State of California Sea-Level Rise Interim Guidance Document

Developed by the Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), with science support provided by the Ocean Protection Council's Science Advisory Team and the California Ocean Science Trust

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Background, Purpose, and Intended Use

This document provides guidance for incorporating sea-level rise (SLR) projections into planning and decision making for projects in California. Governor's Executive Order S-13-08, which was issued on November 14, 2008, included the following:

> *I direct that, prior to release of the final Sea Level Rise Assessment Report from the NAS* [National Academy of Sciences]*, all state agencies within my administration that are planning construction projects in areas vulnerable to future sea level rise shall, for the purposes of planning, consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to sea level rise. However, all projects that have filed a Notice of Preparation, and/or are programmed for construction funding the next five years, or are routine maintenance projects as of the date of this Order may, but are not required to, account for these planning guidelines. Sea level rise estimates should also be used in conjunction with appropriate local information regarding local uplift and subsidence, coastal erosion rates, predicted higher high water levels, storm surge and storm wave data.*

The final report from the National Academy of Sciences (NAS) is unlikely to be released until 2012. The intent of this interim guidance document is to inform and assist state agencies as they develop approaches for incorporating SLR into planning decisions prior to the release of the NAS report and other technical reports (see below for information on planned updates to this document). Specifically, it provides information and recommendations that will enhance consistency across agencies in their development of approaches to SLR. We anticipate that, because of their differing mandates and decision-making processes, state agencies will interpret and use this document in a flexible manner, taking into consideration risk tolerances, timeframes, economic considerations, adaptive capacities, legal requirements and other relevant factors. (Refer to Recommendation #2 below for a discussion of risk tolerance and adaptive capacity.) Although the estimates of future SLR provided in this document are intended to enhance consistency across California state agencies, the document is not intended to prescribe that all state agencies use specific or identical estimates of SLR as part of their assessments or decisions.

Development of this Document

The Sea-Level Rise Task Force (SLR Task Force) of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), led by the Ocean Protection Council (OPC), developed this document. This Task Force includes staff from the following state entities:

- Business, Transportation and Housing Agency,
- Coastal Commission,
- Department of Fish and Game,
- Department of Parks and Recreation,
- Department of Public Health,
- Department of Toxic Substances Control,
- Department of Transportation,
- Department of Water Resources,
- Environmental Protection Agency,
- Governor's Office of Planning and Research,
- Natural Resources Agency,
- Ocean Protection Council,
- San Francisco Bay Conservation and Development Commission,
- State Coastal Conservancy, and
- State Water Resources Control Board.

Staff from these state entities worked collaboratively from July through October 2010 to develop this guidance document and reached agreement on the document's recommendations. Its underlying premise is that SLR potentially will cause many harmful economic, ecological, physical and social impacts and that incorporating SLR into agency decisions can help mitigate some of these potential impacts. For example, SLR will threaten water supplies, coastal development, and infrastructure, but early integration of projected SLR into project designs will lessen these potential impacts.

The SLR Task Force worked with the California Ocean Science Trust (whose Executive Director is the OPC's Science Advisor) to ensure this document was informed by the best available science. A sub-committee of select experts from the OPC's Science Advisory Team responded to questions posed by the SLR Task Force on September 1, 2010 (attached as Appendix A) and their responses informed the policy recommendations below. The following members of the OPC's Science Advisory Team participated in the sub-committee:

- Dr. Dan Cayan, Research Meteorologist, University of California, San Diego, Scripps Institution of Oceanography and U. S. Geological Survey,
- Dr. Gary Griggs, Director of the University of California, Santa Cruz Institute of Marine Science,
- Dr. Sam Johnson, Research Geologist, U.S. Geological Survey, Pacific Science Center, and
- Dr. Tony Haymet, Director of the University of California, San Diego, Scripps Institution of Oceanography.

In addition, OPC staff corresponded with Dr. Stefan Rahmstorf, Professor of Physics of the Oceans, Potsdam University and Mary Tyree, Scripps Institution of Oceanography, to obtain additional information and guidance. Guido Franco, Senior Engineer and Technical Lead for Climate Change Research at the California Energy Commission provided modeling support to develop SLR values for dates prior to 2100.

