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GROUP PROJECT BRIEF

Impacts of Rising Sea Level on Coastal Communities: A Santa Barbara Case Study

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ON THE WEB AT HTTP://WWW.BREN.UCSB.EDU/~SEALEVEL SPRING 2009

Introduction

The link between greenhouse gases and increasing temperatures is well established (1) and the introduction of greenhouse gases from anthropogenic sources has only exacerbated sea level rise rates. Over the past century, sea level has been rising at a rate of 2mm/year but from 1993-2003 rates increased to 3.1mm/year (2, 3). The consensus modeling of the Intergovernmental Panel on Climate Change (IPCC) in 2007 (1) predicted 0.18 to 0.59 m of sea level rise by the end of this century.

IPCC predictions currently ignore the possibility of dynamic fluctuations of ice flow from continental ice sheets in Greenland and Antarctica (4). While unlikely in the near future, the complete melting of the Greenland ice sheet alone would lead to a global sea level rise of 7m and planetary crisis. Integrating IPCC results with current literature on potential changes in Greenland and Antarctic ice flows will provide a more accurate projection of sea level rise by 2100.

Project Significance

California coastal communities are required to have Local Coastal Plans (LCPs) integrated into their General Plan. Executive Order S-13-08 recently issued by Governor Swarzenegar will require that sea level rise impacts be integrated into LCPs starting in 2011. Using Santa Barbara as a case study, this project seeks to estimate the physical and economic impacts of sea level rise on a coastal community with complex, cliff topography. (Past research has been focused on regions with low coastal relief.) This project will serve as a tool for local policy makers and city planners in their efforts to prepare for sea level rise.

Figure 1: Downtown Santa Barbara, CA

Objectives

- Perform literature review to determine the likely range of sea level rise by 2100.
- Identify physical impacts of sea level rise.
- Model physical impacts of sea level rise in Santa Barbara city limits under plausible scenarios.
- Analyze the costs of sea level rise on infrastructure.
- Identify appropriate adaptation and mitigation measures for use by Santa Barbara city officials and planners.

Background Information

Causes of sea level rise include: thermal expansion, glacial melt and localized subsidence events. Currently, scientists estimate thermal expansion accounts for approximately 50% of the sea level rise observed since the 1950s, but as glacial melt rates increase, the proportion of thermal expansion's contribution to sea level rise is likely to decrease (5, 6).

Multiple positive feedbacks, like increased albedo, polar amplification, and warmer oceans, contribute to ice sheet collapse (7). If current IPCC models were to incorporate dynamic changes in ice melt, sea level rise estimates may be twice as high as previous models predicted (8). The recent observations of rapid changes in Greenland and Antarctic ice sheets suggest that future dynamic changes in ice flow needs to be incorporated in sea level rise predictions and planning strategies (4).

Modeling using the IPCC's six warming scenarios with an improved linear approximation of ice melt, Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research estimated a new sea level rise range of 0.5 to 1.4 m by 2100 (9). Rahmstorf emphasized that his ice melt approximation still may not be satisfactorily robust and time-lagged feedbacks like bed lubrication and ocean warming at the base of ice streams could trigger still greater rises in sea level.

By integrating multiple ice melt variables of Greenland's ice sheet into climate models, Pfeffer *et al.* (10) found 2m was the maximum physically possible estimate of sea level rise by 2100. In order to observe a sea level rise greater than 2m, the researchers estimated Greenland's outlet glaciers would have to discharge at an average rate greater than 26.8 km/year – a rate far exceeding any current discharge rates and considered the upper limit of physically possible glacial melt.

Subsidence or uplift can exacerbate or mitigate sea level rise. Santa Barbara coastal areas, comprised of rock folds called reverse faulting anticlines, are experiencing uplift rates of 1-2 millimeters per year. The rate of subsidence occurring in the Goleta slough and downtown areas is similar (11).

In Santa Barbara, coastal erosion occurs each winter during storm events. Sandy beaches gradually recover during late spring to early fall due to a gentle wave climate. Generally, waves break at an angle to shore. Sediment transport is driven by wave energy, often referred to as the alongshore or littoral transport. El Niño–Southern Oscillation patterns play a vital role in erosion in California. La Niña cycles bring cooler, dryer weather. The majority of erosion occurs during El Niño years, where seas are warmer and more storm activity takes place (13).

