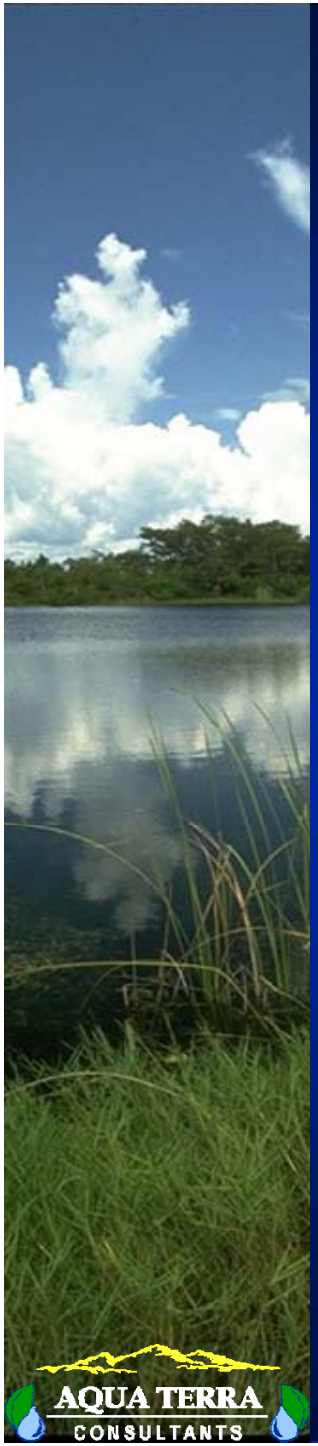
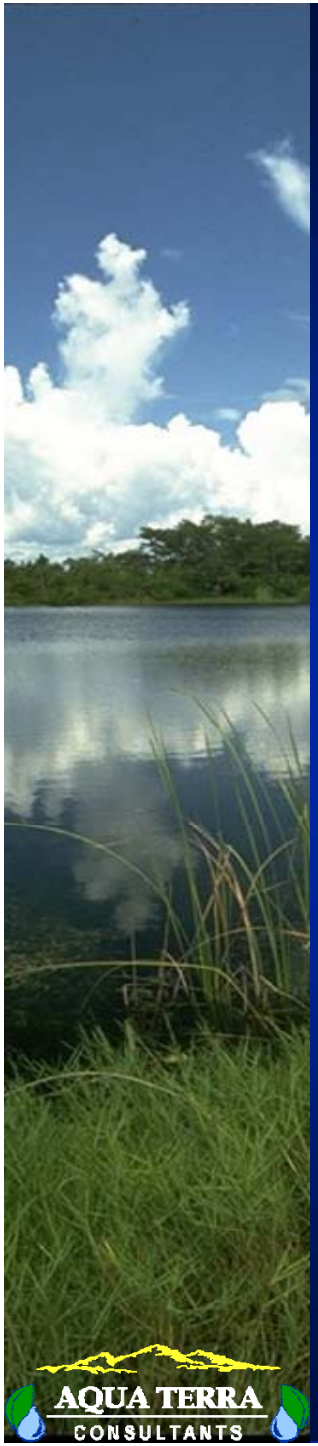


