Appendix Section 9

RICRMP Section 145

Section 145
Climate Change and Sea Level Rise

A. Definitions

1. Climate is the long-term weather average observed within a geographic region, and climate change refers to fluctuations in the Earth's climate system as a result of both natural and anthropogenic causes. Currently the long term climate change trend is evidenced by rising global temperatures; increasing extremes within the hydrologic cycle resulting in more frequent floods and droughts; and rising sea level.

2. Sea level rise refers to the change in mean sea level over time in response to global climate and local tectonic changes. Sea level is the height of the sea with respect to a horizontal control point, or benchmark (e.g., The National Geodetic Vertical Datum of 1929 or NGVD 29; The North American Vertical Datum of 1988 or NAVD 88).

3. Vertical datums are either fixed benchmarks such as NGDV 29 and NAVD 88 or site specific tidal datums such as mean high water, mean low water and mean sea level. NGVD 29 is based on the local mean sea level in 1929, which has changed over time. NAVD 88 is now the official civilian vertical datum for surveying and mapping activities in the United States. The conversion to NAVD 88 should be accomplished on a project-by-project basis. Tidal datums, such as mean sea level (MSL) or mean high water (MHW) vary according to the specific location, and represent the mean heights observed over the National Tidal Datum Epoch. Conversions between the datums can be made at www.tidesandcurrents.noaa.gov or calculated through the US Army Corps of Engineers CORPSCON, http://crunch.tec.army.mil/software/corpscon/corpscon.html.

4. Sea level rise includes *eustatic* contributions - global changes responsible for worldwide variations in sea level (e.g., thermal expansion of seawater, melting glacial ice sheets), and *isostatic* effects - regional changes in land surface elevations that are related to the tectonic response to ice or sediment loading, and land subsidence due to extraction of water or oil. The combination of eustatic and isostatic effects at a particular location is known as relative sea level rise.

B. Findings

1. On very long (geologic) time scales, sea level naturally fluctuates in response to variations in astronomical configurations that cause changes in the Earth's climate system. Since the Last Glacial Maximum (approximately 20,000 years ago), global sea level has risen by over 390 feet (120 meters), as water that was previously trapped in continental ice sheets has made its way into the global ocean.

2. Sea level rise is a direct consequence of global climate change. Greenhouse gas emissions to the atmosphere increase surface warming, which in turn increases the volume of ocean waters due to thermal expansion, and accelerates the melting of glacial ice. Atmospheric greenhouse gas concentrations are already higher than levels at the last interglacial period, when sea levels were 13 to 19 feet (4 to 6 meters) higher than at present (Overpeck et al., 2006). Greenhouse gas concentrations are expected to continue to increase through 2100.

3. Human activities and increased concentrations of greenhouse gasses in the atmosphere have *accelerated* the historic rate of eustatic sea level rise. Over the last 100 years, sea levels have risen 0.56 feet (0.17 m) globally. The average rate of rise during the years between 1961 and 2003 was 0.071 inches per year (1.8 mm/yr), and between 1993 and 2003 the rate nearly doubled to 0.12 inches per year (3.1 mm/yr) (IPCC, 2007).

4. In addition to rising global sea levels, the land surface in Rhode Island is subsiding at a rate of approximately 6 inches (15 cm) per century (Douglas, 1991). The combination of these two effects is evident from the long-term trend recorded by the Newport tide gauge (Figure 1), which indicates a rate of 10.1 in +/- 1.2 in (25.7 cm +/- 3.1 cm) of relative sea level rise over the last century.

5. The rate of sea level rise is accelerating. Future sea level rise, like the recent rise, is not expected to be globally uniform or linear. Some regions will become more substantially inundated than the global average, and others less. Of foremost concern is the trend in eustatic rise as observed from tide-gauge records over the past century. The rate of rise during the past 20 years is 25% faster than the rate of rise in any 20 year period that exists in the instrumental record (Church and White, 2006; Rahmstorf et al., 2007).

6. Model-simulated projections of global sea level over the 21st century also clearly demonstrate accelerated progression. Predictions have ranged from 4 inches (10 cm) to several feet above current levels by the year 2100. As a rule, sea level estimates are increasing as the science of modeling becomes more developed.

