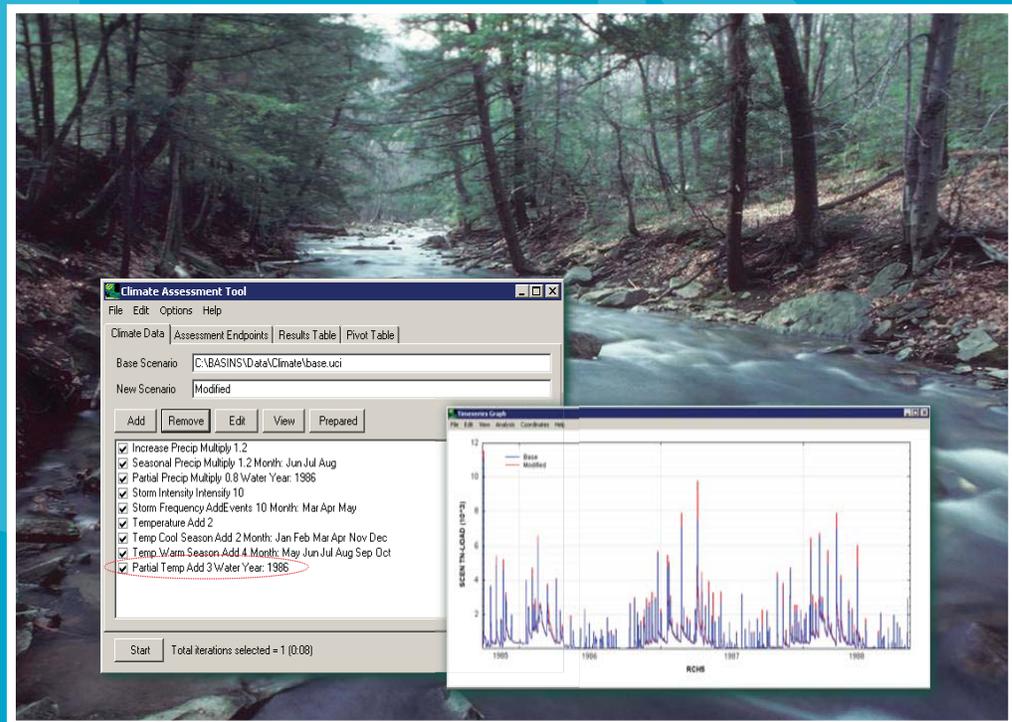


## BASINS 4.0 Climate Assessment Tool (CAT): Supporting Documentation and User's Manual



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# **BASINS 4.0 Climate Assessment Tool (CAT): Supporting Documentation and User's Manual**

Global Change Research Program  
National Center for Environmental Assessment  
Office of Research and Development  
U.S. Environmental Protection Agency  
Washington, DC 20460

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### **Preferred citation:**

U.S. Environmental Protection Agency (EPA). (2009) BASINS 4.0 Climate Assessment Tool (CAT): supporting documentation and user's manual. National Center for Environmental Assessment, Washington, DC; EPA/600/R-08/088F. Available from the National Technical Information Service, Springfield, VA, and online at <http://www.epa.gov>.

# CONTENTS

LIST OF FIGURES .....	v
PREFACE .....	vi
AUTHORS AND REVIEWERS .....	vii
1. EXECUTIVE SUMMARY .....	1-1
2. INTRODUCTION .....	2-1
2.1. BASINS CAT GOALS AND APPROACH .....	2-2
3. BASINS CAT METHODS AND CAPABILITIES .....	3-1
3.1. BASINS .....	3-1
3.2. HSPF .....	3-3
3.3. CLIMATE ASSESSMENT TOOL (CAT) CAPABILITIES .....	3-5
3.3.1. Tools for Developing Climate Change Scenarios .....	3-6
3.3.2. Tools for Assessing Hydrologic and Water Quality Endpoints .....	3-19
3.3.3. Running an HSPF Simulation Using BASINS CAT .....	3-20
3.3.4. Tools for Summarizing and Visualizing Results .....	3-20
3.3.5. Using Scripts to Automate BASINS CAT Applications .....	3-22
4. OVERVIEW OF BASINS CAT .....	4-1
4.1. COMPONENTS OF BASINS CAT INTERFACE .....	4-1
4.1.1. Climate Data .....	4-5
4.1.2. Assessment Endpoints .....	4-12
4.1.3. Running an Assessment .....	4-16
4.1.4. Viewing Results .....	4-18
5. TUTORIALS .....	5-1
5.1. TOOLS FOR DEVELOPING CLIMATE CHANGE SCENARIOS .....	5-7
5.1.1. Modify Historical Precipitation Records .....	5-7
5.1.2. Modify Historical Air Temperature Records and Regenerate Evapotranspiration Record .....	5-39
5.1.3. Combine Multiple Changes to Create a Climate Change Scenario .....	5-65
5.1.4. Creating Spatially Variable Climate Change Scenarios at Multiple Locations .....	5-68
5.1.5. Create Synthetic Climate Change Scenarios .....	5-68
5.1.6. Exporting Climate Change Scenarios as ASCII Text Files .....	5-77
5.2. TOOLS FOR ASSESSING HYDROLOGIC AND WATER QUALITY ENDPOINTS .....	5-81
5.2.1. Endpoint Options .....	5-81
5.2.2. Specify Value Ranges of Concern .....	5-88
5.2.3. Specify Time Periods of Concern (Seasonal and/or Partial Records) .....	5-91
5.3. RUNNING AN HSPF SIMULATION USING BASINS CAT .....	5-94

CONTENTS (continued)

5.4. TOOLS FOR SUMMARIZING AND VISUALIZING RESULTS.....	5-97
5.4.1. Results Tables.....	5-98
5.4.2. Pivot Tables.....	5-100
5.4.3. Exporting Results for Use With External Software .....	5-103
5.4.4. Additional BASINS Tools for Summarizing and Visualizing Results .....	5-106
5.5. USING SCRIPTS TO AUTOMATE BASINS CAT APPLICATIONS .....	5-116
6. A CASE STUDY APPLICATION OF BASINS CAT IN THE MONOCACY RIVER WATERSHED .....	6-1
6.1. BACKGROUND AND GOALS .....	6-1
6.2. METHODS .....	6-2
6.2.1. Regional Climate Change Data .....	6-3
6.2.2. Scenario Analysis .....	6-3
6.3. RESULTS .....	6-5
6.3.1. Synthetic Scenarios .....	6-5
6.3.2. Model-Based Scenarios.....	6-7
6.4. CONCLUSIONS.....	6-9
7. SUPPORTING RESOURCES .....	7-1
7.1. CLIMATE CHANGE DATA AND INFORMATION .....	7-1
7.2. OTHER RESOURCES .....	7-2
REFERENCES .....	R-1

## LIST OF FIGURES

3-1	U.S. EPA BASINS version 4.0 Integrated Modeling System .....	3-2
6-1	The Monocacy River watershed .....	6-2
6-2	Pivot table showing the response of mean annual nitrogen loading (pounds per year) in the Monocacy River to changes in mean annual temperature and precipitation based on the analysis using synthetic scenarios .....	6-6
6-3	Contour plot showing the response of mean annual nitrogen loading (pounds*1,000 per year) in the Monocacy River to changes in mean annual temperature and precipitation based on the analysis using synthetic scenarios.....	6-7
6-4	Scatter plot showing the response of mean annual nitrogen loading (indicated by the color scale in pounds*1,000 per year) in the Monocacy River to model based climate change scenarios from the CARA data set.....	6-8

## PREFACE

The U.S. Environmental Protection Agency's Global Change Research Program (GCRP) is an assessment-oriented program within the Office of Research and Development that focuses on assessing how potential changes in climate and other global environmental stressors can impact water quality, air quality, aquatic ecosystems, and human health in the United States. The Program's focus on water quality is consistent with the *Research Strategy* of the U.S. Climate Change Research Program, the federal umbrella organization for climate change science in the United States government, and is responsive to EPA's mission and responsibilities as defined by the Clean Water Act and the Safe Drinking Water Act. A central goal of the EPA GCRP is to provide EPA program offices, regions, and other stakeholders with tools and information for assessing and responding to any potential future impacts of climate change.

This report provides supporting documentation for the BASINS Climate Assessment Tool (CAT) released with Version 4 of EPA's BASINS modeling system. BASINS CAT was supported by the GCRP, in partnership with the EPA Office of Water, with the goal of increasing the capacity of managers and other stakeholders to conduct watershed based studies of the potential implications of climate variability and change on water and aquatic resources.

This final report reflects a consideration of comments received on an External Review Draft report dated August, 2008 (EPA/600/R-08/088), provided by an external letter peer review and a 30-day public comment period.

Peter Preuss, Ph.D.  
Director  
National Center for Environmental Assessment  
Office of Research and Development  
U.S. Environmental Research Program

## **AUTHORS AND REVIEWERS**

The National Center for Environmental Assessment (NCEA), Office of Research and Development, was responsible for preparing this final report. Preparation of the draft report was conducted by AQUA TERRA Consultants, under EPA Contract EP-C-6-029. Dr. Thomas Johnson served as the Technical Project Officer. Dr. Johnson provided overall direction and technical assistance, and he contributed as an author.

### **AUTHORS**

#### **AQUA TERRA Consultants, Decatur, GA**

Paul Hummel, John Imhoff, John Kittle Jr., and Mark Gray

#### **U.S. Environmental Protection Agency, National Center for Environmental Assessment, Global Change Research Program, Washington, DC**

Thomas Johnson

### **REVIEWERS**

This report was much improved, and the authors are very grateful for the many excellent and thoughtful comments provided by external peer reviewers Douglas Beyerlein, Kaye Brubaker, Billy Johnson, and Bethany Neilson, and EPA internal peer reviewers James Carleton, Yusuf Mohamoud, Jeffery Yang, and Rick Ziegler.

### **ACKNOWLEDGEMENTS**

The authors thank the Global Change Research Program staff in NCEA, particularly Chris Pyke (currently with CTG-Energetics), Britta Bierwagen, Susan Julius, and Chris Weaver for their input and advice throughout this project. We also thank staff in the Office of Science and Technology in the U.S. EPA's Office of Water. Their ideas and assistance contributed greatly to this report and the development of the BASINS CAT tool.



## **1. EXECUTIVE SUMMARY**

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level” (IPCC, 2007). Projecting forward, continued warming temperatures and changes in the amount, form, and intensity of precipitation are expected, albeit with large and poorly understood regional variations.

Water and watershed systems are highly climate sensitive. Climate change could thus impact the ability of water managers to sustainably meet water supply needs, comply with water quality regulations, and protect aquatic ecosystems. To reduce the likelihood of future impacts, water managers must be able to assess potential risks and opportunities, and where appropriate, implement practices and strategies to adapt to future climatic conditions. Meeting this challenge will require tools and information allowing water managers to incorporate consideration of climate change in their decision-making process.

The BASINS Climate Assessment Tool (CAT) was developed in response to a widely acknowledged need for tools and information to help water managers assess and manage the impacts of climate variability and change. BASINS CAT was released in 2007 with Version 4 of EPA’s BASINS modeling system with the goal of increasing the capacity of BASINS users to conduct watershed based studies of the potential implications of climate variability and change on water and aquatic resources.

Specifically, BASINS CAT provides flexible capabilities for creating climate change scenarios, allowing users to quickly assess a wide range of “what if” questions about how weather and climate could affect their systems using the Hydrologic Simulation Program FORTTRAN (HSPF) watershed model. A post-processing capability is also provided for calculating management targets (endpoints) useful to water managers from HSPF model output. Combined with the existing capabilities of HSPF for assessing the effects of land-use change and management practices, BASINS CAT can be used to assess the coupled effects of climate and land-use change, and to guide the development of effective management responses.

Climate change scenarios are created with BASINS CAT by selecting and modifying an arbitrary base period of historical temperature and precipitation data to reflect any desired future change or changes. After selecting a period of historical data to be modified (e.g., from an NCDC weather station used as meteorological input to a watershed model), BASINS CAT facilitates the application of one or more operations, or adjustments, to that baseline time series. Users can adjust historical data using standard arithmetic operators applied monthly, seasonally, or over any other increment of time. This flexibility allows adjustments to be made reflecting

long-term seasonal climate change, as well as short-term, year-to-year changes such as changes in the intensity of periodic drought. In addition, adjustments to a climate variable can also be applied uniformly to all events within a record, or be selectively applied only to those historical events that exceed (or fall below) a specified threshold. Finally, BASINS CAT also provides a capability for users to adjust historical data to increase or decrease the frequency of precipitation events.

The post-processing capability provided by BASINS CAT allows users to calculate hydrologic and water quality endpoints based on any variable or flux simulated and output by the HSPF model. Users can specify one or more hydrologic or water quality endpoints by selecting the appropriate HSPF output time series data, and selecting the attributes of that time series to be calculated (e.g., sum, mean, min, max, 100-yr flood, 7Q10).

BASINS CAT is not a stand-alone model. Rather, BASINS CAT is seamlessly integrated into the BASINS system through a series of graphical user interfaces. Application of BASINS CAT requires a pre-existing, calibrated HSPF application, a WDM file containing HSPF input meteorological time series, and an output file(s) to which HSPF results are output (WDM and/or binary).

This report provides documentation and user support materials for BASINS CAT. A general discussion of BASINS CAT methods and capabilities is provided, followed by a set of detailed, step-by-step tutorials illustrating how to perform specific tasks using the BASIN CAT interface. BASINS CAT supports a wide range of assessment goals including simple screening studies, representation of more complex scenarios based on climate modeling experiments, and systematic sensitivity analyses of watershed endpoints to specific climate drivers. This report also includes a case study assessment illustrating one type of analysis that can be conducted using BASINS CAT; an assessment of the potential impacts of climate change on the hydrology and water quality of a mid-Atlantic watershed.

## 2. INTRODUCTION

There is general consensus among climate scientists that human activities including the combustion of fossil fuels and land-use change have resulted in, and will likely continue to result in, long-term climatic change (IPCC, 2007). The 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level” (IPCC, 2007). The global average temperature has increased 1.4°F in the last century. At the same time many regions have experienced changes in precipitation amount and an increase in the frequency of heavy precipitation events (i.e., the proportion of annual precipitation occurring as heavy precipitation events; IPCC, 2007). Projecting forward, continued warming temperatures and changes in the amount, form, and intensity of precipitation are expected, albeit with large and poorly understood regional variations.

Water and watershed systems are directly influenced by the amount, form, seasonality, and event characteristics of precipitation, as well as air temperature, solar radiation, and wind that affect evaporative loss (Gleick and Adams, 2000). Changes in climate can thus be reflected in key water management targets such as duration flow events (e.g., the 7Q10 low-flow event), maximum water temperatures, or constituent loads required to meet a TMDL or other water quality regulatory requirements. Such changes could impact the ability of water managers to sustainably meet water supply needs, comply with water quality regulations, and protect aquatic ecosystems. To reduce the likelihood of future impacts, water managers must be able to assess climate related risk, and where appropriate, implement practices and strategies to adapt to future climatic conditions. Meeting this challenge will require tools and information allowing water managers to incorporate consideration of climate change into their decision-making process.

The BASINS Climate Assessment Tool (CAT) was developed in response to a widely acknowledged need for tools and information to help water managers assess and manage the impacts of climate variability and change (CCSP, 2003; U.S. EPA, 2008). BASINS CAT was released with BASINS version 4 in 2007, and extends the existing capabilities of BASINS to facilitate watershed based assessments of the potential implications of climate variability and change on water and watershed systems using the Hydrologic Simulation Program FORTTRAN (HSPF) watershed model (Johnson and Kittle, 2006; Imhoff et al., 2007). Specifically, BASINS CAT provides flexible capabilities for creating climate change scenarios allowing users to quickly assess a wide range of “what if” questions about how weather and climate could affect their systems. Combined with the existing capabilities of HSPF for assessing the effects of land-use change and management practices, BASINS CAT can be used to assess the coupled

effects of climate and land-use change, and to guide the development of effective management responses.

This report provides documentation and user support materials for the BASINS CAT. It is composed of 8 chapters. Chapter 1 is an Executive Summary, and Chapter 2 an introduction to BASINS CAT. Chapter 3 provides a narrative description of the basic capabilities of BASINS CAT. Chapter 4 is an overview of the BASINS CAT interface. Chapter 5 provides a set of detailed tutorials illustrating how various tasks are completed using BASINS CAT. Chapter 6 summarizes a case study application of BASINS CAT assessing the potential impacts of climate change on a mid-Atlantic watershed. Chapter 7 lists some supporting resources where users can go for additional information about climate change, and Chapter 8 lists references cited throughout the report.

## **2.1. BASINS CAT GOALS AND APPROACH**

Despite continuing advances in our understanding of climate science and modeling, we currently have a limited ability to predict or forecast long-term future climate at the local and regional scales needed by water managers. A great deal is known, however, about Earth's climate system. Climate models represent our current best understanding of how the climate system works, and can provide much valuable information about how climate could be expected to change in response to changes in anthropogenic forcing such as greenhouse gas emissions. Historical and paleo records of climatic variability also provide valuable information about the type and rates of change that are possible in different regions of the world. Even without accurate forecasts, water managers can use this type of information to evaluate their exposure to climate related risk, and where necessary, to guide the development of management strategies for increasing resilience to a wide range of potential future conditions and events (Sarewitz et al., 2000).

The basic philosophy of BASINS CAT is to provide a flexible set of capabilities for users to create and run with the HSPF model any climate change scenario they determine to be of interest in their specific region or watershed. As used here, the term "scenario" is a possible or plausible future, not necessarily a probable future (IPCC-TGICA, 2007). This capability is intended to support BASINS users interested in assessing the implications of a wide range of "what if" questions about how changes weather and climate could affect their systems.

Scenarios can be developed based on any available information about climate change. The IPCC Task Group on Data and Scenario Support for Impacts and Climate Analysis (TGICA) describes three different types of scenarios based on different types of information about climate: synthetic scenarios, analogue scenarios, and scenarios based on outputs from climate models.

Synthetic scenarios describe techniques where particular climatic attributes are changed by a realistic but arbitrary amount, often according to a qualitative interpretation of climate model simulations for a region. For example, arbitrary adjustments of historical temperatures by 1, 2, 3, and 4°C and historical precipitation by 5, 10, 15, and 20% could be applied in various combinations to create synthetic change scenarios (IPCC-TGICA, 2007). Analogue scenarios are constructed by identifying recorded climate regimes which may resemble the future climate in a given region. These records can be obtained either from the past (temporal analogues) or from a different region at the present time (spatial analogues). Model based scenarios are developed using output from modeling experiments with Global Climate Model (GCM) and Regional Climate Model (RCM) models that simulate the response of the global climate system to increasing greenhouse gas concentrations. Ultimately, the scenarios used in an analysis should depend on the available information about climate change and, equally as important, the goals and requirements of a specific assessment activity. A more detailed discussion of climate models and scenarios based on climate models is provided by the IPCC-TGICA (2007).

Climate change scenarios are created with BASINS CAT by selecting and modifying an arbitrary base period of historical temperature and precipitation data to reflect any desired future change or changes. After selecting a period of historical data to be modified (e.g., from an NCDC weather station used as meteorological input to a watershed model), BASINS CAT facilitates the application of one or more operations or “adjustments” to that baseline time series. Because change scenarios are developed by superimposing a set of changes, or deltas, onto a historical data set, this approach is referred to as a delta method. The advantages of this approach are that it is relatively simple to implement, able to represent a wide range of potential changes, and the change scenarios thus created will incorporate any spatial or temporal structure present in observed weather records. For example, one way to develop scenarios using BASINS CAT is to modify historical weather data from a specific location, e.g., an NCDC weather station, to reflect the broad regional changes projected by a GCM or RCM model. Creating scenarios in this way is a simple but effective form of spatial and temporal downscaling, whereby coarser scale climate change information is superimposed over more spatially (e.g., an individual NCDC weather station) and temporally detailed (e.g., daily or hourly data) historical observations. This approach also allows the creation of scenarios at multiple locations throughout a watershed that maintain the existing spatial correlation, which is particularly important in large or topographically complex watersheds (e.g., by modifying existing weather records from multiple weather stations over the same base period, the observed spatial correlation structure is preserved).

It is important to note that climate change information from a variety of sources can be used to create scenarios. For example, scenarios can be developed to reflect re-occurrence of an extreme historical condition or event, to reflect specific attributes of a projection based on a climate modeling experiment, or be specifically designed to address a hypothesis about the sensitivity of a hydrologic or water quality endpoint to a particular type of climate change. In each case, the capabilities provided by BASINS CAT can be used to apply an appropriate set of changes to a historical data set to create the desired scenarios. The scenarios used in an assessment activity should ultimately depend on the context and goals of the assessment. A listing of potential sources climate change data, information, and tools to support the assessment of climate change impacts on water and watershed systems is provided in the Supporting Resources chapter of this report.

### **3. BASINS CAT METHODS AND CAPABILITIES**

BASINS CAT integrates tools into the BASINS system allowing users to create climate change scenarios by modifying historical weather data, and to use these data as the meteorological inputs to the HSPF watershed model. A capability is also provided to calculate specific hydrologic and water quality endpoints important to watershed management based on HSPF model output time series data (e.g., the 100-year flood or 7Q10 low-flow event). Finally, the BASINS CAT can be used to assess the outcomes of a single climate change scenario, or to automate multiple HSPF runs to determine the sensitivity or general pattern of watershed response to different types and amounts of climate change. These capabilities support a range of assessment goals, e.g., simple screening analysis, systematic sensitivity analysis, or implementing more detailed scenarios based on climate model projections. BASINS CAT is not a complete or stand-alone model. Use of BASINS CAT requires an existing, calibrated HSPF model within the BASINS system.

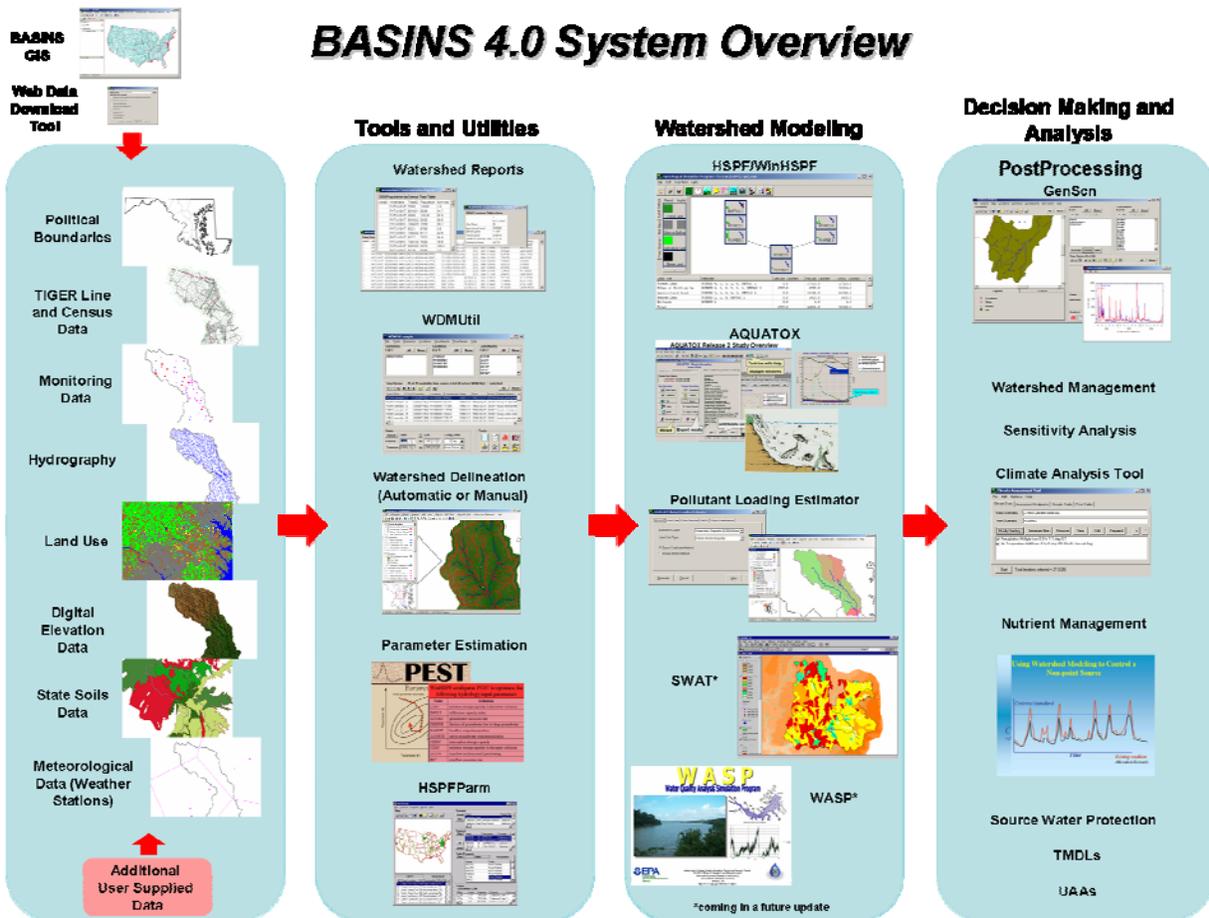
This chapter provides a brief introduction to BASINS and the HSPF model, followed by a more detailed discussion of BASINS CAT tools and capabilities. A comprehensive discussion of BASINS and HSPF is beyond the scope of this report. Supporting documentation and training materials for BASINS and the HSPF model are available on the BASINS web page (U.S. EPA, 2001; see <http://www.epa.gov/waterscience/basins/>).

#### **3.1. BASINS**

EPA's BASINS modeling system is a non-proprietary, multi-purpose environmental analysis system that integrates environmental data, analytical tools, and watershed modeling programs to support the development of cost-effective approaches to watershed management and environmental protection, including TMDLs (U.S. EPA, 2001; see <http://www.epa.gov/waterscience/basins/>). First introduced in 1996, the BASINS system was developed to support assessments of watershed land-use change, pollutant discharges, and management practices on water quality (U.S. EPA, 2007).

The BASINS modeling system combines five components: (1) a comprehensive collection of national cartographic and environmental databases, (2) environmental assessment tools (to summarize results; establish pollutant source/impact interrelationships; and selectively retrieve data); (3) utilities (e.g., import tool, download tool, grid projector, post-processor, and land use, soil classification and overlay tool); (4) automated watershed characterization reports (for eight different data types); and (5) a suite of watershed models including HSPF (Bicknell et al., 2005), SWAT (Neitsch et al., 2005), AQUATOX (Clough and Park, 2006), and PLOAD (U.S. EPA, 2007). Figure 3-1 illustrates the structural relationship among components of the

BASINS system. The main interface to BASINS is provided through a non-proprietary, open-source Geographic Information System (GIS), MapWindow (<http://www.mapwindow.org/>). The GIS provides a framework for linking BASINS modeling tools with environmental data.



**Figure 3-1. U.S. EPA BASINS version 4.0 Integrated Modeling System.**

BASINS CAT is one of several tools intended to support decision making and analysis within BASINS. Other useful features available within BASINS to support comprehensive watershed assessment and data analysis include:

WinHSPF - A graphical user interface (GUI) for HSPF applications useful for implementing watershed management changes (e.g., land use, point sources, BMPs).

WDMUtil - A user interface for WDM files. This tool is particularly helpful in developing WDM files to store both input and output time series for use by HSPF.

GenScn - A post-processing tool for comparing scenarios. GenScn contains a wide array of output capabilities including data listing, graphical plots, and statistical analyses.

In addition, elements of the USGS SWSTAT program have been incorporated into BASINS for statistically analyzing time-series data including duration-frequency analysis, trend analysis, and n-day annual time series (USGS, 2008).

In a 2005 evaluation, BASINS was found to contain the most robust suite of assessment capabilities among 37 current watershed models and modeling systems based on level of complexity, simulation time step, hydrologic regimes, water quality constituents and BMP simulation options (U.S. EPA, 2005).

### **3.2. HSPF**

BASINS CAT is currently available for use with the Hydrological Simulation Program-FORTRAN (HSPF) watershed model (Bicknell et al., 2005). HSPF is a relatively complex, process-based mathematical model developed under joint U.S. EPA and USGS sponsorship for simulating hydrologic and water quality processes in natural and man-made water systems. Since its inception in 1980, HSPF has been widely applied in the planning, design, and operation of water resources systems, and is arguably one of the best verified watershed models currently available. HSPF has been applied to diverse climatic regimes including the tropical rain forests of the Caribbean, arid conditions of Saudi Arabia and the Southwestern United States, the humid Eastern United States and Europe, and snow covered regions of Eastern Canada.

HSPF can be applied to most watersheds using available meteorologic, watershed land use, hydrography, management, hydrologic, and water quality data. HSPF uses this information to simulate the watershed processes governing flow and the transport of materials over land, through various soil zones within watersheds, and within stream channels. The model can be configured to represent all types of land uses, offers the ability to include land-use activities and potential management controls, allows for dynamic simulation, and can provide a detailed representation of critical conditions associated with high flows and wet-weather conditions. The principal model outputs include the flow rates of runoff and mass loads or concentrations of sediment, nutrients, pesticides, and toxic chemicals at selected points within a watershed.

Three application modules are used to simulate different hydrologic/hydraulic and water quality components within watersheds (e.g., Donigian et al., 1983; Mulkey et al., 1986;

Johanson, 1989; Linker et al., 1998; AQUA TERRA and HydroQual, 2001): PERLND, IMPLND, and RCHRES.

PERLND is used to simulate the water quality and quantity processes that occur on pervious land areas. Three flow pathways are represented: overland flow, interflow, and groundwater flow. Snow accumulation and melt are also represented. Major capabilities of the PERLND module include the simulation of water budget and runoff components, snow accumulation and melt, sediment production and removal, accumulation and washoff of user-defined nonpoint pollutants, nitrogen and phosphorus fate and runoff, and pesticide fate and runoff.

IMPLND is used for impervious land surfaces, primarily urban land categories, where little or no infiltration occurs. IMPLND simulates the movement or washing off of water, solids, and other pollutants from the land surface by moving downslope to a pervious area, stream channel, or reservoir. IMPLND also offers the capability to simulate the accumulation and removal of urban solids (i.e., solids on impervious areas) by processes that are independent of storm events (e.g., street cleaning, decay, wind deposition, or scour).

RCHRES, the instream module of HSPF, simulates the flow of water and associated water quality constituents within stream channels and mixed reservoirs. RCHRES capabilities include flow routing by kinematic wave methods, migration of cohesive and non-cohesive sediments between suspension in water and the bed, complex biochemical transformations, adsorption/desorption between dissolved and sediment-associated phases, and detailed representation of processes affecting instream dynamics of BOD, nitrogen, phytoplankton, and pH.

Detailed HSPF documentation including User's Manuals, tutorial exercises, technical notes, and FAQs relating to all aspects of watershed modeling can be found on the BASINS web site: <http://www.epa.gov/waterscience/BASINS/>. Of particular concern, HSPF contains a relatively large number of model parameters requiring adjustment to properly calibrate the model. Model calibration is thus an important and potentially time consuming task. HSPF users can benefit, however, from a wide range of documentation and user support materials developed over decades of model applications. Specific assistance in setting model parameter values is available from the HSPF Application Guide (Donigian et al., 1984), and in the form of Technical Notes available from the EPA BASINS web site. HSPFParm, an interactive database of HSPF model parameters for over 40 watersheds in 14 states is also available to guide the calibration of HSPF models in these areas (Donigian et al., 1998).

It should be noted that there are inherent limits to the appropriate range of climatic changes that can be simulated using a watershed model calibrated with historical data.

Simulating watershed behavior under changing climatic conditions assumes that the model calibration is robust to these changes. This is a particular concern when evaluating climate changes well outside the range of variability experienced during the calibration period. Calibration concerns are not unique to assessments of climate change. Users should use their own discretion in interpreting results.

### **3.3. CLIMATE ASSESSMENT TOOL (CAT) CAPABILITIES**

BASINS CAT provides two general capabilities to BASINS users, a flexible scenario generation capability for creating meteorological time series reflecting any user-determined change in temperature and precipitation for use as input to the HSPF model, and a post-processing capability for calculating management targets (endpoints) useful to water and watershed managers from model output. It is important to note that BASINS CAT does not provide climate change data for any particular region of the United States. Rather, BASINS CAT simply provides a capability for users to create meteorological data reflecting any type of change they wish to consider.

BASINS CAT enables adjustments only to historical precipitation and air temperature records. The adjusted records are contained within the same BASINS Watershed Data Management (WDM) file containing the original, historical weather records. In addition, BASINS CAT provides a view/export capability that (1) displays the changes resulting from a specific adjustment or (2) saves the adjusted weather record as an ASCII file.

Users can adjust historical weather data using standard arithmetic operators applied monthly, seasonally, or over any other increment of time. This flexibility allows adjustments to be made reflecting long-term seasonal climate change, as well as short-term, year-to-year variability such as changes in the intensity of periodic drought. In addition, adjustments to a climate variable can also be applied uniformly to all events, or be selectively applied only on those historical events that exceed (or fall below) a specified threshold. Future climate change is expected to result in an acceleration or intensification of the hydrologic cycle, whereby a greater proportion of annual precipitation occurs as heavy events (Groisman et al., 2005; IPCC, 2007). The ability to selectively adjust only events within user-defined size classes allows climate change scenarios to be created reflecting these changes. Finally, BASINS CAT also provides a capability for users to create time series that contain more frequent precipitation events.

The post-processing capability provided by BASINS CAT allows users to directly calculate hydrologic or water quality endpoint metrics such as 100-year flood, 7Q10 low-flow, an annual water yield, or an annual pollutant load. Other tools within the BASINS system and available to BASINS CAT users provide additional capabilities for time series analysis including

the ability to calculate any x-year, y-duration, high or low-flow event using standard USGS protocols. This capability facilitates the assessment of climate change impacts on specific metrics and management targets important to water and watershed managers (Johnson and Kittle, 2006). Users can select as endpoints any HSPF variable or flux output by the model during a simulation. Users can also tailor an analysis by calculating endpoints based only on a specified time of the year (e.g., a specified month or season of the year), or for specific years within a simulation.

BASINS CAT capabilities are seamlessly integrated into the BASINS system through a series of graphical user interfaces. Application of BASINS CAT requires:

- A pre-existing, calibrated HSPF application
- WDM file containing HSPF input meteorological time series
- Output file(s) to which HSPF results are output (WDM and/or binary)

For an HSPF application developed within BASINS, these elements are created and saved in the BASINS project associated with the application. For an HSPF application developed outside of BASINS, input meteorological time series must come from a WDM file referred to by the HSPF User Control Input (UCI) file. Similarly, output time series must be stored in either a WDM or HSPF binary output file for use by BASINS CAT. For either of these cases, BASINS CAT will first refer to the HSPF application's UCI file. The input meteorological time series and output results referenced by the UCI file will then be loaded into BASINS for use by BASINS CAT. A tutorial demonstrating the set-up of BASINS CAT is provided in Chapter 5.

After a BASINS CAT session has been initiated, BASINS CAT creates the necessary input files and manages all input and output from HSPF. BASINS CAT can also be used to automate the creation and running of multiple climate change scenarios.

### **3.3.1. Tools for Developing Climate Change Scenarios**

Scenarios can be developed based on any available information about climate change. The IPCC Task Group on Data and Scenario Support for Impacts and Climate Analysis (TGICA) describes three different types of scenarios based on different types of information about climate: synthetic scenarios, analogue scenarios, and scenarios based on outputs from climate models. Synthetic scenarios describe techniques where particular climatic attributes are changed by a realistic but arbitrary amount, often according to a qualitative interpretation of climate model simulations for a region. For example, adjustments of baseline temperatures by 1, 2, 3, and 4°C

and baseline precipitation by 5, 10, 15 and 20% could represent various magnitudes of future change (IPCC-TGICA, 2007). Analogue scenarios are constructed by identifying recorded climate regimes which may resemble the future climate in a given region. These records can be obtained either from the past (temporal analogues) or from another region at the present (spatial analogues). Model based scenarios are developed using output from modeling experiments with Global Climate Model (GCM) and Regional Climate Model (RCM) models that simulate the response of the global climate system to increasing greenhouse gas concentrations. A more detailed and excellent discussion of climate models and the development of scenarios for assessing climate change impacts is provided by the IPCC-TGICA (2007).

Scenarios representative of a range of potential changes in future climate can be created using the BASINS CAT interface by making one or more adjustments to a selected historical precipitation and/or air temperature record. A range of changes can be applied to historical time series reflecting different types of climate change (e.g., seasonal temperature changes, annual precipitation totals, high intensity precipitation events), and specific changes can then be assembled to create climate change scenarios for assessment. BASINS CAT can be used to create and run single climate change scenarios. In addition, BASINS CAT can be used to automate the creation and running of multiple synthetic scenarios within a specified range of values for selected change variables (IPCC, 2007).

As noted previously, application of BASINS CAT requires a pre-existing, calibrated HSPF application. Use of any calibrated model to perform analysis of change scenarios assumes the calibrated model is sufficiently robust to realistically simulate watershed behavior under the conditions described by the scenarios. In other words, it must be assumed that change scenarios do not impact basic watershed behavior in such a way that the model parameterization achieved through calibration is no longer valid. This issue is common to any modeling analysis, but is of particular concern when assessing climate change impacts. In many cases, users will want to assess changes in temperature and precipitation falling outside of the range of historical observations used to calibrate the model. It is intuitive that at some point, extremely different climate conditions will strain the validity of calibration. It is not clear, however, where this point is or what the implications are for results. BASINS CAT imposes no constraints on the type and magnitude of changes made. BASINS CAT users should thus be careful to consider the validity of model simulations, particularly when assessing change scenarios falling well outside the range of observed climatic variability.

The following definitions apply throughout this chapter and report. Definitions of the terms “projection,” “prediction,” and “scenario” are from the Intergovernmental Panel on

Climate Change (IPCC, 2007). The terms “scenario component” and “record adjustment” are defined with specific reference to this report and the BASINS CAT tool.

**Projection.** A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions concerning, for example future socioeconomic and technological developments that may or may not be realized, and therefore, are subject to substantial uncertainty (IPCC, 2007).

**Prediction.** A climate prediction (or forecast) is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual, or long-term time scales. Since the future evolution of the climate system can be highly sensitive to initial conditions, such predictions are usually probabilistic in nature (IPCC, 2007).

**Scenario.** A scenario is a plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections but are often based on additional information from other sources, sometimes combined with a narrative storyline (IPCC, 2007)

**Scenario component.** In the context of BASINS CAT, climate change scenarios are composed of one or more specific types of change or scenario components. For example, a single climate change scenario could be defined to include increased precipitation during winter months, decreased precipitation during summer months, and a uniform annual increase in air temperatures. In this example, the scenario is composed of three scenario components. BASINS CAT allows users to create complex climate change scenarios by specifying multiple scenario components (as arithmetic adjustments to baseline temperature and/or precipitation records), and assembling scenarios from one or more scenario components as desired.

**Record adjustment.** The term “record adjustment” refers to a specific arithmetic or other operation carried out on a temperature or precipitation record (time series) to reflect a specific scenario component. For example, a scenario component calling for 20% increase in winter precipitation can be represented by adjusting (here multiplying) each winter precipitation value in the baseline precipitation record by 1.2.

**Full record.** Applying an adjustment to the full record affects all years within the historical time period being adjusted to create a climate change scenario.

**Partial record.** Applying an adjustment to a partial record affects only a selected set of years within the historical time period being adjusted to create a climate change scenario.

Climate change scenarios are created with BASINS CAT by selecting and modifying historical temperature and precipitation time series data from one or more locations (e.g., NCDC weather station(s) used as meteorological input to a watershed model) to reflect any change or changes of interest to a user. After selecting the historical data to be modified, BASINS CAT facilitates the application of one or more modifications or adjustments to each selected time series.

Most HSPF models are set up to receive meteorological input from multiple locations within a watershed. BASINS CAT can be used to make adjustments to any meteorological time series occurring within an HSPF model. The same adjustment(s) can be applied to multiple meteorological data sets simultaneously, e.g., temperature time series data from multiple weather stations (see Tutorial 5.1.1.1). Different adjustments can also be applied to specific data sets, e.g., temperature data from different locations within a watershed are modified independently to reflect spatially variable change scenarios (see Tutorial 5.1.4).

The following sections describe options within BASINS CAT for adjusting historical precipitation and air temperature time series to create climate change scenarios. A discussion of how to combine multiple adjustments or scenario components to a single time series data set is also provided. The tutorials in Chapter 5 provide specific instructions about how to implement the adjustments described here using the BASINS CAT interface.

#### **3.3.1.1. *Modify Historical Precipitation Records***

BASINS CAT allows record adjustments to be made to a historical precipitation record by one or more of the five methods listed below. It should be noted the adjustments listed here are only for precipitation amount (depth per time increment). HSPF uses air temperature to determine whether precipitation occurs as rain or snow. The influence of climate change on precipitation form is thus determined by changes in air temperature.

1. Apply multiplier to full record. All values in a precipitation record (daily or hourly precipitation totals) are multiplied by a specified constant.

2. Apply seasonal multiplier. Precipitation values within a selected period (month or season) of every year are multiplied by a specified constant.
3. Modify partial record. Precipitation values within a selected range of years are multiplied by a specified constant.
4. Represent storm intensification. Apply a constant multiplier to all events within a specified event size class.
5. Add or remove storm events. Events are randomly added or removed to represent changes in precipitation event frequency.

Each of these five options for adjusting precipitation records is described below. Any one or more of these five record adjustment types can be combined to create climate change scenarios.

**3.3.1.1.1. Apply multiplier to full record.** All values in a precipitation record (e.g., a daily or hourly precipitation totals) are multiplied by a specified constant. The assumption is that precipitation will change in a uniform way throughout each year of the full record, either increasing or decreasing by a uniform percent.

Example of a relevant analysis: Evaluate the impact of a uniform 20% increase in precipitation on watershed endpoints.

Applying a constant multiplier to historical values in each year of the full record is the simplest (and coarsest) method of modifying precipitation. This method can be used in a stand-alone manner or as one component of a more complex scenario including additional adjustments. As a stand-alone adjustment, application of a constant multiplier might be performed when more detailed information about the seasonality, year-to-year variability, or changes in storm frequency or intensity is not available. As part of a more complex scenario, other types of change can be superimposed on a uniform change. For example, one might create a precipitation change scenario by first applying a uniform increase to the entire period of record, and then applying an additional, second adjustment only for the largest storm events.

**3.3.1.1.2. Apply seasonal multiplier.** Values within a user-specified month or season of each year of the full record are multiplied by a specified constant. The assumption is that precipitation will change in the specified way only during certain times of year for each year in the full record.

Example of a relevant analysis: Evaluate the impact on watershed endpoints of a uniform 20% seasonal increase in precipitation during the months of June, July, and August for each year of the record.

Climate change is expected to vary seasonally throughout the year in most regions of the United States. For example, greater increases in precipitation are anticipated during winter months in the northeast United States than at other times of the year. A seasonal adjustment to a historical record is achieved by specifying and applying a multiplier to only records within a specific, user defined yearly time interval or season. To define a season, BASINS CAT enables the selection of one month or any combination of months.

**3.3.1.1.3. *Modify partial record.*** Only values within a user-specified range of years contained within the full record are multiplied by a specified constant. The assumption is that precipitation will change only during certain years within the full record, e.g., adjustment is made to a user-specified period of 10 years within a 30-year historical record.

Example of a relevant analysis: Evaluate the effect of climate change-induced drought by decreasing by 20% all precipitation values occurring within the driest water year or years contained within the record.

