Climate Change and Water Resources:
A Primer for Municipal Water Providers

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1. Introduction

A recent collaboration between the AWWA Research Foundation (AwwaRF) and the National Center for Atmospheric Research (NCAR) has led to a new publication "Climate Change and Water Resources: A Primer for Municipal Water Providers" (Miller and Yates 2006). This document tries to dispel some of the misunderstandings about climate change – showing that it is neither an impending catastrophe nor a myth that can be safely ignored. Generally, the Primer 1) summarizes the scientific evidence regarding both natural climate changes and those caused by human activity; 2) describes the hydrologic impacts of climate change and potential consequences for water utilities 3) discusses the nature and sources of uncertainties in these projections and 4) provides guidance on planning and adaptation strategies. In particular, the Primer explains how a warmer climate will intensify the global hydrologic cycle, leading to increases in global average annual precipitation, heavier rainfall events, and possibly longer dry spells. Warmer temperatures will cause snowpacks to melt earlier – shifting seasonal streamflow timing, while changes in storm tracks may leave some regions much drier than now, and others wetter. In addition, water quality will be affected by changes in runoff processes and watershed characteristics, including wildfire impacts.

2. Overview

There is a great deal of misunderstanding surrounding the subject of climate change, often leading to profound confusion regarding its potential impacts on natural resource systems and human wellbeing. Well-intentioned, but misguided attempts by the popular press and movie industry to call attention to the prospect of climate change have left much of the public with the impression that the Earth's climate system is either poised at the brink of cataclysmic change or that global climate change is a myth that they can safely ignore. Neither of those extreme views provides useful guidance to anyone attempting to make informed decisions about the management of climate-sensitive resources.

Here, we will attempt to dispel some of the confusion by summarizing the best available scientific evidence on climate change – including both natural changes and changes that may be caused by human activities. In particular, this primer will focus on what is known about the implications of climate change for the water cycle and the availability and quality of water resources. The goals of this primer are to 1) introduce water utility managers to the science of climate change; 2) suggest the types of impacts it can have on water resources, and 3) provide guidance on planning and adaptation strategies. This guidance primarily reflects the activities of forward-looking utilities that have begun to plan and prepare for these changes, with some additional insights gained from the research community.

Water industry professionals are keenly aware of the fact that climate variability affects the availability and quality of water resources and that runoff or temperature extremes can affect their operations. Unanticipated extremes, such as an unprecedented drought, are likely to pose particularly severe problems. Prudent management focuses on anticipating and mitigating the potential adverse impacts of such natural variability. To plan efficiently, it is important to understand how and why climate may change in the future and how that may affect the resources upon which the water utility industry depends.

Will climate change have significant impacts in the near future on water availability, water quality and the ability of water utilities to meet the needs of their customers at desired levels of reliability and affordability? If so, what types of impacts could occur? What should utilities be doing to assess and prepare for the resulting risks and opportunities? Is this an issue that requires attention now, or will climate change occur so far in the future that water utilities can safely ignore it and concentrate on more pressing concerns? These are the types of questions addressed in the Primer and will be discussed during the presentation.

NCAR

Awwa Research Foundation

SEI STOCKHOLM ENVIRONMENT INSTITUTE US Center

Climate Change and Water Resources

A partnership of the
AWWA Research Foundation
National Center for Atmospheric Research
US EPA Office of Research and Development
Stockholm Environment Institute-US

U.S. Joint Conference on Drinking Water Quality Management and Wastewater Control

National Center for Atmospheric Research

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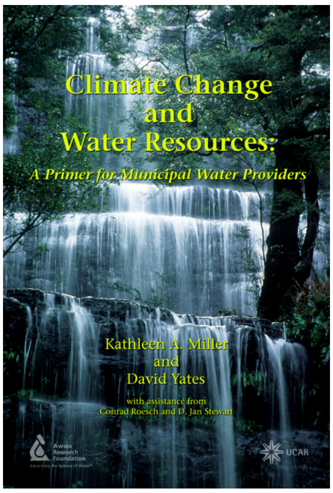
Collaborative Project – Urban Water Utilities:
impacts and response options



GOALS:

- **Dispel confusion about climate change**
- **Assess vulnerabilities to climatic trends; future projections**
  - **Glacier & snowpack reductions;**
  - **Sea-level rise; runoff changes**
  - **Temperatures are highly likely to increases in most places**
  - **Precipitation changes are uncertain**
- **Learn from extreme events:**
  - **Wildfires; droughts; floods**
- **Advance adaptation strategies**
- **http://www.isse.ucar.edu/h2o_primer.jsp**

"Gentlemen, it's time we gave some serious thought to the effects of global warming."

