Using Future Climate Projections to Support Water Resources Decision Making in California

Advanced Climate modeling and Decision-Making Support of Climate Services
20 September -24 September in Aspen, Colorado

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California Department of Water Resources

Department of Water Resources
Modeling Support Branch
Bay-Delta Office
HYDROLOGY

Annual Precipitation
(Year 2005)
in millimeters
- 101 - 500
- 501 - 1,000
- 1,001 - 1,500
- 1,501 - 2,000
- 2,001 - 4,180
Sacramento-San Joaquin Delta
Governor’s Executive Order S-3-05

- Signed June 1, 2005
- Targets to reduce emission levels of greenhouse gases
- Required biennial reports starting January 2006
  - Water supply
  - Public health
  - Agriculture
  - CA coastline
  - Forestry
- Formed Climate Action Team
2006 Report
4 Scenarios (2 GCM x2 GHG)

2009 Report
12 Scenarios (6 GCM x2 GHG)
2009 CAT Future Climate Scenarios

6 Global Climate Models
- GFDL-CM2.1 (USA)
- NCAR-PCM1 (USA)
- CNRM-CM3 (France)
- MPI-ECHAM5 (Germany)
- MIROC3.2med (Japan)
- NCAR-CCSM3 (USA)

2 GHG Emissions Scenarios
- A2 (higher GHG emissions)
  - high population growth
  - regional economic growth
  - fragmented technological changes
- B1 (lower GHG emissions)
  - low population growth
  - rapid economic growth
  - sustainable technology

12 Total Scenarios = 6 GCM x 2 GHG Emissions Scenarios
Using Future Climate Projections in Decision Making

• Sea level rise
• Effects of increasing air temperature on the upper Feather Basin
• Climate change impacts on water supply reliability
Sea Level Rise
Increase ~0.08 in/yr
Total increase from 1900-2003 = 8.15 in
# Sea Level Trends in California

<table>
<thead>
<tr>
<th>CO-OPS Gauge Number - Name</th>
<th>Sea Level Trend (feet/century)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9419750 - Crescent City</td>
<td>-0.16</td>
</tr>
<tr>
<td>9414750 - Alameda</td>
<td>0.29</td>
</tr>
<tr>
<td>9414290 - San Francisco</td>
<td>0.70</td>
</tr>
<tr>
<td>9412110 - Port San Luis</td>
<td>0.30</td>
</tr>
<tr>
<td>9410840 - Santa Monica</td>
<td>0.52</td>
</tr>
<tr>
<td>9410660 - Los Angeles</td>
<td>0.28</td>
</tr>
<tr>
<td>9410230 - La Jolla</td>
<td>0.73</td>
</tr>
<tr>
<td>9410170 - San Diego</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Table 2-6 Relative Sea Level Trends for Eight Tide Gauges Along the Coast of California with 50 Years or More of Record
How much will sea level rise?

What is the likelihood that sea levels will rise by a certain amount?

How can we represent sea level rise effects on Delta salinity in computer models?

How do I plan for it?
Historical extrapolation and air temperature based projections indicate uncertainty ranges for mid-century and end of century.

**Historical Extrapolation**

- **Mid-century**: 0.5 ft
- **End of century**: 1.0 ft

**Air Temp Based**

- **Mid-century**: 0.8-1.0 ft
- **End of century**: 1.8-3.1 ft

**Uncertainty Range**

- **Mid-century**: 0.5-1.3 ft
- **End of century**: 1.4-3.9 ft
Relative Likelihood from 12 Scenarios

- 2050 20% chance 1ft SLR
- 2090 10% chance SLR 2.75-2.80ft

The graph shows the likelihood of sea level rise for various years, with distinct lines representing different years and calculation methods.
Models of SWP and CVP Operations
Need a Way to **Quickly** Represent Delta Water Quality Standard Compliance

Sea Level Rise Artificial Neural Networks

A Delta salinity ANN is a computer program that quickly estimates Delta salinity based on inflows and exports.

An ANN can be used in management tools such as CalSim and CalLite to estimate sea level rise impacts.
Developing Delta Salinity ANNs

1. Use DSM2 to simulate Delta Salinity for SLR scenarios

   • Increase water level at Martinez
   • Increase salinity at Martinez based on DRMS study by Ed Gross

2. Using DSM2 results, “train” SLR ANN to replicate Delta salinity based

   INPUT
   • Northern Delta inflows
   • San Joaquin River flows
   • Delta exports
   • Delta consumptive use
   • Cross Channel gate operations
   • Tidal energy

   Sea Level Rise ANN

   OUTPUT Salinity at:
   • Collinsville
   • Emmaton
   • Jersey Pt
   • Antioch
   • Chipps Is.
   • Old R at Rock Sl.
   • Los Vaqueros
   • Victoria Canal (center)
   • Victoria Canal-Middle R
   • Clifton Court Forebay (SWP)
   • Jones Pumping Plant (CVP)
Non-stationarity in Changing Climate
Finding a suitable successor is crucial for human adaptation to changing climate.
Figure 6-14  April-July Runoff as a percent of water year runoff for the Sacramento River
Changes in Annual Peak Runoff

