5.0 Vulnerability Assessment

5.1 Planning for Climate Change Involves Grappling with Uncertainty

The current extent of human influence on the natural processes of our environment is unprecedented, and human induced climate change as a result of increased greenhouse gas in the atmosphere is underway (Cal-Adapt, 2012b). If society is to adapt to this threat it is essential to understand not only how much the climate is likely to change and in what time frame, but also to characterize and analyze the effects of climate change (Schneider and Kuntz-Duriseti, 2002).

Much of the information that is available is in the form of projections that are based on complicated models of how natural systems will respond to increasing temperatures under different sets of assumptions, referred to as scenarios. Results are reported as ranges of change over different periods of time. For example, the study of future sea level rise by the National Academy of Sciences, 2012, projects that for the California coast south of Cape Mendocino, sea level will rise 1.6–11.8 inches (4–30 cm) by 2030 relative to 2000, 4.7–24.0 inches (12–61 cm) by 2050, and 16.5– 65.7 inches (42–167 cm) by 2100. Different ranges are reported for conditions in which future global carbon emissions continue to grow at different rates. The range of the estimates tends to be larger when a study is more local and/or is forecasting further into the future. Further, even the most sophisticated models are vastly simplified versions of the natural systems they describe, with the associated, often unquantifiable, possibility for error. However, even with uncertainty about the ultimate magnitude of the expected impacts from climate change, we can identify the types of expected impacts with enough confidence to assess our vulnerabilities and map out strategies to limit the negative effects.

It is important to note that many of the impacts we may experience will not be new situations created by previously unknown processes, but rather a worsening of hazards that the community has experienced in the past. Many of these hazards have been addressed in the County Local Hazard Mitigation Plan (LHMP), (County of Santa Cruz, 2010). For example, severe winter storms are experienced periodically in Santa Cruz County. The damage from flooding and coastal waves associated with severe winter storms may worsen as the climate changes due to higher sea levels exacerbating wave damage, coastal erosion, and coastal flooding.

Because climate change will continue to occur regardless of efforts to reduce GHG emissions, it is necessary to prepare for a range of possible effects.

This section of the CAS assesses the particular vulnerabilities of Santa Cruz County to potential impacts from climate change, with a focus on sea level rise and flooding.

The range of possible effects of climate change includes:

- *Sea Level Rise*
- *Flooding*
- *Extreme Storm Events*
- *Coastal Storm Damage, Bluff Erosion, Beach Loss and Landslides*
- *Ocean Acidification*
- *Changes in Precipitation and Climatic Water Deficit*
- *Changes in Temperatures*
- *Increase in Wildland Fires*
- *Impacts to Biodiversity and Habitat*
- *Impacts to Water Supply*
- *Impacts to Public Health*
- *Economic Impacts of Climate Change*
- *Climate Change and Social Vulnerability*

5.2 Sea Level Rise

In the decades ahead, sea level rise is likely to be the process that will generate one of the most obvious effects of climate change in Santa Cruz County, producing some of the most significant impacts on the low-lying areas along the coast. Sea level rise will gradually inundate low-lying areas, which include all of the shoreline and beach areas along the coastline that are presently closest to sea level. These areas of low elevation include Twin Lakes, Corcoran Lagoon, Moran Lake, Potbelly Beach Road, San Andreas Road at Watsonville Slough, Rio Del

Mar Esplanade and Rio Del Mar Flats, Beach Drive and Via Gaviota, and Pajaro Dunes. The low-lying area of Corcoran Lagoon is shown in Figure 5-1.

The greatest uncertainty is the rate at which sea level rise will occur. Several studies from respected research consortiums have used models to generate projections of how much sea level will change by 2030, 2050 and 2100, both globally and closer to home. The analyses model various scenarios of how much greenhouse gas is contributed to the atmosphere in the future.

Figure 5-1: *Erosion of low-lying area near Corcoran Lagoon Apartments. Source: Photo courtesy of the Santa Cruz Sentinel, 2011.*

The three most prominent studies are from the Intergovernmental Panel on Climate Change (2007), The Pacific Institute (Heberger et al. 2009) and the National Academy of Sciences (2012). It should be noted that the most recent study, prepared by the National Academy of Sciences (2012), includes projections for the coast of California, south of Cape Mendocino, which are more geographically specific than previous studies. The “range” of the amount of potential sea level rise in this area is greater than that indicated by previous studies, that is, it includes both lesser and greater amounts of sea level rise as possible outcomes. In the 2012 National Academy of Sciences study, the National Research Council committee projects that for the California coast south of Cape Mendocino, sea level will rise 1.6–11.8 inches (4–30 cm) by 2030 relative to 2000, 4.7–24.0 inches (12–61 cm) by 2050, and 16.5– 65.7 inches (42–167 cm) by 2100. It should be noted that there are major sources of uncertainty in the regional projections related to assumptions about future ice losses and a constant rate of vertical land motion over the projection period. In addition, uncertainties are larger for regional projections than for global projections.

Also of note, in the time between this most recent study and the IPCC study from 2007, observed conditions indicate that the curves that will be most applicable going forward are those that assume the highest levels of continued greenhouse gas emissions worldwide, and which indicate higher levels of sea level rise.

The IPCC developed several long-term Global Emissions Scenarios for Greenhouse Gases in 1990 and 1992. These are attached as Appendix E.

Vulnerability of the Santa Cruz County Coastline to Future Sea Level Rise

Impacts from rising sea level will accelerate coastal erosion, increase the extent of coastal inundation, increase localized elevated groundwater levels, and magnify the impacts of extreme storm and wave events including El Niño[5] events.

The following section discusses how sea level rise, alone or in combination with other changes, could result in adverse impacts on wastewater/sanitary infrastructure, transportation infrastructure, and residential and commercial property. A 2012 study prepared by the National Academy of Sciences projects that sea level will rise 1.6–11.8 inches (4–30 cm) by 2030 relative to 2000, 4.7–24.0 inches (12–61 cm) by 2050, and 16.5–65.7 inches (42–167 cm) by 2100 (National Research Council, 2012). The following discussions refer to a range of sea level

[5] An El Niño is a temporary change in the climate of the Pacific Ocean, in the region around the equator. This affects both the ocean and atmosphere, generally during the northern hemisphere winter. Typically, the ocean surface warms up by a few degrees Celsius. These small changes in ocean temperature can have large effects on the world's climate.

rise for the years 2030, 2050, and 2100. A reference elevation and year is needed to describe when different areas may become vulnerable to inundation, erosion and/or other hazards. This study was chosen because it is now considered the best available science for the State of California as of 2012.

The Monterey Bay Sanctuary Research Foundation, funded by a grant from the State Coastal Conservancy, is conducting the "Monterey Bay Sea Level Rise Vulnerability Assessment" which is assessing the vulnerability of Monterey Bay communities to sea level rise. This work will result in a set of digital maps and GIS data sets that will enable calculation and mapping of coastal flooding and erosion hazards under existing and future conditions to 2100. This study, which is expected to be completed in late 2013, will refine and perhaps extend the following discussion. The results will be incorporated into this CAS when they are available.

Wastewater/Sanitary Infrastructure

City of Sana Cruz Neary Lagoon Wastewater Treatment Plant

Santa Cruz County Sanitation District customers generate approximately 5-6 million gallons of sewage a day, which is transported from the District's Lode Street facility to the City of Santa Cruz Neary Lagoon wastewater treatment plant for treatment and disposal. The ocean outfall from Neary serves portions of the County as well as the City of Santa Cruz and Scotts Valley.

Groundwater level at the Neary Lagoon Wastewater Treatment Facility is very high. The anticipated rise in groundwater due to sea level rise may adversely impact the facility by impacting storage tanks and associated infrastructure (City of Santa Cruz, 2011). A large underground pump gallery is also susceptible to groundwater impacts through infiltration of groundwater through electrical conduits and cracking walls (City of Santa Cruz 2011).

Santa Cruz County Sanitation District Sewer Infrastructure

Numerous pump stations and associated sanitary sewer infrastructure operated by the Santa Cruz County Sanitation District are situated in locations vulnerable to winter storm damage. It is expected that several of these facilities may be increasingly impacted as sea level rises and storms increase. The sanitary sewer collection system contains approximately 200 miles of sanitary sewer pipeline. Approximately 188 miles of pipeline are gravity mains, and approximately 14 miles are force mains. The Santa Cruz County Sanitation District operates 37 sanitary sewer pump stations, eight of which are located close to sea level. The Santa Cruz County Sanitation District's main pump station along the transmission main to the wastewater treatment plant is the D. A. Porath Wastewater Facility located at 2750 Lode Street near 27th Avenue in Live Oak. That facility pumps sewage from the entire district to the City of Santa Cruz for treatment (LAFCO 2011). No impacts from sea level rise are expected to the Lode Street facility.

Table 5-1: Sanitary Sewer Pump Stations Located Near Sea Level

Pump Station	Approximate Elevation in Feet (amsl)	Pump Station Size
Schwan lake	16	Minor Pump Station
14th	18	Minor Pump Station
Moran	18	Minor Pump Station
Aptos 1	16	Minor Pump Station
Aptos Esplanade	14	Major Pump Station
Aptos 3	18	Minor Pump Station
Rio Del Mar/Hidden Beach	28	Major Pump Station
Sand Dollar Lower*	20	Minor Pump Station

Notes: Major Pump Station = 3 to 5 million gallons per day.
Minor Pump Station = Less than 100 connections.
Amsl – above mean sea level
*County Service Area #5 Pump Station. Not in Santa Cruz County Sanitation District.
Source: County of Santa Cruz Sanitation District, 2012.

The Santa Cruz County Sanitation District pump stations located close to sea level are listed in Table 5-1. All of the pump stations listed in Table 5-1 with the exception of Rio Del Mar/Hidden Beach have the potential to be impacted through either coastal erosion or flooding from wave run-up during a severe storm or El Niño (e.g., 1982-83) with an added 16.5–65.7 inches of sea level rise anticipated by the year 2100. Flooding has the potential to impact the operation of the pump station and coastal erosion could undermine the facility.

Coastal Transportation Infrastructure

East Cliff Drive at Twin Lakes State Beach will have increased susceptibility to coastal flooding and inundation. The roadway currently floods during large storm events, and the vulnerability is increased during El Niño conditions. Although portions of East Cliff Drive at Pleasure Point have been armored, the bluff may continue to be impacted over the coming decades due to sea level rise combined with future El Niño events. Smaller ocean front streets such as Sunny Cove, Geoffroy Drive, 23rd Avenue and Rockview in Live Oak; as well as the ocean end of north-south oriented streets, will be vulnerable to damaging storm waves which, once again, are expected to occur more frequently and with greater intensity (Storlazzi and Wingfield, 2005).

Roads at the top edge of coastal bluffs are vulnerable to damage because the rate of retreat of unprotected coastal bluffs is expected to increase in response to increased exposure to storm waves and intense rain events. For example, the portion of Seacliff Drive overlooking Seacliff State Beach in Aptos has a high potential for impacts from coastal bluff erosion. Virtually the entire length of the cliff along Seacliff Drive experienced as much as 15 feet (4.6 meters) of retreat of the top edge of the cliff during the 1997-98 El Niño; these storm-induced failures occurred in the same locations as previous failures (USGS, 2002). Roads at low elevations at the back beach and the subsurface infrastructure within the roads are also particularly vulnerable to coastal erosion. These roads include Las Olas Drive, Via Gaviota, Pot Belly Beach Road, and Beach Drive.