Planned Future Updates

Because the science related to SLR is rapidly advancing, this guidance document will be regularly revised to reflect the latest scientific understanding of how the climate is changing and how this change may affect SLR. Some of the documents that may inform future revisions of this guidance document include, but are not limited to, the following.

<u>Summer 2011</u> Studies supporting the California Vulnerability and Adaptation Project, which includes the following:

1. Hourly sea-level projections[1] for San Diego, La Jolla, Los Angeles, San Francisco, and Crescent City, which include effects of tides, weather, El Niño/Southern Oscillation; and
2. 50 and 100 year coastal flood potential projections (wave run-up)[2] using nearby sea level estimates and a set of ocean wave simulations for the following sites: (1) Silver Strand Beach north of the Mexican border; (2) La Jolla Shores in the City of San Diego; (3) Santa Cruz Boardwalk in central California; (4) Ocean Beach in San Francisco; and (5) beach and harbor locations at Crescent City in northern California.

<u>Summer 2012</u> Report from the National Academy of Sciences Expert Panel on West Coast SLR

<u>Fall 2013</u> Fifth Assessment Report from Intergovernmental Panel on Climate Change, Working Group 1 (the Physical Science Basis)

If staff resources are available, it is likely that this guidance document will be updated annually to incorporate the latest scientific understanding of SLR.

Recommendations

The SLR Task Force reached agreement on the following policy recommendations based upon recent estimates of future SLR from the scientific literature and input from scientists as described above.

1. **Use the ranges of SLR presented in the December 2009 *Proceedings of National Academy of Sciences* publication by Vermeer and Rahmstorf[3] ("Vermeer and Rahmstorf publication") as a starting place and select SLR values based on agency and context-specific considerations of risk tolerance and adaptive capacity.** Table 1 (below) presents SLR projections based on the Vermeer and Rahmstorf publication[4], adjusted to use 2000 as

[1] Work underway by Dan Cayan, Mary Tyree et al. at Scripps Institution of Oceanography, using, among other tools, the model published by Vermeer and Rahmstorf in the *Proceedings of the National Academy of Sciences,* 2009.

[2] Work underway by Peter Bromirski from Scripps Institute of Oceanography.

[3] Available at http://www.pnas.org/content/106/51/21527.full.pdf+html.

[4] The projections by Vermeer and Rahmstorf are for global mean sea level; recent studies of regional mean sea level variability indicate that over long timeframes, sea level along the California coast tends to compare well with the global trends, so these values are not adjusted for regional differences.

a baseline[5]. There remains uncertainty in our understanding of and ability to model a changing climate; nonetheless, the Task Force developed the projections below using the best available science. Refer to Recommendation # 2 for a discussion of time horizon, risk tolerance, and adaptive capacity, which should be considered when choosing values of SLR to use for specific assessments.

Table 1. Sea-Level Rise Projections using 2000 as the Baseline

Year		Average of Models	Range of Models
2030		7 in (18 cm)	5-8 in (13-21 cm)
2050		14 in (36 cm)	10-17 in (26-43 cm)
2070	**Low**	23 in (59 cm)	17-27 in (43-70 cm)
	Medium	24 in (62 cm)	18-29 in (46-74 cm)
	High	27 in (69 cm)	20-32 in (51-81 cm)
2100	**Low**	40 in (101 cm)	31-50 in (78-128 cm)
	Medium	47 in (121 cm)	37-60 in (95-152 cm)
	High	55 in (140 cm)	43-69 in (110-176 cm)

Note: These projections do not account for catastrophic ice melting, so they may underestimate actual SLR. The SLR projections included in this table do not include a safety factor to ensure against underestimating future SLR. For dates after 2050, three different values for SLR are shown - based on low, medium, and high future greenhouse gas emission scenarios. These values are based on the Intergovernmental Panel on Climate Change emission scenarios as follows: B1 for the low projections, A2 for the medium projections and A1FI for the high projections.

