IMPROVING HYDROPOWER GENERATION STRATEGIES FOR THE SYSTEM OF LARGE RESERVOIRS OF NORTHERN CALIFORNIA

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With Comments and Suggestions by
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PRESENTATION FOCUS

Reservoir Management in Northern California under climatic variability and change

A system of reservoirs modulates the climatic and weather variability in order to produce downstream benefits:

- hydroelectric power production
- flood damage mitigation
- water conservation for municipal, industrial and agricultural supply
- ecosystem benefits
- others

Reservoir effectiveness is substantially influenced by

- climatic variability and trends
- demand variability and trends
- changing water markets

Important target of reservoir management is to

- maximize water use efficiency
  (individual uses, individual reservoirs, system)

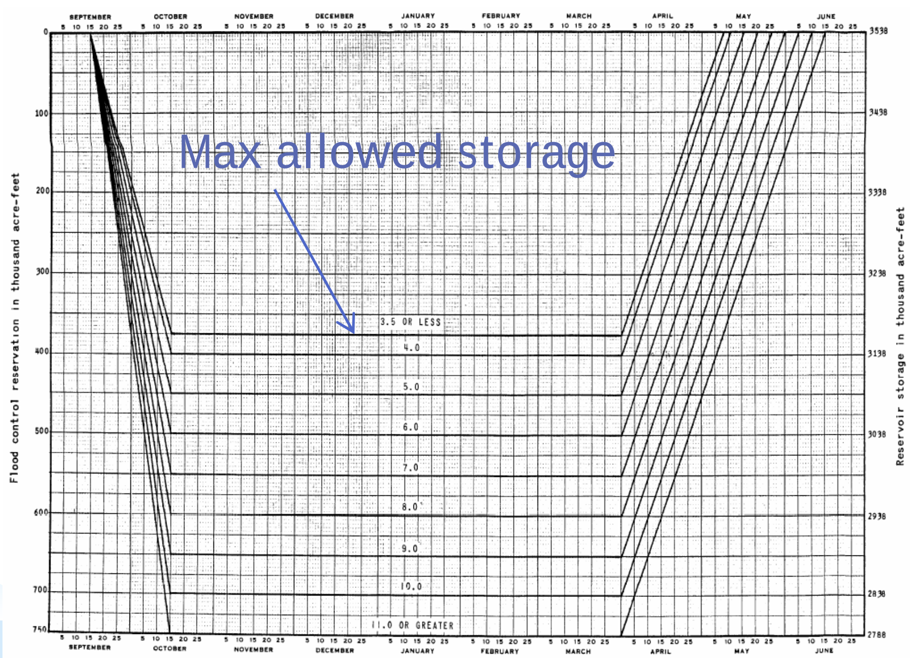
ELEMENTS OF CURRENT RESERVOIR MANAGEMENT

Simulation runs with

- historical data and statistics
- a detailed numerical description of the system

to get a set of operating rules (guide rules) on which to base operational management

(E.G., No precip. forecasts are used for management, only observed precip.)



Oroville Rule Curve

Willis and co-authors (2011) San Francisco Estuary and Watershed Science, 9(2)

ELEMENTS OF CURRENT RESERVOIR MANAGEMENT

Planning involves several stakeholders and several objectives as well as some coordination among reservoir sites

No two systems are the same and generalization is difficult in reservoir management (climate, demands, system structure)

Climate/weather predictions must be translated to system decision variables to be useful for management

E.G., cold water species fisheries management (Huang and others, 2011, JAWRA, 47(4))

Climate/weather prediction		Decision Variable Index
Surface Temperature Wind etc. →	Reservoir Pool Energy Balance & Release Level →	Water Temperature

TWO ISSUES TO DISCUSS

The Integrated Forecast and Management Project (INFORM) for Northern California (prototype demonstration project)

http://www.hrc-lab.org/projects (follow link to INFORM)

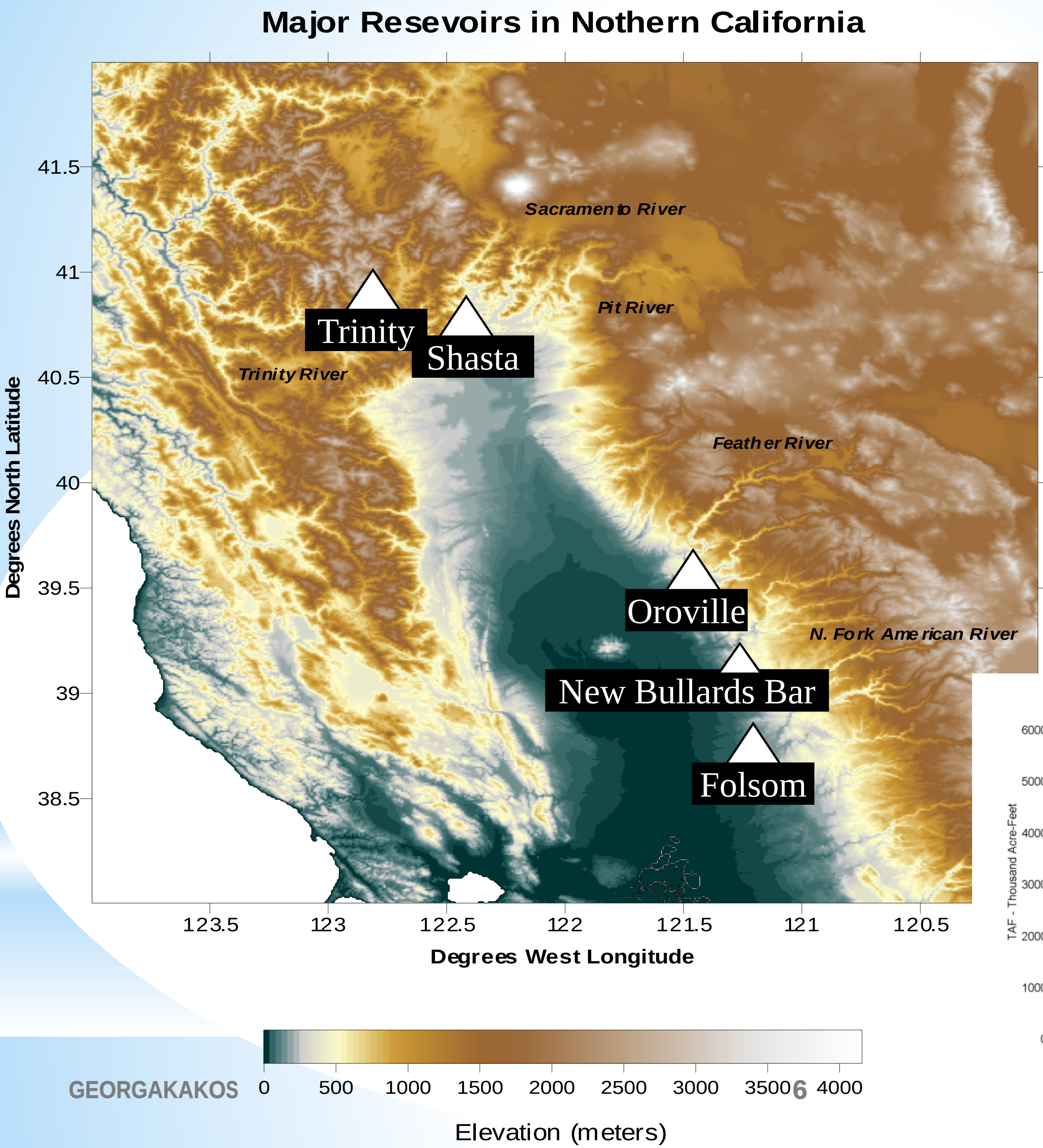
Assessing adaptive reservoir management versus current management through simulation experiments