Flooding of the Pajaro River at both Beach Road and Shell Road at Pajaro Dunes, which currently occurs periodically, is expected to worsen and occur more often as sea level rises. Specifically, more frequent flooding will likely occur on Beach Road near the entrance to Pajaro Dunes where it currently floods periodically. Flooding is also expected to occur within a portion of San Andreas Road located between Watsonville Slough and Beach Road.

Impacts to coastal transportation infrastructure could result in delays in emergency response vehicles if the road is either flooded or washed out. Additional response time may be required by police, ambulance and fire if a detour is necessary. Some roadways such as Las Olas Drive and Beach Drive may be entirely isolated due to flooding or a landslide, making it extremely difficult for emergency response personnel to access in a timely manner. In addition, most roadways also contain numerous underground utilities that may be impacted by a landslide or erosion. This type of damage could result in a large number of residents and businesses in the vicinity without communications or utilities.

Oceanfront Residential and Commercial Properties

The effects of rising sea level can be exacerbated by El Niño occurrences. Sea level along the California coast often rises substantially during El Niño winters, when the eastern Pacific Ocean is warmer than usual and westerly wind patterns are strengthened. A compounding element as the sea level rises is the continued occurrence of winter north Pacific storms, which elevate sea level due to wind and barometric effects, especially during high tides (City of Santa Cruz, 2011). Most of the major historic storm damage along Seacliff and Rio Del Mar has been during El Niño events, and when storm waves arrive simultaneous with high tides and elevated sea levels (e.g., 1982-83 El Niño; see Figure 5-2).

The projected rise in sea level would put most Santa Cruz County oceanfront properties at greater risk from either inundation and/or coastal flooding, or from increased bluff erosion. Unincorporated Santa Cruz County has approximately 29 miles of coastline. Approximately 3 miles of the most intensively developed coastline with primarily residential uses is located in the mid-county community of Live Oak. An additional 3 miles of vulnerable beaches with extensive coastal residential and commercial development occurs from Seacliff to Rio Del Mar.

Figure 5-2: *Damaged homes near Seacliff State Beach and Rio Del Mar during the 1982-83 El Niño.*
Source: Photo courtesy of Gary Griggs.

Some of the most vulnerable areas that would be impacted by sea-level rise in the unincorporated County due to their low coastal elevation are the Rio Del Mar Esplanade/Flats and the many beach front homes located on Pot Belly Beach Road, Las Olas Drive, Beach Drive and Via Gaviota. Under an El Niño condition or storm similar to what was experienced in 1982/83, with the addition of 16.5–65.7 inches of sea-level-rise, most of the commercial and residential areas within the Esplanade would flood. Many of the beachfront homes would also experience varying levels of storm damage and flooding depending upon their elevation, the amount and type of coastal armoring they have protecting them, and other factors. The Seascape Resort development, which is located to the south of Rio Del Mar, would not be vulnerable to sea level rise or coastal erosion due to the generous setback from the face of the bluffs. However, additional vulnerable properties are located along the bluffs in La Selva Beach on Ocean View Drive, The Shore Line, Lily Way, and Sunset Drive. Pajaro Dunes, located at the extreme south end of the County, fronts approximately 1.7 miles of coastline that is vulnerable to sea level rise, coastal flooding, and severe erosion of the dunes on which the homes are constructed.

5.3 Flooding

Flooding and coastal storms present similar risks and are usually related types of hazards in the County of Santa Cruz. Coastal storms can cause increases in tidal elevations (called storm surge), wind speed, coastal erosion, and debris flows, as well as flooding.

During a flood, excess water from rainfall or storm surge accumulates and overflows onto creek banks, beaches, and adjacent floodplains. Floodplains are lowlands adjacent to rivers, lakes and oceans that are subject to recurring floods. Many factors determine the severity of floods, including amount, intensity and duration of rainfall, creek and storm drain system capacity, soil moisture, and the infiltration rate of the ground.

A flood occurs when a waterway receives a discharge greater than its conveyance capacity. Floods may result from intense rainfall, localized drainage problems, tsunamis, or failure of flood control or water supply structures such as levees, dams or reservoirs. Floodwaters can carry large objects downstream with a force strong enough to break utility lines and destroy stationary structures such as homes and bridges. Floodwaters also saturate earth materials, which can result in the instability, collapse and destruction of structures as well as the loss of human life (County of Santa Cruz, 2010).

Most of the known floodplains in the United States have been mapped by the Federal Emergency Management Agency (FEMA), which administers the National Flood Insurance Program (NFIP). Information about floodplains in Santa Cruz County can be found in FEMA's most recent Flood Insurance Study (FIS) and on the Flood Insurance Rate Maps (FIRM). The County FIRM maps are located at http://gissc.co.santa-cruz.ca.us/default.aspx. A small-scale version of all the FIRM panels for the County is provided in Figure 5-3.

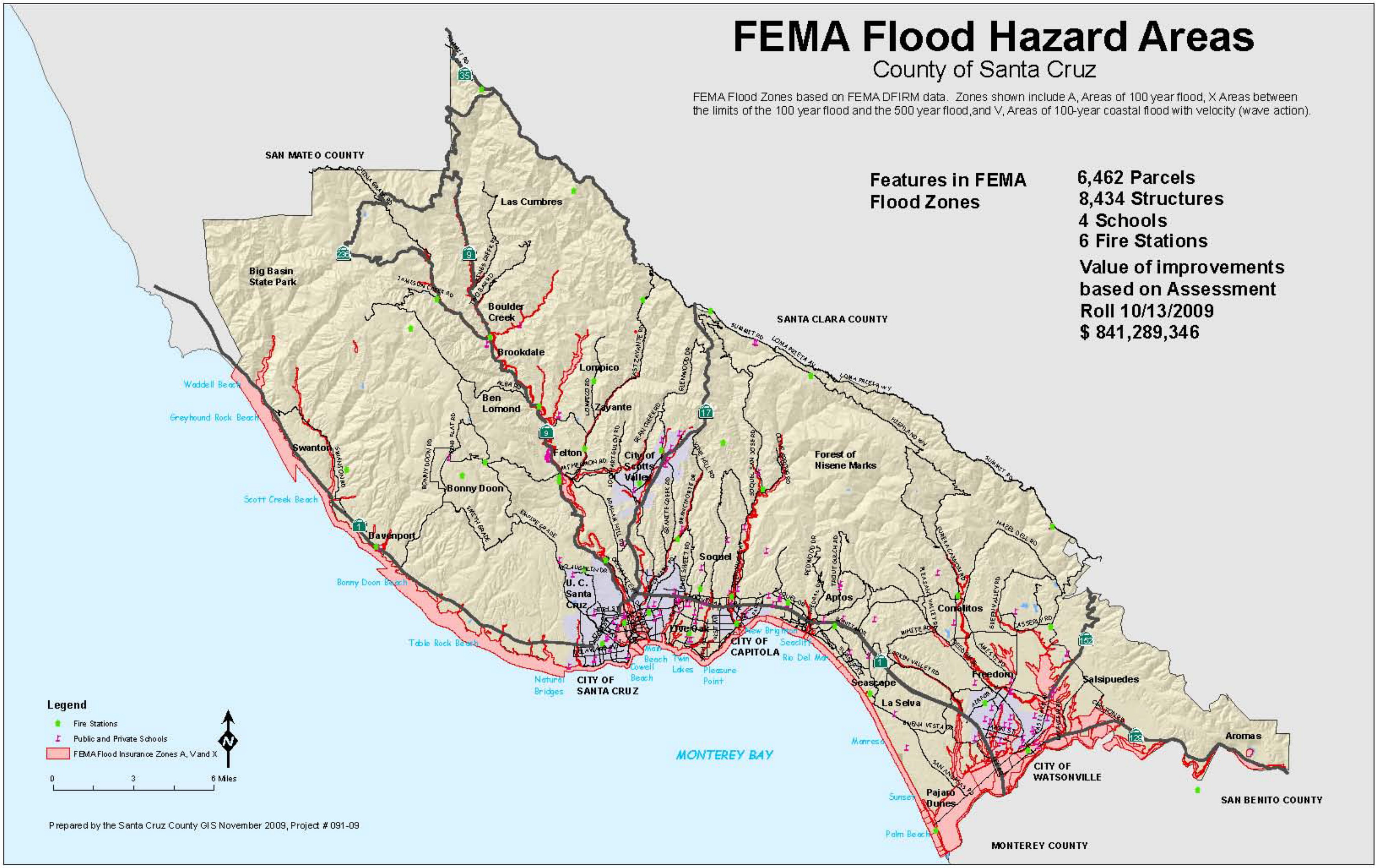

Figure 5-3: County of Santa Cruz FEMA Flood Hazard Areas

Source: County of Santa Cruz, 2009.

Two main rivers in the County that are subject to flooding are the Pajaro River and its tributaries (Corralitos and Salsipuedes creeks), and the San Lorenzo River. The Pajaro River and its floodplain run through agricultural lands within the Pajaro Valley, and through downtown Watsonville. The San Lorenzo River runs through the heavily populated San Lorenzo Valley into downtown Santa Cruz.

Other major creeks in Santa Cruz County adjacent to rural and urban development that are subject to flooding include Aptos Creek, Scott Creek, San Vicente Creek, Valencia Creek, Soquel Creek, Branciforte Creek and their tributaries. The steepness of many of these creek canyons and the surrounding mountain areas results in relatively short warning times, increasing the hazard for those at risk. There are also many smaller creeks and tributaries throughout the County that are subject to flooding. Most of these are tributaries to the major creeks and rivers noted above.

Areas of low-density development characterize most creeks along the North Coast of Santa Cruz County. Flooding of developed areas from storm surges is unlikely in this area, since development has occurred mainly on cliffs and inland of the coastal flood areas. While flooding is still a risk in these areas, there are no occurrences of repetitive loss of property from flooding along the North Coast.

Coastal flooding along the heavily developed Monterey Bay coastline of Santa Cruz County may occur with the simultaneous occurrence of large waves and storm swells during the winter. Storms from the southwest direction produce the type of storm pattern most commonly responsible for the majority of severe coastline flooding. The strong winds combined with high tides that create storm surges are usually accompanied by heavy rains. When storms occur simultaneously with high tides, flood conditions, particularly flooding at the mouth of the Pajaro River and Aptos Creek, are exacerbated (County of Santa Cruz, 2010).

Flooding in Santa Cruz County has occurred in each of the primary drainages and will continue to occur in the future given the right set of meteorological conditions. Previous floods are well documented for all primary drainages with the exception of Aptos Creek, which is not gauged. Major storms and associated flooding have occurred during March 1899, December 1937, February 1940, November 1950, January 1952, December 1955, April 1958, January 1963, January 1967, January 1973, and January 1982. The December 1955, January 1982, and January 1995 storms were the most severe in recent times. As a result of climate change, seasonal precipitation patterns, including timing, intensity, and form of precipitation, are projected to shift. A recent study conducted by the U.S. Geological Survey projects that there will be a shift in peak precipitation from January to February, with less precipitation occurring in the fall (November-December) and spring (March-April) by 2100. The U.S. Geological Survey (USGS) also concluded that while the amount of annual precipitation is not expected to substantially change as a result of climate change, precipitation will be concentrated in mid-winter (Flint, L.E., and Flint, A.L., 2012). As a result, flooding is a growing threat that deserves careful attention as one of the more hazardous impacts of climate change.