Climate change is expected to result in an increased severity of drought in many parts of the United States. This type of change can be represented in a climate change scenario by adjusting historical precipitation values during specified, consecutive periods of time. For example, investigating the impacts of increasing drought can include decreasing the precipitation total for an already low-rainfall year. BASINS CAT can be used to apply a constant multiplier to precipitation data during only a specified portion of the historical record. The user can define the period that will be adjusted in terms of either calendar years or water years (i.e., October to September).

**3.3.1.1.4. *Represent storm intensification.*** Values within a user-specified event size class, where size is defined according to precipitation depth, are multiplied by a specified constant, e.g., change only those values that exceed or fall below a specified event ranking such as the largest 10% of events. The assumption is that future climate change will result in an intensification of the hydrologic cycle, with a larger proportion of annual precipitation occurring in heavy precipitation events (IPCC, 2007; Groisman et al., 2005).

Example of relevant questions/analyses: (a) Evaluate the impact on watershed endpoints of a 10% increase of annual precipitation occurring only within the largest 20% (defined by total storm volume) of the storms present in the historical precipitation record; (b) Evaluate the impact

on watershed endpoints of a 10% decrease in precipitation occurring only in events within the historical record that are among the lowest 90% defined by total storm volume.

BASINS CAT can be used to apply a constant multiplier only to specific rainfall events that exceed or fall below a user-specified storm volume ranking (e.g., largest 10% or smallest 50%). This capability allows changes to be applied only on selected events within user-defined size classes. Implementing this type of adjustment to a historical precipitation record requires specification of a change in precipitation volume resulting from the intensification adjustment and specification of the particular storm events within which this volume is distributed. More specifically, it requires the following steps:

1. Specify a percent change in water volume over the desired period of record (e.g., the entire period of record, a specific season within each year).
2. Specify which storm events are to be adjusted using the following criteria (note the criteria listed below include options for defining what qualifies as an event, as well as specifying an event intensity threshold):
  - a. an event intensity threshold,
  - b. the maximum allowable length of time (hours) that the intensity threshold is not achieved before one event concludes and another begins,
  - c. the minimum volume of a storm event to be considered a candidate for adjustment, and/or
  - d. the minimum duration of a storm event to be considered a candidate for adjustment.
3. Further reduce the collection of storms that will be adjusted (as per #1 above) by specifying the percentage of the total volume of the rainfall record that is to reside in the storms that are included in the adjustment.

Given this information, BASINS CAT computes the total volume of rainfall to be added/removed from the selected storms. This information is then used to calculate and apply a constant multiplier to each selected rainfall event, thus distributing the desired volume among selected events as a constant percent change.

It should be noted that the Synoptic Analysis Tool available within BASINS can be used to characterize precipitation events. This information may be useful to BASINS CAT users to help define appropriate event size classes and other relevant information before specifying adjustments. The Synoptic Analysis Tool can be applied directly, in a stand-alone manner, to any weather record, and provides a capability to sort or group storm events based on volume

(max, sum, mean, cumulative), event duration (max, sum, mean, standard deviation), event intensity (max, mean, standard deviation), and the elapsed time since the last event (max, mean, variance).

**3.3.1.1.5. Add or remove storm events.** Precipitation events are randomly added or removed from a historical precipitation record to represent changes in the frequency of events. The assumption is that changes in annual precipitation totals occur due to changes in the frequency of precipitation events.

Example of a relevant analysis: Evaluate the impact on watershed endpoints of increasing precipitation volume by 10% by adding randomly timed rainfall events with an average intensity greater than 0.1 inches per hour.

BASINS CAT enables users to represent changes in the frequency of precipitation events by randomly selecting and duplicating with a historical time series an existing event (adding) or randomly selecting and removing an existing event from a historical record. Implementing this type of adjustment to a historical precipitation record requires the following steps:

1. Specify a percent change in water volume over the desired period of record (e.g., the entire period of record, a specific season within each year).
2. Specify which storm events will be either duplicated (to increase total precipitation volume) or eliminated (to decrease total precipitation volume); storm events can be defined in terms of any or all of the following attributes:
  - a. an event intensity threshold,
  - b. the maximum allowable length of time (hours) that the intensity threshold is not achieved before one event concludes and another begins,
  - c. the minimum volume of a storm event to be considered a candidate for adjustment, and/or
  - d. the minimum duration of a storm event to be considered a candidate for adjustment.
3. Given this information, BASINS CAT randomly selects precipitation events for removal or duplication elsewhere in the record until the specified change in precipitation volume is reached.

When duplicating storm events, the position in the time series (i.e., the day(s) on which a new event is added) is determined randomly. Accordingly, it is possible for new events to overlap existing events. In such cases the new precipitation is simply added to existing

precipitation for that time interval. BASINS CAT maintains an internal record to avoid duplicating the same storm twice, unless all qualifying storms have been duplicated before meeting the specified volume increase.

### **3.3.1.2. *Modify Historical Air Temperature Records and Regenerate Evapotranspiration Record***

The 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level” (IPCC, 2007).

BASINS CAT can be used to adjust a historical air temperature record by one or more of the three methods below:

1. Add or subtract a constant to full record and regenerate evapotranspiration. All values in a temperature record (daily or hourly air temperature) are increased or decreased by a specified constant.
2. Add or subtract a constant to a specified season and regenerate evapotranspiration. Values occurring within a specified season in the full record are increased or decreased by a specified constant.
3. Add or subtract a constant to a partial record and regenerate evapotranspiration. Values occurring within a specified time period (years) within the full record are increased or decreased by a specified constant.

Each of these three options for adjusting temperature records is described below. As for precipitation, any one or more of these types of adjustments can be combined to create more complex climate change scenarios.

**It is extremely important to note that whenever an adjustment is made to a historical air temperature, the potential evapotranspiration (PET) record used by HSPF must be regenerated to reflect these changes.** HSPF uses the Hamon (1961) method for estimating the potential evapotranspiration based on air temperature. It is very simple to regenerate PET values to reflect modified air temperatures when running a simulation through the BASINS CAT interface. However, regeneration of PET is not an automatic function in BASINS CAT. Users must instruct BASINS CAT to perform the regeneration of PET. HSPF also uses air temperature to determine the form of precipitation and dynamics of snowmelt, which has a major influence on hydrology.

**3.3.1.2.1. Add or subtract a constant to full record and regenerate evapotranspiration.** A constant change in air temperature is added or subtracted from each value in the full record. The assumption is that changes in air temperature will be constant throughout the year, either increasing or decreasing by a specified amount, expressed in degrees.

Example of a relevant analysis: Evaluate the impact of a uniform 2°C increase in air temperature on watershed endpoints; account for effects of temperature change on potential evapotranspiration.

Adding or subtracting a constant value from historical values in each year of the full record is the simplest (and coarsest) method of modifying air temperature. This adjustment can be performed in a stand-alone manner, or as one component of a more complex scenario including additional adjustments. As a stand-alone adjustment, application of a uniform increment or decrement might be performed when more detailed information about seasonal or year-to-year variability of air temperature is not available. As part of a more complex scenario, other types of change can be superimposed on a uniform change. For example, one might create an air temperature change scenario by first applying a uniform increase to the entire period of record, and then applying an additional, second adjustment only during the winter months of each year of the record.

After making a seasonal adjustment to an air temperature record, users must instruct BASINS CAT to regenerate potential evapotranspiration.

**3.3.1.2.2. Add or subtract a constant to a specified season and regenerate evapotranspiration.**

A constant change in air temperature is added or subtracted from values within a user-specified season each year of the full record. The assumption is that air temperature changes will vary seasonally within each year of the full record, with the specified change occurring during a certain month or season and not during other times of the year.

Example of a relevant analysis: Evaluate the impact on watershed endpoints of a uniform 2°C increase in air temperature during the cool months (November through April) and a uniform 4°C increase during the warm months (May through October); account for effects of temperature change on potential evapotranspiration.

BASINS CAT enables the modification of temperature (and computed potential evapotranspiration) values only during a specified portion of the year. Future climate change is likely to be variable seasonally throughout the year. A seasonal adjustment to a historical record is made by specifying and adding or subtracting a constant value to all air temperature values that occur within a user-defined season throughout the record. To define a season, BASINS CAT enables the selection of one month or any combination of months.

After making a seasonal adjustment to an air temperature record, users must instruct BASINS CAT to regenerate potential evapotranspiration.

**3.3.1.2.3. *Add or subtract a constant to a partial record and regenerate evapotranspiration.*** A constant change in air temperature is added or subtracted only from values within a user-specified time period (years) within the full record. The assumption is that air temperature changes will vary from year to year within the full record, with the specified change occurring during a certain year or years and not during others.

Example of a relevant analysis: Evaluate the effect that a uniform increase of 3°C has on drought conditions occurring within the driest water year contained within the simulation period; account for effects of temperature change on potential evapotranspiration.

Investigating the impacts of increasing drought severity can, for example, require increasing the air temperature values and re-computing PET values for a single, specified year within a historical record. Using BASINS CAT, a uniform increment or decrement can be applied to air temperature values during a specified portion of the historical air temperature record. The user can define the period that will be adjusted in terms of either calendar years or water years (i.e., October to September).

After making a seasonal adjustment to an air temperature record, users must instruct BASINS CAT to regenerate potential evapotranspiration.

### **3.3.1.3. *Combine Multiple Adjustments to Create a Climate Change Scenario***

Climate change scenarios are created with BASINS CAT by combining one or more temperature and precipitation adjustment to create a composite change scenario. Users first specify the individual temperature and precipitation adjustments of concern. BASINS CAT then allows users to create climate change scenarios comprised of one or more of these individual adjustments. This approach provides great flexibility for creating and running with HSPF climate change scenarios of varying detail and complexity.

Example of a relevant analysis: Evaluate the impact on watershed endpoints that results from combining the following adjustments to the historical records:

1. 20% increase in summer (June through August) precipitation,
2. 2-degree Celsius increase in air temperature during the cool season (November through April), and
3. 4-degree Celsius increase in air temperature during the warm season (May through October).

After specifying individual temperature and precipitation adjustments, the BASINS CAT interface lists each adjustment made by a user. Each adjustment is preceded by a checkbox. The checkbox allows users to select those adjustments to be used as components of a particular climate change scenario (or set of synthetic scenarios). By selecting and unselecting checkboxes, users can create and run complex precipitation and air temperature change scenarios consisting of multiple adjustments.

#### **3.3.1.4. *Creating Spatially Variable Climate Change Scenarios at Multiple Locations***

Previous sections in this chapter discuss the capabilities of BASINS CAT for adjusting historical time series data to create climate change scenarios. Most HSPF models receive meteorological input from multiple locations, typically NCDC weather stations, within a watershed. Running an assessment using BASINS CAT thus requires that change scenarios be created for meteorological data for multiple locations within a watershed. BASINS CAT provides the option to apply specified adjustment(s) to multiple meteorological data sets simultaneously, e.g., temperature time series data from multiple weather stations (see Tutorial 5.1.1.1). This simple approach is justified in many cases due to limited knowledge of future climate change at fine spatial scales. In certain cases, however, users may wish to create scenarios reflecting spatially variable climate change at different watershed locations. This is a particular concern in large or topographically complex watersheds. BASINS CAT can be used to create spatially variable climate change scenarios for different locations within a watershed by individually selecting and adjusting historical temperature and precipitation time series data sets from each location (see Tutorial 5.1.4).

Example of a relevant analysis: An HSPF model is set up to receive input from two NCDC weather stations. Create climate change scenarios representing a 10% annual increase in precipitation at one weather station, and a 15% annual increase at the second weather station.

To individually adjust time series data from multiple locations (NCDC weather stations), each data set must be selected and adjusted as a separate step. After specifying adjustments to each data set, the BASINS CAT interface will list each adjustment preceded by a checkbox. By selecting and unselecting the appropriate checkboxes, users can create and run spatially variable precipitation and air temperature change scenarios for each weather station used in an HSPF simulation.

#### **3.3.1.5. *Create Synthetic Climate Change Scenarios***

Synthetic scenarios describe techniques where particular climatic attributes are changed by a realistic but arbitrary amount, often according to a qualitative interpretation of climate

model simulations, historical variability, or other available information for a region (IPCC-TGICA, 2007). Application of this approach involves selecting the range of values and step interval for one or more climate variable(s), and then creating and running scenarios based on each possible combination of arbitrarily assigned changes.

Example of a relevant analysis: Assess the sensitivity of watershed endpoints by creating and running multiple scenarios in which precipitation and temperature are adjusted in increments over a range and every possible pair of changes is simulated, e.g., changes in historical air temperature of 1, 2, and 3 degrees C, and changes in historical precipitation of 10, 20, and 30%; account for the effects of temperature change on potential evapotranspiration.

BASINS CAT provides an explicit capability for conducting analyses using synthetic scenarios. Users must specify at least one climate variable of interest, and for each variable, specify the total range of change and step interval of values to be used within this range (e.g., evaluate changes in annual precipitation ranging from 10 to 50%, at a step interval of 10%). BASINS CAT then automates the iterative creation of multiple scenarios, manages the input to HSPF, and manages model output including the creation of tabular summaries. Any adjustment that can be made using the single-run adjustment capabilities of BASINS CAT can also be performed within a series of synthetic runs.

As stated previously, it is important to note that when synthetic scenarios include adjustments to air temperatures, users must instruct BASINS CAT to regenerate potential evapotranspiration.

#### **3.3.1.6. *Exporting BASINS CAT Climate Change Scenarios as Text (ASCII) Files***

BASINS CAT seamlessly links capabilities for modifying historical weather data to create climate change scenarios with the HSPF watershed model. It is possible, however, that some users may wish to create climate change scenarios using BASINS CAT for use with models other than HSPF and/or outside of the BASINS system. To provide this functionality, BASINS CAT offers two options for exporting climate change scenarios as ASCII text files:

1. In cases where a single adjustment is made to a precipitation or an air temperature record, the resulting record can be exported as an ASCII file independent of running the HSPF model.
2. In cases where multiple adjustments are made to a precipitation or an air temperature record, it is necessary to complete an HSPF model run for one or more hydrologic or water quality endpoints. After this has been accomplished, BASINS CAT enables the export of either or both of the precipitation and air temperature records that resulted from

the multiple adjustments performed in defining the climate change scenario; again the export is performed in the form of ASCII files.

### **3.3.2. Tools for Assessing Hydrologic and Water Quality Endpoints**

EPA's Guidelines for Ecological Risk Assessment define an assessment endpoint as an explicit expression of an environmental value that is to be protected (U.S. EPA, 1998). More generally, any ecological attribute of relevance or concern to those conducting an assessment can be considered an endpoint.

Standard HSPF output files from a simulation using BASINS CAT can be saved for later analysis. BASINS CAT also provides, however, a post-processing capability for calculating different hydrologic and water quality endpoints based on model output time series data. This capability is intended to support assessments of climate change impacts on specific metrics or management targets used by managers.

This section describes the capabilities of BASINS CAT for calculating assessment endpoints. The tutorials in Chapter 5 provide specific instructions about how to specify hydrologic and water quality endpoints using the BASINS CAT interface.

#### **3.3.2.1. *Endpoint Options***

BASINS CAT users can specify one or more hydrologic or water quality endpoints to be calculated by selecting appropriate HSPF output time series data, and specifying the attributes of that time series to be calculated (e.g., mean, min, max, 100-yr flood, 7Q10). The options for calculating endpoints are determined by the output from an HSPF simulation, or more specifically, the time series specified as output in the HSPF User Control Input file (UCI file). Endpoint options can be as simple as a few outputs to .WDM data sets in the External Targets block, or can be greatly expanded by using the binary output file.

After selecting an HSPF output time series for calculating an endpoint, the different attributes of the time series that can be calculated are listed in a drop down menu:

- Min
- Max
- Sum
- Average annual sum of values
- Mean
- Geometric Mean
- Variance

- Standard Deviation
- Standard Error of Skew
- Serial Correlation Coefficient
- Coefficient of Variation
- 7Q10 low-flow event
- 100-year flood event (based on log Pearson III method)

### **3.3.2.2. *Specify Value Ranges of Concern***

In certain cases, the value of an endpoint relative to some critical range or threshold value is of interest. Examples include a low flow threshold at which a fish species is subject to harm or numeric state water quality standards for chemical endpoints. BASINS CAT provides an option to visually flag endpoint values in the Results table using one of two different schemes; a 3-tiered, low/favorable/high range color scheme, or a 2-tiered favorable versus unfavorable range color scheme. When viewing results in the Results table, blue coloring is used to denote cells falling below the favorable range, no shading denotes cells falling within the favorable range, and red denotes cells greater than the favorable range. The threshold values and ranges used to determine the rating are set by the user.

### **3.3.2.3. *Specify Time Periods of Concern (Seasonal and/or Partial Records)***

In certain cases, the value of an endpoint during only a particular season of each year, or during a specific year (or water year) within the record, is of interest. BASINS CAT provides an option to visually flag endpoint values in the Results table occurring within a specified period of concern. The time period of concern is set by the user.

### **3.3.3. Running an HSPF Simulation Using BASINS CAT**

Watershed simulations using HSPF can be managed from within the BASINS CAT interface after creating and selecting the climate change scenarios to be considered, and specifying the endpoints to be calculated. The tutorials in Chapter 5 provide specific examples of how to run a simulation using the BASINS CAT interface.

### **3.3.4. Tools for Summarizing and Visualizing Results**

After running an assessment, BASINS CAT users can choose to either export simulation results for analysis or visualization using external software (e.g., MS Excel), or use existing tools within the BASINS system to create expanded summaries and visualization. This section describes additional tools within BASINS for displaying and analyzing the results of HSPF

simulations that may be useful to BASINS CAT users. All HSPF simulation results generated using BASINS CAT can also be exported as ASCII text files for use with other analysis and visualization software.

The information provided in this section is limited to describing approaches and capabilities for summarizing and visualizing results. Chapter 5 provides a set of tutorials that provide specific examples of how to display results.

#### **3.3.4.1. *Results Tables***

Results tables are the most straightforward method for reporting the results of HSPF simulations conducted with BASINS CAT, including calculated endpoint values. The Results table contains values for each endpoint selected by the user (i.e., for each attribute [e.g., mean, min] of each HSPF output variable [e.g., streamflow, sediment load] selected as an endpoint).

#### **3.3.4.2. *Pivot Tables***

In addition to the Results table, BASINS CAT also provides a capability for visualizing and analyzing results of HSPF simulations using a pivot table. A pivot table is a powerful data visualization and analysis tool available in several commercial spreadsheet software programs (e.g., Microsoft Excel, OpenOffice.org). A pivot table can be used to quickly and easily assess relationships among multiple variables. The user sets up and changes the appearance of a pivot table by selecting a variable of concern and variables to use as x and y axes of the pivot table. Values of the variable of concern at each x and y coordinate location are then shown as a function of the coordinates. A pivot table is similar in concept to a contour plot (x and y axes are the same) but expresses its information in the form of tabular numbers rather than graphical contour lines.

#### **3.3.4.3. *Additional BASINS Tools for Summarizing and Visualizing Results***

In addition to the capabilities built directly into BASINS CAT, it is possible to apply other powerful tools available within the BASINS system to summarize and visualize results. HSPF output time series data from a BASINS CAT application can be displayed and analyzed using any of the following BASINS capabilities:

- Graph a time series or multiple time series.
- Display attributes and calculated statistics in the form of a data tree (a method of displaying attributes and data in logical groups that can be collapsed or expanded with the "+" and "-" boxes built into the tree).

- Compute frequency statistics such for specified n-day values and recurrence intervals.
- Calculate and display statistics for user-defined seasons or time periods.
- Generate one time series from one or multiple other time series such as performing unit conversions or mathematical operations (e.g., adding a number of time series).

Specific examples of how to take advantage of these capabilities using other tools within BASINS are provided in Chapter 5.

### **3.3.5. Using Scripts to Automate BASINS CAT Applications**

Scripts provide an efficient and reproducible method for performing repetitive tasks. Scripts can be used to perform all facets of a BASINS CAT application. Both BASINS and MapWindow, the GIS framework upon which BASINS is built, are open-source software products. Both programs and their source code can be downloaded free of charge and run-time licenses are not required. The software architecture of the programs has also been designed to readily allow end users to extend the programs through the use of scripts. MapWindow and BASINS have both been developed in the .Net framework. Any script developed in the .Net language can be run from BASINS.

## **4. OVERVIEW OF BASINS CAT**

BASINS CAT integrates tools into the BASINS system allowing users to create climate change scenarios by modifying historical weather data and to use these data as the meteorological inputs to the HSPF watershed model. A capability is also provided to calculate specific hydrologic and water quality endpoints important to watershed management based on HSPF model output (e.g., the 100-year flood or 7Q10 low-flow event). Finally, BASINS CAT can be used to assess the outcomes of a single climate change scenario, or to automate multiple HSPF runs to determine the sensitivity or general pattern of watershed response to different types and amounts of climate change.

Users can modify historical climate data using standard arithmetic operators applied monthly, seasonally, or over any other increment of time. Increases or decreases in a climate variable (precipitation, air temperature) can be applied uniformly, or they can be selectively applied to only those historical events that exceed (or fall below) a specified magnitude. This capability allows changes to be applied only to events within user-defined size classes, and can be used to represent the projected effects of intensification of the hydrologic cycle, whereby a greater proportion of rainfall occurs as heavy precipitation events. In addition, users are able to create time series that contain more frequent precipitation events. These capabilities provide users with an ability to represent and assess the impacts of a wide range of potential future climatic conditions and events.

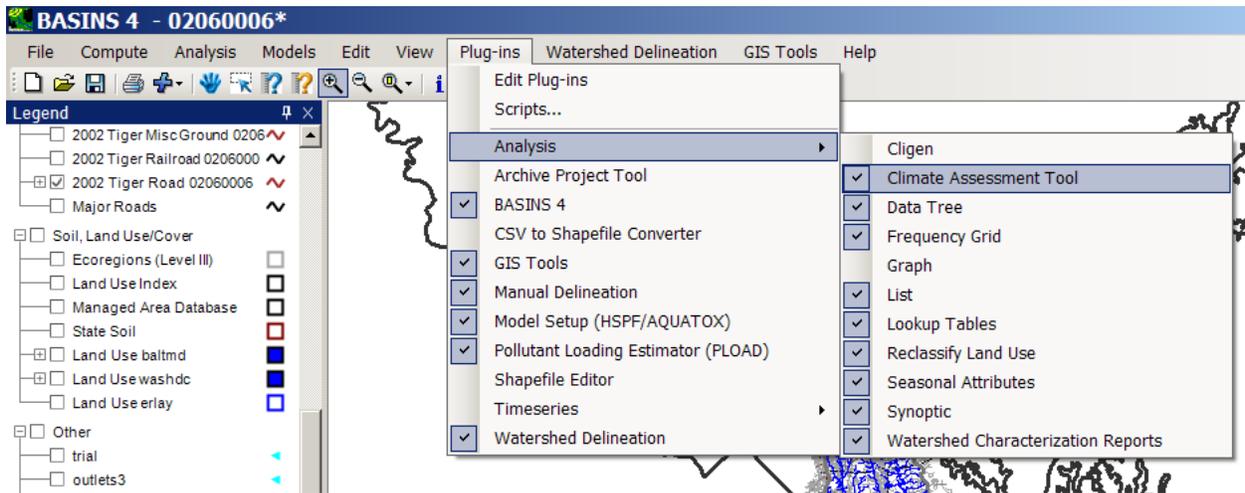
BASINS CAT does not provide climate change scenario data. Rather, the tool provides a capability for quickly creating and running climate change scenarios within the BASINS system. Diverse sources of information such as records of historical and paleo-extreme events, observed trends, and projections based on global or regional scale climate models can be used to guide scenario development. Data requirements will vary depending on assessment goals. BASINS CAT provides capabilities to support a range of assessment goals, e.g., simple screening analysis, systematic sensitivity analysis, or implementing more detailed scenarios based on climate model projections. A variety of other resources are available to provide users with general help and information concerning climate change, scenario development, and climate change impact assessment (See Chapter 7, Supporting Resources).

### **4.1. COMPONENTS OF BASINS CAT INTERFACE**

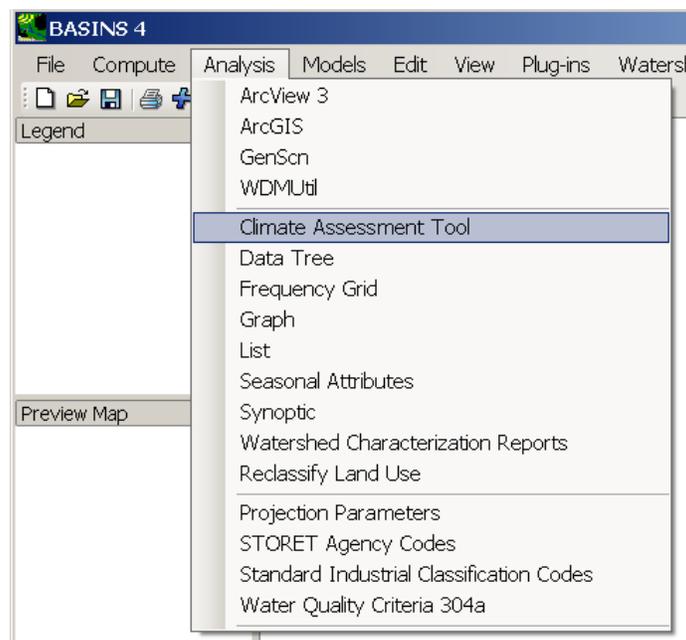
This section provides an overview of the key components of the BASINS CAT interface. It is presented in the format of a tour, and is intended only as a descriptive introduction to the interface. Detailed tutorials describing how to conduct specific tasks using the BASINS CAT interface are presented in Chapter 5. Running BASINS CAT requires that BASINS version 4 be

downloaded and installed to a user's local computer. BASINS 4 can be downloaded from the EPA's BASINS web page (<http://www.epa.gov/waterscience/BASINS/>). Instructions for installation are provided with the download.

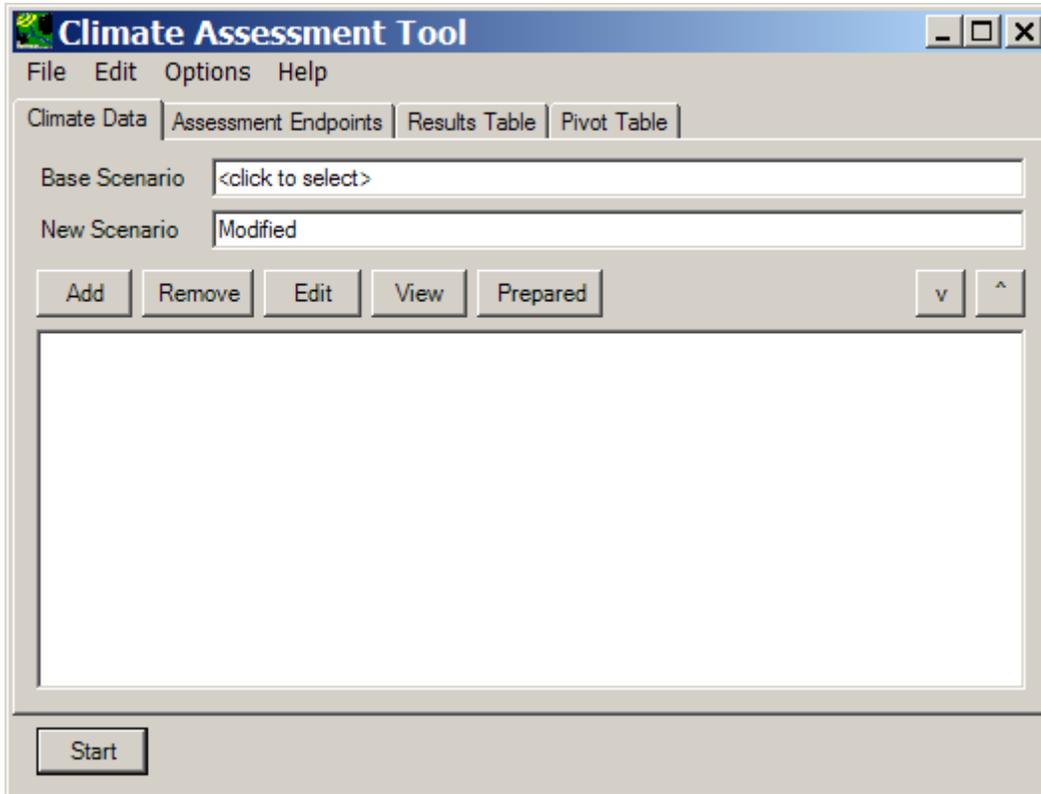
From the BASINS main form, activate BASINS CAT by selecting Climate Assessment Tool from the **Plug-ins:Analysis** menu.



Once activated, the BASINS CAT main form is opened by first clicking **Analysis** on the BASINS menu bar, then **Climate Assessment Tool** on the submenu (or typing **ALT-AC**).



The main BASINS CAT form opens. It contains a menu bar, four tabs, and the **Start** button.



### *Menu Options*

On the **Climate Assessment Tool** menu, the **File** menu option includes choices to **Open an HSPF UCI file**, **Load or Save Climate and Endpoints**, **Load or Save Results**, or to **Save Pivot Table**.

The **Edit** menu option includes choices to **Copy Results** (to copy the results table) or **Copy Pivot** (to copy the pivot table). Both options allow information to be pasted into another document such as MS Word or Excel. Finally, the **Paste Results** option allows the user to paste old results (from another document) into BASINS CAT to view them in the table format, if desired.

Under the **Options** menu, the user can choose whether to copy data only or copy data and table headings.

### ***Tabs***

The **Climate Data** tab allows the user to create climate change scenarios by selecting existing weather time series to be modified and implementing one or more changes or adjustments. The **Assessment Endpoints** tab allows the user to specify the hydrologic and water quality endpoints to be calculated from model output time series data. The **Results Table** and **Pivot Table** tabs are for viewing model output including hydrologic and water quality endpoints computed by the model.

### ***Start Button***

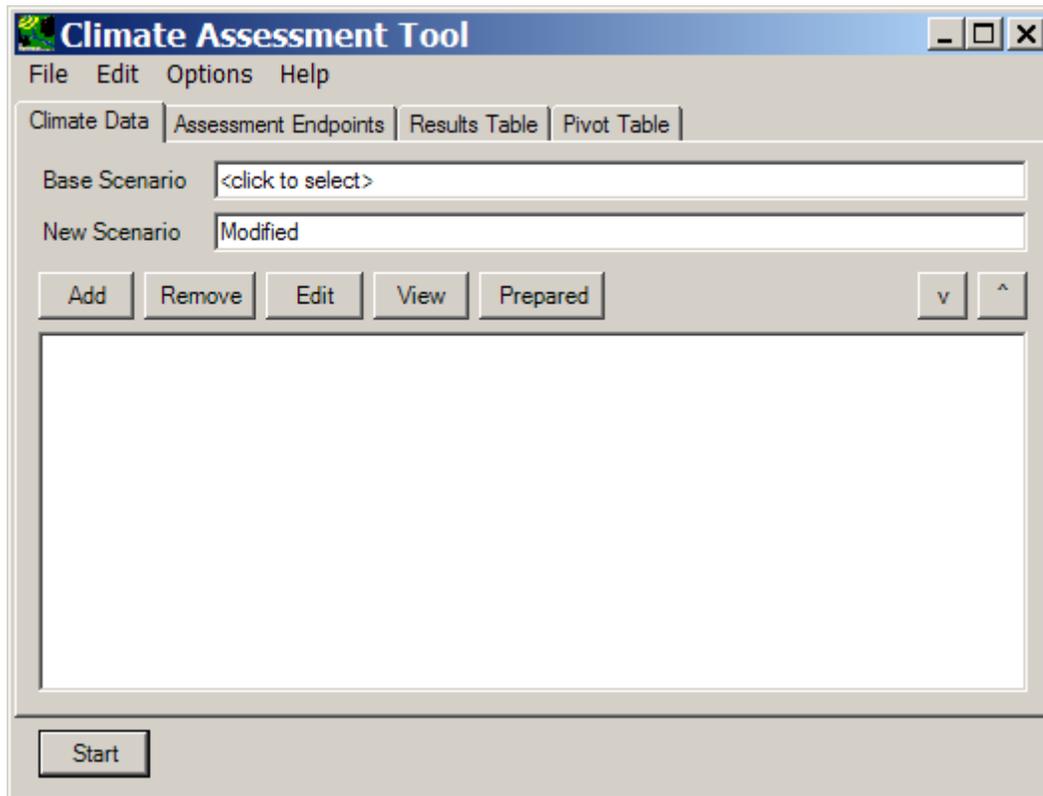
At least one climate scenario and one assessment endpoint are necessary to run the **Climate Assessment Tool**. After selecting all climate data and desired endpoints, press the **Start** button at the bottom of the main BASINS CAT form.

### ***Total Iterations Selected***

Once the desired record adjustments have been specified, the **Total Iterations Selected** shown at the bottom of the form indicates the number of HSPF runs to complete the task. This number can range from 1, when running a single scenario, to greater than 1, when automating multiple runs using synthetic climate change scenarios to determine sensitivity to a range of different record adjustments.

The Climate Assessment Tool makes a separate HSPF run for each distinct combination of input data specified by the user. After the model runs, the calculated endpoint values for each run are displayed so that the user can analyze the impacts of varying input data. Optionally, the user can save the model output to an external file for further analysis.

#### 4.1.1. Climate Data



The **Climate Data** tab is the main form for managing changes to input time series data (i.e., weather data). Users can create climate change scenarios by selecting an existing input time series to be modified and implementing one or more changes (record adjustments) to create a new scenario(s).

The **Base Scenario** field contains the HSPF model User Control Input (UCI) file. When the model is run, a modified UCI file is created, using the name in the **New Scenario** field as the base portion of the file name.

##### ***Add Button***

Clicking the **Add** button will display the **Modify Existing Data** form. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The screen shown below exhibits all features of the form.

**Modify Existing Data**

Modification Name: Storm Frequency

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP # 105

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Storm Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events

Hourly intensity above: 0.1 in/hr

Allow gaps up to: 0 hours

Total volume above: 0 inches

Total duration above: 0 hours

Seasons

Vary only in selected: Months

Jan	Jun	Nov
Feb	Jul	Dec
Mar	Aug	
Apr	Sep	
May	Oct	

The **Modification Name** field is used to provide a text label for identifying the scenario being created. The **Existing Data to Modify** field is used to select the historical data to which the adjustment will be made. When modifying temperature data, the **Compute PET** field is used to select the potential evapotranspiration data set that will be re-computed using the new, modified temperature data as input to Hamon’s PET estimation method. The **How to Modify** field is a pull-down list of options for how the data are to be adjusted. The options include:

- Changing the temperature
- Multiplying existing values by a number
- Adding/Removing storm events
- Adding/Removing volume in extreme events

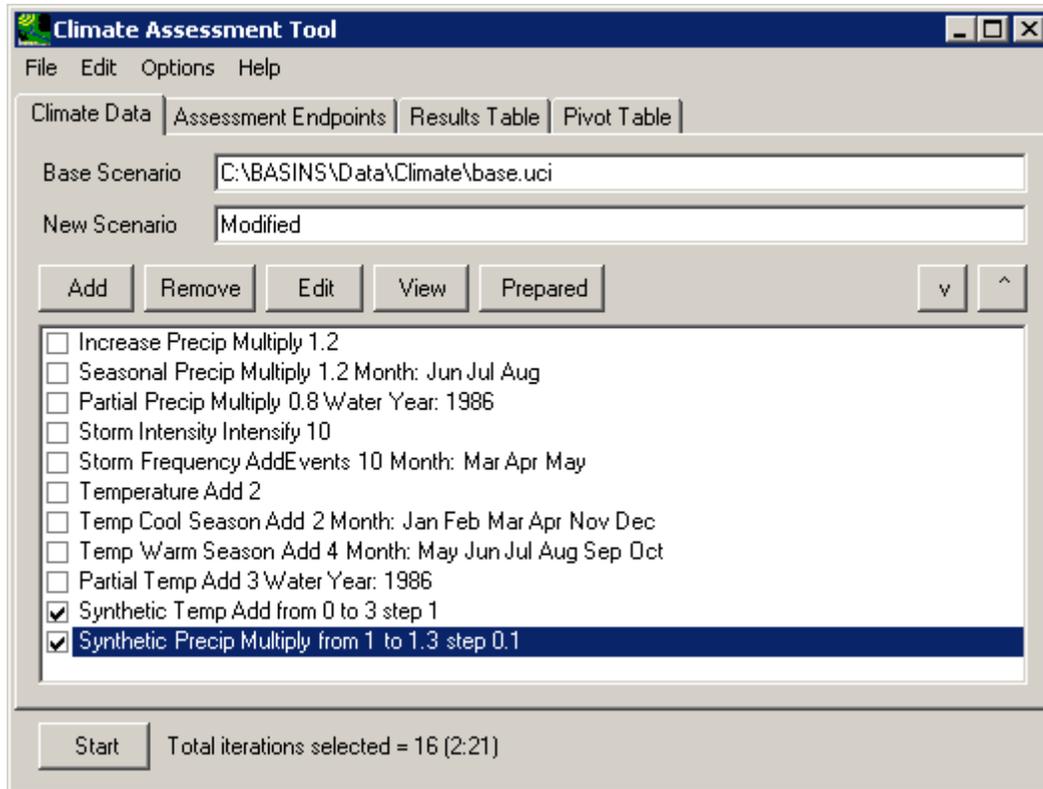
Depending on the option selected, the frame below the **How to Modify** field is updated to input the quantity of the change (e.g., +/- air temperature degrees, % change in precipitation depth). In this frame, there are two modification options: **Single Change** or **Iterate Changes**. The term “iterate,” as used here, refers to the automation of multiple runs in an iterative way. The **Single Change** option will result in one adjustment applied to the data set being modified. The **Iterate Changes** option will result in a range of adjustments to the data set and is used to create synthetic climate change scenarios. To create and run synthetic scenarios, users specify the desired type of change, the range of values to be considered, and the step interval between successive trials. For example, a user can specify an increase in average annual temperature from 0 to 3 degrees at a step interval of 1 degree (units dependent on original data set). BASINS CAT would then automate the creation and processing of four input time series (i.e., reflecting average annual temperature increases of 0, 1, 2, and 3 degrees) for input as distinct model runs. When 2 or more sets of synthetic scenarios are specified, BASINS CAT will systematically create scenarios and assess each possible combination of specified values. For example, if the above temperature change were specified together with changes in annual precipitation from 0 to 30% with a step interval of 10% (i.e., changes of 0, 10, 20, and 30%), BASINS CAT would automate the creation and processing of  $4 \times 4 = 16$  climate change scenarios reflecting each possible combination of values.

The **Events** frame is used to define what precipitation events are considered to be storms when either Adding/Removing storm events or Adding/Removing volume in extreme events. When the **Vary precipitation only in the following Events** checkbox is selected, a set of four elements are made visible for defining storms. The **Hourly intensity above** field specifies the minimum hourly precipitation value (or series of values) that is considered to be an event. The **Allow gaps up to** field defines the number of hours allowed between two sets of storm events to consider them all one event. The **Total volume above** field specifies the minimum amount of total volume in an overall event for the event to be considered a storm. The **Total duration above** field defines the minimum number of hours of consecutive storm values for the values to be considered a storm. When Adding/Removing volume in extreme events, an additional field, **Change ... % of events**, is provided in the frame to specify the percentage of events to change. Leaving this field blank will result in the specified volume change being applied to all qualifying

events. Entering a percentage value will result in the volume change being applied to the highest storms that total that percentage of the data set's volume.

The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. To specify a season, click on the **Vary only in selected** check box and two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items.

As new record adjustments are created, they are added to the text box on the **Climate Data** tab. Each new scenario can be composed of multiple record adjustments to an input time series. By combining multiple adjustments, a wide range of climate change scenarios of varying complexity can be created. After adding an adjustment, it will appear as a line item in the text box below. Checking the box will apply the change to the input series when running BASINS CAT. Unchecking the box will cause the change to be ignored when running BASINS CAT. When multiple changes are applied to an input data set, the changes are implemented in the order they are listed in the text box. This order can be modified through use of the up and down arrows above the list. As individual record adjustments are checked and unchecked, the total number of climate change scenarios is computed. This number is displayed as the **Total iterations selected** at the bottom of the form next to the **Start** button.



### ***Remove Button***

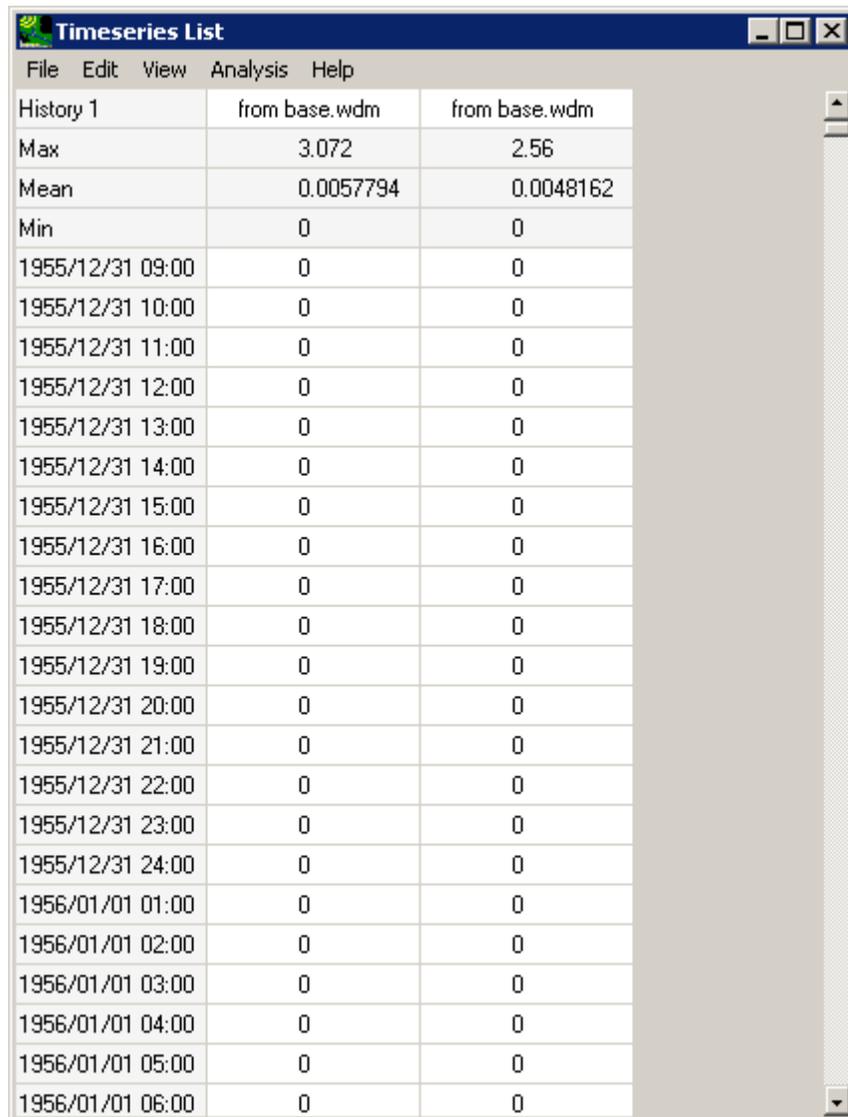
The **Remove** button is used to delete an item from the list of record adjustments. The item to be deleted must first be selected before clicking the **Remove** button.

### ***Edit Button***

The **Edit** button is used to modify an existing record adjustment. The desired adjustment must be selected before clicking the **Edit** button.

### **View Button**

After creating an adjustment, the **View** can be used to see the actual modified data values in tabular form. The **Time series List** form will be displayed. The contents and layout of the listing can be modified through options in the **File**, **Edit**, and **View** menus. A key feature of the time series listing is the ability to export the modified values to an external file for use outside of BASINS CAT. The **File:Save** option will save the listed data values to a tab-separated file.