Georgakakos and co-authors (2011a-b) Journal of Hydrology (on line)

http://www.sciencedirect.com/science/article/pii/S0022169411002939

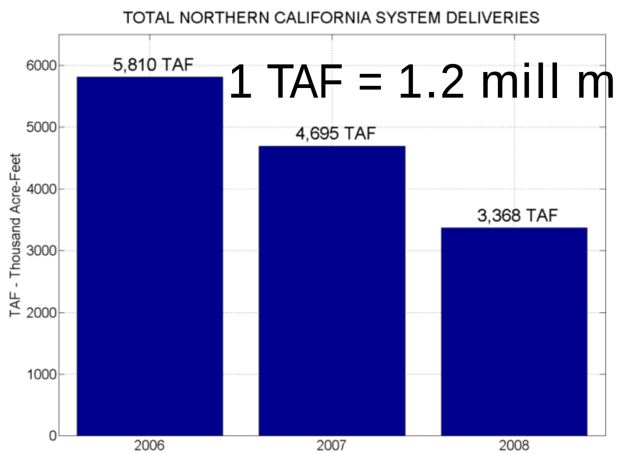
http://www.sciencedirect.com/science/article/pii/S0022169411003015

INFORM Region



VISION
Improve reservoir management in Northern California using climate, hydrologic, and decision science

CHALLENGE



1 TAF = 1.2 mill m^3

SPONSORS-COLLABORATORS

Sponsors:

CALFED Bay Delta Authority
California Energy Commission
National Oceanic and Atmospheric Administration
(CPO and NWS/OHD)

Members of Oversight and Implementation Committee:

California Department of Water Resources
California-Nevada River Forecast Center
Sacramento Area Flood Control Agency
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
National Centers of Environmental Prediction (NCEP)
GIT
HRC

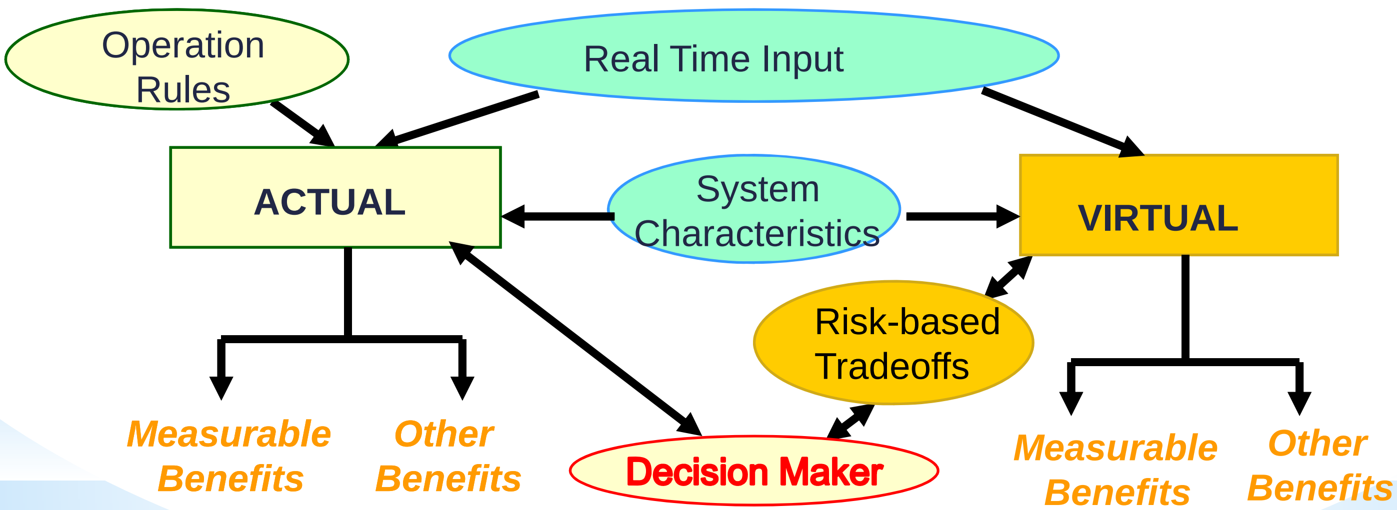
INFORM GOALS AND OBJECTIVES

Implement an integrated forecast-management system for the Northern California reservoirs using real-time data and operational forecast models

(Aspects of actual system to be represented were selected in collaboration with Agencies)