Santa Cruz County's geography focuses rainfall into four primary watersheds: the San Lorenzo River; Soquel Creek; Aptos Creek; and Corralitos/Salsipuedes Creeks. While the Corralitos/Salsipuedes watershed feeds into the Pajaro River and can be a crucial element in exposure to flooding of the Pajaro in the Watsonville area, the Pajaro's drainage is predominantly from Southern Santa Clara, San Benito, and Monterey Counties.

Geographically, the San Lorenzo, Soquel, Aptos, and Corralitos/Salsipuedes drainages are relatively short and steep compared to the Pajaro River drainage system, and have significantly shorter times of concentration and therefore shorter warning times for peak flow incidents. Under a widespread heavy rain scenario (accumulations of 0.30 inches of rain per hour or more), severe flooding is likely on low-lying areas within the basin (County of Santa Cruz, 2010). Based on the 100-year flood plain (Federal Emergency Management Agency - FEMA Zone A), 6,462 developed parcels, 8,434 structures, 6 fire stations, and 4 public schools are located within or intersected by the 100-year flood plain (Figure 5-3). These projected flooding impacts will become more widespread as the climate warms and the 100-year flood plain expands.

As intense rainfall events and flooding increase, extreme runoff periods will also become more common. However, infiltration is not expected to overwhelm sewers and centralized sewage treatment infrastructure, because extensive improvements to raise treatment capacity at the Neary Lagoon Wastewater Treatment Plant have been completed (City of Santa Cruz, 2011).

5.4 Extreme Storm Events

In the first three months of 1983, the west coast of the United States experienced a sequence of strong storms, with the coincidence of El Niño conditions, high astronomical tides, and large waves producing record sea levels along virtually the entire coast. Damage was extensive (e.g., Figure 5-4), with losses totaling $215 million (in 2010 dollars; Griggs et al., 2005). Some models predict that such extreme events will become more common and that heightened sea level will persist longer as sea level rises, increasing the potential for damage (Cayan et al., 2008; Cloern et al., 2011).

Figure 5-4: *The Rio Del Mar Esplanade was damaged during the El Niño winter of 1983 by large waves arriving simultaneously with high tides and elevated sea levels.*
Source: Gary Griggs, University of California, Santa Cruz.

The National Research Council committee reproduced the study by Cloern et al. (2011) using its own sea-level projection for the San Francisco area and the Geophysical Fluid Dynamics Laboratory CM2.1 model. This exercise showed that as mean sea level rises, the incidence of extreme high-sea-level events becomes increasingly common (Figure 5-5). According to the model, the incidence of extreme water heights that exceed the 99.99th percentile level (1.41 meters [55 inches]) above historical mean sea level) increases from the historical rate of approximately 9 hours per decade to more than 250 hours per decade by mid-century, and to more than 12,000 hours per decade by the end of the century. The model also shows that the duration of these extremes would lengthen from a maximum of 1 or 2 hours for the recent historical period to 6 or more hours by 2100, increasing the exposure of the coast to waves (National Research Council, 2012).

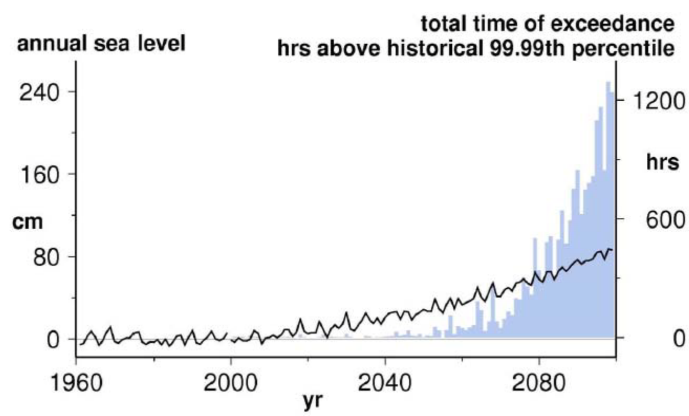

Figure 5-5: *Projected number of hours (blue bars) of extremely high sea level off San Francisco under an assumed sea-level rise and climate change scenario. In this exercise, a sea-level event registers as an exceedance when San Francisco's projected sea level exceeds its recent (1970–2000) 99.99th percentile level, 1.41 meters (55 inches) above historical mean sea level. In the recent historical period, sea level has exceeded this threshold about one time (1 hour) every 14 months. Sea-level rise (black line) during 1960–1999 was arbitrarily set to zero, then increased to the committee's projected level for the San Francisco area over the 21st century (92 cm).*
Source: Adapted from Cloern et al. (2011).

5.5 Coastal Storm Damage, Bluff Erosion, Beach Loss and Landslides

An increase in future coastal storm frequency and/or intensity will increase cliff retreat rates as well as cause potential damage to oceanfront property or public infrastructure. The coastline of northern California, Oregon and Washington have experienced increasingly intense winter storms and greater wave heights over the last 25 years, both of which may be leading to more severe winter erosion (Allan and Komar, 2000). While there is no consensus yet on why storms have been getting stronger, data from wave gauges off the coasts of Oregon and Washington indicate that over a 25 year period from 1975 to 2000, average wave heights have increased from approximately 10 feet to about 13 feet. Over the same period, maximum storm wave heights increased from 36 feet to nearly 50 feet. Greater wave heights when combined with higher sea levels would mean greater erosion at the shoreline.

Storlazzi and Wingfield (2005) of the USGS Pacific Science Center in Santa Cruz recently completed a similar evaluation of changing wave conditions along the central California coast. They analyzed hourly wave data from eight different National Oceanic and Atmospheric Administration (NOAA) buoys deployed off central California between Point Arguello (north of Point Conception) and Cape Mendocino since the early 1980s to determine if and how wave conditions may have changed over the subsequent 22 years. They concluded that wave heights are greater during El Niño months. During the 22 years of recorded wave data examined, monthly significant wave heights (the average of the highest one-third of the waves and a standard index of wave height) increased about 2 cm/year throughout the offshore area. In other words, average wave heights increased about 1.4 feet over the past 22 years. This period was also characterized by a warm Pacific Decadal Oscillation (PDO) cycle dominated by more frequent El Niño conditions. It not yet clear what this means over the long-term, but the trend along the entire Pacific coast has been one of increasing wave heights.

5.5.1 Vulnerability of Santa Cruz County Coastline from Storm Damage

In striking contrast to the slow erosion of hard rocks, erosion can be far more rapid (over 1 foot (30 cm) per year, on average) where the bluffs consist of weaker sedimentary rocks such as shale, siltstone, sandstone, or unconsolidated materials such as dune sand or marine terrace deposits. In these areas cliffs often retreat in a linear fashion, producing relatively straight coastlines. Lithologic, stratigraphic and structural weaknesses or differences are the key factors affecting erosion rates in sedimentary rocks. Cliff erosion is due not only to waves undercutting the base of the cliff, but also to rockfalls, landsliding and slumping higher on the cliff face, often as a result of weakening due to groundwater percolation. The orientation and spacing of joints in the sandstones, siltstones, and mudstones that make up the cliffs surrounding northern Monterey Bay are the dominant factors affecting cliff retreat in this area (Griggs, G.B. and Johnson, R.E. 1979).

The following areas along the unincorporated Santa Cruz County coastline are highly susceptible to damage due to greater intensity of storms associated with climate change.

Twin Lakes Area

The coastline extending from Santa Cruz Harbor to 15th Avenue is expected to face severe winter beach erosion and storm damage by the year 2100 with the projected 16.5–65.7 inches of sea level rise (Figure 5-6). Under a severe storm or El Niño condition as experienced in 1982-83, with the addition of wave run-up and the anticipated sea level rise by 2100, severe flooding and coastal erosion is anticipated. At a roadway elevation of approximately 12 feet above mean sea level (amsl) on E. Cliff Drive at Schwan Lagoon, increased sea level combined with an El Niño condition and more severe storm activity, E. Cliff Drive and many of the residences fronting the roadway along the beach could be severely impacted by flooding and coastal erosion.

Figure 5-6: *Twin Lakes State Beach at Schwan Lagoon Source: California Coastal Records Project, 2012.*

Corcoran Lagoon

The coastline extending from 20th Avenue to Corcoran Lagoon is also expected to face severe beach erosion during winter months by the year 2100, with the projected sea level rise (Figure 5-7). Under a severe El Niño condition or storm event (as experienced in 1982-83) with wave run-up and the anticipated sea level rise, E. Cliff Drive and many of the low-lying oceanfront residences could experience flooding and coastal erosion. The Corcoran Lagoon Apartments shown in Figure 5-7 would be particularly vulnerable to storm damage and flooding due to the low elevation of approximately 10 feet amsl.

Figure 5-7: *Corcoran Lagoon*
Source: California Coastal Records Project, 2012.

Moran Lake

The coastline fronting E. Cliff Drive at Moran Lake (particularly south of Moran Lake) is in a similar situation as Corcoran Lagoon (Figure 5-8). At a roadway elevation of approximately 16 feet amsl, increased sea level combined with and El Niño condition and more severe storm activity, E. Cliff Drive at Moran Lake and many of the residences fronting the beach could be severely impacted by flooding and coastal erosion.

Figure 5-8: *Moran Lake*
Source: California Coastal Records Project, 2012.

East Cliff Drive at Pleasure Point

For decades the County of Santa Cruz has been battling bluff erosion along East Cliff Drive at Pleasure Point (Figure 5-9). East Cliff Drive is designated as a County scenic roadway, and provides public access to the beaches along Pleasure Point as well as access to offshore surfing areas.

Based on both historic aerial photographs that extend back to 1928 and also parcel maps, long-term average annual erosion rates in the 33rd to 41st Avenues area range from about six inches to a foot annually (Griggs and Johnson 1979; Griggs, Patsch, and Savoy 2005; Griggs 1994a; Moore, Benumof, and Griggs 1999; Moore 1998), although erosion rates vary over time and with location due to differences in rock resistance.

Figure 5-9: *East Cliff Drive at Pleasure Point*
Source: California Coastal Records Project, 2012.

To protect East Cliff Drive, already reduced to a single lane of traffic, and the primary utilities that run below it, the County of Santa Cruz constructed approximately 1,100 feet of bluff protection. The project consisted of a soil nail wall and rip rap protection from 33rd Avenue to 36th Avenue, and the construction of a second 300-foot long soil nail wall at the end of 41st Avenue at the Hook. The East Cliff Drive Bluff Protection and Parkway project is intended to increase the longevity of the public right-of-way; project the road and utilities from coastal bluff erosion; and to improve and enhance public access to the coast by constructing a parkway for pedestrians and cyclists. It is not expected that sea level rise will significantly impact the protected bluffs as long as they are maintained in their current condition.