Methods

The region of study for this analysis was limited to the city of Santa Barbara (Fig. 1), encompassing approximately 21 square miles (12). In addition to the main portion of the city, Santa Barbara's boundary reaches into the sea and back onto shore to include the Santa Barbara Airport and the surrounding low-lying wetlands of the Goleta Slough.

Figure 2 - Study site outline: Santa Barbara's city limits.

The digital elevation model (DEM) used for the inundation model was obtained from the United States Geological Survey's National Elevation Dataset (NED USGS Seamless Server) with a resolution of 1/3 arc second (approximately 10m). Areas at contour lines of or below 0m, 0.5m, 1.4m or 2m were delineated to assess area of land permanently inundated at mean sea level.

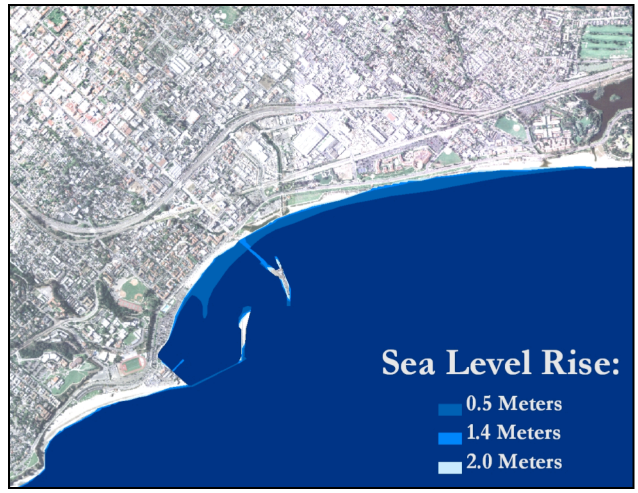

Figure 3 – Downtown Region: Mean sea level rise scenarios.

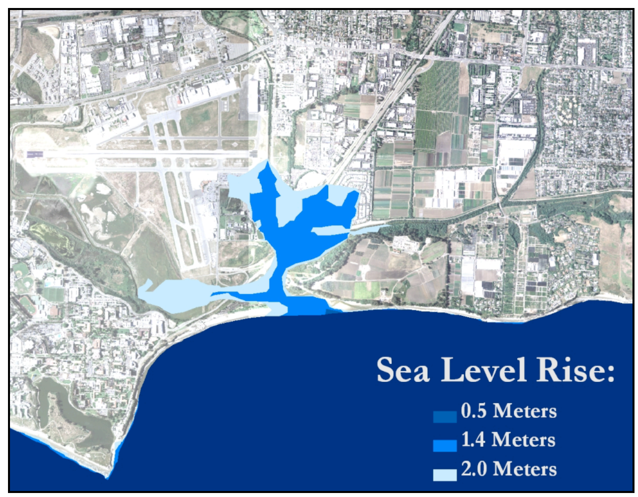

Figure 4 – Airport Region: Mean sea level rise scenarios.

In addition to assessing a mean sea level rise, storm surge was modeled to evaluate the effects of sea level rise on future coastal flood events. Base flood elevations (BFE) are a common way to express extreme high water events (14). BFE events have a 1% or greater probability of occurrence per year (i.e. a 100 year storm). These heights were added to each sea level rise scenario and serve as an estimate of the extent of flooding exacerbated by sea level rise.

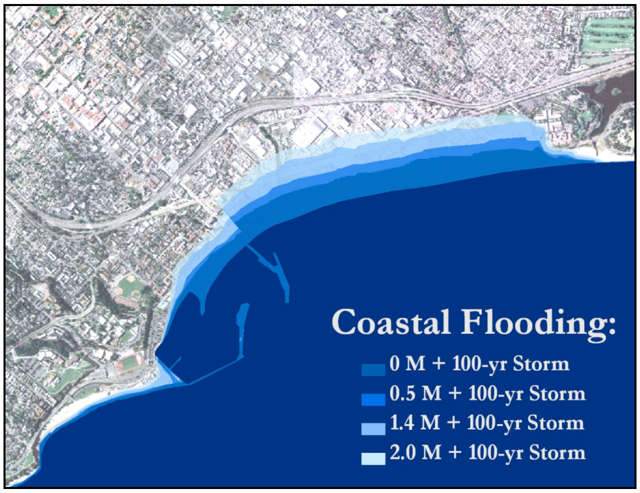

Figure 5 - Downtown/Harbor: SLR and storm flood model.