Perform tests with actual data and with management input

Demonstrate the utility of climate and hydrologic forecasts for water resources management in Northern California for several years



INFORM SYSTEM COMPONENTS

Forecast component

ATM DATA

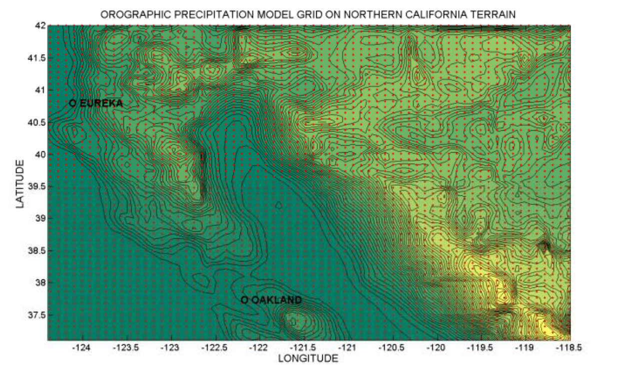
ATM FORECASTS

Adjustments

HYDROLOGIC MODEL

NWS-CNRFC FORECASTERS

Ensemble Forecast



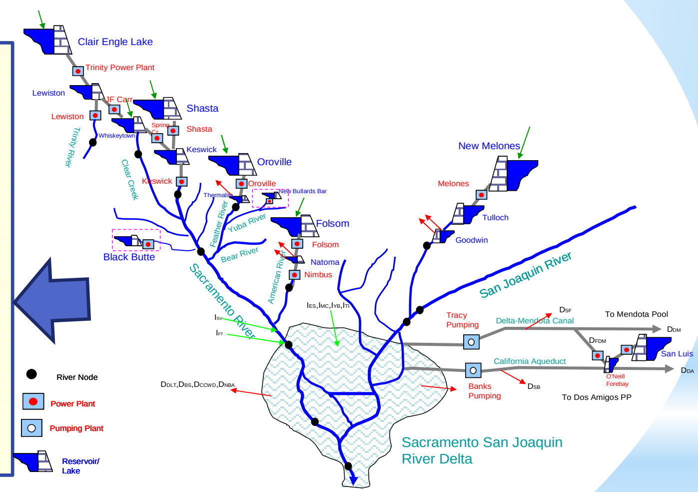
Management component

DECISION MODEL

RESERVOIR MANAGERS

Release Schedule

ASSESSMENT SYSTEM



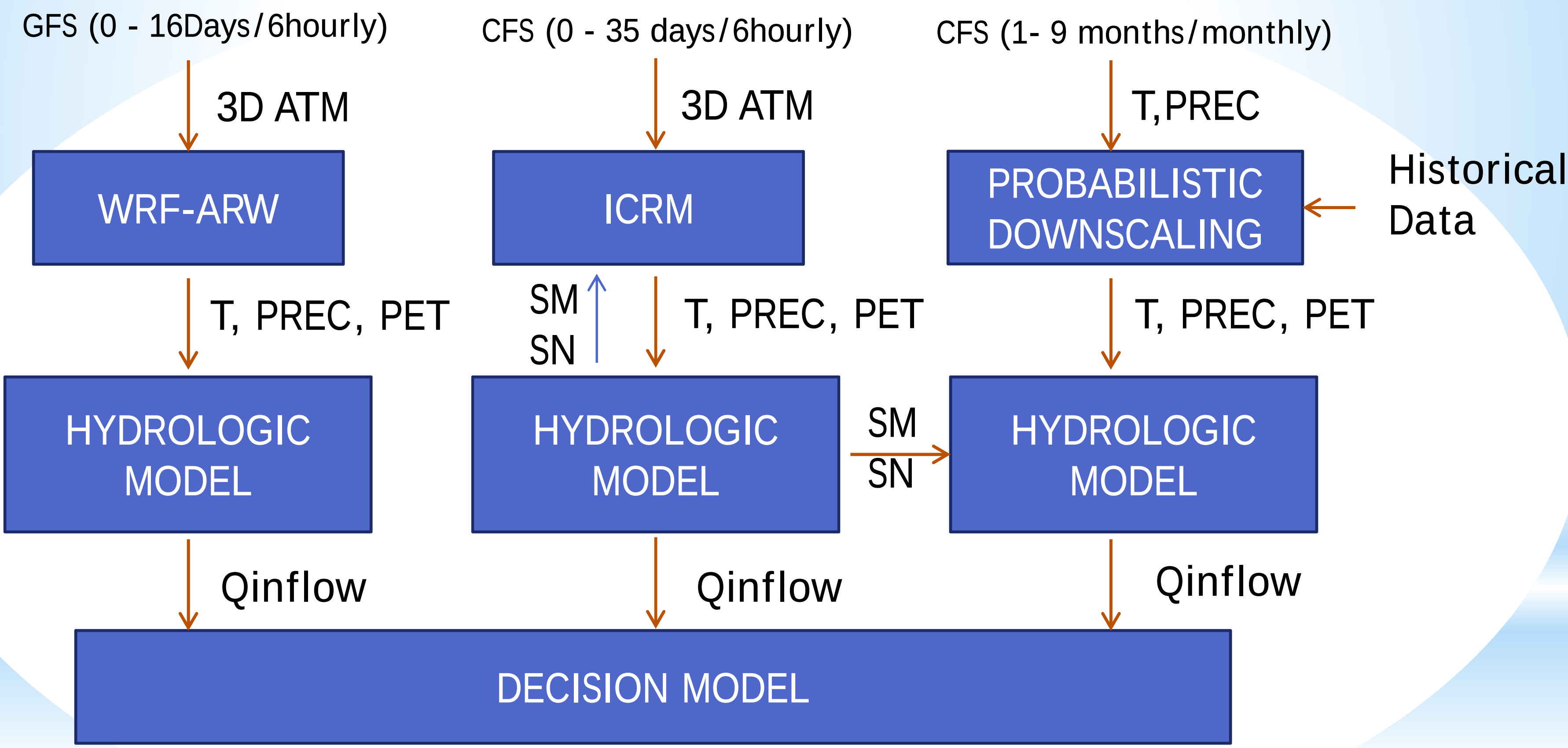
Management Benefits

Water Supply, Flood Control

Hydropower, Env. Protection, etc.