Water Resource Impacts

<u>Most likely</u>:

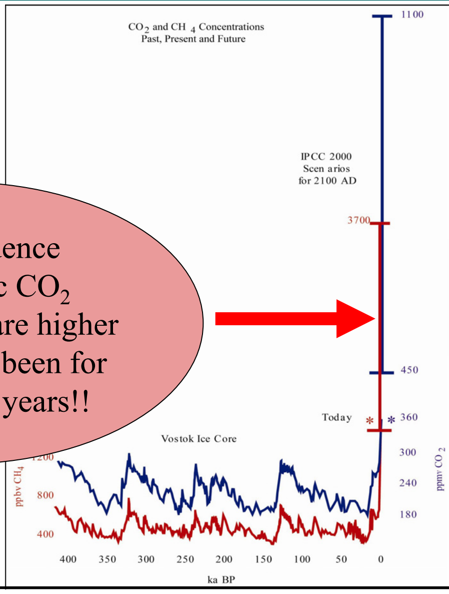
- Global precipitation ↑ ~ 1- 2% per 1°C
- Snow season shorter→ earlier peak flow
- Glacial recession → summer flow ↑ near-term, but ↓ long-term
- Sea level rise → saltwater intrusion, coastal flooding
- More intense precipitation → water quality impacts

Humans and greenhouse gases

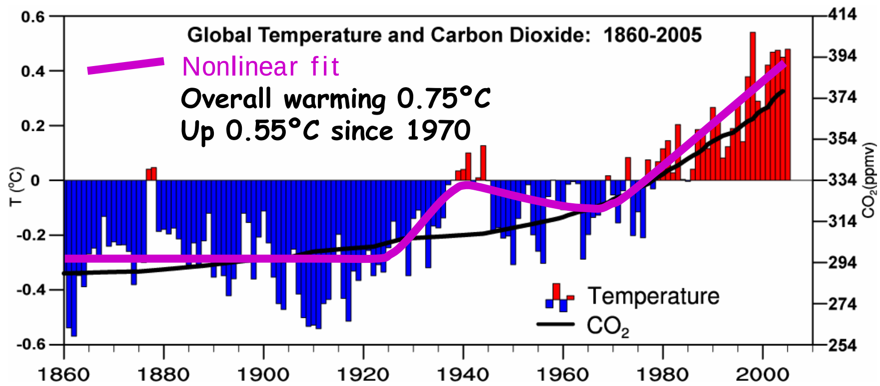
Carbon Dioxide (CO_2)
and Methane (CH_4)

<u>Now:</u>
concentrat
higher than
range over past 40
years

Strong evidence
Atmospheric CO_2 concentrations are higher than they have been for 400 thousand years!!



High Confidence in Surface Temperatures



Annual mean departures from the 1961-90 average for global temperatures, mean 14.0° C, and carbon dioxide concentrations from ice cores and Mauna Loa (1958 on), mean 333.7 ppmv. Updated from Karl and Trenberth 2003.

Precipitation is complex and is not captured in Global Circulation Models

Warming intensifies the hydrologic cycle

Surface temperature increase

↓

Increased Water holding capacity

↘

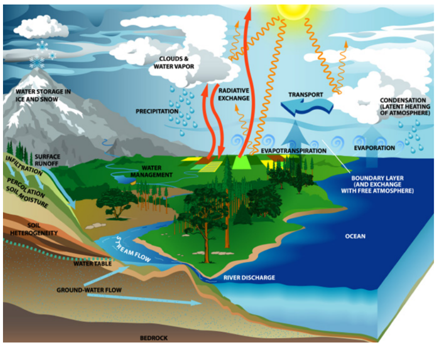
Increased Atmospheric moisture

↙ ↘

Changing Frequency | Increased intensity

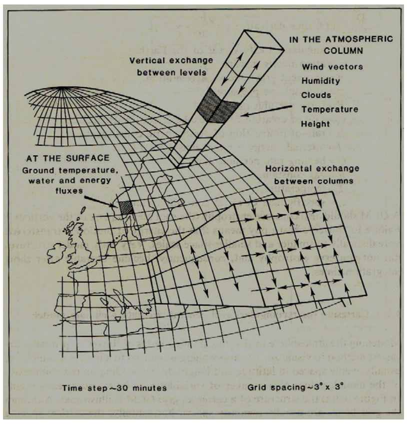
Character of Precipitation?