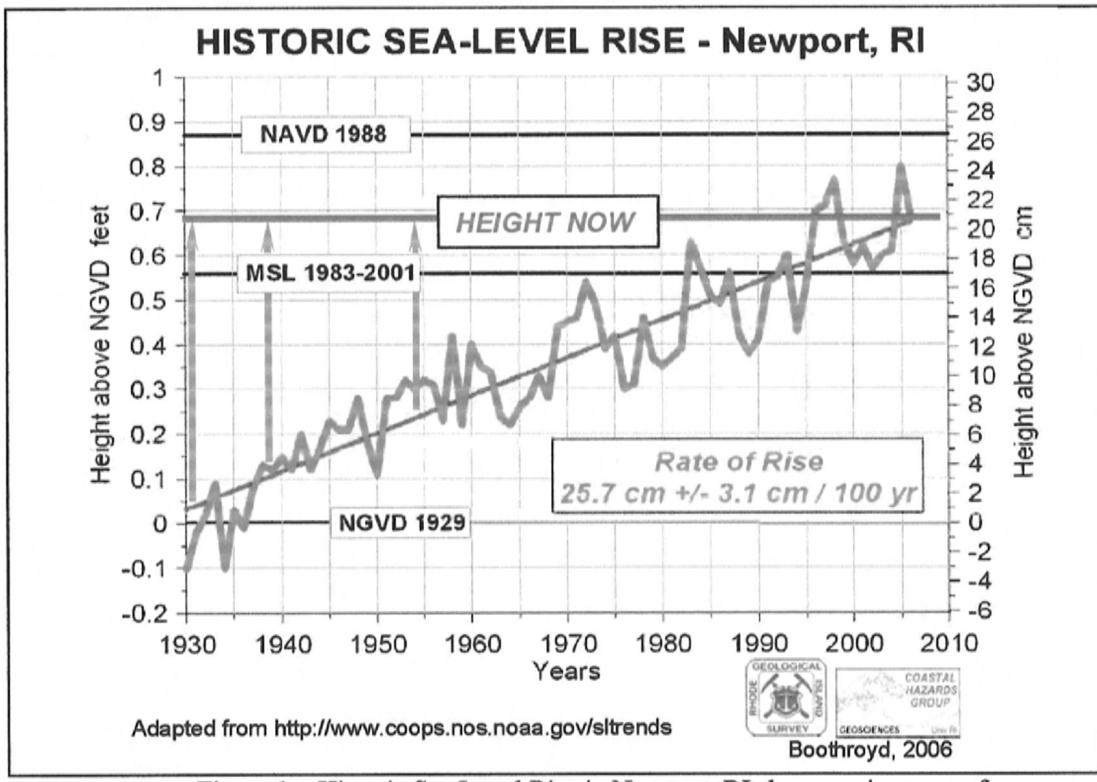

Figure 1 – Historic Sea Level Rise in Newport, RI shows an increase of approximately 0.64 feet between 1930 and 2006

7. When compared with actual observations, modeling scenarios can be quite conservative, as recently observed rates of continental ice melt are greater than those used to generate estimates of sea level rise over the coming century. Since 1990, sea level has been rising faster than the rate predicted by models used to generate IPCC (2001) estimates (Rahmstorf et al., 2007).

8. Higher global temperatures indicate a greater risk of destabilizing the Greenland and West Antarctic ice sheets, yet a great amount of uncertainty remains as to the overall contribution from ice sheet melting. The recent and much publicized Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) projects 7 to 23 in (18 to 59 cm) of eustatic sea level rise in the coming century. These estimates do not include contributions of ice flow dynamics or local subsidence.

9. The most recent science (Rahmstorf, 2007) correlates global sea level rise to global mean surface temperature, which is a good approximation for observations of the 20th century. When this relationship is applied to 21st century warming scenarios, eustatic rise is projected between 1.6 to 4.6 feet (50 to 40 cm) above 1990 levels. Accounting for regional isostatic effects, this estimate suggests that by 2100 sea level in Rhode Island could rise approximately 2 to 5 feet (65 to 155 cm).

10. Climate change will result in wide scale systematic changes in the terrestrial and marine environments. These changes will result in ecosystem shifts that will challenge natural resource managers' efforts to cope and adapt to the new regime.

11. Future increases in relative sea level will displace coastal populations, threaten infrastructure, intensify coastal flooding and ultimately lead to the loss of recreation areas, public space, and coastal wetlands.

12. Coastal infrastructure will become increasingly susceptible to complications from rising sea levels, as the upward trend continues. Residential and commercial structures, roads, and bridges will be more prone to flooding. Sea level rise will also reduce the effectiveness and integrity of existing seawalls and revetments, designed for historically lower water levels.

13. Higher sea levels will result in changes in surface water and groundwater characteristics. Salt intrusion into aquifers will contaminate drinking water supplies and higher water tables will compromise wastewater treatment systems in the coastal zone.

14. Future increase in relative sea level will increase the extent of flood damage over time. Lower elevations will become increasingly susceptible to flooding as storm surge reaches further inland due to both sea level rise in concert with a probable increase in the frequency and intensity of storms predicted from climate change. As a result, more coastal lands will be susceptible to erosion.