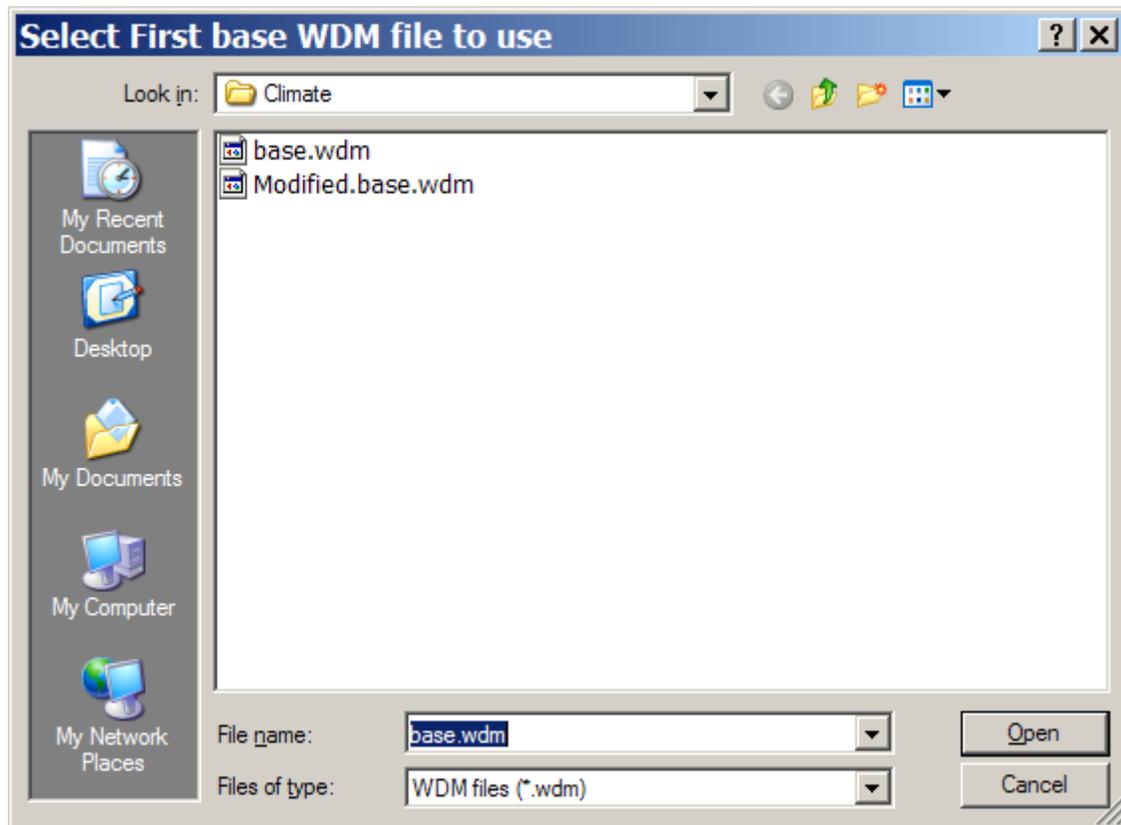


The screenshot shows a window titled "Timeseries List" with a menu bar containing "File", "Edit", "View", "Analysis", and "Help". The main area contains a table with the following data:

History 1	from base.wdm	from base.wdm
Max	3.072	2.56
Mean	0.0057794	0.0048162
Min	0	0
1955/12/31 09:00	0	0
1955/12/31 10:00	0	0
1955/12/31 11:00	0	0
1955/12/31 12:00	0	0
1955/12/31 13:00	0	0
1955/12/31 14:00	0	0
1955/12/31 15:00	0	0
1955/12/31 16:00	0	0
1955/12/31 17:00	0	0
1955/12/31 18:00	0	0
1955/12/31 19:00	0	0
1955/12/31 20:00	0	0
1955/12/31 21:00	0	0
1955/12/31 22:00	0	0
1955/12/31 23:00	0	0
1955/12/31 24:00	0	0
1956/01/01 01:00	0	0
1956/01/01 02:00	0	0
1956/01/01 03:00	0	0
1956/01/01 04:00	0	0
1956/01/01 05:00	0	0
1956/01/01 06:00	0	0

### ***Prepared Button***

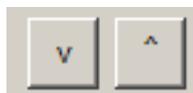
The **Prepared** button allows the user to import scenarios that have been prepared external to BASINS CAT. These prepared inputs must be .WDM files using appropriate HSPF input formats. After selecting **Prepared**, the user will be prompted to **Select First base WDM file to use**.



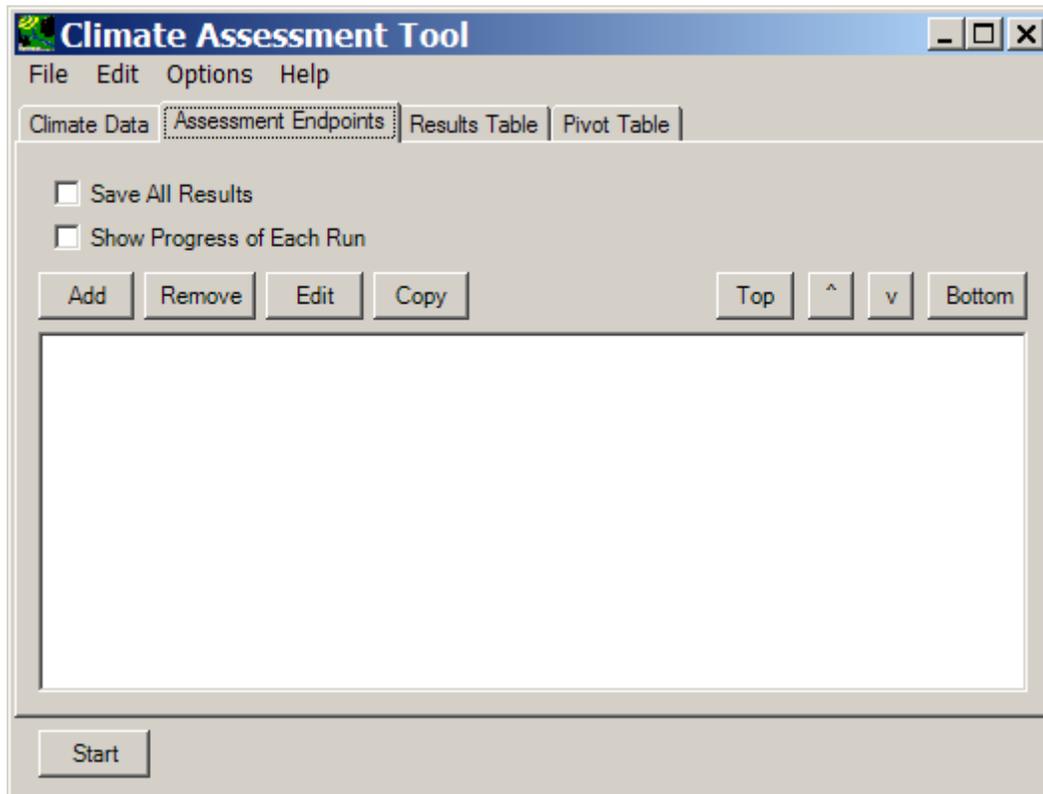
The user should create parallel folders containing the Prepared .WDM files, and choose the **First base .WDM file** when prompted. Note that Prepared inputs cannot be edited in BASINS CAT. While running the model using prepared data, no other (non-prepared) inputs can be used. The user must still select **Endpoints** as usual.

### ***Arrow Buttons***

The arrows on the right side of the form are used to move the list of inputs up and down for organization.



### 4.1.2. Assessment Endpoints



EPA's Guidelines to Ecological Risk Assessment define an assessment endpoint as an explicit expression of an environmental value that is to be protected (U.S. EPA, 1998). More generally, any ecological attribute of relevance or concern to those conducting an assessment can be considered an endpoint. Examples include a particular duration-frequency flow event (e.g., the 100-year flood, 7Q10 low-flow event), the annual water yield from a watershed, or the annual nutrient loading to a stream.

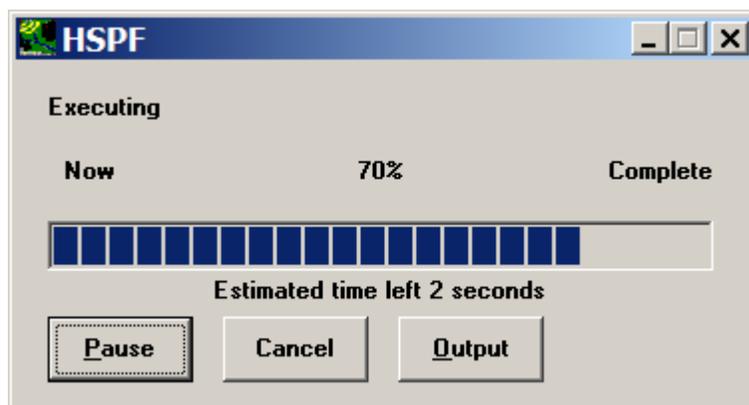
BASINS CAT provides a flexible capability to calculate and display assessment endpoints based on model output time series data. Endpoints are calculated as a post-processing step using output time series data. This capability allows users to quickly generate data for assessing the influence of climate change on hydrologic and water quality endpoints of concern to managers.

The **Assessment Endpoints** tab contains a list of the Endpoints which the user has created. To run the model, at least one climate scenario and one endpoint are necessary.

### ***Check Boxes***

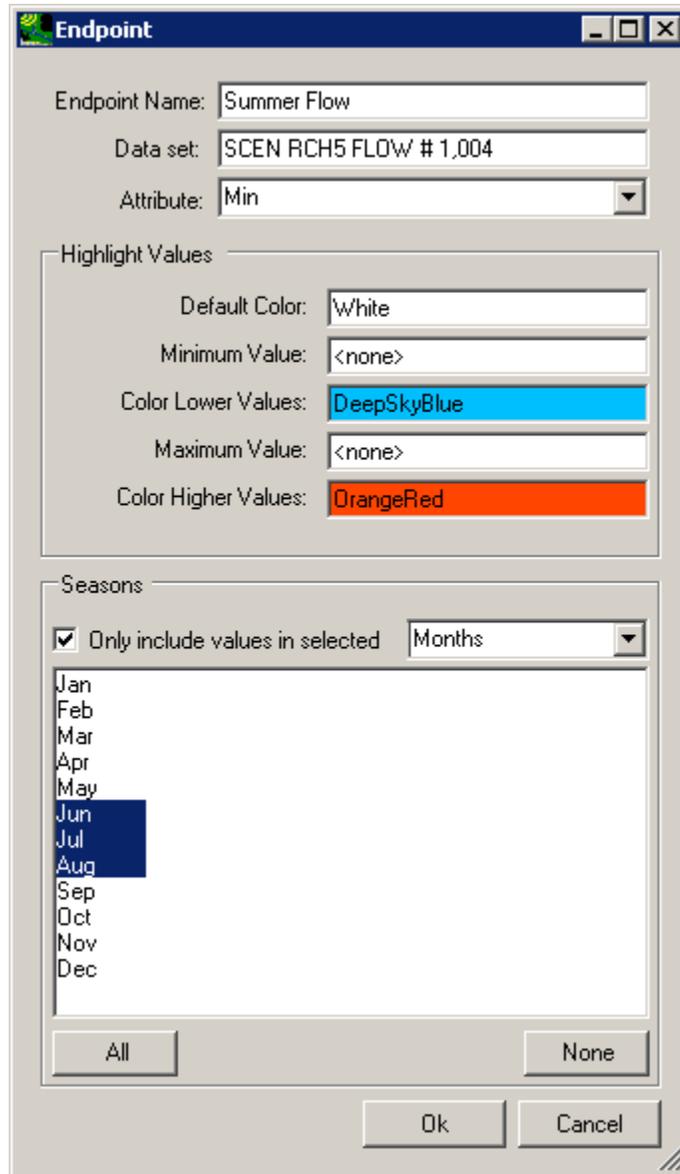
At the top of the tab form, there are two checkboxes for options when the model is run. The user can choose to:

- Save all results - a new set of model inputs and outputs will be saved for each model run, using the text entered in the **New Scenario** field on the **Climate Data** tab as the base name for the new files. Index numbers will be added to file names when multiple scenarios are saved.
- Show progress of each run - the model shows a form (shown below) depicting the progress of each run. This is useful when a particularly long model is being run or a significant number of model runs is to be performed.



### ***Add Button***

Clicking the **Add** button on the **Assessment Endpoints** tab of the BASINS CAT form will display the **Endpoint** form. This form contains the controls needed to define an assessment endpoint, including the endpoint name, the data set to be analyzed, the attribute of the data set to be reported, value ranges of concern, and time periods of concern. The screen shown below exhibits all features of the form.



The **Endpoint Name** field is used to provide a text label for identifying the assessment endpoint being created. The **Data set** field is used to select the model output time series data from which to calculate the endpoint. The **Attribute** pull-down list contains the attributes available for selection as assessment endpoints. BASINS CAT provides a wide array of attributes, from standard statistics (e.g., mean, sum, standard deviation) to duration-frequency statistics (e.g., 7Q10, 100-year flood).

The **Highlight Values** frame allows for endpoint values of concern to be specified. A minimum and maximum range can be specified along with color codes to identify the ranges. Endpoint results within the specified range will be displayed in cells with the **Default Color**

background. Results below the **Minimum Value** will be displayed with the **Color Lower Values** background. Results above the **Maximum Value** will be displayed with the **Color Higher Values** background. Colors for all three ranges can be updated by clicking in the **color** fields.

The **Seasons** frame near the bottom of the form is used for specifying a time subset to be used when computing the endpoint value. To specify a season, click on the **Only include values in selected** check box and two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. For this example, select the **Months** option and the second field will be populated with the months of the year. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items.

As new endpoints are defined, they are added to the text box on the **Assessment Endpoints** tab. Endpoints in this box can be manipulated further through other buttons on this tab.

### ***Remove Button***

Click on an endpoint to select it, and then click the **Remove** button to delete the endpoint.

### ***Edit Button***

Select an endpoint and click the **Edit** button to open the main **Endpoint** form to modify the endpoint.

### ***Copy Button***

If users would like to use a similar endpoint but make a small change (e.g., change which months are selected), click the **Copy** button to create a new, identical endpoint that can be edited more easily than starting over.

### ***Top and Bottom Buttons***

These buttons are useful for organization. Select an endpoint, and then click the **Top** button to bring the endpoint to the top of the list of endpoints on this tab. Similarly, the **Bottom** button will move a selected endpoint to the bottom of the list.

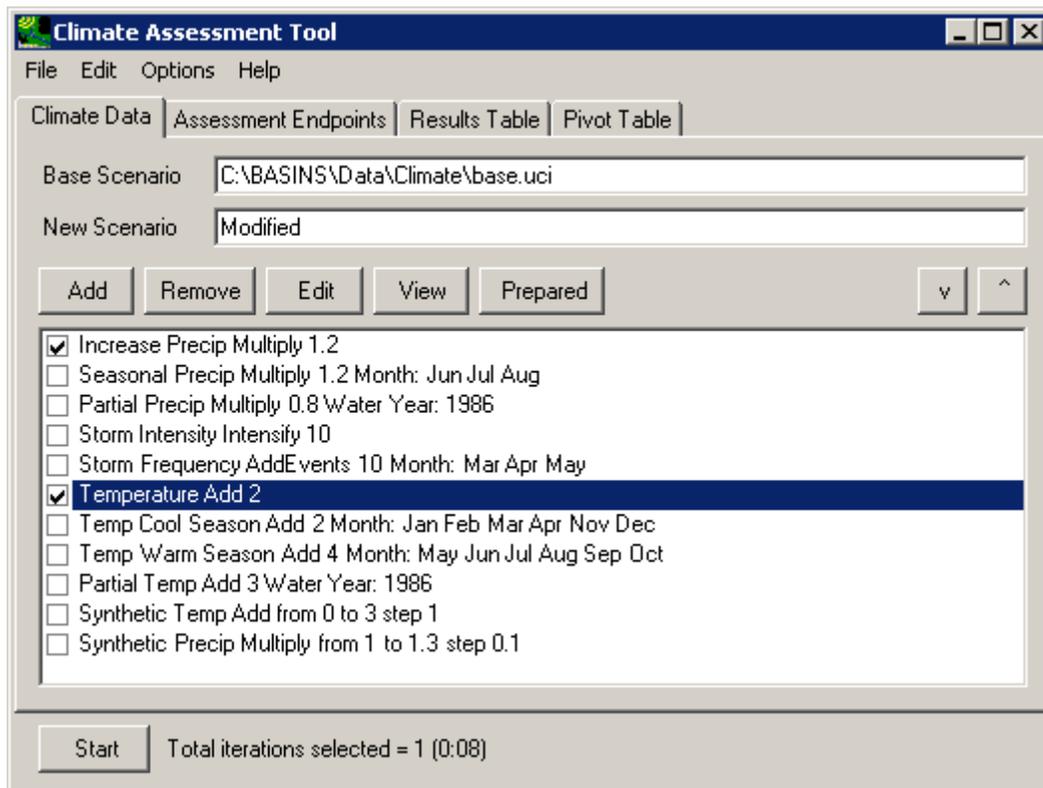
### Arrow Buttons

The **Arrow** buttons on the right side of the form are used to move the list of endpoints up and down for organization.

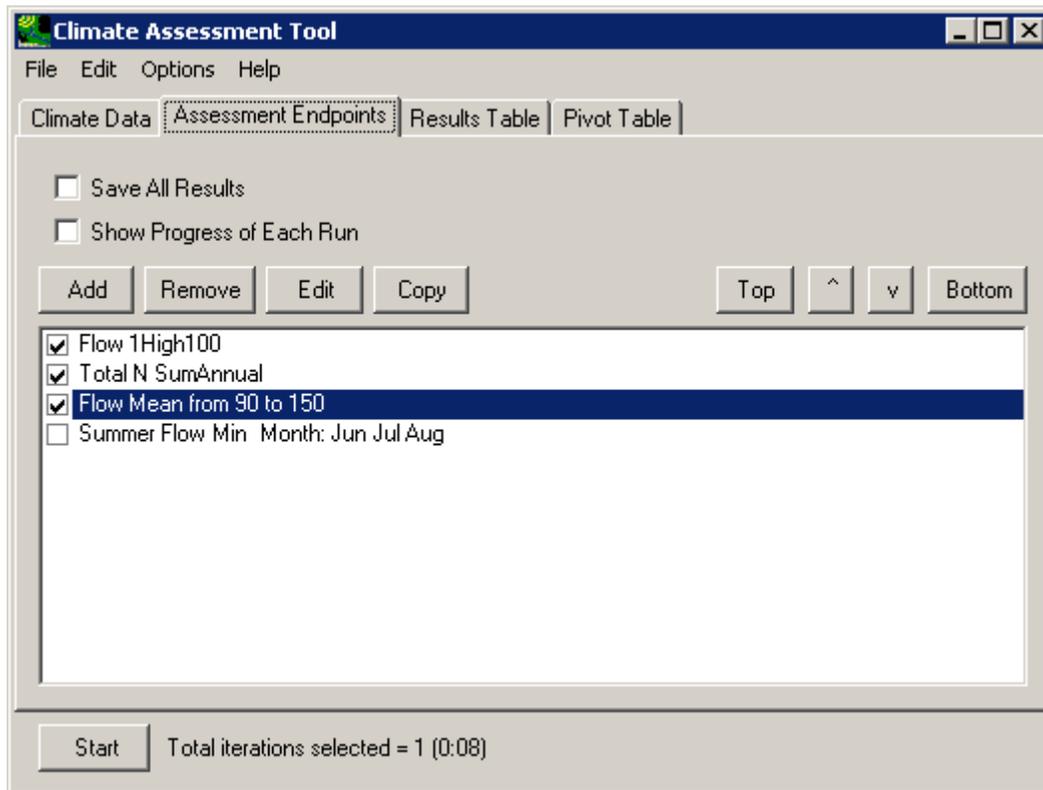


### 4.1.3. Running an Assessment

Before performing an assessment in BASINS CAT, it is necessary to define the climate scenario(s) to be used as input to the model. The Climate Data tab displays a list of the previously defined record adjustments. Each adjustment has a check box for indicating whether or not it is to be included as a component of the climate scenario being developed. The order of adjustments can be controlled by selecting an adjustment and using the up and down arrow buttons above the list. This is particularly important when multiple adjustments are being made to the same values in an input data set (e.g., increasing an entire precipitation record and also increasing a season's storm intensity). When synthetic climate change scenarios are selected for an assessment, multiple scenarios are automatically generated, resulting in multiple model runs. The Total iterations selected label at the bottom of the BASINS CAT form shows the number of model runs based on the selected adjustments (along with an estimate of time required).



The other step required before performing an assessment is selecting hydrologic or water quality endpoints of interest. Any number of endpoints can be selected from available model output. The **Top**, **Bottom**, and **Up/Down Arrow** buttons are useful for arranging the endpoint values in a desired order on the output results table.



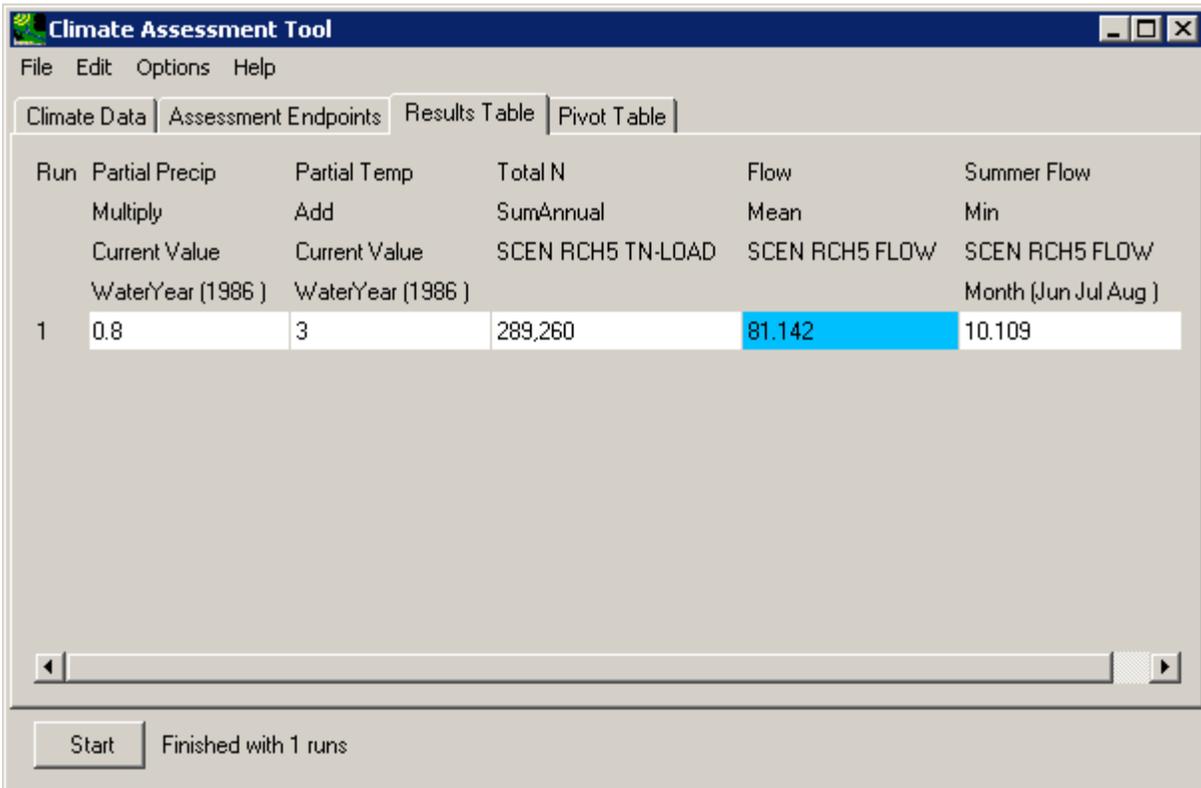
Before model execution, two additional options on the **Assessment Endpoints** tab can be set: **Save All Results** and **Show Progress of Each Run**. The **Save All Results** check box is used to set whether or not all model output is saved, not just the assessment endpoint values. Checking this box will save a new set of output results in the same form as the original model output. The text from the **New Scenario** field on the **Climate Data** tab will be used to build root file names for the new output files. When saving multiple sets of results, this root file name will also have model run number added to it. The **Show Progress of Each Run** check box is used to set whether or not a status monitor will be displayed while the model is running. If a model run is particularly long, or a series of model runs are being made using synthetic data, checking this box can be useful to see the progress of the model run(s).

#### 4.1.4. Viewing Results

BASINS CAT presents results in the form of assessment endpoint values computed from model output time series data. BASINS CAT results can be displayed in both a standard results table and a pivot table. Additionally, it is possible to assess model output results at a greater level of detail through the main BASINS interface.

##### *Results Table*

The **Results Table** tab displays endpoint values computed from model output time series data. If a range of concern was specified for an endpoint and the resulting endpoint value is above or below the specified range, its background color will be set according to the endpoint specification.



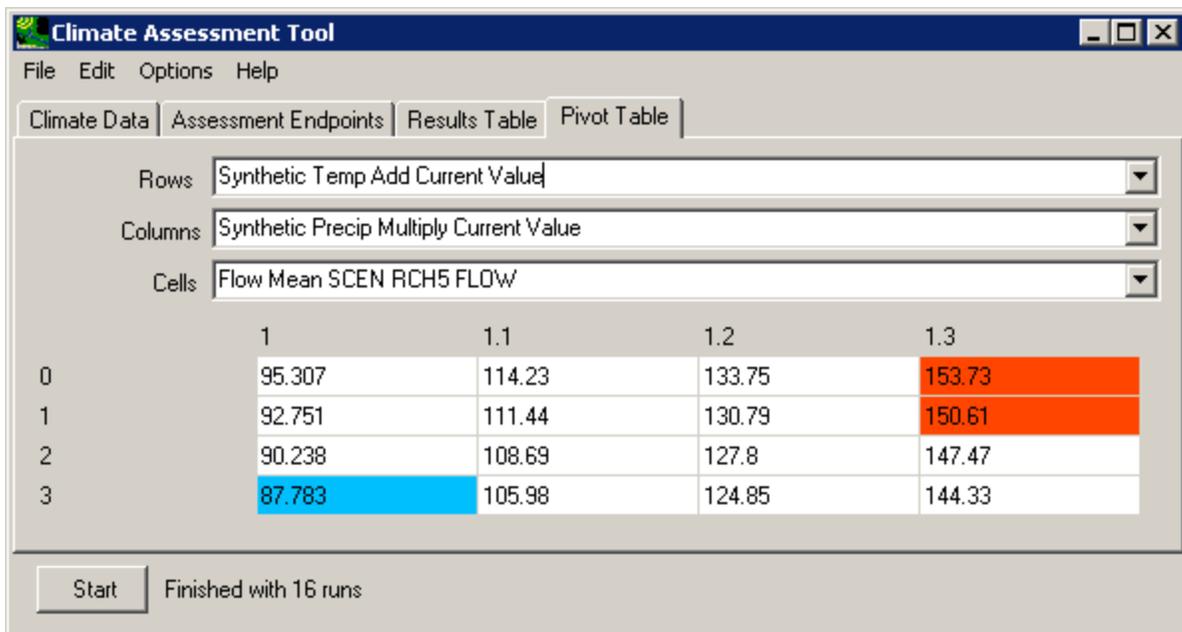
Run	Partial Precip	Partial Temp	Total N	Flow	Summer Flow
	Multiply	Add	SumAnnual	Mean	Min
	Current Value	Current Value	SCEN RCH5 TN-LOAD	SCEN RCH5 FLOW	SCEN RCH5 FLOW
	WaterYear (1986 )	WaterYear (1986 )			Month (Jun Jul Aug )
1	0.8	3	289,260	81.142	10.109

Output tables in BASINS CAT can also be saved to an external file for use outside of the program. The **Save Results** item in the **File** menu will prompt for the file name in which the results are to be saved. Results are saved in a tab-delimited format, suitable for import into Excel and other analysis programs. Additionally, the **Edit:Copy Results** menu option will copy the contents of the results table to the clipboard, making them available for pasting elsewhere.

### ***Pivot Table***

A pivot table is a data visualization and mining tool that allows users to reorganize selected columns and rows of data within a database. The term pivot refers to turning the data to view it from different perspectives. Pivot tables are especially useful for summarizing large amounts of data in a compact format, looking for patterns and relationships within a data set, and organizing data into a format suitable for plotting as a chart.

The **Pivot Table** tab allows users to view model output data (the same data listed in the results table) in a pivot table. The **Rows** and **Columns** fields must be selected from the dropdown lists on this tab. This feature is especially useful when synthetic climate change scenarios are used and the effects of varying climatic changes on a selected endpoint are being investigated. The first two fields of this form are used to specify what element to vary in the **Rows** and **Columns** of the pivot table. The **Cells** field is used to specify what element will be displayed in the pivot table's cells.



As with BASINS CAT's standard **Results Table**, pivot table results can also be saved to an external file. The **File:Save Pivot** option will prompt for the file name in which the pivot table is to be saved. Additionally, the **Edit:Copy Pivot** menu option will copy the contents of the pivot table to the clipboard, making them available for pasting elsewhere.



## 5. TUTORIALS

This chapter provides a set of tutorials illustrating how various tasks are completed using BASINS CAT. Each tutorial is presented as a short demonstration of a specific feature or capability using a sample data set distributed with BASINS 4. Tutorials are presented in an order that approximates how a typical application of BASINS CAT might progress from beginning to end. The organization of tutorials in this chapter is also parallel in structure to the narrative discussion of BASINS CAT capabilities in Section 3.3 of Chapter 3. For example, each option for adjusting precipitation data described in Sections 3.3.1.1.1 through 3.3.1.1.5 has a corresponding tutorial in Chapter 5, Sections 5.1.1 through 5.1.5.

Tutorials in this chapter are organized as follows:

5. BASINS CAT set-up (required tutorial)
  - 5.1 Tools for developing climate change scenarios
  - 5.2 Tools for assessing hydrologic and water quality endpoints
  - 5.3 Running an HSPF simulation using BASINS CAT
  - 5.4 Summarizing and visualizing results

The BASINS CAT Set-up tutorial must be run before any other tutorial. Other than this, there is flexibility in how tutorials can be run. It is not necessary to run every tutorial, although in certain cases (e.g., under Running an Assessment and Summarizing and Visualizing Results), tutorials later in the chapter may refer to information developed in an earlier session. To make this clear to the user, each tutorial will list any tutorials that must previously be run. Additionally, note that screen shots shown in later tutorials may look different than those shown depending on which tutorials are run.

Finally, it should be noted that conducting an analysis with BASINS CAT requires a pre-existing, calibrated HSPF model. BASINS CAT imposes no constraints on the type and magnitude of climate change scenarios that can be created. It is therefore incumbent on BASINS CAT users to consider the validity of any HSPF simulation, particularly when evaluating change scenarios well outside the range of climatic variability observed during the calibration period.

**NOTE: The data shown in the tutorials is for demonstration purpose only and does not represent calibrated model results.**

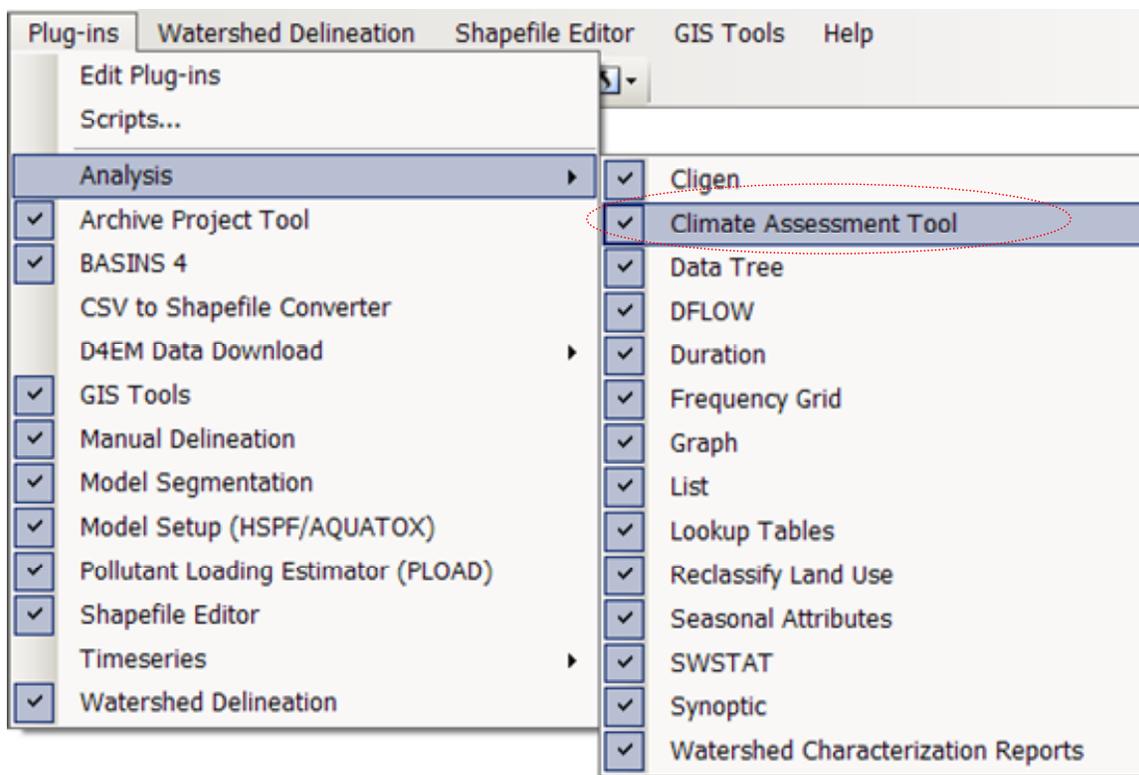
## BASINS CAT Set-up

This tutorial illustrates how to access BASINS CAT from within BASINS and the initial steps required to begin a climate change assessment. **The steps in this tutorial must be performed before running any other tutorials.**

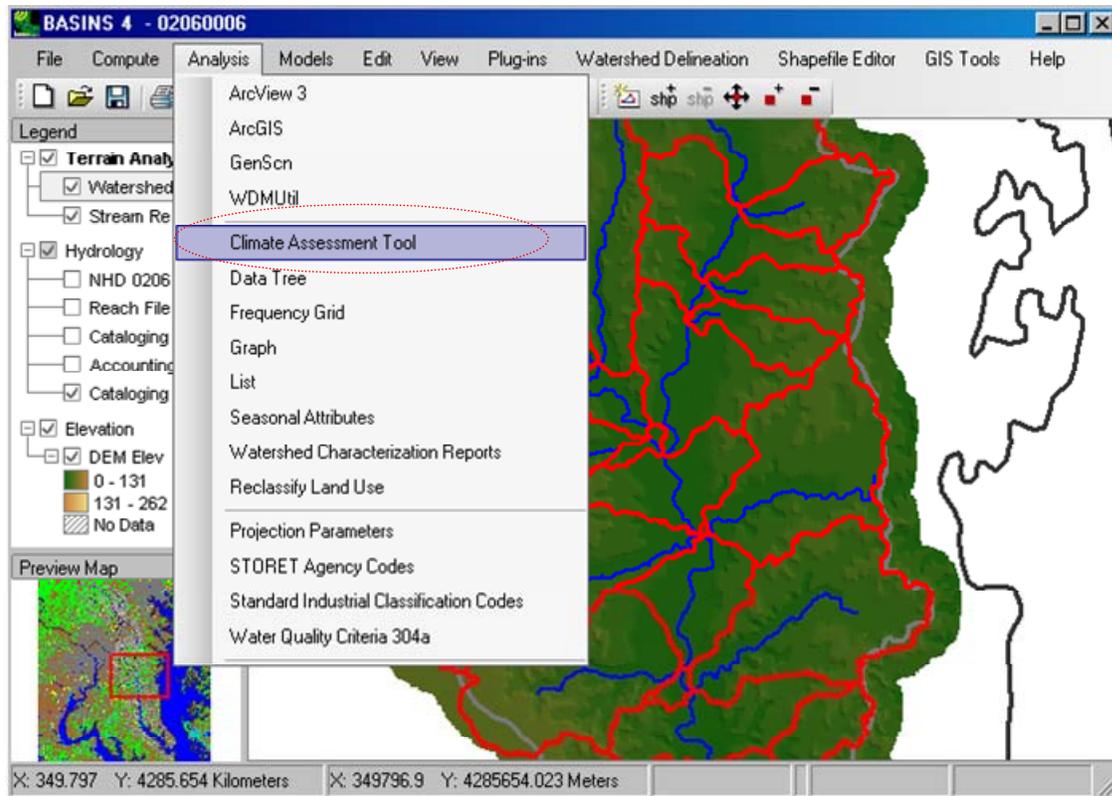
Before beginning this tutorial, it is necessary to review the elements required for using BASINS CAT:

- A calibrated HSPF application
- WDM file containing HSPF input meteorological time series
- Output file(s) to which HSPF is saving results (WDM or binary)

Data used in the tutorials are taken from the sample files provided with the BASINS installation package. These files are found in the \BASINS\data\Climate folder. BASINS CAT is one of various software plug-ins that make up the BASINS system. The first step in setting up BASINS CAT to run in BASINS is to be sure it is loaded as a plug-in. Select **Climate Assessment Tool** from the **Plug-ins:Analysis** submenu by placing a check next to it.



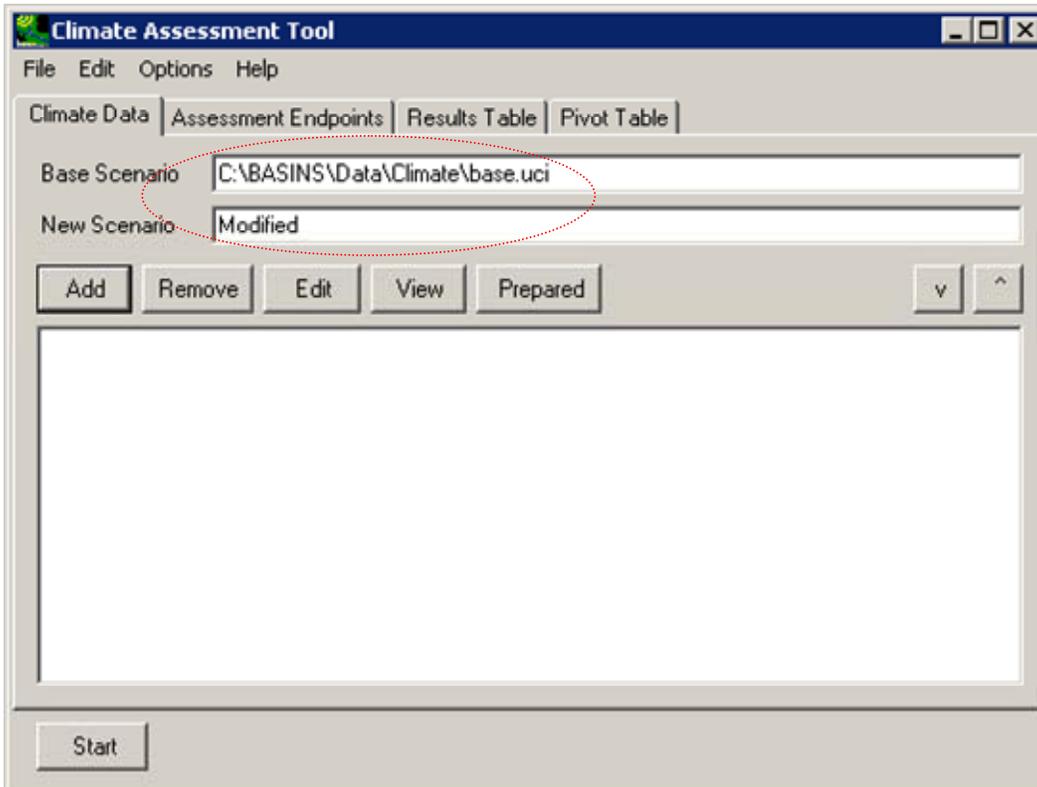
This will add the **Climate Assessment Tool** to the **Analysis** menu. (Note: It is not required for the main BASINS form to appear as shown here.)



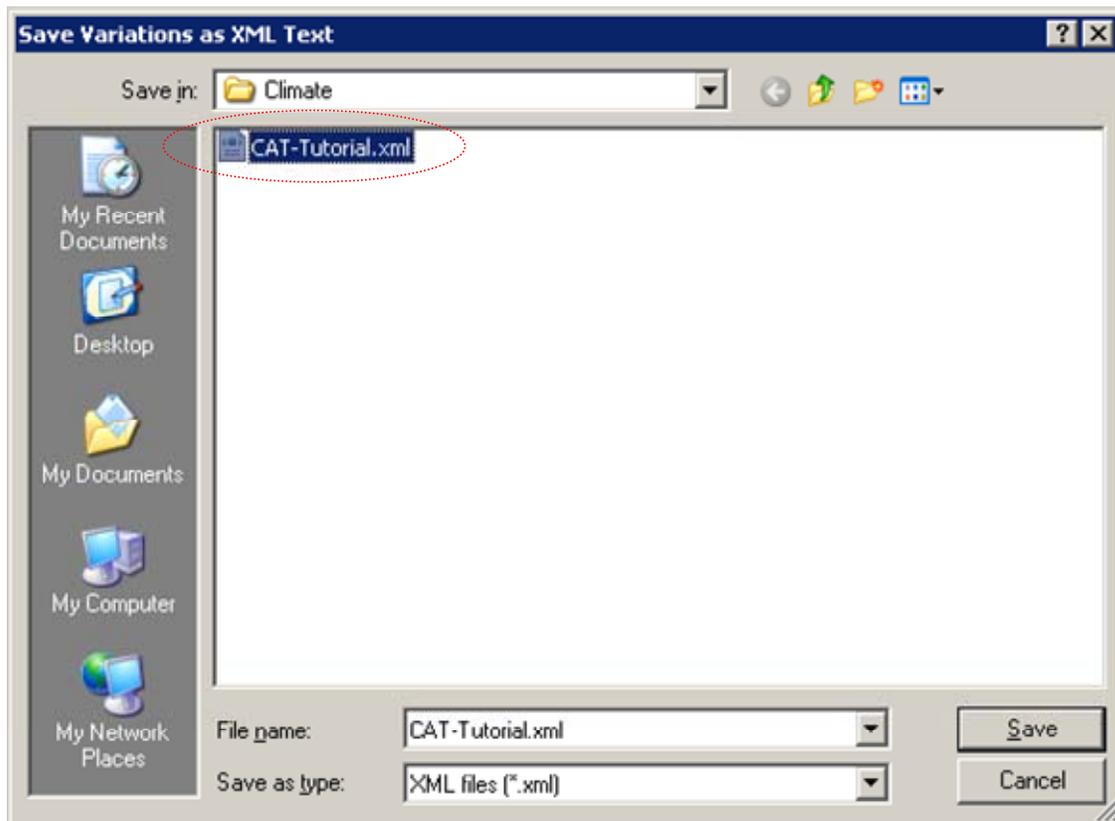
1. Select the **Analysis:Climate Assessment Tool** menu option. The following form will appear.