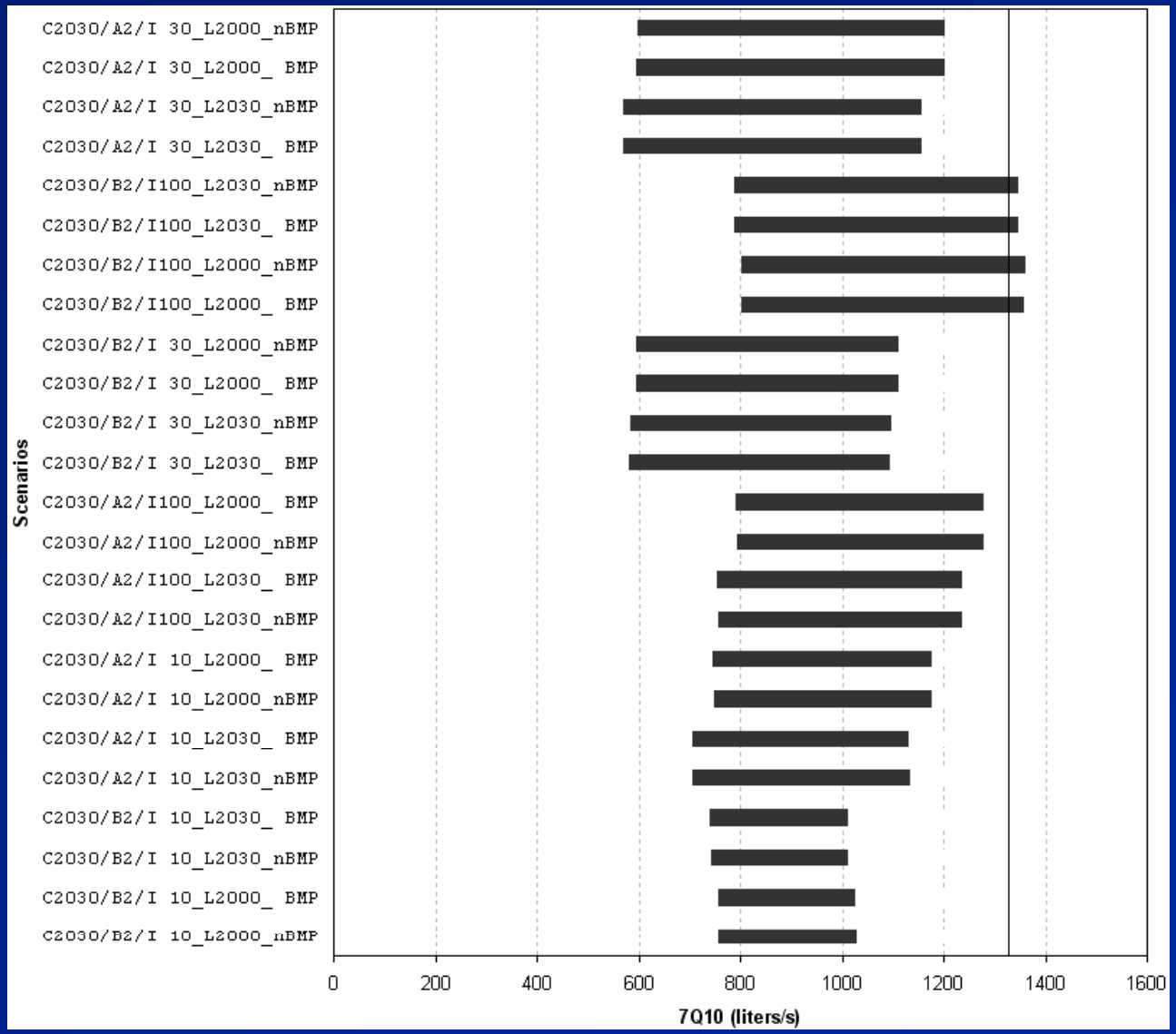
Results

- **What are we going to do with all these numbers!!!**
- **Primary goal – assess sensitivity**
- **Endpoint parameters:**
  - **Mean annual flow**
  - **7Q10**
  - **100-year flood**
  - **Annual total Nitrogen load**
  - **Annual total Phosphorous load**
  - **Annual Sediment load**



Results

7Q10 Projections for 2030 Climate



Data Legend: Emission storyline (A2, B2), Precip Intensity (I10, I30, I100), Landuse (L2030, L2000), BMP implementation (BMP (yes), nBMP (no))

