Report from San Diego County Multi-Jurisdictional Hazard Mitigation Plan Update **Training Workshop #1: Climate Change and Hazards in San Diego**

March, 2014

ICLEI- Local Governments for Sustainability USA



Credits and Acknowledgements

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About this Report

ICLEI- Local Governments for Sustainability, in partnership with The San Diego Foundation and Scripps Institution of Oceanography, is providing technical assistance and stakeholder engagement around the incorporation of climate change impacts and adaptation in the 2015 update to the San Diego County Multi-Jurisdictional Hazard Mitigation Plan. This report provides a summary of material presented at a Training Workshop on March 5th, 2013 and is intended to be used by the County and local jurisdictions in the update of the Hazard Mitigation Plan Risk Assessment. The content of this report may be incorporated into the plan update as appropriate.

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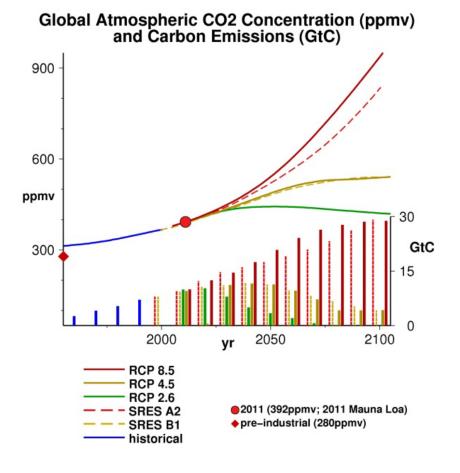
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Climate Projections for the San Diego Region

This section discusses climate change projections for the San Diego region, provided by Dr. Daniel Cayan and his team at Scripps Institution of Oceanography. This section provides background information about the projections and then discusses how temperature, sea level rise, and precipitation are projected to change in the coming decades. The projections are in the form of both trend charts and summary statistics.

Background Information

Emissions Scenarios: The nature of future climate change depends on greenhouse gas (GHG) emissions trends that cannot be predicted with certainty. Emissions scenarios are used to show different potential outcomes. The temperature and precipitation analyses considers projections for two different scenarios, one with relatively lower GHG emissions (RCP 4.5) and one with relatively higher GHG emissions (RCP 8.5).¹ The sea level analysis considers projections for one emissions scenario (SRES B1), a relatively lower emissions scenario.²



¹ RCP stands for Representative Concentration Pathways

² SRES stands for Special Report on Emissions Scenarios

Models: The Scripps team evaluated 31 global climate models (GCMs) for their ability to simulate the annual and seasonal climate of the California/Nevada region and global features of importance to the region, such as El Niño. The Scripps team used 7 models to arrive at projections for temperature (listed below). The precipitation analysis considered 6 of the 7 models listed blow (CanESM2 was not used).

| Model Name | Model Institution |
|------------|---|
| ACCES 1.0 | CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia) |
| CCSM4 | National Center for Atmospheric Research |
| CESM1-BGC | National Science Foundation, Department of Energy, National Center for Atmospheric Research |
| CanESM2 | Canadian Centre for Climate Modelling and Analysis |
| CNRM-CM5 | Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique |
| GFDL-CM3 | Geophysical Fluid Dynamics Laboratory |
| MIROC5 | Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies |

| Global | Climate | Models | Used for | r This Analysis |
|--------|---------|--------|----------|-----------------|
|--------|---------|--------|----------|-----------------|

The analysis of high sea levels considered projections from one model (Geophysical Fluid Dynamics Laboratory- GFDL CM 2.1).

Summary region – Coastal and Inland San Diego: The global climate models have grids that vary in size by degrees in longitude by degrees in latitude (model resolution). In order to make model analyses consistent the output is calculated to a common grid size. The summary statistics shown here for temperature and precipitation are based on model data that has been interpolated to a 2° longitude by 2° latitude grid. This interpolation results in the San Diego region being represented by a grid cell that is coastal (and oceanic) and a grid cell that is inland.



Image from Google Earth showing region covered by coastal and inland data values

Timeframes: The projections for this analysis span from the current year until 2100 with summary statistics for conditions for the decades around 2030, 2050, and 2085. Averages from just one year are misleading as that year could be particularly cool or warm or wet or dry (just as climate varies from year to year now it will also vary from year to year as this century progresses). Thus the averages shown are annual temperature averages over 30-year periods (as noted in tables below). The "historical" values in the table below represent the annual temperature for historical (1970-1999) period from the model simulations. In this kind of analysis, it is important to use the model historical data as a reference, rather than observations, in order to gage the model changes relative to their own historical climatology.