The screenshot shows a window titled "Climate Assessment Tool" with a menu bar containing "File", "Edit", "Options", and "Help". Below the menu bar are four tabs: "Climate Data", "Assessment Endpoints", "Results Table", and "Pivot Table". The "Climate Data" tab is active. It contains two text input fields: "Base Scenario" with the placeholder text "<click to select>" and "New Scenario" with the text "Modified". Below these fields is a row of five buttons: "Add", "Remove", "Edit", "View", and "Prepared". To the right of these buttons are two small square buttons with downward and upward arrow symbols. A large empty rectangular area occupies the center of the window. At the bottom left, there is a "Start" button.

2. Before beginning the process of generating and analyzing climate change scenarios, a base scenario must be specified. All new climate change scenarios will be created from this scenario. To specify this scenario, click in the **Base Scenario** box and select the file \BASINS\data\Climate\base.uci. When this UCI file is selected, all input and output data files (including both WDM and binary file types) specified in the UCI file will be loaded into the BASINS project and made available for use in BASINS CAT. For these tutorials, meteorological data are found in the file \BASINS\data\Climate\base.wdm. Leave the **New Scenario** name as “Modified.”



3. It is advisable to save the state of the Climate Assessment Tool as tutorial exercises are completed. Doing so will save all current specifications made on the main BASINS CAT form (Base Scenario, New Scenario, Climate Data adjustments, Assessment Endpoints) to a file that can be opened at a later time to restore those specifications. This will allow later tutorials, which depend on results from earlier tutorials, to be run without re-running the earlier tutorials. To perform this save, select the **File:Save Climate and Endpoints** menu option from the Climate Assessment Tool form. A file dialogue form will prompt the user for the name of a file in which the state of BASINS CAT will be saved. This saved state can then be retrieved at a later time using the **File:Load Climate and Endpoints** menu option. The file will be saved as type “XML file (\*.xml).”



4. At this point, the generation and assessment of climate change scenarios can be performed. The remaining tutorials contain exercises showing how to generate new climate change scenarios, specify hydrologic or water quality endpoints, run an assessment, and summarize and visualize results. This completes the BASINS CAT Set-up tutorial.

## **5.1. TOOLS FOR DEVELOPING CLIMATE CHANGE SCENARIOS**

Climate change scenarios are created in BASINS CAT by modifying, or adjusting, historical meteorological time series data to reflect a desired change or set of changes. Adjustments can be applied to precipitation and temperature time series. The tutorials in this section illustrate the major types of adjustment that can be made to historical meteorological data using BASINS CAT.

### **5.1.1. Modify Historical Precipitation Records**

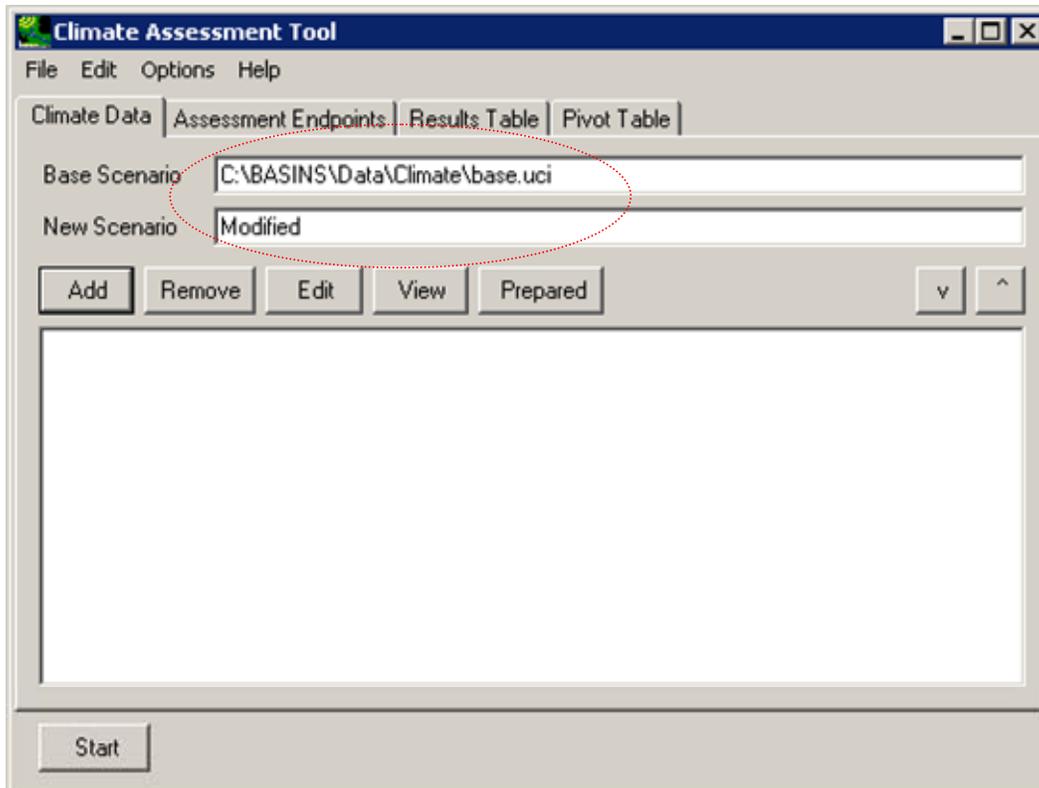
The tutorials in this section demonstrate the following precipitation adjustments:

- Apply multiplier to full record
- Apply seasonal multiplier
- Modify partial record
- Represent storm intensification
- Add or remove storm events

The BASINS CAT Set-up tutorial in Section 5.0 must be run before beginning these tutorials. This is necessary to ensure that the Climate Assessment Tool form is properly initialized.

### 5.1.1.1. *Apply Multiplier to Full Record*

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file (not shown in the image below) added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.



The simplest method of modifying precipitation is to apply a constant multiplier to historical values over the entire span of the model run, or full record. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.1.1.

This tutorial shows how a single multiplier can be applied to an entire historical precipitation data record. The final result of the tutorial is a record adjustment that applies a multiplier to historical precipitation data for use as model input.

1. To begin creating a new record adjustment, click the **Add** button and the **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Increase Precip” in the **Modification Name** field.

The image shows a software dialog box titled "Modify Existing Data". The "Modification Name" field is highlighted with a red dashed circle and contains the text "Increase Precip". Below it, the "Existing Data to Modify" field contains the placeholder text "<click to specify data to modify>" and has a "View" button to its right. The "Compute PET:" field contains the placeholder text "<click to specify PET to replace>" and also has a "View" button. The "How to Modify:" field is a dropdown menu currently set to "Multiply Existing Values by a Number". Below this is a section titled "Number to multiply existing data by" which includes two radio buttons: "Single Change" (which is selected) and "Iterate Changes". A text input field labeled "Value" contains the number "1.1" and is followed by the text "multiplication factor". There are two more sections: "Events" with a checkbox labeled "Vary precipitation only in the following Events" (which is unchecked), and "Seasons" with a checkbox labeled "Vary only in selected" (which is unchecked). At the bottom right of the dialog are "Ok" and "Cancel" buttons.

- To select the precipitation data to modify, click in the **Existing Data to Modify** box and the **Select data to vary** form will be displayed. In the top third of this form, titled **Select Attribute Values to Filter Available Data**, users can filter the type of data to select by Scenario, Location, or Constituent. The data matching your selections will appear in the middle third of the form, titled **Matching Data**. Data sets can then be selected from the **Matching Data** list, which will add them to the **Selected Data** list in the lower third of the form. Clicking on a selected data set in either the **Matching Data** or **Selected Data** lists will unselect it. If all data sets in the **Matching Data** list are desired, it is not necessary to add each one to the Selected Data list.

**Select data to vary**

File Attributes **Select** Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (2221 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (0)

Dates to Include

All Common

Start none

End none

Ok Cancel

- Begin the selection process by looking at the first column, labeled **Scenario**, in the **Select Attribute Values to Filter Available Data** frame. Click on the **OBSERVED** item. All data sets with a Scenario attribute of OBSERVED will be added to the **Matching Data** list. In looking at the last column of the **Matching Data** list, note that there are two data sets with the **Constituent** name **HPRECIP** (hourly precipitation). The HSPF model used in this example is only using precipitation from the Upper Marlboro gage, so click on the data set with **UPMARLBR** and **HPRECIP** as the respective **Location** and **Constituent**. When this data set has moved to the **Selected Data** list, click the **Ok** button.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	UPMARLBR	HPRECIP
----------	----------	---------

Dates to Include

All  Common

Start 1955/12/31 1955/12/31 1955/12/31

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

Note: When selecting the time series data set to adjust, more than one data set may be selected. This allows users to apply the same adjustments to multiple data sets. This is particularly useful for creating climate change scenarios for multiple meteorological inputs (e.g., NCDC weather stations) used in an HSPF simulation. When multiple data sets are selected, this will be reflected on the **Modify Existing Data** form in the **Existing Data to Modify** box. The first data set selected will be listed as described above, but the text "and n more" will be added, where n is the number of additional time series selected. After making an adjustment, the name of the adjustment will not, however, indicate that it will be applied to multiple data sets. It is thus recommended that users select names for adjustments that are appropriately descriptive.

4. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. The **Compute PET** box is for selecting the evapotranspiration data set to modify when a temperature climate scenario is being defined and can be ignored for this example. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, the "Multiply Existing Values by a Number" option will be used. In the **Number to multiply existing data by** frame, there are two modification options: **Single Change** or **Iterate Changes**. The **Single Change** option will result in one adjustment applied to the precipitation data set. The term "iterate", as used here, refers to the automation of multiple runs. The **Iterate Changes** option will result in a series of adjustments to the precipitation data set and is used to create synthetic climate change scenarios as described in Section 3.3.1.5. Use of this option is shown in the tutorial found in Section 5.1.5 Create Synthetic Climate Change Scenarios. For this example, we will use the **Single Change** option. Enter "1.2" in the **Value** field, thus defining the value by which all values in the precipitation data set will be multiplied. The **Events** and **Seasons** frames are not used in this example, because the entire precipitation data record is being multiplied by the designated factor. Click the **Ok** button to complete the scenario definition process.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value:  multiplication factor

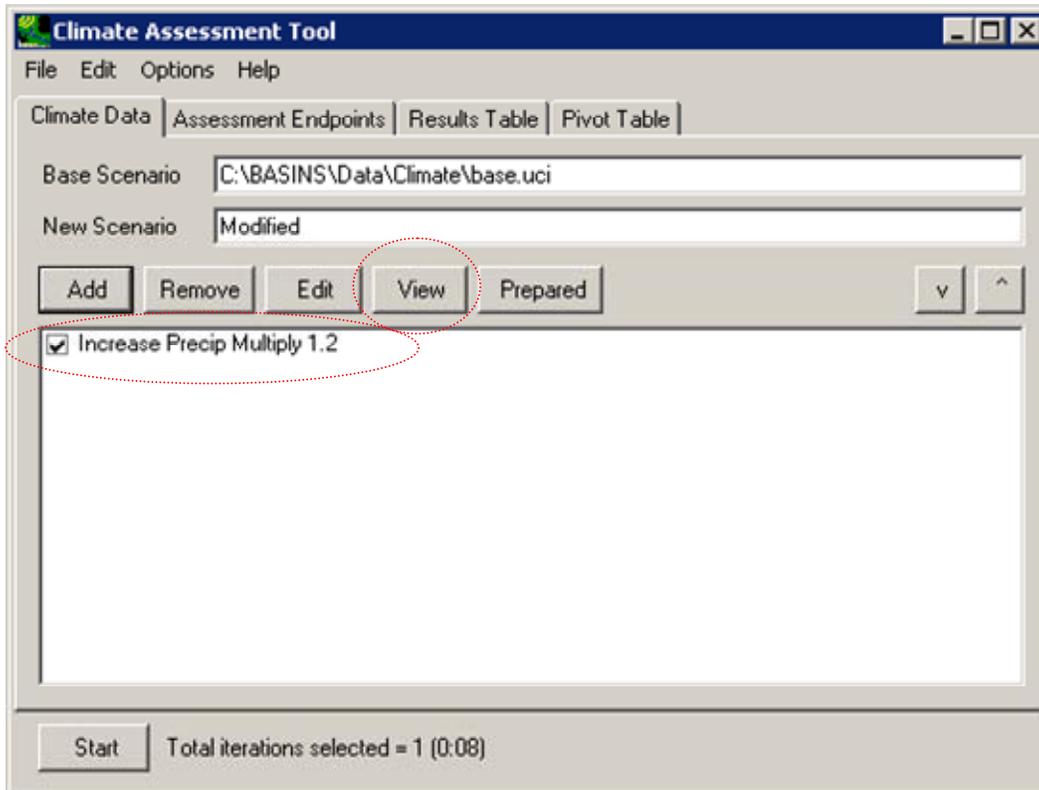
Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

5. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario.



- To view a listing of the modified precipitation data set, click on the newly created record adjustment to select it and then click the **View** button. The **Time series List** form opens, displaying a listing of the values in the modified data set.



The screenshot shows a window titled "Timeseries List" with a menu bar containing "File", "Edit", "View", "Analysis", and "Help". The window displays a table with two columns: the first column contains timestamps and the second column contains numerical values. The table is divided into two sections: "History 1" and "from base.wdm". The "History 1" section includes summary statistics (Min, Max, Mean) and a list of hourly values for 1955. The "from base.wdm" section continues the list of hourly values for 1955 and the beginning of 1956.

History 1	from base.wdm
Min	0
Max	3.072
Mean	0.0057794
1955/12/31 09:00	0
1955/12/31 10:00	0
1955/12/31 11:00	0
1955/12/31 12:00	0
1955/12/31 13:00	0
1955/12/31 14:00	0
1955/12/31 15:00	0
1955/12/31 16:00	0
1955/12/31 17:00	0
1955/12/31 18:00	0
1955/12/31 19:00	0
1955/12/31 20:00	0
1955/12/31 21:00	0
1955/12/31 22:00	0
1955/12/31 23:00	0
1955/12/31 24:00	0
1956/01/01 01:00	0
1956/01/01 02:00	0
1956/01/01 03:00	0
1956/01/01 04:00	0
1956/01/01 05:00	0
1956/01/01 06:00	0

- To view the modified data next to the original, select the **File:Select Data** menu option and the **Select Data** form will be displayed. Like earlier in this tutorial, click the **OBSERVED** item from the **Scenario** list and then click the **OBSERVED, UPMARLBR, HPRECIP** data set from the **Matching Data** list. It will be added to the **Selected Data** list along with the modified precipitation data set that is already in the **Time series List** form. Click **Ok** and the two data sets values will be displayed.

History 1	from base.wdm	from base.wdm
Max	3.072	2.56
Mean	0.0057794	0.0048162
Min	0	0
1955/12/31 09:00	0	0
1955/12/31 10:00	0	0
1955/12/31 11:00	0	0
1955/12/31 12:00	0	0
1955/12/31 13:00	0	0
1955/12/31 14:00	0	0
1955/12/31 15:00	0	0
1955/12/31 16:00	0	0
1955/12/31 17:00	0	0
1955/12/31 18:00	0	0
1955/12/31 19:00	0	0
1955/12/31 20:00	0	0
1955/12/31 21:00	0	0
1955/12/31 22:00	0	0
1955/12/31 23:00	0	0
1955/12/31 24:00	0	0
1956/01/01 01:00	0	0
1956/01/01 02:00	0	0
1956/01/01 03:00	0	0
1956/01/01 04:00	0	0
1956/01/01 05:00	0	0
1956/01/01 06:00	0	0

- To complete this tutorial, close the **Time series** List form and save the state of BASINS CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

### **5.1.1.2. *Apply Seasonal Multiplier***

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

A common climate scenario need is to adjust historical values during a particular month or season of the year over the entire span of the model run. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.1.2.

This tutorial shows how a single multiplier can be applied to precipitation data during a specific month or season of the year. The final result of the tutorial is a climate scenario that applies a multiplier to historical precipitation data only during a single season of the year, here the summer months, for use as model input.

1. To begin creating a new climate scenario, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Seasonal Precip” in the **Modification Name** field.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by \_\_\_\_\_

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- To select the precipitation data to modify, click in the **Existing Data to Modify** box and the **Select data to vary** form will be displayed. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 5.1.1.1. In the first column, under the **Scenario** label, click on the **OBSERVED** item. In looking at the **Matching Data** list, note that there are two data sets with the **Constituent** name **HPRECIP** (hourly precipitation). The HSPF model used in this example is only applying precipitation from the Upper Marlboro gage, so click on the data set with **UPMARLBR** and **HPRECIP** as the respective **Location** and **Constituent**. (Note: It is possible for more than one data set to be selected for use in defining a climate scenario.) When this data set has moved to the **Selected Data** list, click the **Ok** button.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWD
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	UPMARLBR	HPRECIP
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Dates to Include

All  Common

Start 1955/12/31 1955/12/31 1955/12/31

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. The **Compute PET** box is for selecting the evapotranspiration data set to modify when a temperature climate scenario is being defined and can be ignored for this example. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, the “Multiply Existing Values by a Number” option will be used. A detailed description of the **Number to multiply existing data by** frame is found in the tutorial in Section 5.1.1.1. For this example, we will use the **Single Change** option. Enter “1.2” in the **Value** field, thus defining the value by which selected values in the precipitation data set will be multiplied.

The screenshot shows the "Modify Existing Data" dialog box with the following configuration:

- Modification Name:** Seasonal Precip
- Existing Data to Modify:** OBSERVED UPMARLBR HPRECIP (with a "View" button)
- Compute PET:** <click to specify PET to replace> (with a "View" button)
- How to Modify:** Multiply Existing Values by a Number (circled in red)
- Number to multiply existing data by:**
  - Single Change  Iterate Changes
  - Value:** 1.2 (circled in red) multiplication factor
- Events:**  Vary precipitation only in the following Events
- Seasons:**  Vary only in selected

Buttons at the bottom: Ok, Cancel

4. The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. Begin defining this subset by clicking on the **Vary only in selected** check box. Two additional fields will be displayed. The first field is a drop-down list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. For this example, select the **Months** option. The second field will be populated with the months of the year. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. To represent increased precipitation during summer months, select **Jun, Jul, and Aug**.

**Modify Existing Data**

Modification Name: Seasonal Precip

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Multiply Existing Values by a Number

Number to multiply existing data by

Single Change  Iterate Changes

Value: 1.2 multiplication factor

Events

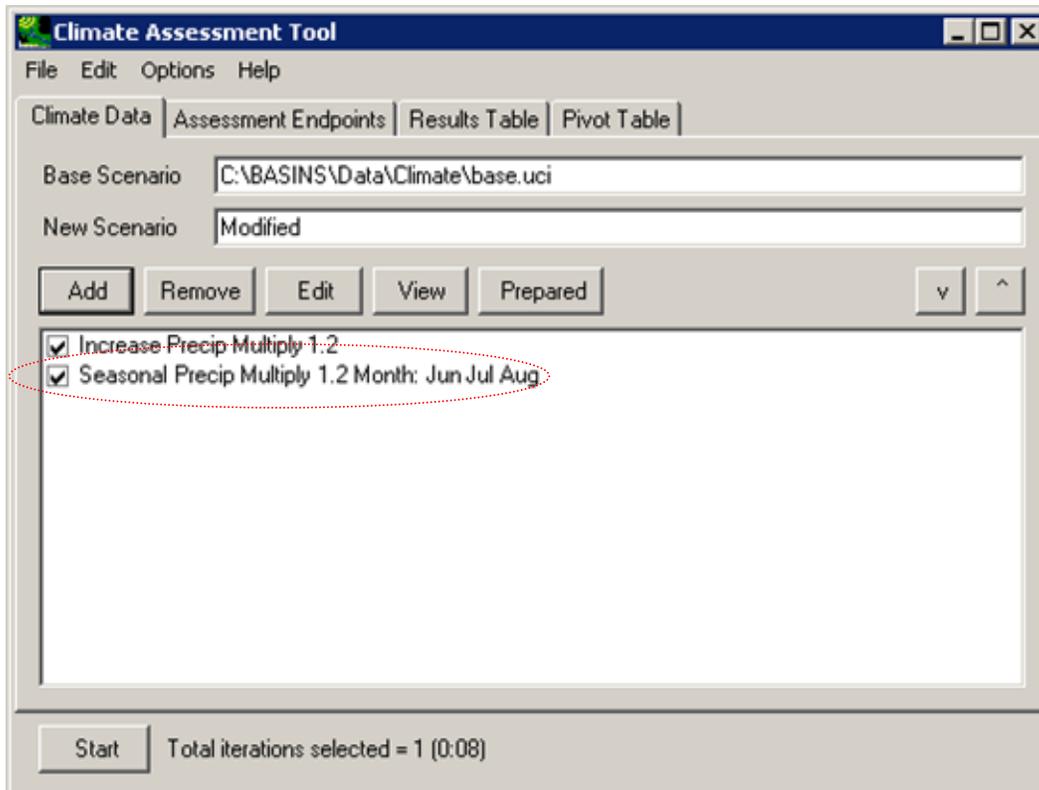
Vary precipitation only in the following Events

Seasons

Vary only in selected Months

Jan	Jun	Nov
Feb	Jul	Dec
Mar	Aug	
Apr	Sep	
May	Oct	

5. Click the **Ok** button to complete the scenario definition process. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario.



6. To complete this tutorial, save the state of CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

### 5.1.1.3. *Modify Partial Record*

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

A common climate scenario need is to adjust historical values during only a particular set of years, or partial record, of the model run. For example, assessing the impacts of increased drought severity can include decreasing the precipitation total for an already low-rainfall year(s), without adjusting rainfall in other years. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.1.3.

This tutorial shows how a single multiplier can be applied to precipitation data during a specific portion of the model run. The final result of the tutorial is a record adjustment that applies a multiplier to historical precipitation data during only a single year of a model run.

1. To begin creating a new climate scenario, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Partial Precip” in the **Modification Name** field.

The image shows a software dialog box titled "Modify Existing Data". The "Modification Name" field is highlighted with a red dashed oval and contains the text "Partial Precip". Below it, there are fields for "Existing Data to Modify" and "Compute PET", both with placeholder text and "View" buttons. The "How to Modify" dropdown is set to "Multiply Existing Values by a Number". A section titled "Number to multiply existing data by" has "Single Change" selected and a "Value" of "1.1" entered. There are also sections for "Events" and "Seasons" with checkboxes for "Vary precipitation only in the following Events" and "Vary only in selected" respectively. "Ok" and "Cancel" buttons are at the bottom.

- To select the precipitation data to modify, click in the **Existing Data to Modify** box. The **Select data to vary** form will be displayed. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 3.1.1.1. In the first column, under the **Scenario** label, click on the **OBSERVED** item. In looking at the **Matching Data** list, note that there are two data sets with the **Constituent** name **HPRECIP** (hourly precipitation). The HSPF model used in this example is only applying precipitation from the Upper Marlboro gage, so click on the data set with **UPMARLBR** and **HPRECIP** as the respective **Location** and **Constituent**. (Note: It is possible for more than one data set to be selected for use in defining a climate scenario.) When this data set has moved to the **Selected Data** list, click the **Ok** button.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	UPMARLBR	HPRECIP
----------	----------	---------

Dates to Include

All Common

Start 1955/12/31 1955/12/31 1955/12/31

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. The **Compute PET** box is for selecting the evapotranspiration data set to modify when a temperature climate scenario is being defined and can be ignored for this example. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, the “Multiply Existing Values by a Number” option will be used. A detailed description of the **Number to multiply existing data by** frame is found in the tutorial in Section 5.1.1.1. For this example, we will use the **Single Change** option. Enter “0.8” in the **Value** field, thus defining the value by which the precipitation values will be multiplied during the year specified in the next step.

**Modify Existing Data**

Modification Name: Partial Precip

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Multiply Existing Values by a Number

Number to multiply existing data by

Single Change  Iterate Changes

Value: 0.8 multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. Begin defining this subset by clicking on the **Vary only in selected** check box. Two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. The sample HSPF model used here will be run for water years 1986 through 1988, with 1986 being the driest. Thus, to help assess the impact of drought, select the **Water Years** option and then select **1986** from the list of available water years.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

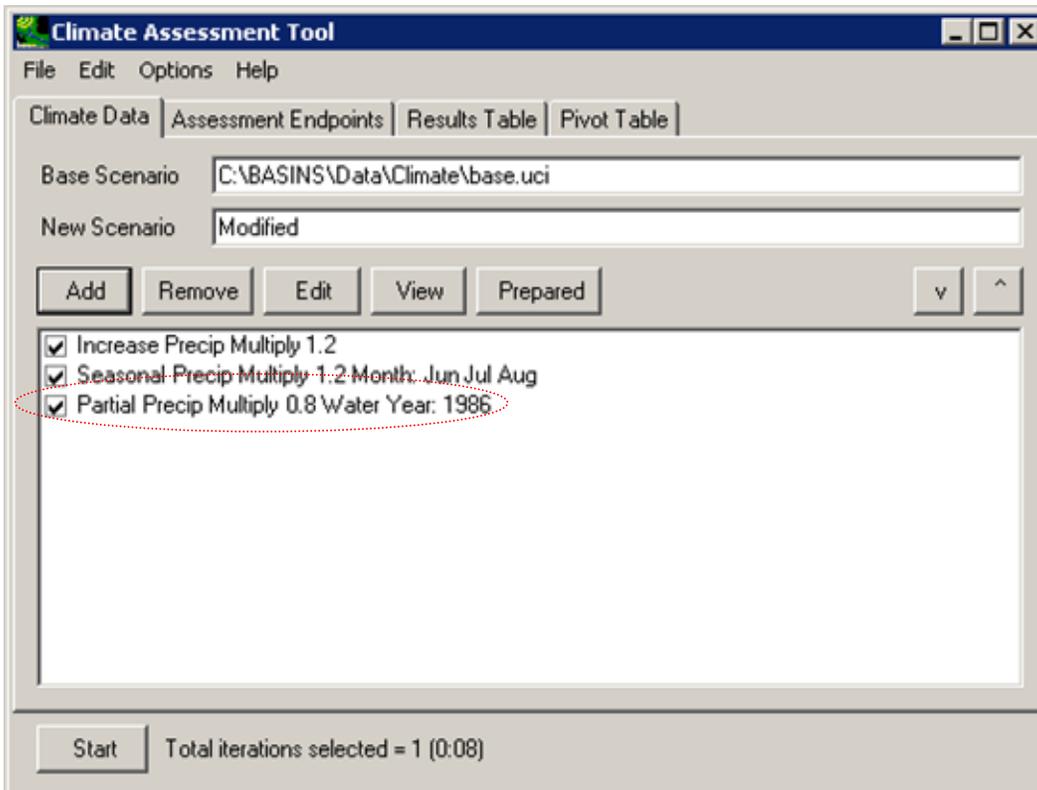
Vary precipitation only in the following Events

Seasons

Vary only in selected

1964	1968	1972	1976	1980	1984	1988
1965	1969	1973	1977	1981	1985	1989
1966	1970	1974	1978	1982	1986	1990
1967	1971	1975	1979	1983	1987	1991

- Click the **Ok** button to complete the scenario definition process. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario.



- To complete this tutorial, save the state of BASINS CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

#### **5.1.1.4. Represent Storm Intensification**

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT has the ability to adjust storm volumes only within selected events within the historical record. This capability allows users to represent changes in the proportion of precipitation occurring in larger versus smaller events. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.1.4.

This tutorial shows how to make adjustments to represent storm intensification. The final result of the tutorial is a climate scenario that applies an increase in storm volumes only to those events within a specified size class.

1. To begin creating a new climate scenario, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. Begin defining this scenario by entering “Storm Intensity” in the **Modification Name** field.

The image shows a software dialog box titled "Modify Existing Data". The "Modification Name" field is highlighted with a red dashed oval and contains the text "Storm Intensity". Below this are fields for "Existing Data to Modify" and "Compute PET", both with placeholder text and "View" buttons. The "How to Modify" dropdown is set to "Multiply Existing Values by a Number". A section titled "Number to multiply existing data by" has "Single Change" selected and a value of "1.1" entered in a text box, followed by the text "multiplication factor". There are also sections for "Events" and "Seasons" with checkboxes for "Vary precipitation only in the following Events" and "Vary only in selected" respectively. "Ok" and "Cancel" buttons are at the bottom.

- Since we will be modifying historical precipitation data, begin the selection process by clicking on the **OBSERVED** item under the **Scenario** list. In looking at the **Matching Data** list, note that there are two data sets with the **Constituent** name **HPRECIP** (hourly precipitation). The HSPF model used in this example is only applying precipitation from the Upper Marlboro gage, so click on the data set with **UPMARLBR** and **HPRECIP** as the respective **Location** and **Constituent**. (Note: It is possible for more than one data set to be selected for use in defining a climate scenario.) When this data set has moved to the **Selected Data** list, click the **Ok** button.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	UPMARLBR	HPRECIP
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Dates to Include

All  Common

Start 1955/12/31 1955/12/31 1955/12/31

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. The **Compute PET** box is for selecting the evapotranspiration data set to modify when a temperature climate scenario is being defined and can be ignored for this example. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, select “Add/Remove Volume in Extreme Events.” The form will be updated to allow for specification of storm intensity modifications.

**Modify Existing Data**

Modification Name: Storm Intensity

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Volume in Extreme Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events Change:  % of volume

Hourly intensity above: 0 in/hr

Allow gaps up to: 0 hours

Total volume above: 0 inches

Total duration above: 0 hours

Seasons

Vary only in selected

4. In the **Percent Change in Volume** frame, leave the **Single Change** option selected and enter a value of “10” percent. It is important to note that this value indicates the percent change in the total water volume for the entire data set. This is the total volume change that will be distributed among the events we specify in the following steps. In the **Events** frame, there are two components available for specifying storm intensification: **Vary precipitation only in the following Events** and **Change a specified % of volume**. By default, the option to **Vary precipitation only in the following Events** is checked. Values can be entered for any or all of the four elements that define an extreme event. Enter “0.1” in the **Hourly intensity above** field, indicating that only events with greater than 0.1 inches/hour will be considered storm events. The **Change ... % of volume** field is used to specify the percentage of the qualifying events to be modified. Leaving this field blank will result in the specified volume change being applied to all qualifying events. Entering a percentage value will result in the volume change being applied to the highest storms that total the specified percentage of the data set’s volume. Enter a value of “20” percent of the volume, which will result in a more intense modification being applied to a smaller subset of storms. BASINS CAT will calculate and add volume to the highest 20% of events over 0.1 inches/hour such that the total added volume equals 10% of the total volume for the entire base data set.

**Modify Existing Data**

Modification Name: Storm Intensity

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Volume in Extreme Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events Change: 20 % of volume

Hourly intensity above: 0.1 in/hr

Allow gaps up to: 0 hours

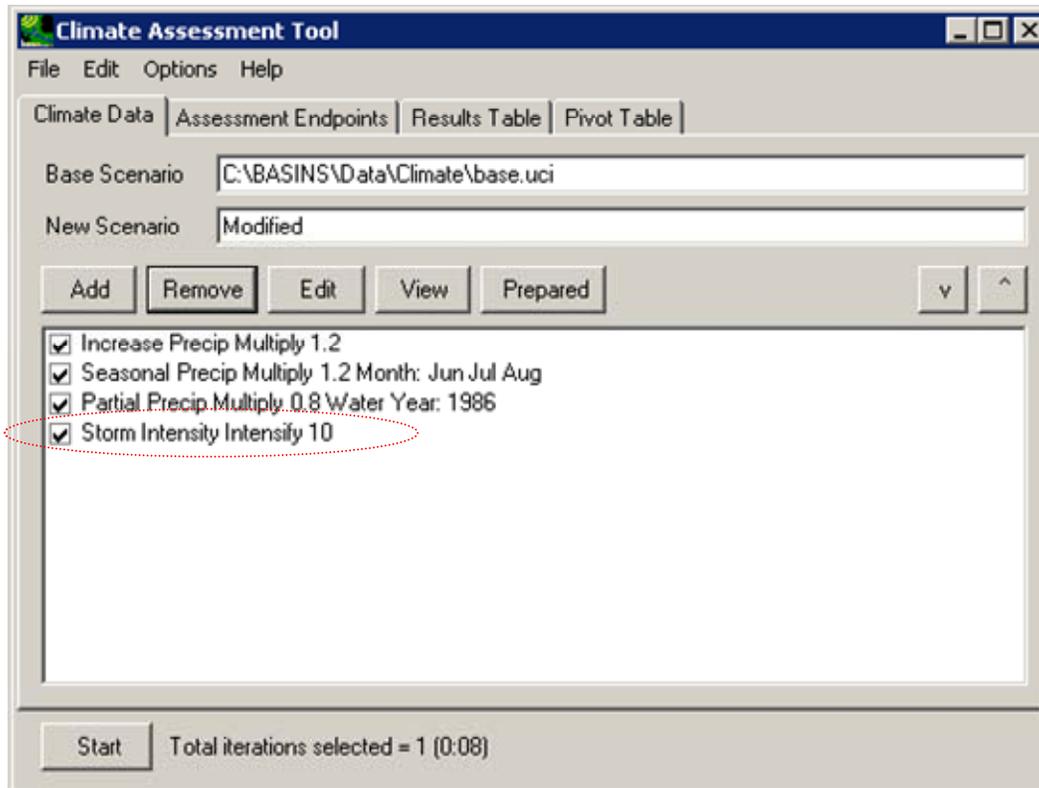
Total volume above: 0 inches

Total duration above: 0 hours

Seasons

Vary only in selected

5. Click the **Ok** button at the bottom of the form. This scenario, as summarized on the main BASINS CAT form, will **intensify** the storms defined on the previous form by adding 10% of the data set's total volume to them.



6. After defining this scenario, the user can use the **View** button to see the values in the modified data sets. Users may also want to save the state of BASINS CAT using the **File:Save Climate and Endpoints** menu option.

#### 5.1.1.5. *Add or Remove Storm Events*

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT has the ability to represent changes in storm frequency by adding or removing storms to a historical record. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.1.5.

This tutorial shows how to make adjustments to represent a change in storm frequency. The final result of the tutorial is a climate scenario that increases the total volume of precipitation by a specified percent by adding storms during selected months in the year.

1. To begin creating a new climate scenario, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. Begin defining this scenario by entering “Storm Frequency” in the **Modification Name** field.

The image shows a software dialog box titled "Modify Existing Data". The "Modification Name" field is highlighted with a red dashed oval and contains the text "Storm Frequency". Below it, the "Existing Data to Modify" field contains the placeholder text "<click to specify data to modify>" and has a "View" button to its right. The "Compute PET" field also contains the placeholder text "<click to specify PET to replace>" and has a "View" button to its right. The "How to Modify" field is a dropdown menu currently set to "Multiply Existing Values by a Number". Below this, there is a section for "Number to multiply existing data by" with a text input field containing "1.1" and the label "multiplication factor". There are two radio buttons: "Single Change" (which is selected) and "Iterate Changes". Below this are two sections: "Events" with a checkbox "Vary precipitation only in the following Events" (which is unchecked), and "Seasons" with a checkbox "Vary only in selected" (which is unchecked). At the bottom right of the dialog are "Ok" and "Cancel" buttons.

- Since we will be modifying historical precipitation data, begin the selection process by clicking on the **OBSERVED** item under the **Scenario** list. In looking at the **Matching Data** list, note that there are two data sets with the **Constituent** name **HPRECIP** (hourly precipitation). The HSPF model used in this example is only applying precipitation from the Upper Marlboro gage, so click on the data set with **UPMARLBR** and **HPRECIP** as the respective **Location** and **Constituent**. (Note: It is possible for more than one data set to be selected for use in defining a climate scenario.) When this data set has moved to the **Selected Data** list, click the **Ok** button.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	UPMARLBR	HPRECIP
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Dates to Include

All Common

Start 1955/12/31 1955/12/31 1955/12/31

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. The **Compute PET** box is for selecting the evapotranspiration data set to modify when a temperature climate scenario is being defined and can be ignored for this example. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, select “Add/Remove Storm Events.” The form will be updated to allow for specification of storm intensity modifications.

**Modify Existing Data**

Modification Name: Storm Frequency

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Storm Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events

Hourly intensity above: 0 in/hr

Allow gaps up to: 0 hours

Total volume above: 0 inches

Total duration above: 0 hours

Seasons

Vary only in selected

4. In the **Percent Change in Volume** frame, leave the **Single Change** option selected and enter a value of “10” percent, indicating the percent change in the total water volume for the entire data set. In the **Events** frame, checking the **Vary precipitation only in the following Events** box causes four fields to be displayed for defining what qualifies as a storm event. Qualifying events will then be randomly selected and duplicated to meet the 10% increase specified above. (Note: Unchecking the box, **Vary precipitation only in the following Events**, results in all precipitation values considered as events qualifying for duplication.) Values can be entered for any or all of the four elements. Enter “0.1” in the **Hourly intensity above** field, indicating that only events with greater than 0.1 inches/hour will be considered storm events.

**Modify Existing Data**

Modification Name: Storm Frequency

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Storm Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events

Hourly intensity above: 0.1 in/hr

Allow gaps up to: 0 hours

Total volume above: 0 inches

Total duration above: 0 hours

Seasons

Vary only in selected

5. The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. Begin defining this subset by clicking on the **Vary only in selected** check box. Two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. For this example, select the **Months** option and the second field will be populated with the months of the year. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. To represent increased storm frequency during spring months, select **Mar**, **Apr**, and **May**.

**Modify Existing Data**

Modification Name: Storm Frequency

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Add/Remove Storm Events

Percent Change in Volume

Single Change  Iterate Changes

Value: 10 %

Events

Vary precipitation only in the following Events

Hourly intensity above: 0.1 in/hr

Allow gaps up to: 0 hours

Total volume above: 0 inches

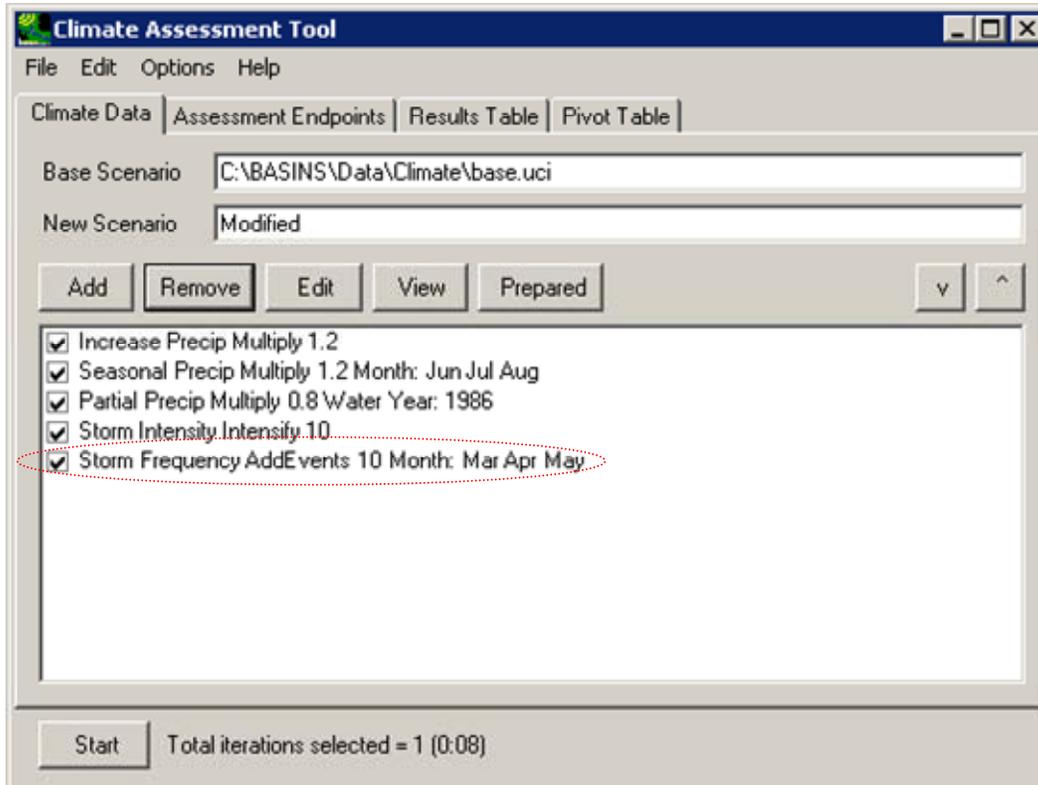
Total duration above: 0 hours

Seasons

Vary only in selected Months

Jan	Jun	Nov
Feb	Jul	Dec
Mar	Aug	
Apr	Sep	
May	Oct	

- Click the **Ok** button at the bottom of the form. This scenario, as summarized on the main BASINS CAT form, will **Add** storms during **Mar, Apr, and May** until a 10% increase in the data set's original volume has been achieved.



- After defining this scenario, the user can use the **View** button to see the values in the modified data sets. Users may also want to save the state of BASINS CAT using the **File:Save Climate and Endpoints** menu option.

### 5.1.2. Modify Historical Air Temperature Records and Regenerate Evapotranspiration Record

The tutorials in this section demonstrate the following adjustments to air temperature records.

- Applying a change to the entire air temperature record and regenerating PET.
- Applying a seasonal change and regenerating PET.
- Applying a change to a portion of the temperature record and regenerating PET.

The BASINS CAT Set-up tutorial in Section 5 must be run before beginning these tutorials. This is necessary to ensure that the Climate Assessment Tool form is properly initialized.

#### **5.1.2.1. *Add or Subtract a Constant to Full Record and Regenerate Evapotranspiration***

To begin this tutorial, the Climate Assessment Tool form should be displayed with the “\Basins\Data\Climate\base.uci” file as the Base Scenario, “Modified” as the New Scenario, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

The simplest method of modifying air temperature is to apply a multiplier to historical values over the entire span, or full record, of the model run. Potential evapotranspiration (PET) data are then regenerated using the modified temperature values. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.2.1.

This tutorial shows how a single change can be applied to an entire historical air temperature data record and how PET data are regenerated from the modified data. The final result of the tutorial is a record adjustment that applies a uniform increase to historical air temperature. PET data will be regenerated, based on the adjusted air temperature record, for use as model input.

1. To begin creating a new record adjustment, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Temperature” in the **Modification Name** field.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- To select the air temperature data to modify, click in the **Existing Data to Modify** box. The **Select data to vary** form will open. In the top third of this form, titled **Select Attribute Values to Filter Available Data**, the user can filter the type of data to select by Scenario, Location, or Constituent. The data matching these selections will appear in the middle third of the form, titled **Matching Data**. Data sets can then be selected from the **Matching Data** list, which will add them to the **Selected Data** list in the lower third of the form. Clicking on a selected data set in either the **Matching Data** or **Selected Data** lists will unselect it. If all data sets in the **Matching Data** list are desired, it is not necessary to add each one to the Selected Data list.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (2221 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (0 of 2221)

Dates to Include

All Common

Start none 1980/01/01

End none 1990/12/31

Ok Cancel

- Begin the selection process by looking at the first column, labeled **Scenario**, in the **Select Attribute Values to Filter Available Data** frame. Click on the **OBSERVED** item, and all data sets with a Scenario attribute of OBSERVED will be added to the **Matching Data** list. In looking at the last column of the **Matching Data** list, note the data set with the **Constituent** name **AIRTMP** (air temperature). Click on this data set and it will be added to the **Selected Data** list. Click the **Ok** button to close the form.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	AIRTMP
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Dates to Include

All  Common

Start 1980/01/01 1980/01/01 1980/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

4. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. When modifying temperature, it is necessary to also re-compute the potential evapotranspiration (PET) using the modified temperature data. Click in the **Compute PET** box to specify which PET data to re-compute.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- In the **Select data to vary** form, again click on the **OBSERVED** item in the **Scenario** column, and then click the **OBSERVED BELTSVIL PET** data set from the **Matching Data** list. Click the **Ok** button to close the **Select data to vary** form.