2. **Consider timeframes, adaptive capacity, and risk tolerance when selecting estimates of SLR.** The timeframe identified for a project is important for SLR assessments and will affect the approach for assessing impacts. Until 2050, there is strong agreement among the various climate models for the amount of SLR that is likely to occur. After mid-century, projections of SLR become more uncertain, because the modeling results diverge and the SLR projections vary depending upon how quickly the international community reduces greenhouse gas emissions. Therefore, for projects with timeframes beyond 2050, it is especially important to consider adaptive capacity, impacts, and risk tolerance to guide decisions of whether to use low, medium, or high SLR projections. Due to differing agencies mandates, stakeholder input and other considerations, agencies may assess the adaptive capacity of a project or action differently.

[5] Vermeer and Rahmstorf's paper presents values using 1990 as a baseline. Here the values are adjusted by subtracting 3.4 cm, which represents 10 years of sea-level rise that has already occurred, at an average rate of 3.4mm/year.

Consequences = Impacts x Adaptive Capacity

The consequences of failing to address SLR for a particular project will depend on both adaptive capacity and the *potential* impacts of SLR to public health and safety, public investments, and the environment. Figure 1 in Appendix B (appended to the end of this document) illustrates how adaptive capacity and potential impacts combine to produce consequences.

Adaptive capacity is the ability of a system to respond to climate change, to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[6] A project that has high adaptive capacity and/or low potential impacts will experience fewer consequences. For example, an unpaved trail built within a rolling easement with space to retreat has high adaptive capacity (because the trail can be relocated as sea level rises) and therefore will experience fewer harmful consequences. In contrast, a new wastewater treatment facility located on a shoreline with no space to relocate inland has low adaptive capacity and high potential impacts from flooding (related to public health and safety, public investments, and the environment). The negative consequences for such a project of failing to consider SLR would therefore be high.

Risk Tolerance

The amount of risk involved in a decision depends on both the consequences and the likelihood of *realized* impacts that may result from SLR. These realized impacts, in turn, depend on the extent to which the project design integrates an accurate projection of SLR. However, current SLR projections provide a range of potential SLR values and lack precision (see Table 1 above). Therefore, agencies must consider and balance the relative risks associated with under- and/or overestimating SLR in making decisions.[7]

Figure 2 in Appendix B illustrates this relationship for a project in which underestimating SLR in the project design will result in harmful realized impacts such as flooding. In this case, harmful impacts are more likely to occur if the project design is based upon a low projection of SLR and less likely if higher estimates of SLR are used. In situations with high consequences (high impacts and/or low adaptive capacity), using a low SLR value therefore involves a higher degree of risk.

[6]Definition of adaptive capacity used in the 2*009 California Climate Adaptation Strategy,* based upon definition provided in *Climate Adaptation: Risk, Uncertainty and Decision-mak*ing, UK CIP (2003), UKCIP Technical Report, Oxford, Willows, R. I. and R. K. Cornell (eds.).

[7] Examples of harmful impacts that might result from underestimating SLR include damage to infrastructure, contamination of water supplies due to saltwater intrusion, and inundation of marsh restoration projects located too low relative to the tides. Examples of harmful impacts that might from overestimating SLR include financial costs of over-engineering shoreline structures, locating in-water development in too shallow a depth to avoid navigational hazards, and marsh restoration projects located too high relative to the tides.

3. **Coordinate with other state agencies when selecting values of SLR and, where appropriate and feasible, use the same projections of sea-level rise.** For agencies that have jurisdiction over the same project, using the same SLR values will increase efficiency of analyses and promote consistency. As of the date of this guidance document, the State Coastal Conservancy (SCC) and the State Lands Commission (SLC) have adopted, and the Delta Vision Blue Ribbon Task Force Independent Science Board[8] has recommended, the use of 55 inches (140 cm) of SLR for 2100. The SCC and the SLC also adopted a policy of using 16 inches (41 cm) as the estimate of SLR for 2050. These values of SLR are not specifically referenced to a particular baseline year and agencies may revise these values as new scientific information becomes available. Agencies may select other values depending on their particular guiding policies and considerations related to risk, ability to incorporate phased adaptation into design, and other factors.