Droughts & Floods



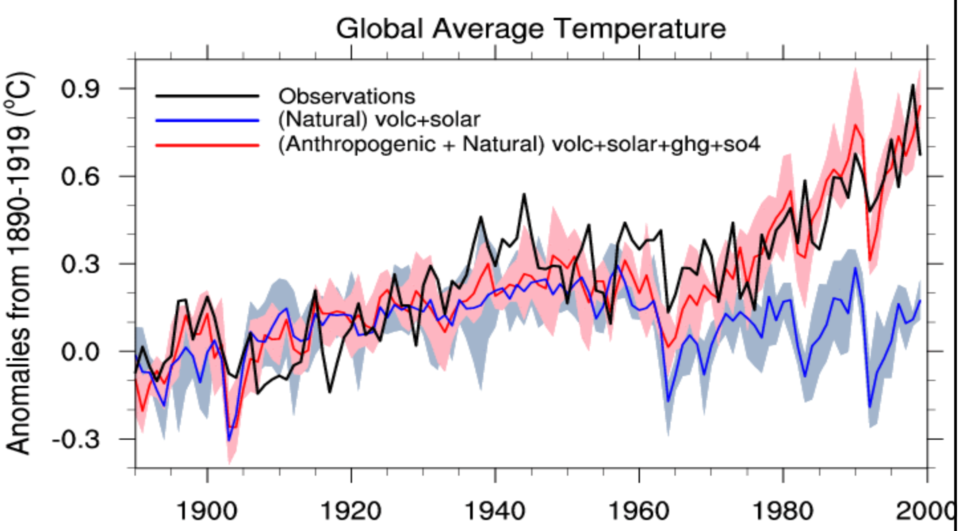
“Of course, I could be wrong.”

Coupled Models of the Ocean, Atmosphere, Cryosphere, and Land

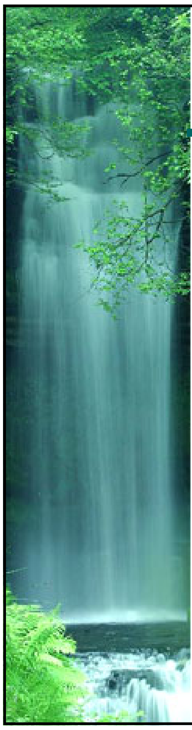


- Global Climate Models
- Good at estimating just that, the Global Climate
- Not as good at estimating regional climate change
- We need orders of magnitude greater computing power!!!

Natural forcings do not account for observed 20th century warming after 1970

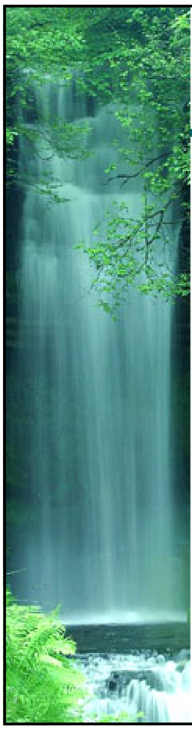


Meehl et al, 2004: J. Climate.

