



**CALFED  
BAY-DELTA  
PROGRAM**

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P. Joseph Grindstaff,  
Director

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Delta Protection Commission

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US Army Corps of Engineers

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Department of Agriculture:

Natural Resources Conservation Service

Department of Commerce:

National Marine Fisheries Service

Western Area Power Administration

September 6, 2007

To: John Kirlin, Executive Director  
Delta Vision Blue Ribbon Task Force

From: Mike Healey  
CALFED Lead Scientist

RE: PROJECTIONS OF SEA LEVEL RISE FOR THE DELTA

Recognizing that sea level rise would likely be an uncertain but contentious issue for the Delta Vision Blue Ribbon Task Force (Task Force) to address, the Science Program requested that the Independent Science Board (ISB), examine the current literature and offer comments, and if possible, recommendations on sea level rise to aid the Task Force. The response of the ISB is attached to this memo. In my opinion, the ISB has provided a very helpful summary of the extensive and confusing science around climate related sea level rise. They also make specific recommendations concerning which of the many projections of sea level rise should guide the Task Force in developing its vision.

Key points made in the ISB memo are first, that current projections of sea level rise by the Intergovernmental Panel on Climate Change (IPCC), are likely very conservative as the models used to develop these projections underestimate recent measured sea level rise. Second, extrapolation from empirical models of sea level rise yields significantly higher estimates of sea level over the next few decades than the IPCC projections. The ISB suggests that the empirical projections are probably a better basis for short to mid term planning. And third, that neither approach to estimating future sea levels takes account of melting of ice in Greenland and Antarctica, which recent studies suggest is accelerating.

Based on their analysis, the ISB suggests that a mid-range rise in sea level this century is likely to be at least 70-100 cm, significantly greater (~200 cm) if ice cap melting accelerates. While the absolute rise is alarming enough, even more alarming is the fact that only a few centimeters of sea level rise will greatly increase the frequency, intensity and duration of extreme water levels. It is these events that pose the greatest risk to Delta levees, infrastructure and private property.

The ISB assessment of rates and magnitude of sea level rise greatly increases one of the key risk factors in decisions about land use, levee integrity, water conveyance, public safety and other important considerations in the Delta Vision. In my view, it is essential that all the current planning processes take the likelihood of greater sea level rise into account. This is particularly true for the Delta Risk Management Strategy

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(DRMS) study, which did not factor any sea level rise into its assessment of levee needs in its draft Phase 2 report.

I trust that you will convey the ISB memo to the Task Force. I will copy it to the DRMS Technical Advisory Committee, The Bay Delta Conservation Plan Steering Committee Members (BDCP), the Ecosystem Restoration Program (ERP) Implementing Agency Managers and other interested parties. Please let me know if you or the Task Force have any questions.

Sincerely,



Mike Healey  
CALFED Lead Scientist

Attachment

cc: Joe Grindstaff, Director, CALFED  
CALFED Deputy Directors  
DRMS Technical Advisory Committee  
BDCP Steering Committee Members  
ERP Implementing Agency Managers



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September 6, 2007

TO: Michael Healey, Lead Scientist  
CALFED Bay-Delta Program

FROM: Jeffrey Mount, Chair  
CALFED Independent Science Board

RE: Sea Level Rise and Delta Planning

In July of this year, you asked that the Independent Science Board (ISB) examine the array of sea level rise projections available in published reports and, based on current scientific understanding, advise the Science Program about which projections are most appropriate for incorporating into on-going planning for the Delta. The ISB discussed this issue at their August, 2007 meeting and have developed recommendations detailed in this memo. It is important to note that this is not an assessment of the state of sea level rise science, but is intended to highlight the large uncertainty in sea level rise projections and recommend ways to incorporate this uncertainty into planning.

Background

Sea level plays a dominant role in the San Francisco Bay-Delta. Water surface elevations and associated fluctuations due to tides, meteorological conditions and freshwater inflows drive Bay-Delta hydrodynamics. Hydrodynamics, in turn, dictate the location and nature of physical habitat, the quantity and quality of water available for export, and the design of the flood control/water supply infrastructure. Change in sea level has the potential to substantially alter Bay-Delta conditions and to constrain future management options.