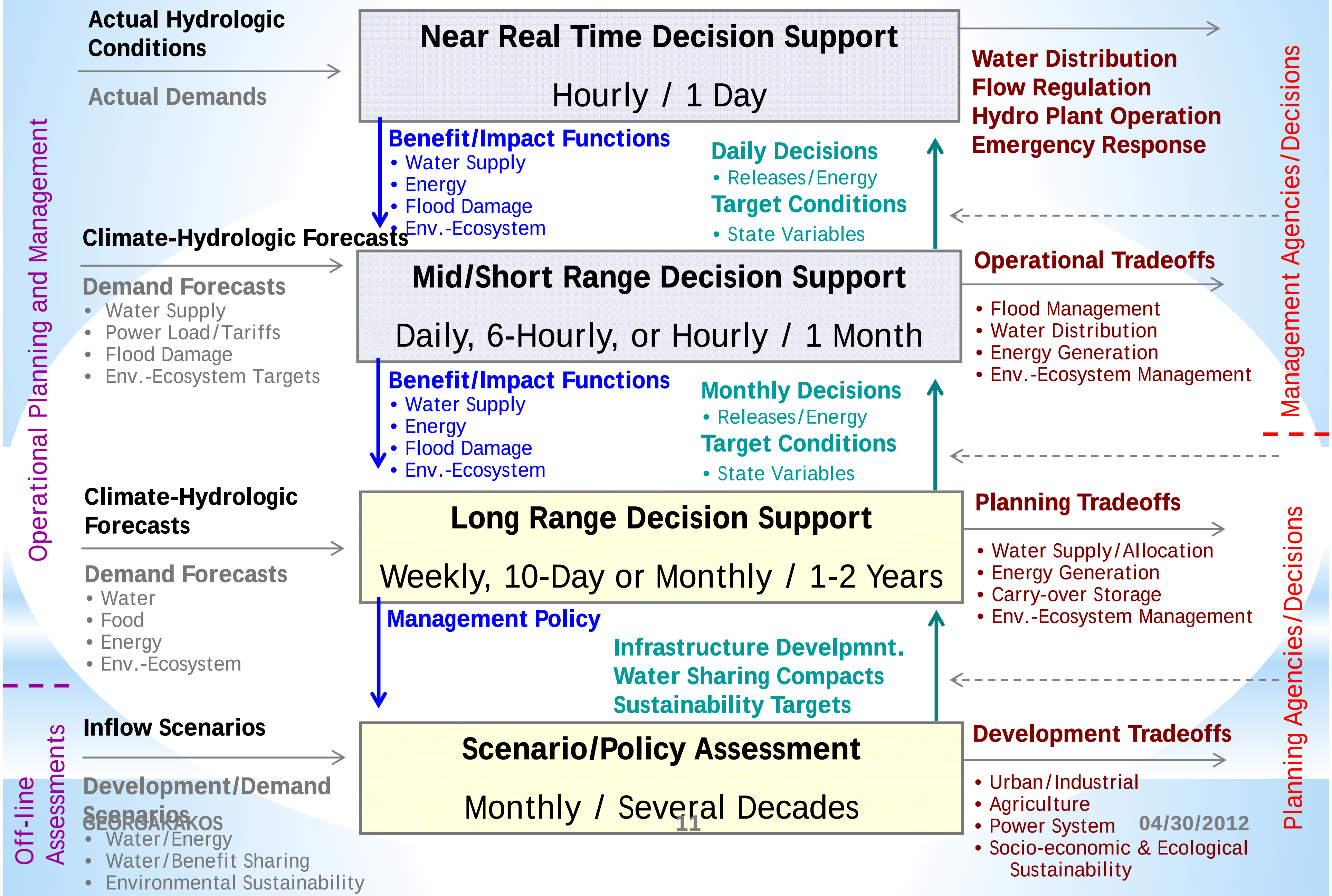
FORECAST ELEMENTS

Integration with operational agency data, forecasts and models
NCEP(GFS&CFS) and CNRFC(NWSRFS&CHPS)