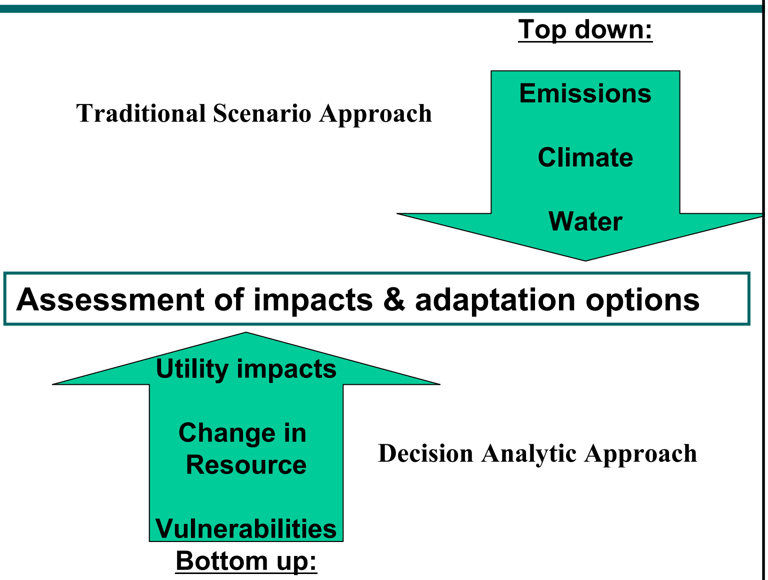


AwwaRF's Climate Change Research Program

- Partnership with the National Center for Atmospheric Research
- Recognition in the CC community for the need to develop adaptation strategies
  - Long residence time of CO_2 commits us to some change
  - Water Resource Sector needs innovate to deal with climate change (and variability)



Methods of Assessment

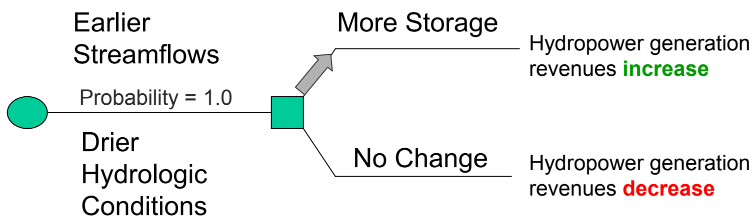


Scenario vs. Decision Analysis

- **Scenario analysis** answers questions like:
  - What is the best adaptation plan for a given climate change scenario?
- **Decision analysis** answers this type of question:
  - What is the best adaptation plan given a range of possible future climate change scenarios?

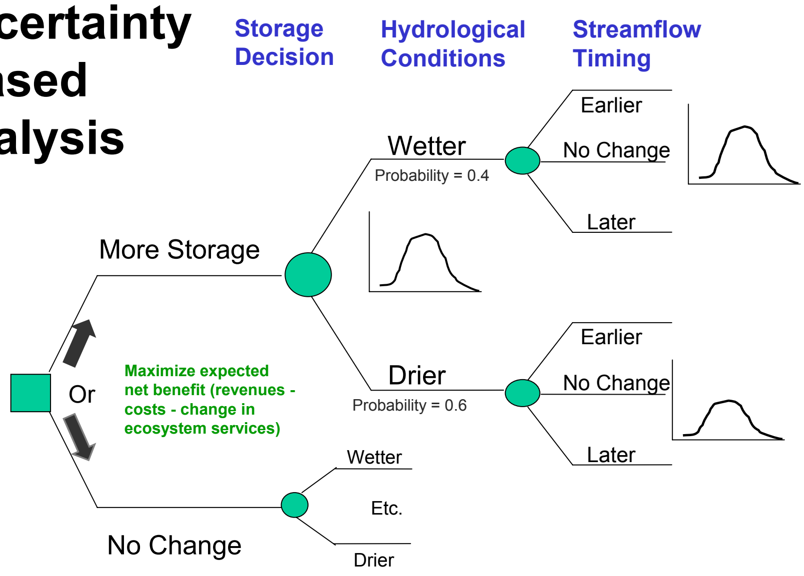
Scenario-Based Analysis

Climate Change Study of the American River Watershed

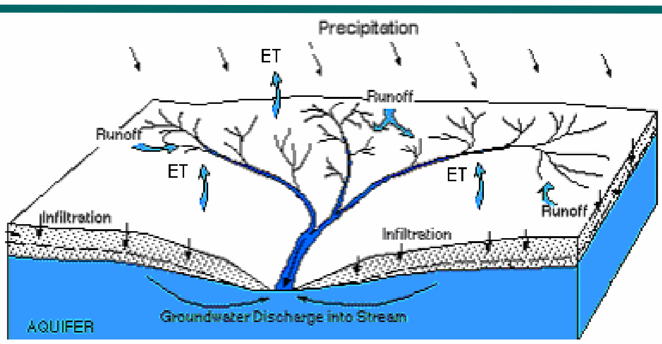


This only tells us what to do if we are **certain** about the future. The reality is that we are **uncertain**.