New Brighton/Seacliff State Beach Area

The beachfront residences in the vicinity of New Brighton and Seacliff State Beaches are expected to face severe storm damage by the year 2100 with the projected sea level rise. Under a severe El Niño condition or storm event (as experienced in 1982-83) with wave run-up and the anticipated sea level rise, severe flooding and coastal erosion could occur. Because many residences are elevated at less than 20 feet amsl, increased sea level combined with and El Niño condition and a severe storm, many of the residences fronting the beach have the potential to be severely impacted by flooding and coastal erosion.

Figure 5-10: *Seacliff State Beach Debris Flow, February 6, 1998*
Source: http://walrus.wr.usgs.gov/elnino/coastal/seacliff-all.html

The waves generated by severe winter storms during the 1982-83 El Niño destroyed the wooden seawall at Seacliff State Beach for the 8th time in 60 years. Heavy rains have also had a significant impact on coastal bluffs, as the bluffs are susceptible to debris-flow type failures during heavy rains (Figure 5-10). The bluffs at Seacliff State Beach are protected from waves by a seasonally dependent, variable-width sandy beach backed by a seawall. Waves only reach the base of the cliffs during extreme storms. Therefore, the sea cliff failures and resulting cliff retreat that occur along this stretch of coast are primarily a result of terrestrial processes (overland flow, groundwater flow, and seismic shaking) (USGS 2002). Based on data compiled by Storlazzi and Griggs, 76 percent of historical storms that caused significant coastal erosion or damage occurred during El Niño years. Global climate change and sea level rise are expected to increase the severity and frequency of storms in the eastern Pacific, thereby increasing the risk to coastal bluff erosion and flooding resulting in damage to beach infrastructure and nearby residences located on Beach Drive, Las Olas Drive and Potbelly Beach Road.

Rio Del Mar Esplanade/Flats and Beach Drive

The Rio Del Mar Esplanade/Flats and the coastline fronting Beach Drive also are expected to face severe storm damage by the year 2100 with the projected sea level rise (Figure 5-11). Under a severe El Niño condition or storm event (as experienced in 1983) with wave run-up and the anticipated sea level rise, much of the residential and commercial properties located in the Rio Del Mar Flats area is likely to flood. The oceanfront residences along Beach Drive could be heavily impacted by severe wave run-up, although many of the beachfront structures have recently been improved or replaced since 1983, and now meet the current 100-year FEMA requirements.

Figure 5-11: *Rio Del Mar Esplanade/Flats*
Source: California Coastal Records Project.

Pajaro Dunes

Figure 5-12: Pajaro Dunes Pelican Point Condominiums
Source: California Coastal Records Project.

The largest beachside development in the area, Pajaro Dunes, consists of 396 condominiums, 24 townhouses, and 145 single-family dwellings (Figure 5-12). All units are built on the active sand dune, with many of the structures built directly on the foredune above the beach or on the beach itself. The pattern in this area over the past 50 to 75 years, which is evident in historical aerial photos, is one of dune erosion during severe storms, followed by gradual build-up of sand during the subsequent calmer years. Thus, although there does not appear to be significant net retreat of shoreline, the advance and retreat of the dunes may move the shoreline 40 or 50 feet during a single winter. Unfortunately, the condominiums and homes do not shift with the dunes. Since the development was initiated in 1969, four major El Niño winters (1978, 1980, 1982-83, and 1997-98) have brought large waves from the west and southwest, combined with storm elevated sea levels, and significantly eroded the dunes. The January 1983 storms cut back the dunes up to 40 feet and left a near-vertical cut measuring 15 to 18 feet that came right to the foundations of many of the homes. Only the emergency emplacement of thousands of tons of rock saved these homes from disaster. At the end of the storm season, a permanent revetment was built along the seaward frontage of this development at a cost of several million dollars. Although the revetment has provided some protection, by the time the 1997-98 El Niño hit Pajaro Dunes, much of the revetment was scattered across the beach. Any resemblance to the original, natural dune environment has disappeared (Griggs, et al., 2005). Impacts associated with 16.5–65.7 inches of sea level rise in combination with a severe storm or El Niño event could result in additional dune erosion and flooding from wave run-up, adversely affecting the residences and condominiums once again.

5.5.2 Vulnerability of Santa Cruz County Beaches from Climate Change

Figure 5-13: Rio Del Mar Beach Erosion
Source: Santa Cruz Sentinel, January 2011.

Practically speaking, the entire coast of California has been retreating or eroding for the past 18,000 years. There is an important distinction, however, between the erosion or retreat of coastal cliffs or bluffs, which is an irreversible process, and the seasonal or longer term erosion of the beaches, which can be recoverable. Thus, even as the coastline continues to retreat landward, beaches will be present as long as the supply of sand to the shoreline is maintained. When the shoreline of California was 10 miles (16 km) to the west, there were beaches on the outer edge of the continental shelf. As sea level rose and the shoreline moved eastward, the beaches migrated with the shoreline because sand continued to be provided by rivers, streams and cliff erosion (State of California, 2002). Figure 5-13 shows the beach erosion at Rio Del Mar Beach that occurred following a substantial storm. Sand was moved offshore during large storm surges and high flows from the mouth of Aptos Creek.

During 1982-83 El Niño storms, Seacliff State Beach was severely eroded. Cross-shore profiles obtained by U.S. Geological Survey scientists (Figure 5-14) show that normal wave activity in succeeding years re-deposited sand, rebuilding the beach (USGS, 2000).

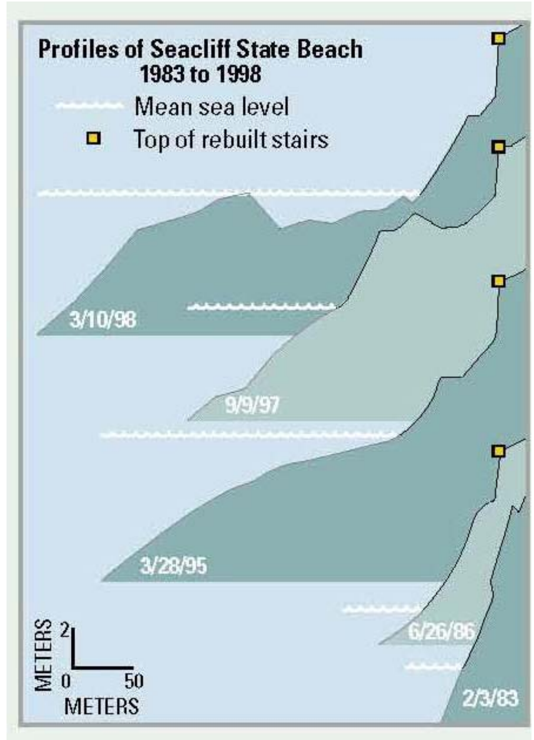

Figure 5-14: *Profiles of Seacliff State Beach 1983-1998*
Source: USGS 2000.

5.5.3 Vulnerability of Santa Cruz County from Increased Landslides

An anticipated increase in precipitation during midwinter months (December and January) may lead to increased impact to roadways and residences from flooding and landslides (Flint, L.E., and Flint, A.L., 2012). Several notable landslides have occurred in Santa Cruz County in recent history. Some of the better-documented landslides include:

Mount Hermon Landslide: The Mountain Hermon landslide moved in the late 1950's after the El Niño year of 1957–1958. This landsliding occurred in an area of suspected older landsliding and the new movement in 1982-83 extended from the Kaiser Quarry to the bottom of Bean Creek blocking Mount Hermon Road, and is one of the reasons for construction of the Mount Hermon bypass.

Rain Storms of January 1982: Severe storms caused multiple landslides throughout the Bay Area and especially in the Santa Cruz Mountains. One very large composite landslide along Love Creek, west of Loch Lomond Reservoir, destroyed a neighborhood and killed ten people. Other landslides, including debris flows, destroyed homes and were responsible for the deaths of several other people. In addition to damage to homes, widespread landslide damage occurred to roadways, driveways, and stream channels.

El Niño Winter Storms of 1983, 1986, 1998, and 2005: These storms caused multiple landslides, particularly debris flows, throughout the Santa Cruz Mountains. During the 1998 winter, many homes were affected by landsliding and several roadways were damaged including Highway 9, Branciforte Road, El Rancho Drive, and Amesti Road. Winter rains also induced landsliding within quarries located throughout the County.

Nelson Road March 2011 Landslide: Saturated soils resulted in a landside of approximately 200 to 300 hundred feet long and about 150 feet wide. It wiped out a power line and cut off about 25 homes from the main road. A temporary access road was constructed to allow access to the stranded homes during debris removal. A permanent bypass is under design with an estimated construction cost of $1.5 million.

5.6 Ocean Acidification

Ocean acidification describes the increase in the acidity of the global oceans resulting from the uptake of human generated carbon dioxide from the atmosphere. Less than half of the carbon dioxide produced by the burning of oil, gas and coal stays in the atmosphere and about a third is dissolved into the oceans. This dissolved carbon dioxide forms a weak acid (carbonic acid) in seawater making it slightly more acidic. While this process has helped remove very large quantities of carbon dioxide from the atmosphere, reducing the greenhouse effects that would have otherwise been significantly greater, it continues to make the oceans more acidic (City of Santa Cruz, 2011).

By the first decade of the 21st century, the acidity of the world oceans had increased by about 30 percent over the pre-industrial revolution level. As carbon dioxide emissions continue with the burning of additional fossil fuels (coal, oil and gas now provide about 87 percent of global energy), additional carbon dioxide will enter the oceans and pH will continue to decrease. Future rates of change will depend upon when and how rapidly the U.S. and the rest of industrialized society move away from a fossil fuel based economy (City of Santa Cruz, 2011).

It is believed that this progressive shift towards increased acidity will gradually affect organisms in the ocean that build their skeletons or shells out of calcium carbonate. Calcium carbonate dissolves in acidic solutions, so the lower the pH, the more difficult it will be for these organisms to either grow new shells or skeletons or maintain their existing health and populations. These include some of the larger and more visible organisms such as coral, sea urchins, and mollusks, but also plankton such as foraminifera, coccolithophores and pteropods. These tiny organisms are at the base of the food chain and provide the food supply for the larger plankton such as krill, which are the primary food source for salmon and other fish, as well as sea birds and baleen whales (City of Santa Cruz, 2011).

Acidification is not yet having a measureable effect on the coastal ocean off Santa Cruz. Considerable research is underway as to how these well documented patterns will affect different types of organisms and how soon. This is a global issue and while it could have some effects on the fauna of the Monterey Bay at some future time, it is beyond the reach of our community to significantly affect these global scale processes (City of Santa Cruz, 2011).

5.7 Precipitation and Climatic Water Deficit

5.7.1 Precipitation

The City of Santa Cruz has a recorded rainfall history that goes back to 1868. The average annual rainfall for the city over this 138-year period is 28.5 inches, and yearly totals range from a low of 10.2 inches in 1924 to a maximum of 61.3 inches in 1941. There are well-documented dry periods with below average rainfall that extended for three or more years in a row, and also wetter periods with rainfall remaining above average for at least three years in a row. Over the past 138 years, however, there is no recognizable trend towards an increase in rainfall. The main trends tend to be higher average rainfalls during warm Pacific Decadal Oscillation (PDO) cycles (1978-2000) and lower average rainfalls during cooler PDO cycles (1945-1978) (City of Santa Cruz 2011).