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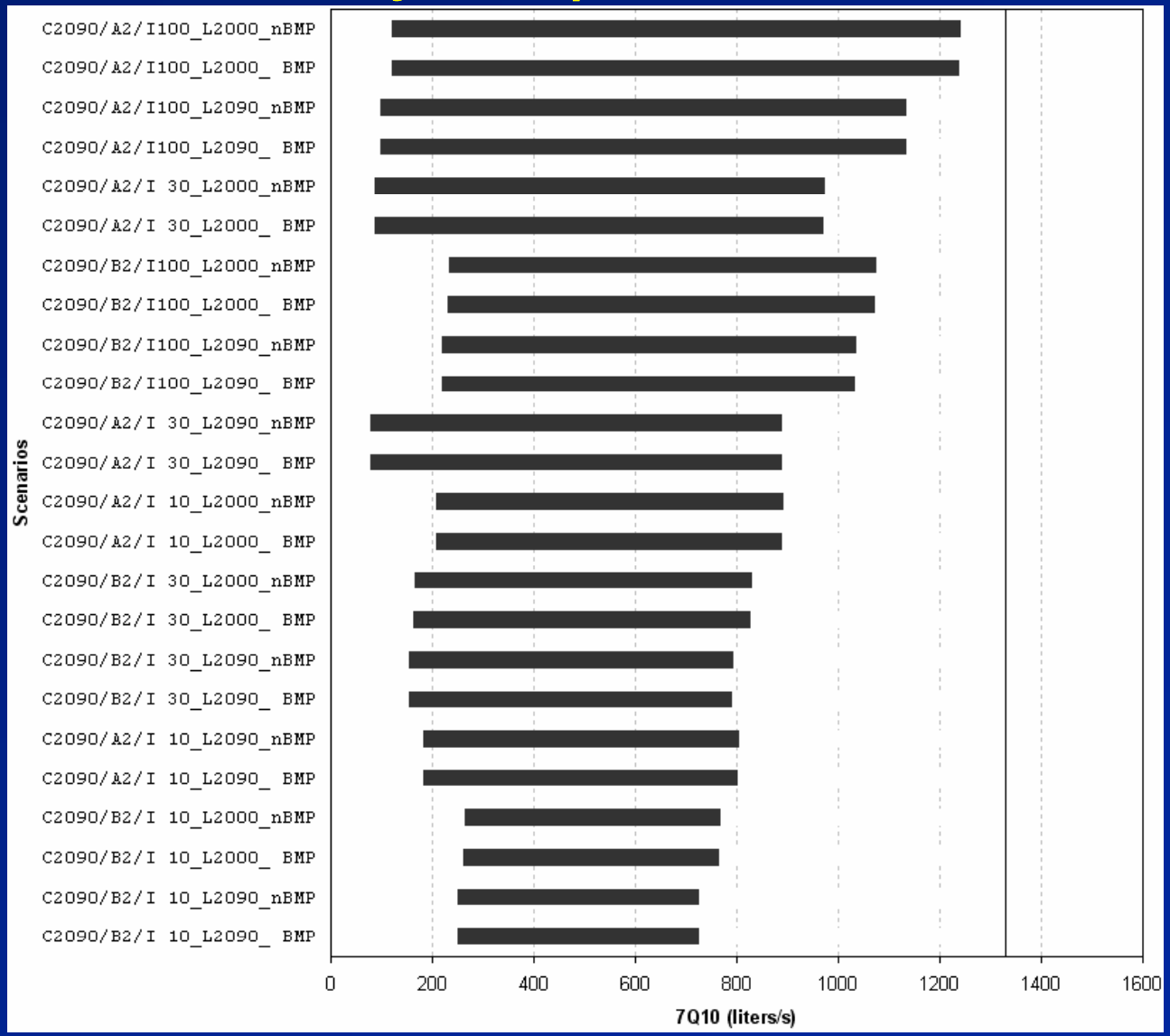
Results

7Q10 Projections for 2090 Climate



Data Legend: Emission storyline (A2, B2), Precip Intensity (I10, I30, I100), Landuse (L2030, L2000), BMP implementation (BMP (yes), nBMP (no))