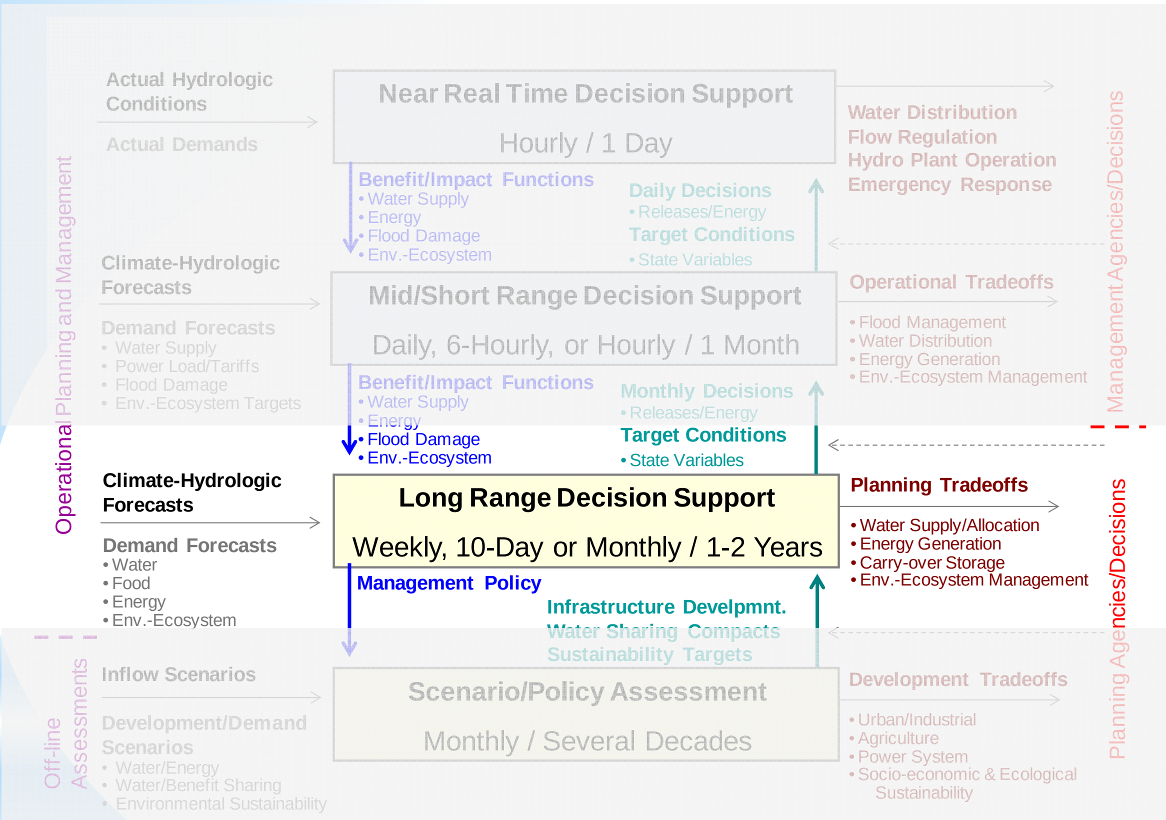
INFORM DSS ELEMENTS

Multiple Objectives, Time Scales, & Decision Makers

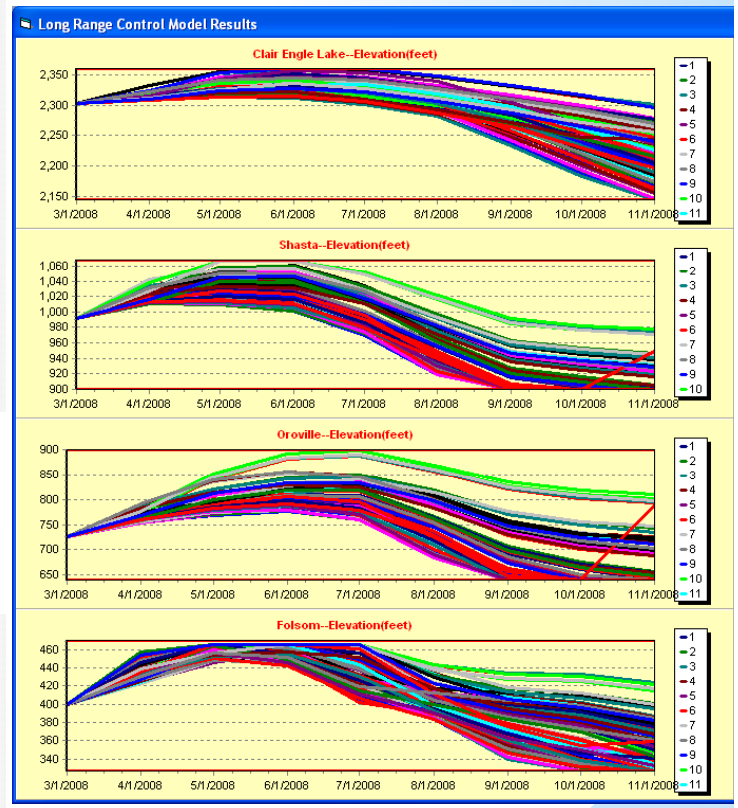


ADAPTIVE MANAGEMENT SYSTEM (INFORM DSS)