<table>
<thead>
<tr>
<th>Pre/Post 1955</th>
<th>Feather</th>
<th>Tuolumne</th>
<th>Eel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>42/52</td>
<td>12/17</td>
<td>93/123</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>33/50</td>
<td>11/19</td>
<td>48/84</td>
</tr>
<tr>
<td>Range</td>
<td>145/232</td>
<td>52/91</td>
<td>165/489</td>
</tr>
</tbody>
</table>

Values in 1000 cfs for annual peaks of 3-day average flows
1904-2004 data used for analysis
Range is maximum-minimum values for time period
Climate Projections for California

Based on IPCC Scenarios
From Dettinger, 2005

**Air Temperature**
- Temperature is increasing

**Precipitation**
- Precipitation patterns uncertain
- Lots of Uncertainty
Upper Feather River Basin

- Inflow to Lake Oroville
- Effects of rising air temperature
  - Precipitation-runoff model PRMS
  - +1°C, +2°C, +3°C, +4°C
A 4°C increase in air temperature shifts 50% inflow from mid-March to mid-Feb
Runoff in April to July

Water supply impacts
Water year types may need to be modified
Year types affect water quality standards

Diagram showing the percentage of annual runoff that occurs in April-July from 1970 to 2005 for different water year types and temperature increases.
SWP-CVP Impacts
SWP-CVP Impact Assessment Methodology

- Delta exports (supply)
- Carryover storage
- Groundwater pumping

- X2 location (environment)
- Vulnerability to System Interruption (reliability)

SWP= State Water Project   CVP=Central Valley Project
<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>95% Confidence Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mid-Century</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>-10%</td>
<td>-3 to -18%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>-7%</td>
<td>0 to -16%</td>
</tr>
<tr>
<td><strong>End of Century</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>-25%</td>
<td>-17 to -33%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>-21%</td>
<td>-15 to -27%</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>95% Confidence Range</td>
</tr>
<tr>
<td>----------------</td>
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<td>-----------------------</td>
</tr>
<tr>
<td><strong>Reservoir Carryover Storage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mid-Century</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>-19%</td>
<td>-6 to -31%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>-15%</td>
<td>-3 to -26%</td>
</tr>
<tr>
<td><strong>End of Century</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>-38%</td>
<td>-24 to -51%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>-33%</td>
<td>-21 to -45%</td>
</tr>
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Mid-century climate projections

End-of-century climate projections
### Sac Valley Groundwater Pumping

<table>
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<tr>
<th>Scenario</th>
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<td><strong>Mid-Century</strong></td>
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</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>+9%</td>
<td>+2 to +15%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>+5%</td>
<td>-2 to +11%</td>
</tr>
<tr>
<td><strong>End of Century</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher GHGE (A2)</td>
<td>+17%</td>
<td>+7 to +24%</td>
</tr>
<tr>
<td>Lower GHGE (B1)</td>
<td>+13%</td>
<td>+7 to +18%</td>
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*Darker shading indicates overlap from A2 and B1 confidence levels.*
Power Supply

### CVP

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<tr>
<td></td>
<td>Higher GHGE (A2)</td>
<td>Lower GHGE (B1)</td>
</tr>
<tr>
<td>CVP Gen.</td>
<td>-11%</td>
<td>-4%</td>
</tr>
<tr>
<td>CVP Use</td>
<td>-14%</td>
<td>-9%</td>
</tr>
<tr>
<td>SWP Gen.</td>
<td>-12%</td>
<td>-5%</td>
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<td>-5%</td>
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### SWP

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System Vulnerability to Operational Interruption

- The SWP-CVP system is vulnerable to operational interruption when water levels go below the lowest outlets (dead storage) in at least one of the main storage reservoirs
  - Trinity, Shasta, Oroville, and/or Folsom
SWP-CVP Vulnerability to Operational Interruption

At mid-century 1 in 6 years is vulnerable for A2
1 in 8 years is vulnerable for B1

By the end of the century 1 in 3 years is vulnerable for A2
1 in 4 years is vulnerable for B1
Amount of Additional Water Needed to Avoid Operational Interruption in Vulnerable Years

At mid-century 750 TAF is needed in vulnerable years for A2
575 TAF is needed in vulnerable years for B1

By the end of the century 750 TAF is needed in vulnerable years for A2
850 TAF is needed in vulnerable years for B1
Take Home Message

• Sea level rise
  – Amount, probability, Delta salinity ANNs

• Effects of increasing air temp on Feather basin
  – ↓ April snowpack, ↓ runoff in April-July
  – ← 50% inflow to Oroville up to a month earlier

• Effects of climate change on SWP and CVP
  – ↓ annual Delta exports, ↓ reservoir carryover storage
  – ↑ annual groundwater pumping
  – → X2 range moves upstream, standard still met
  – ↓ Power supply
  – ↑ vulnerability to operational interruption
www.climatechange.ca.gov
www.water.ca.gov/climatechange/
chung@water.ca.gov