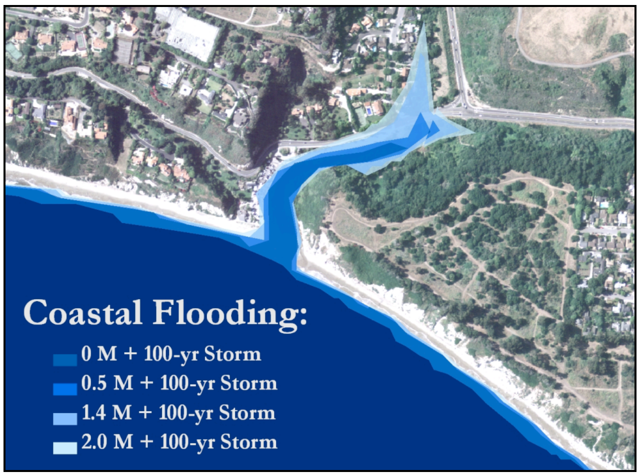

Figure 6 - Arroyo Burro: SLR and storm flood model.

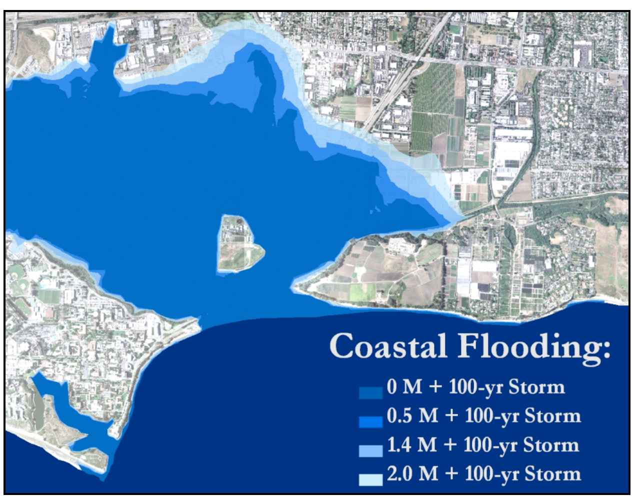

Figure 7 – Airport: SLR and storm flood model

Seventy-five transects were used to model shoreline erosion on Santa Barbara's Mesa over the next 100 years. Erosion rates were derived from stereo aerial photography and referenced from an offshore data point (14). A linear regression was used, taking into account multiple data points, to derive annual erosion rates for the back-beach.

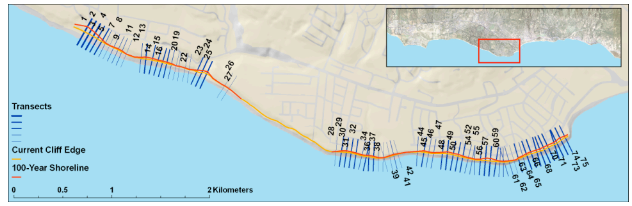

Figure 8 - Erosion transects on the Mesa.

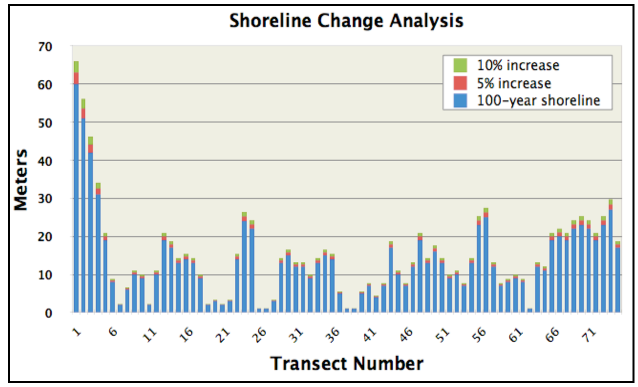

Figure 8 - Extent of erosion on the Mesa by 2100.

City boundaries, tax assessment parcels, and streets were obtained from the Santa Barbara County Spatial Data Catalog (15). Data on hazardous material sites, utilities, essential facilities (i.e. police, fire stations, hospitals) and transportation were obtained from the database for HAZUS, a multi-hazard loss estimation model developed by FEMA and the National Institute of Building Sciences (NIBS). For each of the scenarios, economic impacts were calculated by assessing which economic input layers were located within the inundation zones of each scenario.