Long Range Management Model

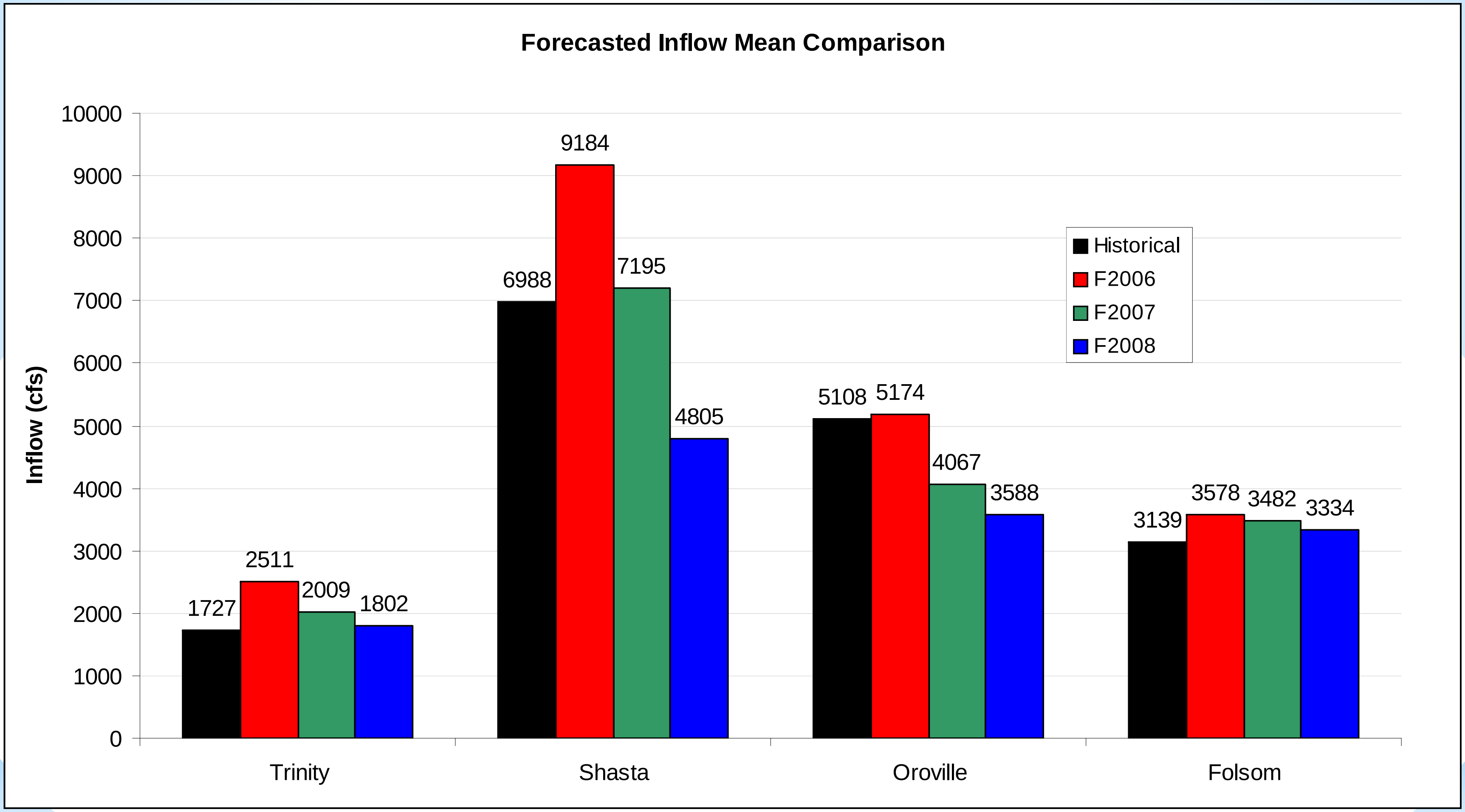


System-wide, stochastic optimization



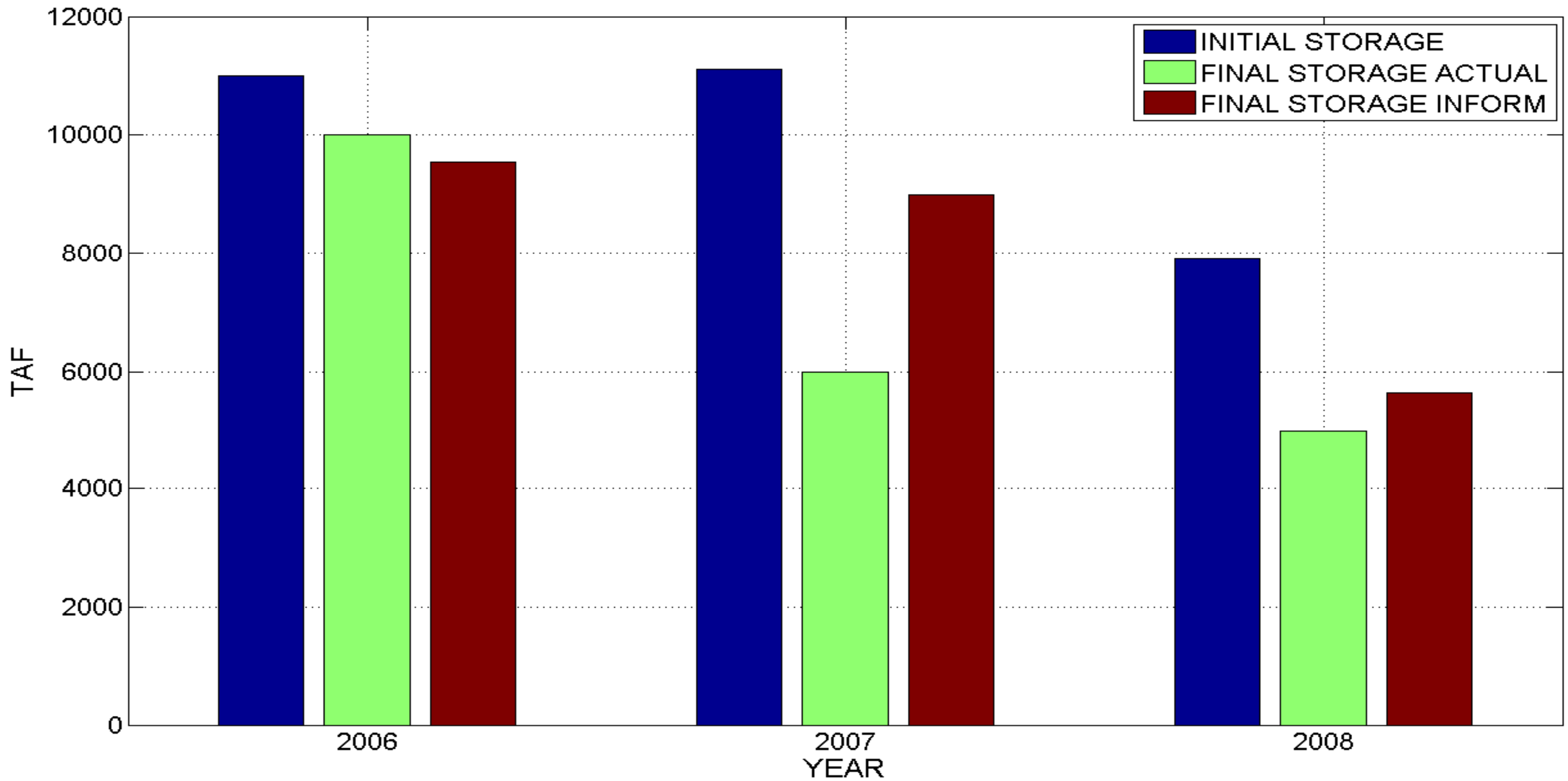
Reference: HRC-GWRI: http://www.energy.ca.gov/pier/project_reports/CEC-500-2006-109.html

Mean Inflow Forecast Comparison (9 Months)
(2006, 2007, 2008)



2006 (Wet); 2007 (Average); 2008 (Dry)