A recent study, "Simulation of Climate Change in San Francisco Bay Basins, California: Case Studies in the Russian River Valley and Santa Cruz Mountains", Flint, L.E., and A.L. Flint, U.S. Geological Survey, 2012, concludes that for Santa Cruz County annual precipitation may slightly increase or slightly decrease a the climate changes, depending on the hydrologic model, but that in either case rain will be compressed into mid winter months, which will create drier than normal conditions in the fall and spring. The study also concluded that more than one drought every decade is anticipated, where historically only about 4 to 5 droughts occurred over a 90 year period. These changes have implications for flooding, water supply, and habitat.

5.7.2 Climatic Water Deficit

Climatic water deficit is an estimate of drought stress on soils and plants. It integrates several variables, including solar radiation, evapotranspiration, soil moisture from precipitation, and air temperature. In a Mediterranean climate, climatic water deficit can be thought of as a proxy for water demand based on irrigation needs, and changes in climatic water deficit effectively quantify the supplemental amount of water needed to maintain current vegetation cover, whether natural vegetation or agricultural crops (Flint, L.E., and A.L. Flint, 2012).

The U.S. Geological Survey (USGS) (Flint, L.E. and A.L. Flint, 2012) evaluated potential changes in climate, evapotranspiration, recharge, runoff, and climatic water deficit in the Santa Cruz Mountains. The study was carried out in collaboration with the County of Santa Cruz, Environmental Health Services. The study finds that the San Francisco Bay Area has experienced a warming trend over the 20th century, and monthly maximum temperatures have increased approximately 1.8°F (1°C) between 1900 and 2000. In general, coastal influences mitigate the warming trend, and effects are more pronounced with increasing distance from the Pacific coast or the bay. Projected temperature trends showed greater agreement than projected precipitation trends.

As noted in section 5.7.1, the hydrologic modeling predicts reduced early and late wet season runoff for the end of the century which could result in an extended dry season and an increased risk of floods in the wet season. Summers are projected to be longer and drier in the future regardless of whether precipitation increases, decreases or is unchanged. As a result of this precipitation pattern water supply could be subject to increased variability, that is, reduced reliability, while water demand is likely to increase during the extended summers. Climatic water deficit is expected to increase as much as 30 percent between 2071 and 2100. In some locations in the County approximately 8 inches (200 millimeters) of additional water may be needed on average to maintain current soil moisture conditions and the current level of climatic water deficit. Extended dry season conditions and the potential for increased drought could also place additional stress on water quality and habitat (Flint, L.E., and A.L. Flint).

The results of this study, which will be integrated into water supply management plans, indicate that water supply may become less dependable and that plants, redwood trees in particular, may be displaced. Biotic impacts of potential changes in the precipitation regime are discussed further in section 5.10.

5.8 Changing Temperatures

Increased greenhouse gases in the atmosphere raises temperatures and alters seasonal temperature patterns. Effects can include changes in average temperature, the timing of seasons, and the degree of cooling that occurs in the evening. In addition to new seasonal temperature patterns, extreme events such as heat waves are projected to occur more frequently and/or last for longer periods of time. Changes in average temperature, when evaluated on large scales (state, national, or global), have a fairly high level of certainty with consistency among various models (State of California 2012b).

According to the Flint, L.E. and A.L. Flint, (2012) study, maximum air temperature in the Bay Area has steadily risen over the last century by 1.8°F (1°C), and all model and scenario projections indicate it will continue to rise. The air temperature projections for the 21st century showed increases from 3.6 to 7.2°F (2 to 4°C) in the Bay Area, but the B1 emissions scenario estimates were less than from the A2 scenario (see Appendix E for descriptions of IPCC scenarios). Decadal (10-year) averages of air temperature in the Bay Area showing historical and future temperatures generated by the global climate models are presented in Figure 5-15.

5.9 Increase in Wildland Fires

Santa Cruz County is ranked 9th among 413 western state counties for percentage of homes in the Wildland Urban Interface (WUI) and 14th among 58 counties in California for fire risk (Headwaters Economics, 2008). Areas such as vacant lots, highway medians, parks, golf courses and rural residential areas describe many areas considered to be WUI. Climate change is expected to result in a low to moderate risk of increases in fire frequency, size, and severity beyond the historic range of natural wildfire variability due to increasing length of the fire season, drier fuels, and decreasing forest health. These changes are being driven by alterations in temperature and precipitation regimes to a warmer and drier condition. In general, the statistical fire model predictions show a greater change in the probability of burning in the distant future (2070–2099) than near future (2010–2039), as would be expected from the greater changes in climate by the end of the century (Krawchuk and Moritz, 2012).

The size, severity, duration and frequency of fires are greatly influenced by climate. Although fires are a natural part of the California landscape, the fire season in California and elsewhere seems to be starting sooner and lasting longer, with climate change being suspected as a key mechanism in this trend (Flannigan et al., 2000; Westerling et al., 2006). The rolling five year average for acres burned by wildfires within all jurisdictions increased in the past two decades from 250,000 to 350,000 acres (1987–1996) to 400,000 to 600,000 acres (1997–2006) (2006, California Wildfire Activity Statistics). In addition, the three largest fire years since 1950 have occurred this past decade, with both 2007 and 2008 exceeding the previous five-year average (California Department of Forestry and Fire Protection, 2010). Wildland fires are influenced by three factors: fuel, weather and topography. Wildlfire spread depends on the type of fuel involved (grass, brush and trees). Weather influences wildland fire behavior with factors such as wind, relative humidity, temperature, fuel moisture and possibly lightning. Several of these factors can modify the rate the fire will burn. Topography is the biggest influence on fire severity (County of Santa Cruz, 2010).

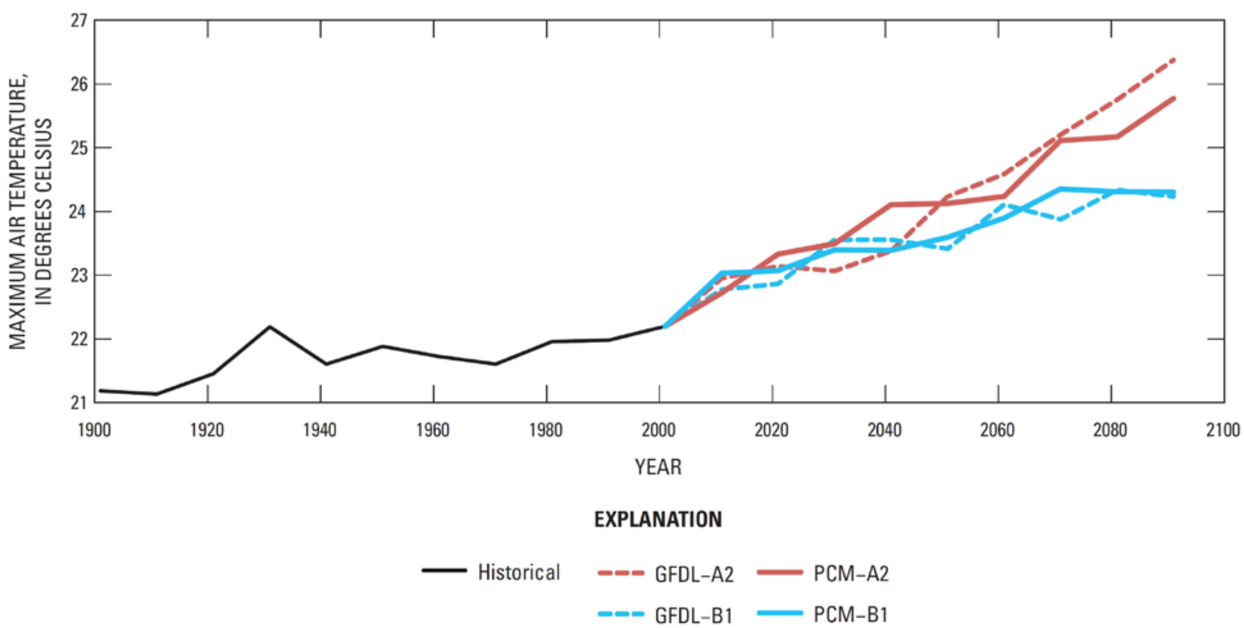

Figure 5-15: *Historical climate and four projections shown by decadal (10-year) average maximum air temperature for the basins in the San Francisco Bay Area, California.*
Source: Flint, L.E. and A.L. Flint, 2012.

In Santa Cruz County there are numerous WUI areas and several areas designated as mutual threat zones. Mutual threat zones are defined as areas where a wildfire would threaten property within the Santa Cruz County Fire Department jurisdiction as well as property covered by another fire protection service. These geographic areas are described as non-State Responsibility Areas. For major emergencies that require more resources than can be provided by a single agency, Santa Cruz County Fire, the University of California at Santa Cruz, other Fire Districts and the State of California (CAL FIRE) have an extensive mutual aid and emergency coordination system covering the entire state. This system allows departments and districts to share personnel and equipment as needed to address and control emergencies (County of Santa Cruz, 2010).

Other areas have been mapped as Critical Fire Hazard Areas due to accumulations of wildfire prone vegetation, steep and dry slopes and the presence of structures vulnerable to wildland fires. These areas are generally situated in the steeper higher elevations of the County. Most of these areas are along the border of Santa Clara County or in the coastal ridges between Highway 9 and Highway 1 (County of Santa Cruz, 2010).

The potential magnitude or severity of future fires can be estimated from experience gained from the recent fires of 2008/2009. In those fires, embers were carried by wind up to one mile, torching of conifers occurred, flame lengths exceeded 100 feet, and area ignition were all observed. In 2008, over 75 structures were destroyed by three fires alone. Similar fuels (Manzanita/Knobcone, Eucalyptus, chaparral, and mixed conifer forestland), topography and weather conditions are expected to be encountered in future fires creating a repeat of extreme fire behavior exhibited in recent large local fires (County of Santa Cruz, 2010).

While normal weather conditions in the Santa Cruz Mountains can be categorized as cold and damp with extensive marine influence (fog), several times each year conditions are created where fuel moisture levels have been measured below five percent with temperatures above 90ºF, and north winds greater than 45 mph (County of Santa Cruz, 2010).

During the past two fire seasons over 13,000 acres have burned in five major fires in Santa Cruz County (see Table 5-2). Each of these fires has burned structures and all have endangered life. Suppression costs alone for these fires have exceeded $60 million. The county endures over 200 wildland fires each year on average (County of Santa Cruz, 2010).

Table 5-2: Previous Wildfires within Santa Cruz County

Fire Name	Year	Acres Burned
Pine Mountain	1948	15,893
Newell Creek	1954	166
Newell Creek No.2	1959	1,326
Austrian Gulch	1961	9,067
Lincoln Hill	1962	3,234
Big Basin No.7	1980	378
Big Basin	1982	300
Rocha No.2	1984	1,239
Lexington	1985	13,122
Croy Fire	2002	3,006
Summit Fire	2008	4,270
Martin Fire	2008	520
Trabing Fire	2008	630
Lockheed Fire	2009	7,819
Loma Fire	2009	485

Source: County of Santa Cruz Local Hazard Mitigation Plan 2010-2015.