Uncertainty: While it is very certain that climate change is happening and changes will grow in future decades, it is important to recognize that there is uncertainty associated with exactly what future conditions will be like. These projections are based on models that represent the scientific community's best understanding of how the global climate system works. Nevertheless, the model estimates vary *a*) because climate forcings, such as greenhouse gas emissions and aerosols, will change in unknown ways in the future, *b*) because the sequence of natural variations, such as El Niño, is not predictable, and *c*) because the climate models themselves are approximations and thus have limitations. Uncertainty tends to increase with a longer time horizon (i.e. scientists are more certain about the conditions in the next two decades compared to conditions in 2100). But, on the other hand, some of the changes that will occur are more certain than others. It is very certain that temperatures will increase and it is very certain that sea level will rise, but how much they will change is uncertain—a range of warming and a range of sea level rise is possible. Also, changes in precipitation are less certain than those of temperature and sea level. Nevertheless, the climate model projections are useful for providing insights and possible scenarios of changes and trends that will affect the intensity, duration, and geographic scope of natural hazards in the years to come.

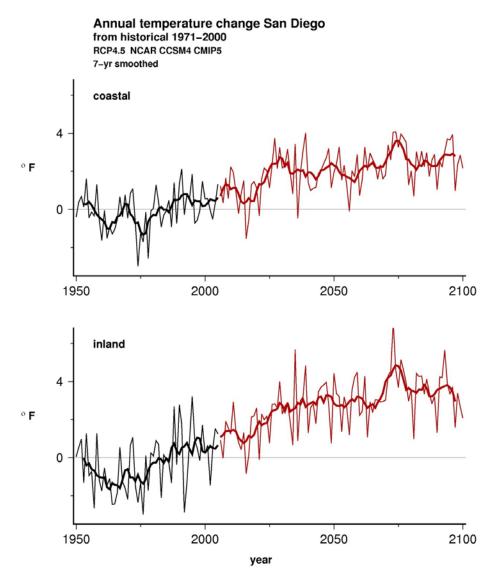
Temperature

This section describes both projected changes in annual average temperature and heat waves. All values are in degrees Fahrenheit (°F).

Annual Average Temperature

Global climate models project that **San Diego will warm 2-3** °**F by 2050** under the relatively low GHG emissions scenario (RCP 4.5). Greater warming can be expected in inland areas than along the coast. Under the higher emissions scenario (RCP 8.5), the warming trend becomes significantly more pronounced after 2050. This tendency occurs in coastal and inland areas.

Annual Average Temperature Trend Charts:



Average Annual Temperature Summary Statistics:

For average annual temperature, the values in the tables below are:

- 1. Taverage: Average annual temperature
- 2. Tmax avg: Average annual maximum temperature (average daytime high temperatures)
- 3. Tmin avg: Average Annual minimum temperatures (average overnight low temperatures)

| eousta. | | | | | | | | |
|-------------|------------|------------------|-------|-------|--|-------|-------|-----|
| | historical | rcp4.5 (low GHG) | | | torical rcp4.5 (low GHG) rcp8.5 (high GHG) | | | HG) |
| Temperature | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- | |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 | |
| Taverage | 65 | 67 | 68 | 69 | 67 | 69 | 71 | |
| Tmax avg | 69 | 72 | 73 | 73 | 72 | 73 | 76 | |
| Tmin avg | 60 | 63 | 64 | 64 | 63 | 64 | 67 | |

| Inland |
|--------|
|--------|

| | historical | rcp4.5 (low GHG) | | | rcp8.5 (high GHG) | | |
|-------------|------------|------------------|-------|-------|-------------------|-------|-------|
| Temperature | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 |
| Taverage | 68 | 71 | 72 | 73 | 71 | 73 | 76 |
| Tmax avg | 82 | 85 | 86 | 87 | 85 | 87 | 90 |
| Tmin avg | 55 | 57 | 59 | 59 | 58 | 59 | 63 |

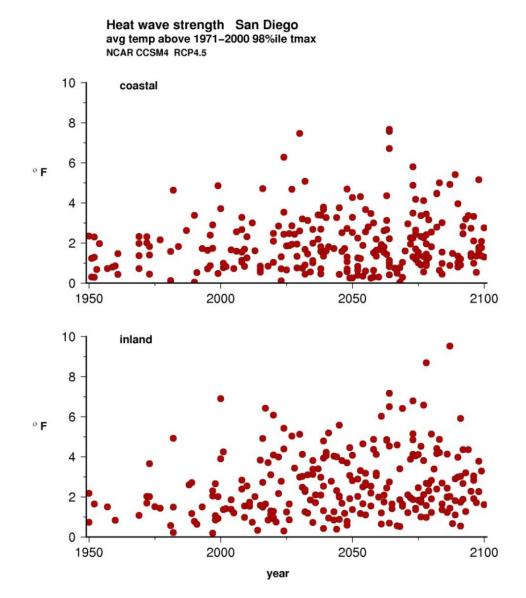
Heat Waves

For this analysis, the definition of a heat wave is the occurrence of the 98th percentile maximum temperature calculated from the historical period of 1970-2000 for at least one day. For coastal areas, a heat wave is defined as at least one day with the temperature reaching 83 °F or higher. For inland areas, a heat wave is at least one day with the temperature reaching 116 degrees °F or higher.