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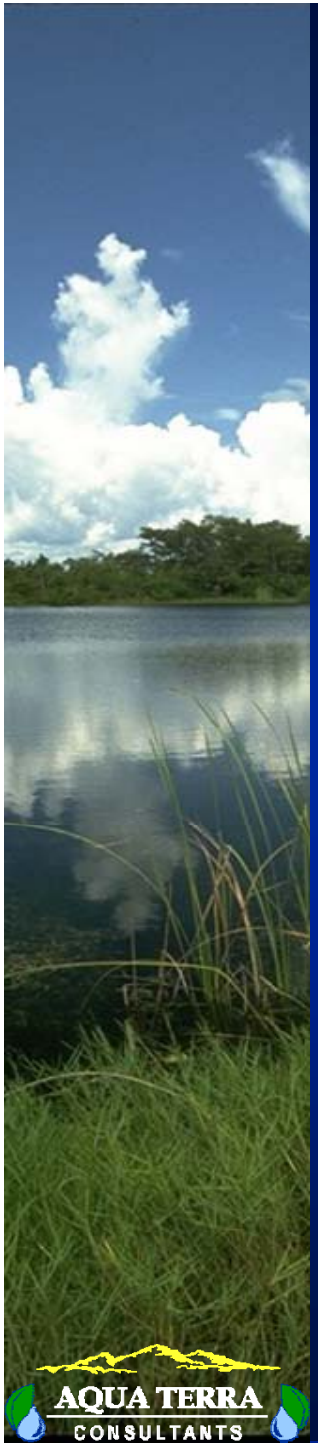
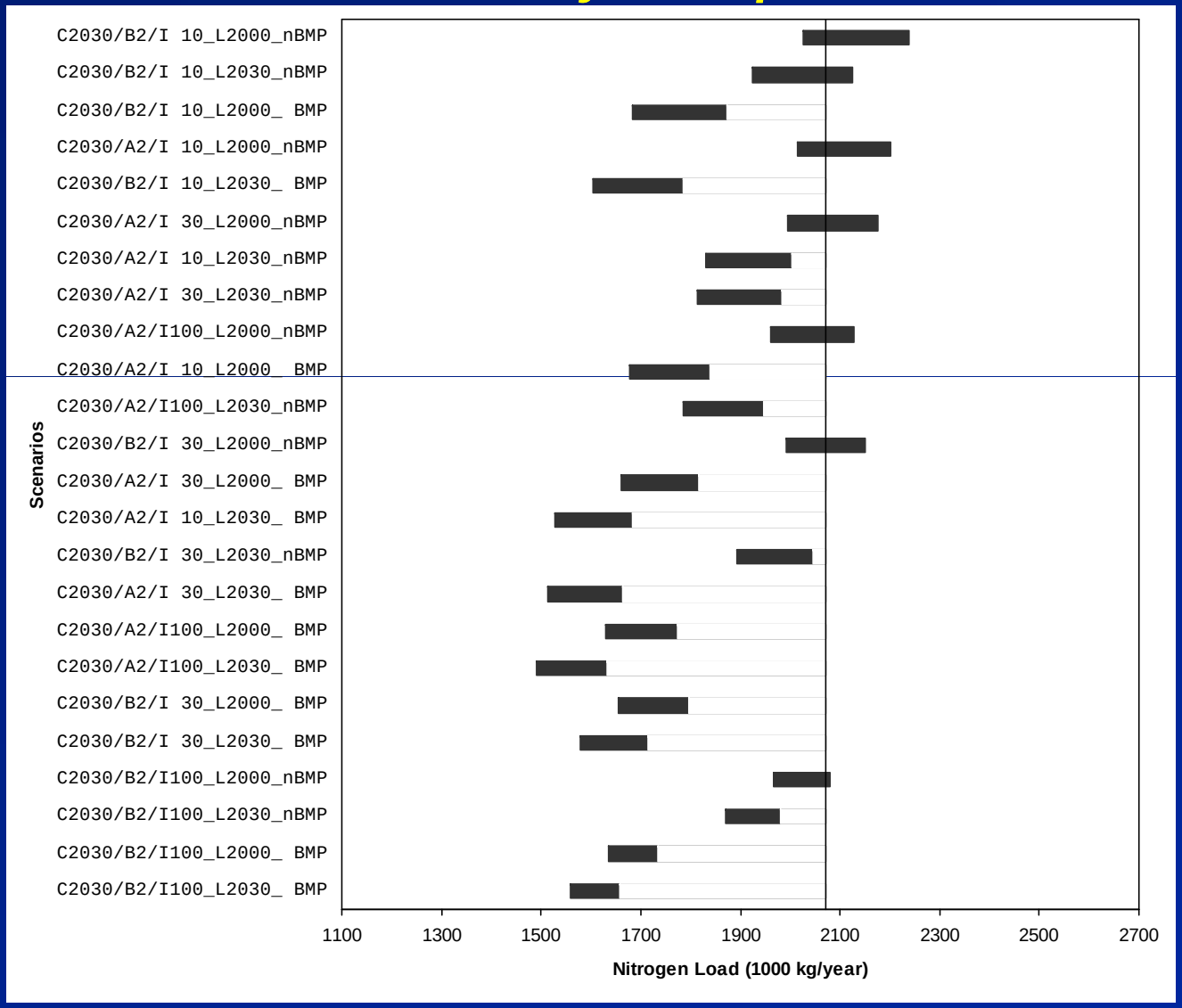


Results

Annual Total N Load Projections for 2030 Climate



Data Legend: Emission storyline (A2, B2), Precip Intensity (I10, I30, I100), Landuse (L2030, L2000), BMP implementation (BMP (yes), nBMP (no))