According to the Cal-Adapt projections for wildfire in the region due to the effects of climate change, there is expected to be a low to moderate change in wildfire risk in the central coast region with the exception of southwestern Monterey County (State of California 2012a). However, it is unknown how much the expected decrease in redwood habitat (L.E. and A.L. Flint, 2012) will affect this projection, as any vegetation community that replaces redwood forest is likely to be a higher fire risk community.

5.10 Impacts to Biodiversity and Habitat

5.10.1 Climate Change

By the end of the century, summer temperatures in Santa Cruz County are predicted to increase by up to 7°F, with a shift in local peak precipitation from January to February with less in the fall (November-December) and spring (March-April) in the future. In addition, more than one drought every decade is anticipated. Historically, about 4 to 5 droughts occurred over a 90 year period (Flint, L.E. and A.L. Flint, 2012). The increase in temperature will promote water loss due to evaporation and transpiration, creating a climatic water deficit for plants. Moreover, a continuation of the trend of 33 percent reduction in the frequency of California summer fog (Johnstone and Dawson, 2010) could exacerbate the drought stress caused by the predicted hotter and likely drier conditions (Mackenzie, A, J. McGraw, and M. Freeman. 2011).

The hotter, drier climate will affect natural biological systems through a variety of mechanisms (Table 5-3). The effects on individual species or communities can be difficult to predict as they will be influenced by many cascading, indirect effects mediated by complex species interactions. What are the consequences for a rare plant that is solely or primarily pollinated by a butterfly species that emigrates in response to a warming climate? While some studies suggest that species that presently co-occur will shift their distributions together in response to climate change such that communities will move together (Breshears et al. 2008), other studies suggest that the unique combinations of temperature and precipitation not currently found in the region, will result in novel communities, or new assemblages of species (Stralberg et al. 2009).

Table 5-3. General Climate Change Impacts on the Biodiversity of Santa Cruz County
Terrestrial Systems
• Shift of plant and animal distributions into regions with currently cooler climate envelopes • Increased or reduced plant and animal species within their current range • Vegetation structure changes • Forests transition to shrublands • Shrublands transition to grasslands • Potentially new plant communities emerge as a result of novel climates • Increase in fire frequency, promoting fire-adapted species and eliminating fire-sensitive species • Increase in pest and pathogen outbreaks due to drought-stressed plants and more fires • Invasion and spread of non-native species
Aquatic Systems
• Reduced stream flow due to evaporation and lowering of groundwater • Increased variability of stream flow • Flooding due to more severe precipitation could alter channel conditions and habitat, and export nutrients and other materials • Seasonal drying up of perennial streams due to drought • Reduced depth and hydroperiod (period of inundation) in sloughs, ponds, and wetlands • Increased water temperature, reduced dissolved oxygen, and increased productivity • Changes in community composition due to shifts in species distributions and interactions • Changes in abundance in response to physical changes and species interactions • Invasion and spread of non-native species
Source: Mackenzie, A, J. McGraw, and M. Freeman. 2011.

The vulnerability of species and communities to climate change depends on their level of exposure, sensitivity, and capacity to adjust to change (Hanson and Hoffman 2011. Table 5-4 identifies types and examples of species and systems that could be most vulnerable based on five considerations (Hanson and Hoffman 2011).

According to Mackenzie, A, J. et al. (2011), of particular concern is the potential effects of climate change on fog frequency. Numerous species within Santa Cruz County are adapted to the coastal fog, which moderates summer high temperatures, creates humidity, and provides water for plant uptake during the otherwise long summer drought. Three systems, which collectively contain a high proportion of the county's biodiversity, rely on summer fog.

- *Coast Redwood Forest:* Coast redwoods (*Sequoia sempervirens*) intercept fog, using it directly and increasing soil moisture used by other species (Dawson, 1998). By adding water to the catchment basin, redwoods contribute to summer stream flows and are also critical to maintaining cool stream temperatures, which are critical for rearing Coho salmon. The USGS simulation of climate change in the Santa Cruz Mountains (Flint, L.E., and A.L. Flint, 2012) concludes that the range of redwoods will be greatly reduced due to the effects of climatic water deficit (see Section 5.13.2).
- *Maritime Chaparral:* Several endemic species of Manzanita, including Ohlone Manzanita (*Arctostaphylos ohloneana*), silverleaf Manzanita (*A. silvicola*), and Santa Cruz Manzanita (*A. andersonii*), are found only within reach of the summer fog. The maritime chaparral communities they dominate also support other plants and diverse animal assemblages.
- *Coastal Prairie:* Floristically rich coastal prairie grasslands occur within reach of the coastal fog, which some species utilize for moisture in the summer (Corbin et al., 2005).

The predictions for future summer fog frequency on California's coast are unclear. While a 33 percent reduction in the frequency of California summer fog has been observed over the past century (Johnstone and Dawson 2010), the predicted increase in temperature differential between coastal and inland areas, which is a major driver of fog, may increase the frequency of summer fog thus mitigating the effects of global change on temperatures in Santa Cruz County. Monitoring will be needed to inform future conservation and management.

Table 5-4: Species and Biological Systems that Could be Most Vulnerable to the Impacts of Climate Change

Criteria	Terrestrial	Aquatic
Specialized Habitat or Microhabitat	• Santa Cruz sandhills endemic species (e.g. Zayante band-winged grasshopper) • Karst cave and cavern endemic species • Coastal dune, wetland, and rock outcrop species including many shorebirds. • Soda Lake alkali plant community • Coastal prairie grassland species • Marbled Murrelet and other redwood forest-obligate species. • Pine Siskin and other Monterey pine species.	• Marsh and other wetland species, including many plants, amphibians, reptiles, and birds (resident and migrants). • Pond-breeding species including Santa Cruz long-toed salamander, California red-legged frog, and western pond turtle. • Tidewater goby and other lagoon species. • California brackish water snail.
Narrow environmental tolerances that are likely to be exceeded.	• Monterey Pine and coast redwood, which require cool, foggy areas. • Maritime chaparral endemic species (e.g. *Arctostaphylos ohloneana*) which require fog. • Black oak and foothill pine, which are at the edge of their elevational range.	• Coho salmon. • Species at the southern end of their range including Pacific giant salamander and rough-skinned newt.
Dependence on specific environmental triggers or cues that are likely to be disrupted.	• Breeding birds. • Migratory species (butterflies, birds, and bats).	• Fish sensitive to the timing of lagoon closures and openings due to precipitation (e.g. steelhead and Coho). • Breeding amphibians, which require specific pond hydroperiods.
Dependence on interspecific interactions that are likely to be disrupted.	• Insect-pollinated plants, especially those with specialist pollinators. • Insectivorous bats, especially specialist (e.g. pallid bats feed largely on Jerusalem crickets).	• Increased stream biological productivity due to higher temperatures could alter competitive relationship in stream assemblages.
Poor ability to colonize new, more suitable locations.	• Many plants. • Limited mobility animals including flightless insects.	• Pond invertebrates, amphibians, and reptiles that cannot disperse through upland habitats, particularly developed areas.
Source: Mackenzie, A, J. McGraw, and M. Freeman. 2011.		

More frequent fire predicted to accompany the hotter, drier climate will likely alter dramatically the structure and species composition of the natural communities within Santa Cruz County (Fried et al. 2004). Across the Central Coast Ecoregion, the extent of shrublands and conifer forests are predicted to decline while the area of grassland increases (Lenihan et. al. 2008). These predictions suggest that maritime chaparral, sandhills, and coastal scrub as well as coast redwood and Pacific Douglas fir forests could decline while more arid grasslands could expand in Santa Cruz County. More research is needed to understand the implications of these regional changes for the species and communities of Santa Cruz County.

5.10.2 Sea Level Effects on Biodiversity

Sea level has risen by nearly eight inches in the past century, and may rise by more than 5.5 feet (16.5–65.7 inches) by the end of this century (National Research Council, 2012). The resulting inundation and attendant erosion and flooding could eliminate coastal habitats, including:

- *Rock Outcroppings* used for roosting and nesting by coastal seabirds, such as double-crested Cormorants, Brown Pelicans, and Pigeon Guillemots, and as haul-out sites for marine mammals including harbor seals;

- *Coastal Wetlands* including salt marsh and brackish marsh, which support a diverse assemblage of shorebirds including Black-Necked Stilt and American Avocet;
- *Bluffs* utilized by nesting birds including Black Swifts, unique plant assemblages featuring succulents (*Dudleya* spp.); and
- *Dunes* utilized by many plant and animal species including nesting Western Snowy Plovers, Monterey spineflower, and globose dune beetles.

While new habitats could be created adjacent to the areas that will be inundated, this will not be possible where the adjacent land is already developed or is armored (e.g. by sea walls or levees). A state-wide analysis found that only 40 percent of the area in Santa Cruz County is suitable for wetland migration (the formation of new wetlands). Protecting this land will be key to mitigating loss due to sea level rise (Mackenzie, A, J. McGraw, and M. Freeman. 2011).

5.10.3 Climate Change Resiliency

There are several ways that the ability of natural systems to persist, or retain the same basic structure and functions, in the face of climate change can be enhanced:

- Protect land featuring a diverse range of geophysical conditions including topographical conditions, soils, slope-aspects, elevations, and localized climates.
- Protect heterogeneous habitats including a range of successional stages (i.e., time since last fire or other disturbance).
- Protect climate change refugia–areas that may buffer species against climate change.
- Protect buffers around key habitat areas where migration is feasible.
- Ensure long-term viability through redundancy: protect areas of each community, habitat, or refuge across the landscape.
- Preserve landscape connectivity by maintaining permeability and protecting critical linkages.
- Monitor climate change and its impacts and adapt conservation strategies to address changing circumstances.

One very effective approach would be to conserve areas that can buffer species from the impacts of a hotter and drier climate change (see Table 5-5). These climate change refugia include areas that are wetter and cooler at present. These areas are generally scattered throughout the county. Wet areas will also be critical to human adaptation to climate change. Protecting intact habitat where wetlands can migrate is another way to add resiliency (Mackenzie, A, J. McGraw, and M. Freeman. 2011).

5.11 Impacts to Water Supply

Water supply consists of the water resources available for agricultural irrigation and production, drinking water, residential use, landscaping, cooling, and power generation. In California, water resources originate in the form of rain or snowfall and are predominantly spread among the Sierra snowpack, the state's water network (including streams, rivers, aqueducts, and reservoirs), and groundwater. Along with the growing population and the health of ecosystems, climate change is one of the major influences on the availability of water resources (State of California 2012a).

The effects of climate change on water supplies will have impacts on agriculture, recreation and tourism, and the economy overall as well as on natural ecosystems. The environment (that is, the water needed to maintain ecosystems) accounts for 48 percent of water use in California, with agricultural use at 41 percent and urban use at 11 percent (Agricultural Issues Center, 2009). Due to projected population growth, however, urban use is expected to increase more than 50 percent by the year 2050 (Kahrl and Roland-Holst, 2008).