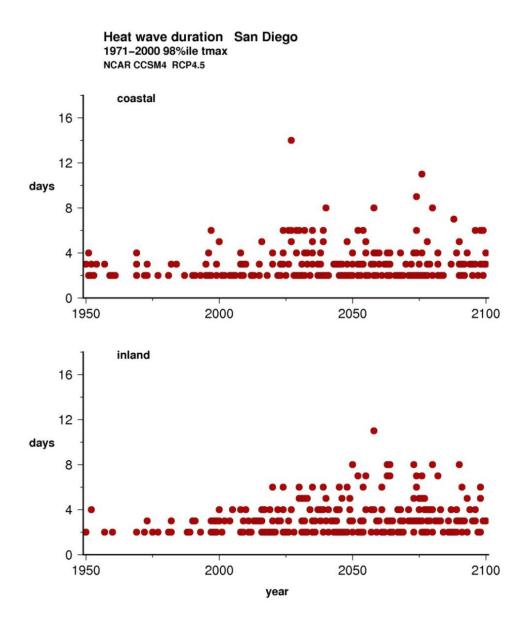
By this definition, heat waves occur about 2 times per year in San Diego's present climate. However, *heat waves are projected to increase in frequency and intensity* (higher maximum temperatures) over the 21st century. The trend chart below shows heat waves occurring with greater frequency and with temperatures reaching farther past the 98th percentile threshold. By mid-century, the San Diego region could see heat waves occurring 12-16 times per year.

Heat waves are also projected to increase in duration (number of days). In the current climate, heat waves last 2 days on average. By mid-century, heat waves are projected to last 3-4 days on average.

Heat Wave Trend Charts:



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Heat Wave Summary Statistics:

For heat waves, the values in the tables below are:

- 4. Days: Average number of heat wave days in a calendar year (Jan-Dec)
- 5. Intensity: Average heat wave intensity (in °F above the 98th percentile)
- 6. Duration: Average heat wave duration (in days)

| | historical | rcp4.5 (low GHG) | | | rcp8.5 (high GHG) | | |
|---------------|------------|------------------|-------|-------|-------------------|-------|-------|
| Heat waves | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 |
| days | 2 | 8 | 13 | 19 | 8 | 16 | 36 |
| intensity (F) | 1 | 2 | 2 | 2 | 2 | 2 | 3 |
| duration | 2 | 3 | 3 | 4 | 3 | 4 | 5 |

| Coastal |
|---------|
|---------|

| Inland | | | | | | | | |
|---------------|------------|------------------|-------|-------|-------|--------------|-------|--|
| | historical | rcp4.5 (low GHG) | | | rcp | 8.5 (high Gl | lG) | |
| Heatwaves | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- | |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 | |
| days | 2 | 8 | 12 | 17 | 9 | 15 | 29 | |
| Intensity (F) | 2 | 3 | 3 | 3 | 3 | 3 | 4 | |
| duration | 2 | 3 | 3 | 4 | 3 | 3 | 5 | |

Sea Level Rise

The table below shows the ranges of sea level rise that the California Coastal Commission³ recommends local jurisdictions plan for based on the National Research Council's (NRC) report on Sea Level Rise in California, Oregon and Washington: Past Present and Future⁴. *San Diego is projected to experience up to two feet of sea level rise by mid-century.*

NRC Average Sea Level Rise Projections for South of Cape Mendocino

| Time Period | Range | Central Estimate | | | | | | |
|-------------|--------------------------------|------------------|--|--|--|--|--|--|
| 2000-2030 | 4 to 30 cm (.13 to .98 ft) | 14.7 ± 5.0 cm | | | | | | |
| 2000-2050 | 12 to 61 cm (.39 to 2.0 ft) | 28.4 ± 9.2 cm | | | | | | |
| 2000-2100 | 42 to 167 cm (1.38 to 5.48 ft) | 91.9 ± 24.9 cm | | | | | | |

³ California Coastal Commission Draft Sea Level Rise Policy Guidance (2013)

http://www.coastal.ca.gov/climate/slr/guidance/CCC_Draft_SLR_Guidance_PR_10142013.pdf

⁴ Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future (2012). http://www.nap.edu/catalog.php?record_id=13389