**Select PET to replace with values computed from air temp...**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	PET
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Dates to Include

Start 1972/01/01 1972/01/01 1972/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

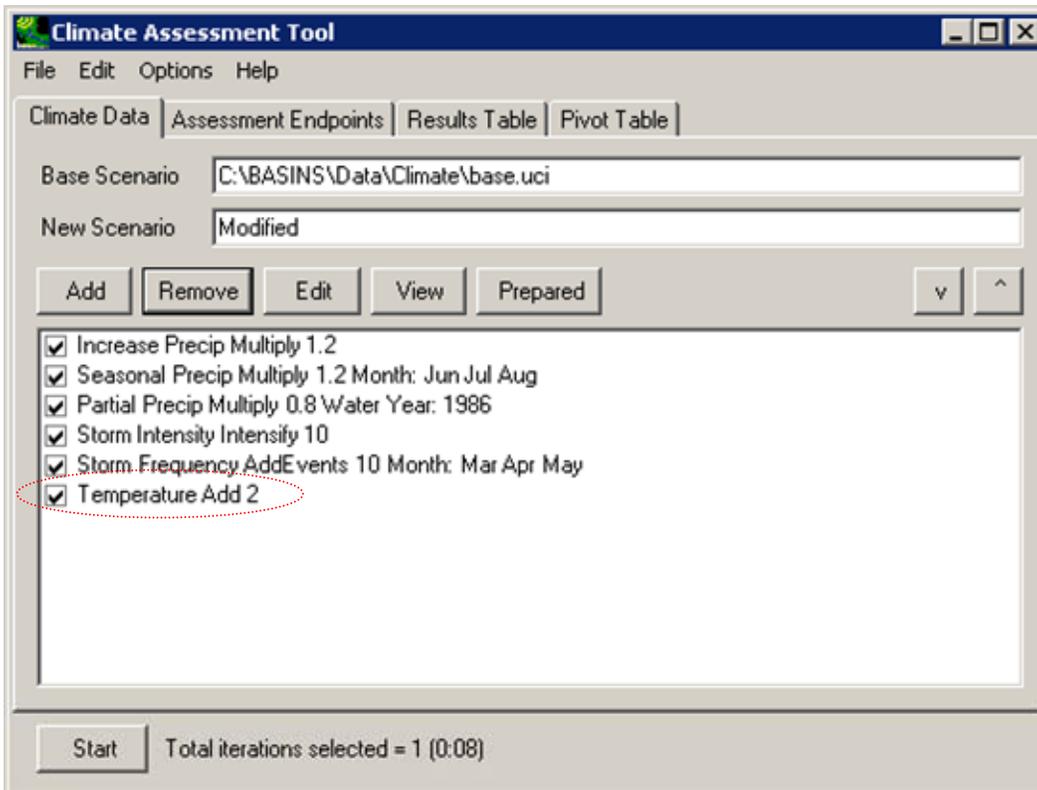
6. The **Modify Existing Data** form has been updated with a description of the selected data set in the **Compute PET** box. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, select the “Change Temperature” option. In the **Degrees to add to each existing temperature value** frame, there are two modification options: **Single Change** or **Iterate Changes**. The term “iterate”, as used here, refers to the automation of multiple runs. The **Single Change** option will result in one adjustment applied to the temperature data set. The **Iterate Changes** option will result in a series of adjustments to the temperature data set and is used to create synthetic climate change scenarios as described in Section 3.3.1.5. Use of this option is shown in the tutorial found in Section 5.1.5. For this example, we will use the **Single Change** option. In the **Value** field, enter “2,” thus defining the amount to be added to all values in the temperature data set. Click the **Ok** button to complete the scenario definition process.

The image shows a software dialog box titled "Modify Existing Data". It contains several input fields and options:

- Modification Name:** Temperature
- Existing Data to Modify:** OBSERVED BELTSVIL AIRTMP (with a "View" button)
- Compute PET:** OBSERVED BELTSVIL PET (with a "View" button)
- How to Modify:** Change Temperature (selected in a dropdown menu)
- Degrees to add to each existing temperature value:**
  - Single Change
  - Iterate Changes
  - Value:** 2 degrees
- Events:**
  - Vary precipitation only in the following Events
- Seasons:**
  - Vary only in selected

At the bottom right, there are "Ok" and "Cancel" buttons.

7. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario.



8. To complete this tutorial, close the data listing and save the state of CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

#### ***5.1.2.2. Add or Subtract a Constant to a Specified Season and Regenerate Evapotranspiration.***

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT allows for the adjustment of temperature (and computed PET) values during only a specified month or season of the year. This flexibility is useful for representing changes that vary seasonally within the year. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.2.2.

This tutorial shows how a change can be applied to a historical air temperature data record for only a specified season of the year, and how PET data are regenerated from the modified data. The final result of the tutorial is an air temperature time series with two different record adjustments, one for cool months, and one for warm months. PET data will be regenerated, based on the adjusted air temperature records, for use as model input.

1. To begin creating the temperature adjustment for cool months, click the **Add** button and the **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Temp Cool Season” in the **Modification Name** field.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- To select the air temperature data to modify, click in the **Existing Data to Modify** box and the **Select data to vary** form will be displayed. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 5.1.2.1. In the first column, under the **Scenario** label, click on the **OBSERVED** item and all data sets with a Scenario attribute of OBSERVED will be added to the **Matching Data** list. Look at the last column of the **Matching Data** list, and note the data set with the **Constituent** name **AIRTMP** (air temperature). Click on this data set and it will be added to the **Selected Data** list. Click the **Ok** button to close the form.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	AIRTMP
----------	----------	--------

Dates to Include

All Common

Start 1980/01/01 1980/01/01 1980/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. When modifying temperature, it is necessary to also re-compute the potential evapotranspiration (PET) using the modified temperature data. Click in the **Compute PET** box to specify which PET data to re-compute.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- In the **Select data to vary** form, again click on the **OBSERVED** item in the **Scenario** column, and then click the **OBSERVED BELTSVIL PET** data set from the **Matching Data** list. Click the **Ok** button to close the **Select data to vary** form.

**Select PET to replace with values computed from air temp...**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
<b>OBSERVED</b>	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
<b>OBSERVED</b>	<b>BELTSVIL</b>	<b>PET</b>
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	PET
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Dates to Include

All  Common

Start 1972/01/01 1972/01/01 1972/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

5. The **Modify Existing Data** form has been updated with a description of the selected data set in the **Compute PET** box. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, the “Change Temperature” option will be used. A detailed description of the **Degrees to add to each existing temperature value** frame is found in the tutorial in Section 5.1.2.1. For this example, we will use the **Single Change** option. In the **Value** field, enter “2,” which will be the temperature increase applied to the air temperature values in the season defined in the next step.

**Modify Existing Data**

Modification Name: Temp Cool Season

Existing Data to Modify: OBSERVED BELTSVIL AIRTMP

Compute PET: OBSERVED BELTSVIL PET

How to Modify: Change Temperature

Degrees to add to each existing temperature value

Single Change  Iterate Changes

Value: 2 degrees

Events

Vary precipitation only in the following Events

Seasons

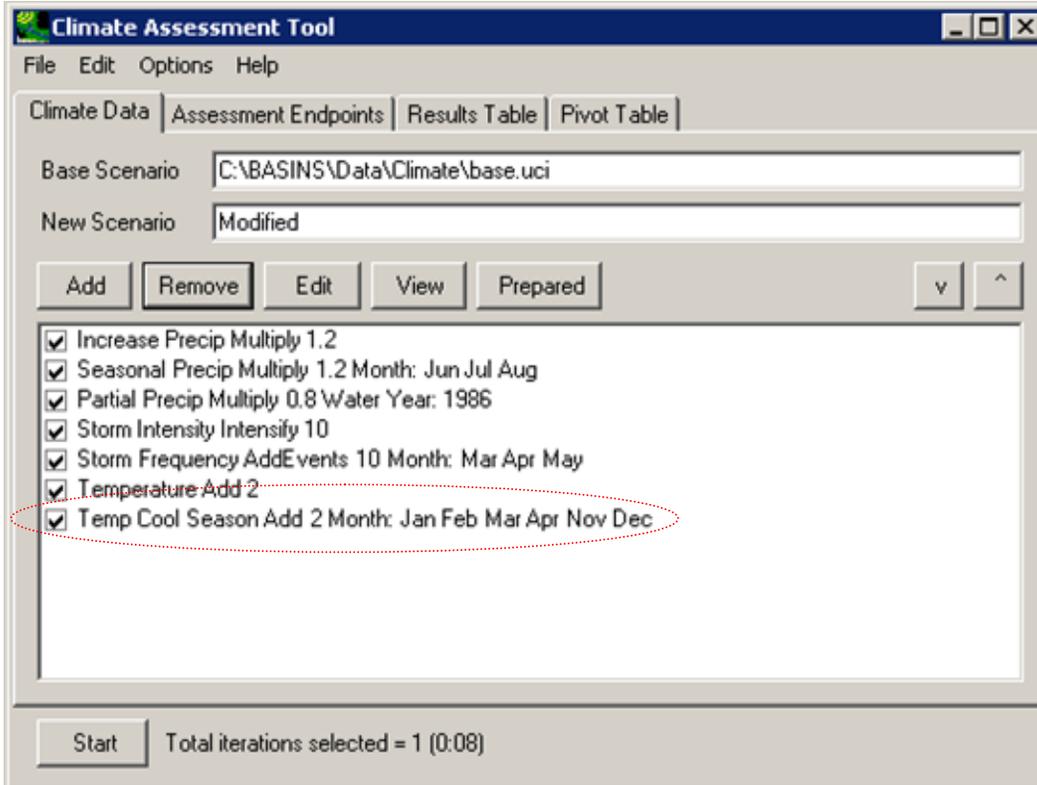
Vary only in selected

6. The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. Begin defining this subset by clicking on the **Vary only in selected** check box and two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. For this example, select the **Months** option and the second field will be populated with the months of the year. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. To apply the 2-degree increase to cooler months, select **Nov** through **Apr**.

The screenshot shows the 'Modify Existing Data' dialog box with the following settings:

- Modification Name: Temp Cool Season
- Existing Data to Modify: OBSERVED BELTSVIL AIRTMP (View)
- Compute PET: OBSERVED BELTSVIL PET (View)
- How to Modify: Change Temperature
- Degrees to add to each existing temperature value: 2 degrees
- Single Change (selected), Iterate Changes
- Events: Vary precipitation only in the following Events (unchecked)
- Seasons: Vary only in selected (checked), Month (dropdown)
- Month list: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
- All (button), None (button)
- Ok (button), Cancel (button)

7. Click the **Ok** button to complete defining the cooler month's temperature adjustment. The newly defined adjustment will be shown on the **Climate Assessment Tool** form. To begin defining the warm month's air temperature adjustment, click the **Add** button again.



8. From the **Modify Existing Data** form, enter “Temp Warm Season” in the **Modification Name** field. Next, repeat steps 2 through 4 to select the same air temperature and PET data sets as before. For the warm month’s adjustment, we will apply a 4-degree increase to the historical data. Select **Change Temperature** from the **How to Modify** list and then enter “4” in the **Value** field. In the **Seasons** frame, again select **Months** from the first list and then select **May** through **Oct**.

**Modify Existing Data**

Modification Name: Temp Warm Season

Existing Data to Modify: OBSERVED BELTSVIL AIRTMP View

Compute PET: OBSERVED BELTSVIL PET View

How to Modify: Change Temperature

Degrees to add to each existing temperature value

Single Change  Iterate Changes

Value: 4 degrees

Events

Vary precipitation only in the following Events

Seasons

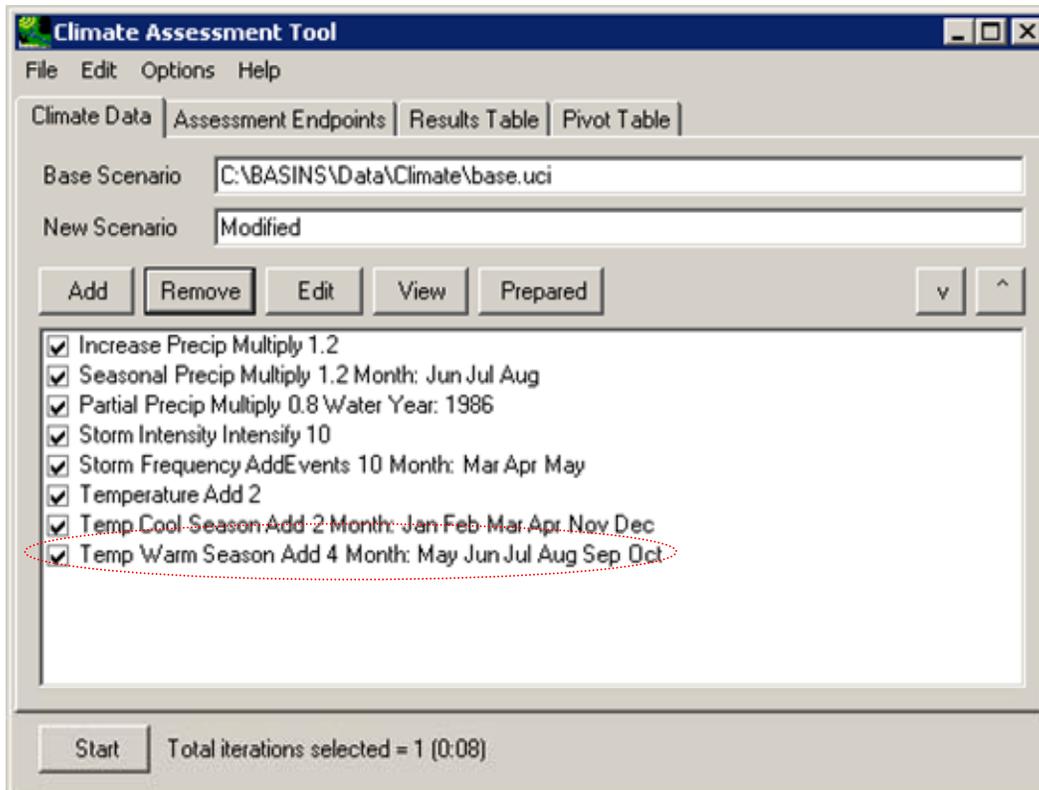
Vary only in selected Month

Jan	Jun	Nov
Feb	Jul	Dec
Mar	Aug	
Apr	Sep	
May	Oct	

All None

Ok Cancel

- Click the **Ok** button to complete defining the warm month's temperature adjustment. The newly defined adjustment will be shown on the **Climate Assessment Tool** form.



- To complete this tutorial, save the state of CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

### **5.1.2.3. Add or Subtract a Constant to a Partial Record and Regenerate Evapotranspiration**

To begin this tutorial, the Climate Assessment Tool form should be displayed with the “\Basins\Data\Climate\base.uci” file as the Base Scenario, “Modified” as the New Scenario, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

A common climate scenario need is to adjust historical values during only a particular set of years, or partial record, of the model run. For example, assessing the impacts of increased drought severity can include increasing the air temperature values, and re-computing PET values, for a specified year or years within the record. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.2.3.

This tutorial shows how a single change can be applied to a historical air temperature data record for a specified portion of the model run, and how PET data are regenerated from the modified data. The final result of the tutorial, in this example, is a record adjustment that increases historical air temperature data for only a single year. PET data are also regenerated based on the adjusted air temperature record for use as model input.

1. To begin creating a new climate scenario, click the **Add** button. The **Modify Existing Data** form will be displayed. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Partial Temp” in the **Modification Name** field.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- To select the air temperature data to modify, click in the **Existing Data to Modify** box. The **Select data to vary** form will be displayed. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 5.1.2.1. In the first column, under the **Scenario** label, click on the **OBSERVED** item and all data sets with a Scenario attribute of OBSERVED will be added to the **Matching Data** list. Look at the last column of the **Matching Data** list, and note the data set with the **Constituent** name **AIRTMP** (air temperature). Click on this data set and it will be added to the **Selected Data** list. Click the **Ok** button to close the form.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	AIRTMP
----------	----------	--------

Dates to Include

All  Common

Start 1980/01/01 1980/01/01 1980/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. When modifying temperature, it is necessary to also re-compute the potential evapotranspiration (PET) using the modified temperature data. Click in the **Compute PET** box to specify which PET data to re-compute.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- In the **Select data to vary** form, again click on the **OBSERVED** item in the **Scenario** column, and then click the **OBSERVED BELTSVIL PET** data set from the **Matching Data** list. Click the **Ok** button to close the **Select data to vary** form.

**Select PET to replace with values computed from air temp...**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWD
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
<b>OBSERVED</b>	<b>BELTSVIL</b>	<b>PET</b>
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	PET
----------	----------	-----

Dates to Include

All  Common

Start 1972/01/01 1972/01/01 1972/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

5. The **Modify Existing Data** form has been updated with a description of the selected data set in the **Compute PET** box. The **How to Modify** box contains a list of methods for modifying the data-set values. For this example, the “Change Temperature” option will be used. A detailed description of the **Degrees to add to each existing temperature value** frame is found in the tutorial under Section 5.1.2.1. For this example, we will use the **Single Change** option. In the **Value** field, enter “3,” which will be the temperature increase applied to the air temperature values in the year specified in the next step.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Degrees to add to each existing temperature value

Single Change  Iterate Changes

Value  degrees

Events

Vary precipitation only in the following Events

Seasons

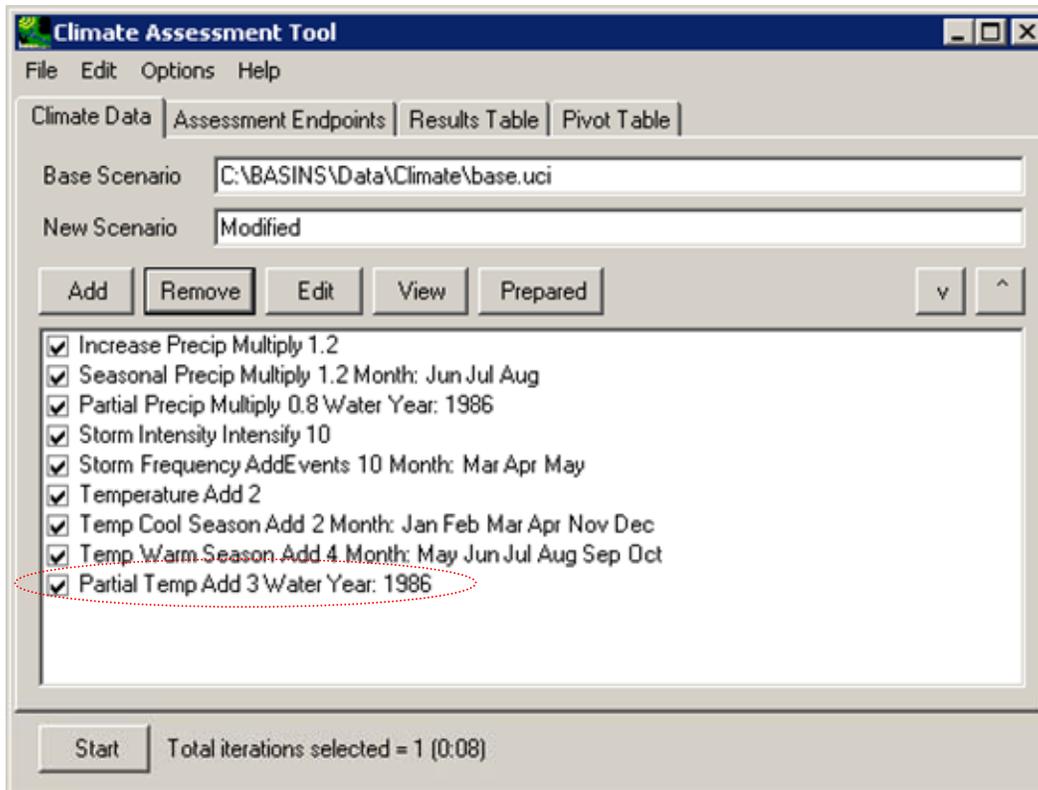
Vary only in selected

6. The **Seasons** frame near the bottom of the form is used for specifying a time subset of the data set to which the modification will be applied. Begin defining this subset by clicking on the **Vary only in selected** check box. Two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. The sample HSPF model used here is run for water years 1986 through 1988, with 1986 being the driest. Thus, to help assess the impact of drought, select the **Water Years** option and then select **1986** from the list of available water years.

The screenshot shows the 'Modify Existing Data' dialog box with the following fields and options:

- Modification Name: Partial Temp
- Existing Data to Modify: OBSERVED BELTSVIL AIRTMP (View button)
- Compute PET: OBSERVED BELTSVIL PET (View button)
- How to Modify: Change Temperature (dropdown)
- Degrees to add to each existing temperature value:
  - Single Change  Iterate Changes
  - Value: 3 degrees
- Events:
  - Vary precipitation only in the following Events
- Seasons:
  - Vary only in selected
  - Water Years (dropdown)
  - List of years: 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990. The year 1986 is highlighted.
  - All (button) None (button)
- Ok (button) Cancel (button)

7. Click the **Ok** button to complete the scenario definition process. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario.



8. To complete this tutorial, save the state of CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

### 5.1.3. Combine Multiple Changes to Create a Climate Change Scenario

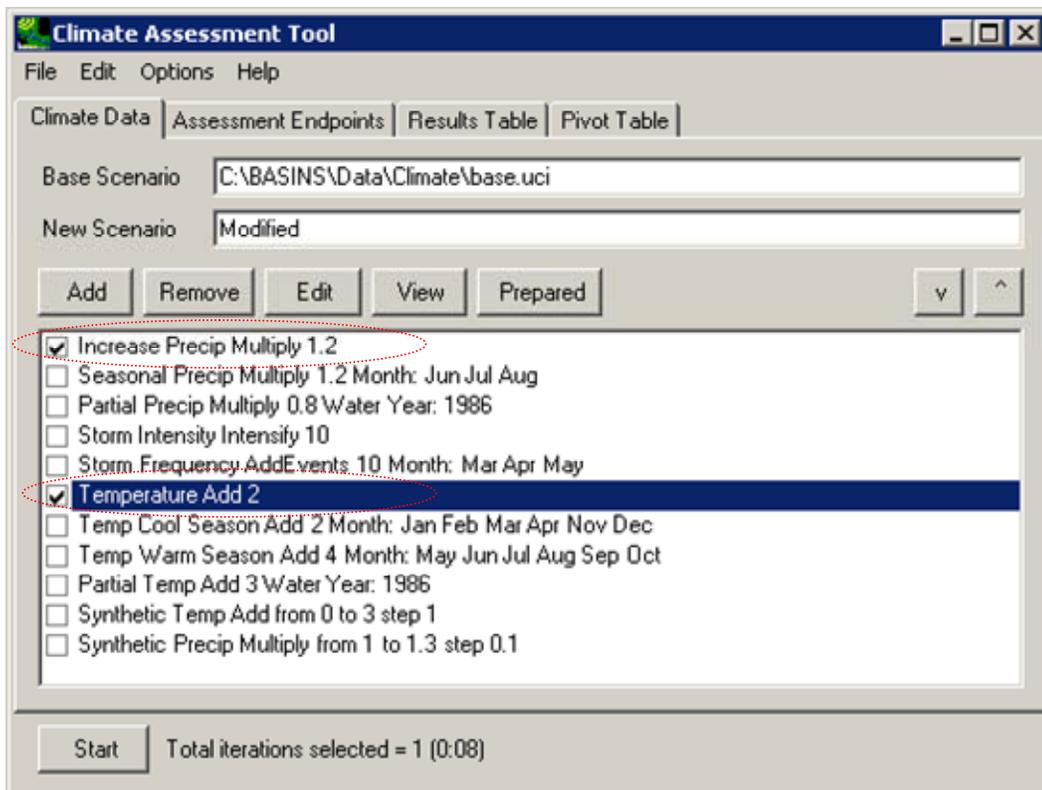
This tutorial illustrates how multiple record adjustments to historical temperature and precipitation data, or scenario components, are combined in a cumulative way to create climate change scenarios. Running this tutorial requires that one or more record adjustments have already been made, such as those illustrated in the previous tutorials (Sections 5.1.1.1 through 5.1.2.3). This tutorial can also be performed using record adjustments other than those shown here.

This tutorial creates two climate change scenarios. The first applies temperature and precipitation changes to each year in the record to create a long-term change scenario. The second applies decreasing precipitation and increasing temperature for a single, selected year to create a scenario representing an increased drought severity.

1. The **Climate Assessment Tool** form displays the previously defined record adjustments in a list on the **Climate Data** tab. Each adjustment has a check box for indicating whether or not it is to be included as a component of the climate scenario being developed. The order of adjustments can be controlled by selecting an adjustment and using the up and down arrow buttons above the list. This is particularly important when multiple adjustments are being made to the same values in an input data set (e.g., increasing an entire precipitation record and also increasing a season's storm intensity). In such a case, the first (i.e., highest in the list) adjustment would be applied to the original record. Ensuing adjustments would then be applied to the record resulting from the previous adjustment in a cumulative way.
2. Begin defining the first climate scenario by selecting the following record adjustments (placing a check in the appropriate checkboxes):

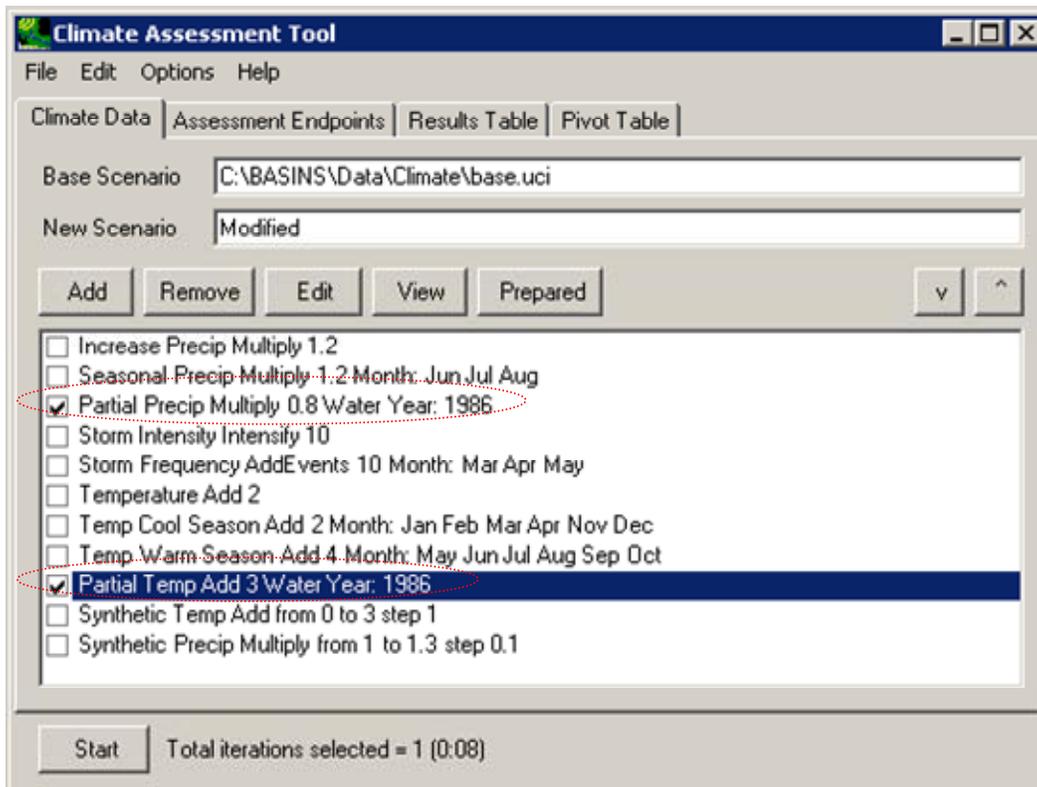
- **Increase Precip Multiply 1.2**
- **Temperature Add 2**

All other record adjustments should be inactive (not checked). This combination of adjustments represents a climate scenario that is available for input to the model. (Note: This scenario will not be run here as this tutorial is only demonstrating how climate change scenarios are defined).



3. Define the second climate change scenario by selecting the following record adjustments:
- **Partial Precip Multiply 0.8 Water Year: 1986**
  - **Partial Temp Add 3 Water Year: 1986**

All other record adjustments should be inactive (not checked). This combination of adjustments represents a climate scenario for assessing an increased severity of drought in a single year during a model run.



4. At the bottom of the BASINS CAT form, a label indicates the number of model runs (or **Total iterations**) that will be performed. For each climate scenario shown here, only one model run will be made. When a synthetic climate scenario is used (see the tutorial in Section 5.1.5), a series of model runs is made, one for each adjustment, or iteration, of the synthetic scenario. If multiple synthetic scenarios are used, a model run is made for each unique combination of adjustments defined by the scenarios. For example, a synthetic temperature scenario with 4 iterations combined with a synthetic precipitation scenario with 3 iterations would result in 12 model runs.

#### **5.1.4. Creating Spatially Variable Climate Change Scenarios at Multiple Locations**

Most HSPF models receive meteorological input from multiple locations, typically NCDC weather stations, within a watershed. Running an assessment using BASINS CAT thus requires that change scenarios be created for meteorological data for multiple locations within a watershed. BASINS CAT provides the option to apply specified adjustment(s) to multiple meteorological data sets simultaneously, e.g., temperature time series data from multiple weather stations (see Tutorial 5.1.1.1).

BASINS CAT can also be used to create spatially variable climate change scenarios for different locations within a watershed by individually selecting and adjusting historical temperature and precipitation time series data sets from each location.

To individually adjust time series data from multiple locations (NCDC weather stations), each data set must be selected and adjusted as a separate step. After specifying adjustments to each data set, the BASINS CAT interface will list each adjustment preceded by a checkbox. By selecting and unselecting the appropriate checkboxes, users can create and run spatially variable precipitation and air temperature change scenarios for each weather station used in an HSPF simulation.

#### **5.1.5. Create Synthetic Climate Change Scenarios**

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT can be used to automate the creation of multiple synthetic climate change scenarios by applying a series of record adjustments within a user-specified range to historical data. For background on how this feature can be used to represent climate change scenarios, see Section 3.3.1.5.

This tutorial shows how a series of adjustments can be applied to the full, historical data set to create synthetic climate change scenarios. The final result of the tutorial is two synthetic scenarios, one that incrementally increases temperature values, and one that incrementally increases precipitation values.

1. To begin creating the synthetic temperature scenario, click the **Add** button. The **Modify Existing Data** form will open. This form contains the controls needed to define a record adjustment, including an identification label, the data set(s) to be modified, and how the data are to be modified. The **Modification Name** field is used to provide a text label for identifying the scenario being created. Begin defining this scenario by entering “Synthetic Temp” in the **Modification Name** field.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- To select the air temperature data to modify, click in the **Existing Data to Modify** box. The **Select data to vary** form will be displayed. A detailed description of this form is found in steps 2 and 3 of the tutorial under Section 5.1.2.1. In the first column, under the **Scenario** label, click on the **OBSERVED** item and all data sets with a Scenario attribute of OBSERVED will be added to the **Matching Data** list. In looking at the last column of the **Matching Data** list, note the data set with the **Constituent** name **AIRTMP** (air temperature). Click on this data set and it will be added to the **Selected Data** list. Click the **Ok** button to close the form.

**Select data to vary**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVL	PET
OBSERVED	BELTSVL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVL	AIRTMP
----------	---------	--------

Dates to Include

All  Common

Start 1980/01/01 1980/01/01 1980/01/01

End 1990/12/31 1990/12/31 1990/12/31

Ok Cancel

3. The **Modify Existing Data** form has now been updated with a description of the selected data set in the **Existing Data to Modify** box. When modifying temperature, it is necessary to also re-compute the potential evapotranspiration (PET) using the modified temperature data. Click in the **Compute PET** box to specify which PET data to re-compute.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- In the **Select data to vary** form, again click on the **OBSERVED** item in the **Scenario** column, and then click the **OBSERVED BELTSVIL PET** data set from the **Matching Data** list. Click the **Ok** button to close the **Select data to vary** form.

**Select PET to replace with values computed from air temp...**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
SCEN	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (27 of 2221)

OBSERVED	01594526	FLOW
OBSERVED	LAUREL	HPRECIP
OBSERVED	UPMARLBR	HPRECIP
OBSERVED	BELTSVIL	PET
OBSERVED	BELTSVIL	AIRTMP
OBSERVED	WASH_NAT	CLOUD
OBSERVED	WASH_NAT	WIND
OBSERVED	WASH_NAT	DEWPT
OBSERVED	WASH_NAT	SOLRAD

Selected Data (1 of 2221)

OBSERVED	BELTSVIL	PET
----------	----------	-----

Dates to Include

All  Common

Start 1972/01/01 1972/01/01 1972/01/01

End 1990/12/31 1990/12/31 1990/12/31

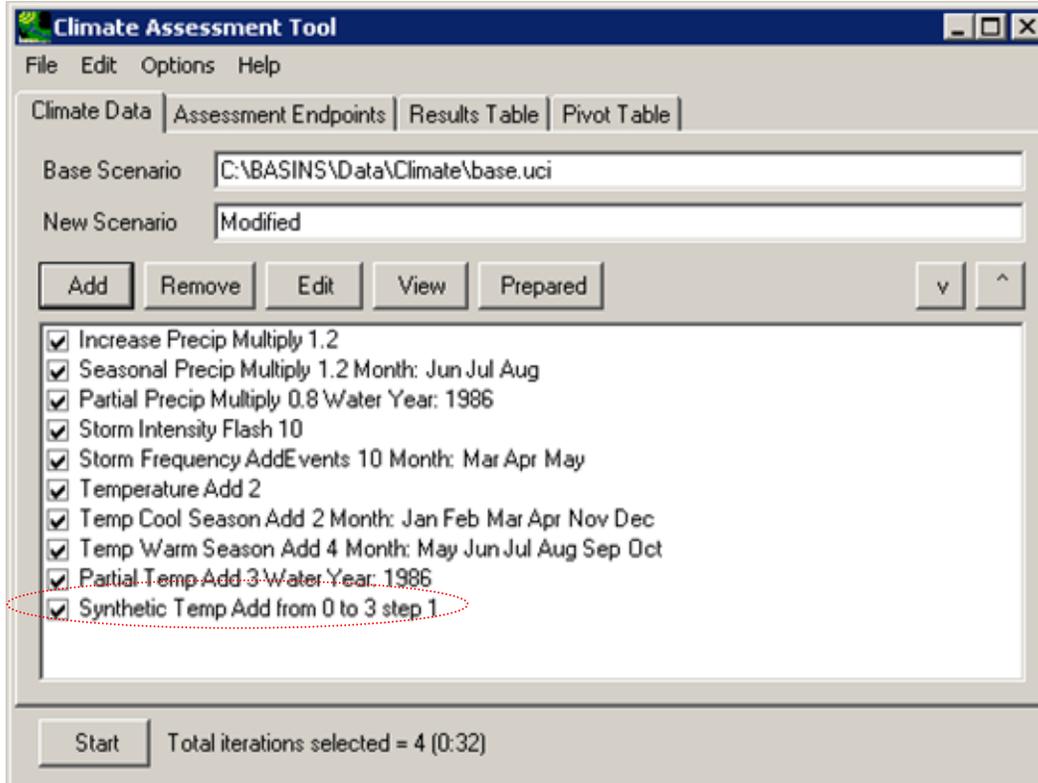
Ok Cancel

5. The **Modify Existing Data** form has been updated with a description of the selected data set in the **Compute PET** box. The **How to Modify** box contains a list of methods for modifying the data-set values. For this scenario, select the “Change Temperature” option. In the **Degrees to add to each existing temperature value** frame, there are two modification options: **Single Change** or **Iterate Changes**. The term “iterate”, as used here, refers to the automation of multiple runs. The **Single Change** option will result in one adjustment applied to the temperature and PET data sets. The **Iterate Changes** option will result in a series of adjustments to the temperature and PET data sets and is used to create synthetic climate change scenarios as defined in Section 3.3.1.5. Click the **Iterate Changes** radio button and the form will be updated to allow entry of **Minimum** and **Maximum** degree changes along with an **Increment** to apply over that range. Enter a **Minimum** value of “0,” a **Maximum** value of “3,” and an **Increment** value of “1.” This will create a synthetic scenario with four iterations, the first being identical to the original data, and the ensuing three having 1 additional degree added to historical temperature data with PET data being computed from each. Click the **Ok** button to complete the scenario definition process.

The screenshot shows the 'Modify Existing Data' dialog box with the following settings:

- Modification Name: Synthetic Temp
- Existing Data to Modify: OBSERVED BELTSVIL AIRTMP (View button)
- Compute PET: OBSERVED BELTSVIL PET (View button)
- How to Modify: Change Temperature
- Degrees to add to each existing temperature value:
  - Single Change
  - Iterate Changes
  - Minimum: 0 degrees
  - Maximum: 3 degrees
  - Increment: 1 Increase this much each iteration from Minimum
- Events:
  - Vary precipitation only in the following Events
- Seasons:
  - Vary only in selected
- Buttons: Ok, Cancel

6. The **Climate Assessment Tool** form is now updated to show the newly defined climate scenario. To begin defining the synthetic precipitation scenario, click the **Add** button again.



7. From the **Modify Existing Data** form, enter “Synthetic Precip” in the **Modification Name** field. Next, click in the **Existing Data to Modify** box to select the precipitation data set to be modified. As in step 2, from the **Select data to vary** form, click the **OBSERVED** item from the **Scenario** list. From the **Matching Data** list, click on the data set with the attributes **OBSERVED UPMARLBR HPRECIP**, and then click the **Ok** button. The **Modify Existing Data** form will be updated to show the selected precipitation data set.

**Modify Existing Data**

Modification Name:

Existing Data to Modify:

Compute PET:

How to Modify:

Number to multiply existing data by

Single Change  Iterate Changes

Value  multiplication factor

Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

8. For the synthetic precipitation scenario, select **Multiply Existing Values by a Number** from the **How to Modify** list. As with the synthetic temperature scenario, click on the **Iterate Changes** option in the **Number to multiply existing data by** frame. Enter a **Minimum** value of “1.0,” a **Maximum** value of “1.3,” and an **Increment** value of “0.1.” This will create a synthetic scenario with four iterations, the first being identical to the original data and the ensuing three having 1/10 additional volume added to the historical precipitation data. Click the **Ok** button to complete the scenario definition process.

**Modify Existing Data**

Modification Name: Synthetic Precip

Existing Data to Modify: OBSERVED UPMARLBR HPRECIP

Compute PET: <click to specify PET to replace>

How to Modify: Multiply Existing Values by a Number

Number to multiply existing data by

Single Change  Iterate Changes

Minimum: 1.0 multiplication factor

Maximum: 1.3 multiplication factor

Increment: 0.1 Increase this much each iteration from Minimum

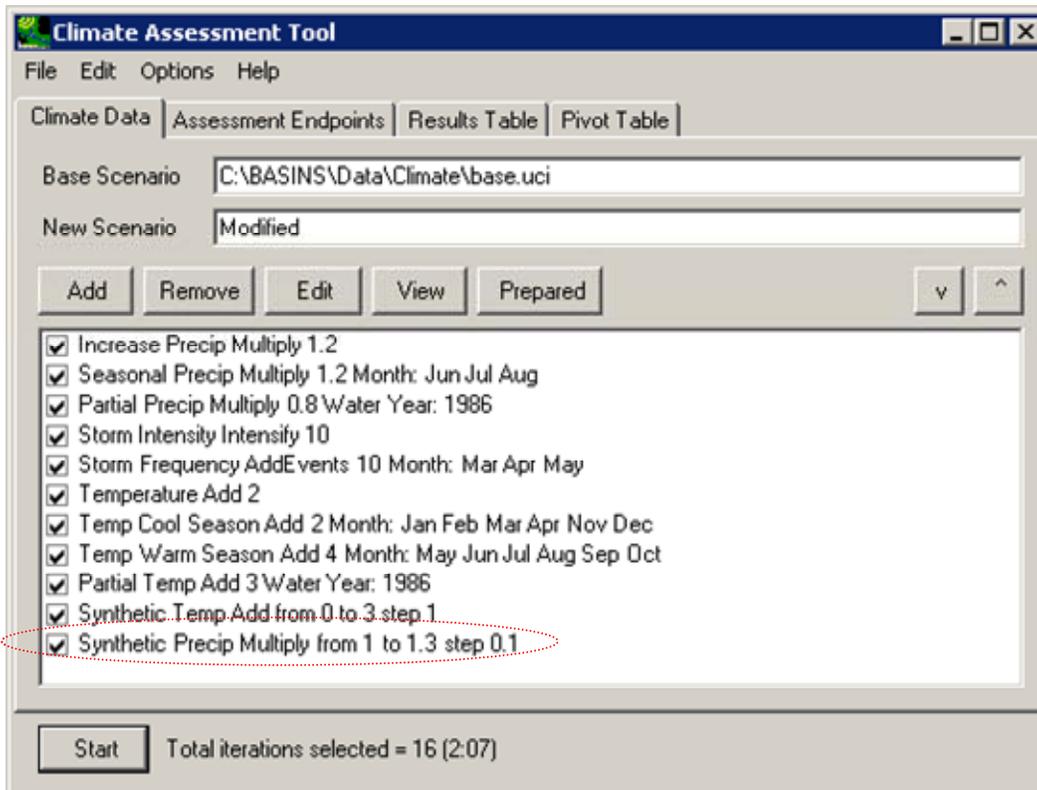
Events

Vary precipitation only in the following Events

Seasons

Vary only in selected

- Click the **Ok** button to complete defining the synthetic precipitation scenario. The newly defined scenario will be shown on the **Climate Assessment Tool** form.



- To complete this tutorial, save the state of BASINS CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

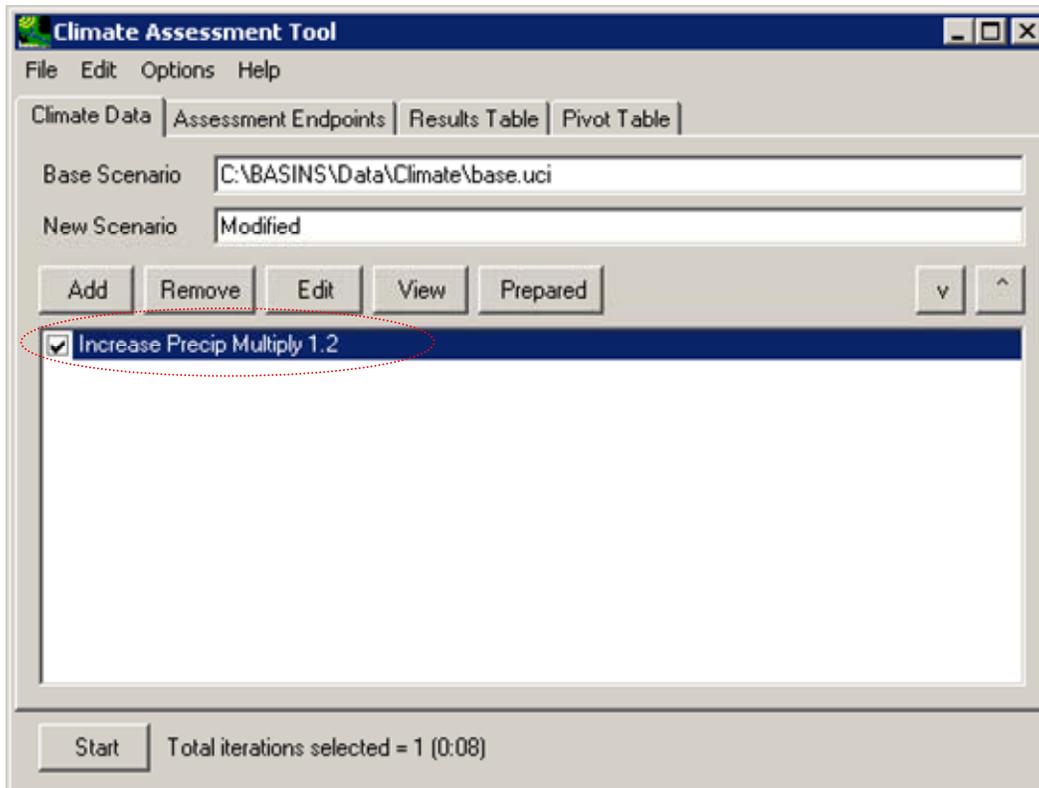
### 5.1.6. Exporting Climate Change Scenarios as ASCII Text Files

This tutorial illustrates how individual record adjustments made using BASINS CAT can be exported to a file for use elsewhere. Examples include a modified temperature or precipitation time series for use with a model external to BASINS. Running this tutorial requires that one or more record adjustments have already been made, such as those illustrated in the previous tutorials (Sections 5.1.1.1 through 5.1.2.3). This tutorial can also be performed using record adjustments other than those shown here.