Uncertainty -Based Analysis



Hydrology Issues

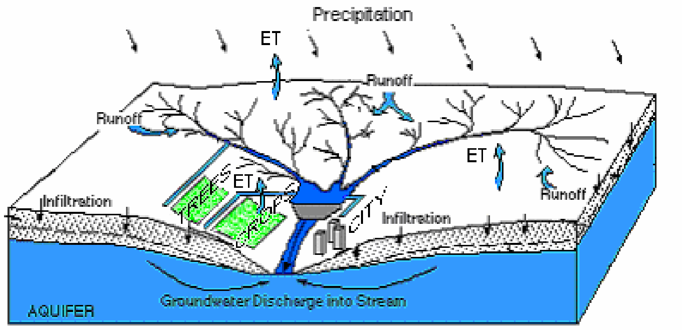


Critical question: How does rainfall on a catchment translate into flow in a river?

Critical question: What pathways does water follow as it moves through a catchment?

Critical question: How does movement along these pathways impact the magnitude, timing, duration and frequency of river flows?

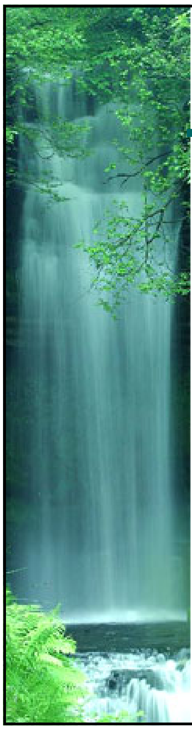
Planning Issues



Critical question: How should water be allocated to various uses in time of shortage, and still be constrained to meet other uses?

Critical question: How should infrastructure in the system (e.g. dams, diversion works, etc) be operated to achieve maximum benefit and/or meet regulatory requirements?

Critical question: How will allocation, operations and operating constraints change if new management strategies are introduced into the system?



WEAP

Integrated Water Resource Management

- Coupled watershed hydrology and water planning model
- GIS-based, graphical drag & drop interface.
- Physical simulation of water demands and supplies.
- Additional simulation modeling: user-created variables and modeling equations.
- Scenario management capabilities.
- Seamless watershed hydrology, water quality and financial modules
- Licensed by the Stockholm Environment Institute, Boston's USA's office

http://weap21.org

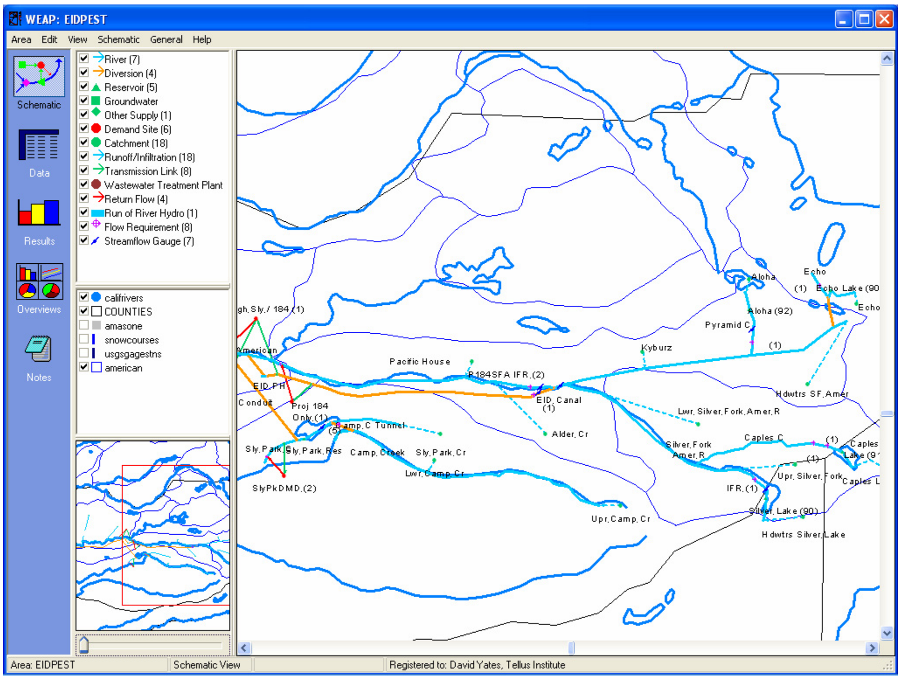
SEI Stockholm Environment Institute US Center