4. **Future SLR projections should not be based on linear extrapolation of historic sea level observations.** For estimates beyond one or two decades, linear extrapolation of SLR based on historic observations is inadequate and would likely underestimate the actual SLR. According to the OPC Science Advisory Team, because of non-linear increases in global temperature and the unpredictability of complex natural systems, linear projections of historical SLR are likely to be inaccurate.

5. **Consider trends in relative local mean sea level.** Relative sea level is the sea level relative to the elevation of the land. In California, the land elevation along the coast is changing due to factors including tectonic activity and subsidence. The National Oceanic and Atmospheric Administration provides a summary of the trends in the measured relative sea level at tidal gauges (water level recorders) in California that have been operating for at least 30 years. Predictions of future sea levels at specific locations will be improved if relative trends in sea level from changes in land elevation are factored into the analysis. http://tidesandcurrents.noaa.gov/sltrends/index.shtml

6. **Consider storms and other extreme events.** [9] Future sea level will be a starting point for many different types of analysis for project design. For example, in determining wave impacts, future mean sea level combined with tides, storm surge and El Niño-Southern Oscillation forcing will establish the elevated water level that will be the input for determining wave forces and wave run-up. Where feasible, consideration should be given to the extreme oceanographic conditions that can occur, given the highest water levels projected to result from SLR over the expected life of a project.

[8] Formerly the CALFED Independent Science Board.

[9] OPC plans to coordinate with agencies to identify methods to use to evaluate storms and other extreme events. At this time, there is not a consistent approach and the methodology will depend on many factors.

7. **Consider changing shorelines.** California's very dynamic coast will evolve under rising sea level and assessments of impacts from SLR to shoreline projects must address local shoreline changes. For example, there could be less significant coastal change due to SLR in areas of high sediment supply (e.g., offshore of large northern CA rivers), whereas the coast may recede or change very dramatically in other areas (low sediment supply, presence of eroding bluffs or dunes, etc.). Existing resources for assessing future erosion/accretion rates include: U.S. Geological Survey report on shoreline changes for California's beach habitat[10] http://pubs.usgs.gov/of/2006/1219/, U.S. Geological Survey report on shoreline changes for California's bluff habitat[11] http://pubs.usgs.gov/of/2007/1133/.

[10] Cheryl Hapke et. al, *National Assessment of Shoreline Change Part 3: Historical Shoreline Change and Associated Coastal Land Loss along Sandy Shorelines of the California Coast* (U.S. Geological Survey Open File Report 2006-1219, 2006).
[11] Cheryl Hapke et. al, *National Assessment of Shoreline Change Part 4: Historical coastal cliff retreat along the California coast* (U.S Geological Survey Open File Report 2007-1133, 2007).

APPENDIX B

FOR ILLUSTRATION PURPOSES ONLY

Figure 1. Consequence = Impacts x Adaptive Capacity

	Low Adaptive Capacity	Medium Adaptive Capacity	High Adaptive Capacity
High Impact	HIGH CONSEQUENCES	HIGH CONSEQUENCES	MEDIUM CONSEQUENCES
Medium Impact	HIGH CONSEQUENCES	MEDIUM CONSEQUENCES	LOW CONSEQUENCES
Low Impact	MEDIUM CONSEQUENCES	LOW CONSEQUENCES	LOW CONSEQUENCES

This figure demonstrates how the consequences of a decision are determined by the amount of impact and by the adaptive capacity. There are higher consequences when there are greater impacts and lower adaptive capacities.

Figure 2. Example of:
Risk = Consequence x Likelihood

For projects where too much sea-level rise would cause project impacts such as flooding,

if use lower estimates of sea-level rise | if use medium estimates of sea-level rise | if use higher estimates of sea-level rise

	Higher Likelihood Impacts	Medium Likelihood Impacts	Lower Likelihood Impacts
High Consequence	HIGH RISK	HIGH RISK	MEDIUM RISK
Medium Consequence	HIGH RISK	MEDIUM RISK	LOW RISK
Low Consequence	MEDIUM RISK	LOW RISK	LOW RISK

This figure demonstrates how the amount of risk is determined by the consequences (impacts and adaptive capacity) and the likelihood of impacts occurring. In this example, using higher SLR estimates lower the project risks."