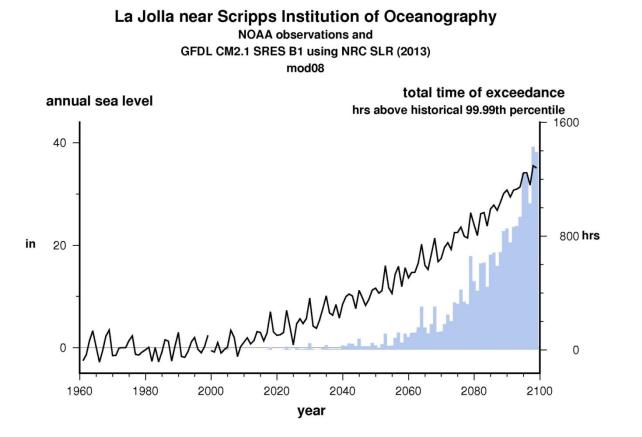
High Sea Levels

It's not only important to consider increases in average sea level, but also consider other fluctuations that will occur on top of the increase in the average, such as high astronomical tides, wind, waves, and storm surge. These fluctuations produce high sea level events.

This analysis of high sea levels uses a model that includes sea level rise, weather, and tidal-related fluctuations in sea level. This analysis defines a high sea level as the 99.99th percentile hourly sea level calculated for the period 1970-1999. The analysis sums the total number of hours in a year that the sea level is at or above this threshold.

The chart below illustrates how as the annual mean sea level increases, *San Diego's shoreline will see increasingly more hours of high sea levels as the century progresses.* In the present climate, San Diego experiences one hour of high sea levels per year on average. By the 2030 period, high sea levels occur 12 hours per year on average. By mid-century, this increases to 62 hours per year. These high sea levels put more natural ecosystems (beaches, cliffs, wetlands) and man-made infrastructure at risk of exposure to flooding and wave action.

High Sea Levels Trend Chart:



High Sea Level Summary Statistics:

| | historical | projection (NRC sea level) | | | |
|------------------------------------|------------|----------------------------|-------|-------|--|
| Sea Level | 1970- | 2015- | 2035- | 2070- | |
| | 1999 | 2044 | 2064 | 2099 | |
| high sea level hours (per year) | 1 | 12 | 62 | 659 | |

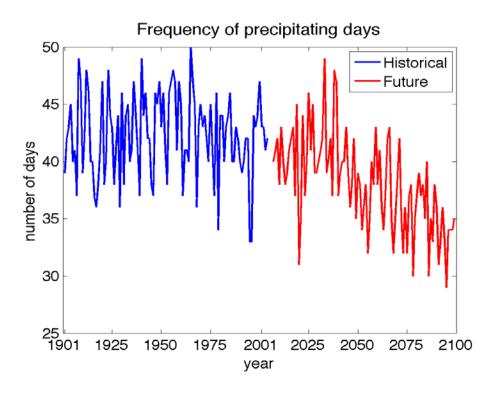
We are not providing sea level rise mapping for this risk assessment. In the future new model estimates will be available. For example, in 2015, CosMoS (Coastal Storm Modeling System) will likely be available for San Diego County. CoSMoS is a dynamic model that includes wind, waves, sediment transport, river/stream flows, and vertical land movement rates. It includes a range of sea level rise and storm scenarios. We recommend that during the next plan update, model estimates such as CoSMos-based sea level rise maps be included in the risk assessment. For the present time, jurisdictions should consider existing sea level rise maps produced by The San Diego Foundation for their risk assessments, which can be found in Appendix A.

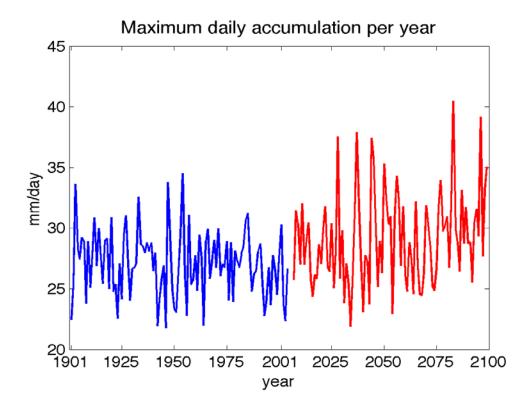
Precipitation

As noted above, projections for precipitation are less certain than those about temperature and sea level rise. Projections indicate that San Diego County is likely to retain its Mediterranean climate with warm, dry summers and relatively cooler and wetter winters. However, projections indicate that San Diego could see drier conditions. Specifically, projections indicate that the number of rainy days per year could decrease. By mid-century the number of rainy days per year could decrease 8-15 percent.