WEAP Example

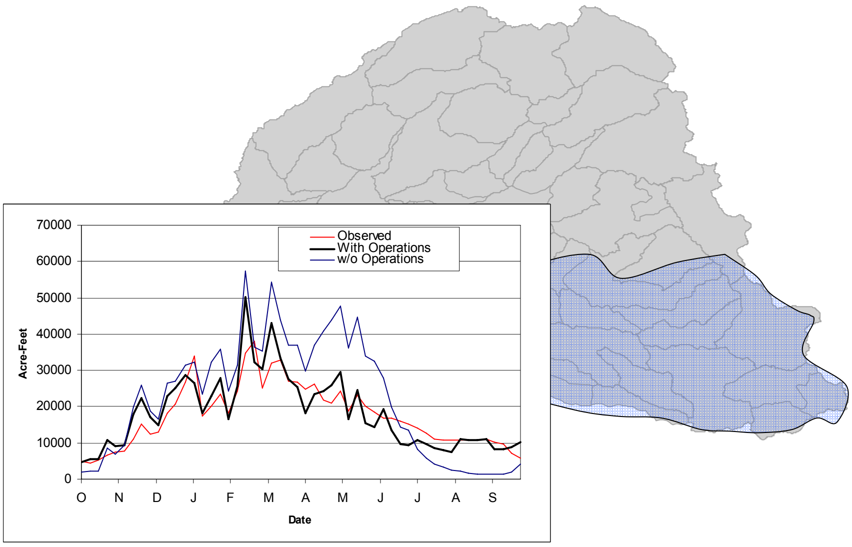
- American River Basin, Northern California
- Simplified Climate Change Scenarios impose a warming and precipitation trend over 20-year period

  +ΔT 2ºC

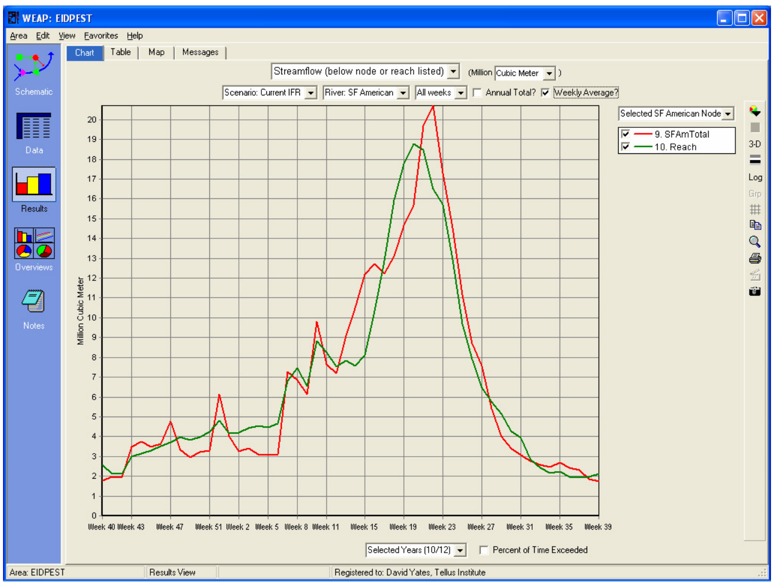
  ± 10% change in precipitation over 20 year period