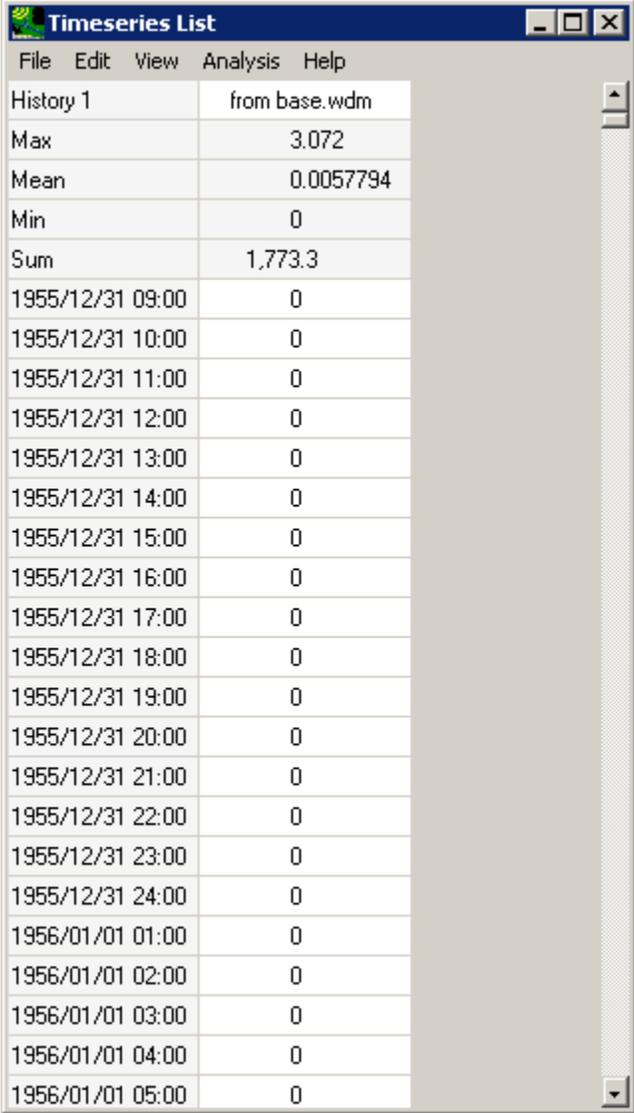
Note that scenarios composed of multiple record adjustments to a single time series, e.g., a temperature record receiving different adjustments for each season of the year, cannot be viewed or saved until an HSPF model run has been made. Accessing this type of modified data is shown in Section 5.4.4.

This tutorial illustrates how to view and save individual record adjustments. Each individual record adjustment made during a BASINS CAT application can be viewed and saved from the **Climate Data** tab.

1. Begin this tutorial by selecting one of the record adjustments shown on the **Climate Data** tab.



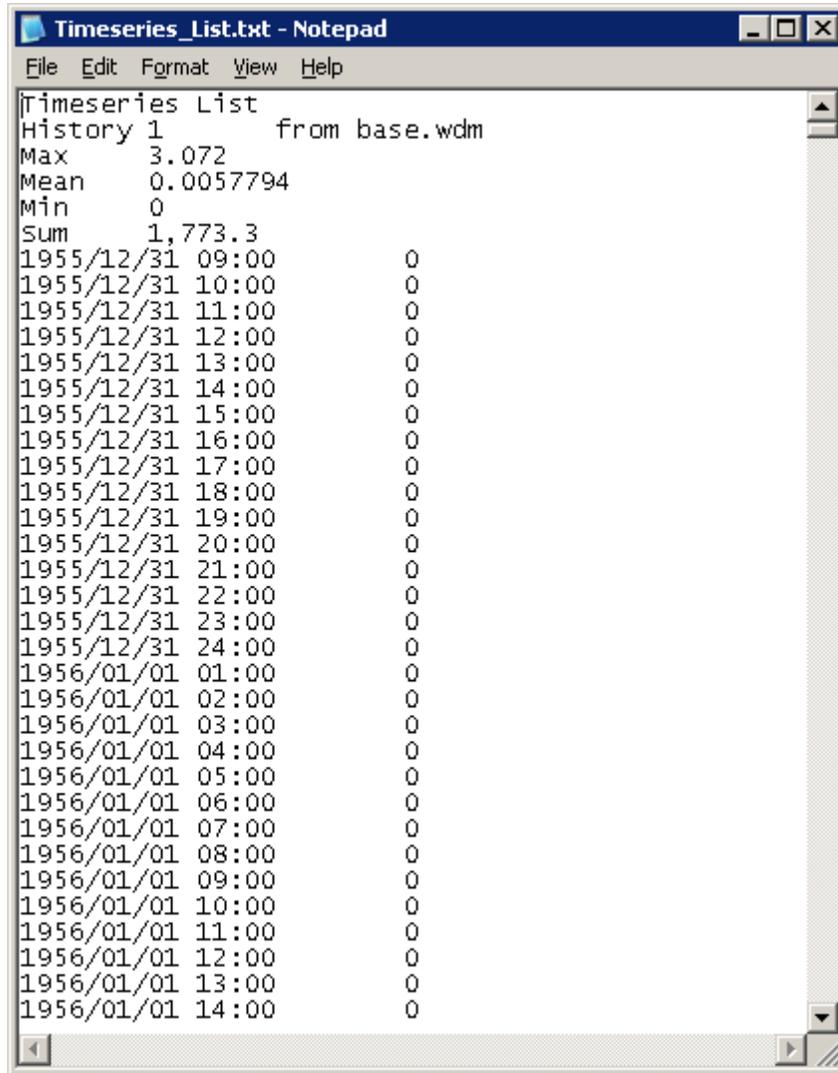
2. Next, click the **View** button and a listing of the modified data set will be displayed.



The screenshot shows a window titled "Timeseries List" with a menu bar containing "File", "Edit", "View", "Analysis", and "Help". The main content area displays a table with two columns. The first column lists various statistics and time intervals, while the second column shows the corresponding values. A vertical scrollbar is visible on the right side of the table.

Timeseries List				
File	Edit	View	Analysis	Help
History 1	from base.wdm			
Max	3.072			
Mean	0.0057794			
Min	0			
Sum	1,773.3			
1955/12/31 09:00	0			
1955/12/31 10:00	0			
1955/12/31 11:00	0			
1955/12/31 12:00	0			
1955/12/31 13:00	0			
1955/12/31 14:00	0			
1955/12/31 15:00	0			
1955/12/31 16:00	0			
1955/12/31 17:00	0			
1955/12/31 18:00	0			
1955/12/31 19:00	0			
1955/12/31 20:00	0			
1955/12/31 21:00	0			
1955/12/31 22:00	0			
1955/12/31 23:00	0			
1955/12/31 24:00	0			
1956/01/01 01:00	0			
1956/01/01 02:00	0			
1956/01/01 03:00	0			
1956/01/01 04:00	0			
1956/01/01 05:00	0			

- From the **Time series List** form, select the **File:Save** menu option and a file dialogue form will allow the user to specify the file to which the listing is to be saved. The values will be saved in a tab-separated format as shown below.



```
Timeseries List
History 1      from base.wdm
Max      3.072
Mean     0.0057794
Min      0
Sum      1,773.3
1955/12/31 09:00      0
1955/12/31 10:00      0
1955/12/31 11:00      0
1955/12/31 12:00      0
1955/12/31 13:00      0
1955/12/31 14:00      0
1955/12/31 15:00      0
1955/12/31 16:00      0
1955/12/31 17:00      0
1955/12/31 18:00      0
1955/12/31 19:00      0
1955/12/31 20:00      0
1955/12/31 21:00      0
1955/12/31 22:00      0
1955/12/31 23:00      0
1955/12/31 24:00      0
1956/01/01 01:00      0
1956/01/01 02:00      0
1956/01/01 03:00      0
1956/01/01 04:00      0
1956/01/01 05:00      0
1956/01/01 06:00      0
1956/01/01 07:00      0
1956/01/01 08:00      0
1956/01/01 09:00      0
1956/01/01 10:00      0
1956/01/01 11:00      0
1956/01/01 12:00      0
1956/01/01 13:00      0
1956/01/01 14:00      0
```

- To end this tutorial, close the **Time series List** form.

## **5.2. TOOLS FOR ASSESSING HYDROLOGIC AND WATER QUALITY ENDPOINTS**

Standard HSPF output files from a simulation using BASINS CAT can be saved for later analysis (see the tutorial in Section 5.3). BASINS CAT also provides, however, a post-processing capability for calculating different hydrologic and water quality endpoints based on HSPF output time series data. As used here, an endpoint is any metric or value of concern that the user wishes to compute from the output of an HSPF simulation. Endpoints can range from simple (e.g., mean streamflow, annual sediment load) to complex (e.g., n-day frequency flow values).

The tutorials in this section illustrate how to:

- Select endpoints to be calculated from HSPF output time series data
- Specify value ranges of concern
- Specify time periods of concern

### **5.2.1. Endpoint Options**

To begin this tutorial, the Climate Assessment Tool form should be displayed with the “\Basins\Data\Climate\base.uci” file as the Base Scenario, “Modified” as the New Scenario, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

This tutorial shows how assessment endpoints are specified with BASINS CAT. The final result of this tutorial is the specification of two assessment endpoints: one for streamflow, and one for total nitrogen loading.

1. The defining of endpoints is performed through the **Assessment Endpoints** tab on the BASINS CAT form. Click on this tab. Begin defining a new endpoint by clicking on the **Add** button. The **Endpoint** form will open. This form contains the controls needed to define an assessment endpoint, including the endpoint name, the model output time series data set to be analyzed, and the attribute of the output data to be calculated. The **Endpoint Name** field is used to provide a text label for identifying the assessment endpoint being created. Begin defining this endpoint by entering “Flow” in the **Endpoint Name** field.

The image shows a screenshot of the 'Endpoint' dialog box in the BASINS CAT software. The dialog box has a title bar with the word 'Endpoint' and standard window controls. The main area contains several input fields and sections:

- Endpoint Name:** A text box containing the word 'Flow', which is circled with a red dashed line.
- Data set:** A text box with the placeholder '<click to select data>'.
- Attribute:** A dropdown menu currently showing 'Mean'.
- Highlight Values:** A section with five rows of color selection:
  - Default Color: White
  - Minimum Value: <none>
  - Color Lower Values: DeepSkyBlue (highlighted in blue)
  - Maximum Value: <none>
  - Color Higher Values: OrangeRed (highlighted in orange)
- Seasons:** A section with a checkbox labeled 'Only include values in selected', which is currently unchecked.

At the bottom right of the dialog box are 'Ok' and 'Cancel' buttons.

- Begin defining the output time series data for the endpoint by clicking in the **Data set** box and the **Select data for endpoint** form will open. A detailed description of this form is found in steps 2 and 3 of the tutorial under Section 5.1.2.1. In the first column, under the **Scenario** label, click on the **SCEN** item and all data sets with a Scenario attribute of SCEN will be added to the **Matching Data** list. In looking at the last column of the **Matching Data** list, note the data set with the **Constituent** name **FLOW**. Click on this data set and it will be added to the **Selected Data** list. Click the **Ok** button to close the form.

**Select data for endpoint**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
<b>SCEN</b>	I:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (4 of 2221)

SCEN	RCH5	TOTAL-N
SCEN	RCH6	SSED
SCEN	RCH5	TN-LOAD
<b>SCEN</b>	<b>RCH5</b>	<b>FLOW</b>

Selected Data (1)

SCEN	RCH5	FLOW
------	------	------

Dates to Include

All  Common

Start 1985/10/01 1985/10/01 1985/10/01

End 1988/09/30 1988/09/30 1988/09/30

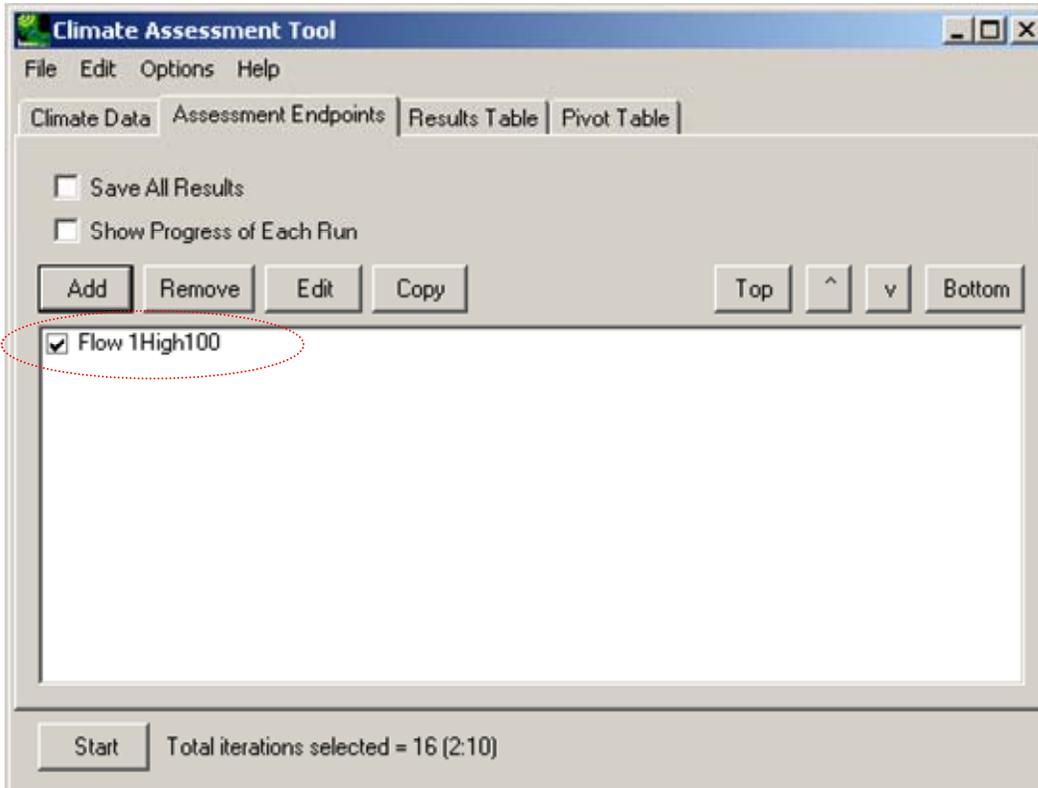
Ok Cancel

3. The **Endpoint** form has now been updated with a description of the selected flow data in the **Data set** box. The **Attribute** pull-down list contains the attributes available for selection as assessment endpoints. BASINS CAT provides a range of attributes, from standard statistics (e.g., mean, sum, standard deviation) to duration-frequency statistics (e.g., 7Q10, 100-year flood). For this example, we will specify an endpoint focused on high flow, so select the **1Hi100** (i.e., 1-day Hi value occurring every 100 years or 100 year flood) item from the list.

The screenshot shows the 'Endpoint' dialog box with the following configuration:

- Endpoint Name: Flow
- Data set: SCEN RCH5 FLOW
- Attribute: 1High100
- Highlight Values:
  - Default Color: White
  - Minimum Value: <none>
  - Color Lower Values: DeepSkyBlue
  - Maximum Value: <none>
  - Color Higher Values: OrangeRed
- Seasons:
  - Only include values in selected

4. Click the **Ok** button to complete defining this endpoint. The **Climate Assessment Tool** form will be updated to show the newly defined end point.



- Next we will define a second assessment endpoint, the average annual total nitrogen load. Begin defining the endpoint by clicking the **Add** button again. Enter “Total N” in the **Endpoint Name** field and then click in the **Data set** box to select the appropriate data set. On the **Select data for endpoint** form, again click the **SCEN** item in the **Scenario** list. From the **Matching Data** list, click on the data set with a constituent name of **TN-LOAD**. Click the **Ok** button to close the form.

**Select data for endpoint**

File Attributes Select Help

Select Attribute Values to Filter Available Data

Scenario	Location	Constituent
OBSERVED	01594526	AGWET
PT-OBS	BELTSVIL	AGWI
<b>SCEN</b>	P:101	AGWO
base	LAUREL	AGWS
	P:101	AIRT
	P:102	AIRTMP

Matching Data (4 of 2221)

SCEN	RCH5	TOTAL-N
SCEN	RCH6	SSED
<b>SCEN</b>	<b>RCH5</b>	<b>TN-LOAD</b>
SCEN	RCH5	FLOW

Selected Data (1 of 2221)

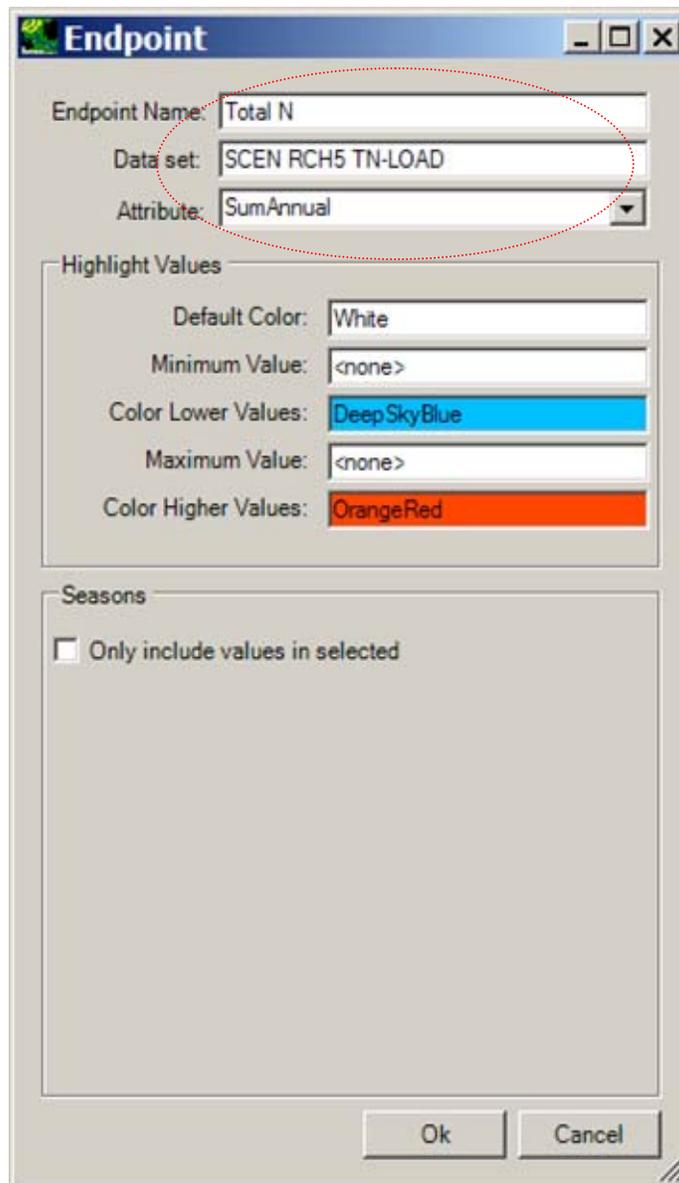
SCEN	RCH5	TN-LOAD
------	------	---------

Dates to Include

Start 1985/10/01 1985/10/01 1985/10/01

End 1988/09/30 1988/09/30 1988/09/30

6. The **Endpoint** form has now been updated with a description of the selected Flow data in the **Data set** box. As opposed to the previous event selected for the flow endpoint, this endpoint will assess annual values. In the **Attribute** list, select the **SumAnnual** item, resulting in an endpoint that reports the average annual total Nitrogen load.

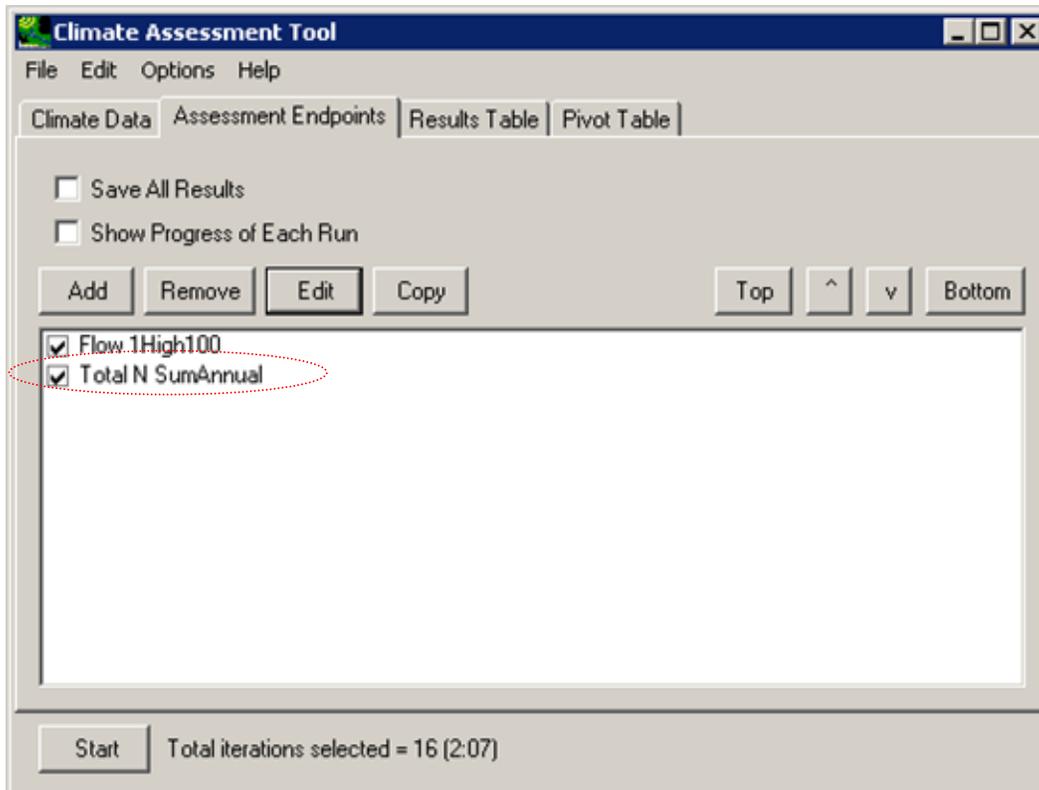


The image shows a software dialog box titled "Endpoint". It contains the following fields and options:

- Endpoint Name:** Total N
- Data set:** SCEN RCH5 TN-LOAD
- Attribute:** SumAnnual
- Highlight Values:**
  - Default Color: White
  - Minimum Value: <none>
  - Color Lower Values: DeepSkyBlue
  - Maximum Value: <none>
  - Color Higher Values: OrangeRed
- Seasons:**
  - Only include values in selected

At the bottom of the dialog are "Ok" and "Cancel" buttons.

7. Click the **Ok** button to complete defining this endpoint. The **Climate Assessment Tool** form now shows both endpoints defined in this tutorial.



8. To complete this tutorial, save the state of CAT, using the **File:Save Climate and Endpoints** menu option, if desired.

### 5.2.2. Specify Value Ranges of Concern

To begin this tutorial, the Climate Assessment Tool form should be displayed with the “\Basins\Data\Climate\base.uci” file as the Base Scenario, “Modified” as the New Scenario, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT provides a capability to visually flag endpoint values in the results table falling within specified ranges. Critically low and/or high values can be entered, along with indicator colors, during endpoint definition. Endpoint values that fall outside of the specified critical range will then be highlighted in the specified indicator color on the results display. This tutorial will demonstrate how to specify value ranges of concern when selecting endpoints.

1. The defining of endpoints is performed through the **Assessment Endpoints** tab on the BASINS CAT form. After clicking on this tab, begin defining a new endpoint by clicking on the **Add** button. The form contains the controls needed to define an assessment endpoint, including the endpoint name, the data set to be analyzed, and the attribute of the data set to be reported. Details of how to define these elements are found in steps 1 through 3 of the tutorial in Section 5.2.1. Begin defining this endpoint by entering “Flow” in the **Endpoint Name** field. Click in the **Data set** box to select the data set to be analyzed using the **Select data for endpoint** form. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 5.1.2.1. On the **Select data for endpoint** form, select the data set with the attributes **SCEN RCH5 FLOW**. Leave the **Attribute** field as the default of **Mean**. The form should now appear as below.

Endpoint

Endpoint Name: Flow

Data set: SCEN RCH5 FLOW

Attribute: Mean

Highlight Values

Default Color: White

Minimum Value: <none>

Color Lower Values: DeepSkyBlue

Maximum Value: <none>

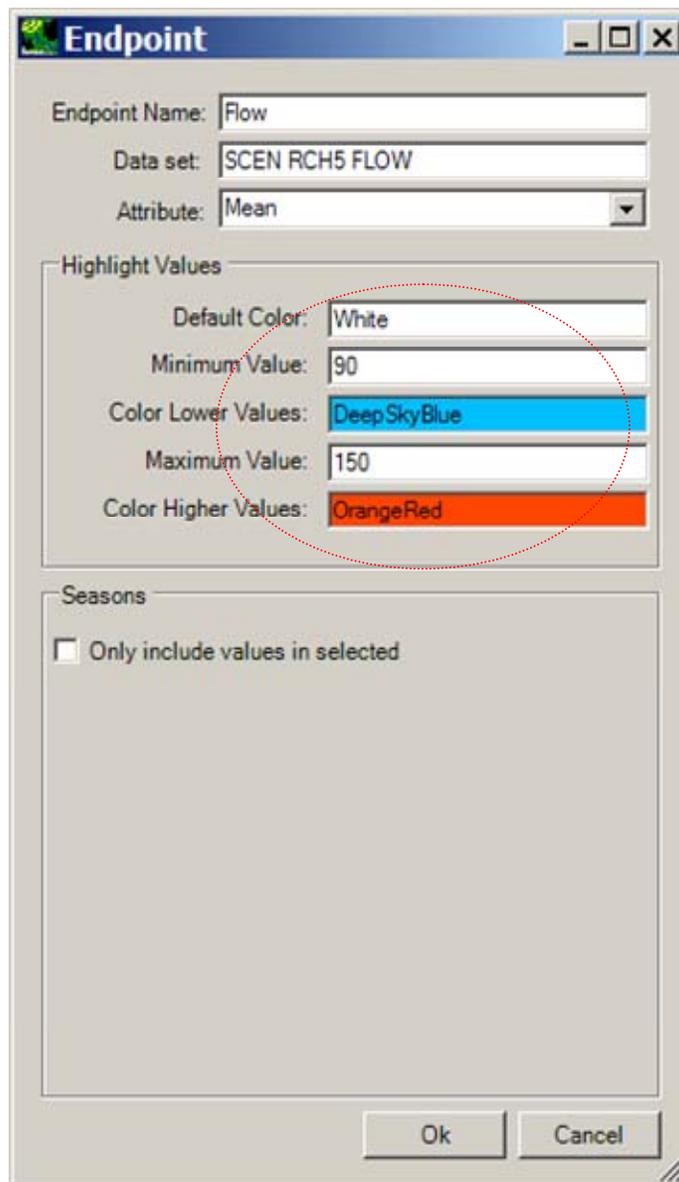
Color Higher Values: OrangeRed

Seasons

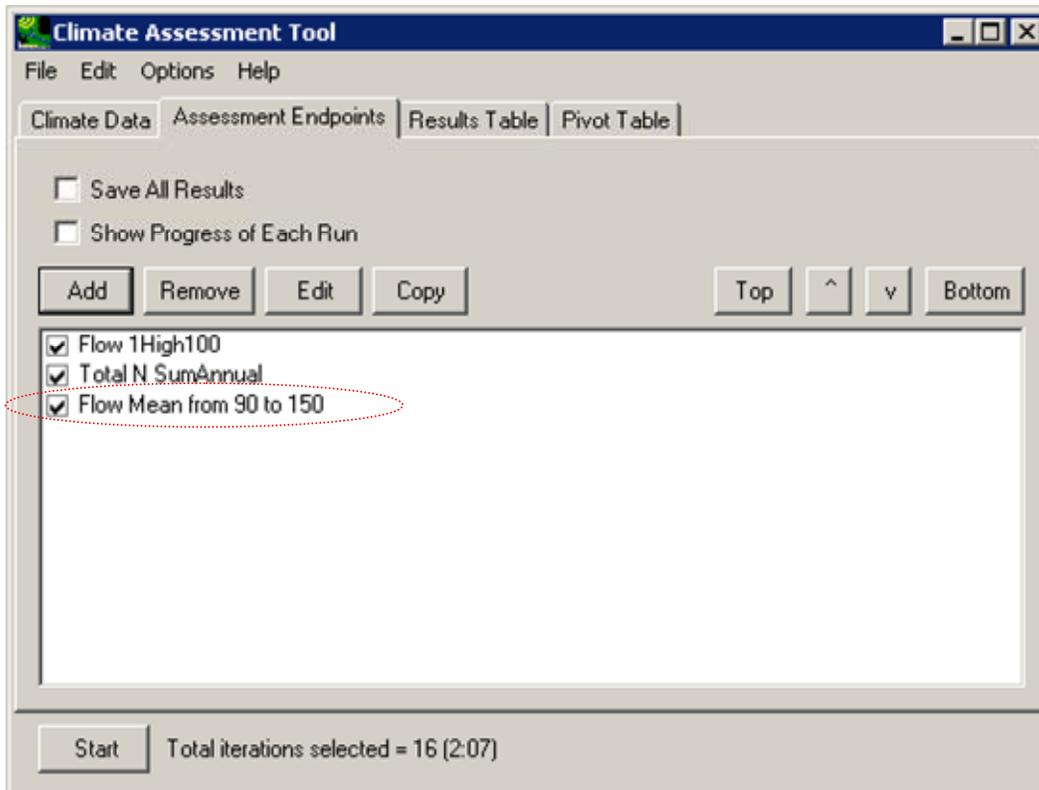
Only include values in selected

Ok Cancel

- The highlight feature in BASINS CAT is provided as an aid to visually interpreting model output. Specifications for this feature are found in the **Highlight Values** frame. In this example, we wish to highlight any streamflow values falling outside of the range from 90 to 150 cubic feet per second. Type in “90” for the **Minimum Value** and “150” for the **Maximum Value**. Results within the specified range will be displayed in cells with the **Default Color** background. Results below the **Minimum Value** will be displayed with the **Color Lower Values** background. Results above the **Maximum Value** will be displayed with the **Color Higher Values** background. Colors for all three ranges can be updated by clicking in the **color** fields.



3. Click the **Ok** to finish defining this endpoint. The newly created endpoint will be displayed on the **Climate Assessment Tool** form.



### 5.2.3. Specify Time Periods of Concern (Seasonal and/or Partial Records)

To begin this tutorial, the **Climate Assessment Tool** form should be displayed with the “\Basins\Data\Climate\base.uci” file as the **Base Scenario**, “Modified” as the **New Scenario**, and the “\Basins\Data\Climate\base.wdm” file added to the BASINS project. These specifications are performed in the BASINS CAT Set-up tutorial in Section 5.0, which must be run before this tutorial.

BASINS CAT provides a capability for calculating assessment endpoints based only on model output time series data within a specified period of time in the model output data set. The selected period of time can be either a series of months or seasons within each year, or a selected year or years within the full output data set. Calculating endpoints based only on selected years within a record can be more appropriate when evaluating climate change scenarios where adjustments are made only to selected years within the record, or a partial record. This tutorial shows how to specify a subset period of time within the full output data set for computing assessment endpoints. The final result of this tutorial is the specification of an assessment endpoint for minimum streamflow during the summer months.

1. The defining of endpoints is performed through the **Assessment Endpoints** tab on the BASINS CAT form. After clicking on this tab, begin defining a new endpoint by clicking on the **Add** button. The **Endpoint** form contains the controls needed to define an assessment endpoint, including the endpoint name, the data set to be analyzed, and the attribute of the data set to be reported. Details of how to define these elements are found in steps 1 through 3 of the tutorial in Section 5.2.1. Begin defining this endpoint by entering “Summer Flow” in the **Endpoint Name** field. Click in the **Data set** box to select the data set to be analyzed using the **Select data for endpoint** form. A detailed description of this form is found in steps 2 and 3 of the tutorial in Section 5.1.2.1. On the **Select data for endpoint** form, select the data set with the attributes **SCEN RCH5 FLOW** from the **Select data for endpoints** form. This endpoint will look at minimum summer flow, so select **Min** from the **Attribute** list. The form should now appear as below.

The screenshot shows the 'Endpoint' dialog box with the following fields and values:

- Endpoint Name: Summer Flow
- Data set: SCEN RCH5 FLOW
- Attribute: Min
- Highlight Values:
  - Default Color: White
  - Minimum Value: <none>
  - Color Lower Values: DeepSkyBlue
  - Maximum Value: <none>
  - Color Higher Values: OrangeRed
- Seasons:
  - Only include values in selected

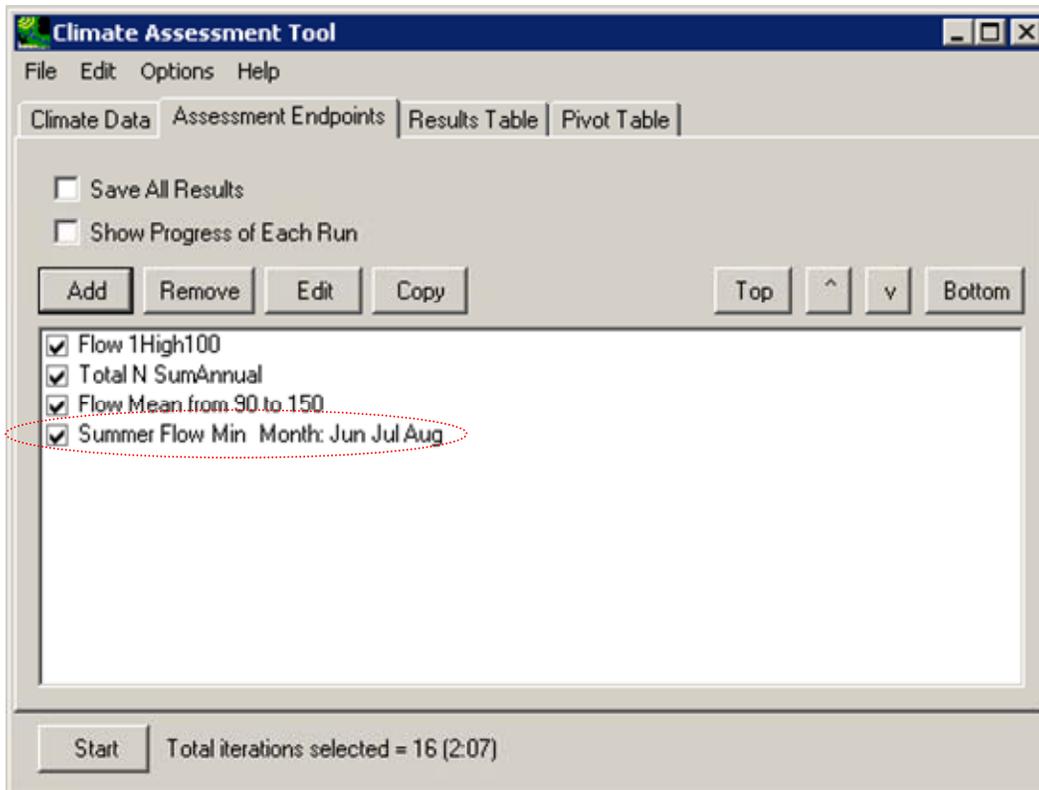
Buttons: Ok, Cancel

2. The **Seasons** frame near the bottom of the form is used for specifying the time period to be used when computing the endpoint value. Begin defining this subset by clicking on the **Only include values in selected** check box and two additional fields will be displayed. The first field is a list of time subset options that includes **Calendar Years**, **Months**, and **Water Years**. The second field will display a list of available time intervals based on the item selected in the first field. For example, selecting **Water Years** from the first field will populate the second field with a list of available water years based on the period of record of the data set. For this example, select the **Months** option and the second field will be populated with the months of the year. Items in the second field can be selected and unselected by clicking on them. Additionally, the buttons below the list can be used to select **All** or **None** of the items. To report endpoint values during summer months, select **Jun, Jul, and Aug**.

The screenshot shows the 'Endpoint' dialog box with the following fields and options:

- Endpoint Name: Summer Flow
- Data set: SCEN RCH5 FLOW
- Attribute: Min
- Highlight Values section:
  - Default Color: White
  - Minimum Value: <none>
  - Color Lower Values: DeepSkyBlue
  - Maximum Value: <none>
  - Color Higher Values: OrangeRed
- Seasons section:
  - Only include values in selected
  - Months (selected from dropdown)
  - List of months: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec. Jun, Jul, and Aug are highlighted in blue.
  - Buttons: All, None
- Buttons: Ok, Cancel

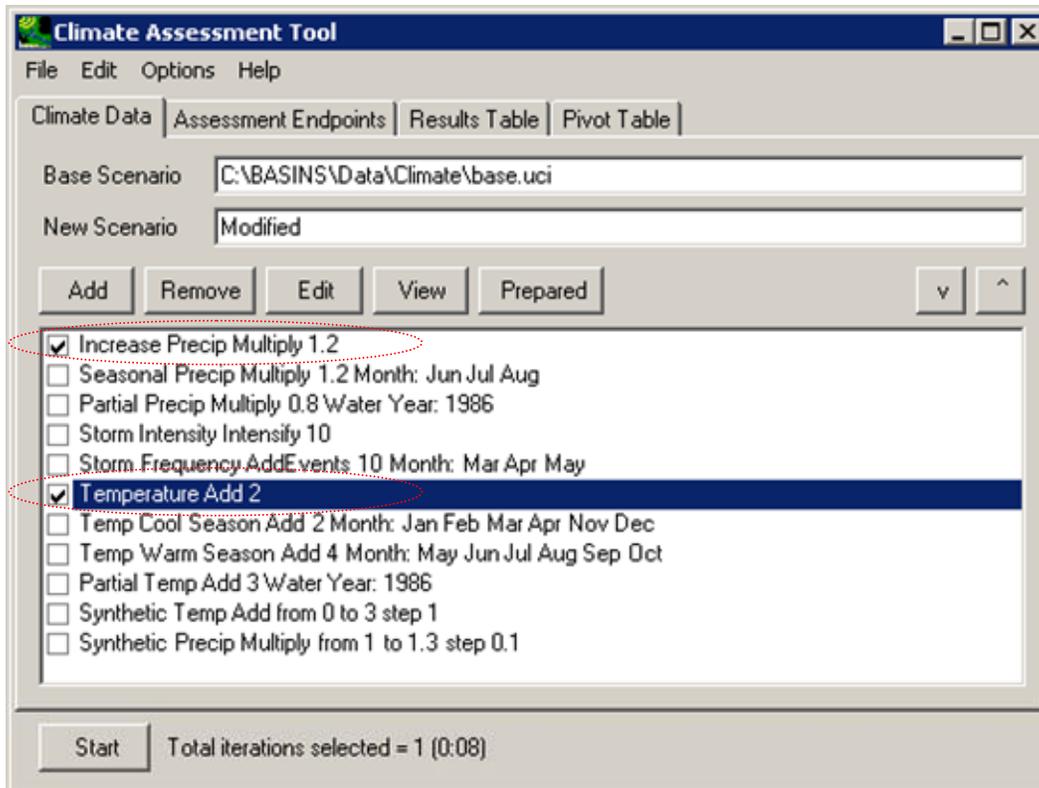
3. Click the **Ok** to complete defining of this endpoint. The newly created endpoint will be displayed on the **Climate Assessment Tool** form.



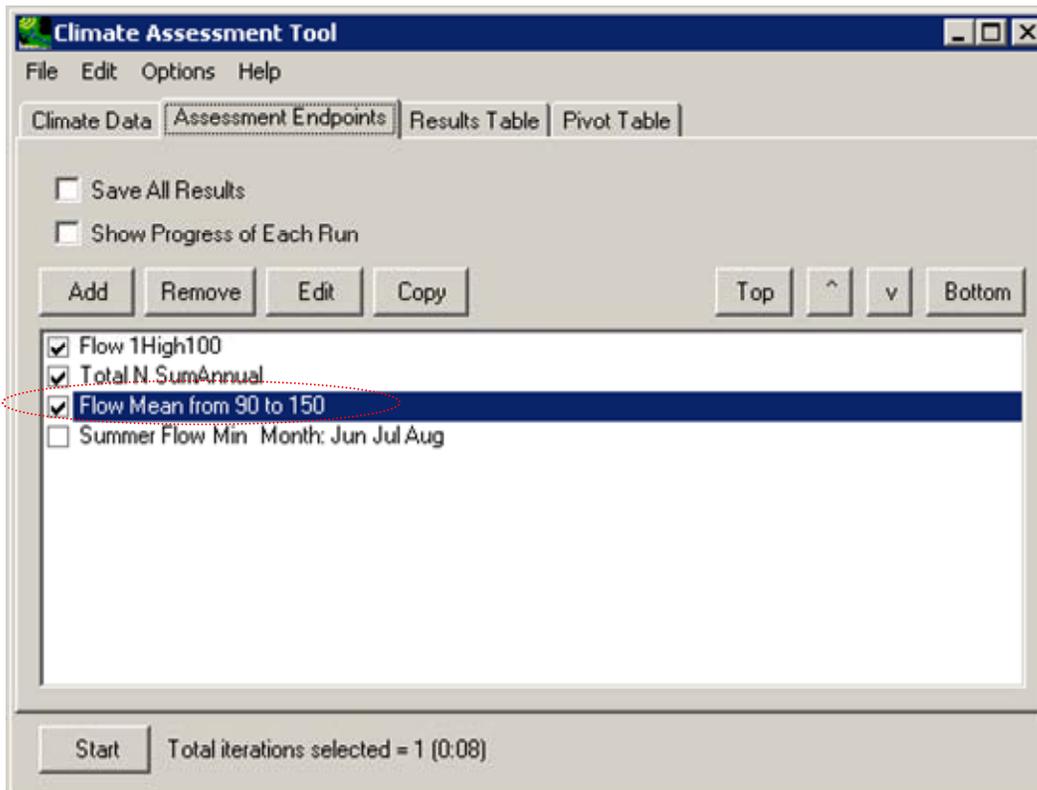
### 5.3. RUNNING AN HSPF SIMULATION USING BASINS CAT

This tutorial demonstrates how to run an HSPF simulation using BASINS CAT. To begin this tutorial, at least one climate change scenario and one hydrologic or water quality endpoint must be defined. Climate change scenarios are defined by selecting any number of record adjustments developed in the tutorials under Section 5.1. Hydrologic or water quality endpoints are defined in the tutorials under Section 5.2. This tutorial refers to climate record adjustments and hydrologic and water quality endpoints defined in the previous tutorials. It is also possible, however, to perform this tutorial using other record adjustments (climate scenarios) and assessment endpoints.