Nevertheless, the models also indicate that the amount of precipitation that accumulates in a single day could increase as the century progresses. With a warmer climate, more water is in the atmosphere, so although it may not rain as often in the San Diego region, when a rain event does occur, it could produce more precipitation.

Precipitation Trend Charts:





Precipitation Summary Statistics:

For precipitation the values in the tables below are:

- 1. Wet days: Average number of precipitating days in a calendar year (precipitation greater than or equal to one mm)
- 2. Max precip: Average maximum daily precipitation (in inches)

| Coastal | | | | | | | | | | | |
|---------------|------------|------------------|-------|-------|-------------------|-------|-------|--|--|--|--|
| Precipitation | historical | rcp4.5 (low GHG) | | | rcp8.5 (high GHG) | | | | | | |
| | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- | | | | |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 | | | | |
| wet days | 85 | 79 | 77 | 75 | 79 | 72 | 70 | | | | |
| max precip | 1.5 | 1.4 | 1.5 | 1.6 | 1.5 | 1.5 | 1.7 | | | | |

| Inland |
|--------|
|--------|

| | historical | rcp4.5 (low GHG) | | | rcp8.5 (high GHG) | | |
|---------------|------------|------------------|-------|-------|-------------------|-------|-------|
| Precipitation | 1970- | 2015- | 2035- | 2070- | 2015- | 2035- | 2070- |
| | 1999 | 2044 | 2064 | 2099 | 2044 | 2064 | 2099 |
| wet days | 82 | 76 | 75 | 74 | 77 | 69 | 68 |
| max precip | 1.2 | 1.3 | 1.3 | 1.3 | 1.2 | 1.3 | 1.4 |

Key Implications for Hazards

This section describes how changing climate conditions affect the location, extent, and probability of future events for various hazards. It also describes some of the impacts associated with these hazards.

Wildfire

Under current climate conditions, wildfire in the San Diego region is a major threat to property, lives, and ecosystems. With hotter temperatures and possibly fewer rainy days in the coming decades, vegetation could become drier. As a result, it is likely that San Diego region will see an increase in the frequency and intensity of fires, making the region more vulnerable to devastating fires like the ones seen in 2003 and 2007.⁵ The fire season could also become longer and less predictable, making firefighting efforts more costly.⁶

An increase in wildfire also impacts public health. Fire-related injuries and death are likely to increase as wildfires occur more frequently.⁷ Wildfires can also be a significant contributor to air pollution. Wildfire smoke contains numerous toxic and hazardous pollutants that are dangerous to breath and can worsen lung disease and other respiratory conditions.⁸

Water shortages/drought

Warming temperatures statewide could result in reduced water supply for the San Diego region. The State Water Project and Colorado River provide 75% to 95% of the water supply for the San Diego region, depending on the year.⁹ Both of these water supplies originate in mountain snowpack. Warming temperatures will result in reduced snowpack, which will translate into reduced water supply.¹⁰ In fact, studies indicate that San Diego's sources of water could shrink by 20 percent or more by 2050.¹¹ An additional threat to water supply is the vulnerability of the levees protecting the California Delta, which feeds the State Water Project.¹² According to the California Adaptation Planning Guide (2012), jurisdictions in the San Diego region must carefully consider the vulnerability of their water supply.

At the same time that the San Diego region's water supply is likely to decrease, water demand is expected to increase approximately 29% by 2050 due to economic growth and population pressures.¹³ Local water managers also report that higher temperatures could lead to increased demand for water

⁵ San Diego's Changing Climate: A Regional Wake-Up Call. A Summary of the Focus 2050 Study Presented by The San Diego Foundation.

⁶ Ibid.

⁷ Ibid.

⁸ Ibid.

⁹ Ibid.

¹⁰ California Adaptation Planning Guide, Understanding Regional Characteristics (2012)

¹¹ San Diego's Changing Climate: A Regional Wake-Up Call. A Summary of the Focus 2050 Study Presented by The San Diego Foundation.

¹² California Adaptation Planning Guide, Understanding Regional Characteristics (2012)

¹³ San Diego's Changing Climate: A Regional Wake-Up Call. A Summary of the Focus 2050 Study Presented by The San Diego Foundation

for irrigation. Water shortages could become more frequent and more severe in the future, straining the local economy.