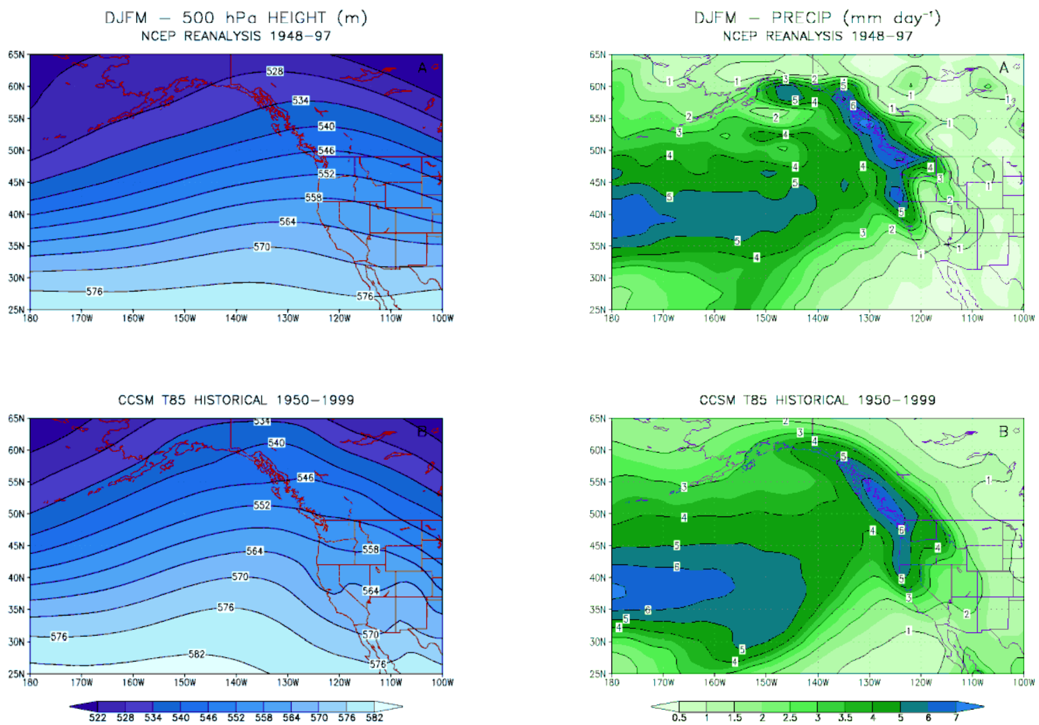
FORECAST UTILITY DEMONSTRATION

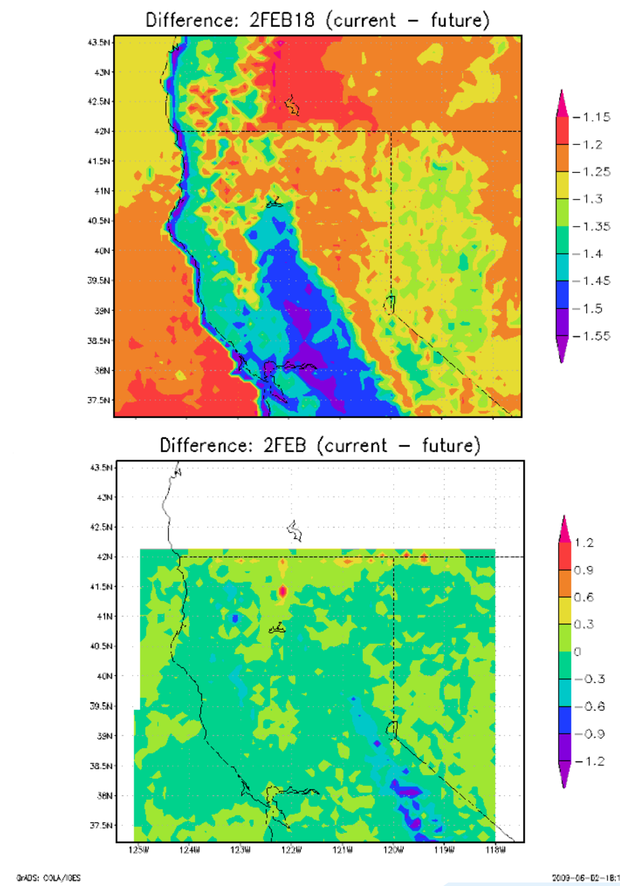


CLIMATE CHANGE STUDY RESULTS

CCSM3 + INFORM (ICRM)

Middle of the Road Emissions Scenario (A1B)