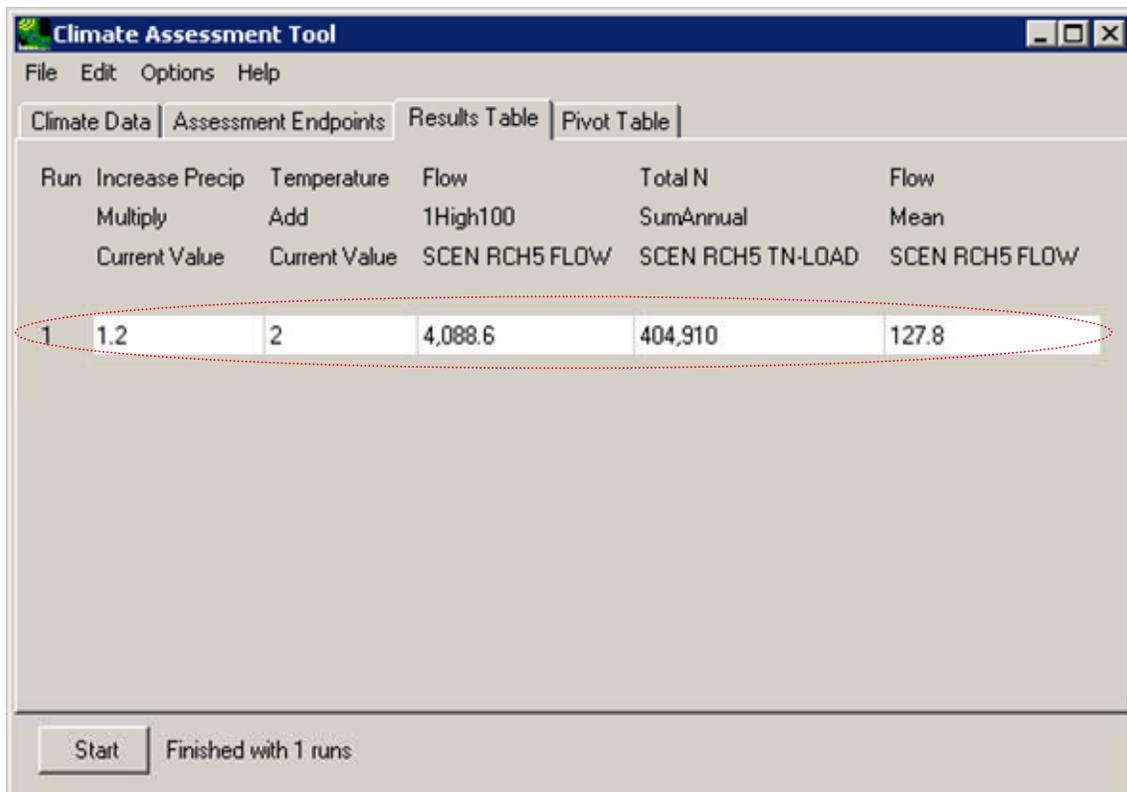
1. The first step in performing an assessment using BASINS CAT is to define the climate scenario(s) to be run by the model. The tutorial in Section 5.1.3 provides examples of this task. Using that tutorial's first scenario as an example, go to the **Climate Data** tab and select the two record adjustments shown below to build a climate scenario for this assessment. Record adjustments are selected by placing a check in the appropriate checkbox. (Note: If you did not perform the tutorials that developed these record adjustments, you can select other adjustments to build a different climate scenario and continue with this exercise.)



- The next step is selecting the hydrologic and water quality endpoints of interest. Any number of endpoints can be selected. For this example, go to the **Assessment Endpoints** tab and select the endpoints shown below. Endpoints are selected by placing a check in the appropriate checkbox. (Note: If you did not perform the tutorials that developed these endpoints, you can select other endpoints and continue with this exercise.)



- Before model execution, two additional options on the **Assessment Endpoints** tab can be set: **Save All Results** and **Show Progress of Each Run**. The **Save All Results** check box is used to specify whether or not all model output time series data is saved, not just the assessment endpoint values. Checking this box will save model output in a new data set. The text entered in the **New Scenario** field on the **Climate Data** tab will be used as the base file name for the new output files. When saving results from synthetic scenarios, this base name will also have model run number added to it (i.e., modified-1, modified-2, etc.). The **Show Progress of Each Run** check box is used to set whether or not a status monitor will be displayed while the model is running. If a model run is particularly long, or a series of model runs are being made using synthetic data, checking this box can be useful to see the progress of the model run(s). For this example, leave these two boxes unchecked. Click the **Start** button to run the model. The **Results Table** tab will be activated to display the endpoint results.



#### 5.4. TOOLS FOR SUMMARIZING AND VISUALIZING RESULTS

The BASINS CAT interface provides standard tabular (results table) and pivot table options for summarizing and visualizing the results of HSPF simulations. Additional graphics and data listing capabilities are also available from within the BASINS system.

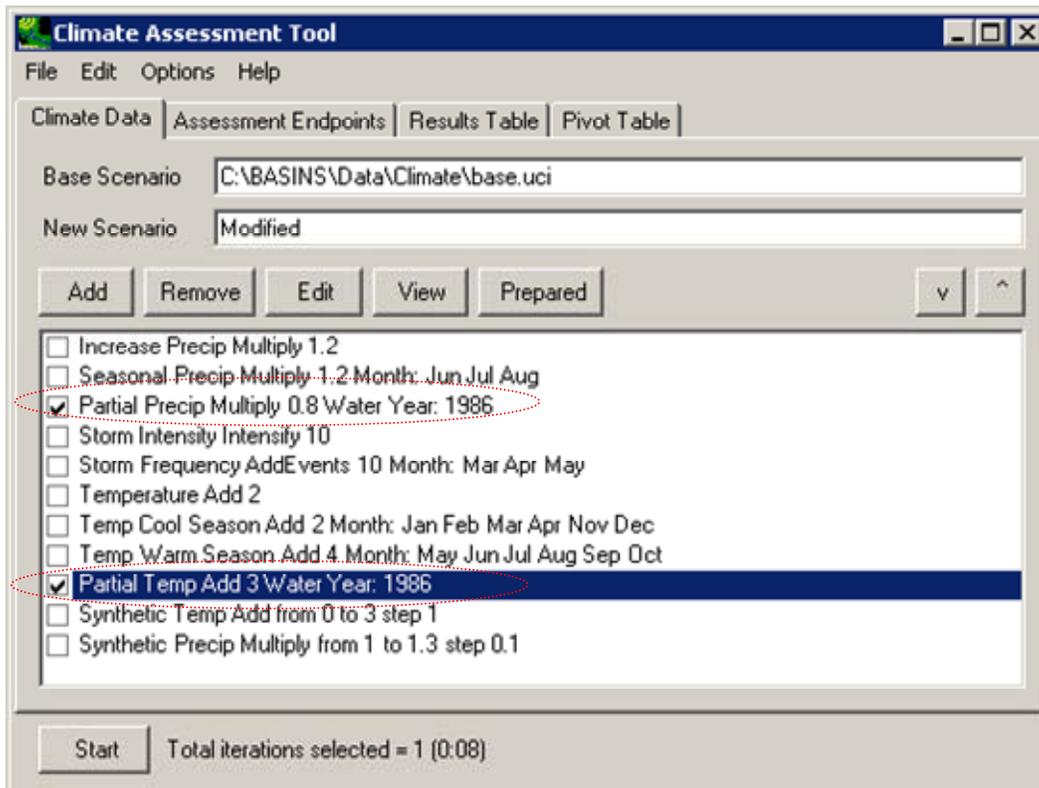
The tutorials in this section illustrate the following options for viewing results:

- Results Tables – BASINS CAT’s tabular output of assessment endpoint values
- Pivot Tables – BASINS CAT’s pivot table output of assessment endpoint values
- Exporting Results - output of assessment endpoint values to files in a format that can be analyzed or visualized using external software
- Additional BASINS Tools - analysis and display features available in BASINS

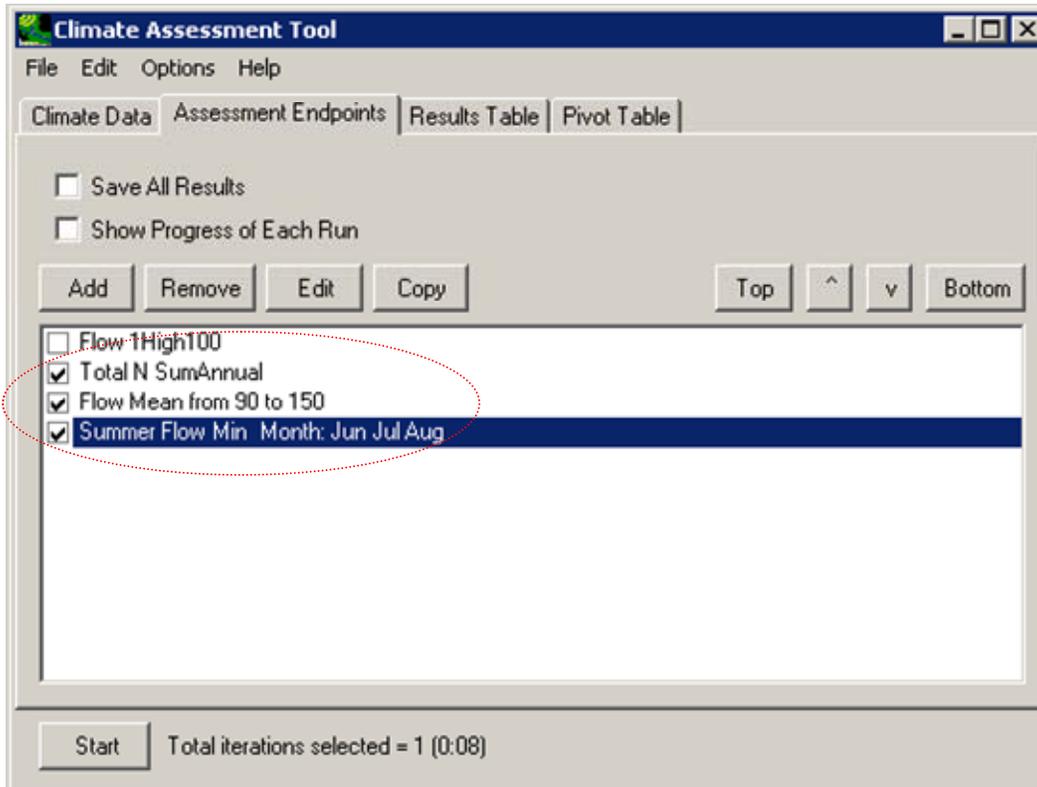
### 5.4.1. Results Tables

This tutorial demonstrates the standard tabular output capabilities of BASINS CAT. To begin this tutorial, at least one climate change scenario and one hydrologic or water quality endpoint must be defined. Climate change scenarios are defined by selecting any number of record adjustments developed in the tutorials under Section 5.1. Hydrologic or water quality endpoints are defined in the tutorials in Section 5.2. This tutorial refers to record adjustments and hydrologic or water quality endpoints developed in previous tutorials. It is also possible, however, to perform this tutorial using other adjustments and endpoints.

1. Begin this example by defining a climate change scenario. Following the second example from the tutorial in Section 5.1.3, go to the **Climate Data** tab and select the record adjustments shown below. (Note: If you did not perform the tutorials that developed these record adjustments, you can select other adjustments to build a different climate scenario and continue with this exercise.)



2. Next, select the hydrologic or water quality endpoints of interest for this assessment. For this example, go to the **Assessment Endpoints** tab and select the endpoints shown below. (Note: If you did not perform the tutorials that developed these endpoints, you can select other endpoints and continue with this exercise.)



- To execute the model run for this assessment, click the **Start** button at the bottom of the form. When the model has completed, BASINS CAT will report the resulting endpoint values on the **Results Table** tab. The BASINS CAT form can be resized to show all resulting values at the same time. Note that for this assessment, the average flow value falls below the minimum value of concern specified for that endpoint (indicated by blue highlighting).

Run	Partial Precip	Partial Temp	Total N	Flow	Summer Flow
	Multiply	Add	SumAnnual	Mean	Min
	Current Value	Current Value	SCEN RCH5 TN-LOAD	SCEN RCH5 FLOW	SCEN RCH5 FLOW
	WaterYear (1986)	WaterYear (1986)			Month (Jun, Jul, Aug)
1	0.8	3	289,260	81.142	10.109

- Output tables in BASINS CAT can also be saved to an external file for use outside of the program. Choose the **Save Results** item from the **File** menu and a dialogue form will prompt for the file name in which the results are to be saved. Results are saved in a tab-delimited format, suitable for import into Excel and other analysis programs.

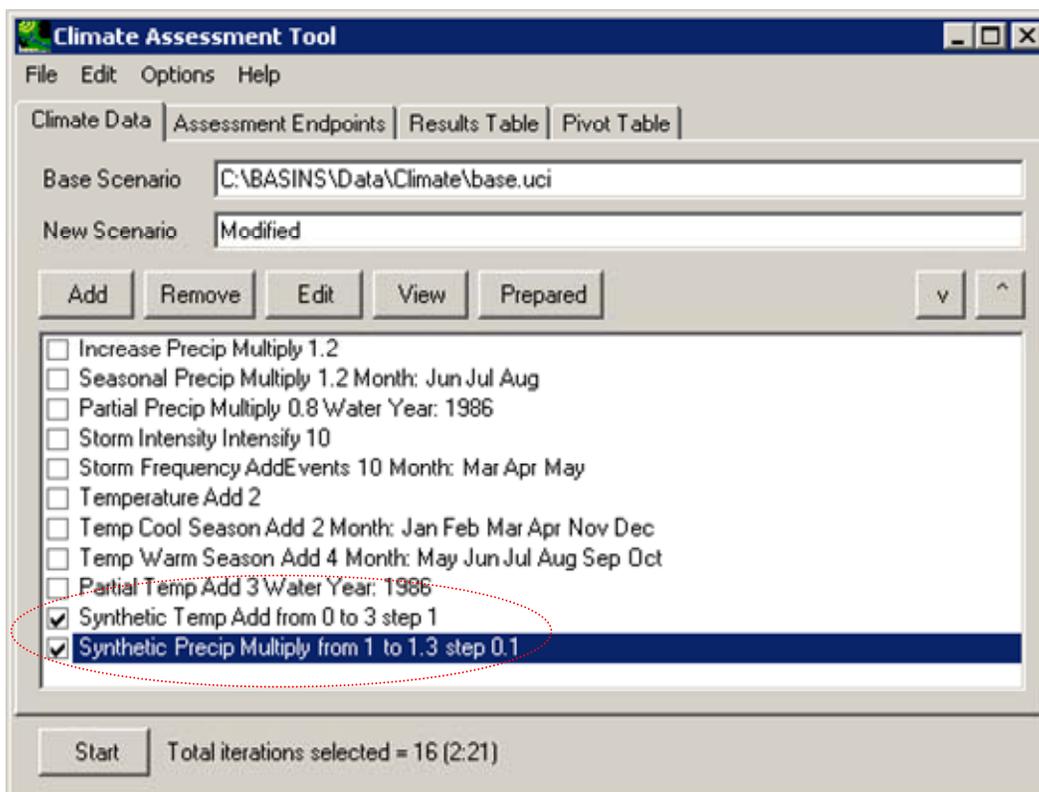
#### 5.4.2. Pivot Tables

This tutorial demonstrates how to view BASINS CAT results in the form of a pivot table. To begin this tutorial, the tutorial in Section 5.1.5 must have been run to create synthetic climate change scenarios for precipitation and temperature. Additionally, at least one hydrologic or water quality endpoint must be defined. Hydrologic or water quality endpoints are defined in the tutorials in Section 5.2.

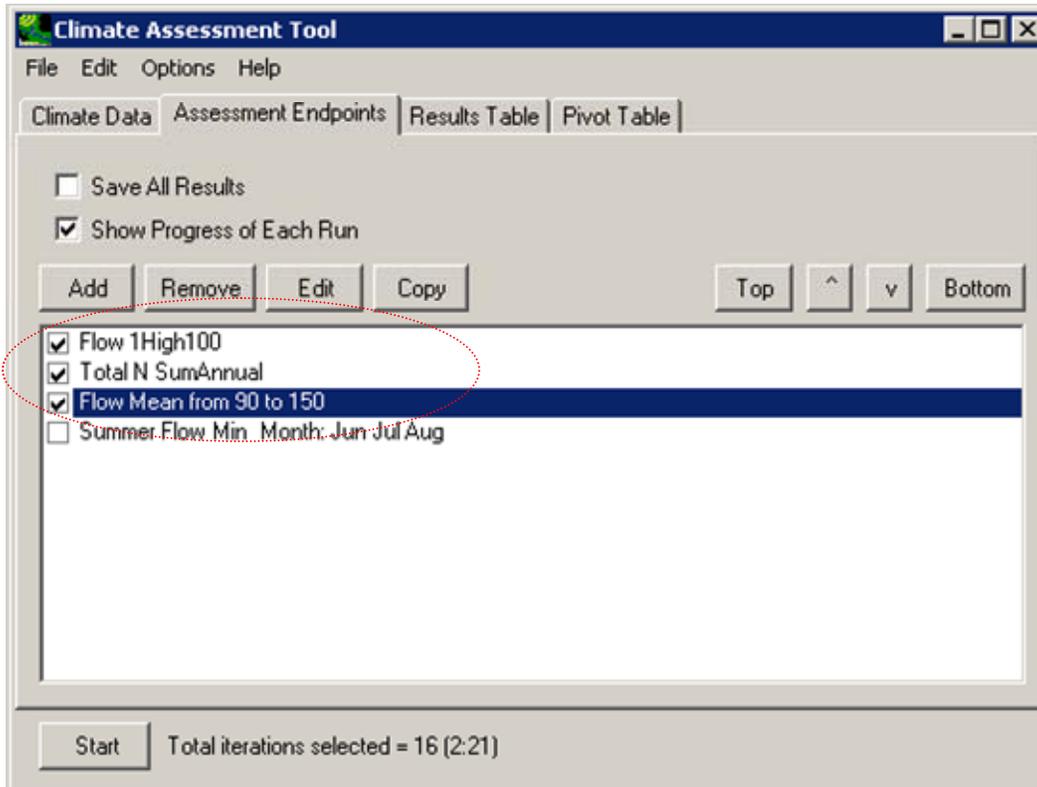
A pivot table is a data visualization and mining tool that allows users to reorganize selected columns and rows of data within a database. The term pivot refers to turning the data to

view it from different perspectives. Pivot tables are useful for summarizing large amounts of data in a compact format, looking for patterns and relationships within a data set, and organizing data into a format suitable for plotting as a chart. The pivot table feature is particularly useful for displaying results produced when running multiple synthetic climate change scenarios.

1. Begin this example by defining a climate change scenario. On the **Climate Data** tab, select the two synthetic climate change scenarios developed in Section 5.1.5, as shown below. Note that since each synthetic scenario has four iterations, a total of 16 model runs will be made, one for each unique combination of precipitation and temperature values.



- Next, select the hydrologic or water quality endpoints of interest for this assessment. For this example, go to the **Assessment Endpoints** tab and select the endpoints shown below. (Note: If you did not perform the tutorials that developed these endpoints, you can select other endpoints and continue with this exercise.)



- Since this assessment will involve 16 model runs, it is advisable to activate the **Show Progress of Each Run** option. This will provide feedback on the rate at which BASINS CAT is processing the model runs. To execute the model runs for this assessment, click the **Start** button at the bottom of the form. When the model has completed, BASINS CAT will report the resulting endpoint values on the **Results Table** tab. Click on the **Pivot Table** tab to explore additional BASINS CAT output features. The first two fields of this form are used to specify what element to vary in the **Rows** and **Columns** of the pivot table. For this exercise, select **Synthetic Temp Add Current Value** and **Synthetic Precip Multiply Current Value** for the **Rows** and **Columns** field values. The **Cells** field is used to specify what element will be displayed in the pivot table's cells. Select **Flow Mean SCEN RCH5 FLOW** for this field and the resulting pivot table will appear as follows.

The screenshot shows the 'Climate Assessment Tool' interface with the 'Pivot Table' tab selected. The 'Rows' dropdown is set to 'Synthetic Temp Add Current Value', the 'Columns' dropdown is set to 'Synthetic Precip Multiply Current Value', and the 'Cells' dropdown is set to 'Flow Mean SCEN RCH5 FLOW'. The resulting pivot table is as follows:

	1	1.1	1.2	1.3
0	95.307	114.23	133.75	153.73
1	92.751	111.44	130.79	150.61
2	90.238	108.69	127.8	147.47
3	87.783	105.98	124.85	144.33

At the bottom of the interface, there is a 'Start' button and the text 'Finished with 16 runs'.

- Note that some of the flow values fall below or above the minimum and maximum values of concern that were specified when defining this endpoint. As desired, users can familiarize themselves with the pivot table's capabilities by changing the selections in the 3 fields above the table.

### 5.4.3. Exporting Results for Use With External Software

This tutorial shows how results from HSPF simulations conducted using BASINS CAT can be exported for analysis and visualization outside of the BASINS system. To perform this tutorial, it is necessary to first complete the tutorial in Section 5.4.2 (Pivot Tables).

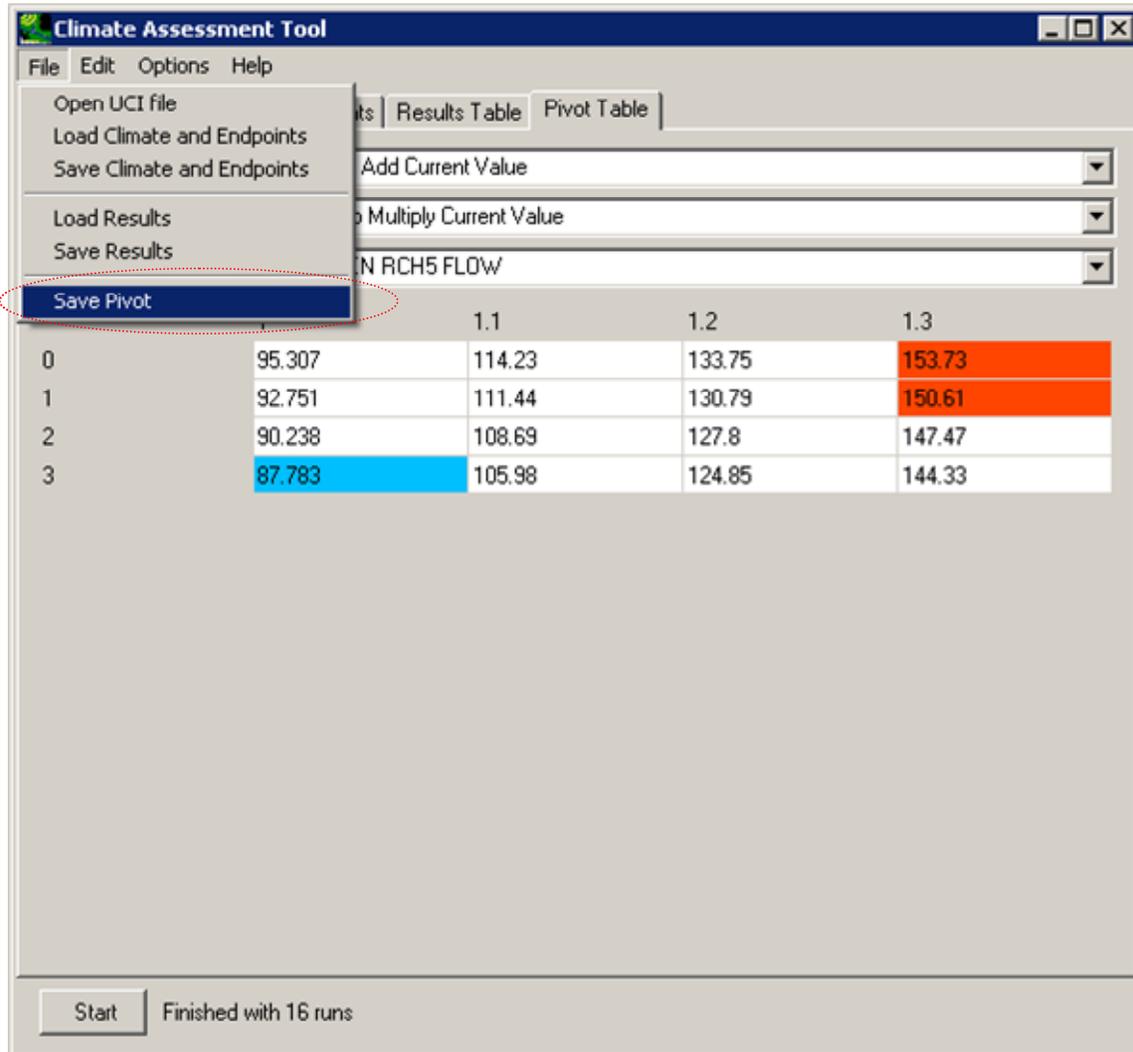
1. This tutorial begins with the final step of the previous tutorial, which should be the display of a pivot table on the BASINS CAT form.

The screenshot shows the 'Climate Assessment Tool' software interface. The window title is 'Climate Assessment Tool'. The menu bar includes 'File', 'Edit', 'Options', and 'Help'. The main area has four tabs: 'Climate Data', 'Assessment Endpoints', 'Results Table', and 'Pivot Table'. The 'Pivot Table' tab is active. Below the tabs, there are three dropdown menus: 'Rows' set to 'Synthetic Temp Add Current Value', 'Columns' set to 'Synthetic Precip Multiply Current Value', and 'Cells' set to 'Flow Mean SCEN RCH5 FLOW'. A data table is displayed with the following values:

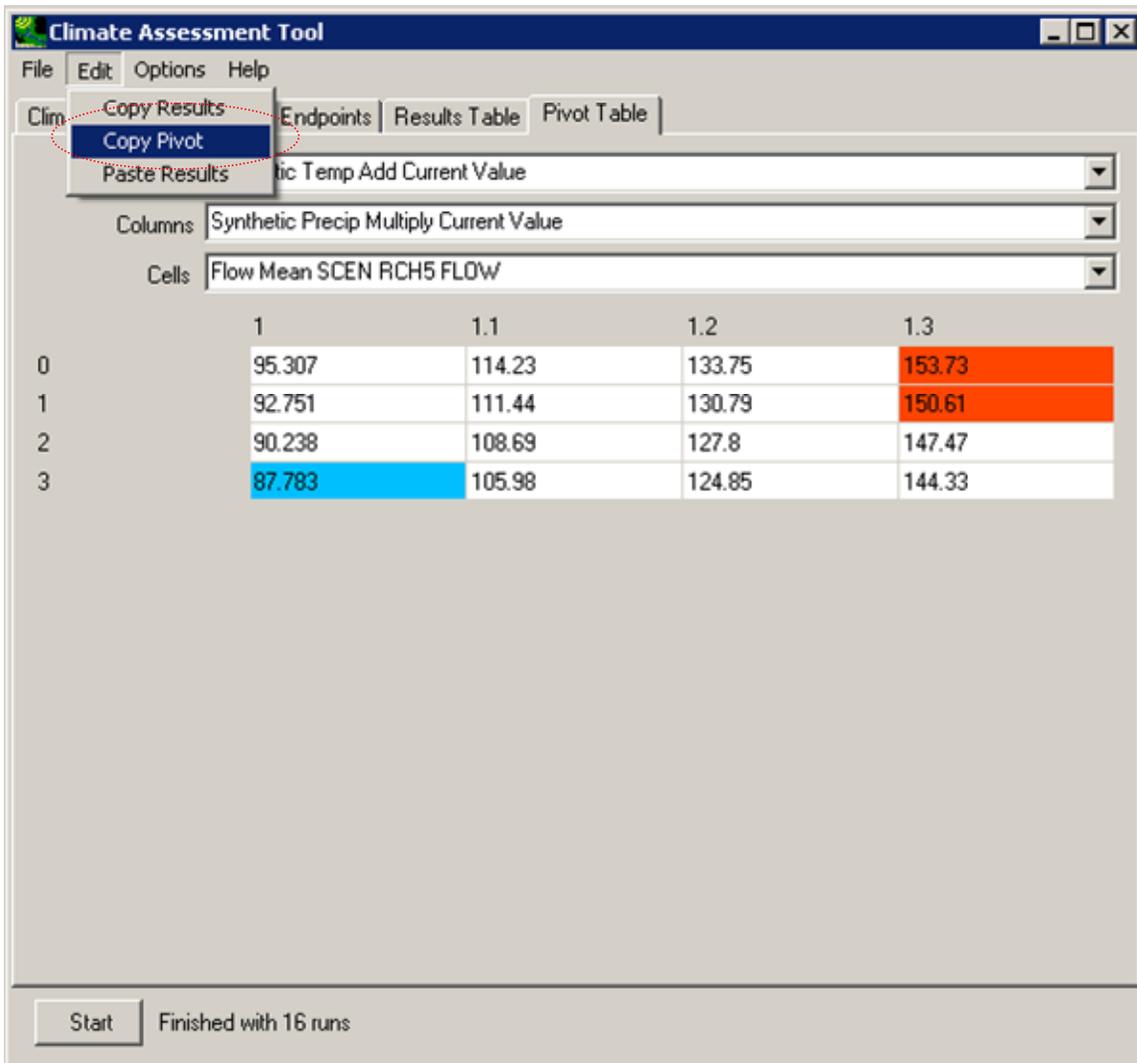
	1	1.1	1.2	1.3
0	95.307	114.23	133.75	153.73
1	92.751	111.44	130.79	150.61
2	90.238	108.69	127.8	147.47
3	87.783	105.98	124.85	144.33

At the bottom of the window, there is a 'Start' button and the text 'Finished with 16 runs'.

- Output results from both the **Pivot Table** can be saved to an external file. The **Save Pivot** option in the **File** menu provides access to saving the table. A file dialogue form will then prompt for the name of the output file. The results will be saved in a tab-delimited format, which are readily imported into Excel and other analysis packages. As described in Section 5.4.1, the Results Table can also be saved to an external file in the same manner.



- Results from the results table or a pivot table can also be copied to the clipboard. These results can then be directly pasted into an external program.

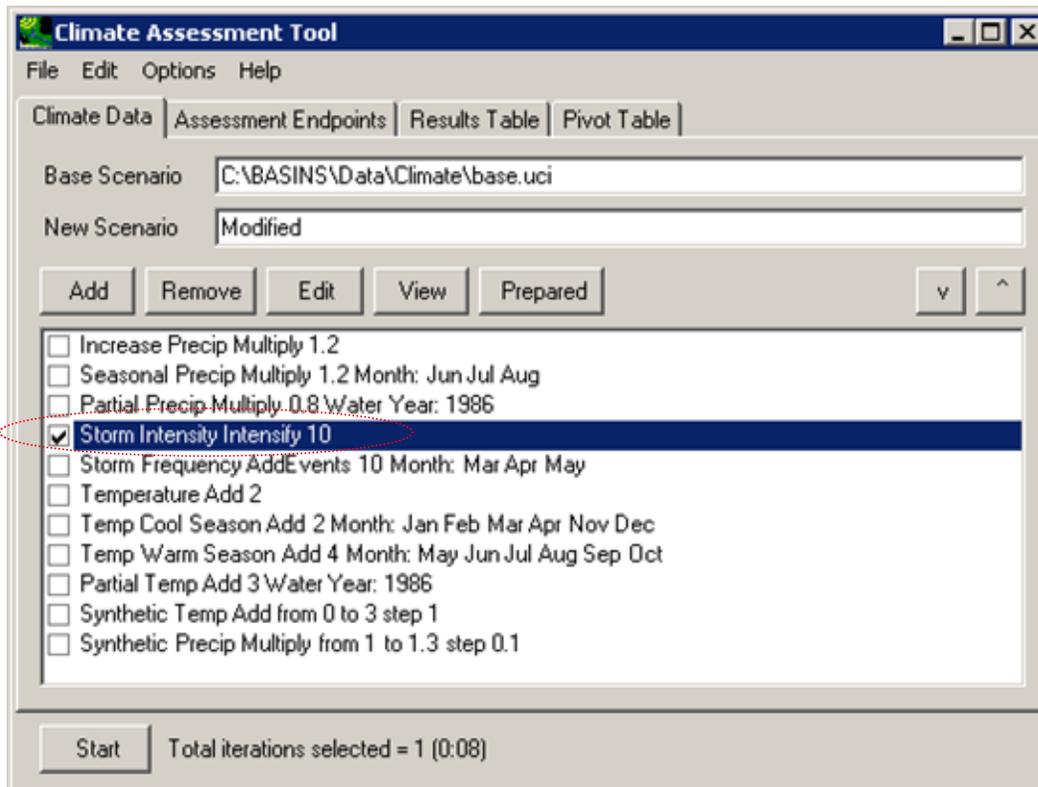


#### 5.4.4. Additional BASINS Tools for Summarizing and Visualizing Results

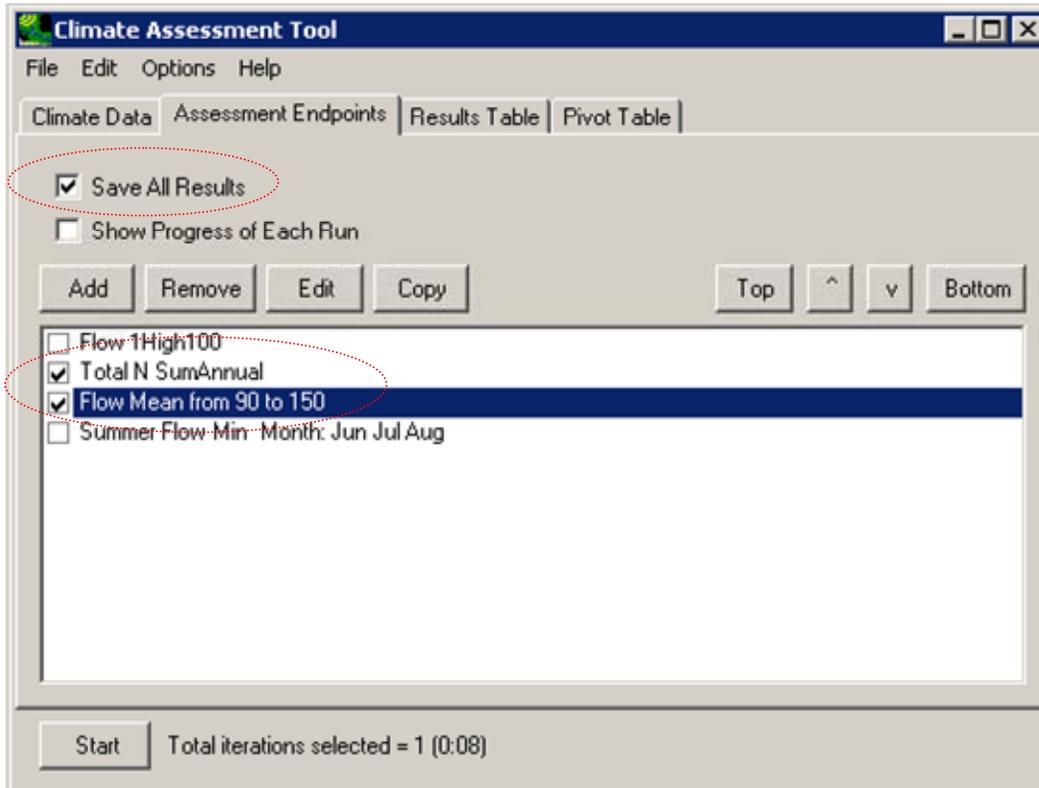
This tutorial demonstrates how to access additional tools within the BASINS system for viewing the results of HSPF simulations using BASINS CAT. To begin this tutorial, at least one climate change scenario and one hydrologic or water quality endpoint must be defined. Climate change scenarios are defined by selecting any number of record adjustments developed in the tutorials under Section 5.1. Hydrologic or water quality endpoints are defined in the tutorials under Section 5.2. This tutorial refers to climate record adjustments and hydrologic and water quality endpoints developed in previous tutorials. It is possible, however, to perform this tutorial using other climate record adjustments and assessment endpoints. More detailed documentation

of data viewing and analysis capabilities within the BASINS system are available from the EPA BASINS web site (<http://www.epa.gov/waterscience/basins/>).

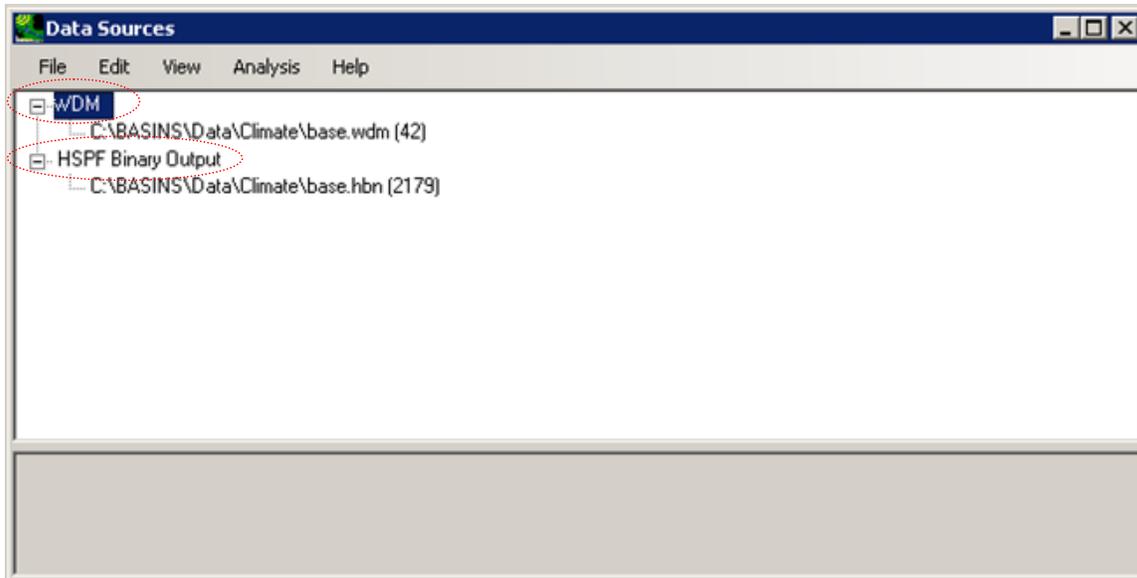
1. Begin this example by defining a climate change scenario. For this example, a simple scenario of intensifying precipitation will be used. (Note: If you did not perform the tutorial that developed this record adjustment, you can select another adjustment to build a different climate scenario and continue with this exercise.)



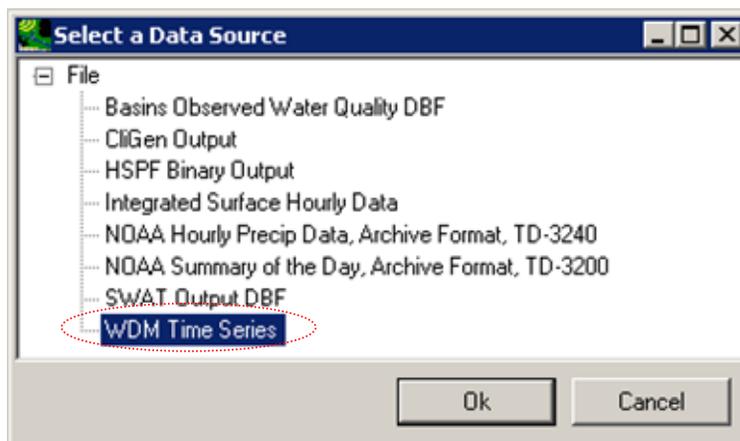
- Next, select the hydrologic or water quality endpoints of interest for this assessment. This example will focus on total nitrogen loads, so go to the **Assessment Endpoints** tab and select the endpoints shown below. (Note: If you did not perform the tutorials that developed these endpoints, you can select other endpoints and continue with this exercise.) This exercise will demonstrate further analysis capabilities within BASINS, so be sure the “Save All Results” option is checked.



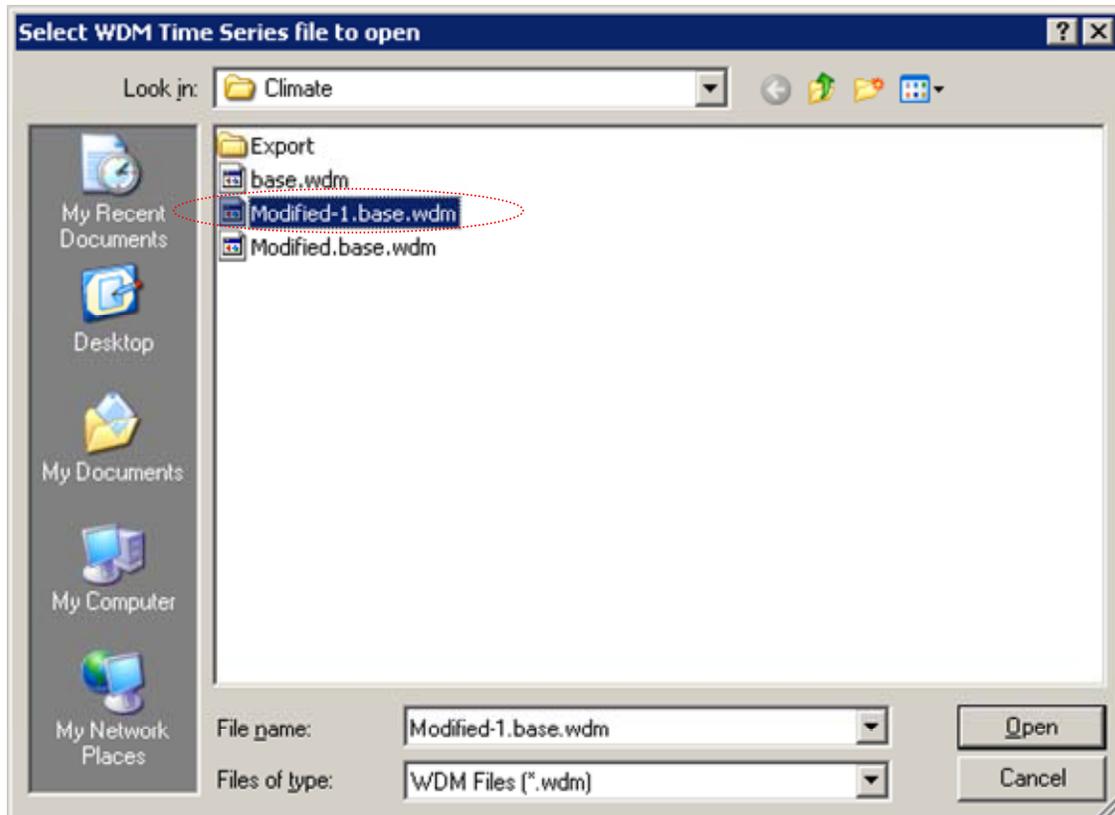
- To execute the model run for this assessment, click the **Start** button at the bottom of the form. When the model has completed, BASINS CAT will report the resulting endpoint values on the **Results Table** tab. To begin using BASINS analysis tools, return to the main BASINS form and select the **Manage Data** option from the **File** menu. The **Data Sources** form shows the data sources that are currently open, these being the WDM and binary output (hbn) file from the Base run. From here the results from the modified climate scenario can be loaded into the current BASINS project. Begin this process by selecting the **Open** option from the **File** menu.