15. At historic rates of sea level rise, the relative surface elevation of a salt marsh is maintained through the process of accretion (the build-up of live and decaying plant parts and inorganic sediments). Yet, at high rates of relative sea level rise as predicted by Ramstorf (2007), accretive processes in coastal wetlands cannot keep pace. These habitats can become submerged, resulting in a loss of salt marsh vegetation and an alteration of habitat types. This has been demonstrated by the rapid salt marsh loss in coastal Louisiana. As salt marshes and other coastal habitats become submerged, they migrate inland. However, coastal development has decreased the amount of upland open space adjacent to these habitats, limiting their ability to migrate landward. Thus, an increase in the rate of relative sea level rise will likely result in significant losses of coastal habitat.

16. The average annual temperature of southern New England coastal waters, including Narragansett Bay, has risen approximately two (2) degrees Fahrenheit since the 1960's. This warming trend is implicated in the change of species composition and abundance in Narragansett Bay waters (Nixon, et al., 2003).

17. Increased water temperatures due to climate change will work synergistically with high nutrient levels to stress eelgrass beds. Eelgrass grows best in cool, clean waters. Even as nutrient levels in the Bay are reduced from wastewater treatment plants, if Bay and coastal waters continue to warm due to climate change, it will adversely impact eelgrass beds (Bintz, et al., 2003).

18. Barrier islands are forced landward with rising sea levels. Increased frontal erosion and retreat of the barriers will cause Rhode Island's south shore to migrate continuously landward with rising sea levels.

19. Due to the timescales associated with climate processes and feedbacks, anthropogenic warming and sea level rise will continue for centuries regardless of steps taken to curb greenhouse gas emissions (IPCC, 2007).

20. Pursuant to R.I.G.L. § 46-23-6, the Council is authorized to develop and adopt policies and regulations necessary to manage the coastal resources of the state and protect life and property from coastal hazards resulting from projected sea level rise and probable increased frequency and intensity of coastal storms due to climate change. The Council is also authorized to collaborate with the State Building Commissioner and adopt freeboard calculations (a factor of added safety above the anticipated flood level), in accordance with R.I.G.L. § 23-27.3-100.1.5.5.

C. Policies

1. The Council will review its policies, plans and regulations to proactively plan for and adapt to climate change and sea level rise. The Council will integrate climate change and sea level rise scenarios into its operations to prepare Rhode Island for these new, evolving conditions and make our coastal areas more resilient.

2. The Council's sea level rise policies are based upon the CRMC's legislative mandate to preserve, protect, and where possible, restore the coastal resources of the state through comprehensive and coordinated long-range planning.

3. The Council recognizes that sea level rise is ongoing and its foremost concern is the accelerated rate of rise and the associated risks to Rhode Island coastal areas today and in the future. Accordingly, for planning and management purposes, it is the Council's policy to accommodate a base rate of expected 3 to 5 foot rise in sea level by 2100 in the siting, design, and implementation of public and private coastal activities and to insure proactive stewardship of coastal ecosystems under these changing conditions. It should be noted that the 3-5 ft. rate of sea level rise assumption embedded in this policy is relatively narrow and low. The Council recognizes that the lower the sea level rise estimate used, the greater the risk that policies and efforts to adapt sea level rise and climate change will prove to be inadequate. Therefore, the policies of the Council may take into account different risk tolerances for differing types of public and private coastal activities. In addition, this long term sea level change base rate will be revisited by the Council periodically to address new scientific evidence.

D. References

Bintz, J., S. Nixon, B. Buckley, and S. Granger. 2003. Impacts of temperature and nutrients on coastal lagoon plant communities. *Estuaries* Vol. 26, No. 3, p. 765-776.

Church, J.A., & White, N.J. (2006). A 20th century acceleration in global sea-level rise. *Geophysical Research Letters, 33*, L01602-L01604.

Douglas, B.C. (1991). Global sea level rise. *Journal of Geophysical Research, 96*(C4), 6981-6992.

IPCC. (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY: Cambridge University Press.

IPCC. (2007a). *Climate Change 2007: The Physical Science Basis. Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: UNEP.

Nixon, S., S. Granger, and B. Buckley. 2003. The Warming of Narragansett Bay. 41° North. Vol. 2, Issue 1. Rhode Island Sea Grant and the University of Rhode Island Coastal Institute.

Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B., & Kiehl, J.T. (2006). Paleoclimate evidence for future ice-sheet instability and rapid sea-level rise. *Science, 311*, 1747-1750.

Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise. *Science, 315*, 368-370.

Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E., & Somerville, R.C.J. (2007). Recent climate observations compared to projections. *Science, 316*(5825), 709.