Table 5-5: Potential Climate Change Refugia in Santa Cruz County		
Refugia	**Contribution to Climate Resiliency**	**Occurrence in Santa Cruz County**
Coastal Areas	• The ocean buffers temperature increases. • Fog can further ameliorate climate change.	• Approximately 40 miles of coastline; most of the county is within 15 miles of the coast. • Long, coastal valleys convey cooler air inland.
Streams and Riparian Areas	• Source of perennial water for animals. • Feature cooler microclimates due to evaporation and transpiration. • Create corridors that can facilitate animal movement in response to climate change.	• 850 miles of streams, 550 miles of which are perennial. • Stream network is pervasive and collectively connects much of the county. • Some streams, particularly in the Pajaro Valley, are highly degraded.
Ponds, Lakes, Sloughs, and Reservoirs	• Source of water for animals. • Feature cooler microclimates due to evaporation and transpiration.	• At least 90 water bodies totaling more than 1,500 acres. • Most features are in the Pajaro Valley.
Seeps and Springs	• Source of perennial water.	• 20 mapped seeps and springs (USGS), though likely many more occur in the landscape.
North-facing Slopes	• Cooler microclimate due to reduced solar insolation and typically greater vegetation cover and thus evapotranspiration.	• More than 36,000 acres of north-facing slopes (aspects of 340 to 20 degrees), scattered throughout the county. • Variable, mountainous topography results in north-facing slopes being well-distributed within the county.
Steep Elevation Gradients	• Reduce the distance species need to move along an elevation gradient. • Precipitation and winter minimum temperature increase with elevation, though so does summer maximum temperature in Santa Cruz County.	• Elevation ranges from sea level to approximately 3,400 feet. • Steep terrain occurs within contiguous habitat patches on Ben Lomond Mountain (which receives high precipitation) and near Mount Umunhum and Loma Prieta.
Source: Mackenzie, A, J. McGraw, and M. Freeman. 2011.		

Climate change threatens several aspects of a community's water supply. It can affect the source of a community's water (e.g., precipitation and groundwater recharge, etc.) as well as a community's use behavior. The USGS projects increasing drought and decreased groundwater recharge (Flint, L.E., and A.L. Flint, 2012). For coastal areas of Santa Cruz County, sea level rise can threaten groundwater resources due to sea water intrusion.

A drought is a period of dry weather that persists long enough to cause serious problems such as crop damage and/or water supply shortages. Droughts may not be predictable, but they should be expected. They occur with some regularity and varying levels of severity. The magnitude and duration of a drought is something that can be predicted based on historical records and should be taken into account in water resources planning. In recent history, Santa Cruz County experienced three drought periods: 1976-77, 1987-1992, and most recently in 2007-09. It is expected that the effects of climate change will result in more severe droughts of longer duration.

Water supply in Santa Cruz County is provided by a number of independent water agencies, as shown in Table 5-6 below. Fifty-seven percent of the County population is served by the two largest jurisdictions, the cities of Santa Cruz and Watsonville, with substantial parts of their service areas outside of the city limits. Thirty-seven percent of the Santa Cruz customers (32,500 people) and 20 percent of the Watsonville customers (12,000 people) are outside the city limits. Almost all of the jurisdictions are experiencing some kind of water supply shortfall from overdraft of the groundwater basin, inadequate supply during a drought, or inadequate facilities to meet current demands. Forty-six percent of County population is served by water agencies that get more than 50 percent of their supply from surface water. It is those sources that are most susceptible to drought.

The County of Santa Cruz Department of Environmental Health Services (EHS) is preparing an Integrated Regional Water Management Plan (IRWMP). A chapter of the IRWMP will feature a discussion of the potential effects of climate change on the Santa Cruz water planning region, including an evaluation of vulnerabilities to the effects of climate change and potential adaptation responses to those vulnerabilities. This analysis will be informed by work conducted by the United States Geological Survey (USGS) Pacific Coastal and Marine Science Center, which assessed potential hydrologic changes in the watersheds such as rainfall, runoff, recharge, soil moisture, base flow, and groundwater conditions. In addition to the USGS work, EHS is working on an analysis of potential climate change impacts from sea level rise and increased ocean energy on water resources infrastructure and natural resources. The IRWMP will use the USGS work along with the coastal vulnerability analysis to apply a risk matrix that evaluates the likelihood of impacts occurring in the future and the magnitude of the potential consequences. The risk matrix will be used to identify priority adaptation strategies. A Draft of the IRWMP is expected to be completed in mid 2013.

Table 5-6: Water Suppliers within Santa Cruz County

Water Supplier	Connections	Population	Water use (acre-feet/yr)	Ground	Surface	Current Shortfall
Santa Cruz City Water Dept.	25,000	95,000	11,800	4%	96%	Drought
Watsonville City Water Dept.	15,000	63,700	9,300	89%	11%	Overdraft
Soquel Creek Water District	15,000	49,000	5,400	100%	0	Overdraft
San Lorenzo Valley (SLVWD) Northern	5,300	16,500	1,500	40%	60%	Drought
SLVWD Southern	785	2,500	400	100%	0	Overdraft
SLVWD Felton	1,300	4,000	455	0	100%	Drought
Scotts Valley Water District	3,600	11,300	1,700	100%	0	Overdraft
Central Water District	800	2,700	600	100%	0	OK
Lompico Creek Water District	500	1,300	70	20%	80%	Drought
Big Basin Water Company	580	1,500	240	15%	85%	?
Mount Hermon Association	530	1,400	250	100%	0	Overdraft
Forest Lakes Mutual Water Company	330	900	140	100%	0	Facilities
130 Smaller Water Systems (5-199 connections)*	5,000	14,000	3,500	95%	5%	OK
Individual Users*	8,000	20,800	6,000	95%	5%	OK
Pajaro Agriculture	n/a	n/a	48,000	100%	0	Overdraft
Total	**81,725**	**284,600**	**89,355**	**--**	**--**	**--**

Note: *Values are estimated
Source: County of Santa Cruz Local Hazard Mitigation Plan, 2010.

5.12 Impacts to Public Health

Much of the available information has been generated by the Center for Disease Control and Prevention (CDC) and the California Department of Public Health (CDPH). In Santa Cruz County the predicted health effects of climate change include increased incidence of emerging diseases and vector-borne disease if ecological changes lead to migration of insect and animal disease vectors, and physical and mental health impacts associated with severe weather events, such as flooding, when they cause population dislocation and infrastructure loss. Though extreme heat may be moderated in our coastal location, inland areas of the County can experience much higher temperatures. An increase in temperature can exacerbate existing respiratory disease, cardiovascular disease and stroke. Wildfires are also expected to increase in frequency and severity as drought takes hold, which may cause respiratory distress, exacerbation of existing disease, physical and mental dislocation, as well as some number of direct fatalities.

Further, geographic, racial, and income disparities make some segments of the population more vulnerable to health impacts than others (California Department of Public Health 2012). Adapting to these conditions may include identifying the most vulnerable populations in the County in order to emphasize adaptation strategies that are appropriate for those populations. Building and Fire codes that address wildfire, emergency response plans for wildfire, and the various plans that are in place for responding to infectious disease, should be assessed for opportunities to strengthen prevention and emergency response.

The Mosquito and Vector Control (MAVC) program, County Service Area 53, is an existing resource for controlling the incidence of vector-borne and zoonotic disease. As a County Service Area administered as a division under the Agricultural Commissioner, the MAVC is responsible for public health pest control. To meet these challenges the County Board of Supervisors and cities have authorized the MAVC to put landowner and resident-approved funding mechanisms in place to conduct surveillance, education and biorational integrated control strategies to reduce mosquitoes and other vectors.

5.13 Economic Impacts of Climate Change

Santa Cruz County has many industries; however, agriculture, tourism, forestry, and commercial fishing may suffer significantly from climate change. Partnerships should be formed with businesses in these four industries to determine how to build flexibility into businesses in order to minimize economic disruption. Disruption planning must address the requirements of these industries for reliable transportation systems and other assistance.

5.13.1 Agriculture

Agriculture is a major portion of economic activity in Santa Cruz County. Agriculture will be affected by projected changes in weather, precipitation, water supply, and sea level rise.

Specifically, the projected increase in climatic water deficit and reduction in aquifer recharge adds to longstanding concerns about adequate water supply for irrigation. Refer to sections 5.7.1 and 5.7.2 for a discussion of changing precipitation patterns and climatic water deficit. Adapting to the potential for decreased water for irrigation will likely involve elements of increased conservation of water, continued effort to reduce sea water intrusion, water supply development where feasible and environmentally sustainable, and the industry positioning itself to be flexible with cropping pattern and farming practices. Flexibility in the industry will also be necessary to adapt pest management practices as climate change affects the timing and type of threats from agricultural pests. Sea level rise may exacerbate difficulties on coastal farms where soil is becoming compromised by brackish water overflowing from coastal sloughs and drainages.

5.13.2 Forestry

Forests occupy much of the unincorporated land area in Santa Cruz County. As noted in the emissions inventory, the County has approximately 143,000 acres of redwood and redwood-Douglas-fir forest and 19,900 acres of oak woodland (Mackenzie, A., J. McGraw, and M. Freeman, 2011). Potential alterations to temperature, precipitation regime and fog dynamics from climate change will influence tree survival and growth, forest composition, forest health and productivity. At the same time the intensity of ecosystem disturbances from wildfire, insects, and pathogens is likely to increase. `

By using a long-term index of daily maximum land temperatures, Johnstone and Dawson (2010) infer a 33 percent reduction in fog frequency since the early 20th century. Tree physiological data suggests that coast redwood and other ecosystems along the United States west coast may be increasingly drought stressed under a summer climate of reduced fog frequency and greater evaporative demand. Since 1901, the average number of hours of fog along the coast in summer has dropped from 56 percent to 42 percent, which is a loss of about three hours per day. This trend is expected to continue into the future as a result of climate change.

A study completed in 2012 by the USGS for the County of Santa Cruz concluded that redwood forests currently living at the edge of their suitable range are most at risk, and in the Santa Cruz Mountains the population may be largely reduced to populations located on north and northeast facing slopes.(Flint, L.E., and Flint, A.L., 2012).

A comprehensive and integrated study of climate impacts on coastal redwoods is being conducted in partnership with researchers from the University of California, Berkeley, Humboldt State University and the California Academy of Sciences. One important aspect of the initiative is to use a wide range of global climate model outputs to examine the potential future distribution of coastal redwoods. Once finalized, the range shift projections will be used to prioritize land acquisitions for conservation, and to disseminate information to key decision-makers (Save the Redwoods League, 2012).