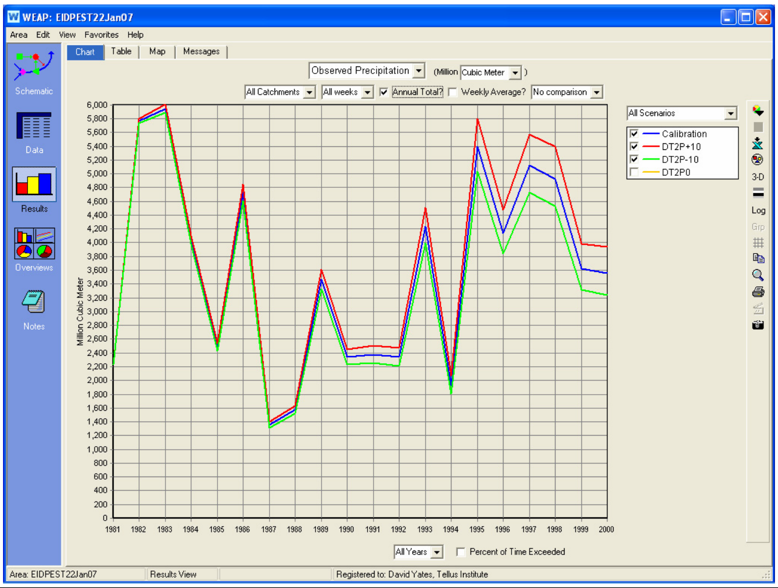
South Fork American



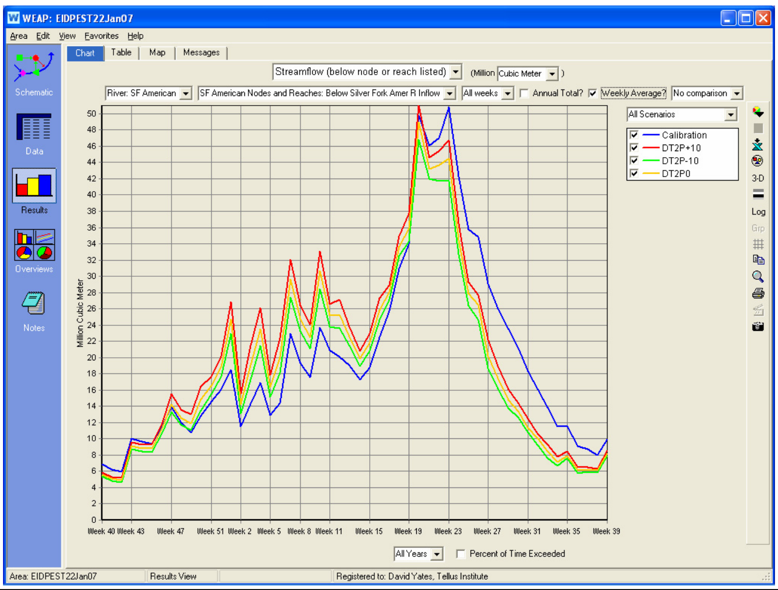
Calibration Results: Weekly Avg ('92-02)



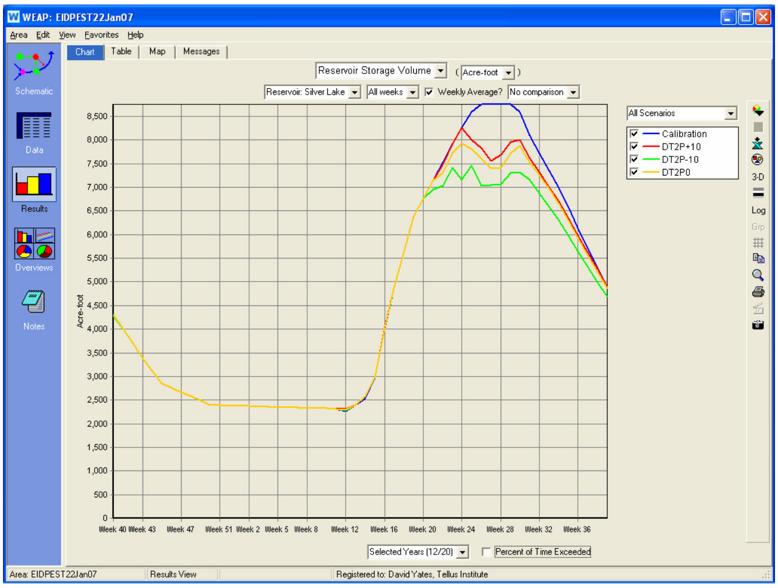
Total Annual Precipitation, 20 Years



Change in Avg. Monthly Runoff



Reservoir Storage



WEAP Requirements/Features

- Windows 95 or later (Borland Delphi, not ported to Linux)
- Imports from/exports to Excel and Word (not required).
- Uses standard ArcView GIS “shape” files. ArcView is not required.
- Available for download at http://www.weap21.org
- User Interface can accommodate other languages (currently)
  - Korean, Chinese, Portuguese, Spanish, English