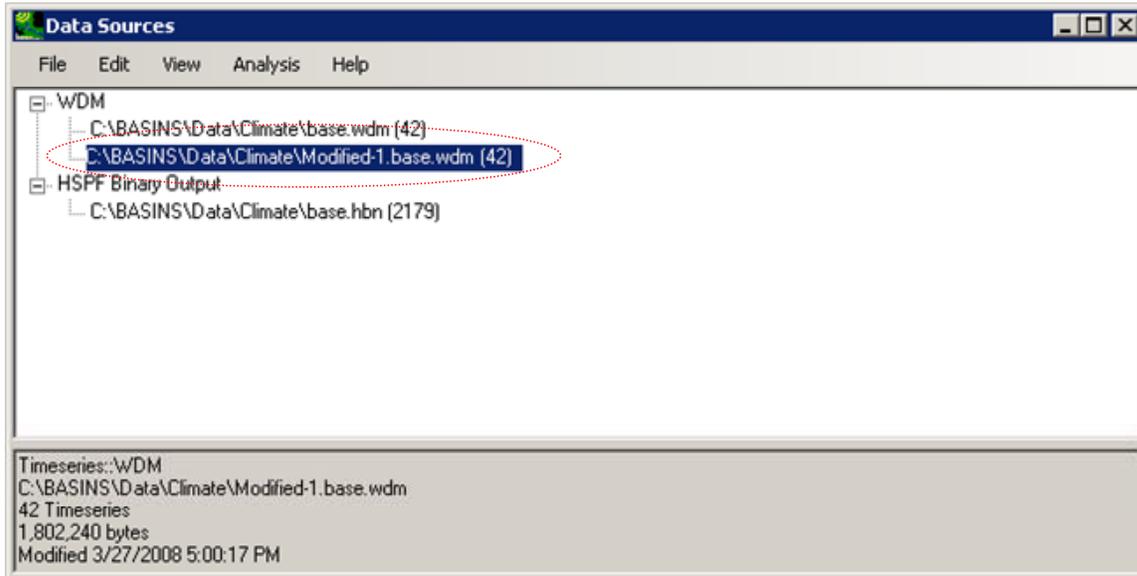
- The **Select a Data Source** form displays the various data formats that BASINS can read. Click on the **WDM Time Series** item and then click the **Ok** button.



5. As BASINS CAT scenarios are run, their results are stored in a copy of the base WDM file, but containing the modified input and output data. The file name is comprised of the **New Scenario** and **Base Scenario** names (e.g., modified.base.wdm). If multiple scenarios are run and the **Save All Results** option is selected (as in step 2 above), additional WDM file copies are created with numbers inserted in their file names. The most recently run scenario will be stored in the WDM file with the largest number. On the ensuing dialogue form, select the WDM file starting with “modified” and having the highest number, if any, in the file name.



6. The **Data Sources** form will now list this WDM file along with the “Base” files.



- The **Data Sources** form can now be closed. The **Analysis** menu contains a variety of features to aid in assessment. To view the daily Nitrogen loads, select the **List** option from this menu and the user will be prompted for the data sets to be listed. In the third column, labeled **Constituent**, scroll down and select the **TN-LOAD** item. Two data sets with the same **Scenario**, **Location**, and **Constituent** are available. To distinguish between the two, it is necessary to change the attribute listed in one of the three columns. Go to the first column, labeled **Scenario**, and click the pull-down list at the top of the column. Scroll up the list and select the **Data Source** attribute, which shows the file name of each data set.

Select Data

File Attributes Select Help

Select Attribute Values to Filter Available Data

Data Source	Location	Constituent
C:\BASINS\Data\Climate\Modified+	01594526	TAU
C:\BASINS\Data\Climate\base.hbn	BELTSVIL	<b>TN-LOAD</b>
C:\BASINS\Data\Climate\base.wdm	I:101	TOC
	LAUREL	TOTAL-N
	P:101	TOTAL-P
	P:102	TW

Matching Data (2 of 2263)

Data Source	Location	Constituent
C:\BASINS\Data\Climate\base.wdm	RCH5	TN-LOAD
C:\BASINS\Data\Climate\Modified+	RCH5	TN-LOAD

Selected Data

Dates to Include

All Common

Start none

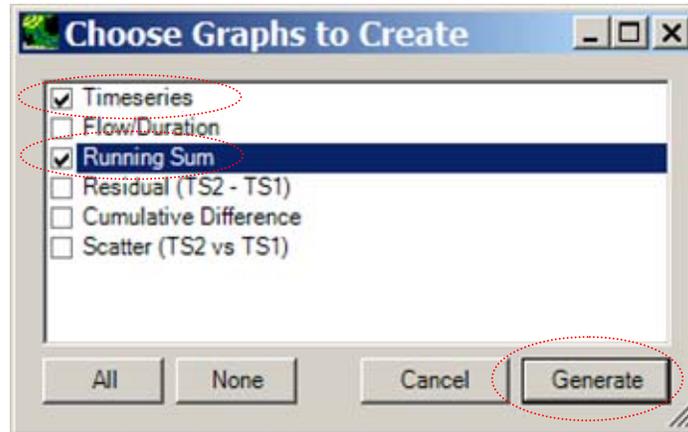
End none

Ok Cancel

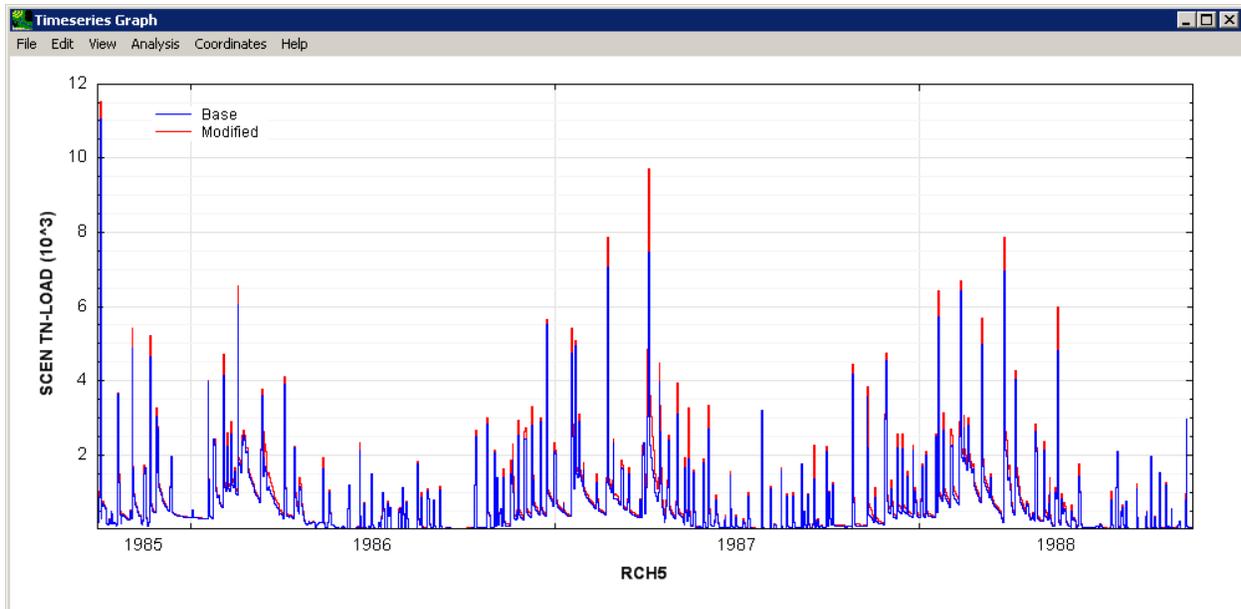
8. Clicking the **Ok** will automatically select the two **Matching** data sets and generate the listing of the data sets' values. A variety of attributes are available for display at the top of the listing. These are accessed through the **File:Select Attributes** menu option. Select this option and customize the listing as desired.

Data Source	C:\BASINS\Data\Climate\base.wdm	C:\BASINS\Data\Climate\Modified-1.base.wdm
Max	11,020	11,504
Mean	625.49	713.03
Min	3.9019	4.3894
Sum	685,540	781,480
SumAnnual	228,510	260,490
1985/10/01 24:00	163.58	163.58
1985/10/02 24:00	849.26	1,006.4
1985/10/03 24:00	11,020	11,504
1985/10/04 24:00	267.79	278.6
1985/10/05 24:00	604.84	650.71
1985/10/06 24:00	679.62	727.14
1985/10/07 24:00	601.42	641.71
1985/10/08 24:00	522.34	556.87
1985/10/09 24:00	259.36	276.52
1985/10/10 24:00	118.9	127.79
1985/10/11 24:00	94.873	101.83
1985/10/12 24:00	239.72	256.34
1985/10/13 24:00	141.76	150.43
1985/10/14 24:00	469.52	476.14
1985/10/15 24:00	390.83	393.01
1985/10/16 24:00	148.28	155.77
1985/10/17 24:00	172.96	181.99
1985/10/18 24:00	121.37	127.5
1985/10/19 24:00	52.456	54.957
1985/10/20 24:00	101.61	106.07

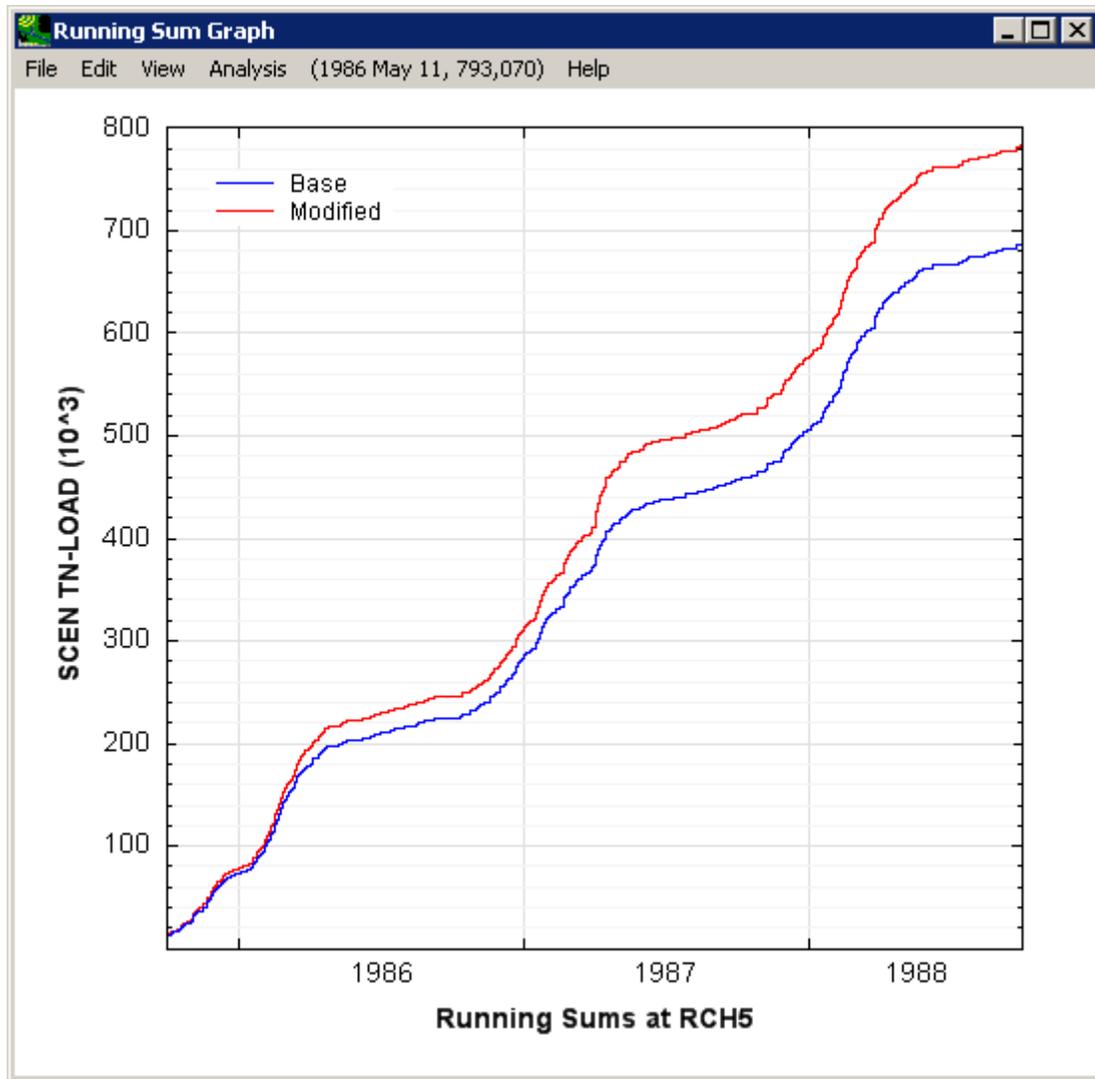
9. The **Analysis** menu on the **Time series List** form contains many of the same analysis functions as the main BASINS form. Select the **Graph** option from the Analysis menu and the **Choose Graphs to Create** form is displayed.



10. To see two examples of different graphs, select the **Time series** and **Running Sum** graphs and then click the **Generate** button.



11. BASINS graphs can be manipulated in a variety of ways including resizing, zooming, and customizing the various graph components.



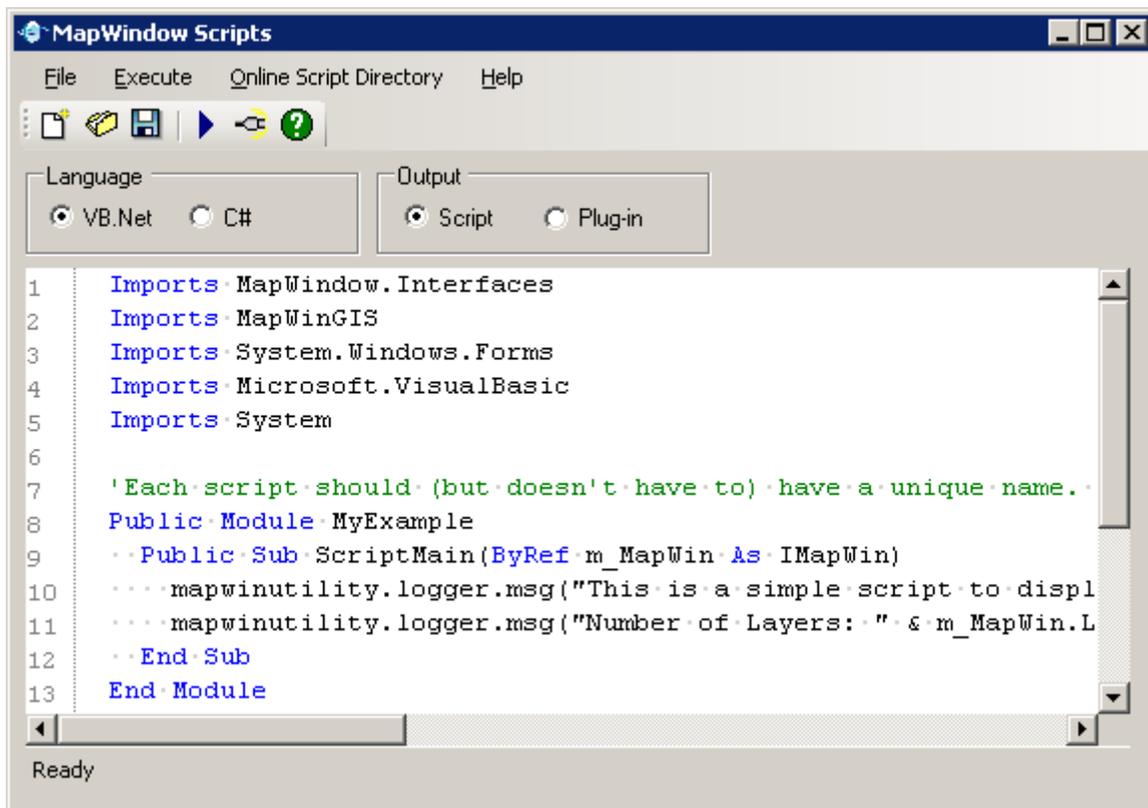
12. Along with listing and graphing, the BASINS system contains many other time series analysis features including duration-frequency computations, seasonal statistic computation, generation of additional time series from existing time series, and creation of time series of distinct events that are above or below a threshold. In particular, the SWSTAT plug-in contains many standard USGS statistical analysis techniques. It is found under the **Analysis** menu on the main BASINS form, though, like BASINS CAT, it may first need to be loaded as a plug-in.

## 5.5. USING SCRIPTS TO AUTOMATE BASINS CAT APPLICATIONS

This tutorial demonstrates how to run scripts from BASINS to perform BASINS CAT functions. Scripts are not necessary to run BASINS CAT, but are a potentially valuable resource for BASINS CAT users. Scripts provide a way to automate repetitive tasks in BASINS CAT, and also create a record of how procedures were accomplished. This tutorial is run from the main BASINS form and requires no actual BASINS CAT interaction.

BASINS is an open-source software product, thus, its source code is readily available to any user. There can, however, be a steep learning curve associated with the use of scripts within BASINS. Users with programming experience may be able to develop scripts with little assistance, while others will likely need additional guidance. Training for using scripts is outside the scope of this document. The MapWindow web site ([www.mapwindow.org](http://www.mapwindow.org)) provides basic materials on developing scripts.

Begin this tutorial by leaving the BASINS CAT form and returning to the main BASINS form. Scripts written in .Net programming languages such as VB.Net or C# can be accessed and run from the BASINS interface. Select the **Scripts...** option from the **Plug-ins** menu and the **MapWindow Scripts** form will be displayed.



The screenshot shows the 'MapWindow Scripts' application window. The title bar reads 'MapWindow Scripts'. The menu bar includes 'File', 'Execute', 'Online Script Directory', and 'Help'. The toolbar contains icons for file operations and execution. Below the toolbar are two groups of radio buttons: 'Language' with 'VB.Net' selected and 'C#' unselected; and 'Output' with 'Script' selected and 'Plug-in' unselected. The main text area displays a VB.NET script with the following code:

```
1 Imports MapWindow.Interfaces
2 Imports MapWinGIS
3 Imports System.Windows.Forms
4 Imports Microsoft.VisualBasic
5 Imports System
6
7 'Each script should (but doesn't have to) have a unique name.
8 Public Module MyExample
9     Public Sub ScriptMain(ByRef m_MapWin As IMapWin)
10        ... mapwinutility.logger.msg("This is a simple script to displ
11        ... mapwinutility.logger.msg("Number of Layers: " & m_MapWin.L
12    End Sub
13 End Module
```

The status bar at the bottom of the window displays 'Ready'.

This form provides an interface to open or save existing scripts or to start a new script using the **File** menu or the icons below the menu bar. The **Execute** option allows for a script to be run or for a script to be compiled as a plug-in for use in MapWindow/BASINS. Access to an online repository of scripts is also provided through the **Online Script Directory**.

The code below shows a simple script that performs basic BASINS CAT functions. After a number of declarations (“Const” and “Dim” statements), the WDM file is opened (variable “lOriginalData”) and the data set to be modified is set (variable “lOriginalPrecip”). The climate variations for this assessment are then specified (variable “lVariation”), including the “Name,” the “Operation” type, the “Min” and “Max” value, and the “Increment.” In this case, there will only be one variation, an increase of 10% (i.e., multiply by 1.1) to the historical precipitation record. The assessment is then run with a call to “modCAT.ScenarioRun” and the model output time series data are stored in the variable “lResults.” Lastly, the script simply reports the count of output time series. The script could readily be expanded to extract additional and more detailed information from the output time series.

```

MapWindow Scripts
File Execute Online Script Directory Help
Language: VB.Net C#
Output: Script Plug-in
1 Imports MapWindow.Interfaces
2 Imports MapWinUtility
3
4 Imports atcUtility
5 Imports atcData
6 Imports atcClimateAssessmentTool
7 Imports atcWDM
8
9 Module ClimateAssessmentFromScript
10     Private Const pTestPath As String = "D:\Basins\data\Climate"
11     Private Const pBaseName As String = "base"
12     Private Const pScenName As String = "scriptDemo"
13
14     Public Sub ScriptMain(ByRef aMapWin As IMapWin)
15         Dim lResults As New atcCollection
16
17         ChDriveDir(pTestPath)
18
19         Dim lOriginalData As New atcDataSourceWDM
20         lOriginalData.Open(pBaseName & ".wdm")
21         Dim lOriginalPrecip As atcTimeseries = lOriginalData.DataSets.FindData("ID", "105").Item(0)
22
23         Dim lVariation As New atcVariation
24         With lVariation
25             .DataSets.Add(lOriginalPrecip)
26             .Name = "Adjust Precip"
27             .ComputationSource = New atcTimeseriesMath.atcTimeseriesMath
28             .Operation = "Multiply"
29             .Min = 1.1
30             .Max = 1.1
31             .Increment = 0.1
32         End With
33         Dim lModifiedData As atcDataGroup = .StartIteration()
34         lResults = modCAT.ScenarioRun(pBaseName & ".uci", pScenName, lModifiedData, "", True, True, True)
35         Logger.Dbg("AllDone:" & lResults.Count)
36     End Sub
37 End Module
38
Ready

```



## **6. A CASE STUDY APPLICATION OF BASINS CAT IN THE MONOCACY RIVER WATERSHED**

This chapter presents a case study application of BASINS CAT assessing the potential effects of climate change on the hydrology and water quality of a mid-Atlantic watershed. BASINS CAT supports a wide range of assessment goals including simple screening studies, representation of more complex scenarios based on climate modeling experiments, and systematic sensitivity analyses of watershed endpoints to specific climate drivers. This case study illustrates just one type of analysis and the data that can be generated using the BASINS CAT. Accordingly, the presentation of results is limited to just a few illustrative examples of analyses performed. Other applications of BASINS CAT could employ different methods for creating scenarios, or focus on hydrologic, water quality, or biological endpoints not considered here.

### **6.1. BACKGROUND AND GOALS**

The Monocacy River flows from south-central Pennsylvania to central Maryland, and is a tributary of the Potomac River and Chesapeake Bay (Figure 6-1). During the latter half of the twentieth century, human activities within the Chesapeake Bay watershed resulted in severe ecological impairment, principally due to nutrient pollution and associated reductions in dissolved oxygen and water clarity. To address this problem, in 1983 a government partnership called the Chesapeake Bay Program (CBP) was established among Maryland, Virginia, Pennsylvania, the District of Columbia, and the federal government with the goal of restoring water quality and living resources throughout the Chesapeake Bay and tributaries.

Future climate change could impact the ability of the CBP to meet restoration goals, but the nature and magnitude of impacts are not well understood (Pyke et al., 2008). The goal of this study was to assess the potential magnitude of climate change impacts on nitrogen, phosphorus, and sediment loading to the Chesapeake Bay. The study focuses on a single, representative Chesapeake Bay subwatershed and the future year 2030. Nitrogen, phosphorus, and sediment were selected as endpoints because of the influence these constituents have on Chesapeake Bay dissolved oxygen, water clarity, and organisms such as crabs, fish, and plankton. The planning horizon of 2030 was selected to be consistent with a concurrent CBP effort assessing the impacts of land-use change on water quality. The results presented here, however, do not consider land-use change.

The Monocacy watershed is 1,927 km<sup>2</sup> in size, with approximately 60% in agriculture, 33% forested, and 7% urban. The city of Frederick, MD, and its suburbs are the largest urban area within the watershed. The Monocacy is categorized as a Maryland Wild and Scenic River,

but it has one of the greatest nonpoint source pollution problems in the state due in large part to runoff from the 3,500 farms, livestock operations, and dairies in the watershed. A USGS stream gage is located near the mouth of the river.



**Figure 6-1. The Monocacy River watershed.**

## **6.2. METHODS**

The Monocacy assessment was conducted using BASINS CAT and the HSPF watershed model to create and run multiple climate change scenarios. Climate change scenarios were created by modifying hourly temperature and precipitation records for a 16-year period of historical data, from 1984 to 2000, from eight NCDC weather stations located within or near the watershed. As discussed previously, this delta change approach allows scenarios to be created at multiple locations throughout the watershed (e.g., NCDC weather stations) while maintaining the existing spatial correlation structure among neighboring locations.

HSPF was considered a good model for this study for two reasons. First, the influence of climate change on watershed processes is complex, and the relatively detailed representation

of watershed processes in HSPF was considered an advantage to adequately capture the system sensitivities to changes in temperature and precipitation. This is particularly true given the focus on the biologically reactive endpoints, nitrogen and phosphorus. Second, it was important that the model used in this study be comparable with a model used by the CBP to assess other program outcomes, the Phase 5 Community Watershed Model, which is based on HSPF. In this study, to ensure consistency with CBP modeling practices, the Monocacy HSPF model in BASINS was set up and parameterized using the same land use, BMP, and parameter values as used by the Phase 5 Community Watershed Model.

### **6.2.1. Regional Climate Change Data**

Climate change scenarios for this study were created based on climate model projection data for the Monocacy Watershed acquired through Penn State University's Consortium of Atlantic Regional Assessments project (CARA; <http://www.cara.psu.edu/>). CARA provides spatially referenced data on projected changes in temperature and precipitation throughout the mid-Atlantic region from climate modeling experiments using seven GCM models from the IPCC Third Assessment Report (IPCC, 2001). Data is provided for each of the seven GCM models, and for two future greenhouse gas emissions storylines, one moderately high (A2), and one moderately low (B2), resulting in a total of 14 climate change scenarios. CARA data are presented as future changes, or deltas, relative to the base period, 1971 to 2000. Data are available for the future periods 2010 to 2039, 2040 to 2069, and 2070 to 2099, and are summarized for each season of the year (Dec/Jan/Feb; Mar/Apr/May; Jun/Jul/Aug; Sep/Oct/Nov). CARA data is interpolated spatially from the original GCM grid resolution to 1/8 degree resolution.

The set of CARA projection data captures a plausible range of future climate change in the Monocacy Watershed. Scenarios based on these projections, in turn, were used to identify the potential range of changes in nitrogen, phosphorus, and sediment loads in the Monocacy River. Note that the CARA web site also includes general information about climate change, the use of climate change scenarios for assessing impacts, and land-use change for the mid-Atlantic region. Additional information about the CARA data is available at <http://www.cara.psu.edu/climate/models.asp>.

### **6.2.2. Scenario Analysis**

Climate change scenarios were created and analyzed in two ways to address different questions about system sensitivity to climate change. The first analysis used a set of synthetic scenarios to gain a fundamental understanding of important system properties, e.g., thresholds

and non-linear behaviors. Synthetic scenarios describe techniques where particular climatic attributes are changed by a realistic but arbitrary amount, often according to a qualitative interpretation of climate model simulations for a region (IPCC-TGICA, 2007). The results of these types of analyses are particularly useful for providing insights about the type and amount of change necessary to threaten a management target or push the system past a threshold. In this study, a set of 42 synthetic scenarios were created and run with the HSPF model reflecting different combinations of arbitrarily assigned changes in temperature and precipitation. Baseline temperatures were adjusted by 0, 2, 4, 6, 8, and 10°F, and baseline precipitation volume by -10, -5, 0, 5, 10, 15, and 20%. In this case, changes in precipitation were made by adjusting all precipitation events in the 1984 to 2000 historical base period using a constant multiplier. Although these scenarios assume arbitrary combinations of potential changes, the ranges of temperature and precipitation change considered reflect projected changes for this region by the end of the century from the CARA data set.

The second analysis in the Monocacy assessment used model-based climate change scenarios created by applying the appropriate change statistics (deltas) from each CARA model projection to an arbitrary base period of historical, hourly temperature and precipitation data (1984 to 2000) from 8 NCDC weather stations used in the Monocacy simulation. Collectively, these represent a set of internally consistent climate change scenarios reflecting different assumptions about future greenhouse gas emissions and different GCM representations of the climate system.

The projected seasonal changes in mean air temperature and precipitation totals relative to the base period 1971 to 2000 were acquired for each of these 14 climate change scenarios in the CARA data set for period 2010 to 2039 (the averaging period in the CARA data set closest to the 2030 planning horizon of the CBP). The CARA data set does not provide any information about changes in precipitation intensity. It is generally expected, however, that as climate changes, a greater proportion of annual precipitation will occur in larger magnitude events (IPCC, 2007). Accordingly, to capture a range of plausible changes in event intensity, scenarios were created for this analysis by applying the projected seasonal changes from each scenario in three ways: (1) as a constant multiplier applied equally to all events within the specified season, (2) as a constant multiplier applied only to the largest 30% of events within the specified season, and (3) as a constant multiplier applied only to the largest 10% of events within the specified season. These 3 assumptions capture a plausible range of future changes in the distribution of precipitation among different magnitude events based on observed trends during the twentieth century (e.g., during this period there was a general trend throughout the United States towards increases in the proportion of annual precipitation occurring in roughly

the largest 30% magnitude events; Groisman et al., 2005). A total of 42 model-based scenarios were thus created (coincidentally, the same number as in the first analysis) based on seasonally variable climate change projections from the CARA data set (14 CARA scenarios and 3 assumptions per scenario for applying projected changes in precipitation).

Each of the 42 scenarios was created using BASINS CAT by specifying a set of adjustments to historical temperature and precipitation time series for the base period, 1984 to 2000. More specifically, each scenario consisted of a set of four adjustments to the historical temperature time series, one for each season of the year; and four adjustments to the historical precipitation time series, one for each season of the year (expressed as a percent change) and assumption about the distribution of precipitation changes among events.

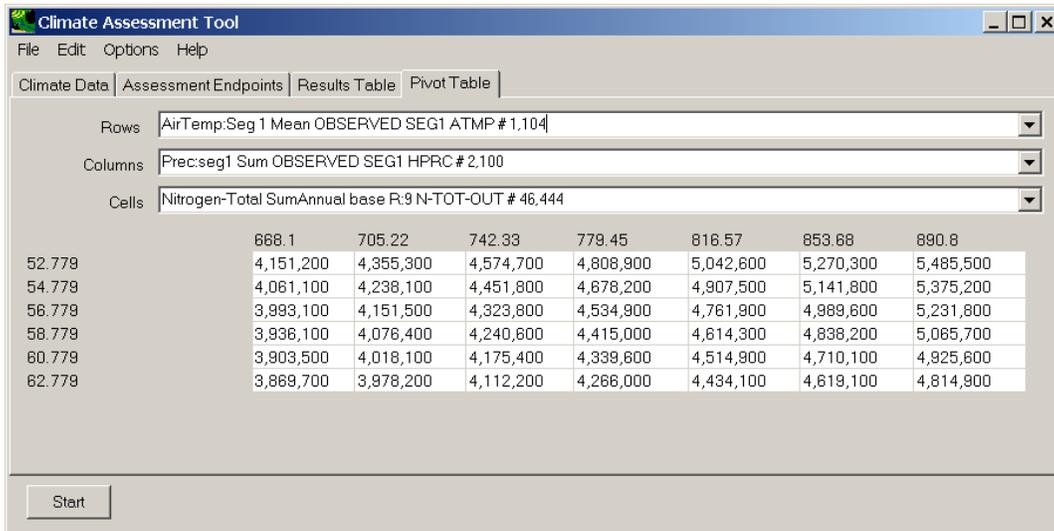
The Monocacy assessment did not consider future changes in land use, sea level rise, or other factors potentially affecting the Chesapeake Bay. All watershed simulations assumed current land use conditions.

### **6.3. RESULTS**

The purpose of this case study is to provide an example of the types of analyses supported by BASINS CAT. Accordingly, this section does not provide a detailed discussion of results and conclusions from the Monocacy assessment. The results presented here are for a single endpoint, mean annual nitrogen loading, and include only a single graphic display of data generated using each analyses discussed above. Other applications of BASINS CAT, depending on the study goals, could involve other methods of analysis, and may address a range of hydrologic, water quality, or biological endpoints.

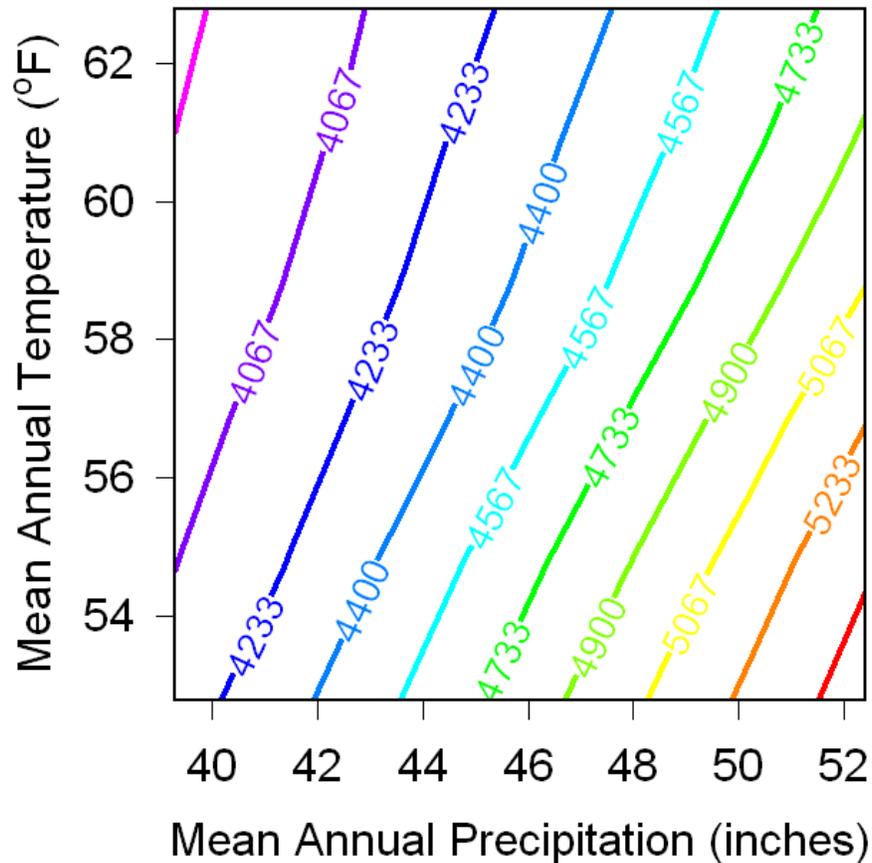
#### **6.3.1. Synthetic Scenarios**

After completing a series of HSPF simulations using BASINS CAT, a summary of results can be viewed by selecting the “Results Table” tab from the BASINS CAT opening form. This data can be exported and used with any third-party database, spreadsheet, or plotting package. In addition, the “Pivot Table” tab in BASINS CAT provides a powerful tool for quickly exploring the response of any selected endpoint as a function of any two other variables. For example, Figure 6-2 shows, in pivot table format, the response of mean annual nitrogen loading in the Monocacy River to changes in mean annual temperature and precipitation based on the analysis using synthetic scenarios.



**Figure 6-2 Pivot table showing the response of mean annual nitrogen loading (pounds per year) in the Monocacy River to changes in mean annual temperature and precipitation based on the analysis using synthetic scenarios.**

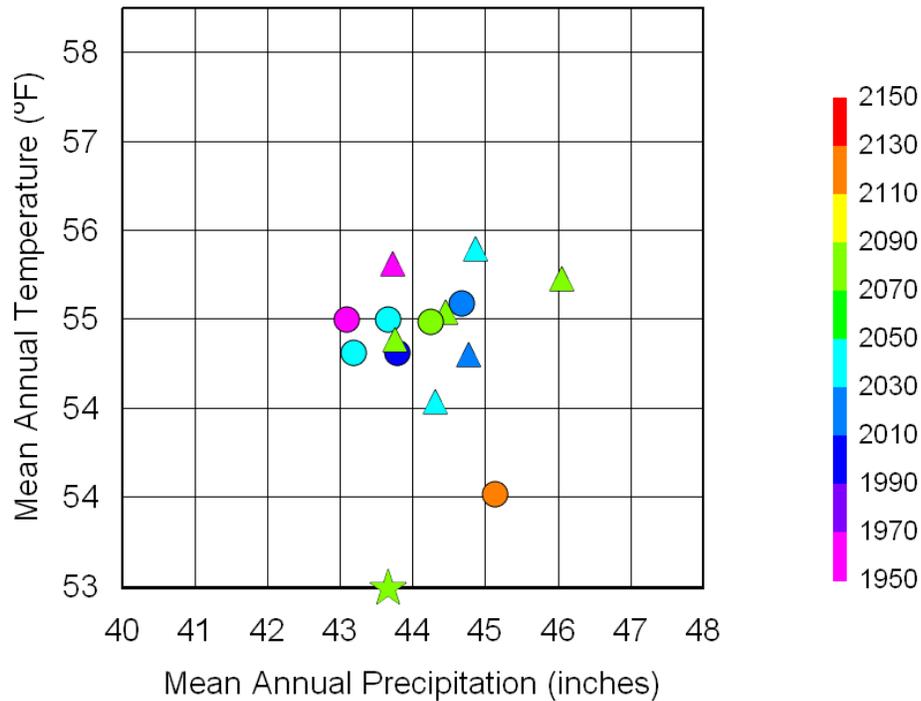
Figure 6-3 shows the same data contained in Figure 6-2 but in a different format. The plot is based on output from 42 HSPF simulations generated using the automated (iterative) run capability of the BASINS CAT. Contours were generated by interpolation from the original 42 points, or synthetic scenarios, evaluated. The plot illustrates graphically the changes in annual nitrogen loads resulting from changes in precipitation and temperature. Nitrogen loads generally increase or decrease with increasing and decreasing precipitation, respectively, reflecting changes in runoff. Nitrogen loads decrease with increases in air temperature, most likely a response to decreased runoff resulting from increased evapotranspiration. The simulated change in nitrogen loads resulting from any combination of precipitation and temperature change can be seen by moving from the star, which represents current climate, along different trajectories within the plot. Generally, mean annual nitrogen loading is shown to change about 1.1% per percent change in mean annual precipitation (relative to current conditions), and about 2% per degree F change in mean annual air temperature. This type of quantitative information can be developed for any endpoint of concern, and can be useful for assessing the risk of climate change impacting a management target or goal (e.g., a target nutrient load). It should be noted that BASINS CAT does not provide a direct capability for making contour plots such as Figure 6-3. The contour plot shown here was created using a third party plotting software (DPlot) from tabular HSPF output data generated by BASINS CAT (shown in the Results Table tab).



**Figure 6-3. Contour plot showing the response of mean annual nitrogen loading (pounds\*1,000 per year) in the Monocacy River to changes in mean annual temperature and precipitation based on the analysis using synthetic scenarios. The current mean annual temperature and precipitation are indicated by the black star.**

### 6.3.2. Model-Based Scenarios

Figure 6-4 shows the response of mean annual nitrogen loading in the Monocacy River to the model-based, seasonally variable climate change scenarios developed from climate change projection data in the CARA data set. The data shown are from HSPF simulations of only the 14 scenarios created by applying a uniform multiplier to all events (i.e., these results do not reflect changes in the proportion of precipitation occurring in large magnitude events). BASINS CAT was used to create and run each scenario.



**Figure 6-4. Scatter plot showing the response of mean annual nitrogen loading (indicated by the color scale in pounds\*1,000 per year) in the Monocacy River to model based climate change scenarios from the CARA data set. Circles represent projections based on the A2 emissions storyline, triangles represent projections based on the B2 emissions storyline, and the star represents current mean annual temperature and precipitation.**

Current climate is indicated on the plot by the star. The spatial distribution of the points shows the range of projected changes in mean annual temperature and precipitation from the 7 GCM models and two emissions storylines. All projections show warming mean annual temperatures by 2030. Projections vary with respect to changes in mean annual precipitation, with some showing increases, and others decreases. The color scale indicates the range changes in mean annual nitrogen loading in response to projected changes in climate. Changes in mean annual precipitation for these scenarios ranged from about -1 to 5%, and changes in mean annual temperature from about 1 to 3°F. The resulting changes in mean annual nitrogen loads ranged from about -5 to 3%. The projected decreases are likely to result from decreases in streamflow also projected by 2030.

As with the analysis of synthetic scenarios, this type of quantitative information can be developed for various or multiple endpoints of concern, and can be useful for determining the

range of potential changes in a key management target resulting from plausible future changes in climate (in this case based on model projection data). Figure 6-4 was created using a third party plotting software (DPlot) from tabular HSPF output data generated by BASINS CAT (shown in the Results Table tab).

#### **6.4. CONCLUSIONS**

The case study described in this chapter is a brief example of an analysis conducted using BASINS CAT, assessing the sensitivity of a single water quality parameter, nitrogen, to a range of plausible changes in climate. Results suggest that nitrogen loading is sensitive to projected changes in climate in this watershed, although the direction of change is unclear due to differences in projected future changes in precipitation. Similar analyses could be conducted using the BASINS CAT tool assessing a wide range of user-specified climate change scenarios and/or hydrologic and water quality endpoints.



## 7. SUPPORTING RESOURCES

### 7.1. CLIMATE CHANGE DATA AND INFORMATION

Future climate change is expected to vary considerably in different regions of the country. Selected sources of climate change information, data, and guidance concerning the use of climate change data are listed below. Most of the sources listed below provide climate change projections developed from climate modeling experiments using Global Climate Models (GCM) or Regional Climate Models (RCM). Information from these and other sources may be used to develop scenarios for different regions of the United States. Note that this is not an exhaustive list. Information and guidance about climate change in different parts of the country can be obtained from additional sources including government agencies, universities, and other groups. Over time, additional information about climate change will become available as climate models are improved, new modeling experiments are conducted, new monitoring data becomes available, and research such as investigations of paleo-climate better reveal historical patterns of climate variability and change.

IPCC Data Distribution Centre (DDC): <http://www.ipcc-data.org/>

Lawrence Livermore National Laboratory, Program for Climate Model Diagnosis and Intercomparison: [http://www-pcmdi.llnl.gov/ipcc/about\\_ipcc.php](http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php)

Lawrence Livermore National Laboratory/Bureau of Reclamation/Santa Clara University: [http://gdo-dcp.ucllnl.org/downscaled\\_cmip3\\_projections/dcpInterface.html](http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html)

North American Regional Climate Change Assessment Program (NARCCAP): <http://www.narccap.ucar.edu/data/index.html>

Consortium of Atlantic Regional Assessments (CARA; mid-Atlantic U.S. region): <http://www.cara.psu.edu/climate/models.asp>

University of Washington, Climate Impacts Group (northwest U.S. region): <http://www.cses.washington.edu/data/ipccar4/>

## **7.2. OTHER RESOURCES**

A large and rapidly growing amount of information about climate change, climate change impacts, and adaptation to climate change is becoming available. The list below provides a brief listing of resources. This list is far from exhaustive, however, and is intended only as a starting point for those interested in learning more about this issue.

The U.S. EPA's climate change web site provides a range of information about climate change and potential climate change impacts. <http://www.epa.gov/climatechange/>

The U.S. Climate Change Science Program (CCSP) web site provides links to information and products from the U.S. Global Change Research Program. <http://www.climatechange.gov/>

The NOAA Climate Program Office web site provides links to information and products from NOAA, including links to the NOAA Regional Integrated Sciences and Assessments (RISA) projects. [http://www.climate.noaa.gov/cpo\\_pa/risa/](http://www.climate.noaa.gov/cpo_pa/risa/)

The USGS climate change science web site provides access to a range of information about climate change, climate change impacts, and adaptation to climate change. <http://geochange.er.usgs.gov/>

The NASA climate change web site provides arrange of information about climate change. <http://climate.jpl.nasa.gov/>

The Intergovernmental Panel on Climate Change (IPCC) web site provides a wealth of scientific information and products including links to the 2007 Fourth Assessment Report. <http://www.ipcc.ch/>

The IPCC Task Group on Scenarios for Climate Impact Analysis gives guidance on developing scenarios and conducting climate change impact assessments. [http://www.ipcc-data.org/guidelines/TGICA\\_guidance\\_sdciaa\\_v2\\_final.pdf](http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf)

The California Climate Change Portal provides a wide range of information about climate change, climate change impacts, and adaptation to climate change for the state of California. <http://www.climatechange.ca.gov/>

The Consortium for Atlantic Regional Assessment (CARA) web site has a useful climate change primer along with some climate change scenarios for the mid-Atlantic and northeastern US. <http://www.cara.psu.edu/>

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