The researchers examined the entire 450-mile native range of the coastal redwood, most of which is now covered with second and third growth forests. Although the study is not yet completed, several important patterns have emerged:

- The southernmost part of the current range of coastal redwood is in jeopardy of not being able to maintain redwoods into the future (see Figure 5-16).
- Suitable habitat for coastal redwood may expand into the southern and central coast of Oregon by mid-century.
- There is a large difference in the amount of suitable habitat under different greenhouse gas emission scenarios. Under a scenario involving major global shifts to renewable energy sources (the "B1" scenario), much of the existing habitat for coastal redwoods would likely persist into the future. Under a more business-as-usual scenario of continued high global emissions (the "A2" scenario), the suitable habitat for coastal redwoods is dramatically reduced. Current research reveals that the A2 scenario assumptions are being exceeded. See Appendix E for a description of IPCC Global Emissions Scenarios.
- Under either scenario, there are 'climate refuges' for coast redwood that overlap with existing important protected areas. These regions of persistence may become high priority targets areas to expand protection and manage for connectivity to other protected areas (Data Basin 2012)

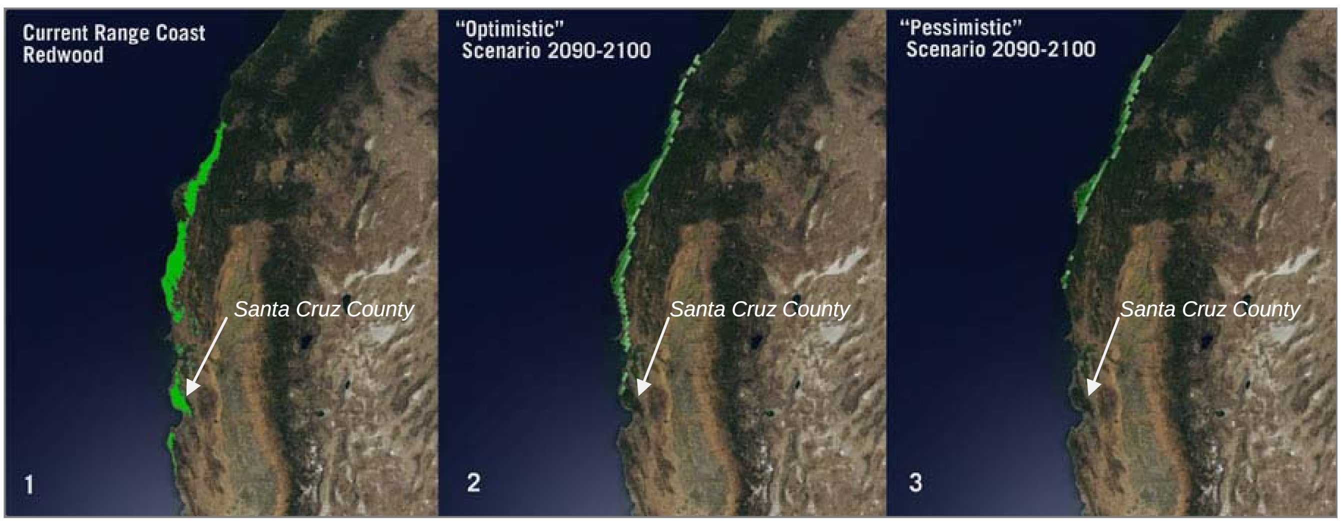

Figure 5-16: *The Anticipated Impact of Climate Change on the Future Distribution of Coast Redwood Forests*
Under an "optimistic" outcome, in which CO_2 levels in the atmosphere remain relatively low, much of the current coast redwood habitat remains. Under a "pessimistic" outcome, in which we continue emitting greenhouse gases at the current rate, much of the current habitat for coast redwoods is no longer suitable. In addition to informing strategies for conservation planning, these results demonstrate that reductions of emissions today will affect the future survival of coast redwoods.
Source: Data Basin 2012

Changes in temperature, precipitation, coastal fog, and wildfire risk will change forest productivity (see preceding discussions in Chapter 5 for a complete discussion of these vulnerabilities). Consequences for the forestry industry are likely to be slower growth, stressed trees, or insect epidemic. Some forests are at greater risk of stand-replacement wildfires that damage or destroy long-term investment while requiring post-fire planting, road maintenance, and other actions (State of California 2012b). Santa Cruz County is located at the southern extent of the current range of coast redwood. This is the area of the range that is at greatest risk of disappearing.

5.13.3 Tourism

California has the nation's largest ocean economy, valued at about $47 billion/year, with the great majority of this connected to coastal recreation and tourism as well as shipping and ports. Many of the facilities and much of the infrastructure that support these industries, as well as the state's many miles of public beaches, are within just a few feet of present sea level (California Energy Commission, 2012). Tourism ranks, alongside agriculture, as one of the top employers and revenue-producing industries in Santa Cruz County, generating over $500 million in direct travel expenditures annually. Tourism also generates over $14 million in taxes for local government, which helps to pay for police and fire protection, road repairs, park maintenance and social services (source: Santa Cruz County Conference and Visitors Council, 2012).

Tourism in Santa Cruz depends on beaches, coastal recreation, and on attractions that are close to the ocean. Rising sea level threatens the beaches with increased erosion, severe storms and flooding that can damage infrastructure, access, and tourist attractions. Several key roads and bridges are at low elevation and close to the coast where they are vulnerable to flooding, storm waves and erosion.

It is typical that triple-digit temperatures in the interior areas of California draw visitors to the Santa Cruz area. Several million people live within a few hours drive from Santa Cruz. Much of the County's local commerce depends on those daily and weekly summer visitors drawn in part by cooler coastal temperatures. This attraction could increase as summer temperatures grow in surrounding inland areas. In this sense, climate change presents an economic opportunity for Santa Cruz County, but this is balanced against costs to protect infrastructure and potential loss of redwood habitat (refer to section 5.13.2), beaches and other natural resources that attract visitors.

5.14 Climate Change and Social Vulnerability

Social vulnerability is defined as "the intersection of the exposure, sensitivity and adaptive capacity of a person or group of people" to climate change (Pacific Institute, 2010). In the social vulnerability literature, data are used to assess the people most at risk to climate change due to a combination of their social and demographic characteristics (e.g., economic status, age, and ethnicity), level of exposure to impacts likely to occur, sensitivity to impacts (e.g., health condition, occupation), and adaptive capacity (e.g., networks, knowledge, attitudes) (Wongbusarakum and Loper, 2011; Cutter et al., 2009).

To compare overall social vulnerability to climate change among areas within California, a single vulnerability index that combines data from 19 vulnerability factors was used by the Pacific Institute (2012) to calculate a vulnerability index for each of the 7,049 census tracts in the state. A higher score indicated the population within a tract had greater social vulnerability to climate-related disturbances. According to the study, approximately 50 percent (125,000) of the population of Santa Cruz County would have low social vulnerability to the effects of climate change, while 27 percent (66,700) would have medium social vulnerability, and approximately 24 percent (59,900) would have high vulnerability to climate change. Four factors (lacking a high-school diploma, low-income, non-English speaking, and people of color) were the primary drivers for the most vulnerable census tracts that were analyzed statewide (Pacific Institute, 2012). Other factors in order of high to low vulnerability included the following: foreign born, overweight, renters, no vehicle, pre-term births, under-18 population, impervious land cover, unemployment, outdoor workers, pregnant women, lack of tree canopy, no air conditioning, food deserts, institutionalized population, and population over 65 living alone.

Climate risk is a function of exposure and vulnerability. Vulnerability index score maps were overlaid with maps of projected exposure to extreme heat, particulate matter, coastal flooding, and wildfire to identify areas with high social vulnerability and high projected exposure to climate change disturbances. The areas of overlap indicated those locations with heightened risk of being impacted by these climate changes as a result of exposure and social vulnerability. Geographically, the majority of Santa Cruz County would experience low social vulnerability. However, the extreme southeast area of the County would likely experience medium and high social vulnerability, while areas of the City of Santa Cruz may experience medium social vulnerability (Pacific Institute 2012).

5.14.1 Extreme Heat

Climate change is projected to increase the frequency and intensity of extreme heat events. Areas with historically moderate temperatures such as Santa Cruz County may have unexpected heat spells, and areas that already have intense heat may have more extreme, longer and/or more frequent periods of heat. Inland areas of Santa Cruz County such as the San Lorenzo Valley, the Summit, and Eureka Canyon can experience much higher temperatures than coastal areas. Extreme heat events can lead to heat-related illness and death, particularly for the elderly.

In a recent social vulnerability study by the Pacific Institute (2012), the magnitude of extreme heat was measured in terms of the number of days that the daily maximum temperature exceeds the 95th percentile historical (1971-2000) local high-heat threshold during the summer months (May 1 through October 31). By definition, the 95th percentile high-heat threshold is the local temperature exceeded 7.6 days per year, on average, over the summer months during the historical period (1971-2000). The 95th percentile temperature fell within 80°–90°F in many of the coastal and northern counties, and for comparison, reached over 100 degrees in much of the Central Valley and southern California.

Climate change within this 1971 to 2000 time period increased the number of extreme heat events across the state. The largest increases in the number of days exceeding the local high heat threshold were in the inland and southern parts of California. For example, in Inyo County, the number of days exceeding the local high heat threshold (101°F) increased from 7.6 days under historic conditions to 40 days under the low emissions (B1) scenario and 71 days under the medium emissions (A2) scenario by 2070–2099. The coast experienced considerably smaller increases. . Santa Cruz County's average 95th percentile daily maximum temperature from May 1 to October 31 over the historical period (1971-2000) is 87.1°F under the B1 scenario and 87.3°F under the A2 scenario (2070–2099). The number of days exceeding the local high heat threshold (87.1°F) increased from 7.6 days under historic conditions to 21 days under the B1 scenario and 34 days under the A2 scenario by 2070–2099. Refer to Appendix E for a description of IPCC Global Emissions Scenarios A2 and B1.

Exposure to extreme heat was much greater under the A2 scenario than under the B1 scenario. By the end of the century, 28 million Californians, about 76 percent of the population, would face more than 38 days of temperatures that currently occur on the hottest 7.6 days of the year. Of those with high exposure to extreme heat, about 37 percent, or 10.1 million people, also live in areas of high social vulnerability. For Santa Cruz County, under the B1 scenario, no one of high social vulnerability would be affected. However, under the A2 scenario (2070–2099), some 25,800 socially vulnerable people could be affected by exposure to increased heat. Of those affected, 21,820 would be of low social vulnerability and the remaining 4,010 would be of medium vulnerability (Pacific Institute, 2012). It should be noted that extreme heat events are less likely to occur in the Central Coast Region than in California's inland valleys. When they do occur, however, vulnerable populations may be severely affected because of a historic lack of adaptive capacity to historically milder temperatures (State of California, 2012a).

5.14.2 Coastal Flooding

Under the B1 scenario (see Appendix E), with 39 inches rise in sea level, nearly 420,000 people in California are expected to be exposed to coastal flood risk by the end of the century. Under the A2 scenario, with 55 inches of rise in sea levels, more than 480,000 people along the California coast are expected to be exposed to coastal flood risk by the end of the century. Under both A2 and B1 scenarios, about 18 percent of those exposed to coastal flooding live in areas with high social vulnerability. San Mateo County has a large number of people living in areas with high social vulnerability, as does Marin, Monterey, Orange, and Ventura counties. About 43 percent of those exposed to flooding from sea level rise live in areas with a medium social vulnerability. The remainder of people live in areas with low social vulnerability (Pacific Institute, 2012).

In Santa Cruz County under the B1 scenario, over 14,000 people live in census tracts expected to be exposed to coastal flood risk by the end of the century. Under the A2 scenario, 16,000 people live in census tracts that are expected to be exposed. The greatest number of people exposed for both scenarios live in areas with medium social vulnerability. (Pacific Institute, 2012).

5.14.3 Wildland Fire

According to the California Climate Change Adaptation Policy Guide (State of California, 2012), a low to moderate change in wildland fire risk is projected for the Central Coast Region. Cal-Adapt projections also suggest that Santa Cruz County would have a low to moderate change in projected fire risk (State of California 2012a). All of those people living in areas with a high change in wildland fire risk are located in southern California. Climate change is not anticipated to substantially change the current risk of wildfire under either the B1 or A2 climate change scenarios.

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