Global sea level rise is a well-documented phenomenon, both in the paleoclimatic record as well as the historical record. Tidal gage records indicate that sea level during the 20<sup>th</sup> century has risen an average of 2mm/yr (.08 in) during a period of 0.7°C warming. Recent studies suggest that since 1990, global sea level has been rising at a rate of approximately 3.5 mm/yr (.14 in/yr)<sup>1</sup>. The cause of sea level rise stems from two processes: 1) thermal expansion of sea water as the surface layer warms, and 2) increase in mass of sea water associated with melting of land-based glaciers, snowfields and ice sheets.

Recent research supported by the California Energy Commission<sup>2</sup> (CEC) and continued under the CALFED-sponsored CaSCADE program, shows that sea level

<sup>1</sup> Church, J.A and N.J. White 2006 *A 20<sup>th</sup> Century Acceleration in Global Sea-Level Rise* Geophysical Research Letters, v. 33, article no. L01602

<sup>2</sup> Cayan, D. *et al.* 2006 *Projecting Future Sea Level* California Climate change Center White Paper CEC-500-2005-202-SF Accessed at <http://www.climatechange.ca.gov/research/climate/projecting.html>

rise will impact the Delta principally by increasing the frequency, duration and magnitude of water level extremes. These extreme events occur at various periodicities and are associated with high astronomical tides and Pacific climate disturbances, such as El Niño. The CEC study showed that under moderate climate warming and a sea level rise of 3 mm/year (12 in./century), extreme high water events in the Delta--those that exceed 99.99% of historical high water levels and severely impact levees--increases from exceptionally rare today to an average of around 600 hours/year by 2100. This work also showed that roughly 100 of these hours would coincide with very high runoff conditions, further amplifying the impacts of sea level rise. **In sum, even under modest sea level rise and climate warming projections, extreme high water levels that are considered rare today will likely be very common by the end of this century.**

#### Sea Level Rise Projections

Early in 2007, the Intergovernmental Panel on Climate Change (IPCC) released its latest assessment of the scientific basis for projections of future climate conditions, including global average sea level rise<sup>3</sup>. As noted in the press, in comparison with the IPCC's 2001 assessment, the latest sea level rise projections appear to have narrowed the range of potential sea level rise and lowered the magnitude of projected sea level rise. This was viewed by some outside of the IPCC as indication that: 1) uncertainty regarding sea level rise had decreased and 2) the problem of sea level rise itself appeared to be less than originally stated. However, both the methods used to derive the IPCC 2007 sea level projections, along with extensive new published research in 2007 suggest that this more optimistic view of future sea level rise may be unwarranted.

The IPCC projections are based on physical models that attempt to account for thermal expansion of the oceans and storage changes in land-based glaciers and ice fields. These models, by necessity, simplify the complex processes of ocean circulation and ice melting. The IPCC midrange projection for sea level rise this century is 20-43 cm (8-17 inches), with a full range of variability of 18-59 cm (7-23 inches). The range of variability reflects model differences and uncertainties as well as differences in greenhouse gas emission scenarios. The IPCC model effort is consensus-based, reflecting the agreement of numerous international scientists.

During the past year, there have been major advances in the science of sea level rise. Paradoxically, these advances have increased the uncertainty of projections in sea level rise, at least temporarily. These advances have also led to strong criticism of the approach that the IPCC used in establishing its projections<sup>4</sup>. One criticism is that the models used to project sea level rise tend to under-predict historical sea level rises, most notably failing to capture recent increases. Indeed, models that use empirical historical relationships between global temperatures and sea level rise perform better

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<sup>3</sup> IPCC 2007 *Climate Change 2007: The Physical Basis—Summary for Policymakers* Accessed at <http://www.ipcc.ch/SPM2feb07.pdf>

<sup>4</sup> summary in Kerr 2007 *Science NOW* Accessed at <http://Sciencenow.sciencemag.org/cgi/content/full/2007/215/2>

than the IPCC 2007 models<sup>5</sup>. When applied to the range of emission scenarios used by IPCC 2007, empirical models project a mid-range rise this century of 70-100 cm (28-39 in.) with a full range of variability of 50-140 cm (20-55 in.), substantially higher than IPCC 2007 projections. However, foremost among the criticisms is the failure of the IPCC to include dynamical instability of ice sheets on Greenland and Antarctica in their projections for sea level rise.