Extreme Heat

San Diego is facing an increase in the frequency, duration, and strength of heat waves, as described above by heat wave plots and statistics. Nevertheless, residents of coastal areas are vulnerable when the temperature spikes, because they are less accustomed to the heat and they are less likely to have air conditioning. Research also indicates that heat waves are likely to become more humid in the future and with nighttime temperatures staying high, further stressing public health.¹⁴

Extreme heat is exacerbated by the "urban heat island effect", whereby impervious surfaces, such as concrete and asphalt, absorb heat and result in greater warming in urban areas compared to rural areas. Urban heat islands exacerbate the public health impacts that heat waves have upon the more vulnerable populations.¹⁵

Extreme heat events put vulnerable populations, such as the elderly, children, chronically ill, and people who work outside at risk of heat-related illnesses and even death. Extreme heat events highlight the importance of thoughtful social vulnerability analysis.¹⁶ For example, socially isolated elderly persons are especially vulnerable. People who live in urban areas with high impervious surface coverage and no access to air conditioning are also especially vulnerable.

Extreme heat also has secondary impacts, such as power outages and poor air quality. Heat events, and the increased use of air conditioning, can lead to power outages, which makes the events even more dangerous.¹⁷ Hotter temperatures may also lead to poorer air quality because ozone formation, a component of smog, increases with higher temperatures.¹⁸

Electricity Shortages

Higher temperatures, especially during more frequent and intense heat waves, will stress the electricity generation and distribution system as cooling needs cause electricity demand to spike. Without adequate planning, hotter summers and more intense heat waves could result in blackouts and power outages.¹⁹ In addition, inland areas have greater cooling needs and are expected to warm faster than

¹⁴ Gershunov, A., and K. Guirguis (2012), California heat waves in the present and future, Geophysical Research Letters., 39, L18710

¹⁵ Ibid.

¹⁶ Governor's Office of Emergency Services (2013) California Multi-Hazard Mitigation Plan ¹⁷ Ibid.

¹⁸ USGCRP (2009). *Global Climate Change Impacts in the United States* . Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). United States Global Change Research Program. Cambridge University Press, New York, NY, USA.

¹⁹ San Diego's Changing Climate: A Regional Wake-Up Call. A Summary of the Focus 2050 Study Presented by The San Diego Foundation

coastal areas, so future population growth would lead to demand for electricity that could be even more strained.²⁰

While higher temperatures could lead to high electricity demand, higher temperatures could also lead to reductions in electricity supply. Hydroelectric power, a key source of electricity during the summer peak demand period, could see reduced capacity due to the loss of snowpack in the Sierra Nevada²¹ and also in the mountain ranges feeding the Columbia River. Transmission lines also experience lower efficiencies in high heat.²² Furthermore, transmission lines are vulnerable to damage by wildfires, which are likely to occur more frequently in the coming decades.²³

Coastal Flooding and Erosion

With rising sea levels, low-lying areas could become inundated more frequently and with increasingly higher water levels. In addition, storm related flooding may reach father inland and occur more often²⁴. Beaches and cliffs could also see increased erosion as they are exposed to more hours of high sea levels and wave action.²⁵

According to the Sea Level Rise Adaptation Strategy for the San Diego Bay, the sectors most vulnerable to sea level rise are storm water, wastewater, shoreline parks, transportation facilities, commercial buildings, and ecosystems. Low-lying communities, such as Imperial Beach, Coronado, Mission Beach, La Jolla Shores, Del Mar, and Oceanside may be particularly vulnerable to sea level rise.²⁶ In addition, some of San Diego's military installations and the region controlled by the Port of San Diego may also be affected.²⁷

²⁰ Ibid.

²¹ Our Changing Climate 2012, Vulnerability and Adaptation to the Increasing Risks from Climate Change in California. A Summary Report on the Third Assessment from the California Climate Change Center.

²² Ibid. ²³ Ibid.

²⁴ San Diego's Changing Climate: A Regional Wake-Up Call. A Summary of the Focus 2050 Study Presented by The San Diego Foundation

²⁵ Ibid.

²⁶ Ibid.

²⁷ Ibid.