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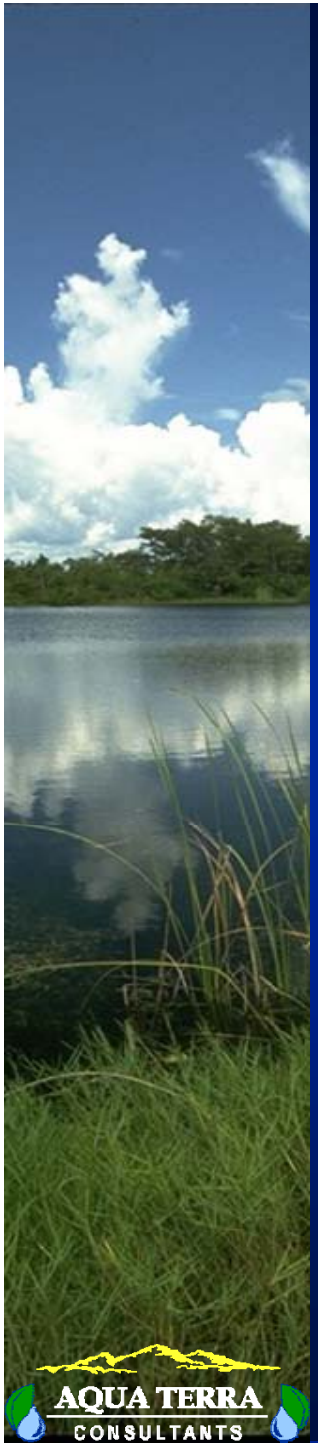
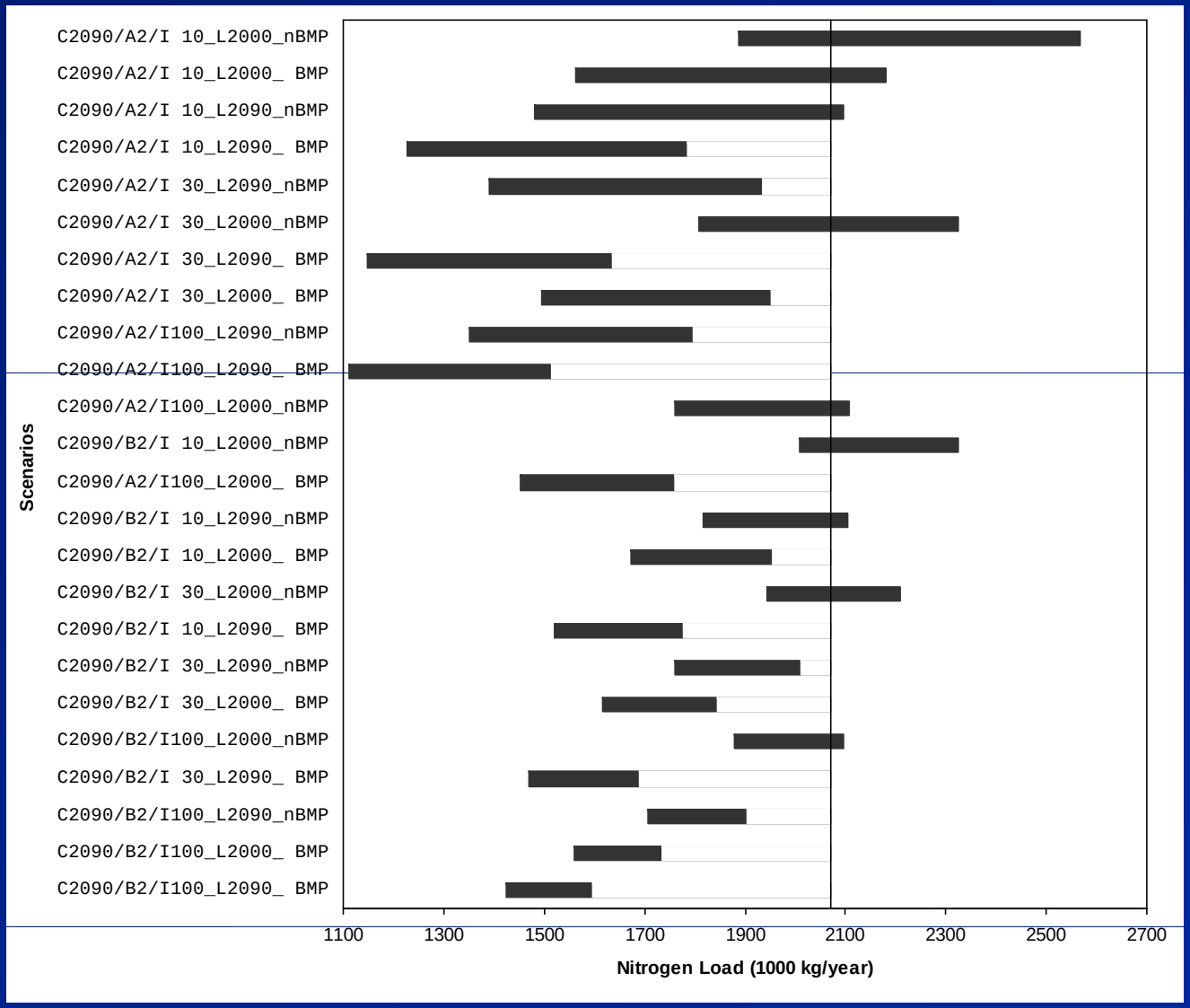