Melting of the ice sheets of Greenland and Antarctica has the potential to raise sea level 70 m. For most of the 20<sup>th</sup> century, the ice sheets have remained relatively stable, with melting contributing a minor fraction to sea level rise. However, during the past year numerous studies have demonstrated that the mass balance (input from snowfall versus losses due to melting or detachment) of these ice sheets is shifting toward more rapid loss, most likely in response to warming of the atmosphere and oceans<sup>6</sup>. The recent rate of mass loss in these ice sheets exceeds current physical model predictions. As many authors have pointed out, increased rates of ice sheet flow involving meltwater lubrication of the ice sheet bed or the removal of buttressing ice shelves, may be accelerating the rate of ice loss on Antarctica and Greenland. The IPCC 2007 report explicitly chose not to incorporate the uncertainty associated with this process into their sea level projections. Recent publications that have examined this issue suggest that, under business as usual emissions scenarios, dynamical instability of ice sheets may add as much as 1 m (39.4 in) to sea level rise by 2100<sup>7</sup>.

#### Recommendations

The ability of current physical models to project sea level rise are limited. This stems in part from our poor understanding of and current inability to model the response of Greenland and Antarctic ice sheets to atmospheric and oceanic warming. Given the costs associated with levee failure in the Delta, the ISB feels it would be a mistake for the various planning processes now underway (BDCP, Delta Vision, DRMS) to base their planning on the conservative 2007 IPCC estimates of sea level rise. Although there is some disagreement about mechanisms of ice sheet disintegration, current advances in understanding coupled with new physical measurements all point toward the same conclusion: dynamical instability of ice sheets will likely contribute significantly to future sea level rise, with the potential for very rapid increases of up to a meter (39.4 in.) by 2100 from ice sheets alone. For this reason, the range of sea level projections based on greenhouse gas emission scenarios contained in the IPCC 2007 report should be viewed, at best, as minima for planning purposes.

The board recommends that planning efforts use three approaches to incorporate sea level rise uncertainty. First, given the inability of current physical models to accurately simulate historic and future sea level rise, until future model refinements

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<sup>5</sup> Rahmstorf, S 2007 *A Semi-Empirical Approach to Projecting Sea-Level Rise* Science v. 315, pp. 368-370.

<sup>6</sup> Shepherd, A. and D. Wingham 2007 *Recent Sea-Level Contributions of the Antarctic and Greenland Ice Sheets* Science, v. 315, pp. 1529-1532.

<sup>7</sup> Hansen J et al 2007 *Dangerous human-made interference with climate: a GISS modelE study* Atmospheric Chemistry and Physics, v. 7, pp.2287-2312.

are available, it is prudent to use existing empirically-based models for short to medium term planning purposes. The most recent empirical models project a mid-range rise this century of 70-100 cm (28-39 in.) with a full range of variability of 50-140 cm (20-55 in.). It is important to acknowledge that these empirical models also do not include dynamical instability of ice sheets and likely underestimate long term sea level rise. Second, we recommend adopting a concept that the scientific and engineering community has been advocating for flood management for some time. This involves developing a system that can not only withstand a design sea level rise, but also minimizes damages and loss of life for low-probability events or unforeseen circumstances that exceed design standards. Finally, the board recommends the specific incorporation of the potential for higher-than-expected sea level rise rates into long term infrastructure planning and design. In this way, options that can be efficiently adapted to the potential for significantly higher sea level rise over the next century will be favored over those that use "fixed" targets for design. After all, the current debates over uncertainty in sea level rise are less about how much rise is going to occur and more about when it is going to occur.