Appendix A: Sea Level Rise Maps

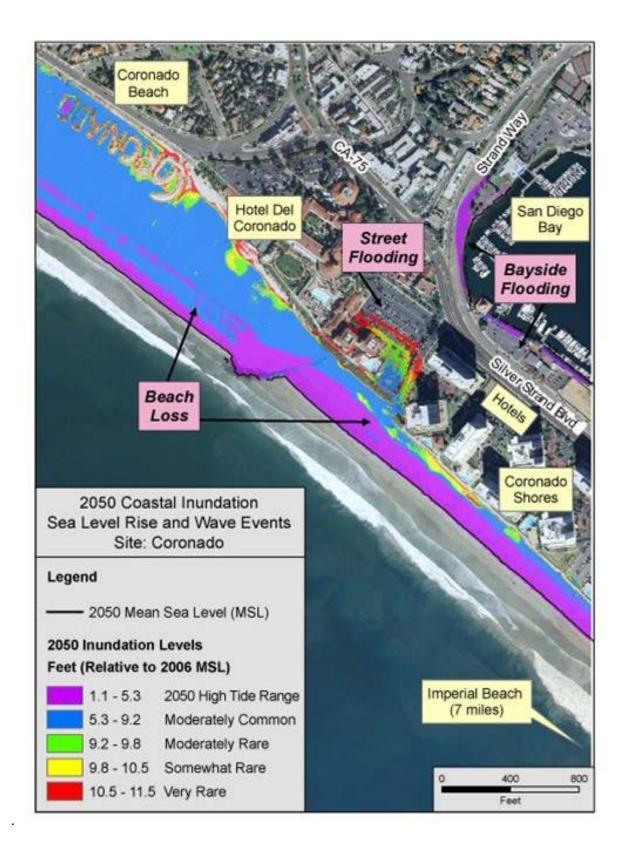
Focus 2050 Maps

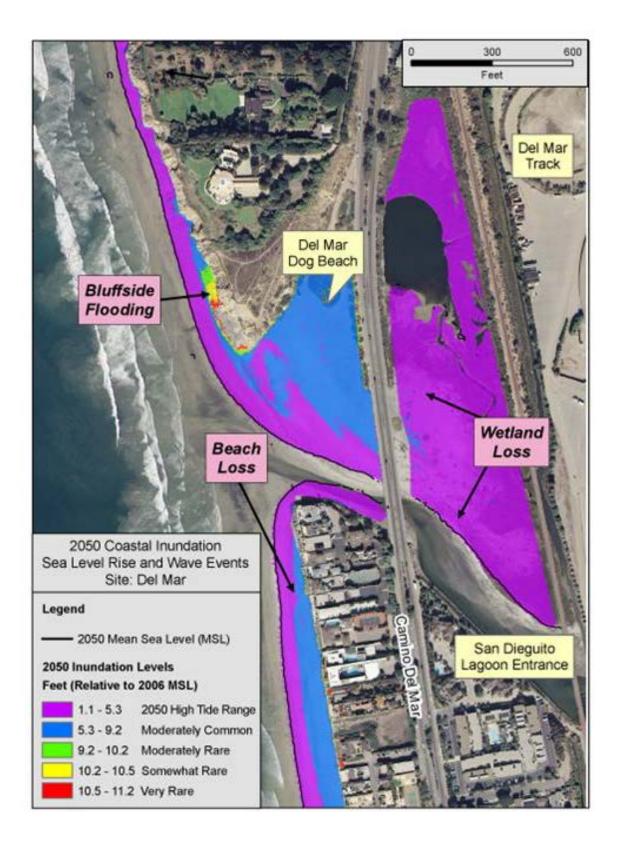
As part of Focus 2050 Regional Assessment, the Coastal Data Information Program (CDIP) at Scripps Institution of Oceanography produced a series of maps for the six low lying areas in San Diego County²⁸. They are included below for reference by local jurisdictions during the risk assessment update. These maps are considered conservative since they only include the impact of waves on the portions of the shoreline exposed to the open ocean. Therefore, the back-bay areas only show inundation due to sea level plus tides and do not show any wave activity. In addition, the maps do not account for potential changes in shoreline elevation that could occur with future wave erosion. This could have a cumulative effect and cause increased inundation as wave erosion removes portions of the current shoreline.

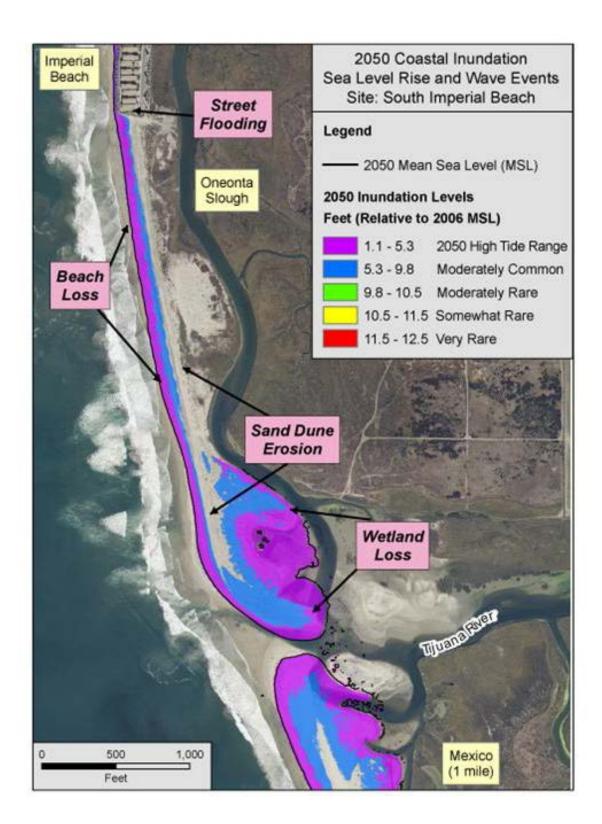
These maps can also be downloaded here:

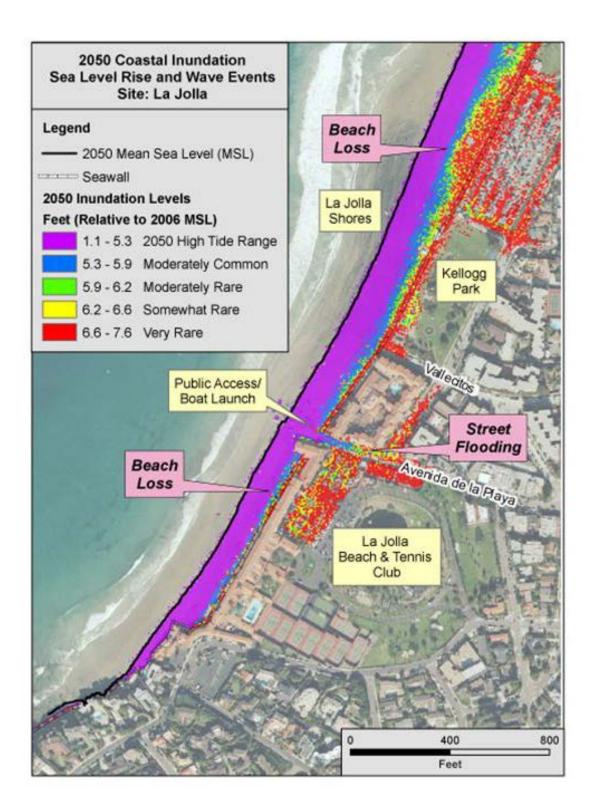
http://www.sdfoundation.org/TSDFProjects/BlaskerRoseMiahforEnvironment/PublishedBlaskerResearc h/SeaLevelRiseMaps.aspx

²⁸ More detail about the maps can be found here : <u>http://www.energy.ca.gov/2009publications/CEC-500-2009-</u> 027/CEC-500-2009-027-F.PDF

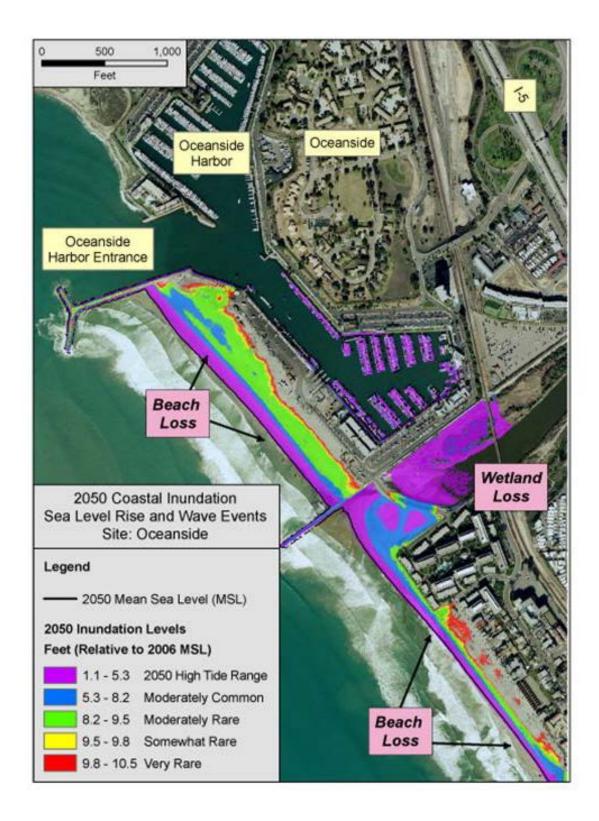












San Diego Bay Sea Level Rise Maps

These maps were developed for the Sea Level Rise Adaptation Strategy for San Diego Bay and are based upon research performed by Dr. Rick Gersberg of San Diego State University with support from a grant by the San Diego Foundation.²⁹ GIS layers showing flooding were created through a "bathtub" modeling method, which does not account for a number of factors—such as topography of the Bay floor, wave run-up, and erosion—that could increase or decrease the extent of the inundation and flooding. The method also does not account for existing shoreline protection infrastructure such as sea walls or revetments. Finally, this model cannot account for future changes to land use and land form. Despite these drawbacks, the maps provide meaningful information on low-lying areas that could be exposed to inundation or flooding under various sea level rise scenarios. Additional maps with more detailed exposure for various sectors can be found in the strategy report.

²⁹ <u>http://www.icleiusa.org/static/San_Diego_Bay_SLR_Adaptation_Strategy_Complete.pdf</u>