REAL-TIME INFLOW FORECASTS SIMULATED

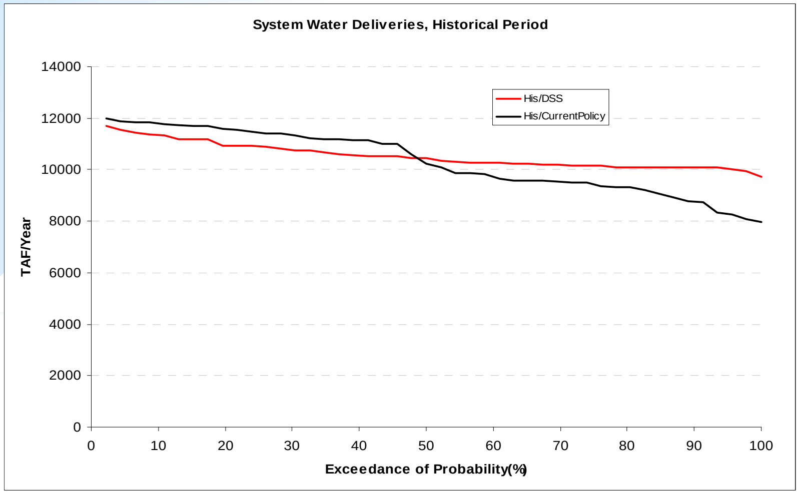
CLIMATE CHANGE STUDY RESULTS

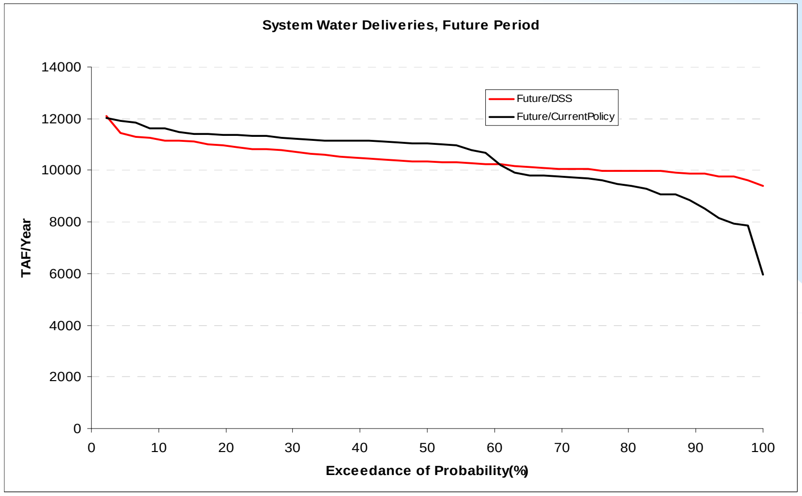
Main Policy Differences

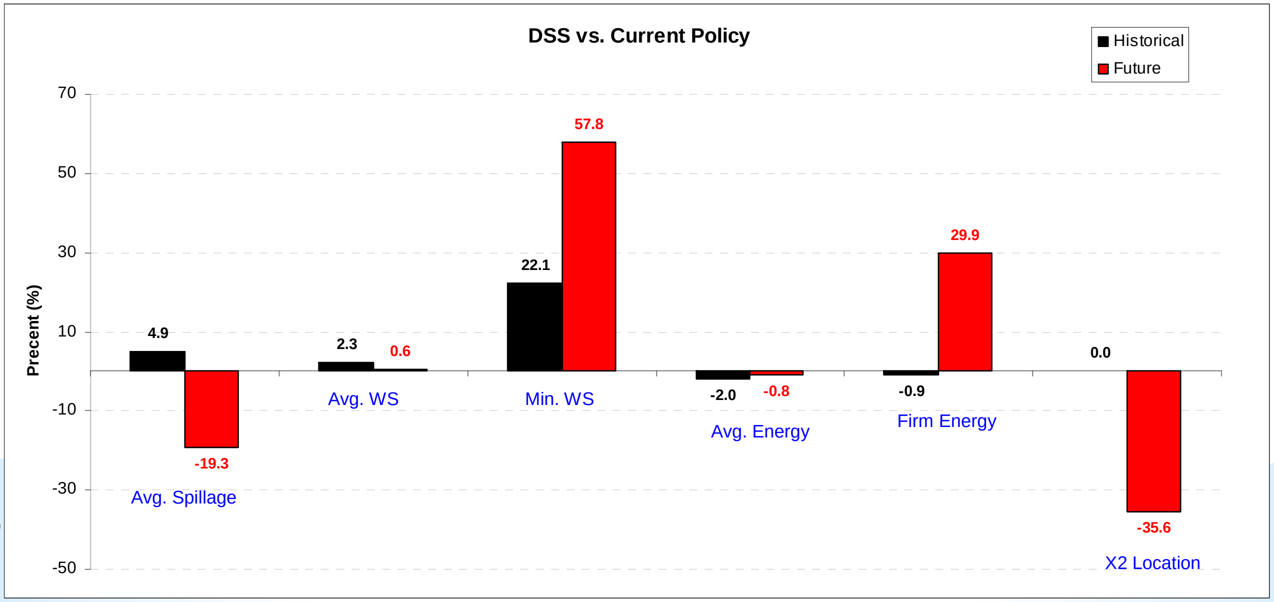
Current Policy	*Adaptive Policy*
Focuses on current month	Optimizes over the next 9 months
Deterministic	Risk based
Adjusts demand targets twice a year	Re-optimizes every month
Follows Coordinated Operations Agreement in extra water allocation	Finds optimal allocation strategy each time

CLIMATE CHANGE STUDY RESULTS

Current versus Adaptive Management Policies under a Changing Climate







CLIMATE CHANGE STUDY RESULTS

Current versus Adaptive Management Policies under a Changing Climate

F_E : Firm energy

E_A : Average Annual Energy

P : Precipitation

T : Temperature

$\frac{\Delta V}{\Delta T}$: Sensitivity of V on T conditioned on:

(a) $\Delta P = 0$; (b) CCSM3.0 (A1B)

The reduction in firm energy per unit temperature increase in future climate when adaptive INFORM management is used is more than **5.5 times** **less** than reduction when current management is used.

The reduction in average annual energy per unit temperature increase in future climate when adaptive management is used is **1.6 times** **less** than reduction when current management is used.

CONCLUSION

Integrated forecast and reservoir management demonstrates significant capability for mitigating water resources impacts of climate and weather variability and uncertainty, particularly for extremes (droughts and floods)

ADVANCES
INFORM (2002-2011)

- First prototype demonstration project to support the operational use of climate weather and hydrologic forecasts for water resources planning and management

- Development of a template for multi agency coordination for adaptive water management under climatic variability and change
(in conjunction with more detailed simulation systems)

- Framework for continued improvement of operational forecast and management tools

MEETING CHALLENGES

Challenge:

Institutional issues for using INFORM in Northern California: Management processes are legally and institutionally vested in traditional procedures and are change resistant

- collocation of main forecast and management agencies in Sacramento and coordination exists for the federal and state projects but is essentially limited to flood management issues and needs improvement during normal or dry hydrologic periods
- coordination is not accompanied by integrative/adaptive tools that encompass the applicable range of time scales, sectors and prediction uncertainty
- unintended consequence: discourages the use of key scientific advances (hydroclimatic forecasting, multi-reservoir optimization, uncertainty characterization, and integrated water resources management)

Response:

INFORM approach is designed to support a truly coordinated, interactive, and adaptive decision process that consistently reconciles long-, mid-, and short-term operational objectives and decisions

- institutional and legal processes best concern themselves with establishing the framework, broad objectives, and criteria for shared water management and not with laying down policy specifics
- with agency coordination, the adaptive risk-based INFORM approach may become institutional practice as a real time screening and planning tool for identifying beneficial release policies

Thank You

INFORM Contributing Scientists/Engineers

HRC

K.P. Georgakakos, PI, Hydroclimatology

N.E. Graham, Co-PI, Climate Science & Prediction

T.M. Carpenter, Hydrometeorological Forecasting

M. Murphy, J. Wang, and F.-Y. Cheng, Mesoscale Meteorological Modeling

E. Shamir, Hydrologic Modeling

C. Spencer and J. Sperfslage, Computer Science

GWRI

A.P. Georgakakos, Co-PI, Decision Science

Huaming Yao, Hydropower

Martin Kistenmacher, Uncertainty Mgt

Dongha Kim, Routing/Temperature Models