Results

Annual Total N Load Projections for 2090 Climate



Data Legend: Emission storyline (A2, B2), Precip Intensity (I10, I30, I100), Landuse (L2030, L2000), BMP implementation (BMP (yes), nBMP (no))

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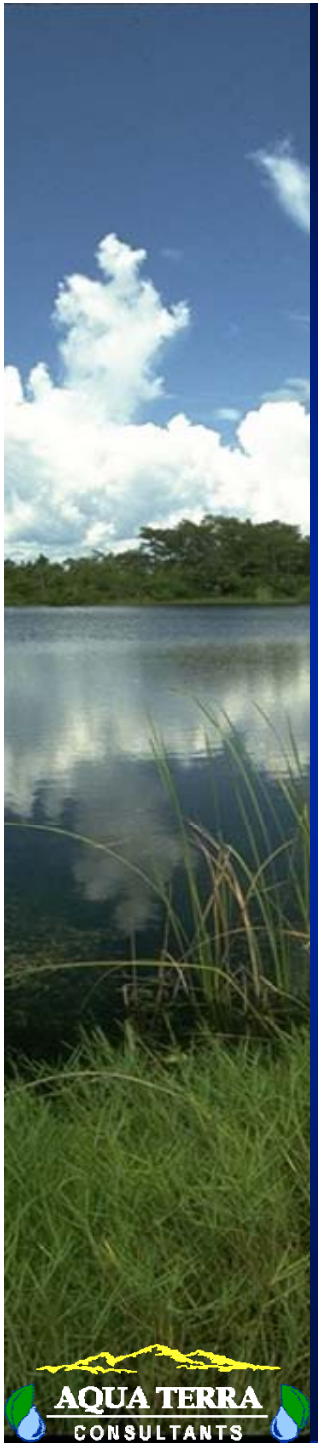
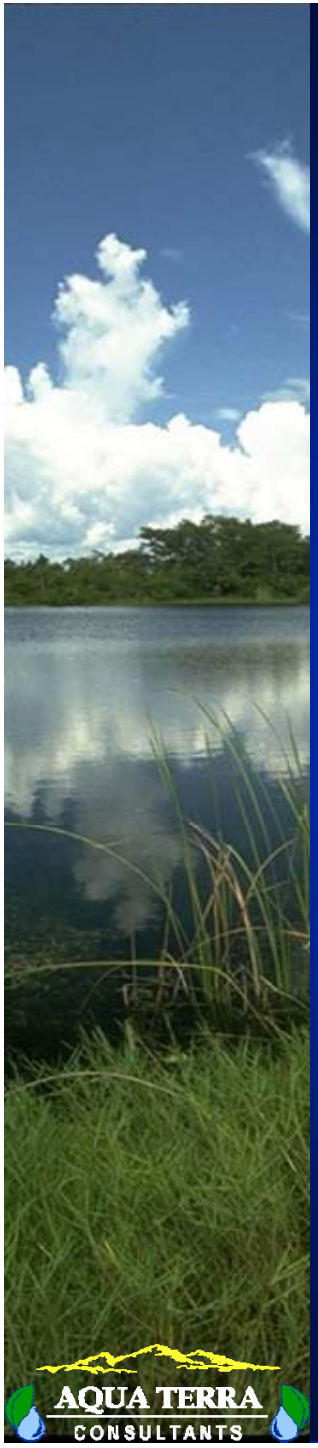


Conclusions

- **Study begins to assess sensitivity of hydrologic and water quality endpoints to combined effects of climate, land use, and management changes**
- **Assessed variability across models and across future time points**
- **Variability increases further into the future**
- **Precipitation intensity plays a major role in the influence of endpoint values, especially nutrients and sediment**



Acknowledgment

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