Results and Discussion

Under a 0.5m mean sea level rise, an area of approximately 0.07km^2 is affected which is almost exclusively soft, sandy beach area. This half-meter addition still has a noticeable impact on coastal storm flooding; causing flood elevations to further overtop Cabrillo Boulevard downtown (~0.4km^2) and parts of the airport region (~3.3 km^2).

A 1.4m rise would begin to pose a threat to Goleta Beach Park and decrease the drainage capacity of Goleta Slough. In addition, the breakwater at the harbor may be damaged and Chase Palm Park could be partially inundated. Combining this scenario with a major coastal storm causes flooding of Cliff Drive at Arroyo Burro Park and additional flooding risk at the airport and downtown.

In a 2m rise scenario, the sea moves in further. Water borders the edges of Cabrillo Boulevard downtown.

Low-lying areas of Hwy. 217 and Sandspit Road are inundated. Coupled with a coastal flood, affected area grows even larger, and substantial portions of railroads are affected downtown (approx. 5km).

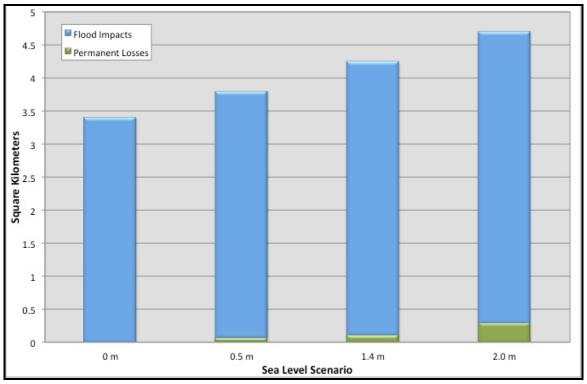

Figure 8 - Total land affected, square kilometers

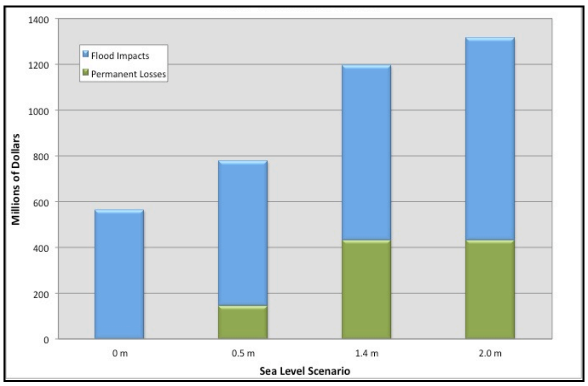

Figure 9 - Total value of land and property affected.

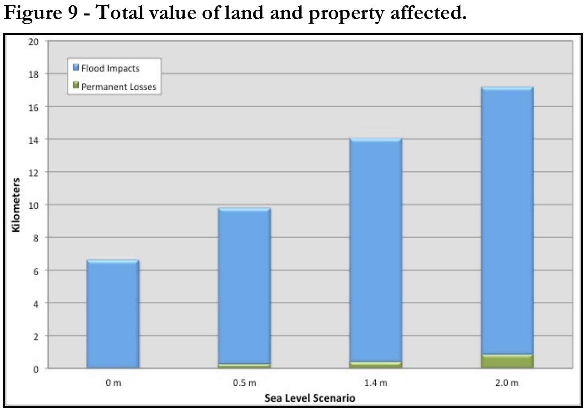

Figure 10 - Total road impacts, kilometers.

Adaptation costs such as increased beach nourishment, coastal armoring, or sea wall structures could be associated with many of the aforementioned sea level rise scenarios, particularly to protect the airport area. Because it is difficult to predict the economic climate of any city in 100 years, cost-benefit analyses should be performed to determine suitable protective measures to implement.

Conclusions

The impact of future sea level rise on the city of Santa Barbara will largely be due to damages from increased flooding during major storm events. Under each of the scenarios used, a mean sea level rise could severely affect beach/public park access and require more money to be spent on preventative measures. In order to manage sea level rise along the coast, city managers must update the local coastal plan to incorporate necessary land use and zoning adjustments.

Sea level rise is likely to affect local coastal communities such as Santa Barbara in a number of ways. Frequency and magnitude of coastal flooding is likely to increase. Cliff erosion and loss of beach due to permanent inundation will reduce buffer to intense winter storms. These all translate to an increased probability of economic impacts such as building and infrastructure losses, all of which need to be addressed by local and regional policymakers in the near future.

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